

AN INTERNATIONAL CODE

2010 ASME Boiler & Pressure Vessel Code

2011a Addenda

July 1, 2011

II

Part A

Ferrous Material Specifications (Beginning to SA-450)

MATERIALS

ASME Boiler and Pressure Vessel Committee on Materials



The American Society of
Mechanical Engineers

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2010 ASME

BOILER AND PRESSURE VESSEL CODE

(10)

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Addenda, which include additions and revisions to individual Sections of the Code, will be sent automatically to purchasers of the applicable Sections up to the publication of the 2013 Code. The 2010 Code is available only in the loose-leaf format; accordingly, the Addenda will be issued in the loose-leaf format.

INTERPRETATIONS

ASME issues written replies to inquiries concerning interpretation of technical aspects of the Code. The Interpretations for each individual Section will be published separately and will be included as part of the update service to that Section. Interpretations of Section III, Divisions 1

and 2, will be included with the update service to Subsection NCA.

Interpretations of the Code are posted in January and July at <http://cstools.asme.org/interpretations/cfm>.

CODE CASES

The Boiler and Pressure Vessel Committee meets regularly to consider proposed additions and revisions to the Code and to formulate Cases to clarify the intent of existing requirements or provide, when the need is urgent, rules for materials or constructions not covered by existing Code rules. Those Cases that have been adopted will appear in the appropriate 2010 Code Cases book: “Boilers and Pressure Vessels” and “Nuclear Components.” Supplements will be sent automatically to the purchasers of the Code Cases books up to the publication of the 2013 Code.

FOREWORD

(10)
(a)

The American Society of Mechanical Engineers set up a committee in 1911 for the purpose of formulating standard rules for the construction of steam boilers and other pressure vessels. This committee is now called the Boiler and Pressure Vessel Committee.

The Committee's function is to establish rules of safety, relating only to pressure integrity, governing the construction¹ of boilers, pressure vessels, transport tanks and nuclear components, and inservice inspection for pressure integrity of nuclear components and transport tanks, and to interpret these rules when questions arise regarding their intent. This Code does not address other safety issues relating to the construction of boilers, pressure vessels, transport tanks and nuclear components, and the inservice inspection of nuclear components and transport tanks. The user of the Code should refer to other pertinent codes, standards, laws, regulations, or other relevant documents. With few exceptions, the rules do not, of practical necessity, reflect the likelihood and consequences of deterioration in service related to specific service fluids or external operating environments. Recognizing this, the Committee has approved a wide variety of construction rules in this Section to allow the user or his designee to select those which will provide a pressure vessel having a margin for deterioration in service so as to give a reasonably long, safe period of usefulness. Accordingly, it is not intended that this Section be used as a design handbook; rather, engineering judgment must be employed in the selection of those sets of Code rules suitable to any specific service or need.

This Code contains mandatory requirements, specific prohibitions, and nonmandatory guidance for construction activities. The Code does not address all aspects of these activities and those aspects that are not specifically addressed should not be considered prohibited. The Code is not a handbook and cannot replace education, experience, and the use of engineering judgment. The phrase *engineering judgment* refers to technical judgments made by knowledgeable designers experienced in the application of the Code. Engineering judgments must be consistent with Code philosophy and such judgments must never be used to overrule mandatory requirements or specific prohibitions of the Code.

¹ *Construction*, as used in this Foreword, is an all-inclusive term comprising materials, design, fabrication, examination, inspection, testing, certification, and pressure relief.

The Committee recognizes that tools and techniques used for design and analysis change as technology progresses and expects engineers to use good judgment in the application of these tools. The designer is responsible for complying with Code rules and demonstrating compliance with Code equations when such equations are mandatory. The Code neither requires nor prohibits the use of computers for the design or analysis of components constructed to the requirements of the Code. However, designers and engineers using computer programs for design or analysis are cautioned that they are responsible for all technical assumptions inherent in the programs they use and they are responsible for the application of these programs to their design.

The Code does not fully address tolerances. When dimensions, sizes, or other parameters are not specified with tolerances, the values of these parameters are considered nominal and allowable tolerances or local variances may be considered acceptable when based on engineering judgment and standard practices as determined by the designer.

The Boiler and Pressure Vessel Committee deals with the care and inspection of boilers and pressure vessels in service only to the extent of providing suggested rules of good practice as an aid to owners and their inspectors.

The rules established by the Committee are not to be interpreted as approving, recommending, or endorsing any proprietary or specific design or as limiting in any way the manufacturer's freedom to choose any method of design or any form of construction that conforms to the Code rules.

The Boiler and Pressure Vessel Committee meets regularly to consider revisions of the rules, new rules as dictated by technological development, Code Cases, and requests for interpretations. Only the Boiler and Pressure Vessel Committee has the authority to provide official interpretations of this Code. Requests for revisions, new rules, Code Cases, or interpretations shall be addressed to the Secretary in writing and shall give full particulars in order to receive consideration and action (see Submittal of Technical Inquiries to the Boiler and Pressure Vessel Committee). Proposed revisions to the Code resulting from inquiries will be presented to the Standards Committees for appropriate action. The action of the Standards Committees becomes effective only after confirmation by letter ballot of the Committees and approval by ASME.

Proposed revisions to the Code approved by the Committee are submitted to the American National Standards Institute and published at <http://cstools.asme.org/csconnect/public/index.cfm?PublicReview=Revisions> to invite comments from all interested persons. After the allotted time for public review and final approval by ASME, revisions are published in updates to the Code.

Code Cases may be used in the construction of components to be stamped with the Certification Mark beginning with the date of their approval by ASME.

After Code revisions are approved by ASME, they may be used beginning with the date of issuance. Revisions, except for revisions to material specifications in Section II, Parts A and B, become mandatory six months after such date of issuance, except for boilers or pressure vessels contracted for prior to the end of the six-month period. Revisions to material specifications are originated by the American Society for Testing and Materials (ASTM) and other recognized national or international organizations, and are usually adopted by ASME. However, those revisions may or may not have any effect on the suitability of material, produced to earlier editions of specifications, for use in ASME construction. ASME material specifications approved for use in each construction Code are listed in the Guideline for Acceptable ASTM Editions and in the Guideline for Acceptable Non-ASTM Editions, in Section II, Parts A and B. These Guidelines list, for each specification, the latest edition adopted by ASME, and earlier and later editions considered by ASME to be identical for ASME construction.

The Boiler and Pressure Vessel Committee in the formulation of its rules and in the establishment of maximum design and operating pressures considers materials, construction, method of fabrication, inspection, and safety devices.

The Code Committee does not rule on whether a component shall or shall not be constructed to the provisions of the Code. The Scope of each Section has been established to identify the components and parameters considered by the Committee in formulating the Code rules.

Questions or issues regarding compliance of a specific component with the Code rules are to be directed to the ASME Certificate Holder (Manufacturer). Inquiries concerning the interpretation of the Code are to be directed

to the ASME Boiler and Pressure Vessel Committee. ASME is to be notified should questions arise concerning improper use of the Certification Mark.

The specifications for materials given in Section II are identical with or similar to those of specifications published by ASTM, AWS, and other recognized national or international organizations. When reference is made in an ASME material specification to a non-ASME specification for which a companion ASME specification exists, the reference shall be interpreted as applying to the ASME material specification. Not all materials included in the material specifications in Section II have been adopted for Code use. Usage is limited to those materials and grades adopted by at least one of the other Sections of the Code for application under rules of that Section. All materials allowed by these various Sections and used for construction within the scope of their rules shall be furnished in accordance with material specifications contained in Section II or referenced in the Guidelines for Acceptable Editions in Section II, Parts A and B, except where otherwise provided in Code Cases or in the applicable Section of the Code. Materials covered by these specifications are acceptable for use in items covered by the Code Sections only to the degree indicated in the applicable Section. Materials for Code use should preferably be ordered, produced, and documented on this basis; Guidelines for Acceptable Editions in Section II, Parts A and B list editions of ASME and year dates of specifications that meet ASME requirements and which may be used in Code construction. Material produced to an acceptable specification with requirements different from the requirements of the corresponding specifications listed in the Guidelines for Acceptable Editions in Part A or Part B may also be used in accordance with the above, provided the material manufacturer or vessel manufacturer certifies with evidence acceptable to the Authorized Inspector that the corresponding requirements of specifications listed in the Guidelines for Acceptable Editions in Part A or Part B have been met. Material produced to an acceptable material specification is not limited as to country of origin.

When required by context in this Section, the singular shall be interpreted as the plural, and vice-versa; and the feminine, masculine, or neuter gender shall be treated as such other gender as appropriate.

STATEMENT OF POLICY ON THE USE OF THE CERTIFICATION MARK AND CODE AUTHORIZATION IN ADVERTISING

(10)
(a)

ASME has established procedures to authorize qualified organizations to perform various activities in accordance with the requirements of the ASME Boiler and Pressure Vessel Code. It is the aim of the Society to provide recognition of organizations so authorized. An organization holding authorization to perform various activities in accordance with the requirements of the Code may state this capability in its advertising literature.

Organizations that are authorized to use the Certification Mark for marking items or constructions that have been constructed and inspected in compliance with the ASME Boiler and Pressure Vessel Code are issued Certificates of Authorization. It is the aim of the Society to maintain the standing of the Certification Mark for the benefit of the users, the enforcement jurisdictions, and the holders of the Certification Mark who comply with all requirements.

Based on these objectives, the following policy has been established on the usage in advertising of facsimiles of the Certification Mark, Certificates of Authorization, and reference to Code construction. The American Society of

Mechanical Engineers does not “approve,” “certify,” “rate,” or “endorse” any item, construction, or activity and there shall be no statements or implications that might so indicate. An organization holding the Certification Mark and/or a Certificate of Authorization may state in advertising literature that items, constructions, or activities “are built (produced or performed) or activities conducted in accordance with the requirements of the ASME Boiler and Pressure Vessel Code,” or “meet the requirements of the ASME Boiler and Pressure Vessel Code.” An ASME corporate logo shall not be used by any organization other than ASME.

The Certification Mark shall be used only for stamping and nameplates as specifically provided in the Code. However, facsimiles may be used for the purpose of fostering the use of such construction. Such usage may be by an association or a society, or by a holder of the Certification Mark who may also use the facsimile in advertising to show that clearly specified items will carry the Certification Mark. General usage is permitted only when all of a manufacturer’s items are constructed under the rules.

STATEMENT OF POLICY ON THE USE OF ASME MARKING TO IDENTIFY MANUFACTURED ITEMS

(a)

The ASME Boiler and Pressure Vessel Code provides rules for the construction of boilers, pressure vessels, and nuclear components. This includes requirements for materials, design, fabrication, examination, inspection, and stamping. Items constructed in accordance with all of the applicable rules of the Code are identified with the official Certification Mark described in the governing Section of the Code.

Markings such as “ASME,” “ASME Standard,” or any other marking including “ASME” or the Certification Mark

shall not be used on any item that is not constructed in accordance with all of the applicable requirements of the Code.

Items shall not be described on ASME Data Report Forms nor on similar forms referring to ASME that tend to imply that all Code requirements have been met when, in fact, they have not been. Data Report Forms covering items not fully complying with ASME requirements should not refer to ASME or they should clearly identify all exceptions to the ASME requirements.

(a)

SUBMITTAL OF TECHNICAL INQUIRIES TO THE BOILER AND PRESSURE VESSEL COMMITTEE — MANDATORY

1 INTRODUCTION

(a) The following information provides guidance to Code users for submitting technical inquiries to the Committee. See Guideline on the Approval of New Materials Under the ASME Boiler and Pressure Vessel Code in Section II, Parts C and D for additional requirements for requests involving adding new materials to the Code. Technical inquiries include requests for revisions or additions to the Code rules, requests for Code Cases, and requests for Code interpretations, as described below.

(1) *Code Revisions*. Code revisions are considered to accommodate technological developments, address administrative requirements, incorporate Code Cases, or to clarify Code intent.

(2) *Code Cases*. Code Cases represent alternatives or additions to existing Code rules. Code Cases are written as a question and reply, and are usually intended to be incorporated into the Code at a later date. When used, Code Cases prescribe mandatory requirements in the same sense as the text of the Code. However, users are cautioned that not all jurisdictions or owners automatically accept Code Cases. The most common applications for Code Cases are:

(a) to permit early implementation of an approved Code revision based on an urgent need

(b) to permit the use of a new material for Code construction

(c) to gain experience with new materials or alternative rules prior to incorporation directly into the Code

(3) *Code Interpretations*. Code Interpretations provide clarification of the meaning of existing rules in the Code, and are also presented in question and reply format. Interpretations do not introduce new requirements. In cases where existing Code text does not fully convey the meaning that was intended, and revision of the rules is required to support an interpretation, an Intent Interpretation will be issued and the Code will be revised.

(b) The Code rules, Code Cases, and Code Interpretations established by the Committee are not to be considered as approving, recommending, certifying, or endorsing any proprietary or specific design, or as limiting in any way

the freedom of manufacturers, constructors, or owners to choose any method of design or any form of construction that conforms to the Code rules.

(c) Inquiries that do not comply with these provisions or that do not provide sufficient information for the Committee's full understanding may result in the request being returned to the inquirer with no action.

2 INQUIRY FORMAT

Submittals to the Committee shall include:

(a) *Purpose*. Specify one of the following:

(1) revision of present Code rules

(2) new or additional Code rules

(3) Code Case

(4) Code Interpretation

(b) *Background*. Provide the information needed for the Committee's understanding of the inquiry, being sure to include reference to the applicable Code Section, Division, Edition, Addenda (if applicable), paragraphs, figures, and tables. Preferably, provide a copy of the specific referenced portions of the Code.

(c) *Presentations*. The inquirer may desire or be asked to attend a meeting of the Committee to make a formal presentation or to answer questions from the Committee members with regard to the inquiry. Attendance at a Committee meeting shall be at the expense of the inquirer. The inquirer's attendance or lack of attendance at a meeting shall not be a basis for acceptance or rejection of the inquiry by the Committee.

3 CODE REVISIONS OR ADDITIONS

Requests for Code revisions or additions shall provide the following:

(a) *Proposed Revisions or Additions*. For revisions, identify the rules of the Code that require revision and submit a copy of the appropriate rules as they appear in the Code, marked up with the proposed revision. For additions, provide the recommended wording referenced to the existing Code rules.

(b) *Statement of Need*. Provide a brief explanation of the need for the revision or addition.

(c) *Background Information*. Provide background information to support the revision or addition, including any data or changes in technology that form the basis for the request that will allow the Committee to adequately evaluate the proposed revision or addition. Sketches, tables, figures, and graphs should be submitted as appropriate. When applicable, identify any pertinent paragraph in the Code that would be affected by the revision or addition and identify paragraphs in the Code that reference the paragraphs that are to be revised or added.

4 CODE CASES

Requests for Code Cases shall provide a Statement of Need and Background Information similar to that defined in 3(b) and 3(c), respectively, for Code revisions or additions. The urgency of the Code Case (e.g., project underway or imminent, new procedure, etc.) must be defined and it must be confirmed that the request is in connection with equipment that will bear the Certification Mark, with the exception of Section XI applications. The proposed Code Case should identify the Code Section and Division, and be written as a *Question* and a *Reply* in the same format as existing Code Cases. Requests for Code Cases should also indicate the applicable Code Editions and Addenda (if applicable) to which the proposed Code Case applies.

5 CODE INTERPRETATIONS

(a) Requests for Code Interpretations shall provide the following:

(1) *Inquiry*. Provide a condensed and precise question, omitting superfluous background information and, when possible, composed in such a way that a “yes” or a “no” *Reply*, with brief provisos if needed, is acceptable. The question should be technically and editorially correct.

(2) *Reply*. Provide a proposed *Reply* that will clearly and concisely answer the *Inquiry* question. Preferably, the

Reply should be “yes” or “no,” with brief provisos if needed.

(3) *Background Information*. Provide any background information that will assist the Committee in understanding the proposed *Inquiry* and *Reply*.

(b) Requests for Code Interpretations must be limited to an interpretation of a particular requirement in the Code or a Code Case. The Committee cannot consider consulting type requests such as the following:

(1) a review of calculations, design drawings, welding qualifications, or descriptions of equipment or parts to determine compliance with Code requirements;

(2) a request for assistance in performing any Code-prescribed functions relating to, but not limited to, material selection, designs, calculations, fabrication, inspection, pressure testing, or installation;

(3) a request seeking the rationale for Code requirements.

6 SUBMITTALS

Submittals to and responses from the Committee shall meet the following:

(a) *Submittal*. Inquiries from Code users shall be in English and preferably be submitted in typewritten form; however, legible handwritten inquiries will also be considered. They shall include the name, address, telephone number, fax number, and e-mail address, if available, of the inquirer and be mailed to the following address:

Secretary

ASME Boiler and Pressure Vessel Committee

Three Park Avenue

New York, NY 10016-5990

As an alternative, inquiries may be submitted via e-mail to: SecretaryBPV@asme.org.

(b) *Response*. The Secretary of the ASME Boiler and Pressure Vessel Committee or of the appropriate Subcommittee shall acknowledge receipt of each properly prepared inquiry and shall provide a written response to the inquirer upon completion of the requested action by the Code Committee.

(a)

PERSONNEL

ASME Boiler and Pressure Vessel Standards Committees, Subgroups, and Working Groups

As of January 1, 2011

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PREFACE

(10)

The American Society of Mechanical Engineers (ASME) and the American Society for Testing and Materials (ASTM) have cooperated for more than fifty years in the preparation of material specifications adequate for safety in the field of pressure equipment for ferrous and nonferrous materials, contained in Section II (Part A — Ferrous and Part B — Nonferrous) of the ASME Boiler and Pressure Vessel Code.

The evolution of this cooperative effort is contained in Professor A. M. Greene's "History of the ASME Boiler Code," which was published as a series of articles in *Mechanical Engineering* from July 1952 through August 1953 and is now available from ASME in a special bound edition. The following quotations from this history, which was based upon the minutes of the ASME Boiler and Pressure Vessel Committee, will help focus on the cooperative nature of the specifications found in Section II, Material Specifications.

"General discussion of material specifications comprising Paragraphs 1 to 112 of Part 2 and the advisability of having them agree with ASTM specifications," (1914).

"ASME Subcommittee appointed to confer with ASTM," (1916).

"Because of this cooperation the specifications of the 1918 Edition of the ASME Boiler Code were more nearly in agreement with ASTM specifications. In the 1924 Edition of the Code, 10 specifications were in complete agreement with ASTM specifications, 4 in substantial agreement and 2 covered materials for which ASTM had no corresponding specifications."

"In Section II, Material Specifications, the paragraphs were given new numbers beginning with S-1 and extending to S-213," (1925).

"Section II was brought into agreement with changes made in the latest ASTM specifications since 1921," (1932).

"The Subcommittee on Material Specifications arranged for the introduction of the revisions of many of the specifications so that they would agree with the latest form of the earlier ASTM specifications..., " (1935).

From the preceding, it is evident that many of the material specifications were prepared by the Boiler and Pressure Vessel Code Committees, then subsequently, by cooperative action, modified and identified as ASTM specifications. Section II, Parts A and B, currently contain many

material specifications which are identical with the corresponding ASTM specifications and some which have been modified for Code usage. Many of these specifications are published in dual format. That is, they contain both U.S. Customary units and SI units. The metrication protocols followed in the specifications are those adopted by ASTM, and are usually to the rules of IEEE/ASTM 10-1997 Standard for the Use of the International System of Units (SI): The Modern Metric System.

In 1969, the American Welding Society began publication of specifications for welding rods, electrodes, and filler metals, hitherto issued by ASTM. The Boiler and Pressure Vessel Committee has recognized this new arrangement, and is now working with AWS on these specifications. Section II, Part C, contains the welding material specifications approved for Code use.

In 1992, the ASME Board of Pressure Technology Codes and Standards endorsed the use of non-ASTM material for Boiler and Pressure Vessel Code applications. It is the intent to follow the procedures and practices currently in use to implement the adoption of non-ASTM materials.

All identical specifications are indicated by the ASME/originating organization symbols. The specifications prepared and copyrighted by ASTM, AWS, and other originating organizations are reproduced in the Code with the permission of the respective Society. The ASME Boiler and Pressure Vessel Committee has given careful consideration to each new and revised specification, and has made such changes as they deemed necessary to make the specification adaptable for Code usage. In addition, ASME has furnished ASTM with the basic requirements that should govern many proposed new specifications. Joint action will continue an effort to make the ASTM, AWS, and ASME specifications identical.

To ensure that there will be a clear understanding on the part of the users of Section II, ASME publishes both the identical specifications and those amended for Code usage in three Parts every three years, in the same page size to match the other sections of the Code, and updates are issued to provide the latest changes in Section II specifications.

The ASME Boiler and Pressure Vessel Code has been adopted into law by 50 states and many municipalities in the United States and by all of the Canadian provinces.

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SA-216/SA-216M	Steel Castings, Carbon, Suitable for Fusion Welding for High-Temperature Service	331
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SA-638/SA-638M	Precipitation Hardening Iron Base Superalloy Bars, Forgings, and Forging Stock for High-Temperature Service.....	1141
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SA-666	Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate and Flat Bar	1171
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SA-995	Castings, Austenitic-Ferritic (Duplex) Stainless Steel, for Pressure-Containing Parts.....	1557

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SPECIFICATION REMOVAL

(10)

From time to time, it becomes necessary to remove specifications from this Part of Section II. This occurs because the sponsoring society (e.g., ASTM, AWS, CEN) has notified ASME that the specification has either been replaced with another specification, or that there is no known use and production of a material. Removal of a specification from this Section also results in concurrent removal of the same specification from Section IX and from all of the ASME Boiler and Pressure Vessel Construction Codes that reference the material. This action effectively prohibits further use of the material in ASME Boiler and Pressure Vessel construction.

The following specifications will be dropped from this Section in the next Addenda (if applicable), unless information concerning current production and use of the material is received before December 1 of this year:

SA-557/SA-557M-90a (discontinued by ASTM in 1995, replaced by A 178/A 178M)¹

SA-731/SA-731M-91 (discontinued by ASTM in 1995, replaced by A 268/A 268M)¹

If you are currently using and purchasing new material to this specification for ASME Boiler and Pressure Vessel Code construction, and if discontinuance of this specification would present a hardship, please notify the Secretary of the ASME Boiler and Pressure Vessel Committee, at the address shown below:

Secretary
ASME Boiler and Pressure Vessel Committee
Three Park Avenue
New York, NY 10016-5990
Tel: (212) 591-8533
Fax: (212) 591-8501

¹ The replacement specifications are currently in Section II, Part A.

GUIDELINE ON THE APPROVAL OF NEW MATERIALS UNDER THE ASME BOILER AND PRESSURE VESSEL CODE

Code Policy. It is the policy of the ASME Boiler and Pressure Vessel Committee to adopt for inclusion in Section II only such specifications as have been adopted by the American Society for Testing and Materials (ASTM), by the American Welding Society (AWS), and by other recognized national or international organizations.

It is expected that requests for Code approval will normally be for materials for which there is a recognized national or international specification. For materials made to a recognized national or international specification other than those of ASTM or AWS, the inquirer shall give notice to the standards developing organization that a request has been made to ASME for adoption of their specification under the ASME Code and shall request that the organization grant ASME permission to reprint the specification. For other materials, a request shall be made to ASTM, AWS, or a recognized national or international organization to develop a specification that can be presented to the Code Committee.

It is the policy of the ASME Boiler and Pressure Vessel Committee to consider requests to adopt new materials only from boiler, pressure vessel, or nuclear power plant component Manufacturers or users. Further, such requests should be for materials for which there is a reasonable expectation of use in a boiler, pressure vessel, or nuclear power plant component constructed to the rules of one of the Sections of this Code. Requests for new materials shall be accompanied by a communication from an ASME Certificate Holder, an end user, or an organization that specifies materials and contracts with Certificate Holders for the construction of products to the rules of one of the sections of this Code. The letter shall state the Inquirer's name and status as one of these three types of organizations.

Application. The inquirer shall identify to the Committee the Section or Sections and Divisions of the Code in which the new material is to be incorporated, the temperature range of application, whether cyclic service is to be considered, and whether external pressure service is to be considered. The inquirer shall identify all product forms, size ranges, and specifications for which incorporation is desired.

Mechanical Properties. Together with the specification for the material, the inquirer shall furnish the Committee with adequate data on which to base design values for inclusion in the applicable tables. The data shall include values of ultimate tensile strength, yield strength, reduction of area, and elongation, at 100°F (or 50°C) intervals, from room temperature to 100°F (or 50°C) above the maximum intended use temperature, unless the maximum intended use temperature does not exceed 100°F. Any heat treatment that is required to produce the mechanical properties should be fully described.

If adoption is desired at temperatures at which time-dependent behavior may be expected to control design values, stress-rupture and creep rate data for these time-dependent properties shall be provided, starting at temperatures about 50°F (or 25°C) below the temperature where time-dependent properties may govern (see Appendix 1 of Section II, Part D) and extending to about 100°F (or 50°C) above the maximum intended use temperature. The longest rupture time at each test temperature must be in excess of 6000 hr and the shortest about 100 hr, with at least three additional tests at stresses selected to provide rupture times nominally equally spaced in log (time); i.e., times nominally of 100, 300, 800, 2200, and 6000 hr at each test temperature. Obviously, longer times and additional tests are beneficial. The interval between successive test temperatures shall be chosen such that rupture lives shall not differ by more than a factor of about 10 at any given stress for two adjacent temperatures. In general, test temperatures should be in about 50°F (or 25°C) intervals if maximum test times are no longer than 6000 hr. The goal of the testing is to facilitate data analysis to estimate the average and minimum stresses for rupture in 100,000 hr and an average creep rate of 10^{-5} %/hr for each temperature where design stresses are established. Alternative test plans that deviate from the prior description but achieve the overall objective may be considered.

Minimum creep rate data shall be provided over the same range of temperatures as above, with the lowest stress at each temperature selected to achieve a minimum creep rate of 1.0 to 2.0×10^{-4} %/hr or less. Creep rate data may be obtained in the course of stress-rupture testing or may be

obtained on additional specimens. If it can be conclusively demonstrated that creep rate does not control the design stresses, the creep rate data may be sparse in relation to the stress-rupture data. Submission of creep curves for evaluation of creep rate behavior is acceptable and encouraged.

For materials that will be used in welded applications, sufficient time-dependent data shall be provided for weldments and filler metals to allow ASME to assess the properties in comparison with the base material. In the time-dependent range, this includes providing stress-rupture data for specimen tests in excess of 6000 hr at each temperature and for each welding process. In addition, minimum creep rate data on filler metals shall also be provided to rates below 1.0 to 2.0×10^{-4} %/hr.

If adoption at temperatures below room temperature is requested, and if it is desired to take design advantage of increased strength at lower temperatures, data on the time-independent properties shall be provided at 100°F (or 50°C) intervals to and including the lowest intended use temperature.

Notch toughness data shall be provided for materials for which Code toughness rules would be expected to apply. The data shall include test results for the intended lowest service metal temperature and for the range of material thicknesses desired. For welded construction, the notch toughness data shall include the results of Code toughness tests for weld metal and heat-affected zone for weldments made by the intended welding processes.

If the material is to be used in components that operate under external pressure, stress-strain curves (tension or compression) shall be furnished, at 100°F (or 50°C) intervals over the range of design temperatures desired. External pressure charts are based on the early portion (up to 1% strain) of the stress-strain curve. The stress-strain curve (not load versus extension) shall be determined using a Class B-2 or better accuracy extensometer as defined in ASTM E 83. Numerical data, when available, should be submitted. The data should include the original cross-sectional area of the test specimen and stress-strain curves with units marked on them.

If the material is to be used in cyclic service and the construction Code in which adoption is desired requires explicit consideration of cyclic behavior, fatigue data shall also be furnished over the range of design temperatures desired.

In general, for all mechanical properties, data shall be provided from at least three heats of material meeting all of the requirements of a specification for at least one product form for which adoption is desired, for each test at each test temperature. When adoption for both cast and wrought product forms is desired, data from at least three heats each of a wrought and of a cast product form shall be submitted. It is desired that the data represent all product

forms for which adoption is desired. For product forms for which the properties may be size dependent, data from products of different sizes, including the largest size for which adoption is desired, shall be provided.

Test methods employed shall be those referenced in or by the material specifications, or shall be appropriate ASTM test methods or recommended practices for the properties tested.

Information describing service experience in the temperature range contemplated will be useful to the Committee.

Other Properties. The inquirer shall furnish to the Committee adequate data necessary to establish values for coefficient of thermal expansion, thermal conductivity and diffusivity, Young's modulus, shear modulus, and Poisson's ratio, when the construction Code in which adoption is desired requires explicit consideration of these properties. Data shall be provided over the range of temperatures for which the material is to be used.

Weldability. The inquirer shall furnish complete data on the weldability of material intended for welding, including data on procedure qualification tests made in accordance with the requirements of Section IX. Welding tests shall be made over the full range of thickness in which the material is to be used. Pertinent information, such as postweld heat treatment required, susceptibility to air hardening, effect of welding procedure and heat-affected zone and weld metal notch toughness, and the amount of experience in welding the material shall be given.

Physical Changes. For new materials, it is important to know the structural stability characteristics and the degree of retention of properties with exposure at temperature. The influence of fabrication practices, such as forming, welding, and thermal treatment, on the mechanical properties, ductility, and microstructure of the material are important, particularly where degradation in properties may occur. Where particular temperature ranges of exposure or heat treatment, cooling rates, combinations of mechanical working and thermal treatments, fabrication practices, exposure to particular environments, etc., cause significant changes in the mechanical properties, microstructure, resistance to brittle fracture, etc., it is of prime importance to call attention to those conditions that should be avoided in service or in manufacture of parts or vessels from the material.

Requests for Additional Data. The Committee may request additional data, including data on properties or material behavior not explicitly treated in the construction Code in which adoption is desired.

New Materials Checklist. To assist inquirers desiring Code coverage for new materials, or extending coverage of existing materials, the Committee has developed the following checklist of items that ought to be addressed by

each inquiry. The Committee reserves the right to request additional data and application information when considering new materials.

(a) Has a qualified inquirer request been provided?

(b) Has a request either for revision to existing Code requirements or for a Code Case been defined?

(c) Has a letter to ASTM or AWS been submitted requesting coverage of the new material in a specification, and has a copy been submitted to the Committee? Alternatively, is this material already covered by a specification issued by a recognized national or international organization and has an English language version been provided?

(d) Has the construction Code and Division coverage been identified?

(e) Has the material been defined as ferrous or nonferrous and has the application (product forms, size range, and specification) been defined?

(f) Has the range (maximum/minimum) of temperature application been defined?

(g) Has mechanical property data been submitted (ultimate tensile strength, yield strength, reduction of area, and elongation at 100°F or 50°C intervals, from room temperature to 100°F or 50°C above the maximum intended use temperature for three heats of appropriate product forms and sizes)?

(h) If requested temperatures of coverage are above those at which time-dependent properties begin to govern design values, has appropriate time-dependent property data for base metal, weld metal, and weldments been submitted?

(i) If coverage below room temperature is requested, has appropriate mechanical property data below room temperature been submitted?

(j) Have toughness considerations required by the construction Code been defined and has appropriate data been submitted?

(k) Have external pressure considerations been defined and have stress-strain curves been submitted for the establishment of external pressure charts?

(l) Have cyclic service considerations and service limits been defined and has appropriate fatigue data been submitted?

(m) Has physical properties data (coefficient of thermal expansion, thermal conductivity and diffusivity, Young's modulus, shear modulus, Poisson's ratio) been submitted?

(n) Have welding requirements been defined and has procedure qualification test data been submitted?

(o) Has influence of fabrication practices on material properties been defined?

Requirements for Requests for ASME Acceptance of Material Specifications of Recognized National or International Organizations Other Than ASTM or AWS. The Committee will consider only requests for

specifications in the English language and in U.S. or SI/metric units. The Committee will consider accepting specifications of recognized national or international organizations, such as, but not limited to, American Petroleum Institute (API), ASTM, AWS, Canadian Standards Association (CSA), European Committee for Standardization (CEN), and Japanese Standards Association (JIS). Material specifications of other than national or international organizations, such as those of material producers and suppliers, will not be considered for acceptance.

Requirements for Recognized National or International Specifications. Acceptable material specifications will be identified by date or edition. Approved edition(s) will be stated in the subtitle of the ASME specification. Eventually, acceptable previous editions will be listed in Section II, Parts A and B. Minimum requirements that must be contained in a material specification for which acceptance is being requested include such items as name of national or international organization, scope, reference documents, process, manufacture, conditions for delivery, heat treatment, chemical and tensile requirements, forming properties, testing specifications and requirements, workmanship, finish, marking, inspection, and rejection.

Publication of Recognized National or International Specifications. Specifications for which ASME has not been given permission to publish by the originating organization will be referenced on a cover sheet in Section II, Parts A and B. Information on obtaining a copy of those documents will be maintained in Nonmandatory Appendix A of those Parts. Documents that are referenced in accepted national or international material specifications will not be published by ASME. However, information on obtaining a copy of those documents will be maintained in Nonmandatory Appendix A of Section II, Parts A and B. Additions and exceptions to the material specification will be noted in the subtitle of the specification.

CEN Specifications. European standards are adopted by CEN in three official versions (English, French, and German). After the CEN adoption, to become applicable in a member country of CEN, a European standard shall be given the status of a national standard. During this process

(a) the text of the EN standard shall remain unaltered and shall be included as adopted by CEN.

(b) National Forewords and/or Annexes may be added to cover specific national practices, but shall not be in contradiction with the EN standard.

(c) a prefix XX (e.g., XX = BS for United Kingdom, NF for France, and DIN for Germany) is added to the designation of the EN standard (e.g., BS EN 10028-1 and NF EN 10028-1).

(d) the date of adoption as a national standard will differ from the date of adoption as an EN standard and may differ from one country to another.

Written or electronic copies of EN standards can only be obtained from European national standardization bodies as XX EN (CEN does not sell EN standards). Consequently, in order to maintain coherence and homogeneity in the reference system, the mentions in the subtitle of the corresponding ASME specification will refer to the EN standard number without any prefix and to the year of approval by CEN. It shall also be mentioned in the cover sheet that the national parts do not apply for the ASME specification.

Code Case. The Code Committee will consider the issuance of an ASME Code Case, permitting the use of a new material, provided that the following conditions are met:

(a) the inquirer provides evidence that a request for coverage of the material in a specification has been made to ASTM or a recognized national or international organization

(b) the material is commercially available and can be purchased within the proposed specification requirements

(c) the inquirer shows that there will be a reasonable demand for the material by industry and that there exists an urgency for approval by means of a Code Case

(d) the requests for approval of the material shall clearly describe it in specification form, including such items as scope, process, manufacture, conditions for delivery, heat treatment, chemical and tensile requirements, forming properties, testing specifications and requirements, workmanship, finish, marking, inspection, and rejection

(e) all other requirements identified previously under Code Policy and Application apply

(f) the inquirer shall furnish the Code Committee with all the data specified in this Guideline

GUIDELINE ON ACCEPTABLE ASTM EDITIONS

All materials, originating from an ASTM specification, allowed by the various Code Sections and used for construction within the scope of their rules shall be furnished in accordance with the Material Specifications contained within Section II and this guideline except where otherwise provided in Code Cases or in the applicable Section of the Code. Materials covered by these Specifications are acceptable for use in items covered by the Code Sections only to the degree indicated in the applicable Section. Materials for Code use should preferably be ordered, produced, and documented on this basis; however, material produced under an ASTM Specification listed in Table

ED-1 may be used in lieu of the corresponding ASME Specification as listed in this guideline. Material produced to an ASME or ASTM Specification with requirements different from the requirements of the corresponding Specification may also be used in accordance with the above, provided the material manufacturer or vessel manufacturer certifies with evidence acceptable to the Authorized Inspector that the corresponding Specification requirements have been met. This guideline lists the Specifications, originating from ASTM, and their acceptable dates of issue as well as the Book sections of the ASME Boiler Code in which the specification is approved for use.

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(a)

TABLE ED-1

Specifications	Book Section							Nuc. Code Case	Non Nuc. Code Case	Latest Adopted ASTM	Other Acceptable ASTM Editions
	I	III	IV	VIII-1	VIII-2	VIII-3	XII				
SA-6/SA-6M Identical	-General Requirements, Rolled Products					...	...	×	...	07	88c through 07
(a) SA-20/SA-20M Identical	-General Requirements, Plates					×	...	...	×	09	88 through 09
SA-29/SA-29M Identical	-General Requirements, Bars					...	...	...	×	05	88 through 05
SA-31 Identical except that certification is mandatory in 3.1.7, 14, and an editorial change to 3.1.1 of the ordering requirements	×	...	...	...	...	...	...	...	...	04 ^{e1} (R09)	00 through 04 ^{e1} (R09)
SA-36/SA-36M Identical	×	×	×	×	×	...	×	×	×	05	88 through 05
SA-47/SA-47M Identical except for the deletion of welded repair references in 11.2 and 11.3 and mandatory certification in 14.1	...	...	...	×	...	...	...	...	...	99(R09)	84 through 99(R09)
SA-53/SA-53M Identical except for the insertion of test practices in 11.1, and editorial corrections to Table X4.1	×	×	×	×	...	...	×	...	×	01	88a through 01
SA-105/SA-105M Identical	×	×	×	×	×	×	×	×	×	05	87a through 05
(10) SA-106/SA-106M Identical	×	×	×	×	×	×	×	×	×	08	88a through 08
SA-134 Identical except for additional requirement as shown in the specification	...	...	×	...	...	...	...	...	...	96(R05)	85 through 96(R05)

TABLE ED-1 (Cont'd)

Specifications	Book Section							Nuc. Code Case	Non Nuc. Code Case	Latest Adopted ASTM	Other Acceptable ASTM Editions
	I	III	IV	VIII-1	VIII-2	VIII-3	XII				
SA-135 Identical	×	×	×	01	88 through 01
SA-178/SA-178M Identical	×	×	×	×	×	...	×	×	×	95	89 through 95
SA-179/SA-179M Identical	×	×	90a(R05)	88a through 90a(R05)
SA-181/SA-181M Identical	×	×	×	×	×	...	×	×	×	06	87 through 06
SA-182/SA-182M Identical except for the inclusion of Grade F316Ti in 6.3.1. For ASTM editions prior to -07, for Grades F45 and F56, direct or in-process heat treatment is prohibited. For Grades F91 and F911, other acceptable ASTM editions are limited to -05 and later.	×	×	...	×	×	...	×	×	×	07	87a through 07
SA-192/SA-192M Identical	×	...	×	×	×	91	88 through 91
SA-193/SA-193M Identical	...	×	×	×	×	×	×	×	×	07	05 through 07
SA-194/SA-194M Identical. For Grades 2H, 2, 4, 7, and 16, other acceptable ASTM Editions are limited to -03 and later. For Grades 2HM and 7M, other acceptable ASTM Editions are limited to -04 and later.	...	×	×	×	...	07a	87 through 07a
SA-202/SA-202M Identical	×	×	93	82 through 93
SA-203/SA-203M Identical	×	×	...	×	×	...	×	97(R03)	82 through 97(R03)
SA-204/SA-204M Identical	×	×	...	×	×	...	×	×	...	03(R07)	88 through 03(R07)
SA-209/SA-209M Identical	×	×	×	...	×	03(R07)	88 through 03(R07)
SA-210/SA-210M Identical except for editorial differences in Table 2	×	×	×	×	×	...	×	×	×	95	88 through 95
SA-213/SA-213M Identical except for the additional H Grade heat treatment requirements in 6.2 and Grades T23, T24, T91, T911, T92, and T122 are limited to -06a and later.	×	×	×	×	×	...	×	×	×	08	01a through 08
SA-214/SA-214M Identical	×	×	90a	88 through 90a
SA-216/SA-216M Identical except for addition of 2.3 and editorial differences in 2.1 and 10.1	×	×	×	×	×	...	×	×	×	07	84b through 07
SA-217/SA-217M Identical	×	×	...	×	×	...	×	×	×	07	93 through 07
SA-225/SA-225M Identical	×	×	×	×	03(R07)	86 through 03(R07)
SA-231/SA-231M Identical except that certification requirements in 13.1 are mandatory	×	96	...

(10)

TABLE ED-1 (Cont'd)

Specifications	Book Section							Nuc. Code Case	Non Nuc. Code Case	Latest Adopted ASTM	Other Acceptable ASTM Editions
	I	III	IV	VIII-1	VIII-2	VIII-3	XII				
SA-232/SA-232M Identical	×	91	...
SA-234/SA-234M Identical except for Grades WP91 and WP911, other acceptable ASTM editions are limited to - 05 and later.	×	×	...	×	×	...	×	×	×	07	82a through 07
SA-240/SA-240M Identical	×	×	×	×	×	...	×	×	×	04	88c through 04
SA-249/SA-249M Identical except for the deletion of S5, which addresses unstraightened tubes, and S9 is mandatory when 100% joint efficiency is required.	×	×	×	×	×	...	×	×	×	04a	88b through 04a
SA-250/SA-250M Identical except that Supplementary Requirement S1 is mandatory when 100% weld joint efficiency is required.	×	×	×	...	×	05(R09)	88a through 05(R09)
(a) SA-263 Identical	09	88 through 09
(a) SA-264 Identical	09	88 through 09
(a) SA-265 Identical	09	88 through 09
SA-266/SA-266M Identical	×	×	×	×	×	...	×	×	×	03a(R08)	87 through 03a(R08)
SA-268/SA-268M Identical	×	×	...	×	×	...	×	...	×	05a	88b through 05a
SA-275/SA-275M - Magnetic Particle Examination of Forgings Identical except battery powered yokes not permitted prior to -06.	06	86 through 06
SA-276 Identical	×	97	...
SA-278/SA-278M Identical except for an editorial change to 5.1.1 and a change to 16.1 making certification mandatory.	×	×	01(R06)	85 through 01(R06)
SA-283/SA-283M Identical	...	×	...	×	×	...	×	×	...	03(R07)	88 through 03(R07)
SA-285/SA-285M Identical	×	×	×	×	×	...	×	...	×	03(R07)	82(R87) through 03(R07)
SA-299/SA-299M Identical	×	×	...	×	×	...	×	×	...	04	82(R87) through 04
SA-302/SA-302M Identical	×	×	...	×	×	...	×	×	×	03(R07)	82 through 03(R07)
(10) SA-307 Identical except for the deletion of the term "private label distributor" from para. 13.1.1.	...	×	×	×	×	×	...	07b	00 through 07b
SA-311/SA-311M Identical except for the deletion of 5.1.11, revision of Table 1 footnote A, and editorial change to 5.1.9, and 11.1 revised to make certification mandatory.	×	×	04(R10)	90b through 04(R10)

TABLE ED-1 (Cont'd)

Specifications	Book Section							Nuc. Code Case	Non Nuc. Code Case	Latest Adopted ASTM	Other Acceptable ASTM Editions	
	I	III	IV	VIII-1	VIII-2	VIII-3	XII					
SA-312/SA-312M Identical except for the deletion of 5.2, revision to 6.2 to add "H" Grade heat treatment requirements, and editorial differences in 7.1 and Table 1 and an editorial correction to the Cr and Ni percent chemical composition for UNS S31002 in Table 1	x	x	...	x	x	x	x	x	x	01a	88a through 01a	
SA-320/SA-320M Identical except for editorial clarification of exemption of carbide solution treated austenitic material from impact test requirements in 6.2.1.1.	...	x	x	x	x	x	x	x	...	07	01 through 07	(10)
SA-325 Identical except for the deletion of the term "private label distributor" in 15.1 and 15.5	...	x	x	x	...	...	x	x	...	07a	86a through 07a	
SA-333/SA-333M Identical except for the deletion of 12.3 that conflicts with 15	...	x	...	x	x	...	x	x	x	04a	94 through 04a	
SA-334/SA-334M Identical	...	x	...	x	x	...	x	...	...	04a(R10)	88 ^{e1} through 04a(R10)	
SA-335/SA-335M Identical except for the addition of hardness requirements for P23 and P911 in 9.3 and 14.2.1, and the correction of UNS numbers for P9 and P91.	x	x	...	x	x	x	x	x	x	06	88a through 06	
SA-336/SA-336M Identical	x	x	...	x	x	x	x	x	x	07	06a through 07	
SA-350/SA-350M ¹ Identical except for the deletion of 6.1.2 and 14.1, revision to 14.2.5, and test reports have been made mandatory	...	x	...	x	x	...	x	...	x	02b	87 through 02b	
SA-351/SA-351M Identical	x	x	x	x	x	...	x	x	x	00	86 through 00	
SA-352/SA-352M Identical	...	x	...	x	x	...	x	...	x	06	88 through 06	
SA-353/SA-353M Identical	...	x	...	x	x	...	x	...	x	09	87 through 09	(a)
SA-354 Identical except for the deletion of the term "private label distributor" in 15.1 and 15.3.5	...	x	x	x	...	...	x	x	...	07a	86 through 07a	
SA-358/SA-358M Identical except for clarified heat treatment requirements in 6.3.1, the deletion of 6.3.2.2 for HT-O pipe and 6.3.2.3 for HT-SO pipe, an editorial difference in 1.2, and the following additional requirements apply as shown in the specification.	...	x	...	x	...	...	x	x	x	01	88 through 01	
SA-369/SA-369M Identical	x	x	...	x	x	...	x	x	x	06	88 through 06	
SA-370 Identical	- Mechanical Testing of Steel Products					...	...	x	x	05	77 through 05	
SA-372/SA-372M Identical	...	x	...	x	x	x	x	...	x	03(R08)	02 through 03(R08)	
SA-376/SA-376M Identical except for the deletion of HT-O option from 6.2 and 14.1 and clarification of heat treatment requirements in 6.2	x	x	...	x	x	...	x	x	x	06	88 through 06	
SA-387/SA-387M Identical. For Grade 91, acceptable ASTM editions are limited to -06 and later.	x	x	...	x	x	x	x	x	x	06a	88 through 06a	

TABLE ED-1 (Cont'd)

Specifications	Book Section							Nuc. Code Case	Non Nuc. Code Case	Latest Adopted ASTM	Other Acceptable ASTM Editions
	I	III	IV	VIII-1	VIII-2	VIII-3	XII				
SA-388/SA-388M Identical	- Ultrasonic Testing of Forgings				...	...	...	...	×	07	04 through 07
SA-395/SA-395M Identical	...	...	...	×	...	...	×	×	×	99(R09)	80 through 99(R09)
SA-403/SA-403M Identical except for the correction of Table 2 Ni minimum for Grade WP S38815, clarified heat treatment requirements in 6.1 and 6.4, the deletion of 304/304L/304N in 14.5, and the deletion of 5.14 and 5.15. For H Grades, other acceptable ASTM editions are limited to -02 and later.	...	×	...	×	×	...	×	×	×	07	86 through 07
SA-409/SA-409M Identical except for clarified heat treatment requirements for H grade stainless steels and S30815 editorial corrections in 5.3.1 and Tables 1, 2, and 3, deletion of 5.3.2.2 and 5.3.2.3 for the non-heat treated pipe provisions, and the inclusion of a grain size requirement in 5.1.1 for H grade stainless steels. A requirement for ASME Stamping has been added and editorial requirements apply as shown in the subtitle of the specification	...	×	...	×	...	...	×	...	×	95a ^{e1}	88 through 95a ^{e1}
(10) SA-414/SA-414M Identical	...	×	×	×	...	...	×	...	×	07	88 through 07
SA-420/SA-420M Identical	...	×	...	×	×	...	×	...	...	04	85a through 04
SA-423/SA-423M Identical	×	...	...	×	×	...	...	...	...	95(R04)	89 through 95(R04)
SA-426/SA-426M Identical except for a correction to the molybdenum content for Grade CP91 in Table 1.	...	×	...	...	...	...	...	×	...	07	80 through 07
SA-435/SA-435M Identical	- Straight Beam Ultrasonic of Plates				...	...	...	...	...	90(R07)	82(R87) through 90(R07)
SA-437/SA-437M Identical	...	×	...	...	...	...	×	...	...	06	84b through 06
(10) SA-449 Identical except for requiring all mating fastener components to be coated by the same zinc-coating process in 5.1.4 and the deletion of private label distributor in 16.1 and 16.3.2, and removal of reference to bolts in para. 6.4.	...	×	...	×	...	...	×	×	...	07b	87 through 07b
SA-450/SA-450M Identical	- General Requirements for Tubes				...	...	...	...	×	96	88a through 96
SA-451/SA-451M Identical except for editorial differences in 15.1.	...	×	...	...	...	...	...	...	...	06	80(R85) through 06
(a) SA-453/SA-453M Identical except for the requirement contained in para. 5.1 that material and fasteners conform to the chemical requirements in Table 3.	...	×	...	×	...	×	×	×	...	04	00 through 04
SA-455/SA-455M Identical	...	×	×	×	...	...	×	...	×	03(R07)	82(R87) through 03(R07)
SA-476 Identical except for editorial changes in 4.1.6 and 13.1 to make certification mandatory	...	...	...	×	...	...	...	...	...	00(R09)	82 through 00(R09)
SA-479/SA-479M Identical except for editorial changes to Tables 1 and 2.	×	×	×	×	×	×	×	×	×	04	87b through 04

TABLE ED-1 (Cont'd)

Specifications	Book Section							Nuc. Code Case	Non Nuc. Code Case	Latest Adopted ASTM	Other Acceptable ASTM Editions	
	I	III	IV	VIII-1	VIII-2	VIII-3	XII					
SA-480/SA-480M Identical	- General Requirements - Flat Products					...	...	...	...	03c	88 through 03c	
SA-484/SA-484M Identical	- General Requirements Wrought SS Products					...	...	...	...	98	87 through 98	
SA-487/SA-487M Identical	...	×	...	×	×	...	×	×	×	93(R07)	88 through 93(R07)	
SA-494/SA-494M	- See Section II, Part B											
SA-508/SA-508M Identical except for revision prior to -05b. For these A 966/A 966M added to 2.1, 3.1, and 7.2.1 revised to allow A 966 in revisions prior to -05 ^{e1} reference to Notes 2 and 3 in 6.1.2.2 should be 3 and 4 respectively.	...	×	...	×	×	×	×	×	×	05b(R10)	87 through 05b(R10)	
SA-513 Identical except that Supplementary Requirements S6 and either S7 or S8 at the manufacturer's option are mandatory	...	...	×	...	...	...	...	...	...	00	...	
SA-515/SA-515M Identical	×	×	×	×	×	...	×	×	×	03(R07)	82 through 03(R07)	
SA-516/SA-516M Identical. The reference to Footnote B in Table 1 shall apply to the -04, -05, and -05e editions.	×	×	×	×	×	×	×	×	×	06	86 through 06	
SA-517/SA-517M Identical except for Grades A, B, E, F, J, P, and deletion of fusion in 1.1	...	×	...	×	×	×	×	×	...	06	87a ^{e1} through 06	
SA-522/SA-522M Identical	...	×	...	×	×	...	×	...	...	07	87 through 07	
SA-524 Identical	...	×	...	×	×	...	×	×	...	93	88 through 93	
SA-530/SA-530M Identical	- General Requirements for Pipe					...	...	...	...	99	88a through 99	
SA-533/SA-533M Identical	...	×	...	×	×	×	×	×	...	09	87 through 09	(a)
SA-537/SA-537M Identical	...	×	...	×	×	...	×	...	×	08	86 through 08	(a)
SA-540/SA-540M Identical	...	×	...	×	×	...	×	×	...	06	84a through 06	(10)
SA-541/SA-541M Identical	...	×	...	×	×	×	×	×	×	05(R10)	...	
SA-542/SA-542M Identical	...	...	...	×	×	...	...	×	×	09	88 through 09	(a)
SA-543/SA-543M Identical	...	...	...	×	×	×	...	...	...	09	87 through 09	(a)

TABLE ED-1 (Cont'd)

Specifications	Book Section							Nuc. Code Case	Non Nuc. Code Case	Latest Adopted ASTM	Other Acceptable ASTM Editions
	I	III	IV	VIII-1	VIII-2	VIII-3	XII				
SA-553/SA-553M Identical	...	×	...	×	×	...	×	...	×	06	87b through 06
SA-556/SA-556M Identical	...	...	...	×	...	...	×	...	...	90a(R95) ^{e1}	88 through 90a(R95) ^{e1}
SA-557/SA-557M Identical	...	...	...	×	...	...	×	...	...	90a	88 through 90a
SA-562/SA-562M Identical	...	...	...	×	...	...	×	...	...	06	82(R87) through 06
SA-563 Identical except for deletion of the term "private label distributor" in paras. 14.7 and 14.9 and editorially corrected title.	...	...	...	×	×	...	...	×	...	07a	84 through 07a
SA-564/SA-564M Identical	...	×	...	×	...	×	×	×	...	04(R09)	87b through 04(R09)
(10) SA-568/SA-568M Identical	- General Requirements for Steel Sheet					...	...	...	...	07a	02 through 07a
SA-572/SA-572M Identical	...	...	...	...	...	...	×	...	...	06	01 through 06
SA-574 Identical except that Table 1 on chemical requirements has been deleted and Supplementary Requirement S1 is now mandatory. Paragraphs 6.1 and 6.2 have been revised to refer to Table S1.1 and 6.3 has been deleted.	...	×	...	×	...	...	×	×	...	04 ^{e1}	97a through 04 ^{e1}
SA-577/SA-577M Identical	- Ultrasonic Angle Beam of Plates					...	...	...	...	90(R07)	86 through 90(R07)
SA-578/SA-578M Identical	- Ultrasonic Straight Beam of Plates					...	...	...	...	07	85 through 07
SA-587 Identical except for deletion of 1.5	...	×	...	×	...	...	×	...	...	93	88 through 93
SA-592/SA-592M Identical	...	×	...	×	×	...	×	×	...	04(R09)	85 through 04(R09)
SA-609/SA-609M Identical	- Ultrasonic Longitudinal Beam - Castings					...	...	...	...	91(R07)	83 through 91(R07)
SA-612/SA-612M Identical	...	×	...	×	...	...	×	...	...	03(R07)	87 through 03(R07)
SA-638/SA-638M Identical except for an editorial correction in 6.2	...	×	...	...	...	×	...	×	×	00(R04)	87 through 00(R04)
SA-645/SA-645M Identical	...	...	...	×	×	...	×	...	×	05	87(R91) through 05
SA-649/SA-649M Identical	...	...	...	...	...	...	...	...	×	04	91a through 04
SA-656/SA-656M Identical	...	...	...	...	...	...	...	×	...	00a	...

TABLE ED-1 (Cont'd)

Specifications	Book Section							Nuc. Code Case	Non Nuc. Code Case	Latest Adopted ASTM	Other Acceptable ASTM Editions
	I	III	IV	VIII-1	VIII-2	VIII-3	XII				
SA-660 Identical	×	×	96(R10)	88 through 96(R10)
SA-662/SA-662M Identical	×	×	...	×	03(R07)	86 through 03(R07)
SA-666 Identical	×	03	90 through 03
SA-667/SA-667M Identical	×	87(R08)	...
SA-671 Identical except for additional requirements that apply as shown in Specification	...	×	×	94	85 through 94
SA-672 Identical except for the deletion of pipe Grade K. The additional requirements apply as shown in the Specification.	...	×	94	81 through 94
SA-675/SA-675M Identical except that Supplementary S7 is mandatory and Grades 65 [450] and 70 [485] have been added to S7. Certification is mandatory.	×	×	×	×	×	...	×	×	...	03 ^{e1} (R09)	...
SA-688/SA-688M Identical except that in the case of the -96 and -98 ASTM revisions, solution treatment of Grade UNS N08367 is mandatory	...	×	...	×	×	...	×	04	88a through 04
SA-691 Identical except that the additional requirements apply as shown in the Specification	...	×	×	...	98(R07)	85a through 98(R07)
SA-693 Identical except for aligning the elongation requirements for Gr. XM-16 and correction of the max. hardness for Gr. XM-12 and 630 in Table 5. Also a revision to Note B of Table 1.	...	×	02 ^{e1}	88 through 02 ^{e1}
SA-695 Identical for Type B only	...	×	...	×	×	90b	84 through 90b
SA-696 Identical	...	×	90a(R06)	85 through 90a(R06)
SA-703/SA-703M Identical	- General Requirements for Castings					...	...	...	...	07	87b through 07
SA-705/SA-705M Identical	...	×	×	×	×	...	95(R09)	87a through 95(R09)
SA-723/SA-723M Identical except that for Class 2a the minimum elongation shall be 13.5%.	...	×	×	×	02	...
SA-724/SA-724M Identical	×	×	×	×	09	88 through 09
SA-727/SA-727M Identical	...	×	...	×	×	...	×	02(R07)	...
SA-731/SA-731M Identical except for an editorial correction in Table 2	×	×	91	88 through 91
SA-736/SA-736M Identical	03(R07)	88 through 03(R07)

(a)

TABLE ED-1 (Cont'd)

	Specifications	Book Section						Nuc. Code Case	Non Nuc. Code Case	Latest Adopted ASTM	Other Acceptable ASTM Editions	
		I	III	IV	VIII-1	VIII-2	VIII-3					XII
(a)	SA-737/SA-737M Identical	...	×	...	×	×	...	×	...	...	09	87(R91) thru 09
(a)	SA-738/SA-738M Identical	...	×	...	×	×	×	×	...	×	07	87a through 07
	SA-739 Identical	...	×	...	×	×	...	...	...	...	90a(R06)	81a through 90a(R06)
	SA-745/SA-745M Identical except for deletion of 1.5	- Ultrasonic of Stainless Steel Forgings					...	...	...	...	94(R09)	...
	SA-747/SA-747M Identical except for the revision of the mandatory ordering requirements of 4.1.6 and the mandatory use of Supplementary Requirement S15 of SA-781/SA-781M	...	...	...	×	...	...	...	...	...	04	86 through 04
	SA-748/SA-748M Identical	...	...	...	×	...	...	...	...	...	87(R08)	...
	SA-749/SA-749M Identical	- General Requirements for Steel Strip					...	...	...	...	97(R02)	...
	SA-751 Identical except for editorial corrections to an element designation in Tables 1 and 2	- Chemical Analysis Test Methods for Steel					...	...	...	...	01(R06)	89a through 01(R06)
	SA-765/SA-765M Identical	...	...	...	×	×	...	×	...	...	01	94 through 01
(a)	SA-770/SA-770M Identical except for editorial correction to Table 2	- Tension Testing of Steel Plates					...	...	...	×	03(R07)	86(R90) ^{e1} through 03(R07)
	SA-781/SA-781M Identical	- Common Requirements for Castings					...	...	...	...	06	87a through 06
	SA-788 Identical	- General Requirements for Forgings					...	...	...	...	06	05c through 06
	SA-789/SA-789M Identical except that the sulfur content for S32808 in Table 1 is corrected to 0.010.	...	...	...	×	...	...	×	...	×	05b	88a through 05b
	SA-790/SA-790M Identical except that the sulfur content for S32808 in Table 2 is corrected to 0.010.	...	...	...	×	...	...	×	...	×	08	88 through 08
	SA-803/SA-803M Identical	...	...	...	×	×	...	×	...	...	03	96 through 03
	SA-813/SA-813M Identical except for the addition of grain size requirements for H grades and S30815, the deletion of heat treat omitted options, and adding a minimum heat treat temperature for S30815.	...	×	...	×	×	...	×	...	...	01(R05)	88a through 01(R05)
	SA-814/SA-814M Identical	...	×	...	×	×	...	×	...	...	05	88a through 05
	SA-815/SA-815M Identical except for the deletion of 5.14 and 5.15.	...	...	...	...	...	...	×	...	...	08	86 through 08
	SA-832/SA-832M Identical	...	...	...	×	×	×	...	...	...	06	84(R89) through 06

TABLE ED-1 (Cont'd)

Specifications	Book Section							Nuc. Code Case	Non Nuc. Code Case	Latest Adopted ASTM	Other Acceptable ASTM Editions
	I	III	IV	VIII-1	VIII-2	VIII-3	XII				
SA-834 Identical	- Common Requirements for Iron Castings					...	...	...	...	95(R06)	84 through 95(R06)
SA-836/SA-836M Identical	...	...	...	×	...	...	×	...	×	02(R07)	...
SA-841/SA-841M Identical	...	...	...	...	...	...	...	...	...	03a(R07)	88 through 03a(R07)
SA-905 Identical	...	...	...	...	...	×	...	...	...	93	91 through 93
SA-941 Identical	...	...	...	...	...	...	...	...	...	06a	99b through 06a
SA-960/SA-960M Identical	...	...	...	...	...	...	...	...	...	07	99b through 07
SA-961/SA-961M Identical except for the deletion of the time requirement for purchaser rejection of material in para. 18.1	...	...	...	...	...	...	...	...	...	07	99 through 07
SA-962/SA-962M Identical	...	...	...	...	...	...	...	...	...	07	99 through 07
SA-965/SA-965M Identical	x	x	...	x	...	x	x	x	x	06a	...
SA-985/SA-985M Identical	- General Requirements, castings				...	...	...	...	...	04a	03 through 04a
SA-995 Identical	...	...	...	...	...	...	...	×	×	98(R07)	...
SA-999/SA-999M Identical except for the editions prior to 04a, para. 6.2.1 on grade substitution of the 04a edition applies.	- General Requirements, Pipes				...	...	...	...	...	04a(R09)	01 through 04a(R09)
SA-1008/SA-1008M Identical except for the addition of 8.1.1.1 on mechanical properties for pressure vessel design	...	...	...	×	...	...	×	...	...	01a	00 through 01a
SA-1010/SA-1010M Identical except for an editorial correction to a column heading in Table 2.	...	...	...	...	...	...	...	...	...	01 ^{e1} (R09)	...
SA-1011/SA-1011M Identical	...	...	...	...	...	...	...	...	...	06b	01a through 06b
SA-1016/SA-1016M Identical	- General Requirements, Tubes					...	...	...	...	04a	01 through 04a
SA-1017/SA-1017M Identical. For Grade 122, acceptable editions 07 and later.	...	...	...	...	...	...	...	...	×	07	01 through 07
SF-568M Identical	- Threaded Metric Fasteners				...	...	...	...	...	98	93a through 98

NOTE:

- (1) SA-350/SA-350M Grade LF2 forgings, made to revisions earlier than the 2001 ASME Boiler and Pressure Vessel Code, or to ASTM Specification A 350/A 350M with year dates from 1987 through 1997 are acceptable for either Class 1 or Class 2 applications, unless Supplementary Requirement S4 was used to test forgings at a higher test temperature.

GUIDELINE ON ACCEPTABLE NON-ASTM EDITIONS

All materials originating from a non-ASTM Specification allowed by the various Code Sections and used for construction within the scope of their rules shall be furnished in accordance with the Material Specifications contained within Section II and this guideline except where otherwise provided in Code Cases or in the applicable Section of the Code. Materials covered by these Specifications are acceptable for use in items covered by the Code Sections only to the degree indicated in the applicable Section. Materials for Code use should preferably be ordered, produced, and documented on this basis; however, material produced under a non-ASTM Specification listed in Table ED-2 may be used in lieu of the corresponding

ASME Specification as listed in this Appendix. Material produced to an ASME or a non-ASTM Specification with requirements different from the requirements of the corresponding Specification may also be used in accordance with the above, provided the material manufacturer or vessel manufacturer certifies with evidence acceptable to the Authorized Inspector that the corresponding Specification requirements have been met. This guideline lists the non-ASTM Specifications, originating not from ASTM and their acceptable dates of issue as well as the Book sections of the ASME Boiler Code in which the specification is approved for use.

(10)
(a) **TABLE ED-2**

	Specifications	Book Section						Nuc. Code Case	Non Nuc. Code Case	Latest Adopted	Other Acceptable Editions
		I	III	IV	VIII-1	VIII-2	VIII-3				
(a)	SA/AS-1548 Identical except for marking as shown in the specification.	×	...	...	×	...	...	...	...	2008	2008
	SA/CSA-G40.21 Identical except for marking as shown in the specification.	...	...	...	×	...	...	×	...	2004	Only 1992 and 2004
(a)	SA/EN 10028-2 Identical except for marking, tension test and quality as shown in the specification. For Grade 13CrMo4-5, other acceptable editions is limited to 2009.	×	...	...	×	...	...	×	...	2009	2003 through 2009
(10) (a)	SA/EN 10028-3 Identical except for marking and quality as shown in the specification.	...	...	...	×	...	...	×	...	2009	2003 through 2009
	SA/EN 10028-7 Identical except for marking as shown in the specification.	...	...	...	×	...	...	...	...	2007	2000 through 2007
	SA/GB 6654 Identical except for marking as shown in the specification.	...	...	...	×	...	...	...	...	1996	1996
(a)	SA/JIS G3118 Identical except for marking, mechanical properties and welding repairs as shown in the specification. Annex, supplementary quality requirements, does not apply.	×	...	...	...	...	...	...	...	2005	2000 through 2005
	SA/JIS G4303 Identical except for marking, mechanical properties and welding repairs as shown in the specification. Annex, supplementary quality requirements, does not apply.	×	...	...	...	...	...	...	...	1998	1998

GENERAL NOTE: The date of publication of the European standards considered in this Guideline is the year of approval of the standard by CEN. This date appears in the body of the standard on the page starting with EN; dates appearing on the front page of an XX EN standard (e.g., XX = BS or NF or DIN) correspond only to the date of adoption by each member country.

GUIDELINES ON MULTIPLE MARKING OF MATERIALS

BACKGROUND

A common inquiry topic is the permissibility of using material that is identified with two or more specifications (or grades, classes, or types), even if they have different strengths, or even if one of them is not permitted for use in the construction code of application. The Committee has addressed variants of these questions in several interpretations: I-89-11, IIA-92-08, VIII-1-89-269, and VIII-1-89-197.

GUIDELINES

The construction codes individually define what materials may be used in boilers, vessels, and components constructed in compliance to their rules. If a material meets all of the requirements for a specification for which it is marked, including documentation, if any, and if it meets all requirements for use imposed by the construction code, it may be used. The construction codes, in general, do not address the case of materials marked with more than one specification, grade, class, or type, so these guidelines are offered for clarification.

ACCEPTABILITY OF MULTIPLE MARKING

Dual or multiple marking is acceptable, as long as the material so marked meets all of the requirements of all the specifications, grades, classes, and types with which it is marked.

All of the measured and controlled attributes of the multiply-marked grades or specifications must overlap (e.g., chemistry, mechanical properties, dimensions, and tolerances) and the material so marked must exhibit values that fall within the overlaps. Further, the controlled but unmeasured attributes of the specifications or grades must overlap (e.g., melting practices, heat treatments, and inspection.)

Many specifications or grades have significant overlap of chemistry ranges or properties. It is common for material manufacturers to produce materials that satisfy more than

one specification, grade, class, or type. Examples are SA-53 and SA-106 (some grades and classes); SA-213 TP304L and TP304; SA-213 TP304 and 304H; and SA-106 B and SA-106 C.

PROHIBITION ON MULTIPLE MARKING

Dual or multiple marking is not acceptable if two or more specifications to which the material is marked have mutually exclusive requirements.

This prohibition includes more than just chemistry and property requirements. Examples are SA-515 and SA-516; the former requires melting to coarse grain practice while the latter requires melting to fine grain practice. Another example is SA-213 TP304L and TP304H; the carbon content ranges of these grades have no overlap.

GRADE SUBSTITUTION

Grade substitution is not permitted. Grade substitution occurs when: (1) the material contains an element (other than nitrogen) that is unspecified for one of the grades marked; and (2) the amount of that element present in the material meets the minimum and maximum composition limits for that element in another grade of a specification contained in Section II, Part A or Part B, whether or not it is also so marked.

For example, a material meets all of the composition limits for SA-240 304, contains 0.06C and 0.02N, but also contains 0.45% Ti. This material cannot be marked or provided as meeting SA-240 304 because the Ti content meets the requirements of SA-240 321 [which is, Ti greater than $5 \times (C + N)$ but less than 0.7.].

Another material, with identical composition, except 0.35% Ti, may be marked SA-240 304 because the Ti content does not meet the minimum requirement for 321. The Ti content is just a residual.

MARKING SELECTION

If a material is marked with specifications, grades, classes, or types, it may be used with the allowable stresses,

design stress intensities, or ratings appropriate for any of the markings on the material, as long as the material specification, grade, class, and type is permitted by the code of construction governing the boiler, vessel, or component in which the material is to be used. However, once the designer has selected which marking applies (specification, grade, class types, etc.), the designer must use all the design values appropriate for that selection and may not mix and match values from any other specifications, grades, classes, types, etc., with which the material may be marked.

OTHER MARKINGS

Any other markings, such as marking of non-ASME or non-ASTM material specifications, have no relevance, even if those markings are for materials explicitly prohibited by the construction code being used. That is, as long as the *one* marking, and the documentation required by the material and by the construction code, shows that it meets all the requirements for use of that material in that construction code, any additional markings are irrelevant.

SUMMARY OF CHANGES

The 2011 Code, which includes Addenda changes, is being issued in its entirety. While the pages of the Code are printed in loose-leaf format for the users' convenience, it is advisable that the existing 2010 pages be retained for reference. The next Edition of the Code will be published in 2013.

A Special Notice may be posted on the ASME Web site in advance of the next edition of the Boiler and Pressure Vessel Code to provide approved revisions to Code requirements. Such revisions may be used on the date posted and will become mandatory 6 months after the date of issuance in the next edition. A Special Notice may also include a revision to a Code Case. The superseded version of the Code Case shall not be used.

Errata to the BPV Code may be posted on the ASME Web site to provide corrections to incorrectly published items, or to correct typographical or grammatical errors in BPV Codes. Such errata shall be used on the date posted.

Information regarding Special Notices and Errata is published on the ASME Web site under the Boiler and Pressure Vessel Code Resources Page at <http://www.asme.org/kb/standards/publications/bpvc-resources>.

Changes in this Addenda, given below, are identified on the pages by a margin note, **(a)**, placed next to the affected area. Revisions to the 2010 Edition are indicated by **(10)**. For the listing below, the *Page* references the affected area. A margin note, **(a)**, placed next to the heading indicates *Location*. Revisions are listed under *Change*.

The Record Numbers listed below are explained in more detail in "List of Changes in Record Number Order" following the Summary of Changes.

<i>Page</i>	<i>Location</i>	<i>Change (Record Number)</i>
xi, xii	Foreword	Tenth and fourteenth paragraphs revised
xiii	Statement of Policy on the Use of the Certification Mark and Code Authorization in Advertising	Revised
xiii	Statement of Policy on the Use of the Certification Mark and Code Authorization in Advertising	Revised
xiv, xv	Submittal of Technical Inquiries to the Boiler and Pressure Vessel Committee — Mandatory	Editorially revised
xvi–xviii	Personnel	Updated
xxix	ASTM Personnel	Updated to reflect 2011 Addenda
xliv–liii	Guideline on Acceptable ASTM Editions	Updated to reflect 2011 Addenda

<i>Page</i>	<i>Location</i>	<i>Change (Record Number)</i>
liv	Guideline on Acceptable Non-ASTM Editions	Updated to reflect 2011 Addenda
83–124	SA-20/SA-20M	Revised in its entirety (10-1171)
393–399	SA-263	Revised in its entirety (10-1172)
401–407	SA-264	Revised in its entirety (10-1173)
409–415	SA-265	Revised in its entirety (10-1174)
591–595	SA-353/SA-353M	(1) Title revised (10-1175) (2) Revised in its entirety (10-1175)
811–817	SA-453/SA-453M	(1) Title revised (07-911) (2) Revised in its entirety (07-911)
937	SA-516/SA-516M	Table 1 Note (b) corrected by errata (10-479)
971–976	SA-533/SA-533M	Revised in its entirety (10-1176)
977–981	SA-537/SA-537M	Revised in its entirety (10-1177)
1001–1005	SA-542/SA-542M	Revised in its entirety (10-1178)
1007–1009	SA-543/SA-543M	Revised in its entirety (10-1179)
1275–1278	SA-724/SA-724M	Revised in its entirety (10-1181)
1297–1299	SA-737/SA-737M	Revised in its entirety (10-1182)
1301–1306	SA-738/SA-738M	Revised in its entirety (07-748)
1351–1358	SA-770/SA-770M	Revised in its entirety (07-1105)
1633	SA/AS 1548	Subtitle revised (08-1531)
1637	SA/EN 10028-2	(1) Subtitle revised (09-1680) (2) Paragraph 1.1 revised (09-1680)
1639	SA/EN 10028-3	(1) Subtitle revised (09-1681) (2) Paragraph 1.1 revised (09-1681)
1645	SA/JIS G3118	Revised in its entirety (09-1104)

NOTE:

Volume 61 of the Interpretations to Section II, Part A, of the ASME Boiler and Pressure Vessel Code follows the last page of this Addenda to Section II, Part A.

LIST OF CHANGES IN RECORD NUMBER ORDER

Record Number	Change
07-748	Updated SA-738/SA-738M to later (2007) version of ASTM A 738/A 738M.
07-911	Updated SA-453/SA 453M to later (2004) version of ASTM A 453/A 453M with the additional requirement contained in 5.1 that materials and fasteners shall conform to Table 3, Chemical Requirements.
07-1105	Updated SA-770/SA-770M to later [2003(R07)] version of ASTM A 770/A 770M.
08-1531	Updated SA/AS 1548 edition year on the title page and in Table ED-2.
09-1104	Updated cover sheet for SA/JIS G3118 to later (2005) edition of JIS G3118
09-1680	Updated cover sheet for SA/EN 10028-2 to later (2009) edition of EN 10028-2.
09-1681	Marked plates for which normalizing has been replaced by normalizing rolling with “+NR” instead of “+N.”
	Updated cover sheet for SA/EN 10028-3 to later (2009) edition of EN 10028-3.
10-479	Marked plates for which normalizing has been replaced by normalizing rolling with “+NR” instead of “+N.”
	Errata to correct footnote (b) in Table 3 of SA-516/SA-516M.
10-1171	Updated SA-20/SA-20M to later (2009) version of ASTM A 20/A 20M.
10-1172	Updated SA-263/SA-263M to later (2009) version of ASTM A 263/A 263M.
10-1173	Updated SA-264/SA-264M to later (2009) version of ASTM A 264/A 264M.
10-1174	Updated SA-265/SA-265M to later (2009) version of ASTM A 265/A 265M.
10-1175	Updated SA-353/SA-353M to later (2009) version of ASTM A 353/A 353M.
10-1176	Updated SA-533/SA-533M to later (2009) version of ASTM A 533/A 533M.
10-1177	Updated SA-537/SA-537M to later (2008) version of ASTM A 537/A 537M.
10-1178	Updated SA-542/SA-542M to later (2009) version of ASTM A 542/A 542M.
10-1179	Updated SA-543/SA-543M to later (2009) version of ASTM A 543/A 543M.
10-1181	Updated SA-724/SA-724M to later (2009) version of ASTM A 724/A 724M.
10-1182	Updated SA-737/SA-737M to later (2009) version of ASTM A 737/A 737M.

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SPECIFICATION FOR GENERAL REQUIREMENTS FOR ROLLED STRUCTURAL STEEL BARS, PLATES, SHAPES, AND SHEET PILING



SA-6/SA-6M



(Identical with ASTM Specification A 6/A 6M-07.)

1. Scope

1.1 This general requirements specification covers a group of common requirements that, unless otherwise specified in the applicable product specification, apply to rolled structural steel bars, plates, shapes, and sheet piling covered by each of the following product specifications issued by ASTM:

ASTM Designation	Title of Specification
A 36/A 36M	Carbon Structural Steel
A 131/A 131M	Structural Steel for Ships
A 242/A 242M	High-Strength Low-Alloy Structural Steel
A 283/A 283M	Low and Intermediate Tensile Strength Carbon Steel Plates
A 328/A 328M	Steel Sheet Piling
A 514/A 514M	High-Yield Strength, Quenched and Tempered Alloy Steel Plate Suitable for Welding
A 529/A 529M	High-Strength Carbon-Manganese Steel of Structural Quality
A 572/A 572M	High-Strength Low-Alloy Columbium-Vanadium Steel
A 573/A 573M	Structural Carbon Steel Plates of Improved Toughness
A 588/A 588M	High-Strength Low-Alloy Structural Steel with 50 ksi (345 MPa) Minimum Yield Point to 4 in. [100 mm] Thick
A 633/A 633M	Normalized High-Strength Low-Alloy Structural Steel Plates
A 656/A 656M	Hot-Rolled Structural Steel, High-Strength Low-Alloy Plate with Improved Formability
A 678/A 678M	Quenched-and-Tempered Carbon and High-Strength Low-Alloy Structural Steel Plates
A 690/A 690M	High-Strength Low-Alloy Steel H-Piles and Sheet Piling for Use in Marine Environments

ASTM Designation	Title of Specification
A 709/A 709M	Carbon and High-Strength Low-Alloy Structural Steel Shapes, Plates, and Bars and Quenched-and-Tempered Alloy Structural Steel Plates for Bridges
A 710/A 710M	Age-Hardening Low-Carbon Nickel-Copper-Chromium-Molybdenum-Columbium Alloy Structural Steel Plates
A 769/A 769M	Carbon and High-Strength Electric Resistance Welded Steel Structural Shapes
A 786/A 786M	Rolled Steel Floor Plates
A 808/A 808M	High-Strength Low-Alloy Carbon, Manganese, Columbium, Vanadium Steel of Structural Quality with Improved Notch Toughness
A 827/A 827M	Plates, Carbon Steel, for Forging and Similar Applications
A 829/A 829M	Plates, Alloy Steel, Structural Quality
A 830/A 830M	Plates, Carbon Steel, Structural Quality, Furnished to Chemical Composition Requirements
A 852/A 852M	Quenched and Tempered Low-Alloy Structural Steel Plate with 70 ksi [485 MPa] Minimum Yield Strength to 4 in. [100 mm] Thick
A 857/A 857M	Steel Sheet Piling, Cold Formed, Light Gage
A 871/A 871M	High-Strength Low Alloy Structural Steel Plate with Atmospheric Corrosion Resistance
A 913/A 913M	Specification for High-Strength Low-Alloy Steel Shapes of Structural Quality, Produced by Quenching and Self-Tempering Process (QST)
A 945/A 945M	Specification for High-Strength Low-Alloy Structural Steel Plate with Low Carbon and Restricted Sulfur

ASTM Designation	Title of Specification
	for Improved Weldability, Formability, and Toughness
A 950/A 950M	Specification for Fusion Bonded Epoxy-Coated Structural Steel H-Piles and Sheet Piling
A 992/A 992M	Specification for Steel for Structural Shapes for Use in Building Framing
A 1026	Specification for Alloy Steel Structural Shapes for Use in Building Framing
A 1043/A 1043M	Specification for Structural Steel with Low Yield to Tensile Ratio for Use in Buildings

1.2 Annex A1 lists permitted variations in dimensions and mass (Note 1) in SI units. The values listed are not exact conversions of the values in Tables 1 to 31 inclusive but are, instead, rounded or rationalized values. Conformance to Annex A1 is mandatory when the “M” specification designation is used.

NOTE 1 — The term “weight” is used when inch-pound units are the standard; however, under SI, the preferred term is “mass.”

1.3 Annex A2 lists the dimensions of some shape profiles.

1.4 Appendix X1 provides information on coil as a source of structural products.

1.5 Appendix X2 provides information on the variability of tensile properties in plates and structural shapes.

1.6 Appendix X3 provides information on weldability.

1.7 Appendix X4 provides information on cold bending of plates, including suggested minimum inside radii for cold bending.

1.8 This general requirements specification also covers a group of supplementary requirements that are applicable to several of the above product specifications as indicated therein. Such requirements are provided for use where additional testing or additional restrictions are required by the purchaser, and apply only where specified individually in the purchase order.

1.9 In case of any conflict in requirements, the requirements of the applicable product specification prevail over those of this general requirements specification.

1.10 Additional requirements that are specified in the purchase order and accepted by the supplier are permitted, provided that such requirements do not negate any of the requirements of this general requirements specification or the applicable product specification.

1.11 For purposes of determining conformance with this general requirements specification and the applicable product specification, values are to be rounded to the nearest unit in the right-hand place of figures used in expressing

the limiting values in accordance with the rounding method of Practice E 29.

1.12 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system is to be used independently of the other, without combining values in any way.

1.13 This general requirements specification and the applicable product specification are expressed in both inch-pound units and SI units; however, unless the order specifies the applicable “M” specification designation (SI units), the structural product is furnished to inch-pound units.

1.14 The text of this general requirements specification contains notes and/or footnotes that provide explanatory material. Such notes and footnotes, excluding those in tables and figures, do not contain any mandatory requirements.

2. Referenced Documents

2.1 ASTM Standards:

- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 673/A 673M Specification for Sampling Procedure for Impact Testing of Structural Steel
- A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Shipment
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- A 829/A 829M Specification for Alloy Structural Steel Plates
- A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E 112 Test Methods for Determining Average Grain Size
- E 208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels

2.2 American Welding Society Standards:

- A5.1 Mild Steel Covered Arc-Welding Electrodes
- A5.5 Low-Alloy Steel Covered Arc-Welding Electrodes

2.3 U.S. Military Standards:

- MIL-STD-129 Marking for Shipment and Storage
- MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage

2.4 U.S. Federal Standard:

- Fed. Std. No. 123 Marking for Shipments (Civil Agencies)

2.5 AIAG Standard:

- AIAG B-1 Bar Code Symbology Standard

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 Plates (other than floor plates) — Flat, hot-rolled steel, ordered to thickness or weight [mass] and typically width and length, commonly classified as follows:

3.1.1.1 When Ordered to Thickness:

(1) Over 8 in. [200 mm] in width and 0.230 in. [6 mm] or over in thickness.

(2) Over 48 in. [1200 mm] in width and 0.180 in. [4.5 mm] or over in thickness.

3.1.1.2 When Ordered to Weight [Mass]:

(1) Over 8 in. [200 mm] in width and 9.392 lb/ft² [47.10 kg/m²] or heavier.

(2) Over 48 in. [1200 mm] in width and 7.350 lb/ft² [35.32 kg/m²] or heavier.

3.1.1.3 Discussion — Steel products are available in various thickness, width, and length combinations depending upon equipment and processing capabilities of various manufacturers and processors. Historic limitations of a product based upon dimensions (thickness, width, and length) do not take into account current production and processing capabilities. To qualify any product to a particular product specification requires all appropriate and necessary tests be performed and that the results meet the limits prescribed in that product specification. If the necessary tests required by a product specification cannot be conducted, the product cannot be qualified to that specification. This general requirement standard contains permitted variations for the commonly available sizes. Permitted variations for other sizes are subject to agreement between the customer and the manufacturer or processor, whichever is applicable.

3.1.1.4 Slabs, sheet bars, and skelp, though frequently falling in the foregoing size ranges, are not classed as plates.

3.1.1.5 Coils are excluded from qualification to the applicable product specification until they are decoiled, leveled or straightened, formed (if applicable), cut to length, and, if required, properly tested by the processor in accordance with ASTM specification requirements (see Sections 9, 10, 11, 12, 13, 14, 15, 18, and 19 and the applicable product specification).

3.1.2 Shapes (Flanged Sections):

3.1.2.1 structural-size shapes — rolled flanged sections having at least one dimension of the cross section 3 in. [75 mm] or greater.

3.1.2.2 bar-size shapes — rolled flanged sections having a maximum dimension of the cross section less than 3 in. [75 mm].

3.1.2.3 “W” shapes — doubly-symmetric, wide-flange shapes with inside flange surfaces that are substantially parallel.

3.1.2.4 “HP” shapes — are wide-flange shapes generally used as bearing piles whose flanges and webs are of the same nominal thickness and whose depth and width are essentially the same.

3.1.2.5 “S” shapes — doubly-symmetric beam shapes with inside flange surfaces that have a slope of approximately 16²/₃%.

3.1.2.6 “M” shapes — doubly-symmetric shapes that cannot be classified as “W,” “S,” or “HP” shapes.

3.1.2.7 “C” shapes — channels with inside flange surfaces that have a slope of approximately 16²/₃%.

3.1.2.8 “MC” shapes — channels that cannot be classified as “C” shapes.

3.1.2.9 “L” shapes — shapes having equal-leg and unequal-leg angles.

3.1.3 sheet piling — rolled steel sections that are capable of being interlocked, forming a continuous wall when individual pieces are driven side by side.

3.1.4 bars — rounds, squares, and hexagons, of all sizes; flats ¹³/₆₄ in. (0.203 in.) and over [over 5 mm] in specified thickness, not over 6 in. [150 mm] in specified width; and flats 0.230 in. and over [over 6 mm] in specified thickness, over 6 to 8 in. [150 to 200 mm] inclusive, in specified width.

3.1.5 exclusive — when used in relation to ranges, as for ranges of thickness in the tables of permissible variations in dimensions, is intended to exclude only the greater value of the range. Thus, a range from 60 to 72 in. [1500 to 1800 mm] exclusive includes 60 in. [1500 mm], but does not include 72 in. [1800 mm].

3.1.6 rimmed steel — steel containing sufficient oxygen to give a continuous evolution of carbon monoxide during solidification, resulting in a case or rim of metal virtually free of voids.

3.1.7 semi-killed steel — incompletely deoxidized steel containing sufficient oxygen to form enough carbon monoxide during solidification to offset solidification shrinkage.

3.1.8 capped steel — rimmed steel in which the rimming action is limited by an early capping operation. Capping is carried out mechanically by using a heavy metal cap on a bottle-top mold or chemically by an addition of aluminum or ferrosilicon to the top of the molten steel in an open-top mold.

3.1.9 killed steel — steel deoxidized, either by addition of strong deoxidizing agents or by vacuum treatment, to reduce the oxygen content to such a level that no reaction occurs between carbon and oxygen during solidification.

3.1.10 mill edge — the normal edge produced by rolling between horizontal finishing rolls. A mill edge does

not conform to any definite contour. Mill edge plates have two mill edges and two trimmed edges.

3.1.11 universal mill edge — the normal edge produced by rolling between horizontal and vertical finishing rolls. Universal mill plates, sometimes designated UM Plates, have two universal mill edges and two trimmed edges.

3.1.12 sheared edge — the normal edge produced by shearing. Sheared edge plates are trimmed on all edges.

3.1.13 gas cut edge — the edge produced by gas flame cutting.

3.1.14 special cut edge — usually the edge produced by gas flame cutting involving special practices such as pre-heating or post-heating, or both, in order to minimize stresses, avoid thermal cracking and reduce the hardness of the gas cut edge. In special instances, special cut edge is used to designate an edge produced by machining.

3.1.15 sketch — when used to describe a form of plate, denotes a plate other than rectangular, circular, or semi-circular. Sketch plates may be furnished to a radius or with four or more straight sides.

3.1.16 normalizing — a heat treating process in which a steel plate is reheated to a uniform temperature above the upper critical temperature and then cooled in air to below the transformation range.

3.1.17 plate-as-rolled — when used in relation to the location and number of tests, the term refers to the unit plate rolled from a slab or directly from an ingot. It does not refer to the condition of the plate.

3.1.18 fine grain practice — a steelmaking practice that is intended to produce a killed steel that is capable of meeting the requirements for fine austenitic grain size.

3.1.18.1 Discussion — It normally involves the addition of one or more austenitic grain refining elements in amounts that have been established by the steel producer as being sufficient. Austenitic grain refining elements include, but are not limited to, aluminum, columbium, titanium, and vanadium.

3.1.19 structural product — a hot-rolled steel plate, shape, sheet piling, or bar.

3.1.20 coil — hot-rolled steel in coiled form that is intended to be processed into a finished structural product.

3.1.21 manufacturer — the organization that directly controls the conversion of steel ingots, slabs, blooms, or billets, by hot-rolling, into an as-rolled structural product or into coil; and for structural products produced from as-rolled structural products, the organization that directly controls, or is responsible for, the operations involved in finishing the structural product.

3.1.21.1 Discussion — Such finishing operations include leveling or straightening, hot forming or cold forming (if applicable), welding (if applicable), cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

3.1.22 processor — the organization that directly controls, or is responsible for, the operations involved in the processing of coil into a finished structural product. Such processing operations include decoiling, leveling or straightening, hot-forming or cold-forming (if applicable), welding (if applicable), cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

3.1.22.1 Discussion — The processing operations need not be done by the organization that did the hot rolling of the coil. If only one organization is involved in the hot rolling and processing operations, that organization is termed the *manufacturer* for the hot rolling operation and the *processor* for the processing operations. If more than one organization is involved in the hot rolling and processing operations, the organization that did the hot rolling is termed the *manufacturer* and an organization that does one or more processing operations is termed a *processor*.

3.2 Refer to Terminology A 941 for additional definitions of terms used in this standard.

4. Ordering Information

4.1 Information items to be considered, if appropriate, for inclusion in purchase orders are as follows:

4.1.1 ASTM product specification designation (see 1.1) and year-date,

4.1.2 Name of structural product (plate, shape, bar, or sheet piling),

4.1.3 Shape designation, or size and thickness or diameter,

4.1.4 Grade, class, and type designation, if applicable,

4.1.5 Condition (see Section 6), if other than as-rolled,

4.1.6 Quantity (weight [mass] or number of pieces),

4.1.7 Length,

4.1.8 Exclusion of either structural product produced from coil or structural product produced from an as-rolled structural product (see 5.3 and Appendix X1), if applicable,

4.1.9 Heat treatment requirements (see 6.2 and 6.3), if any,

4.1.10 Testing for fine austenitic grain size (see 8.3.2),

4.1.11 Mechanical property test report requirements (see Section 14), if any,

4.1.12 Special packaging, marking, and loading for shipment requirements (see Section 19), if any,

4.1.13 Supplementary requirements, if any, including any additional requirements called for in the supplementary requirements,

4.1.14 End use, if there are any end-use-specific requirements (see 18.1, 11.3.4, Table 22 or Table A1.22, and Table 24 or Table A1.24)

4.1.15 Special requirements (see 1.10), if any, and

4.1.16 Repair welding requirements (see 9.5), if any.

5. Materials and Manufacture

5.1 The steel shall be made in an open-hearth, basic-oxygen, or electric-arc furnace, possibly followed by additional refining in a ladle metallurgy furnace (LMF), or secondary melting by vacuum-arc remelting (VAR) or electroslag remelting (ESR).

5.2 The steel shall be strand cast or cast in stationary molds.

5.2.1 *Strand Cast:*

5.2.1.1 When heats of the same nominal chemical composition are consecutively strand cast at one time, the heat number assigned to the cast product need not be changed until all of the steel in the cast product is from the following heat.

5.2.1.2 When two consecutively strand cast heats have different nominal chemical composition ranges, the manufacturer shall remove the transition material by an established procedure that positively separates the grades.

5.3 Structural products shall be produced from an as-rolled structural product or from coil.

5.4 Where part of a heat is rolled into an as-rolled structural product and the balance of the heat is rolled into coil, each part shall be tested separately.

5.5 Structural products produced from coil shall not contain splice welds, unless previously approved by the purchaser.

6. Heat Treatment

6.1 Where the structural product is required to be heat treated, such heat treatment shall be performed by the manufacturer, the processor, or the fabricator, unless otherwise specified in the applicable product specification.

NOTE 2 — When no heat treatment is required, the manufacturer or processor has the option of heat treating the structural product by normalizing, stress relieving, or normalizing then stress relieving to meet the applicable product specification.

6.2 Where the heat treatment is to be performed by other than the manufacturer, the order shall so state.

6.2.1 Where the heat treatment is to be performed by other than the manufacturer, the structural products shall be accepted on the basis of tests made on test specimens taken from full thickness test coupons heat treated in accordance with the requirements specified in the applicable product specification or in the purchase order. If the heat-treatment temperatures are not specified, the manufacturer or processor shall heat treat the test coupons under conditions he considers appropriate, provided that the purchaser is informed of the procedure followed in heat treating the test coupons.

6.3 Where the heat treatment is to be performed by the manufacturer or the processor, the structural product shall be heat treated as specified in the applicable product specification, or as specified in the purchase order, provided that the heat treatment specified by the purchaser is not in conflict with the requirements of the applicable product specification.

6.4 Where normalizing is to be performed by the fabricator, the structural product shall be either normalized or heated uniformly for hot forming, provided that the temperature to which the structural product is heated for hot forming does not significantly exceed the normalizing temperature.

6.5 The use of cooling rates that are faster than those obtained by cooling in air to improve the toughness shall be subject to approval by the purchaser, and structural products so treated shall be tempered subsequently in the range from 1100 to 1300 °F [595 to 705 °C].

7. Chemical Analysis

7.1 *Heat Analysis:*

7.1.1 Sampling for chemical analysis and methods of analysis shall be in accordance with Test Methods, Practices, and Terminology A 751.

7.1.2 For each heat, the heat analysis shall include determination of the content of carbon, manganese, phosphorus, sulfur, silicon, nickel, chromium, molybdenum, copper, vanadium, columbium; any other element that is specified or restricted by the applicable product specification for the applicable grade, class, and type; and any austenitic grain refining element whose content is to be used in place of austenitic grain size testing of the heat (see 8.3.2).

7.1.3 Except as allowed by 7.1.4 for primary heats, heat analyses shall conform to the heat analysis requirements of the applicable product specification for the applicable grade, class, and type.

7.1.4 Where vacuum-arc remelting or electroslag remelting is used, a remelted heat is defined as all ingots remelted from a single primary heat. If the heat analysis of the primary heat conforms to the heat analysis requirements of the applicable product specification for the applicable grade, class, and type, the heat analysis for the remelted heat shall be determined from one test sample taken from one remelted ingot, or the product of one remelted ingot, from the primary heat. If the heat analysis of the primary heat does not conform to the heat analysis requirements of the applicable product specification for the applicable grade, type, and class, the heat analysis for the remelted heat shall be determined from one test sample taken from each remelted ingot, or the product of each remelted ingot, from the primary heat.

7.2 Product Analysis — For each heat, the purchaser shall have the option of analyzing representative samples taken from the finished structural product. Sampling for chemical analysis and methods of analysis shall be in accordance with Test Methods, Practices, and Terminology A 751. The product analyses so determined shall conform to the heat analysis requirements of the applicable product specification for the applicable grade, class, and type, subject to the permitted variations in product analysis given in Table A. If a range is specified, the determinations of any element in a heat shall not vary both above and below the specified range. Rimmed or capped steel is characterized by a lack of homogeneity in its composition, especially for the elements carbon, phosphorus, and sulfur. Therefore, the limitations for these elements shall not be applicable unless misapplication is clearly indicated.

7.3 Referee Analysis — For referee purposes, Test Methods, Practices, and Terminology A 751 shall be used.

7.4 Grade Substitution — Alloy steel grades that meet the chemical requirements of Table 1 of Specification A 829 shall not be substituted for carbon steel grades.

8. Metallurgical Structure

8.1 Where austenitic grain size testing is required, such testing shall be in accordance with Test Methods E 112 and at least 70% of the grains in the area examined shall meet the specified grain size requirement.

8.2 Coarse Austenitic Grain Size — Where coarse austenitic grain size is specified, one austenitic grain size test per heat shall be made and the austenitic grain size number so determined shall be in the range of 1 to 5, inclusive.

8.3 Fine Austenitic Grain Size:

8.3.1 Where fine austenitic grain size is specified, except as allowed in 8.3.2, one austenitic grain size test per heat shall be made and the austenitic grain size number so determined shall be 5 or higher.

NOTE 3 — Such austenitic grain size numbers may be achieved with lower contents of austenitic grain refining element than 8.3.2 requires for austenitic grain size testing to be waived.

8.3.2 Unless testing for fine austenitic grain size is specified in the purchase order, an austenitic grain size test need not be made for any heat that has, by heat analysis, one or more of the following:

8.3.2.1 A total aluminum content of 0.020% or more.

8.3.2.2 An acid soluble aluminum content of 0.015% or more.

8.3.2.3 A content for an austenitic grain refining element that exceeds the minimum value agreed to by the purchaser as being sufficient for austenitic grain size testing to be waived, or

8.3.2.4 Contents for the combination of two or more austenitic grain refining elements that exceed the applicable minimum values agreed to by the purchaser as being sufficient for austenitic grain size testing to be waived.

9. Quality

9.1 General — Structural products shall be free of injurious defects and shall have a workmanlike finish.

NOTE 4 — Unless otherwise specified, structural products are normally furnished in the as-rolled condition and are subjected to visual inspection by the manufacturer or processor. Non-injurious surface or internal imperfections, or both, may be present in the structural product as delivered and the structural product may require conditioning by the purchaser to improve its appearance or in preparation for welding, coating, or other further operations.

More restrictive requirements may be specified by invoking supplementary requirements or by agreement between the purchaser and the supplier.

Structural products that exhibit injurious defects during subsequent fabrication are deemed not to comply with the applicable product specification. (See 17.2.) Fabricators should be aware that cracks may initiate upon bending a sheared or burned edge during the fabrication process; this is not considered to be a fault of the steel but is rather a function of the induced cold-work or the heat-affected zone.

The conditioning requirements in 9.2, 9.3, and 9.4 limit the conditioning allowed to be performed by the manufacturer or processor. Conditioning of imperfections beyond the limits of 9.2, 9.3, and 9.4 may be performed by parties other than the manufacturer or processor at the discretion of the purchaser.

9.2 Plate Conditioning:

9.2.1 The grinding of plates by the manufacturer or processor to remove imperfections on the top or bottom surface shall be subject to the limitations that the area ground is well faired without abrupt changes in contour and the grinding does not reduce the thickness of the plate by (1) more than 7% under the nominal thickness for plates ordered to weight per square foot or mass per square metre, but in no case more than $\frac{1}{8}$ in. [3 mm]; or (2) below the permissible minimum thickness for plates ordered to thickness in inches or millimetres.

9.2.2 The deposition of weld metal (see 9.5) following the removal of imperfections on the top or bottom surface of plates by chipping, grinding, or arc-air gouging shall be subject to the following limiting conditions:

9.2.2.1 The chipped, ground, or gouged area shall not exceed 2% of the area of the surface being conditioned.

9.2.2.2 After removal of any imperfections preparatory to welding, the thickness of the plate at any location shall not be reduced by more than 30% of the nominal thickness of the plate. (Specification A 131/A 131M restricts the reduction in thickness to 20% maximum.)

9.2.3 The deposition of weld metal (see 9.5) following the removal of injurious imperfections on the edges of plates by grinding, chipping, or arc-air gouging by the manufacturer or processor shall be subject to the limitation that, prior to welding, the depth of the depression, measured from the plate edge inward, is not more than the thickness of the plate or 1 in. [25 mm], whichever is the lesser.

9.3 *Structural Size Shapes, Bar Size Shapes, and Sheet Piling Conditioning:*

9.3.1 The grinding, or chipping and grinding, of structural size shapes, bar size shapes, and sheet piling by the manufacturer or processor to remove imperfections shall be subject to the limitations that the area ground is well faired without abrupt changes in contour and the depression does not extend below the rolled surface by more than (1) $\frac{1}{32}$ in. [1 mm], for material less than $\frac{3}{8}$ in. [10 mm] in thickness; (2) $\frac{1}{16}$ in. [2 mm], for material $\frac{3}{8}$ to 2 in. [10 to 50 mm] inclusive in thickness; or (3) $\frac{1}{8}$ in. [3 mm], for material over 2 in. [50 mm] in thickness.

9.3.2 The deposition of weld metal (see 9.5) following removal of imperfections that are greater in depth than the limits listed in 9.3.1 shall be subject to the following limiting conditions:

9.3.2.1 The total area of the chipped or ground surface of any piece prior to welding shall not exceed 2% of the total surface area of that piece.

9.3.2.2 The reduction of thickness of the material resulting from removal of imperfections prior to welding shall not exceed 30% of the nominal thickness at the location of the imperfection, nor shall the depth of depression prior to welding exceed $1\frac{1}{4}$ in. [32 mm] in any case except as noted in 9.3.2.3.

9.3.2.3 The deposition of weld metal (see 9.5) following grinding, chipping, or arc-air gouging of the toes of angles, beams, channels, and zees and the stems and toes of tees shall be subject to the limitation that, prior to welding, the depth of the depression, measured from the toe inward, is not more than the thickness of the material at the base of the depression or $\frac{1}{2}$ in. [12.5 mm], whichever is the lesser.

9.3.2.4 The deposition of weld metal (see 9.5) and grinding to correct or build up the interlock of any sheet piling section at any location shall be subject to the limitation that the total surface area of the weld not exceed 2% of the total surface area of the piece.

9.4 *Bar Conditioning:*

9.4.1 The conditioning of bars by the manufacturer or processor to remove imperfections by grinding, chipping, or some other means shall be subject to the limitations that the conditioned area is well faired and the affected sectional area is not reduced by more than the applicable permitted variations (see Section 12).

9.4.2 The deposition of weld metal (see 9.5) following chipping or grinding to remove imperfections that are greater in depth than the limits listed in 9.4.1 shall be subject to the following conditions:

9.4.2.1 The total area of the chipped or ground surface of any piece, prior to welding, shall not exceed 2% of the total surface area of the piece.

9.4.2.2 The reduction of sectional dimension of a round, square, or hexagon bar, or the reduction in thickness of a flat bar, resulting from removal of an imperfection, prior to welding, shall not exceed 5% of the nominal dimension or thickness at the location of the imperfection.

9.4.2.3 For the edges of flat bars, the depth of the conditioning depression prior to welding shall be measured from the edge inward and shall be limited to a maximum depth equal to the thickness of the flat bar or $\frac{1}{2}$ in. [12.5 mm], whichever is less.

9.5 *Repair by Welding:*

9.5.1 *General Requirements:*

9.5.1.1 Repair by welding shall be in accordance with a welding procedure specification (WPS) using shielded metal arc welding (SMAW), gas metal arc welding (GMAW), flux cored arc welding (FCAW), or submerged arc welding (SAW) processes. Shielding gases used shall be of welding quality.

9.5.1.2 Electrodes and electrode-flux combinations shall be in accordance with the requirements of AWS Specification A5.1, A5.5, A5.17, A5.18, A5.20, A5.23, A5.28, or A5.29, whichever is applicable. For SMAW, low hydrogen electrodes shall be used.

9.5.1.3 Electrodes and electrode-flux combinations shall be selected so that the tensile strength of the deposited weld metal (after any required heat treatment) is consistent with the tensile strength specified for the base metal being repaired.

9.5.1.4 Welding electrodes and flux materials shall be dry and protected from moisture during storage and use.

9.5.1.5 Prior to repair welding, the surface to be welded shall be inspected to verify that the imperfections

intended to be removed have been removed completely. Surfaces to be welded and surfaces adjacent to the weld shall be dry and free of scale, slag, rust, moisture, grease, and other foreign material that would prevent proper welding.

9.5.1.6 Welders and welding operators shall be qualified in accordance with the requirements of ANSI/AWS D1.1 or ASME Section IX, except that any complete joint penetration groove weld qualification also qualifies the welder or welding operator to do repair welding.

9.5.1.7 Repair welding of structural products shall be in accordance with a welding procedure specification (WPS) that is in accordance with the requirements of ANSI/AWS D1.1 or ASME Section IX, with the following exceptions or clarifications:

- (1) The WPS shall be qualified by testing a complete joint penetration groove weld or a surface groove weld.
- (2) The geometry of the surface groove weld need not be described in other than a general way.
- (3) An ANSI/AWS D1.1 prequalified complete joint penetration groove weld WPS is acceptable.
- (4) Any material not listed in the prequalified base metal-filler metal combinations of ANSI/AWS D1.1 also is considered to be prequalified if its chemical composition and mechanical properties are comparable to those for one of the prequalified base metals listed in ANSI/AWS D1.1.
- (5) Any material not listed in ASME Section IX also is considered to be a material with an S-number in ASME Section IX if its chemical composition and its mechanical properties are comparable to those for one of the materials listed in ASME Section IX with an S-number.

9.5.1.8 When so specified in the purchase order, the WPS shall include qualification by Charpy V-notch testing, with the test locations, test conditions, and the acceptance criteria meeting the requirements specified for repair welding in the purchase order.

9.5.1.9 When so specified in the purchase order, the welding procedure specification (WPS) shall be subject to approval by the purchaser prior to repair welding.

9.5.2 *Structural Products with a Specified Minimum Tensile Strength of 100 ksi [690 MPa] or Higher* — Repair welding of structural products with a specified minimum tensile strength of 100 ksi [690 MPa] or higher shall be subject to the following additional requirements:

9.5.2.1 When so specified in the purchase order, prior approval for repair by welding shall be obtained from the purchaser.

9.5.2.2 The surface to be welded shall be inspected using a magnetic particle method or a liquid penetrant method to verify that the imperfections intended to be removed have been completely removed. When magnetic

particle inspection is employed, the surface shall be inspected both parallel and perpendicular to the length of the area to be repaired.

9.5.2.3 When weld repairs are to be post-weld heat-treated, special care shall be exercised in the selection of electrodes to avoid those compositions that embrittle as a result of such heat treatment.

9.5.2.4 Repairs on structural products that are subsequently heat-treated at the mill shall be inspected after heat treatment; repairs on structural products that are not subsequently heat-treated at the mill shall be inspected no sooner than 48 h after welding. Such inspection shall use a magnetic particle method or a liquid penetrant method; where magnetic particle inspection is involved, such inspection shall be both parallel to and perpendicular to the length of the repair.

9.5.2.5 The location of the weld repairs shall be marked on the finished piece.

9.5.3 *Repair Quality* — The welds and adjacent heat-affected zone shall be sound and free of cracks, the weld metal being thoroughly fused to all surfaces and edges without undercutting or overlap. Any visible cracks, porosity, lack of fusion, or undercut in any layer shall be removed prior to deposition of the succeeding layer. Weld metal shall project at least $\frac{1}{16}$ in. (2 mm) above the rolled surface after welding, and the projecting metal shall be removed by chipping or grinding, or both, to make it flush with the rolled surface, and to produce a workmanlike finish.

9.5.4 *Inspection of Repair* — The manufacturer or processor shall maintain an inspection program to inspect the work to see that:

9.5.4.1 Imperfections have been completely removed.

9.5.4.2 The limitations specified above have not been exceeded.

9.5.4.3 Established welding procedures have been followed, and

9.5.4.4 Any weld deposit is of acceptable quality as defined above.

10. Test Methods

10.1 All tests shall be conducted in accordance with Test Methods and Definitions A 370.

10.2 Yield strength shall be determined either by the 0.2% offset method or by the 0.5% extension under load method, unless otherwise stated in the material specification.

10.3 *Rounding Procedures* — For purposes of determining conformance with the specification, a calculated value shall be rounded to the nearest 1 ksi [5 MPa] tensile and

yield strength, and to the nearest unit in the right-hand place of figures used in expressing the limiting value for other values in accordance with the rounding method given in Practice E 29.

10.4 For full-section test specimens of angles, the cross-sectional area used for calculating the yield and tensile strengths shall be a theoretical area calculated on the basis of the weight of the test specimen (see 12.1).

11. Tension Tests

11.1 Condition — Test specimens for non-heat-treated structural products shall be taken from test coupons that are representative of the structural products in their delivered condition. Test specimens for heat-treated structural products shall be taken from test coupons that are representative of the structural products in their delivered condition, or from separate pieces of full thickness or full section from the same heat similarly heat treated.

11.1.1 Where the plate is heat treated with a cooling rate faster than still-air cooling from the austenitizing temperature, one of the following shall apply in addition to other requirements specified herein:

11.1.1.1 The gage length of the tension test specimen shall be taken at least $1T$ from any as-heat treated edge where T is the thickness of the plate and shall be at least $\frac{1}{2}$ in. [12.5 mm] from flame cut or heat-affected-zone surfaces.

11.1.1.2 A steel thermal buffer pad, $1T$ by $1T$ by at least $3T$, shall be joined to the plate edge by a partial penetration weld completely sealing the buffered edge prior to heat treatment.

11.1.1.3 Thermal insulation or other thermal barriers shall be used during the heat treatment adjacent to the plate edge where specimens are to be removed. It shall be demonstrated that the cooling rate of the tension test specimen is no faster than, and not substantially slower than, that attained by the method described in 11.1.1.2.

11.1.1.4 When test coupons cut from the plate but heat treated separately are used, the coupon dimensions shall be not less than $3T$ by $3T$ by T and each tension specimen cut from it shall meet the requirements of 11.1.1.1.

11.1.1.5 The heat treatment of test specimens separately in the device shall be subject to the limitations that (1) cooling rate data for the plate are available; (2) cooling rate control devices for the test specimens are available; and, (3) the method has received prior approval by the purchaser.

11.2 Orientation — For plates wider than 24 in. [600 mm], test specimens shall be taken such that the longitudinal axis of the test specimen is transverse to the

final direction of rolling of the plate. Test specimens for all other structural products shall be taken such that the longitudinal axis of the test specimen is parallel to the final direction of rolling.

11.3 Location:

11.3.1 Plates — Test specimens shall be taken from a corner of the plate.

11.3.2 *W and HP Shapes with Flanges 6 in. [150 mm] or Wider* — Test specimens shall be selected from a point in the flange $\frac{2}{3}$ of the way from the flange centerline to the flange toe.

11.3.3 *Shapes Other Than Those in 11.3.2* — Test specimens shall be selected from the webs of beams, channels, and zees; from the stems of rolled tees; and from the legs of angles and bulb angles, except where full-section test specimens for angles are used and the elongation acceptance criteria are increased accordingly. (See 11.6.2)

11.3.4 Bars:

11.3.4.1 Test specimens for bars to be used for pins and rollers shall be taken so that the axis is: midway between the center and the surface for pins and rollers less than 3 in. [75 mm] in diameter; 1 in. [25 mm] from the surface for pins and rollers 3 in. [75 mm] and over in diameter; or as specified in Annex A1 of Test Methods and Definitions A 370 if the applicable foregoing requirement is not practicable.

11.3.4.2 Test specimens for bars other than those to be used for pins and rollers shall be taken as specified in Annex A1 of Test Methods and Definitions A 370.

11.4 Test Frequency:

11.4.1 *Structural Products Produced from an As-Rolled Structural Product* — The minimum number of pieces or plates-as-rolled to be tested for each heat and strength gradation, where applicable, shall be as follows, except that it shall be permissible for any individual test to represent multiple strength gradations:

11.4.1.1 As given in Table B, or

11.4.1.2 One taken from the minimum thickness in the heat and one taken from the maximum thickness in the heat, where thickness means the specified thickness, diameter, or comparable dimension, whichever is appropriate for the applicable structural product rolled.

11.4.2 *Structural Products Produced from Coil and Furnished without Heat Treatment or with Stress Relieving Only:*

11.4.2.1 Except as allowed by 11.4.4, the minimum number of coils to be tested for each heat and strength gradation, where applicable, shall be as given in Table C, except that it shall be permissible for any individual coil to represent multiple strength gradations.

11.4.2.2 Except as required by 11.4.2.3, two tension test specimens shall be taken from each coil tested, with the first being taken immediately prior to the first structural product to be qualified, and the second being taken from the approximate center lap.

11.4.2.3 If, during decoiling, the amount of material decoiled is less than that required to reach the approximate center lap, the second test for the qualification of the decoiled portion of such a coil shall be taken from a location adjacent to the end of the innermost portion decoiled. For qualification of successive portions from such a coil, an additional test shall be taken adjacent to the innermost portion decoiled, until a test is obtained from the approximate center lap.

11.4.3 *Structural Products Produced from Coil and Furnished Heat Treated by other than Stress Relieving* — The minimum number of pieces to be tested for each heat and strength gradation, where applicable, shall be as follows, except that it shall be permissible for any individual test to represent multiple strength gradations:

11.4.3.1 As given in Table B, or

11.4.3.2 One taken from the minimum thickness in the heat and one taken from the maximum thickness in the heat, where thickness means the specified thickness, diameter, or comparable dimension, whichever is appropriate for the applicable structural product rolled.

11.4.4 *Structural Products Produced from Coil and Qualified Using Test Specimens Heat Treated by Other than Stress Relieving* — The minimum number of pieces to be tested for each heat and strength gradation, where applicable, shall be as follows, except that it shall be permissible for any individual test to represent multiple strength gradations:

11.4.4.1 As given in Table B, or

11.4.4.2 One taken from the minimum thickness in the heat, where thickness means the specified thickness, diameter, or comparable dimension, whichever is appropriate for the applicable structural product rolled.

11.5 Preparation:

11.5.1 Plates:

11.5.1.1 Tension test specimens for plates $\frac{3}{4}$ in. [20 mm] and under in thickness shall be the full thickness of the plates. The test specimens shall conform to the requirements shown in Fig. 3 of Test Methods and Definitions A 370 for either the $1\frac{1}{2}$ in. [40 mm] wide test specimen or the $\frac{1}{2}$ in. [12.5 mm] wide test specimen.

11.5.1.2 For plates up to 4 in. [100 mm], inclusive, in thickness, the use of $1\frac{1}{2}$ in. [40 mm] wide test specimens, full thickness of the plate and conforming to the requirements shown in Fig. 3 of Test Methods and Definitions

A 370, shall be subject to the limitation that adequate testing machine capacity is available.

11.5.1.3 For plates over $\frac{3}{4}$ in. [20 mm] in thickness, except as permitted in 11.5.1.2, tension test specimens shall conform to the requirements shown in Fig. 4 of Test Methods and Definitions A 370 for the 0.500 in. [12.5 mm] diameter test specimen. The axis of such test specimens shall be located midway between the center of thickness and the top or bottom surface of the plate.

11.5.2 Shapes:

11.5.2.1 Except where angles are tested in full section, tension test specimens for shapes $\frac{3}{4}$ in. [20 mm] and under in thickness shall be the full thickness of the shape. Such test specimen shall conform to the requirements shown in Fig. 3 of Test Methods and Definitions A 370 for either the $1\frac{1}{2}$ in. [40 mm] wide test specimen or the $\frac{1}{2}$ in. [12.5 mm] wide test specimen.

11.5.2.2 For shapes up to 5 in. [125 mm], inclusive, in thickness, the use of $1\frac{1}{2}$ in. [40 mm] wide test specimens, full thickness of the shape and conforming to the requirements shown in Fig. 3 of Test Methods and Definitions A 370, shall be subject to the limitation that adequate testing machine capacity is available.

11.5.2.3 For shapes over $\frac{3}{4}$ in. [20 mm] in thickness, except as permitted in 11.5.2.2, tension test specimens shall conform to the requirements shown in Fig. 4 of Test Methods and Definitions A 370 for the 0.500 in. [12.5 mm] diameter test specimens. The axis of such test specimens shall be located midway between the center of thickness and the top or bottom surface of the shape.

11.5.3 Bars:

11.5.3.1 Except as otherwise provided below, test specimens for bars shall be in accordance with Annex A1 of Test Methods and Definitions A 370.

11.5.3.2 Except as provided in 11.5.3.5, test specimens for bars $\frac{3}{4}$ in. [20 mm] and under in thickness may conform to the requirements shown in Fig. 3 of Test Methods and Definitions A 370 for either the $1\frac{1}{2}$ in. [40 mm] wide test specimen or the $\frac{1}{2}$ in. [12.5 mm] wide specimen.

11.5.3.3 Except as provided in 11.5.3.4 and 11.5.3.5, test specimens for bars over $\frac{3}{4}$ in. [20 mm] in thickness or diameter shall conform either to the requirements for the $1\frac{1}{2}$ in. [40 mm] or $\frac{1}{2}$ in. [12.5 mm] wide test specimen shown in Fig. 3 of Test Methods and Definitions A 370, or to the requirements for the 0.500 in. [12.5 mm] diameter test specimen shown in Fig. 4 of Test Methods and Definitions A 370.

11.5.3.4 For bars other than those to be used for pins and rollers, the manufacturer or processor shall have the option of using test specimens that are machined to a thickness or diameter of at least $\frac{3}{4}$ in. [20 mm] for a length of at least 9 in. [230 mm].

11.5.3.5 Test specimens for bars to be used for pins and rollers shall conform to the requirements shown in Fig. 4 of Test Methods and Definitions A 370 for the 0.500 in. [12.5 mm] diameter test specimen.

11.6 Elongation Requirement Adjustments:

11.6.1 Due to the specimen geometry effect encountered when using the rectangular tension test specimen for testing thin material, adjustments in elongation requirements must be provided for thicknesses under 0.312 in. [8 mm]. Accordingly, the following deductions from the base elongation requirements shall apply:

Nominal Thickness Range, in. [mm]	Elongation Deduction, %
0.299–0.311 [7.60–7.89]	0.5
0.286–0.298 [7.30–7.59]	1.0
0.273–0.285 [7.00–7.29]	1.5
0.259–0.272 [6.60–6.99]	2.0
0.246–0.258 [6.20–6.59]	2.5
0.233–0.245 [5.90–6.19]	3.0
0.219–0.232 [5.50–5.89]	3.5
0.206–0.218 [5.20–5.49]	4.0
0.193–0.205 [4.90–5.19]	4.5
0.180–0.192 [4.60–4.89]	5.0
0.166–0.179 [4.20–4.59]	5.5 ^A
0.153–0.165 [3.90–4.19]	6.0 ^A
0.140–0.152 [3.60–3.89]	6.5 ^A
0.127–0.139 [3.20–3.59]	7.0 ^A
<0.127 [3.20]	7.5 ^A

^A Elongation deductions for thicknesses less than 0.180 in. [4.60 mm] apply to plates and structural shapes only.

11.6.2 Due to the specimen geometry effect encountered when using full-section test specimens for angles, the elongation requirements for structural-size angles shall be increased by six percentage points when full-section test specimens are used.

11.6.3 Due to the inherently lower elongation that is obtainable in thicker structural products, adjustments in elongation requirements shall be provided. For structural products over 3.5 in. [90 mm] in thickness, a deduction of 0.5 percentage point from the specified percentage of elongation in 2 in. [50 mm] shall be made for each 0.5 in. [12.5 mm] increment of thickness over 3.5 in. [90 mm], up to a maximum deduction of 3.0 percentage points. Accordingly, the following deductions from the base elongation requirements shall apply:

Nominal Thickness Range, in. [mm]	Elongation Deduction, %
3.500–3.999 [90.00–102.49]	0.5
4.000–4.499 [102.50–114.99]	1.0
4.500–4.999 [115.00–127.49]	1.5
5.000–5.499 [127.50–139.99]	2.0
5.500–5.999 [140.00–152.49]	2.5
6.000 and thicker [152.50 and thicker]	3.0

11.6.4 The tensile property requirements tables in many of the product specifications covered by this general requirements specification specify elongation requirements in both 8 in. [200 mm] and 2 in. [50 mm] gage lengths. Unless otherwise provided in the applicable product specification, both requirements are not required to be applied simultaneously and the elongation need only be determined in the gage length appropriate for the test specimen used. After selection of the appropriate gage length, the elongation requirement for the alternative gage length shall be deemed not applicable.

11.7 Yield Strength Application:

11.7.1 When test specimens do not exhibit a well-defined disproportionate yield point, yield strength shall be determined and substituted for yield point.

11.7.2 The manufacturer or processor shall have the option of substituting yield strength for yield point if the test specimen exhibits a well-defined disproportionate yield point.

11.7.3 Yield strength shall be determined either by the 0.2% offset method or by the 0.5% extension-under-load method.

11.8 Product Tension Tests — This specification does not provide requirements for product tension testing subsequent to shipment (see 15.1). Therefore, the requirements of 11.1 to 11.7 inclusive and Section 13 apply only for tests conducted at the place of manufacture prior to shipment.

NOTE 5 — Compliance to Specification A 6/A 6M and the applicable product specification by a manufacturer or processor does not preclude the possibility that product tension test results might vary outside specified ranges. The tensile properties will vary within the same heat or piece, be it as-rolled, control-rolled, or heat-treated. Tension testing according to the requirements of Specification A 6/A 6M does not provide assurance that all products of a heat will be identical in tensile properties with the products tested. If the purchaser wishes to have more confidence than that provided by Specification A 6/A 6M testing procedures, additional testing or requirements, such as Supplementary Requirement S4, should be imposed.

11.8.1 Appendix X2 provides additional information on the variability of tensile properties in plates and structural shapes

12. Permitted Variations in Dimensions and Weight [Mass]

12.1 One cubic foot of rolled steel is assumed to weigh 490 lb. One cubic metre of rolled steel is assumed to have a mass of 7850 kg.

12.2 Plates — The permitted variations for dimensions and weight [mass] shall not exceed the applicable limits in Tables 1–15 [Annex A1, Tables A1.1 to A1.15], inclusive.

12.3 Shapes:

12.3.1 Annex A2 lists the designations and dimensions, in both inch-pound and SI units, of shapes that are

most commonly available. Radii of fillets and toes of shape profiles vary with individual manufacturers and therefore are not specified.

12.3.2 The permitted variations in dimensions shall not exceed the applicable limits in Tables 16–25 [Annex A1, Tables A1.16 to A1.25], inclusive. Permitted variations for special shapes not listed in such tables shall be as agreed upon between the manufacturer and the purchaser.

NOTE 6 — Permitted variations are given in Tables 16 to 25 [Annex A1, Tables A1.16 to A1.25], inclusive, for some shapes that are not listed in Annex A2 (that is, bulb angles, tees, zeos). Addition of such sections to Annex A2 will be considered by Subcommittee A01.02 when and if a need for such listing is shown.

12.3.3 *Shapes Having One Dimension of the Cross Section 3 in. [75 mm] or Greater (Structural-Size Shapes)* — The cross-sectional area or weight [mass] of each shape shall not vary more than 2.5% from the theoretical or specified amounts except for shapes with a nominal weight of less than 100 lb/ft, in which the variation shall range from –2.5% to +3.0% from the theoretical cross-sectional area or the specified nominal weight [mass].

12.4 *Sheet Piling* — The weight [mass] of each steel sheet pile shall not vary more than 2.5% from the theoretical or specified weight [mass]. The length of each steel sheet pile shall be not less than the specified length, and not more than 5 in. [125 mm] over the specified length.

12.5 *Hot-Rolled Bars* — The permitted variations in dimensions shall not exceed the applicable limits in Tables 26–31 [Annex A1, Tables A1.26 to A1.31], inclusive.

13. Retests

13.1 If any test specimen shows defective machining or develops flaws, the manufacturer or processor shall have the option of discarding it and substituting another test specimen.

13.2 If the percentage of elongation of any tension test specimen is less than that specified and any part of the fracture is more than $\frac{3}{4}$ in. [20 mm] from the center of the gage length of a 2 in. [50 mm] specimen or is outside the middle half of the gage length of an 8 in. [200 mm] specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

13.3 Except as provided in 13.3.1, if the results from an original tension specimen fails to meet the specified requirements, but are within 2 ksi [14 MPa] of the required tensile strength, within 1 ksi [7 MPa] of the required yield strength or yield point, or within 2 percentage points of the required elongation, a retest shall be permitted to replace the failing test. A retest shall be performed for the failing original test, with the specimen being randomly

selected from the heat. If the results of the retest meet the specified requirements, the heat or lot shall be approved.

13.3.1 For structural products that are tested as given in Table C, both tests from each coil tested to qualify a heat are required to meet all mechanical property requirements. Should either test fail to do so, then that coil shall not be used to qualify the heat; however, the portion of that individual coil that is bracketed by acceptable tests (see 11.4.2.3) is considered to be qualified.

13.4 Quenched and tempered steel plates shall be subject to any additional retest requirements contained in the applicable product specification.

13.5 When the full-section option of 11.3.3 is used and the elongation falls below the specified requirement, the manufacturer or processor shall have the option of making another test using a test specimen permitted in 11.5.2.

14. Test Reports

14.1 Test reports for each heat supplied are required and they shall report the following:

14.1.1 The applicable product specification designation, including year-date and whichever of grade, class, and type are specified in the purchase order, to which the structural product is furnished.

14.1.2 The heat number, heat analysis (see 7.1), and nominal sizes.

NOTE 7 — If the amount of copper, chromium, nickel, molybdenum, or silicon is less than 0.02%, the heat analysis for that element may be reported as <0.02%. If the amount of columbium or vanadium is less than 0.008%, the heat analysis for that element may be reported as <0.008%.

14.1.3 For structural products that are tested as given in Table B, two tension test results appropriate to qualify the shipment (see 11.4), except that only one tension test result need be reported if the shipment consists of a single piece or plate-as-rolled.

14.1.3.1 In reporting elongation values, both the percentage increase and the original gage length shall be stated.

14.1.4 For structural products that are required to be heat treated, either by the applicable product specification or by the purchase order, all heat treatments, including temperature ranges and times at temperature, unless the purchaser and the supplier have agreed to the supply of a heat treatment procedure in place of the actual temperatures and times.

14.1.4.1 Subcritical heat treatment to soften thermally cut edges need not be reported, except for structural products having a specified minimum tensile strength of 95 ksi [655 MPa] or higher, unless such subcritical heating is accomplished at temperatures at least 75°F [40°C] lower than the minimum tempering temperature.

14.1.5 The results of any required austenitic grain size tests (see 8.2 or 8.3, whichever is applicable).

14.1.6 The results of any other test required by the applicable product specification, the applicable supplementary requirements, and the purchase order.

14.2 The thickness of the structural product tested is not necessarily the same as an individual ordered thickness, given that it is the heat that is tested, rather than each ordered item. Tests from specified thicknesses in accordance with 11.4 and encompassing the thicknesses in a shipment shall be sufficient for qualifying the structural product in the shipment. Such test thicknesses are not required to be within previously tested and shipped thicknesses from the same heat.

14.3 For structural products produced from coil that are supplied in the as-rolled condition or have been heat treated by stress relieving only, the test report shall state "Produced from Coil." Both test results shall be reported for each qualifying coil, and the location within the coil for each test shall be stated.

14.4 For structural products produced from coil, both the manufacturer and the processor shall be identified on the test report.

14.5 When full-section test specimens have been used for the qualification of angles, that information shall be stated on the test report.

14.6 A signature is not required on the test report; however, the document shall clearly identify the organization submitting the report. Notwithstanding the absence of a signature, the organization submitting the report is responsible for the content of the report.

14.7 For structural products finished by other than the original manufacturer, the supplier of the structural product shall also provide the purchaser with a copy of the original manufacturer's test report.

14.8 A test report, certificate of inspection, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document shall meet the requirements of the applicable product specification and shall conform to any existing EDI agreement between the purchaser and the supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission shall be responsible for the content of the report.

NOTE 8 — The industry definition as invoked here is: EDI is the computer to computer exchange of business information in a standard format such as ANSI ASC X12.

15. Inspection and Testing

15.1 The inspector representing the purchaser shall have free entry, at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the structural product ordered. The manufacturer shall afford the inspector all reasonable facilities to be satisfied that the structural product is being furnished in accordance with this general requirements specification, the applicable product specification, and the purchase order. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere with the operation of the manufacturer's works.

15.2 Where structural products are produced from coil, 15.1 shall apply to the processor instead of the manufacturer, and the place of process shall apply instead of the place of manufacture. Where structural products are produced from coil and the processor is different from the manufacturer, the inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed to all parts of the manufacturer's works that concern the manufacture of the structural product ordered.

16. Retreatment

16.1 If any heat-treated structural product fails to meet the mechanical property requirements of the applicable product specification, the manufacturer or the processor shall have the option of heat treating the structural product again. All mechanical property tests shall be repeated and the structural product shall be reexamined for surface defects when it is resubmitted for inspection.

17. Rejection

17.1 Any rejection based upon product analysis made in accordance with the applicable product specification shall be reported to the supplier and samples that represent the rejected structural product shall be preserved for 2 weeks from the date of notification of such rejection. In case of dissatisfaction with the results of the tests, the supplier shall have the option of making claim for a rehearing within that time.

17.2 The purchaser shall have the option of rejecting structural product that exhibits injurious defects subsequent to its acceptance at the manufacturer's or processor's works, and so notifying the manufacturer or processor.

18. Identification of Structural Products

18.1 Required Plate Markings:

18.1.1 Except as allowed by 18.1.4.2 and 18.6, plates shall be legibly marked with the following: applicable

ASTM designation (see 1.1) (year-date not required); “G” or “MT” if applicable (see 18.1.2); applicable grade; heat number; size and thickness; and name, brand, or trademark of the manufacturer (for plates produced from an as-rolled structural product) or the processor (for plates produced from coil).

18.1.2 Plates that are required to be heat treated, but have not been so heat treated, shall be marked, by the manufacturer or processor, with the letter “G” (denoting green) following the required ASTM designation mark, except that “G” marking is not necessary if such plates are for shipment, for the purpose of obtaining the required heat treatment, to an organization under the manufacturer’s control. Such plates shall have been qualified for shipment on the basis of test specimens that have been so heat treated. Plates that are required to be heat treated, and have been so heat treated, shall be marked, by the party that performed the heat treatment, with the letter “MT” (denoting material treated) following the required ASTM designation mark.

18.1.3 Except as allowed by 18.1.4.2 and 18.6, the required markings for plates shall be by steel die stamping, paint marking, or by means of permanently affixed, colorfast, weather-resistant labels or tags. It shall be the responsibility of the supplier that all required markings be intact and fully legible upon receipt by the purchaser.

18.1.4 Location of Markings:

18.1.4.1 The required markings for plates shall be in at least one place on each finished plate.

18.1.4.2 For secured lifts of all sizes of plates $\frac{3}{8}$ in. [10 mm] (or $\frac{5}{16}$ in. [8 mm] for material specified for bridge construction end use) or under in thickness, and for secured lifts of all thicknesses of plates 36 in. [900 mm] or under in width, the manufacturer or processor shall have the option of placing such markings on only the top piece of each lift, or of showing such markings on a substantial tag attached to each lift, unless otherwise specified.

18.2 Shapes:

18.2.1 Except as allowed by 18.2.2 and 18.6, shapes shall be marked with the heat number, size of section, length, and mill identification marks on each piece. Shapes with the greatest cross-sectional dimension greater than 6 in. [150 mm] shall have the manufacturer’s name, brand, or trademark shown in raised letters at intervals along the length. In addition, shapes shall be identified with the ASTM designation (year-date not required) and grade, either by marking each piece individually, by permanently affixing a colorfast, weather-resistant label or tag, or, if bundled, by attaching a substantial tag to the bundle.

18.2.2 Bundling for shipment of small shapes with the greatest cross-sectional dimension not greater than 6 in. [150 mm] is permissible. Each lift or bundle shall be

marked or substantially tagged showing the identification information listed in 18.2.1.

18.2.3 It shall be permissible for the manufacturer to make a full size bundle at the end of a heat by adding product from a consecutively rolled heat of the same nominal chemical composition. The manufacturer shall identify a bundle consisting of product from two heats with the number of the first heat rolled or identify both heats. The manufacturer shall maintain records of the heats contained in each bundle.

18.3 Steel Sheet Piling — Steel sheet piling shall be marked with the heat number, size of section, length, and mill identification marks on each piece, either by marking, or by permanently affixing colorfast, weather-resistant label or tag. The manufacturer’s name, brand, or trademark shall be shown in raised letters at intervals along the length.

18.4 Bars — Bars of all sizes, when loaded for shipment, shall be properly identified with the name or brand of manufacturer, purchaser’s name and order number, the ASTM designation number (year-date not required), grade number where appropriate, size and length, weight [mass] of lift, and the heat number for identification. Unless otherwise specified, the method of marking is at the manufacturer’s option and shall be made by hot stamping, cold stamping, painting, or marking tags attached to the lifts of bars. Bars are not required to be die-stamped.

18.4.1 It shall be permissible for the manufacturer to make a full size bundle at the end of a heat by adding product from a consecutively rolled heat of the same nominal chemical composition. The manufacturer shall identify a bundle consisting of product from two heats with the number of the first heat rolled or identify both heats. The manufacturer shall maintain records of the heats contained in each bundle.

18.5 Bar Coding — In addition to the requirements of 18.1 to 18.4 inclusive, the manufacturer or processor shall have the option of using bar coding as a supplementary identification method.

NOTE 9 — Bar coding should be consistent with AIAG Standards.

18.6 Subdivided Material:

18.6.1 Except as allowed by 18.6.2, pieces separated from a master structural product by an organization other than the original manufacturer shall be identified with the ASTM designation (year-date not required), grade, heat number, and the heat treatment identification, if applicable, along with the trademark, brand, or name of the organization subdividing the structural product. The identification methods shall be in accordance with the requirements of 18.1 to 18.4 inclusive, except that the raised letters method for shapes and steel sheet piling is not required. If the original manufacturer’s identification remains intact, the

structural product need not be additionally identified by the organization supplying the structural product.

18.6.2 It shall be permissible for pieces from the same heat of structural product to be bundled or placed in secured lifts, with the identification specified in 18.6.1 placed on the top piece of each lift or shown on a substantial tag attached to each bundle or lift.

19. Packaging, Marking, and Loading for Shipment

19.1 Packaging, marking, and loading for shipment shall be in accordance with Practices A 700.

19.2 When Level A is specified, and when specified in the contract or order, and for direct procurement by

or direct shipment to the U.S. government, preservation, packaging, and packing shall be in accordance with the Level A requirements of MIL-STD-163.

19.3 When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. government, marking for shipment, in addition to requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for military agencies and with Fed. Std. No. 123 for civil agencies.

20. Keywords

20.1 bars; general requirements; plates; rolled; shapes; sheet piling; structural steel

TABLE A
PERMITTED VARIATIONS IN PRODUCT ANALYSIS

Element	Upper Limit, or Maximum Specified Value, %	Permitted Variations, %	
		Under Minimum Limit	Over Maximum Limit
Carbon	to 0.15 incl	0.02	0.03
	over 0.15 to 0.40 incl	0.03	0.04
	over 0.40 to 0.75 incl	0.04	0.05
	over 0.75	0.04	0.06
Manganese ^A	to 0.60 incl	0.05	0.06
	over 0.60 to 0.90 incl	0.06	0.08
	over 0.90 to 1.20 incl	0.08	0.10
	over 1.20 to 1.35 incl	0.09	0.11
	over 1.35 to 1.65 incl	0.09	0.12
	over 1.65 to 1.95 incl	0.11	0.14
	over 1.95	0.12	0.16
Phosphorus	to 0.04 incl	...	0.010
	over 0.04 to 0.15 incl	...	^B
Sulfur	to 0.06 incl	...	0.010
	over 0.06	^B	^B
Silicon	to 0.30 incl	0.02	0.03
	over 0.30 to 0.40 incl	0.05	0.05
	over 0.40 to 2.20 incl	0.06	0.06
Nickel	to 1.00 incl	0.03	0.03
	over 1.00 to 2.00 incl	0.05	0.05
	over 2.00 to 3.75 incl	0.07	0.07
	over 3.75 to 5.30 incl	0.08	0.08
	over 5.30	0.10	0.10
Chromium	to 0.90 incl	0.04	0.04
	over 0.90 to 2.00 incl	0.06	0.06
	over 2.00 to 4.00 incl	0.10	0.10
Molybdenum	to 0.20 incl	0.01	0.01
	over 0.20 to 0.40 incl	0.03	0.03
	over 0.40 to 1.15 incl	0.04	0.04
Copper	0.20 minimum only	0.02	...
	to 1.00 incl	0.03	0.03
	over 1.00 to 2.00 incl	0.05	0.05
Titanium	to 0.15 incl	0.01 ^C	0.01
Vanadium	to 0.10 incl	0.01 ^C	0.01
	over 0.10 to 0.25 incl	0.02	0.02
	over 0.25	0.02	0.03
	minimum only specified	0.01	...
Boron	any	^B	^B
Columbium	to 0.10 incl	0.01 ^C	0.01
Zirconium	to 0.15 incl	0.03	0.03
Nitrogen	to 0.030 incl	0.005	0.005

Note 1 — Where "... ." appears in this table there is no requirement.

^A Permitted variations in manganese content for bars and bar size shapes shall be: to 0.90 incl ± 0.03 ; over 0.90 to 2.20 incl ± 0.06 .

^B Product analysis not applicable.

^C 0.005% if the minimum of the range is 0.01%.

INDEX TO TABLES OF PERMITTED VARIATIONS

Dimension	Table	
	Inch-Pound Units	SI Units
Camber		
Plates, Carbon Steel; Sheared and Gas-Cut	12	A1.12
Plates, Carbon Steel; Universal Mill	11	A1.11
Plates, Other than Carbon Steel; Sheared, Gas-Cut and Universal Mill	11	A1.11
Shapes, Rolled; S, M, C, MC, and L	21	A1.21
Shapes, Rolled; W and HP	24	A1.24
Shapes, Split; L and T	25	A1.25
Cross Section of Shapes and Bars		
Flats	26	A1.26
Hexagons	28	A1.28
Rounds and Squares	27	A1.27
Shapes, Rolled; L, Bulb Angles, and Z	17	A1.17
Shapes, Rolled; W, HP, S, M, C, and MC	16	A1.16
Shapes, Rolled; T	18	A1.18
Shapes, Split; L and T	25	A1.25
Diameter		
Plates, Sheared	6	A1.6
Plates, Other than Alloy Steel, Gas-Cut	7	A1.7
Plates, Alloy Steel, Gas-Cut	10	A1.10
Rounds	27	A1.27
End Out-of-Square		
Shapes, Other than W	20	A1.20
Shapes, W	22	A1.22
Shapes, Milled, Other than W	23	A1.23
Flatness		
Plates, Carbon Steel	13	A1.13
Plates, Other than Carbon Steel	14	A1.14
Plates, Restrictive—Carbon Steel	S27.1	S27.2
Plates, Restrictive—Other than Carbon Steel	S27.3	S27.4
Length		
Bars	30	A1.30
Bars, Recut	31	A1.31
Plates, Sheared and Universal Mill	3	A1.3
Plates, Other than Alloy Steel, Gas-Cut	9	A1.9
Plates, Alloy Steel, Gas-Cut	8	A1.8
Plates, Mill Edge	4	A1.4
Shapes, Rolled; Other than W	19	A1.19
Shapes, Rolled; W and HP	22	A1.22
Shapes, Split; L and T	25	A1.25
Shapes, Milled	23	A1.23
Straightness		
Bars	29	A1.29
Shapes, Other than W	21	A1.21
Sweep		
Shapes, W and HP	24	A1.24
Thickness		
Flats	26	A1.26
Plates, Ordered to Thickness	1	A1.1
Waviness		
Plates	15	A1.15
Weight [Mass]		
Plates, Ordered to Weight [Mass]	2	A1.2
Width		
Flats	26	A1.26
Plates, Sheared	3	A1.3
Plates, Universal Mill	5	A1.5
Plates, Other than Alloy Steel, Gas-Cut	9	A1.9
Plates, Alloy Steel, Gas-Cut	8	A1.8
Plates, Mill Edge	4	A1.4

TABLE B
MINIMUM NUMBER OF TENSION TESTS REQUIRED

Thickness ^A Range Rolled for the Heat	Thickness ^A Difference Between Pieces or Plates-as-rolled in the Thickness ^A Range	Minimum Number of Tension Tests Required
Under $\frac{3}{8}$ in. [10 mm]	$\frac{1}{16}$ in. [2 mm] or less	Two ^B tests per heat, taken from different pieces or plates-as-rolled having any thickness ^A in the thickness ^A range
	More than $\frac{1}{16}$ in. [2 mm]	Two ^B tests per heat, one taken from the minimum thickness ^A in the thickness ^A range and one taken from the maximum thickness ^A in the thickness ^A range
$\frac{3}{8}$ to 2 in. [10 to 50 mm], incl	Less than $\frac{3}{8}$ in. [10 mm]	Two ^B tests per heat, taken from different pieces or plates-as-rolled having any thickness ^A in the thickness ^A range.
	$\frac{3}{8}$ in. [10 mm] or more	Two ^B tests per heat, one taken from the minimum thickness ^A in the thickness ^A range and one taken from the maximum thickness ^A in the thickness ^A range
Over 2 in. [50 mm]	Less than 1 in. [25 mm]	Two ^B tests per heat, taken from different pieces or plates-as-rolled having any thickness ^A in the thickness ^A range
	1 in. [25 mm] or more	Two ^B tests per heat, one taken from the minimum thickness ^A in the thickness ^A range and one taken from the maximum thickness ^A in the thickness ^A range

^A Thickness means the specified thickness, diameter, or comparable dimension, whichever is appropriate for the specific structural product rolled.

^B One test, if only one piece or plate-as-rolled is to be qualified.

TABLE C
MINIMUM NUMBER OF COILS REQUIRED TO BE TENSION TESTED

Thickness ^A Difference Between Coils in the Heat	Minimum Number of Coils Required to Be Tension Tested
Less than $\frac{1}{16}$ in. [2 mm]	Two ^B coils per heat, at any thickness ^A in the heat
$\frac{1}{16}$ in. [2 mm] or more	Two ^B coils per heat, one at the minimum thickness ^A in the heat and one at the maximum thickness ^A in the heat

NOTE — See 11.4.2.2 and 11.4.2.3 for the number of tests to be taken per coil.

^A Thickness means the specified thickness, diameter, or comparable dimension, whichever is appropriate for the specific structural product rolled.

^B One coil, if the product of only one coil is to be qualified.

TABLE 1
PERMITTED VARIATIONS IN THICKNESS FOR RECTANGULAR, CARBON, HIGH-STRENGTH, LOW-ALLOY, AND ALLOY-STEEL PLATES, 15 IN. AND UNDER IN THICKNESS WHEN ORDERED TO THICKNESS

Specified Thickness, in.	Permitted Variations Over Specified Thickness for Widths Given in Inches, in.											
	48 and under	Over 48 to 60, excl	60 to 72, excl	72 to 84, excl	84 to 96, excl	96 to 108, excl	108 to 120, excl	120 to 132, excl	132 to 144, excl	144 to 168, excl	168 to 182, excl	182 and over
To $\frac{1}{4}$, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	...	...	...
$\frac{1}{4}$ to $\frac{5}{16}$, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	...	...	...
$\frac{5}{16}$ to $\frac{3}{8}$, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	...	...
$\frac{3}{8}$ to $\frac{7}{16}$, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.06	...
$\frac{7}{16}$ to $\frac{1}{2}$, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.06	...
$\frac{1}{2}$ to $\frac{5}{8}$, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.07	...
$\frac{5}{8}$ to $\frac{3}{4}$, excl	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.06	0.07	0.07
$\frac{3}{4}$ to 1, excl	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.07	0.08	0.09
1 to 2, excl	0.06	0.06	0.06	0.06	0.06	0.07	0.08	0.10	0.10	0.11	0.13	0.16
2 to 3, excl	0.09	0.09	0.09	0.10	0.10	0.11	0.12	0.13	0.14	0.15	0.15	...
3 to 4, excl	0.11	0.11	0.11	0.11	0.11	0.13	0.14	0.14	0.14	0.15	0.17	...
4 to 6, excl	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.20	0.20	...
6 to 10, excl	0.23	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.27	0.28	...
10 to 12, excl	0.29	0.29	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.35	...
12 to 15, incl	0.29	0.29	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	...

Note 1 — Tables 1–31, inclusive, contain permitted variations in dimensions and weight stated in inch-pound units.

Note 2 — Permitted variation under specified thickness, 0.01 in.

Note 3 — Thickness to be measured at $\frac{3}{8}$ to $\frac{3}{4}$ in. from the longitudinal edge.

Note 4 — For thicknesses measured at any location other than that specified in Note 3, the permitted variations over specified thickness shall be $1\frac{3}{4}$ times the amounts in this table, rounded to the nearest 0.01 in.

Note 5 — Where "... " appears in this table, there is no requirement.

TABLE 2
PERMITTED VARIATIONS IN WEIGHT FOR RECTANGULAR SHEARED PLATES AND UNIVERSAL MILL PLATES 613.0 LB/FT² AND UNDER WHEN ORDERED TO WEIGHT

Specified Weights, lb/ft ²	Permitted Variation in Average Weight of Lots ⁴ for Widths Given in Inches, Expressed in Percentage of the Specified Weights per Square Foot																							
	48 and Under		Over 48 to 60, excl		60 to 72, excl		72 to 84, excl		84 to 96, excl		96 to 108, excl		108 to 120, excl		120 to 132, excl		132 to 144, excl		144 to 168, excl		168 and over			
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under		
To 10, excl	4.0	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	7.5	3.0	9.0	3.0	11.0	3.0	13.0	3.0	...	...	...	...
10 to 12.5, excl	4.0	3.0	4.5	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.5	3.0	7.0	3.0	8.0	3.0	9.0	3.0	12.0	3.0	...	...
12.5 to 15.0, excl	4.0	3.0	4.0	3.0	4.5	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	7.5	3.0	8.0	3.0	11.0	3.0	...	...
15 to 17.5, excl	3.5	3.0	3.5	3.0	4.0	3.0	4.5	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	7.0	3.0	9.0	3.0	10.0	3.0		
17.5 to 20, excl	3.5	2.5	3.5	2.5	3.5	3.0	4.0	3.0	4.5	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	8.0	3.0	9.0	3.0		
20 to 25, excl	3.5	2.5	3.5	2.5	3.5	3.0	3.5	3.0	4.0	3.0	4.0	3.0	4.5	3.0	5.0	3.0	5.5	3.0	7.0	3.0	8.0	3.0		
25 to 30, excl	3.0	2.5	3.5	2.5	3.5	2.5	3.5	3.0	3.5	3.0	3.5	3.0	4.0	3.0	4.5	3.0	5.0	3.0	6.5	3.0	7.0	3.0		
30 to 40, excl	3.0	2.0	3.0	2.0	3.0	2.0	3.0	2.0	3.5	2.0	3.5	2.5	3.5	2.5	4.0	3.0	4.5	3.0	6.0	3.0	6.5	3.0		
40 to 81.7, excl	2.5	2.0	3.0	2.0	3.0	2.0	3.0	2.0	3.5	2.0	3.5	2.0	3.5	2.5	3.5	3.0	4.0	3.0	5.5	3.0	6.0	3.0		
81.7 to 122.6, excl	2.5	2.0	3.0	2.0	3.0	2.0	3.0	2.0	3.5	2.0	3.5	2.0	3.5	2.5	3.5	3.0	3.5	3.0	4.0	3.0	4.5	3.0		
122.6 to 163.4, excl	2.5	1.5	2.5	1.5	2.5	1.5	2.5	1.5	2.5	2.0	2.5	2.0	2.5	2.0	2.5	2.0	2.5	2.0	3.0	2.0	3.5	2.0		
163.4 to 245.1, excl	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	3.0	1.0	3.5	1.0		
245.1 to 409.0, excl	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	3.0	1.0		
409.0 to 490.1, excl	2.0	1.0	2.0	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0		
490.1 to 613.0, excl	2.0	1.0	2.0	1.0	2.0	1.0	2.0	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0		

Note 1 — Permitted variations in overweight for lots of circular and sketch plates shall be 1¼ times the amounts in this table.

Note 2 — Permitted variations in overweight for single plates shall be 1½ times the amounts in this table.

Note 3 — Permitted variations in overweight for circular and sketch plates shall be 1½ times the amounts in this table.

Note 4 — The adopted standard density of rolled steel is 490 lb/ft³.

Note 5 — Where "... " appears in this table, there is no requirement.

⁴ The term "lot" means all the plates of each tabular width and weight group represented in each shipment.

TABLE 3
PERMITTED VARIATIONS IN WIDTH AND LENGTH FOR SHEARED PLATES 1½ IN. AND UNDER IN THICKNESS;
LENGTH ONLY OF UNIVERSAL MILL PLATES 2½ IN. AND UNDER IN THICKNESS

Specified Dimensions, in.		Permitted Variations Over Specified Width and Length ^A for Thicknesses Given in Inches, or Equivalent Weights Given in Pounds per Square Foot, in.							
		To ⅜, excl		⅜ to ⅝, excl		⅝ to 1, excl		1 to 2, incl ^B	
		To 15.3, excl		15.3 to 25.5, excl		25.5 to 40.8, excl		40.8 to 81.7, incl	
		Width	Length	Width	Length	Width	Length	Width	Length
To 120, excl	To 60, excl	⅜	1½	7/16	⅝	1½	¾	⅝	1
	60 to 84, excl	7/16	⅝	1½	11/16	⅝	7/8	¾	1
	84 to 108, excl	1½	¾	⅝	7/8	¾	1	1	1½
	108 and over	⅝	7/8	¾	1	7/8	1½	1½	1¼
120 to 240, excl	To 60, excl	⅜	¾	1½	7/8	⅝	1	¾	1½
	60 to 84, excl	1½	¾	⅝	7/8	¾	1	7/8	1¼
	84 to 108, excl	9/16	7/8	11/16	15/16	13/16	1½	1	1¾
	108 and over	⅝	1	¾	1½	7/8	1¼	1½	1¾
240 to 360, excl	To 60, excl	⅜	1	1½	1½	⅝	1¼	¾	1½
	60 to 84, excl	1½	1	⅝	1½	¾	1¼	7/8	1½
	84 to 108, excl	9/16	1	11/16	1½	7/8	1¾	1	1½
	108 and over	11/16	1½	7/8	1¼	1	1¾	1¼	1¾
360 to 480, excl	To 60, excl	7/16	1½	1½	1¼	⅝	1¾	¾	1½
	60 to 84, excl	1½	1¼	⅝	1¾	¾	1½	7/8	1½
	84 to 108, excl	9/16	1¼	¾	1¾	7/8	1½	1	1¾
	108 and over	¾	1¾	7/8	1½	1	1¾	1¼	1¾
480 to 600, excl	To 60, excl	7/16	1¼	1½	1½	⅝	1¾	¾	1¾
	60 to 84, excl	1½	1¾	⅝	1½	¾	1¾	7/8	1¾
	84 to 108, excl	⅝	1¾	¾	1½	7/8	1¾	1	1¾
	108 and over	¾	1½	7/8	1¾	1	1¾	1¼	1¾
600 to 720, excl	To 60, excl	1½	1¾	⅝	1¾	¾	1¾	7/8	2¼
	60 to 84, excl	⅝	1¾	¾	1¾	7/8	1¾	1	2¼
	84 to 108, excl	⅝	1¾	¾	1¾	7/8	1¾	1½	2¼
	108 and over	7/8	1¾	1	2	1½	2¼	1¼	2½
700 and over	To 60, excl	9/16	2	¾	2½	7/8	2¼	1	2¾
	60 to 84, excl	¾	2	7/8	2½	1	2¼	1½	2¾
	84 to 108, excl	¾	2	7/8	2½	1	2¼	1¼	2¾
	108 and over	1	2	1½	2¾	1¼	2½	1¾	3

^A Permitted variation under specified width and length, ¼ in.

^B Permitted variations in length apply also to Universal Mill plates up to 12 in. in width for thicknesses over 2 to 2½ in., incl, except for alloy steel up to 2 in. thick.

TABLE 4
PERMITTED VARIATIONS IN WIDTH FOR MILL EDGE
CARBON AND HIGH-STRENGTH, LOW-ALLOY PLATES
PRODUCED ON STRIP MILLS
 (Applies to Plates Produced from Coil and to Plates
 Produced from an As-Rolled Structural Product)

Specified Width, in.	Permitted Variation Over Specified Width, in. ⁴
To 14, excl	$\frac{7}{16}$
14 to 17, excl	$\frac{1}{2}$
17 to 19, excl	$\frac{9}{16}$
19 to 21, excl	$\frac{5}{8}$
21 to 24, excl	$\frac{11}{16}$
24 to 26, excl	$\frac{13}{16}$
26 to 28, excl	$\frac{15}{16}$
28 to 35, excl	$1\frac{1}{8}$
35 to 50, excl	$1\frac{1}{4}$
50 to 60, excl	$1\frac{1}{2}$
60 to 65, excl	$1\frac{5}{8}$
65 to 70, excl	$1\frac{3}{4}$
70 to 80, excl	$1\frac{7}{8}$
80 and over	2

⁴ No permitted variation under specified width.

TABLE 5
PERMITTED VARIATIONS IN ROLLED WIDTH FOR UNIVERSAL MILL PLATES
15 IN. AND UNDER IN THICKNESS

Specified Width, in.	Permitted Variations over Specified Width ⁴ for Thicknesses Given in Inches or Equivalent Weights Given in Pounds per Square Foot, in.					
	To $\frac{3}{8}$, excl	$\frac{3}{8}$ to $\frac{5}{8}$, excl	$\frac{5}{8}$ to 1, excl	1 to 2, incl	Over 2 to 10, incl	Over 10 to 15, incl
	To 15.3, excl	15.3 to 25.5, excl	25.5 to 40.8, excl	40.8 to 81.7, incl	81.7 to 409.0, incl	409.0 to 613.0, incl
Over 8 to 20, excl	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$
20 to 36, excl	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{9}{16}$
36 and over	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$

⁴ Permitted variation under specified width, $\frac{1}{8}$ in.

TABLE 6
PERMITTED VARIATIONS IN DIAMETER FOR
SHEARED CIRCULAR PLATES 1 IN. AND UNDER IN
THICKNESS

Specified Diameters, in.	Permitted Variation Over Specified Diameter for Thicknesses Given in Inches, in. ⁴		
	To $\frac{3}{8}$, excl	$\frac{3}{8}$ to $\frac{5}{8}$, excl	$\frac{5}{8}$ to 1, incl
To 32, excl	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$
32 to 84, excl	$\frac{5}{16}$	$\frac{7}{16}$	$\frac{9}{16}$
84 to 108, excl	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$
108 to 130, excl	$\frac{7}{16}$	$\frac{9}{16}$	$\frac{11}{16}$
130 and over	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$

⁴ No permitted variation under specified diameter.

TABLE 7
PERMITTED VARIATIONS IN DIAMETER FOR GAS-CUT CIRCULAR PLATES
(Not Applicable to Alloy Steel)

Specified Diameter, in.	Permitted Variation Over Specified Diameter for Thicknesses Given in Inches, in. ⁴					
	to 1, excl	1 to 2, excl	2 to 4, excl	4 to 6, excl	6 to 8, excl	8 to 15, incl
To 32, excl	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$
32 to 84, excl	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$
84 to 108, excl	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
108 to 130, excl	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{11}{16}$	$\frac{7}{8}$	1	$1\frac{1}{8}$
130 and over	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$

⁴ No permitted variation under specified diameter.

TABLE 8
PERMITTED VARIATIONS IN WIDTH AND LENGTH
FOR RECTANGULAR PLATES WHEN GAS CUTTING IS
SPECIFIED OR REQUIRED
(Applies to Alloy Steel Specifications Only)

Specified Thickness, in.	Permitted Variation Over Specified Width and Length, in.
To 2, excl	$\frac{3}{4}$
2 to 4, excl	1
4 to 6, excl	$1\frac{1}{8}$
6 to 8, excl	$1\frac{5}{16}$
8 to 15, incl	$1\frac{1}{2}$

Note 1 — These permitted variations shall be taken all under or divided over and under, if so specified.

Note 2 — Plates with universal rolled edges will be gas cut to length only.

TABLE 9
PERMITTED VARIATIONS IN WIDTH AND LENGTH
FOR RECTANGULAR PLATES WHEN GAS CUTTING IS
SPECIFIED OR REQUIRED
(Not Applicable to Alloy Steel)

Specified Thickness, in.	Permitted Variation Over Specified Width and Length, in.
To 2, excl	$\frac{1}{2}$
2 to 4, excl	$\frac{5}{8}$
4 to 6, excl	$\frac{3}{4}$
6 to 8, excl	$\frac{7}{8}$
8 to 15, incl	1

Note 1 — These permitted variations may be taken all under or divided over and under, if so specified.

Note 2 — Plates with universal rolled edges will be gas cut to length only.

TABLE 10
PERMITTED VARIATIONS IN DIAMETER FOR GAS-CUT CIRCULAR PLATES
 (Applies to Alloy Steel Specifications Only)

Specified Diameter, in.	Permitted Variations Over Specified Diameter for Specified Thicknesses Given in Inches, in. ⁴					
	to 1, excl	1 to 2, excl	2 to 4, excl	4 to 6, excl	6 to 8, excl	8 to 15, incl
To 32, excl	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	1	1
32 to 84, excl	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$
84 to 108, excl	$\frac{5}{8}$	$\frac{3}{4}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$
108 to 130, incl	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$

⁴ No permitted variation under specified diameter.

TABLE 11
PERMITTED CAMBER⁴ FOR CARBON STEEL, HIGH-STRENGTH
LOW-ALLOY STEEL, AND ALLOY STEEL UNIVERSAL MILL PLATES AND
HIGH-STRENGTH LOW-ALLOY STEEL AND ALLOY STEEL SHEARED,
SPECIAL-CUT, OR GAS-CUT RECTANGULAR PLATES

Specified Thickness, in.	Specified Weight, lb/ft ²	Specified Width, in.	Permitted Camber, in.
To 2, incl	to 81.7, incl	all	$\frac{1}{8} \times$ (no. of feet of length/5)
Over 2 to 15, incl	81.7 to 613.0, incl	to 30, incl	$\frac{3}{16} \times$ (no. of feet of length/5)
Over 2 to 15, incl	81.7 to 613.0, incl	over 30	$\frac{1}{4} \times$ (no. of feet of length/5)

⁴ Camber as it relates to plates is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

TABLE 12
PERMITTED CAMBER⁴ FOR SHEARED PLATES AND
GAS-CUT RECTANGULAR PLATES, ALL
THICKNESSES
 (Applies to Carbon Steel Only)

$$\text{Permitted camber, in.} = \frac{1}{8} \times (\text{number of feet of length}/5)$$

⁴ Camber as it relates to plates is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

TABLE 13
PERMITTED VARIATIONS FROM A FLAT SURFACE FOR STANDARD FLATNESS CARBON STEEL PLATES

Specified Thickness, in.	Specified Weight, lb/ft ²	Permitted Variations from a Flat Surface for Specified Widths Given in Inches, in. ^{A,B}											
		To 36, excl	36 to 48, excl	48 to 60, excl	60 to 72, excl	72 to 84, excl	84 to 96, excl	96 to 108, excl	108 to 120, excl	120 to 144, excl	144 to 168, excl	168 to 180, excl	Over 180
To 1/4, excl	To 10.2, excl	9/16	3/4	15/16	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	...	...	...
1/4 to 3/8, excl	10.2 to 15.3, excl	1/2	5/8	3/4	15/16	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	...	...	...
3/8 to 1/2, excl	15.3 to 20.4, excl	1/2	9/16	5/8	5/8	3/4	7/8	1	1 1/8	1 1/4	1 1/8	2 1/8	...
1/2 to 3/4, excl	20.4 to 30.6, excl	7/16	1/2	9/16	5/8	5/8	3/4	1	1	1 1/8	1 1/2	2	...
3/4 to 1, excl	30.6 to 40.8, excl	7/16	1/2	9/16	5/8	5/8	5/8	3/4	7/8	1	1 1/8	1 1/4	...
1 to 2, excl	40.8 to 81.7, excl	3/8	1/2	1/2	9/16	9/16	5/8	5/8	5/8	1 1/16	1 1/8	1 1/2	...
2 to 4, excl	81.7 to 163.4, excl	5/16	3/8	7/16	1/2	1/2	1/2	1/2	9/16	5/8	7/8	1 1/8	...
4 to 6, excl	163.4 to 245.1, excl	3/8	7/16	1/2	1/2	9/16	9/16	5/8	3/4	7/8	7/8	1	...
6 to 8, excl	245.1 to 326.8, excl	7/16	1/2	1/2	5/8	11/16	3/4	7/8	7/8	1	1	1	...
8 to 10, excl	326.8 to 409.0, excl	1/2	1/2	5/8	11/16	3/4	13/16	7/8	15/16	1	1	1	...
10 to 12, excl	409.0 to 490.1, excl	1/2	5/8	3/4	13/16	7/8	15/16	1	1	1	1	1	...
12 to 15, excl	490.1 to 613.0, incl	5/8	3/4	13/16	7/8	15/16	1	1	1	1	1	1	...

Note 1 — When the longer dimension is under 36 in., the permitted variation from a flat surface shall not exceed 1/4 in. When the longer dimension is from 36 to 72 in., incl, the permitted variation from a flat surface shall not exceed 75% of the tabular amount for the specified width, but in no case less than 1/4 in.

Note 2 — These permitted variations apply to plates that have a specified minimum tensile strength of not more than 60 ksi or comparable chemical composition or hardness. The limits in this table are increased 50% for plates that have a higher specified minimum tensile strength or comparable chemical composition or hardness.

Note 3 — This table and these notes cover the permitted variations from a flat surface for circular and sketch plates, based upon the maximum dimensions of such plates.

Note 4 — Where "... " appears in this table, there is no requirement.

Note 5 — Plates must be in a horizontal position on a flat surface when flatness is measured.

^A Permitted Variation from a Flat Surface for Length — The longer dimension specified is considered the length, and the permitted variation from a flat surface along the length shall not exceed the tabular amount for the specified width for plates up to 12 ft in length, or in any 12 ft for longer plates.

^B Permitted Variation from a Flat Surface for Width — The permitted variation from a flat surface across the width shall not exceed the tabular amount for the specified width.

TABLE 14
PERMITTED VARIATIONS FROM A FLAT SURFACE FOR STANDARD FLATNESS HIGH-STRENGTH LOW-ALLOY STEEL AND ALLOY STEEL PLATES,
HOT ROLLED OR THERMALLY TREATED

Specified Thickness, in.	Specified Weight, lb/ft ²	Permitted Variations from a Flat Surface for Specified Widths, in. ^{A,B}											
		To 36, excl	36 to 48, excl	48 to 60, excl	60 to 72, excl	72 to 84, excl	84 to 96, excl	96 to 108, excl	108 to 120, excl	120 to 144, excl	144 to 168, excl	168 to 180, excl	Over 180
To 1/4, excl	To 10.2, excl	13/16	1 1/8	1 3/8	1 7/8	2	2 1/4	2 3/8	2 5/8	2 3/4	...	...	...
1/4 to 3/8, excl	10.2 to 15.3, excl	3/4	1 1/8	1 1/8	1 3/8	1 3/4	1 7/8	2	2 1/4	2 3/8	...	...	...
3/8 to 1/2, excl	15.3 to 20.4, excl	3/4	7/8	1 1/8	1 5/16	1 1/8	1 5/16	1 1/2	1 3/8	1 7/8	2 3/4	3 1/8	3 1/8
1/2 to 3/4, excl	20.4 to 30.6, excl	5/8	3/4	1 1/8	7/8	1	1 1/8	1 1/4	1 3/8	1 5/8	2 1/4	3	3
3/4 to 1, excl	30.6 to 40.8, excl	5/8	3/4	7/8	7/8	1 5/16	1	1 1/8	1 5/16	1 1/2	2	2 5/8	2 5/8
1 to 2, excl	40.8 to 81.7, excl	9/16	5/8	3/4	1 1/8	7/8	1 5/16	1	1	1	1 5/8	2 1/4	2 1/4
2 to 4, excl	81.7 to 163.4, excl	1/2	9/16	1 1/8	3/4	3/4	3/4	3/4	7/8	1	1 1/4	1 5/8	1 5/8
4 to 6, excl	163.4 to 245.1, excl	9/16	1 1/8	3/4	3/4	7/8	7/8	1 5/16	1 1/8	1 1/4	1 1/4	1 1/2	1 1/2
6 to 8, excl	245.1 to 326.8, excl	5/8	3/4	3/4	1 5/16	1	1 1/8	1 1/4	1 5/16	1 1/2	1 1/2	1 1/2	1 1/2
8 to 10, excl	326.8 to 409.0, excl	3/4	1 3/8	1 5/16	1	1 1/8	1 1/4	1 5/16	1 3/8	1 1/2	1 1/2	1 1/2	1 1/2
10 to 12, excl	409.0 to 490.1, excl	3/4	1 5/16	1 1/8	1 1/4	1 5/16	1 3/8	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2
12 to 15, incl	490.1 to 613.0, incl	7/8	1	1 1/8	1 5/16	1 3/8	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2

Note 1 — When the longer dimension is under 36 in., the permitted variation from a flat surface shall not exceed 3/8 in. When the larger dimension is from 36 to 72 in., incl, the permitted variation from a flat surface shall not exceed 75% of the tabular amount for the specified width.

Note 2 — This table and these notes cover the permitted variations from a flat surface for circular and sketch plates, based upon the maximum dimensions of such plates.

Note 3 — Where "... " appears in this table, there is no requirement.

Note 4 — Plates must be a horizontal position on a flat surface when flatness is measured.

^A Permitted Variation from a Flat Surface for Length — The longer dimension specified is considered the length, and the permitted variation from a flat surface along the length shall not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft for longer plates.

^B Permitted Variation from a Flat Surface for Width — The permitted variation from a flat surface across the width shall not exceed the tabular amount for the specified width.

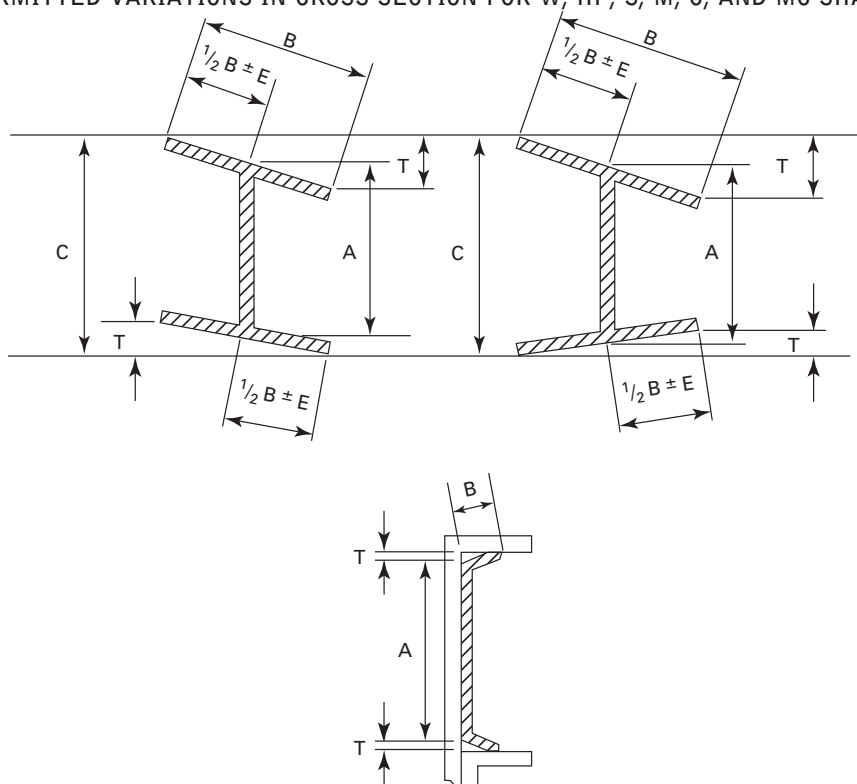
TABLE 15
PERMITTED VARIATIONS IN WAVINESS FOR STANDARD FLATNESS PLATES

Permitted Variation from a Flat Surface (from Table 13 or 14), in.	Permitted Variation in Waviness, in., When Number of Waves in 12 ft is						
	1	2	3	4	5	6	7
$\frac{5}{16}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{16}$
$\frac{3}{8}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{16}$
$\frac{7}{16}$	$\frac{7}{16}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{16}$
$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{16}$
$\frac{9}{16}$	$\frac{9}{16}$	$\frac{7}{16}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{8}$
$\frac{5}{8}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{8}$
$\frac{11}{16}$	$\frac{11}{16}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{1}{8}$
$\frac{3}{4}$	$\frac{3}{4}$	$\frac{9}{16}$	$\frac{7}{16}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{1}{8}$
$\frac{13}{16}$	$\frac{13}{16}$	$\frac{5}{8}$	$\frac{7}{16}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{1}{8}$
$\frac{7}{8}$	$\frac{7}{8}$	$\frac{11}{16}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{1}{8}$
$\frac{15}{16}$	$\frac{15}{16}$	$\frac{11}{16}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{3}{16}$
1	1	$\frac{3}{4}$	$\frac{9}{16}$	$\frac{7}{16}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{3}{16}$
$1\frac{1}{8}$	$1\frac{1}{8}$	$\frac{7}{8}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{3}{16}$
$1\frac{1}{4}$	$1\frac{1}{4}$	$\frac{15}{16}$	$\frac{11}{16}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{1}{4}$
$1\frac{3}{8}$	$1\frac{3}{8}$	$1\frac{1}{16}$	$\frac{3}{4}$	$\frac{9}{16}$	$\frac{7}{16}$	$\frac{5}{16}$	$\frac{1}{4}$
$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{8}$	$\frac{7}{8}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{4}$
$1\frac{5}{8}$	$1\frac{5}{8}$	$1\frac{1}{4}$	$\frac{15}{16}$	$\frac{11}{16}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{5}{16}$
$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{5}{16}$	1	$\frac{3}{4}$	$\frac{9}{16}$	$\frac{7}{16}$	$\frac{5}{16}$
$1\frac{7}{8}$	$1\frac{7}{8}$	$1\frac{7}{16}$	$1\frac{1}{16}$	$\frac{13}{16}$	$\frac{9}{16}$	$\frac{7}{16}$	$\frac{5}{16}$
2	2	$1\frac{1}{2}$	$1\frac{1}{8}$	$\frac{7}{8}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{8}$
$2\frac{1}{8}$	$2\frac{1}{8}$	$1\frac{5}{8}$	$\frac{3}{16}$	$\frac{7}{8}$	$\frac{11}{16}$	$\frac{1}{2}$	$\frac{3}{8}$
$2\frac{1}{4}$	$2\frac{1}{4}$	$1\frac{11}{16}$	$1\frac{1}{4}$	$\frac{15}{16}$	$\frac{11}{16}$	$\frac{9}{16}$	$\frac{3}{8}$
$2\frac{3}{8}$	$2\frac{3}{8}$	$1\frac{13}{16}$	$1\frac{5}{16}$	1	$\frac{3}{4}$	$\frac{9}{16}$	$\frac{7}{16}$
$2\frac{1}{2}$	$2\frac{1}{2}$	$1\frac{7}{8}$	$1\frac{7}{16}$	$1\frac{1}{16}$	$\frac{13}{16}$	$\frac{9}{16}$	$\frac{7}{16}$
$2\frac{5}{8}$	$2\frac{5}{8}$	2	$1\frac{1}{2}$	$1\frac{1}{8}$	$\frac{13}{16}$	$\frac{5}{8}$	$\frac{7}{16}$
$2\frac{3}{4}$	$2\frac{3}{4}$	$2\frac{1}{16}$	$\frac{9}{16}$	$1\frac{1}{8}$	$\frac{7}{8}$	$\frac{5}{8}$	$\frac{1}{2}$
$2\frac{7}{8}$	$2\frac{7}{8}$	$2\frac{3}{16}$	$1\frac{5}{8}$	$1\frac{3}{16}$	$\frac{15}{16}$	$\frac{11}{16}$	$\frac{1}{2}$
3	3	$2\frac{1}{4}$	$1\frac{11}{16}$	$1\frac{1}{4}$	$\frac{15}{16}$	$\frac{11}{16}$	$\frac{9}{16}$
$3\frac{1}{8}$	$3\frac{1}{8}$	$2\frac{3}{8}$	$1\frac{3}{4}$	$1\frac{5}{16}$	1	$\frac{3}{4}$	$\frac{9}{16}$

Note 1 — Waviness denotes the maximum deviation of the surface of the plate from a plane parallel to the surface of the point of measurement and contiguous to the surface of the plate at each of the two adjacent wave peaks, when the plate is resting on a flat horizontal surface, as measured in an increment of less than 12 ft of length. The permitted variation in waviness is a function of the permitted variation from a flat surface as obtained from Table 13 or 14, whichever is applicable.

Note 2 — Plates must be in a horizontal position on a flat surface when waviness is measured.

TABLE 16
PERMITTED VARIATIONS IN CROSS SECTION FOR W, HP, S, M, C, AND MC SHAPES



Permitted Variations in Sectional Dimensions Given, in.									Permitted Variations Over or Under Theoretical Web Thicknesses Given in Inches, in.	
Shape	Section Nominal Sizes, in.	A, Depth		B, Flange Width		T + T' ^A Flanges Out-of-Square ^B	E, Web off-Center ^C	C, Maximum Depth at any Cross Section over Theoretical Depth, in.		
		Over Theoretical	Under Theoretical	Over Theoretical	Under Theoretical				3/16 and Under	Over 3/16
W and HP	Up to 12, incl	1/8	1/8	1/4	3/16	1/4	3/16	1/4	...	...
	Over 12	1/8	1/8	1/4	3/16	5/16	3/16	1/4	...	...
S and M	3 to 7, incl	3/32	1/16	1/8	1/8	1/32	3/16	...	...	...
	Over 7 to 14, incl	1/8	3/32	5/32	5/32	1/32	3/16	...	...	...
	Over 14 to 24, incl	3/16	1/8	3/16	3/16	1/32	3/16	...	...	...
C and MC	1 1/2 and under	1/32	1/32	1/32	1/32	1/32	...	...	0.010	0.015
	Over 1 1/2 to 3, excl	1/16	1/16	1/16	1/16	1/32	...	...	0.015	0.020
	3 to 7, incl	3/32	1/16	1/8	1/8	1/32	...	...	...	...
	Over 7 to 14, incl	1/8	3/32	1/8	5/32	1/32	...	...	...	...
	Over 14	3/16	1/8	1/8	3/16	1/32	...	...	...	...

Note 1 — A is measured at center line of web for S, M, and W and HP shapes; at back of web for C and MC shapes. Measurement is over-all for C shapes under 3 in. B is measured parallel to flange. C is measured parallel to web.

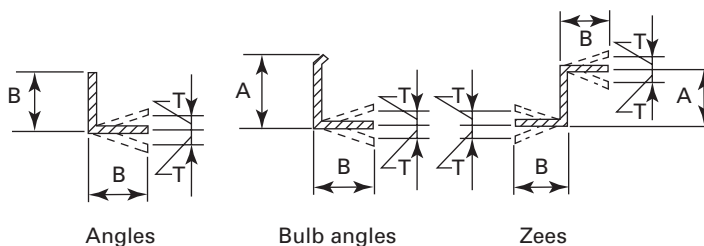
Note 2 — Where "... " appears in this table, there is no requirement.

^A T + T' applies when flanges of channels are toed in or out. For channels 5/8 in. and under in depth, the permitted out-of-square is 3/64 in./in. of depth.

^B Permitted variation is per inch of flange width for S, M, C, and MC shapes.

^C Permitted variation of 5/16 in. max for sections over 426 lb/ft.

TABLE 17
PERMITTED VARIATIONS IN CROSS SECTION FOR ANGLES (L SHAPES), BULB ANGLES, AND ZEES



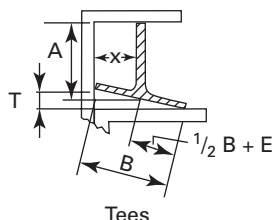
Section	Nominal Size, in.	Permitted Variations in Sectional Dimensions Given, in.					Permitted Variations Over or Under Theoretical Thickness for Thicknesses Given in Inches, in.		
		A , Depth		B , Flange Width or Length of Leg		T , Out-of-Square per Inch of B	$\frac{3}{16}$ and under	Over $\frac{3}{16}$ to $\frac{3}{8}$, incl	Over $\frac{3}{8}$
		Over Theoretical	Under Theoretical	Over Theoretical	Under Theoretical				
Angles ⁴ (L Shapes)	1 and under	...	...	$\frac{1}{32}$	$\frac{1}{32}$	$\frac{3}{128} B$	0.008	0.010	...
	Over 1 to 2, incl	...	...	$\frac{3}{64}$	$\frac{3}{64}$	$\frac{3}{128} B$	0.010	0.010	0.012
	Over 2 to 3, excl	...	...	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{3}{128} B$	0.012	0.015	0.015
	3 to 4, incl	...	...	$\frac{1}{8}$	$\frac{3}{32}$	$\frac{3}{128} B$	...	...	...
	Over 4 to 6, incl	...	...	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{128} B$	...	...	...
	Over 6	...	...	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{3}{128} B$	...	...	...
Bulb angles	(Depth) 3 to 4, incl	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{32}$	$\frac{3}{128} B$	...	...	...
	Over 4 to 6, incl	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{128} B$	...	...	...
	Over 6	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{3}{128} B$	...	...	...
Zees	3 to 4, incl	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{32}$	$\frac{3}{128} B$	...	...	...
	Over 4 to 6, incl	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{128} B$	...	...	...

Note 1—Where “...” appears in this table, there is no requirement.

⁴ For unequal leg angles, longer leg determines classification.

^B $\frac{3}{128}$ in./in. = $1\frac{1}{2}^\circ$.

TABLE 18
PERMITTED VARIATIONS IN SECTIONAL DIMENSIONS FOR ROLLED TEES



Permitted Variations in Sectional Dimensions Given, in.											
Tees											
Nominal Size ^A	A, Depth ^B		B, Width ^B		T, Out-of-Square per inch of B	E, Web-off-Center	Stem Out-of-Square ^C	Thickness of Flange		Thickness of Stem	
	Over	Under	Over	Under				Over	Under	Over	Under
1¼ and under	3/64	3/64	3/64	3/64	...	...	1/32	0.010	0.010	0.005	0.020
Over 1¼ to 2, incl	1/16	1/16	1/16	1/16	...	...	1/16	0.012	0.012	0.010	0.020
Over 2 to 3, excl	3/32	3/32	3/32	3/32	...	...	3/32	0.015	0.015	0.015	0.020
3 to 5, incl	3/32	1/16	1/8	1/8	1/32	3/32	...	...	...	...	...
Over 5 to 7, incl	3/32	1/16	1/8	1/8	1/32	1/8	...	...	...	...	...

Note 1 — * Back of square and center line of stem are to be parallel when measuring "out-of-square."

Note 2 — Where "... " appears in this table, there is no requirement.

^A The longer member of an unequal tee determines the size for permitted variations.

^B Measurements for both depth and width are overall.

^C Stem-out-of-square is the permitted variation from its true position of the center line of stem, measured at the point.

TABLE 19
PERMITTED VARIATIONS IN LENGTH FOR S, M, C, MC, L, T, Z, AND BULB ANGLE SHAPES

Permitted Variations from Specified Length for Lengths Given in Feet, in.														
Nominal Size, ^A in.	5 to 10, excl		10 to 20, excl		20 to 30, incl		Over 30 to 40, incl		Over 40 to 50, incl		Over 50 to 65, incl		Over 65 ft	
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
Under 3	5/8	0	1	0	1½	0	2	0	2½	0	2½	0	...	...
3 and over	1	0	1½	0	1¾	0	2¼	0	2¾	0	2¾	0	...	...

Note 1 — Where "... " appears in this table, there is no requirement.

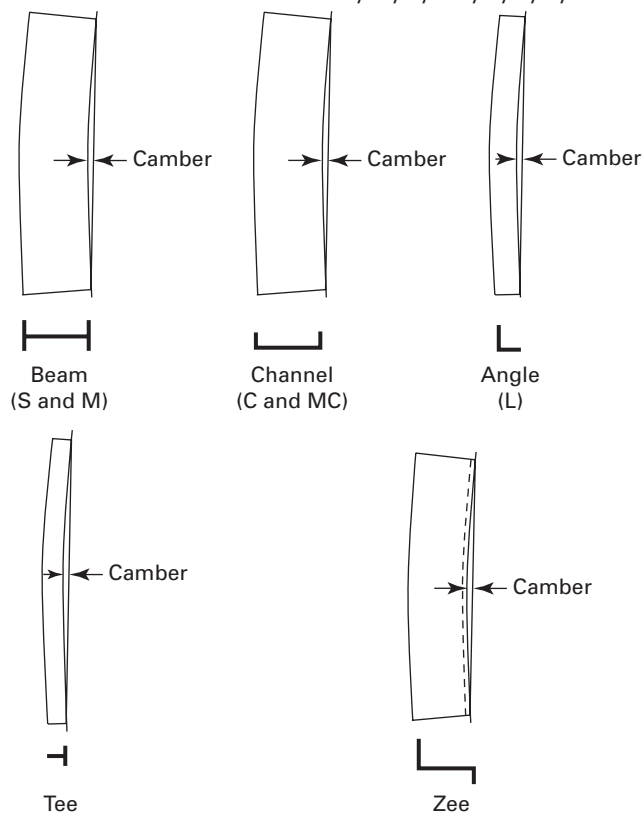
^A Greatest cross-sectional dimension.

TABLE 20
PERMITTED VARIATIONS IN END OUT-OF-SQUARE
FOR S, M, C, MC, L, T, Z, AND BULB ANGLE SHAPES

Shapes	Permitted Variation
S, M, C, and MC	$\frac{1}{64}$ in. per inch of depth
L ⁴	$\frac{3}{128}$ in. per inch of leg length or $1\frac{1}{2}^\circ$
Bulb angles	$\frac{3}{128}$ in. per inch of depth or $1\frac{1}{2}^\circ$
Rolled Tees ⁴	$\frac{1}{64}$ in. per inch of flange or stem
Zees	$\frac{3}{128}$ in. per inch of sum of both flange lengths

⁴ Permitted variations in end out-of-square are determined on the longer members of the shape.

TABLE 21
PERMITTED VARIATIONS IN STRAIGHTNESS FOR S, M, C, MC, L, T, Z, AND BULB ANGLE SHAPES



Positions for Measuring Camber of Shapes

Variable	Nominal Size, ⁴ in.	Permitted Variation, in.
Camber	under 3	$\frac{1}{4}$ in. in any 5 ft, or $\frac{1}{4} \times$ (number of feet of total length/5)
	3 and over	$\frac{1}{8} \times$ (number of feet of total length/5)
Sweep	all	Due to the extreme variations in flexibility of these shapes, permitted variations for sweep are subject to negotiations between the manufacturer and the purchaser for the individual sections involved.

⁴ Greatest cross-sectional dimension.

TABLE 22
PERMITTED VARIATIONS IN LENGTH FOR W AND HP SHAPES

W and HP Shapes	Permitted Variations from Specified Length for Lengths Given in Feet, in. ^{A,B}			
	30 ft and Under		Over 30 ft	
	Over	Under	Over	Under
Beams 24 in. and under in nominal depth	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$ plus $\frac{1}{16}$ for each additional 5 ft or fraction thereof	$\frac{3}{8}$
Beams over 24 in. in nominal depth and all columns	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$ plus $\frac{1}{16}$ for each additional 5 ft or fraction thereof	$\frac{1}{2}$

^A For HP and W shapes specified in the order for use as bearing piles, the permitted variations in length are plus 5 in. and minus 0 in. These permitted variations in length also apply to sheet piles.

^B The permitted variations in end out-of-square for W and HP shapes shall be 1/64 in. per inch of depth, or per inch of flange width if the flange width is larger than the depth.

TABLE 23
PERMITTED VARIATIONS IN LENGTH AND END OUT-OF-SQUARE, MILLED SHAPES

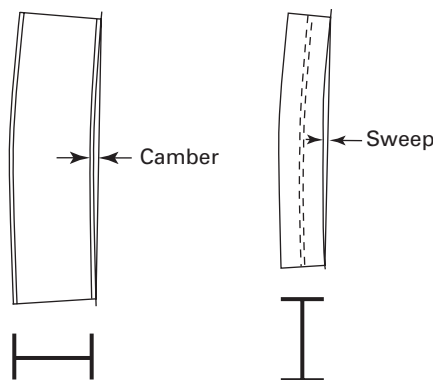
Nominal, Depth, in.	Length, ft ^B	Permitted Variations in Length and End Out-of-Square, in. ^A					
		Milled Both Ends ^C			Milled One-End ^C		
		Length		End Out-of-Square	Length		End Out-of-Square (for Milled End)
		Over	Under		Over	Under	
6 to 36	6 to 70	$\frac{1}{32}$	$\frac{1}{32}$	$\frac{1}{32}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{32}$

^A Length is measured along center line of web. Measurements are made with the steel and tape at the same temperature.

^B The permitted variations in length and end out-of-square are additive.

^C End out-of-square are measured by (a) squaring from the center line of the web and (b) squaring from the center line of the flange. The measured variation from true squareness in either plane shall not exceed the total tabular amount.

TABLE 24
PERMITTED VARIATIONS IN STRAIGHTNESS FOR W AND HP SHAPES



Positions for Measuring Camber and Sweep of W and HP Shapes

	Permitted Variation in Straightness, in.
Camber and sweep	$\frac{1}{8} \times (\text{number of feet of total length}/10)^4$
When certain sections ^B with a flange width approximately equal to depth are specified in the order for use as columns:	
Lengths of 45 ft and under	$\frac{1}{8} \times (\text{number of feet of total length}/10)$ but not over $\frac{3}{8}$
Lengths over 45 ft	$\frac{3}{8} + [\frac{1}{8} \times (\text{Number of feet of total length} - 45)/10]$

^A Sections with a flange width less than 6 in., permitted variation for sweep, in. = $\frac{1}{8}$ in. \times (number of feet of total length/5).

^B Applies only to:

- 8-in. deep sections 31 lb/ft and heavier,
- 10-in. deep sections 49 lb/ft and heavier,
- 12-in. deep sections 65 lb/ft and heavier, and
- 14-in. deep sections 90 lb/ft and heavier.

For other sections specified in the order for use as columns, the permitted variation is subject to negotiation with the manufacturer.

TABLE 25
PERMITTED VARIATIONS IN DIMENSIONS FOR
SPLIT TEES AND SPLIT ANGLES (L SHAPES)^A

Specified Depth, in.	Permitted Variation Over or Under Specified Depth, ^B in.
To 6, excl (beams and channels)	$\frac{1}{8}$
6 to 16, excl (beams and channels)	$\frac{3}{16}$
16 to 20, excl (beams and channels)	$\frac{1}{4}$
20 to 24, excl (beams)	$\frac{5}{16}$
24 and over (beams)	$\frac{3}{8}$

^A The permitted variations in length for split tees or angles are the same as those applicable to the section from which the tees or angles are split.

^B The above permitted variations in depth of tees or angles include the permitted variations in depth for the beams or channels before splitting. Permitted variations in dimensions and straightness, as set up for the beams or channels from which these tees or angles are cut, apply, except:

$$\text{straightness} = \frac{1}{8} \text{ in.} \times (\text{length in feet}/5).$$

TABLE 26
PERMITTED VARIATIONS IN SECTIONAL DIMENSIONS FOR SQUARE-EDGE AND ROUND-EDGE FLAT BARS

Specified Widths, in.	Permitted Variations Over or Under Specified Thickness, for Thicknesses Given in Inches, in.							Permitted Variations from Specified Width, in.	
	0.203 to 0.230, excl	0.230 to 1/4, excl	1/4 to 1/2, incl	Over 1/2 to 1, incl	Over 1 to 2, incl	Over 2 to 3, incl	Over 3	Over	Under
To 1, incl	0.007	0.007	0.008	0.010	...	...	...	1/64	1/64
Over 1 to 2, incl	0.007	0.007	0.012	0.015	1/32	...	...	1/32	1/32
Over 2 to 4, incl	0.008	0.008	0.015	0.020	1/32	3/64	3/64	1/16	1/32
Over 4 to 6, incl	0.009	0.009	0.015	0.020	1/32	3/64	3/64	3/32	1/16
Over 6 to 8, incl	^A	0.015	0.016	0.025	1/32	3/64	1/16	1/8 ^B	3/32 ^B

Note 1— Where "... " appears in this table, there is no requirement.

^A Flats over 6 to 8 in., incl, in width are not available as hot-rolled carbon steel bars in thickness under 0.230 in.

^B For flats over 6 to 8 in., in width, and 3 in. incl in thickness.

TABLE 27
PERMITTED VARIATIONS IN SECTIONAL DIMENSIONS FOR ROUND AND SQUARE BARS AND ROUND-CORNERED SQUARES

Specified Size, in.	Permitted Variations from Specified Size, in.		Permitted Out-of-Round or Out-of-Square, in. ⁴
	Over	Under	
To 5/16	0.005	0.005	0.008
Over 5/16 to 7/16, incl	0.006	0.006	0.009
Over 7/16 to 5/8, incl	0.007	0.007	0.010
Over 5/8 to 7/8, incl	0.008	0.008	0.012
Over 7/8 to 1, incl	0.009	0.009	0.013
Over 1 to 1 1/8, incl	0.010	0.010	0.015
Over 1 1/8 to 1 1/4, incl	0.011	0.011	0.016
Over 1 1/4 to 1 3/8, incl	0.012	0.012	0.018
Over 1 3/8 to 1 1/2, incl	0.014	0.014	0.021
Over 1 1/2 to 2, incl	1/64	1/64	0.023
Over 2 to 2 1/2, incl	1/32	0	0.023
Over 2 1/2 to 3 1/2, incl	3/64	0	0.035
Over 3 1/2 to 4 1/2, incl	1/16	0	0.046
Over 4 1/2 to 5 1/2, incl	5/64	0	0.058
Over 5 1/2 to 6 1/2, incl	1/8	0	0.070
Over 6 1/2 to 8 1/4, incl	5/32	0	0.085
Over 8 1/4 to 9 1/2, incl	3/16	0	0.100
Over 9 1/2 to 10, incl	1/4	0	0.120

⁴ Out-of-round is the difference between the maximum and minimum diameters of the bar, measured at the same transverse cross section. Out-of-square section is the difference in perpendicular distance between opposite faces, measured at the same transverse cross section.

TABLE 28
PERMITTED VARIATIONS IN SECTIONAL DIMENSIONS FOR HEXAGONS

Specified Sizes Between Opposite Sides, in.	Permitted Variations from Specified Size, in.		Permitted Out-of-Hexagon Section, Three Measurements, in. ⁴
	Over	Under	
1/2 and under	0.007	0.007	0.011
Over 1/2 to 1, incl	0.010	0.010	0.015
Over 1 to 1 1/2, incl	0.021	0.013	0.025
Over 1 1/2 to 2, incl	1/32	1/64	1/32
Over 2 to 2 1/2, incl	3/64	1/64	3/64
Over 2 1/2 to 3 1/2, incl	1/16	1/64	1/16

⁴ Out-of-hexagon section is the greatest difference in distance between any two opposite faces measured at the same transverse cross section.

TABLE 29
PERMITTED VARIATIONS IN STRAIGHTNESS FOR BARS

Permitted Variations in Straightness, in. ⁴
1/4 in any 5 ft, and 1/4 × (number of feet of total length/5)

⁴ Permitted variations in straightness do not apply to hot-rolled bars if any subsequent heating operation has been performed.

TABLE 30
PERMITTED VARIATIONS IN LENGTH FOR HOT-CUT STEEL BARS^A

Specified Sizes of Rounds, Squares, and Hexagons, in.	Specified Sizes of Flats, in.		Permitted Variations Over Specified Length Given in Feet, in. (No Variation Under)				
			5 to 10, excl	10 to 20, excl	20 to 30, excl	30 to 40, excl	40 to 60, incl
	Thickness	Width					
To 1, incl	To 1, incl	To 3, incl	$\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{4}$	$1\frac{3}{4}$	$2\frac{1}{4}$
Over 1 to 2, incl	Over 1	To 3, incl	$\frac{5}{8}$	1	$1\frac{1}{2}$	2	$2\frac{1}{2}$
Over 1 to 2, incl	To 1, incl	Over 3 to 6, incl	$\frac{5}{8}$	1	$1\frac{1}{2}$	2	$2\frac{1}{2}$
Over 2 to 5, incl	Over 1	Over 3 to 6, incl	1	$1\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{3}{4}$
Over 5 to 10, incl	...	...	2	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$
	0.230 to 1, incl	Over 6 to 8, incl	$\frac{3}{4}$	$1\frac{1}{4}$	$1\frac{3}{4}$	$3\frac{1}{2}$	4
	Over 1 to 3, incl	Over 6 to 8, incl	$1\frac{1}{4}$	$1\frac{3}{4}$	2	$3\frac{1}{2}$	4
Hot Sawing							
2 to 5, incl ^B	1 and over	3 and over	^B	$1\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{3}{4}$
Over 5 to 10, incl	...	...	^B	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$

Note 1— Where “. . .” appears in this table, there is no requirement.

^A For flats over 6 to 8 in., incl, in width and over 3 in. in thickness, consult the manufacturer for permitted variations in length.

^B Smaller sizes and shorter lengths are not commonly hot sawed.

TABLE 31
**PERMITTED VARIATIONS IN LENGTH FOR BARS
RECUT BOTH ENDS AFTER STRAIGHTENING^{A,B}**

Sizes of Rounds, Squares, Hexagons, Width of Flats and Maximum Dimension of Other Sections, in.	Permitted Variations from Specified Lengths Given in Feet, in.			
	To 12, incl		Over 12	
	Over	Under	Over	Under
To 3, incl	$\frac{3}{16}$	$\frac{1}{16}$	$\frac{1}{4}$	$\frac{1}{16}$
Over 3 to 6, incl	$\frac{1}{4}$	$\frac{1}{16}$	$\frac{3}{8}$	$\frac{1}{16}$
Over 6 to 8, incl	$\frac{3}{8}$	$\frac{1}{16}$	$\frac{1}{2}$	$\frac{1}{16}$
Rounds over 8 to 10, incl	$\frac{1}{2}$	$\frac{1}{16}$	$\frac{5}{8}$	$\frac{1}{16}$

^A For flats over 6 to 8 in., incl, in width, and over 3 in. in thickness, consult the manufacturer or processor for permitted variations in length.

^B Permitted variations are sometimes required all over or all under the specified length, in which case the sum of the two permitted variations applies.

SUPPLEMENTARY REQUIREMENTS

The following standardized supplementary requirements are for use when desired by the purchaser. Those that are considered suitable for use with each material specification are listed in the specification. Other tests may be performed by agreement between the supplier and the purchaser. These additional requirements shall apply only when specified in the order, in which event the specified tests shall be made by the manufacturer or processor before shipment of the material.

S1. Vacuum Treatment

S1.1 The steel shall be made by a process that includes vacuum degassing while molten. Unless otherwise agreed upon with the purchaser, it is the responsibility of the manufacturer to select suitable process procedures.

S2. Product Analysis

S2.1 Product analyses shall be made for those elements specified or restricted by the applicable product specification for the applicable grade, class, and type. Specimens for analysis shall be taken adjacent to or from the tension test specimen, or from a sample taken from the same relative location as that from which the tension test specimen was taken.

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons

S3.1 Prior to testing, the test specimens representing the structural product for acceptance purposes for mechanical properties shall be thermally treated to simulate a post-weld heat treatment below the critical temperature (A_{C3}), using the heat treatment parameters (such as temperature range, time, and cooling rates) specified in the order. The test results for such heat-treated test specimens shall meet the applicable product specification requirements.

S4. Additional Tension Test

S4.1 Plate — One tension test shall be made from each unit plate rolled from a slab or directly from an ingot, except that for quenched and tempered plates, a test shall be taken from each unit plate heat treated. The results obtained shall be reported on the mill test reports when such tests are required by the order.

S5. Charpy V-Notch Impact Test

S5.1 Charpy V-notch impact tests shall be conducted in accordance with Specification A 673/A 673M.

S5.2 The frequency of testing, the test temperature to be used, and the absorbed energy requirements shall be as specified on the order.

S6. Drop-Weight Test (for Material 0.625 in. [16 mm] and over in Thickness)

S6.1 Drop-weight tests shall be made in accordance with Test Method E 208. The specimens shall represent the material in the final condition of heat treatment. Agreement shall be reached between the purchaser and the manufacturer or processor as to the number of pieces to be tested and whether a maximum nil-ductility transition (NDT) temperature is mandatory or if the test results are for information only.

S8. Ultrasonic Examination

S8.1 The material shall be ultrasonically examined in accordance with the requirements specified on the order.

S15. Reduction of Area Measurement

S15.1 The reduction of area, as determined on the 0.500 in. [12.5 mm] diameter round tension test specimen in accordance with Methods and Definitions A 370, shall not be less than 40%.

S18. Maximum Tensile Strength

S18.1 Steel having a specified minimum tensile strength of less than 70 ksi [485 MPa] shall not exceed the minimum specified tensile strength by more than 30 ksi [205 MPa].

S18.2 Steel having a minimum specified tensile strength of 70 ksi [485 MPa] or higher shall not exceed the minimum specified tensile strength by more than 25 ksi [170 MPa].

S23. Copper-Bearing Steel (for improved atmospheric corrosion resistance)

S23.1 The copper content shall be a minimum of 0.20% on heat analysis, 0.18 on product analysis.

S26. Subdivided Material-Marking of Individual Pieces

S26.1 Subdivided pieces shall be individually identified by marking, stenciling, or die stamping the applicable product specification designation (year-date not required), grade, heat number, and the heat treatment identification, if applicable, along with the trademark, brand, or name of the organization that subdivided the structural product. As an alternative, individual subdivided pieces shall be identified by a code traceable to the original required identification, provided that the trademark, name, or brand of the organization that subdivided the structural product is also placed on the structural product and the original required identification, cross referenced on the code, is furnished with the structural product.

S27. Restrictive Plate Flatness

S27.1 As-rolled or normalized carbon steel plates ordered to restrictive flatness shall conform to the permitted variations from a flat surface given in Table S27.1 or Table S27.2, whichever is applicable.

S27.2 As-rolled or normalized high-strength low-alloy steel plates ordered to restrictive flatness shall conform to the permitted variations from a flat surface given in Table S27.3 or Table S27.4, whichever is applicable.

S28. Fine Grain Practice

S28.1 The steel shall be made to fine grain practice.

S29. Fine Austenitic Grain Size

S29.1 The requirements for fine austenitic grain size (see 8.1 and 8.3) shall be met.

S30. Charpy V-Notch Impact Test for Structural Shapes: Alternate Core Location

S30.1 For shapes with a flange thickness equal to or greater than $1\frac{1}{2}$ in. [38.1 mm] that are specified in the purchase order to be tested in accordance with this supplementary requirement, Charpy V-notch impact tests shall be conducted in accordance with Specification A 673/A 673M, using specimens taken from the alternate core location. Unless otherwise specified in the purchase order, the minimum average absorbed energy for each test shall be 20 ft•lbf [27 J] and the test temperature shall be 70°F [21 °C].

S30.2 The frequency of testing shall be Frequency (H), except that, for rolled shapes produced from ingots, the frequency shall be Frequency (P) and the specimens shall be taken from a location representing the top of an ingot or part of an ingot used to produce the product represented by such specimens.

S31. Maximum Carbon Equivalent for Weldability

S31.1 Plates and shapes shall be supplied with a specific maximum carbon equivalent value as specified by the purchaser. This value shall be based upon heat analysis. The required chemical analysis as well as the carbon equivalent shall be reported.

S31.2 The carbon equivalent shall be calculated using the following formula:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S31.3 For additional information on the weldability of steel, see Appendix X3.

S32. Single Heat Bundles

S32.1 Bundles containing shapes or bars shall be from a single heat of steel.

TABLE S27.1
PERMITTED VARIATIONS FROM A FLAT SURFACE FOR AS-ROLLED OR NORMALIZED CARBON STEEL PLATES
ORDERED TO HALF-STANDARD FLATNESS

Specified Thickness, in.	Specified Weights, lb/ft ²	Permitted Variations From a Flat Surface for Specified Widths Given in Inches, in.					
		48 to 60, excl.	60 to 72, excl.	72 to 84, excl.	84 to 96, excl.	96 to 108, excl.	108 to 120, incl.
To $\frac{1}{4}$, excl.	To 10.2 excl.	$\frac{15}{32}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$
$\frac{1}{4}$ to $\frac{3}{8}$, excl.	10.2 to 15.3, excl.	$\frac{3}{8}$	$\frac{15}{32}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$
$\frac{3}{8}$ to $\frac{1}{2}$, excl.	15.3 to 20.4, excl.	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$
$\frac{1}{2}$ to $\frac{3}{4}$, excl.	20.4 to 30.6, excl.	$\frac{9}{32}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$
$\frac{3}{4}$ to 1, excl.	30.6 to 40.8, excl.	$\frac{9}{32}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$
1 to 2, incl.	40.8 to 51.7, incl.	$\frac{1}{4}$	$\frac{9}{32}$	$\frac{9}{32}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$

NOTE 1 — *Permitted Variation From a Flat Surface Along the Length* — The longer dimension specified is considered the length, and the permitted variation from a flat surface along the length shall not exceed the tabular amount for the specified width in plates up to 12 ft. in length, or in any 12 ft. of longer plates.

NOTE 2 — *Permitted Variation From a Flat Surface Across the Width* — The permitted variation from a flat surface across the width shall not exceed the tabular amount for the specified width.

NOTE 3 — When the longer dimension is under 36 in., the permitted variation from a flat surface shall not exceed $\frac{1}{4}$ in. in each direction. When the longer dimension is from 36 to 72 in., incl., the permitted variation from a flat surface shall not exceed 75% of the tabular amount for the specified width, but in no case less than $\frac{1}{4}$ in.

NOTE 4 — The permitted variations given in this table apply to plates that have a minimum specified tensile strength not over 60 ksi or comparable chemistry or hardness. For plates specified to a higher minimum tensile strength or compatible chemistry or hardness, the permitted variations are $1\frac{1}{2}$ times the amounts in this table.

NOTE 5 — This table and these notes cover the permitted variations from a flat surface for circular and sketch plates, based upon the maximum dimensions of such plates.

NOTE 6 — Permitted variations in waviness do not apply.

NOTE 7 — Plates must be in a horizontal position on a flat surface when flatness is measured.

TABLE S27.2
PERMITTED VARIATIONS FROM A FLAT SURFACE FOR AS-ROLLED OR NORMALIZED CARBON STEEL PLATES
ORDERED TO HALF-STANDARD FLATNESS

Specified Thickness, mm	Specified Weights, kg/m ²	Permitted Variations From a Flat Surface for Specified Widths Given in Millimeters, mm					
		1200 to 1500, excl.	1500 to 1800, excl.	1800 to 2100, excl.	2100 to 2400, excl.	2400 to 2700, excl.	2700 to 3000, incl.
To 6, excl.	To 47.1 excl.	12	16	17	19	20	22
6 to 10, excl.	47.1 to 78.5, excl.	9	12	14	16	17	19
10 to 12, excl.	78.5 to 94.2, excl.	8	8	9	11	12	14
12 to 20, excl.	94.2 to 157.0, excl.	7	8	8	9	12	12
20 to 25, excl.	157.0 to 196.2, excl.	7	8	8	8	9	11
25 to 50, incl.	196.2 to 392.5, incl.	6	7	7	8	8	8

NOTE 1 — *Permitted Variation From a Flat Surface Along the Length* — The longer dimension specified is considered the length, and the permitted variation from a flat surface along the length shall not exceed the tabular amount for the specified width in plates up to 3700 mm in length, or in any 3700 mm of longer plates.

NOTE 2 — *Permitted Variation From a Flat Surface Across the Width* — The permitted variation from a flat surface across the width shall not exceed the tabular amount for the specified width.

NOTE 3 — When the longer dimension is under 900 mm, the permitted variation from a flat surface shall not exceed 6 mm in each direction. When the longer dimension is from 900 to 1800 mm, incl., the permitted flatness variation should not exceed 75% of the tabular amount for the specified width, but in no case less than 6 mm.

NOTE 4 — The permitted variations given in this table apply to plates that have a minimum specified tensile strength not over 415 MPa or comparable chemistry or hardness. For plates specified to a higher minimum tensile strength or compatible chemistry or hardness, the permitted variations are 1½ times the amounts in this table.

NOTE 5 — This table and these notes cover the permitted variations from a flat surface for circular and sketch plates, based upon the maximum dimensions of such plates.

NOTE 6 — Permitted variations in waviness do not apply.

NOTE 7 — Plates must be in a horizontal position on a flat surface when flatness is measured.

TABLE S27.3
PERMITTED VARIATIONS FROM A FLAT SURFACE FOR AS-ROLLED OR NORMALIZED HIGH-STRENGTH LOW-ALLOY STEEL PLATES ORDERED TO HALF-STANDARD FLATNESS

Specified Thickness, in.	Specified Weights, lb/ft ²	Permitted Variations From a Flat Surface for Specified Widths Given in Inches, in.					
		48 to 60, excl.	60 to 72, excl.	72 to 84, excl.	84 to 96, excl.	96 to 108, excl.	108 to 120, incl.
To ¼, excl.	To 10.2 excl.	11/16	15/16	1	1 1/8	1 3/16	1 5/16
¼ to 3/8, excl.	10.2 to 15.3, excl.	9/16	11/16	7/8	15/16	1	1 1/8
3/8 to 1/2, excl.	15.3 to 20.4, excl.	15/32	15/32	9/16	21/32	3/4	13/16
1/2 to 3/4, excl.	20.4 to 30.6, excl.	13/32	7/16	1/2	9/16	5/8	11/16
3/4 to 1, excl.	30.6 to 40.8, excl.	7/16	7/16	15/32	1/2	9/16	21/32
1 to 2, incl.	40.8 to 51.7, incl.	3/8	13/32	7/16	15/32	1/2	1/2

NOTE 1 — *Permitted Variation From a Flat Surface Along the Length* — The longer dimension specified is considered the length, and the permitted variation from a flat surface along the length shall not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft of longer plates.

NOTE 2 — *Permitted Variation From a Flat Surface Across the Width* — The permitted variation from a flat surface across the width shall not exceed the tabular amount for the specified width.

NOTE 3 — When the longer dimension is under 36 in., the permitted variation from a flat surface shall not exceed 3/8 in. in each direction. When the longer dimension is from 36 to 72 in., incl., the permitted variation from a flat surface shall not exceed 75% of the tabular amount for the specified width, but in no case less than 3/8 in.

NOTE 4 — This table and these notes cover the permitted variations from a flat surface for circular and sketch plates, based upon the maximum dimensions of those plates.

NOTE 5 — Permitted variations in waviness do not apply.

NOTE 6 — Plates must be in a horizontal position on a flat surface when flatness is measured.

TABLE S27.4
**PERMITTED VARIATIONS FROM A FLAT SURFACE FOR AS-ROLLED OR NORMALIZED HIGH-STRENGTH LOW-
 ALLOY STEEL PLATES ORDERED TO HALF-STANDARD FLATNESS**

Specified Thickness, mm	Specified Weights, kg/m ²	Permitted Variations From a Flat Surface for Specified Widths Given in Millimeters, mm					
		1200 to 1500, excl.	1500 to 1800, excl.	1800 to 2100, excl.	2100 to 2400, excl.	2400 to 2700, excl.	2700 to 3000, incl.
To 6, excl.	To 47.1 excl.	17	24	25	28	30	33
6 to 10, excl.	47.1 to 78.5, excl.	14	17	22	24	25	28
10 to 12, excl.	78.5 to 94.2, excl.	12	12	14	16	19	20
12 to 20, excl.	94.2 to 157.0, excl.	11	11	12	14	16	17
20 to 25, excl.	157.0 to 196.2, excl.	11	11	12	12	14	16
25 to 50, incl.	196.2 to 392.5, incl.	9	10	11	12	12	12

NOTE 1 — *Permitted Variation From a Flat Surface Along the Length* — The longer dimension specified is considered the length, and the permitted variation from a flat surface along the length shall not exceed the tabular amount for the specified width in plates up to 3700 mm in length, or in any 3700 mm of longer plates.

NOTE 2 — *Permitted Variation From a Flat Surface Across the Width* — The permitted variation from a flat surface across the width shall not exceed the tabular amount for the specified width.

NOTE 3 — When the longer dimension is under 900 mm, the permitted variation from a flat surface shall not exceed 10 mm in each direction. When the longer dimension is from 900 to 1800 mm, incl., the permitted variation from a flat surface shall not exceed 75% of the tabular amount for the specified width, but in no case less than 10 mm.

NOTE 4 — This table and these notes cover the permitted variations from a flat surface for circular and sketch plates, based upon the maximum dimensions of such plates.

NOTE 5 — Permitted variations in waviness do not apply.

NOTE 6 — Plates must be in a horizontal position on a flat surface when flatness is measured.

ANNEXES

(Mandatory Information)

A1. PERMITTED VARIATIONS IN DIMENSIONS AND MASS IN SI UNITS

A1.1 Tables A1.1 through A1.31 contain permitted variations in dimensions and mass stated in SI units.

TABLE A1.1
PERMITTED VARIATIONS IN THICKNESS FOR RECTANGULAR CARBON, HIGH-STRENGTH LOW-ALLOY, AND
ALLOY STEEL PLATES, 300 MM AND UNDER IN THICKNESS WHEN ORDERED TO THICKNESS

Specified Thickness, mm	Permitted Variations Over Specified Thickness for Widths Given in Millimetres, mm										
	1200 and Under	Over 1200 to 1500, excl	1500 to 1800, excl	1800 to 2100, excl	2100 to 2400, excl	2400 to 2700, excl	2700 to 3000, excl	3000 to 3300, excl	3300 to 3600, excl	3600 to 4200, excl	4200 and Over
5.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	...	...
5.5	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	...	...
6.0	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.1	...	...
7.0	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.2	1.4	...
8.0	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.2	1.4	...
9.0	0.8	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.3	1.5	...
10.0	0.8	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.3	1.5	1.7
11.0	0.8	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.3	1.5	1.7
12.0	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.0	1.3	1.5	1.8
14.0	0.8	0.8	0.8	0.8	0.9	0.9	1.0	1.1	1.3	1.5	1.8
16.0	0.8	0.8	0.8	0.8	0.9	0.9	1.0	1.1	1.3	1.5	1.8
18.0	0.8	0.8	0.8	0.8	0.9	1.0	1.1	1.2	1.4	1.6	2.0
20.0	0.8	0.8	0.8	0.8	0.9	1.0	1.2	1.2	1.4	1.6	2.0
22.0	0.8	0.9	0.9	0.9	1.0	1.1	1.3	1.3	1.5	1.8	2.0
25.0	0.9	0.9	1.0	1.0	1.0	1.2	1.3	1.5	1.5	1.8	2.2
28.0	1.0	1.0	1.1	1.1	1.1	1.3	1.4	1.8	1.8	2.0	2.2
30.0	1.1	1.1	1.2	1.2	1.2	1.4	1.5	1.8	1.8	2.1	2.4
32.0	1.2	1.2	1.3	1.3	1.3	1.5	1.6	2.0	2.0	2.3	2.6
35.0	1.3	1.3	1.4	1.4	1.4	1.6	1.7	2.3	2.3	2.5	2.8
38.0	1.4	1.4	1.5	1.5	1.5	1.7	1.8	2.3	2.3	2.7	3.0
40.0	1.5	1.5	1.6	1.6	1.6	1.8	2.0	2.5	2.5	2.8	3.3
45.0	1.6	1.6	1.7	1.8	1.8	2.0	2.3	2.8	2.8	3.0	3.5
50.0	1.8	1.8	1.8	2.0	2.0	2.3	2.5	3.0	3.0	3.3	3.8
55.0	2.0	2.0	2.0	2.2	2.2	2.5	2.8	3.3	3.3	3.5	3.8
60.0	2.3	2.3	2.3	2.4	2.4	2.8	3.0	3.4	3.4	3.8	4.0
70.0	2.5	2.5	2.5	2.6	2.6	3.0	3.3	3.5	3.6	4.0	4.0
80.0	2.8	2.8	2.8	2.8	2.8	3.3	3.5	3.5	3.6	4.0	4.0
90.0	3.0	3.0	3.0	3.0	3.0	3.5	3.5	3.5	3.6	4.0	4.4
100.0	3.3	3.3	3.3	3.3	3.5	3.8	3.8	3.8	3.8	4.4	4.4
110.0	3.5	3.5	3.5	3.5	3.5	3.8	3.8	3.8	3.8	4.4	4.4
120.0	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	4.8	4.8
130.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	5.2	5.2
140.0	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	5.6	5.6
150.0	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	5.6	5.6
160.0	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	5.6	5.6
180.0	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	6.3	6.3
200.0	5.8	5.8	6.0	6.0	6.0	6.0	6.0	6.0	6.0	7.0	7.0
250.0	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	8.8
300.0	7.5	7.5	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0

Note 1 — Permitted variation under specified thickness, 0.3 mm.

Note 2 — Thickness to be measured at 10 to 20 mm from the longitudinal edge.

Note 3 — For specified thicknesses not listed in this table, the permitted variations in thickness shall be as given for the next higher value of specified thickness that is listed in this table.

Note 4 — For thickness measured at any location other than that specified in Note 2, the permitted variations over specified thickness shall be $1\frac{3}{4}$ times the amounts in this table, rounded to the nearest 0.1 mm.

Note 5 — Where "... " appears in this table, there is no requirement.

TABLE A1.2
PERMITTED VARIATIONS IN MASS FOR RECTANGULAR SHEARED PLATES AND UNIVERSAL MILL PLATES 2983 kg/m² AND UNDER
WHEN ORDERED TO MASS

Specified Mass, kg/m ²	Permitted Variations in Average Mass of Lots ⁴ for Widths Given in Millimetres, Expressed in Percentage of the Specified Masses per Square Metre																			
	1200 and Under		Over 1200 to 1500, excl		1500 to 1800, excl		1800 to 2100, excl		2100 to 2400, excl		2400 to 2700, excl		2700 to 3000, excl		3000 to 3300, excl		3300 to 3600, excl		3600 to 4200, excl	
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
To 51.02, excl	4.0	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	7.5	3.0	9.0	3.0	...	...	...	...	...	...
51.02 to 62.80, excl	4.0	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	6.5	3.0	7.0	3.0	8.0	3.0	...	...	...	...
62.80 to 74.58, excl	4.0	3.0	4.0	3.0	4.5	3.0	5.0	3.0	5.5	3.0	5.5	3.0	6.0	3.0	7.5	3.0	8.0	3.0	11	3.0
74.58 to 86.35, excl	3.5	3.0	3.5	3.0	4.0	3.0	4.5	3.0	5.0	3.0	5.0	3.0	5.5	3.0	6.0	3.0	7.0	3.0	9.0	3.0
86.35 to 102.0, excl	3.5	2.5	3.5	2.5	3.5	3.0	4.0	3.0	4.5	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	8.0	3.0
102.0 to 125.6, excl	3.5	2.5	3.5	2.5	3.5	3.0	3.5	3.0	4.0	3.0	4.0	3.0	4.5	3.0	5.0	3.0	5.5	3.0	7.0	3.0
125.6 to 149.2, excl	3.0	2.5	3.5	2.5	3.5	3.0	3.5	3.0	3.5	3.0	3.5	3.0	4.0	3.0	4.5	3.0	5.0	3.0	6.5	3.0
149.2 to 196.2, excl	3.0	2.0	3.0	2.0	3.0	2.0	3.0	2.0	3.5	2.0	3.5	2.5	3.5	2.5	4.0	3.0	4.5	3.0	6.0	3.0
196.2 to 392.5, excl	2.5	2.0	3.0	2.0	3.0	2.0	3.0	2.0	3.5	2.0	3.5	2.0	3.5	2.5	3.5	3.0	3.5	3.0	5.5	3.0
392.5 to 588.8, excl	2.5	2.0	3.0	2.0	3.0	2.0	3.0	2.0	3.5	2.0	3.5	2.0	3.5	2.5	3.5	3.0	3.5	3.0	4.0	3.0
588.8 to 785.0, excl	2.5	1.5	2.5	1.5	2.5	1.5	2.5	1.5	2.5	2.0	2.5	2.0	2.5	2.0	2.5	2.0	2.5	2.0	3.0	2.0
785.0 to 1178, excl	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	3.0	1.0
1178 to 1962, excl	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	3.0	1.0
1962 to 2355, excl	2.0	1.0	2.0	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0
2355 to 2983, incl	2.0	1.0	2.0	1.0	2.0	1.0	2.0	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0

Note 1 — Permitted variations in excess mass for lots of circular and sketch plates shall be $1\frac{1}{4}$ times the amounts in this table.

Note 2 — Permitted variations in excess mass for single plates shall be $1\frac{1}{3}$ times the amounts in this table.

Note 3 — Permitted variations in excess mass for single circular and sketch plates shall be $1\frac{2}{3}$ times the amounts in this table.

Note 4 — The adopted standard density for rolled steel is 7850 kg/m³.

Note 5 — Where "... " appears in this table, there is no requirement.

⁴ The term "lot" means all the plates of each tabular width and mass group represented in each shipment.

TABLE A1.3
PERMITTED VARIATIONS IN WIDTH AND LENGTH FOR SHEARED PLATES 40 MM AND UNDER IN THICKNESS;
LENGTH ONLY OF UNIVERSAL MILL PLATES 65 MM AND UNDER IN THICKNESS

Specified Dimensions, mm		Permitted Variations Over Specified Width and Length ^A for Thicknesses Given in Millimetres and Equivalent Masses Given in Kilograms per Square Metre, mm							
		To 10.5 excl		10.5 to 16, excl		16 to 25, excl		25 to 50, incl ^B	
		To 78.50, excl		78.50 to 125.6, excl		125.6 to 196.2, excl		196.2 to 392.5, excl	
		Width	Length	Width	Length	Width	Length	Width	Length
To 3000, excl	To 1500, excl	10	13	11	16	13	19	16	25
	1500 to 2100, excl	11	16	13	18	16	22	19	25
	2100 to 2700, excl	13	19	16	22	19	25	25	29
	2700 and over	16	22	19	25	22	29	29	32
3000 to 6000, excl	To 1500, excl	10	19	13	22	16	25	19	29
	1500 to 2100, excl	13	19	16	22	19	25	22	32
	2100 to 2700, excl	14	22	18	24	21	29	25	35
	2700 and over	16	25	19	29	22	32	29	35
6000 to 9000, excl	To 1500, excl	10	25	13	29	16	32	19	38
	1500 to 2100, excl	13	25	16	29	19	32	22	38
	2100 to 2700, excl	14	25	18	32	22	35	25	38
	2700 and over	18	29	22	32	25	35	32	44
9000 to 12 000, excl	To 1500, excl	11	29	13	32	16	35	19	41
	1500 to 2100, excl	13	32	16	35	19	38	22	41
	2100 to 2700, excl	14	32	19	35	22	38	25	48
	2700 and over	19	35	22	38	25	41	32	48
12 000 to 15 000, excl	To 1500, excl	11	32	13	38	16	41	19	48
	1500 to 2100, excl	13	35	16	38	19	41	22	48
	2100 to 2700, excl	16	35	19	38	22	41	25	48
	2700 and over	19	38	22	41	25	44	32	48
15 000 to 18 000, excl	To 1500, excl	13	44	16	48	19	48	22	57
	1500 to 2100, excl	16	44	19	48	22	48	25	57
	2100 to 2700, excl	16	44	19	48	22	48	29	57
	2700 and over	22	44	25	51	29	57	32	64
18 000 and over	To 1500, excl	14	51	19	54	22	57	25	70
	1500 to 2100, excl	19	51	22	54	25	57	29	70
	2100 to 2700, excl	19	51	22	54	25	57	32	70
	2700 and over	25	51	29	60	32	64	35	76

^A Permitted variations under specified width and length, 6 mm.

^B Permitted variations in length apply also to Universal Mill plates up to 300 mm in width for thicknesses over 50 to 65 mm, incl, except for alloy steel up to 50 mm thick.

TABLE A1.4
PERMITTED VARIATIONS IN WIDTH FOR MILL EDGE
CARBON AND HIGH STRENGTH LOW-ALLOY PLATES
PRODUCED ON STRIP MILLS
 (Applies to Plates Produced from Coil and to Plates
 Produced From an As-Rolled Structural Product)

Specified Width, mm	Permitted Variation Over Specified Width, mm ⁴
To 360, excl	11
360 to 430, excl	13
430 to 480, excl	14
480 to 530, excl	16
530 to 610, excl	17
610 to 660, excl	21
660 to 710, excl	24
710 to 890, excl	29
890 to 1270, excl	32
1270 to 1520, excl	38
1520 to 1650, excl	41
1650 to 1780, excl	44
1780 to 2030, excl	47
2030 and over	51

⁴ No permitted variation under specified width.

TABLE A1.5
PERMITTED VARIATIONS IN ROLLED WIDTH FOR UNIVERSAL MILL PLATES 380 MM AND
UNDER IN THICKNESS

Specified Width, mm	Permitted Variations Over Specified Width ⁴ for Thickness Given in Millimetres or Equivalent Masses Given in Kilograms per Square Metre, mm					
	To 10, excl	10 to 16, excl	16 to 25, incl	25 to 50, incl	Over 50 to 250, incl	Over 250 to 400, incl
	To 78.50, excl	78.50 to 125.6, excl	125.6 to 196.2, excl	196.2 to 392.5, incl	Over 392.5 to 1962, incl	Over 1962 to 3140, incl
Over 200 to 500, excl	3	3	5	6	10	13
500 to 900, excl	5	6	8	10	11	14
900 and over	8	10	11	13	14	16

⁴ Permitted variation under specified width, 3 mm.

TABLE A1.6
PERMITTED VARIATIONS IN DIAMETER FOR SHEARED CIRCULAR PLATES
25 MM AND UNDER IN THICKNESS

Specified Diameters, mm	Permitted Variations Over Specified Diameter for Thicknesses Given in Millimetres, mm ⁴		
	To 10, excl	10 to 16, excl	16 to 25, incl
To 800, excl	6	10	13
800 to 2100, excl	8	11	14
2100 to 2700, excl	10	13	16
2700 to 3300, excl	11	14	17
3300 and over	13	16	19

⁴ No permitted variation under specified diameter.

TABLE A1.7
PERMITTED VARIATIONS IN DIAMETER FOR GAS-CUT
CIRCULAR PLATES
 (Not Applicable to Alloy Steel)

Specified Diameters, mm	Permitted Variations Over Specified Diameter for Thicknesses Given, mm ⁴					
	To 25, excl	25 to 50, excl	50 to 100, excl	100 to 150, excl	150 to 200, excl	200 to 400, incl
To 800, excl	10	10	13	13	16	19
800 to 2100, excl	10	13	13	16	19	22
2100 to 2700, excl	13	14	16	19	22	25
2700 to 3300, excl	13	14	17	22	25	29
3300 and over	16	19	22	25	29	32

⁴ No permitted variations under specified diameter.

TABLE A1.8
PERMITTED VARIATIONS IN WIDTH AND LENGTH
FOR RECTANGULAR PLATES WHEN GAS CUTTING IS
SPECIFIED OR REQUIRED
 (Applies to Alloy Steel Specifications Only)

Specified Thickness, mm	Permitted Variation Over Specified Width and Length, mm
To 50, excl	19
50 to 100, excl	25
100 to 150, excl	29
150 to 200, excl	33
200 to 400, excl	38

Note 1 — Plates with universal rolled edges will be gas cut to length only.

Note 2 — These permitted variations shall be taken all under or divided over and under, if so specified.

TABLE A1.9
PERMITTED VARIATIONS IN WIDTH AND LENGTH
FOR RECTANGULAR PLATES WHEN GAS CUTTING IS
SPECIFIED OR REQUIRED
 (Not Applicable to Alloy Steel)

Specified Thickness, mm	Permitted Variations Over Specified Width and Length, mm ⁴
To 50, excl	13
50 to 100, excl	16
100 to 150, excl	19
150 to 200, excl	22
200 to 400, incl	25

Note 1 — Plates with universal rolled edges will be gas cut to length only.

⁴ These permitted variations may be taken all under or divided over and under, if so specified.

TABLE A1.10
PERMITTED VARIATIONS IN DIAMETER FOR GAS-CUT
CIRCULAR PLATES
 (Applies to Alloy Steel Specifications Only)

Specified Diameter, mm	Permitted Variations Over Specified Diameter for Specified Thicknesses Given in Millimetres, mm ⁴					
	To 25, excl	25 to 50, excl	50 to 100, excl	100 to 150, excl	150 to 200, excl	200 to 400, incl
To 800, excl	13	13	19	19	25	25
800 to 2100, excl	13	16	22	25	29	32
2100 to 2700, excl	16	19	25	29	32	35
2700 to 3300, incl	22	25	29	32	35	38

⁴ No permitted variations under specified diameter.

TABLE A1.11
PERMITTED CAMBER⁴ FOR CARBON STEEL, HIGH-
STRENGTH LOW-ALLOY STEEL, AND ALLOY STEEL
UNIVERSAL MILL PLATES AND HIGH-STRENGTH
LOW-ALLOY STEEL AND ALLOY STEEL SHEARED OR
GAS-CUT RECTANGULAR PLATES

Specified Width, mm	Permitted Camber, mm
To 750, incl	Length in millimetres/300
Over 750 to 1500	Length in millimetres/250

⁴ Camber as it relates to plates is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

TABLE A1.12
PERMITTED CAMBER⁴ FOR SHEARED PLATES AND
GAS-CUT RECTANGULAR PLATES, ALL THICKNESSES
 (Applies to Carbon Steel Only)

Permitted camber, mm = length in millimetres/500
--

⁴ Camber as it relates to plates is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

TABLE A1.13
PERMITTED VARIATIONS FROM A FLAT SURFACE FOR STANDARD FLATNESS CARBON STEEL PLATES

Specified Thickness, mm	Specified Mass, kg/m ²	Permitted Variations From a Flat Surface for Specified Widths Given in Millimetres, mm ^{A,B}										
		To 900, excl	900 to 1200, excl	1200 to 1500, excl	1500 to 1800, excl	1800 to 2100, excl	2100 to 2400, excl	2400 to 2700, excl	2700 to 3000, excl	3000 to 3600, excl	3600 to 4200, excl	4200 and over
To 6, excl	To 47.1, excl	14	19	24	32	35	38	41	44	48	...	...
6 to 10, excl	47.1 to 78.5, excl	13	16	19	24	29	32	35	38	41	...	...
10 to 12, excl	78.5 to 94.2, excl	13	14	16	16	19	22	25	29	32	48	54
12 to 20, excl	94.2 to 157.0, excl	11	13	14	16	16	19	25	25	29	38	51
20 to 25, excl	157.0 to 196.2, excl	11	13	14	16	16	16	19	22	25	35	44
25 to 50, excl	196.2 to 392.5, excl	10	13	13	14	14	16	16	16	18	29	38
50 to 100, excl	392.5 to 785.0, excl	8	10	11	13	13	13	13	14	16	22	29
100 to 150, excl	785.0 to 1178, excl	10	11	13	13	14	14	16	19	22	22	25
150 to 200, excl	1178 to 1570, excl	11	13	13	16	18	19	22	22	25	25	25
200 to 250, excl	1570 to 1962, excl	13	13	16	18	19	21	22	24	25	25	25
250 to 300, excl	1962 to 2355, excl	13	16	19	21	22	24	25	25	25	25	25
300 to 400, incl	2355 to 3140, incl	16	19	21	22	24	25	25	25	25	25	...

Note 1 — When the longer dimension is under 900 mm, the permitted variation from a flat surface shall not exceed 6 mm. When the longer dimension is from 900 to 1800 mm, incl, the permitted variation from a flat surface shall not exceed 75% of the tabular amount for the specified width, but in no case less than 6 mm.

Note 2 — These permitted variations apply to plates that have a specified minimum tensile strength of not more than 415 MPa or comparable chemical composition or hardness. The limits in the table are increased 50% for plates that have a higher specified minimum tensile strength or comparable chemical composition or hardness.

Note 3 — This table and these notes cover the permitted variations from a flat surface for circular and sketch plates, based upon the maximum dimensions of such plates.

Note 4 — Where "... " appears in this table, there is no requirement.

Note 5 — Plates must be in a horizontal position on a flat surface when flatness is measured.

^A *Permitted Variation From a Flat Surface Along the Length* — The longer dimension specified is considered the length, and the permitted variation from a flat surface along the length shall not exceed the tabular amount for the specified width for plates up to 4000 mm in length, or in any 4000 mm for longer plates.

^B *Permitted Variation from a Flat Surface Across the Width* — The permitted variation from a flat surface across the width shall not exceed the tabular amount for the specified width.

TABLE A1.14
PERMITTED VARIATIONS FROM A FLAT SURFACE FOR STANDARD FLATNESS HIGH-STRENGTH LOW-ALLOY
STEEL AND ALLOY STEEL PLATES, HOT ROLLED OR THERMALLY TREATED

Specified Thickness, mm	Specified Mass, kg/m ²	Permitted Variations From a Flat Surface for Specified Widths Given in Millimetres, mm ^{A,B}										
		To 900, excl	900 to 1200, excl	1200 to 1500, excl	1500 to 1800, excl	1800 to 2100, excl	2100 to 2400, excl	2400 to 2700, excl	2700 to 3000, excl	3000 to 3600, excl	3600 to 4200, excl	4200 and over
To 6, excl	To 47.1, excl	21	29	35	48	51	57	60	67	70	...	...
6 to 10, excl	47.1 to 78.5, excl	19	24	29	35	44	48	51	57	60	...	...
10 to 12, excl	78.5 to 94.2, excl	19	22	24	24	29	33	38	41	48	70	79
12 to 20, excl	94.2 to 157.0, excl	16	19	22	22	25	29	32	35	41	57	76
20 to 25, excl	157.0 to 196.2, excl	16	19	22	22	24	25	29	33	38	51	67
25 to 50, excl	196.2 to 392.5, excl	14	16	19	21	22	24	25	25	25	41	57
50 to 100, excl	392.5 to 785.0, excl	13	14	18	19	19	19	19	22	25	32	41
100 to 150, excl	785.0 to 1178, excl	14	18	19	19	22	22	24	29	32	32	38
150 to 200, excl	1178 to 1570, excl	16	19	19	24	25	29	32	33	38	38	38
200 to 250, excl	1570 to 1962, excl	19	21	24	25	29	32	33	35	38	38	38
250 to 300, excl	1962 to 2355, excl	19	24	29	32	33	35	38	38	38	38	38
300 to 400, incl	2355 to 3140, incl	22	25	30	33	35	38	38	38	38	38	38

Note 1 — When the longer dimension is under 900 mm, the permitted variation from a flat surface shall not exceed 10 mm. When the longer dimension is from 900 to 1800 mm, incl, the permitted variation from a flat surface shall not exceed 75% of the tabular amount for the specified width.

Note 2 — This table and these notes cover the permitted variations from a flat surface for circular and sketch plates, based upon the maximum dimensions of such plates.

Note 3 — Where "... " appears in this table, there is no requirement.

Note 4 — Plates must be in a horizontal position on a flat surface when flatness is measured.

^A Permitted Variation from a Flat Surface Along the Length — The longer dimension specified is considered the length, and permitted variations from a flat surface along the length shall not exceed the tabular amount for the specified width in plates up to 4000 mm in length, or in any 4000 mm for longer plates.

^B Permitted Variation from a Flat Surface Across the Width — The permitted variation from a flat surface across the width shall not exceed the tabular amount for the specified width.

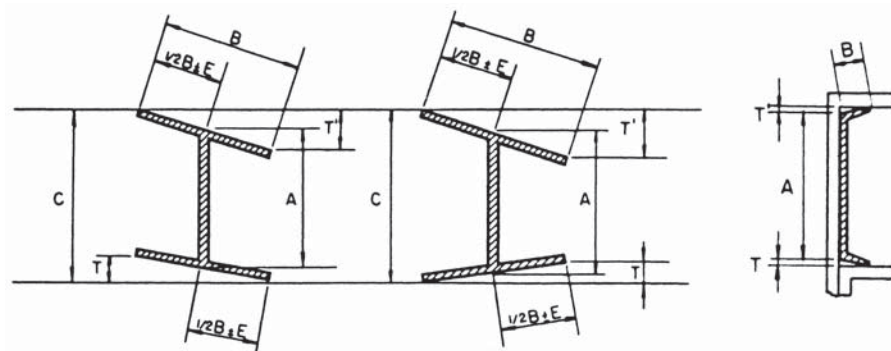
TABLE A1.15
PERMITTED VARIATIONS IN WAVINESS FOR STANDARD FLATNESS PLATES

Permitted Variation From a Flat Surface (from Table A1.13 or A1.14) mm	Permitted Variations in Waviness, mm, When Number of Waves in 4000 mm is						
	1	2	3	4	5	6	7
8	8	6	5	3	3	2	2
10	10	8	5	5	3	2	2
11	11	8	6	5	3	3	2
13	13	10	8	5	5	3	2
14	14	11	8	6	5	3	2
16	16	13	10	6	5	3	2
17	17	13	10	8	5	5	2
19	19	14	11	8	6	5	2
21	21	16	11	8	6	5	2
22	22	17	13	10	6	5	2
24	24	17	13	10	8	6	5
25	25	19	14	11	8	6	5
29	29	22	16	13	10	6	5
32	32	24	17	13	10	8	6
35	35	27	19	14	11	8	6
38	38	29	22	16	13	10	6
41	41	32	24	17	13	10	8
44	44	33	25	19	14	11	8
48	48	37	27	21	14	11	8
51	51	38	29	22	16	13	10
54	54	41	30	22	17	13	10
57	57	43	32	24	17	14	10
60	60	46	33	25	19	14	11
64	64	48	37	27	21	14	11
67	67	51	38	29	21	16	11
70	70	52	40	29	22	16	13
73	73	56	41	30	24	17	13
76	76	57	43	32	24	17	14
79	79	60	44	33	25	19	14

Note 1 — Waviness denotes the maximum deviation of the surface of the plate from a plane parallel to the surface of the point of measurement and contiguous to the surface of the plate at each of the two adjacent wave peaks, when the plate is resting on a flat horizontal surface, as measured in an increment of less than 4000 mm of length. The permitted variation in waviness is a function of the permitted variation from a flat surfaced as obtained from Table A1.13 or A1.14, whichever is applicable.

Note 2 — Plates must be in a horizontal position on a flat surface when waviness is measured.

TABLE A1.16
PERMITTED VARIATIONS IN CROSS SECTION FOR W, HP, S, M, C, AND MC SHAPES



		Permitted Variations in Sectional Dimensions Given, mm							Permitted Variations Over or Under Theoretical Web Thickness for Thicknesses Given in Millimetres, mm	
Shape	Section Nominal Size, mm	<i>A</i> , Depth		<i>B</i> , Flange Width		<i>T</i> + <i>T</i> ^{<i>A</i>} Flanges Out-of-Square ^{<i>B</i>}	<i>E</i> , Web off Center ^{<i>C</i>}	<i>C</i> , Maximum Depth at any Cross Section over Theoretical Depth		
		Over Theoretical	Under Theoretical	Over Theoretical	Under Theoretical				5 and Under	Over 5
W and HP	up to 310, incl	4	3	6	5	6	5	6	...	...
	over 310	4	3	6	5	8	5	6	...	...
S and M	75 to 180, incl	2	2	3	3	0.03	5	...	...	...
	over 180 to 360, incl	3	2	4	4	0.03	5	...	...	...
	over 360 to 610, incl	5	3	5	5	0.03	5	...	...	...
C and MC	40 and under	1	1	1	1	0.03	...	...	0.2	0.4
	over 40 to 75, excl	2	2	2	2	0.03	...	...	0.4	0.5
	75 to 180, incl	3	2	3	3	0.03	...	...	...	...
	over 180 to 360, incl	3	3	3	4	0.03	...	...	...	...
	over 360	5	4	3	5	0.03	...	...	...	...

Note 1 — A is measured at center lines of web for S, M, W, and HP shapes; at back of web for C and MC shapes. Measurement is overall for C shapes under 75 mm. B is measured parallel to flange. C is measured parallel to web.

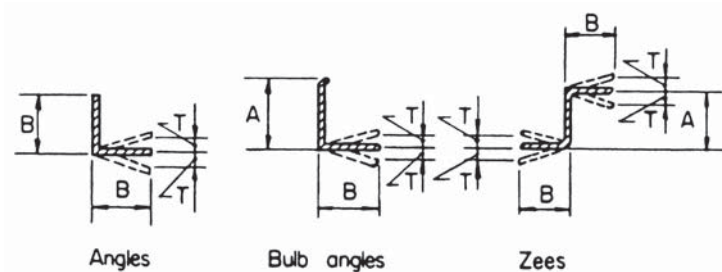
Note 2 — Where "... " appears in this table, there is no requirement.

^A $T + T'$ applies when flanges of channels are toed in or out. For channels 16 mm and under in depth, the permitted out-of-square is 0.05 mm/mm of depth. The permitted variation shall be rounded to the nearest millimetre after calculation.

^B Permitted variation is per millimetre of flange width for S, M, C, and MC shapes.

^C Permitted variation of 8 mm max for sections over 634 kg/m.

TABLE A1.17
PERMITTED VARIATIONS IN CROSS SECTION FOR ANGLES (L SHAPES), BULB ANGLES, AND ZEES



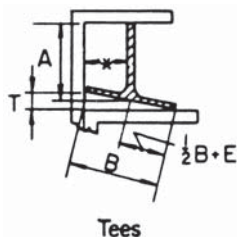
		Permitted Variations in Sectional Dimensions Given, mm					Permitted Variations Over or Under Theoretical Thickness for Thicknesses Given in Millimetres, mm		
Section	Nominal Size, mm	A, Depth		B, Flange Width, or Length of Leg		T, Out-of-Square, per Millimetre of B			
		Over Theoretical	Under Theoretical	Over Theoretical	Under Theoretical		5 and Under	Over 5 to 10	Over 10
Angles ^A (L shapes)	25 and under	...	...	1	1	0.026^B	0.2	0.2	...
	over 25 to 50, incl	...	...	1	1	0.026^B	0.2	0.2	0.3
	over 50 to 75, excl	...	...	2	2	0.026^B	0.3	0.4	0.4
	75 to 100, incl	...	...	3	2	0.026^B	...	...	...
	over 100 to 150 incl	...	...	3	3	0.026^B	...	...	...
	over 150	...	...	5	3	0.026^B	...	...	...
Bulb angles	(depth) 75 to 100, incl	3	2	4	2	0.026^B	...	...	...
	over 100 to 150, incl	3	2	4	3	0.026^B	...	...	...
	over 150	3	2	5	3	0.026^B	...	...	...
Zees	75 to 100, incl	3	2	4	2	0.026^B	...	...	...
	over 100 to 150, incl	3	2	4	3	0.026^B	...	...	...

Note 1 — Where "... " appears in this table, there is no requirement.

^A For unequal leg angles, longer leg determines classification.

^B $0.026 \text{ mm/mm} = 1\frac{1}{2}\%$. The permitted variation shall be rounded to the nearest millimetre after calculation.

TABLE A1.18
PERMITTED VARIATIONS IN SECTIONAL DIMENSIONS FOR ROLLED TEES



Nominal Size ^A	Permitted Variations in Sectional Dimensions Given, mm										
	A, Depth ^B		B, Width ^B		T, Out-of-Square per Millimetre of B	E, Web-off-Center, max	Stem Out-of-Square ^C	Thickness of Flange		Thickness of Stem	
	Over	Under	Over	Under				Over	Under	Over	Under
30 and under	1	1	1	1	...	...	1	0.2	0.2	0.1	0.5
Over 30 to 50, incl	2	2	2	2	...	...	2	0.3	0.3	0.2	0.5
Over 50 to 75, excl	2	2	2	2	...	...	2	0.4	0.4	0.4	0.5
75 to 125, incl	2	2	3	3	0.03	2	...	...	...	...	...
Over 125 to 180, incl	2	2	3	3	0.03	3	...	...	...	...	...

Note 1 — * Back of square and center line of stem are to be parallel when measuring "out-of-square."

Note 2 — Where "... " appears in this table, there is no requirement.

^A The longer member of an unequal tee determines the size for Permitted variations.

^B Measurements for both depth and width are overall.

^C Stem-out-of-square is the permitted variation from its true position of the center line of stem, measured at the point.

TABLE A1.19
PERMITTED VARIATIONS IN LENGTH FOR S, M, C, MC, L, T, Z, AND BULB ANGLE SHAPES

Nominal Size, ^A mm	Permitted Variations from Specified Length for Lengths Given in Metres, mm													
	1.5 to 3, excl		3 to 6, excl		6 to 9, incl		Over 9 to 12, incl		Over 12 to 15, incl		Over 15 to 20, incl		Over 20 m	
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
Under 75	16	0	25	0	38	0	51	0	64	0	64	0	...	...
75 and over	25	0	38	0	45	0	57	0	70	0	70	0	...	...

Note 1 — Where "... " appears in this table, there is no requirement.

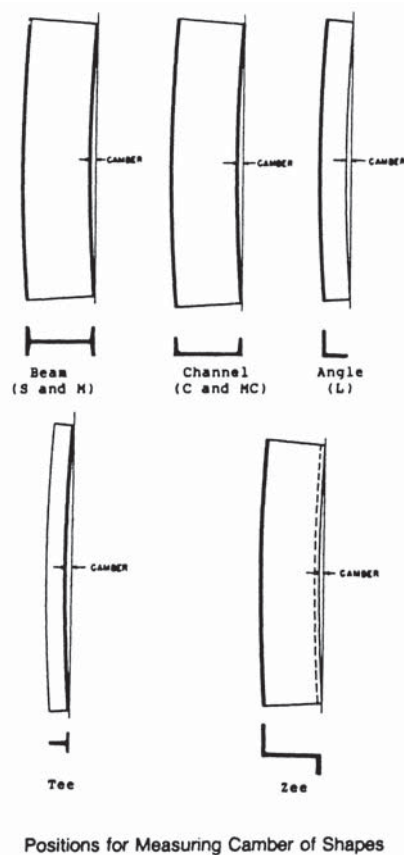
^A Greatest cross-sectional dimension.

TABLE A1.20
PERMITTED VARIATIONS IN END OUT-OF-SQUARE FOR S, M, C, MC, L, T, Z, AND BULB ANGLE SHAPES

Shapes	Permitted Variation
S, M, C, and MC	0.017 mm/mm of depth
L ^A	0.026 mm/mm of leg length or 1½°
Bulb angles	0.026 mm/mm of depth or 1½°
Rolled tees ^A	0.017 mm/mm of flange or stem
Zees	0.026 mm/mm of sum of both flange lengths

^A Permitted variations in ends out-of-square are determined on the longer members of the shape.

TABLE A1.21
PERMITTED VARIATIONS IN STRAIGHTNESS FOR S, M, C, MC, L, T, Z, AND BULB ANGLE SHAPES



Variable	Nominal Size, ⁴ mm	Permitted Variation, mm
Camber	under 75	4 × number of metres of total length
	75 and over	2 × number of metres of total length
Sweep	all	Due to the extreme variations in flexibility of these shapes, permitted variations for sweep are subject to negotiations between the manufacturer and the purchaser for the individual sections involved.

⁴ Greatest cross-sectional dimension.

TABLE A1.22
PERMITTED VARIATIONS IN LENGTH FOR W AND HP SHAPES

W Shapes	Permitted Variations From Specified Length for Lengths Given in Metres, mm ^{A,B}			
	9 and Under		Over 9	
	Over	Under	Over	Under
Beams 610 mm and under in nominal depth	10	10	10 plus 1 for each additional 1 m or fraction thereof	10
Beams over 610 mm in nominal depth and all columns	13	13	13 plus 1 for each additional 1 m or fraction thereof	13

^A For HP shapes or W shapes specified in the order for use as bearing piles, the permitted variations in length are plus 125 and minus 0 mm. These permitted variations in length also apply to sheet piles

^B The permitted variations in end out-of-square for W and HP shapes shall be 0.016 mm per millimetre of depth, or per millimetre of flange width if the flange width is larger than the depth. The permitted variations shall be rounded to the nearest millimetre after calculation.

TABLE A1.23
PERMITTED VARIATIONS FOR LENGTH AND END OUT-OF-SQUARE, MILLED SHAPES

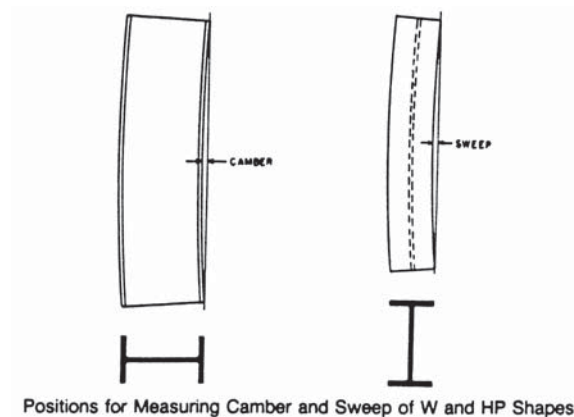
Nominal Depth, mm	Length, ^B m	Permitted Variations in Length and End Out-of-Square, mm ^A					
		Milled Both Ends ^C			Milled One End ^C		
		Length		End Out-of-Square	Length		End Out-of-Square (for Milled End)
		Over	Under		Over	Under	
150 to 920	2 to 21	1	1	1	6	6	1

^A The permitted variations in length and end out-of-square are additive.

^B Length is measured along center line of web. Measurements are made with the steel and tape at the same temperature.

^c End out-of-square is measured by (a) squaring from the center line of the web and (b) squaring from the center line of the flange. The measured variation from true squareness in either plane shall not exceed the total tabular amount.

TABLE A1.24
PERMITTED VARIATIONS IN STRAIGHTNESS FOR W AND HP SHAPES



	Permitted Variation in Straightness, mm
Camber and sweep	$1 \times \text{number of metres of total length}^4$
When certain sections ^B with a flange width approximately equal to depth are specified in the order for use as columns:	
Lengths of 14 m and under	$1 \times \text{number of metres of total length, but not over 10}$
Lengths over 14 m	$10 + [1 \times (\text{number of metres of total length} - 14 \text{ m})]$

⁴ Sections with a flange width less than 150 mm, permitted variation for sweep, mm = 2 × number of metres of total length.

^B Applies only to:

200-mm deep sections — 46.1 kg/m and heavier,
250-mm deep sections — 73 kg/m and heavier,
310-mm deep sections — 97 kg/m and heavier, and
360-mm deep sections — 116 kg/m and heavier.

For other sections specified in the order for use as columns, the permitted variation is subject to negotiation with the manufacturer.

TABLE A1.25
PERMITTED VARIATIONS IN DIMENSIONS FOR
SPLIT TEES AND SPLIT ANGLES (L SHAPES)⁴

Specified Depth, mm	Permitted Variation over or under Specified Depth, ⁵ mm
To 150, excl (beams and channels)	3
150 to 410, excl (beams and channels)	5
410 to 510, excl (beams and channels)	6
510 to 610, excl (beams)	8
610 and over (beams)	10

⁴ The permitted variations in length for split tees or angles are the same as those applicable to the section from which the tees or angles are split.

⁵ The above permitted variations in depth of tees or angles include the permitted variations in depth for the beams or channels before splitting. Permitted variations in dimensions and straightness, as set up for the beams or channels from which these tees or angles are cut, apply, except

$$\text{straightness} = 2 \text{ mm} \times \text{length in metres}$$

TABLE A1.26
PERMITTED VARIATIONS IN SECTIONAL DIMENSIONS FOR SQUARE-EDGE AND ROUND-EDGE FLAT BARS

Specified Widths, mm	Permitted Variations Over or Under Specified Thickness, for Thicknesses Given in millimetres, mm						Permitted Variations from Specified Width, mm	
	Over 5 to 6, incl	Over 6 to 12, incl	Over 12 to 25, incl	Over 25 to 50, incl	Over 50 to 75	Over 75	Over	Under
To 25, incl	0.18	0.20	0.25	...	...	...	0.5	0.5
Over 25 to 50, incl	0.18	0.30	0.40	0.8	...	...	1.0	1.0
Over 50 to 100, incl	0.20	0.40	0.50	0.8	1.2	1.2	1.5	1.0
Over 100 to 150, incl	0.25	0.40	0.50	0.8	1.2	1.2	2.5	1.5
Over 150 to 200, incl	⁴	0.40	0.65	0.8	1.2	1.6	3.0	2.5

Note 1 — Where “...” appears in this table there is no requirement.

⁴ Flats over 150 to 200 mm, incl, in width are not available as hot-rolled bars in thickness 6 mm and under.

TABLE A1.27
PERMITTED VARIATIONS IN SECTIONAL
DIMENSIONS FOR ROUND AND SQUARE BARS AND
ROUND-CORNERED SQUARES

Specified Sizes, mm	Permitted Variation Over or Under Specified Size		Permitted Out-of-Round or Out-of-Square Section ^A	
	mm	%	mm	%
Up to 7.0, incl	0.13	...	0.20	...
Over 7.0 to 11.0, incl	0.15	...	0.22	...
Over 11.0 to 15.0, incl	0.18	...	0.27	...
Over 15.0 to 19.0, incl	0.20	...	0.30	...
Over 19.0 to 250, incl	...	1 ^B	...	1½ ^B

Note 1 — Where “...” appears in this table, there is no requirement.

^A Out-of-round is the difference between the maximum and minimum diameters of the bar, measured at the same transverse cross section. Out-of-square section is the difference in perpendicular distance between opposite faces, measured at the same transverse cross section.

^B The permitted variation shall be rounded to the nearest tenth of a millimetre after calculation.

TABLE A1.28
PERMITTED VARIATIONS IN SECTIONAL
DIMENSIONS FOR HEXAGONS

Specified Sizes Between Opposite Sides, mm	Permitted Variations from Specified Size, mm		Out-of-Hexagon Section, mm ^A
	Over	Under	
To 13 incl	0.18	0.18	0.3
Over 13 to 25 incl	0.25	0.25	0.4
Over 25 to 40 incl	0.55	0.35	0.6
Over 40 to 50 incl	0.8	0.40	0.8
Over 50 to 65 incl	1.2	0.40	1.2
Over 65 to 80 incl	1.6	1.6	

^A Out-of-hexagon section is the greatest difference in distance between any two opposite faces, measured at the same transverse cross section.

TABLE A1.29
PERMITTED VARIATIONS IN STRAIGHTNESS FOR
BARS

Maximum Permitted Variation in Straightness, mm ^A
6 mm in any 1500 mm and (length in millimetres/250) ^B

^A Permitted variations in straightness do not apply to hot-rolled bars if any subsequent heating operation has been performed.

^B Round to the nearest whole millimetre.

TABLE A1.30
PERMITTED VARIATIONS IN LENGTH FOR HOT-CUT STEEL BARS^A

Specified Sizes of Rounds, Squares, and Hexagons, mm	Specified Sizes of Flats, mm		Permitted Variations Over Specified Lengths Given in Metres, mm (No Variation Under)				
	Thickness	Width	1.5 to 3, excl	3 to 6, excl	6 to 9, excl	9 to 12, excl	12 to 18, incl
To 25, incl	to 25, incl	to 75, incl	15	20	35	45	60
Over 25 to 50, incl	over 25	to 75, incl	15	25	40	50	65
	to 25, incl	over 75 to 150, incl	15	25	40	50	65
Over 50 to 125, incl	over 25	over 75 to 150, incl	25	40	45	60	70
Over 125 to 250, incl	...	...	50	65	70	75	85
	over 6 to 25, incl	over 150 to 200, incl	20	30	45	90	100
	over 25 to 75, incl	over 150 to 200, incl	30	45	50	90	100
Bar size sections	...	...	15	25	40	50	65
Hot Sawing							
50 to 125, incl	25 and over	75 and over	^B	40	45	60	70
Over 125 to 250, incl	...	...	^B	65	70	75	85

Note 1 — Where "... " appears in this table, there is no requirement.

^A For flats over 150 to 200 mm, incl, in width and over 75 mm in thickness, consult the manufacturer for permitted variations in length.

^B Smaller sizes and shorter lengths are not commonly hot sawed.

TABLE A1.31
**PERMITTED VARIATIONS IN LENGTH FOR BARS
RECUT BOTH ENDS AFTER STRAIGHTENING^{A,B}**

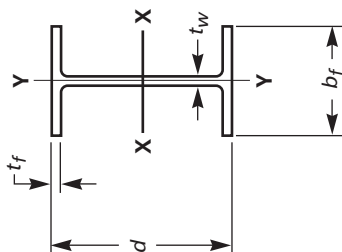
Sizes of Rounds, Squares, Hexagons, Widths of Flats and Maximum Dimensions of Other Sections, mm	Permitted Variations Over Specified Length Given in Metres, mm (No Variation Under)	
	to 3.7, incl	over 3.7
To 75, incl	6	8
Over 75 to 150, incl	8	11
Over 150 to 200, incl	11	14
Rounds over 200 to 250, incl	14	18

^A For flats over 150 to 200 mm, incl, in width, and over 75 mm in thickness, consult the manufacturer or the processor for permitted variations in length.

^B Permitted variations are sometimes required all over or all under the specified length, in which case the sum of the two permitted variations applies.

A2. DIMENSIONS OF STANDARD SHAPE PROFILES

A2.1 Listed herein are dimensions and weight [mass] of some standard shape profiles. The values stated in inch-pound units are independent of the values stated in SI units, and the values from the two systems are not to be combined in any way. Unless the order specifies the applicable “M” specification designation (SI units), the material shall be furnished to inch-pound units.

TABLE A2.1
"W" SHAPES

Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A_f in. ²	Depth d_f in.	Flange		Web Thickness t_{wy} in. ⁴	Designation (Nominal Depth in Millimetres and Mass in Kilograms per Metre)	Area A_f mm ²	Depth d_f mm	Flange		Web Thickness t_{wy} mm ⁴
			Width b_f in.	Thickness t_f in. ⁴					Width b_f mm	Thickness t_f mm ⁴	
W44 x 335	98.7	44.02	15.945	1.770	1.025	W1100 x 499	63 500	1 118	405	45.0	26.0
x 290	85.8	43.62	15.825	1.575	0.865	x 433	55 100	1 108	402	40.0	22.0
x 262	77.2	43.31	15.750	1.415	0.785	x 390	49 700	1 100	400	36.0	20.0
x 230	67.9	42.91	15.750	1.220	0.710	x 343	43 600	1 090	400	31.0	18.0
W40 x 593	174.4	42.99	16.690	3.230	1.790	W1000 x 883	112 500	1 092	424	82.0	45.5
x 503	147.8	42.05	16.415	2.755	1.535	x 748	95 300	1 068	417	70.0	39.0
x 431	126.7	41.26	16.220	2.360	1.340	x 642	81 800	1 048	412	60.0	34.0
x 397	117.0	40.95	16.120	2.200	1.220	x 591	75 300	1 040	409	55.9	31.0
x 372	109.4	40.63	16.065	2.045	1.160	x 554	70 600	1 032	408	52.0	29.5
x 362	107.0	40.55	16.020	2.010	1.120	x 539	68 700	1 030	407	51.1	28.4
x 324	95.3	40.16	15.910	1.810	1.000	x 483	61 500	1 020	404	46.0	25.4
x 297	87.4	39.84	15.825	1.650	0.930	x 443	56 400	1 012	402	41.9	23.6
x 277	81.3	39.69	15.830	1.575	0.830	x 412	52 500	1 008	402	40.0	21.1
x 249	73.3	39.38	15.750	1.420	0.750	x 371	47 300	1 000	400	36.1	19.0
x 215	63.3	38.98	15.750	1.220	0.650	x 321	40 800	990	400	31.0	16.5
x 199	58.4	38.67	15.750	1.065	0.650	x 296	37 700	982	400	27.1	16.5

TABLE A2.1
"W" SHAPES (CONT'D)

Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A_f in. ²	Depth d_f in.	Flange		Web Thickness t_w in.	Designation (Nominal Depth in Millimetres and Mass in Kilograms per Metre)	Area A_f mm ²	Depth d_f mm	Flange		Web Thickness t_w mm
			Width b_f in.	Thickness t_f in.					Width b_f mm	Thickness t_f mm	
W40 × 392	115.3	41.57	12.360	2.520	1.415	W1000 × 584	74 400	1 056	314	64.0	36.0
× 331	97.5	40.79	12.165	2.125	1.220	× 494	62 900	1 036	309	54.0	31.0
× 327	95.9	40.79	12.130	2.130	1.180	× 486	61 900	1 036	308	54.1	30.0
× 294	86.2	40.39	12.010	1.930	1.060	× 438	55 600	1 026	305	49.0	26.9
× 278	81.9	40.16	11.970	1.810	1.025	× 415	52 800	1 020	304	46.0	26.0
× 264	77.6	40.00	11.930	1.730	0.960	× 393	50 100	1 016	303	43.9	24.4
× 235	68.9	39.69	11.890	1.575	0.830	× 350	44 600	1 008	302	40.0	21.1
× 211	62.0	39.37	11.810	1.415	0.750	× 314	40 000	1 000	300	35.9	19.1
× 183	53.7	38.98	11.810	1.200	0.650	× 272	34 600	990	300	31.0	16.5
× 167	49.1	38.59	11.810	1.025	0.650	× 249	31 700	980	300	26.0	16.5
× 149	43.8	38.20	11.810	0.830	0.630	× 222	28 200	970	300	21.1	16.0
W36 × 652	191.7	41.05	17.575	3.540	1.970	W920 × 970	123 700	1 043	446	89.9	50.0
× 529	155.6	39.79	17.220	2.910	1.610	× 787	100 400	1 011	437	73.9	40.9
× 487	143.2	39.33	17.105	2.680	1.500	× 725	92 400	999	434	68.1	38.1
× 441	129.7	38.85	16.965	2.440	1.360	× 656	83 700	987	431	62.0	34.5
× 395	116.2	38.37	16.830	2.200	1.220	× 588	75 000	975	427	55.9	31.0
× 361	106.1	37.99	16.730	2.010	1.120	× 537	68 500	965	425	51.1	28.4
× 330	97.0	37.67	16.630	1.850	1.020	× 491	62 600	957	422	47.0	25.9
× 302	88.8	37.33	16.655	1.680	0.945	× 449	57 600	948	423	42.7	24.0
× 282	82.9	37.11	16.595	1.570	0.885	× 420	53 500	943	422	39.9	22.5
× 262	77.0	36.85	16.550	1.440	0.840	× 390	49 700	936	420	36.6	21.3
× 247	72.5	36.67	16.510	1.350	0.800	× 368	46 800	931	419	34.3	20.3
× 231	68.0	36.49	16.470	1.260	0.760	× 344	43 900	927	418	32.0	19.3
W36 × 256	75.4	37.43	12.215	1.730	0.960	W920 × 381	48 600	951	310	43.9	24.4
× 232	68.1	37.12	12.120	1.570	0.870	× 345	44 000	943	308	39.9	22.1
× 210	61.8	36.69	12.180	1.360	0.830	× 313	39 900	932	309	34.5	21.1
× 194	57.0	36.49	12.115	1.260	0.765	× 289	36 800	927	308	32.0	19.4
× 182	53.6	36.33	12.075	1.180	0.725	× 271	34 600	923	307	30.0	18.4
× 170	50.0	36.17	12.030	1.100	0.680	× 253	32 300	919	306	27.9	17.3
× 160	47.0	36.01	12.000	1.020	0.650	× 238	30 300	915	305	25.9	16.5
× 150	44.2	35.85	11.975	0.940	0.625	× 223	28 500	911	304	23.9	15.9
× 135	39.7	35.55	11.950	0.790	0.600	× 201	25 600	903	304	20.1	15.2

TABLE A2.1
"W" SHAPES (CONT'D)

Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A_f in. ²	Depth d_f in.	Flange		Web Thickness t_w , in. ⁴	Designation (Nominal Depth in Millimetres and Mass in Kilograms per Metre)	Area A_f mm ²	Depth d_f mm	Flange		Web Thickness t_w , mm ⁴
			Width b_f in.	Thickness t_f , in. ⁴					Width b_f , mm	Thickness t_f , mm ⁴	
W33 × 387	114.0	35.95	16.200	2.280	1.260	W840 × 576	73 500	913	411	57.9	32.0
× 354	104.1	35.55	16.100	2.090	1.160	× 527	67 200	903	409	53.1	29.5
× 318	93.5	35.16	15.985	1.890	1.040	× 473	60 300	893	406	48.0	26.4
× 291	85.6	34.84	15.905	1.730	0.960	× 433	55 200	885	404	43.9	24.4
× 263	77.4	34.53	15.805	1.570	0.870	× 392	49 900	877	401	39.9	22.1
× 241	70.9	34.18	15.860	1.400	0.830	× 359	45 700	868	403	35.6	21.1
× 221	65.0	33.93	15.805	1.275	0.775	× 329	41 900	862	401	32.4	19.7
× 201	59.1	33.68	15.745	1.150	0.715	× 299	38 100	855	400	29.2	18.2
W33 × 169	49.5	33.82	11.500	1.220	0.670	W840 × 251	31 900	859	292	31.0	17.0
× 152	44.7	33.49	11.565	1.055	0.635	× 226	28 800	851	294	26.8	16.1
× 141	41.6	33.30	11.535	0.960	0.605	× 210	26 800	846	293	24.4	15.4
× 130	38.3	33.09	11.510	0.855	0.580	× 193	24 700	840	292	21.7	14.7
× 118	34.7	32.86	11.480	0.740	0.550	× 176	22 400	835	292	18.8	14.0
W30 × 391	115.0	33.19	15.590	2.440	1.360	W760 × 582	74 200	843	396	62.0	34.5
× 357	104.8	32.80	15.470	2.240	1.240	× 531	67 600	833	393	56.9	31.5
× 326	95.7	32.40	15.370	2.050	1.140	× 484	61 700	823	390	52.1	29.0
× 292	85.7	32.01	15.255	1.850	1.020	× 434	55 300	813	387	47.0	25.9
× 261	76.7	31.61	15.155	1.650	0.930	× 389	49 500	803	385	41.9	23.6
× 235	69.0	31.30	15.055	1.500	0.830	× 350	44 500	795	382	38.1	21.1
× 211	62.0	30.94	15.105	1.315	0.775	× 314	40 000	786	384	33.4	19.7
× 191	56.1	30.68	15.040	1.185	0.710	× 284	36 200	779	382	30.1	18.0
× 173	50.8	30.44	14.985	1.065	0.655	× 257	32 800	773	381	27.1	16.6
W30 × 148	43.5	30.67	10.480	1.180	0.650	W760 × 220	28 100	779	266	30.0	16.5
× 132	38.9	30.31	10.545	1.000	0.615	× 196	25 100	770	268	25.4	15.6
× 124	36.5	30.17	10.515	0.930	0.585	× 185	23 500	766	267	23.6	14.9
× 116	34.2	30.01	10.495	0.850	0.565	× 173	22 100	762	267	21.6	14.4
× 108	31.7	29.83	10.475	0.760	0.545	× 161	20 500	758	266	19.3	13.8
× 99	29.1	29.65	10.450	0.670	0.520	× 147	18 800	753	265	17.0	13.2
× 90	26.4	29.53	10.400	0.610	0.470	× 134	17 000	750	264	15.5	11.9

TABLE A2.1
"W" SHAPES (CONT'D)

Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A_f in. ²	Depth d_f in.	Flange		Web Thickness t_w , in. ⁴	Designation (Nominal Depth in Millimetres and Mass in Kilograms per Metre)	Area A_f mm ²	Depth d_f mm	Flange		Web Thickness t_w , mm ⁴
			Width b_f in.	Thickness t_f , in. ⁴					Width b_f , mm	Thickness t_f , mm ⁴	
W27 X 539	158.4	32.52	15.255	3.540	1.970	W690 X 802	102 200	826	387	89.9	50.0
X 368	108.1	30.39	14.665	2.480	1.380	X 548	69 800	772	372	63.0	35.1
X 336	98.7	30.00	14.550	2.280	1.260	X 500	63 700	762	369	57.9	32.0
X 307	90.2	29.61	14.445	2.090	1.160	X 457	58 200	752	367	53.1	29.5
X 281	82.6	29.29	14.350	1.930	1.060	X 419	53 300	744	364	49.0	26.9
X 258	75.7	28.98	14.270	1.770	0.980	X 384	48 900	736	362	45.0	24.9
X 235	69.1	28.66	14.190	1.610	0.910	X 350	44 600	728	360	40.9	23.1
X 217	63.8	28.43	14.115	1.500	0.830	X 323	41 100	722	359	38.1	21.1
X 194	57.0	28.11	14.035	1.340	0.750	X 289	36 800	714	356	34.0	19.0
X 178	52.3	27.81	14.085	1.190	0.725	X 265	33 700	706	358	30.2	18.4
X 161	47.4	27.59	14.020	1.080	0.660	X 240	30 600	701	356	27.4	16.8
X 146	42.9	27.38	13.965	0.975	0.605	X 217	27 700	695	355	24.8	15.4
W27 X129	37.8	27.63	10.010	1.100	0.610	W69 X 192	24 400	702	254	27.9	15.5
X 114	33.5	27.29	10.070	0.930	0.570	X 170	21 600	693	256	23.6	14.5
X 102	30.0	27.09	10.015	0.830	0.515	X 152	19 400	688	254	21.1	13.1
X 94	27.7	26.92	9.990	0.745	0.490	X 140	17 900	684	254	18.9	12.4
X 84	24.8	26.71	9.960	0.640	0.460	X 125	16 000	678	253	16.3	11.7
W24 X 370	108.0	27.99	13.660	2.720	1.520	W610 X 551	70 200	711	347	69.1	38.6
X 335	98.4	27.52	13.520	2.480	1.380	X 498	63 500	699	343	63.0	35.1
X 306	89.8	27.13	13.405	2.280	1.260	X 455	57 900	689	340	57.9	32.0
X 279	82.0	26.73	13.305	2.090	1.160	X 415	52 900	679	338	53.1	29.5
X 250	73.5	26.34	13.185	1.890	1.040	X 372	47 400	669	335	48.0	26.4
X 229	67.2	26.02	13.110	1.730	0.960	X 341	43 400	661	333	43.9	24.4
X 207	60.7	25.71	13.010	1.570	0.870	X 307	39 100	653	330	39.9	22.1
X 192	56.3	25.47	12.950	1.460	0.810	X 285	36 100	647	329	37.1	20.6
X 176	51.7	25.24	12.890	1.340	0.750	X 262	33 300	641	327	34.0	19.0
X 162	47.7	25.00	12.955	1.220	0.705	X 241	30 800	635	329	31.0	17.9
X 146	43.0	24.74	12.900	1.090	0.650	X 217	27 700	628	328	27.7	16.5
X 131	38.5	24.48	12.855	0.960	0.605	X 195	24 800	622	327	24.4	15.4
X 117	34.4	24.26	12.800	0.850	0.550	X 174	22 200	616	325	21.6	14.0
X 104	30.6	24.06	12.750	0.750	0.500	X 155	19 700	611	324	19.0	12.7

TABLE A2.1
"W" SHAPES (CONT'D)

Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A_f in. ²	Depth d_f in.	Flange		Web Thickness t_w in. ⁴	Designation (Nominal Depth in Millimetres and Mass in Kilograms per Metre)	Area A_f mm ²	Depth d_f mm	Flange		Web Thickness t_w mm ⁴
			Width b_f in.	Thickness t_f in. ⁴					Width b_f mm	Thickness t_f mm ⁴	
W24 × 103	30.3	24.53	9.000	0.980	0.550	W610 × 153	19 600	623	229	24.9	14.0
× 94	27.7	24.31	9.065	0.875	0.515	× 140	17 900	617	230	22.2	13.1
× 84	24.7	24.10	9.020	0.770	0.470	× 125	15 900	612	229	19.6	11.9
× 76	22.4	23.92	8.990	0.680	0.440	× 113	14 500	608	228	17.3	11.2
× 68	20.1	23.73	8.965	0.585	0.415	× 101	13 000	603	228	14.9	10.5
W24 × 62	18.2	23.74	7.040	0.590	0.430	W610 × 92	11 700	603	179	15.0	10.9
× 55	16.2	23.57	7.005	0.505	0.395	× 82	10 500	599	178	12.8	10.0
W21 × 201	59.2	23.03	12.575	1.630	0.910	W530 × 300	38 200	585	319	41.4	23.1
× 182	53.7	22.72	12.500	1.480	0.830	× 272	34 600	577	317	37.6	21.1
× 166	48.9	22.48	12.420	1.360	0.750	× 248	31 500	571	315	34.5	19.0
× 147	43.2	22.06	12.510	1.150	0.720	× 219	27 900	560	318	29.2	18.3
× 132	38.8	21.83	12.440	1.035	0.650	× 196	25 000	554	316	26.3	16.5
× 122	35.9	21.68	12.390	0.960	0.600	× 182	23 200	551	315	24.4	15.2
× 111	32.7	21.51	12.340	0.875	0.550	× 165	21 100	546	313	22.2	14.0
× 101	29.8	21.36	12.290	0.800	0.500	× 150	19 200	543	312	20.3	12.7
W21 × 93	27.3	21.62	8.420	0.930	0.580	W530 × 138	17 600	549	214	23.6	14.7
× 83	24.3	21.43	8.355	0.835	0.515	× 123	15 700	544	212	21.2	13.1
× 73	21.5	21.24	8.295	0.740	0.455	× 109	13 900	539	211	18.8	11.6
× 68	20.0	21.13	8.270	0.685	0.430	× 101	12 900	537	210	17.4	10.9
× 62	18.3	20.99	8.240	0.615	0.400	× 92	11 800	533	209	15.6	10.2
× 55	16.2	20.80	8.220	0.522	0.375	× 82	10 500	528	209	13.3	9.50
× 48	14.1	20.62	8.140	0.430	0.350	× 72	9 180	524	207	10.9	9.00
W21 × 57	16.7	21.06	6.555	0.650	0.405	W530 × 85	10 800	535	166	16.5	10.3
× 50	14.7	20.83	6.530	0.535	0.380	× 74	9 480	529	166	13.6	9.7
× 44	13.0	20.66	6.500	0.450	0.350	× 66	8 390	525	165	11.4	8.9

TABLE A2.1
"W" SHAPES (CONT'D)

Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Designation (Nominal Depth in Millimetres and Mass in Kilograms per Metre)			Flange		Web Thickness t_w , in. ⁴	Depth d_f in.	Width b_f in.	Thickness t_f , in. ⁴	Area A_f in. ²	Depth d_f mm	Width b_f , mm	Thickness t_f , mm ⁴	Web Thickness t_w , mm ⁴
W18 × 311	91.5	22.32	12.005	2.740	1.520	W460 × 464	567	305	69.6	59 100	567	305	69.6	38.6
× 283	83.2	21.85	11.890	2.500	1.400	× 421	555	302	63.5	53 700	555	302	63.5	35.6
× 258	75.9	21.46	11.770	2.300	1.280	× 384	545	299	58.4	49 000	545	299	58.4	32.5
× 234	68.8	21.06	11.650	2.110	1.160	× 349	535	296	53.6	44 400	535	296	53.6	29.5
× 211	62.1	20.67	11.555	1.910	1.060	× 315	525	293	48.5	40 100	525	293	48.5	26.9
× 192	56.4	20.35	11.455	1.750	0.960	× 286	517	291	44.4	36 400	517	291	44.4	24.4
× 175	51.3	20.04	11.375	1.590	0.890	× 260	509	289	40.4	33 100	509	289	40.4	22.6
× 158	46.3	19.72	11.300	1.440	0.810	× 235	501	287	36.6	29 900	501	287	36.6	20.6
× 143	42.1	19.49	11.220	1.320	0.730	× 213	495	285	33.5	27 100	495	285	33.5	18.5
× 130	38.2	19.25	11.160	1.200	0.670	× 193	489	283	30.5	24 700	489	283	30.5	17.0
× 119	35.1	18.97	11.265	1.060	0.655	× 177	482	286	26.9	22 600	482	286	26.9	16.6
× 106	31.1	18.73	11.200	0.940	0.590	× 158	476	284	23.9	20 100	476	284	23.9	15.0
× 97	28.5	18.59	11.145	0.870	0.535	× 144	472	283	22.1	18 400	472	283	22.1	13.6
× 86	25.3	18.39	11.090	0.770	0.480	× 128	467	282	19.6	16 300	467	282	19.6	12.2
× 76	22.3	18.21	11.035	0.680	0.425	× 113	463	280	17.3	14 400	463	280	17.3	10.8
W18 × 71	20.8	18.47	7.635	0.810	0.495	W460 × 106	469	194	20.6	13 400	469	194	20.6	12.6
× 65	19.1	18.35	7.590	0.750	0.450	× 97	466	193	19.0	12 300	466	193	19.0	11.4
× 60	17.6	18.24	7.555	0.695	0.415	× 89	463	192	17.7	11 400	463	192	17.7	10.5
× 55	16.2	18.11	7.530	0.630	0.390	× 82	460	191	16.0	10 500	460	191	16.0	9.9
× 50	14.7	17.99	7.495	0.570	0.355	× 74	457	190	14.5	9 480	457	190	14.5	9.0
W18 × 46	13.5	18.06	6.060	0.605	0.360	W460 × 68	459	154	15.4	8 710	459	154	15.4	9.1
× 40	11.8	17.90	6.015	0.525	0.315	× 60	455	153	13.3	7 610	455	153	13.3	8.0
× 35	10.3	17.70	6.000	0.425	0.300	× 52	450	152	10.8	6 650	450	152	10.8	7.6
W16 × 100	29.4	16.97	10.425	0.985	0.585	W410 × 149	431	265	25.0	19 000	431	265	25.0	14.9
× 89	26.2	16.75	10.365	0.875	0.525	× 132	425	263	22.2	16 900	425	263	22.2	13.3
× 77	22.6	16.52	10.295	0.760	0.455	× 114	420	261	19.3	14 600	420	261	19.3	11.6
× 67	19.7	16.33	10.235	0.665	0.395	× 100	415	260	16.9	12 700	415	260	16.9	10.0
W16 × 57	16.8	16.43	7.120	0.715	0.430	W410 × 85	417	181	18.2	10 800	417	181	18.2	10.9
× 50	14.7	16.26	7.070	0.630	0.380	× 75	413	180	16.0	9 480	413	180	16.0	9.7
× 45	13.3	16.13	7.035	0.565	0.345	× 67	410	179	14.4	8 580	410	179	14.4	8.8
× 40	11.8	16.01	6.995	0.505	0.305	× 60	407	178	12.8	7 610	407	178	12.8	7.7
× 36	10.6	15.86	6.985	0.430	0.295	× 53	403	177	10.9	6 840	403	177	10.9	7.5
W16 × 31	9.12	15.88	5.525	0.440	0.275	W410 × 46.1	403	140	11.2	5 880	403	140	11.2	7.0
× 26	7.68	15.69	5.500	0.345	0.250	× 38.8	399	140	8.8	4 950	399	140	8.8	6.4

TABLE A2.1
"W" SHAPES (CONT'D)

Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Designation (Nominal Depth in Millimetres and Mass in Kilograms per Metre)				Flange		Depth d_f mm	Area A_f mm ²	Web Thickness t_w in. ⁴	Flange		Web Thickness t_w mm ⁴
	Area A_f in. ²	Depth d_f in.	Width b_f in.	Thickness t_f in. ⁴						Width b_f mm	Thickness t_f mm ⁴	
W14 × 730	215.0	22.42	17.890	4.910	3.070	W360 × 1086	569	139 000	3.070	454	125.0	78.0
× 665	196.0	21.64	17.650	4.520	2.830	× 990	550	126 000	2.830	448	115.0	71.9
× 605	178.0	20.92	17.415	4.160	2.595	× 900	531	115 000	2.595	442	106.0	65.9
× 550	162.0	20.24	17.200	3.820	2.380	× 818	514	105 000	2.380	437	97.0	60.5
× 500	147.0	19.60	17.010	3.500	2.190	× 744	498	94 800	2.190	432	88.9	55.6
× 455	134.0	19.02	16.835	3.210	2.015	× 677	483	86 500	2.015	428	81.5	51.2
× 426	125.0	18.67	16.695	3.035	1.875	× 634	474	80 600	1.875	424	77.1	47.6
× 398	117.0	18.29	16.590	2.845	1.770	× 592	465	75 500	1.770	421	72.3	45.0
× 370	109.0	17.92	16.475	2.660	1.655	× 551	455	70 300	1.655	418	67.6	42.0
× 342	101.0	17.54	16.360	2.470	1.540	× 509	446	65 200	1.540	416	62.7	39.1
× 311	91.4	17.12	16.230	2.260	1.410	× 463	435	59 000	1.410	412	57.4	35.8
× 283	83.3	16.74	16.110	2.070	1.290	× 421	425	53 700	1.290	409	52.6	32.8
× 257	75.6	16.38	15.995	1.890	1.175	× 382	416	48 800	1.175	406	48.0	29.8
× 233	68.5	16.04	15.890	1.720	1.070	× 347	407	44 200	1.070	404	43.7	27.2
× 211	62.0	15.72	15.800	1.560	0.980	× 314	399	40 000	0.980	401	39.6	24.9
× 193	56.8	15.48	15.710	1.440	0.890	× 287	393	36 600	0.890	399	36.6	22.6
× 176	51.8	15.22	15.650	1.310	0.830	× 262	387	33 400	0.830	398	33.3	21.1
× 159	46.7	14.98	15.565	1.190	0.745	× 237	380	30 100	0.745	395	30.2	18.9
× 145	42.7	14.78	15.500	1.090	0.680	× 216	375	27 500	0.680	394	27.7	17.3
W14 × 132	38.8	14.66	14.725	1.030	0.645	W360 × 196	372	25 000	0.645	374	26.2	16.4
× 120	35.3	14.48	14.670	0.940	0.590	× 179	368	22 800	0.590	373	23.9	15.0
× 109	32.0	14.32	14.605	0.860	0.525	× 162	364	20 600	0.525	371	21.8	13.3
× 99	29.1	14.16	14.565	0.780	0.485	× 147	360	18 800	0.485	370	19.8	12.3
× 90	26.5	14.02	14.520	0.710	0.440	× 134	356	17 100	0.440	369	18.0	11.2
W14 × 82	24.1	14.31	10.130	0.855	0.510	W360 × 122	363	15 500	0.510	257	21.7	13.0
× 74	21.8	14.17	10.070	0.785	0.450	× 110	360	14 100	0.450	256	19.9	11.4
× 68	20.0	14.04	10.035	0.720	0.415	× 101	357	12 900	0.415	255	18.3	10.5
× 61	17.9	13.89	9.995	0.645	0.375	× 91	353	11 500	0.375	254	16.4	9.5
W14 × 53	15.6	13.92	8.060	0.660	0.370	W360 × 79	354	10 100	0.370	205	16.8	9.4
× 48	14.1	13.79	8.030	0.595	0.340	× 72	350	9 100	0.340	204	15.1	8.6
× 43	12.6	13.66	7.995	0.530	0.305	× 64	347	8 130	0.305	203	13.5	7.7
W14 × 38	11.2	14.10	6.770	0.515	0.310	W360 × 58	358	7 230	0.310	172	13.1	7.9
× 34	10.0	13.98	6.745	0.455	0.285	× 51	355	6 450	0.285	171	11.6	7.2
× 30	8.85	13.84	6.730	0.385	0.270	× 44.6	352	5 710	0.270	171	9.8	6.9

TABLE A2.1
"W" SHAPES (CONT'D)

Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A_f , in. ²	Depth d_f , in.	Flange		Web Thickness t_{wg} in. ⁴	Designation (Nominal Depth in Millimetres and Mass in Kilograms per Metre)	Area A_f , mm ²	Depth d_f , mm	Flange		Web Thickness t_{wg} mm ⁴
			Width b_f , in.	Thickness t_f in. ⁴					Width b_f mm	Thickness t_f mm ⁴	
W14 × 26 × 22	7.69 6.49	13.91 13.74	5.025 5.000	0.420 0.335	0.255 0.230	W360 × 39.0 × 32.9	4 960 4 190	353 349	128 127	10.7 8.5	6.5 5.8
W12 × 336 × 305 × 279 × 252 × 230 × 210 × 190 × 170 × 152 × 136 × 120 × 106 × 96 × 87 × 79 × 72 × 65	98.8 89.6 81.9 74.1 67.7 61.8 55.8 50.0 44.7 39.9 35.3 31.2 28.2 25.6 23.2 21.1 19.1	16.82 16.32 15.85 15.41 15.05 14.71 14.38 14.03 13.71 13.41 13.12 12.89 12.71 12.53 12.38 12.25 12.12	13.385 13.235 13.140 13.005 12.895 12.790 12.670 12.570 12.480 12.400 12.320 12.220 12.160 12.125 12.080 12.040 12.000	2.955 2.705 2.470 2.250 2.070 1.900 1.735 1.560 1.400 1.250 1.105 0.990 0.900 0.810 0.735 0.670 0.605	1.775 1.625 1.530 1.395 1.285 1.180 1.060 0.960 0.870 0.790 0.710 0.610 0.550 0.515 0.470 0.430 0.390	W310 × 500 × 454 × 415 × 375 × 342 × 313 × 283 × 253 × 226 × 202 × 179 × 158 × 143 × 129 × 117 × 107 × 97	63 700 57 800 52 800 47 800 43 700 39 900 36 000 32 300 28 800 25 700 22 800 20 100 18 200 16 500 15 000 13 600 12 300	427 415 403 391 382 374 365 356 348 341 333 327 323 318 314 311 308	340 336 334 330 328 325 322 319 317 315 313 310 309 308 307 306 305	75.1 68.7 62.7 57.2 52.6 48.3 44.1 39.6 35.6 31.8 28.1 25.1 22.9 20.6 18.7 17.0 15.4	45.1 41.3 38.9 35.4 32.6 30.0 26.9 24.4 22.1 20.1 18.0 15.5 14.0 13.1 11.9 10.9 9.9
W12 × 58 × 53	17.0 15.6	12.19 12.06	10.010 9.995	0.640 0.575	0.360 0.345	W310 × 86 × 79	11 000 10 100	310 306	254 254	16.3 14.6	9.1 8.8
W12 × 50 × 45 × 40	14.7 13.2 11.8	12.19 12.06 11.94	8.080 8.045 8.005	0.640 0.575 0.515	0.370 0.335 0.295	W310 × 74 × 67 × 60	9 480 8 520 7 610	310 306 303	205 204 203	16.3 14.6 13.1	9.4 8.5 7.5
W12 × 35 × 30 × 26	10.3 8.79 7.65	12.50 12.34 12.22	6.560 6.520 6.490	0.520 0.440 0.380	0.300 0.260 0.230	W310 × 52 × 44.5 × 38.7	6 650 5 670 4 940	317 313 310	167 166 165	13.2 11.2 9.7	7.6 6.6 5.8
W12 × 22 × 19 × 16 × 14	6.48 5.57 4.71 4.16	12.31 12.16 11.99 11.91	4.030 4.005 3.990 3.970	0.425 0.350 0.265 0.225	0.260 0.235 0.220 0.200	W310 × 32.7 × 28.3 × 23.8 × 21.0	4 180 3 590 3 040 2 680	313 309 305 303	102 102 101 101	10.8 8.9 6.7 5.7	6.6 6.0 5.6 5.1

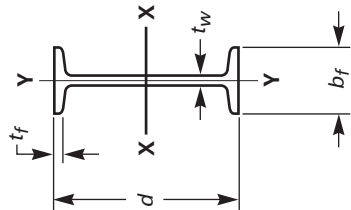
TABLE A2.1
"W" SHAPES (CONT'D)

Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A_f in. ²	Depth d_f in.	Flange		Web Thickness t_w in. ⁴	Designation (Nominal Depth in Millimetres and Mass in Kilograms per Metre)	Area A_f mm ²	Depth d_f mm	Flange		Web Thickness t_w mm ⁴
			Width b_f in.	Thickness t_f in. ⁴					Width b_f mm	Thickness t_f mm ⁴	
W10 × 112 × 100 × 88 × 77 × 68 × 60 × 54 × 49	32.9	11.36	10.415	1.250	0.755	W250 × 167	21 200	289	265	31.8	19.2
	29.4	11.10	10.340	1.120	0.680	× 149	19 000	282	263	28.4	17.3
	25.9	10.84	10.265	0.990	0.605	× 131	16 700	275	261	25.1	15.4
	22.6	10.60	10.190	0.870	0.530	× 115	14 600	269	259	22.1	13.5
	20.0	10.40	10.130	0.770	0.470	× 101	12 900	264	257	19.6	11.9
	17.6	10.22	10.080	0.680	0.420	× 89	11 400	260	256	17.3	10.7
	15.8	10.09	10.030	0.615	0.370	× 80	10 200	256	255	15.6	9.4
	14.4	9.98	10.000	0.560	0.340	× 73	9 290	253	254	14.2	8.6
	13.3	10.10	8.020	0.620	0.350	W250 × 67	8 580	257	204	15.7	8.9
	11.5	9.92	7.985	0.530	0.315	× 58	7 420	252	203	13.5	8.0
W10 × 30 × 26 × 22	9.71	9.73	7.960	0.435	0.290	× 49.1	6 260	247	202	11.0	7.4
	8.84	10.47	5.810	0.510	0.300	W250 × 44.8	5 700	266	148	13.0	7.6
	7.61	10.33	5.770	0.440	0.260	× 38.5	4 910	262	147	11.2	6.6
	6.49	10.17	5.750	0.360	0.240	× 32.7	4 190	258	146	9.1	6.1
W10 × 19 × 17 × 15 × 12	5.62	10.24	4.020	0.395	0.250	W250 × 28.4	3 630	260	102	10.0	6.4
	4.99	10.11	4.010	0.330	0.240	× 25.3	3 220	257	102	8.4	6.1
	4.41	9.99	4.000	0.270	0.230	× 22.3	2 850	254	102	6.9	5.8
	3.54	9.87	3.960	0.210	0.190	× 17.9	2 280	251	101	5.3	4.8
W8 × 67 × 58 × 48 × 40 × 35 × 31	19.7	9.00	8.280	0.935	0.570	W200 × 100	12 700	229	210	23.7	14.5
	17.1	8.75	8.220	0.810	0.510	× 86	11 000	222	209	20.6	13.0
	14.1	8.50	8.110	0.685	0.400	× 71	9 100	216	206	17.4	10.2
	11.7	8.25	8.070	0.560	0.360	× 59	7 550	210	205	14.2	9.1
	10.3	8.12	8.020	0.495	0.310	× 52	6 650	206	204	12.6	7.9
	9.13	8.00	7.995	0.435	0.285	× 46.1	5 890	203	203	11.0	7.2

TABLE A2.1
"W" SHAPES (CONT'D)

Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A_f in. ²	Depth d_f in.	Flange		Web Thickness t_w in. ⁴	Designation (Nominal Depth in Millimetres and Mass in Kilograms per Metre)	Area A_f mm ²	Depth d_f mm	Flange		Web Thickness t_w mm ⁴
			Width b_f in.	Thickness t_f in. ⁴					Width b_f mm	Thickness t_f mm ⁴	
W8 × 28 × 24	8.25 7.08	8.06 7.93	6.535 6.495	0.465 0.400	0.285 0.245	W200 × 41.7 × 35.9	5 320 4 570	205 201	166 165	11.8 10.2	7.2 6.2
W8 × 21 × 18	6.16 5.26	8.28 8.14	5.270 5.250	0.400 0.330	0.250 0.230	W200 × 31.3 × 26.6	3 970 3 390	210 207	134 133	10.2 8.4	6.4 5.8
W8 × 15 × 13 × 10	4.44 3.84 2.96	8.11 7.99 7.89	4.015 4.000 3.940	0.315 0.255 0.205	0.245 0.230 0.170	W200 × 22.5 × 19.3 × 15.0	2 860 2 480 1 910	206 203 200	102 102 100	8.0 6.5 5.2	6.2 5.8 4.3
W6 × 25 × 20 × 15	7.34 5.87 4.43	6.38 6.20 5.99	6.080 6.020 5.990	0.455 0.365 0.260	0.320 0.260 0.230	W150 × 37.1 × 29.8 × 22.5	4 740 3 790 2 860	162 157 152	154 153 152	11.6 9.3 6.6	8.1 6.6 5.8
W6 × 16 × 12 × 9 × 8.5	4.74 3.55 2.68 2.52	6.28 6.03 5.90 5.83	4.030 4.000 3.940 3.940	0.405 0.280 0.215 0.195	0.260 0.230 0.170 0.170	W150 × 24.0 × 18.0 × 13.5 × 13	3 060 2 290 1 730 1 630	160 153 150 148	102 102 100 100	10.3 7.1 5.5 4.9	6.6 5.8 4.3 4.3
W5 × 19 × 16	5.54 4.68	5.15 5.01	5.030 5.000	0.430 0.360	0.270 0.240	W130 × 28.1 × 23.8	3 590 3 040	131 127	128 127	10.9 9.1	6.9 6.1
W4 × 13	3.83	4.16	4.060	0.345	0.280	W100 × 19.3	2 470	106	103	8.8	7.1

⁴ Actual flange and web thicknesses vary due to mill rolling practices; however, permitted variations for such dimensions are not addressed.

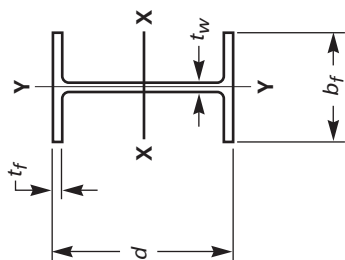
TABLE A2.2
"S" SHAPES

Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A , in.^2	Depth d , in.	Flange		Web Thickness t_w , in.	Designation (Nominal Depth in Millimetres and Mass in Kilograms per Metre)	Area A , mm^2	Depth d , mm	Flange		Web Thickness t_w , mm
			Width b_f , in.	Thickness t_f , in.					Width b_f , mm	Thickness t_f , mm	
S 24 x 121 x 106	35.6 31.2	24.50 24.50	8.050 7.870	1.090 1.090	0.800 0.620	S 610 x 180 x 158	23 000 20 100	622 622	204 200	27.7 27.7	20.3 15.7
S 24 x 100 x 90 x 80	29.3 26.5 23.5	24.00 24.00 24.00	7.245 7.125 7.000	0.870 0.870 0.870	0.745 0.625 0.500	S 610 x 149 x 134 x 119	18 900 17 100 15 200	610 610 610	184 181 178	22.1 22.1 22.1	18.9 15.9 12.7
S 20 x 96 x 86	28.2 25.3	20.30 20.30	7.200 7.060	0.920 0.920	0.800 0.660	S 510 x 143 x 128	18 200 16 300	516 516	183 179	23.4 23.4	20.3 16.8
S 20 x 75 x 66	22.0 19.4	20.00 20.00	6.385 6.255	0.795 0.795	0.635 0.505	S 510 x 112 x 98	14 200 12 500	508 508	162 159	20.2 20.2	16.1 12.8
S 18 x 70 x 54.7	20.6 16.1	18.00 18.00	6.251 6.001	0.691 0.691	0.711 0.461	S 460 x 104 x 81.4	13 300 10 400	457 457	159 152	17.6 17.6	18.1 11.7
S 15 x 50 x 42.9	14.7 12.6	15.00 15.00	5.640 5.501	0.622 0.622	0.550 0.411	S 380 x 74 x 64	9 480 8 130	381 381	143 140	15.8 15.8	14.0 10.4
S 12 x 50 x 40.8	14.7 12.0	12.00 12.00	5.477 5.252	0.659 0.659	0.687 0.462	S 310 x 74 x 60.7	9 480 7 740	305 305	139 133	16.7 16.7	17.4 11.7

TABLE A2.2
"S" SHAPES (CONT'D)

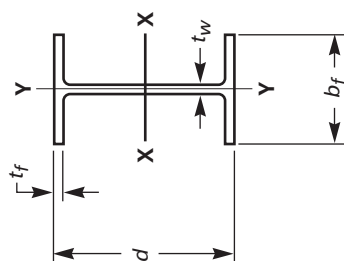
Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A_f in. ²	Depth d_f in.	Flange		Web Thickness t_w in. ⁴	Designation (Nominal Depth in Millimetres and Mass in Kilograms per Metre)	Area A_f mm ²	Depth d_f mm	Flange		Web Thickness t_w mm ⁴
			Width b_f in.	Thickness t_f in. ⁴					Width b_f mm	Thickness t_f mm ⁴	
S 12 x 35 x 31.8	10.3 9.35	12.00 12.00	5.078 5.000	0.544 0.544	0.428 0.350	S 310 x 52 x 47.3	6 650 6 030	305 305	129 127	13.8 13.8	10.9 8.9
S 10 x 35 x 25.4	10.3 7.46	10.00 10.00	4.944 4.661	0.491 0.491	0.594 0.311	S 250 x 52 x 37.8	6 650 4 810	254 254	126 118	12.5 12.5	15.1 7.9
S 8 x 23 x 18.4	6.77 5.41	8.00 8.00	4.171 4.001	0.425 0.425	0.441 0.271	S 200 x 34 x 27.4	4 370 3 480	203 203	106 102	10.8 10.8	11.2 6.9
S 6 x 17.25 x 12.5	5.07 3.67	6.00 6.00	3.565 3.332	0.359 0.359	0.465 0.232	S 150 x 25.7 x 18.6	3 270 2 360	152 152	91 85	9.1 9.1	11.8 5.9
S 5 x 10	2.94	5.00	3.004	0.326	0.214	S 130 x 15	1 880	127	76	8.3	5.4
S 4 x 9.5 x 7.7	2.79 2.26	4.00 4.00	2.796 2.663	0.293 0.293	0.326 0.193	S 100 x 14.1 x 11.5	1 800 1 450	102 102	71 68	7.4 7.4	8.3 4.9
S 3 x 7.5 x 5.7	2.21 1.67	3.00 3.00	2.509 2.330	0.260 0.260	0.349 0.170	S 75 x 11.2 x 8.5	1 430 1 080	76 76	64 59	6.6 6.6	8.9 4.3

⁴ Actual flange and web thicknesses vary due to mill rolling practices; however, permitted variations for such dimensions are not addressed.

TABLE A2.3
"M" SHAPES

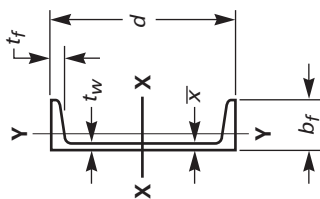
Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A_f in.^2	Depth d_f in.	Flange		Web Thickness t_w in. ⁴	Designation (Nominal Depth in Millimetres and Mass in Kilograms per Metre)	Area A_f mm^2	Depth d_f mm	Flange		Web Thickness t_w mm ⁴
			Width b_f in.	Thickness t_f in. ⁴					Width b_f mm	Thickness t_f mm ⁴	
M 12.5 × 12.4	3.66	12.534	3.750	0.228	0.155	M 318 × 18.5	2 361	318	95	5.8	3.9
M 12.5 × 11.6	3.43	12.500	3.500	0.211	0.155	M 318 × 17.3	2 213	317	89	5.4	3.9
M 12 × 11.8	3.47	12.00	3.065	0.225	0.177	M 310 × 17.6	2 240	305	78	5.7	4.5
M 12 × 10.8	3.18	11.97	3.065	0.210	0.160	M 310 × 16.1	2 050	304	78	5.3	4.1
M 12 × 10.0	2.94	11.97	3.250	0.180	0.149	M 310 × 14.9	1 900	304	83	4.6	3.8
M 10 × 9.0	2.65	10.00	2.690	0.206	0.157	M 250 × 13.4	1 710	254	68	4.6	3.6
M 10 × 8.0	2.35	9.95	2.690	0.182	0.141	M 250 × 11.9	1 520	253	68	5.2	4.0
M 10 × 7.5	2.21	9.99	2.688	0.173	0.130	M 250 × 11.2	1 430	253	68	4.4	3.3
M 8 × 6.5	1.92	8.00	2.281	0.189	0.135	M 200 × 9.7	1 240	203	57	4.8	3.4
M 8 × 6.2	1.81	8.00	2.281	0.177	0.129	M 200 × 9.2	1 170	203	58	4.5	3.3
M 6 × 4.4	1.29	6.00	1.844	0.171	0.114	M 150 × 6.6	832	152	47	4.3	2.9
M 6 × 3.7	1.09	5.92	2.000	0.129	0.098	M 150 × 5.5	703	150	51	3.3	2.5
M 5 × 18.9	5.55	5.00	5.003	0.416	0.316	M 130 × 28.1	3 580	127	127	10.6	8.0
M 4 × 6.0	1.78	3.80	3.80	0.160	0.130	M 100 × 8.9	1 150	97	97	4.1	3.3
M 4 × 4.08	1.20	4.00	2.250	0.170	0.115	M 100 × 6.1	775	102	57	4.3	2.9
M 4 × 3.45	1.029	4.00	2.250	0.130	0.092	M 100 × 5.1	665	102	57	3.3	2.8
M 4 × 3.2	0.94	4.00	2.250	0.130	0.092	M 100 × 4.8	610	102	57	3.3	2.3
M 3 × 2.9	0.853	3.00	2.250	0.130	0.090	M 75 × 4.3	550	76	57	3.3	2.3

⁴ Actual flange and web thicknesses vary due to mill rolling practices; however, permitted variations for such dimensions are not addressed.

TABLE A2.4
"HP" SHAPES

Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A_f in. ²	Depth d_f in.	Flange		Web Thickness t_w in. ⁴	Designation (Nominal Depth in Millimetres and Mass in Kilograms per Metre)	Area A_f mm ²	Depth d_f mm	Flange		Web Thickness t_w mm ⁴
			Width b_f in.	Thickness t_f in. ⁴					Width b_f mm	Thickness t_f mm ⁴	
HP14 x 117	34.4	14.21	14.885	0.805	0.805	HP360 x 174	22 200	361	378	20.4	20.4
x 102	30.0	14.01	14.785	0.705	0.705	x 152	19 400	356	376	17.9	17.9
x 89	26.1	13.83	14.695	0.615	0.615	x 132	16 800	351	373	15.6	15.6
x 73	21.4	13.61	14.585	0.505	0.505	x 108	13 800	346	370	12.8	12.8
HP12 x 84	24.6	12.28	12.295	0.685	0.685	HP310 x 125	15 900	312	312	17.4	17.4
x 74	21.8	12.13	12.215	0.610	0.605	x 110	14 100	308	310	15.5	15.4
x 63	18.4	11.94	12.125	0.515	0.515	x 93	11 900	303	308	13.1	13.1
x 53	15.5	11.78	12.045	0.435	0.435	x 79	10 000	299	306	11.0	11.0
HP10 x 57	16.8	9.99	10.225	0.565	0.565	HP250 x 85	10 800	254	260	14.4	14.4
x 42	12.4	9.70	10.075	0.420	0.415	x 62	8 000	246	256	10.7	10.5
HP8 x 36	10.6	8.02	8.155	0.445	0.455	HP200 x 53	6 840	204	207	11.3	11.3

⁴ Actual flange and web thicknesses vary due to mill rolling practices; however, permitted variations for such dimensions are not addressed.

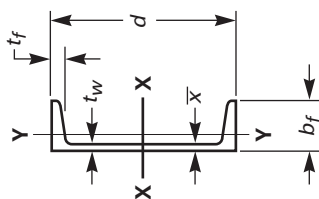
TABLE A2.5
"C" SHAPES

Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A_f in. ²	Depth d_f in.	Flange		Web Thickness t_w in. ⁴	Designation (Nominal Depth in Millimetres and Mass in Kilograms per Metre)	Area A_f mm ²	Depth d_f mm	Flange		Web Thickness t_w mm ⁴
			Width b_f in.	Thickness t_f in. ⁴					Width b_f mm	Thickness t_f mm ⁴	
C 15 × 50 × 40 × 33.9	14.7	15.00	3.716	0.650	0.716	C 380 × 74	9 480	381	94	16.5	18.2
	11.8	15.00	3.520	0.650	0.520	× 60	7 610	381	89	16.5	13.2
	9.96	15.00	3.400	0.650	0.400	× 50.4	6 430	381	86	16.5	10.2
C 12 × 30 × 25 × 20.7	8.82	12.00	3.170	0.501	0.510	C 310 × 45	5 690	305	80	12.7	13.0
	7.35	12.00	3.047	0.501	0.387	× 37	4 740	305	77	12.7	9.8
	6.09	12.00	2.942	0.501	0.282	× 30.8	3 930	305	74	12.7	7.2
C 10 × 30 × 25 × 20 × 15.3	8.82	10.00	3.033	0.436	0.673	C 250 × 45	5 690	254	76	11.1	17.1
	7.35	10.00	2.886	0.436	0.526	× 37	4 740	254	73	11.1	13.4
	5.88	10.00	2.739	0.436	0.379	× 30	3 790	254	69	11.1	9.6
C 9 × 20 × 15 × 13.4	4.49	10.00	2.600	0.436	0.240	× 22.8	2 900	254	65	11.1	6.1
	5.88	9.00	2.648	0.413	0.448	C 230 × 30	3 790	229	67	10.5	11.4
	4.41	9.00	2.485	0.413	0.285	× 22	2 850	229	63	10.5	7.2
C 8 × 18.75 × 13.75 × 11.5	3.94	9.00	2.433	0.413	0.233	× 19.9	2 540	229	61	10.5	5.9
	5.51	8.00	2.527	0.390	0.487	C 200 × 27.9	3 550	203	64	9.9	12.4
	4.04	8.00	2.343	0.390	0.303	× 20.5	2 610	203	59	9.9	7.7
C 7 × 14.75 × 12.25 × 9.8	3.38	8.00	2.260	0.390	0.220	× 17.1	2 180	203	57	9.9	5.6
	4.33	7.00	2.299	0.366	0.419	C 180 × 22	2 790	178	58	9.3	10.6
	3.60	7.00	2.194	0.366	0.314	× 18.2	2 320	178	55	9.3	8.0
	2.87	7.00	2.090	0.366	0.210	× 14.6	1 850	178	53	9.3	5.3

TABLE A2.5
"C" SHAPES (CONT'D)

Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A_f in. ²	Depth d_f in.	Flange		Web Thickness t_w in. ⁴	Designation (Nominal Depth in Millimetres and Mass in Kilograms per Metre)	Area A_f mm ²	Depth d_f mm	Flange		Web Thickness t_w mm ⁴
			Width b_f in.	Thickness t_f in. ⁴					Width b_f mm	Thickness t_f mm ⁴	
C6 × 13 × 10.5 × 8.2	3.83	6.00	2.157	0.343	0.437	C 150 × 19.3 × 15.6 × 12.2	2 470	152	54	8.7	11.1
	3.09	6.00	2.034	0.343	0.314		1 990	152	51	8.7	8.0
	2.40	6.00	1.920	0.343	0.200		1 550	152	48	8.7	5.1
C5 × 9 × 6.7	2.64	5.00	1.885	0.320	0.325	C 130 × 13 × 10.4	1 700	127	47	8.1	8.3
	1.97	5.00	1.750	0.320	0.190		1 270	127	44	8.1	4.8
C4 × 7.25 × 6.25 × 5.4 × 4.5	2.13	4.00	1.721	0.296	0.321	C 100 × 10.8 × 9.3 × 8 × 6.7	1 370	102	43	7.5	8.2
	1.84	4.00	1.647	0.272	0.247		1 187	102	42	6.9	6.3
	1.59	4.00	1.584	0.296	0.184		1 030	102	40	7.5	4.7
	1.32	4.00	1.584	0.296	0.125		852	102	40	7.5	3.2
C3 × 6 × 5 × 4.1 × 3.5	1.76	3.00	1.596	0.273	0.356	C 75 × 8.9 × 7.4 × 6.1 × 5.2	1 130	76	40	6.9	9.0
	1.47	3.00	1.498	0.273	0.258		948	76	37	6.9	6.6
	1.21	3.00	1.410	0.273	0.170		781	76	35	6.9	4.3
	1.03	3.00	1.372	0.273	0.132		665	76	35	6.9	3.4

⁴ Actual flange and web thicknesses vary due to mill rolling practices; however, permitted variations for such dimensions are not addressed.

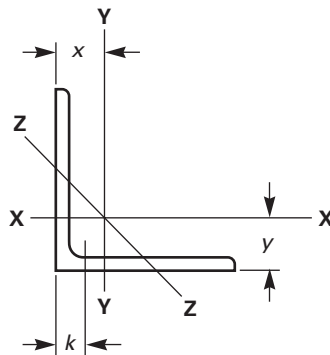
TABLE A2.6
"MC" SHAPES

Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A_f in. ²	Depth d_f in.	Flange		Web Thickness t_w in.	Designation (Nominal Depth in Millimetres and Mass in Kilograms per Metre)	Area A_f mm ²	Depth d_f mm	Flange		Web Thickness t_w mm
			Width b_f in.	Thickness t_f in.					Width b_f mm	Thickness t_f mm	
MC 18 × 58 × 51.9 × 45.8 × 42.7	17.1	18.00	4.200	0.625	0.700	MC 460 × 86	11 000	457	107	15.9	17.8
	15.3	18.00	4.100	0.625	0.600	× 77.2	9 870	457	104	15.9	15.2
	13.5	18.00	4.000	0.625	0.500	× 68.2	8 710	457	102	15.9	12.7
	12.6	18.00	3.950	0.625	0.450	× 63.5	8 130	457	100	15.9	11.4
MC 13 × 50 × 40 × 35 × 31.8	14.7	13.00	4.412	0.610	0.787	MC 330 × 74	9 480	330	112	15.5	20.0
	11.8	13.00	4.185	0.610	0.560	× 60	7 610	330	106	15.5	14.2
	10.3	13.00	4.072	0.610	0.447	× 52	6 640	330	103	15.5	11.4
	9.35	13.00	4.000	0.610	0.375	× 47.3	6 030	330	102	15.5	9.5
MC 12 × 50 × 45 × 40 × 35 × 31	14.7	12.00	4.135	0.700	0.835	MC 310 × 74	9 480	305	105	17.8	21.2
	13.2	12.00	4.010	0.700	0.710	× 67	8 502	305	102	17.8	18.0
	11.8	12.00	3.890	0.700	0.590	× 60	7 610	305	98	17.8	15.0
	10.3	12.00	3.765	0.700	0.465	× 52	6 620	305	96	17.8	11.8
	9.12	12.00	3.670	0.700	0.370	× 46	5 890	305	93	17.8	9.4
MC 12 × 14.3 × 10.6	4.19	12.00	2.125	0.313	0.250	MC 310 × 21.3	2 700	305	54	8.0	6.4
	3.10	12.00	1.500	0.309	0.190	× 15.8	2 000	305	38	7.8	4.8
MC 10 × 41.1 × 33.6 × 28.5	12.1	10.00	4.321	0.575	0.796	MC 250 × 61.2	7 810	254	110	14.6	20.2
	9.87	10.00	4.100	0.575	0.575	× 50	6 370	254	104	14.6	14.6
	8.37	10.00	3.950	0.575	0.425	× 42.4	5 400	254	100	14.6	10.8

TABLE A2.6
"MC" SHAPES (CONT'D)

Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot)	Area A_f			Depth d_f		Flange		Web Thickness $t_{w\theta}$ in. ⁴	Designation (Nominal Depth in Millimetres and Mass in Kilograms per Metre)	Area A_f mm ²	Depth d_f mm	Flange		Web Thickness $t_{w\theta}$ mm ⁴
	in. ²	in.	in.	Width b_f in.	Thickness t_f in. ⁴	Width b_f mm	Thickness t_f mm ⁴							
MC 10 × 25 × 22	7.35 6.45	10.00 10.00	3.405 3.315	0.575 0.575	0.380 0.290	MC 250 × 37 × 33	4 740 4 160	254 254	86 84	14.6 14.6	9.7 7.4			
MC 10 × 8.4 × 6.5	2.46 1.91	10.00 10.00	1.500 1.170	0.280 0.202	0.170 0.152	MC 250 × 12.5 × 9.7	1 590 1 240	254 254	38 28	7.1 5.1	4.3 3.9			
MC 9 × 25.4 × 23.9	7.47 7.02	9.00 9.00	3.500 3.450	0.550 0.550	0.450 0.400	MC 230 × 37.8 × 35.6	4 820 4 530	229 229	88 87	14.0 14.0	11.4 10.2			
MC 8 × 22.8 × 21.4	6.70 6.28	8.00 8.00	3.502 3.450	0.525 0.525	0.427 0.375	MC 200 × 33.9 × 31.8	4 320 4 050	203 203	88 87	13.3 13.3	10.8 9.5			
MC 8 × 20 × 18.7	5.88 5.50	8.00 8.00	3.025 2.978	0.500 0.500	0.400 0.353	MC 200 × 29.8 × 27.8	3 790 3 550	203 203	76 75	12.7 12.7	10.2 9.0			
MC 8 × 8.5	2.50	8.00	1.874	0.311	0.179	MC 200 × 12.6	1 610	203	47	7.9	4.5			
MC 7 × 22.7 × 19.1	6.67 5.61	7.00 7.00	3.603 3.452	0.500 0.500	0.503 0.352	MC 180 × 33.8 × 28.4	4 300 3 620	178 178	91 87	12.7 12.7	12.8 8.9			
MC 6 × 18 × 15.3	5.29 4.50	6.00 6.00	3.504 3.500	0.475 0.385	0.379 0.340	MC 150 × 26.8 × 22.8	3 410 2 900	152 152	88 88	12.1 9.8	9.6 8.6			
MC 6 × 16.3 × 15.1	4.79 4.44	6.00 6.00	3.000 2.941	0.475 0.475	0.375 0.316	MC 150 × 24.3 × 22.5	3 090 2 860	152 152	76 74	12.1 12.1	9.5 8.0			
MC 6 × 12	3.53	6.00	2.497	0.375	0.310	MC 150 × 17.9	2 280	152	63	9.5	7.9			
MC 6 × 7.0 × 6.5	2.07 1.93	6.00 6.00	1.875 1.850	0.291 0.291	0.179 0.155	MC 150 × 10.4 × 9.7	1 341 1 250	152 152	48 47	7.4 7.4	4.5 3.9			
MC 4 × 13.8	4.02	4.00	2.500	0.500	0.500	MC 100 × 20.5	2 594	102	64	13	13			
MC 3 × 7.1	2.09	3.00	1.938	0.351	0.312	MC 75 × 10.6	1 348	76	49	8.9	7.9			

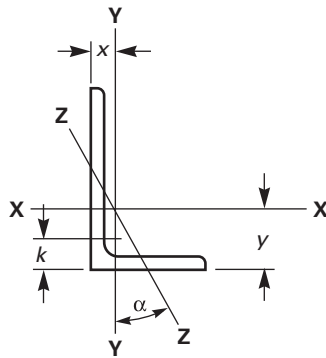
TABLE A2.7
"L" SHAPES (EQUAL LEGS)



Size and Thickness, in.	Weight per Foot, lb	Area, in. ²	Size and Thickness, mm	Mass per Metre, kg	Area, mm ²
L8 × 8 × 1 ¹ / ₈	56.9	16.7	L203 × 203 × 28.6	84.7	10 800
L8 × 8 × 1	51.0	15.0	L203 × 203 × 25.4	75.9	9 680
L8 × 8 × 7 ⁷ / ₈	45.0	13.2	L203 × 203 × 22.2	67.0	8 500
L8 × 8 × 3 ³ / ₄	38.9	11.4	L203 × 203 × 19.0	57.9	7 360
L8 × 8 × 5 ⁵ / ₈	32.7	9.61	L203 × 203 × 15.9	48.7	6 200
L8 × 8 × 9 ⁹ / ₁₆	29.6	8.68	L203 × 203 × 14.3	44.0	5 600
L8 × 8 × 1 ¹ / ₂	26.4	7.75	L203 × 203 × 12.7	39.3	5 000
L6 × 6 × 1	37.4	11.0	L152 × 152 × 25.4	55.7	7 100
L6 × 6 × 7 ⁷ / ₈	33.1	9.73	L152 × 152 × 22.2	49.3	6 280
L6 × 6 × 3 ³ / ₄	28.7	8.44	L152 × 152 × 19.0	42.7	5 450
L6 × 6 × 5 ⁵ / ₈	24.2	7.11	L152 × 152 × 15.9	36.0	4 590
L6 × 6 × 9 ⁹ / ₁₆	21.9	6.43	L152 × 152 × 14.3	32.6	4 150
L6 × 6 × 1 ¹ / ₂	19.6	5.75	L152 × 152 × 12.7	29.2	3 710
L6 × 6 × 7 ⁷ / ₁₆	17.2	5.06	L152 × 152 × 11.1	25.6	3 270
L6 × 6 × 3 ³ / ₈	14.9	4.36	L152 × 152 × 9.5	22.2	2 810
L6 × 6 × 5 ⁵ / ₁₆	12.4	3.65	L152 × 152 × 7.9	18.5	2 360
L5 × 5 × 7 ⁷ / ₈	27.2	7.98	L127 × 127 × 22.2	40.5	5 150
L5 × 5 × 3 ³ / ₄	23.6	6.94	L127 × 127 × 19.0	35.1	4 480
L5 × 5 × 5 ⁵ / ₈	20.0	5.86	L127 × 127 × 15.9	29.8	3 780
L5 × 5 × 1 ¹ / ₂	16.2	4.75	L127 × 127 × 12.7	24.1	3 070
L5 × 5 × 7 ⁷ / ₁₆	14.3	4.18	L127 × 127 × 11.1	21.3	2 700
L5 × 5 × 3 ³ / ₈	12.3	3.61	L127 × 127 × 9.5	18.3	2 330
L5 × 5 × 5 ⁵ / ₁₆	10.3	3.03	L127 × 127 × 7.9	15.3	1 960
L4 × 4 × 3 ³ / ₄	18.5	5.44	L102 × 102 × 19.0	27.5	3 510
L4 × 4 × 5 ⁵ / ₈	15.7	4.61	L102 × 102 × 15.9	23.4	2 970
L4 × 4 × 1 ¹ / ₂	12.8	3.75	L102 × 102 × 12.7	19.0	2 420
L4 × 4 × 7 ⁷ / ₁₆	11.3	3.31	L102 × 102 × 11.1	16.8	2 140
L4 × 4 × 3 ³ / ₈	9.8	2.86	L102 × 102 × 9.5	14.6	1 850
L4 × 4 × 5 ⁵ / ₁₆	8.2	2.40	L102 × 102 × 7.9	12.2	1 550
L4 × 4 × 1 ¹ / ₄	6.6	1.94	L102 × 102 × 6.4	9.8	1 250
L3 ¹ / ₂ × 3 ¹ / ₂ × 1 ¹ / ₂	11.1	3.25	L89 × 89 × 12.7	16.5	2 100
L3 ¹ / ₂ × 3 ¹ / ₂ × 7 ⁷ / ₁₆	9.8	2.87	L89 × 89 × 11.1	14.6	1 850
L3 ¹ / ₂ × 3 ¹ / ₂ × 3 ³ / ₈	8.5	2.48	L89 × 89 × 9.5	12.6	1 600
L3 ¹ / ₂ × 3 ¹ / ₂ × 5 ⁵ / ₁₆	7.2	2.09	L89 × 89 × 7.9	10.7	1 350
L3 ¹ / ₂ × 3 ¹ / ₂ × 1 ¹ / ₄	5.8	1.69	L89 × 89 × 6.4	8.6	1 090

TABLE A2.7
 "L" SHAPES (EQUAL LEGS) (CONT'D)

Size and Thickness, in.	Weight per Foot, lb	Area, in. ²	Size and Thickness, mm	Mass per Metre, kg	Area, mm ²
L3 × 3 × 1/2	9.4	2.75	L76 × 76 × 12.7	14.0	1 770
L3 × 3 × 7/16	8.3	2.43	L76 × 76 × 11.1	12.4	1 570
L3 × 3 × 3/8	7.2	2.11	L76 × 76 × 9.5	10.7	1 360
L3 × 3 × 5/16	6.1	1.78	L76 × 76 × 7.9	9.1	1 150
L3 × 3 × 1/4	4.9	1.44	L76 × 76 × 6.4	7.3	929
L3 × 3 × 3/16	3.71	1.09	L76 × 76 × 4.8	5.5	703
L2 1/2 × 2 1/2 × 1/2	7.7	2.25	L64 × 64 × 12.7	11.4	1 450
L2 1/2 × 2 1/2 × 3/8	5.9	1.73	L64 × 64 × 9.5	8.7	1 120
L2 1/2 × 2 1/2 × 5/16	5.0	1.46	L64 × 64 × 7.9	7.4	942
L2 1/2 × 2 1/2 × 1/4	4.1	1.19	L64 × 64 × 6.4	6.1	768
L2 1/2 × 2 1/2 × 3/16	3.07	0.90	L64 × 64 × 4.8	4.6	581
L2 × 2 × 3/8	4.7	1.36	L51 × 51 × 9.5	7.0	877
L2 × 2 × 5/16	3.92	1.15	L51 × 51 × 7.9	5.8	742
L2 × 2 × 1/4	3.19	0.938	L51 × 51 × 6.4	4.7	605
L2 × 2 × 3/16	2.44	0.715	L51 × 51 × 4.8	3.6	461
L2 × 2 × 1/8	1.65	0.484	L51 × 51 × 3.2	2.4	312
L1 3/4 × 1 3/4 × 1/4	2.77	0.813	L44 × 44 × 6.4	4.1	525
L1 3/4 × 1 3/4 × 3/16	2.12	0.621	L44 × 44 × 4.8	3.1	401
L1 3/4 × 1 3/4 × 1/8	1.44	0.422	L44 × 44 × 3.2	2.1	272
L1 1/2 × 1 1/2 × 1/4	2.34	0.688	L38 × 38 × 6.4	3.4	444
L1 1/2 × 1 1/2 × 3/16	1.80	0.527	L38 × 38 × 4.8	2.7	340
L1 1/2 × 1 1/2 × 5/32	1.52	0.444	L38 × 38 × 4.0	2.2	286
L1 1/2 × 1 1/2 × 1/8	1.23	0.359	L38 × 38 × 3.2	1.8	232
L1 1/4 × 1 1/4 × 1/4	1.92	0.563	L32 × 32 × 6.4	2.8	363
L1 1/4 × 1 1/4 × 3/16	1.48	0.434	L32 × 32 × 4.8	2.2	280
L1 1/4 × 1 1/4 × 1/8	1.01	0.297	L32 × 32 × 3.2	1.5	192
L1 × 1 × 1/4	1.49	0.438	L25 × 25 × 6.4	2.2	283
L1 × 1 × 3/16	1.16	0.340	L25 × 25 × 4.8	1.8	219
L1 × 1 × 1/8	0.80	0.234	L25 × 25 × 3.2	1.2	151
L 3/4 × 3/4 × 1/8	0.59	0.172	L19 × 19 × 3.2	0.9	111

TABLE A2.8
"L" SHAPES (UNEQUAL LEGS)

Size and Thickness, in.	Weight per Foot, lb	Area, in. ²	Size and Thickness, mm	Mass per Metre, kg	Area, mm ²
L8 × 6 × 1	44.2	13.0	L203 × 152 × 25.4	65.5	8 390
L8 × 6 × $\frac{7}{8}$	39.1	11.5	L203 × 152 × 22.2	57.9	7 420
L8 × 6 × $\frac{3}{4}$	33.8	9.94	L203 × 152 × 19.0	50.1	6 410
L8 × 6 × $\frac{5}{8}$	28.5	8.36	L203 × 152 × 15.9	42.2	5 390
L8 × 6 × $\frac{9}{16}$	25.7	7.56	L203 × 152 × 14.3	38.1	4 880
L8 × 6 × $\frac{1}{2}$	23.0	6.75	L203 × 152 × 12.7	34.1	4 350
L8 × 6 × $\frac{7}{16}$	20.2	5.93	L203 × 152 × 11.1	29.9	3 830
L8 × 4 × 1	37.4	11.0	L203 × 102 × 25.4	55.4	7 100
L8 × 4 × $\frac{7}{8}$	33.1	9.73	L203 × 102 × 22.2	49.3	6 280
L8 × 4 × $\frac{3}{4}$	28.7	8.44	L203 × 102 × 19.0	42.5	5 450
L8 × 4 × $\frac{5}{8}$	24.2	7.11	L203 × 102 × 15.9	36.0	4 590
L8 × 4 × $\frac{9}{16}$	21.9	6.43	L203 × 102 × 14.3	32.4	4 150
L8 × 4 × $\frac{1}{2}$	19.6	5.75	L203 × 102 × 12.7	29.0	3 710
L8 × 4 × $\frac{7}{16}$	17.2	5.06	L203 × 102 × 11.1	25.6	3 260
L7 × 4 × $\frac{3}{4}$	26.2	7.69	L178 × 102 × 19.0	38.8	4 960
L7 × 4 × $\frac{5}{8}$	22.1	6.48	L178 × 102 × 15.9	32.7	4 180
L7 × 4 × $\frac{1}{2}$	17.9	5.25	L178 × 102 × 12.7	26.5	3 390
L7 × 4 × $\frac{7}{16}$	15.7	4.62	L178 × 102 × 11.1	23.4	2 980
L7 × 4 × $\frac{3}{8}$	13.6	3.98	L178 × 102 × 9.5	20.2	2 570
L6 × 4 × $\frac{7}{8}$	27.2	7.98	L152 × 102 × 22.2	40.3	5 150
L6 × 4 × $\frac{3}{4}$	23.6	6.94	L152 × 102 × 19.0	35.0	4 480
L6 × 4 × $\frac{5}{8}$	20.0	5.86	L152 × 102 × 15.9	29.6	3 780
L6 × 4 × $\frac{9}{16}$	18.1	5.31	L152 × 102 × 14.3	26.8	3 430
L6 × 4 × $\frac{1}{2}$	16.2	4.75	L152 × 102 × 12.7	24.0	3 060
L6 × 4 × $\frac{7}{16}$	14.3	4.18	L152 × 102 × 11.1	21.2	2 700
L6 × 4 × $\frac{3}{8}$	12.3	3.61	L152 × 102 × 9.5	18.2	2 330
L6 × 4 × $\frac{5}{16}$	10.3	3.03	L152 × 102 × 7.9	15.3	1 950
L6 × $3\frac{1}{2}$ × $\frac{1}{2}$	15.3	4.50	L152 × 89 × 12.7	22.7	2 900
L6 × $3\frac{1}{2}$ × $\frac{3}{8}$	11.7	3.42	L152 × 89 × 9.5	17.3	2 210
L6 × $3\frac{1}{2}$ × $\frac{5}{16}$	9.8	2.87	L152 × 89 × 7.9	14.5	1 850

TABLE A2.8
 "L" SHAPES (UNEQUAL LEGS) (CONT'D)

Size and Thickness, in.	Weight per Foot, lb	Area, in. ²	Size and Thickness, mm	Mass per Metre, kg	Area, mm ²
L5 × 3½ × ¾	19.8	5.81	L127 × 89 × 19.0	29.3	3 750
L5 × 3½ × ⅝	16.8	4.92	L127 × 89 × 15.9	24.9	3 170
L5 × 3½ × ½	13.6	4.00	L127 × 89 × 12.7	20.2	2 580
L5 × 3½ × ⅜	10.4	3.05	L127 × 89 × 9.5	15.4	1 970
L5 × 3½ × ⅜	8.7	2.56	L127 × 89 × 7.9	12.9	1 650
L5 × 3½ × ¼	7.0	2.06	L127 × 89 × 6.4	10.4	1 330
L5 × 3 × ½	12.8	3.75	L127 × 76 × 12.7	19.0	2 420
L5 × 3 × ⅞	11.3	3.31	L127 × 76 × 11.1	16.7	2 140
L5 × 3 × ⅜	9.8	2.86	L127 × 76 × 9.5	14.5	1 850
L5 × 3 × ⅝	8.2	2.40	L127 × 76 × 7.9	12.1	1 550
L5 × 3 × ¼	6.6	1.94	L127 × 76 × 6.4	9.8	1 250
L4 × 3½ × ½	11.9	3.50	L102 × 89 × 12.7	17.6	2 260
L4 × 3½ × ⅜	9.1	2.67	L102 × 89 × 9.5	13.5	1 720
L4 × 3½ × ⅝	7.7	2.25	L102 × 89 × 7.9	11.4	1 450
L4 × 3½ × ¼	6.2	1.81	L102 × 89 × 6.4	9.2	1 170
L4 × 3 × ⅝	13.6	3.98	L102 × 76 × 15.9	20.2	2 570
L4 × 3 × ½	11.1	3.25	L102 × 76 × 12.7	16.4	2 100
L4 × 3 × ⅜	8.5	2.48	L102 × 76 × 9.5	12.6	1 600
L4 × 3 × ⅝	7.2	2.09	L102 × 76 × 7.9	10.7	1 350
L4 × 3 × ¼	5.8	1.69	L102 × 76 × 6.4	8.6	1 090
L3½ × 3 × ½	10.2	3.00	L89 × 76 × 12.7	15.1	1 940
L3½ × 3 × ⅞	9.1	2.65	L89 × 76 × 11.1	13.5	1 710
L3½ × 3 × ⅜	7.9	2.30	L89 × 76 × 9.5	11.7	1 480
L3½ × 3 × ⅝	6.6	1.93	L89 × 76 × 7.9	9.8	1 250
L3½ × 3 × ¼	5.4	1.56	L89 × 76 × 6.4	8.0	1 010
L3½ × 2½ × ½	9.4	2.75	L89 × 64 × 12.7	13.9	1 770
L3½ × 2½ × ⅜	7.2	2.11	L89 × 64 × 9.5	10.7	1 360
L3½ × 2½ × ⅝	6.1	1.78	L89 × 64 × 7.9	9.0	1 150
L3½ × 2½ × ¼	4.9	1.44	L89 × 64 × 6.4	7.3	929
L3 × 2½ × ½	8.5	2.50	L76 × 64 × 12.7	12.6	1 610
L3 × 2½ × ⅞	7.6	2.21	L76 × 64 × 11.1	11.3	1 430
L3 × 2½ × ⅜	6.6	1.92	L76 × 64 × 9.5	9.8	1 240
L3 × 2½ × ⅝	5.6	1.62	L76 × 64 × 7.9	8.3	1 050
L3 × 2½ × ¼	4.5	1.31	L76 × 64 × 6.4	6.7	845
L3 × 2½ × ⅜	3.39	0.996	L76 × 64 × 4.8	5.1	643
L3 × 2 × ½	7.7	2.25	L76 × 51 × 12.7	11.5	1 450
L3 × 2 × ⅜	5.9	1.73	L76 × 51 × 9.5	8.8	1 120
L3 × 2 × ⅝	5.0	1.46	L76 × 51 × 7.9	7.4	942
L3 × 2 × ¼	4.1	1.19	L76 × 51 × 6.4	6.1	768
L3 × 2 × ⅜	3.07	0.902	L76 × 51 × 4.8	4.6	582
L2½ × 2 × ⅜	5.3	1.55	L64 × 51 × 9.5	7.9	1 000
L2½ × 2 × ⅝	4.5	1.31	L64 × 51 × 7.9	6.7	845
L2½ × 2 × ¼	3.62	1.06	L64 × 51 × 6.4	5.4	684
L2½ × 2 × ⅜	2.75	0.809	L64 × 51 × 4.8	4.2	522
L2½ × 1½ × ¼	3.19	0.938	L64 × 38 × 6.4	4.8	605
L2½ × 1½ × ⅜	2.44	0.715	L64 × 38 × 4.8	3.6	461
L2 × 1½ × ¼	2.77	0.813	L51 × 38 × 6.4	4.2	525
L2 × 1½ × ⅜	2.12	0.621	L51 × 38 × 4.8	3.1	401
L2 × 1½ × ⅝	1.44	0.422	L51 × 38 × 3.2	2.1	272

APPENDICES

(Nonmandatory Information)

X1. COIL AS A SOURCE OF STRUCTURAL PRODUCTS

X1.1 Continuous wide hot strip rolling mills are normally equipped with coilers. Regardless of the different types of systems employed during or following the rolling operations, it is common for the steel to be reeled into the coiler at temperatures in the stress-relieving range. In general, such temperatures are higher as the steel thickness increases. The coils subsequently cool to ambient temperature with outer and inner laps cooling more rapidly than central laps. The difference in cooling rate can result in measurable differences in the mechanical properties throughout a coil. Data confirm reduced yield and tensile strength with increased percent elongation for the steel with slower cooling rates from the coiling temperature to ambient. Such differences are in addition to the effects on mechanical properties caused by differences in heat analysis and chemical segregation.

X2. VARIATION OF TENSILE PROPERTIES IN PLATES AND SHAPES

X2.1 The tension testing requirements of Specification A 6/A 6M are intended only to characterize the tensile properties of a heat of steel for determination of conformance to the requirements of the applicable product specification. Such testing procedures are not intended to define the upper or lower limits of tensile properties at all possible test locations within a heat of steel. It is well known and documented that tensile properties will vary within a heat or individual piece of steel as a function of chemical composition, processing, testing procedure and other factors. It is, therefore, incumbent on designers and engineers to use sound engineering judgement when using tension test results shown on mill test reports. The testing procedures of Specification A 6/A 6M have been found to provide structural products adequate for normal structural design criteria.

X2.2 A survey of the variation to be expected in tensile properties obtained from plates and structural shapes was conducted by the American Iron and Steel Institute (AISI). The results of this survey are contained in a *Contributions to the Metallurgy of Steel* entitled “The Variation of Product Analysis and Tensile Properties—Carbon Steel Plates and Wide Flange Shapes” (SU/18, SU/19 and SU/20), published in September 1974. The data are presented in tables

of probability that tensile properties at other than the official location may differ from those of the reported test location. Another survey sponsored by the AISI entitled “Statistical Analysis of Structural Plate Mechanical Properties” was published in January 2003. That survey analyzed the results of variability testing on more modern as-rolled steels that were generally of higher minimum yield strength steels and also compared those results statistically to the previous surveys.

X2.3 Specification A 6/A 6M contains no requirements applicable to product tension tests; conformance to the applicable product specification is determined on the basis of tests performed at the place of manufacture or processing prior to shipment, unless otherwise specified.

X2.4 A Task Group of ASTM Subcommittee A01.02 has determined, based on review of the earlier AISI data, that the variation in tensile properties of plates and structural shapes can be expressed as a function of specified requirements: one standard deviation equals approximately 4% of required tensile strength, 8% of required yield strength, and 3 percentage points of required elongation. The January 2003 survey resulted in similar findings.

X2.5 Acceptance criteria for product testing based upon these values, either below the minimum or above the maximum allowed by the applicable product specification, are generally acceptable to manufacturers. Such tolerances could be considered by users of structural products as a reasonable basis for acceptance of structural products that, due to their inherent variability, deviate from the applicable product specification requirements when subjected to product tension testing.

X3. WELDABILITY OF STEEL

X3.1 *Weldability* is a term that usually refers to the relative ease with which a metal can be welded using conventional practice. Difficulties arise in steel when the cooling rates associated with weld thermal cycles produce microstructures (for example, martensite) that are susceptible to brittle fracture or, more commonly, hydrogen-induced (or cold) cracking. (Solidification or hot cracking is a relatively rare phenomenon that will not be addressed here. See Randall for further information.)

X3.2 The relative sensitivity of steels to forming cold cracking microstructures is called hardenability and can

be measured in a number of ways. Perhaps the most popular method of assessing this is by the carbon equivalent (CE) formula, which attempts to equate the relative hardening contributions of a steel's constituent elements (for example, manganese, vanadium) to an equivalent amount of carbon, which is the most significant hardening agent. The most popular formula is the IIW (International Institute of Welding) equation presented in S31.2, which has been found suitable for predicting hardenability in a wide range of commonly used carbon-manganese and low alloy steels.

X3.3 It should be noted, however, that for the current generation of low carbon (<0.10%) low alloy steels that derive strength from a combination of microalloys and thermal processing methods, the use of other formulae may more accurately assess hardenability and cold cracking sensitivity.

X3.4 For a vast number of common structural applications it is unnecessary to specify the use of CE limits. However, in order to obtain a higher level of confidence in avoiding cold cracking, the chemistry controls in S31 are available. A purchaser who specifies the use of S31 should be aware that there are several factors involved in the judicious selection of a maximum CE value, such as the following:

X3.4.1 Actual production joint restraint/base metal thickness(es),

X3.4.2 Filler metal and base metal strength compatibility,

X3.4.3 Deposited weld metal diffusible hydrogen content,

X3.4.4 Preheat and interpass temperatures,

X3.4.5 Filler metal and base metal cleanliness, and

X3.4.6 Heat input.

X3.5 Though it is widely believed that low CE steels are immune to weld cracking problems, failure to consider these factors and others have resulted in weld or base metal HAZ (heat affected zone) cracks in such steels.

X3.6 It is important to note that carbon equivalence is only a qualitative assessment of potential welding problems, and should never be solely relied on to ensure weld integrity. The proper use of welding specifications, coupled

with the knowledge of actual construction conditions, must also be used.

X4. RADIUS FOR COLD BENDING

X4.1 Suggested minimum inside bend radii for cold forming are referenced to Group Designations A to F inclusive as defined in Table X4.1. The suggested radii listed in Table X4.2 should be used as minimums in typical shop fabrication. Material that does not form satisfactorily when fabricated in accordance with Table X4.2 may be subject to rejection pending negotiation with the steel supplier. When tighter bends are required, the manufacturer should be consulted.

X4.2 The bend radius and the radius of the male die should be as liberal as the finished part will permit. The width across the shoulders of the female die should be at least eight times the plate thickness. Higher strength steels require larger die openings. The surface of the dies in the area of radius should be smooth.

X4.2.1 Since cracks in cold bending commonly originate from the outside edges, shear burrs and gas cut edges should be removed by grinding. Sharp corners on edges and on punched or gas cut holes should be removed by chamfering or grinding to a radius.

X4.2.2 If possible, parts should be formed such that the bend line is perpendicular to the direction of final rolling. If it is necessary to bend with the bend line parallel to the direction of final rolling, a more generous radius is suggested ($1\frac{1}{2}$ times applicable value given in Table X4.2 for bend lines perpendicular to the direction of rolling).

X4.3 References:

X4.3.1 Holt, G. E., et al, "Minimum Cold Bend Radii Project—Final Report," Concurrent Technologies Corporation, January 27, 1997.

X4.3.2 Brockenbrough, R. L., "Fabrication Guidelines for Cold Bending," R. L. Brockenbrough & Associates, June 28, 1998.

X4.3.3 Both of these references are available from American Iron and Steel Institute, 1101 17th Street NW, Washington, DC 20036-4700.

TABLE X4.1
GROUP DESIGNATIONS FOR COLD BENDING

Specification	Grade	Group Designation ^A
A 36/A 36M	^B	B
A 131/A 131M	A, B, D, CS and E	B
	A, B, D, CS and E (all cold flanging)	B
	AH32, DH32, EH32 and FH32	C
	AH36, DH36, EH36 and FH36	C
	AH40, DH40, EH40 and FH40	C
A 242/A 242M	^B	C
A 283/A 283M	A or B	A
	C or D	B
A 514/A 514M	any	F
A 529/A 529M	50 [345] or 55 [380]	C
A 572/A 572M	42 [290]	B
	50 [345]	C
	55 [380]	D
	60 [415] or 65 [450]	E
A 573/A 573M	58 [400] or 65 [450]	B
	70 [485]	C
A 588/A 588M	any	C
A 633/A 633M	any	B
A 656/A 656M	50 [345]	B
	60 [415]	D
	70 [485]	E
	80 [550]	F
A 678/A 678M	A or B	C
	C or D	D
A 709/A 709M	36 [250]	B
	50 [345] or 50W [345W]	C
	70W [485W] or HPS70W [HPS485W]	D
	100 [690] or 100W [690W]	F
A 710/A 710M	A	F
A 808/A 808M	^B	C
A 852/A 852M	^B	D
A 871/A 871M	60 [415] or 65 [450]	E
A 945/A 945M	50 [345] or 65 [450]	B

^A Steels having a ratio of specified minimum tensile strength to specified minimum yield strength of 1.15 or less are in Group F; other steels are in Groups A to E inclusive, which are grouped on the basis of their having similar specified values for minimum elongation in 2 in. [50 mm].

^B Grade designations are not applicable for this specification.

TABLE X4.2
SUGGESTED MINIMUM INSIDE RADII FOR COLD BENDING^A

Group Designation ^B	Thickness (t), in. [mm]			
	Up to ¾ in. [20 mm]	Over ¾ in. [20 mm]	Over 1 in. [25 mm]	Over 2 in. [50 mm]
		To 1 [25 mm, incl.]	To 2 in. [50 mm], incl.	
A	1.5t	1.5t	1.5t	1.5t
B	1.5t	1.5t	1.5t	2.0t
C	1.5t	1.5t	2.0t	2.5t
D	1.5t	1.5t	2.5t	3.0t
E	1.5t	1.5t	3.0t	3.5t
F	1.75t	2.25t	4.5t	5.5t

^A Values are for bend lines perpendicular to the direction of final rolling. These radii apply when the precautions listed in X 4.2 are followed. If bend lines are parallel to the direction of the final rolling, multiply values by 1.5.

^B Steel specifications included in the group designations may not include the entire thickness range shown in this table.

SPECIFICATION FOR GENERAL REQUIREMENTS FOR STEEL PLATES FOR PRESSURE VESSELS



SA-20/SA-20M



(Identical with ASTM Specification A 20/A 20M-09.)

(a)

1. Scope

1.1 This general requirements specification covers a group of common requirements that, unless otherwise specified in the applicable product specification, apply to rolled steel plates for pressure vessels covered by each of the following product specifications issued by ASTM:

Title of Specification	ASTM Designation
Pressure Vessel Plates, Alloy Steel, Chromium-Manganese Silicon	A 202/A 202M
Pressure Vessel Plates, Alloy Steel, Nickel	A 203/A 203M
Pressure Vessel Plates, Alloy Steel, Molybdenum	A 204/A 204M
Pressure Vessel Plates, Alloy Steel, Manganese-Vanadium	A 225/A 225M
Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength	A 285/A 285M
Pressure Vessel Plates, Carbon Steel, Manganese-Silicon	A 299/A 299M
Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum-Nickel	A 302/A 302M
Pressure Vessel Plates, Alloy Steel, 9 Percent Nickel Double-Normalized and Tempered	A 353/A 353M
Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum	A 387/A 387M
Pressure Vessel Plates, Carbon Steel, High Strength Manganese	A 455/A 455M
Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service	A 515/A 515M
Pressure Vessel Plates, Carbon Steel, Moderate- and Lower-Temperature Service	A 516/A 516M
Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered	A 517/A 517M
Pressure Vessel Plates, Alloy Steel, Quenched and Tempered Manganese-Molybdenum and Manganese-Molybdenum-Nickel	A 533/A 533M
Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel	A 537/A 537M
Pressure Vessel Plates, Alloy Steel, Quenched and Tempered Chromium-Molybdenum	A 542/A 542M

Title of Specification	ASTM Designation
Pressure Vessel Plates, Alloy Steel, Quenched and Tempered Nickel-Chromium-Molybdenum	A 543/A 543M
Pressure Vessel Plates, Alloy Steel, Quenched and Tempered 8 and 9 Percent Nickel	A 553/A 553M
Pressure Vessel Plates, Carbon Steel, Manganese-Titanium for Glass or Diffused Metallic Coatings	A 562/A 562M
Pressure Vessel Plates, Carbon Steel, High Strength, for Moderate and Lower Temperature Service	A 612/A 612M
Pressure Vessel Plates, Five Percent Nickel Alloy Steel, Specially Heat Treated	A 645/A 645M
Pressure Vessel Plates, Carbon-Manganese, for Moderate and Lower Temperature Service	A 662/A 662M
Pressure Vessel Plates, Carbon Steel, Quenched and Tempered, for Welded Layered Pressure Vessels	A 724/A 724M
Pressure Vessel Plates, Alloy Steel and High-Strength Low-Alloy Steel, Quenched and Tempered	A 734/A 734M
Pressure Vessel Plates, Low-Carbon Manganese-Molybdenum-Columbium Alloy Steel, for Moderate and Lower Temperature Service	A 735/A 735M
Pressure Vessel Plates, Low-Carbon Age-Hardening Nickel-Copper-Chromium-Molybdenum-Columbium Alloy Steel	A 736/A 736M
Pressure Vessel Plates, High-Strength Low-Alloy Steel	A 737/A 737M
Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel, for Moderate and Lower Temperature Service	A 738/A 738M
Pressure Vessel Plates, Quenched and Tempered, Manganese-Chromium-Molybdenum-Silicon-Zirconium Alloy Steel	A 782/A 782M
Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum-Vanadium	A 832/A 832M

Title of Specification	ASTM Designation
Pressure Vessel Plates, Produced by the Thermo-Mechanical Control Process (TMCP)	A 841/A 841M
Pressure Vessel Plates, 9% Nickel Alloy, Produced by the Direct-Quenching Process	A 844/A 844M
Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum-Tungsten	A 1017/A 1017M
Pressure Vessel Plates, Alloy Steel, Higher Strength Chromium-Molybdenum-Tungsten	A 1041/A 1041M

1.1.1 This general requirements specification also covers a group of supplementary requirements that are applicable to several of the above product specifications as indicated therein. Such requirements are provided for use if additional testing or additional restrictions are required by the purchaser, and apply only if specified individually in the purchase order.

1.2 Appendix X1 provides information on coil as a source of plates for pressure vessels.

1.3 Appendix X2 provides information on the variability of tensile properties in plates for pressure vessels.

1.4 Appendix X3 provides information on the variability of Charpy-V-Notch impact test properties in plates for pressure vessels.

1.5 Appendix X4 provides information on cold bending of plates, including suggested minimum inside radii for cold bending.

1.6 These materials are intended to be suitable for fusion welding. When the steel is to be welded, it is presupposed that a welding procedure suitable for the grade of steel and intended use or service will be utilized.

1.7 In case of any conflict in requirements, the requirements of the applicable product specification prevail over those of this general requirements specification.

1.8 Additional requirements that are specified in the purchase order and accepted by the supplier are permitted, provided that such requirements do not negate any of the requirements of this general requirements specification or the applicable product specification.

1.9 For purposes of determining conformance with this general requirements specification and the applicable product specification, values are to be rounded to the nearest unit in the right-hand place of figures used in expressing the limiting values in accordance with the rounding method of Practice E 29.

1.10 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other.

Combining values from the two systems may result in non-conformance with the standard.

1.11 This general requirements specification and the applicable product specification are expressed in both inch-pound units and SI units; unless the order specifies the applicable “M” specification designation (SI units), the plates are to be furnished to inch-pound units.

2. Referenced Documents

2.1 ASTM Standards:

- A 202/A 202M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Manganese-Silicon
- A 203/A 203M Specification for Pressure Vessel Plates, Alloy Steel, Nickel
- A 204/A 204M Specification for Pressure Vessel Plates, Alloy Steel, Molybdenum
- A 225/A 225M Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Vanadium-Nickel
- A 285/A 285M Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength
- A 299/A 299M Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Silicon
- A 302/A 302M Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum-Nickel
- A 353/A 353M Specification for Pressure Vessel Plates, Alloy Steel, 9 Percent Nickel, Double-Normalized and Tempered
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 387/A 387M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum
- A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates
- A 455/A 455M Specification for Pressure Vessel Plates, Carbon Steel, High-Strength Manganese
- A 515/A 515M Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service
- A 516/A 516M Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service
- A 517/A 517M Specification for Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered
- A 533/A 533M Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered, Manganese-Molybdenum and Manganese-Molybdenum-Nickel
- A 537/A 537M Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel
- A 542/A 542M Specification for Pressure Vessel Plates, Alloy Steel, Quenched-and-Tempered, Chromium-Molybdenum, and Chromium-Molybdenum-Vanadium

- A 543/A 543M Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered Nickel-Chromium-Molybdenum
 - A 553/A 553M Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered 8 and 9% Nickel
 - A 562/A 562M Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Titanium for Glass or Diffused Metallic Coatings
 - A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates
 - A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications
 - A 612/A 612M Specification for Pressure Vessel Plates, Carbon Steel, High Strength, for Moderate and Lower Temperature Service
 - A 645/A 645M Specification for Pressure Vessel Plates, 5% and 5½% Nickel Alloy Steels, Specially Heat Treated
 - A 662/A 662M Specification for Pressure Vessel Plates, Carbon-Manganese-Silicon Steel, for Moderate and Lower Temperature Service
 - A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Shipment
 - A 724/A 724M Specification for Pressure Vessel Plates, Carbon-Manganese-Silicon Steel, Quenched and Tempered, for Welded Pressure Vessels
 - A 734/A 734M Specification for Pressure Vessel Plates, Alloy Steel and High-Strength Low-Alloy Steel, Quenched-and-Tempered
 - A 735/A 735M Specification for Pressure Vessel Plates, Low-Carbon Manganese-Molybdenum-Columbium Alloy Steel, for Moderate and Lower Temperature Service
 - A 736/A 736M Specification for Pressure Vessel Plates, Low-Carbon Age-Hardening Nickel-Copper-Chromium-Molybdenum-Columbium and Nickel-Copper-Manganese-Molybdenum-Columbium Alloy Steel
 - A 737/A 737M Specification for Pressure Vessel Plates, High-Strength, Low-Alloy Steel
 - A 738/A 738M Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel, for Moderate and Lower Temperature Service
 - A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
 - A 770/A 770M Specification for Through-Thickness Tension Testing of Steel Plates for Special Applications
 - A 782/A 782M Specification for Pressure-Vessel Plates, Quenched-and-Tempered, Manganese-Chromium-Molybdenum-Silicon Zirconium Alloy Steel
 - A 832/A 832M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum-Vanadium
 - A 841/A 841M Specification for Steel Plates for Pressure Vessels, Produced by Thermo-Mechanical Control Process (TMCP)
 - A 844/A 844M Specification for Steel Plates, 9% Nickel Alloy, for Pressure Vessels, Produced by the Direct-Quenching Process
 - A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
 - A 1017/A 1017M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum-Tungsten
 - A 1041/A 1041M Specification for Pressure Vessel Plates, Alloy Steel, Higher Strength Chromium-Molybdenum-Tungsten
 - E 21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials
 - E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
 - E 112 Test Methods for Determining Average Grain Size
 - E 208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels
 - E 709 Guide for Magnetic Particle Testing
- 2.2 American Society of Mechanical Engineers Code:**
ASME Boiler and Pressure Vessel Code Section IX, Welding Qualifications
- 2.3 U.S. Federal Standard:**
Fed. Std. No. 123 Marking for Shipment (Civil Agencies)
- 2.4 Automotive Industry Action Group Standard:**
B1 Bar Code Symbology Standard
- 3. Terminology**
- 3.1 Definitions of Terms Specific to This Standard:**
- 3.1.1 coil** — hot-rolled steel in coil form for processing into finished plates.
- 3.1.2 exclusive** — when used in relation to ranges, as for ranges of thicknesses in the tables of permissible variations in dimensions, the term is intended to exclude only the greater value of the range. Thus, a range from 60 to 72 in. [1500 to 1800 mm] *exclusive* includes 60 in. [1500 mm], but does not include 72 in. [1800 mm].
- 3.1.3 heat treatment terms** — see 3.1.8, and Terminology A 941.
- 3.1.4 hot forming** — a forming operation producing permanent deformation, performed after the plate has been heated to the temperature required to produce grain refinement.
- 3.1.5 manufacturer** — the organization that directly controls the conversion of steel ingots or slabs, by hot rolling, into plate-as-rolled or into coil; and for plates produced from plate-as-rolled, the organization that directly controls, or is responsible for, one or more of the operations involved in finishing the plates. Such finishing operations

include leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

3.1.5.1 Discussion — The finishing operations need not be done by the organization that did the hot rolling of the plate. For plates produced from coil, see also 3.1.13.1.

3.1.6 plate identifier — the alpha, numeric, or alpha-numeric designation used to identify the plate.

3.1.7 plates — flat hot-rolled steel, ordered to thickness or weight and typically to width and length, commonly available by size as follows:

Width, in. [mm]	Thickness, in. [mm]
Over 8 [200]	Over 0.229 [6.0 mm and over]
Over 48 [1200]	Over 0.179 [4.6 mm and over]

3.1.7.1 Discussion — Steel plates are available in various thickness, width, and length combinations dependent upon equipment and processing capabilities of various manufacturers and processors. Historic limitations of a plate based upon dimensions (thickness, width, and length) do not take into account current production and processing capabilities. To qualify any plate to a particular product specification requires that all appropriate and necessary tests be performed and that the results meet the limits prescribed in that product specification. If the necessary tests required by a product specification can not be conducted, the plate can not be qualified to that specification. This general requirements specification contains permitted variations for the commonly available sizes. Permitted variations for other sizes are subject to agreement between the purchaser and the manufacturer or processor, whichever is applicable.

3.1.8 precipitation heat treatment — a subcritical temperature thermal treatment performed to cause precipitation of submicroscopic constituents, and so forth, to result in enhancement of some desirable property.

3.1.9 processor — the organization that directly controls, or is responsible for, operations involved in the processing of coil into finished plates. Such processing operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

3.1.9.1 Discussion — The processing operations need not be done by the organization that did the hot rolling of the coil. If only one organization is involved in the hot rolling and processing operations, that organization is termed the *manufacturer* for the hot rolling operation and the *processor* for the processing operations. If more than one organization is involved in the hot rolling and processing operations, the organization that did the hot rolling

is termed the *manufacturer* and the organization that does one or more processing operations is termed a *processor*.

3.2 Refer to Terminology A 941 for additional terms used in this standard.

4. Ordering Information

4.1 Orders should include the following information, as necessary, to adequately describe the desired product.

4.1.1 Quantity (weight [mass] or number of plates),

4.1.2 Dimensions,

4.1.3 Name of product (for example, plates, carbon steel; plates, alloy steel),

4.1.4 Specification designation (including type, class, and grade as applicable) and year-date,

4.1.5 Condition (as-rolled, normalized, quenched and tempered, etc. If heat treatment of plate is to be performed by the fabricator, this is to be stated. Also, if purchaser specifies a heat-treatment cycle, this is to be stated),

4.1.6 Impact test requirements, if any (see Section 12). (For Charpy V-notch test, include test specimen orientation, testing temperature, and acceptance criteria. For drop-weight test, give testing temperature),

4.1.7 Exclusion of either plates produced from coil or plates produced from plate-as-rolled, if applicable. (See 5.4 and Appendix X1.)

4.1.8 Limits for grain refining elements other than aluminum, if applicable (see 8.2.4),

4.1.9 Paint marking (see 13.2.1),

4.1.10 Supplementary requirements, if any (test specimen heat treatment, special impact test requirements, etc.), and

4.1.11 Additional requirements, if any.

5. Materials and Manufacture

5.1 The steel shall be made in an open-hearth, basic-oxygen, or electric-arc furnace, possibly followed by additional refining in a ladle metallurgy furnace (LMF), or by another method; or secondary melting by vacuum-arc remelting (VAR), electroslag remelting (ESR), or another method.

5.2 The steel may be strand cast or cast in stationary molds.

5.2.1 Strand Cast Slabs:

5.2.1.1 If heats of the same nominal chemical composition are consecutively strand cast at one time, the heat number assigned to the cast product (slab) may remain

unchanged until all of the steel in the slab is from the following heat.

5.2.1.2 When two consecutively strand cast heats have different nominal chemical composition ranges, the manufacturer shall remove the transition material by any established procedure that positively separates the grades.

5.3 The ratio of reduction of thickness from a strand-cast slab to plate shall be at least 3.0:1, except that reduction ratios as low as 2.0:1 are permitted if all of the following limitations are met:

5.3.1 The purchaser agrees to the use of such reduction ratios.

5.3.2 The applicable product specification is A 299/A 299M, A 515/A 515M, A 516/A 516M, A 537/A 537M, A 662/A 662M, or A 737/A 737M.

5.3.3 The specified plate thickness is 3.0 in. [75 mm] or more.

5.3.4 One or more of the following low hydrogen practices are used: vacuum degassing during steelmaking; controlled soaking of the slabs or plates; or controlled slow cooling of the slabs or plates.

5.3.5 The sulfur content is 0.004% or less, based upon heat analysis.

5.3.6 One or more of the following practices are used: electromagnetic stirring during strand casting; soft reduction during strand casting; heavy pass reductions or other special practices during plate rolling; or combined forging and rolling during plate rolling.

5.3.7 The plates are ultrasonically examined in accordance with Specification A 578/A 578M, Level C based on continuous scanning over 100% of the plate surface.

5.3.8 The plates are through-thickness tension tested in accordance with Specification A 770/A 770M.

5.4 Unless otherwise specified in the purchase order, plates shall be produced from plate-as-rolled or from coil.

5.5 Coils are excluded from qualification to the applicable product specification until they are decoiled, leveled, cut to length, and tested by the processor in accordance with the specified requirements (see Sections 9, 10, 11, 12, 13, 14, 15, 16, and 20.)

5.5.1 Plates produced from coil shall not contain splice welds, unless approved by the purchaser.

6. Heat Treatment

6.1 If plates are required to be heat treated, the heat treatment shall be performed by the manufacturer, the processor, or the fabricator, unless otherwise specified in the applicable product specification.

6.2 If the heat treatment required by the applicable product specification is to be performed by the purchaser or the purchaser's agent, and the plates are to be supplied by the manufacturer or processor in a condition other than that required by the applicable product specification, the order shall so state.

6.2.1 If plates are ordered without the heat treatment required by the applicable product specification, heat treatment of the plates to conform to the requirements of the applicable product specification shall be the responsibility of the purchaser.

6.3 If heat treatment is to be performed, the plates shall be heat treated as specified in the applicable product specification. The purchaser may specify the heat treatment to be used provided it is not in conflict with the requirements of the applicable product specification.

6.4 If normalizing is to be performed by the fabricator, the plates shall be either normalized or heated uniformly for hot forming, provided that the temperature to which the plates are heated for hot forming does not significantly exceed the normalizing temperature.

6.5 If no heat treatment is required, the manufacturer or processor shall have the option of heat treating the plates by normalizing, stress relieving, or normalizing and then stress relieving to meet the requirements of the applicable product specification.

6.6 If approved by the purchaser, cooling rates faster than those obtained by cooling in air are permissible to achieve specified mechanical properties, provided that the plates are subsequently tempered in the temperature range from 1100 to 1300°F [595 to 705°C].

7. Chemical Composition

7.1 Heat Analysis

7.1.1 Sampling for chemical analysis and methods of analysis shall be in accordance with Test Methods, Practices, and Terminology A 751.

7.1.2 For each heat, the heat analysis shall include determination of the content of carbon, manganese, phosphorus, sulfur, silicon, nickel, chromium, molybdenum, copper, vanadium, columbium; any other element that is specified or restricted by the applicable product specification for the applicable grade, class, and type; aluminum, if the aluminum content is to be used in place of austenitic grain size testing of the heat (see 8.2.2.1); and any other austenitic grain refining element for which limits are specified in the purchase order (see 8.2.4).

7.1.3 Heat analyses shall conform to the heat analysis requirements of the applicable product specification for the applicable grade, class, and type. In addition, for elements

that are listed in Table 1 but are not specified or restricted in the applicable product specification for the applicable grade, class, and type, heat analyses shall conform to the applicable heat analysis limits given in Table 1.

7.2 Product Analysis:

7.2.1 Sampling for chemical analysis and methods of analysis shall be in accordance with Test Methods, Practices, and Terminology A 751.

7.2.2 For each plate-as-rolled, the purchaser shall have the option of chemically analyzing a broken tension test specimen or a sample taken from the same relative location as that from which the tension test specimen was obtained.

7.2.3 For elements that are specified or restricted by the applicable product specification for the applicable grade, class, and type, product analyses shall conform to the product analysis requirements of the applicable product specification for the applicable grade, class, and type.

7.2.4 For elements that are listed in Table 1 but are not specified or restricted by the applicable product specification for the applicable grade, class, and type, product analyses shall conform to the applicable product analysis limits given in Table 1.

7.3 Referee Analysis — For referee purposes, Test Methods, Practices, and Terminology A 751 shall be used.

8. Metallurgical Structure

8.1 If coarse austenitic grain size is specified, the steel shall have a carburized austenitic grain size number in the range from 1 to 5, inclusive, as determined by the McQuaid-Ehn Test. Determinations shall be in accordance with Test Methods E 112, Plate IV, by carburizing for 8 h at 1700°F [925°C]. At least 70% of the grains in the area examined shall conform to the specified grain size requirement. One test per heat shall be made.

8.2 Fine Austenitic Grain Size:

8.2.1 If fine austenitic grain size is specified, aluminum shall be used as the grain refining element, except as allowed by 8.2.4.

8.2.2 If fine austenitic grain size is specified, except as allowed by 8.2.2.1, the steel shall have a carburized austenitic grain size number of 5 or higher (finer) as determined by the McQuaid-Ehn test in accordance with Test Methods E 112, Plate IV. One test per heat shall be made.

8.2.2.1 If aluminum is used as the grain refining element, the fine austenitic grain size requirement shall be deemed to be fulfilled if, on heat analysis, the aluminum content is not less than 0.020% total aluminum or, alternatively, 0.015% acid soluble aluminum.

8.2.3 If specified in the purchase order, one McQuaid-Ehn test (see 8.1) per heat shall be made and the austenitic grain size of the steel, as represented by the test, shall be Number 5 or finer.

8.2.4 By agreement between the purchaser and the manufacturer or processor, elements other than aluminum may be used for grain refining. In such instances, the heat analysis limits for the element, or elements, permitted shall be as specified in the purchase order. In addition, the McQuaid-Ehn test of 8.2.3 shall be required.

9. Quality

9.1 General — Plates shall be free of injurious defects and shall have a workmanlike finish.

9.2 Surface Imperfections:

9.2.1 For plates produced from plate-as-rolled, all injurious surface imperfections shall be removed by the manufacturer. For plates produced from coil, all injurious surface imperfections shall be removed by the processor.

9.2.1.1 Shallow imperfections shall be ground to sound metal; the ground area shall be well faired and the thickness of the ground plate shall not be reduced below the minimum thickness permitted.

9.2.1.2 All surface imperfections, the removal of which will reduce the plate thickness below the minimum thickness permitted, shall be cause for rejection of the plate, except that, by agreement with the purchaser, the metal so removed may be replaced with weld metal (see 9.4).

9.3 Edge Imperfections:

9.3.1 Laminar-type discontinuities 1 in. [25 mm] and less in length visible to the unaided eye on an edge of a plate as prepared for shipment by the manufacturer or processor are acceptable and do not require exploration.

9.3.2 All larger discontinuities shall be explored to determine their depth and extent. Discontinuities shall be considered continuous when located in the same plane within 5% of the plate thickness and separated by a distance less than the length of the smaller of two adjacent discontinuities.

9.3.3 Indications visible to the unaided eye on the cut edges of a plate as prepared for shipment by the manufacturer or processor shall not exceed the limits given in Columns 1 and 2 of Table A1.14 [A2.14].

9.3.4 Larger indications shall be removed by the manufacturer or processor by grinding, provided that the resultant cavity does not exceed the limits given in Columns 3 and 4 of Table A1.14 [A2.14].

9.3.5 Indications of greater magnitude shall be cause for rejection of the plate, except that, by agreement with

the purchaser, the defects may be removed and replaced with weld metal (see 9.4).

9.3.6 Indications on the edges of a plate cut during the fabrication shall be cause for rejection of the plate at the discretion of the purchaser if the magnitude exceeds the limits given in Columns 5 and 6 of Table A1.14 [A2.14]. The defects may be removed and replaced with weld metal (see 9.4).

9.3.7 Fabricators should be aware that edge cracks may initiate upon bending a sheared or burned edge during the fabrication process. This is not considered to be a fault of the steel, but is rather a function of the induced cold work or heat affected zone.

9.4 Repair by Welding:

9.4.1 Repair welding shall be permitted only with the approval of the purchaser.

9.4.2 Preparation for repair welding shall include inspection to confirm complete removal of the defect.

9.4.3 Repairs shall be made utilizing welding procedures qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code and repair welding shall be done by welders or welding operators meeting the qualification requirements of Section IX.

9.4.4 The weld metal shall have the A-number analysis corresponding to the equivalent ASME P-number of the plate, except that A-1 or A-2 analysis weld metal may be employed for P-1 plates. Other weld metals may be employed that are compatible with the plate being repaired, if so approved by the purchaser. Such weld metals shall be qualified in accordance with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

9.4.5 If Charpy impact tests of the plate are required, the welding procedure qualification tests shall also include Charpy impact tests of the weld, the heat-affected zone, and the plate, and the test results shall be reported to the purchaser.

9.4.6 If the plate is subjected to normalizing, quenching and tempering, hot forming, or post-weld heat treating, the welding procedure qualification test plates and the weld repaired plate shall be subjected to the thermal heat treatment as specified by the purchaser.

9.4.7 In addition, repair welds shall meet the requirements of the construction code specified by the purchaser.

10. Test Methods

10.1 All tests shall be conducted in accordance with Test Methods and Definitions A 370.

10.2 Yield strength shall be determined by either the 0.2% offset method or the 0.5% extension under load

method, unless otherwise stated in the applicable product specification.

10.3 Rounding Procedures — For purposes of determining conformance with the applicable product specification, a calculated value shall be rounded to the nearest 1 ksi [5 MPa] for tensile and yield strengths, and to the nearest unit in the right-hand place of figures used in expressing the limiting value for other values, in accordance with the rounding method given in Practice E 29.

11. Tension Tests

11.1 Number of Test Coupons:

11.1.1 Plates Produced from As-Rolled Plates — For other than quenched and tempered plates, one tension test coupon shall be taken from each plate-as-rolled. Two tension test coupons shall be taken from each quenched and tempered plate, as heat treated. If plates are furnished by the manufacturer or processor in accordance with 11.4.2 and qualified by using test specimens taken from heat-treated test coupons (including normalized, normalized and tempered, and quenched and tempered), one tension test coupon shall be taken from each plate-as-rolled (see Terminology A 941 for the definition of plate-as-rolled).

11.1.2 Plates Produced from Coil and Furnished without Heat Treatment or with Stress Relieving Only — Except as allowed by 11.1.2.1 and 11.1.4, a minimum of three tension coupons shall be taken from each coil as follows:

11.1.2.1 The first test coupon shall be taken immediately prior to the first plate to be qualified to the applicable product specification, the second test coupon shall be taken from the approximate center lap, and the third test coupon shall be taken immediately after the last plate to be qualified to the applicable product specification. If, during decoiling, the amount of material decoiled is less than that required to reach the next standard test location, a test for qualification of that particular portion of the coil shall be made from a test coupon taken from a location adjacent to the innermost portion decoiled.

11.1.2.2 All plates between any two test locations that meet the requirements of the applicable product specification are acceptable.

11.1.2.3 All plates between a test location that fails to meet the requirements of the applicable product specification and an adjacent test location that meets the requirements of the applicable product specification are rejectable, except that the processor has the option to make other tests after cutting back the coil in either direction.

11.1.3 Plates Produced from Coil and Furnished Heat Treated by Other than Stress Relieving — For other than quenched and tempered plates, one tension test coupon

shall be taken from each coil. Two tension test coupons shall be taken from each quenched and tempered plate, as heat treated.

11.1.4 Plates Produced from Coil and Qualified Using Test Specimens Taken from Test Coupons Heat Treated by Other than Stress Relieving — One tension test coupon shall be taken from each coil.

11.2 Orientation of Test Specimens — The longitudinal axis of the tension test specimens shall be transverse to the final rolling direction of the plate.

11.3 Location of Test Coupons — Tension test coupons shall be taken from a corner of the plate. For quenched and tempered plates, the two tension test coupons shall be taken from opposite ends of the plate.

11.4 Tests from Heat-Treated Plates:

11.4.1 If heat treatment is performed by the manufacturer or processor, the test specimens shall be taken from the plate in the heat-treated condition or from full-thickness coupons simultaneously heat treated with the plate.

11.4.2 If heat treatment is to be performed by the fabricator, the plates shall be accepted on the basis of tests made on test specimens taken from full-thickness coupons heat treated in accordance with the requirements specified in the applicable product specification or the purchase order. If the heat-treatment temperatures are not specified, the manufacturer or processor shall heat treat the coupons under conditions it considers appropriate. The purchaser shall be informed of the procedure followed in heat treating the specimens.

11.4.3 If approved by the purchaser, the procedures of 11.4.2 may be implemented on plates heat treated by the manufacturer or processor.

11.4.4 For plates that are heat treated with a cooling rate faster than still-air cooling from the austenitizing temperature, one of the following shall apply in addition to other requirements specified herein:

11.4.4.1 The gage length of the tension test specimen shall be taken at least $1T$ from any as-heat treated edge, where T is the thickness of the plate, and shall be at least $\frac{1}{2}$ in. [12.5 mm] from flame-cut or heat-affected-zone surfaces.

11.4.4.2 A steel thermal buffer pad, $1T$ by $1T$ by at least $3T$, shall be joined to the plate edge by a partial penetration weld completely sealing the buffered edge prior to heat treatment.

11.4.4.3 Thermal insulation or other thermal barriers shall be used during the heat treatment adjacent to the plate edge where the test specimens are to be removed. It shall be demonstrated that the cooling rate of the tension test specimen is no faster than, and not substantially slower than, that attained by the method described in 11.4.4.2.

11.4.4.4 When test coupons cut from the plate but heat treated separately are used, the coupon dimensions shall be not less than $3T$ by $3T$ by T and each tension test specimen cut from it shall meet the requirements of 11.4.4.1.

11.4.4.5 If cooling rate data for the plate and cooling rate control devices for the test coupons are available, the test coupons may be heat treated separately in the device, provided that this method is approved by the purchaser.

11.5 Test Specimen Preparation:

11.5.1 Tension test specimens for plates $\frac{3}{4}$ in. [20 mm] and under in thickness shall be the full thickness of the plates. The test specimens shall conform to the requirements for either the $\frac{1}{2}$ in. [40 mm] wide or the $\frac{1}{2}$ in. [12.5 mm] wide rectangular tension test specimen of Test Methods and Definitions A 370. The $\frac{1}{2}$ in. [40 mm] wide test specimen may have both edges parallel. The $\frac{1}{2}$ in. [12.5 mm] wide specimen may have a maximum nominal thickness of $\frac{3}{4}$ in. [20 mm].

11.5.2 For plates up to 4 in. [100 mm], inclusive, in thickness, tension test specimens may be the full thickness of the plate and conform to the requirements for the $\frac{1}{2}$ in. [40 mm] wide rectangular tension test specimen of Test Methods and Definitions A 370 if adequate testing machine capacity is available.

11.5.3 For plates over $\frac{3}{4}$ in. [20 mm] in thickness, except as permitted in 11.5.2, tension test specimens shall conform to the requirements for the 0.500 in. [12.5 mm] diameter test specimen of Test Methods and Definitions A 370. The axis of the test specimen shall be located midway between the center of thickness and the top or bottom surface of the plate.

11.6 Elongation Requirement Adjustments:

11.6.1 Due to the specimen geometry effect encountered when using the rectangular tension test specimen for testing thin plate, adjustments in elongation requirements must be provided for thicknesses under 0.312 in. [8 mm]. Accordingly, the following deductions shall be made from the base elongation requirements in the applicable product specification:

Plate Nominal Thickness Range, in. [mm]	Elongation Deduction, %
0.299–0.311 [7.60–7.89]	0.5
0.286–0.298 [7.30–7.59]	1.0
0.273–0.285 [7.00–7.29]	1.5
0.259–0.272 [6.60–6.99]	2.0
0.246–0.258 [6.20–6.59]	2.5
0.233–0.245 [5.90–6.19]	3.0
0.219–0.232 [5.50–5.89]	3.5
0.206–0.218 [5.20–5.49]	4.0
0.193–0.205 [4.90–5.19]	4.5
0.180–0.192 [4.60–4.89]	5.0

11.6.2 Due to the inherently lower elongation that is obtainable in thicker plate, adjustments in elongation requirements in 2 in. [50 mm] gage length shall be provided for thicknesses over 3.5 in. [90 mm]. Accordingly, the following deductions shall be made from the base elongation requirements in 2 in. [50 mm] prescribed in the applicable product specification:

Plate Nominal Thickness Range, in. [mm]	Elongation Deduction, %
3.501–3.999 [90.00–102.49]	0.5
4.000–4.499 [102.50–114.99]	1.0
4.500–4.999 [115.00–127.49]	1.5
5.000–5.499 [127.50–139.99]	2.0
5.500–5.999 [140.00–152.49]	2.5
6.000 and thicker [152.50 and thicker]	3.0

11.6.3 A characteristic of certain types of alloy steels is a local disproportionate increase in the degree of necking down or contraction of the test specimens during the tension test, resulting in a decrease in the percentage of elongation as the gage length is increased. The effect is not so pronounced in thicker plates. For such material, if so stated in the applicable product specification for plates up to $\frac{3}{4}$ in. [20 mm], inclusive, in thickness, if the percentage of elongation of an 8 in. [200 mm] gage length test specimen falls not more than 3 percentage points below the amount prescribed, the elongation shall be considered satisfactory if the percentage of elongation in 2 in. [50 mm] across the break is not less than 25%.

11.6.4 The tensile requirements tables in many of the product specifications covered by this general requirements specification specify elongation requirements in both 8 in. [200 mm] and 2 in. [50 mm] gage lengths. Unless otherwise provided in the applicable product specification, both requirements are not required to be applied simultaneously, and the elongation need only be determined in the gage length appropriate for the test specimen used. After selection of the appropriate gage length, the elongation requirement for the alternative gage length shall be deemed not applicable.

11.7 This specification does not provide requirements for product tension testing subsequent to shipment (see 15.1). Therefore, the requirements of 11.1 through 11.6 and Section 16 apply only for tests conducted at the place of manufacture prior to shipment. Compliance to Specification A 20/A 20M and the applicable product specification does not preclude the possibility that product tension test results may vary outside specified ranges. The tensile properties will vary within the same plate-as-rolled or piece, be it as-rolled, control-rolled, or heat-treated. The purchaser should, therefore, be aware that tension testing in accordance with the requirements of Specification A 20/A 20M does not provide assurance that all products of a plate-as-rolled will be identical in tensile properties

with the products tested. If the purchaser wishes to have more confidence than that provided by Specification A 20/A 20M testing procedures, additional testing or requirements, such as Supplementary Requirement S4, should be imposed.

11.8 Appendix X2 provides additional information on the variability of tensile properties in plates for pressure vessels.

12. Notch-Toughness Tests

12.1 Charpy V-Notch Tests:

12.1.1 Number of Tests — Except for quenched and tempered plates, and except as allowed by 12.1.1.1 and 12.1.1.2, one impact test (3 specimens) for each specified orientation (see 12.1.2) shall be made from each plate-as-rolled. For quenched and tempered plates, one impact test shall be made from each plate, as heat treated.

12.1.1.1 Plates Ordered Without the Heat Treatment Specified by the Applicable Product Specification — If the applicable product specification requires heat treatment but the plates are ordered without such heat treatment and Charpy V-notch tests are specified, one coupon shall be taken from each plate-as-rolled. The coupon shall be heat treated in accordance with the applicable product specification and the purchase order and the plate shall be qualified by test specimens taken from the heat-treated coupon.

12.1.1.2 Plates Produced from Coil — If Charpy V-notch tests are specified, the number of impact tests required shall be the same as the number specified for tension tests in 11.1.2 or 11.1.3, whichever is applicable. The test coupons shall be taken from the material after decoiling and leveling.

12.1.2 Orientation of Test Specimens — The long axis of the test specimens shall be oriented either longitudinal (parallel to the final direction of rolling) or transverse (transverse to the final direction of rolling), as specified in the applicable product specification or the purchase order.

12.1.3 Location of Test Coupons — The impact test coupons shall be taken adjacent to the tension test coupons. The impact test coupons shall be subject to the same requirements as those specified for tension tests in 11.4, except that the provisions of 11.4.4.1 apply to the area under the notch of the impact test specimen instead of to the gage length of the tension test specimen.

12.1.4 Test Method — Impact testing shall be performed in accordance with Test Methods and Definitions A 370 using Charpy V-notch (Type A) specimens as shown in Test Methods and Definitions A 370. Except as allowed by 12.1.4.1, full-size specimens (0.394 by 0.394 in. [10 by 10 mm]) shall be used if the plate thickness permits,

and their central axis shall correspond as near as practical to the $\frac{1}{4}t$ plane in the plate thickness t . If the plate thickness is insufficient to obtain full-size specimens, the largest possible subsize specimens shall be used.

12.1.4.1 For plates that normally have absorbed energy values in excess of 180 ft•lbf [245 J] if tested using full-size specimens at the specified testing temperature, subsize 0.394 by 0.264 in. [10 by 6.7 mm] specimens may be used in lieu of full-size specimens; however, if this option is used, the acceptance value shall be 75 ft•lbf [100 J] minimum for each test specimen and the lateral expansion in mils [micrometres] shall be reported.

12.1.5 Test Temperature — The test temperature shall be as specified in the purchase order, except that the manufacturer or processor shall have the option of using a lower test temperature. If a test temperature is not specified in the purchase order, tests shall be conducted at a temperature no higher than is given in Table A1.15 [A2.15] for the applicable product specification, grade, class, and plate thickness. The actual test temperature used shall be reported with the test results.

12.1.6 Acceptance Criteria — Unless otherwise agreed upon, the acceptance criteria shall be as given in Table A1.15 [A2.15] for the applicable product specification, grade, class, and plate thickness.

12.1.6.1 If the acceptance criteria is based upon energy absorption of a full-size specimen, the acceptance criteria for the various subsize specimens shall be as given in Table A1.16 [A2.16], except as otherwise provided in 12.1.4.1.

12.1.6.2 If the acceptance criterion is based upon lateral expansion opposite the notch, the acceptance value shall be the same for all sizes of test specimens.

12.1.7 Marking — The letters “LTV” shall be stenciled or stamped on each plate following the class number, grade, etc.

12.1.8 Variability — The impact properties of steel can vary within the same plate-as-rolled or piece, be it as-rolled, control-rolled, or heat-treated. The purchaser should, therefore, be aware that testing of one plate-as-rolled does not provide assurance that all locations within a plate-as-rolled will be identical in toughness with the location tested. Normalizing or quenching and tempering the product will reduce the degree of variation.

12.1.8.1 Appendix X3 provides additional information on the variability of Charpy V-notch test properties in plates for pressure vessels.

12.2 Drop-Weight Tests:

12.2.1 Where specified, one drop-weight test, consisting of a set of two test specimens, shall be made to the same frequency stated in 12.1.1 in accordance with Method E 208.

12.2.2 The test coupons shall be obtained adjacent to a tension test coupon. For plates produced from coil, the test coupon locations shall be the same as for Charpy V-notch tests. (See 12.1.) The provisions of 12.1.3 shall also apply.

12.2.3 The testing temperature shall be as specified in the applicable product specification or the purchase order.

12.2.4 Acceptance shall be on the basis of *no-break* performance of both test specimens at the specified testing temperature.

12.2.5 The plates shall be marked as required in 12.1.7, except that the letters “LTD” shall be used instead of “LTV.”

13. Identification of Plates

13.1 Required Markings:

13.1.1 Except as allowed by 13.4, plates shall be legibly marked with the following information: applicable ASTM designation (see 1.1) (year of issue not required); “G” or “MT” if applicable (see 13.1.2); applicable grade, type, and class; heat number; plate identifier; and name, brand, or trademark of the manufacturer (for plates produced in discrete cut lengths of flat product) or the processor (for plates produced from coil and for subdivided plates (see 13.4)).

13.1.2 Plates that are required to be heat treated, but have not been so heat treated, shall be marked, by the manufacturer or processor, with the letter “G” (denoting green) following the required ASTM designation mark, except that “G” marking is not necessary if such plates are for shipment, for the purpose of obtaining the required heat treatment, to an organization under the manufacturer’s control. Such plates shall have been qualified for shipment on the basis of test specimens that have been so heat treated. Plates that are required to be heat treated, and have been so heat treated, shall be marked, by the party that performed the heat treatment, with the letters “MT” (denoting material treated) following the required ASTM designation mark.

NOTE 1 — Any stress relief of test specimens intended to simulate post-weld heat treatment is not included in the above heat treatment.

13.2 Types of Marking:

13.2.1 Except as allowed by 13.4, the required markings for plates over $\frac{1}{4}$ in. [6 mm] in thickness shall be by steel die stamping, unless paint marking is specified in the purchase order.

13.2.2 Except as allowed by 13.4, the required markings for plates $\frac{1}{4}$ in. [6 mm] and under in thickness shall be by paint marking or by steel die stamping using low-stress (either round-nose or interrupted-dot) impressions.

13.3 Location of Markings:

13.3.1 Except as allowed by 13.4, the required markings for plates with a maximum lengthwise or crosswise dimension more than 72 in. [1800 mm] shall be in at least two places on each finished plate, at least 12 in. [300 mm] from the edges of the plate.

13.3.2 Except as allowed by 13.4, the required markings for plates with a maximum lengthwise and crosswise dimension of 72 in. [1800 mm] or less shall be in at least one place on each finished plate, approximately midway between the center and an edge of the plate.

13.4 Subdivided Plates:

13.4.1 By agreement between the purchaser and the manufacturer or processor, each subdivided plate (a plate separated from a master plate) shall be legibly marked with the name, brand, or trademark of the organization that subdivided the plate plus a code traceable to the required markings, provided that the information required in 13.1, cross referenced to that code, is furnished with the plates.

13.4.2 By agreement between the purchaser and the manufacturer or processor, subdivided plates that are from the same master plate and placed in secured lifts shall have the information required in 13.1 paint marked on the top piece of each lift or shown on a substantial tag attached to each lift.

13.5 Bar Coding — In addition to the requirements of 13.1 to 13.4 inclusive, the manufacturer or processor shall have the option of using bar coding as a supplementary identification method.

NOTE 2 — Bar coding should be consistent with AIAG Standard B 1.

14. Permissible Variations in Dimensions or Mass

14.1 One cubic foot of rolled steel shall be assumed to weigh 490 lb, unless otherwise stated in the applicable product specification. One cubic metre of rolled steel is assumed to have a mass of 7850 kg, unless otherwise stated in the applicable product specification.

14.2 For carbon steel plates the permissible variations for dimensions shall not exceed the applicable limits stated in Annex A1, Table A1.1 to Table A1.9, and Table A1.13 [Annex A2, Table A2.1 to Table A2.9, and Table A2.13].

14.3 For alloy steel plates the permissible variations for dimensions shall not exceed the applicable limits stated in Annex 1, Table A1.1 to Table A1.4, Table A1.8, and Table A1.10 to Table A1.13. [Annex 2, Table A2.1 to Table A2.4, Table A2.8 and Table A2.10 to Table A2.13].

14.4 Conversions of Permitted Variations from Fractions of an Inch to Decimals — Permitted variations in dimensions for products covered by this specification are

generally given as fractions of inch and these remain the official permitted variations, where so stated. If the material is to be measured by equipment reporting dimensions as decimals, conversion of permitted variations from fractions of an inch to decimals shall be made to three decimal places; using the rounding method prescribed in Practice E 29.

15. Inspection and Testing

15.1 The inspector representing the purchaser shall have entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the plate ordered. The manufacturer shall afford the inspector all reasonable facilities to be satisfied that the plate is being furnished in accordance with this general requirements specification, the applicable product specification, and the purchase order. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the manufacturer's works.

15.2 If plates are produced from coil, 15.1 shall apply to the "processor" instead of to the "manufacturer" and the "place of process" shall apply instead of the "place of manufacture." If plates are produced from coil and the processor is different from the manufacturer, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the plate ordered.

16. Retests

16.1 Tension Test — In addition to the provisions of Test Methods and Definitions A 370, the following retest provisions shall apply:

16.1.1 If any test specimen shows defective machining, or develops flaws, it may be discarded and another test specimen substituted.

16.1.2 If the percentage of elongation of any tension test specimen is less than that specified, and any part of the fracture is more than $\frac{3}{4}$ in. [20 mm] from the center of the gage length of a 2 in. [50 mm] test specimen or is outside the middle half of the gage length of an 8 in. [200 mm] test specimen as indicated by scribe marks on the test specimen before testing, one retest shall be allowed.

16.1.3 If the results from an original tension test specimen fail to meet the specified requirements but are within 2 ksi [10 MPa] of the required tensile strength or within 1 ksi [5 MPa] of the required yield strength or yield point, or within 2 percentage points of the required

elongation or reduction of area, one retest shall be permitted to replace the failing test.

16.1.4 The results of the retest shall meet the specified requirements.

16.2 Charpy V-Notch Tests:

16.2.1 The retest provisions of Test Methods and Definitions A 370 shall apply, except that the 5 ft•lbf [7 J] absolute minimum for an individual specimen shall not apply if two thirds of the specified minimum average is less than 5 ft•lbf [7 J].

16.2.2 If Charpy V-notch impact test lateral expansion values are specified, if the value of one specimen falls below the specified minimum value and not below $\frac{2}{3}$ of the specified minimum value, and if the average of the three specimens equals or exceeds the specified minimum value, a retest of three additional specimens may be made. Each of the three retest specimens shall equal or exceed the specified minimum value.

16.2.3 If the required values are not obtained on Charpy V-notch retests as specified in 16.2.1 and 16.2.2, or if the values in the initial test are below the values required for retest, no further retests are permitted unless the plate is heat treated or reheat treated. After heat treatment or reheat treatment, a set of three specimens shall be tested and each shall equal or exceed the specified minimum value.

16.2.4 If the option of 12.1.4.1 is used and the test result falls below the 75 ft•lbf [100 J] minimum specified, another test may be made using full-size test specimens.

17. Retreatment

17.1 If any heat-treated plate fails to meet the mechanical requirements of the applicable product specification, the manufacturer or processor shall have the option of heat treating the plate again. All mechanical-property tests shall be repeated and the plate surface shall be reexamined for surface defects when it is resubmitted for inspection.

18. Rejection

18.1 Any rejection based upon product analysis made in accordance with the applicable product specification shall be reported to the supplier and samples that represent the rejected plate shall be preserved for 2 weeks from the date of notification of such rejection. In case of dissatisfaction with the results of the tests, the supplier shall have the option of making claim for a rehearing within that time.

18.2 Plates that show injurious defects subsequent to their acceptance at the manufacturer's or processor's works may be rejected. In such cases, the manufacturer or processor shall be notified.

19. Test Reports

19.1 The manufacturer or processor shall report the results of all tests required by the applicable product specification, the applicable supplementary requirements, and the purchase order. The heat number, the plate identifier of the plate tested, and the nominal plate thickness shall be shown on the test report. The year-date of the specification to which the plates are furnished shall be included in the test report.

19.1.1 In reporting elongation values, both the percentage increase and the original gage length shall be stated.

NOTE 3 — Where Table 1 applies and the amount of any element listed therein is less than 0.02%, the applicable analysis for that element may be reported as "<0.02%."

19.2 For plates rolled from a strand-cast slab with a reduction ratio in the range from 2.0:1 to 3.0:1, exclusive, the specific practices (see 5.3.4 and 5.3.6) that were used by the manufacturer shall be reported, and the test reports shall state that the limitations of 5.3 have been met.

19.3 All heat treatment, exclusive of subcritical heating to soften thermally cut edges, shall be reported, including temperature ranges and times at temperature. This exclusion does not apply to those plates with specified minimum tensile strengths of 95 ksi [655 MPa] or higher, unless such subcritical heating is accomplished at temperatures at least 75°F [40°C] below the minimum tempering temperature. The reports shall state whether the plates only, the test coupons only, or both plates and test coupons were heat treated.

19.4 If Charpy V-notch tests are specified, the test specimen size used shall be reported.

19.5 If so specified in the purchaser order, the manufacturer shall also furnish a certificate of compliance stating that the plates have been manufactured, inspected, and tested in accordance with the requirements of the applicable product specification. For plates produced from coil, the processor shall furnish the required certification.

19.6 For plates produced from coil and furnished without heat treatment or with stress relieving only, the results of all tests required by 11.1.2 shall be reported for each qualifying coil.

19.7 A signature is not required on the test report; however, the document shall clearly identify the organization submitting the report. Notwithstanding the absence of a signature, the organization submitting the report is responsible for the content of the report.

19.8 Copies of the original manufacturer's test report shall be included with any subsequent test report.

19.9 A test report, certificate of compliance, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document must meet the requirements of the invoked ASTM standard(s) and conform to any existing EDI agreement between the purchaser and the supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

TABLE 1
LIMITS ON ELEMENTS (SEE 7.1.3 and 7.2.4)

Copper, max. % ^A	Heat analysis	0.40
	Product analysis	0.43
Nickel, max. % ^A	Heat analysis	0.40
	Product analysis	0.43
Chromium, max. % ^{A,B}	Heat analysis	0.30
	Product analysis	0.34
Molybdenum, max. % ^{A,B}	Heat analysis	0.12
	Product analysis	0.13
Vanadium, max. % ^C	Heat analysis	0.03
	Product analysis	0.04
Columbium, max. % ^D	Heat analysis	0.02
	Product analysis	0.03
Titanium, max. % ^E	Heat analysis	0.03
	Product analysis	0.04

^A In addition for each heat, based upon the heat analysis, the sum of copper, nickel, chromium, and molybdenum shall not exceed 1.00%, unless one or more of those elements are specified or restricted by the applicable product specification for the applicable grade, class, and type.

^B In addition for each heat, based upon the heat analysis, the sum of chromium and molybdenum shall not exceed 0.32% unless one or both of those elements are specified or restricted by the applicable product specification for the applicable grade, class, and type.

^C By agreement between the purchaser and the supplier, the heat analysis limit for vanadium is permitted to be increased to a value not higher than 0.10%, and the product analysis limit for vanadium is permitted to be increased to a value not higher than 0.11%.

^D By agreement between the purchaser and the supplier, the heat analysis limit for columbium is permitted to be increased to a value not higher than 0.05%, and the product analysis limit for columbium is permitted to be increased to a value not higher than 0.06%.

^E By agreement between the purchaser and the supplier, the heat analysis limit for titanium is permitted to be increased to a value not higher than 0.04%, and the product analysis limit for titanium is permitted to be increased to a value not higher than 0.05%.

20. Packaging, Marking, and Loading for Shipment

20.1 Packaging, marking, and loading for shipment shall be in accordance with those procedures recommended by Practices A 700.

20.2 *For USA Government Procurement* — Marking for shipment of material for civil agencies shall be in accordance with Fed. Std. No. 123.

21. Keywords

21.1 general delivery requirement; pressure containing parts; pressure vessel steels; steel plates; steel plates for pressure vessel applications

TABLE 2
MAXIMUM CARBON EQUIVALENT FOR WELDABILITY

Specified Minimum UTS	Maximum Carbon Equivalent Value	
	Thickness up to 2 in. [50 mm] Incl.	Thickness Over 2 in. [50 mm]
ksi [MPa]		
60 ≤ UTS < 70 [415 ≤ UTS < 485]	0.45	0.46
70 ≤ UTS < 80 [485 ≤ UTS < 550]	0.47	0.48 ^A
UTS ≥ 80 [UTS ≥ 550]	0.48 ^{A,B}	...

^A If simulated PWHT of the test coupons is specified (S3), the maximum carbon equivalent value may be increased up to 0.50 upon agreement between purchaser and supplier.

^B Applicable to quenched-and-tempered material; for other conditions, maximum carbon equivalent shall be by agreement between purchaser and supplier.

TABLE 3
PERMISSIBLE VARIATIONS FROM FLATNESS FOR
CARBON STEEL PLATES AS-ROLLED OR NORMALIZED ORDERED TO RESTRICTIVE FLATNESS

Specified Thickness, in.	Permissible Variations From a Flat Surface for Specified Widths, in.					
	48 to 60, Excl.	60 to 72, Excl.	72 to 84, Excl.	84 to 96, Excl.	96 to 108, Excl.	108 to 120, Incl.
To $\frac{1}{4}$, excl.	$\frac{3}{4}$	$\frac{15}{16}$	Z	Z	Z	Z
$\frac{1}{4}$ to $\frac{3}{8}$, excl.	$\frac{9}{16}$	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{15}{16}$	$\frac{1}{2}$	$\frac{1}{8}$
$\frac{3}{8}$ to $\frac{1}{2}$, excl.	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$
$\frac{1}{2}$ to $\frac{3}{4}$, excl.	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$
$\frac{3}{4}$ to 1, excl.	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$
1 to 2, incl.	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$

NOTE 1 — *Flatness Variations for Length* — The longer dimension specified is considered the length, and variation in flatness along the length shall not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft of longer plates.

NOTE 2 — *Flatness Variations for Width* — The flatness variation across the width shall not exceed the tabular amount for the specified width.

NOTE 3 — When the longer dimension is under 36 in., the variation in flatness along the length and across the width shall not exceed $\frac{1}{4}$ in. in each direction. When the longer dimension is from 36 to 72 in., inclusive, the permissible flatness variation shall not exceed 75% of the tabular amount for the specified width, but in no case less than $\frac{1}{4}$ in.

NOTE 4 — The variations given in this table apply to plates that have a minimum specified tensile strength not over 60 ksi or comparable chemistry or hardness. For plates specified to a higher minimum tensile strength or comparable chemistry or hardness, the permissible variations are $1\frac{1}{2}$ times the amounts shown in the table above.

NOTE 5 — This table and these notes cover the flatness variations of circular and sketch plates based on the maximum dimensions of those plates.

NOTE 6 — Waviness tolerances for rectangular plates, universal mill plates, and circular and sketch plates do not apply.

NOTE 7 — A "Z" indicates that there is no published restricted value for the size.

NOTE 8 — Plates shall be in a horizontal position on a flat surface when flatness is measured.

TABLE 4
PERMISSIBLE VARIATIONS FROM FLATNESS FOR
CARBON STEEL PLATES AS-ROLLED OR NORMALIZED ORDERED TO RESTRICTIVE FLATNESS

Specified Thickness, mm	Permissible Variations From a Flat Surface for Specified Widths, mm					
	1200 to 1500, Excl.	1500 to 1800, Excl.	1800 to 2100, Excl.	2100 to 2400, Excl.	2400 to 2700, Excl.	2700 to 3000, Incl.
To 6, excl.	18	24	Z	Z	Z	Z
6 to 10, excl.	15	18	22	24	27	29
10 to 12, excl.	8	8	10	11	13	15
12 to 20, excl.	7	8	8	10	13	13
20 to 25, excl.	7	8	8	8	10	11
25 to 50, excl.	7	7	7	8	8	8

NOTE 1 — *Flatness Variations for Length* — The longer dimension specified is considered the length, and variation in flatness along the length shall not exceed the tabular amount for the specified width in plates up to 3700 mm in length, or in any 3700 mm of longer plates.

NOTE 2 — *Flatness Variations for Width* — The flatness variation across the width shall not exceed the tabular amount for the specified width.

NOTE 3 — When the longer dimension is under 900 mm, the variation in flatness along the length and across the width shall not exceed 6 mm in each direction. When the longer dimension is from 900 to 1800 mm, inclusive, the permissible flatness variation shall not exceed 75% of the tabular amount for the specified width, but in no case less than 6 mm.

NOTE 4 — The variations given in this table apply to plates that have a minimum specified tensile strength not over 415 MPa or comparable chemistry or hardness. For plates specified to a higher minimum tensile strength or comparable chemistry or hardness, the permissible variations are $1\frac{1}{2}$ times the amounts shown in the table below.

NOTE 5 — This table and these notes cover the flatness variations of circular and sketch plates based on the maximum dimensions of those plates.

NOTE 6 — Waviness tolerances for rectangular plates, universal mill plates, and circular and sketch plates do not apply.

NOTE 7 — A "Z" indicates that there is no published restricted value for the size.

NOTE 8 — Plates shall be in a horizontal position on a flat surface when flatness is measured.

TABLE 5
PERMISSIBLE VARIATIONS FROM FLATNESS FOR HIGH-STRENGTH
LOW-ALLOY STEEL PLATES AS-ROLLED OR NORMALIZED ORDERED TO RESTRICTIVE FLATNESS

Specified Thickness, in.	Permissible Variations From a Flat Surface for Specified Widths, in.					
	48 to 60, Excl.	60 to 72, Excl.	72 to 84, Excl.	84 to 96, Excl.	96 to 108, Excl.	108 to 120, Incl.
To 1/4, excl.	1 ¹ / ₁₆	1 ⁷ / ₁₆	Z	Z	Z	Z
1/4 to 3/8, excl.	7/8	1 ¹ / ₁₆	1 ⁵ / ₁₆	1 ⁷ / ₁₆	1 ¹ / ₂	1 ¹¹ / ₁₆
3/8 to 1/2, excl.	1/2	1/2	9/16	1 ¹ / ₁₆	3/4	1 ³ / ₁₆
1/2 to 3/4, excl.	7/16	7/16	1/2	9/16	5/8	1 ¹ / ₁₆
3/4 to 1, excl.	7/16	7/16	1/2	1/2	9/16	1 ¹ / ₁₆
1 to 2, incl.	3/8	7/16	7/16	1/2	1/2	1/2

NOTE 1 — *Flatness Variations for Length* — The longer dimension specified is considered the length, and variation in flatness along the length shall not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft of longer plates.

NOTE 2 — *Flatness Variations for Width* — The flatness variation across the width shall not exceed the tabular amount for the specified width.

NOTE 3 — When the longer dimension is under 36 in., the variation in flatness along the length and across the width shall not exceed 3/8 in. in each direction. When the larger dimension is from 36 to 72 in., inclusive, the permissible flatness variation shall not exceed 75% of the tabular amount for the specified width, but in no case less than 3/8 in.

NOTE 4 — This table and these notes cover the flatness variations of circular and sketch plates based on the maximum dimensions of those plates.

NOTE 5 — Waviness tolerances for rectangular plates, universal mill plates, and circular and sketch plates do not apply.

NOTE 6 — A "Z" indicates that there is no published restricted value for the size.

NOTE 7 — Plates shall be in a horizontal position on a flat surface when flatness is measured.

TABLE 6
PERMISSIBLE VARIATIONS FROM FLATNESS FOR HIGH-STRENGTH
LOW-ALLOY STEEL PLATES AS-ROLLED OR NORMALIZED ORDERED TO RESTRICTIVE FLATNESS

Specified Thickness, mm	Permissible Variations From a Flat Surface for Specified Widths, mm					
	1200 to 1500, Excl.	1500 to 1800, Excl.	1800 to 2100, Excl.	2100 to 2400, Excl.	2400 to 2700, Excl.	2700 to 3000, Incl.
To 6, excl.	27	36	Z	Z	Z	Z
6 to 10, excl.	22	27	33	36	39	43
10 to 12, excl.	12	12	15	17	19	21
12 to 20, excl.	11	11	13	15	16	18
20 to 25, excl.	11	11	12	13	15	17
25 to 50, excl.	10	11	11	12	13	13

NOTE 1 — *Flatness Variations for Length* — The longer dimension specified is considered the length, and variation in flatness along the length shall not exceed the tabular amount for the specified width in plates up to 3700 mm in length, or in any 3700 mm of longer plates.

NOTE 2 — *Flatness Variations for Width* — The flatness variation across the width shall not exceed the tabular amount for the specified width.

NOTE 3 — When the longer dimension is under 900 mm, the variation in flatness along the length and across the width shall not exceed 10 mm in each direction. When the larger dimension is from 900 to 1800 mm, inclusive, the permissible flatness variation shall not exceed 75% of the tabular amount for the specified width, but in no case less than 10 mm.

NOTE 4 — This table and these notes cover the variations for flatness of circular and sketch plates based on the maximum dimensions of those plates.

NOTE 5 — Waviness tolerances for rectangular plates, universal mill plates, and circular and sketch plates do not apply.

NOTE 6 — A "Z" indicates that there is no published restricted value for the size.

NOTE 7 — Plates shall be in a horizontal position on a flat surface when flatness is measured.

SUPPLEMENTARY REQUIREMENTS

The following standardized supplementary requirements are for use if desired by the purchaser. Those that are considered suitable for use with a product specification are listed in the product specification. Other tests may be performed by agreement between the manufacturer or processor and the purchaser. These supplementary requirements shall apply only if specified in the purchase order, in which event the specified tests shall be made by the manufacturer or processor before shipment of the plates.

S1. Vacuum Treatment

S1.1 The steel shall be made by a process that includes vacuum degassing while molten. Unless otherwise agreed upon with the purchaser, it is the responsibility of the manufacturer to select suitable process procedures.

S2. Product Analysis

S2.1 A product analysis shall be made of each plate as rolled. The specimens for analysis shall be taken adjacent to or from a broken tension test specimen.

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons

S3.1 Prior to testing, the test coupons representing the plate for acceptance purposes for mechanical properties shall be thermally treated to simulate a post-weld heat treatment below the critical temperature (A_{c3}), using the heat treatment parameters (such as temperature range, time, and cooling rates) specified in the purchase order. For tests using specimens taken from such heat treated test coupons, the test results shall meet the requirements of the applicable product specification.

S4. Additional Tension Test

S4.1 Other Than Quenched-and-Tempered Plates — In addition to the required single tension test, a second tension test shall be made using a test specimen taken from a test coupon taken from a corner of the plate-as-rolled on the end opposite the single test specimen and in a direction parallel to the single test specimen. The results obtained using this second test specimen shall meet the requirements of the applicable product specification.

S4.2 Quenched-and-Tempered Plates 2 in. [50 mm] or Greater in Thickness — In addition to the required tension tests, two additional test coupons shall be taken from the bottom corner of the plate. One shall be taken at the center of the plate thickness and the other immediately beneath the surface. Mandatory conformance of these additional

tests with the specified properties shall be a matter of agreement between the manufacturer and the purchaser.

S5. Charpy V-Notch Impact Test

S5.1 Charpy V-notch impact tests shall be conducted in accordance with 12.1.

S5.2 The orientation of the test specimens, whether longitudinal or transverse to the direction of rolling, shall be as specified in the purchase order.

S5.3 The test temperature and the required acceptance criteria, if other than those required in 12.1, shall be as specified in the purchase order.

S5.4 The recorded results shall include test specimen orientation, test specimen size, test temperature, absorbed energy values, and, if specified in the purchase order for other than Class VI plates, lateral expansion opposite the notch. The percent shear fracture appearance shall also be recorded if specified in the purchase order.

S6. Drop-Weight Test (for Plates 0.625 in. [16 mm] and Over in Thickness)

S6.1 Drop-weight tests shall be made in accordance with the requirements of Test Method E 208. The specimens shall represent the plates in the final condition of heat treatment. Agreement shall be reached between the purchaser and the manufacturer or processor as to the number of plates to be tested and whether a maximum NDT temperature is mandatory or if the test results are for information only.

S7. High-Temperature Tension Tests

S7.1 A short-time elevated temperature tension test shall be made to represent each plate or each heat of steel as indicated by the purchaser. The specimens for testing shall be obtained as required for the room temperature tension tests specified in the body of this general requirements specification. The high-temperature tests shall be made in accordance with the requirements of Practice E 21.

Mandatory conformance of such additional tests with the specified properties shall be a matter for agreement between the manufacturer or processor and the purchaser.

S8. Ultrasonic Examination in Accordance with A 435/A 435M

S8.1 All plates shall be ultrasonically examined in accordance with the requirements of Specification A 435/A 435M.

S9. Magnetic Particle Examination

S9.1 All plate edges shall be examined by magnetic particles in accordance with the procedures covered in Practice E 709. The acceptability of defects revealed by this examination shall be judged in accordance with the requirements for quality in 9.3.

S10. Charpy V-Notch Impact Transition Curve

S10.1 Sufficient impact tests of the same specimen size shall be made from the plate test material to establish a transition curve. The test temperature range shall be wide enough to establish the upper and lower shelf energies, with sufficient testing at intermediate temperatures to permit plotting a reasonable smooth curve. A plot of the data is not required. The manufacturer shall report the specimen orientation, test temperature, and absorbed energy for each specimen tested. Lateral expansion and percent shear shall also be reported when specified in the purchase order. The number of plates tested and the specimen orientation shall be the same as in 12.1 unless otherwise specified in the purchase order.

S11. Ultrasonic Examination in Accordance with A 577/A 577M

S11.1 All plates shall be ultrasonically examined in accordance with the requirements of Specification A 577/A 577M.

S12. Ultrasonic Examination in Accordance with A 578/A 578M

S12.1 All plates shall be ultrasonically examined in accordance with the requirements of Specification A 578/A 578M. The acceptance level shall be as specified in the purchase order.

S13. NDT Temperature Determination

S13.1 The NDT temperature shall be established in accordance with Method E 208 using coupons from a single

plate. The number of plates to be so tested shall be subject to agreement between the purchaser and the manufacturer or processor.

S15. Reduction of Area Measurement

S15.1 A reduction of area measurement shall be taken while making the required tension test. Reduction of area shall be determined only on the 0.500 in. [12.5 mm] round specimen as shown in Fig. 5 of Test Methods and Definitions A 370. The minimum acceptance limit shall be 40%.

S16. Thermal Stress Relief of Mechanical Test Coupons

S16.1 Test coupons representing the plates shall be thermally stress relieved by gradually and uniformly heating them to a temperature between 1100 and 1200°F [595 and 650°C], or a temperature range otherwise agreed upon between the manufacturer or processor and the purchaser, holding at temperature for at least 1 h/in. [2.4 min/mm] of thickness and cooling in still air to a temperature not exceeding 600°F [315°C].

S17. Vacuum Carbon-Deoxidized Steel

S17.1 Material shall be vacuum carbon-deoxidized, in which case the silicon content at the time of vacuum deoxidizing shall be 0.12% maximum, and the content of deoxidizers such as aluminum, zirconium, and titanium should be kept low enough to allow deoxidation by carbon. The test report shall indicate that the steel was vacuum carbon-deoxidized. The minimum heat analysis and product analysis requirements for silicon do not apply to vacuum carbon-deoxidized steel.

S19. Restricted Chemical Requirements

S19.1 Restricted heat analysis and product analysis limits are applicable, as specified in the purchase order.

S20. Maximum Carbon Equivalent for Weldability

S20.1 Plates shall be supplied with a specific maximum carbon equivalent value. This value shall be based upon the heat analysis. The required chemical analysis as well as the carbon equivalent shall be reported.

S20.2 The carbon equivalent shall be calculated using the following formula:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S20.3 The maximum value of the carbon equivalent for carbon steels (including C-Mn, C-Mn-Si, C-Mn-Si-Al steels), are given in Table 2.

S21. Restricted Limits on Elements

S21.1 For each heat, based upon the heat analysis, the content shall not exceed 0.35% for copper, 0.25% for nickel, 0.25% for chromium, 0.08% for molybdenum, or 0.70% for the sum of those four elements.

S22. Through-Thickness Tension Tests

S22.1 Through-thickness tension tests shall be made in accordance with the requirements of Specification A 770/A 770M. (See Ordering Information in Specification A 770/A 770M for the additional information that may be needed.)

S24. Strain Age Test

S24.1 Test coupons shall be given a strain age treatment designated by the purchaser. Charpy V-notch tests shall be conducted on the strain aged specimens. Heat treatment, strain aging, test temperature, and acceptance criteria shall be as agreed upon between the manufacturer or processor and the purchaser.

S25. Weldability

S25.1 Weldability tests shall be conducted. The type of test and the acceptance criteria shall be as agreed upon between the manufacturer or processor and the purchaser.

S26. Low-Sulfur Steels

S26.1 The steel shall be made to 0.010% sulfur maximum. Lower sulfur levels and sulfide shape control practices can be specified by agreement between the manufacturer or processor and the purchaser.

S27. Restrictive Plate Flatness

S27.1 Carbon steel plates, as-rolled or normalized, shall conform to the permissible restrictive variations from flatness given in Table 3 or Table 4.

S27.2 High-strength low-alloy steel plates, as-rolled or normalized, shall conform to the permissible restrictive variations from flatness given in Table 5 or Table 6.

S28. Heat Treatment in the Working Zone of a Surveyed Furnace

S28.1 Plates shall be heat treated in the working zone of a furnace that has been surveyed in accordance with Test Method A 991/A 991M, provided that such working zone was established using a variation of 25°F [15°C] or less from the furnace set point.

S28.2 The test report shall indicate that S28 applies.

ANNEXES

(Mandatory Information)

A1. PERMISSIBLE VARIATIONS IN DIMENSIONS, ETC. — INCH-POUND UNITS

A1.1 Listed below are permissible variations in dimensions, and notch toughness information, expressed in inch-pound units of measurement.

TABLE A1.1
PERMISSIBLE VARIATIONS IN THICKNESS FOR RECTANGULAR PLATES

Specified Thickness, in.	Tolerance Over Specified Thickness for Widths Given, in.											
	48 and Under	Over 48 to 60, Excl.	60 to 72, Excl.	72 to 84, Excl.	84 to 96, Excl.	96 to 108, Excl.	108 to 120, Excl.	120 to 132, Excl.	132 to 144, Excl.	144 to 168, Excl.	168 to 182, Excl.	182 and Over
To $\frac{1}{4}$, excl.	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	...	...	...
$\frac{1}{4}$ to $\frac{5}{16}$, excl.	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	...	...	...
$\frac{5}{16}$ to $\frac{3}{8}$, excl.	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	...	...
$\frac{3}{8}$ to $\frac{7}{16}$, excl.	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.06	...
$\frac{7}{16}$ to $\frac{1}{2}$, excl.	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.06	...
$\frac{1}{2}$ to $\frac{5}{8}$, excl.	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.07	...
$\frac{5}{8}$ to $\frac{3}{4}$, excl.	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.06	0.07	...
$\frac{3}{4}$ to 1, excl.	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.07	0.08	0.09
1 to 2, excl.	0.06	0.06	0.06	0.06	0.06	0.07	0.08	0.10	0.10	0.11	0.13	0.16
2 to 3, excl.	0.09	0.09	0.09	0.10	0.10	0.11	0.12	0.13	0.14	0.15	0.15	...
3 to 4, excl.	0.11	0.11	0.11	0.11	0.11	0.13	0.14	0.14	0.14	0.15	0.17	...
4 to 6, excl.	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.20	0.20	...
6 to 10, excl.	0.23	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.27	0.28	...
10 to 12, excl.	0.29	0.29	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.35	...
12 to 15, incl.	0.29	0.29	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	...

NOTE 1 — Permissible variation under specified thickness, 0.01 in.

NOTE 2 — Thickness to be measured at $\frac{3}{8}$ to $\frac{3}{4}$ in. from the longitudinal edge.

NOTE 3 — For thickness measured at any location other than that specified in Note 2, the permissible maximum over-tolerance shall be increased by 75%, rounded to the nearest 0.01 in.

TABLE A1.2
PERMISSIBLE VARIATIONS IN WIDTH AND LENGTH FOR SHEARED PLATES $1\frac{1}{2}$ IN. AND UNDER IN THICKNESS;
LENGTH ONLY FOR UNIVERSAL MILL PLATES $2\frac{1}{2}$ IN. AND UNDER IN THICKNESS

Specified Dimensions, in.		Permissible Variations Over Specified Width and Length ^A for Thicknesses Given in Inches, in.							
		To $\frac{3}{8}$, Excl.		$\frac{3}{8}$ to $\frac{5}{8}$, Excl.		$\frac{5}{8}$ to 1, Excl.		1 to 2, Incl. ^B	
Length	Width	Width	Length	Width	Length	Width	Length	Width	Length
To 120, excl.	over 8 to 60, excl.	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{7}{16}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{5}{8}$	1
	60 to 84, excl.	$\frac{7}{16}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{11}{16}$	$\frac{5}{8}$	$\frac{7}{8}$	$\frac{3}{4}$	1
	84 to 108, excl.	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{7}{8}$	$\frac{3}{4}$	1	1	$1\frac{1}{8}$
	108 and over	$\frac{5}{8}$	$\frac{7}{8}$	$\frac{3}{4}$	1	$\frac{7}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{4}$
120 to 240, excl.	over 8 to 60, excl.	$\frac{3}{8}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{7}{8}$	$\frac{5}{8}$	1	$\frac{3}{4}$	$1\frac{1}{8}$
	60 to 84, excl.	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{7}{8}$	$\frac{3}{4}$	1	$\frac{7}{8}$	$1\frac{1}{4}$
	84 to 108, excl.	$\frac{9}{16}$	$\frac{7}{8}$	$\frac{11}{16}$	$\frac{15}{16}$	$\frac{13}{16}$	$1\frac{1}{8}$	1	$1\frac{3}{8}$
	108 and over	$\frac{5}{8}$	1	$\frac{3}{4}$	$1\frac{1}{8}$	$\frac{7}{8}$	$1\frac{1}{4}$	$1\frac{1}{8}$	$1\frac{3}{8}$
240 to 360, excl.	over 8 to 60, excl.	$\frac{3}{8}$	1	$\frac{1}{2}$	$1\frac{1}{8}$	$\frac{5}{8}$	$1\frac{1}{4}$	$\frac{3}{4}$	$1\frac{1}{2}$
	60 to 84, excl.	$\frac{1}{2}$	1	$\frac{5}{8}$	$1\frac{1}{8}$	$\frac{3}{4}$	$1\frac{1}{4}$	$\frac{7}{8}$	$1\frac{1}{2}$
	84 to 108, excl.	$\frac{9}{16}$	1	$\frac{11}{16}$	$1\frac{1}{8}$	$\frac{7}{8}$	$1\frac{3}{8}$	1	$1\frac{1}{2}$
	108 and over	$\frac{11}{16}$	$1\frac{1}{8}$	$\frac{7}{8}$	$1\frac{1}{4}$	1	$1\frac{3}{8}$	$1\frac{1}{4}$	$1\frac{3}{4}$
360 to 480, excl.	over 8 to 60, excl.	$\frac{7}{16}$	$1\frac{1}{8}$	$\frac{1}{2}$	$1\frac{1}{4}$	$\frac{5}{8}$	$1\frac{3}{8}$	$\frac{3}{4}$	$1\frac{5}{8}$
	60 to 84, excl.	$\frac{1}{2}$	$1\frac{1}{4}$	$\frac{5}{8}$	$1\frac{3}{8}$	$\frac{3}{4}$	$1\frac{1}{2}$	$\frac{7}{8}$	$1\frac{5}{8}$
	84 to 108, excl.	$\frac{9}{16}$	$1\frac{1}{4}$	$\frac{3}{4}$	$1\frac{3}{8}$	$\frac{7}{8}$	$1\frac{1}{2}$	1	$1\frac{7}{8}$
	108 and over	$\frac{3}{4}$	$1\frac{3}{8}$	$\frac{7}{8}$	$1\frac{1}{2}$	1	$1\frac{5}{8}$	$1\frac{1}{4}$	$1\frac{7}{8}$
480 to 600, excl.	over 8 to 60, excl.	$\frac{7}{16}$	$1\frac{1}{4}$	$\frac{1}{2}$	$1\frac{1}{2}$	$\frac{5}{8}$	$1\frac{5}{8}$	$\frac{3}{4}$	$1\frac{7}{8}$
	60 to 84, excl.	$\frac{1}{2}$	$1\frac{3}{8}$	$\frac{5}{8}$	$1\frac{1}{2}$	$\frac{3}{4}$	$1\frac{5}{8}$	$\frac{7}{8}$	$1\frac{7}{8}$
	84 to 108, excl.	$\frac{5}{8}$	$1\frac{3}{8}$	$\frac{3}{4}$	$1\frac{1}{2}$	$\frac{7}{8}$	$1\frac{5}{8}$	1	$1\frac{7}{8}$
	108 and over	$\frac{3}{4}$	$1\frac{1}{2}$	$\frac{7}{8}$	$1\frac{5}{8}$	1	$1\frac{3}{4}$	$1\frac{1}{4}$	$1\frac{7}{8}$
600 to 720, excl.	over 8 to 60, excl.	$\frac{1}{2}$	$1\frac{3}{4}$	$\frac{5}{8}$	$1\frac{7}{8}$	$\frac{3}{4}$	$1\frac{7}{8}$	$\frac{7}{8}$	$2\frac{1}{4}$
	60 to 84, excl.	$\frac{5}{8}$	$1\frac{3}{4}$	$\frac{3}{4}$	$1\frac{7}{8}$	$\frac{7}{8}$	$1\frac{7}{8}$	1	$2\frac{1}{4}$
	84 to 108, excl.	$\frac{5}{8}$	$1\frac{3}{4}$	$\frac{3}{4}$	$1\frac{7}{8}$	$\frac{7}{8}$	$1\frac{7}{8}$	$1\frac{1}{8}$	$2\frac{1}{4}$
	108 and over	$\frac{7}{8}$	$1\frac{3}{4}$	1	2	$1\frac{1}{8}$	$2\frac{1}{4}$	$1\frac{1}{4}$	$2\frac{1}{2}$
720 and over	over 8 to 60, excl.	$\frac{9}{16}$	2	$\frac{3}{4}$	$2\frac{1}{8}$	$\frac{7}{8}$	$2\frac{1}{4}$	1	$2\frac{3}{4}$
	60 to 84, excl.	$\frac{3}{4}$	2	$\frac{7}{8}$	$2\frac{1}{8}$	1	$2\frac{1}{4}$	$1\frac{1}{8}$	$2\frac{3}{4}$
	84 to 108, excl.	$\frac{3}{4}$	2	$\frac{7}{8}$	$2\frac{1}{8}$	1	$2\frac{1}{4}$	$1\frac{1}{4}$	$2\frac{3}{4}$
	108 and over	1	2	$1\frac{1}{8}$	$2\frac{3}{8}$	$1\frac{1}{4}$	$2\frac{1}{2}$	$1\frac{3}{8}$	3

^A Permissible variation under specified width and length: $\frac{1}{4}$ in.

^B Permissible variations in length apply also to Universal Mill plates up to 12 in. in width for thicknesses over 2 to $2\frac{1}{2}$ in., incl., except for alloy steel up to 2 in. thick.

TABLE A1.3
PERMISSIBLE VARIATIONS IN ROLLED WIDTH FOR
UNIVERSAL MILL CARBON STEEL, HIGH-STRENGTH LOW-ALLOY STEEL, AND
ALLOY-STEEL PLATES 15 IN. AND UNDER IN THICKNESS

Specified Width, in.	Variations Over Specified Width for Thicknesses Given, in.					
	To $\frac{3}{8}$, Excl.	$\frac{3}{8}$ to $\frac{5}{8}$, Excl.	$\frac{5}{8}$ to 1, Excl.	1 to 2, Incl.	Over 2 to 10, Incl.	Over 10 to 15, Incl.
Over 8 to 20, excl.	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$
20 to 36, excl.	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{9}{16}$
36 and over	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$

NOTE 1 — Permissible variation under specified width shall be $\frac{1}{8}$ in.

TABLE A1.4
PERMISSIBLE VARIATIONS IN
DIAMETER FOR SHEARED CIRCULAR
CARBON STEEL, HIGH-STRENGTH
LOW-ALLOY STEEL, AND ALLOY-STEEL PLATES
1 IN. AND UNDER IN THICKNESS

Specified Diameter, in.	Permissible Variations Over Specified Diameter for Thicknesses Given, in.		
	To $\frac{3}{8}$, Excl.	$\frac{3}{8}$ to $\frac{5}{8}$, Excl.	$\frac{5}{8}$ to 1, Incl.
To 32, excl.	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$
32 to 84, excl.	$\frac{5}{16}$	$\frac{7}{16}$	$\frac{9}{16}$
84 to 108, excl.	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$
108 to 130, incl.	$\frac{7}{16}$	$\frac{9}{16}$	$\frac{11}{16}$

NOTE 1 — No permissible variations under specified diameter.

TABLE A1.5
PERMISSIBLE VARIATIONS IN WIDTH AND LENGTH
FOR RECTANGULAR CARBON STEEL AND
HIGH-STRENGTH LOW-ALLOY STEEL PLATES
WHEN GAS CUTTING IS SPECIFIED OR REQUIRED

Specified Thickness, in.	Variations Over for All Specified Widths or Lengths, in.
To 2, excl.	$\frac{1}{2}$
2 to 4, excl.	$\frac{5}{8}$
4 to 6, excl.	$\frac{3}{4}$
6 to 8, excl.	$\frac{7}{8}$
8 to 15, incl.	1

NOTE 1 — These variations may be taken all under or divided over and under, if so specified.

NOTE 2 — Plates with universal rolled edges will be gas cut to length only.

TABLE A1.6
PERMISSIBLE VARIATIONS IN DIAMETER FOR GAS-CUT
CIRCULAR CARBON STEEL AND HIGH-STRENGTH LOW-ALLOY STEEL PLATES

Specified Diameter, in.	Variations Over Specified Diameter for Thicknesses Given, in.					
	To 1, Excl.	1 to 2, Excl.	2 to 4, Excl.	4 to 6, Excl.	6 to 8, Excl.	8 to 15, Incl.
To 32, excl.	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$
32 to 84, excl.	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$
84 to 108, excl.	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
108 to 130, excl.	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{11}{16}$	$\frac{7}{8}$	1	$1\frac{1}{8}$
130 and over	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$

NOTE 1 — No permissible variations under specified diameter.

TABLE A1.7
PERMISSIBLE CAMBER FOR
CARBON STEEL SHEARED OR GAS-CUT
RECTANGULAR PLATES ALL THICKNESSES

Maximum permissible camber, in. = $\frac{1}{8}$ in. \times (number of feet of
length/5)

NOTE 1 — Camber, as it relates to plates, is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

TABLE A1.8
PERMISSIBLE CAMBER FOR CARBON STEEL, HIGH-
STRENGTH LOW-ALLOY STEEL, AND ALLOY STEEL
UNIVERSAL MILL PLATES AND HIGH-STRENGTH
LOW-ALLOY STEEL AND ALLOY STEEL SHEARED OR
GAS-CUT RECTANGULAR PLATES

Dimension, in.		Camber for Thickness and Widths Given
Thickness	Width	
To 2, incl.	All	$\frac{1}{8}$ in. \times (number of feet of length/5)
Over 2 to 15, incl.	To 30, incl.	$\frac{3}{16}$ in. \times (number of feet of length/5)
Over 2 to 15, incl.	Over 30	$\frac{1}{4}$ in. \times (number of feet of length/5)

TABLE A1.9
PERMISSIBLE VARIATIONS FROM FLATNESS FOR CARBON STEEL PLATES

Specified Thickness, in.	Variations From a Flat Surface for Specified Widths, in.										
	Over 8 to 36, Excl.	36 to 48, Excl.	48 to 60, Excl.	60 to 72, Excl.	72 to 84, Excl.	84 to 96, Excl.	96 to 108, Excl.	108 to 120, Excl.	120 to 144, Excl.	144 to 168, Excl.	168 and Over
To $\frac{1}{4}$, excl.	$\frac{9}{16}$	$\frac{3}{4}$	$\frac{15}{16}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	...	...
$\frac{1}{4}$ to $\frac{3}{16}$, excl.	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{15}{16}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	...	...
$\frac{3}{16}$ to $\frac{1}{2}$, excl.	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{8}$	$2\frac{1}{8}$
$\frac{1}{2}$ to $\frac{3}{4}$, excl.	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{3}{4}$	1	$\frac{1}{8}$	$\frac{1}{2}$	2
$\frac{3}{4}$ to 1, excl.	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$\frac{3}{8}$	$1\frac{3}{4}$
1 to 2, excl.	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$1\frac{1}{16}$	$\frac{1}{8}$	$1\frac{1}{2}$
2 to 4, excl.	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{7}{8}$	$1\frac{1}{8}$
4 to 6, excl.	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{7}{8}$	1
6 to 8, excl.	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	$1\frac{1}{16}$	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{7}{8}$	1	1	1
8 to 10, excl.	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	$1\frac{1}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1	1	1
10 to 12, excl.	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1	1	1	1	1
12 to 15, incl.	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1	1	1	1	1	...

NOTE 1 — *Flatness Variations for Length* — The longer dimension specified is considered the length, and variation in flatness along the length shall not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft of longer plates.

NOTE 2 — *Flatness Variations for Width* — The flatness variation across the width shall not exceed the tabular amount for the specified width.

NOTE 3 — When the longer dimension is under 36 in., the variation in flatness along the length and across the width shall not exceed $\frac{1}{4}$ in. in each direction. When the longer dimension is from 36 to 72 in., inclusive, the flatness variation shall not exceed 75% of the tabular amount for the specified width, but in no case less than $\frac{1}{4}$ in.

NOTE 4 — The tolerances given in this table apply to plates that have a minimum specified tensile strength not over 60 ksi or comparable chemistry or hardness. For plates specified to a higher minimum tensile strength or comparable chemistry or hardness, the limits given in the table are increased to $1\frac{1}{2}$ times the amounts in the above table.

NOTE 5 — This table and notes cover the flatness tolerances of circular and sketch plates, based on the maximum dimensions of those plates.

NOTE 6 — Plates shall be in a horizontal position on a flat surface when flatness is measured.

TABLE A1.10
PERMISSIBLE VARIATIONS IN WIDTH AND LENGTH
FOR RECTANGULAR ALLOY STEEL PLATES WHEN
GAS CUTTING IS SPECIFIED OR REQUIRED

Specified Thickness, in.	Variations Over for All Specified Widths and Lengths, in.
To 2, excl.	$\frac{3}{4}$
2 to 4, excl.	1
4 to 6, excl.	$1\frac{1}{8}$
6 to 8, excl.	$1\frac{5}{16}$
8 to 15, incl.	$1\frac{1}{2}$

NOTE 1 — These variations may be taken all under or divided over and under, if so specified.

NOTE 2 — Plates with universal rolled edges will be gas cut to length only.

TABLE A1.11
PERMISSIBLE VARIATIONS IN DIAMETER FOR
GAS-CUT CIRCULAR ALLOY STEEL PLATES

Specified Diameter, in.	Variations Over Specified Diameter for Thicknesses Given, in.					
	To 1, Excl.	1 to 2, Excl.	2 to 4, Excl.	4 to 6, Excl.	6 to 8, Excl.	8 to 15, Incl.
To 32, excl.	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	1	1
32 to 84, excl.	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$
84 to 108, excl.	$\frac{5}{8}$	$\frac{3}{4}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$
108 to 130, incl.	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$

NOTE 1 — No permissible variations under specified diameter.

TABLE A1.12
PERMISSIBLE VARIATIONS FROM FLATNESS FOR HIGH-STRENGTH LOW-ALLOY STEEL AND ALLOY STEEL PLATES

Variations From a Flat Surface for Specified Widths, in.											
	Over 8 to 36, Excl.	36 to 48, Excl.	48 to 60, Excl.	60 to 72, Excl.	72 to 84, Excl.	84 to 96, Excl.	96 to 108, Excl.	108 to 120, Excl.	120 to 144, Excl.	144 to 168, Excl.	168 and Over
Specified Thickness, in.	To 1/4, excl.	13/16	1 3/8	1 7/8	2	2 1/4	2 3/8	2 5/8	2 3/4	...	...
	1 1/4 to 3/8, excl.	3/4	1 5/16	1 3/8	1 3/4	1 7/8	2	2 1/4	2 3/8	...	...
	3/8 to 1/2, excl.	3/4	1 5/16	1 5/16	1 1/8	1 5/16	1 1/2	1 5/8	1 7/8	2 3/4	3 1/8
	1/2 to 3/4, excl.	5/8	3/4	13 1/16	1	1 1/8	1 1/4	1 3/8	1 5/8	2 1/4	3
	3/4 to 1, excl.	5/8	3/4	7/8	15 1/16	1	1 1/8	1 5/16	1 1/2	2	2 5/8
	1 to 2, excl.	9/16	5/8	3/4	13 1/16	7/8	1	1	1	1 5/8	2 1/4
	2 to 4, excl.	1/2	9 1/16	11 1/16	3/4	3/4	3/4	7/8	1	1 1/4	1 5/8
	4 to 6, excl.	9/16	11 1/16	3/4	3/4	7/8	7/8	15 1/16	1 1/4	1 1/4	1 5/8
	6 to 8, excl.	5/8	3/4	3/4	15 1/16	1	1 1/8	1 1/4	1 5/16	1 1/2	1 1/2
	8 to 10, excl.	3/4	13 1/16	15 1/16	1	1 1/8	1 1/4	1 5/16	1 3/8	1 1/2	1 1/2
	10 to 12, excl.	3/4	15 1/16	1 1/8	1 1/4	1 5/16	1 3/8	1 1/2	1 1/2	1 1/2	1 1/2
	12 to 15, incl.	7/8	1	13 1/16	1 5/16	1 3/8	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2

NOTE 1 — *Flatness Tolerances for Length* — The longer dimension specified is considered the length, and variations from a flat surface along the length shall not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft of longer plates.

NOTE 2 — *Flatness Tolerances for Width* — The flatness variation across the width shall not exceed the tabular amount for the specified width.

NOTE 3 — When the longer dimension is under 36 in., the variation shall not exceed $\frac{3}{8}$ in. When the larger dimension is from 36 to 72 in., incl., the variation shall not exceed 75% of the tabular amount for the specified width.

NOTE 4 — This table and notes cover the tolerance for flatness of circular and sketch plates, based on the maximum dimensions of those plates.

NOTE 5 — Plates shall be in a horizontal position on a flat surface when flatness is measured.

TABLE A1.13
WAVINESS TOLERANCES FOR RECTANGULAR PLATES, UNIVERSAL MILL PLATES,
CIRCULAR PLATES, AND SKETCH PLATES

Flatness Tolerance from Tables A1.9 and A1.12	When Number of Waves in 12 ft is:						
	1	2	3	4	5	6	7
$\frac{5}{16}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{16}$
$\frac{3}{8}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{16}$
$\frac{7}{16}$	$\frac{7}{16}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{16}$
$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{16}$
$\frac{9}{16}$	$\frac{9}{16}$	$\frac{7}{16}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{8}$
$\frac{5}{8}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{8}$
$\frac{11}{16}$	$\frac{11}{16}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{1}{8}$
$\frac{3}{4}$	$\frac{3}{4}$	$\frac{9}{16}$	$\frac{7}{16}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{1}{8}$
$\frac{13}{16}$	$\frac{13}{16}$	$\frac{5}{8}$	$\frac{7}{16}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{1}{8}$
$\frac{7}{8}$	$\frac{7}{8}$	$\frac{11}{16}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{1}{8}$
$\frac{15}{16}$	$\frac{15}{16}$	$\frac{11}{16}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{3}{16}$
1	1	$\frac{3}{4}$	$\frac{9}{16}$	$\frac{7}{16}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{3}{16}$
$1\frac{1}{8}$	$1\frac{1}{8}$	$\frac{7}{8}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{3}{16}$
$1\frac{1}{4}$	$1\frac{1}{4}$	$\frac{15}{16}$	$\frac{11}{16}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{1}{4}$
$1\frac{3}{8}$	$1\frac{3}{8}$	$1\frac{1}{16}$	$\frac{3}{4}$	$\frac{9}{16}$	$\frac{7}{16}$	$\frac{5}{16}$	$\frac{1}{4}$
$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{8}$	$\frac{7}{8}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{4}$
$1\frac{5}{8}$	$1\frac{5}{8}$	$1\frac{1}{4}$	$\frac{15}{16}$	$\frac{11}{16}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{5}{16}$
$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{5}{16}$	1	$\frac{3}{4}$	$\frac{9}{16}$	$\frac{7}{16}$	$\frac{5}{16}$
$1\frac{7}{8}$	$1\frac{7}{8}$	$1\frac{7}{16}$	$1\frac{1}{16}$	$\frac{13}{16}$	$\frac{9}{16}$	$\frac{7}{16}$	$\frac{5}{16}$
2	2	$1\frac{1}{2}$	$1\frac{1}{8}$	$\frac{7}{8}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{8}$
$2\frac{1}{8}$	$2\frac{1}{8}$	$1\frac{5}{8}$	$1\frac{3}{16}$	$\frac{7}{8}$	$\frac{11}{16}$	$\frac{1}{2}$	$\frac{3}{8}$
$2\frac{1}{4}$	$2\frac{1}{4}$	$1\frac{11}{16}$	$1\frac{1}{4}$	$\frac{15}{16}$	$\frac{11}{16}$	$\frac{9}{16}$	$\frac{3}{8}$
$2\frac{3}{8}$	$2\frac{3}{8}$	$1\frac{13}{16}$	$1\frac{5}{16}$	1	$\frac{3}{4}$	$\frac{9}{16}$	$\frac{7}{16}$
$2\frac{1}{2}$	$2\frac{1}{2}$	$1\frac{7}{8}$	$1\frac{7}{16}$	$1\frac{1}{16}$	$\frac{13}{16}$	$\frac{9}{16}$	$\frac{7}{16}$
$2\frac{5}{8}$	$2\frac{5}{8}$	2	$1\frac{1}{2}$	$1\frac{1}{8}$	$\frac{13}{16}$	$\frac{5}{8}$	$\frac{7}{16}$
$2\frac{3}{4}$	$2\frac{3}{4}$	$2\frac{1}{16}$	$1\frac{9}{16}$	$1\frac{1}{8}$	$\frac{7}{8}$	$\frac{5}{8}$	$\frac{1}{2}$
$2\frac{7}{8}$	$2\frac{7}{8}$	$2\frac{3}{16}$	$1\frac{5}{8}$	$1\frac{3}{16}$	$\frac{15}{16}$	$\frac{11}{16}$	$\frac{1}{2}$
3	3	$2\frac{1}{4}$	$1\frac{11}{16}$	$1\frac{1}{4}$	$\frac{15}{16}$	$\frac{11}{16}$	$\frac{9}{16}$
$3\frac{1}{8}$	$3\frac{1}{8}$	$2\frac{3}{8}$	$1\frac{3}{4}$	$1\frac{5}{16}$	1	$\frac{3}{4}$	$\frac{9}{16}$

NOTE 1 — Waviness denotes the deviation of the top or bottom surface from a horizontal line, when the plate is resting on a flat surface, as measured in an increment of less than 12 ft of length. The waviness tolerance is a function of the flatness tolerance as obtained from Tables A1.9 and A1.12.

TABLE A1.14
VISIBLE EDGE INDICATIONS EXTENDING APPROXIMATELY PARALLEL TO ROLLED SURFACES

Plate Specification and Thickness	Acceptable		Remove by Grinding		Acceptable on Edges Cut in Fabrication	
	Depth	Length ^A	Depth	Length ^A	Depth	Length ^A
Column	1	2	3	4	5	6
Other than killed, ^B to 2 in., incl.	$\frac{1}{8}$ in. max.	Any	Over $\frac{1}{8}$ in. to $\frac{1}{4}$ in., incl.	Over 1 in.	$\frac{1}{4}$ in. max.	Any
Killed, ^C to 6 in., incl.	$\frac{1}{16}$ in. max.	Any	Over $\frac{1}{16}$ in. to $\frac{1}{8}$ in., incl.	Over 1 in.	$\frac{1}{8}$ in. max.	Any
Killed, ^C over 6 in.	$\frac{1}{8}$ in. max.	Any	Over $\frac{1}{8}$ in. to $\frac{1}{2}$ in., incl.	Over 1 in.	$\frac{1}{2}$ in. max.	Any

^A Laminar-type discontinuities 1 in. and less in length are acceptable and do not require exploration.

^B Specifications: A 285; A 433; A 442 in thicknesses to 1 in., incl.; or A 455.

^C The specification in 1.1 of this standard, other than those listed in the above footnote B.

TABLE A1.15
GENERALLY AVAILABLE GRADE-THICKNESS-MINIMUM TEST TEMPERATURE COMBINATIONS
MEETING CHARPY V-NOTCH REQUIREMENTS INDICATED (NORMALIZED OR QUENCHED AND TEMPERED CONDITION)

Acceptance Criteria Charpy V-Notch			Test Temperature, °F for Plate Thicknesses (Unless Otherwise Agreed Upon)				
Class ^B	Energy Absorption		Specification and Grade ^A	1 in. and Under	Over 1 in. to 2 in., Incl.	Over 2 in. to 3 in., Incl.	Over 3 in. to 5 in., Incl.
	Minimum Average For 3 Specimens ^C ft-lbf	Minimum for 1 Specimen ^C ft-lbf					
I	10	7	A 285 Grade A A 285 Grade B A 285 Grade C	+40 +50 +60	+60 +70 +80	...	...
II	13	10	A 455	+25	...	...	...
III	13	10	A 203 Grade A A 203 Grade D A 442 Grade 55 (1½ in. max. thickness) A 442 Grade 60 (1½ in. max. thickness) A 516 Grade 55 A 516 Grade 60 A 516 Grade 65 A 537 Class 1 (Over 2½–4 in.) A 662 Grade A A 662 Grade B	-90 -150 -60 -60 -60 -75 -60	-90 -150 -20 -15 -60 -50 -50 ... -75 -60	-75 -125 -50 -50 -40 -75 ...	... ... ... ... -50 -50 -25 -50
IV	15	12	A 203 Grade B A 203 Grade E A 203 Grade F (4 in. max.) A 299 A 516 Grade 70 A 537 Class 1 (2½ in. max.) A 537 Class 2 (Over 2½–4 in.) A 662 Grade C	-90 -150 ... +20 -50 -80 ... -50	-90 -150 ... +30 -40 -75 ... -50	-75 -125 -160 +30 -30 -75 -75 ...	... ... -160 +40 -20 ... -50 ...

TABLE A1.15
GENERALLY AVAILABLE GRADE-THICKNESS-MINIMUM TEST TEMPERATURE COMBINATIONS
MEETING CHARPY V-NOTCH REQUIREMENTS INDICATED (NORMALIZED OR QUENCHED AND TEMPERED CONDITION) (CONT'D)

Acceptance Criteria Charpy V-Notch			Test Temperature, °F for Plate Thicknesses (Unless Otherwise Agreed Upon)				
Class ^B	Energy Absorption		Specification and Grade ^A	1 in. and Under			Over 3 in. to 5 in., Incl.
	Minimum Average For 3 Specimens ^C ft-lbf	Minimum for 1 Specimen ^C ft-lbf		Over 1 in. to 2 in., Incl.	Over 2 in. to 3 in., Incl.		
V	20	15	A 203 Grade F A 537 Class 2 (2½ in. max.) A 612 A 724 Grade A	-160 -90 -50 -50	-160 -90 ... ...	... -90
Lateral Expansion Mils. Minimum Each Specimen Transverse Test							
VI		15	A 353 A 553 Type I A 553 Type II A 645 A 517 all (2½ in. max. thickness) A 724 Grade B	-320 -320 -275 -275 ^A -50	-320 -320 -275 -275 ^A ...	... ... ... ... ...

NOTE 1 — The minimum temperatures listed are for longitudinal tests. For transverse tests, the available minimum temperature may be somewhat higher.

^A Testing temperature as specified in the purchase order but no higher than 32°F.

^B Class I is *Other Than Killed* with a specified minimum tensile strength of 65 ksi or lower.

Class II is *Other Than Killed* with a specified minimum tensile strength of over 65 ksi to 75 ksi.

Class III is *Killed* with a specified minimum tensile strength of 65 ksi or lower.

Class IV is *Killed* with a specified minimum tensile strength of over 65 ksi to 75 ksi.

Class V is *Killed* with a specified minimum tensile strength of over 75 ksi to but not including 95 ksi.

Class VI is *Killed* with a specified minimum tensile strength of 95 ksi or over.

^C Full size (10 by 10 mm) specimens.

TABLE A1.16
CHARPY V-NOTCH TEST ACCEPTANCE CRITERIA FOR VARIOUS SUBSIZE SPECIMENS⁴

Full Size, 10 by 10 mm		$\frac{3}{4}$ Size, 10 by 7.5 mm		$\frac{2}{3}$ Size, 10 by 6.7 mm		$\frac{1}{2}$ Size, 10 by 5 mm		$\frac{1}{3}$ Size, 10 by 3.3 mm		$\frac{1}{4}$ Size, 10 by 2.5 mm	
ft-lbf	[J]	ft-lbf	[J]	ft-lbf	[J]	ft-lbf	[J]	ft-lbf	[J]	ft-lbf	[J]
40	[54]	30	[41]	27	[37]	20	[27]	13	[18]	10	[14]
35	[48]	26	[35]	23	[31]	18	[24]	12	[16]	9	[12]
30	[41]	22	[30]	20	[27]	15	[20]	10	[14]	8	[11]
25	[34]	19	[26]	17	[23]	12	[16]	8	[11]	6	[8]
20	[27]	15	[20]	13	[18]	10	[14]	7	[10]	5	[7]
16	[22]	12	[16]	11	[15]	8	[11]	5	[7]	4	[5]
15	[20]	11	[15]	10	[14]	8	[11]	5	[7]	4	[5]
13	[18]	10	[14]	9	[12]	6	[8]	4	[5]	3	[4]
12	[16]	9	[12]	8	[11]	6	[8]	4	[5]	3	[4]
10	[14]	8	[11]	7	[10]	5	[7]	3	[4]	2	[3]
7	[10]	5	[7]	5	[7]	4	[5]	2	[3]	2	[3]

⁴ Interpolation shall be made for specimens with widths intermediate of those listed. Interpolated values shall be rounded to the nearest whole number as prescribed in Practice E 29.

TABLE A1.17
**PERMISSIBLE VARIATIONS IN WIDTH FOR MILL
EDGE CARBON STEEL AND HIGH-STRENGTH LOW-
ALLOY STEEL PLATES PRODUCED ON STRIP MILLS**

Specified Width, in.	Variations Over Specified Width, in. ⁴
To 14, excl.	$\frac{7}{16}$
14 to 17, excl.	$\frac{1}{2}$
17 to 19, excl.	$\frac{9}{16}$
19 to 21, excl.	$\frac{5}{8}$
21 to 24, excl.	$\frac{11}{16}$
24 to 26, excl.	$\frac{13}{16}$
26 to 28, excl.	$\frac{15}{16}$
28 to 35, excl.	$1\frac{1}{8}$
35 to 50, excl.	$1\frac{1}{4}$
50 to 60, excl.	$1\frac{1}{2}$
60 to 65, excl.	$1\frac{5}{8}$
65 to 70, excl.	$1\frac{3}{4}$
70 to 80, excl.	$1\frac{7}{8}$
80 and over	2

NOTE 1 — Applies to plates produced from coil and plates produced from plate-as-rolled.

⁴ No permissible variation under specified width.

A2. PERMISSIBLE VARIATIONS IN DIMENSIONS, ETC. — SI UNITS

A2.1 Listed herein are permissible variations in dimensions, and notch toughness information, expressed in SI units.

TABLE A2.1
PERMISSIBLE VARIATIONS IN THICKNESS FOR RECTANGULAR PLATES

Specified Thickness, mm	Tolerance Over Specified Thickness for Widths Given in Millimeters, mm										
	1200 and Under	Over 1200 to 1500, Excl.	1500 to 1800, Excl.	1800 to 2100, Excl.	2100 to 2400, Excl.	2400 to 2700, Excl.	2700 to 3000, Excl.	3000 to 3300, Excl.	3300 to 3600, Excl.	3600 to 4200, Excl.	4200 and Over
5.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	...	...
5.5	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	...	...
6.0	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.1	...	...
7.0	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.4	1.4	...
8.0	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.2	1.4	...
9.0	0.8	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.3	1.5	...
10.0	0.8	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.3	1.5	1.7
11.0	0.8	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.3	1.5	1.7
12.0	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.0	1.3	1.5	1.8
14.0	0.8	0.8	0.8	0.8	0.9	0.9	1.0	1.1	1.3	1.5	1.8
16.0	0.8	0.8	0.8	0.8	0.9	0.9	1.0	1.1	1.3	1.5	1.8
18.0	0.8	0.8	0.8	0.8	0.9	1.0	1.1	1.2	1.4	1.6	2.0
20.0	0.8	0.8	0.8	0.8	0.9	1.0	1.2	1.2	1.4	1.6	2.0
22.0	0.8	0.9	0.9	0.9	1.0	1.1	1.3	1.3	1.5	1.8	2.0
25.0	0.9	0.9	1.0	1.0	1.0	1.2	1.3	1.5	1.5	1.8	2.2
28.0	1.0	1.0	1.1	1.1	1.1	1.3	1.4	1.8	1.8	2.0	2.2
30.0	1.1	1.1	1.2	1.2	1.2	1.4	1.5	1.8	1.8	2.1	2.4
32.0	1.2	1.2	1.3	1.3	1.3	1.5	1.6	2.0	2.0	2.3	2.6
35.0	1.3	1.3	1.4	1.4	1.4	1.6	1.7	2.3	2.3	2.5	2.8
38.0	1.4	1.4	1.5	1.5	1.5	1.7	1.8	2.3	2.3	2.7	3.0
40.0	1.5	1.5	1.6	1.6	1.6	1.8	2.0	2.5	2.5	2.8	3.3
45.0	1.6	1.6	1.7	1.8	1.8	2.0	2.3	2.8	2.8	3.0	3.5
50.0	1.8	1.8	1.8	2.0	2.0	2.3	2.5	3.0	3.0	3.3	3.8
55.0	2.0	2.0	2.0	2.2	2.2	2.5	2.8	3.3	3.3	3.5	3.8
60.0	2.3	2.3	2.3	2.4	2.4	2.8	3.0	3.4	3.4	3.8	4.0
70.0	2.5	2.5	2.5	2.6	2.6	3.0	3.3	3.5	3.6	4.0	4.0
80.0	2.8	2.8	2.8	2.8	2.8	3.3	3.5	3.5	3.6	4.0	4.0
90.0	3.0	3.0	3.0	3.0	3.0	3.5	3.5	3.5	3.6	4.0	4.4
100.0	3.3	3.3	3.3	3.3	3.5	3.8	3.8	3.8	3.8	4.4	4.4
110.0	3.5	3.5	3.5	3.5	3.5	3.8	3.8	3.8	3.8	4.4	4.4
120.0	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	4.8	4.8
130.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	5.2	5.2
140.0	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	5.6	5.6
150.0	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	5.6	5.6
160.0	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	5.6	5.6
180.0	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	6.3	6.3
200.0	5.8	5.8	6.0	6.0	6.0	6.0	6.0	6.0	6.0	7.0	7.0
250.0	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	8.8
300.0	7.5	7.5	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0

NOTE 1 — Permissible variation under specified thickness, 0.3 mm.

NOTE 2 — Thickness shall be measured 10 to 20 mm from the longitudinal edge.

NOTE 3 — For specified thicknesses other than those shown, the tolerances for the next higher thickness shall apply.

NOTE 4 — For thickness measured at any location other than that specified in Note 2, the permissible maximum over tolerance shall be increased by 75%, rounded to the nearest 0.1 mm.

TABLE A2.2
PERMISSIBLE VARIATIONS IN WIDTH AND LENGTH FOR
SHEARED PLATES 40 MM AND UNDER IN THICKNESS; LENGTH ONLY FOR UNIVERSAL MILL PLATES
65 MM AND UNDER IN THICKNESS

Specified Dimensions, mm		Permissible Variations Over Specified Width and Length ^A for Thicknesses Given in Millimeters, mm							
Length	Width	To 10, Excl.		10 to 16, Excl.		16 to 25, Excl.		25 to 50, Incl. ^B	
		Width	Length	Width	Length	Width	Length	Width	Length
To 3,000 excl.	To 1500, excl.	10	13	11	16	13	19	16	25
	1500 to 2100, excl.	11	16	13	17	16	22	19	25
	2100 to 2700, excl.	13	19	16	22	19	25	25	29
	2700 and over	16	22	19	25	22	29	29	32
3,000 to 6,000 excl.	To 1500, excl.	10	19	13	22	16	25	19	29
	1500 to 2100, excl.	13	19	16	22	19	25	22	32
	2100 to 2700, excl.	14	22	17	24	21	29	25	35
	2700 and over	16	25	19	29	22	32	29	35
6,000 to 9,000, excl.	To 1500, excl.	10	25	13	29	16	32	19	38
	1500 to 2100, excl.	13	25	16	29	19	32	22	38
	2100 to 2700, excl.	14	25	17	32	22	35	25	38
	2700 and over	17	29	22	32	25	35	32	44
9,000 to 12,000, excl.	To 1500, excl.	11	29	13	32	16	35	19	41
	1500 to 2100, excl.	13	32	16	35	19	38	22	41
	2100 to 2700, excl.	14	32	19	35	22	38	25	48
	2700 and over	19	35	22	38	25	41	32	48
12,000 to 15,000, excl.	To 1500, excl.	11	32	13	38	16	41	19	48
	1500 to 2100, excl.	13	35	16	38	19	41	22	48
	2100 to 2700, excl.	16	35	19	38	22	41	25	48
	2700 and over	19	38	22	41	25	44	32	48
15,000 to 18,000, excl.	To 1500, excl.	13	44	16	48	19	48	22	57
	1500 to 2100, excl.	16	44	19	48	22	48	25	57
	2100 to 2700, excl.	16	44	19	48	22	48	29	57
	2700 and over	22	44	25	51	29	57	32	64
18,000 and over	To 1500, excl.	14	51	19	54	22	57	25	70
	1500 to 2100, excl.	19	51	22	54	25	57	29	70
	2100 to 2700, excl.	19	51	22	54	25	57	32	70
	2700 and over	25	51	29	60	32	64	35	76

^A Permissible variation under in specified width and length: 6 mm.

^B Permissible variations in length apply also to Universal Mill plates up to 300 mm in width for thicknesses over 50 to 65 mm, incl., except for alloy steel up to 50 mm thick.

TABLE A2.3
PERMISSIBLE VARIATIONS IN ROLLED WIDTH FOR UNIVERSAL
MILL CARBON STEEL, HIGH-STRENGTH LOW-ALLOY STEEL PLATES,
AND ALLOY STEEL PLATES 400 MM AND UNDER IN THICKNESS

Specified Width, mm	Variations Over Specified Width for Thickness Given, mm					
	To 10, Excl.	10 to 16, Excl.	16 to 25, Excl.	25 to 50, Excl.	Over 50 to 250, Incl.	Over 250 to 400, Incl.
Over 200 to 500, excl.	3	3	5	6	10	13
500 to 900, excl.	5	6	8	10	11	14
900 and over	8	10	11	13	14	16

NOTE 1 — Permissible variation under specified width shall be 3 mm.

TABLE A2.4
PERMISSIBLE VARIATIONS IN DIAMETER FOR
SHEARED CIRCULAR CARBON STEEL, HIGH-
STRENGTH LOW-ALLOY STEEL, AND ALLOY STEEL
PLATES 25 MM AND UNDER IN THICKNESS

Specified Diameters, mm	Permissible Variations Over Specified Diameter for Thicknesses Given, mm		
	To 10, Excl.	10 to 16, Excl.	16 to 25, Incl.
To 800, excl.	6	10	13
800 to 2100, excl.	8	11	14
2100 to 2700, excl.	10	13	16
2700 to 3300, excl.	11	14	17
3300 and over	13	16	19

NOTE 1 — No permissible variations under specified diameter.

TABLE A2.6
PERMISSIBLE VARIATIONS IN DIAMETER FOR
GAS-CUT CIRCULAR CARBON STEEL AND
HIGH-STRENGTH LOW-ALLOY STEEL PLATES

Specified Diameters, mm	Variations Over Specified Diameter for Thicknesses Given, mm					
	To 25, Excl.	25 to 50, Excl.	50 to 100, Excl.	100 to 150, Excl.	150 to 200, Excl.	200 to 400, Excl.
To 800, excl.	10	10	13	13	16	19
800 to 2100, excl.	10	13	13	16	19	22
2100 to 2700, excl.	13	14	16	19	22	25
2700 to 3300, excl.	13	14	17	22	25	29
3300 and over	16	19	22	25	29	32

NOTE 1 — No permissible variations under specified diameter.

TABLE A2.5
PERMISSIBLE VARIATIONS IN WIDTH AND LENGTH
FOR RECTANGULAR CARBON STEEL AND HIGH-
STRENGTH LOW-ALLOY STEEL PLATES WHEN GAS
CUTTING IS SPECIFIED OR REQUIRED

Specified Thickness, mm	Variations Over for All Specified Widths or Lengths, mm
To 50, excl.	13
50 to 100, excl.	16
100 to 150, excl.	19
150 to 200, excl.	22
200 to 400, incl.	25

NOTE 1 — These variations may be taken all under or divided over and under, if so specified.

NOTE 2 — Plates with universal rolled edges will be gas cut to length only.

TABLE A2.7
PERMISSIBLE CAMBER FOR CARBON STEEL
SHEARED OR GAS-CUT RECTANGULAR PLATES
ALL THICKNESSES

Maximum permissible camber, mm = length in millimeters/500

NOTE 1 — Camber, as it relates to plates, is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

TABLE A2.8
PERMISSIBLE CAMBER FOR CARBON STEEL,
HIGH-STRENGTH LOW-ALLOY STEEL, AND
ALLOY STEEL UNIVERSAL MILL PLATES
AND HIGH-STRENGTH LOW-ALLOY STEEL
AND ALLOY STEEL SHEARED OR GAS-CUT
RECTANGULAR PLATES

Width, mm	Camber for Width Given, mm
To 750, incl.	Length/300
Over 750 to 1500	Length/250

NOTE 1 — Camber, as it relates to plates, is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

TABLE A2.9
PERMISSIBLE VARIATIONS FROM FLATNESS FOR CARBON STEEL PLATES

Specified Thickness, mm	Permissible Variations from a Flat Surface for Specified Widths, mm										
	To 900, Excl.	900 to 1200	1200 to 1500	1500 to 1800	1800 to 2100	2100 to 2400	2400 to 2700	2700 to 3000	3000 to 3600	3600 to 4200	4200 and Over
To 6, excl.	14	19	24	32	35	38	41	44	48	...	...
6 to 10, excl.	13	16	19	24	29	32	35	38	41	...	...
10 to 12, excl.	13	14	16	16	19	22	25	29	32	48	54
12 to 20, excl.	11	13	14	16	16	19	25	25	29	38	51
20 to 25, excl.	11	13	14	16	16	16	19	22	25	35	44
25 to 50, excl.	10	13	13	14	14	16	16	16	18	29	38
50 to 100, excl.	8	10	11	13	13	13	13	14	16	22	29
100 to 150, excl.	10	11	13	13	14	14	16	19	22	22	25
150 to 200, excl.	11	13	13	16	18	19	22	22	25	25	25
200 to 250, excl.	13	13	16	18	19	21	22	24	25	25	25
250 to 300, excl.	13	16	19	21	22	24	25	25	25	25	25
300 to 400, incl.	16	19	21	22	24	25	25	25	25	25	...

NOTE 1 — *Flatness Variations for Length* — The longer dimension specified is considered the length, and variation in flatness along the length shall not exceed the tabular amount for the specified width in plates up to 4000 mm in length, or in any 4000 mm of longer plates.

NOTE 2 — *Flatness Variations for Width* — The flatness variation across the width shall not exceed the tabular amount for the specified width.

NOTE 3 — When the longer dimension is under 900 mm, the variation in flatness along the length and across the width shall not exceed 6 mm in each direction. When the longer dimension is from 900 to 1800 mm, inclusive, the flatness variation shall not exceed 75% of the tabular amount for the specified width, but in no case less than 6 mm.

NOTE 4 — The tolerances given in this table apply to plates that have a minimum specified tensile strength not over 415 MPa or comparable chemistry or hardness. For plates specified to a higher minimum tensile strength or comparable chemistry or hardness, the limits given in the table are increased to $1\frac{1}{2}$ times the amounts in the above table.

NOTE 5 — This table and notes cover the flatness tolerances of circular and sketch plates, based on the maximum dimensions of those plates.

NOTE 6 — Plates shall be in a horizontal position on a flat surface when flatness is measured.

TABLE A2.10
PERMISSIBLE VARIATIONS IN WIDTH AND LENGTH
FOR RECTANGULAR ALLOY STEEL PLATES WHEN
GAS CUTTING IS SPECIFIED OR REQUIRED

Specified Thickness, mm	Variations Over for All Specified Widths and Lengths, mm
To 50, excl.	19
50 to 100, excl.	25
100 to 150, excl.	29
150 to 200, excl.	33
200 to 400, incl.	38

NOTE 1 — These variations may be taken all under or divided over and under, if so specified.

NOTE 2 — Plates with universal rolled edges will be gas cut to length only.

TABLE A2.11
PERMISSIBLE VARIATIONS IN DIAMETER FOR
GAS CUT CIRCULAR ALLOY STEEL PLATES

Specified Diameter, mm	Variations Over Specified Diameter for Thicknesses Given, mm					
	To 25, Excl.	25 to 50, Excl.	50 to 100, Excl.	100 to 150, Excl.	150 to 200, Excl.	200 to 400, Incl.
To 800, excl.	13	13	19	19	25	25
800 to 2100, excl.	13	16	22	25	29	32
2100 to 2700, excl.	16	19	25	29	32	35
2700 to 3300, incl.	22	25	29	32	35	38

NOTE 1 — No permissible variations under specified diameter.

TABLE A2.12
PERMISSIBLE VARIATIONS FROM FLATNESS FOR HIGH-STRENGTH LOW-ALLOY STEEL AND
ALLOY STEEL PLATES

Specified Thickness, mm	Flatness Tolerances for Specified Widths, mm										
	To 900, Excl.	900 to 1200	1200 to 1500	1500 to 1800	1800 to 2100	2100 to 2400	2400 to 2700	2700 to 3000	3000 to 3600	3600 to 4200	4200 and Over
To 6, excl.	21	29	35	48	51	57	60	67	70	...	...
6 to 10, excl.	19	24	29	35	44	48	51	57	60	...	...
10 to 12, excl.	19	22	24	24	29	33	38	41	48	70	79
12 to 20, excl.	16	19	21	22	25	29	32	35	41	57	76
20 to 25, excl.	16	19	22	22	24	25	29	33	38	51	67
25 to 50, excl.	14	16	19	21	22	24	25	25	25	41	57
50 to 100, excl.	13	14	18	19	19	19	19	22	25	32	41
100 to 150, excl.	14	18	19	19	22	22	24	29	32	32	38
150 to 200, excl.	16	19	19	24	25	29	32	33	38	38	38
200 to 250, excl.	19	21	24	25	29	32	33	35	38	38	38
250 to 300, excl.	19	24	29	32	33	35	38	38	38	38	38
300 to 400, incl.	22	25	30	33	35	38	38	38	38	38	38

NOTE 1 — *Flatness Tolerances for Length* — The longer dimension specified is considered the length, and variations from a flat surface along the length shall not exceed the tabular amount for the specified width in plates up to 4000 mm in length, or in any 4000 mm of longer plates.

NOTE 2 — *Flatness Tolerances for Width* — The flatness variation across the width shall not exceed the tabular amount for the specified width.

NOTE 3 — When the longer dimension is under 900 mm, the variation shall not exceed 10 mm. When the larger dimension is from 900 to 1800 mm, incl., the variation shall not exceed 75% of the tabular amount for the specified width.

NOTE 4 — This table and notes cover the tolerances for flatness of circular and sketch plates, based on the maximum dimensions of those plates.

NOTE 5 — Plates shall be in a horizontal position on a flat surface when flatness is measured.

TABLE A2.13
WAVINESS TOLERANCES FOR RECTANGULAR PLATES,
UNIVERSAL MILL PLATES, CIRCULAR PLATES, AND SKETCH PLATES

Flatness Tolerance from Tables A2.9 and A2.12	When Number of Waves in 4000 mm is:						
	1	2	3	4	5	6	7
8	8	6	5	3	3	2	2
10	10	8	5	5	3	2	2
11	11	8	6	5	3	3	2
13	13	10	8	5	5	3	2
14	14	11	8	6	5	3	2
16	16	13	10	6	5	3	2
17	17	13	10	8	5	5	2
19	19	14	11	8	6	5	2
21	21	16	11	8	6	5	2
22	22	17	13	10	6	5	2
24	24	17	13	10	8	6	5
25	25	19	14	11	8	6	5
29	29	22	16	13	10	6	5
32	32	24	17	13	10	8	6
35	35	27	19	14	11	8	6
38	38	29	22	16	13	10	6
41	41	32	24	17	13	10	8
44	44	33	25	19	14	11	8
48	48	37	27	21	14	11	8
51	51	38	29	22	16	13	10
54	54	41	30	22	17	13	10
57	57	43	32	24	17	14	10
60	60	46	33	25	19	14	11
64	64	48	37	27	21	14	11
67	67	51	38	29	21	16	11
70	70	52	40	29	22	16	13
73	73	56	41	30	24	17	13
76	76	57	43	32	24	17	14
79	79	60	44	33	25	19	14

NOTE 1 — Waviness denotes the deviation of the top or bottom surface from a horizontal line, when the plate is resting on a flat surface, as measured in an increment of less than 4000 mm of length. The waviness tolerance is a function of the flatness tolerance as obtained from Tables A2.9 and A2.12.

TABLE A2.14
VISIBLE EDGE INDICATIONS EXTENDING APPROXIMATELY PARALLEL TO ROLLED SURFACES

Plate Specification and Thickness	Acceptable		Remove by Grinding		Acceptable on Edges Cut in Fabrication	
	Depth	Length ^A	Depth	Length ^A	Depth	Length ^A
Column	1	2	3	4	5	6
Other than killed, ^B to 50 mm, incl.	3 mm, max.	Any	Over 3 to 6 mm, incl.	Over 25 mm	6 mm max.	Any
Killed, ^C to 150 mm, incl.	2 mm, max.	Any	Over 2 to 3 mm, incl.	Over 25 mm	3 mm max.	Any
Killed, ^C over 150 mm	3 mm, max.	Any	Over 3 to 13 mm, incl.	Over 25 mm	13 mm max.	Any

^A Laminar-type discontinuities 25 mm and less in length are acceptable and do not require exploration.

^B Specifications: A 285; A 433; A 442 in thicknesses to 25 mm, incl.; or A 455.

^C The specifications in 1.1 of this Standard, other than those listed in the above Table Footnote B.

TABLE A2.15
GENERALLY AVAILABLE GRADE-THICKNESS-MINIMUM TEST TEMPERATURE COMBINATIONS
MEETING CHARPY V-NOTCH REQUIREMENTS INDICATED
(NORMALIZED OR QUENCHED AND TEMPERED CONDITION)

Acceptance Criteria Charpy V-Notch			Test Temperature, °C, for Plate Thicknesses (Unless Otherwise Agreed Upon)				
Energy Absorption							
Class ^A	Minimum Average For 3 Specimens ^B , J	Minimum for 1 Specimen ^B , J	Specification and Grade				
				25 mm and Under	Over 25 mm to 50 mm, Incl.	Over 50 mm to 75 mm, Incl.	Over 75 mm to 125 mm, Incl.
I	14	10	A 285 Grade A	+4	+16	...	...
			A 285 Grade B	+10	+21	...	...
			A 285 Grade C	+16	+27	...	...
II	18	14	A 455	-4	...	...	...
III	18	14	A 203 Grade A	-68	-68	-60	...
			A 203 Grade D	-101	-101	-87	...
			A 442 Grade 55 (38 mm max. thickness)	...	-29	...	...
			A 442 Grade 60 (38 mm max. thickness)	...	-26	...	...
			A 516 Grade 55	-51	-51	-46	-46
			A 516 Grade 60	-51	-46	-46	-46
			A 516 Grade 65	-51	-46	-40	-32
			A 537 Class 1 (Over 64-100 mm)	...	...	-60	-46
			A 662 Grade A	-60	-60	...	...
			A 662 Grade B	-51	-51	...	...
IV	20	16	A 203 Grade B	-68	-68	-60	...
			A 203 Grade E	-101	-101	-87	...
			A 203 Grade F (100 mm max.)	...	...	-107	-107
			A 299	-7	-1	-1	+4
			A 516 Grade 70	-46	-40	-35	-29
			A 537 Class 1 (64 mm max.)	-62	-60	-60	...
			A 537 Class 2 (Over 64-100 mm)	...	...	-60	-46
			A 662 Grade C	-46	-46	...	...

TABLE A2.15
 GENERALLY AVAILABLE GRADE-THICKNESS-MINIMUM TEST TEMPERATURE COMBINATIONS
 MEETING CHARPY V-NOTCH REQUIREMENTS INDICATED
 (NORMALIZED OR QUENCHED AND TEMPERED CONDITION) (CONT'D)

Acceptance Criteria Charpy V-Notch			Test Temperature, °C, for Plate Thicknesses (Unless Otherwise Agreed Upon)				
Energy Absorption			Specification and Grade	25 mm and Under	Over	Over	Over
Class ⁴	Minimum Average For 3 Specimens ^B , J	Minimum for 1 Specimen ^B , J			25 mm to 50 mm, Incl.	50 mm to 75 mm, Incl.	75 mm to 125 mm, Incl.
V	27	20	A 203 Grade F	−107	−107	...	...
			A 537 Class 2 (64 mm max.)	−68	−68	−68	...
			A 612	−46	...	...	...
			A 724 Grade A	−46	...	...	...
Lateral Expansion mm, Minimum Each Specimen Transverse Test							
VI	0.38	...	A 353	−196	−196	...	...
			A 553 Type I	−196	−196	...	...
			A 553 Type II	−170	−170	...	...
			A 645	−170 _C	−170 _C	...	...
			A 517 all (64 mm max. thickness)			...	...
			A 724 Grade B	−46	...	...	...

NOTE 1 — The minimum temperatures listed are for longitudinal tests. For transverse tests, the available minimum temperature may be somewhat higher.

^A Class I is *Other Than Killed* with a specified minimum tensile strength of 450 MPa or lower.

Class II is *Other Than Killed* with a specified minimum tensile strength of over 450 to 520 MPa, incl.

Class III is *Killed* with a specified minimum tensile strength of 450 MPa or lower.

Class IV is *Killed* with a specified minimum tensile strength of over 450 to 520 MPa, incl.

Class V is *Killed* with a specified minimum tensile strength of over 520 MPa to but not including 655 MPa.

Class VI is *Killed* with a specified minimum tensile strength of 655 MPa or over.

^B Full size (10 by 10 mm) specimens.

^C Testing temperature as specified in the purchase order, but no higher than 0°C.

TABLE A2.16
PERMISSIBLE VARIATIONS IN WIDTH FOR MILL
EDGE CARBON STEEL AND HIGH-STRENGTH LOW-
ALLOY STEEL PLATES PRODUCED ON STRIP MILLS

Specified Width, mm	Variations Over Specified Width, mm ⁴
To 360, excl.	11
360 to 430, excl.	13
430 to 480, excl.	14
480 to 530, excl.	16
530 to 610, excl.	17
610 to 660, excl.	21
660 to 710, excl.	24
710 to 890, excl.	29
890 to 1270, excl.	32
1270 to 1520, excl.	38
1520 to 1650, excl.	41
1650 to 1780, excl.	44
1780 to 2030, excl.	47
2030 and over	51

NOTE 1 — Applies to plates produced from coil and plates produced from plate-as-rolled.

⁴ No permissible variation under specified width.

APPENDICES

(Nonmandatory Information)

X1. COILED STEEL

X1.1 Continuous wide hot strip rolling mills are normally equipped with coilers. Regardless of the different types of systems employed during or following the rolling operations, it is common for the steel to be reeled into the coiler at temperatures in the stress-relieving range. In general, such temperatures are higher as the steel thickness increases. The coils subsequently cool to ambient temperature with outer and inner laps cooling more rapidly than central laps. The difference in cooling rate can result in measurable differences in the mechanical properties throughout a coil. Data confirm reduced yield and tensile strength, and increased percent elongation, for the product with slower cooling rates from the coiling temperature to ambient. Such differences are in addition to the effects on mechanical properties caused by differences in heat analysis and chemical segregation.

X2. VARIATION OF TENSILE PROPERTIES IN PLATE-AS-ROLLED

X2.1 The tension requirements of this general requirements specification are intended only to characterize the tensile properties of a plate-as-rolled for determination of conformance to the requirements of the applicable product specifications. Such testing procedures are not intended to define the upper or lower limits of tensile properties at all possible test locations within a plate-as-rolled. It is well known and documented that tensile properties vary within a plate-as-rolled or individual piece of steel as a function of chemical composition, processing, testing procedure, and other factors. It is, therefore, incumbent on designers and engineers to use sound engineering judgement when using tension test results shown on mill test reports. The testing procedures of this general requirements specification have been found to provide plate adequate for normal pressure vessel design criteria.

X2.2 A survey of the variation to be expected in tensile properties obtained from plates and structural shapes was conducted by the American Iron and Steel Institute (AISI). The results of this survey are contained in a *Contributions to the Metallurgy of Steel* entitled "The Variation of Product Analysis and Tensile Properties—Carbon Steel Plates, and Wide Flange Shapes" (SU/18, SU/19, and SU/20), published in September 1974. The data are presented in tables of probability that tensile properties at other than

the official location may differ from those of the reported test location.

X2.3 This general requirements specification contains no requirements applicable to product tension tests; conformance to the applicable product specification is determined on the basis of tests performed at the place of manufacture or processing prior to shipment, unless otherwise specified.

X2.4 A Task Group of ASTM Subcommittee A01.11 has determined, based on review of the AISI data (SU20), that the variation in tensile properties within a plate-as-rolled can be expressed as a function of specified requirements; one standard deviation equals approximately 3% of required tensile strength, 5% of required yield strength, and 3 percentage points of required elongation.

X3. VARIATION IN CHARPY V-NOTCH TESTS

X3.1 A survey of the variation to be expected in Charpy V-Notch test results obtained from three common fine grain plate steels was conducted by the American Iron and Steel Institute (AISI). The results of the survey are contained in a *Contributions to the Metallurgy of Steel* entitled, "The Variations of Charpy V-Notch Impact Test Properties in Steel Plates," (SU/24), published January 1979. The survey data consists of test values obtained from six locations in addition to the locations specified in 12.1.3 of this specification. The plate conditions tested involved as-rolled, normalized, and quench and tempered. Sufficient full-size specimens were taken from each sample so that three longitudinal and three transverse specimens could be broken at three test temperatures defined for each grade. The data is presented in tables of probability that impact properties at other than the official location which may differ from those of the reported test location. Additional data of the same type, but utilizing samples from thicker plates, was published by AISI as SU/27.

X4. RADIUS FOR COLD BENDING

X4.1 Suggested minimum inside bend radii for cold forming are referenced to group Designations A through F as defined in Table X4.1. The suggested radii listed in Table X4.2 should be used as minimums in typical shop fabrication. Material that does not form satisfactorily when fabricated in accordance with Table X4.2 may be subject to rejection pending negotiation with the steel supplier.

When tighter bends are required, the manufacturer should be consulted.

X4.2 The bend radius and the radius of the male die should be as liberal as the finished part will permit. The width across the shoulders of the female die should be at least 8 times the plate thickness. Higher strength steels require larger die openings. The surface of the dies in the area of radius should be smooth.

X4.3 Since cracks in cold bending commonly originate from the outside edges, shear burrs and gas cut edges should be removed by grinding. Sharp corners on edges and on punched or gas cut holes should be removed by chamfering or grinding to a radius.

X4.4 If possible, parts should be formed such that the bend line is perpendicular to the direction of final rolling.

If it is necessary to bend with the bend line parallel to the direction of final rolling, a more generous radius is suggested ($1\frac{1}{2}$ times applicable value given in Table X4.2 for bend lines perpendicular to the direction of rolling).

X4.5 References

Holt, G. E., et al. "Minimum Cold Bend Radii Project—Final Report," Concurrent Technologies Corporation, January 27, 1997.

Brockenbrough, R. L., "Fabrication Guidelines for Cold Bending," R. L. Brockenbrough & Associates, June 28, 1998.

Both of these references are available from American Iron and Steel Institute, 1101 17th Street NW, Washington, DC 20036-4700.

TABLE X4.1
GROUP DESIGNATIONS FOR COLD BENDING

Specification	Class Where Applicable	Grade Where Applicable	Group Designation ^A
A 202/A 202M	...	A	D
		B	E
A 203/A 203M	...	A, D	B
		B, E	C
		F	D
A 204/A 204M	...	A	B
		B	C
		C	D
A 225/A 225M	...	C, D	D
A 285/A 285M	...	A, B, C	A
A 299/A 299M	...	A, B	D
A 302/A 302M	...	A, C, D	D
		B	E
A 353/A 353M	...	...	D
A 387/A 387M	1, 2	2, 11, 12	C
	1	5, 9, 21, 21L, 22, 22L	E
	2	5, 9, 21, 22, 91	E
A 455/A 455M	...	...	C
A 515/A 515M	...	60 or 65	B
		70	C
A 516/A 516M	...	55	A
		60, 65	B
		70	C
A 517/A 517M	...	A, B, C, E, F, H, J, K, M, P, Q, S, T	F
A 533/A 533M	1, 2, 3	A, B, C, D	E
A 537/A 537M	1, 2 ^B , 3 ^B	...	C
	2 ^C , 3 ^C	...	D
A 542/A 542M ^D	1, 2	...	F
	3, 4	...	D
	4a	...	E
A 543/A 543M	1, 2, 3	B, C	F
A 553/A 553M ^D	...	...	D
A 562/A 562M	...	...	A
A 612/A 612M	...	...	C
A 645/A 645M	...	...	D
A 662/A 662M	...	A, B	B
		C	C
A 724/A 724M	...	A, C	D
		B	E
A 734/A 734M ^D	...	...	D
A 735/A 735M	1, 2, 3, 4	...	E
A 736/A 736M	1, 2, 3	A, C	D
A 737/A 737M	...	B, C	B
A 738/A 738M	...	A, B	D
		C ^B	C
		C ^C	D
A 782/A 782M	1, 2	...	E
	3	...	F
A 832/A 832M	...	21V, 22V, 23V	E
A 841/A 841M	1, 2	A, B, C	C
	3	D	F
A 844/A 844M	...	...	D
A 1017/A 1017M	...	23, 122	D
		911	E
A 1041/A 1041M	...	315, 315T	F

^A Steels in Groups A to E inclusive are grouped on the basis of similar specified values for minimum elongation in 2 in. [50 mm]; Group F includes steels that have a specified minimum elongation in 2 in. [50 mm] of 16 or less, and steels that have a ratio of specified minimum tensile strength to specified minimum yield strength of 1.15 or less.

^B For thicknesses of 4 in. [100 mm] and less.

^C For thicknesses over 4 in. [100 mm].

^D For any type.

TABLE X4.2
SUGGESTED MINIMUM INSIDE RADII FOR
COLD BENDING^A

Group Designation ^B	Thickness (t), in. [mm]			
	Up to ¾ in. [20 mm]	Over ¾ in. [20 mm]	Over 1 in. [25 mm]	Over 2 in. [50 mm]
		to 1 in. [25 mm], Incl.	to 2 in. [50 mm], Incl.	
A	1.5t	1.5t	1.5t	1.5t
B	1.5t	1.5t	1.5t	2.0t
C	1.5t	1.5t	2.0t	2.5t
D	1.5t	1.5t	2.5t	3.0t
E	1.5t	1.5t	3.0t	3.5t
F	1.75t	2.25t	4.5t	5.5t

^A Values are for bend lines perpendicular to the direction of final rolling. These radii apply when the precautions listed in X4.2 are followed. If bend lines are parallel to the direction of final rolling, multiply values by 1.5.

^B Steels specifications included in the group designations may not include the entire thickness range shown in this table.

SPECIFICATION FOR STEEL BARS, CARBON AND ALLOY, HOT-WROUGHT, GENERAL REQUIREMENTS FOR



SA-29/SA-29M



(Identical with ASTM Specification A 29/A 29M-05.)

1. Scope

1.1 This specification covers a group of common requirements which, unless otherwise specified in the purchase order or in an individual specification, shall apply to carbon and alloy steel bars under each of the following ASTM specifications (or under any other ASTM specification which invokes this specification or portions thereof):

Title of Specification	ASTM Designation ^A
<i>Hot-Rolled Carbon Steel Bars:</i>	
Steel Bars, Carbon, Quenched and Tempered	A 321
Steel Bars and Shapes, Carbon Rolled from "T" Rails	A 499
Steel Bars, Carbon, Merchant Quality, M-Grades	A 575
Steel Bars, Carbon, Hot-Wrought, Special Quality	A 576
Steel Bars, Carbon, Merchant Quality, Mechanical Properties	A 663/A 663M
Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties	A 675/A 675M
Steel Bars for Springs, Carbon and Alloy	A 689
<i>Cold-Finished Carbon Steel Bars:</i>	
Steel Bars, Carbon and Alloy, Cold-Finished	A 108
Cold-Drawn Stress-Relieved Carbon Steel Bars Subject to Mechanical Property Requirements	A 311/A 311M
<i>Hot-Rolled Alloy Steel Bars:</i>	
Steel Bars, Alloy, Standard Grades	A 322
Carbon and Alloy Steel Bars Subject to End-Quench Hardenability Requirements	A 304
Steel Bars, Alloy, Hot-Wrought or Cold-Finished, Quenched and Tempered	A 434
Steel Bars, Alloy, Hot-Wrought, for Elevated Temperature or Pressure-Containing Parts, or Both	A 739
<i>Cold-Finished Alloy Steel Bars:</i>	
Steel Bars, Alloy, Hot-Rolled or Cold-Finished, Quenched and Tempered	A 434

Title of Specification	ASTM Designation ^A
Steel Bars, Carbon, Hot-Wrought or Cold-Finished, Special Quality, for Pressure Piping Components	A 696

^AThese designations refer to the latest issue of the respective specifications, which appear either in the *Annual Book of ASTM Standards*, Vol 01.05, or as reprints obtainable from ASTM.

1.2 In case of any conflict in requirements, the requirements of the purchase order, the individual material specification, and this general specification shall prevail in the sequence named.

1.3 The values stated in inch-pound units or SI units are to be regarded as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.4 For purposes of determining conformance to this specification and the various material specifications referenced in 1.1, dimensional values shall be rounded to the nearest unit in the right-hand place of figures used in expressing the limiting values in accordance with the rounding method of Practice E 29.

NOTE 1 — Specification A 29 previously listed dimensional tolerances for cold-finished bars; these are now found in Specification A 108.

2. Referenced Documents

2.1 ASTM Standards:

A 108 Specification for Steel Bars, Carbon and Alloy, Cold-Finished

- A 304 Specification for Carbon and Alloy Steel Bars Subject to End-Quench Hardenability Requirements
- A 311/A 311M Specification for Cold-Drawn, Stress-Relieved Carbon Steel Bars Subject to Mechanical Property Requirements
- A 321 Specification for Steel Bars, Carbon, Quenched and Tempered
- A 322 Specification for Steel Bars, Alloy, Standard Grades
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 434 Specification for Steel Bars, Alloy, Hot-Wrought or Cold-Finished, Quenched and Tempered
- A 499 Specification for Steel Bars and Shapes, Carbon Rolled from "T" Rails
- A 575 Specification for Steel Bars, Carbon, Merchant Quality, M-Grades
- A 576 Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality
- A 663/A 663M Specification for Steel Bars, Carbon, Merchant Quality, Mechanical Properties
- A 675/A 675M Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties
- A 689 Specification for Carbon and Alloy Steel Bars for Springs
- A 696 Specification for Steel Bars, Carbon, Hot-Wrought or Cold-Finished, Special Quality for Pressure Piping Components
- A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment
- A 739 Specification for Steel Bars, Alloy, Hot-Wrought, for Elevated Temperature or Pressure-Containing Parts, or Both
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E 112 Test Methods for Determining Average Grain Size

2.2 Federal Standards:

- Fed. Std. No. 123 Marking for Shipment (Civil Agencies)
- Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products

2.3 Military Standard:

- MIL-STD-163 Steel Mill Products—Preparation for Shipment and Storage

2.4 Other Standards:

- AIAG B-1 Bar Code Symbology Standard for 3-of-9 Bar Codes
- AIAG B-5 02.00 Primary Metals Tag Application Standard

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

- 3.1.1 Hot-Wrought Steel Bars** — Steel bars produced by hot forming ingots, blooms, billets, or other semifinished

forms to yield straight lengths (or coils, depending upon size, section, and mill equipment) in sections that are uniform throughout their length, and in the following sections and sizes:

3.1.1.1 Rounds — $\frac{7}{32}$ to 10.0 in. [5.5 to 250 mm], inclusive,

3.1.1.2 Squares — $\frac{7}{32}$ to 6.0 in. [6 to 160 mm], inclusive,

3.1.1.3 Round-Cornered Squares — $\frac{7}{32}$ to 8.0 in. [6 to 200 mm], inclusive,

3.1.1.4 Flats — $\frac{1}{4}$ to 8 in. inclusive, in width: $\frac{13}{64}$ in. in minimum thickness up to 6 in. in width; and 0.230 in. in minimum thickness for over 6 to 8 in. in width, inclusive [over 5 mm in thickness up to 150 mm in width; and over 6 mm in thickness for over 150 mm through 200 mm in width]. Maximum thickness for all widths is 4 in. [100 mm].

3.1.1.5 Hexagons and Octagons — $\frac{1}{4}$ to $4\frac{1}{16}$ in. [6 to 103 mm], inclusive, between parallel surfaces,

3.1.1.6 Bar Size Shapes — Angles, channels, tees, zees, when their greatest cross-sectional dimension is under 3 in. [75 mm], and

3.1.1.7 Special Bar Sections — Half-rounds, ovals, half-ovals, other special bar size sections.

3.1.2 Cold-Finished Steel Bars — Steel bars produced by cold finishing previously hot-wrought bars by means of cold drawing, cold forming, turning, grinding, or polishing (singly or in combination) to yield straight lengths or coils in sections that are uniform throughout their length and in the following sections and sizes:

3.1.2.1 Rounds — 9 in. [230 mm] and under in diameter,

3.1.2.2 Squares — 6 in. [150 mm] and under between parallel surfaces,

3.1.2.3 Hexagons — 4 in. [100 mm] and under between parallel surfaces,

3.1.2.4 Flats — $\frac{1}{8}$ in. [3 mm] and over in thickness and not over 12 in. [300 mm] in width, and

3.1.2.5 Special Bar Sections:

3.1.3 Lot — Unless otherwise specified in the contract or order, a lot shall consist of all bars submitted for inspection at the same time of the same heat, condition, finish, size, or shape. For bars specified in the quenched and tempered condition, when heat treated in batch-type furnaces, a lot shall consist of all bars from the same heat, of the same prior condition, the same size, and subjected to the same heat treatment in one tempering charge. For bars specified in the quenched and tempered condition, when heat treated without interruption in a continuous-type furnace, a lot shall consist of all bars from the same

heat, of the same prior condition, of the same size, and subjected to the same heat treatment.

4. Chemical Composition

4.1 Limits:

4.1.1 The chemical composition shall conform to the requirements specified in the purchase order or the individual product specifications. For convenience the grades commonly specified for carbon steel bars are shown in Tables 1 and 2. Bars may be ordered to these grade designations and when so ordered shall conform to the specified limits by heat analysis.

4.1.2 When compositions other than those shown in Tables 1 and 2 are required, the composition limits shall be prepared using the ranges and limits shown in Table 3 for carbon steel and Table 4 for alloy steel.

4.2 Heat or Cast Analysis:

4.2.1 The chemical composition of each heat or cast shall be determined by the manufacturer in accordance with Test Methods, Practices, and Terminology A 751.

4.2.2 The heat or cast analysis shall conform to the requirements specified in the product specification or purchase order. These can be the heat chemical range and limit for a grade designated in Tables 1 and 2, or another range and limit in accordance with 4.1.2, or with requirements of the product specification.

NOTE 2 — Heat analysis for lead is not determinable since lead is added to the ladle stream while each ingot is poured. When specified as an added element to a standard steel, the percentage of lead is reported as 0.15 to 0.35 incl, which is the range commonly specified for this element.

4.2.3 If requested or required, the heat analysis shall be reported to the purchaser or his representative.

4.2.4 Reporting of significant figures and rounding shall be in accordance with Test Methods, Practices, and Terminology A 751.

4.3 Product Analysis:

4.3.1 Merchant quality carbon bar steel is not subject to rejection for product analysis unless misapplication of a heat is clearly indicated.

4.3.2 Analyses may be made by the purchaser from finished bars other than merchant quality representing each heat of open-hearth, basic-oxygen, or electric-furnace steel. The chemical composition thus determined shall not vary from the limits specified in the applicable specification by more than the amounts prescribed in Table 5 and Table 6, but the several determinations of any element, excluding lead, in a heat may not vary both above and below the specified range. Rimmed or capped steel is characterized by a lack of homogeneity in its composition, especially for the elements carbon, phosphorus, and sulfur; therefore,

when rimmed or capped steel is specified or required, the limitations for these elements shall not be applicable. Because of the degree to which phosphorus and sulfur segregate, the limitations for these elements shall not be applicable to rephosphorized or resulfurized steels.

4.3.3 Samples for product analysis shall be taken by one of the following methods:

4.3.3.1 Applicable to small sections whose cross-sectional area does not exceed 0.75 in.² [500 mm²] such as rounds, squares, hexagons, and the like. Chips are taken by milling or machining the full cross section of the piece. Drilling is not a feasible method for sampling sizes 0.75 in.² and smaller.

4.3.3.2 Applicable to products where the width of the cross section greatly exceeds the thickness, such as bar size shapes and light flat bars. Chips are taken by drilling entirely through the steel at a point midway between the edge and the middle of the section, or by milling or machining the entire cross section.

4.3.3.3 Applicable to large rounds, squares semi-finished, etc. Chips are taken at any point midway between the outside and the center of the piece by drilling parallel to the axis or by milling or machining the full cross section. In cases where these methods are not practicable, the piece may be drilled on the side, but chips are not taken until they represent the portion midway between the outside and the center.

4.3.3.4 When the steel is subject to tension test requirements, the tension test specimen can also be used for product analysis. In that case, chips for product analysis can be taken by drilling entirely through the tension test specimens or by the method described in 4.3.3.1.

4.3.4 When chips are taken by drilling, the diameter of the drill used shall conform to the following:

Area of Sample Cross Section, in. ² (cm ²)	Approximate Drill Diameter, in. (mm)
16 [100] or less	½ [12.5]
Over 16 [100]	1 [25.0]

4.3.5 The minimum number of samples to be taken from material representing the same heat or lot before rejection by the purchaser shall be as follows:

	Minimum Number of Samples
15 tons [15 Mg] and under	4
Over 15 tons [15 Mg]	6

4.3.6 In case the number of pieces in a heat is less than the number of samples required, one sample from each piece shall be considered sufficient.

4.3.7 In the event that product analysis determinations are outside the permissible limits as prescribed in

4.3.2, additional samples shall be analyzed and the acceptability of the heat negotiated between the purchaser and the producer.

4.4 Referee Analysis — In case a referee analysis is required and agreed upon to resolve a dispute concerning the results of a chemical analysis, the referee analysis shall be performed in accordance with the latest issue of Test Methods, Practices, and Terminology A 751, unless otherwise agreed upon between the manufacturer and the purchaser.

5. Grain Size Requirement

5.1 Austenitic Grain Size:

5.1.1 When a coarse austenitic grain size is specified, the steel shall have a grain size number of 1 to 5 exclusive as determined in accordance with Test Methods E 112. Conformance to this grain size of 70% of the grains in the area examined shall constitute the basis of acceptance. One test per heat shall be made.

5.1.2 When a fine austenitic grain size is specified, the steel shall have a grain size number of 5 or higher as determined in accordance with Test Methods E 112. Conformance to this grain size of 70% of the area examined shall constitute the basis of acceptance. One test per heat shall be made unless the provisions of 5.1.2.1 or 5.1.2.2 are exercised.

5.1.2.1 When aluminum is used as the grain refining element, the fine austenitic grain size requirement shall be deemed to be fulfilled if, on heat analysis, the aluminum content is not less than 0.020% total aluminum or, alternately, 0.015% acid soluble aluminum. The aluminum content shall be reported. The grain size test specified in 5.1.2 shall be the referee test.

5.1.2.2 By agreement between purchaser and supplier, columbium or vanadium or both may be used for grain refining instead of or with aluminum. When columbium or vanadium is used as a grain refining element, the fine austenitic grain size requirement shall be deemed to be fulfilled if, on heat analysis, the columbium or vanadium content is as follows (the content of the elements shall be reported with the heat analysis):

Steels having 0.25% carbon or less:	
Cb	0.025 min
V	0.05 min
Steels having over 0.25% carbon:	
Cb	0.015 min
V	0.02 min
The maximum contents shall be:	
Cb	0.05 max
V	0.08 max
Cb + V	0.06 max

5.1.2.3 When provisions of 5.1.2.1 or 5.1.2.2 are exercised, a grain size test is not required unless specified by the purchaser. Unless otherwise specified, fine austenitic grain size shall be certified using the analysis of grain refining element(s).

5.1.2.4 Referee Test — In the event that the chemical analysis of columbium or vanadium does not meet the requirements of 5.1.2.2, the grain size test shown in 5.1.2 shall be the referee test unless an alternative test method is agreed upon between the manufacturer and the purchaser.

6. Mechanical Property Requirements

6.1 Test Specimens:

6.1.1 Selection — Test specimens shall be selected in accordance with the requirements of the applicable product specification or in accordance with Supplement I of the latest issue of Test Methods and Definitions A 370, in the sequence named.

6.1.2 Preparation — Unless otherwise specified in the applicable product specification, test specimens shall be prepared in accordance with the latest issue of Test Methods and Definitions A 370, and especially Supplement I thereof.

6.2 Methods of Mechanical Testing — All mechanical tests shall be conducted in accordance with the latest issue of Test Methods and Definitions A 370, and especially Supplement I thereof, on steel bar products.

6.3 Retests:

6.3.1 If any test specimen shows defective machining or develops flaws, the specimen may be discarded and another substituted.

6.3.2 If the percentage elongation of any tension specimen is less than that specified and any part of the fracture is more than $\frac{3}{4}$ in. [20 mm] from the center of a 2 in. [50 mm] specimen, or is outside the middle half of the gage length of an 8 in. [200 mm] specimen as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

6.3.3 For “as-wrought” material, if the results for any original tension specimen are within 2000 psi [14 MPa] of the required tensile strength, within 1000 psi [7 MPa] of the required yield point, or within 2% of the required elongation, retesting shall be permitted. If the original testing required only one test, the retest shall consist of two random tests from the heat or lot involved. If the original testing required two tests of which one failed by the amounts listed in this paragraph, the retest shall be made on one random test from the heat or lot. If the results on the retest specimen or specimens meet the specified requirements, the heat or test lot will be accepted. If the results of one retest specimen do not meet the specified requirements, the material is subject to rejection.

6.3.4 For thermally treated bars, if the results of the mechanical tests do not conform to the requirements specified, two more tests may be selected for each bar failing, and each of these retests shall conform to the requirements of the product specification.

6.3.5 If a bend specimen fails, due to conditions of bending more severe than required by the specification, a retest shall be permitted from the heat or test lot involved for which one random specimen for each original specimen showing failure shall be used. If the results on the retest specimen meet the requirements of the specification, the heat or test lot will be accepted.

7. Dimensions, Mass, and Permissible Variations

7.1 Hot-Wrought Bars — The permissible variations for dimensions of hot-wrought carbon and alloy steel bars shall not exceed the applicable limits stated in Annex A1 for inch-pound values and Annex A2 for metric values.

8. Workmanship, Finish, and Appearance

8.1 The material shall be free of injurious defects and shall have a workmanlike finish.

9. Rework and Retreatment

9.1 For thermally treated bars only, the manufacturer may retreat a lot one or more times, and retests shall be made in the same manner as the original tests. Each such retest shall conform to the requirements specified.

10. Inspection

10.1 The inspector representing the purchaser shall have entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

10.2 All required tests and inspection shall be made by the manufacturer prior to shipment.

11. Rejection

11.1 Unless otherwise specified, any rejection because of noncompliance to the requirements of the specification shall be reported by the purchaser to the manufacturer within 30 working days after receipt of samples.

11.2 Material that shows imperfections capable of adversely affecting processability subsequent to its acceptance at the purchaser's works will be rejected, and the manufacturer shall be notified.

12. Rehearing

12.1 Samples that represent rejected material shall be preserved for two weeks from the date rejection is reported to the manufacturer. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

13. Product Marking

13.1 Civilian Procurement — Bars of all sizes, when loaded for shipment, shall be properly identified with the name or brand of manufacturer, purchaser's name and order number, the ASTM designation (year date is not required), grade number where appropriate, size and length, weight of lift, and the heat number for identification. Unless otherwise specified, the method of marking is at the manufacturer's option and may be made by hot stamping, cold stamping, painting, or marking tags attached to the lifts of bars.

13.1.1 Bar code marking may be used as an auxiliary method of identification. Such bar-code markings shall be of the 3-of-9 type and shall conform to AIAG B1. When barcoded tags are used, they shall conform to AIAG B5.

13.2 Government Procurement:

13.2.1 Marking for shipment shall be in accordance with the requirements specified in the contract or order and shall be in accordance with MIL-STD-163 for military agencies and in accordance with Fed. Std. No. 123 for civil agencies.

13.2.2 For government procurement by the Defense Supply Agency, the bars shall be continuously marked for identification in accordance with Fed. Std. No. 183.

14. Packaging

14.1 Civilian Procurement — Unless otherwise specified, the bars shall be packaged and loaded in accordance with Practices A 700.

14.2 Government Procurement — MIL-STD-163 shall apply when packaging is specified in the contract or order, or when Level A for preservation, packaging, and packing is specified for direct procurement by or direct shipment to the government.

15. Keywords

15.1 alloy steel bars; carbon steel bars; cold finished steel bars; general delivery requirements; hot wrought steel bars; steel bars

TABLE 1
GRADE DESIGNATIONS AND CHEMICAL
COMPOSITIONS OF CARBON STEEL BARS

Grade Designation	Heat Chemical Ranges and Limits, %			
	Carbon	Manganese	Phosphorus, max	Sulfur, max ^A
Nonresulfurized Carbon Steels ^{B,C,D,E,F}				
1005	0.06 max	0.35 max	0.040	0.050
1006	0.08 max	0.25–0.40	0.040	0.050
1008	0.10 max	0.30–0.50	0.040	0.050
1010	0.08–0.13	0.30–0.60	0.040	0.050
1011	0.08–0.13	0.60–0.90	0.040	0.050
1012	0.10–0.15	0.30–0.60	0.040	0.050
1013	0.11–0.16	0.50–0.80	0.040	0.050
1015	0.13–0.18	0.30–0.60	0.040	0.050
1016	0.13–0.18	0.60–0.90	0.040	0.050
1017	0.15–0.20	0.30–0.60	0.040	0.050
1018	0.15–0.20	0.60–0.90	0.040	0.050
1019	0.15–0.20	0.70–1.00	0.040	0.050
1020	0.18–0.23	0.30–0.60	0.040	0.050
1021	0.18–0.23	0.60–0.90	0.040	0.050
1022	0.18–0.23	0.70–1.00	0.040	0.050
1023	0.20–0.25	0.30–0.60	0.040	0.050
1025	0.22–0.28	0.30–0.60	0.040	0.050
1026	0.22–0.28	0.60–0.90	0.040	0.050
1029	0.25–0.31	0.60–0.90	0.040	0.050
1030	0.28–0.34	0.60–0.90	0.040	0.050
1034	0.32–0.38	0.50–0.80	0.040	0.050
1035	0.32–0.38	0.60–0.90	0.040	0.050
1037	0.32–0.38	0.70–1.00	0.040	0.050
1038	0.35–0.42	0.60–0.90	0.040	0.050
1039	0.37–0.44	0.70–1.00	0.040	0.050
1040	0.37–0.44	0.60–0.90	0.040	0.050
1042	0.40–0.47	0.60–0.90	0.040	0.050
1043	0.40–0.47	0.70–1.00	0.040	0.050
1044	0.43–0.50	0.30–0.60	0.040	0.050
1045	0.43–0.50	0.60–0.90	0.040	0.050
1046	0.43–0.50	0.70–1.00	0.040	0.050
1049	0.46–0.53	0.60–0.90	0.040	0.050
1050	0.48–0.55	0.60–0.90	0.040	0.050
1053	0.48–0.55	0.70–1.00	0.040	0.050
1055	0.50–0.60	0.60–0.90	0.040	0.050
1059	0.55–0.65	0.50–0.80	0.040	0.050
1060	0.55–0.65	0.60–0.90	0.040	0.050
1064	0.60–0.70	0.50–0.80	0.040	0.050
1065	0.60–0.70	0.60–0.90	0.040	0.050
1069	0.65–0.75	0.40–0.70	0.040	0.050
1070	0.65–0.75	0.60–0.90	0.040	0.050
1071	0.65–0.70	0.75–1.05	0.040	0.050
1074	0.70–0.80	0.50–0.80	0.040	0.050
1075	0.70–0.80	0.40–0.70	0.040	0.050
1078	0.72–0.85	0.30–0.60	0.040	0.050
1080	0.75–0.88	0.60–0.90	0.040	0.050
1084	0.80–0.93	0.60–0.90	0.040	0.050
1086	0.80–0.93	0.30–0.50	0.040	0.050
1090	0.85–0.98	0.60–0.90	0.040	0.050
1095	0.90–1.03	0.30–0.50	0.040	0.050

TABLE 1
GRADE DESIGNATIONS AND CHEMICAL
COMPOSITIONS OF CARBON STEEL BARS (CONT'D)

Grade Designation	Heat Chemical Ranges and Limits, %				
	Carbon	Manganese	Phosphorus, max	Sulfur, max ^A	
Resulfurized Carbon Steels ^{B,D,F}					
1108	0.08–0.13	0.60–0.80	0.040	0.08–0.13	
1109	0.08–0.13	0.60–0.90	0.040	0.08–0.13	
1110	0.08–0.13	0.30–0.60	0.040	0.08–0.13	
1116	0.14–0.20	1.10–1.40	0.040	0.16–0.23	
1117	0.14–0.20	1.00–1.30	0.040	0.08–0.13	
1118	0.14–0.20	1.30–1.60	0.040	0.08–0.13	
1119	0.14–0.20	1.00–1.30	0.040	0.24–0.33	
1132	0.27–0.34	1.35–1.65	0.040	0.08–0.13	
1137	0.32–0.39	1.35–1.65	0.040	0.08–0.13	
1139	0.35–0.43	1.35–1.65	0.040	0.13–0.20	
1140	0.37–0.44	0.70–1.00	0.040	0.08–0.13	
1141	0.37–0.45	1.35–1.65	0.040	0.08–0.13	
1144	0.40–0.48	1.35–1.65	0.040	0.24–0.33	
1145	0.42–0.49	0.70–1.00	0.040	0.04–0.07	
1146	0.42–0.49	0.70–1.00	0.040	0.08–0.13	
1151	0.48–0.55	0.70–1.00	0.040	0.08–0.13	
Grade Designation	Rephosphorized and Resulfurized Carbon Steels ^{D,F}				
	Carbon	Manganese	Phosphorus	Sulfur	Lead
1211	0.13 max	0.60–0.90	0.07–0.12	0.10–0.15	...
1212	0.13 max	0.70–1.00	0.07–0.12	0.16–0.23	...
1213	0.13 max	0.70–1.00	0.07–0.12	0.24–0.33	...
1215	0.09 max	0.75–1.05	0.04–0.09	0.26–0.35	...
12L13	0.13 max	0.70–1.00	0.07–0.12	0.24–0.33	0.15–0.35
12L14	0.15 max	0.85–1.15	0.04–0.09	0.26–0.35	0.15–0.35
12L15	0.09 max	0.75–1.05	0.04–0.09	0.26–0.35	0.15–0.35
Grade Designation	High-Manganese Carbon Steels ^{B,C,D,E,F}				
	Former Designation	Carbon	Manganese	Phosphorus, max	Sulfur, max
1513	...	0.10–0.16	1.10–1.40	0.040	0.050
1518	...	0.15–0.21	1.10–1.40	0.040	0.050
1522	...	0.18–0.24	1.10–1.40	0.040	0.050
1524	1024	0.19–0.25	1.35–1.65	0.040	0.050
1525	...	0.23–0.29	0.80–1.10	0.040	0.050
1526	...	0.22–0.29	1.10–1.40	0.040	0.050
1527	1027	0.22–0.29	1.20–1.50	0.040	0.050
1536	1036	0.30–0.37	1.20–1.50	0.040	0.050
1541	1041	0.36–0.44	1.35–1.65	0.040	0.050
1547	...	0.43–0.51	1.35–1.65	0.040	0.050
1548	1048	0.44–0.52	1.10–1.40	0.040	0.050
1551	1051	0.45–0.56	0.85–1.15	0.040	0.050
1552	1052	0.47–0.55	1.20–1.50	0.040	0.050
1561	1061	0.55–0.65	0.75–1.05	0.040	0.050
1566	1066	0.60–0.71	0.85–1.15	0.040	0.050
1572	1072	0.65–0.76	1.00–1.30	0.040	0.050

TABLE 1
GRADE DESIGNATIONS AND CHEMICAL
COMPOSITIONS OF CARBON STEEL BARS (CONT'D)

Grade Designation	Heat Chemical Ranges and Limits, percent			
	Merchant Quality M Series Carbon Steel Bars			
	Carbon	Manganese ^G	Phosphorus, max	Sulfur, max
M 1008	0.10 max	0.25–0.60	0.04	0.05
M 1010	0.07–0.14	0.25–0.60	0.04	0.05
M 1012	0.09–0.16	0.25–0.60	0.04	0.05
M 1015	0.12–0.19	0.25–0.60	0.04	0.05
M 1017	0.14–0.21	0.25–0.60	0.04	0.05
M 1020	0.17–0.24	0.25–0.60	0.04	0.05
M 1023	0.19–0.27	0.25–0.60	0.04	0.05
M 1025	0.20–0.30	0.25–0.60	0.04	0.05
M 1031	0.26–0.36	0.25–0.60	0.04	0.05
M 1044	0.40–0.50	0.25–0.60	0.04	0.05

^A Maximum unless otherwise indicated.

^B When silicon is required, the following ranges and limits are commonly specified: 0.10%, max, 0.10% to 0.20%, 0.15% to 0.35%, 0.20% to 0.40%, or 0.30% to 0.60%.

^C Copper can be specified when required as 0.20% minimum.

^D When lead is required as an added element to a standard steel, a range of 0.15 to 0.35% inclusive is specified. Such a steel is identified by inserting the letter "L" between the second and third numerals of the grade designation, for example, 10 L 45. A cast or heat analysis is not determinable when lead is added to the ladle stream.

^E When boron treatment for killed steels is specified, the steels can be expected to contain 0.0005 to 0.003% boron. If the usual titanium additive is not permitted, the steels can be expected to contain up to 0.005% boron.

^F The elements bismuth, calcium, selenium, or tellurium may be added as agreed upon between purchaser and supplier.

^G Unless prohibited by the purchaser, the manganese content may exceed 0.60% on heat analysis to a maximum of 0.75%, provided the carbon range on heat analysis has the minimum and maximum reduced by 0.01% for each 0.05% manganese over 0.60%.

TABLE 2
GRADE DESIGNATIONS AND CHEMICAL COMPOSITIONS OF ALLOY STEEL BARS

Grade Designation	Heat Chemical Ranges and Limits, %							
	Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon ⁴	Nickel	Chromium	Molybdenum
1330	0.28–0.33	1.60–1.90	0.035	0.040	0.15 to 0.35	...	...	...
1335	0.33–0.38	1.60–1.90	0.035	0.040	0.15 to 0.35	...	...	...
1340	0.38–0.43	1.60–1.90	0.035	0.040	0.15 to 0.35	...	...	...
1345	0.43–0.48	1.60–1.90	0.035	0.040	0.15 to 0.35	...	...	...
4012	0.09–0.14	0.75–1.00	0.035	0.040	0.15 to 0.35	...	...	0.15–0.25
4023	0.20–0.25	0.70–0.90	0.035	0.040	0.15 to 0.35	...	...	0.20–0.30
4024	0.20–0.25	0.70–0.90	0.035	0.035–0.050	0.15 to 0.35	...	...	0.20–0.30
4027	0.25–0.30	0.70–0.90	0.035	0.040	0.15 to 0.35	...	...	0.20–0.30
4028	0.25–0.30	0.70–0.90	0.035	0.035–0.050	0.15 to 0.35	...	...	0.20–0.30
4032	0.30–0.35	0.70–0.90	0.035	0.040	0.15 to 0.35	...	...	0.20–0.30
4037	0.35–0.40	0.70–0.90	0.035	0.040	0.15 to 0.35	...	...	0.20–0.30
4042	0.40–0.45	0.70–0.90	0.035	0.040	0.15 to 0.35	...	...	0.20–0.30
4047	0.45–0.50	0.70–0.90	0.035	0.040	0.15 to 0.35	...	...	0.20–0.30
4118	0.18–0.23	0.70–0.90	0.035	0.040	0.15 to 0.35	...	0.40–0.60	0.08–0.15
4120	0.18–0.23	0.90–1.20	0.035	0.040	0.15 to 0.35	...	0.40–0.60	0.13–0.20
4121	0.18–0.23	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.45–0.65	0.20–0.30
4130	0.28–0.33	0.40–0.60	0.035	0.040	0.15 to 0.35	...	0.80–1.10	0.15–0.25
4135	0.33–0.38	0.70–0.90	0.035	0.040	0.15 to 0.35	...	0.80–1.10	0.15–0.25
4137	0.35–0.40	0.70–0.90	0.035	0.040	0.15 to 0.35	...	0.80–1.10	0.15–0.25
4140	0.38–0.43	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.80–1.10	0.15–0.25
4142	0.40–0.45	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.80–1.10	0.15–0.25
4145	0.43–0.48	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.80–1.10	0.15–0.25
4147	0.45–0.50	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.80–1.10	0.15–0.25
4150	0.48–0.53	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.80–1.10	0.15–0.25
4161	0.56–0.64	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.70–0.90	0.25–0.35
4320	0.17–0.22	0.45–0.65	0.035	0.040	0.15 to 0.35	1.65–2.00	0.40–0.60	0.20–0.30
4340	0.38–0.43	0.60–0.80	0.035	0.040	0.15 to 0.35	1.65–2.00	0.70–0.90	0.20–0.30
E4340	0.38–0.43	0.65–0.85	0.025	0.025	0.15 to 0.35	1.65–2.00	0.70–0.90	0.20–0.30
4419	0.18–0.23	0.45–0.65	0.035	0.040	0.15 to 0.35	...	...	0.45–0.60
4422	0.20–0.25	0.70–0.90	0.035	0.040	0.15 to 0.35	...	...	0.35–0.45
4427	0.24–0.29	0.70–0.90	0.035	0.040	0.15 to 0.35	...	...	0.35–0.45
4615	0.13–0.18	0.45–0.65	0.035	0.040	0.15 to 0.35	1.65–2.00	...	0.20–0.30
4620	0.17–0.22	0.45–0.65	0.035	0.040	0.15 to 0.35	1.65–2.00	...	0.20–0.30
4621	0.18–0.23	0.70–0.90	0.035	0.040	0.15 to 0.35	1.65–2.00	...	0.20–0.30
4626	0.24–0.29	0.45–0.65	0.035	0.040	0.15 to 0.35	0.70–1.00	...	0.15–0.25
4715	0.13–0.18	0.70–0.90	0.035	0.040	0.15 to 0.35	0.70–1.00	0.45–0.65	0.45–0.60
4718	0.16–0.21	0.70–0.90	0.035	0.040	0.15 to 0.35	0.90–1.20	0.35–0.55	0.30–0.40
4720	0.17–0.22	0.50–0.70	0.035	0.040	0.15 to 0.35	0.90–1.20	0.35–0.55	0.15–0.25
4815	0.13–0.18	0.40–0.60	0.035	0.040	0.15 to 0.35	3.25–3.75	...	0.20–0.30
4817	0.15–0.20	0.40–0.60	0.035	0.040	0.15 to 0.35	3.25–3.75	...	0.20–0.30
4820	0.18–0.23	0.50–0.70	0.035	0.040	0.15 to 0.35	3.25–3.75	...	0.20–0.30
5015	0.12–0.17	0.30–0.50	0.035	0.040	0.15 to 0.35	...	0.30–0.50	...
5046	0.43–0.48	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.20–0.35	...
5115	0.13–0.18	0.70–0.90	0.035	0.040	0.15 to 0.35	...	0.70–0.90	...
5120	0.17–0.22	0.70–0.90	0.035	0.040	0.15 to 0.35	...	0.70–0.90	...
5130	0.28–0.33	0.70–0.90	0.035	0.040	0.15 to 0.35	...	0.80–1.10	...
5132	0.30–0.35	0.60–0.80	0.035	0.040	0.15 to 0.35	...	0.75–1.00	...
5135	0.33–0.38	0.60–0.80	0.035	0.040	0.15 to 0.35	...	0.80–1.05	...
5140	0.38–0.43	0.70–0.90	0.035	0.040	0.15 to 0.35	...	0.70–0.90	...
5145	0.43–0.48	0.70–0.90	0.035	0.040	0.15 to 0.35	...	0.70–0.90	...
5147	0.46–0.51	0.70–0.95	0.035	0.040	0.15 to 0.35	...	0.85–1.15	...
5150	0.48–0.53	0.70–0.90	0.035	0.040	0.15 to 0.35	...	0.70–0.90	...
5155	0.51–0.59	0.70–0.90	0.035	0.040	0.15 to 0.35	...	0.70–0.90	...
5160	0.56–0.61	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.70–0.90	...

TABLE 2
GRADE DESIGNATIONS AND CHEMICAL COMPOSITIONS OF ALLOY STEEL BARS (CONT'D)

Grade Designation	Heat Chemical Ranges and Limits, %							
	Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon ^A	Nickel	Chromium	Molybdenum
E50100	0.98–1.10	0.25–0.45	0.025	0.025	0.15 to 0.35	...	0.40–0.60	...
E51100	0.98–1.10	0.25–0.45	0.025	0.025	0.15 to 0.35	...	0.90–1.15	...
E52100	0.98–1.10	0.25–0.45	0.025	0.025	0.15 to 0.35	...	1.30–1.60	...
52100 ^B	0.93–1.05	0.25–0.45	0.025	0.015	0.15 to 0.35	...	1.35–1.60	...
6118	0.16–0.21	0.50–0.70	0.035	0.040	0.15 to 0.35	...	0.50–0.70	(0.10–0.15 V)
6150	0.48–0.53	0.70–0.90	0.035	0.040	0.15 to 0.35	...	0.80–1.10	(0.15 min V)
8115	0.13–0.18	0.70–0.90	0.035	0.040	0.15 to 0.35	0.20–0.40	0.30–0.50	0.08–0.15
8615	0.13–0.18	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8617	0.15–0.20	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8620	0.18–0.23	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8622	0.20–0.25	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8625	0.23–0.28	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8627	0.25–0.30	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8630	0.28–0.33	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8637	0.35–0.40	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8640	0.38–0.43	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8642	0.40–0.45	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8645	0.43–0.48	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8650	0.48–0.53	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8655	0.51–0.59	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8660	0.56–0.64	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8720	0.18–0.23	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.20–0.30
8740	0.38–0.43	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.20–0.30
8822	0.20–0.25	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.30–0.40
9254	0.51–0.59	0.60–0.80	0.035	0.040	1.20–1.60	...	0.60–0.80	...
9255	0.51–0.59	0.70–0.95	0.035	0.040	1.80–2.20	...	...	...
9259	0.56–0.64	0.75–1.00	0.035	0.040	0.70–1.10	...	0.45–0.65	...
9260	0.56–0.64	0.75–1.00	0.035	0.040	1.80–2.20	...	...	...
E9310	0.08–0.13	0.45–0.65	0.025	0.025	0.15 to 0.30	3.00–3.50	1.00–1.40	0.08–0.15
Standard Boron Steels^C								
50B44	0.43–0.48	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.20–0.60	...
50B46	0.44–0.49	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.20–0.35	...
50B50	0.48–0.53	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.40–0.60	...
50B60	0.56–0.64	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.40–0.60	...
51B60	0.56–0.64	0.75–1.00	0.035	0.040	0.15 to 0.35	...	0.70–0.90	...
81B45	0.43–0.48	0.75–1.00	0.035	0.040	0.15 to 0.35	0.20–0.40	0.35–0.55	0.08–0.15
94B17	0.15–0.20	0.75–1.00	0.035	0.040	0.15 to 0.35	0.30–0.60	0.30–0.50	0.08–0.15
94B30	0.28–0.33	0.75–1.00	0.035	0.040	0.15 to 0.35	0.30–0.60	0.30–0.50	0.08–0.15

^A Silicon may be specified by the purchaser as 0.10% maximum. The need for 0.10% maximum generally relates to severe cold-formed parts.

^B The purchaser may also require the following maximums: copper 0.30%; aluminum 0.050%; oxygen 0.0015%.

^C These steels can be expected to contain 0.0005 to 0.003% boron. If the usual titanium additive is not permitted, the steels can be expected to contain up to 0.005% boron.

Note 1 — Small quantities of certain elements are present in alloy steels, which are not specified or required. These elements are considered as incidental and may be present to the following maximum amounts: copper, 0.35%; nickel, 0.25%; chromium, 0.20%; and molybdenum, 0.06%.

Note 2 — Where minimum and maximum sulfur content is shown it is indicative of resulfurized steel.

Note 3 — The chemical ranges and limits shown in Table 2 are produced to product analysis tolerances shown in Table 6.

Note 4 — Standard alloy steels can be produced with a lead range of 0.15–0.35%. Such steels are identified by inserting the letter "L" between the second and third numerals of the AISI number, for example, 41 L 40. A cast or heat analysis is not determinable when lead is added to the ladle stream.

TABLE 3
HEAT ANALYSIS CHEMICAL RANGES AND LIMITS OF
CARBON STEEL BARS

Chemical Ranges and Limits, %			
Element	When Maximum of Specified Elements is:	Range	Lowest Maximum
Carbon ^A	...	...	0.06
	to 0.12, incl	...	...
	over 0.12 to 0.25, incl	0.05	...
	over 0.25 to 0.40, incl	0.06	...
	over 0.40 to 0.55, incl	0.07	...
	over 0.55 to 0.80, incl	0.10	...
	over 0.80	0.13	...
Manganese	...	...	0.35
	to 0.40, incl	0.15	...
	over 0.40 to 0.50, incl	0.20	...
	over 0.50 to 1.65, incl	0.30	...
Phosphorus	to 0.040, incl	...	0.040 ^B
	over 0.040 to 0.08, incl	0.03	...
	over 0.08 to 0.13, incl	0.05	...
Sulfur	to 0.050, incl	...	0.050 ^B
	over 0.050 to 0.09, incl	0.03	...
	over 0.09 to 0.15, incl	0.05	...
	over 0.15 to 0.23, incl	0.07	...
	over 0.23 to 0.50, incl	0.09	...
Silicon ^C	...	...	0.10
	to 0.10, incl	...	...
	over 0.10 to 0.15, incl	0.08	...
	over 0.15 to 0.20, incl	0.10	...
	over 0.20 to 0.30, incl	0.15	...
	over 0.30 to 0.60, incl	0.20	...
Copper	When copper is required 0.20 min is generally used		
Lead ^D	When lead is required, a range of 0.15 to 0.35 is specified		
Bismuth ^E			
Calcium ^E			
Selenium ^E			
Tellurium ^E			

^A The carbon ranges shown in the column headed "Range" apply when the specified maximum limit for manganese does not exceed 1.10%. When the maximum manganese limit exceeds 1.10%, add 0.01 to the carbon ranges shown above.

^B For steels produced in merchant quality the phosphorus maximum is 0.04% and the sulfur maximum is 0.05%.

^C It is not common practice to produce a rephosphorized and resulfurized carbon steel to specified limits for silicon because of its adverse effect on machinability.

^D A cast or heat analysis is not determinable when lead is added to the ladle stream.

^E Element specification range as agreed upon between purchaser and supplier.

TABLE 4
HEAT ANALYSIS CHEMICAL RANGES AND LIMITS OF
ALLOY STEEL BARS

Chemical Ranges and Limits, %			
Element	When Maximum of Specified Element is:	Open-Hearth or Basic-Oxygen Steel	Electric Furnace Steel
Carbon	To 0.55, incl	0.05	0.05
	Over 0.55–0.70, incl	0.08	0.07
	Over 0.70 to 0.80, incl	0.10	0.09
	Over 0.80–0.95, incl	0.12	0.11
	Over 0.95–1.35, incl	0.13	0.12
Manganese	To 0.60, incl	0.20	0.15
	Over 0.60–0.90, incl	0.20	0.20
	Over 0.90–1.05, incl	0.25	0.25
	Over 1.05–1.90, incl	0.30	0.30
Phosphorus	Basic open-hearth or basic-oxygen steel		0.035
	Acid open-hearth steel		0.050
	Basic electric-furnace steel		0.025
	Acid electric-furnace steel		0.050
Sulfur	To 0.050, incl	0.015	0.015
	Over 0.050–0.07, incl	0.02	0.02
	Over 0.07–0.10, incl	0.04	0.04
	Over 0.10–0.14, incl	0.05	0.05
	Basic open-hearth or basic-oxygen steel		0.040
Silicon	Acid open-hearth steel		0.050
	Basic electric-furnace steel		0.025
	Acid electric-furnace steel		0.050
	To 0.20, incl	0.08	0.08
	Over 0.20–0.30, incl	0.15	0.15
Nickel	Over 0.30–0.60, incl	0.20	0.20
	Over 0.60–1.00, incl	0.30	0.30
	Over 1.00–2.20, incl	0.40	0.35
	Acid steels ^B		
	Over 5.30–10.00, incl	1.00	1.00
Chromium	To 0.50, incl	0.20	0.20
	Over 0.50–1.50, incl	0.30	0.30
	Over 1.50–2.00, incl	0.35	0.35
	Over 2.00–3.00, incl	0.40	0.40
	Over 3.00–5.30, incl	0.50	0.50
	Over 5.30–10.00, incl	1.00	1.00
	To 0.40, incl	0.15	0.15
	Over 0.40–0.90, incl	0.20	0.20
Molybdenum	Over 0.90–1.05, incl	0.25	0.25
	Over 1.05–1.60, incl	0.30	0.30
	Over 1.60–1.75, incl	^C	0.35
	Over 1.75–2.10, incl	^C	0.40
	Over 2.10–3.99, incl	^C	0.50
	To 0.10, incl	0.05	0.05
Tungsten	Over 0.10–0.20, incl	0.07	0.07
	Over 0.20–0.50, incl	0.10	0.10
	Over 0.50–0.80, incl	0.15	0.15
	Over 0.80–1.15, incl	0.20	0.20
	To 0.50, incl	0.20	0.20
Tungsten	Over 0.50–1.00, incl	0.30	0.30
	Over 1.00–2.00, incl	0.50	0.50
	Over 2.00–4.00, incl	0.60	0.60

TABLE 4
HEAT ANALYSIS CHEMICAL RANGES AND LIMITS OF
ALLOY STEEL BARS (CONT'D)

Chemical Ranges and Limits, %			
Element	When Maximum of Specified Element is:	Open-Hearth or Basic-Oxygen Steel	Electric Furnace Steel
Vanadium	To 0.25, incl	0.05	0.05
	Over 0.25–0.50, incl	0.10	0.10
Aluminum	Up to 0.10, incl	0.05	0.05
	Over 0.10–0.20, incl	0.10	0.10
	Over 0.20–0.30, incl	0.15	0.15
	Over 0.30–0.80, incl	0.25	0.25
	Over 0.80–1.30, incl	0.35	0.35
	Over 1.30–1.80, incl	0.45	0.45
Copper	To 0.60, incl	0.20	0.20
	Over 0.60–1.50, incl	0.30	0.30
	Over 1.50–2.00, incl	0.35	0.35

Note 1 — Boron steels can be expected to have 0.0005% minimum boron content.

Note 2 — Alloy steels can be produced with a lead range of 0.15–0.35%. A cast or heat analysis is not determinable when lead is added to the ladle stream.

^A Applies to only nonrephosphorized and nonresulfurized steels.

^B Minimum silicon limit for acid open-hearth or acid electric-furnace alloy steels is 0.15%.

^C Not normally produced in open-hearth.

TABLE 5
PERMISSIBLE VARIATIONS FOR PRODUCT ANALYSIS
OF CARBON STEEL

Element	Limit, or Maximum of Specified Range, %	Over Maximum Limit, %	Under Minimum Limit, %
Carbon ^A	0.25 and under	0.02	0.02
	over 0.25 to 0.55, incl	0.03	0.03
	over 0.55	0.04	0.04
Manganese	0.90 and under	0.03	0.03
	over 0.90 to 1.65, incl	0.06	0.06
Phosphorus ^{A,B}	basic steels	0.008	...
	acid bessemer steel	0.01	0.01
Sulfur ^{A,B}		0.008	...
Silicon	0.35 and under	0.02	0.02
	over 0.35 to 0.60, incl	0.05	0.05
Copper	under minimum only	...	0.02
Lead ^C	0.15 to 0.35, incl	0.03	0.03

^A Rimmed and capped steels are not subject to rejection on product analysis unless misapplication is clearly indicated.

^B Resulfurized or rephosphorized steels are not subject to rejection on product analysis for these elements unless misapplication is clearly indicated.

^C Product analysis tolerance for lead applies both over and under to a specified range of 0.15 to 0.35%.

TABLE 6
PERMISSIBLE VARIATIONS FOR PRODUCT ANALYSIS
OF ALLOY STEEL

Elements	Limit, or Maximum of Specified Range, %	Permissible Variations Over Maximum Limit or Under Minimum Limit, %
Carbon	0.30 and under	0.01
	over 0.30 to 0.75, incl	0.02
	over 0.75	0.03
Manganese	0.90 and under	0.03
	over 0.90 to 2.10, incl	0.04
Phosphorus	over maximum only	0.005
Sulfur	0.060 and under	0.005
Silicon	0.40 and under	0.02
	over 0.40 to 2.20, incl	0.05
Nickel	1.00 and under	0.03
	over 1.00 to 2.00, incl	0.05
	over 2.00 to 5.30, incl	0.07
	over 5.30 to 10.00, incl	0.10
Chromium	0.90 and under	0.03
	over 0.90 to 2.10, incl	0.05
	over 2.10 to 3.99, incl	0.10
Molybdenum	0.20 and under	0.01
	over 0.20 to 0.40, incl	0.02
	over 0.40 to 1.15, incl	0.03
Vanadium	0.10 and under	0.01
	over 0.10 to 0.25, incl	0.02
	over 0.25 to 0.50, incl	0.03
	minimum value specified, under minimum limit only	0.01
Tungsten	1.00 and under	0.04
	over 1.00 to 4.00, incl	0.08
Aluminum	0.10 and under	0.03
	over 0.10 to 0.20, incl	0.04
	over 0.20 to 0.30, incl	0.05
	over 0.30 to 0.80, incl	0.07
	over 0.80 to 1.80, incl	0.10
Lead ^A	0.15 to 0.35, incl	0.03
Copper	to 1.00 incl	0.03
	over 1.00 to 2.00, incl	0.05

^A Product analysis tolerance for lead applies both over and under to a specified range of 0.15 to 0.35%.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order.

S1. Flat Bar Thickness Tolerances

S1.1 When flat bars are specified in metric units to a thickness under tolerance of 0.3 mm, the thickness tolerance of Table S1.1 shall apply.

TABLE S1.1
THICKNESS AND WIDTH TOLERANCES FOR HOT-WROUGHT SQUARE-EDGE AND ROUND-EDGE FLAT BARS
ORDERED TO 0.3 MM UNDER TOLERANCE⁴

Specified Width, mm	Tolerances over Specified Thickness for Thickness Given, mm					Tolerance from Specified Width, mm	
	Over 6 to 12, incl	Over 12 to 25, incl	Over 25 to 50, incl	Over 50 to 75, incl	Over 75	Over	Under
To 25, incl	...	...	...	...	...	0.5	0.5
Over 25 to 50, incl	...	0.5	1.3	...	...	1.0	1.0
Over 50 to 100, incl	0.5	0.7	1.3	2.1	2.1	1.5	1.0
Over 100 to 150, incl	0.5	0.7	1.3	2.1	2.1	2.5	1.5
Over 150 to 200, incl	0.5	1.0	1.3	2.1	2.9	3.0	2.5

Note — Tolerance under specified thickness 0.3 mm.

⁴ When a square is held against a face and an edge of a square-edge flat bar, the edge shall not deviate by more than 3° or 5% of the thickness.

ANNEXES

(Mandatory Information)

A1. PERMISSIBLE VARIATIONS IN DIMENSIONS, ETC. — INCH-POUND UNITS

A1.1 Listed below are permissible variations in dimensions expressed in inch-pound units of measurement.

TABLE A1.1
PERMISSIBLE VARIATIONS IN CROSS SECTION FOR
HOT-WROUGHT ROUND, SQUARE, AND ROUND-
CORNERED SQUARE BARS OF STEEL

Specified Size, in.	Permissible Variation from Specified Size, in. ^A		Out-of-Round or Out-of-Square, in. ^B
	Over	Under	
To $\frac{5}{16}$, incl	0.005	0.005	0.008
Over $\frac{5}{16}$ to $\frac{7}{16}$, incl	0.006	0.006	0.009
Over $\frac{7}{16}$ to $\frac{5}{8}$, incl	0.007	0.007	0.010
Over $\frac{5}{8}$ to $\frac{7}{8}$, incl	0.008	0.008	0.012
Over $\frac{7}{8}$ to 1, incl	0.009	0.009	0.013
Over 1 to $1\frac{1}{8}$, incl	0.010	0.010	0.015
Over $1\frac{1}{8}$ to $1\frac{1}{4}$, incl	0.011	0.011	0.016
Over $1\frac{1}{4}$ to $1\frac{3}{8}$, incl	0.012	0.012	0.018
Over $1\frac{3}{8}$ to $1\frac{1}{2}$, incl	0.014	0.014	0.021
Over $1\frac{1}{2}$ to 2, incl	$\frac{1}{64}$	$\frac{1}{64}$	0.023
Over 2 to $2\frac{1}{2}$, incl	$\frac{1}{32}$	0	0.023
Over $2\frac{1}{2}$ to $3\frac{1}{2}$, incl	$\frac{3}{64}$	0	0.035
Over $3\frac{1}{2}$ to $4\frac{1}{2}$, incl	$\frac{1}{16}$	0	0.046
Over $4\frac{1}{2}$ to $5\frac{1}{2}$, incl	$\frac{5}{64}$	0	0.058
Over $5\frac{1}{2}$ to $6\frac{1}{2}$, incl	$\frac{1}{8}$	0	0.070
Over $6\frac{1}{2}$ to $8\frac{1}{4}$, incl	$\frac{5}{32}$	0	0.085
Over $8\frac{1}{4}$ to $9\frac{1}{2}$, incl	$\frac{3}{16}$	0	0.100
Over $9\frac{1}{2}$ to 10, incl	$\frac{1}{4}$	0	0.120

^A Steel bars are regularly cut to length by shearing or hot sawing, which can cause end distortion resulting in those portions of the bar being outside the applicable size tolerance. When this end condition is objectionable, a machine cut end should be considered.

^B Out-of-round is the difference between the maximum and minimum diameters of the bar, measured at the same cross section. Out-of-square is the difference in the two dimensions at the same cross section of a square bar between opposite faces.

TABLE A1.2
PERMISSIBLE VARIATIONS IN CROSS SECTION FOR
HOT-WROUGHT HEXAGONAL BARS OF STEEL

Specified Sizes Between Opposite Sides, in.	Permissible Variations from Specified Size, in. ^A		Out-of-Hexagon (Carbon Steel and Alloy Steel) or Out-of-Octagon (Alloy Steel), in. ^B
	Over	Under	
To $\frac{1}{2}$, incl	0.007	0.007	0.011
Over $\frac{1}{2}$ to 1, incl	0.010	0.010	0.015
Over 1 to $1\frac{1}{2}$, incl	0.021	0.013	0.025
Over $1\frac{1}{2}$ to 2, incl	$\frac{1}{32}$	$\frac{1}{64}$	$\frac{1}{32}$
Over 2 to $2\frac{1}{2}$, incl	$\frac{3}{64}$	$\frac{1}{64}$	$\frac{3}{64}$
Over $2\frac{1}{2}$ to $3\frac{1}{2}$, incl	$\frac{1}{16}$	$\frac{1}{64}$	$\frac{1}{16}$
Over $3\frac{1}{2}$ to $4\frac{1}{2}$, incl	$\frac{5}{64}$	$\frac{1}{64}$	$\frac{5}{64}$

^A Steel bars are regularly cut to length by shearing or hot sawing, which can cause end distortion resulting in those portions of the bar being outside the applicable size tolerance. When this end condition is objectionable, a machine cut end should be considered.

^B Out-of-hexagon or out-of-octagon is the greatest difference between any two dimensions at the same cross section between opposite faces.

TABLE A1.3
PERMISSIBLE VARIATIONS IN THICKNESS AND WIDTH FOR HOT-WROUGHT SQUARE EDGE AND ROUND EDGE FLAT BARS^A

Specified Width, in.	Permissible Variations in Thickness, for Thickness Given, Over and Under, in. ^B							Permissible Variations in Width, in.	
	0.203 to 0.230, excl	0.230 to ¼, excl	¼ to ½, incl	Over ½ to 1, incl	Over 1 to 2, incl	Over 2 to 3, incl	Over 3	Over	Under
To 1, incl	0.007	0.007	0.008	0.010	...	...	...	1/64	1/64
Over 1 to 2, incl	0.007	0.007	0.012	0.015	1/32	...	...	1/32	1/32
Over 2 to 4, incl	0.008	0.008	0.015	0.020	1/32	3/64	3/64	1/16	1/32
Over 4 to 6, incl	0.009	0.009	0.015	0.020	1/32	3/64	3/64	3/32	1/16
Over 6 to 8, incl	^C	0.015	0.016	0.025	1/32	3/64	1/16	1/8	3/32

^A When a square is held against a face and an edge of a square edge flat bar, the edge shall not deviate by more than 3° or 5% of the thickness.

^B Steel bars are regularly cut to length by shearing or hot sawing, which can cause end distortion resulting in those portions of the bar being outside the applicable size tolerance. When this end condition is objectionable, a machine cut end should be considered.

^C Flats over 6 to 8 in., incl, in width, are not available as hot-wrought steel bars in thickness under 0.230 in.

TABLE A1.4
PERMISSIBLE VARIATIONS IN THICKNESS, LENGTH, AND OUT-OF-SQUARE FOR HOT-WROUGHT BAR SIZE ANGLES OF CARBON STEEL

Specified Length of Leg, in. ^A	Permissible Variations in Thickness, for Thicknesses Given, Over and Under, in.			Permissible Variations for Length of Leg, Over and Under, in.
	To 3/16, incl	Over 3/16 to 3/8, incl	Over 3/8	
To 1, incl	0.008	0.010	...	1/32
Over 1 to 2, incl	0.010	0.010	0.012	3/64
Over 2 to 3, excl	0.012	0.015	0.015	1/16

^A The longer leg of an unequal angle determines the size for tolerance. The out-of-square tolerance in either direction is 1/2°.

TABLE A1.6
PERMISSIBLE VARIATIONS IN DIMENSIONS FOR HOT-WROUGHT BAR SIZE TEES OF CARBON STEEL

Specified Size of Tee, in. ^A	Permissible Variations in Size, in.						Stem out- of- Square ^C
	Width or Depth ^B		Thickness of Flange		Thickness of Stem		
	Over	Under	Over	Under	Over	Under	
To 1 1/4, incl	3/64	3/64	0.010	0.010	0.005	0.020	1/32
Over 1 1/4 to 2, incl	1/16	1/16	0.012	0.012	0.010	0.020	1/16
Over 2 to 3, excl	3/32	3/32	0.015	0.015	0.015	0.020	3/32

^A The longer member of the unequal tee determines the size for tolerances.

^B Measurements for both width and depth are overall.

^C Stem out-of-square is the variation from its true position of the center line of the stem measured at the point.

TABLE A1.5
PERMISSIBLE VARIATIONS IN DIMENSIONS FOR HOT-WROUGHT BAR SIZE CHANNELS OF CARBON STEEL

Specified Size of Channel, in.	Permissible Variations in Size, Over and Under, in.				Out-of-Square ^A if Either Flange, in./in. of Flange Width
	Depth of Section ^B	Width of Flanges ^B	Thickness of Web for Thickness Given		
			To $\frac{3}{16}$, incl	Over $\frac{3}{16}$	
To $1\frac{1}{2}$, incl	$\frac{1}{32}$	$\frac{1}{32}$	0.010	0.015	$\frac{1}{32}$
Over $1\frac{1}{2}$ to 3, excl	$\frac{1}{16}$	$\frac{1}{16}$	0.015	0.020	$\frac{1}{32}$

^A For channels 5/8 in. and under in depth, the out-of-square tolerance is 3/64 in./in. of depth.

^B Measurements for depth of section and width of flanges are overall.

TABLE A1.7
PERMISSIBLE VARIATIONS IN DIMENSIONS FOR HALF-ROUNDS, OVALS, HALF-OVALS, AND OTHER SPECIAL BAR SIZE SECTIONS

Due to mill facilities, tolerances on half-rounds, ovals, half-ovals, and other special bar size sections vary among the manufacturers and such tolerances should be negotiated between the manufacturer and the purchaser.

TABLE A1.8
PERMISSIBLE VARIATIONS IN LENGTH FOR HOT-WROUGHT ROUNDS, SQUARES, HEXAGONS, FLATS, AND BAR
SIZE SECTIONS OF STEEL

Specified Size of Rounds, Squares, and Hexagons, in.	Specified Size of Flats, in.		Permissible Variations Over Specified Length, in. ⁴				
	Thickness	Width	5 to 10 ft, excl	10 to 20 ft, excl	20 to 30 ft, excl	30 to 40 ft, excl	40 to 60 ft, excl
Mill Shearing							
To 1, incl	to 1, incl	to 3, incl	$\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{4}$	$1\frac{3}{4}$	$2\frac{1}{4}$
Over 1 to 2, incl	over 1	to 3, incl	$\frac{5}{8}$	1	$1\frac{1}{2}$	2	$2\frac{1}{2}$
	to 1, incl	over 3 to 6, incl	$\frac{5}{8}$	1	$1\frac{1}{2}$	2	$2\frac{1}{2}$
Over 2 to 5, incl	over 1	over 3 to 6, incl	1	$1\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{3}{4}$
Over 5 to 10, incl	...	...	2	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$
	0.230 to 1, incl	over 6 to 8, incl	$\frac{3}{4}$	$1\frac{1}{4}$	$1\frac{3}{4}$	$3\frac{1}{2}$	4
	over 1 to 3, incl	over 6 to 8, incl	$1\frac{1}{4}$	$1\frac{3}{4}$	2	$3\frac{1}{2}$	4
Bar Size Sections	...	...	$\frac{5}{8}$	1	$1\frac{1}{2}$	2	$2\frac{1}{2}$
Hot Sawing							
2 to $3\frac{1}{2}$, incl	1 and over	3 and over	^B	$1\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{3}{4}$
Over $3\frac{1}{2}$ to 5, incl				2	$2\frac{1}{4}$	$2\frac{5}{8}$	3
Over 5 to 10, incl	...	...	^B	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$

⁴ No permissible variations under.

^B Smaller sizes and shorter lengths are not hot sawed.

TABLE A1.9
PERMISSIBLE VARIATIONS IN LENGTH FOR
RECUTTING OF BARS MEETING SPECIAL
STRAIGHTNESS TOLERANCES

Sizes of Rounds, Squares, Hexagons, Width of Flats and Maximum Dimension of Other Sections, in. ⁴	Tolerances Over Specified Length, in. ⁴	
	To 12 ft, incl	Over 12 ft
To 3, incl	$\frac{1}{4}$	$\frac{5}{16}$
Over 3 to 6, incl	$\frac{5}{16}$	$\frac{7}{16}$
Over 6 to 8, incl	$\frac{7}{16}$	$\frac{9}{16}$
Rounds over 8 to 10, incl	$\frac{9}{16}$	$\frac{11}{16}$

⁴ No tolerance under.

TABLE A1.10
PERMISSIBLE VARIATIONS IN STRAIGHTNESS FOR
HOT-WROUGHT BARS AND BAR SIZE SECTIONS OF
STEEL⁴

Standard tolerances	$\frac{1}{4}$ in. in any 5 ft and ($\frac{1}{4}$ in. \times length in ft)/5
Special tolerances	$\frac{1}{8}$ in. in any 5 ft and ($\frac{1}{8}$ in. \times length in ft)/5

⁴ Because of warpage, straightness tolerances do not apply to bars if any subsequent heating operation or controlled cooling has been performed.

A2. DIMENSIONAL TOLERANCES — SI UNITS

A2.1 Listed below are permissible variations in dimensions expressed in SI units of measurement.

TABLE A2.1
TOLERANCES IN SECTIONAL DIMENSIONS FOR
ROUND AND SQUARE BARS AND ROUND-CORNERED
SQUARE BARS

Size, mm	Tolerance from Specified Size, Over and Under, mm or % ^A	Out-of-Round, or Out-of-Square Section, ^B mm or % ^A
To 7, incl	0.13 mm	0.20 mm
Over 7 to 11, incl	0.15 mm	0.22 mm
Over 11 to 15, incl	0.18 mm	0.27 mm
Over 15 to 19, incl	0.20 mm	0.30 mm
Over 19 to 250, incl	1%	1.5%

^A The tolerance shall be rounded to the nearest tenth of a millimetre after calculation.

^B Out-of-round is the difference between the maximum and the minimum diameters of the bar, measured at the same cross section. Out-of-square is the difference in the two dimensions at the same cross section of a square bar between opposite faces.

TABLE A2.2
TOLERANCES IN CROSS SECTION FOR HOT-WROUGHT
HEXAGONAL AND OCTAGONAL STEEL BARS

Specified Size Between Opposite Sides, mm	Tolerance from Specified Size, mm		Out of Hexagon or Out of Octagon, mm ^A
	Over	Under	
To 13, incl	0.18	0.18	0.3
Over 13 to 25, incl	0.25	0.25	0.4
Over 25 to 40, incl	0.55	0.35	0.6
Over 40 to 50, incl	0.8	0.40	0.8
Over 50 to 65, incl	1.2	0.40	1.2
Over 65 to 80, incl	1.6	0.40	1.6
Over 80 to 100, incl	2.0	0.40	2.0

^A Out of hexagon or out of octagon is the greatest difference between any two dimensions at the cross section between opposite faces.

TABLE A2.3
THICKNESS AND WIDTH TOLERANCES FOR HOT-WROUGHT SQUARE-EDGE AND ROUND-EDGE FLAT BARS^{A,B}

Specified Width, mm	Tolerances from Specified Thickness for Thickness Given Over and Under, mm						Tolerances from Specified Width, mm	
	Over 5 to 6, incl	Over 6 to 12, incl	Over 12 to 25, incl	Over 25 to 50, incl	Over 50 to 75	Over 75	Over	Under
To 25, incl	0.18	0.20	0.25	...	...	...	0.5	0.5
Over 25 to 50, incl	0.18	0.30	0.40	0.8	...	...	1.0	1.0
Over 50 to 100, incl	0.20	0.40	0.50	0.8	1.2	1.2	1.5	1.0
Over 100 to 150, incl	0.25	0.40	0.50	0.8	1.2	1.2	2.5	1.5
Over 150 to 200, incl	^A	0.40	0.65	0.8	1.2	1.6	3.0	2.5

^A When a square is held against a face and an edge of a square edge flat bar, the edge shall not deviate by more than 3° or 5% of the thickness.

^B Flats over 150 to 200 mm, incl in width are not available as hot-wrought bars in thickness 6 mm and under.

TABLE A2.4
THICKNESS, LENGTH, AND OUT-OF-SQUARE
TOLERANCES FOR HOT-WROUGHT BAR SIZE ANGLES

Specified Length of Leg, mm ^{A,B}	Tolerances in Thickness for Thickness Given, Over and Under, mm			Tolerances for Length of Leg Over and Under, mm
	To 5, incl	Over 5 to 10, incl	Over 10	
To 50, incl	0.2	0.2	0.3	1
Over 50 to 75, excl	0.3	0.4	0.4	2

^A The longer leg of an unequal angle determines the size for tolerance.

^B Out of square tolerances in either direction is $1\frac{1}{2}^\circ = 0.026$ mm/mm.

TABLE A2.5
DIMENSIONAL TOLERANCES FOR HOT-WROUGHT BAR
SIZE CHANNELS

Tolerances in Size, Over and Under, mm					
Specified Size of Channel, mm	Depth of Section ^A	Width of Flanges ^A	Thickness of Web		Out of Square of Either Flange per mm of Flange Width, ^B mm
			To 5, incl	Over 5	
To 40, incl	1	1	0.2	0.4	0.03
Over 40 to 75, excl	2	2	0.4	0.5	0.03

^A Measurements for depth of section and width of flanges are overall.

^B For channels 16 mm and under in depth, out of square tolerance is 0.05 mm/mm.

TABLE A2.6
DIMENSIONAL TOLERANCES FOR HOT-WROUGHT BAR
SIZE TEES

Specified Size of Tee, ^A mm	Tolerances in Size, mm						Stem Out of Square ^C
	Width or Depth, ^B		Thickness of Flange		Thickness of Stem		
	Over	Under	Over	Under	Over	Under	
To 30, incl	1	1	0.2	0.2	0.1	0.5	1
Over 30 to 50, incl	2	2	0.3	0.3	0.2	0.5	2
Over 50 to 75, excl	2	2	0.4	0.4	0.4	0.5	2

^A The longer member of the unequal tee determines the size for tolerances.

^B Measurements for width and depth are overall.

^C Stem out of square is the tolerance from its true position of the center line of the stem measured at the point.

TABLE A2.7
PERMISSIBLE VARIATIONS IN DIMENSIONS FOR
HALF-ROUNDS, OVALS, HALF-OVALS, AND OTHER
SPECIAL BAR SIZE SECTIONS

Due to mill facilities, tolerances on half-rounds, ovals, and other special bar size sections vary among the manufacturers and such tolerances should be negotiated between the manufacturer and the purchaser.

TABLE A2.8
LENGTH TOLERANCES FOR HOT-WROUGHT ROUNDS, SQUARES, HEXAGONS, OCTAGONS, FLATS,
AND BAR SIZE SECTIONS

Specified Size of Rounds, Squares, Hexagons and Octagons, mm	Specified Size of Flats, mm		Tolerances over Specified Length, mm ^A				
	Thickness	Width	1500 to 3000, excl	3000 to 6000, excl	6000 to 9000, excl	9000 to 12 000, excl	12 000 to 18 000, excl
Hot Shearing							
To 25, incl	to 25, incl	to 75, incl	15	20	35	45	60
Over 25 to 50, incl	over 25	to 75, incl	15	25	40	50	65
	to 25, incl	over 75 to 150, incl	15	25	40	50	65
Over 50 to 125, incl	over 25	over 75 to 150, incl	25	40	45	60	70
Over 125 to 250, incl	...	...	50	65	70	75	85
Bar Size Sections	over 6 to 25, incl	over 150 to 200, incl	20	30	45	90	100
	over 25 to 75, incl	over 150 to 200, incl	30	45	50	90	100
	...	...	15	25	40	50	65
Hot Sawing							
50 to 90, incl	25 and over	75 and over	^B	40	45	60	70
Over 90 to 125, incl				50	60	65	75
Over 125 to 250, incl	...	...	^B	65	70	75	85

^A No tolerance under.^B Smaller sizes and shorter lengths are not hot sawed.

TABLE A2.9
LENGTH TOLERANCES FOR RECUTTING OF BARS
MEETING SPECIAL STRAIGHTNESS TOLERANCES

Sizes of Rounds, Squares, Hexagons, Octagons, Widths of Flats and Maximum Dimensions of Other Sections, mm	Tolerances over Specified Length, mm ^A	
	To 3700 mm, incl	Over 3700 mm
To 75, incl	6	8
Over 75 to 150, incl	8	11
Over 150 to 200, incl	11	14
Rounds over 200 to 250, incl	14	18

^A No tolerance under.

TABLE A2.10
STRAIGHTNESS TOLERANCES FOR HOT-WROUGHT
BARS AND
BAR SIZE SECTIONS^A

Standard tolerances	6 mm in any 1500 mm and (length in mm/250) ^B
Special tolerances	3 mm in any 1500 mm and (length in mm/500) ^B

^A Because of warpage, straightness tolerances do not apply to bars if any subsequent heating operation or controlled cooling has been performed.

^B Round to the nearest whole millimetre.

SPECIFICATION FOR STEEL RIVETS AND BARS FOR RIVETS, PRESSURE VESSELS



SA-31

[Identical with ASTM Specification A 31-04^{e1}(R09) except for an editorial change in 3.1.1 and mandatory certification in 3.1.7 and 14.]

1. Scope

1.1 This specification covers steel rivets for use in boilers and pressure vessels and steel bars for use in the manufacture of rivets.

1.2 Two grades are covered:

1.2.1 Grade A — Bars having a yield point of 23 000 psi (160 MPa) minimum with no controls on carbon content.

1.2.2 Grade B — Bars having a yield point of 29 000 psi (200 MPa) minimum with carbon 0.28% maximum.

1.2.3 Rivets are manufactured from the applicable bar grade.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 ASTM Standards:

- A 29/A 29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought, General Requirements for
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

2.2 ASME Standards:

- B18.1.1 Small Solid Rivets $\frac{7}{16}$ Inch Nominal Diameter and Smaller
- B18.1.2 Large Rivets $\frac{1}{2}$ Inch Nominal Diameter and Larger
- B18.24 Part Identifying Number (PIN) Code System Standard for B18 Fastener Products

3. Ordering Information

3.1 Orders for rivets and bars under this specification shall include:

3.1.1 Specification designation and date of issue,

3.1.2 Quantity — Number of pieces for rivets and weight for bars,

3.1.3 Name of product and grade (A or B),

3.1.4 Size (diameter and length),

3.1.5 Rivet head type,

3.1.6 If inspection at point of manufacture is required,

3.1.7 Certification (Section 14), and

3.1.8 Additional testing or special requirements, if required.

3.1.9 For establishment of a part identifying system, see ASME B18.24.

NOTE 1 — A typical ordering description is: ASTM A 31 – 82, 10 000 pieces, steel rivets Grade A, $\frac{1}{2}$ by 2 in., button head, test reports required.

4. Materials and Manufacture

4.1 The steel shall be made by any of the following processes: open-hearth, electric-furnace, or basic-oxygen.

4.2 Rivets shall be manufactured from rivet bars conforming to the applicable grade ordered.

4.3 Rivets shall be manufactured by hot- or cold-heading.

4.4 Bars shall be furnished as rolled and not pickled, blast cleaned, or oiled. At producer's option, bars may be cleaned for inspection or cold drawn.

5. Chemical Composition

5.1 The steel shall conform to chemical composition prescribed in Table 1.

5.2 Heat Analysis — An analysis of each heat of steel shall be made by the bar manufacturer to determine for Grades A and B the percentages of carbon, manganese, phosphorus, and sulfur. This analysis shall be made from a test ingot taken during the pouring of the heat. The chemical composition thus determined shall be reported to the purchaser or his representative and shall conform to the requirements for heat analysis in accordance with Table 1.

5.3 Product Analysis — An analysis may be made by the purchaser from finished materials representing each heat. The chemical composition thus determined shall conform to the requirements for product analysis prescribed in Table 1.

5.4 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted.

5.5 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A 751.

6. Mechanical Properties

6.1 Rivet Bend Tests:

6.1.1 The rivet shank of Grade A steel shall stand being bent cold through 180° flat on itself, as shown in Fig. 1, without cracking on the outside of the bent portion.

6.1.2 The rivet shank of Grade B steel shall stand being bent cold through 180° without cracking on the outside of the bent portion in accordance with Table 2.

6.2 Rivet Flattening Tests — The rivet head shall stand being flattened, while hot, to a diameter $2\frac{1}{2}$ times the diameter of the shank, as shown in Fig. 2, without cracking at the edges.

6.3 Bar Tensile Properties — Bars shall conform to the tensile requirements in accordance with Table 3.

6.4 Bar Bend Tests:

6.4.1 The test specimen for Grade A steel bars shall stand being bent cold through 180° flat on itself without cracking on the outside of the bent portion.

6.4.2 The test specimen for Grade B steel bars shall stand being bent cold through 180° without cracking on the outside of the bent portion to an inside diameter which shall have a relation to the diameter of the specimen in accordance with Table 4.

7. Dimensions, Mass, and Permissible Variations

7.1 Rivets:

7.1.1 The dimensions of rivets shall conform to B18.1.2 for nominal diameters in. and larger and B18.1.1 for nominal diameters $\frac{7}{16}$ in. and less.

7.1.2 Snap gage measurement shall be made at the point of minimum diameter, but it is not required that the rivet shall turn completely in the gage. Measurements of the maximum tolerance shall be made with a ring gage, all rivets to slip full to the head in the gage of the required size for the various diameters.

7.2 Bars — The diameter of hot-finished rivet bars shall not vary from the size specified by more than the amounts in accordance with Table 5.

8. Workmanship, Finish, and Appearance

8.1 Rivets — The finished rivets shall be true to form, concentric, and free of injurious defects.

8.2 Bars:

8.2.1 Bars shall be free of visible pipe, undue segregation, and injurious surface imperfections.

8.2.2 Surface Finish — The bars shall have a commercial hot-wrought finish obtained by conventional hot rolling. See 4.4 for producer's descaling option.

9. Number of Tests and Retests

9.1 Rivets — Sampling for rivet bend and rivet flattening tests shall be in accordance with Guide F 1470, detection process.

9.2 Bars:

9.2.1 Two tension tests shall be made from each heat, unless the finished material from a heat is less than 50 tons (45 Mg), when one tension test will be sufficient. However, for material 2 in. (51 mm) and under in thickness, when the material from one heat differs $\frac{3}{8}$ in. (9.5 mm) or more in thickness, one tension test shall be made from both the thickest and the thinnest material rolled regardless of the weight represented. Each test shall conform to the specified requirements.

9.2.2 Retests on bars may be made in accordance with Specification A 29/A 29M.

10. Specimen Preparation

10.1 Rivets — Rivets shall be tested in their full-size finished condition.

10.2 Bars:

10.2.1 Test specimen selection and preparation shall be in accordance with Specification A 29/A 29M and Test Methods and Definitions A 370.

10.2.2 Tension and bend test specimens for rivet bars which have been cold drawn shall be normalized before testing.

11. Test Methods

11.1 Rivets — Rivet bend and flattening tests shall be in accordance with the manufacturers standard test procedures.

11.2 Bars — Tension and bend tests shall be conducted in accordance with Test Methods and Definitions A 370, and especially Supplement I thereof, on steel bar products.

12. Inspection

12.1 If the testing described in Section 9 is required by the purchaser, it shall be specified in the inquiry and contract or order.

12.2 The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities, without charge, to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

13. Rejection and Rehearing

13.1 Rivets — Rivets that fail to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

13.2 Bars — Rejection and rehearing shall be in accordance with Specification A 29/A 29M.

14. Certification

14.1 The manufacturer shall furnish certification that the material was manufactured and tested in accordance with this specification together with a report of the heat analysis (5.2) and mechanical property test results (Section 6) as applicable to the product ordered. The report shall include the manufacturer's name, ASTM designation, grade, heat number (bars only), and authorized signature.

15. Responsibility

15.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser.

16. Packaging and Package Marking

16.1 Rivets — Rivets shall be properly packed and marked to prevent damage and loss during shipment.

16.2 Bars — Bars shall be packed and marked in accordance with Specification A 29/A 29M.

17. Keywords

17.1 bars; carbon steel; pressure vessel rivets; rivets; steel

FIG. 1 BEND TEST OF RIVET

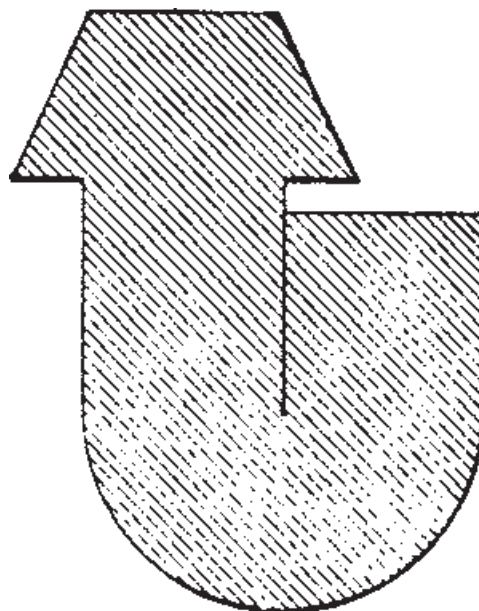
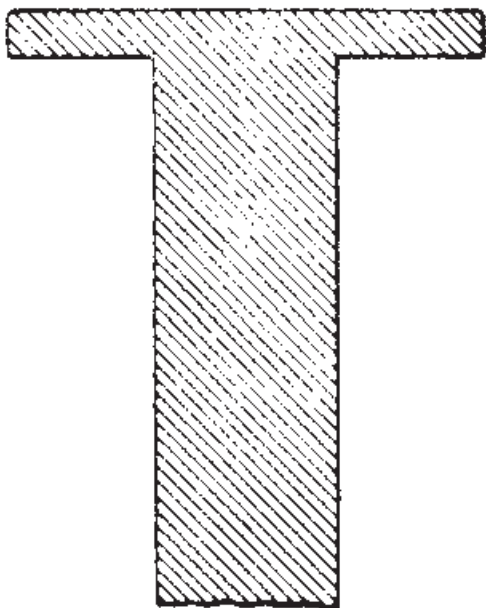


FIG. 2 FLATTENING TEST OF RIVET

TABLE 1
CHEMICAL REQUIREMENTS

	Grade A		Grade B	
	Heat Analysis	Product Analysis	Heat Analysis	Product Analysis
Carbon, max., %	...	...	0.28	0.31
Manganese, %	0.30–0.60	0.27–0.63	0.30–0.80	0.27–0.83
Phosphorus, max., %	0.040	0.048	0.040	0.048
Sulfur, max., %	0.050	0.058	0.050	0.058

TABLE 2
BEND REQUIREMENTS, RIVETS

Diameter of Rivet Shank, in.	Ratio of Bend Diameter to Diameter of Rivet Shank	
	Grade A	Grade B
$\frac{3}{4}$ and under	flat	1
Over $\frac{3}{4}$	flat	$1\frac{1}{2}$

TABLE 3
TENSILE REQUIREMENTS, BARS

	Grade A	Grade B
Tensile strength, psi (MPa)	45 000–55 000 (310–380)	58 000–68 000 (400–470)
Yield point, min., psi (MPa)	23 000 (160)	29 000 (200)
Elongation in 8 in. or 200 mm, min., %	27	22
Elongation in 2 in. or 50 mm, min., %	33	25

TABLE 4
BEND REQUIREMENTS, BARS

Specimen Diameter, in.	Ratio of Bend Diameter to Diameter of Specimen	
	Grade A	Grade B
$\frac{3}{4}$ and under	flat	$\frac{1}{2}$
Over $\frac{3}{4}$	flat	1

TABLE 5
PERMISSIBLE VARIATIONS IN THE SIZE OF
HOT-ROLLED ROUNDS

Specified Size, in.	Variations from Size, in.		Out-of-Round, ⁴ in.
	Over	Under	
$\frac{5}{16}$ and under	0.005	0.005	0.008
Over $\frac{5}{16}$ to $\frac{7}{16}$, incl	0.006	0.006	0.009
Over $\frac{7}{16}$ to $\frac{5}{8}$, incl	0.007	0.007	0.010
Over $\frac{5}{8}$ to $\frac{7}{8}$, incl	0.008	0.008	0.012
Over $\frac{7}{8}$ to 1, incl	0.009	0.009	0.013
Over 1 to $1\frac{1}{8}$, incl	0.010	0.010	0.015
Over $1\frac{1}{8}$ to $1\frac{1}{4}$, incl	0.011	0.011	0.016
Over $1\frac{1}{4}$ to $1\frac{3}{4}$, incl	0.012	0.012	0.018
Over $1\frac{3}{4}$ to $1\frac{1}{2}$, incl	0.014	0.014	0.021

⁴ Out-of-round is the difference between the maximum and minimum diameters of the bar, measured at the same cross-section.

SPECIFICATION FOR CARBON STRUCTURAL STEEL



SA-36/SA-36M



(Identical with ASTM Specification A 36/A 36M-05.)

1. Scope

1.1 This specification covers carbon steel shapes, plates, and bars of structural quality for use in riveted, bolted, or welded construction of bridges and buildings, and for general structural purposes.

1.2 Supplementary requirements are provided for use where additional testing or additional restrictions are required by the purchaser. Such requirements apply only when specified in the purchase order.

1.3 When the steel is to be welded, a welding procedure suitable for the grade of steel and intended use or service is to be utilized. See Appendix X3 of Specification A 6/A 6M for information on weldability.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system is to be used independently of the other, without combining values in any way.

1.5 The text of this specification contains notes or footnotes, or both, that provide explanatory material. Such notes and footnotes, excluding those in tables and figures, do not contain any mandatory requirements.

1.6 For structural products produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results, of A 6/A 6M apply.

2. Referenced Documents

2.1 ASTM Standards:

- A 6/A 6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling
- A 27/A 27M Specification for Steel Castings, Carbon, for General Application

A 307 Specification for Carbon Steel Bolts and Studs, 60 000 psi Tensile Strength

A 325 Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength

A 325M Specification for Structural Bolts, Steel, Heat Treated 830 MPa Minimum Tensile Strength [Metric]

A 500 Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes

A 501 Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing

A 502 Specification for Rivets, Steel, Structural

A 563 Specification for Carbon and Alloy Steel Nuts

A 563M Specification for Carbon and Alloy Steel Nuts [Metric]

A 668/A 668M Specification for Steel Forgings, Carbon and Alloy, for General Industrial Use

A 1011/A 1011M Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural High Strength Low Alloy, and High Strength Low Alloy with Improved Formability

F 568M Specification for Carbon and Alloy Steel Externally Threaded Metric Fasteners

3. Appurtenant Materials

3.1 When components of a steel structure are identified with this ASTM designation but the product form is not listed in the scope of this specification, the material shall conform to one of the standards listed in Table 1 unless otherwise specified by the purchaser.

4. General Requirements for Delivery

4.1 Structural products furnished under this specification shall conform to the requirements of the current edition of Specification A 6/A 6M, for the specific structural product ordered, unless a conflict exists in which case this specification shall prevail.

4.2 Coils are excluded from qualification to this specification until they are processed into a finished structural product. Structural products produced from coil means structural products that have been cut to individual lengths from a coil. The processor directly controls, or is responsible for, the operations involved in the processing of a coil into a finished structural product. Such operations include decoiling, leveling or straightening, hot-forming or cold-forming (if applicable), cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1 — For structural products produced from coil and furnished without heat treatment or with stress relieving only, two test results are to be reported for each qualifying coil. Additional requirements regarding structural products produced from coil are described in Specification A 6/A 6M.

5. Bearing Plates

5.1 Unless otherwise specified, plates used as bearing plates for bridges shall be subjected to mechanical tests and shall conform to the tensile requirements of Section 8.

5.2 Unless otherwise specified, mechanical tests shall not be required for plates over 1½ in. [40 mm] in thickness used as bearing plates in structures other than bridges, subject to the requirement that they shall contain 0.20 to 0.33% carbon by heat analysis, that the chemical composition shall conform to the requirements of Table 2 in phosphorus and sulfur content, and that a sufficient discard shall be made to secure sound plates.

6. Materials and Manufacture

6.1 The steel for plates and bars over ½ in. [12.5 mm] in thickness and shapes with flange or leg thicknesses over 1 in. [25 mm] shall be semi-killed or killed.

7. Chemical Composition

7.1 The heat analysis shall conform to the requirements prescribed in Table 2, except as specified in 5.2.

7.2 The steel shall conform on product analysis to the requirements prescribed in Table 2, subject to the product analysis tolerances in Specification A 6/A 6M.

8. Tension Test

8.1 The material as represented by the test specimen, except as specified in 5.2 and 8.2, shall conform to the requirements as to the tensile properties prescribed in Table 3.

8.2 Shapes less than 1 in.² [645 mm²] in cross section and bars, other than flats, less than ½ in. [12.5 mm] in thickness or diameter need not be subjected to tension tests by the manufacturer, provided that the chemical composition used is appropriate for obtaining the tensile properties in Table 3.

9. Keywords

9.1 bars; bolted construction; bridges; buildings; carbon; plates; riveted construction; shapes; steel; structural steel; welded construction

TABLE 1
APPURTENANT MATERIAL SPECIFICATIONS

Material	ASTM Designation
Steel rivets	A 502, Grade 1
Bolts	A 307, Grade A or F 568M, Class 4.6
High-strength bolts	A 325 or A 325M
Steel nuts	A 563 or A 563M
Cast steel	A 27/A 27M, Grade 65–35 [450–240]
Forgings (carbon steel)	A 668, Class D
Hot-rolled sheets and strip	A 1011/A 1011M, SS Grade 36 [250] Type 1 or Type 2 or A 1018/A 1018M SS Grade 36 [250]
Cold-formed tubing	A 500, Grade B
Hot-formed tubing	A 501
Anchor bolts	F 1554

NOTE 1 — The specifier should be satisfied of the suitability of these materials for the intended application. Chemical composition and/or mechanical properties may be different than specified in A 36/A 36M.

TABLE 2
CHEMICAL REQUIREMENTS

Product Thickness, in. [mm]	Shapes ^A	Plates ^B				Bars ^B			
		To $\frac{3}{4}$ [20], Incl.	Over $\frac{3}{4}$ to $1\frac{1}{2}$ [20 to 40], Incl.	Over $1\frac{1}{2}$ to $2\frac{1}{2}$ [40 to 65], Incl.	Over $2\frac{1}{2}$ to 4 [65 to 100], Incl.	Over 4 [100]	To $\frac{3}{4}$ [20], Incl.	Over $\frac{3}{4}$ to $1\frac{1}{2}$ [20 to 40], Incl.	Over $1\frac{1}{2}$ to 4 [40 to 100], Incl.
Carbon, max., %	0.26	0.25	0.25	0.26	0.27	0.29	0.26	0.27	0.28
Manganese, %	...	...	0.80–1.20	0.80–1.20	0.85–1.20	0.85–1.20	...	0.60–0.90	0.60–0.90
Phosphorus, max., %	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Sulfur, max., %	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Silicon, %	0.40 max.	0.40 max.	0.40 max.	0.15–0.40	0.15–0.40	0.15–0.40	0.40 max.	0.40 max.	0.40 max.
Copper, min., % when copper steel is specified	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

NOTE 1 — Where “...” appears in this table, there is no requirement. The heat analysis for manganese shall be determined and reported as described in the heat analysis section of Specification A 6/A 6M.

^A Manganese content of 0.85–1.35% and silicon content of 0.15–0.40% is required for shapes with flange thickness over 3 in. [75 mm].

^B For each reduction of 0.01 percentage point below the specified carbon maximum, an increase of 0.06 percentage point manganese above the specified maximum will be permitted, up to the maximum of 1.35%.

TABLE 3
TENSILE REQUIREMENTS^A

Plates, Shapes,^B and Bars:	
Tensile strength, ksi [MPa]	58–80 [400–550]
Yield point, min., ksi [MPa]	36 [250] ^C
Plates and Bars^{D,E}:	
Elongation in 8 in. [200 mm], min., %	20
Elongation in 2 in. [50 mm], min., %	23
Shapes:	
Elongation in 8 in. [200 mm], min., %	20
Elongation in 2 in. [50 mm], min., %	21 ^B

^A See the Orientation subsection in the Tension Tests section of Specification A 6/A 6M.

^B For wide flange shapes with flange thickness over 3 in. [75 mm], the 80 ksi [550 MPa] maximum tensile strength does not apply and a minimum elongation in 2 in. [50 mm] of 19% applies.

^C Yield point 32 ksi [220 MPa] for plates over 8 in. [200 mm] in thickness.

^D Elongation not required to be determined for floor plate.

^E For plates wider than 24 in. [600 mm], the elongation requirement is reduced two percentage points. See Elongation Requirement Adjustments subsection under the Tension Tests section of Specification A 6/A 6M.

SUPPLEMENTARY REQUIREMENTS

These requirements shall not apply unless specified in the order. Standardized supplementary requirements for use at the option of the purchaser are listed in Specification A 6/A 6M. Those that are considered suitable for use with this specification are listed by title.

S5. Charpy V-Notch Impact Test

S30. Charpy V-Notch Impact Test for Structural Shapes: Alternate Core Location

S32. Single Heat Bundles

S32.1 Bundles containing shapes or bars shall be from a single heat of steel.

In addition, the following optional supplementary requirement is also suitable for use with this specification.

S97. Limitation on Rimmed or Capped Steel

S97.1 The steel shall be other than rimmed or capped.

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SPECIFICATION FOR FERRITIC MALLEABLE IRON CASTINGS



SA-47/SA-47M

[Identical with ASTM Specification A 47/A 47M-99(R09), except for the deletion of welded repair references in 11.2 and 11.3, and mandatory certification in 14.1.]

1. Scope

1.1 This specification covers ferritic malleable castings for general engineering usage at temperatures from normal ambient to approximately 400°C (750°F).

1.2 No precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting and those of a test specimen cast from the same iron (see Appendix X1).

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 ASTM Standards:

- A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
- A 247 Test Method for Evaluating the Microstructure of Graphite in Iron Castings
- A 644 Terminology Relating to Iron Castings
- E 8 Test Methods for Tension Testing of Metallic Materials
- E 10 Test Method for Brinell Hardness of Metallic Materials
- E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
- E 140 Hardness Conversion Tables for Metals

2.2 Military Standard:

MIL-STD-129 Marking for Shipment and Storage

2.3 Federal Standard:

Fed. Std. No. 123 Marking for Domestic Shipment (Civilian Agencies)

3. Terminology

3.1 Definitions — Definitions for many terms common to iron are found in Terminology A 644.

4. Classification

4.1 Castings ordered and produced under this specification are classified under the following grades based on tests on separately cast test bars. Separately cast test bars shall be poured from the same lot of iron as the castings they represent and shall be heat treated with those castings except as provided in 7.2.3.

4.1.1 Grade 32510 [Grade 22010]:

4.1.1.1 The first three digits of the grade designation indicate the minimum yield strength ($\times 100$ psi [MPa]) and the last two digits indicate the minimum elongation (% in 2 in. [50 mm]).

5. Ordering Information

5.1 The purchase order for castings ordered under this specification shall state the specification designation, the year in which the specification was issued, and the grade of malleable iron to be supplied. Any option or special additions to the basic requirements of this specification shall be clearly and fully stipulated.

6. Chemical Composition

6.1 The chemical composition of the iron shall be such as to produce the structural and mechanical properties required by this specification.

7. Mechanical Properties

7.1 Factors influencing the properties of castings and their relationship to those of test specimens and separate test castings are discussed in Appendix X1.

7.2 Tension Test Specimens:

7.2.1 The tension test specimens shall be cast to the form and dimensions shown in Fig. 1 or Fig. 2, in the same kind of molding material used for the production castings. At least three such specimens shall be cast from a representative ladle of iron either from each batch-melted heat or, in continuous melting, from each 4 h pour period during which the purchaser's castings were poured, or as otherwise agreed upon between manufacturer and purchaser.

7.2.2 All test specimens shall be suitably identified with the designation of either the batch-melted heat or the pour period of a continuous heat.

7.2.3 All test specimens shall be heat treated in the same production furnaces and in the same cycles as the castings they represent. However, in those instances wherein the critical sections of the production castings differ appreciably from that of the central portion of the test specimens, the time cycle for tempering the test specimens may be altered from that of the production lot in order to obtain similar microstructures or hardness, or both, in both specimen and castings. In such cases the hardness of the specimens shall be tested and reported along with the tensile test results.

7.2.4 The tension test is usually performed on unmachined specimens. However, for referee work, the specimen may be machined from the standard cast bar to the dimensions shown in Fig. 3.

7.3 Tension Test Method:

7.3.1 The gage length of the standard tension specimen shall be 2.00 ± 0.01 in. [50.0 ± 0.3 mm].

7.3.2 The diameter used to compute the cross-sectional area shall be the average between the largest and smallest diameters in that section of the 2 in. [50 mm] gage length having the smallest diameter and shall be measured to the nearest 0.001 in. [0.2 mm]. No cast bar having a mean diameter less than 0.590 in. [15.0 mm] shall be accepted for test.

7.3.3 After reaching a stress equivalent to approximately half of the anticipated yield stress, the speed of the moving head of the testing machine shall not exceed 0.50 in./min [12.5 mm/min] through the breaking load.

7.3.4 While the values for yield point and yield strength are not identical, they are sufficiently close for most applications of ferritic malleable irons to be used interchangeably. They may be determined by any of the approved techniques described in the paragraphs on Determination of Yield Strength and Yield Point of Test Methods E 8. If determined as yield strength, that stress producing an extension under load of 0.01 in. [0.25 mm] over the 2 in. [50 mm] gage length (for example, 0.5% extension) or an offset of 0.2% shall be taken as the yield stress, which shall be converted to yield strength by dividing by

the original cross-sectional area of the gage length found in accordance with 7.3.2. It shall be reported to the nearest 100 psi [MPa]. In referee work, yield strength shall be determined as the stress that produces an extension under load of 0.5% of the gage length.

7.3.5 The tensile strength shall be the maximum load carried by the specimen during the test divided by the original cross-sectional area of the gage length, as found in accordance with 7.3.2. It shall be reported to the nearest 100 psi [MPa].

7.3.6 The elongation is the increase in gage length after fracture of a tensile specimen, measured to the nearest 0.01 in. [0.25 mm], expressed as a percentage of the original gage length. It shall be reported to the nearest 0.5%.

7.4 Retesting:

7.4.1 If, after testing, a specimen shows evidence of a defect, another tension test may be made on a companion specimen. Also, a retest shall be permitted whenever fracture occurs outside the central 50% of the gage length.

7.4.2 If the results of a valid test fail to conform to the requirements of this specification, two retests shall be made. If either retest fails to meet the specification, the castings represented by these test specimens shall be rejected. A valid test is one wherein the test specimen has been properly prepared and appears to be sound and on which the approved test procedure has been followed.

7.4.3 If sufficient companion test bars are unavailable, the manufacturer shall have the option of testing a specimen cut from a representative casting. Therefore, as stated in X1.3, the mechanical properties of such tension test specimen removed from a production casting will not necessarily correspond to those of a standard separately cast test specimen, the values in Table 1 do not apply. Instead, the mechanical properties of the test specimen from the casting must equal or exceed the average of those from similar test specimens removed from the same location from two castings of the same design where separately cast test bars meet the requirements of Table 1.

7.4.4 If the first test results indicate that a reheat treatment is needed to meet the test requirements, the entire lot of castings and the representative test specimens shall be reheat treated together. Testing shall then be repeated in accordance with 7.4.1–7.4.3.

7.4.5 The results of all tests, including retests, shall be posted in permanent record, which shall state any abnormalities observed during the test and in the fractured ends. Such records shall be kept for at least 1 year after shipment of the production castings and shall be available for examination by the purchaser or by his authorized representative.

7.4.6 If not covered in the purchase agreement, the frequency of tension testing shall be in accordance with 7.2.1 and sufficiently often to ensure uniformity of product and compliance with minimum test requirements.

7.4.7 Tension test results, obtained in accordance with the above subsections, must conform to the values of Table 1 for acceptance under this specification except as provided in 7.4.3.

7.4.8 When agreed upon between manufacturer and purchaser, tested specimens or unbroken test bars shall be preserved by the manufacturer for a period of three months after the date of the test report.

7.5 Hardness Test — If the purchase agreement requires hardness testing, the acceptable hardness range shall be stated and a test location clearly shown on the covering drawing(s).

7.5.1 Hardness Test Method — The Brinell method of hardness testing in accordance with Test Method E 10 shall be employed whenever possible.

7.5.2 For castings of such size or shape that do not permit Brinell testing with the standard 3000-kgf load, the 500 kgf may be employed, the hardness number being reported as HB 10/500/15. In very unusual cases where it is impossible to use the Brinell method, the Rockwell test may be substituted, using Test Methods E 18 with an appropriate Rockwell scale. Conversions of hardness values from one method to another according to Standard E 140, which does not specifically cover cast irons, are approximate only and, therefore, are generally inadvisable.

7.5.3 Sufficient material shall be removed from the cast surface to ensure that the measured surface is representative.

7.5.4 Sampling procedures and the frequency of hardness testing shall be fully detailed on the purchase agreement. Otherwise, hardness tests shall be performed at the discretion of the producer.

7.5.5 Castings failing to conform to the required hardness range may be reheat treated and retested. If after reheat treating they still fail the hardness requirements, they shall be rejected.

7.5.6 Typical hardness maximums for this grade of malleable iron are listed in Table 2.

8. Microstructure Requirements

8.1 The microstructure of the malleable iron shall consist of temper carbon nodules distributed through a ferritic matrix and shall be free of excessive pearlite, massive carbides, and primary graphite.

8.2 When agreed upon by the purchaser and producer, the maximum decarburization at any as-cast surface after heat treatment may be stipulated in writing, as measured by visual depletion of combined carbon after polishing, etching in nital, and viewing at 100×

8.3 In reference work, the metallographic practice recommended in Test Method A 247 shall be followed.

9. Soundness Requirements

9.1 All castings, on visual examination, shall be sound and free of obvious shrinkage and porosity.

9.2 If the purchaser requires soundness tests to be performed, it shall be so stated in the purchase agreement, and the method and soundness requirements shall be detailed.

10. Dimensional Requirements

10.1 The castings shall conform to the dimensions given on drawings furnished by the purchaser, or to the dimensions established by the pattern equipment supplied by the purchaser, or as agreed upon in specific cases to gages supplied by the purchaser. Variations in any solid dimensions will be permitted, as shown in Table 3, unless otherwise agreed upon by the foundry and purchaser.

11. Workmanship, Finish and Appearance

11.1 The surface of the casting shall be inspected visually, particularly in critical areas, for such surface defects as cracks, hot tears, adhering sand and scale, cold shuts, and gas holes.

11.2 No repairing or plugging of any kind shall be permitted unless written permission is granted by the purchaser. Welding or brazing is not permitted under any circumstances.

11.3 DELETED

12. Responsibility for Inspection

12.1 Unless otherwise specified in the contract or purchase order, the manufacturer shall be responsible for carrying out all the tests and inspections required by this specification, using his own or other reliable facilities, and he shall maintain complete records of all such tests and inspections. Such records shall be available for review by the purchaser.

12.2 The purchaser reserves the right to perform any inspection set forth in the specification where such inspections are deemed necessary to ensure that supplies and services conform to the prescribed requirements.

13. Rejection and Rehearing

13.1 Any casting or lot of castings failing to comply with the requirements of this specification may, where possible, be reprocessed, retested, and reinspected. If the

tests and inspections on the reprocessed casting(s) show compliance with this specification, the castings shall be acceptable; if they do not, they shall be rejected.

13.2 If the purchaser should find that a casting or lot of castings fails to comply with this specification subsequent to receipt at his facility, he shall so notify the manufacturer promptly and in no case later than six weeks after receipt of the shipment, stating clearly his basis for rejection. In case of dissatisfaction with the purchaser's claim, the manufacturer may apply for a hearing before final rejection of the shipment.

14. Certification

14.1 A manufacturer's certification or compliance statement that the casting or lot of castings was made, sampled, tested, and inspected in accordance with this specification, including a report of test results signed by an authorized agent of the manufacturer, shall be furnished at the time of shipment, and such certification or compliance statement shall be the basis for acceptance of the casting or lot of castings.

TABLE 1
TENSION TEST REQUIREMENTS

Inch-Pound Grades			
English Grade	Tensile Strength, min, psi	Yield Strength, min, psi	Elongation in 2 in., min, %
32510	50 000	32 500	10
Metric Grades			
Metric Grade	Tensile Strength, min, MPa	Yield Strength, min, MPa	Elongation in 50 mm, min, %
22010	340	220	10

15. Product Marking

15.1 When the size of the casting permits, each casting shall bear the identifying mark of the manufacturer and the part or pattern number at a location shown on the covering drawing and, if not shown on the drawing, at such a location at the discretion of the producer that the identification will not interfere with subsequent processing and service of the casting.

16. Packaging and Package Marking

16.1 Unless otherwise stated in the contract or order, the cleaning, preservation, and packing of castings for shipment shall be in accordance with the manufacturer's commercial practice. Packaging and marking shall also be adequate to identify the contents and to ensure acceptance and safe delivery by the carrier for the mode of transportation employed.

16.2 U.S. Government Procurement — When specified in the contract or purchase order, marking for shipment shall be in accordance with the requirements of Fed. Std. No. 123 and MIL-STD-129.

TABLE 2
TYPICAL HARDNESS

Inch-Pound Grade [Metric Grade]	Hardness, Maximum HB	Indentation Value Diameters, mm
325 10 [22010]	156	4.8

TABLE 3
**PERMISSIBLE VARIATION IN ANY
SOLID DIMENSION**

Size, in. [mm]	Tolerance, ± in. [mm]
Up to 1 [Up to 25]	0.03 [0.8]
1 to 6 [25 to 150]	0.06 [1.6]
6 to 12 [151 to 300]	0.12 [3.2]
12 to 18 [301 to 460]	0.15 [3.8]
18 to 24 [461 to 600]	0.19 [4.8]
24 to 36 [601 to 900]	0.22 [5.6]

FIG. 1 TENSION TEST SPECIMEN

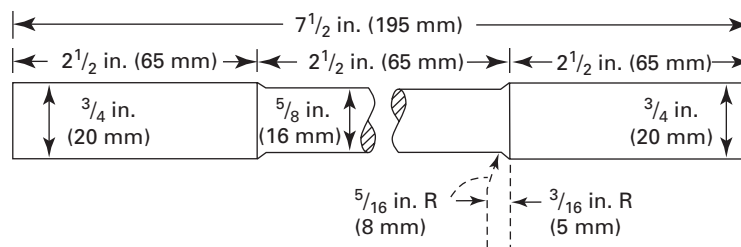
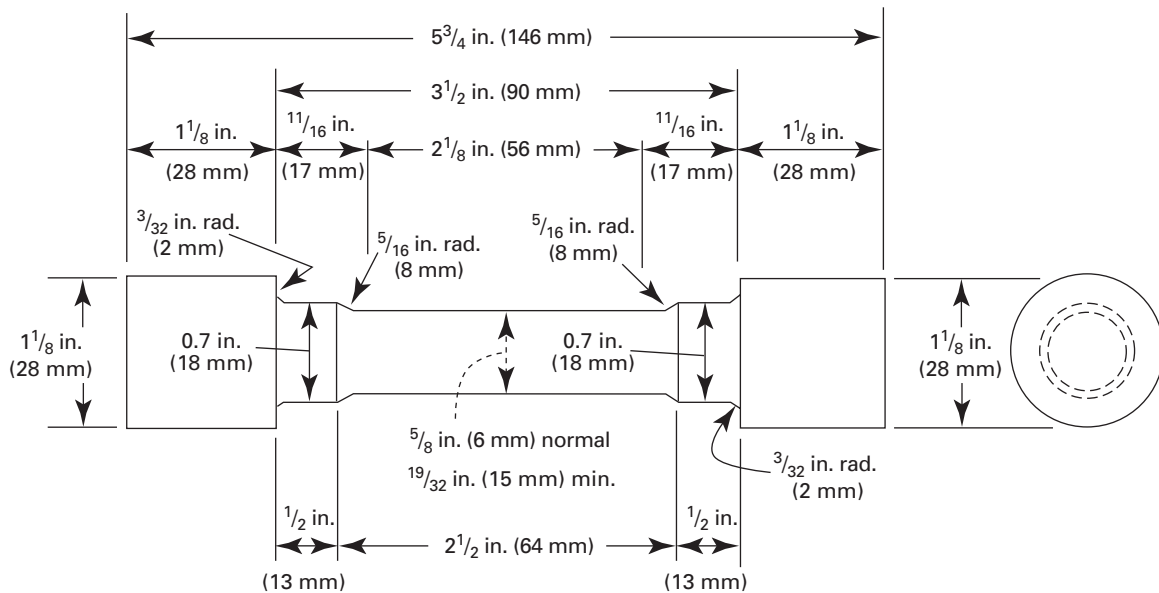
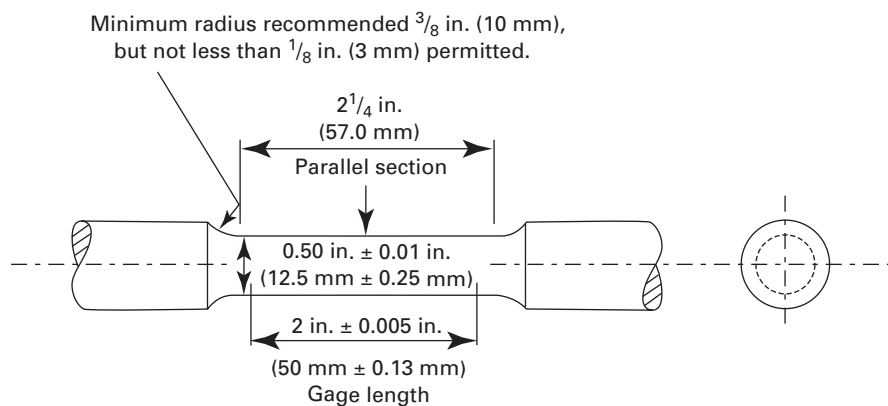


FIG. 2 ALTERNATIVE UNMACHINED TENSION TEST SPECIMEN



NOTE 1 — Modifications may be made in the dimensions indicated above for those details of the specimen outside of the gage length as required by testing procedure and equipment.

FIG. 3 MACHINED TENSION TEST SPECIMEN



NOTE 1 — The gage length and fillets shall be as shown, but the ends may be of any shape to fit the holders of the testing machine in such a way that the load shall be axial. The reduced section shall have a gradual taper from the ends toward the center, with the ends 0.003 to 0.005 in. [0.08 to 0.13 mm] larger in diameter than the center.

SUPPLEMENTARY REQUIREMENTS

S1. Special Conditions

S1.1 If agreed upon in writing by the foundry and purchaser, the malleable iron castings may be required to meet special conditions, hardness or other property dimensions, surface quality, or a combination of conditions.

S2. Test Lugs

S2.1 If requested in writing or if included on the pattern(s) or pattern drawing(s), test lugs may be cast on all castings of sufficient size to permit their incorporation. The size of such lugs shall be proportional to the thickness of the casting. On castings over 24 in. [600 mm] in length, a test lug shall be cast near each end such as not to interfere with any subsequent processing of the castings. The purchase order shall stipulate whether the foundry's inspector or the purchaser's inspector shall break, inspect, and pass judgment on the fracture quality of these test lugs.

S3. Destructive Tests

S3.1 At the option of the purchaser or his representative, a casting of each design ordered may be tested to destruction, or otherwise broken up, to determine the presence of any manufacturing condition that might be detrimental to the serviceability of the casting.

S4. Special Tension Specimens

S4.1 If tension specimens are to be machined from castings, their location in the casting, the specimen dimensions, and the required properties shall be agreed upon in writing by the foundry and purchaser.

S5. Zinc-Coated Castings

S5.1 When specified in the contract or purchase order, castings shall be zinc-coated by the hot-dip process in accordance with Specification A 153. Castings shall be of a composition that will preclude the possibility of galvanizing embrittlement, or shall be either cooled from the anneal or subsequently heat treated so as to be immunized against such embrittlement. If regalvanizing is required, procedures for regalvanizing castings and determining the effect on the casting performance must be agreed upon between the purchaser and the seller.

S6. Marking of Casting for Government Procurement

S6.1 When castings are specified for government procurement, the location of the permanent markings specified in 15.1, as well as any special marking for mechanical or physical properties (either permanent or temporary), shall be as indicated on the government drawings or sketches.

APPENDIX

(Nonmandatory Information)

X1. MECHANICAL PROPERTIES OF CASTINGS

X1.1 The mechanical properties of malleable iron castings are influenced by a number of factors, including the cooling rate during solidification, chemical composition, the heat treatment, the design of the casting, section thickness, and the location and effectiveness of gates, risers, and chills.

X1.2 Because of the complexity of these factors in influencing the properties of the final product, no precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting or between the properties of a casting and those of a test specimen cast from the same iron. When such a relationship is important and must be known for a specific application, it may be determined by appropriate experimentation.

X1.3 The specimen specified in 7.2.1 as the standard tensile test bar for malleable iron has a $\frac{5}{8}$ in. [16 mm] diameter test section that reasonably represents a typical

section of the general run of malleable iron castings. Furthermore, the initial freezing of malleable irons as homogeneous white iron, together with the heat treatment that is inherent in the manufacture of malleable iron, tends to reduce the section-sensitivity effect. Therefore, where experimentation into precise properties within a given casting would be infeasible, this standard test bar, made like any typical casting, should provide a practical approximation of the properties that can be expected in average sound malleable iron casting.

X1.4 If malleable iron castings are welded, the microstructure of the iron is markedly affected, particularly in the heat-affected zone. Therefore, since this may adversely affect the properties of the casting, the welding of malleable iron castings should be done under strict metallurgical control, followed by appropriate post-weld heat treatment, to minimize the substantial reductions in ductility, impact resistance, and machinability that could result, particularly in the vicinity of the weldment. Nevertheless, it is generally considered inadvisable to join castings to similar castings or to other materials, by fusion welding out in the field, or in manufactured assemblies, without fully testing the entire completed part.

SPECIFICATION FOR PIPE, STEEL, BLACK AND HOT-DIPPED, ZINC-COATED, WELDED AND SEAMLESS



SA-53/SA-53M

(Identical with ASTM Specification A 53/A 53M-01 except for the insertion of test practices in 11.1.1, and editorial correction to Table X4.1.)

1. Scope

1.1 This specification covers seamless and welded black and hot-dipped galvanized steel pipe in NPS $\frac{1}{8}$ to NPS 26 [DN 6 to DN 650] (Note 1), inclusive, with nominal wall thickness (Note 2) as given in Table X2.2 and Table X2.3. It shall be permissible to furnish pipe having other dimensions (Note 2) provided such pipe complies with all other requirements of this specification.

NOTE 1 — The dimensionless designators NPS (nominal pipe size) [DN (diameter nominal)] have been substituted in this specification for such traditional terms as “nominal diameter,” “size,” and “nominal size.”

NOTE 2 — The term nominal wall thickness has been assigned for the purpose of convenient designation, existing in name only, and is used to distinguish it from the actual wall thickness, which may vary over or under the nominal wall thickness.

1.2 This specification covers the following types and grades:

1.2.1 *Type F* — Furnace-butt welded, continuous welded Grade A,

1.2.2 *Type E* — Electric-resistance welded, Grades A and B, and

1.2.3 *Type S* — Seamless, Grades A and B.

NOTE 3 — See Appendix X1 for definitions of types of pipe.

1.3 Pipe ordered under this specification is intended for mechanical and pressure applications and is also acceptable for ordinary uses in steam, water, gas, and air lines. It is suitable for welding, and suitable for forming operations involving coiling, bending, and flanging, subject to the following qualifications:

1.3.1 Type F is not intended for flanging.

1.3.2 When Types S and E are required for close coiling or cold bending, Grade A is the preferred grade. This provision is not intended to prohibit the cold bending of Grade B pipe.

1.3.3 Type E is furnished either nonexpanded or cold expanded at the option of the manufacturer.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 The following precautionary caveat pertains only to the test method portion, Sections 9, 10, 11, 15, 16, and 17 of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.6 The text of this specification contains notes or footnotes, or both, that provide explanatory material. Such notes and footnotes, excluding those in tables and figures, do not contain any mandatory requirements.

2. Referenced Documents

2.1 ASTM Standards:

- A 90/A 90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe
- A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- A 865 Specification for Threaded Couplings, Steel, Black or Zinc-Coated (Galvanized) Welded or Seamless, for Use in Steel Pipe Joints

B 6 Specification for Zinc
 E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
 E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing
 E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation
 E 570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products
 E 1806 Practice for Sampling Steel and Iron for Determination of Chemical Composition

2.2 ANSI Standards:

ASC X12

B1.20.1 Pipe Threads, General Purpose

2.3 ASME Standard:

B36.10 Welded and Seamless Wrought Steel Pipe

2.4 Military Standards:

MIL-STD-129 Marking for Shipment and Storage

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage

2.5 Federal Standards:

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products

2.6 API Standard:

5L Specification for Line Pipe

3. Ordering Information

3.1 Information items to be considered, if appropriate, for inclusion in the purchase order are as follows:

3.1.1 Specification designation (A 53 or A 53M, including year of issue),

3.1.2 Quantity (feet, metres, or number of lengths),

3.1.3 Grade (see Table 1),

3.1.4 Type (see 1.2 and Table 2),

3.1.5 Finish (black or galvanized),

3.1.6 Size (either nominal (NPS) [DN] and weight class or schedule number, or both; or outside diameter and nominal wall thickness, Table X2.2 and Table X2.3),

3.1.7 Length (specific or random, Section 18),

3.1.8 End finish (plain end or threaded, Section 13),

3.1.8.1 Threaded and coupled, if desired,

3.1.8.2 Threads only (no couplings), if desired,

3.1.8.3 Plain end, if desired,

3.1.8.4 Couplings power tight, if desired,

3.1.8.5 Taper tapped couplings for NPS 2 [DN 50] and smaller, if desired,

3.1.9 Close coiling, if required (see 8.2),

3.1.10 Skelp for tension tests, if permitted (see 17.2),

3.1.11 Certification (see Section 22),

3.1.12 End use of material,

3.1.13 Special requirements, and

3.1.14 Selection of applicable level of preservation and packaging and level of packing required, if other than as specified or if MIL-STD-163 applies (see 21.2).

4. Materials and Manufacture

4.1 The steel for both seamless and welded pipe shall be made by one or more of the following processes: open-hearth, electric-furnace, or basic-oxygen.

4.2 When steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

4.3 The weld seam of electric-resistance welded pipe in Grade B shall be heat treated after welding to a minimum of 1000°F [540°C] so that no untempered martensite remains, or otherwise processed in such a manner that no untempered martensite remains.

4.4 When pipe is cold expanded, the amount of expansion shall not exceed 1½% of the outside diameter pipe size.

5. Chemical Composition

5.1 The steel shall conform to the requirements as to chemical composition in Table 1 and the chemical analysis shall be in accordance with Test Methods, Practices, and Terminology A 751.

6. Product Analysis

6.1 The purchaser is permitted to perform an analysis of two pipes from each lot of 500 lengths, or fraction thereof. Samples for chemical analysis, except for spectrographic analysis, shall be taken in accordance with Practice E 1806. The chemical composition thus determined shall conform to the requirements specified in Table 1.

6.2 If the analysis of either pipe does not conform to the requirements specified in Table 1, analyses shall be made on additional pipes of double the original number from the same lot, each of which shall conform to the requirements specified.

7. Tensile Requirements

7.1 The material shall conform to the requirements as to tensile properties prescribed in Table 2.

7.2 The yield strength corresponding to a permanent offset of 0.2% of the gage length of the specimen or to a total extension of 0.5% of the gage length under load shall be determined.

7.3 The test specimen taken across the weld shall show a tensile strength not less than the minimum tensile strength specified for the grade of pipe ordered. This test will not be required for pipe under NPS 8 [DN 200].

7.4 Transverse tension test specimens for electric-welded pipe NPS 8 [DN 200] and larger shall be taken opposite the weld. All transverse test specimens shall be approximately 1½ in. [40 mm] wide in the gage length, and shall represent the full wall thickness of the pipe from which the specimen was cut. This test is required for NPS 8 [DN 200] and larger.

8. Bending Requirements

8.1 For pipe NPS 2 [DN 50] and under, a sufficient length of pipe shall be capable of being bent cold through 90° around a cylindrical mandrel, the diameter of which is twelve times the outside diameter of the pipe, without developing cracks at any portion and without opening the weld.

8.2 When ordered for close coiling, the pipe shall stand being bent cold through 180° around a cylindrical mandrel, the diameter of which is eight times the outside diameter of the pipe, without failure.

8.3 Double-extra-strong pipe over NPS 1¼ [DN 32] need not be subjected to the bend test.

9. Flattening Test

9.1 The flattening test shall be made on pipe over NPS 2 [DN 50] with all thicknesses extra strong and lighter.

9.2 Seamless Pipe:

9.2.1 For seamless pipe, a test specimen at least 2½ in. [60 mm] in length shall be flattened cold between parallel plates in two steps. During the first step, which is a test for ductility, no cracks or breaks on the inside, outside, or end surfaces, except as provided for in 9.7, shall occur until the distance between the plates is less than the value of H calculated as follows:

$$H = (1 + e) t / (e + t/D)$$

where:

H = distance between flattening plates, in. [mm]
(Note 4),

e = deformation per unit length (constant for a given grade of steel, 0.09 for Grade A, and 0.07 for Grade B),

t = nominal wall thickness, in. [mm], and
 D = specified outside diameter, in. [mm]

9.2.2 During the second step, which is a test for soundness, the flattening shall be continued until the test specimen breaks or the opposite sides of the pipe meet. Evidence of laminated or unsound material that is revealed during the entire flattening test shall be cause for rejection.

NOTE 4 — The H values have been calculated for standard and extra-heavy weight sizes from NPS 2½ to NPS 24 [DN 65 to DN 600], inclusive, and are shown in Table X2.1.

9.3 Electric-Resistance-Welded Pipe — A test specimen at least 4 in. [100 mm] in length shall be flattened cold between parallel plates in three steps, with the weld located either 0° or 90° from the line of direction of force as required in 9.3.1 or 9.3.2, whichever is applicable. During the first step, which is a test for ductility of the weld, no cracks or breaks on the inside or outside surfaces at the weld shall occur until the distance between the plates is less than two thirds of the specified diameter of the pipe. As a second step, the flattening shall be continued as a test for ductility away from the weld. During the second step, no cracks or breaks on the inside or outside surfaces away from the weld, except as provided for in 9.7, shall occur until the distance between the plates is less than one third of the specified outside diameter of the pipe but is not less than five times the wall thickness of the pipe. During the third step, which is a test for soundness, the flattening shall be continued until the test specimen breaks or the opposite walls of the pipe meet. Evidence of laminated or unsound material or of incomplete weld that is revealed by the flattening test shall be cause for rejection.

9.3.1 For pipe produced in single lengths, the flattening test specified in 9.3 shall be made using a test specimen taken from each end of each length of pipe. The tests from each end shall be made alternately with the weld at 0° and at 90° from the line of direction of force.

9.3.2 For pipe produced in multiple lengths, the flattening test specified in 9.3 shall be made as follows:

9.3.2.1 Test specimens taken from, and representative of, the front end of the first pipe intended to be supplied from each coil, the back end of the last pipe intended to be supplied from each coil, and each side of any intermediate weld stop location shall be flattened with the weld located at 90° from the line of direction of force.

9.3.2.2 Test specimens taken from pipe at any two locations intermediate to the front end of the first pipe and the back end of the last pipe intended to be supplied from each coil shall be flattened with the weld located at 0° from the line of direction of force.

9.3.3 For pipe that is to be subsequently reheated throughout its cross section and hot formed by a reducing process, the manufacturer shall have the option of obtaining

the flattening test specimens required by 9.3.1 or 9.3.2, whichever is applicable, either prior to or after such hot reducing.

9.4 Continuous-Welded Pipe — A test specimen at least 4 in. [100 mm] in length shall be flattened cold between parallel plates in three steps. The weld shall be located at 90° from the line of direction of force. During the first step, which is a test for ductility of the weld, no cracks or breaks on the inside, outside, or end surfaces at the weld shall occur until the distance between the plates is less than three fourths of the specified diameter of the pipe. As a second step, the flattening shall be continued as a test for ductility away from the weld. During the second step, no cracks or breaks on the inside, outside, or end surfaces away from the weld, except as provided for in 9.7, shall occur until the distance between the plates is less than 60% of the specified outside diameter of the pipe. During the third step, which is a test for soundness, the flattening shall be continued until the test specimen breaks or the opposite walls of the pipe meet. Evidence of laminated or unsound material or of incomplete weld that is revealed by the flattening test shall be cause for rejection.

9.5 Surface imperfections in the test specimen before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements in Section 14.

9.6 Superficial ruptures as a result of surface imperfections shall not be cause for rejection.

9.7 When low D -to- t ratio tubulars are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the 6 and 12 o'clock locations, cracks at these locations shall not be cause for rejection if the D -to- t ratio is less than 10.

10. Hydrostatic Test

10.1 The hydrostatic test shall be applied, without leakage through the pipe wall, to each length of pipe except as provided in 11.2 for seamless pipe.

10.2 Each length of plain-end pipe shall be hydrostatically tested to the pressures prescribed in Table X2.2, and each threaded-and-coupled length shall be hydrostatically tested to the pressures prescribed in Table X2.3. It shall be permissible, at the discretion of the manufacturer, to perform the hydrostatic test on pipe with plain ends, with threads only, or with threads and couplings and also shall be permissible to test pipe in either single lengths or multiple lengths.

NOTE 5 — The hydrostatic test pressures given herein are inspection test pressures, are not intended as a basis for design, and do not have any direct relationship to working pressures.

10.3 The minimum hydrostatic test pressure required to satisfy these requirements need not exceed 2500 psi [17 200 kPa] for NPS 3 [DN 80] and under, nor 2800 psi [19 300 kPa] for all sizes over NPS 3 [DN 80]. This does not prohibit testing at a higher pressure at the manufacturer's option. The hydrostatic pressure shall be maintained for not less than 5 s for all sizes of seamless and electric-welded pipe.

11. Nondestructive Electric Test

11.1 Type E Pipe:

11.1.1 The weld seam of each length of ERW pipe NPS 2 [DN 50] and larger shall be tested with a nondestructive electric test in accordance with Practice E 213, E 309, or E 570 as follows:

11.1.2 Ultrasonic and Electromagnetic Inspection — Any equipment utilizing the ultrasonic or electromagnetic principles and capable of continuous and uninterrupted inspection of the weld seam shall be used. The equipment shall be checked with an applicable reference standard as described in 11.1.3 at least once every working turn or not more than 8 h to demonstrate its effectiveness and the inspection procedures. The equipment shall be adjusted to produce well-defined indications when the reference standard is scanned by the inspection unit in a manner simulating the inspection of the product.

11.1.3 Reference Standards — The length of the reference standards shall be determined by the pipe manufacturer, and they shall have the same specified diameter and thickness as the product being inspected. Reference standards shall contain machined notches, one on the inside surface and one on the outside surface, or a drilled hole, as shown in Fig. 1, at the option of the pipe manufacturer. The notches shall be parallel to the weld seam, and shall be separated by a distance sufficient to produce two separate and distinguishable signals. The $\frac{1}{8}$ -in. [3.2-mm] hole shall be drilled through the wall and perpendicular to the surface of the reference standard as shown in Fig. 1. Care shall be taken in the preparation of the reference standard to ensure freedom from fins or other edge roughness, or distortion of the pipe.

NOTE 6 — The calibration standards defined in 11.1.3 are convenient standards for calibration of nondestructive testing equipment. The dimensions of such standards are not to be construed as the minimum sizes of imperfections detectable by such equipment.

11.1.4 Acceptance Limits — Table 3 gives the height of acceptance limit signals in percent of the height of signals produced by reference standards. Imperfections in the weld seam that produce a signal greater than the acceptance limit signal given in Table 3 shall be considered a defect unless the pipe manufacturer can demonstrate that

the imperfection does not reduce the effective wall thickness beyond 12½% of the specified wall thickness.

11.2 Seamless Pipe — As an alternative to the hydrostatic test, and when specified by the purchaser, the full body of each seamless pipe shall be tested with a nondestructive electric test in accordance with Practices E 213, E 309, or E 570. In this case each length so furnished shall include the mandatory marking of the letters “NDE.” Except as provided in 11.2.6.2 it is the intent of this test to reject pipe with imperfections which produce test signals equal to or greater than that of the calibration standard.

11.2.1 When the nondestructive electric test is performed, the lengths shall be marked with the letters “NDE.” The certification, when required, shall state Nondestructive Electric Tested and shall indicate which of the tests was applied. Also, the letters NDE shall be appended to the product specification number and material grade shown on the certification.

11.2.2 The following information is intended to facilitate the use of this specification.

11.2.2.1 The calibration standards defined in 11.2.3 through 11.2.5 are convenient standards for calibration of nondestructive testing equipment. The dimensions of such standards are not to be construed as the minimum sizes of imperfections detectable by such equipment.

11.2.2.2 The ultrasonic testing referred to in this specification is capable of detecting the presence and location of significant longitudinally or circumferentially oriented imperfections; however, different techniques need to be employed for the detection of differently oriented imperfections. Ultrasonic testing is not necessarily capable of detecting short, deep imperfections.

11.2.2.3 The eddy current examination referenced in this specification has the capability of detecting significant discontinuities, especially of the short abrupt type.

11.2.2.4 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented discontinuities. The provisions of this specification only require longitudinal calibration for flux leakage. Different techniques need to be employed for the detection of differently oriented imperfections.

11.2.2.5 The hydrostatic test referred to in 10.2 has the capability of finding imperfections of a size permitting the test fluid to leak through the tube wall and may be either visually seen or detected by a loss of pressure. Hydrostatic testing is not necessarily capable of detecting very tight through-the-wall imperfections or imperfections that extend an appreciable distance into the wall without complete penetration.

11.2.2.6 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of imperfections that are capable of being detected in the specific application of these examinations is directed to discuss this with the manufacturer of the tubular product.

11.2.3 For ultrasonic testing, the calibration reference notches shall be at the option of the producer, and shall be any one of the three common notch shapes shown in Practice E 213. The depth of notch shall not exceed 12.5% of the specified wall thickness of the pipe or 0.004 in. [0.1 mm], whichever is greater.

11.2.4 For eddy current testing, the calibration pipe shall contain, at the option of the producer, any one of the following calibration standards to establish a minimum sensitivity level for rejection.

11.2.4.1 Drilled Hole — Depending upon the pipe diameter the calibration pipe shall contain three holes spaced 120° apart or four holes spaced 90° apart and sufficiently separated longitudinally to ensure separately distinguishable responses. The holes shall be drilled radially and completely through the pipe wall, care being taken to avoid distortion of the pipe while drilling. Depending upon the pipe diameter the calibration pipe shall contain the following hole:

NPS	DN	Diameter of Drilled Hole
≤ ½	≤ 15	0.039 in. (1 mm)
> ½ ≤ 1 ¼	> 15 ≤ 32	0.055 in. (1.4 mm)
> 1 ¼ ≤ 2	> 32 ≤ 50	0.071 in. (1.8 mm)
> 2 ≤ 5	> 50 ≤ 125	0.087 in. (2.2 mm)
> 5	> 125	0.106 in. (2.7 mm)

11.2.4.2 Transverse Tangential Notch — Using a round tool or file with a ¼ in. [6 mm] diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. The notch shall have a depth not exceeding 12.5% of the specified wall thickness of the pipe or 0.012 in. [0.3 mm], whichever is greater.

11.2.4.3 Longitudinal Notch — A notch 0.031 in. [0.8 mm] or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the pipe, to have a depth not exceeding 12.5% of the specified wall thickness of the tube or 0.012 in. [0.3 mm], whichever is greater. The length of the notch shall be compatible with the testing method.

11.2.4.4 Compatibility — The discontinuity in the calibration pipe shall be compatible with the testing equipment and the method being used.

11.2.5 For flux leakage testing, the longitudinal calibration reference notches shall be straight sided notches machined in a radial plane parallel to the pipe axis. For wall thickness under 0.500 in. [12.7 mm], outside and inside notches shall be used. For wall thickness equal and above 0.500 in. [12.7 mm], only an outside notch shall be

used. Notch depth shall not exceed 12.5% of the specified wall thickness, or 0.012 in. [0.3 mm], whichever is greater. Notch length shall not exceed 1 in. [25 mm], and the width shall not exceed the depth. Outside diameter and inside diameter notches shall be located sufficiently apart to allow separation and identification of the signals.

11.2.6 Pipe containing one or more imperfections that produce a signal equal to or greater than the signal produced by the calibration standard shall be rejected or the area producing the signal shall be rejected.

11.2.6.1 Test signals produced by imperfections that cannot be identified, or produced by cracks or crack-like imperfections, shall result in rejection of the pipe, unless it is repaired and retested. To be accepted, the pipe must pass the same specification test to which it was originally subjected, provided that the remaining wall thickness is not decreased below that permitted by the specification. It shall be permissible to reduce the outside diameter at the point of grinding by the amount so removed.

11.2.6.2 It shall be permissible to evaluate test signals produced by visual imperfections in accordance with provisions of Section 14. A few examples of these imperfections would be straightener marks, cutting chips, scratches, steel die stamps, stop marks, or pipe reducer ripple.

11.2.7 The test methods described in this section are not necessarily capable of inspecting the end portion of pipes. This condition is referred to as end effect. The length of the end effect shall be determined by the manufacturer and, when specified in the purchase order, reported to the purchaser.

12. Permissible Variations in Weight and Dimensions

12.1 Weight — The weight of the pipe as specified in Table X2.2 and Table X2.3 or as calculated from the relevant equation in ASME B36.10M shall not vary by more than $\pm 10\%$.

NOTE 7 — The weight tolerance is determined from the weights of the customary lifts of pipe as produced for shipment by the mill, divided by the number of feet of pipe in the lift. On pipe sizes over NPS 4 [DN 100], where individual lengths are weighed, the weight tolerance is applicable to the individual length.

12.2 Diameter — For pipe NPS $1\frac{1}{2}$ [DN 40] and under, the outside diameter at any point shall not vary more than $\pm \frac{1}{64}$ in. [0.4 mm] from the standard specified. For pipe NPS 2 [DN 50] and over, the outside diameter shall not vary more than $\pm 1\%$ from the standard specified.

12.3 Thickness — The minimum wall thickness at any point shall be not more than 12.5% under the nominal wall thickness specified. The minimum wall thickness on

inspection shall conform to the requirements in Table X2.4.

13. End Finish

13.1 When ordered with plain ends, the pipe shall be furnished to the following practice, unless otherwise specified.

13.1.1 NPS $1\frac{1}{2}$ [DN 40] and Smaller — Unless otherwise specified on the purchase order, end finish shall be at the option of the manufacturer.

13.1.2 NPS 2 [DN 50] and Larger:

13.1.2.1 Pipe of standard or extra strong weights, or in wall thickness less than 0.500 in. [12.7 mm], other than double extra strong pipe, shall be plain-end beveled with ends beveled to an angle of 30° , $+5^\circ$, -0° , measured from a line drawn perpendicular to the axis of the pipe, and with a root face of $\frac{1}{16}$ in. $\pm \frac{1}{32}$ in. [1.6 mm \pm 0.8 mm].

13.1.2.2 Pipe with wall thicknesses over 0.500 in. [12.7 mm], and all double extra strong, shall be plain-end square cut.

13.2 When ordered with threaded ends, the pipe ends shall be provided with a thread in accordance with the gaging practice and tolerances of ANSI B1.20.1. For standard-weight pipe NPS 6 [DN 150] and smaller, refer to Table X3.1 for threading data. For standard-weight pipe NPS 8 [DN 200] and larger and all sizes of extra-strong weight and double extra-strong weight, refer to Table X3.2 for threading data. Threaded pipe NPS 4 [DN 100] and larger shall have thread protectors on the ends not protected by a coupling.

13.3 When ordered with couplings, one end of each length of pipe shall be provided with a coupling manufactured in accordance with Specification A 865. The coupling threads shall be in accordance with the gaging practice of ANSI B1.20.1. The coupling shall be applied handling-tight, unless power-tight is specified on the order. Couplings are to be made of steel. Taper-tapped couplings shall be furnished on all weights of threaded pipe sizes NPS $2\frac{1}{2}$ [DN 65] and larger. For pipe NPS 2 [DN 50] and smaller, it is regular practice to furnish straight-tapped couplings for standard-weight pipe and taper-tapped couplings for extra-strong and double extra-strong pipe. If taper-tapped couplings are required for pipe NPS 2 [DN 50] and smaller on standard-weight pipe, it is recommended that line pipe threads in accordance with API Specification 5L be ordered. The taper-tapped couplings provided on line pipe in these sizes may be used on mill-threaded standard-weight pipe of the same size.

14. Workmanship, Finish and Appearance

14.1 The pipe manufacturer shall explore a sufficient number of visual surface imperfections to provide reasonable assurance that they have been properly evaluated with respect to depth.

14.2 Surface imperfections that penetrate more than $12\frac{1}{2}\%$ of the nominal wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with defects shall be given one of the following dispositions:

14.2.1 The defect shall be removed by grinding, provided that the remaining wall thickness is within specified limits,

14.2.2 Type S pipe and the parent metal of Type E pipe, except within $\frac{1}{2}$ in. [13 mm] of the fusion line of the electric resistance seam, are permitted to be repaired in accordance with the welding provisions of 14.5. Repair welding of Type F pipe and the weld seam of Type E is prohibited.

14.2.3 The section of pipe containing the defect may be cut off within the limits of requirement on length, or

14.2.4 Rejected.

14.3 At the purchaser's discretion, pipe shall be subjected to rejection if surface defects repaired in accordance with 14.2 are not scattered, but appear over a large area in excess of what is considered a workmanlike finish. Disposition of such pipe shall be a matter of agreement between the manufacturer and the purchaser.

14.4 When imperfections or defects are removed by grinding, a smooth curved surface shall be maintained, and the wall thickness shall not be decreased below that permitted by this specification. It shall be permissible to reduce the outside diameter at the point of grinding by the amount so removed.

14.4.1 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In the case of a dispute, the measurement determined by use of the mechanical caliper shall govern.

14.5 Weld repair shall be permitted only subject to approval of the purchaser and in accordance with Specification A 530/A 530M.

14.6 The finished pipe shall be reasonably straight.

14.7 The pipe shall contain no dents greater than 10% of the pipe diameter or $\frac{1}{4}$ in. [6 mm], whichever is smaller, measured as a gap between the lowest point of the dent and a prolongation of the original contour of the pipe. Cold-formed dents deeper than $\frac{1}{8}$ in. [3 mm] shall be free of sharp bottom gouges; it shall be permissible to remove the gouges by grinding, provided that the remaining wall

thickness is within specified limits. The length of the dent in any direction shall not exceed one half the pipe diameter.

15. Number of Tests

15.1 Except as required by 15.2, one of each of the tests specified in Section 7, 8.2, and Section 9 shall be made on test specimens taken from one length of pipe from each lot of each pipe size. For continuous-welded pipe, a lot shall contain no more than 25 tons [23 Mg] of pipe for pipe sizes NPS $1\frac{1}{2}$ [DN 40] and smaller, and no more than 50 tons [45 Mg] of pipe for pipe sizes NPS 2 [DN 50] and larger. For seamless and electric-resistance-welded pipe, a lot shall contain no more than one heat, and at the option of the manufacturer shall contain no more than 500 lengths of pipe (as initially cut after the final pipe-forming operation, prior to any further cutting to the required ordered lengths) or 50 tons [45 Mg] of pipe.

15.2 The number of flattening tests for electric-resistance-welded pipe shall be in accordance with 9.3.1 or 9.3.2, whichever is applicable.

15.3 Except as allowed by 11.2, each length of pipe shall be subjected to the hydrostatic test specified in Section 10.

16. Retests

16.1 If the results of the mechanical tests of any lot do not conform to the requirements specified in Sections 7, 8, and 9, retests are permitted to be made on additional pipe of double the original number from the same lot, each of which shall conform to the requirements specified.

16.2 For pipe produced in single lengths, if any section of the pipe fails to comply with the requirements of 9.3, it shall be permissible to cut other sections from the same end of the same length until satisfactory tests are obtained, except that the finished pipe shall not be shorter than 80% of its length after the original cropping; otherwise the length shall be rejected. For pipe produced in multiple lengths, it shall be permissible to cut retests from each end of each individual length in the multiple. Such tests shall be made with the weld alternately 0° and 90° from the line of direction of force.

17. Test Methods

17.1 The test specimens and the tests required by this specification shall conform to those described in the latest issue of Test Methods and Definitions A 370.

17.2 The longitudinal tension test specimen shall be taken from the end of the pipe or, for continuous-welded pipe, it shall be permissible to be taken from the skelp, at

a point approximately 90° from the weld, and shall not be flattened between gage marks. The sides of each specimen shall be parallel between gage marks. If desired, the tension tests are permitted to be made on the full section of pipe. When impracticable to pull a test specimen in full section, the standard 2-in. [50-mm] gage length tension test specimen shown in Fig. A2.3 of Test Methods and Definitions A 370 is acceptable.

17.3 Transverse weld test specimens from electric-resistance-welded pipe shall be taken with the weld at the center of the specimen. All transverse test specimens shall be approximately 1½ in. [40 mm] wide in the gage length and shall represent the full wall thickness of the pipe from which the specimen was cut.

17.4 Test specimens for the bend and flattening tests shall be taken from pipe. Test specimens for the flattening test shall be smooth on the ends and free from burrs.

17.5 All specimens shall be tested at room temperature.

18. Lengths

18.1 Unless otherwise specified, pipe lengths shall be in accordance with the following regular practice.

18.1.1 Pipe of weights lighter than extra strong shall be in single-random lengths of 16 to 22 ft [4.88 to 6.71 m], but not more than 5% of the total number of threaded lengths are permitted to be jointers (two pieces coupled together). When ordered with plain ends, 5% are permitted to be in lengths of 12 to 16 ft [3.66 to 4.88 m].

18.1.2 Pipe of extra-strong and heavier weights shall be in random lengths of 12 to 22 ft [3.66 to 6.71 m]. Five percent are permitted to be in lengths of 6 to 12 ft [1.83 to 3.66 m].

18.1.3 When extra-strong or lighter pipe is ordered in double-random lengths, the minimum lengths shall be not less than 22 ft [6.71 m], with a minimum average for the order of 35 ft [10.67 m].

18.1.4 When lengths longer than single random are required for wall thicknesses heavier than extra-strong, the length shall be subject to negotiation.

18.1.5 When pipe is furnished with threads and couplings, the length shall be measured to the outer face of the coupling.

19. Galvanized Pipe

19.1 Galvanized pipe ordered under this specification shall be coated with zinc inside and outside by the hot-dip process. The zinc used for the coating shall be any grade of zinc conforming to Specification B 6.

19.2 *Weight of Coating* — The weight of zinc coating shall be not less than 1.8 oz/ft² [0.55 kg/m²] as determined

from the average results of the two specimens taken for test in the manner prescribed in 19.5 and not less than 1.6 oz/ft² [0.49 kg/m²] for either of these specimens. The weight of coating expressed in ounces per square foot shall be calculated by dividing the total weight of zinc, inside plus outside, by the total area, inside plus outside, of the surface coated. Each specimen shall have not less than 1.3 oz/ft² [0.40 kg/m²] of zinc coating on each surface, calculated by dividing the total weight of zinc on the given surface (outside or inside) by the area of the surface coated (outside or inside).

19.3 *Weight of Coating Test* — The weight of zinc coating shall be determined by a stripping test in accordance with Test Method A 90/A 90M. The total zinc on each specimen shall be determined in a single stripping operation.

19.4 *Test Specimens* — Test specimens for determination of weight of coating shall be cut approximately 4 in. [100 mm] in length.

19.5 *Number of Tests* — Two test specimens for the determination of weight of coating shall be taken, one from each end of one length of galvanized pipe selected at random from each lot of 500 lengths or fraction thereof, of each size.

19.6 *Retests* — If the weight of coating of any lot does not conform to the requirements specified in 19.2, retests of two additional pipes from the same lot shall be made, each of which shall conform to the requirements specified.

19.7 When pipe ordered under this specification is to be galvanized, the tension, flattening, and bend tests shall be made on the base material before galvanizing. When specified, results of the mechanical tests on the base material shall be reported to the purchaser. If it is impracticable to make the mechanical tests on the base material before galvanizing, it shall be permissible to make such tests on galvanized samples, and any flaking or cracking of the zinc coating shall not be considered cause for rejection. When galvanized pipe is bent or otherwise fabricated to a degree that causes the zinc coating to stretch or compress beyond the limit of elasticity, some flaking of the coating is acceptable.

20. Inspection

20.1 The inspector representing the purchaser shall have entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at

the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

21. Rejection

21.1 The purchaser is permitted to inspect each length of pipe received from the manufacturer and, if it does not meet the requirements of this specification based on the inspection and test method as outlined in the specification, the length shall be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

21.2 Pipe found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, shall be set aside and the manufacturer notified. Such pipe shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement.

22. Certification

22.1 The producer or supplier shall, upon request, furnish to the purchaser a certificate of inspection stating that the material has been manufactured, sampled, tested, and inspected in accordance with this specification (including year of issue), and has been found to meet the requirements.

22.2 Report — For Types E and S, the producer or supplier shall furnish to the purchaser a chemical analysis report for the elements specified in Table 1.

22.3 EDI — A certificate of inspection or chemical analysis report printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The use and format of the EDI document are subject to agreement between the purchaser and the supplier.

NOTE 8 — EDI is the computer to computer exchange of business information in a standard format such as ANSI ASC X12.

22.4 Notwithstanding the absence of a signature, the organization submitting the certificate of inspection or chemical analysis report is responsible for its content.

23. Product Marking

23.1 Except as allowed by 23.5 and 23.6, each length of pipe shall be legibly marked in the following sequence by rolling, stamping, or stenciling to show:

23.1.1 Manufacturer's name or mark,

23.1.2 Specification number (year of issue not required),

NOTE 9 — Pipe that complies with multiple compatible specifications may be marked with the appropriate designation for each specification.

23.1.3 Size (NPS and weight class, schedule number, or nominal wall thickness; or specified outside diameter and nominal wall thickness),

23.1.4 Grade (A or B),

23.1.5 Type of pipe (F, E, or S),

23.1.6 Test pressure, seamless pipe only (if applicable, in accordance with Table 4),

23.1.7 Nondestructive electric test, seamless pipe only (if applicable, in accordance with Table 4),

23.2 Unless another marking format is specified in the purchase order, length shall be marked in feet and tenths of a foot, or metres to two decimal places, dependent upon the units to which the pipe was ordered. The location of such marking shall be at the option of the manufacturer.

23.3 Heat number, lot number, run number, or a combination thereof shall be marked at the option of the manufacturer, unless specific marking is specified in the purchase order. The location of such marking shall be at the option of the manufacturer.

23.4 Any additional information desired by the manufacturer or specified in the purchase order.

23.5 For pipe NPS 1½ [DN 40] and smaller that is bundled, it shall be permissible to mark this information on a tag securely attached to each bundle.

23.6 When pipe sections are cut into shorter lengths by a subsequent producer for resale as material, the processor shall transfer complete identification including the name or brand of the manufacturer, to each unmarked cut length, or to metal tags securely attached to unmarked pipe bundled in accordance with the requirements of 23.5. The same material designation shall be included with the information transferred, and the processor's name, trademark, or brand shall be added.

23.7 Bar Coding — In addition to the requirements in 23.1, 23.5, and 23.6, bar coding is acceptable as a supplementary identification method. It is recommended that bar coding be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

24. Government Procurement

24.1 When specified in the contract, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163. The applicable levels shall be as specified in the contract. Marking for shipment of

such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 or Federal Std. No. 183 if continuous marking is required, for military agencies.

24.2 Inspection — Unless otherwise specified in the contract, the producer is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract, the manufacturer shall use its own or any other suitable facilities for performing the inspection and test requirements specified herein, unless otherwise disapproved by the purchaser in the contract or purchase order. The purchaser shall have the right to perform any of the inspections and tests set forth

in this specification where deemed necessary to ensure that the material conforms to prescribed requirements.

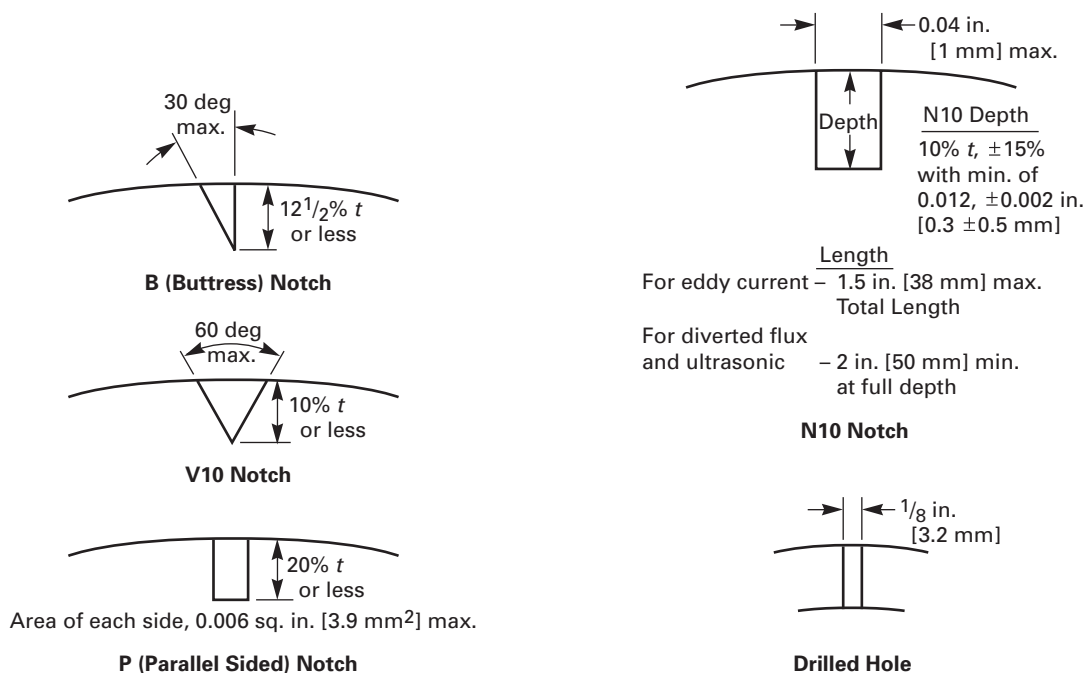
25. Packaging and Package Marking

25.1 When specified on the purchase order, packaging, marking, and loading or shipment shall be in accordance with those procedures recommended by Practices A 700.

26. Keywords

26.1 black steel pipe; seamless steel pipe; steel pipe; welded steel pipe; zinc coated steel pipe

FIG. 1 CALIBRATION STANDARDS

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, max, %								
	Carbon	Manganese	Phosphorus	Sulfur	Copper ^A	Nickel ^A	Chromium ^A	Molybdenum ^A	Vanadium ^A
Type S (seamless pipe)									
Open-hearth, electric-furnace, or basic-oxygen:									
Grade A	0.25	0.95	0.05	0.045	0.40	0.40	0.40	0.15	0.08
Grade B	0.30	1.20	0.05	0.045	0.40	0.40	0.40	0.15	0.08
Type E (electric-resistance-welded)									
Open-hearth, electric-furnace, or basic-oxygen:									
Grade A	0.25	0.95	0.05	0.045	0.40	0.40	0.40	0.15	0.08
Grade B	0.30	1.20	0.05	0.045	0.40	0.40	0.40	0.15	0.08
Type F (furnace-welded pipe)									
Open-hearth, electric-furnace, or basic oxygen									
Grade A	0.30	1.20	0.05	0.045	0.40	0.40	0.40	0.15	0.08

^A The combination of these five elements shall not exceed 1.00%.

TABLE 2
TENSILE REQUIREMENTS

	Type F	Types E and S	
	Open-Hearth, Basic Oxygen, or Electric- Furnace, Grade A	Grade A	Grade B
Tensile strength, min, psi [MPa]	48 000 [330]	48 000 [330]	60 000 [415]
Yield strength, min, psi [MPa]	30 000 [205]	30 000 [205]	35 000 [240]
Elongation in 2 in. [50 mm]	<i>A,B</i>	<i>A,B</i>	<i>A,B</i>

^A The minimum elongation in 2 in. [50 mm] shall be that determined by the following equation:

$$e = 625\,000 [1940] A^{0.2}/U^{0.9}$$

where:

e = minimum elongation in 2 in. [50 mm] in percent rounded to the nearest percent

A = cross-sectional area of the tension specimen, rounded to the nearest 0.01 in.² [1 mm²], based on the specified outside diameter or the nominal specimen width and specified wall thickness. If the area calculated is equal to or greater than 0.75 in.² [500 mm²], then the value 0.75 in.² [500 mm²] shall be used, and

U = specified tensile strength, psi [MPa]

^B See Table X4.1 or Table X4.2, whichever is applicable, for minimum elongation values for various size tension specimens and grades.

TABLE 3
ACCEPTANCE LIMITS

Type Notch	Size of Hole		Acceptance Limit Signal, %
	in.	mm	
N10, V10	1/8	3.2	100
B.P.	...	...	80

TABLE 4
MARKING OF SEAMLESS PIPE

Hydro	NDE	Marking
Yes	No	Test pressure
No	Yes	NDE
Yes	Yes	Test pressure/NDE

APPENDICES

(Nonmandatory Information)

X1. DEFINITIONS OF TYPES OF PIPE

X1.1 *Type F, Furnace-Butt-Welded Pipe, Continuous-Welded* — Pipe produced in continuous lengths from coiled skelp and subsequently cut into individual lengths, having its longitudinal butt joint forge welded by the mechanical pressure developed in rolling the hot-formed skelp through a set of round pass welding rolls.

X1.2 *Type E, Electric-Resistance-Welded Pipe* — Pipe produced in individual lengths or in continuous lengths from coiled skelp and subsequently cut into individual lengths, having a longitudinal butt joint wherein coalescence is produced by the heat obtained from resistance of the pipe to the flow of electric current in a circuit of which

the pipe is a part, and by the application of pressure.

X1.3 *Type S, Wrought Steel Seamless Pipe* — Wrought steel seamless pipe is a tubular product made without a welded seam. It is manufactured by hot working steel and, if necessary, by subsequently cold finishing the hot-worked tubular product to produce the desired shape, dimensions, and properties.

X2. TABLES FOR DIMENSIONAL AND CERTAIN MECHANICAL REQUIREMENTS

X2.1 Tables X2.1–X2.4 address dimensional and certain mechanical requirements.

TABLE X2.1
CALCULATED H VALUES FOR SEAMLESS PIPE

NPS Designator	DN Designator	Outside Diameter, in. [mm]	Nominal Wall Thickness, in. [mm]	Distance, in. [mm], Between Plates " H " by Formula: $H = (1 + e)t(e + t/D)$	
				Grade A	Grade B
2½	65	2.875 [73.0]	0.203 [5.16]	1.378 [35.0]	1.545 [39.2]
			0.276 [7.01]	1.618 [41.1]	1.779 [45.2]
3	80	3.500 [88.9]	0.216 [5.49]	1.552 [39.4]	1.755 [44.6]
			0.300 [7.62]	1.861 [47.3]	2.062 [52.4]
3½	90	4.000 [101.6]	0.226 [5.74]	1.682 [42.7]	1.912 [48.6]
			0.318 [8.08]	2.045 [51.9]	2.276 [57.8]
4	100	4.500 [114.3]	0.237 [6.02]	1.811 [46.0]	2.067 [52.5]
			0.337 [8.56]	2.228 [56.6]	2.489 [63.2]
5	125	5.563 [141.3]	0.258 [6.55]	2.062 [52.4]	2.372 [60.2]
			0.375 [9.52]	2.597 [66.0]	2.920 [74.2]
6	150	6.625 [168.3]	0.280 [7.11]	2.308 [58.6]	2.669 [67.8]
			0.432 [10.97]	3.034 [77.1]	3.419 [86.8]
8	200	8.625 [219.1]	0.277 [7.04]	2.473 [62.8]	2.902 [73.7]
			0.322 [8.18]	2.757 [70.0]	3.210 [81.5]
			0.500 [12.70]	3.683 [93.5]	4.181 [106.2]
10	250	10.750 [273.0]	0.279 [7.09] ^A	2.623 [66.6]	3.111 [79.0]
			0.307 [7.80]	2.823 [71.7]	3.333 [84.7]
			0.365 [9.27]	3.210 [81.5]	3.757 [95.4]
			0.500 [12.70]	3.993 [101.4]	4.592 [116.6]
12	300	12.750 [323.8]	0.300 [7.62]	3.105 [78.9]	3.683 [93.5]
			0.375 [9.52]	3.423 [86.9]	4.037 [102.5]
			0.500 [12.70]	4.218 [107.1]	4.899 [124.4]
14	350	14.000 [355.6]	0.375 [9.52]	3.500 [88.9]	4.146 [105.3]
			0.500 [12.70]	4.336 [110.1]	5.061 [128.5]
16	400	16.000 [406.4]	0.375 [9.52]	3.603 [91.5]	4.294 [109.1]
			0.500 [12.70]	4.494 [114.1]	5.284 [134.2]
18	450	18.000 [457]	0.375 [9.52]	3.688 [93.7]	4.417 [112.2]
			0.500 [12.70]	4.628 [117.6]	5.472 [139.0]
20	500	20.000 [508]	0.375 [9.52]	3.758 [95.5]	4.521 [114.8]
			0.500 [12.70]	4.740 [120.4]	5.632 [143.1]
24	600	24.000 [610]	0.375 [9.52]	3.869 [98.3]	4.686 [119.0]
			0.500 [12.70]	4.918 [124.9]	5.890 [149.6]

^A Special order only.

TABLE X2.2
DIMENSIONS, WEIGHTS, AND TEST PRESSURES FOR PLAIN END PIPE

NPS Designator	DN Designator	Outside Diameter, in. [mm]	Nominal Wall Thickness, in. [mm]	Nominal Weight [Mass] per Unit Length, Plain End, lb/ft [kg/m]	Weight Class	Schedule No.	Test Pressure, ⁴ psi [kPa]	
							Grade A	Grade B
$\frac{1}{8}$	6	0.405 [10.3]	0.068 [1.73]	0.24 [0.37]	STD	40	700 [4800]	700 [4800]
			0.095 [2.41]	0.31 [0.47]	XS	80	850 [5900]	850 [5900]
$\frac{1}{4}$	8	0.540 [13.7]	0.088 [2.24]	0.43 [0.63]	STD	40	700 [4800]	700 [4800]
			0.119 [3.02]	0.54 [0.80]	XS	80	850 [5900]	850 [5900]
$\frac{3}{8}$	10	0.675 [17.1]	0.091 [2.31]	0.57 [0.84]	STD	40	700 [4800]	700 [4800]
			0.126 [3.20]	0.74 [1.10]	XS	80	850 [5900]	850 [5900]
$\frac{1}{2}$	15	0.840 [21.3]	0.109 [2.77]	0.85 [1.27]	STD	40	700 [4800]	700 [4800]
			0.147 [3.73]	1.09 [1.62]	XS	80	850 [5900]	850 [5900]
			0.188 [4.78]	1.31 [1.95]	...	160	900 [6200]	900 [6200]
			0.294 [7.47]	1.72 [2.55]	XXS	...	1000 [6900]	1000 [6900]
$\frac{3}{4}$	20	1.050 [26.7]	0.113 [2.87]	1.13 [1.69]	STD	40	700 [4800]	700 [4800]
			0.154 [3.91]	1.48 [2.20]	XS	80	850 [5900]	850 [5900]
			0.219 [5.56]	1.95 [2.90]	...	160	950 [6500]	950 [6500]
			0.308 [7.82]	2.44 [3.64]	XXS	...	1000 [6900]	1000 [6900]
1	25	1.315 [33.4]	0.133 [3.38]	1.68 [2.50]	STD	40	700 [4800]	700 [4800]
			0.179 [4.55]	2.17 [3.24]	XS	80	850 [5900]	850 [5900]
			0.250 [6.35]	2.85 [4.24]	...	160	950 [6500]	950 [6500]
			0.358 [9.09]	3.66 [5.45]	XXS	...	1000 [6900]	1000 [6900]
$1\frac{1}{4}$	32	1.660 [42.2]	0.140 [3.56]	2.27 [3.39]	STD	40	1200 [8300]	1300 [9000]
			0.191 [4.85]	3.00 [4.47]	XS	80	1800 [12 400]	1900 [13 100]
			0.250 [6.35]	3.77 [5.61]	...	160	1900 [13 100]	2000 [13 800]
			0.382 [9.70]	5.22 [7.77]	XXS	...	2200 [15 200]	2300 [15 900]
$1\frac{1}{2}$	40	1.900 [48.3]	0.145 [3.68]	2.72 [4.05]	STD	40	1200 [8300]	1300 [9000]
			0.200 [5.08]	3.63 [5.41]	XS	80	1800 [12 400]	1900 [13 100]
			0.281 [7.14]	4.86 [7.25]	...	160	1950 [13 400]	2050 [14 100]
			0.400 [10.16]	6.41 [9.56]	XXS	...	2200 [15 200]	2300 [15 900]
2	50	2.375 [60.3]	0.154 [3.91]	3.66 [5.44]	STD	40	2300 [15 900]	2500 [17 200]
			0.218 [5.54]	5.03 [7.48]	XS	80	2500 [17 200]	2500 [17 200]
			0.344 [8.74]	7.47 [11.11]	...	160	2500 [17 200]	2500 [17 200]
			0.436 [11.07]	9.04 [13.44]	XXS	...	2500 [17 200]	2500 [17 200]
$2\frac{1}{2}$	65	2.875 [73.0]	0.203 [5.16]	5.80 [8.63]	STD	40	2500 [17 200]	2500 [17 200]
			0.276 [7.01]	7.67 [11.41]	XS	80	2500 [17 200]	2500 [17 200]
			0.375 [9.52]	10.02 [14.90]	...	160	2500 [17 200]	2500 [17 200]
			0.552 [14.02]	13.71 [20.39]	XXS	...	2500 [17 200]	2500 [17 200]
3	80	3.500 [88.9]	0.125 [3.18]	4.51 [6.72]	...	...	1290 [8900]	1500 [1000]
			0.156 [3.96]	5.58 [8.29]	...	...	1600 [11 000]	1870 [12 900]
			0.188 [4.78]	6.66 [9.92]	...	...	1930 [13 330]	2260 [15 600]
			0.216 [5.49]	7.58 [11.29]	STD	40	2220 [15 300]	2500 [17 200]
			0.250 [6.35]	8.69 [12.93]	...	...	2500 [17 200]	2500 [17 200]
			0.281 [7.14]	9.67 [14.40]	...	...	2500 [17 200]	2500 [17 200]
			0.300 [7.62]	10.26 [15.27]	XS	80	2500 [17 200]	2500 [17 200]
			0.438 [11.13]	14.34 [21.35]	...	160	2500 [17 200]	2500 [17 200]
			0.600 [15.24]	18.60 [27.68]	XXS	...	2500 [17 200]	2500 [17 200]
$3\frac{1}{2}$	90	4.000 [101.6]	0.125 [3.18]	5.18 [7.72]	...	...	1120 [7700]	1310 [19 000]
			0.156 [3.96]	6.41 [9.53]	...	...	1400 [6700]	1640 [11 300]

TABLE X2.2
DIMENSIONS, WEIGHTS, AND TEST PRESSURES FOR PLAIN END PIPE (CONT'D)

NPS Designator	DN Designator	Outside Diameter, in. [mm]	Nominal Wall Thickness, in. [mm]	Nominal Weight [Mass] per Unit Length, Plain End, lb/ft [kg/m]	Weight Class	Schedule No.	Test Pressure, ⁴ psi [kPa]	
							Grade A	Grade B
4	100	4.500 [114.3]	0.188 [4.78]	7.66 [11.41]	...	...	1690 [11 700]	1970 [13 600]
			0.226 [5.74]	9.12 [13.57]	STD	40	2030 [14 000]	2370 [16 300]
			0.250 [6.35]	10.02 [14.92]	...	...	2250 [15 500]	2500 [17 200]
			0.281 [7.14]	11.17 [16.63]	...	...	2500 [17 200]	2500 [17 200]
			0.318 [8.08]	12.52 [18.63]	XS	80	2800 [19 300]	2800 [19 300]
			0.125 [3.18]	5.85 [8.71]	...	...	1000 [6900]	1170 [8100]
			0.156 [3.96]	7.24 [10.78]	...	...	1250 [8600]	1460 [10 100]
			0.188 [4.78]	8.67 [12.91]	...	...	1500 [10 300]	1750 [12 100]
			0.219 [5.56]	10.02 [14.91]	...	...	1750 [12 100]	2040 [14 100]
			0.237 [6.02]	10.80 [16.07]	STD	40	1900 [13 100]	2210 [15 200]
			0.250 [6.35]	11.36 [16.90]	...	...	2000 [13 800]	2330 [16 100]
			0.281 [7.14]	12.67 [18.87]	...	...	2250 [15 100]	2620 [18 100]
			0.312 [7.92]	13.97 [20.78]	...	...	2500 [17 200]	2800 [19 300]
			0.337 [8.56]	15.00 [22.32]	XS	80	2700 [18 600]	2800 [19 300]
			0.438 [11.13]	19.02 [28.32]	...	120	2800 [19 300]	2800 [19 300]
			0.531 [13.49]	22.53 [33.54]	...	160	2800 [19 300]	2800 [19 300]
			0.674 [17.12]	27.57 [41.03]	XXS	...	2800 [19 300]	2800 [19 300]
5	125	5.563 [141.3]	0.156 [3.96]	9.02 [13.41]	...	...	1010 [7000]	1180 [8100]
			0.188 [4.78]	10.80 [16.09]	...	...	1220 [8400]	1420 [9800]
			0.219 [5.56]	12.51 [18.61]	...	...	1420 [9800]	1650 [11 400]
			0.258 [6.55]	14.63 [21.77]	STD	40	1670 [11 500]	1950 [13 400]
			0.281 [7.14]	15.87 [23.62]	...	...	1820 [12 500]	2120 [14 600]
			0.312 [7.92]	17.51 [26.05]	...	...	2020 [13 900]	2360 [16 300]
			0.344 [8.74]	19.19 [28.57]	...	...	2230 [15 400]	2600 [17 900]
			0.375 [9.52]	20.80 [30.94]	XS	80	2430 [16 800]	2800 [19 300]
			0.500 [12.70]	27.06 [40.28]	...	120	2800 [19 300]	2800 [19 300]
			0.625 [15.88]	32.99 [49.11]	...	160	2800 [19 300]	2800 [19 300]
			0.750 [19.05]	38.59 [57.43]	XXS	...	2800 [19 300]	2800 [19 300]
6	150	6.625 [168.3]	0.188 [4.78]	12.94 [19.27]	...	...	1020 [7000]	1190 [8200]
			0.219 [5.56]	15.00 [22.31]	...	...	1190 [8200]	1390 [9600]
			0.250 [6.35]	17.04 [25.36]	...	...	1360 [9400]	1580 [10 900]
			0.280 [7.11]	18.99 [28.26]	STD	40	1520 [10 500]	1780 [12 300]
			0.312 [7.92]	21.06 [31.32]	...	...	1700 [11 700]	1980 [13 700]
			0.344 [8.74]	23.10 [34.39]	...	...	1870 [12 900]	2180 [15 000]
			0.375 [9.52]	25.05 [37.28]	...	...	2040 [14 100]	2380 [16 400]
			0.432 [10.97]	28.60 [42.56]	XS	80	2350 [16 200]	2740 [18 900]
			0.562 [14.27]	36.43 [54.20]	...	120	2800 [19 300]	2800 [19 300]
			0.719 [18.26]	45.39 [67.56]	...	160	2800 [19 300]	2800 [19 300]
			0.864 [21.95]	53.21 [79.22]	XXS	...	2800 [19 300]	2800 [19 300]
8	200	8.625 [219.1]	0.188 [4.78]	16.96 [25.26]	...	...	780 [5400]	920 [6300]
			0.203 [5.16]	18.28 [27.22]	...	...	850 [5900]	1000 [6900]
			0.219 [5.56]	19.68 [29.28]	...	...	910 [6300]	1070 [7400]
			0.250 [6.35]	22.38 [33.31]	...	20	1040 [7200]	1220 [8400]
			0.277 [7.04]	24.72 [36.31]	...	30	1160 [7800]	1350 [9300]
			0.312 [7.92]	27.73 [41.24]	...	...	1300 [9000]	1520 [10 500]
			0.322 [8.18]	28.58 [42.55]	STD	40	1340 [9200]	1570 [10 800]
			0.344 [8.74]	30.45 [45.34]	...	...	1440 [9900]	1680 [11 600]
			0.375 [9.52]	33.07 [49.20]	...	...	1570 [10 800]	1830 [12 600]
			0.406 [10.31]	35.67 [53.08]	...	60	1700 [11 700]	2000 [13 800]
			0.438 [11.13]	38.33 [57.08]	...	...	1830 [12 600]	2130 [14 700]
			0.500 [12.70]	43.43 [64.64]	XS	80	2090 [14 400]	2430 [16 800]
			0.594 [15.09]	51.00 [75.92]	...	100	2500 [17 200]	2800 [19 300]

TABLE X2.2
DIMENSIONS, WEIGHTS, AND TEST PRESSURES FOR PLAIN END PIPE (CONT'D)

NPS Designator	DN Designator	Outside Diameter, in. [mm]	Nominal Wall Thickness, in. [mm]	Nominal Weight [Mass] per Unit Length, Plain End, lb/ft [kg/m]	Weight Class	Schedule No.	Test Pressure, ⁴ psi [kPa]	
							Grade A	Grade B
10	250	10.750 [273.0]	0.719 [18.26]	60.77 [90.44]	...	120	2800 [19 300]	2800 [19 300]
			0.812 [20.62]	67.82 [100.92]	...	140	2800 [19 300]	2800 [19 300]
			0.875 [22.22]	72.49 [107.88]	XXS	...	2800 [19 300]	2800 [19 300]
			0.906 [23.01]	74.76 [111.27]	...	160	2800 [19 300]	2800 [19 300]
			0.188 [4.78]	21.23 [31.62]	...	...	630 [4300]	730 [5000]
			0.203 [5.16]	22.89 [34.08]	...	...	680 [4700]	800 [5500]
			0.219 [5.56]	24.65 [36.67]	...	...	730 [5000]	860 [5900]
			0.250 [6.35]	28.06 [41.75]	...	20	840 [5800]	980 [6800]
			0.279 [7.09]	31.23 [46.49]	...	...	930 [6400]	1090 [7500]
			0.307 [7.80]	34.27 [51.01]	...	30	1030 [7100]	1200 [8300]
			0.344 [8.74]	38.27 [56.96]	...	...	1150 [7900]	1340 [9200]
			0.365 [9.27]	40.52 [60.29]	STD	40	1220 [8400]	1430 [9900]
			0.438 [11.13]	48.28 [71.87]	...	...	1470 [10 100]	1710 [11 800]
			0.500 [12.70]	54.79 [81.52]	XS	60	1670 [11 500]	1950 [13 400]
			0.594 [15.09]	64.49 [95.97]	...	80	1990 [13 700]	2320 [16 000]
			0.719 [18.26]	77.10 [114.70]	...	100	2410 [16 600]	2800 [19 300]
12	300	12.750 [323.8]	0.844 [21.44]	89.38 [133.00]	...	120	2800 [19 300]	2800 [19 300]
			1.000 [25.40]	104.23 [155.09]	XXS	140	2800 [19 300]	2800 [19 300]
			1.125 [28.57]	115.75 [172.21]	...	160	2800 [19 300]	2800 [19 300]
			0.203 [5.16]	27.23 [40.55]	...	...	570 [3900]	670 [4600]
			0.219 [5.56]	29.34 [43.63]	...	...	620 [4300]	720 [5000]
			0.250 [6.35]	33.41 [49.71]	...	20	710 [4900]	820 [5700]
			0.281 [7.14]	37.46 [55.75]	...	...	790 [5400]	930 [6400]
			0.312 [7.92]	41.48 [61.69]	...	...	880 [6100]	1030 [7100]
			0.330 [8.38]	43.81 [65.18]	...	30	930 [6400]	1090 [7500]
			0.344 [8.74]	45.62 [67.90]	...	...	970 [6700]	1130 [7800]
			0.375 [9.52]	49.61 [73.78]	STD	...	1060 [7300]	1240 [8500]
			0.406 [10.31]	53.57 [79.70]	...	40	1150 [7900]	1340 [9200]
			0.438 [11.13]	57.65 [85.82]	...	...	1240 [8500]	1440 [9900]
			0.500 [12.70]	65.48 [97.43]	XS	...	1410 [9700]	1650 [11 400]
			0.562 [14.27]	73.22 [108.92]	...	60	1590 [11 000]	1850 [12 800]
			0.688 [17.48]	88.71 [132.04]	...	80	1940 [13 400]	2270 [15 700]
14	350	14.000 [355.6]	0.844 [21.44]	107.42 [159.86]	...	100	2390 [16 500]	2780 [19 200]
			1.000 [25.40]	125.61 [186.91]	XXS	120	2800 [19 300]	2800 [19 300]
			1.125 [28.57]	139.81 [208.00]	...	140	2800 [19 300]	2800 [19 300]
			1.312 [33.32]	160.42 [238.68]	...	160	2800 [19 300]	2800 [19 300]
			0.210 [5.33]	30.96 [46.04]	...	...	540 [3700]	630 [4300]
			0.219 [5.56]	32.26 [47.99]	...	...	560 [3900]	660 [4500]
			0.250 [6.35]	36.75 [54.69]	...	10	640 [4400]	750 [5200]
			0.281 [7.14]	41.21 [61.35]	...	...	720 [5000]	840 [5800]
			0.312 [7.92]	45.65 [67.90]	...	20	800 [5500]	940 [6500]
			0.344 [8.74]	50.22 [74.76]	...	...	880 [6100]	1030 [7100]
			0.375 [9.52]	54.62 [81.25]	STD	30	960 [6600]	1120 [7700]
			0.438 [11.13]	63.50 [94.55]	...	40	1130 [7800]	1310 [9000]
			0.469 [11.91]	67.84 [100.94]	...	...	1210 [8300]	1410 [9700]
			0.500 [12.70]	72.16 [107.39]	XS	...	1290 [8900]	1500 [10 300]
			0.594 [15.09]	85.13 [126.71]	...	60	1530 [10 500]	1790 [12 300]
			0.750 [19.05]	106.23 [158.10]	...	80	1930 [13 300]	2250 [15 500]
			0.938 [23.83]	130.98 [194.96]	...	100	2410 [16 600]	2800 [19 300]
			1.094 [27.79]	150.93 [224.65]	...	120	2800 [19 300]	2800 [19 300]
			1.250 [31.75]	170.37 [253.56]	...	140	2800 [19 300]	2800 [19 300]
			1.406 [35.71]	189.29 [281.70]	...	160	2800 [19 300]	2800 [19 300]
			2.000 [50.80]	256.56 [381.83]	...	...	2800 [19 300]	2800 [19 300]

TABLE X2.2
DIMENSIONS, WEIGHTS, AND TEST PRESSURES FOR PLAIN END PIPE (CONT'D)

NPS Designator	DN Designator	Outside Diameter, in. [mm]	Nominal Wall Thickness, in. [mm]	Nominal Weight [Mass] per Unit Length, Plain End, lb/ft [kg/m]	Weight Class	Schedule No.	Test Pressure, ⁴ psi [kPa]	
							Grade A	Grade B
16	400	16.000 [406.4]	2.125 [53.97]	269.76 [401.44]	...	...	2800 [19 300]	2800 [19 300]
			2.200 [55.88]	277.51 [413.01]	...	...	2800 [19 300]	2800 [19 300]
			2.500 [63.50]	307.34 [457.40]	...	...	2800 [19 300]	2800 [19 300]
			0.219 [5.56]	36.95 [54.96]	...	...	490 [3400]	570 [3900]
			0.250 [6.35]	42.09 [62.64]	...	10	560 [3900]	660 [4500]
			0.281 [7.14]	47.22 [70.30]	...	...	630 [4300]	740 [5100]
			0.312 [7.92]	52.32 [77.83]	...	20	700 [4800]	820 [5700]
			0.344 [8.74]	57.57 [85.71]	...	...	770 [5300]	900 [6200]
			0.375 [9.52]	62.64 [93.17]	STD	30	840 [5800]	980 [6800]
			0.438 [11.13]	72.86 [108.49]	...	...	990 [6800]	1150 [7900]
			0.469 [11.91]	77.87 [115.86]	...	...	1060 [7300]	1230 [8500]
			0.500 [12.70]	82.85 [123.30]	XS	40	1120 [7700]	1310 [9000]
			0.656 [16.66]	107.60 [160.12]	...	60	1480 [10 200]	1720 [11 900]
			0.844 [21.44]	136.74 [203.53]	...	80	1900 [13 100]	2220 [15 300]
			1.031 [26.19]	164.98 [245.56]	...	100	2320 [16 000]	2710 [18 700]
			1.219 [30.96]	192.61 [286.64]	...	120	2740 [18 900]	2800 [19 300]
			1.438 [36.53]	223.85 [333.19]	...	140	2800 [19 300]	2800 [19 300]
			1.594 [40.49]	245.48 [365.35]	...	160	2800 [19 300]	2800 [19 300]
18	450	18.000 [457]	0.250 [6.35]	47.44 [70.60]	...	10	500 [3400]	580 [4000]
			0.281 [7.14]	53.23 [79.24]	...	...	560 [3900]	660 [4500]
			0.312 [7.92]	58.99 [87.75]	...	20	620 [4300]	730 [5000]
			0.344 [8.74]	64.93 [96.66]	...	...	690 [4800]	800 [5500]
			0.375 [9.52]	70.65 [105.10]	STD	...	750 [5200]	880 [6100]
			0.406 [10.31]	76.36 [113.62]	...	...	810 [5600]	950 [6500]
			0.438 [11.13]	82.23 [122.43]	...	30	880 [6100]	1020 [7000]
			0.469 [11.91]	87.89 [130.78]	...	...	940 [6500]	1090 [7500]
			0.500 [12.70]	93.54 [139.20]	XS	...	1000 [6900]	1170 [8100]
			0.562 [14.27]	104.76 [155.87]	...	40	1120 [7700]	1310 [9000]
			0.750 [19.05]	138.30 [205.83]	...	60	1500 [10 300]	1750 [12 100]
			0.938 [23.83]	171.08 [254.67]	...	80	1880 [13 000]	2190 [15 100]
			1.156 [29.36]	208.15 [309.76]	...	100	2310 [15 900]	2700 [18 600]
			1.375 [34.92]	244.37 [363.64]	...	120	2750 [19 000]	2800 [19 300]
			1.562 [39.67]	274.48 [408.45]	...	140	2800 [19 300]	2800 [19 300]
			1.781 [45.24]	308.79 [459.59]	...	160	2800 [19 300]	2800 [19 300]
20	500	20.000 [508]	0.250 [6.35]	52.78 [78.55]	...	10	450 [3100]	520 [3600]
			0.281 [7.14]	59.23 [88.19]	...	...	510 [3500]	590 [4100]
			0.312 [7.92]	65.66 [97.67]	...	...	560 [3900]	660 [4500]
			0.344 [8.74]	72.28 [107.60]	...	...	620 [4300]	720 [5000]
			0.375 [9.52]	78.67 [117.02]	STD	20	680 [4700]	790 [5400]
			0.406 [10.31]	84.04 [126.53]	...	...	730 [5000]	850 [5900]
			0.438 [11.13]	91.59 [136.37]	...	...	790 [5400]	920 [6300]
			0.469 [11.91]	97.92 [145.70]	...	...	850 [5900]	950 [6500]
			0.500 [12.70]	104.23 [155.12]	XS	30	900 [6200]	1050 [7200]
			0.594 [15.09]	123.23 [183.42]	...	40	1170 [8100]	1250 [8600]
			0.812 [20.62]	166.56 [247.83]	...	60	1460 [10 100]	1710 [11 800]
			1.031 [26.19]	209.06 [311.17]	...	80	1860 [12 800]	2170 [15 000]
			1.281 [32.54]	256.34 [381.53]	...	100	2310 [15 900]	2690 [18 500]
			1.500 [38.10]	296.65 [441.49]	...	120	2700 [18 600]	2800 [19 300]
			1.750 [44.45]	341.41 [508.11]	...	140	2800 [19 300]	2800 [19 300]
			1.969 [50.01]	379.53 [564.81]	...	160	2800 [19 300]	2800 [19 300]
24	600	24.000 [610]	0.250 [6.35]	63.47 [94.46]	...	10	380 [2600]	440 [3000]
			0.281 [7.14]	71.25 [106.08]	...	...	420 [2900]	490 [3400]

TABLE X2.2
DIMENSIONS, WEIGHTS, AND TEST PRESSURES FOR PLAIN END PIPE (CONT'D)

NPS Designator	DN Designator	Outside Diameter, in. [mm]	Nominal Wall Thickness, in. [mm]	Nominal Weight [Mass] per Unit Length, Plain End, lb/ft [kg/m]	Weight Class	Schedule No.	Test Pressure, ⁴ psi [kPa]	
							Grade A	Grade B
			0.312 [7.92]	79.01 [117.51]	...	...	470 [3200]	550 [3800]
			0.344 [8.74]	86.99 [129.50]	...	...	520 [3600]	600 [4100]
			0.375 [9.52]	94.71 [140.88]	STD	20	560 [3900]	660 [4500]
			0.406 [10.31]	102.40 [152.37]	...	...	610 [4200]	710 [4900]
			0.438 [11.13]	110.32 [164.26]	...	...	660 [4500]	770 [5300]
			0.469 [11.91]	117.98 [175.54]	...	...	700 [4800]	820 [5700]
			0.500 [12.70]	125.61 [186.94]	XS	...	750 [5200]	880 [6100]
			0.562 [14.27]	140.81 [209.50]	...	30	840 [5800]	980 [6800]
			0.688 [17.48]	171.45 [255.24]	...	40	1030 [7100]	1200 [8300]
			0.938 [23.83]	231.25 [344.23]	...	...	1410 [9700]	1640 [11 300]
			0.969 [24.61]	238.57 [355.02]	...	60	1450 [10 000]	1700 [11 700]
			1.219 [30.96]	296.86 [441.78]	...	80	1830 [12 600]	2130 [14 700]
			1.531 [38.89]	367.74 [547.33]	...	100	2300 [15 900]	2680 [18 500]
			1.812 [46.02]	429.79 [639.58]	...	120	2720 [18 800]	2800 [19 300]
			2.062 [52.37]	483.57 [719.63]	...	140	2800 [19 300]	2800 [19 300]
			2.344 [59.54]	542.64 [807.63]	...	160	2800 [19 300]	2800 [19 300]
26	650	26.000 [660]	0.250 [6.35]	68.82 [102.42]	...	...	350 [2400]	400 [2800]
			0.281 [7.14]	77.26 [115.02]	...	...	390 [2700]	450 [3100]
			0.312 [7.92]	85.68 [127.43]	...	10	430 [3000]	500 [3400]
			0.344 [8.74]	94.35 [140.45]	...	...	480 [3300]	560 [3900]
			0.375 [9.52]	102.72 [152.80]	STD	...	520 [3600]	610 [4200]
			0.406 [10.31]	111.08 [165.28]	...	...	560 [3900]	660 [4500]
			0.438 [11.13]	119.69 [178.20]	...	...	610 [4200]	710 [4900]
			0.469 [11.91]	128.00 [190.46]	...	...	650 [4500]	760 [5200]
			0.500 [12.70]	136.30 [202.85]	XS	20	690 [4800]	810 [5600]
			0.562 [14.27]	152.83 [227.37]	...	...	780 [5400]	910 [6300]

⁴ The minimum test pressure for outside diameters and wall thicknesses not listed shall be computed by the formula given below. The computed test pressure shall be used in all cases with the following exceptions:

(1) When the wall thickness is greater than the heaviest wall thickness shown for a given diameter, the test pressure for the heaviest wall listed shall be the required test pressure.

(2) For Grades A and B in sizes under NPS 2 [DN 50], when the wall thickness is lighter than the lightest shown for a given diameter, use the test pressure given for the lightest wall thickness of the table for the diameter involved.

(3) For all sizes of Grades A and B pipe smaller than NPS 2 [DN 50], the test pressure has been arbitrarily assigned. Test pressures for intermediate outside diameters need not exceed those for the next larger listed size.

$$P = 2St/D$$

where:

P = minimum hydrostatic test pressure, psi [kPa],

S = 0.60 times the specified minimum yield strength, psi [kPa],

t = nominal wall thickness, in. [mm], and

D = specified outside diameter, in. [mm].

TABLE X2.3
DIMENSIONS, WEIGHTS, AND TEST PRESSURES FOR THREADED AND COUPLED PIPE

NPS Designator	DN Designator	Outside Diameter, in. [mm]	Nominal Wall Thickness, in. [mm]	Nominal Weight [Mass] per Unit Length, Threaded and Coupled, lb/ft [kg/m]	Weight Class	Schedule No.	Test Pressure, psi [kPa]	
							Grade A	Grade B
$\frac{1}{8}$	6	0.405 [10.3]	0.068 [1.73]	0.25 [0.37]	STD	40	700 [4800]	700 [4800]
			0.095 [2.41]	0.32 [0.46]	XS	80	850 [5900]	850 [5900]
$\frac{1}{4}$	8	0.540 [13.7]	0.088 [2.24]	0.43 [0.63]	STD	40	700 [4800]	700 [4800]
			0.119 [3.02]	0.54 [0.80]	XS	80	850 [5900]	850 [5900]
$\frac{3}{8}$	10	0.675 [17.1]	0.091 [2.31]	0.57 [0.84]	STD	40	700 [4800]	700 [4800]
			0.126 [3.20]	0.74 [1.10]	XS	80	850 [5900]	850 [5900]
$\frac{1}{2}$	15	0.840 [21.3]	0.109 [2.77]	0.86 [1.27]	STD	40	700 [4800]	700 [4800]
			0.147 [3.73]	1.09 [1.62]	XS	80	850 [5900]	850 [5900]
			0.294 [7.47]	1.72 [2.54]	XXS	...	1000 [6900]	1000 [6900]
$\frac{3}{4}$	20	1.050 [26.7]	0.113 [2.87]	1.14 [1.69]	STD	40	700 [4800]	700 [4800]
			0.154 [3.91]	1.48 [2.21]	XS	80	850 [5900]	850 [5900]
			0.308 [7.82]	2.45 [3.64]	XXS	...	1000 [6900]	1000 [6900]
1	25	1.315 [33.4]	0.133 [3.38]	1.69 [2.50]	STD	40	700 [4800]	700 [4800]
			0.179 [4.55]	2.19 [3.25]	XS	80	850 [5900]	850 [5900]
			0.358 [9.09]	3.66 [5.45]	XXS	...	1000 [6900]	1000 [6900]
$1\frac{1}{4}$	32	1.660 [42.2]	0.140 [3.56]	2.28 [3.40]	STD	40	1000 [6900]	1100 [7600]
			0.191 [4.85]	3.03 [4.49]	XS	80	1500 [10 300]	1600 [11 000]
			0.382 [9.70]	5.23 [7.76]	XXS	...	1800 [12 400]	1900 [13 100]
$1\frac{1}{2}$	40	1.900 [48.3]	0.145 [3.68]	2.74 [4.04]	STD	40	1000 [6900]	1100 [7600]
			0.200 [5.08]	3.65 [5.39]	XS	80	1500 [10 300]	1600 [11 000]
			0.400 [10.16]	6.41 [9.56]	XXS	...	1800 [12 400]	1900 [13 100]
2	50	2.375 [60.3]	0.154 [3.91]	3.68 [5.46]	STD	40	2300 [15 900]	2500 [17 200]
			0.218 [5.54]	5.08 [7.55]	XS	80	2500 [17 200]	2500 [17 200]
			0.436 [11.07]	9.06 [13.44]	XXS	...	2500 [17 200]	2500 [17 200]
$2\frac{1}{2}$	65	2.875 [73.0]	0.203 [5.16]	5.85 [8.67]	STD	40	2500 [17 200]	2500 [17 200]
			0.276 [7.01]	7.75 [11.52]	XS	80	2500 [17 200]	2500 [17 200]
			0.552 [14.02]	13.72 [20.39]	XXS	...	2500 [17 200]	2500 [17 200]
3	80	3.500 [88.9]	0.216 [5.49]	7.68 [11.35]	STD	40	2200 [15 200]	2500 [17 200]
			0.300 [7.62]	10.35 [15.39]	XS	80	2500 [17 200]	2500 [17 200]
			0.600 [15.24]	18.60 [27.66]	XXS	...	2500 [17 200]	2500 [17 200]
$3\frac{1}{2}$	90	4.000 [101.6]	0.226 [5.74]	9.27 [13.71]	STD	40	2000 [13 800]	2400 [16 500]
			0.318 [8.08]	12.67 [18.82]	XS	80	2800 [19 300]	2800 [19 300]
4	100	4.500 [114.3]	0.237 [6.02]	10.92 [16.23]	STD	40	1900 [13 100]	2200 [15 200]
			0.337 [8.56]	15.20 [22.60]	XS	80	2700 [18 600]	2800 [19 300]
			0.674 [17.12]	27.62 [41.09]	XXS	...	2800 [19 300]	2800 [19 300]
5	125	5.563 [141.3]	0.258 [6.55]	14.90 [22.07]	STD	40	1700 [11 700]	1900 [13 100]
			0.375 [9.52]	21.04 [31.42]	XS	80	2400 [16 500]	2800 [19 300]
			0.750 [19.05]	38.63 [57.53]	XXS	...	2800 [19 300]	2800 [19 300]
6	150	6.625 [168.3]	0.280 [7.11]	19.34 [28.58]	STD	40	1500 [10 300]	1800 [12 400]
			0.432 [10.97]	28.88 [43.05]	XS	80	2300 [15 900]	2700 [18 600]
			0.864 [21.95]	53.19 [79.18]	XXS	...	2800 [19 300]	2800 [19 300]
8	200	8.625 [219.1]	0.277 [7.04]	25.53 [38.07]	...	30	1200 [8300]	1300 [9000]
			0.322 [8.18]	29.35 [43.73]	STD	40	1300 [9000]	1600 [11 000]
			0.500 [12.70]	44.00 [65.41]	XS	80	2100 [14 500]	2400 [16 500]
			0.875 [22.22]	72.69 [107.94]	XXS	...	2800 [19 300]	2800 [19 300]
10	250	10.750 [273.0]	0.279 [7.09]	32.33 [48.80]	...	...	950 [6500]	1100 [7600]
			0.307 [7.80]	35.33 [53.27]	...	30	1000 [6900]	1200 [8300]
			0.365 [9.27]	41.49 [63.36]	STD	40	1200 [8300]	1400 [9700]
			0.500 [12.70]	55.55 [83.17]	XS	60	1700 [11 700]	2000 [13 800]
12	300	12.750 [323.8]	0.330 [8.38]	45.47 [67.72]	...	30	950 [6500]	1100 [7600]
			0.375 [9.52]	51.28 [76.21]	STD	...	1100 [7600]	1200 [8300]
			0.500 [12.70]	66.91 [99.4]	XS	...	1400 [9700]	1600 [11 000]

TABLE X2.4
TABLE OF MINIMUM WALL THICKNESSES ON INSPECTION FOR NOMINAL PIPE WALL THICKNESSES

Nominal Wall Thickness (t_n), in. [mm]	Minimum Wall Thickness on Inspection (t_m), in. [mm]	Nominal Wall Thickness (t_n), in. [mm]	Minimum Wall Thickness on Inspection (t_m), in. [mm]	Nominal Wall Thickness (t_n), in. [mm]	Minimum Wall Thickness on Inspection (t_m), in. [mm]
0.068 [1.73]	0.060 [1.52]	0.294 [7.47]	0.257 [6.53]	0.750 [19.05]	0.656 [16.66]
0.088 [2.24]	0.077 [1.96]	0.300 [7.62]	0.262 [6.65]	0.812 [20.62]	0.710 [18.03]
0.091 [2.31]	0.080 [2.03]	0.307 [7.80]	0.269 [6.83]	0.844 [21.44]	0.739 [18.77]
0.095 [2.41]	0.083 [2.11]	0.308 [7.82]	0.270 [6.86]	0.864 [21.94]	0.756 [19.20]
0.109 [2.77]	0.095 [2.41]	0.312 [7.92]	0.273 [6.93]	0.875 [22.22]	0.766 [19.46]
0.113 [2.87]	0.099 [2.51]	0.318 [8.08]	0.278 [7.06]	0.906 [23.01]	0.793 [20.14]
0.119 [3.02]	0.104 [2.64]	0.322 [8.18]	0.282 [7.16]	0.938 [23.82]	0.821 [20.85]
0.125 [3.18]	0.109 [2.77]	0.330 [8.38]	0.289 [7.34]	0.968 [24.59]	0.847 [21.51]
0.126 [3.20]	0.110 [2.79]	0.337 [8.56]	0.295 [7.49]	1.000 [25.40]	0.875 [22.22]
0.133 [3.38]	0.116 [2.95]	0.343 [8.71]	0.300 [7.62]	1.031 [26.19]	0.902 [22.91]
0.140 [3.56]	0.122 [3.10]	0.344 [8.74]	0.301 [7.65]	1.062 [26.97]	0.929 [23.60]
0.145 [3.68]	0.127 [3.23]	0.358 [9.09]	0.313 [7.95]	1.094 [27.79]	0.957 [24.31]
0.147 [3.73]	0.129 [3.28]	0.365 [9.27]	0.319 [8.10]	1.125 [28.58]	0.984 [24.99]
0.154 [3.91]	0.135 [3.43]	0.375 [9.52]	0.328 [8.33]	1.156 [29.36]	1.012 [25.70]
0.156 [3.96]	0.136 [3.45]	0.382 [9.70]	0.334 [8.48]	1.219 [30.96]	1.067 [27.08]
0.179 [4.55]	0.157 [3.99]	0.400 [10.16]	0.350 [8.89]	1.250 [31.75]	1.094 [27.79]
0.187 [4.75]	0.164 [4.17]	0.406 [10.31]	0.355 [9.02]	1.281 [32.54]	1.121 [28.47]
0.188 [4.78]	0.164 [4.17]	0.432 [10.97]	0.378 [9.60]	1.312 [33.32]	1.148 [29.16]
0.191 [4.85]	0.167 [4.24]	0.436 [11.07]	0.382 [9.70]	1.343 [34.11]	1.175 [29.85]
0.200 [5.08]	0.175 [4.44]	0.437 [11.10]	0.382 [9.70]	1.375 [34.92]	1.203 [30.56]
0.203 [5.16]	0.178 [4.52]	0.438 [11.13]	0.383 [9.73]	1.406 [35.71]	1.230 [31.24]
0.216 [5.49]	0.189 [4.80]	0.500 [12.70]	0.438 [11.13]	1.438 [36.53]	1.258 [31.95]
0.218 [5.54]	0.191 [4.85]	0.531 [13.49]	0.465 [11.81]	1.500 [38.10]	1.312 [33.32]
0.219 [5.56]	0.192 [4.88]	0.552 [14.02]	0.483 [12.27]	1.531 [38.89]	1.340 [34.04]
0.226 [5.74]	0.198 [5.03]	0.562 [14.27]	0.492 [12.50]	1.562 [39.67]	1.367 [34.72]
0.237 [6.02]	0.207 [5.26]	0.594 [15.09]	0.520 [13.21]	1.594 [40.49]	1.395 [35.43]
0.250 [6.35]	0.219 [5.56]	0.600 [15.24]	0.525 [13.34]	1.750 [44.45]	1.531 [38.89]
0.258 [6.55]	0.226 [5.74]	0.625 [15.88]	0.547 [13.89]	1.781 [45.24]	1.558 [39.57]
0.276 [7.01]	0.242 [6.15]	0.656 [16.66]	0.574 [14.58]	1.812 [46.02]	1.586 [40.28]
0.277 [7.04]	0.242 [6.15]	0.674 [17.12]	0.590 [14.99]	1.968 [49.99]	1.722 [43.74]
0.279 [7.09]	0.244 [6.20]	0.688 [17.48]	0.602 [15.29]	2.062 [52.37]	1.804 [45.82]
0.280 [7.11]	0.245 [6.22]	0.719 [18.26]	0.629 [15.98]	2.344 [59.54]	2.051 [52.10]
0.281 [7.14]	0.246 [6.25]				

Note 1 — The following equation, upon which this table is based, shall be applied to calculate minimum wall thickness from nominal wall thickness:

$$t_n \times 0.875 = t_m$$

where:

t_n = nominal wall thickness, in. [mm], and
 t_m = minimum wall thickness, in. [mm].

The wall thickness is expressed to three decimal places, the fourth decimal place being carried forward or dropped in accordance with Practice E 29.

Note 2 — This table is a master table covering wall thicknesses available in the purchase of different classifications of pipe, but it is not meant to imply that all of the walls listed therein are obtainable under this specification.

X3. BASIC THREADING DATA

X3.1 Figure X3.1 is to be used with Table X3.1. Figure X3.2 is to be used with Table X3.2.

FIG. X3.1 DIMENSIONS OF HAND TIGHT ASSEMBLY FOR USE WITH TABLE X3.1

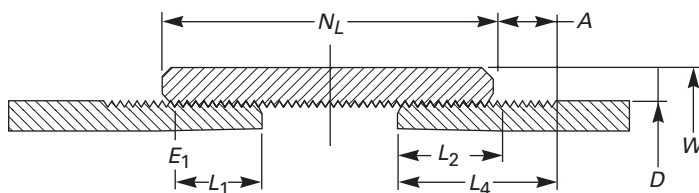


TABLE X3.1
BASIC THREADING DATA FOR STANDARD-WEIGHT NPS 6 [DN 50] AND UNDER

Pipe			Threads					Coupling		
NPS Designator	DN Designator	Outside Diameter, in. [mm] D	Number per inch	End of Pipe to Hand Tight Plane, in. [mm] L_1	Effective Length, in. [mm] L_2	Total Length, in. [mm] L_4	Pitch Diameter at Hand Tight Plane, in. [mm] E_1	Outside Diameter, in. [mm] W	Length, min., in. [mm] N_L	Hand Tight Stand-Off (Number of Threads) A
$\frac{1}{8}$	6	0.405 [10.3]	27	0.1615 [4.1021]	0.2638 [6.7005]	0.3924 [9.9670]	0.37360 [9.48944]	0.563 [14.3]	$\frac{3}{4}$ [19]	4
$\frac{1}{4}$	8	0.540 [13.7]	18	0.2278 [5.7861]	0.4018 [10.2057]	0.5946 [15.1028]	0.49163 [12.48740]	0.719 [18.3]	$1\frac{1}{8}$ [29]	$5\frac{1}{2}$
$\frac{3}{8}$	10	0.675 [17.1]	18	0.240 [6.096]	0.4078 [10.3581]	0.6006 [15.2552]	0.62701 [15.92605]	0.875 [22.2]	$1\frac{1}{8}$ [29]	5
$\frac{1}{2}$	15	0.840 [21.3]	14	0.320 [8.128]	0.5337 [13.5560]	0.7815 [19.8501]	0.77843 [19.77212]	1.063 [27.0]	$1\frac{1}{2}$ [38]	5
$\frac{3}{4}$	20	1.050 [26.7]	14	0.339 [8.611]	0.5457 [13.8608]	0.7935 [20.1549]	0.98887 [25.11730]	1.313 [33.4]	1 [40]	5
1	25	1.315 [33.4]	$11\frac{1}{2}$	0.400 [10.160]	0.6828 [17.3431]	0.9845 [25.0063]	1.23863 [31.46120]	1.576 [40.0]	$1\frac{15}{16}$ [49]	5
$1\frac{1}{4}$	32	1.660 [42.2]	$11\frac{1}{2}$	0.420 [10.668]	0.7068 [17.9527]	1.0085 [25.6159]	1.58338 [40.21785]	1.900 [48.3]	2 [50]	5
$1\frac{1}{2}$	40	1.900 [48.3]	$11\frac{1}{2}$	0.420 [10.668]	0.7235 [18.3769]	1.0252 [26.0401]	1.82234 [46.28744]	2.200 [55.9]	2 [50]	$5\frac{1}{2}$
2	50	2.375 [60.3]	$11\frac{1}{2}$	0.436 [11.074]	0.7565 [19.2151]	1.0582 [26.8783]	2.29627 [58.32526]	2.750 [69.8]	$2\frac{1}{16}$ [52]	$5\frac{1}{2}$
$2\frac{1}{2}$	65	2.875 [73.0]	8	0.682 [17.323]	1.1376 [28.8950]	1.5712 [39.9085]	2.76216 [70.15886]	3.250 [82.5]	$3\frac{1}{16}$ [78]	$5\frac{1}{2}$
3	80	3.500 [88.9]	8	0.766 [19.456]	1.2000 [30.4800]	1.6337 [41.4960]	3.38850 [86.06790]	4.000 [101.6]	$3\frac{3}{16}$ [81]	$5\frac{1}{2}$
$3\frac{1}{2}$	90	4.000 [101.6]	8	0.821 [20.853]	1.2500 [31.7500]	1.6837 [42.7660]	3.88881 [98.77577]	4.625 [117.5]	$3\frac{5}{16}$ [84]	$5\frac{1}{2}$
4	100	4.500 [114.3]	8	0.844 [21.438]	1.3000 [33.0200]	1.7337 [44.0360]	4.38713 [111.43310]	5.000 [127.0]	$3\frac{7}{16}$ [87]	5
5	125	5.563 [141.3]	8	0.937 [23.800]	1.4063 [35.7200]	1.8400 [46.7360]	5.44929 [138.41200]	6.296 [159.9]	$3\frac{11}{16}$ [94]	5
6	150	6.625 [168.3]	8	0.958 [24.333]	1.5125 [38.4175]	1.9462 [49.4335]	6.50597 [165.25164]	7.390 [187.7]	$4\frac{15}{16}$ [125]	6

Note 1 — All dimensions in this table are nominal and subject to mill tolerances.

Note 2 — The taper of threads is $\frac{3}{4}$ in./ft [62.5 mm/m] on the diameter.

FIG. X3.2 DIMENSIONS OF HAND TIGHT ASSEMBLY FOR USE WITH TABLE X3.2

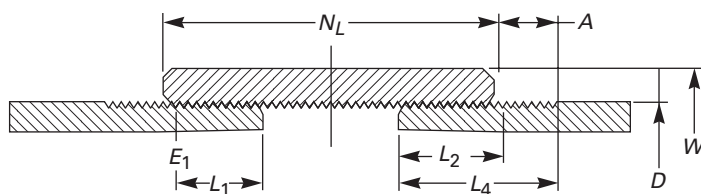


TABLE X3.2
BASIC THREADING DATA FOR STANDARD-WEIGHT PIPE IN NPS 8 [DN 200] AND LARGER, AND ALL SIZES OF
EXTRA-STRONG AND DOUBLE-EXTRA-STRONG WEIGHT

Pipe			Threads					Coupling		
NPS Designator	DN Designator	Outside Diameter, in. [mm] <i>D</i>	Number per inch	End of Pipe to Hand Tight Plane, in. [mm] <i>L₁</i>	Effective Length, in. [mm] <i>L₂</i>	Total Length, in. [mm] <i>L₄</i>	Pitch Diameter at Hand Tight Plane, in. [mm] <i>E₁</i>	Outside Diameter, in. [mm] <i>W</i>	Length, min., in. [mm] <i>N_L</i>	Hand Tight Stand-Off (Number of Threads) <i>A</i>
1/8	6	0.405 [10.3]	27	0.1615 [4.1021]	0.2638 [6.7005]	0.3924 [9.9670]	0.37360 [9.48944]	0.563 [14.3]	1 1/16 [27]	3
1/4	8	0.540 [13.7]	18	0.2278 [5.7861]	0.4018 [10.2057]	0.5946 [15.1028]	0.49163 [12.48740]	0.719 [18.3]	1 5/8 [41]	3
3/8	10	0.675 [17.1]	18	0.240 [6.096]	0.4078 [10.3581]	0.6006 [15.2552]	0.62701 [15.92605]	0.875 [22.2]	1 5/8 [41]	3
1/2	15	0.840 [21.3]	14	0.320 [8.128]	0.5337 [13.5560]	0.7815 [19.8501]	0.77843 [19.77212]	1.063 [27.0]	2 1/8 [54]	3
3/4	20	1.050 [26.7]	14 1/2	0.339 [8.611]	0.5457 [13.8608]	0.7935 [20.1549]	0.98887 [25.11730]	1.313 [33.4]	2 1/8 [54]	3
1	25	1.315 [33.4]	11	0.400 [10.160]	0.6828 [17.3431]	0.9845 [25.0063]	1.23863 [31.46120]	1.576 [40.0]	2 5/8 [67]	3
1 1/4	32	1.660 [42.2]	11 1/2	0.420 [10.668]	0.7068 [17.9527]	1.0085 [25.6159]	1.58338 [40.21785]	2.054 [52.2]	2 3/4 [70]	3
1 1/2	40	1.900 [48.3]	11 1/2	0.420 [10.668]	0.7235 [18.3769]	1.0252 [26.0401]	1.82234 [46.28744]	2.200 [55.9]	2 3/4 [70]	3
2	50	2.375 [60.3]	11 1/2	0.436 [11.074]	0.7565 [19.2151]	1.0582 [26.8783]	2.29627 [58.32526]	2.875 [73.0]	2 7/8 [73]	3
2 1/2	65	2.875 [73.0]	8	0.682 [17.323]	1.1375 [28.8950]	1.5712 [39.9085]	2.76216 [70.15886]	3.375 [85.7]	4 1/8 [105]	2
3	80	3.500 [88.9]	8	0.766 [19.456]	1.2000 [30.4800]	1.6337 [41.4960]	3.38850 [86.06790]	4.000 [101.6]	4 1/4 [108]	2
3 1/2	90	4.000 [101.6]	8	0.821 [20.853]	1.2500 [31.7500]	1.6837 [42.7660]	3.88881 [98.77577]	4.625 [117.5]	4 3/8 [111]	2
4	100	4.500 [114.3]	8	0.844 [21.438]	1.3000 [33.0200]	1.7337 [44.0360]	4.38713 [111.43310]	5.200 [132.1]	4 1/2 [114]	2
5	125	5.563 [141.3]	8	0.937 [23.800]	1.4063 [35.7200]	1.8400 [46.7360]	5.44929 [138.41200]	6.296 [159.9]	4 5/8 [117]	2
6	150	6.625 [168.3]	8	0.958 [24.333]	1.5125 [38.4175]	1.9462 [49.4335]	6.50597 [165.25164]	7.390 [187.7]	4 7/8 [124]	2
8	200	8.625 [219.1]	8	1.063 [27.000]	1.7125 [43.4975]	2.1462 [54.5135]	8.50003 [215.90076]	9.625 [244.5]	5 1/4 [133]	2

TABLE X3.2
BASIC THREADING DATA FOR STANDARD-WEIGHT PIPE IN NPS 8 [DN 200] AND LARGER, AND ALL SIZES OF
EXTRA-STRONG AND DOUBLE-EXTRA-STRONG WEIGHT (CONT'D)

Pipe				Threads				Coupling		
NPS Designator	DN Designator	Outside Diameter, in. [mm] <i>D</i>	Number per inch	End of Pipe to Hand Tight Plane, in. [mm] <i>L₁</i>	Effective Length, in. [mm] <i>L₂</i>	Total Length, in. [mm] <i>L₄</i>	Pitch Diameter at Hand Tight Plane, in. [mm] <i>E₁</i>	Outside Diameter, in. [mm] <i>W</i>	Length, min., in. [mm] <i>N_L</i>	Hand Tight Stand-Off (Number of Threads) <i>A</i>
10	250	10.750 [273.0]	8	1.210 [30.734]	1.9250 [48.8950]	2.3587 [59.9110]	10.62094 [269.77188]	11.750 [298.4]	5 $\frac{3}{4}$ [146]	2
12	300	12.750 [323.8]	8	1.360 [34.544]	2.1250 [53.9750]	2.5587 [64.9910]	12.61781 [320.49237]	14.000 [355.6]	6 $\frac{1}{8}$ [156]	2
14	350	14.000 [355.6]	8	1.562 [39.675]	2.2500 [57.1500]	2.6837 [68.1660]	13.87263 [352.36480]	15.000 [381.0]	6 $\frac{3}{8}$ [162]	2
16	400	16.000 [406.4]	8	1.812 [46.025]	2.4500 [62.2300]	2.8837 [73.2460]	15.87575 [403.24405]	17.000 [432]	6 $\frac{3}{4}$ [171]	2
18	450	18.000 [457]	8	2.000 [50.800]	2.6500 [67.3100]	3.0837 [78.3260]	17.87500 [454.02500]	19.000 [483]	7 $\frac{1}{8}$ [181]	2
20	500	20.000 [508]	8	2.125 [53.975]	2.8500 [72.3900]	3.2837 [83.4060]	19.87031 [504.70587]	21.000 [533]	7 $\frac{5}{8}$ [194]	2

Note 1 — The taper of threads is $\frac{3}{4}$ in./ft [62.5 mm/m] on the diameter.

X4. ELONGATION VALUES

X4.1 Tabulated in Table X4.1 are the minimum elongation values calculated by the equation given in Table 2.

TABLE X4.1
ELONGATION VALUES

Area, A , in. ²	Tension Test Specimen			Elongation in 2 in., min, %	
	Nominal Wall Thickness, in.			Specified Tensile Strength, psi	
	$\frac{3}{4}$ in. Specimen	1 in. Specimen	$1\frac{1}{2}$ in. Specimen	48 000	60 000
0.75 and greater	0.994 and greater	0.746 and greater	0.497 and greater	36	30
0.74	0.980–0.993	0.735–0.745	0.490–0.496	36	29
0.73	0.967–0.979	0.726–0.734	0.484–0.489	36	29
0.72	0.954–0.966	0.715–0.725	0.477–0.483	36	29
0.71	0.941–0.953	0.706–0.714	0.471–0.476	36	29
0.70	0.927–0.940	0.695–0.705	0.464–0.470	36	29
0.69	0.914–0.926	0.686–0.694	0.457–0.463	36	29
0.68	0.900–0.913	0.675–0.685	0.450–0.456	35	29
0.67	0.887–0.899	0.666–0.674	0.444–0.449	35	29
0.66	0.874–0.886	0.655–0.665	0.437–0.443	35	29
0.65	0.861–0.873	0.646–0.654	0.431–0.436	35	29
0.64	0.847–0.860	0.635–0.645	0.424–0.430	35	29
0.63	0.834–0.846	0.626–0.634	0.417–0.423	35	29
0.62	0.820–0.833	0.615–0.625	0.410–0.416	35	28
0.61	0.807–0.819	0.606–0.614	0.404–0.409	35	28
0.60	0.794–0.806	0.595–0.605	0.397–0.403	35	28
0.59	0.781–0.793	0.586–0.594	0.391–0.396	34	28
0.58	0.767–0.780	0.575–0.585	0.384–0.390	34	28
0.57	0.754–0.766	0.566–0.574	0.377–0.383	34	28
0.56	0.740–0.753	0.555–0.565	0.370–0.376	34	28
0.55	0.727–0.739	0.546–0.554	0.364–0.369	34	28
0.54	0.714–0.726	0.535–0.545	0.357–0.363	34	28
0.53	0.701–0.713	0.526–0.534	0.351–0.356	34	28
0.52	0.687–0.700	0.515–0.525	0.344–0.350	34	27
0.51	0.674–0.686	0.506–0.514	0.337–0.343	33	27
0.50	0.660–0.673	0.495–0.505	0.330–0.336	33	27
0.49	0.647–0.659	0.486–0.494	0.324–0.329	33	27
0.48	0.634–0.646	0.475–0.485	0.317–0.323	33	27
0.47	0.621–0.633	0.466–0.474	0.311–0.316	33	27
0.46	0.607–0.620	0.455–0.465	0.304–0.310	33	27
0.45	0.594–0.606	0.446–0.454	0.297–0.303	33	27
0.44	0.580–0.593	0.435–0.445	0.290–0.296	32	27
0.43	0.567–0.579	0.426–0.434	0.284–0.289	32	26
0.42	0.554–0.566	0.415–0.425	0.277–0.283	32	26
0.41	0.541–0.553	0.406–0.414	0.271–0.276	32	26
0.40	0.527–0.540	0.395–0.405	0.264–0.270	32	26
0.39	0.514–0.526	0.386–0.394	0.257–0.263	32	26
0.38	0.500–0.513	0.375–0.385	0.250–0.256	32	26
0.37	0.487–0.499	0.366–0.374	0.244–0.249	31	26

TABLE X4.1
ELONGATION VALUES (CONT'D)

Area, A , in. ²	Tension Test Specimen			Elongation in 2 in., min, %	
	Nominal Wall Thickness, in.			Specified Tensile Strength, psi	
	$\frac{3}{4}$ in. Specimen	1 in. Specimen	$1\frac{1}{2}$ in. Specimen	48 000	60 000
0.36	0.474–0.486	0.355–0.365	0.237–0.243	31	26
0.35	0.461–0.473	0.346–0.354	0.231–0.236	31	25
0.34	0.447–0.460	0.335–0.345	0.224–0.230	31	25
0.33	0.434–0.446	0.326–0.334	0.217–0.223	31	25
0.32	0.420–0.433	0.315–0.325	0.210–0.216	30	25
0.31	0.407–0.419	0.306–0.314	0.204–0.209	30	25
0.30	0.394–0.406	0.295–0.305	0.197–0.203	30	25
0.29	0.381–0.393	0.286–0.294	0.191–0.196	30	24
0.28	0.367–0.380	0.275–0.285	0.184–0.190	30	24
0.27	0.354–0.366	0.266–0.274	0.177–0.183	29	24
0.26	0.340–0.353	0.255–0.265	0.170–0.176	29	24
0.25	0.327–0.339	0.246–0.254	0.164–0.169	29	24
0.24	0.314–0.326	0.235–0.245	0.157–0.163	29	24
0.23	0.301–0.313	0.226–0.234	0.151–0.156	29	23
0.22	0.287–0.300	0.215–0.225	0.144–0.150	28	23
0.21	0.274–0.286	0.206–0.214	0.137–0.143	28	23
0.20	0.260–0.273	0.195–0.205	0.130–0.136	28	23
0.19	0.247–0.259	0.186–0.194	0.124–0.129	27	22
0.18	0.234–0.246	0.175–0.185	0.117–0.123	27	22
0.17	0.221–0.233	0.166–0.174	0.111–0.116	27	22
0.16	0.207–0.220	0.155–0.165	0.104–0.110	27	22
0.15	0.194–0.206	0.146–0.154	0.097–0.103	26	21
0.14	0.180–0.193	0.135–0.145	0.091–0.096	26	21
0.13	0.167–0.179	0.126–0.134	0.084–0.090	25	21
0.12	0.154–0.166	0.115–0.125	0.077–0.083	25	20
0.11	0.141–0.153	0.106–0.114	0.071–0.076	25	20
0.10	0.127–0.140	0.095–0.105	0.064–0.070	24	20
0.09	0.114–0.126	0.086–0.094	0.057–0.063	24	19
0.08	0.100–0.113	0.075–0.085	0.050–0.056	23	19
0.07	0.087–0.099	0.066–0.074	0.044–0.049	22	18
0.06	0.074–0.086	0.055–0.065	0.037–0.043	22	18
0.05	0.061–0.073	0.046–0.054	0.031–0.036	21	17
0.04	0.047–0.060	0.035–0.045	0.024–0.030	20	16
0.03	0.034–0.046	0.026–0.034	0.017–0.023	19	16
0.02	0.020–0.033	0.015–0.025	0.010–0.016	17	14
0.01 and less	0.019 and less	0.014 and less	0.009 and less	15	12

X4.2 Tabulated in Table X4.2 are the minimum elongation values calculated by the equation given in Table 2.

**TABLE X4.2
ELONGATION VALUES**

Area, A , mm ²	Tension Test Specimen			Elongation in 50 mm, min, %	
	Nominal Wall Thickness, mm			Specified Tensile Strength, MPa	
	19 mm Specimen	25 mm Specimen	38 mm Specimen	330	415
500 and greater	26.3 and greater	20.0 and greater	13.2 and greater	36	30
480–499	25.3–26.2	19.2–19.9	12.7–13.1	36	30
460–479	24.2–25.2	18.4–19.1	12.1–12.6	36	29
440–459	23.2–24.1	17.6–18.3	11.6–12.0	36	29
420–439	22.1–23.1	16.8–17.5	11.1–11.5	35	29
400–419	21.1–22.0	16.0–16.7	10.6–11.0	35	29
380–399	20.0–21.0	15.2–15.9	10.0–10.5	35	28
360–379	19.0–19.9	14.4–15.0	9.5–9.9	34	28
340–359	17.9–18.9	13.6–14.3	9.0–9.4	34	28
320–339	16.9–17.8	12.8–13.5	8.5–8.9	34	27
300–319	15.8–16.8	12.0–12.7	7.9–8.4	33	27
280–299	14.8–15.7	11.2–11.9	7.4–7.8	33	27
260–279	13.7–14.7	10.4–11.1	6.9–7.3	32	26
240–259	12.7–13.6	9.6–10.3	6.4–6.8	32	26
220–239	11.6–12.6	8.8–9.5	5.8–6.3	31	26
200–219	10.5–11.5	8.0–8.7	5.3–5.7	31	25
190–199	10.0–10.4	7.6–7.9	5.0–5.2	30	25
180–189	9.5–9.9	7.2–7.5	4.8–4.9	30	24
170–179	9.0–9.4	6.8–7.1	4.5–4.7	30	24
160–169	8.4–8.9	6.4–6.7	4.2–4.4	29	24
150–159	7.9–8.3	6.0–6.3	4.0–4.1	29	24
140–149	7.4–7.8	5.6–5.9	3.7–3.9	29	23
130–139	6.9–7.3	5.2–5.5	3.5–3.6	28	23
120–129	6.3–6.8	4.8–5.1	3.2–3.4	28	23
110–119	5.8–6.2	4.4–4.7	2.9–3.1	27	22
100–109	5.3–5.7	4.0–4.3	2.7–2.8	27	22
90–99	4.8–5.2	3.6–3.9	2.4–2.6	26	21
80–89	4.2–4.7	3.2–3.5	2.1–2.3	26	21
70–79	3.7–4.1	2.8–3.1	1.9–2.0	25	21
60–69	3.2–3.6	2.4–2.7	1.6–1.8	24	20
50–59	2.7–3.1	2.0–2.3	...	24	19
40–49	2.1–2.6	1.6–1.9	...	23	19
30–39	1.6–2.0	22	18

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SPECIFICATION FOR CARBON STEEL FORGINGS FOR PIPING APPLICATIONS



SA-105/SA-105M



(Identical with ASTM Specification A 105/A 105M-05.)

1. Scope

1.1 This specification covers forged carbon steel piping components for ambient- and higher-temperature service in pressure systems. Included are flanges, fittings, valves, and similar parts ordered either to dimensions specified by the purchaser or to dimensional standards such as the MSS, ASME, and API specifications referenced in Section 2. Forgings made to this specification are limited to a maximum weight of 10 000 lb [4540 kg]. Larger forgings may be ordered to Specification A 266/A 266M. Tubesheets and hollow cylindrical forgings for pressure vessel shells are not included within the scope of this specification. Although this specification covers some piping components machined from rolled bar and seamless tubular products (see 4.2), it does not cover raw material produced in these product forms.

1.2 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.3 Specification A 266/A 266M covers other steel forgings and Specifications A 675/A 675M and A 696 cover other steel bars.

1.4 This specification is expressed in both inch-pound units and SI units. However, unless the order specifies the applicable “M” specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

NOTE 1 — The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as “nominal diameter,” “size,” and “nominal size.”

2. Referenced Documents

2.1 In addition to those reference documents listed in Specification A 961, the following list of standards apply to this specification:

2.2 ASTM Standards:

- A 266/A 266M Specification for Carbon Steel Forgings for Pressure Vessel Components
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 675/A 675M Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties
- A 696 Specification for Steel Bars, Carbon, Hot-Wrought or Cold-Finished, Special Quality, for Pressure Piping Components
- A 788 Specification for Steel Forgings, General Requirements
- A 961 Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications

2.3 MSS Standards:

- SP 44 Standard for Steel Pipe Line Flanges

2.4 ASME Standards:

- B16.5 Dimensional Standards for Steel Pipe Flanges and Flanged Fittings
- B16.9 Wrought Steel Butt welding Fittings
- B16.10 Face-to-Face and End-to-End Dimensions of Ferrous Valves
- B16.11 Forged Steel Fittings, Socket Weld, and Threaded
- B16.34 Valves-Flanged, Threaded and Welding End
- B16.47 Large Diameter Steel Flanges

2.5 ASME Boiler and Pressure Vessel Code:
Section IX Welding Qualifications

2.6 API Standards:
API-600 Flanged and Butt-Welding-End Steel Gate Valves
API-602 Compact Design Carbon Steel Gate Valves for Refinery Use

3. Ordering Information

3.1 See Specification A 961.

3.1.1 Additional requirements (see 12.2).

4. General Requirements

4.1 Product furnished to this specification shall conform to the requirements of Specification A 961, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the requirements of Specification A 961 constitutes nonconformance with this specification. In case of a conflict between the requirements of this specification and Specification A 961, this specification shall prevail.

4.2 Except as permitted by Section 6 in Specification A 961, the finished product shall be a forging as defined in the Terminology Section of Specification A 788.

5. Heat Treatment

5.1 Heat treatment is not a mandatory requirement of this specification except for the following piping components:

5.1.1 Flanges above Class 300,¹

5.1.2 Flanges of special design where the design pressure at the design temperature exceeds the pressure-temperature ratings of Class 300, Group 1.1,

5.1.3 Flanges of special design where the design pressure or design temperature are not known,

5.1.4 Piping components other than flanges which meet both of the following criteria: (1) over NPS 4 and (2) above Class 300, and

5.1.5 Piping components of Special Class² other than flanges which meet both of the following criteria: (1) over NPS 4 and (2) when the working pressure at the operating temperature exceeds the tabulated values for Special Class 300, Group 1.1.

5.2 Heat treatment, when required by 5.1 shall be annealing, normalizing, or normalizing and tempering or

quenching and tempering in accordance with Specification A 961.

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements specified in Table 1.

6.2 Steels to which lead has been added shall not be used.

7. Mechanical Properties

7.1 The material shall conform to the mechanical property requirements prescribed in Table 2 and Table 3.

7.2 For normalized, normalized and tempered, or quenched and tempered forgings, the central axis of the test specimen shall correspond to the $\frac{1}{4} T$ plane or deeper position, where T is the maximum heat-treated thickness of the represented forging. In addition, for quenched and tempered forgings, the midlength of the test specimen shall be at least T from any second heat-treated surface. When section thickness does not permit this positioning, the test specimen shall be positioned as near as possible to the prescribed location.

7.3 Tension Tests:

7.3.1 One tension test shall be made for each heat of as-forged components.

7.3.2 One tension test shall be made from each heat-treating charge. If more than one heat is included in such a charge, each heat shall be tested.

7.3.2.1 When the heat-treating temperatures are the same and the furnaces (either batch or continuous type), are controlled within $\pm 25^{\circ}\text{F}$ [$\pm 14^{\circ}\text{C}$] and equipped with recording pyrometers so that complete records of heat treatment are available, then one tension test from each heat is required instead of one test from each heat in each heat-treatment charge. The test specimen material shall be included with a furnace charge.

7.3.3 Testing shall be performed in accordance with Test Methods and Definitions A 370. The largest feasible round specimen as described in Test Methods and Definitions A 370 shall be used except when hollow cylindrically shaped parts are machined from seamless tubulars. The gage length for measuring elongation shall be four times the diameter of the test section. When hollow cylindrically shaped parts are machined from seamless tubular materials, strip tests may be used.

7.3.4 Forgings too small to permit obtaining a sub-size specimen of 0.250 in. [6.35 mm] diameter or larger (see Test Methods and Definitions A 370) parallel to the dimension of maximum working, and produced in equipment unsuitable for the production of a separately forged

¹ For definition of Class 300, see ASME B16.5.

² For definition of special class, see ASME B16.34.

test bar such as an automatic or semi-automatic press, may be accepted on the basis of hardness only. One percent of the forgings per lot (see Note 2), or ten forgings, whichever is the lesser number, shall be selected at random, prepared, and tested using the standard Brinell test in Test Methods and Definitions A 370. The locations of the indentations shall be at the option of the manufacturer but shall be selected to be representative of the forging as a whole. One indentation per forging shall be required but additional indentations may be made to establish the representative hardness. The hardness of all forgings so tested shall be 137 to 187 HB inclusive.

NOTE 2 — A lot is defined as the product from a mill heat or if heat treated, the product of a mill heat per furnace charge.

7.4 Hardness Tests — Except when only one forging is produced, a minimum of two forgings shall be hardness tested per batch or continuous run as defined in 7.3.2.1 to ensure that forgings are within the hardness limits given in Table 2. When only one forging is produced, it shall be hardness tested as defined in 7.3.2.1 to ensure it is within the hardness limits given in Table 2. Testing shall be in accordance with Test Methods and Definitions A 370. The purchaser may verify that the requirement has been met by testing at any location on the forging, provided such testing does not render the forging useless.

8. Hydrostatic Tests

8.1 Such tests shall be conducted by the forging manufacturer only when Supplementary Requirement S8 in Specification A 961 is specified.

9. Retreatment

9.1 If the results of the mechanical tests do not conform to the requirement specified, the manufacturer may heat treat or reheat treat the forgings as applicable and repeat the test specified in Section 7.

10. Repair by Welding

10.1 Repair of defects by the manufacturer is permissible for forgings made to dimensional standards such as those of ASME or for other parts made for stock by the manufacturer. Prior approval of the purchaser is required to repair-weld special forgings made to the purchaser's requirements.

10.2 Weld repairs shall be made by a process that does not produce undesirably high levels of hydrogen in the welded areas.

10.3 All forgings repaired by welding shall be post-weld heat treated between 1100°F [593°C] and the lower

transformation temperature for a minimum of $\frac{1}{2}$ h/in. [$\frac{1}{2}$ h/25.4 mm] of maximum section thickness, or alternatively annealed, normalized and tempered, or quenched and tempered. If the forging was not previously heat treated, the original tempering temperature was exceeded, or the forging was fully heat treated in the post weld cycle, then the forging shall be tested in accordance with Section 7 on completion of the cycle.

10.4 The mechanical properties of the procedure-qualification weldment shall, when tested in accordance with Section IX of the ASME Boiler and Pressure Vessel Code, conform with the requirements listed in Table 2 for the thermal condition of repair-welded forgings.

11. Rejection and Rehearing

11.1 Each forging that develops injurious defects during shop working or application shall be rejected and the manufacturer notified.

12. Certification

12.1 Identification Marking — For forgings made to specified dimensions, when agreed upon by the purchaser, and for forgings made to dimensional standards, application of identification marks as required in Specification A 961 shall be the certification that the forgings have been furnished in accordance with the requirements of this specification. The specification designation included on test reports shall include year date and revision letter, if any.

12.2 Test Reports — When test reports are required, the manufacturer shall also provide the following, where applicable:

12.2.1 Type heat treatment, Section 5,

12.2.2 Tensile property results, Section 7 (Table 2), report the yield strength and ultimate strength, in ksi [MPa], elongation and reduction in area, in percent; and, if longitudinal strip tension specimens are used, report the width of the gage length,

12.2.3 Chemical analysis results, Section 6 (Table 1). When the amount of an unspecified element is less than 0.02%, then the analysis for that element may be reported as "< 0.02%,"

12.2.4 Hardness results, Section 7 (Table 2), and

12.2.5 Any supplementary testing required by the purchase order.

13. Product Marking

13.1 If the forgings have been quenched and tempered, the letters "QT" shall be stamped on the forgings following this specification number.

13.2 Forgings repaired by welding shall be marked with the letter “W” following this specification number.

13.3 When test reports are required for larger products, the markings shall consist of the manufacturer’s symbol or name, this specification number, and such other markings as necessary to identify the part with the test report (13.1 and 13.2 shall apply). The specification number marked on the forgings need not include specification year date and revision letter.

13.4 Bar Coding — In addition to the requirements in Specification A 961 and 13.3, bar coding is acceptable as a supplemental identification method. The purchaser may

specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

14. Keywords

14.1 pipe fittings, steel; piping applications; pressure containing parts; steel flanges; steel forgings, carbon; steel valves; temperature service applications, elevated; temperature service applications, high

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %
Carbon	0.35 max.
Manganese	0.60–1.05
Phosphorus	0.035 max.
Sulfur	0.040 max.
Silicon	0.10–0.35
Copper	0.40 max. [Note (1)]
Nickel	0.40 max. [Note (1)]
Chromium	0.30 max. [Notes (1), (2)]
Molybdenum	0.12 max. [Notes (1), (2)]
Vanadium	0.08 max.

GENERAL NOTE: For each reduction of 0.01% below the specified carbon maximum (0.35%), an increase of 0.06% manganese above the specified maximum (1.05%) will be permitted up to a maximum of 1.35%.

NOTES:

- (1) The sum of copper, nickel, chromium, molybdenum and vanadium shall not exceed 1.00%.
- (2) The sum of chromium and molybdenum shall not exceed 0.32%.

TABLE 2
MECHANICAL REQUIREMENTS [NOTE (1)]

Tensile strength, min., psi [MPa]	70 000 [485]
Yield strength, min., psi [MPa] [Note (2)]	36 000 [250]
Elongation in 2 in. or 50 mm, min., %:	
Basic minimum elongation for walls $\frac{5}{16}$ in. [7.9 mm] and over in thickness, strip tests.	30
When standard round 2 in. or 50 mm gage length or smaller proportionally sized specimen with the gage length equal to 4D is used	22
For strip tests, a deduction for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{5}{16}$ in. [7.9 mm] from the basic minimum elongation of the percentage points of Table 3	1.50 [Note (3)]
Reduction of area, min., % [Note (4)]	30
Hardness, HB, max.	187

NOTES:

- (1) For small forgings, see 7.3.4.
- (2) Determined by either the 0.2% offset method or the 0.5% extension-under-load method.
- (3) See Table 3 for computed minimum values.
- (4) For round specimens only.

TABLE 3
COMPUTED MINIMUM VALUES

Wall Thickness		Elongation in 2 in. or 50 mm, min., %
in.	mm	
$\frac{5}{16}$ (0.312)	7.9	30.00
$\frac{9}{32}$ (0.281)	7.1	28.50
$\frac{1}{4}$ (0.250)	6.4	27.00
$\frac{7}{32}$ (0.219)	5.6	25.50
$\frac{3}{16}$ (0.188)	4.8	24.00
$\frac{5}{32}$ (0.156)	4.0	22.50
$\frac{1}{8}$ (0.125)	3.2	21.00
$\frac{3}{32}$ (0.094)	2.4	19.50
$\frac{1}{16}$ (0.062)	1.6	18.00

GENERAL NOTE: The above table gives the computed minimum elongation values for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value is determined by the following equation:

$$E = 48T + 15.00$$

where:

E = elongation in 2 in. or 50 mm, %, and
 T = actual thickness of specimen, in. [mm]

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, and order.

S1. Hardness

S1.1 The purchaser may check the hardness of any or all forgings supplied at any location on the forging and the hardness shall be 137 to 187 HB. All forgings not within the specified hardness range shall be rejected.

S2. Heat Treatment

S2.1 All forgings shall be heat treated as specified by the purchaser.

S2.2 When forgings not requiring heat treatment by 5.1 are supplied heat treated by purchaser request, the basis for determining conformance with Table 2 and Table 3 shall be hardness testing per 7.4 and either (1) tensile testing of heat treated forgings per 7.2, or (2) tensile tests from as-forged forgings or separately forged test blanks, as agreed upon between the supplier and purchaser.

S2.3 When test reports are required, and tensile test results were obtained from as-forged forgings or as-forged test blanks, it shall be so indicated on the test report.

S2.4 In addition to the marking required by Section 13, this specification shall be followed by the letter: A for annealed, N for normalized, NT for normalized and tempered, or QT for quenched and tempered, as appropriate.

S3. Marking Small Forgings

S3.1 For small products where the space for marking is less than 1 in. [25 mm] in any direction, test reports are mandatory and marking may be restricted to only such symbols or codes as are necessary to identify the parts with the test reports.

S3.2 When the configuration or size does not permit marking directly on the forging, the marking method shall be a matter of agreement between the manufacturer and the purchaser.

S4. Carbon Equivalent

S4.1 The maximum carbon equivalent, based on heat analysis, shall be 0.47 for forgings with a maximum section thickness of 2 in. or less, and 0.48 for forgings with a maximum section thickness of greater than 2 in.

S4.2 Determine the carbon equivalent (CE) as follows:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S4.3 A lower maximum carbon equivalent may be agreed upon between the supplier and the purchaser.

SPECIFICATION FOR SEAMLESS CARBON STEEL PIPE FOR HIGH-TEMPERATURE SERVICE



SA-106/SA-106M



(Identical with ASTM Specification A 106/A 106M-08)

(10)

1. Scope

1.1 This specification covers seamless carbon steel pipe for high-temperature service (Note 1) in NPS $\frac{1}{8}$ to NPS 48 [DN 6 to DN 1200] (Note 2) inclusive, with nominal (average) wall thickness as given in ASME B36.10M. It shall be permissible to furnish pipe having other dimensions provided such pipe complies with all other requirements of this specification. Pipe ordered under this specification shall be suitable for bending, flanging, and similar forming operations, and for welding. When the steel is to be welded, it is presupposed that a welding procedure suitable to the grade of steel and intended use or service will be utilized.

NOTE 1 — It is suggested, consideration be given to possible graphitization.

NOTE 2 — The dimensionless designator NPS (nominal pipe size) [DN (diameter nominal)] has been substituted in this standard for such traditional terms as “nominal diameter,” “size,” and “nominal size.”

1.2 Supplementary requirements of an optional nature are provided for seamless pipe intended for use in applications where a superior grade of pipe is required. These supplementary requirements call for additional tests to be made and when desired shall be so stated in the order.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 The following precautionary caveat pertains only to the test method portion, Sections 11, 12, and 13 of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

- A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe
- E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing
- E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation
- E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings
- E 570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

2.2 ASME Standard:

- ASME B36.10M Welded and Seamless Wrought Steel Pipe

2.3 Military Standards:

- MIL-STD-129 Marking for Shipment and Storage
- MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

2.4 Federal Standard:

- Fed. Std. No. 123 Marking for Shipments (Civil Agencies)
- Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products

2.5 Other Standards:

- SSPC-SP 6 Surface Preparation Specification No. 6

3. Ordering Information

3.1 The inclusion of the following, as required will describe the desired material adequately, when ordered under this specification:

- 3.1.1** Quantity (feet, metres, or number of lengths),
- 3.1.2** Name of material (seamless carbon steel pipe),
- 3.1.3** Grade (Table 1),
- 3.1.4** Manufacture (hot-finished or cold-drawn),

3.1.5 Size (NPS [DN] and weight class or schedule number, or both; outside diameter and nominal wall thickness; or inside diameter and nominal wall thickness),

3.1.6 Special outside diameter tolerance pipe (16.2.2),

3.1.7 Inside diameter tolerance pipe, over 10 in. [250 mm] ID (16.2.3),

3.1.8 Length (specific or random, Section 17),

3.1.9 Optional requirements (Section 9 and S1 to S8),

3.1.10 Test report required (Section on Certification of Specification A 530/A 530M),

3.1.11 Specification designation (A 106 or A 106M, including year-date),

3.1.12 End use of material,

3.1.13 Hydrostatic test in accordance with Specification A 530/A 530M or 13.3 of this specification, or NDE in accordance with Section 14 of this specification.

3.1.14 Special requirements.

4. Process

4.1 The steel shall be killed steel, with the primary melting process being open-hearth, basic-oxygen, or electric-furnace, possibly combined with separate degassing or refining. If secondary melting, using electroslag remelting or vacuum-arc remelting is subsequently employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

4.2 Steel cast in ingots or strand cast is permissible. When steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

4.3 For pipe NPS 1½ [DN 40] and under, it shall be permissible to furnish hot finished or cold drawn.

4.4 Unless otherwise specified, pipe NPS 2 [DN 50] and over shall be furnished hot finished. When agreed upon between the manufacturer and the purchaser, it is permissible to furnish cold-drawn pipe.

5. Heat Treatment

5.1 Hot-finished pipe need not be heat treated. Cold-drawn pipe shall be heat treated after the final cold draw pass at a temperature of 1200°F (650°C) or higher.

6. General Requirements

6.1 Material furnished to this specification shall conform to the applicable requirements of the current edition

of Specification A 530/A 530M unless otherwise provided herein.

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

8. Heat Analysis

8.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified in Section 7. If the secondary melting processes of 5.1 are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the manufacturer, if the latter has not manufactured the steel, shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Section 7.

9. Product Analysis

9.1 At the request of the purchaser, analyses of two pipes from each lot (see 20.1) shall be made by the manufacturer from the finished pipe. The results of these analyses shall be reported to the purchaser or the purchaser's representative and shall conform to the requirements specified in Section 7.

9.2 If the analysis of one of the tests specified in 9.1 does not conform to the requirements specified in Section 7, analyses shall be made on additional pipes of double the original number from the same lot, each of which shall conform to requirements specified.

10. Tensile Requirements

10.1 The material shall conform to the requirements as to tensile properties given in Table 2.

11. Bending Requirements

11.1 For pipe NPS 2 [DN 50] and under, a sufficient length of pipe shall stand being bent cold through 90° around a cylindrical mandrel, the diameter of which is twelve times the outside diameter (as shown in ASME B36.10M) of the pipe, without developing cracks. When ordered for close coiling, the pipe shall stand being bent cold through 180° around a cylindrical mandrel, the diameter of which is eight times the outside diameter (as shown in ASME B36.10M) of the pipe, without failure.

11.2 For pipe whose diameter exceeds 25 in. [635 mm] and whose diameter to wall thickness ratio, where the

diameter to wall thickness ratio is the specified outside diameter divided by the nominal wall thickness, is 7.0 or less, the bend test shall be conducted. The bend test specimens shall be bent at room temperature through 180° with the inside diameter of the bend being 1 in. [25 mm] without cracking on the outside portion of the bent portion.

Example: For 28 in. [711 mm] diameter 5.000 in. [127 mm] thick pipe the diameter to wall thickness ratio = $28/5 = 5.6$ [$711/127 = 5.6$].

12. Flattening Tests

12.1 Although testing is not required, pipe shall be capable of meeting the flattening test requirements of Supplementary Requirement S3, if tested.

13. Hydrostatic Test

13.1 Except as allowed by 13.2, 13.3, and 13.4, each length of pipe shall be subjected to the hydrostatic test without leakage through the pipe wall.

13.2 As an alternative to the hydrostatic test at the option of the manufacturer or where specified in the purchase order, it shall be permissible for the full body of each pipe to be tested with a nondestructive electric test described in Section 14.

13.3 Where specified in the purchase order, it shall be permissible for pipe to be furnished without the hydrostatic test and without the nondestructive electric test in Section 14; in this case, each length so furnished shall include the mandatory marking of the letters “NH.” It shall be permissible for pipe meeting the requirements of 13.1 or 13.2 to be furnished where pipe without either the hydrostatic or nondestructive electric test has been specified in the purchase order; in this case, such pipe need not be marked with the letters “NH.” Pipe that has failed either the hydrostatic test of 13.1 or the nondestructive electric test of 13.2 shall not be furnished as “NH” pipe.

13.4 Where the hydrostatic test and the nondestructive electric test are omitted and the lengths marked with the letters “NH,” the certification, where required, shall clearly state “Not Hydrostatically Tested,” and the letters “NH” shall be appended to the product specification number and material grade shown on the certification.

14. Nondestructive Electric Test

14.1 As an alternative to the hydrostatic test at the option of the manufacturer or where specified in the purchase order as an alternative or addition to the hydrostatic test, the full body of each pipe shall be tested with a nondestructive electric test in accordance with Practice E 213, E 309, or E 570. In such cases, the marking of each

length of pipe so furnished shall include the letters “NDE.” It is the intent of this nondestructive electric test to reject pipe with imperfections that produce test signals equal to or greater than that produced by the applicable calibration standard.

14.2 Where the nondestructive electric test is performed, the lengths shall be marked with the letters “NDE.” The certification, where required, shall state “Nondestructive Electric Tested” and shall indicate which of the tests was applied. Also, the letters “NDE” shall be appended to the product specification number and material grade shown on the certification.

14.3 The following information is for the benefit of the user of this specification:

14.3.1 The reference standards defined in 14.4 through 14.6 are convenient standards for calibration of nondestructive testing equipment. The dimensions of such standards are not to be construed as the minimum sizes of imperfections detectable by such equipment.

14.3.2 The ultrasonic testing referred to in this specification is capable of detecting the presence and location of significant longitudinally or circumferentially oriented imperfections; however, different techniques need to be employed for the detection of such differently oriented imperfections. Ultrasonic testing is not necessarily capable of detecting short, deep imperfections.

14.3.3 The eddy current examination referenced in this specification has the capability of detecting significant imperfections, especially of the short abrupt type.

14.3.4 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented imperfections; however, different techniques need to be employed for the detection of such differently oriented imperfections.

14.3.5 The hydrostatic test referred to in Section 13 has the capability of finding defects of a size permitting the test fluid to leak through the tube wall and may be either visually seen or detected by a loss of pressure. Hydrostatic testing is not necessarily capable of detecting very tight, through-the-wall imperfections or imperfections that extend an appreciable distance into the wall without complete penetration.

14.3.6 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific applications of these examinations is directed to discuss this with the manufacturer of the tubular product.

14.4 For ultrasonic testing, the calibration reference notches shall be, at the option of the producer, any one of the three common notch shapes shown in Practice E 213.

The depth of notch shall not exceed $12\frac{1}{2}\%$ of the specified wall thickness of the pipe or 0.004 in. [0.1 mm], whichever is greater.

14.5 For eddy current testing, the calibration pipe shall contain, at the option of the producer, any one of the following discontinuities to establish a minimum sensitivity level for rejection:

14.5.1 Drilled Hole — The calibration pipe shall contain depending upon the pipe diameter three holes spaced 120° apart or four holes spaced 90° apart and sufficiently separated longitudinally to ensure separately distinguishable responses. The holes shall be drilled radially and completely through the pipe wall, care being taken to avoid distortion of the pipe while drilling. Depending upon the pipe diameter the calibration pipe shall contain the following hole:

NPS	DN	Diameter of Drilled Hole
$\leq \frac{1}{2}$	≤ 15	0.039 in. (1 mm)
$> \frac{1}{2} \leq 1\frac{1}{4}$	$> 15 \leq 32$	0.055 in. (1.4 mm)
$> 1\frac{1}{4} \leq 2$	$> 32 \leq 50$	0.071 in. (1.8 mm)
$> 2 \leq 5$	$> 50 \leq 125$	0.087 in. (2.2 mm)
> 5	> 125	0.106 in. (2.7 mm)

14.5.2 Transverse Tangential Notch — Using a round tool or file with a $\frac{1}{4}$ in. [6 mm] diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. The notch shall have a depth not exceeding $12\frac{1}{2}\%$ of the specified wall thickness of the pipe or 0.004 in. [0.1 mm], whichever is greater.

14.5.3 Longitudinal Notch — A notch 0.031 in. [0.8 mm] or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the pipe, to have a depth not exceeding $12\frac{1}{2}\%$ of the specified wall thickness of the tube or 0.004 in. [0.1 mm], whichever is greater. The length of the notch shall be compatible with the testing method.

14.5.4 Compatibility — The discontinuity in the calibration pipe shall be compatible with the testing equipment and the method being used.

14.6 For flux leakage testing, the longitudinal calibration reference notches shall be straight-sided notches machined in a radial plane parallel to the pipe axis. For wall thicknesses under $\frac{1}{2}$ in. [12.7 mm], outside and inside notches shall be used; for wall thicknesses equal to and above $\frac{1}{2}$ in. [12.7 mm], only an outside notch shall be used. Notch depth shall not exceed $12\frac{1}{2}\%$ of the specified wall thickness, or 0.004 in. [0.1 mm], whichever is greater. notch length shall not exceed 1 in. [25 mm], and the width shall not exceed the depth. Outside diameter and inside diameter notches shall be located sufficiently apart to allow separation and identification of the signals.

14.7 Pipe containing one or more imperfections that produce a signal equal to or greater than the signal produced by the calibration standard shall be rejected or the area producing the signal shall be reexamined.

14.7.1 Test signals produced by imperfections which cannot be identified, or produced by cracks or crack-like imperfections shall result in rejection of the pipe, unless it is repaired and retested. To be accepted, the pipe must pass the same specification test to which it was originally subjected, provided that the remaining wall thickness is not decreased below that permitted by this specification. The OD at the point of grinding may be reduced by the amount so reduced.

14.7.2 Test signals produced by visual imperfections such as those listed below may be evaluated in accordance with the provisions of Section 18:

14.7.2.1 Dinges,

14.7.2.2 Straightener marks,

14.7.2.3 Cutting chips,

14.7.2.4 Scratches,

14.7.2.5 Steel die stamps,

14.7.2.6 Stop marks, or

14.7.2.7 Pipe reducer ripple.

14.8 The test methods described in this section are not necessarily capable of inspecting the end portion of pipes, a condition referred to as “end effect.” The length of such end effect shall be determined by the manufacturer and, when specified in the purchase order, reported to the purchaser.

15. Nipples

15.1 Nipples shall be cut from pipe of the same dimensions and quality described in this specification.

16. Dimensions, Mass, and Permissible Variations

16.1 Mass — The mass of any length of pipe shall not vary more than 10% over and 3.5% under that specified. Unless otherwise agreed upon between the manufacturer and the purchaser, pipe in NPS 4 [DN 100] and smaller may be weighed in convenient lots; pipe larger than NPS 4 [DN 100] shall be weighed separately.

16.2 Diameter — Except as provided for thin-wall pipe in paragraph 11.2 of Specification A 530/A 530M, the tolerances for diameter shall be in accordance with the following:

16.2.1 Except for pipe ordered as special outside diameter tolerance pipe or as inside diameter tolerance pipe, variations in outside diameter shall not exceed those given in Table 3.

16.2.2 For pipe over 10 in. [250 mm] OD ordered as special outside diameter tolerance pipe, the outside diameter shall not vary more than 1% over or 1% under the specified outside diameter.

16.2.3 For pipe over 10 in. [250 mm] ID ordered as inside diameter tolerance pipe, the inside diameter shall not vary more than 1% over or 1% under the specified inside diameter.

16.3 Thickness — The minimum wall thickness at any point shall not be more than 12.5% under the specified wall thickness.

17. Lengths

17.1 Pipe lengths shall be in accordance with the following regular practice:

17.1.1 The lengths required shall be specified in the order, and

17.1.2 No jointers are permitted unless otherwise specified.

17.1.3 If definite lengths are not required, pipe may be ordered in single random lengths of 16 to 22 ft [4.8 to 6.7 m] with 5% 12 to 16 ft [3.7 to 4.8 m], or in double random lengths with a minimum average of 35 ft [10.7 m] and a minimum length of 22 ft [6.7 m] with 5% 16 to 22 ft [4.8 to 6.7 m].

18. Workmanship, Finish and Appearance

18.1 The pipe manufacturer shall explore a sufficient number of visual surface imperfections to provide reasonable assurance that they have been properly evaluated with respect to depth. Exploration of all surface imperfections is not required but consideration should be given to the necessity of exploring all surface imperfections to assure compliance with 18.2.

18.2 Surface imperfections that penetrate more than 12½% of the nominal wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with such defects shall be given one of the following dispositions:

18.2.1 The defect shall be removed by grinding, provided that the remaining wall thickness is within the limits specified in 16.3.

18.2.2 Repaired in accordance with the repair welding provisions of 18.6.

18.2.3 The section of pipe containing the defect may be cut off within the limits of requirements on length.

18.2.4 Rejected.

18.3 To provide a workmanlike finish and basis for evaluating conformance with 18.2 the pipe manufacturer

shall remove by grinding the following noninjurious imperfections:

18.3.1 Mechanical marks and abrasions — such as cable marks, dings, guide marks, roll marks, ball scratches, scores, and die marks—and pits, any of which imperfections are deeper than ¼ in. [1.6 mm].

18.3.2 Visual imperfections commonly referred to as scabs, seams, laps, tears, or slivers found by exploration in accordance with 18.1 to be deeper than 5% of the nominal wall thickness.

18.4 At the purchaser's discretion, pipe shall be subjected to rejection if surface imperfections acceptable under 18.2 are not scattered, but appear over a large area in excess of what is considered a workmanlike finish. Disposition of such pipe shall be a matter of agreement between the manufacturer and the purchaser.

18.5 When imperfections or defects are removed by grinding, a smooth curved surface shall be maintained, and the wall thickness shall not be decreased below that permitted by this specification. The outside diameter at the point of grinding is permitted to be reduced by the amount so removed.

18.5.1 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In case of dispute, the measurement determined by use of the mechanical caliper shall govern.

18.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A 530/A 530M.

18.7 The finished pipe shall be reasonably straight.

19. End Finish

19.1 The Pipe shall be furnished to the following practice, unless otherwise specified.

19.1.1 NPS 1½ [DN 40] and Smaller — All walls shall be either plain-end square cut, or plain-end beveled at the option of the manufacturer.

19.1.2 NPS 2 [DN 50] and Larger — Walls through extra strong weights, shall be plain-end-beveled.

19.1.3 NPS 2 [DN 50] and Larger — Walls over extra strong weights, shall be plain-end square cut.

19.2 Plain-end beveled pipe shall be plain-end pipe having a bevel angle of 30°, + 5° or ± 0°, as measured from a line drawn perpendicular to the axis of the pipe with a root face of ¼ in. ± ½ in. [1.6 ± 0.8 mm]. Other bevel angles may be specified by agreement between the purchaser and the manufacturer.

20. Sampling

20.1 For product analysis (see 9.1) and tensile tests (see 21.1), a lot is the number of lengths of the same size and wall thickness from any one heat of steel; of 400 lengths or fraction thereof, of each size up to, but not including, NPS 6 [DN 150]; and of 200 lengths or fraction thereof of each size NPS 6 [DN 150] and over.

20.2 For bend tests (see 21.2), a lot is the number of lengths of the same size and wall thickness from any one heat of steel, of 400 lengths or fraction thereof, of each size.

20.3 For flattening tests, a lot is the number of lengths of the same size and wall thickness from any one heat of steel, of 400 lengths or fraction thereof of each size over NPS 2 [DN 50], up to but not including NPS 6 [DN 150], and of 200 lengths or fraction thereof, of each size NPS 6 [DN 150] and over.

21. Number of Tests

21.1 The tensile requirements specified in Section 10 shall be determined on one length of pipe from each lot (see 20.1).

21.2 For pipe NPS 2 [DN 50] and under, the bend test specified in 11.1 shall be made on one pipe from each lot (see 20.2). The bend test, where used as required by 11.2, shall be made on one end of 5% of the pipe from each lot. For small lots, at least one pipe shall be tested.

21.3 If any test specimen shows flaws or defective machining, it shall be permissible to discard it and substitute another test specimen.

22. Retests

22.1 If the percentage of elongation of any tension test specimen is less than that given in Table 1 and any part of the fracture is more than $\frac{3}{4}$ in. [19 mm] from the center of the gage length of a 2 in. [50 mm] specimen as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed. If a specimen breaks in an inside or outside surface flaw, a retest shall be allowed.

23. Test Specimens and Test Methods

23.1 On NPS 8 [DN 200] and larger, specimens cut either longitudinally or transversely shall be acceptable for the tension test. On sizes smaller than NPS 8 [DN 200], the longitudinal test only shall be used.

23.2 When round tension test specimens are used for pipe wall thicknesses over 1.0 in. [25.4 mm], the mid—length of the longitudinal axis of such test specimens shall be from a location midway between the inside and outside surfaces of the pipe.

23.3 Test specimens for the bend test specified in Section 11 and for the flattening tests shall consist of sections cut from a pipe. Specimens for flattening tests shall be smooth on the ends and free from burrs, except when made on crop ends.

23.4 Test specimens for the bend test specified in 11.2 shall be cut from one end of the pipe and, unless otherwise specified, shall be taken in a transverse direction. One test specimen shall be taken as close to the outer surface as possible and another from as close to the inner surface as possible. The specimens shall be either $\frac{1}{2}$ by $\frac{1}{2}$ in. [12.5 by 12.5 mm] in section or 1 by $\frac{1}{2}$ in. [25 by 12.5 mm] in section with the corners rounded to a radius not over $\frac{1}{16}$ in. [1.6 mm] and need not exceed 6 in. [150 mm] in length. The side of the samples placed in tension during the bend shall be the side closest to the inner and outer surface of the pipe respectively.

23.5 All routine check tests shall be made at room temperature.

24. Certification

24.1 When test reports are requested, in addition to the requirements of Specification A 530/A 530M, the producer or supplier shall furnish to the purchaser a chemical analysis report for the elements specified in Table 1.

25. Product Marking

25.1 In addition to the marking prescribed in Specification A 530/A 530M, the marking shall include heat number, the information as per Table 4, an additional symbol “S” if one or more of the supplementary requirements apply; the length, OD 1%, if ordered as special outside diameter tolerance pipe; ID 1%, if ordered as special inside diameter tolerance pipe; the schedule number, weight class, or nominal wall thickness; and, for sizes larger than NPS 4 [DN 100], the weight. Length shall be marked in feet and tenths of a foot [metres to two decimal places], depending on the units to which the material was ordered, or other marking subject to agreement. For sizes NPS $1\frac{1}{2}$, $1\frac{1}{4}$, 1, and $\frac{3}{4}$ [DN 40, 32, 25, and 20], each length shall be marked as prescribed in Specification A 530/A 530M. These sizes shall be bundled in accordance with standard mill practice and the total bundle footage marked on the bundle tag; individual lengths of pipe need not be marked with footage. For sizes less than NPS $\frac{3}{4}$ [DN 20], all the required markings shall be on the bundle tag or on each length of pipe and shall include the total footage; individual lengths of pipe need not be marked with footage. If not marked on the bundle tag, all required marking shall be on each length.

25.2 When pipe sections are cut into shorter lengths by a subsequent processor for resale as material, the processor

shall transfer complete identifying information, including the name or brand of the manufacturer to each unmarked cut length, or to metal tags securely attached to bundles of unmarked small diameter pipe. The same material designation shall be included with the information transferred, and the processor's name, trademark, or brand shall be added.

25.3 Bar Coding — In addition to the requirements in 25.1 and 25.2, bar coding is acceptable as a supplementary identification method. The purchaser may specify in the order a specific bar coding system to be used.

26. Government Procurement

26.1 When specified in the contract, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163. The applicable levels shall be as specified in the contract. Marking for the shipment

of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 or Fed. Std. No. 183 if continuous marking is required for military agencies.

26.2 Inspection — Unless otherwise specified in the contract, the producer is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract, the producer shall use his own, or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that the material conforms to the prescribed requirements.

27. Keywords

27.1 carbon steel pipe; seamless steel pipe; steel pipe

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %		
	Grade A	Grade B	Grade C
Carbon, max ^A	0.25	0.30	0.35
Manganese	0.27–0.93	0.29–1.06	0.29–1.06
Phosphorus, max	0.035	0.035	0.035
Sulfur, max	0.035	0.035	0.035
Silicon, min	0.10	0.10	0.10
Chrome, max ^B	0.40	0.40	0.40
Copper, max ^B	0.40	0.40	0.40
Molybdenum, max ^B	0.15	0.15	0.15
Nickel, max ^B	0.40	0.40	0.40
Vanadium, max ^B	0.08	0.08	0.08

^A For each reduction of 0.01% below the specified carbon maximum, an increase of 0.06% manganese above the specified maximum will be permitted up to a maximum of 1.35%.

^B These five elements combined shall not exceed 1%.

TABLE 2
TENSILE REQUIREMENTS

	Grade A		Grade B		Grade C	
Tensile strength, min, psi (MPa)	48 000 [330]		60 000 [415]		70 000 [485]	
Yield strength, min, psi (MPa)	30 000 [205]		35 000 [240]		40 000 [275]	
	Longitu- dinal	Transverse	Longitu- dinal	Transverse	Longitu- dinal	Transverse
Elongation in 2 in. [50 mm], min, %:						
Basic minimum elongation transverse strip tests, and for all small sizes tested in full section	35	25	30	16.5	30	16.5
When standard round 2 in. [50 mm] gage length test specimen is used	28	20	22	12	20	12
For longitudinal strip tests	A		A		A	
For transverse strip tests, a deduction for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{5}{16}$ in. [7.9 mm] from the basic minimum elongation of the following percentage shall be made		1.25		1.00		1.00

^A The minimum elongation in 2 in. [50 mm] shall be determined by the following equation:

$$e = 625\,000 A^{0.2} / U^{0.9}$$

for inch-pound units, and

$$e = 1\,940 A^{0.2} / U^{0.9}$$

for SI units,

where:

e = minimum elongation in 2 in. [50 mm], %, rounded to the nearest 0.5%.

A = cross-sectional area of the tension test specimen, in.² [mm²], based upon specified outside diameter or nominal specimen width and specified wall thickness rounded to the nearest 0.01 in.² [mm²]. If the area thus calculated is greater than 0.75 in.² [500 mm²], then the value 0.75 in.² [500 mm²] shall be used, and

U = specified tensile strength, psi [MPa].

TABLE 3
VARIATIONS IN OUTSIDE DIAMETER

NPS [DN Designator]	Permissible Variations in Outside Diameter			
	Over		Under	
	in.	mm	in.	mm
$\frac{1}{8}$ to $1\frac{1}{2}$ [6 to 40], incl	$\frac{1}{64}$ (0.015)	0.4	$\frac{1}{64}$ (0.015)	0.4
Over $1\frac{1}{2}$ to 4 [40 to 100], incl	$\frac{1}{32}$ (0.031)	0.8	$\frac{1}{32}$ (0.031)	0.8
Over 4 to 8 [100 to 200], incl	$\frac{1}{16}$ (0.062)	1.6	$\frac{1}{32}$ (0.031)	0.8
Over 8 to 18 [200 to 450], incl	$\frac{3}{32}$ (0.093)	2.4	$\frac{1}{32}$ (0.031)	0.8
Over 18 to 26 [450 to 650], incl	$\frac{1}{8}$ (0.125)	3.2	$\frac{1}{32}$ (0.031)	0.8
Over 26 to 34 [650 to 850], incl	$\frac{5}{32}$ (0.156)	4.0	$\frac{1}{32}$ (0.031)	0.8
Over 34 to 48 [850 to 1200], incl	$\frac{3}{16}$ (0.187)	4.8	$\frac{1}{32}$ (0.031)	0.8

TABLE 4
MARKING

Hydro	NDE	Marking
Yes	No	Test Pressure
No	Yes	NDE
No	No	NH
Yes	Yes	Test Pressure/NDE

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical composition requirements shall be rejected.

S2. Transverse Tension Test

S2.1 A transverse tension test shall be made on a specimen from one end or both ends of each pipe NPS 8 [DN 200] and over. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails to meet the required tensile properties (tensile, yield, and elongation), that length shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest.

S3. Flattening Test, Standard

S3.1 For pipe over NPS 2 [DN 50], a section of pipe not less than $2\frac{1}{2}$ in. [63.5 mm] in length shall be flattened cold between parallel plates until the opposite walls of the pipe meet. Flattening tests shall be in accordance with Specification A 530/A 530M, except that in the formula used to calculate the “H” value, the following “e” constants shall be used:

- 0.08 for Grade A
- 0.07 for Grades B and C

S3.2 When low D -to- t ratio tubulars are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be cause for rejection if the D -to- t ratio is less than ten.

S3.3 The flattening test shall be made on one length of pipe from each lot of 400 lengths or fraction thereof of each size over NPS 2 [DN 50], up to but not including NPS 6 [DN 150], and from each lot of 200 lengths or fraction thereof, of each size NPS 6 [DN 150] and over.

S3.4 Should a crop end of a finished pipe fail in the flattening test, one retest is permitted to be made from the failed end. Pipe shall be normalized either before or after the first test, but pipe shall be subjected to only two normalizing treatments.

S4. Flattening Test, Enhanced

S4.1 The flattening test of Specification A 530/A 530M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness, that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S5. Metal Structure and Etching Test

S5.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate sections of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free from injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S6. Carbon Equivalent

S6.1 The steel shall conform to a carbon equivalent (CE) of 0.50 maximum as determined by the following formula:

$$CE = \%C + \frac{\%Mn}{6} + \frac{\%Cr + \%Mo + \%V}{5} + \frac{\%Ni + \%Cu}{15}$$

S6.2 A lower CE maximum may be agreed upon between the purchaser and the producer.

S6.3 The CE shall be reported on the test report.

S7. Heat Treated Test Specimens

S7.1 At the request of the purchaser, one tensile test shall be performed by the manufacturer on a test specimen

from each heat of steel furnished which has been either stress relieved at 1250°F or normalized at 1650°F, as specified by the purchaser. Other stress relief or annealing temperatures, as appropriate to the analysis, may be specified by agreement between the purchaser and the manufacturer. The results of this test shall meet the requirements of Table 1.

S8. Internal Cleanliness—Government Orders

S8.1 The internal surface of hot finished ferritic steel pipe and tube shall be manufactured to a free of scale condition equivalent to the visual standard listed in SSPC-SP 6. Cleaning shall be performed in accordance with a written procedure that has been shown to be effective. This procedure shall be available for audit.

S9. Requirements for Carbon Steel Pipe for Hydrofluoric Acid Alkylation Service

S9.1 Pipe shall be provided in the normalized heat-treated condition.

S9.2 The carbon equivalent (CE), based upon heat analysis, shall not exceed 0.43% if the specified wall thickness is equal to or less than 1 in. [25.4 mm] or 0.45% if the

specified wall thickness is greater than 1 in. [25.4 mm].

S9.3 The carbon equivalent (CE) shall be determined using the following formula:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S9.4 Based upon heat analysis in mass percent, the vanadium content shall not exceed 0.02%, the niobium content shall not exceed 0.02%, and the sum of the vanadium and niobium contents shall not exceed 0.03%.

S9.5 Based upon heat analysis in mass percent, the sum of the nickel and copper contents shall not exceed 0.15%.

S9.6 Based upon heat analysis in mass percent, the carbon content shall not be less than 0.18%.

S9.7 Welding consumables of repair welds shall be of low hydrogen type. E60XX electrodes shall not be used and the resultant weld chemical composition shall meet the chemical composition requirements specified for the pipe.

S9.8 The designation “HF-N” shall be stamped or marked on each pipe to signify that the pipe complies with this supplementary requirement.

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SPECIFICATION FOR PIPE, STEEL, ELECTRIC-FUSION (ARC)-WELDED (SIZES NPS 16 AND OVER)



SA-134

[Identical with ASTM Specification A 134-96 (R05) except that the following additional requirement applies.]

All products furnished under this SA specification are intended for application under the rules for ASME Section III for Class III piping. Furnishing of such products is limited to manufacturers who hold the appropriate ASME Certification Mark. Weld procedures, welder, and welding machine operators shall be qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX. The product shall meet all applicable requirements of Class III Piping including those requirements pertaining to heat treatment and butt welds. *The plate used to fabricate the pipe shall conform to SA-283 or SA-285.* Authorized inspection at the point of manufacture, and application of the appropriate Certification Mark is required.

The applicable ASME Partial Data Report Form, signed by an Authorized Inspector, and a certified mill test report shall be furnished for each lot of pipe. The term "lot" applies to all pipe of the same mill heat of material and wall thickness which is heat treated in one furnace charge. For pipe which is not heat treated, or which is heat treated in a continuous furnace, a lot shall consist of each 200 ft (61 m) or fraction thereof of all pipe of the same mill heat of material and wall thickness, subjected to the same heat treatment. For pipe which is heat treated in a batch-type furnace which is automatically controlled within a 50°F range and equipped with recording pyrometers so that the heating records are available, a lot may be defined the same as for continuous furnaces. Each length of pipe shall be marked in such a manner as to identify each such piece with the lot and the certified mill test report.

1. Scope

1.1 This specification covers electric-fusion (arc)-welded straight seam or spiral seam steel pipe NPS 16 and over in diameter (inside or outside as specified by purchaser), with wall thicknesses up to $\frac{3}{4}$ in. (19.0 mm), inclusive. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification.

NOTE 1 — Acceptability for many services may be controlled by codes or standards such as those published by the American National Standards Institute and American Society of Mechanical Engineers.

NOTE 2 — For testing methods not specifically covered in this specification, reference can be made to Test Methods and Definitions A 370, with particular reference to Annex A 2 on Steel Tubular Products.

NOTE 3 — A comprehensive listing of standardized pipe dimensions is contained in ANSI B 36.10.

1.2 The values stated in inch-pound units are to be regarded as the standard.

NOTE 4 — The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter", "size", and "nominal size".

1.3 The following precautionary caveat pertains specifically to Section 5 of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

- A 36/A 36M Specification for Carbon Structural Steel
- A 283/A 283M Specification for Low and Intermediate Tensile Strength Carbon Steel Plates
- A 285/A 285M Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 570/A 570M Specification for Steel, Sheet and Strip, Carbon, Hot-Rolled, Structural Quality

2.2 ASME Boiler and Pressure Vessel Code:
Section IX Welding Qualifications

2.3 American National Standards Institute Standard:

B 16.25 Buttwelding Ends

B 36.10 Welded and Seamless Wrought Steel Pipe

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, meters, or number of lengths),

3.1.2 Name of material (electric-fusion-(arc) welded pipe),

3.1.3 Grade (Section 4),

3.1.4 Size (inside or outside diameter and nominal wall thickness),

3.1.5 Length (specified or random),

3.1.6 Specific straightness requirements (see 12.3),

3.1.7 End finish (Section 15),

3.1.8 Hydrostatic test pressure (Section 11),

3.1.9 ASTM designation, and

3.1.10 End use of material.

4. Material

4.1 The steel from which the pipe is made shall conform to Specifications A 283/A 283M, A 285/A 285M, A 570, or A 36/A 36M or to other ASTM specifications for equally suitable weldable material, as specified: For purposes of marking and certification, when required, the pipe grade of material shall be established by the A xxx plate specification designation and plate grade, when applicable.

5. Manufacture

5.1 The longitudinal edges of the steel shall be shaped to give the most satisfactory results by the particular welding process employed. The steel shall then be properly formed and may be tacked preparatory to welding. The weld shall be made by automatic means (except tack welds) and shall be of reasonably uniform width and height for the entire length of the pipe. By agreement between the purchaser and the manufacturer, manual welding by qualified procedure and welders may be used as an equal alternate under this specification.

5.2 All longitudinal seams, spiral seams, and shop girth seams shall be butt-welded.

6. Number of Production Weld Tests

6.1 One weld test specimen specified in Section 8 shall be made from each lot of 3000 ft (900 m) of pipe or fraction thereof of each size and wall thickness.

6.2 If any test specimen shows defective machining or develops flaws not associated with the welding, it may be discarded and another specimen substituted.

6.3 Each length of pipe shall be subjected to the hydrostatic test specified in Section 11, unless otherwise specified in 11.3.

7. Retests

7.1 If any specimen tested in accordance with Section 10 fails to meet the requirements, retests of two additional specimens from the same lot of pipe shall be made, each of which shall meet the requirements specified. If any of the retests fail to conform to the requirements, test specimens may be taken from each untested pipe length at the manufacturer's option. Each specimen shall meet the requirements specified, or that pipe shall be rejected.

8. Test Specimens of Production Welds

8.1 The weld-test specimens for the reduced-section tension test shall be taken perpendicularly across the weld and from the end of the pipe or alternatively, from flat test pieces of material conforming to the requirements in the specifications used in the manufacture of the pipe. The alternative weld-test specimens shall be welded with the same procedure and by the same operator and equipment, and in sequence with the welding of the longitudinal joints in the pipe. The test pieces shall have the weld approximately in the middle of the specimen. The specimens shall be straightened cold, and shall be tested at room temperature.

8.2 Reduced-section tension-test specimens shall be prepared in accordance with Fig. number 21 of Test Methods and Definitions A 370.

9. Qualification of Welding Procedure

9.1 The welding procedure shall be qualified in accordance with the American Welding Society Standard Qualification Procedure or ASME Section IX of the Boiler and Pressure Vessel Code as agreed to between the manufacturer and the purchaser using the tests and test values specified in 9.2 and 9.3. Thicknesses less than $\frac{3}{8}$ in. (10 mm) shall be qualified for each wall thickness of pipe manufactured. Thicknesses $\frac{3}{8}$ to $\frac{3}{4}$ in. (10 mm to 19.0 mm), inclusive, shall be qualified in $\frac{3}{8}$ in. (10 mm) thickness.

9.2 Two reduced-section tension specimens (transverse weld) made in accordance with Fig. number 21 of Test Methods and Definitions A 370, with the weld reinforcement removed, shall show a tensile strength not less than 100% of the minimum specified tensile strength of the base material used.

9.3 Two face-bend test specimens shall be prepared in accordance with Fig. number 2 (a) of Test Methods and Definitions A 370 and shall withstand being bent 180° in a jig substantially in accordance with Fig. 30 of Test Methods and Definitions A 370. The bend test shall be acceptable if no cracks or other defects exceeding $\frac{1}{8}$ in. (3.2 mm) in any direction be present in the weld metal or between the weld and the pipe metal after bending. Cracks that originate along the edges of the specimens during testing and that are less than $\frac{1}{4}$ in. (6.3 mm) in any direction, shall not be considered.

10. Tensile Properties of Production Welds

10.1 Reduced-section tension test specimens required in Section 8 taken perpendicularly across the weld with the weld reinforcement removed, shall show a tensile strength not less than 95% of the specified minimum strength of the steel. At the manufacturer's option, the test may be made without removing the weld reinforcement, in which case the tensile strength shall be not less than the specified minimum tensile strength for the grade of steel used.

11. Hydrostatic Test (Note 5)

11.1 Each length of pipe shall be tested by the manufacturer to a hydrostatic pressure that will produce in the pipe wall a stress of 60% of the specified minimum yield point of the steel used at room temperature. The pressure shall be determined by the following equation:

$$P = 2St/D$$

where:

P = minimum hydrostatic test pressure, psi (Note 6)
(not to exceed 2800 psi (19 MPa)),

S = 0.60 times the minimum specified yield point of the steel used, psi (MPa),

t = specified wall thickness, in. (mm), and

D = specified outside diameter, in. (mm).

NOTE 5 — A hydrostatic sizing operation is not to be considered a hydrostatic test or a substitute for it.

NOTE 6 — When the diameter and wall thickness of pipe are such that the capacity limits of testing equipment are exceeded by these requirements, the test pressures may be reduced by agreement between the purchaser and the manufacturer.

11.2 Test pressure shall be held for not less than 5 s, or for a longer time as agreed upon between the purchaser and the manufacturer.

NOTE 7 — When agreed upon between the purchaser and the manufacturer and so stated on the order, pipe may be tested to one and one half times the specified working pressure, except that the maximum test pressure shall not exceed 2800 psi (19 MPa) nor shall the maximum fiber

stress exceed 85% of specified minimum yield point of steel or to a fiber stress that does not exceed 85% of the specified minimum yield point of the steel or 2800-psi (19-MPa) test pressure.

11.3 When specified in the order, pipe may be furnished without hydrostatic testing and each length so furnished shall include the mandatory marking of the letters "NH". Additionally, the certification, when required, shall state "Not Hydrostatically Tested" and the specification number and material grade, as shown on the certification, shall be followed by the letters "NH".

12. Permissible Variations in Weights and Dimensions

12.1 Thickness and Weight — The wall thickness and weight for welded pipe under this specification shall be governed by the requirements of the specifications to which the steel was ordered.

12.2 Circumference — The outside circumference of the pipe shall not vary more than $\pm 0.5\%$ from the nominal outside circumference based upon the diameter specified, except that the circumference at ends shall be sized, if necessary, to meet the requirements of Section 14.

12.3 Straightness — Finished pipe shall be commercially straight. When specific straightness requirements are desired, the order should so state, and the tolerances shall be a matter of agreement between the purchaser and the manufacturer.

12.4 Ovality — Out-of-roundness — The difference between major and minor outside diameter shall not exceed 1%. Closer tolerances may be established by agreement between the manufacturer and the purchaser. Where the D/T (outside diameter/wall thickness) is over 120, internal bracing should be utilized to achieve sizing of ends and ovality shall be by agreement between the manufacturer and purchaser.

13. Lengths

13.1 Pipe lengths shall be supplied in accordance with the following regular practice:

13.1.1 The lengths shall be as specified on the order with a tolerance of $\pm \frac{1}{2}$ in. (13 mm), except that the shorter lengths from which test coupons have been cut may also be shipped.

13.1.2 When random lengths are specified, pipe shall be furnished in lengths having a minimum average of 29 ft (9 m) with a minimum length of 20 ft (6 m), but not more than 5% may be under 25 ft (8 m).

13.2 Pipe lengths containing circumferentially welded joints (Note 8) shall be permitted by agreement between the manufacturer and the purchaser. Tests of these welded

joints shall be made in accordance with the procedure tests specified in Section 9 and the production weld tests specified in Section 10. The number of production weld tests shall be one per each lot of 100 joints or fraction thereof, but not less than one for each welder or welding operator.

NOTE 8 — Joints are defined for the purpose of this specification as a circumferential welded seam lying in one plane, used to join lengths of straight pipe.

14. Ends

14.1 Pipe shall be furnished with a plain right-angle cut or with bevel ends as specified. All burrs at the ends of pipe shall be removed.

14.1.1 Unless otherwise specified, pipe with beveled ends shall meet the requirements of ANSI B 16.25.

14.2 Unless otherwise specified, the outside circumference of pipe ends for a distance of not less than 4 in. (100 mm) shall not vary more than $\pm 60\%$ of the nominal wall thickness of the pipe from the nominal outside circumference based on the diameter specified, except that the tolerance shall not be less than $\pm \frac{3}{16}$ in. (5 mm).

14.3 By agreement between the manufacturer and the purchaser the ends of the pipe may be sized within agreed-upon tolerances if necessary to meet the requirements of special installations.

15. Finish

15.1 Repair by Welding — The welding of injurious defects in the pipe wall, provided their depth does not exceed one third the specified wall thickness, will be permitted. Defects in the welds, such as sweats or leaks, shall be repaired or the piece rejected at the option of the manufacturer. Repairs of this nature shall be made by completely removing the defect, cleaning the cavity, and then welding.

15.2 All repaired pipe shall be tested hydrostatically in accordance with Section 11, unless otherwise specified in 11.3.

16. Inspection

16.1 The inspector representing the purchaser shall have entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection shall be made at the place of manufacture

prior to shipment and unless otherwise specified, shall be so conducted as not to interfere unnecessarily with the operation of the works. If agreed upon, the manufacturer shall notify the purchaser in time so that he may have his inspector present to witness any part of the manufacture or tests that may be desired. The certification shall include reference to this specification and the pipe grade (ASTM plate specification designation and plate grade, when applicable).

16.2 Certification — Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification together with a report of the chemical and tensile tests shall be furnished. When hydrostatic test is omitted, the certificate shall include the letters "NH".

17. Rejection

17.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and test method as outlined in the specification, the length may be rejected, and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

17.2 Pipe found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such pipe shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement between the purchaser and the manufacturer.

18. Certification

18.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification, including year date, together with a report of the chemical and tensile tests shall be furnished. The pipe grade shall be identified by the plate specification designation (year date not required) and the plate grade (where applicable).

19. Product Marking

19.1 Each section of pipe shall be marked with the manufacturer's distinguishing marking, this specification number and the pipe grade. The marking need not include the year date of the pipe or plate specification.

19.2 Bar Coding — In addition to the requirements in 19.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

20. Protective Coating

20.1 If agreed upon between the purchaser and the manufacturer, the pipe shall be given a protective coating of the kind and in the manner specified by the purchaser.

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SPECIFICATION FOR ELECTRIC-RESISTANCE- WELDED STEEL PIPE



SA-135



(Identical with ASTM Specification A 135-01.)

1. Scope

1.1 This specification covers two grades of electric-resistance-welded steel pipe in NPS 2 to NPS 30 inclusive, with nominal (average) wall thickness up to 0.500 in. (12.70 mm), inclusive, and in nominal sizes NPS 3/4 to NPS 5 inclusive with nominal (average) wall thickness 0.083 in. (2.11 mm) to 0.134 in. (3.40 mm), depending on size. Pipe having other dimensions (Note 1) may be furnished provided such pipe complies with all other requirements of this specification. The pipe is intended for conveying gas, vapor, water or other liquid; only Grade A is adapted for flanging and bending (Note 2). The suitability of pipe for various purposes is somewhat dependent upon its dimensions, properties, and conditions of service, so that the purpose for which the pipe is intended should be stated in the order. The pipe may be furnished either nonexpanded or cold expanded at the option of the manufacturer. When pipe is cold expanded, the amount of expansion shall not exceed 1.5% of the outside diameter pipe size.

NOTE 1 — A comprehensive listing of standardized pipe dimensions is contained in ASME B36.10.

NOTE 2 — This provision is not intended to prohibit the cold bending of Grade B pipe.

1.2 The values stated in inch-pound units are to be regarded as the standard. The SI values, given in parentheses, are for information only.

2. Referenced Documents

2.1 ASTM Standards:

- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 865 Specification for Threaded Couplings, Steel, Black and Zinc-Coated (Galvanized) Welded or Seamless, for Use in Steel Pipe Joints

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

E 6 Terminology Relating to Methods of Mechanical Testing

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 273 Practice for Ultrasonic Examination of Longitudinal Welded Pipe and Tubing

E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation

2.2 ANSI Standard:

B1.20.1 Pipe Threads, General Purpose

2.3 Federal Standards:

Fed. STD No. 123 Marking for Shipments (Civil Agencies)

Fed. STD No. 183 Continuous Identification Marking of Iron and Steel Products

2.4 Military Standards:

MIL-STD-129 Marking for Shipment and Storage

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

2.5 ASME Standard:

B36.10 Welded and Seamless Wrought Steel Pipe

3. Terminology

3.1 For definitions of terms relating to steel manufacturing and properties, refer to Terminology A 941.

3.2 For definitions of terms relating to mechanical testing, refer to Terminology E 6.

3.3 Definitions of Terms Specific to This Standard:

3.3.1 *burr, n* — a rough or sharp edge left on pipe ends by cutting or sawing.

3.3.2 *lot, n* — all pipe of the same size, wall thickness and rolled length that is produced from the same heat of steel and subject to the same heat treatment.

3.3.3 *black thread, n* — a thread crease exhibiting the original pipe surface after machining.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

4.1.1 Quantity (feet or number of lengths),

4.1.2 Name of material (electric-resistance-welded pipe),

4.1.3 Specification designation and year of issue,

4.1.4 Grade (see Table 1),

4.1.5 Size (nominal size, or outside diameter; and nominal wall thickness),

4.1.6 Length (specific or random, see 12.4),

4.1.7 End finish (plain or threaded, see 13.2),

4.1.7.1 Threaded and coupled, if specified,

4.1.7.2 Threads only, if specified,

4.1.7.3 Plain end, if specified,

4.1.8 Alternative electric test (see Section 11),

4.1.9 Tension test specimen (see Section 15),

4.1.10 Heat analysis, if required (see 6.1),

4.1.11 Certificate of compliance, if required (see Section 19), and

4.1.12 Special requirements.

5. Manufacture

5.1 The steel shall be made by either or both of the following processes: basic-oxygen or electric-furnace.

5.2 Steel may be cast in ingots or may be strand cast. When steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

5.3 The pipe shall be manufactured from flat rolled steel in individual lengths or in continuous length by electric-resistance or electric-induction welding without the addition of extraneous material.

5.4 The weld seam of electric-resistance welded pipe to Grade B pipe shall be heat treated after welding to a

minimum temperature of 1000 °F (540 °C) or processed in such a manner that no untempered martensite remains.

6. Chemical Composition

6.1 The steel shall conform to the requirements prescribed in Table 2, based on the heat analysis. When specified in the order, the heat analyses shall be reported to the purchaser or a representative of the purchaser.

7. Product Analysis

7.1 An analysis may be made by the purchaser on samples of pipe selected at random and shall conform to the requirements specified in Table 2. Methods and Practices relating to chemical analysis shall be in accordance with Test Method, Practices, and Terminology A 751.

8. Mechanical Properties Requirements

8.1 Tensile Properties:

8.1.1 The material shall conform to the requirements as to tensile properties prescribed in Table 1.

8.1.2 The yield strength shall be determined by the offset method utilizing 0.2% of the gage length or by the total extension under load method using 0.5% of the gage length.

8.1.3 Longitudinal test specimens shall be full-size longitudinal test specimens (see Figure A2.1 of Test Methods and Definitions A 370) or longitudinal strip test specimens (see Specimen No. 4 in Fig. A2.3 of Test Methods and Definitions A 370).

8.2 The test specimen taken across the weld shall show a tensile strength not less than the minimum tensile strength specified for the grade of pipe ordered. This test will not be required for pipe under NPS 8.

9. Flattening Test

9.1 A specimen at least 4 in. (102 mm) in length shall be flattened cold between parallel plates in three steps with the weld located either 0° or 90° from the line of direction of force as required in 9.2. During the first step, which is a test for ductility of the weld, no cracks or breaks on the inside or outside surfaces shall occur until the distance between the plates is less than two thirds of the original outside diameter of the pipe. As a second step, the flattening shall be continued. During the second step, which is a test for ductility exclusive of the weld, no cracks or breaks on the inside or outside surfaces shall occur until the distance between the plates is less than one third of the original outside diameter of the pipe but is not less than five times the wall thickness of the pipe. During the third step, which

is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet. Evidence of laminated or unsound material or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

9.2 For pipe produced in single lengths, the flattening test specified in 9.1 shall be made on both crop ends cut from each length of pipe. The tests from each end shall be made alternately with the weld at 0° and at 90° from the line of direction of force. For pipe produced in multiple lengths, the flattening test shall be made on crop ends representing the front and back of each coil with the weld at 90° from the line of direction of force, and on two intermediate rings representing each coil with the weld 0° from the line of direction of force.

9.3 Surface imperfections in the test specimen before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements in Section 13.

9.4 Superficial cracks as a result of surface imperfections shall not be cause for rejection.

10. Hydrostatic Test

10.1 Except as provided for in 10.3, each length of pipe shall be hydrostatically tested at the mill, without leakage through the wall, to a pressure calculated from the following eq. 1:

$$P = 2St/D \quad (1)$$

where:

P = minimum hydrostatic test pressure, psi (MPa).
The test pressure need not exceed 2500 psi (17.24 MPa),

S = allowable fiber stress 18 000 psi (124 MPa) for Grade A and 21 000 psi (144 MPa) for Grade B.
This does not prohibit testing at higher pressure at the manufacturer's option,

t = specified wall thickness, in., and

D = specified outside diameter, in.

Plain end pipe may be tested at the discretion of the manufacturer in single lengths or in multiple lengths.

10.2 The hydrostatic pressure shall be maintained for not less than 5 s.

10.3 When specified in the order, pipe may be furnished without hydrostatic testing, and each length so furnished shall include with the mandatory marking the letters "NH."

NOTE 3 — This provision is not intended to apply to light wall (Schedule 10) pipe listed in Table X1.1.

10.4 When certification is required by the purchaser and the hydrostatic test has been omitted, the certification

shall clearly state "Not Hydrostatically Tested." The specification number and material grade, as shown on the certification, shall be followed by the letters "NH."

11. Nondestructive Examination Requirements

11.1 As an alternate to the hydrostatic test for Schedule 10 pipe in sizes NPS $\frac{3}{4}$ to NPS 5 inclusive, and when accepted by the purchaser, each pipe shall be tested with a nondestructive electric test in accordance with Practice E 213, Practice E 273, or Practice E 309. It is the intent of this test to reject pipe containing defects.

11.2 Recognized methods for meeting this test are electromagnetic (eddy current) or ultrasonic.

11.3 The following information is for the benefit of the user of this specification:

11.3.1 The ultrasonic examination referred to in this specification is intended to detect longitudinal imperfections having a reflective area similar to or larger than the reference notch. The examination may not detect circumferentially oriented imperfections of short, deep imperfections.

11.3.2 The eddy-current examination referenced in this specification has the capability of detecting significant imperfections, especially of the short, abrupt type.

11.3.3 The hydrostatic test referred to in Section 10 is a test method provided for in many product specifications. This test has the capability of finding imperfections of a size permitting the test fluid to leak through the tube wall and may be either visually seen or detected by a loss of pressure. This test may not detect very tight, through-the-wall imperfections or imperfections that extend an appreciable distance into the wall without complete penetration.

11.3.4 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of imperfections that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

11.4 In order to accommodate the various types of nondestructive electric testing equipment and techniques in use, the calibration pipe shall contain, at the option of the producer, any one or more of the following discontinuities to establish a minimum sensitivity level for rejection:

11.4.1 Drilled Hole — A hole not larger than 0.031-in. (0.8-mm) diameter shall be drilled radially and completely through pipe wall, preferably in the weld area, care being taken to avoid distortion of the pipe while drilling.

11.4.2 Transverse Tangential Notch — A notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe preferably in the weld

area. Said notch shall have a depth not exceeding 12.5% of the nominal wall thickness of the pipe or 0.004 in. (0.10 mm), whichever is greater.

11.4.3 Longitudinal Notch — A notch 0.031 in. (0.8 mm) or less in width shall be machined in a radial plane parallel to the pipe axis on the outside surface of the pipe preferably in the weld area, to have a depth not exceeding 12.5% of the nominal wall thickness of the pipe or 0.004 in. (0.10 mm), whichever is greater.

11.5 Pipe producing a signal equal to or greater than the calibration imperfection shall be rejected.

12. Dimensions, Weight, and Permissible Variations

12.1 Weight — The weight of any length of pipe other than Schedule 10 shall not vary more than 3.5% under or 10% over that specified, but the carload weight shall be not more than 1.75% under the nominal weight. The weight of pipe furnished to Schedule 10 shall not vary more than $\pm 10\%$ from that calculated using the weight (mass) per unit length prescribed in Appendix Table X1.1. The weight of the pipe shall be calculated from the relevant equation in ASME B36.10 and with a constant of 10.69 rather than 10.68.

NOTE 4 — A system of standard pipe sizes has been approved by the American National Standards Institute as American National Standard for Welded and Seamless Wrought Steel Pipe (ASME B36.10).

12.2 Diameter — The outside diameter shall not vary more than $\pm 1\%$ from the nominal size specified.

12.3 Minimum Wall Thickness — The minimum wall thickness at any point shall be not more than 12.5% under the specified wall thickness.

NOTE 5 — The minimum wall thickness on inspection is shown in Table X1.2 of the Appendix.

12.4 Lengths:

12.4.1 Except as allowed in 12.4.2, pipe shall be furnished in lengths averaging 38 ft (11.6 m) or over, with a minimum length of 20 ft (6.1 m), but no more than 5% may be under 32 ft (9.8 m). Joints made by welding are permissible. When threaded pipe is ordered, joints shall be made by threaded connections and shall not exceed 5% of the order.

12.4.2 Unless otherwise specified, Schedule 10 pipe shall be between 16 and 22 ft (4.9 and 6.7 m) for a minimum of 90% of the footage furnished, with any balance being shorter lengths at least 8 ft (2.4 m) long.

13. Workmanship, Finish, and Appearance

13.1 The finished pipe shall be reasonably straight and free of defects. Surface imperfections in excess of 12.5% of the nominal wall thickness shall be considered defects.

13.2 End Finish:

13.2.1 Schedule 10 Pipe — Pipe furnished to Schedule 10 shall be plain end only. All inside and outside cutting burrs shall be removed. This generally involves breaking the corners.

13.2.2 Ends, Plain End Pipe — Unless otherwise specified, plain end pipe for use with the Dresser or Dayton type coupling shall be reamed both outside and inside sufficiently to remove all burrs. Plain end pipe for welding shall be beveled on the outside to an angle of 30° with a tolerance of $+5^\circ$ and -0° and with a width of flat at the end of the pipe of $\frac{1}{16}$ \pm $\frac{1}{32}$ in. (1.6 \pm 0.8 mm). When material is ordered beveled to any other than a 30° angle, it should be understood that the angle is to be measured from a line drawn perpendicular to the axis of the pipe. This means that a greater amount of material is removed with a 60° angle than with a 30° angle. Pipe shall be sufficiently free from indentations, projections, or roll marks for a distance of 8 in. (203 mm) from the end of the pipe to make a tight joint with the rubber gasket type of coupling. All plain end pipe intended for Dresser or Dayton type joints or for welding, sizes NPS 10 and smaller in outside diameter specified, shall be not more than $\frac{1}{32}$ in. (0.8 mm) smaller than the outside diameter specified for a distance of 8 in. (203 mm) from the ends of the pipe and shall permit the passing for a distance of 8 in. (203 mm) of a ring gage that has a bore $\frac{1}{16}$ in. (1.6 mm) larger than the outside diameter specified of the pipe. Sizes larger than NPS 10 shall be not more than $\frac{1}{32}$ in. (0.8 mm) smaller than the nominal outside diameter for a distance of 8 in. (203 mm) from the end of the pipe and shall permit the passing for a distance of 8 in. (203 mm) of a ring gage which has a bore $\frac{3}{32}$ in. (2.4 mm) larger than the nominal outside diameter of the pipe.

13.2.3 Ends, Threaded Pipe — Each end of threaded pipe shall be reamed to remove all burrs. All threads shall be in accordance with the American National Standard Pipe Threads (Note 6) and cut so as to make a tight joint when the pipe is tested at the mill to the specified internal hydrostatic pressure. The variation from the standard, when tested with the standard working gage, shall not exceed one and one-half turns either way. Pipe shall not be rounded by hammering in order to get a full thread. There shall be not more than two black threads for $\frac{3}{4}$ -in. (19.0-mm) taper among the perfect threads. Black threads should not be confused with imperfect threads, such as those torn, shaven, or broken.

NOTE 6 — A complete description of the American National Standard Pipe Threads applicable to pipe, valves, and fittings is contained in the American National Standard for Pipe Threads (ANSI B1.20.1); also "Screw-Thread Standards for Federal Services, 1942," National Bureau of Standards *Handbook H* 28, January, 1942, the pertinent data in both sources being identical.

13.3 Couplings — Each length of threaded pipe shall be provided with one coupling manufactured in accordance with Specification A 865 except that the coupling may be wrought iron (Note 7). Threads shall be cut so as to make a tight joint. Taper-tapped couplings shall be furnished on all weights of threaded pipe NPS 2½ and larger.

NOTE 7 — For sizes NPS 2 and smaller, it is commercial practice to furnish straight-tapped couplings for standard-weight (Schedule 40) pipe and taper-tapped couplings for extra-strong (Schedule 80) and double-extra-strong pipe. If taper-tapped couplings are required for sizes NPS 2 and smaller on standard weight (Schedule 40) pipe, line pipe in accordance with Specification 5L of the American Petroleum Institute should be ordered, thread lengths to be in accordance with the American National Standard for Pipe Threads (ANSI B1.20.1). Taper-tapped couplings for sizes NPS 2 and smaller in standard weight may be used on mill-threaded standard weight type of the same size.

13.4 Protective Coating:

13.4.1 After the pipe has been subjected to the hydrostatic test, and if required by the purchaser, it shall be thoroughly cleaned of all dirt, oil, grease, loose scale, and rust; then dried, and given a protective coating of the kind and in the manner specified by the purchaser. Pipe furnished to Schedule 10 shall be normally shipped with a light coating of processing oil. If so specified, the pipe can be given a mill coating or a special coating.

14. Weld Repair

14.1 Welding Repair:

14.2 Defects in the pipe wall, provided their depth does not exceed one third the specified wall thickness, shall be repaired by electric welding. Defects in the welds such as sweats or leaks, unless otherwise specified, shall be repaired or the piece rejected at the option of the manufacturer. Repairs of this nature shall be made by completely removing the defect, cleaning the cavity, and then electric welding.

14.3 All repaired pipe shall be retested hydrostatically in accordance with Section 10.

15. Sampling

15.1 Chemical Analysis:

15.1.1 Samples for chemical analysis, except for spectrochemical analysis, shall be taken in accordance with Practice E 59. The number of samples shall be determined as follows:

NPS	Numbers of Samples Selected
Under 6	2 from each lot of 400 pipes or fraction thereof
6 to 20, incl	2 from each lot of 200 pipes or fraction thereof
Over 20 to 30, incl	2 from each lot of 100 pipes or fraction thereof

15.2 Tension Test:

15.2.1 One longitudinal tension test shall be made on length (Note 8) from each lot of 400 lengths or fraction

thereof of each size under NPS 8 and one transverse body and one transverse weld tension test on one length from each lot of 200 lengths or fraction thereof of each size NPS 8 to NPS 20 and on one length from each lot of 100 lengths or fraction thereof of each size over NPS 20 to NPS 30. When taken from the skelp, the number of tests shall be determined in the same manner as when taken from the finished pipe.

NOTE 8 — Length is defined as the length as ordered, except that in the case of orders for cut lengths shorter than double random, which is defined as the length as rolled, prior to cutting to the required short lengths.

15.3 Flattening Test:

15.3.1 The flattening test specified in 9.1 shall be made on both crop ends cut from each length of pipe. When pipe is produced in multiple lengths, flattening tests are required on the crop ends from the front and back ends of each coil and on two intermediate rings representing each coil.

15.4 Hydrostatic Test:

15.4.1 Each length of pipe shall be subjected to the hydrostatic test specified in Section 10.

16. Test, Retest, and Resampling

16.1 Chemical Analysis:

16.1.1 If the results of the analysis of either length of pipe do not conform to the requirements specified in Section 7, analyses of two additional lengths from the same lot shall be made, each of which shall conform to the requirements specified.

16.2 Tension Test:

16.2.1 The test specimens and the tests required by this specification shall conform to those described in Test Methods and Definitions A 370, except that all specimens shall be tested at room temperature.

16.2.2 The longitudinal tension test specimen shall be taken from the end of the pipe, or by agreement between the manufacturer and the purchaser may be taken from the skelp, at a point approximately 90° from the weld, and shall not be flattened between gage marks. The sides of each specimen shall be parallel between gage marks. At the manufacturer option, the tension test may be made on full section of pipe.

16.2.3 Transverse weld test specimens shall be taken with the weld at the center of the specimen. Transverse body test specimens shall be taken opposite to the weld. All transverse test specimens shall be approximately 1½ in. (38.1 mm) wide in the gage length and shall represent the full wall thickness of the pipe from which the specimen was cut.

16.2.4 If any test specimen shows defective machining or develops flaws not associated with the quality of the steel or the welding, it may be discarded and another specimen substituted.

16.2.5 If the results of the tension tests of any lot do not conform to the requirements specified in 9.1, retests of two additional lengths from the same lot shall be made, each of which shall conform to the requirements specified.

16.2.6 If the percentage of elongation of any tension test specimen is less than that specified in 8.1, and any part of the fracture is more than $\frac{3}{4}$ in. (19.0 mm) from the center of the gage length as indicated by scribe scratches marked on the specimen before testing, the specimen may be discarded and another substituted.

16.3 Flattening Test:

16.3.1 Specimens for flattening tests shall be smooth at the ends and free from burrs.

16.3.2 If any section of the pipe fails to comply with the requirements of 9.1, for pipe produced in single lengths, other sections may be cut from the same end of the same length until satisfactory tests are obtained, except that the finished pipe shall not be shorter than 80% of its length after the initial cropping; otherwise, the length shall be rejected. For pipe produced in multiple lengths, retests may be cut from each end of each individual length in the multiple; such tests shall be made with the weld alternately 0° and 90° from the line of direction of force.

16.4 All specimens shall be tested at room temperature.

17. Inspection

17.1 The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except check analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the manufacturer's operation.

18. Rejection

18.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and test method as outlined in the specification,

the length may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

18.2 Pipe found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such pipe shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement.

19. Certificate of Compliance

19.1 When specified in the purchase order, the producer or supplier shall furnish to the purchaser a certificate of compliance stating that the pipe has been manufactured, sampled, tested and inspected in accordance with this specification (including the year of issue) and has been found to meet the requirements.

20. Identification of Material

20.1 Each length of pipe shall be legibly marked with appropriate symbols by stenciling, stamping, or rolling to show the manufacturer's name, the size, the specification designation, the grade, and the hydrostatic test pressure when tested, or the letters "NH" when not tested.

20.2 In addition to the requirements in 20.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

21. Packaging, Marking, and Loading for Shipment

21.1 When specified on the purchase order, packaging, marking, and loading for shipment shall be in accordance with Practices A 700.

21.2 When specified in the contract or purchase order, the material shall be preserved, packaged, and packed in accordance with MIL-STD 163. The applicable levels shall be as specified in the contract. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD 129 or Fed. Std. No. 183 if continuous marking is required for military agencies.

22. Keywords

22.1 eddy current testing; electric resistance welded pipe; hydrostatic testing; plain end pipe; Schedule 10 pipe; threaded pipe

TABLE 1
TENSILE REQUIREMENTS

	Grade A	Grade B
Tensile strength, min, ksi (MPa)	48 (331)	60 (414)
Yield strength, min, ksi (MPa)	30 (207)	35 (241)
Elongation in 2 in. (50 mm), min, %:		
For pipe having a specified wall thickness of $\frac{5}{16}$ in. (7.9 mm) or more, if tested using a longitudinal strip test specimen.	35	30
For pipe having a specified wall thickness of less than $\frac{5}{16}$ in. (7.9 mm), if tested using a longitudinal strip test specimen.	^A	^B
For pipe of any size, if tested using a full-size longitudinal test specimen.	35	30

^A The minimum elongation shall be determined by the following equation, with the calculated value rounded to the nearest percent:

$$E = 56t + 16.5$$

where:

E = elongation in 2 in. (50 mm), min, %, and
 t = specified wall thickness, in.

^B The minimum elongation shall be determined by the following equation, with the calculated value rounded to the nearest percent:

$$E = 48t + 14.00$$

where:

E = elongation in 2 in. (50 mm), min, %, and
 t = specified wall thickness, in.

TABLE 2
CHEMICAL REQUIREMENTS

Element	Composition, max, %	
	Grade A	Grade B
Carbon	0.25	0.30
Manganese	0.95	1.20
Phosphorus	0.035	0.035
Sulfur	0.035	0.035

APPENDIX

(Nonmandatory Information)

X1. ADDITIONAL DATA

X1.1 Additional data on dimensions nominal weights and test pressures is provided in Table X1.1.

X1.2 Additional data on wall thicknesses are provided in Table X1.2.

TABLE X1.1
DIMENSIONS, NOMINAL WEIGHTS, AND TEST PRESSURES FOR LIGHT WALL STEEL PIPE

NPS	Outside Diameter, in. (mm)	Schedule 10		Test Pressure, psi (MPa) ⁴	
		Specified Wall Thickness ⁴ in. (mm)	Weight (Mass) per Unit Length, lb/ft (kg/m)	Grade A	Grade B
3/4	1.050 (26.7)	0.083 (2.11)	0.86 (1.28)	2500 (17.24)	2500 (17.24)
1	1.315 (33.4)	0.109 (2.77)	1.40 (2.09)	2500 (17.24)	2500 (17.24)
1 1/4	1.660 (42.2)	0.109 (2.77)	1.81 (2.69)	2400 (16.55)	2500 (17.24)
1 1/2	1.900 (48.3)	0.109 (2.77)	2.09 (3.11)	2100 (14.48)	2400 (16.55)
2	2.375 (60.3)	0.109 (2.77)	2.64 (3.93)	1700 (11.72)	1900 (13.10)
2 1/2	2.875 (73.0)	0.120 (3.05)	3.53 (5.26)	1500 (10.34)	1700 (11.72)
3	3.500 (88.9)	0.120 (3.05)	4.34 (6.46)	1200 (8.27)	1400 (9.65)
3 1/2	4.000 (101.6)	0.120 (3.05)	4.98 (7.41)	1000 (6.89)	1200 (8.27)
4	4.500 (114.3)	0.120 (3.05)	5.62 (8.37)	900 (6.21)	1100 (7.58)
5	5.563 (141.3)	0.134 (3.40)	7.78 (11.58)	850 (5.86)	1000 (6.89)

⁴ The test pressures are calculated by the following equation (but need not exceed 2500 psi or 17.24 MPa):

$$P = 2St/D$$

where:

P = pressure, psi (MPa)

S = fiber stress, 60% of the specified minimum yield strength, psi (MPa),

t = specified wall thickness, in. (mm), and

D = specified outside diameter, in. (mm).

TABLE X1.2
MINIMUM PERMISSIBLE WALL THICKNESS ON INSPECTION

Specified Wall Thickness (t), in. (mm)	Minimum Permissible Wall Thickness (t_m), in. (mm)	Specified Wall Thickness (t), in. (mm)	Minimum Permissible Wall Thickness (t_m), in. (mm)	Specified Wall Thickness (t), in. (mm)	Minimum Permissible Wall Thickness (t_m), in. (mm)
0.068 (1.73)	0.060 (1.52)	0.294 (7.47)	0.257 (6.53)	0.750 (19.05)	0.656 (16.66)
0.088 (2.24)	0.077 (1.96)	0.300 (7.62)	0.262 (6.65)	0.812 (20.62)	0.710 (18.03)
0.091 (2.31)	0.080 (2.03)	0.307 (7.80)	0.269 (6.83)	0.843 (21.41)	0.738 (18.75)
0.095 (2.41)	0.083 (2.11)	0.308 (7.82)	0.270 (6.86)	0.864 (21.95)	0.756 (19.20)
0.113 (2.87)	0.099 (2.51)	0.312 (7.92)	0.273 (6.93)	0.875 (22.23)	0.766 (19.46)
0.119 (3.02)	0.104 (2.64)	0.318 (8.08)	0.278 (7.06)	0.906 (23.01)	0.793 (20.14)
0.125 (3.18)	0.109 (2.77)	0.322 (8.18)	0.282 (7.16)	0.937 (23.80)	0.820 (20.83)
0.126 (3.20)	0.110 (2.79)	0.330 (8.38)	0.289 (7.34)	0.968 (24.59)	0.847 (21.51)
0.133 (3.38)	0.116 (2.95)	0.337 (8.56)	0.295 (7.49)	1.000 (25.40)	0.875 (22.23)
0.140 (3.56)	0.122 (3.10)	0.343 (8.71)	0.300 (7.62)	1.031 (26.19)	0.902 (22.91)
0.145 (3.68)	0.127 (3.23)	0.344 (8.74)	0.301 (7.65)	1.062 (26.97)	0.929 (23.60)
0.147 (3.73)	0.129 (3.28)	0.358 (9.09)	0.313 (7.95)	1.093 (27.76)	0.956 (24.28)
0.154 (3.91)	0.135 (3.43)	0.365 (9.27)	0.319 (8.10)	1.125 (28.58)	0.984 (24.99)
0.156 (3.96)	0.136 (3.45)	0.375 (9.53)	0.328 (8.33)	1.156 (29.36)	1.012 (25.70)
0.179 (4.55)	0.157 (3.99)	0.382 (9.70)	0.334 (8.48)	1.218 (30.94)	1.066 (27.08)
0.187 (4.75)	0.164 (4.17)	0.400 (10.16)	0.350 (8.89)	1.250 (31.75)	1.094 (27.79)
0.188 (4.78)	0.164 (4.17)	0.406 (10.31)	0.355 (9.02)	1.281 (32.54)	1.121 (28.47)
0.191 (4.85)	0.167 (4.24)	0.432 (10.97)	0.378 (9.60)	1.312 (33.33)	1.148 (29.16)
0.200 (5.08)	0.175 (4.45)	0.436 (11.07)	0.382 (9.70)	1.343 (34.11)	1.175 (29.85)
0.203 (5.16)	0.178 (4.52)	0.437 (11.10)	0.382 (9.70)	1.375 (34.93)	1.203 (30.56)
0.216 (5.49)	0.189 (4.80)	0.438 (11.13)	0.383 (9.73)	1.406 (35.71)	1.230 (31.24)
0.218 (5.54)	0.191 (4.85)	0.500 (12.70)	0.438 (11.13)	1.437 (36.53)	1.258 (31.95)
0.219 (5.56)	0.192 (4.88)	0.531 (13.49)	0.465 (11.81)	1.500 (38.10)	1.312 (33.33)
0.226 (5.74)	0.198 (5.03)	0.552 (14.02)	0.483 (12.27)	1.531 (38.89)	1.340 (34.04)
0.237 (6.02)	0.207 (5.26)	0.562 (14.27)	0.492 (12.50)	1.562 (39.68)	1.367 (34.72)
0.250 (6.35)	0.219 (5.56)	0.593 (15.06)	0.519 (13.18)	1.593 (40.46)	1.394 (35.41)
0.258 (6.55)	0.226 (5.74)	0.600 (15.24)	0.525 (13.34)	1.750 (44.45)	1.531 (38.89)
0.276 (7.01)	0.242 (6.15)	0.625 (15.88)	0.547 (13.89)	1.781 (45.24)	1.558 (39.57)
0.277 (7.04)	0.242 (6.15)	0.656 (16.66)	0.574 (14.58)	1.812 (46.03)	1.586 (40.28)
0.279 (7.09)	0.244 (6.20)	0.674 (17.12)	0.590 (14.99)	1.968 (49.99)	1.722 (43.74)
0.280 (7.11)	0.245 (6.22)	0.687 (17.45)	0.601 (15.27)	2.062 (52.38)	1.804 (45.82)
0.281 (7.14)	0.246 (6.25)	0.719 (18.24)	0.629 (15.98)	2.343 (59.51)	2.050 (52.07)

NOTE 1 — The following equation, upon which this table is based, is used to derive the minimum permissible wall thickness values from the specified wall thickness values, with the calculated values rounded to three decimal places in accordance with the rounding method of Practice E 29:

$$t_m \times 0.875 = t$$

where:

t_m = minimum permissible wall thickness, in.
 t = specified wall thickness, in.

NOTE 2 — This table is a master table covering wall thicknesses available in the purchase of different classifications of pipe, but it is not meant to imply that all of the walls listed therein are obtainable under this specification.

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SPECIFICATION FOR ELECTRIC-RESISTANCE-WELDED CARBON STEEL AND CARBON-MANGANESE STEEL BOILER AND SUPERHEATER TUBES



SA-178/SA-178M



(Identical with ASTM Specification A 178/A 178M-95.)

1. Scope

1.1 This specification covers minimum-wall-thickness, electric-resistance-welded tubes made of carbon steel and carbon-manganese steel intended for use as boiler tubes, boiler flues, superheater flues, and safe ends.

NOTE 1 — Type C and D tubes are not suitable for safe-ending for forge welding.

1.2 The tubing sizes and thicknesses usually furnished to this specification are $\frac{1}{2}$ to 5 in. [12.7 to 127 mm] in outside diameter and 0.035 to 0.320 in. [0.9 to 9.1 mm], inclusive, in minimum wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.4 When these products are to be used in applications conforming to ISO Recommendations for Boiler Construction, the requirements of Specification A 520 shall supplement and supersede the requirements of this specification.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

2. Referenced Documents

2.1 ASTM Standards:

- A 226/A 226M Specification for Electric-Resistance-Welded Carbon Steel Boiler and Superheater Tubes for High-Pressure Service
- A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes
- A 520 Specification for Supplementary Requirements for Seamless and Electric-Resistance-Welded Carbon Steel Tubular Products for High-Temperature Service Conforming to ISO Recommendations for Boiler Construction.
- E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing
- E 273 Practice for Ultrasonic Examination of Longitudinal Welded Pipe and Tubing

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

- 3.1.1** Quantity (feet, metres, or number of lengths),
- 3.1.2** Name of material (electric-resistance-welded tubes),
- 3.1.3** Grade (A, C, or D, Table 1),
- 3.1.4** Size (outside diameter and minimum wall thickness),
- 3.1.5** Length (specific or random),
- 3.1.6** Optional requirements (product analysis, Section 7; crush test, Section 10; hydrostatic or nondestructive electric test, 11.6),
- 3.1.7** Test report required (Certification Section of Specification A 450/A 450M),
- 3.1.8** Specification, and designation,

3.1.9 Individual supplementary requirements, if required, and

3.1.10 Special requirements.

4. Manufacture

4.1 The steel for Grade D shall be killed.

4.2 Tubes shall be made by electric-resistance welding.

5. Heat Treatment

5.1 After welding, all tubes shall be heat treated at a temperature of 1650°F [900°C] or higher and followed by cooling in air or in the cooling chamber of a controlled-atmosphere furnace. Cold-drawn tubes shall be heat treated after the final cold-draw pass at a temperature of 1200° [650°C] or higher.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

6.2 When a grade is ordered under this specification, supplying an alloy grade that specifically requires the addition of any element other than those listed in Table 1 is not permitted.

7. Product Analysis

7.1 When requested on the purchase order, a product analysis shall be made by the manufacturer or supplier from one tube per 100 pieces for sizes over 3 in. [76.2 mm] and one tube per 250 pieces for sizes 3 in. [76.2 mm] and under; or when tubes are identified by heat, one tube per heat shall be analyzed. The chemical composition thus determined shall conform to the requirements specified.

7.2 If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock or tubes shall be made. Both retests, for the elements in question, shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (Note 2) shall be rejected or, at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes which do not meet the requirements of the specifications shall be rejected.

NOTE 2 — A lot consists of 250 tubes for sizes 3 in. [76.2 mm] and under and of 100 tubes for sizes over 3 in. [76.2 mm], prior to cutting to length.

8. General Requirements

8.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M unless otherwise provided herein.

9. Tensile Requirements

9.1 Grade C and D tubes shall conform to the requirements as to tensile properties prescribed in Table 2.

NOTE 3: *Explanatory Note* — For purposes of design the following tensile properties may be assumed for Grade A tubes:

Tensile strength, min, ksi [MPa]	47 [325]
Yield Strength, min, ksi [MPa]	26 [180]
Elongation in 2 in. or 50 mm, min, %	35

10. Crush Test

10.1 When required by the purchaser, crushing tests shall be made on sections of tube 2½ in. [63 mm] in length which shall stand crushing longitudinally without cracking, splitting, or opening at the weld, as follows:

Wall Thickness of Tubes, in. [mm]	Height of Crushed Section, in. [mm]	
	Grade A Tubes	Grade C and D Tubes
0.135 [3.43] and under	¾ [19] or until outside folds are in contact	Crush tests not required
Over 0.135 [3.43]	1¼ [32]	...

10.2 Table 3 gives the computed minimum elongation values for each 1/32 in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined by the following equation:

$$E = 48t + 15.00 \quad [E = 1.87t + 15.00]$$

where:

E = elongation in 2 in. or 50 mm, %, and,
 t = actual thickness of specimen, in. [mm].

10.3 For tubing less than 1 in. [25.4 mm] in outside diameter, the length of the specimen shall be 2½ times the outside diameter of the tube. Slight surface checks shall not be cause for rejection.

11. Mechanical Tests Required

11.1 Flattening Test:

11.1.1 For Grade A, one flattening test shall be made on specimens from each of two tubes from each lot (Note 2)

or fraction thereof, and from each 2000 ft [600 m] or fraction thereof of safe-end material.

11.1.2 For Grades C and D, one flattening test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof.

11.2 Flange Test:

11.2.1 For Grade A, one flange test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof, and from each 2000 ft [600 m] or fraction thereof of safe-end material.

11.2.2 For Grades C and D, one flange test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof. The width of the flange shall not be less than 75% of that specified in Specification A 450/A 450M.

11.3 Crush Test — For Grade A, when required by the purchaser, one crush test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof, and from each 2000 ft [600 m] or fraction thereof of safe-end material.

11.4 Tension Test — For Grades C and D, one tension test shall be made on specimens from each of two tubes from each lot. The term *lot* for tension test requirements applies to all tubes prior to cutting, of the same nominal diameter and wall thickness, which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace, at the same temperature, time at heat, and furnace speed.

11.5 Reverse Flattening Test — One reverse flattening test shall be made on each 1500 ft [450 m] of finished tubing.

11.6 Hydrostatic or Nondestructive Electric Test — Each tube shall be subjected to either the hydrostatic or the nondestructive electric test. The purchaser may specify which test is to be used.

12. Forming Operations

12.1 When inserted in the boiler, tubes shall withstand expanding and beading without showing cracks or flaws, or opening at the weld. When properly manipulated, superheater tubes shall withstand all forging, welding, and bending operations necessary for application without developing defects.

13. Product Marking

13.1 In addition to the marking prescribed in Specification A 450/A 450M, the letters “ERW” shall be legibly stenciled on each tube, or marked on a tag attached to the bundle or box in which the tubes are shipped.

13.2 The manufacturer’s name or symbol may be placed permanently on each tube by rolling or light stamping before normalizing. If a single stamp is placed on the tube by hand, this mark should not be less than 8 in. [200 mm] from one end of the tube.

14. Keywords

14.1 boiler tube; resistance welded steel tube; steel tube, carbon; welded steel tube

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %		
	Grade A, Low-Carbon Steel	Grade C, Medium- Carbon Steel	Grade D, Carbon-Manganese Steel
Carbon	0.06–0.18	0.35 max	0.27 max
Manganese	0.27–0.63	0.80 max	1.00–1.50
Phosphorus, max	0.035	0.035	0.030
Sulfur, max	0.035	0.035	0.015
Silicon	. . .	. . .	0.10 min

TABLE 2
TENSILE REQUIREMENTS

	Grade C	Grade D
Tensile strength, min, ksi [MPa]	60 [415]	70 [485]
Yield strength, min, ksi [MPa]	37 [255]	40 [275]
Elongation in 2 in. or 50 mm, min, %	30	30
For longitudinal strip tests a deduction for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{5}{16}$ in. [8 mm] from the basic minimum elongation of the following percentage points shall be made.	1.50 ^A	1.50 ^A

^A See Table 3 for the computed minimum values:

TABLE 3
MINIMUM ELONGATION VALUES

Wall Thickness		Elongation in 2 in. or 50 mm, min, % ^A
in.	mm	
$\frac{5}{16}$ (0.312)	8	30
$\frac{9}{32}$ (0.281)	7.2	29
$\frac{1}{4}$ (0.250)	6.4	27
$\frac{7}{32}$ (0.219)	5.6	26
$\frac{3}{16}$ (0.188)	4.8	24
$\frac{5}{32}$ (0.156)	4	22
$\frac{1}{8}$ (0.125)	3.2	21
$\frac{3}{32}$ (0.094)	2.4	20
$\frac{1}{16}$ (0.062)	1.6	18

^A Calculated elongation requirements shall be rounded to the nearest whole number.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements may become a part of the specification when specified in the inquiry or invitation to bid, and production order or contract. These requirements shall not be considered, unless specified in the order and the necessary tests shall be made at the mill.

S1. Additional Testing of Welded Tubing for ASME Requirements

S1.1 The weld seam of each tube shall be subjected to an ultrasonic inspection employing Practices E 273 or E 213 with the rejection criteria referenced in Specification A 450/A 450M.

S1.2 If Practice E 273 is employed, a 100% volumetric inspection of the entire length of each tube shall also be performed using one of the nondestructive electric tests

permitted by Specification A 450/A 450M.

S1.3 The test methods described in the supplement may not be capable of inspecting the end portions of tubes. This condition is referred to as end effect. This portion, as determined by the manufacturer, shall be removed and discarded.

S1.4 In addition to the marking prescribed in Specification A 450/A 450M, “S1” shall be added after the grade designation.

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SPECIFICATION FOR SEAMLESS COLD-DRAWN LOW-CARBON STEEL HEAT-EXCHANGER AND CONDENSER TUBES



SA-179/SA-179M



[Identical with ASTM Specification A 179/A 179M-90a(R05).]

1. Scope

1.1 This specification covers minimum-wall-thickness, seamless cold-drawn low-carbon steel tubes for tubular heat exchangers, condensers, and similar heat transfer apparatus.

1.2 This specification covers tubes $\frac{1}{8}$ to 3 in. [3.2 to 76.2 mm], inclusive, in outside diameter.

NOTE 1 — Tubing smaller in outside diameter and having a thinner wall than indicated in this specification is available. Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in outside diameter or with a wall thickness under 0.015 in. [0.4 mm].

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

2. Referenced Document

2.1 ASTM Standard:

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

3. General Requirements

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

4.1.1 Quantity (feet, metres, or number of lengths), (10)

4.1.2 Name of material (seamless tubes),

4.1.3 Manufacture (cold-drawn),

4.1.4 Size (outside diameter and minimum wall thickness),

4.1.5 Length (specific or random),

4.1.6 Optional requirements (product analysis, Section 9, flange test, 11.3),

4.1.7 Test report required (Certification Section of Specification A 450/A 450M),

4.1.8 Specification number, and

4.1.9 Special requirements.

5. Manufacture

5.1 Tubes shall be made by the seamless process and shall be cold drawn.

6. Heat Treatment

6.1 Tubes shall be heat treated after the final cold draw pass at a temperature of 1200°F [650°C] or higher.

7. Surface Condition

7.1 Finished tubes shall be free of scale. A slight amount of oxidation will not be considered as scale.

8. Chemical Composition

8.1 The steel shall conform to the following requirements as to chemical composition:

Carbon, %	0.06–0.18
Manganese, %	0.27–0.63
Phosphorus, max, %	0.035
Sulfur, max, %	0.035

8.2 Supplying an alloy grade that specifically requires the addition of any element other than those listed in 8.1 is not permitted.

9. Product Analysis

9.1 When requested on the purchase order, a product analysis shall be made by the supplier from one tube per 250 pieces or when tubes are identified by heat, one tube per heat shall be analyzed. The chemical composition thus determined shall conform to the requirements specified.

9.2 If the original test for product analysis fails, retests of two additional billets or tubes shall be made. Both retests, for the elements in question shall meet the requirements of this specification; otherwise all remaining material in the heat or lot (Note 2) shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes which do not meet the requirements of the specification shall be rejected.

NOTE 2 — A lot consists of 250 tubes.

10. Hardness Requirements

10.1 The tube shall have a hardness number not exceeding 72 HRB.

11. Mechanical Tests Required

11.1 Flattening Test — One flattening test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof.

11.2 Flaring Test — One flaring test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof.

11.3 Flange Test — When specified as a substitute for the flaring test, for tubes having a wall thickness (actual mean wall) less than 10% of the outside diameter, one test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof. For tubes other than specified above, the flange test shall not be required.

11.4 Hardness Test — Rockwell hardness tests shall be made on specimens from two tubes from each lot. The term *lot* applies to all tubes, prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

11.5 Hydrostatic Test — Each tube shall be subjected to the hydrostatic test, or instead of this test, a nondestructive electric test may be used when specified by the purchaser.

12. Product Marking

12.1 In addition to the marking prescribed in Specification A 450/A 450M, the marking shall include the name and order number of the purchaser.

EXPLANATORY NOTE

NOTE — For purposes of design, the following tensile properties may be assumed:

Tensile strength, min, ksi [MPa]	47 [325]
Yield strength, min, ksi [MPa]	26 [180]
Elongation in 2 in. or 50 mm, min, %	35

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SPECIFICATION FOR CARBON STEEL FORGINGS, FOR GENERAL-PURPOSE PIPING



SA-181/SA-181M



(Identical with ASTM Specification A 181/A 181M-06)

1. Scope

1.1 This specification covers nonstandard as-forged fittings, valve components, and parts for general service. Forgings made to this specification are limited to a maximum weight of 10 000 lb [4540 kg]. Larger forgings may be ordered to Specification A 266/A 266M.

1.2 Two classes of material are covered, designated as Classes 60 and 70, respectively, and are classified in accordance with their mechanical properties as specified in 6.1.

1.3 This specification is expressed in both inch-pound units and SI units. However, unless the order specifies the applicable “M” specification designation (SI units), the material shall be furnished to inch-pound units.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

- 2.1 ASTM Standards:**
 A 266/A 266M Specification for Carbon Steel Forgings for Pressure Vessel Components
 A 788/A 788M Specification for Steel Forgings, General Requirements
 A 961/A 961M Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications

3. General Requirements and Ordering Information

3.1 Product furnished to this specification shall conform to the requirements of Specification A 961/A 961M,

including any supplementary requirements that are indicated in the purchase order. Failure to comply with the requirements of Specification A 961/A 961M constitutes non-conformance with this specification.

3.2 It is the purchaser’s responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. Examples of such information include but are not limited to the ordering information in Specification A 961/A 961M and the following:

3.2.1 Supplementary requirements, and

3.2.2 Additional requirements (See 4.3, 9.1, 10.2, 12.1, and 12.2).

3.3 If the requirements of this specification are in conflict with the requirements of Specification A 961/A 961M, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 Except for flanges of all types, hollow, cylindrically shaped parts may be machined from hot-rolled or forged bar, provided that the axial length of the part is approximately parallel to the metal flow lines of the stock. Other parts, excluding flanges of all types, up to and including NPS 4 may be machined from hot-rolled or forged bar. Elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

4.2 Except as permitted in 4.1, the finished product shall be a forging as defined in the Terminology section (exclusively) of Specification A 788/A 788M.

4.3 When specified in the order, the manufacturer shall submit for approval of the purchaser a sketch showing the shape of the rough forging before machining.

4.4 Forgings shall be protected against sudden or too rapid cooling from the rolling or forging while passing through the critical range.

4.5 Heat treatment is neither required nor prohibited, but when applied, heat treatment shall consist of tempering, annealing, normalizing, or normalizing and tempering.

5. Chemical Composition

5.1 An analysis of each heat shall be made by the manufacturer to determine the percentages of the elements specified in Table 1. The chemical composition thus determined shall conform to the requirements in Table 1.

6. Mechanical Properties

6.1 The material shall conform to the requirements as to tensile properties prescribed in Table 2.

7. Number of Tests

7.1 One tension test shall be made from each heat.

7.2 If any test specimen is defectively machined, it may be discarded and another specimen substituted.

8. Retests

8.1 When one or more representative test specimens do not conform to specification requirements for the tested characteristic, only a single retest for each nonconforming characteristic may be performed to establish product acceptability. Retests shall be performed on twice the number of representative specimens that were originally nonconforming. When any retest specimen does not conform to specification requirements for the characteristic in question, the lot represented by that specimen shall be rejected, heat-treated or reheat-treated in accordance with 4.5, and tested in accordance with Sections 6 and 7.

9. Reports of Testing

9.1 Upon request of the purchaser in the contract or order, a report of the test results and chemical analyses shall be furnished. The specification designation included on reports of testing shall include year of issue and revision letter, if any.

10. Repair by Welding

10.1 Repair welding, by the manufacturer, is permissible for parts made to dimensional standards such as those of ANSI or equivalent standards.

10.2 Prior approval of the purchaser shall be required to weld repair special parts made to the purchaser's requirements.

10.3 The composition of the weld deposits shall be similar to the base metal and in accordance with the procedure qualification for the applicable material. Welding shall be accomplished with a weld procedure designed to produce low hydrogen in the weldment. Short-circuit gas metal arc welding is permissible only with the approval of the purchaser.

11. Marking of Forgings

11.1 Identification marks consisting of the manufacturer's symbol or name, designation of service rating, Specification number, class, and size shall be legibly forged or stamped on each forging, and in such a position as not to injure the usefulness of the forgings.

11.2 Bar Coding — In addition to the requirements in 11.1, bar coding is acceptable as a supplementary identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts the bar code may be applied to the box or a substantially applied tag.

12. Certificate of Compliance

12.1 When specified in the purchase order or contract, a producer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. The specification designation included on certificates of compliance shall include year of issue and revision letter, if any.

12.2 When specified in the purchase order or contract, a report of the test results shall be furnished.

13. Keywords

13.1 pipe fittings, steel; piping applications; pressure containing parts; steel forgings, carbon; steel valves

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, % Classes 60 and 70
Carbon, max.	0.35
Manganese, max.	1.10 ⁴
Phosphorus, max.	0.05
Silicon	0.10–0.35
Sulfur, max.	0.05

⁴ Manganese may be increased to 1.35% max. provided the carbon is reduced 0.01% for each 0.06% increase in manganese over the limit shown in the table.

TABLE 2
TENSILE REQUIREMENTS

	Class 60	Class 70
Tensile strength, min., ksi [MPa]	60 [415]	70 [485]
Yield strength, ⁴ min., ksi [MPa]	30 [205]	36 [250]
Elongation in 2 in. [50 mm], min., %	22	18
Reduction of area, min., %	35	24

⁴ Determined by either the 0.2% offset method or the 0.5% extension-under-load method.

SUPPLEMENTARY REQUIREMENTS

S1. Carbon Equivalent

S1.1 The maximum carbon equivalent based on heat analysis shall be as follows:

Class	Maximum Carbon Equivalent Value	
	Maximum Section Thickness Less Than or Equal to 2 in.	Maximum Section Thickness Greater Than 2 in.
60	0.45	0.46
70	0.47	0.48

S1.2 Determine the carbon equivalent (CE) as follows:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S1.3 A lower maximum carbon equivalent may be agreed upon between the supplier and the purchaser.

S1.4 When this Supplementary Requirement is invoked, all elements in the carbon equivalent formula shall be analyzed and the amounts reported.

SPECIFICATION FOR FORGED OR ROLLED ALLOY AND STAINLESS STEEL PIPE FLANGES, FORGED FITTINGS, AND VALVES AND PARTS FOR HIGH- TEMPERATURE SERVICE



SA-182/SA-182M

(Identical with ASTM Specification A 182/A 182M-07 except for the inclusion of Grade F316Ti in 6.3.1.)

1. Scope

1.1 This specification covers forged low alloy and stainless steel piping components for use in pressure systems. Included are flanges, fittings, valves, and similar parts to specified dimensions or to dimensional standards, such as the ASME specifications that are referenced in Section 2.

1.2 For bars and products machined directly from bar, refer to Specifications A 479/A 479M and A 739 for the similar grades available in those specifications. Products made to this specification are limited to a maximum weight of 10 000 lb [4540 kg]. For larger products and products for other applications, refer to Specifications A 336/A 336M and A 965/A 965M for the similar ferritic and austenitic grades, respectively, available in those specifications.

1.3 Several grades of low alloy steels and ferritic, martensitic, austenitic, and ferritic-austenitic stainless steels are included in this specification. Selection will depend upon design and service requirements.

1.4 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable “M” specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore,

each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 In addition to the referenced documents listed in Specification A 961/A 961M, the following list of standards apply to this specification.

2.2 ASTM Standards:

- A 234/A 234M Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service
- A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
- A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings
- A 336/A 336M Specification for Alloy Steel Forgings for Pressure and High-Temperature Parts
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 403/A 403M Specification for Wrought Austenitic Stainless Steel Piping Fittings
- A 479/A 479M Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels
- A 484/A 484M Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings
- A 739 Specification for Steel Bars, Alloy, Hot-Wrought, for Elevated Temperature or Pressure-Containing Parts, or Both
- A 763 Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels
- A 788/A 788M Specification for Steel Forgings, General Requirements

A 961/A 961M Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications

A 965/A 965M Specification for Steel Forgings, Austenitic, for Pressure and High Temperature Parts

E 112 Text Methods for Determining Average Grain Size

E 165 Test Method for Liquid Penetrant Examination

E 340 Test Method for Macroetching Metals and Alloys

2.3 ASME Boiler and Pressure Vessel Codes:

Section IX Welding Qualifications

SFA-5.4 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes

SFA-5.5 Specification for Low-Alloy Steel Covered Arc-Welding Electrodes

SFA-5.9 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes

SFA-5.11 Specification for Nickel and Nickel-Alloy Covered Welding Electrodes

3. Ordering Information

3.1 It is the purchaser's responsibility to specify in the purchase order information necessary to purchase the needed material. In addition to the ordering information guidelines in Specification A 961/A 961M, orders should include the following information:

3.1.1 Additional requirements (see 6.2.1, Table 2 footnotes, 8.3, and 17.2), and

3.1.2 Requirement, if any, that manufacturer shall submit drawings for approval showing the shape of the rough forging before machining and the exact location of test specimen material (see 8.3.1).

4. General Requirements

4.1 Product furnished to this specification shall conform to the requirements of Specification A 961/A 961M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 961/A 961M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 961/A 961M, this specification shall prevail.

5. Manufacture

5.1 The low-alloy ferritic steels shall be made by the open-hearth, electric-furnace, or basic-oxygen process with the option of separate degassing and refining processes in each case.

5.2 The stainless steels shall be melted by one of the following processes: (a) electric-furnace (with the option of separate degassing and refining processes); (b) vacuum-furnace; or (c) one of the former followed by vacuum or electroslag-consumable remelting. Grade FXM-27Cb may be produced by electron-beam melting.

5.3 A sufficient discard shall be made to secure freedom from injurious piping and undue segregation.

5.4 The material shall be forged as close as practicable to the specified shape and size. Except for flanges of any type, forged or rolled bar may be used without additional hot working for small cylindrically shaped parts within the limits defined by Specification A 234/A 234M for low alloy steels and martensitic stainless steels and Specification A 403/A 403M for austenitic and ferritic-austenitic stainless steels. Elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

5.5 Except as provided for in 5.4, the finished product shall be a forging as defined in the Terminology section of Specification A 788.

6. Heat Treatment

6.1 After hot working, forgings shall be cooled to a temperature below 1000°F [538°C] prior to heat treating in accordance with the requirements of Table 1.

6.2 Low Alloy Steels and Ferritic and Martensitic Stainless Steels — The low alloy steels and ferritic and martensitic stainless steels shall be heat treated in accordance with the requirements of 6.1 and Table 1.

6.2.1 Liquid Quenching — When agreed to by the purchaser, liquid quenching followed by tempering shall be permitted provided the temperatures in Table 1 for each grade are utilized.

6.2.1.1 Marking — Parts that are liquid quenched and tempered shall be marked "QT."

6.2.2 Alternatively, Grade F 1, F 2, and F 12, Classes 1 and 2 may be given a heat treatment of 1200°F [650°C] minimum after final hot or cold forming.

6.3 Austenitic and Ferritic-Austenitic Stainless Steels — The austenitic and ferritic-austenitic stainless steels shall be heat treated in accordance with the requirements of 6.1 and Table 1.

6.3.1 Alternatively, immediately following hot working, while the temperature of the forging is not less than the minimum solution annealing temperature specified in Table 1, forgings made from austenitic grades (except grades F 304H, F 309H, F 310, F 310H, F 316H, F 316Ti, F 321, F 321H, F 347, F 347H, F 348, F 348H, F 45, and F 56) may be individually rapidly quenched in accordance with the requirements of Table 1.

6.3.2 See Supplementary Requirement S8 if a particular heat treatment method is to be employed.

6.4 Time of Heat Treatment — Heat treatment of forgings may be performed before machining.

6.5 Forged or Rolled Bar — Forged or rolled austenitic stainless bar from which small cylindrically shaped parts are to be machined, as permitted by 5.4, and the parts machined from such bar, without heat treatment after machining, shall be furnished to the annealing requirements of Specification A 479/A 479M or this specification, with subsequent light cold drawing and straightening permitted (see Supplementary Requirement S3 if annealing must be the final operation).

7. Chemical Composition

7.1 A chemical heat analysis in accordance with Specification A 961/A 961M shall be made and conform to the chemical composition prescribed in Table 2.

7.2 Grades to which lead, selenium, or other elements are added for the purpose of rendering the material free-machining shall not be used.

7.3 Starting material produced to a specification that specifically requires the addition of any element beyond those listed in Table 2 for the applicable grade of material is not permitted.

7.4 Steel grades covered in this specification shall not contain an unspecified element, other than nitrogen in stainless steels, for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element having a required minimum content. For this requirement, a grade is defined as an alloy described individually and identified by its own UNS designation or Grade designation and identification symbol in Table 2.

7.5 Product Analysis — The purchaser may make a product analysis on products supplied to this specification in accordance with Specification A 961/A 961M.

8. Mechanical Properties

8.1 The material shall conform to the requirements as to mechanical properties for the grade ordered as listed in Table 3.

8.2 Mechanical test specimens shall be obtained from production forgings, or from separately forged test blanks prepared from the stock used to make the finished product. In either case, mechanical test specimens shall not be removed until after all heat treatment is complete. If repair welding is required, test specimens shall not be removed until after post-weld heat treatment is complete, except

for ferritic grades when the post-weld heat treatment is conducted at least 50°F [30°C] below the actual tempering temperature. When test blanks are used, they shall receive approximately the same working as the finished product. The test blanks shall be heat treated with the finished product and shall approximate the maximum cross section of the forgings they represent.

8.3 For normalized and tempered, or quenched and tempered forgings, the central axis of the test specimen shall correspond to the $\frac{1}{4} T$ plane or deeper position where T is the maximum heat-treated thickness of the represented forging. In addition, for quenched and tempered forgings, the mid-length of the test specimen shall be at least T from any second heat-treated surface. When the section thickness does not permit this positioning, the test specimen shall be positioned as near as possible to the prescribed location, as agreed to by the purchaser and the supplier.

8.3.1 With prior purchase approval, the test specimen for ferritic steel forgings may be taken at a depth (t) corresponding to the distance from the area of significant stress to the nearest heat-treated surface and at least twice this distance ($2t$) from any second surface. However, the test depth shall not be nearer to one treated surface than $\frac{3}{4}$ in. [19 mm] and to the second treated surface than $1\frac{1}{2}$ in. [38 mm]. This method of test specimen location would normally apply to contour-forged parts, or parts with thick cross-sectional areas where $\frac{1}{4} T \times T$ testing (see 8.3) is not practical. Sketches showing the exact test locations shall be approved by the purchaser when this method is used.

8.3.2 Metal Buffers — The required distances from heat-treated surfaces may be obtained with metal buffers instead of integral extensions. Buffer material may be carbon or low-alloy steel, and shall be joined to the forging with a partial penetration weld that seals the buffered surface. Specimens shall be located at $\frac{1}{2}$ in. [13 mm] minimum from the buffered surface of the forging. Buffers shall be removed and the welded areas subjected to magnetic particle test to ensure freedom from cracks unless the welded areas are completely removed by subsequent machining.

8.4 For annealed low alloy steels, ferritic stainless steels, and martensitic stainless steels, and also for austenitic and ferritic-austenitic stainless steels, the test specimen may be taken from any convenient location.

8.5 Tension Tests:

8.5.1 Low Alloy Steels and Ferritic and Martensitic Stainless Steels — One tension test shall be made for each heat in each heat treatment charge.

8.5.1.1 When the heat-treating cycles are the same and the furnaces (either batch or continuous type) are controlled within $\pm 25^\circ\text{F}$ [$\pm 14^\circ\text{C}$] and equipped with recording pyrometers so that complete records of heat treatment are

available, then only one tension test from each heat of each forging type (see Note 1) and section size is required, instead of one test from each heat in each heat-treatment charge.

NOTE 1 — “Type” in this case is used to describe the forging shape such as a flange, ell, tee, and the like.

8.5.2 Austenitic and Ferritic-Austenitic Stainless Steel Grades — One tension test shall be made for each heat.

8.5.2.1 When heat treated in accordance with 6.1, the test blank or forging used to provide the test specimen shall be heat treated with a finished forged product.

8.5.2.2 When the alternative method in 6.3.1 is used, the test blank or forging used to provide the test specimen shall be forged and quenched under the same processing conditions as the forgings they represent.

8.5.3 Testing shall be performed in accordance with Test Methods and Definitions A 370 using the largest feasible of the round specimens. The gage length for measuring elongation shall be four times the diameter of the test section.

8.6 Hardness Tests:

8.6.1 Except when only one forging is produced, a minimum of two pieces per batch or continuous run as defined in 8.6.2 shall be hardness tested in accordance with Test Methods and Definitions A 370 to ensure that the forgings are within the hardness limits given for each grade in Table 3. The purchaser may verify that the requirement has been met by testing at any location on the forging provided such testing does not render the forging useless.

8.6.2 When the reduced number of tension tests permitted by 8.5.1.1 is applied, additional hardness tests shall be made on forgings or samples, as defined in 8.2, scattered throughout the load (see Note 2). At least eight samples shall be checked from each batch load, and at least one check per hour shall be made from a continuous run. When the furnace batch is less than eight forgings, each forging shall be checked. If any check falls outside the prescribed limits, the entire lot of forgings shall be reheat treated and the requirements of 8.5.1 shall apply.

NOTE 2 — The tension test required in 8.5.1 is used to determine material capability and conformance in addition to verifying the adequacy of the heat-treatment cycle. Additional hardness tests in accordance with 8.6.2 are required when 8.5.1.1 is applied to ensure the prescribed heat-treating cycle and uniformity throughout the load.

8.7 Notch Toughness Requirements — Grades F 3V, F 3VCb, and F 22V.

8.7.1 Impact test specimens shall be Charpy V-notch Type, as shown in Fig. 11a of Test Methods and Definitions A 370. The usage of subsize specimens due to material limitations must have prior purchaser approval.

8.7.2 The Charpy V-notch test specimens shall be obtained as required for tension tests in 8.2, 8.3 and 8.5. One set of three Charpy V-notch specimens shall be taken from each tensile specimen location.

8.7.3 The longitudinal axis and mid-length of impact specimen shall be located similarly to the longitudinal axis of the tension test specimens. The axis of the notch shall be normal to the nearest heat-treated surface of the forging.

8.7.4 The Charpy V-notch tests shall meet a minimum energy absorption value of 40 ft-lbf [54 J] average of three specimens. One specimen only in one set may be below 40 ft-lbf [54 J], and it shall meet a minimum value of 35 ft-lbf [48 J].

8.7.5 The impact test temperature shall be 0°F [−18°C].

9. Grain Size for Austenitic Grades

9.1 All H grades and grade F 63 shall be tested for average grain size by Test Methods E 112.

9.1.1 Grades F 304H, F 309H, F 310H, and F 316H shall have a grain size of ASTM No. 6 or coarser.

9.1.2 Grades F 321H, F 347H, and F 348H shall have a grain size of ASTM No. 7 or coarser.

9.1.3 Grade F 63 shall have a grain size of ASTM No. 3 or finer.

10. Corrosion Testing for Austenitic Grades

10.1 Corrosion testing is not required by this specification.

10.2 Austenitic grades shall be capable of meeting the intergranular corrosion test requirements described in Supplementary Requirement S4.

11. Retreatment

11.1 If the results of the mechanical tests do not conform to the requirements specified, the manufacturer may reheat treat the forgings and repeat the tests specified in Section 8.

12. Workmanship, Finish, and Appearance

12.1 Forgings shall conform to the requirements of Specification A 961/A 961M.

12.2 The forgings shall be free of scale, machining burrs which might hinder fit-up, and other injurious imperfections as defined herein. The forgings shall have a workmanlike finish, and machined surfaces (other than surfaces having special requirements) shall have a surface finish not to exceed 250 AA (arithmetic average) roughness height.

13. Repair by Welding

13.1 Weld repairs shall be permitted (see Supplementary Requirement S9 of Specification A 961/A 961M) at the discretion of the manufacturer with the following limitations and requirements:

13.1.1 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

13.1.2 The weld metal shall be deposited using the electrodes specified in Table 4 except as otherwise provided in Supplementary Requirement S5. The electrodes shall be purchased in accordance with ASME Specifications SFA-5.4, SFA-5.5, SFA-5.9, or SFA-5.11. The submerged arc process with neutral flux, the gas metal-arc process, the gas tungsten-arc process, and gas shielded processes using flux-core consumables, may be used.

13.1.3 Defects shall be completely removed prior to welding by chipping or grinding to sound metal as verified by magnetic-particle inspection in accordance with Test Method A 275/A 275M for the low alloy steels and ferritic, martensitic, or ferritic-austenitic stainless steels, or by liquid-penetrant inspection in accordance with Test Method E 165 for all grades.

13.1.4 After repair welding, the welded area shall be ground smooth to the original contour and shall be completely free of defects as verified by magnetic-particle or liquid-penetrant inspection, as applicable.

13.1.5 The preheat, interpass temperature, and post-weld heat treatment requirements given in Table 4 shall be met. Austenitic stainless steel forgings may be repair-welded without the post-weld heat treatment of Table 4, provided purchaser approval is obtained prior to repair.

13.1.6 Repair by welding shall not exceed 10% of the surface area of the forging nor $33\frac{1}{3}\%$ of the wall thickness of the finished forging or $\frac{3}{8}$ in. [9.5 mm], whichever is less, without prior approval of the purchaser.

13.1.7 When approval of the purchaser is obtained, the limitations set forth in 13.1.6 may be exceeded, but all other requirements of Section 13 shall apply.

13.1.8 No weld repairs are permitted for F 6a Classes 3 and 4.

13.1.9 Post-weld heat treatment times for F 36 are: for Class 1, up to 2 in. [50 mm] in thickness, 1 h per in. [25 mm], 15 minutes minimum, and over 2 in. [50 mm], 15 minutes for each additional in. of thickness or fraction thereof; for Class 2, 1 h per in. [25 mm], $\frac{1}{2}$ h minimum.

14. Inspection

14.1 Inspection provisions of Specification A 961/A 961M apply.

15. Rejection and Rehearing

15.1 The purchaser shall comply with the provisions of Specification A 961/A 961M.

16. Certification

16.1 In addition to the certification requirements of Specification A 961/A 961M, test reports shall be furnished to the purchaser or his representative.

16.2 Test reports shall include certification that all requirements of this specification have been met. The specification designation included on test reports shall include year of issue and revision letter, if any. The manufacturer shall provide the following where applicable:

16.2.1 Type heat treatment, Section 6,

16.2.2 Product analysis results, Section 8 of Specification A 961/A 961M,

16.2.3 Tensile property results, Section 8 (Table 3), report the yield strength and ultimate strength, in ksi [MPa], elongation and reduction in area, in percent,

16.2.4 Chemical analysis results, Section 7 (Table 2),

16.2.5 Hardness results, Section 8 (Table 3),

16.2.6 Grain size results, Section 9, and

16.2.7 Any supplementary testing required by the purchase order.

17. Product Marking

17.1 In addition to the marking requirements of Specification A 961/A 961M, the manufacturer's name (see Note 3) or symbol shall be permanently marked on each forging.

NOTE 3 — For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification, and the results have been determined to meet the requirements of this specification.

17.1.1 Quenched and tempered low alloy or martensitic stainless forgings shall be stamped with the letters "QT" following the specification designation.

17.1.2 Forgings repaired by welding shall be marked with the letter "W" following the Specification designation. When repair-welded austenitic stainless steel forgings have not been postweld heat treated in accordance with Table 4, the letters "WNS" shall be marked following the specification designation.

17.1.3 When test reports are required, the markings shall consist of the manufacturer's symbol or name, the grade symbol, and such other markings as necessary to identify the part with the test report (17.1.1 and 17.1.2 shall apply).

17.1.4 Parts meeting all requirements for more than one class or grade may be marked with more than one class or grade designation such as F 304/F 304H, F 304/F 304L, and the like.

17.2 Bar Coding — In addition to the requirements in 17.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

18. Keywords

18.1 austenitic stainless steel; chromium alloy steel; chromium-molybdenum steel; ferritic/austenitic stainless steel; ferritic stainless steel; martensitic stainless steel; nickel alloy steel; notch toughness requirements; pipe fittings; piping applications; pressure containing parts; stainless steel fittings; stainless steel forgings; steel; steel flanges; steel forgings, alloy; steel valves; temperature service applications, elevated; temperature service applications, high; wrought material

TABLE 1
HEAT TREATING REQUIREMENTS

Grade	Heat Treat Type	Austenitizing/Solutioning Temperature, Min. or Range, °F (°C) ^A	Cooling Media	Quenching Cool Below °F (°C)	Tempering Temperature, Min. or Range, °F (°C)
Low Alloy Steels					
F 1	anneal	1650 [900]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1650 [900]	air cool	<i>B</i>	1150 [620]
F 2	anneal	1650 [900]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1650 [900]	air cool	<i>B</i>	1150 [620]
F 5, F 5a	anneal	1750 [955]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1750 [955]	air cool	<i>B</i>	1250 [675]
F 9	anneal	1750 [955]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1750 [955]	air cool	<i>B</i>	1250 [675]
F 10	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 91	normalize and temper	1900–1975 [1040–1080]	air cool	<i>B</i>	1350–1470 [730–800]
F 92	normalize and temper	1900–1975 [1040–1080]	air cool	<i>B</i>	1350 [730]
F 122	normalize and temper	1900–1975 [1040–1080]	air cool	<i>B</i>	1350–1470 [730–800]
F 911	normalize and temper	1900–1975 [1040–1080]	air cool or liquid	<i>B</i>	1365–1435 [740–780]
F 11, Classes 1, 2, and 3	anneal	1650 [900]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1650 [900]	air cool	<i>B</i>	1150 [620]
F 12, Classes 1 and 2	anneal	1650 [900]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1650 [900]	air cool	<i>B</i>	1150 [620]
F 21, F 3V, and F 3VCb	anneal	1750 [955]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1750 [955]	air cool	<i>B</i>	1250 [675]
F 22, Classes 1 and 3	anneal	1650 [900]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1650 [900]	air cool	<i>B</i>	1250 [675]
F 22V	normalize and temper or quench and temper	1650 [900]	air cool or liquid	<i>B</i>	1250 [675]
F 23	normalize and temper	1900–1875 [1040–1080]	air cool	<i>B</i>	1350–1470 [730–800]
F 24	normalize and temper	1800–1975 [980–1080]	air cool or liquid	<i>B</i>	1350–1470 [730–800]
FR	anneal	1750 [955]	furnace cool	<i>B</i>	<i>B</i>
	normalize	1750 [955]	air cool	<i>B</i>	<i>B</i>
	normalize and temper	1750 [955]	air cool	<i>B</i>	1250 [675]
F36, Class 1	normalize and temper	1650 [900]	air cool	<i>B</i>	1100 [595]
F36, Class 2	normalize and temper	1650 [900]	air cool	<i>B</i>	1100 [595]
	quench and temper	1650 [900]	accelerated air cool or liquid		1100 [595]
Martensitic Stainless Steels					
F 6a Class 1	anneal	not specified	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	not specified	air cool	400 [205]	1325 [725]
	temper	not required	<i>B</i>	<i>B</i>	1325 [725]
F 6a Class 2	anneal	not specified	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	not specified	air cool	400 [205]	1250 [675]
	temper	not required	<i>B</i>	<i>B</i>	1250 [675]
F 6a Class 3	anneal	not specified	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	not specified	air cool	400 [205]	1100 [595]
F 6a Class 4	anneal	not specified	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	not specified	air cool	400 [205]	1000 [540]
F 6b	anneal	1750 [955]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1750 [955]	air cool	400 [205]	1150 [620]
F 6NM	normalize and temper	1850 [1010]	air cool	200 [95]	1040–1120 [560–600]
Ferritic Stainless Steels					
F XM-27Cb	anneal	1850 [1010]	furnace cool	<i>B</i>	<i>B</i>
F 429	anneal	1850 [1010]	furnace cool	<i>B</i>	<i>B</i>
F 430	anneal	not specified	furnace cool	<i>B</i>	<i>B</i>

TABLE 1
HEAT TREATING REQUIREMENTS (CONT'D)

Grade	Heat Treat Type	Austenitizing/Solutioning Temperature, Min. or Range, °F (°C) ^A	Cooling Media	Quenching Cool Below °F (°C)	Tempering Temperature, Min. or Range, °F (°C)
Austenitic Stainless Steels					
F 304	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 304H	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 304L	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 304N	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 304LN	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 309H	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 310	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 310H	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 310MoLN	solution treat and quench	1900–2010 [1050–1100]	liquid	500 [260]	<i>B</i>
F 316	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 316H	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 316L	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 316N	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 316LN	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 316Ti	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 317	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 317L	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 347	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 347H	solution treat and quench	2000 [1095]	liquid	500 [260]	<i>B</i>
F 348	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 348H	solution treat and quench	2000 [1095]	liquid	500 [260]	<i>B</i>
F 321	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 321H	solution treat and quench	2000 [1095]	liquid	500 [260]	<i>B</i>
F XM-11	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F XM-19	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 20	solution treat and quench	1700–1850 [925–1010]	liquid	500 [260]	<i>B</i>
F 44	solution treat and quench	2100 [1150]	liquid	500 [260]	<i>B</i>
F 45	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 46	solution treat and quench	2010–2140 [1100–1140]	liquid	500 [260]	<i>B</i>
F 47	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 48	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 49	solution treat and quench	2050 [1120]	liquid	500 [260]	<i>B</i>
F 56	solution treat and quench	2050–2160 [1120–1180]	liquid	500 [260]	<i>B</i>
F 58	solution treat and quench	2085 [1140]	liquid	500 [260]	<i>B</i>
F 62	solution treat and quench	2025 [1105]	liquid	500 [260]	<i>B</i>
F 63	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 64	solution treat and quench	2010–2140 [1100–1170]	liquid	500 [260]	<i>B</i>
F 904L	solution treat and quench	1920–2100 [1050–1150]	liquid	500 [260]	<i>B</i>
Ferritic-Austenitic Stainless Steels					
F 50	solution treat and quench	1925 [1050]	liquid	500 [260]	<i>B</i>
F 51	solution treat and quench	1870 [1020]	liquid	500 [260]	<i>B</i>
F 52 ^C	...	...	liquid	500 [260]	<i>B</i>
F 53	solution treat and quench	1880 [1025]	liquid	500 [260]	<i>B</i>
F 54	solution treat and quench	1920–2060 [1050–1125]	liquid	500 [260]	<i>B</i>
F 55	solution treat and quench	2010–2085 [1100–1140]	liquid	500 [260]	<i>B</i>
F 57	solution treat and quench	1940 [1060]	liquid	175 [80]	<i>B</i>
F 59	solution treat and quench	1975–2050 [1080–1120]	liquid	500 [260]	<i>B</i>
F 60	solution treat and quench	1870 [1020]	liquid	500 [260]	<i>B</i>
F 61	solution treat and quench	1920–2060 [1050–1125]	liquid	500 [260]	<i>B</i>
F 65	solution treat and quench	1905–2100 [1040–1150]	liquid	500 [260]	<i>B</i>

^A Minimum unless temperature range is listed.

^B Not applicable.

^C Grade F 52 shall be solution treated at 1825 to 1875°F [995 to 1025°C] 30 min/in. of thickness and water quenched.

TABLE 2
CHEMICAL REQUIREMENTS^A

Identifi- cation Symbol	UNS Designa- tion	Grade	Composition, %											Tita- nium	Other Elements	
			Carbon	Man- gane- se	Phos- phorus	Sulfur	Silicon	Nickel	Chromium	Molyb- denum	Colum- bium					
Low Alloy Steels																
F 1	K12822	carbon-molybdenum	0.28	0.60–0.90	0.045	0.045	0.15–0.35	...	...	...	0.44–0.65	...	...	...	...	...
F 2 ^B	K12122	0.5% chromium, 0.5% molybdenum	0.05–0.21	0.30–0.80	0.040	0.040	0.10–0.60	...	...	0.50–0.81	0.44–0.65	...	...	...	...	...
F 5 ^C	K41545	4 to 6% chromium	0.15	0.30–0.60	0.030	0.030	0.50	0.50	4.0–6.0	0.44–0.65	...	...	...	...	...	...
F 5a ^C	K42544	4 to 6% chromium	0.25	0.60	0.040	0.040	0.50	0.50	4.0–6.0	0.44–0.65	...	...	...	...	...	...
F 9	K90941	9% chromium	0.15	0.30–0.60	0.030	0.030	0.50–1.00	...	...	8.0–10.0	0.90–1.10	...	...	...	...	...
F 10	S33100	20 nickel, 8 chromium	0.10–0.20	0.50–0.80	0.040	0.030	1.00–1.40	19.0–22.0	7.0–9.0	...	...	...	...	...	...	...
F 91	K90901	9% chromium, 1% molybdenum, 0.2% vanadium plus columbium and nitrogen	0.08–0.12	0.30–0.60	0.020	0.010	0.20–0.50	0.40	8.0–9.5	0.85–1.05	0.06–0.10	...	...	...	N 0.03–0.07 Al 0.02 ^D V 0.18–0.25 Ti 0.01 ^D	
F 92	...	9% chromium, 1.8% tungsten, 0.2% vanadium plus columbium	0.07–0.13	0.30–0.60	0.020	0.010	0.50	0.40	8.50–9.50	0.30–0.60	0.04–0.09	...	...	...	Zr 0.01 ^D V 0.15–0.25 N 0.030–0.070 Al 0.04 W 1.50–2.00 B 0.001–0.006 V 0.15–0.30	
F 122	K91271	11% chromium, 2% tungsten, 0.2% vanadium plus molybde- num, columbium copper, nickel, nitrogen, and boron	0.07–0.14	0.70	0.020	0.010	0.50	0.50	10.00–11.50	0.25–0.60	0.04–0.10	...	...	...	B0.005 N 0.0040–0.100 Al 0.02 ^D Cu 0.30–1.70 W 1.50–2.50 Ti 0.01 ^D Zr 0.01 ^D W 0.90–1.10 Al 0.02 ^D N 0.04–0.09 V 0.18–0.25 B 0.0003–0.006 Ti 0.01 ^D Zr 0.01 ^D	
F 911	...	9% chromium, 1% molybdenum, 0.2% vanadium plus columbium and nitrogen	0.09–0.13	0.30–0.60	0.020	0.010	0.10–0.50	0.40	8.5–9.5	0.90–1.10	0.060–0.10	...	...	...	...	...
F 11 Class 1	K11597	1.25% chromium, 0.5% molybdenum	0.05–0.15	0.30–0.60	0.030	0.030	0.50–1.00	...	1.00–1.50	0.44–0.65	...	...	...	...	...	...
F 11 Class 2	K11572	1.25% chromium, 0.5% molybdenum	0.10–0.20	0.30–0.80	0.040	0.040	0.50–1.00	...	1.00–1.50	0.44–0.65	...	...	...	...	...	...
F 11 Class 3	K11572	1.25% chromium, 0.5% molybdenum	0.10–0.20	0.30–0.80	0.040	0.040	0.50–1.00	...	1.00–1.50	0.44–0.65	...	...	...	...	...	...
F 12 Class 1	K11562	1% chromium, 0.5% molybdenum	0.05–0.15	0.30–0.60	0.045	0.045	0.50 max	...	0.80–1.25	0.44–0.65	...	...	...	...	...	...
F 12 Class 2	K11564	1% chromium, 0.5% molybdenum	0.10–0.20	0.30–0.80	0.040	0.040	0.10–0.60	...	0.80–1.25	0.44–0.65	...	...	...	...	...	...
F 21	K31545	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50 max	...	2.7–3.3	0.80–1.06	...	...	...	...	...	...
F 3V	K31830	3% chromium, 1% molybdenum, 0.25% vanadium plus boron and titanium	0.05–0.18	0.30–0.60	0.020	0.020	0.10	...	2.8–3.2	0.90–1.10	...	...	...	...	...	...
F 3VCb	K31390	3% chromium, 1% molybdenum, 0.25% vanadium plus boron, columbium, and titanium	0.10–0.15	0.30–0.60	0.020	0.010	0.10	0.25	2.7–3.3	0.90–1.10	0.015–0.070	0.015	...	...	...	...
F 22 Class 1	K21590	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50	...	2.00–2.50	0.87–1.13	...	...	...	...	...	...
F 22 Class 3	K21590	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50	...	2.00–2.50	0.87–1.13	...	...	...	...	...	...

TABLE 2
CHEMICAL REQUIREMENTS^A (CONT'D)

Identifi- cation Symbol	UNS Designa- tion	Grade	Composition, %										
			Carbon	Man- ganese	Phos- phorus	Sulfur	Silicon	Nickel	Chromium	Molyb- denum	Colum- bium	Tita- nium	Other Elements
Low Alloy Steels (Cont'd)													
F 22V	K31835	2.25% chromium, 1% molybdenum, 0.25% vanadium	0.11-0.15	0.30-0.60	0.015	0.010	0.10	0.25	2.00-2.50	0.90-1.10	0.07	0.030	Cu 0.20 V 0.25-0.35 B 0.002 Ca 0.015 ^E
F 23	K41650	2.25% chromium, 1.6% tungsten, 0.25% vanadium, plus molybde- num, columbium, and boron	0.04-0.10	0.10-0.60	0.030	0.010	0.50	...	1.90-2.60	0.05-0.30	0.02-0.08	...	V 0.20-0.30 B 0.0005-0.006 N 0.030 Al 0.030 W 1.45-1.75 V 0.20-0.30
F 24	K30736	2.25% chromium, 1% molybdenum, 0.25% vanadium plus titanium and boron	0.05-0.10	0.30-0.70	0.020	0.010	0.15-0.45	...	2.20-2.60	0.90-1.10	...	0.06-0.10 N 0.12 Al 0.020	B 0.0015-0.0070 Cu 0.75-1.25 N 0.020 Al 0.050 Cu 0.50-0.80 V 0.02
FR	K22035	2% nickel, 1% copper	0.20	0.40-1.06	0.045	0.050	...	1.60-2.24	...	...	...	...
F 36	K21001	1.15% nickel, 0.65% copper, molybdenum, and columbium	0.10-0.17	0.80-1.20	0.030	0.025	0.25-0.50	1.0-0.1.30	0.30	0.25-0.50	0.015-0.045	...	
Martensitic Stainless Steels													
F 6a	S41000	13% chromium 410 ^F	0.15	1.00	0.040	0.030	1.00	0.50	11.5-13.5	...	...	...	...
F 6b	S41026	13% chromium, 0.5% molybdenum	0.15	1.00	0.020	0.020	1.00	1.00-2.00	11.5-13.5	0.40-0.60	...	...	Cu 0.50
F 6NM	S41500	13% chromium, 4% nickel	0.05	0.50-1.00	0.030	0.030	0.60	3.5-5.5	11.5-14.0	0.50-1.00	...	...	...
Ferritic Stainless Steels													
F XM-27Cb ^G	S44627	27 chromium, 1 molybdenum XM-27 ^F	0.010	0.40	0.020	0.020	0.40	0.50	25.0-27.5	0.75-1.50	0.05-0.20	...	N 0.015 Cu 0.20
F 429	S42900	15 chromium 429 ^F	0.12	1.00	0.040	0.030	0.75	0.50	14.0-16.0	...	...	...	...
F 430	S43000	17 chromium 430 ^F	0.12	1.00	0.040	0.030	0.75	0.50	16.0-18.0	...	...	...	...
Austenitic Stainless Steels													
F 304 ^H	S30400	18 chromium, 8 nickel 304 ^F	0.08	2.00	0.045	0.030	1.00	8.0-11.0	18.0-20.0	...	...	...	...
F 304H	S30409	18 chromium, 8 nickel 304H ^F	0.04-0.10	2.00	0.045	0.030	1.00	8.0-11.0	18.0-20.0	...	...	...	...
F 304L ^H	S30403	18 chromium, 8 nickel, low carbon 304L ^F	0.030	2.00	0.045	0.030	1.00	8.0-13.0	18.0-20.0	...	...	...	...

TABLE 2
CHEMICAL REQUIREMENTS^A (CONT'D)

Identifi- cation Symbol	UNS Designa- tion	Grade	Composition, %										
			Carbon	Man- ganese	Phos- phorus	Sulfur	Silicon	Nickel	Chromium	Molyb- denum	Colum- bium	Tita- nium	Other Elements
Austenitic Stainless Steels (Cont'd)													
F 304N ^I	S30451	18 chromium, 8 nickel, modified with nitrogen 304N ^F	0.08	2.00	0.045	0.030	1.00	8.0–10.5	18.0–20.0	...	...	...	...
F 304LN ^I	S30453	18 chromium, 8 nickel, modified with nitrogen 304LN ^F	0.030	2.00	0.045	0.030	1.00	8.0–10.5	18.0–20.0	...	...	...	...
F 309H	S30909	23 chromium, 13.5 nickel 309H ^F	0.04–0.10	2.00	0.045	0.030	1.00	12.0–15.0	22.0–24.0	...	...	...	...
F 310	S31000	25 chromium, 20 nickel 310 ^F	0.25	2.00	0.045	0.030	1.00	19.0–22.0	24.0–26.0	...	...	...	...
F 310H	S31009	25 chromium, 20 nickel 310H ^F	0.04–0.10	2.00	0.045	0.030	1.00	19.0–22.0	24.0–26.0	...	...	...	...
F 310MoLN	S31050	25 chromium, 22 nickel, modified with molybdenum and nitrogen, low carbon 310MoLN ^F	0.030	2.00	0.030	0.015	0.40	21.0–23.0	24.0–26.0	2.00–3.00	...	...	N 0.10–0.16
F 316 ^H	S31600	18 chromium, 8 nickel, modified with molybdenum 316 ^F	0.08	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...
F 316H	S31609	18 chromium, 8 nickel, modified with molybdenum 316H ^F	0.04–0.10	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...
F 316L ^H	S31603	18 chromium, 8 nickel, modified with molybdenum, low carbon 316L ^F	0.030	2.00	0.045	0.030	1.00	10.0–15.0	16.0–18.0	2.00–3.00	...	...	...
F 316N ^I	S31651	18 chromium, 8 nickel, modified with molybdenum and nitrogen 316N ^F	0.08	2.00	0.045	0.030	1.00	11.0–14.0	16.0–18.0	2.00–3.00	...	...	...
F 316LN ^I	S31653	18 chromium, 8 nickel, modified with molybdenum and nitrogen 316LN ^F	0.030	2.00	0.045	0.030	1.00	11.0–14.0	16.0–18.0	2.00–3.00	...	...	...
F 316Ti	S31635	18 chromium, 8 nickel, modified with molybdenum and nitrogen 316Ti	0.08	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00	...	J	N 0.10 max
F 317	S31700	19 chromium, 13 nickel, 3.5 molybdenum 317 ^F	0.08	2.00	0.045	0.030	1.00	11.0–15.0	18.0–20.0	3.0–4.0	...	...	...
F 317L	S31703	19 chromium, 13 nickel, 3.5 molybdenum 317L ^F	0.030	2.00	0.045	0.030	1.00	11.0–15.0	18.0–20.0	3.0–4.0	...	...	...
F 321	S32100	18 chromium, 8 nickel modified with titanium 321 ^F	0.08	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	...	...	K	...
F 321H	S32109	18 chromium, 8 nickel, modified with titanium 321H ^F	0.04–0.10	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	...	...	L	...
F 347	S34700	18 chromium, 8 nickel modified with columbium 347 ^F	0.08	2.00	0.045	0.030	1.00	9.0–13.0	17.0–20.0	...	M	...	...
F 347H	S34709	18 chromium, 8 nickel, modified with columbium 347H ^F	0.04–0.10	2.00	0.045	0.030	1.00	9.0–13.0	17.0–20.0	...	N	...	...

TABLE 2
CHEMICAL REQUIREMENTS^A (CONT'D)

Identification Symbol	UNS Designation	Grade	Composition, %										
			Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Columbium	Titanium	Other Elements
Austenitic Stainless Steels (Cont'd)													
F 348	S34800	18 chromium, 8 nickel, modified with columbium 348 ^F	0.08	2.00	0.045	0.030	1.00	9.0–13.0	17.0–20.0	...	<i>M</i>	...	Co 0.20 Ta 0.10
F 348H	S34809	18 chromium, 8 nickel, modified with columbium 348H ^F	0.04–0.10	2.00	0.045	0.030	1.00	9.0–13.0	17.0–20.0	...	<i>N</i>	...	Co 0.20 Ta 0.10
F XM-11	S21904	20 chromium, 6 nickel, 9 manganese XM-11 ^F	0.040	8.0–10.0	0.060	0.030	1.00	5.5–7.5	19.0–21.5	...	...	...	N 0.15–0.40
F XM-19	S20910	22 chromium, 13 nickel, 5 manganese XM-19 ^F	0.06	4.0–6.0	0.040	0.030	1.00	11.5–13.5	20.5–23.5	1.50–3.00	0.10–0.30	...	N 0.20–0.40 V 0.10–0.30 Cu 3.0–4.0
F 20	N08020	35 nickel, 20 chromium, 3.5 copper, 2.5 molybdenum	0.07	2.00	0.045	0.035	1.00	32.0–38.0	19.0–21.0	2.00–3.00	8xCmin-1.00	...	...
F 44	S31254	20 chromium, 18 nickel, 6 molybdenum, low carbon	0.020	1.00	0.030	0.010	0.80	17.5–18.5	19.5–20.5	6.0–6.5	...	...	Cu 0.50–1.00 N 0.18–0.22 N 0.14–0.20
F 45	S30815	21 chromium, 11 nickel, modified with nitrogen and cerium	0.05–0.10	0.80	0.040	0.030	1.40–2.00	10.0–12.0	20.0–22.0	...	...	...	Ce 0.03–0.08 Cu 0.50 N 0.10
F 46	S30600	18 chromium, 15 nickel, 4 silicon	0.018	2.00	0.020	0.020	3.7–4.3	14.0–15.5	17.0–18.5	0.20	...	...	...
F 47	S31725	19 chromium, 15 nickel, 4 molybdenum 317LM ^F	0.030	2.00	0.045	0.030	0.75	13.0–17.5	18.0–20.0	4.0–5.0	...	...	...
F 48	S31726	19 chromium, 15 nickel, 4 molybdenum 317LMN ^F	0.030	2.00	0.045	0.030	0.75	13.5–17.5	17.0–20.0	4.0–5.0	...	...	N 0.10–0.20
F 49	S34565	24 chromium, 17 nickel, 6 manganese, 5 molybdenum	0.030	5.0–7.0	0.030	0.010	1.00	16.0–18.0	23.0–25.0	4.0–5.0	0.10	...	N 0.40–0.60
F 56	S33228	32 nickel, 27 chromium with columbium	0.04–0.08	1.00	0.020	0.015	0.30	31.0–33.0	26.0–28.0	...	0.6–1.0	...	Ce 0.05–0.10 Al 0.025
F 58	S31266	24 chromium, 20 nickel, 6 molybdenum, 2 tungsten with nitrogen	0.030	2.0–4.0	0.035	0.020	1.00	21.0–24.0	23.0–25.0	5.2–6.2	...	...	N 0.35–0.60 Cu 1.00–2.50 W 1.50–2.50
F 62	N08367	21 chromium, 25 nickel, 6.5 molybdenum	0.030	2.00	0.040	0.030	1.00	23.5–25.5	20.0–22.0	6.0–7.0	...	...	N 0.18–0.25 Cu 0.75
F 63	S32615	18 chromium, 20 nickel, 5.5 silicon	0.07	2.00	0.045	0.030	4.8–6.0	19.0–22.0	16.5–19.5	0.30–1.50	...	...	Cu 1.50–2.50
F 64	S30601	17.5 chromium, 17.5 nickel, 5.3 silicon	0.015	0.50–0.80	0.030	0.013	5.0–5.6	17.0–18.0	17.0–18.0	0.20	...	...	Cu 0.35, N 0.05
F 904L	N08904	21 chromium, 26 nickel, 4.5 molybdenum 904L ^F	0.020	2.00	0.040	0.030	1.00	23.0–28.0	19.0–23.0	4.0–5.0	...	...	Cu 1.00–2.00 N 0.10
Ferritic-Austenitic Stainless Steels													
F 50	S31200	25 chromium, 6 nickel, modified with nitrogen	0.030	2.00	0.045	0.030	1.00	5.5–6.5	24.0–26.0	1.20–2.00	...	...	N 0.14–0.20

TABLE 2
CHEMICAL REQUIREMENTS^A (CONT'D)

Identification Symbol	UNS Designation	Grade	Composition, %									
			Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Columbium	Titanium	Other Elements
Ferritic-Austenitic Stainless Steels (Cont'd)												
51	S31803	22 chromium, 5.5 nickel, modified with nitrogen	0.030	2.00	0.030	0.020	1.00	4.5-6.5	21.0-23.0	2.5-3.5	...	N 0.08-0.20
52	S32950	26 chromium, 3.5 nickel, 1.0 molybdenum	0.030	2.00	0.035	0.010	0.60	3.5-5.2	26.0-29.0	1.00-2.50	...	N 0.15-0.35
53	S32750	25 chromium, 7 nickel, 4 molybdenum, modified with nitrogen 2507 ^F	0.030	1.20	0.035	0.020	0.80	6.0-8.0	24.0-26.0	3.0-5.0	...	N 0.24-0.32 Cu 0.50
54	S39274	25 chromium, 7 nickel, modified with nitrogen and tungsten	0.030	1.00	0.030	0.020	0.80	6.0-8.0	24.0-26.0	2.5-3.5	...	N 0.24-0.32 Cu 0.20-0.80 W 1.50-2.50
55	S32760	25 chromium, 7 nickel, 3.5 molybdenum, modified with nitrogen and tungsten	0.030	1.00	0.030	0.010	1.00	6.0-8.0	24.0-26.0	3.0-4.0	...	N 0.20-0.30 Cu 0.50-1.00 W 0.50-1.00 ^D
57	S39277	26 chromium, 7 nickel, 3.7 molybdenum	0.025	0.80	0.025	0.002	0.80	6.5-8.0	24.0-26.0	3.0-4.0	...	Cu 1.20-2.00 W 0.80-1.20 N 0.23-0.33
59	S32520	25 chromium, 6.5 nickel, 4 molybdenum with nitrogen	0.030	1.50	0.035	0.020	0.80	5.5-8.0	24.0-26.0	3.0-5.0	...	N 0.20-0.35 Cu 0.50-3.00
60	S32205	22 chromium, 5.5 nickel, 3 molybdenum, modified with nitrogen 2205 ^F	0.030	2.00	0.030	0.020	1.00	4.5-6.5	22.0-23.0	3.0-3.5	...	N 0.14-0.20
61	S32550	26 chromium, 6 nickel, 3.5 molybdenum with nitrogen and copper 255 ^E	0.040	1.50	0.040	0.030	1.00	4.5-6.5	24.0-27.0	2.9-3.9	...	Cu 1.50-2.50 N 0.10-0.25
65	S32906	29 chromium, 6.5 nickel, 2 molybdenum with nitrogen	0.030	0.80-1.50	0.030	0.030	0.80	5.8-7.5	28.0-30.0	1.5-2.6	...	Cu 0.80 N 0.30-0.40

^A All values are maximum unless otherwise stated.

^B Grade F 2 was formerly assigned to the 1% chromium, 0.5% molybdenum grade which is now Grade F 12.

^C The present grade F 5a (0.25 max carbon) previous to 1955 was assigned the identification symbol F 5. Identification symbol F 5 in 1955 was assigned to the 0.15 max carbon grade to be consistent with ASTM specifications for other products such as pipe, tubing, bolting, welding fittings, and the like.

^D Applies to both heat and product analyses.

^E For Grade F22V, rare earth metals (REM) may be added in place of calcium, subject to agreement between the producer and the purchaser. In that case the total amount of REM shall be determined and reported.

^F Naming system developed and applied by ASTM.

^G Grade F XM-27Cb shall have a nickel plus copper content of 0.50% max. Product analysis tolerance over the maximum specified limit for carbon and nitrogen shall be 0.002%.

^H Grades F 304, F 304L, F 316, and F 316L shall have a maximum nitrogen content of 0.10%.

^I Grades F 304N, F 316N, F 304LN, and F 316LN shall have a nitrogen content of 0.10% to 0.16%.

^J Grade F 316Ti shall have a titanium content not less than five times the carbon plus nitrogen content and not more than 0.70%.

^K Grade F 321 shall have a titanium content of not less than four times the carbon content and not more than 0.70%.

^L Grade F 321H shall have a titanium content of not less than four times the carbon content and not more than 0.70%.

^M Grades F 347 and F 348 shall have a columbium content of not less than ten times the carbon content and not more than 1.10%.

^N Grades F 347H and F 348H shall have a columbium content of not less than eight times the carbon content and not more than 1.10%.

^O % Cr + 3.3 x % Mo + 16 x % N = 40 min.

TABLE 3
TENSILE AND HARDNESS REQUIREMENTS

Grade Symbol	Tensile Strength, Min., ksi [MPa]	Yield Strength, Min., ksi [MPa] ^A	Elongation in 2 in. [50 mm] or 4D, Min., %	Reduction of Area, Min., %	Brinell Hardness Number
Low Alloy Steels					
F 1	70 [485]	40 [275]	20	30	143–192
F 2	70 [485]	40 [275]	20	30	143–192
F 5	70 [485]	40 [275]	20	35	143–217
F 5a	90 [620]	65 [450]	22	50	187–248
F 9	85 [585]	55 [380]	20	40	179–217
F 10	80 [550]	30 [205]	30	50	...
F 91	85 [585]	60 [415]	20	40	248 max.
F 92	90 [620]	64 [440]	20	45	269 max.
F 122	90 [620]	58 [400]	20	40	250 max.
F 911	90 [620]	64 [440]	18	40	187–248
F 11 Class 1	60 [415]	30 [205]	20	45	121–174
F 11 Class 2	70 [485]	40 [275]	20	30	143–207
F 11 Class 3	75 [515]	45 [310]	20	30	156–207
F 12 Class 1	60 [415]	32 [220]	20	45	121–174
F 12 Class 2	70 [485]	40 [275]	20	30	143–207
F 21	75 [515]	45 [310]	20	30	156–207
F 3V and F 3VCb	85–110 [585–760]	60 [415]	18	45	174–237
F 22 Class 1	60 [415]	30 [205]	20	35	170 max.
F 22 Class 3	75 [515]	45 [310]	20	30	156–207
F 22V	85–110 [585–760]	60 [415]	18	45	174–237
F 23	74 [510]	58 [400]	20	40	220 max.
F 24	85 [585]	60 [415]	20	40	248 max.
FR	63 [435]	46 [315]	25	38	197 max.
F 36 Class 1	90 [620]	64 [440]	15	...	252 max.
F 36 Class 2	95.5 [660]	66.5 [460]	15	...	252 max.
Martensitic Stainless Steels					
F 6a Class 1	70 [485]	40 [275]	18	35	143–207
F 6a Class 2	85 [585]	55 [380]	18	35	167–229
F 6a Class 3	110 [760]	85 [585]	15	35	235–302
F 6a Class 4	130 [895]	110 [760]	12	35	263–321
F 6b	110–135 [760–930]	90 [620]	16	45	235–285
F 6NM	115 [790]	90 [620]	15	45	295 max.
Ferritic Stainless Steels					
F XM-27Cb	60 [415]	35 [240]	20	45	190 max.
F 429	60 [415]	35 [240]	20	45	190 max.
F 430	60 [415]	35 [240]	20	45	190 max.
Austenitic Stainless Steels					
F 304	75 [515] ^B	30 [205]	30	50	...
F 304H	75 [515] ^B	30 [205]	30	50	...
F 304L	70 [485] ^C	25 [170]	30	50	...
F 304N	80 [550]	35 [240]	30 ^D	50 ^E	...
F 304LN	75 [515] ^B	30 [205]	30	50	...
F 309H	75 [515] ^B	30 [205]	30	50	...
F 310	75 [515] ^B	30 [205]	30	50	...
F 310MoLN	78 [540]	37 [255]	25	40	...
F 310H	75 [515] ^B	30 [205]	30	50	...
F 316	75 [515] ^B	30 [205]	30	50	...
F 316H	75 [515] ^B	30 [205]	30	50	...
F 316L	70 [485] ^C	25 [170]	30	50	...
F 316N	80 [550]	35 [240]	30 ^D	50 ^E	...
F 316LN	75 [515] ^B	30 [205]	30	50	...

TABLE 3
TENSILE AND HARDNESS REQUIREMENTS (CONT'D)

Grade Symbol	Tensile Strength, Min., ksi [MPa]	Yield Strength, Min., ksi [MPa] ^A	Elongation in 2 in. [50 mm] or 4D, Min., %	Reduction of Area, Min., %	Brinell Hardness Number
Austenitic Stainless Steels (Cont'd)					
F 316Ti	75 [515]	30 [205]	30	40	...
F 317	75 [515] ^B	30 [205]	30	50	...
F 317L	70 [485] ^C	25 [170]	30	50	...
F 347	75 [515] ^B	30 [205]	30	50	...
F 347H	75 [515] ^B	30 [205]	30	50	...
F 348	75 [515] ^B	30 [205]	30	50	...
F 348H	75 [515] ^B	30 [205]	30	50	...
F 321	75 [515] ^B	30 [205]	30	50	...
F 321H	75 [515] ^B	30 [205]	30	50	...
F XM-11	90 [620]	50 [345]	45	60	...
F XM-19	100 [690]	55 [380]	35	55	...
F 20	80 [550]	35 [240]	30	50	...
F 44	94 [650]	44 [300]	35	50	...
F 45	87 [600]	45 [310]	40	50	...
F 46	78 [540]	35 [240]	40	50	...
F 47	75 [525]	30 [205]	40	50	...
F 48	80 [550]	35 [240]	40	50	...
F 49	115 [795]	60 [415]	35	40	...
F 56	73 [500]	27 [185]	30	35	...
F 58	109 [750]	61 [420]	35	50	...
F 62	95 [655]	45 [310]	30	50	...
F 63	80 [550]	32 [220]	25	...	192 max
F 64	90 [620]	40 [275]	35	50	217 max
F 904L	71 [490]	31 [215]	35	...	...
Ferritic-Austenitic Stainless Steels					
F 50	100–130 [690–900]	65 [450]	25	50	...
F 51	90 [620]	65 [450]	25	45	...
F 52	100 [690]	70 [485]	15	...	...
F 53	116 [800] ^F	80 [550] ^F	15	...	310 max.
F 54	116 [800]	80 [550]	15	30	310 max.
F 55	109–130 [750–895]	80 [550]	25	45	...
F 57	118 [820]	85 [585]	25	50	...
F 59	112 [770]	80 [550]	25	40	...
F 60	95 [655]	70 [485]	25	45	...
F 61	109 [750]	80 [550]	25	50	...
F 65	109 [750]	80 [550]	25	...	...

^A Determined by the 0.2% offset method. For ferritic steels only, the 0.5% extension-under-load method may also be used.

^B For sections over 5 in. [130 mm] in thickness, the minimum tensile strength shall be 70 ksi [485 MPa].

^C For sections over 5 in. [130 mm] in thickness, the minimum tensile strength shall be 65 ksi [450 MPa].

^D Longitudinal. The transverse elongation shall be 25% in 2 in. or 50 mm, min.

^E Longitudinal. The transverse reduction of area shall be 45% min.

^F For sections over 2 in. [50 mm] in thickness, the minimum tensile strength shall be 106 ksi [730 MPa]; the minimum yield strength shall be 75 ksi [515 MPa].

TABLE 4
REPAIR WELDING REQUIREMENTS

Grade Symbol	Electrodes ^A	Recommended Preheat and Interpass Temperature Range, °F [°C]	Post-Weld Heat-Treatment Temperature, Min. or Range, °F [°C]
Low Alloy Steels			
F 1	E 7018-A1	200–400 [95–205]	1150 [620]
F 2	E 8018-B1	300–600 [150–315]	1150 [620]
F 5	E 502-15 or 16	400–700 [205–370]	1250 [675]
F 5a	E 502-15 or 16	400–700 [205–370]	1250 [675]
F 9	E 505-15 or 16	400–700 [205–370]	1250 [675]
F 10 ^B	...	...	...
F 91	9% Cr, 1% Mo, VCbN	400–700 [205–370]	1350–1470 [730–800]
F 92	9% Cr, 0.5% Mo, 1.5% W, VCbNiN	400–700 [205–370]	1350–1470 [730–800]
F 122	11% Cr, 2% W, MoVCbCuN	400–700 [205–370]	1350–1470 [730–800]
F 911	9% Cr, 1% Mo, 1% W, VCbN	400–700 [205–370]	1300 [705]
F 11, Classes 1, 2, and 3	E 8018-B2	300–600 [150–315]	1150 [620]
F 12, Classes 1 and 2	E 8018-B2	300–600 [150–315]	1150 [620]
F 21	E 9018-B3	300–600 [150–315]	1250 [675]
F 3V and F 3VCb	3% Cr, 1% Mo, ¼% V-Ti	300–600 [150–315]	1250 [675]
F 22 Class 1	E 9018-B3	300–600 [150–315]	1250 [675]
F 22 Class 3	E 9018-B3	300–600 [150–315]	1250 [675]
F 22V	2.25% Cr, 1% Mo, 0.25% V-Cb	300–600 [150–315]	1250 [675]
F 23	2.25% Cr, 1.6% W, 0.25% V-Mo-Cb-B	300–600 [150–315]	1350–1470 [730–800] ^C
F 24	2.25% Cr, 1% Mo, 0.25% V	200–400 [95–205] ^C	1350–1470 [730–800]
F 36, Class 1	1.5 Ni, 0.65 Cu, Mo, Cb	400–700 [205–370]	1100–1200 [595–650]
F 36, Class 2	1.5 Ni, 0.65 Cu, Mo, Cb	400–700 [205–370]	1000–1150 [540–620]
Martensitic Stainless Steels			
F 6a, Class 1	E 410-15 or 16	400–700 [205–370]	1250 [675]
F 6a, Class 2	E 410-15 or 16	400–700 [205–370]	1250 [675]
F 6b	13% Cr, 1½% Ni, ½% Mo	400–700 [205–370]	1150 [620]
F 6NM	13% Cr, 4% Ni	300–700 [150–370]	1050 [565]
Ferritic Stainless Steels			
F XM-27Cb	26% Cr, 1% Mo	NR ^D	NR
F 429	E 430-16	400–700 [205–370]	1400 [760]
F 430	E 430-16	NR	1400 [760]
FR	E 8018-C2	NR	NR
Austenitic Stainless Steels			
F 304	E 308-15 or 16	NR	1900 [1040] + WQ ^E
F 304L	E 308L-15 to 16	NR	1900 [1040] + WQ
F 304H	E 308-15 or 16	NR	1900 [1040] + WQ
F 304N	E 308-15 or 16	NR	1900 [1040] + WQ
F 304LN	E 308L-15 or 16	NR	1900 [1040] + WQ
F 309H	E 309-15 or 16 ^F	NR	1900 [1040] + WQ
F 310	E 310-15 or 16	NR	1900 [1040] + WQ
F 310H	E 310-15 or 16	NR	1900 [1040] + WQ
F 310MoLN	E 310Mo-15 or 16	NR	1920–2010 [1050–1100] + WQ
F 316	E 316-15 or 16	NR	1900 [1040] + WQ
F 316L	E 316L-15 or 16	NR	1900 [1040] + WQ
F 316H	E 316-15 or 16	NR	1900 [1040] + WQ
F 316N	E 316-15 or 16	NR	1900 [1040] + WQ
F 316LN	E 316L-15 or 16	NR	1900 [1040] + WQ
F 316Ti	E 316-15 or 16	NR	1900 [1040] + WQ
F 317	E 317-15 or 16	NR	1900 [1040] + WQ
F 317L	E 317L-15 or 16	NR	1900 [1040] + WQ
F 321 ^B	E 347-15 or 16	NR	1900 [1040] + WQ
F 321H ^B	E 347-15 or 16	NR	1925 [1050] + WQ
F 347	E 347-15 or 16	NR	1900 [1040] + WQ
F 347H	E 347-15 or 16	NR	1925 [1050] + WQ

TABLE 4
REPAIR WELDING REQUIREMENTS (CONT'D)

Grade Symbol	Electrodes ^A	Recommended Preheat and Interpass Temperature Range, °F [°C]	Post-Weld Heat-Treatment Temperature, Min. or Range, °F [°C]
Austenitic Stainless Steels (Cont'd)			
F 348	E 347-15 or 16	NR	1900 [1040] + WQ
F 348H	E 347-15 or 16	NR	1925 [1050] + WQ
F XM-11	XM-10W	NR	NR
F XM-19	XM-19W	NR	NR
F 20	E/ER-320, 320LR	NR	1700–1850 [925–1010] + WQ
F 44	E NiCrMo-3	NR	2100 [1150] + WQ
F 45 ^B	...	...	...
F 46	...	...	...
F 47	... ^G	...	2100 [1150] + WQ
F 48	... ^G	...	2100 [1150] + WQ
F 49	... ^G	...	2100 [1150] + WQ
F 58	E NiCrMo-10	...	2100 [1150] + WQ
F 62	E NiCrMo-3	NR	2025 [1105] + WQ
F 904L	E NiCrMo-3	NR	1920–2100 [1050–1150] + WQ
Ferritic-Austenitic Stainless Steels			
F 50	25% Cr, 6% Ni, 1.7% Mo	NR	NR
F 51	22% Cr, 5.5% Ni, 3% Mo	NR	NR
F 52	26% Cr, 8% Ni, 2% Mo	NR	NR
F 53	25% Cr, 7% Ni, 4% Mo	NR	NR
F 54	25% Cr, 7% Ni, 3% Mo, W	NR	NR
F 55	25% Cr, 7% Ni, 3.5% Mo	NR	NR
F 57	25% Cr, 7% Ni, 3% Mo, 1.5% Cu, 1% W	NR	NR
F 59	E NiCrMo-10	NR	NR
F 60	22% Cr, 5.5% Ni, 3% Mo	NR	NR
F 61	26% Cr, 9% Ni, 3.5% Mo	NR	NR
F 65	29% Cr, 6.5% Ni, 2% Mo	NR	NR

^A Electrodes shall comply with ASME SFA-5.4, SFA-5.5, and corresponding ER grades of SFA-5.9 or SFA-5.11.

^B Purchaser approval required.

^C Not required for not below 0.500 in. [12.7 mm].

^D NR = not required.

^E WQ = water quench.

^F Filler metal shall additionally have 0.04% minimum carbon.

^G Match filler metal is available. Fabricators have also used AWS A5.14, Class ER, NiCrMo-3, and AWS A5.11, Class E, NiCrMo-3 filler metals.

SUPPLEMENTARY REQUIREMENTS

In addition to any of the supplementary requirements of Specification A 961/A 961M the following supplementary requirements shall apply only when specified by the purchaser in the order.

S1. Macroetch Test

S1.1 A sample forging shall be sectioned and etched to show flow lines and internal imperfections. The test shall be conducted according to Test Method E 340. Details of the test shall be agreed upon between the manufacturer and the purchaser.

S2. Heat Treatment Details

S2.1 The manufacturer shall furnish a detailed test report containing the information required in 16.2 and shall include all pertinent details of the heat-treating cycle given the forgings.

S3. Material for Optimum Resistance to Stress-Corrosion Cracking

S3.1 Austenitic stainless steel shall be furnished in the solution-annealed condition as a final operation with no subsequent cold working permitted, except, unless specifically prohibited by the purchaser, straightening of bars from which parts are machined is permitted to meet the requirements of Specification A 484/A 484M.

S4. Corrosion Tests

S4.1 All austenitic stainless steel shall pass intergranular corrosion tests performed in accordance with Practice E of Practices A 262.

S4.2 Intergranular corrosion tests shall be performed on specimens of ferritic stainless steels as described in Practices A 763.

S4.3 For both the austenitic and ferritic stainless steels, details concerning the number of specimens and their source and location are to be a matter of agreement between the manufacturer and the purchaser.

S5. Special Filler Metal

S5.1 In repair welded F 316, F 316L, F 316H, and F 316N forgings, the deposited weld metal shall conform

to E 308 composition wire. Forgings repair welded with E 308 weld metal shall be marked F____W 308.

S6. Hardness Test

S6.1 Each forging shall be hardness tested and shall meet the requirements of Table 3.

S7. Alternate Heat Treatment (Grades F 91 and F 92)

S7.1 Grade F 91 shall be normalized in accordance with Section 6 and tempered at a temperature, to be specified by the purchaser, less than 1350°F [730°C]. It shall be the purchaser's responsibility to subsequently temper at 1350°F [730°C] minimum to conform to the requirements of the specification. All mechanical tests shall be made on material heat treated in accordance with Section 6. The certification shall reference this supplementary requirement indicating the tempering temperature applied. The notation "S7" shall be included with the required marking of the forging.

S8. Heat Treatment of Austenitic Forgings

S8.1 The purchaser shall specify the heat-treatment method (in 6.1 or in 6.3.1) that shall be employed.

S8.2 The manufacturer shall provide a test report containing the information required in 16.2 and shall include a statement of the heat-treatment method employed.

S9. Grain Size for Austenitic Grades

S9.1 Forgings made from austenitic grades other than H grades shall be tested for average grain size by Test Method E 112. Details of the test shall be agreed upon between the manufacturer and the purchaser.

S10. Stabilization Treatment

S10.1 Subsequent to the solution anneal for Grades F 321, F 321H, F 347, F 347H, F 348, and F 348H, these

grades shall be given a stabilization heat treatment at 1500 to 1600°F [815 to 870°C] for a minimum of 2 h/in. [4.7 min/mm] of thickness and then cooling in the furnace or in air. In addition to the marking required in Section 17, the grade designation symbol shall be followed by the symbol “S10.”

S11. Grain Size Requirements for Non-H-Grade Austenitic Steels Used Above 1000°F [540°C]

S11.1 Non-H grades of austenitic stainless steels shall have a grain size of No. 7 or coarser as determined in accordance with Test Methods E 112. The grain size so determined shall be on a certified test report.

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SPECIFICATION FOR SEAMLESS CARBON STEEL BOILER TUBES FOR HIGH-PRESSURE SERVICE



SA-192/SA-192M



(Identical with ASTM Specification A 192/A 192M-91.)

1. Scope

1.1 This specification covers minimum-wall thickness, seamless carbon steel boiler and superheater tubes for high-pressure service.

1.2 The tubing sizes and thicknesses usually furnished to this specification are $\frac{1}{2}$ in. to 7 in. [12.7 to 177.8 mm] outside diameter and 0.085 to 1.000 in. [2.2 to 25.4 mm], inclusive, in minimum wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in [3.2 mm] inside diameter or 0.015 in. [0.4 mm] thickness.

1.4 When these products are to be used in applications conforming to ISO Recommendations for Boiler Construction, the requirements of Specification A 520 shall supplement and supersede the requirements of this specification.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Documents

2.1 ASTM Standards:

- A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes
- A 520 Specification for Supplementary Requirements for Seamless and Electric-Resistance-Welded Carbon Steel

Tubular Products for High-Temperature Service Conforming to ISO Recommendations for Boiler Construction

3. General Requirements

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

- 4.1.1** Quantity (feet, metres, or number of lengths),
- 4.1.2** Name of material (seamless tubes),
- 4.1.3** Manufacture (hot-finished or cold-drawn),
- 4.1.4** Size (outside diameter and minimum wall thickness),
- 4.1.5** Length (specific or random),
- 4.1.6** Optional Requirements (Section 8),
- 4.1.7** Test report required (see section on Certification of Specification A 450/A 450M),
- 4.1.8** Specification designation, and
- 4.1.9** Special requirements.

5. Manufacture

5.1 Tubes shall be made by the seamless process and shall be either hot-finished or cold-finished, as specified.

6. Heat Treatment

6.1 Hot-finished tubes need not be heat treated. Cold-finished tubes shall be heat treated after the final cold-finished at a temperature of 1200°F [650°C] or higher.

7. Chemical Composition

7.1 The steel shall conform to the following requirements as to chemical composition:

Carbon, %	0.06–0.18
Manganese, %	0.27–0.63
Phosphorus, max	0.035
Sulfur, max, %	0.035
Silicon, max, %	0.25

7.2 Supplying an alloy grade of steel that specifically requires the addition of any element other than those listed in 7.1 is not permitted.

8. Product Analysis

8.1 When requested on the purchase order, a product analysis shall be made by the supplier from one tube per 100 pieces for sizes over 3 in. [76.2 mm] and one tube per 250 pieces for sizes 3 in. [76.2 mm] and under; or when tubes are identified by heat, one tube per heat shall be analyzed. The chemical composition thus determined shall conform to the requirements specified.

8.2 If the original test for product analysis fails, retests of two additional billets or tubes shall be made. Both retests, for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (see Note) shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes which do not meet the requirements of the specification shall be rejected.

NOTE — A lot consists of 250 tubes for sizes 3 in. [76.2 mm] and under and of 100 tubes for sizes over 3 in. [76.2 mm], prior to cutting to length.

9. Hardness Requirements

9.1 The tubes shall have a hardness number not exceeding the following:

Brinell Hardness Number
(Tubes 0.200 in. [5.1 mm] and over in wall thickness)
137 HB

Rockwell Hardness
Number (Tubes less than 0.200 in. [5.1 mm] in wall thickness)
77 HRB

10. Mechanical Tests Required

10.1 Flattening Test — One flattening test shall be made on specimens from each of two tubes selected from each lot (see Note) or fraction thereof.

10.2 Flaring Test — One flaring test shall be made on specimens from each end of two tubes selected from each lot (see Note) or fraction thereof. These tubes shall be selected apart from those used for the flattening test.

10.3 Hardness Test — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot. The term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

10.4 Hydrostatic Test — Each tube shall be subjected to the hydrostatic pressure test, or instead of this test, a nondestructive test may be used when specified by the purchaser.

11. Forming Operations

11.1 Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws. Superheater tubes when properly manipulated shall stand all forging, welding, and bending operations necessary for application without developing defects.

12. Product Marking

12.1 In addition to the marking prescribed in Specification A 450/A 450M, the marking shall indicate whether the tube is hot finished or cold finished.

EXPLANATORY NOTE

NOTE — For purposes of design, the following tensile properties may be assumed:

Tensile strength, min, ksi [MPa]	47 [325]
Yield strength, min, ksi [MPa]	26 [180]
Elongation in 2 in. or 50 mm, min, %	35

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SPECIFICATION FOR ALLOY-STEEL AND STAINLESS STEEL BOLTING MATERIALS FOR HIGH-TEMPERATURE OR HIGH PRESSURE SERVICE AND OTHER SPECIAL PURPOSE APPLICATIONS



SA-193/SA-193M



(Identical with ASTM Specification A 193/A 193M-07.)

1. Scope

1.1 This specification covers alloy and stainless steel bolting material for pressure vessels, valves, flanges, and fittings for high temperature or high pressure service, or other special purpose applications. The term *bolting material* as used in this specification covers bars, bolts, screws, studs, stud bolts, and wire. Bars and wire shall be hot-wrought. The material may be further processed by centerless grinding or by cold drawing. Austenitic stainless steel may be carbide solution treated or carbide solution treated and strain-hardened. When strain hardened austenitic steel is ordered, the purchaser should take special care to ensure that Appendix X1 is thoroughly understood.

1.2 Several grades are covered, including ferritic steels and austenitic stainless steels designated B5, B8, and so forth. Selection will depend upon design, service conditions, mechanical properties, and high temperature characteristics.

NOTE 1 — The committee formulating this specification has included fifteen steel types that have been rather extensively used for the present purpose. Other compositions will be considered for inclusion by the committee from time to time as the need becomes apparent.

NOTE 2 — For grades of alloy-steel bolting material suitable for use at the lower range of high temperature applications, reference should be made to Specification A 354.

NOTE 3 — For grades of alloy-steel bolting material suitable for use in low temperature applications, reference should be made to Specification A 320/A 320M.

1.3 Nuts for use with this bolting material are covered in Section 14.

1.4 Supplementary Requirements S1 through S10 are provided for use when additional tests or inspection are

desired. These shall apply only when specified in the purchase order.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable *M* specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 ASTM Standards:

- A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
- A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
- A 320/A 320M Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low-Temperature Service
- A 354 Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners
- A 788/A 788M Specification for Steel Forgings, General Requirements
- A 962/A 962M Specification for Common Requirements for Steel Fasteners or Fastener Materials, or Both, Intended for Use at Any Temperature from Cryogenic to the Creep Range

- B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
- B 696 Specification for Coatings of Cadmium Mechanically Deposited
- B 766 Specification for Electrodeposited Coatings of Cadmium
- E 18 Test Methods for Rockwell Hardness of Metallic Materials
- E 21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials
- E 112 Test Methods for Determining Average Grain Size
- E 139 Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials
- E 150 Recommended Practice for Conducting Creep and Creep-Rupture Tension Tests of Metallic Materials Under Conditions of Rapid Heating and Short Times
- E 151 Recommended Practice for Tension Tests of Metallic Materials at Elevated Temperatures With Rapid Heating and Conventional or Rapid Strain Rates
- E 292 Test Methods for Conducting Time-for-Rupture Notch Tension Tests of Materials
- E 328 Test Methods for Stress Relaxation for Materials and Structures
- E 566 Practice for Electromagnetic (Eddy-Current) Sorting of Ferrous Metals
- E 709 Guide for Magnetic Particle Examination
- E 606 Practice for Strain-Controlled Fatigue Testing
- F 1940 Test Method for Process Control Verification to Prevent Hydrogen Embrittlement in Plated or Coated Fasteners
- F 1941 Specification for Electrodeposited Coatings on Threaded Fasteners (Unified Inch Screw Threads (UN/UNR))

2.2 ANSI Standards:

- B1.1 Screw Threads
- B18.2.1 Square and Hex Bolts and Screws
- B18.2.3.1M Metric Hex Cap Screws
- B18.3 Hexagon Socket and Spline Socket Screws
- B18.3.1M Metric Socket Head Cap Screws

2.3 AIAG Standard:

- AIAG B-5 02.00 Primary Metals Identification Tag Application Standard

3. General Requirements and Ordering Information

3.1 The inquiry and orders shall include the following, as required, to describe the desired material adequately:

3.1.1 Heat-treated condition (that is, normalized and tempered, or quenched and tempered, for the ferritic materials, and carbide solution treated (Class 1), carbide solution treated after finishing (Class 1A), and carbide solution treated and strain-hardened (Classes 2, 2B and 2C), for the

austenitic stainless steels; Classes 1B and 1C apply to the carbide solution-treated nitrogen-bearing stainless steels; Class 1D applies to material carbide solution treated by cooling rapidly from the rolling temperature),

3.1.2 Description of items required (that is, bars, bolts, screws, or studs),

3.1.3 Nuts, if required by purchaser, in accordance with 14.1,

3.1.4 Supplementary requirements, if any, and

3.1.5 Special requirements, in accordance with 7.3, 7.5.1, 11.2, 15.1, and 16.1.

3.2 Coatings — Coatings are prohibited unless specified by the purchaser (See Supplementary Requirement S13). When coated fasteners are ordered the purchaser should take special care to ensure that Appendix X2 is thoroughly understood.

4. Common Requirements

4.1 Material and fasteners supplied to this specification shall conform to the requirements of Specification A 962/A 962M. These requirements include test methods, finish, thread dimensions, marking, certification, optional supplementary requirements, and others. Failure to comply with the requirements of Specification A 962/A 962M constitutes nonconformance with this specification. In case of conflict between this specification and Specification A 962/A 962M, this specification shall prevail.

5. Manufacture (Process)

5.1 The steel shall be produced by any of the following processes: open-hearth, basic-oxygen, electric-furnace, or vacuum-induction melting (VIM). The molten steel may be vacuum-treated prior to or during pouring of the ingot or strand casting.

5.2 Quality — See Specification A 962/A 962M for requirements.

6. Discard

6.1 A sufficient discard shall be made to secure freedom from injurious piping and undue segregation.

7. Heat Treatment

7.1 Ferritic steels shall be properly heat treated as best suits the high temperature characteristics of each grade. Immediately after rolling or forging, the bolting material shall be allowed to cool to a temperature below the cooling transformation range. The materials which are to be furnished in the liquid-quenched condition shall then be uniformly reheated to the proper temperature to refine the

grain (a group thus reheated being known as a *quenching charge*) and quenched in a liquid medium under substantially uniform conditions for each quenching charge. Use of water quenching is prohibited for any ferritic grade when heat treatment is part of the fastener manufacturing process. This prohibition does not apply to heat treated bar or to fasteners machined therefrom. The materials that are to be furnished in the normalized or air-quenched condition shall be reheated to the proper temperature to refine the grain and cooled uniformly in air to a temperature below the transformation temperature range. The material, whether liquid-quenched or normalized, shall then be uniformly reheated for tempering. The minimum tempering temperature shall be as specified in Table 2 and Table 3.

7.1.1 Quenched and tempered or normalized and tempered ferritic material that is subsequently cold drawn for dimensional control shall be stress-relieved after cold drawing. The minimum stress-relief temperature shall be 100°F [55°C] below the tempering temperature. Tests for mechanical properties shall be performed after stress relieving.

7.2 Both B6 and B6X materials shall be held, at the tempering temperature for a minimum time of 1 h. Identification Symbol B 6X material may be furnished in the as-rolled-and-tempered condition. Cold working is permitted with the hardness limitation (26 HRC maximum) of Table 2 for the B 6X grade.

7.3 All austenitic stainless steels shall receive a carbide solution treatment (see 7.3.1–7.3.4 for specific requirements for each class). Classes 1, 1B, 1C (Grades B8R and B8S only), 2, 2B, and 2C can apply to bar, wire, and finished fasteners. Class 1A (all grades) and Class 1C (Grades B8RA and B8SA only) can apply to finished fasteners. Class 1D applies only to bar and wire and finished fasteners that are machined directly from Class 1D bar or wire without any subsequent hot or cold working.

7.3.1 *Classes 1 and 1B, and Class 1C Grades B8R and B8S* — After rolling of the bar, forging, or heading, whether done hot or cold, the material shall be heated from ambient temperature and held a sufficient time at a temperature at which the chromium carbide will go into solution and then shall be cooled at a rate sufficient to prevent the precipitation of the carbide.

7.3.2 *Class 1D* — Rolled or forged Grades B8, B8M, B8P, B8LN, B8MLN, B8N, B8MN, B8R, and B8S bar shall be cooled rapidly immediately following hot working while the temperature is above 1750°F [955°C] so that grain boundary carbides are in solution. Class 1D shall be restricted to applications at temperatures less than 850°F [455°C].

7.3.3 *Class 1A and Class 1C Grades B8RA and B8SA* — Finished fasteners shall be carbide solution treated

after all rolling, forging, heading, and threading operations are complete. This designation does not apply to starting material such as bar. Fasteners shall be heated from ambient temperature and held a sufficient time at a temperature at which the chromium carbide will go into solution and then shall be cooled at a rate sufficient to prevent the precipitation of the carbide.

7.3.4 *Classes 2, 2B, and 2C* — Material shall be carbide solution treated by heating from ambient temperature and holding a sufficient time at a temperature at which the chromium carbide will go into solution and then cooling at a rate sufficient to prevent the precipitation of the carbide. Following this treatment the material shall then be strain hardened to achieve the required properties.

NOTE 4 — Heat treatment following operations performed on a limited portion of the product, such as heading, may result in non-uniform grain size and mechanical properties through the section affected.

7.4 If scale-free bright finish is required, this shall be specified in the purchase order.

7.5 B7 and B7M bolting material shall be heat treated by quenching in a liquid medium and tempering. For B7M bolting, the final heat treatment, which may be the tempering operation if conducted at 1150°F [620°C] minimum, shall be done after all machining and forming operations, including thread rolling and any type of cutting. Surface preparation for hardness testing, nondestructive evaluation, or ultrasonic bolt tensioning is permitted.

7.5.1 Unless otherwise specified, material for Grade B7 may be heat treated by the Furnace, the Induction or the Electrical Resistance method.

NOTE 5 — It should be taken into consideration that stress-relaxation properties may vary from heat lot to heat lot or these properties may vary from one heat treating method to another. The purchaser may specify Supplementary Requirement S8, if stress-relaxation testing is desired.

7.6 Material Grade B16 shall be heated to a temperature range from 1700 to 1750°F [925 to 955°C] and oil quenched. The minimum tempering temperature shall be as specified in Table 2.

8. Chemical Composition

8.1 Each alloy shall conform to the chemical composition requirements prescribed in Table 1.

8.2 The steel shall not contain an unspecified element for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element. Furthermore, elements present in concentrations greater than 0.75 weight/% shall be reported.

9. Heat Analysis

9.1 An analysis of each heat of steel shall be made by the manufacturer to determine the percentages of the

elements specified in Section 8. The chemical composition thus determined shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Section 8. Should the purchaser deem it necessary to have the transition zone of two heats sequentially cast discarded, the purchaser shall invoke Supplementary Requirement S3 of Specification A 788.

10. Mechanical Properties

10.1 Tensile Properties:

10.1.1 Requirements — The material as represented by the tension specimens shall conform to the requirements prescribed in Table 2 at room temperature after heat treatment. Alternatively, stainless strain hardened headed fasteners (Class 2, 2B, and 2C) shall be tested full size after strain hardening to determine tensile strength and yield strength and shall conform to the requirements prescribed in Table 2. Should the results of full size tests conflict with results of tension specimen tests, full size test results shall prevail.

10.1.2 Full Size Fasteners, Wedge Tensile Testing — When applicable, see 13.1.3, headed fasteners shall be wedge tested full size and shall conform to the tensile strength shown in Table 2. The minimum full size breaking strength (lbf) for individual sizes shall be as follows:

$$T_s = UTS \times A_s \quad (1)$$

where:

T_s = wedge tensile strength

UTS = tensile strength specified in Table 2, and

A_s = stress area, square inches, as shown in ANSI B1.1 or calculated as follows:

$$A_s = 0.785 (D - (0.974/n))^2 \quad (2)$$

where:

D = nominal thread size, and

n = the number of threads per inch

10.2 Hardness Requirements:

10.2.1 The hardness shall conform to the requirements prescribed in Table 2. Hardness testing shall be performed in accordance with either Specification A 962/A 962M or with Test Methods F 606.

10.2.2 Grade B7M — The maximum hardness of the grade shall be 235 HB or 99 HRB. The minimum hardness shall not be less than 200 HB or 93 HRB. Conformance to this hardness shall be ensured by testing the hardness of each stud or bolt by Brinell or Rockwell B methods in accordance with 10.2.1. The use of 100% electromagnetic testing for hardness as an alternative to 100% indentation hardness testing is permissible when qualified by sampling

using indentation hardness testing. Each lot tested for hardness electromagnetically shall be 100% examined in accordance with Practice E 566. Following electromagnetic testing for hardness a random sample of a minimum of 100 pieces of each heat of steel in each lot (as defined in 13.1.1) shall be tested by indentation hardness methods. All samples must meet hardness requirements to permit acceptance of the lot. If any one sample is outside of the specified maximum or minimum hardness, the lot shall be rejected and either reprocessed and resampled or tested 100% by indentation hardness methods. Product that has been 100% tested and found acceptable shall have a line under the grade symbol.

10.2.2.1 Surface preparation for indentation hardness testing shall be in accordance with Test Methods E 18. Hardness tests shall be performed on the end of the bolt or stud. When this is impractical, the hardness test shall be performed elsewhere.

11. Workmanship, Finish, and Appearance

11.1 Bolts, screws, studs, and stud bolts shall be pointed and shall have a workmanlike finish. Points shall be flat and chamfered or rounded at option of the manufacturer. Length of point on studs and stud bolts shall be not less than one nor more than two complete threads as measured from the extreme end parallel to the axis. Length of studs and stud bolts shall be measured from first thread to first thread.

11.2 Bolt heads shall be in accordance with the dimensions of ANSI B18.2.1 or ANSI B18.2.3.1M. Unless otherwise specified in the purchase order, the Heavy Hex Screws Series should be used, except the maximum body diameter and radius of fillet may be the same as for the Heavy Hex Bolt Series. The body diameter and head fillet radius for sizes of Heavy Hex Cap Screws and Bolts that are not shown in their respective tables in ANSI B18.2.1 or ANSI B18.2.3.1M may be that shown in the corresponding Hex Cap Screw and Bolt Tables respectively. Socket head fasteners shall be in accordance with ANSI B18.3 or ANSI B18.3.1M.

12. Retests

12.1 If the results of the mechanical tests of any test lot do not conform to the requirements specified, the manufacturer may retreat such lot not more than twice, in which case two additional tension tests shall be made from such lot, all of which shall conform to the requirements specified.

13. Test Specimens

13.1 Number of Tests — For heat-treated bars, one tension test shall be made for each diameter of each heat

represented in each tempering charge. When heat treated without interruption in continuous furnaces, the material in a lot shall be the same heat, same prior condition, same size, and subjected to the same heat treatment. Not fewer than two tension tests are required for each lot containing 20 000 lb [9000 kg] or less. Every additional 10 000 lb [4500 kg] or fraction thereof requires one additional test.

13.1.1 For studs, bolts, screws, and so forth, one tension test shall be made for each diameter of each heat involved in the lot. Each lot shall consist of the following:

Diameter, in. [mm]	Lot Size
1 $\frac{1}{8}$ [30] and under	1500 lb [780 kg] or fraction thereof
Over 1 $\frac{1}{8}$ [30] to 1 $\frac{3}{4}$ [42], incl	4500 lb [2000 kg] or fraction thereof
Over 1 $\frac{3}{4}$ [42] to 2 $\frac{1}{2}$ [64], incl	6000 lb [2700 kg] or fraction thereof
Over 2 $\frac{1}{2}$ [64]	100 pieces or fraction thereof

13.1.2 Tension tests are not required to be made on bolts, screws, studs, or stud bolts that are fabricated from heat-treated bars furnished in accordance with the requirements of this specification and tested in accordance with 13.1, provided they are not given a subsequent heat treatment.

13.1.3 Full Size Specimens, Headed Fasteners — Headed fasteners 1 $\frac{1}{2}$ in. in body diameter and smaller, with body length three times the diameter or longer, and that are produced by upsetting or forging (hot or cold) shall be subjected to full size testing in accordance with 10.1.2. This testing shall be in addition to tensile testing as specified in 10.1.1. The lot size shall be as shown in 13.1.1. Failure shall occur in the body or threaded section with no failure, or indications of failure, such as cracks, at the junction of the head and shank.

14. Nuts

14.1 Bolts, studs, and stud bolts shall be furnished with nuts, when specified in the purchase order. Nuts shall conform to Specification A 194/A 194M.

15. Rejection and Rehearing

15.1 Unless otherwise specified in the basis of purchase, any rejection based on product analysis shall be reported to the manufacturer within 30 days from the receipt of samples by the purchaser.

15.2 Material that shows defects subsequent to its acceptance at the place of manufacture shall be rejected, and the manufacturer shall be notified.

15.3 Product Analysis — Samples that represent rejected material shall be preserved for two weeks from the date of the test report. In the case of dissatisfaction

with the results of the test, the manufacturer may make claim for a rehearing within that time.

16. Certification

16.1 The producer of the raw material or finished fasteners shall furnish a certification to the purchaser or his representative showing the results of the chemical analysis, macroetch examination (Carbon and Alloy Steels Only), and mechanical tests, and state the method of heat treatment employed.

16.2 Certification shall also include at least the following:

16.2.1 A statement that the material or the fasteners, or both, were manufactured, sampled, tested, and inspected in accordance with the specification and any supplementary requirements or other requirements designated in the purchase order or contract and was found to meet those requirements.

16.2.2 The specification number, year date, and identification symbol.

17. Product Marking

17.1 The marking symbol and manufacturer's identification symbol shall be applied to one end of studs $\frac{3}{8}$ in. [10 mm] in diameter and larger and to the heads of bolts $\frac{1}{4}$ in. [6 mm] in diameter and larger. (If the available area is inadequate, the marking symbol may be placed on one end with the manufacturer's identification symbol placed on the other end.) The marking symbol shall be as shown in Table 4 and Table 5. Grade B7M, which has been 100% evaluated in conformance with the specification, shall have a line under the marking symbol to distinguish it from B7M produced to previous specification revisions not requiring 100% hardness testing.

17.2 For bolting materials, including threaded bars, furnished bundled and tagged or boxed, the tags and boxes shall carry the marking symbol for the material identification and the manufacturer's identification symbol or name.

17.3 For purposes of product marking, the manufacturer is considered the organization that certifies the fastener was manufactured, sampled, tested, and inspected in accordance with the specification and the results have been determined to meet the requirements of this specification.

17.4 Bar Coding — In addition to the requirements in 17.1, 17.2, and 17.3, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with AIAG Standard B-5 02.00. If used on small items, the bar code may be applied to the box or a substantially applied tag.

18. Keywords

18.1 hardness; heat treatment

TABLE 1
CHEMICAL REQUIREMENTS (COMPOSITION, PERCENT) [NOTE (1)]

Type		Ferritic Steels			
Grade		B5		B6 and B6X	
Description		5% Chromium		12% Chromium	
UNS Designation		S41000 (410)			
		Product Variation, Over or Under [Note (2)]		Product Variation, Over or Under [Note (2)]	
Range		Range		Range	
Carbon	0.10 min	0.01 under	0.08–0.15	0.01 over	
Manganese, max	1.00	0.03 over	1.00	0.03 over	
Phosphorus, max	0.040	0.005 over	0.040	0.005 over	
Sulfur, max	0.030	0.005 over	0.03	0.005 over	
Silicon	1.00 max	0.05 over	1.00 max	0.05 over	
Chromium	4.0–6.0	0.10	11.5–13.5	0.15	
Molybdenum	0.40–0.65	0.05	...	...

Type		Ferritic Steels			
Grade		B7, B7M		B16	
Description		Chromium-Molybdenum [Note (3)]		Chromium-Molybdenum-Vanadium	
		Product Variation, Over or Under [Note (2)]		Product Variation, Over or Under [Note (2)]	
Range		Range		Range	
Carbon	0.37–0.49 [Note (4)]	0.02	0.36–0.47	0.02	
Manganese	0.65–1.10	0.04	0.45–0.70	0.03	
Phosphorus, max	0.035	0.005 over	0.035	0.005 over	
Sulfur, max	0.040	0.005 over	0.040	0.005 over	
Silicon	0.15–0.35	0.02	0.15–0.35	0.02	
Chromium	0.75–1.20	0.05	0.80–1.15	0.05	
Molybdenum	0.15–0.25	0.02	0.50–0.65	0.03	
Vanadium	...	...	0.25–0.35	0.03	
Aluminum, max % [Note (5)]	...	...	0.015	...	

Type		Austenitic Steels, [Note (6)] Classes 1, 1A, 1D, and 2							
Grade		B8, B8A		B8C, B8CA		B8M, B8MA, B8M2, B8M3		B8P, B8PA	
UNS Designation		S30400 (304)		S34700 (347)		S31600 (316)		S30500	
		Product Variation, Over or Under [Note (2)]		Product Variation, Over or Under [Note (2)]		Product Variation, Over or Under [Note (2)]		Product Variation, Over or Under [Note (2)]	
Range		Range		Range		Range		Range	
Carbon, max	0.08	0.01 over	0.08	0.01 over	0.08	0.01 over	0.12	0.01 over	
Manganese, max	2.00	0.04 over	2.00	0.04 over	2.00	0.04 over	2.00	0.04 over	
Phosphorus, max	0.045	0.010 over	0.045	0.010 over	0.045	0.010 over	0.045	0.010 over	
Sulfur, max	0.030	0.005 over	0.030	0.005 over	0.030	0.005 over	0.030	0.005 over	
Silicon, max	1.00	0.05 over	1.00	0.05 over	1.00	0.05 over	1.00	0.05 over	
Chromium	18.0–20.0	0.20	17.0–19.0	0.20	16.0–18.0	0.20	17.0–19.0	0.20	
Nickel	8.0–11.0	0.15	9.0–12.0	0.15	10.0–14.0	0.15	11.0–13.0	0.15	
Molybdenum	...	...	...	...	2.00–3.00	0.10	...	...
Columbium + tantalum	...	...	10 × carbon content, min; 1.10 max	0.05 under	...	...	...	...

TABLE 1
CHEMICAL REQUIREMENTS (COMPOSITION, PERCENT) [NOTE (1)] (CONT'D)

Type	Austenitic Steels, [Note (6)] Classes 1A, 1B, 1D, and 2					
Grade	B8N, B8NA		B8MN, B8MNA		B8MLCuN, B8MLCuNA	
UNS Designation	S30451 (304N)		S31651 (316N)		S31254	
	Range	Product Variation, Over or Under [Note (2)]	Range	Product Variation, Over or Under [Note (2)]	Range	Product Variation Over or Under [Note (2)]
Carbon, max	0.08	0.01 over	0.08	0.01 over	0.020	0.005 over
Manganese, max	2.00	0.04 over	2.00	0.04 over	1.00	0.03 over
Phosphorus, max	0.045	0.010 over	0.045	0.010 over	0.030	0.005 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over	0.010	0.002 over
Silicon, max	1.00	0.05 over	1.00	0.05 over	0.80	0.05 over
Chromium	18.0–20.0	0.20	16.0–18.0	0.20	19.5–20.5	0.20
Nickel	8.0–11.0	0.15	10.0–13.0	0.15	17.5–18.5	0.15
Molybdenum	...	...	2.00–3.00	0.10	6.0–6.5	0.10
Nitrogen	0.10–0.16	0.01	0.10–0.16	0.01	0.18–0.22	0.02
Copper	...	...	...	...	0.50–1.00	...
Type	Austenitic Steels [Note (6)], Classes 1, 1A, and 2					
Grade	B8T, B8TA					
UNS Designation	S32100 (321)					
	Range					Product Variation, Over or Under [Note (2)]
Carbon, max	0.08					0.01 over
Manganese, max	2.00					0.04 over
Phosphorus, max	0.045					0.010 over
Sulfur, max	0.030					0.005 over
Silicon, max	1.00					0.05 over
Chromium	17.0–19.0					0.15
Nickel	9.0–12.0					0.20
Titanium	5 × (C + N) min, 0.70 max [Note (7)]					0.05 under
Type	Austenitic Steels [Note (6)], Classes 1C and 1D					
Grade	B8R, B8RA			B8S, B8SA		
UNS Designation	S20910			S21800		
	Range	Product Variation, Over or Under [Note (2)]	Range	Product Variation, Over or Under [Note (2)]		
Carbon, max	0.06	0.01 over	0.10	0.01 over		
Manganese	4.0–6.0	0.05	7.0–9.0	0.06		
Phosphorus, max	0.045	0.005 over	0.060	0.005 over		
Sulfur, max	0.030	0.005 over	0.030	0.005 over		
Silicon	1.00 max	0.05 over	3.5–4.5	0.15		
Chromium	20.5–23.5	0.25	16.0–18.0	0.20		
Nickel	11.5–13.5	0.15	8.0–9.0	0.10		
Molybdenum	1.50–3.00	0.10	...	...
Nitrogen	0.20–0.40	0.02	0.08–0.18	0.01		
Columbium + tantalum	0.10–0.30	0.05	...	...
Vanadium	0.10–0.30	0.02	...	...

TABLE 1
CHEMICAL REQUIREMENTS (COMPOSITION, PERCENT) [NOTE (1)] (CONT'D)

Type	Austenitic Steels [Note (6)], Classes 1, 1A and 1D			
Grade	B8LN, B8LNA		B8MLN, B8MLNA	
UNS Designation	S30453		S31653	
	Range	Product Variation, Over or Under [Note (2)]	Range	Product Variation, Over or Under [Note (2)]
Carbon, max	0.030	0.005 over	0.030	0.005 over
Manganese	2.00	0.04 over	2.00	0.04 over
Phosphorus, max	0.045	0.010 over	0.045	0.010 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over
Silicon	1.00	0.05 over	1.00	0.05 over
Chromium	18.0–20.0	0.20	16.0–18.0	0.20
Nickel	8.0–11.0	0.15	10.0–13.0	0.15
Molybdenum	...	...	2.00–3.00	0.10
Nitrogen	0.10–0.16	0.01	0.10–0.16	0.01

NOTES:

- (1) The intentional addition of Bi, Se, Te, and Pb is not permitted.
- (2) Product analysis — Individual determinations sometimes vary from the specified limits on ranges as shown in the tables. The several determinations of any individual element in a heat may not vary both above and below the specified range.
- (3) Typical steel compositions used for this grade include 4140, 4142, 4145, 4140H, 4142H, and 4145H.
- (4) For bar sizes over $3\frac{1}{2}$ in. [90 mm], inclusive, the carbon content may be 0.50%, max. For the B7M grade, a minimum carbon content of 0.28% is permitted, provided that the required tensile properties are met in the section sizes involved; the use of AISI 4130 or 4130H is allowed.
- (5) Total of soluble and insoluble.
- (6) Classes 1 and 1D are solution treated. Classes 1, 1B and some 1C (B8R and B8S) products are made from solution treated material. Class 1A (B8A, B8CA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA and B8MNA) and some Class 1C (B8RA and B8SA) products are solution treated in the finished condition. Class 2 products are solution treated and strain hardened.
- (7) Nitrogen content is to be reported for this grade.

TABLE 2
MECHANICAL REQUIREMENTS — INCH PRODUCTS

Grade	Diameter, in.	Minimum Tempering Temperature, °F	Tensile Strength, Min., ksi	Yield Strength, Min., 0.2% offset, ksi	Elongation in 4D, Min., %	Reduction of Area, Min., %	Hardness, Max.
Ferritic Steels							
B5 4 to 6% chromium	up to 4, incl.	1100	100	80	16	50	...
B6 13% chromium	up to 4, incl.	1100	110	85	15	50	...
B6X 13% chromium	up to 4, incl.	1100	90	70	16	50	26 HRC
B7 Chromium-molybdenum	2½ and under	1100	125	105	16	50	321 HB or 35 HRC
	over 2½ to 4	1100	115	95	16	50	321 HB or 35 HRC
	over 4 to 7	1100	100	75	18	50	321 HB or 35 HRC
B7M [Note (1)] Chromium-molybdenum	4 and under	1150	100	80	18	50	235 HB or 99 HRB
	over 4 to 7	1150	100	75	18	50	235 BHN or 99 HRB
B16 Chromium-molybdenum- vanadium	2½ and under	1200	125	105	18	50	321 HB or 35 HRC
	over 2½ to 4	1200	110	95	17	45	321 HB or 35 HRC
	over 4 to 8	1200	100	85	16	45	321 HB or 35 HRC

TABLE 2
MECHANICAL REQUIREMENTS — INCH PRODUCTS (CONT'D)

Grade, Diameter, in.	Heat Treatment [Note (2)]	Tensile Strength, min, ksi	Yield Strength, min, 0.2 % offset, ksi	Elongation in 4D, min, %	Reduction of Area, min %	Hardness, max
Austenitic Steels						
Classes 1 and 1D: B8, B8M, B8P, B8LN, B8MLN, all diameters	carbide solution treated	75	30	30	50	223 HB or 96 HRB [Note (3)]
Class 1: B8C, B8T, all diameters	carbide solution treated	75	30	30	50	223 HB or 96 HRB [Note (3)]
Class 1A: B8A, B8CA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, B8MNA, B8MLCuNA, all diameters	carbide solution treated in the finished condition	75	30	30	50	192 HB or 90 HRB
Classes 1B and 1D: B8N, B8MN, and B8MLCuN, all diameters	carbide solution treated	80	35	30	40	223 HB or 96 HRB [Note (3)]
Classes 1C and 1D: B8R, all diameters	carbide solution treated	100	55	35	55	271 HB or 28 HRC
Class 1C: B8RA, all diameters	carbide solution treated in the finished condition	100	55	35	55	271 HB or 28 HRC
Classes 1C and 1D: B8S, all diameters	carbide solution treated	95	50	35	55	271 HB or 28 HRC
Class 1C: B8SA, all diameters	carbide solution treated in the finished condition	95	50	35	55	271 HB or 28 HRC
Class 2: B8, B8C, B8P, B8T, and B8N [Note (4)] ¾ and under	carbide solution treated and strain hardened	125	100	12	35	321 HB or 35 HRC
over ¾ to 1, incl		115	80	15	35	321 HB or 35 HRC
over 1 to 1¼ incl		105	65	20	35	321 HB or 35 HRC
over 1¼ to 1½ incl		100	50	28	45	321 HB or 35 HRC
Class 2: B8M, B8MN, B8MLCuN [Note (4)] ¾ and under	carbide solution treated and strain hardened	110	95	15	45	321 HB or 35 HRC
over ¾ to 1 incl		100	80	20	45	321 HB or 35 HRC
over 1 to 1¼ incl		95	65	25	45	321 HB or 35 HRC
over 1¼ to 1½ incl		90	50	30	45	321 HB or 35 HRC
Class 2B: B8, B8M2 [Note (4)] 2 and under	carbide solution treated and strain hardened	95	75	25	40	321 HB or 35 HRC
over 2 to 2½ incl		90	65	30	40	321 HB or 35 HRC
over 2½ to 3 incl		80	55	30	40	321 HB or 35 HRC
Class 2C: B8M3 [Note (4)] 2 and under	carbide solution treated and strain hardened	85	65	30	60	321 HB or 35 HRC
over 2		85	60	30	60	321 HB or 35 HRC

NOTES:

- (1) To meet the tensile requirements, the Brinell hardness shall be over 200 HB (93 HRB).
- (2) Class 1 is solution treated. Class 1A is solution treated in the finished condition for corrosion resistance; heat treatment is critical due to physical property requirement. Class 2 is solution treated and strain hardened. Austenitic steels in the strain-hardened condition may not show uniform properties throughout the section particularly in sizes over ¾ in. in diameter.
- (3) For sizes ¾ in. in diameter and smaller, a maximum hardness of 241 HB (100 HRB) is permitted.
- (4) For diameters 1½ and over, center (core) properties may be lower than indicated by test reports which are based on values determined at ½ radius.

TABLE 3
MECHANICAL REQUIREMENTS — METRIC PRODUCTS

Class	Diameter, mm	Minimum Tempering Temperature, °C	Tensile Strength, min, MPa	Yield Strength, min, 0.2% offset, MPa	Elongation in 4D, min, %	Reduction of Area, min, %	Hardness, max
Ferritic Steels							
B5 4 to 6% chromium	up to M100, incl	593	690	550	16	50	...
B6 13% chromium	up to M100, incl	593	760	585	15	50	...
B6X 13% chromium	up to M100, incl	593	620	485	16	50	26 HRC
B7 Chromium-molybdenum	M64 and under	593	860	720	16	50	321 HB or 35 HRC
	over M64 to M100	593	795	655	16	50	321 HB or 35 HRC
	over M100 to M180	593	690	515	18	50	321 HB or 35 HRC
B7M ⁴ Chromium-molybdenum	M100 and under	620	690	550	18	50	235 HB or 99 HRB
	over M100 to M180	620	690	515	18	50	235 BHN or 99 HRB
B16 Chromium-molybdenum-vanadium	M64 and under	650	860	725	18	50	321 HB or 35 HRC
	over M64 to M100	650	760	655	17	45	321 HB or 35 HRC
	over M100 to M180	650	690	585	16	45	321 HB or 35 HRC
Class	Diameter, mm	Heat Treatment ^B	Tensile Strength, min, MPa	Yield Strength, min, 0.2% offset, MPa	Elongation in 4D, min, %	Reduction of Area, min, %	Hardness, max
Austenitic Steels							
Classes 1 and 1D: B8, B8M, B8P, B8LN, B8MLN, all diameters	carbide solution treated		515	205	30	50	223 HB ^C or 96 HRB
Class 1: B8C, B8T, all diameters	carbide solution treated		515	205	30	50	223 HB ^C or 96 HRB
Class 1A: B8A, B8CA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, B8MNA, B8MLCuNA, all diameters	carbide solution treated in the finished condition		515	205	30	50	192 HB or 90 HRB
Classes 1B and 1D: B8N, B8MN, and B8MLCuN, all diameters	carbide solution treated		550	240	30	40	223 HB ^C or 96 HRB
Classes 1C and 1D: B8R, all diameters	carbide solution treated		690	380	35	55	271 HB ^C or 28 HRC
Class 1C: B8RA, all diameters	carbide solution treated in the finished condition		690	380	35	55	271 HB or 28 HRC
Classes 1C and 1D: B8S, all diameters	carbide solution treated		655	345	35	55	271 HB or 28 HRC
Class 1C: B8SA, all diameters	carbide solution treated in the finished condition		655	345	35	55	271 HB or 28 HRC

TABLE 3
MECHANICAL REQUIREMENTS — METRIC PRODUCTS (CONT'D)

Class Diameter, mm	Heat Treatment ^B	Tensile Strength, min, MPa	Yield Strength, min, 0.2% offset, MPa	Elongation in 4D, min, %	Reduction of Area, min, %	Hardness, max
Austenitic Steels (CONT'D)						
Class 2: B8, B8C, B8P, B8T, and B8N ^D M20 and under	carbide solution treated and strain hardened	860	690	12	35	321 HB or 35 HRC
over M20 to M24, incl		795	550	15	35	321 HB or 35 HRC
over M24 to M30, incl		725	450	20	35	321 HB or 35 HRC
over M30 to M36, incl		690	345	28	45	321 HB or 35 HRC
Class 2: B8M, B8MN, B8MLCuN ^D M20 and under	carbide solution treated and strain hardened	760	655	15	45	321 HB or 35 HRC
over M20 to M24, incl		690	550	20	45	321 HB or 35 HRC
over M24 to M30, incl		655	450	25	45	321 HB or 35 HRC
over M30 to M36, incl		620	345	30	45	321 HB or 35 HRC
Class 2B: B8, B8M2 ^D M48 and under	carbide solution treated and strain hardened	655	515	25	40	321 HB or 35 HRC
over M48 to M64, incl		620	450	30	40	321 HB or 35 HRC
over M64 to M72, incl		550	380	30	40	321 HB or 35 HRC
Class 2C: B8M3 ^D M48 and under	carbide solution treated and strain hardened	585	450	30	60	321 HB or 35 HRC
over M48		585	415	30	60	321 HB or 35 HRC

^A To meet the tensile requirements, the Brinell hardness shall be over 200 HB (93 HRB).

^B Class 1 is solution treated. Class 1A is solution treated in the finished condition for corrosion resistance; heat treatment is critical due to physical property requirement. Class 2 is solution treated and strain hardened. Austenitic steels in the strain-hardened condition may not show uniform properties throughout the section particularly in sizes over M20 mm in diameter.

^C For sizes M20 mm in diameter and smaller, a maximum hardness of 241 HB (100 HRB) is permitted.

^D For diameters M38 and over, center (core) properties may be lower than indicated by test reports which are based on values determined at $\frac{1}{2}$ radius.

TABLE 4
MARKING OF FERRITIC STEELS

Grade	Marking
B5	B5
B6	B6
B6X	B6X
B7	B7
B7M [Note (1)]	B7M
	B7M
B16	B16
B16+	B16R
Supplement S12	

NOTE:

(1) For explanations, see 10.2.2 and 17.1.

TABLE 5
MARKING OF AUSTENITIC STEELS

Class	Grade	Marking
Class 1	B8	B8
	B8C	B8C
	B8M	B8M
	B8P	B8P
	B8T	B8T
	B8LN	B8F or B8LN
	B8MLN	B8G or B8MLN
Class 1A	B8A	B8A
	B8CA	B8B or B8CA
	B8MA	B8D or B8MA
	B8PA	B8H or B8PA
	B8TA	B8J or B8TA
	B8LNA	B8L or B8LNA
	B8MLNA	B8K or B8MLNA
	B8NA	B8V or B8NA
	B8MNA	B8W or B8MNA
	B8MLCuNA	B9K or B8MLCuNA
Class 1B	B8N	B8N
	B8MN	B8Y or B8MN
	B8MLCuN	B9J or B8MLCuN
Class 1C	B8R	B9A or B8R
	B8RA	B9B or B8RA
	B8S	B9D or B8S
	B8SA	B9F or B8SA
Class 1D	B8	B94
	B8M	B95
	B8P	B96
	B8LN	B97
	B8MLN	B98
	B8N	B99
	B8MN	B100
	B8R	B101
Class 2	B8	<u>B8SH</u>
	B8C	<u>B8CSH</u>
	B8P	<u>B8PSH</u>
	B8T	<u>B8TSH</u>
	B8N	<u>B8NSH</u>
	B8M	<u>B8MSH</u>
	B8MN	<u>B8YSH</u>
	B8MLCuN	<u>B8JSH</u>
Class 2B	B8M2	<u>B9G or B8M2</u>
	B8	<u>B9</u>
Class 2C	B8M3	<u>B9H or B8M3</u>

SUPPLEMENTARY REQUIREMENTS

These requirements shall not apply unless specified in the order and in the Ordering Information, in which event the specified tests shall be made before shipment of the product.

S1. High-Temperature Tests

S1.1 Tests to determine high temperature properties shall be made in accordance with Practice E 21, and Practices E 139, E 292, E 150, and E 151.

S2. Charpy Impact Tests

S2.1 Charpy impact tests based on the requirements of Specification A 320/A 320M, Section 6 and 7 shall be made as agreed between the manufacturer and the purchaser. When testing temperatures are as low as those specified in Specification A 320/A 320M, bolting should be ordered to that specification in preference to this specification.

S3. 100% Hardness Testing of Grade B7M

S3.1 Each Grade B7M bolt or stud shall be tested for hardness by indentation method and shall meet the requirements specified in Table 2.

S4. Hardness Testing of Grade B16

S4.1 For bolts or studs 2½ in. [65 mm] or smaller, the hardness for Grade B16 shall be measured on or near the end of each bolt or stud using one of the methods prescribed in 10.2.1 for the Brinell or Rockwell C test. The hardness shall be in the range 253-319 HB or 25-34 HRC.

S5. Product Marking

S5.1 Grade and manufacturer's identification symbols shall be applied to one end of studs and to the heads of bolts of all sizes. (If the available area is inadequate, the grade symbol may be marked on one end and the manufacturer's identification symbol marked on the other end.) For bolts smaller than ¼ in. [6 mm] in diameter and studs smaller than ⅜ in. [10 mm] in diameter and for ¼ in. [6 mm] in diameter studs requiring more than a total of three symbols, the marking shall be a matter of agreement between the purchaser and the manufacturer.

S6. Stress Relieving

S6.1 A stress-relieving operation shall follow straightening after heat treatment.

S6.2 The minimum stress-relieving temperature shall be 100°F [55°C] below the tempering temperature. Tests for mechanical properties shall be performed after stress relieving.

S7. Magnetic Particle Inspection

S7.1 Bars shall be magnetic particle examined in accordance with Guide E 709. Bars with indications of cracks or seams are subject to rejection if the indications extend more than 3% of the diameter into the bar.

S8. Stress-Relaxation Testing

S8.1 Stress-Relaxation Testing, when required, shall be done in accordance with Practice E 328. The test shall be performed at 850°F [454°C] for a period of 100 h. The initial stress shall be 50 M psi (345 MPa). The residual stress at 100 h shall be 17 M psi (117 MPa) minimum.

S9. Grain Size Requirements for Non H Grade Austenitic Steels Used Above 1000°F

S9.1 For design metal temperatures above 1000°F [540°C], the material shall have a grain size of No. 7 or coarser as determined in accordance with Test Methods E 112. The grain size so determined shall be reported on the Certificate of Test.

S10. Hardness Testing of Class 2 Bolting Materials for ASME Applications

S10.1 The maximum hardness shall be Rockwell C35 immediately under the thread roots. The hardness shall be taken on a flat area at least ⅛ in. [3 mm] across, prepared by removing threads, and no more material than necessary shall be removed to prepare the flat areas. Hardness determinations shall be made at the same frequency as tensile tests.

S11. Thread Forming

S11.1 Threads shall be formed after heat treatment. Application of this supplemental requirement to grade B7M or the grades listed in 7.3.3 is prohibited.

S12. Stress Rupture Testing of Grade B16

S12.1 One test shall be made for each heat treat lot. Testing shall be conducted using a combination test bar in accordance with Test methods E 292. Rupture shall occur in the smooth section of each test specimen. The test shall be conducted at 1100°F [595°C] and 20 ksi [140 MPa]. The test shall be continued until the sample ruptures. Rupture life shall be 25 h minimum. Testing is not required on material less than $\frac{1}{2}$ in. [12 mm] thick.

S12.2 When a purchase order for fastener invokes S12, the product marking supplied shall be “B16R.”

S13. Coatings on Bolting Materials

S13.1 It is the purchaser’s responsibility to specify in the purchase order all information required by the coating facility. Examples of such information may include but are not limited to the following:

S13.1.1 Reference to the appropriate coating specification and type, thickness, location, modification to dimensions, and hydrogen embrittlement relief.

S13.1.2 Reference to Specifications A 153/A 153M, B 695, B 696, B 766, or F 1941, Test Method F 1940, or other standards.

APPENDICES

(Nonmandatory Information)

X1. STRAIN HARDENING OF AUSTENITIC STEELS

X1.1 Strain hardening is the increase in strength and hardness that results from plastic deformation below the recrystallization temperature (cold work). This effect is produced in austenitic stainless steels by reducing oversized bars or wire to the desired final size by cold drawing or other process. The degree of strain hardening achievable in any alloy is limited by its strain hardening characteristics. In addition, the amount of strain hardening that can be produced is further limited by the variables of the process, such as the total amount of cross-section reduction, die angle, and bar size. In large diameter bars, for example, plastic deformation will occur principally in the outer regions of the bar so that the increased strength and hardness due to strain hardening is achieved predominantly near the surface of the bar. That is, the smaller the bar, the greater the penetration of strain hardening.

X1.2 Thus, the mechanical properties of a given strain hardened fastener are dependent not just on the alloy, but also on the size of bar from which it is machined. The minimum bar size that can be used, however, is established

by the configuration of the fastener so that the configuration can affect the strength of the fastener.

X1.3 For example, a stud of a particular alloy and size may be machined from a smaller diameter bar than a bolt of the same alloy and size because a larger diameter bar is required to accommodate the head of the bolt. The stud, therefore, is likely to be stronger than the same size bolt in a given alloy.

X2. COATINGS AND APPLICATION LIMITS

X2.1 Use of coated fasteners at temperatures above approximately one-half the melting point (Fahrenheit or Celsius) of the coating is not recommended unless consideration is given to the potential for liquid and solid metal embrittlement, or both. The melting point of elemental zinc is approximately 780°F [415°C]. Therefore, application of zinc-coated fasteners should be limited to temperatures less than 390°F [210°C]. The melting point of cadmium is approximately 600°F [320°C]. Therefore, application of cadmium-coated fasteners should be limited to temperatures less than 300°F [160°C].

SPECIFICATION FOR CARBON AND ALLOY STEEL NUTS FOR BOLTS FOR HIGH PRESSURE OR HIGH TEMPERATURE SERVICE, OR BOTH



SA-194/SA-194M



(Identical with ASTM Specification A 194/A 194M-07a.)

1. Scope

1.1 This specification covers a variety of carbon, alloy, and martensitic stainless steel nuts in the size range $\frac{1}{4}$ through 4 in. and metric M6 through M100 nominal. It also covers austenitic stainless steel nuts in the size range $\frac{1}{4}$ in. and M6 nominal and above. These nuts are intended for high-pressure or high-temperature service, or both. Grade substitutions without the purchaser's permission are not allowed.

1.2 Bars from which the nuts are made shall be hot-wrought. The material may be further processed by centerless grinding or by cold drawing. Austenitic stainless steel may be solution annealed or annealed and strain-hardened. When annealed and strain hardened austenitic stainless steel is ordered in accordance with Supplementary Requirement S1, the purchaser should take special care to ensure that 8.2.2, Supplementary Requirement S1, and Appendix X1 are thoroughly understood.

1.3 Supplementary requirements (S1 through S8) of an optional nature are provided. These shall apply only when specified in the inquiry, contract, and order.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 ASTM Standards:

- A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
- A 276 Specification for Stainless Steel Bars and Shapes
- A 320/A 320M Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low-Temperature Service
- A 962/A 962M Specification for Common Requirements for Steel Fasteners or Fastener Materials, or Both, Intended for Use at Any Temperature from Cryogenic to the Creep Range
- B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
- B 696 Specification for Coatings of Cadmium Mechanically Deposited
- B 766 Specification for Electrodeposited Coatings of Cadmium
- E 112 Test Methods for Determining Average Grain Size
- F 1940 Test Method for Process Control Verification to Prevent Hydrogen Embrittlement in Plated or Coated Fasteners
- F 1941 Specification for Electrodeposited Coatings on Threaded Fasteners (Unified Inch Screw Threads (UN/UNR))

2.2 American National Standards:

- B 1.1 Unified Screw Threads
- B 1.2 Gages and Gaging for Unified Inch Screw Threads
- B 1.13M Metric Screw Threads
- B 18.2.2 Square and Hex Nuts
- B 18.2.4.6M Metric Heavy Hex Nuts

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 Austenitic Grades — All grades with a prefix of "8" or "9."

3.1.2 Ferritic Grades — Grades 1, 2, 2H, 2HM, 3, 4, 6, 6F, 7, 7M, and 16.

3.1.3 Lot:

3.1.3.1 Unless otherwise specified (see 3.1.3.2), a lot is the quantity of nuts of a single nominal size and grade produced by the same manufacturing process.

3.1.3.2 When Supplementary Requirement S5 is invoked on the purchase order, the following definitions of a lot shall apply:

For Grade 8 Nuts — The quantity of all the nuts of a single nominal diameter and grade made from the same heat of steel and made by the same manufacturing process.

For All Other Grade Nuts (see 8.2 and 8.1.2.1) — All the nuts of a single nominal diameter and grade made from the same heat number and heat treated in the same batch if batch-type heat treating equipment is used or heat treated in the same continuous run of not more than 8 h under the same conditions if continuous-type heat treating equipment is used.

3.1.4 Type

3.1.4.1 *For Grade 8 Nuts* — Variations within the grade designated by a letter and differentiated by chemistry and by manufacturing process.

3.1.4.2 *For Grade 6 Nuts* — Variations within the grade designated by the letter F as differentiated by chemical additions made for machineability.

3.1.5 Series — The dimensional relationship and geometry of the nuts as described in ANSI B 18.2.2 or B 18.2.4.6M.

4. Ordering Information

4.1 The inquiry and order for material under this specification shall include the following as required to describe the material adequately:

4.1.1 Specification designation, year date, and grade, issue date and revision letter,

4.1.2 Quantity, number of pieces,

4.1.3 Dimensions (see Section 9),

4.1.4 Options in accordance with 8.2.2.1, 9.1, 9.2, 10.3, and 12, and

4.1.5 Supplementary Requirements, if any.

4.2 Coatings — Coatings are prohibited unless specified by the purchaser (see Supplementary Requirements S7 and S8). When coated nuts are ordered, the purchaser should take special care to ensure that Appendix X2 is thoroughly understood.

4.3 See Supplementary Requirement S3 for nuts to be used in low temperature applications (Specification A 320/A 320M).

5. Common Requirements

5.1 Material and fasteners supplied to this specification shall conform to the requirements of Specification A 962/A 962M. These requirements include test methods, finish, thread dimensions, marking, certification, optional supplementary requirements, and others. Failure to comply with the requirements of Specification A 962/A 962M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 962/A 962M, this specification shall prevail.

6. Manufacture (Process)

6.1 Stainless steels for all types of Grade 6 and 8 nuts shall be made by one of the following processes:

6.1.1 Electric-furnace (with separate degassing and refining optional),

6.1.2 Vacuum induction furnace, or

6.1.3 Either of the above followed by electroslag remelting, or consumable-arc remelting.

6.2 The steel producer shall exercise adequate control to eliminate excessive unhomogeneity, nonmetallics, pipe, porosity, and other defects.

6.3 Grades 1 and 2 nuts shall be hot or cold forged, or shall be machined from hot-forged, hot-rolled, or cold-drawn bars.

6.3.1 All Grade 1 and 2 nuts made by cold forging or by machining from cold-drawn bars shall be stress-relief annealed at a temperature of at least 1000°F [538°C].

6.3.2 Grade 1 and 2 nuts made by hot forging or by machining from hot-forged or hot-rolled bars need not be given any stress relief annealing treatment.

6.4 Grades 2H, 2HM, 3, 4, 6, 6F, 7, 7M, and 16 nuts shall be hot- or cold-forged or shall be machined from hot-forged, hot-rolled, or cold-drawn bars and shall be heat treated to meet the required mechanical properties. These grades shall be reheated above the critical range of the steel, quenched in a suitable medium, and then tempered at a temperature not less than the following:

Grade	Minimum Tempering Temperature, °F [°C]
2H	850 [455]
2HM	1150 [620]
3	1050 [565]
4	1100 [595]
6 and 6F	1100 [595]
7	1100 [595]
7M	1150 [620]
16	1200 [650]

Nuts machined from bar heat treated in accordance with this specification need not be reheat-treated. For Grade

2HM and 7M nuts, a final stress relief shall be done at or above the minimum tempering temperature after all forming, machining, and tapping operations. This final stress relief may be the tempering operation.

6.4.1 Grade 6 and 6F nuts shall be tempered for a minimum of 1 h at the temperature.

6.5 Grades 8, 8C, 8M, 8T, 8F, 8P, 8N, 8MN, 8R, 8S, 8LN, 8MLN, 8MLCuN, and 9C nuts shall be hot or cold forged, or shall be machined from hot-forged, hot-rolled or cold-drawn bars.

6.6 Grades 8A, 8CA, 8MA, 8TA, 8FA, 8PA, 8NA, 8MNA, 8RA, 8SA, 8LNA, 8MLNA, 8MLCuNA, and 9CA nuts shall be hot- or cold-forged or shall be machined from hot-forged, hot-rolled, or cold-drawn bars and the nuts shall subsequently be carbide-solution treated by heating them for a sufficient time at a temperature to dissolve chromium carbides followed by cooling at a rate sufficient to prevent reprecipitation of the carbides.

7. Chemical Composition

7.1 Each alloy shall conform to the chemical composition requirements prescribed in Table 1.

8. Mechanical Requirements

8.1 Hardness Test:

8.1.1 Requirements:

8.1.1.1 All nuts shall meet the hardness requirements specified in Table 2.

8.1.1.2 Sample nuts of Grades 1, 2, 2H, 2HM, 3, 4, 7, 7M, and 16 which have been given the treatment described in 8.1.5 shall meet the minimum hardness specified in Table 2.

8.1.2 Number of Tests — (Grades 1, 2, 2H, 3, 4, 7, and 16 and all types of Grade 6):

8.1.2.1 Tests on the number of sample nuts in accordance with the following table shall be performed by the manufacturer following all production heat treatments:

Lot Size	Samples
Up to 800	1
801 to 8000	2
8001 to 22 000	3
Over 22 000	5

8.1.2.2 In addition, a hardness test shall be performed by the manufacturer in accordance with 8.1.5 on one sample nut selected from each nominal diameter and series from each grade and heat number following completion of all production heat treatments.

8.1.3 Number of Tests, Grades 2HM and 7M:

8.1.3.1 Each nut shall be tested by Brinell or Rockwell methods to ensure product conformance.

8.1.3.2 In addition, 8.1.2.2 shall be met.

8.1.4 Number of Tests, All Types of Grade 8 — Tests on the number of sample nuts in accordance with 8.1.2.1 shall be performed by the manufacturer.

8.1.5 Test 2 — In addition to the testing required by 8.1.2.1 the manufacturer shall also perform hardness tests on sample nuts after the following test heat treatment. After completion of all production heat treatments heat the specimen nuts to the temperatures indicated below for 24 h, then slow cool. Test at room temperature.

Grade ^A	Temperature, °F [°C]
1	850 [455]
2, 2H, 2HM	1000 [540]
3, 4, 7, 7M	1100 [590]
16	1200 [650]

^A Nuts intended to be coated with zinc or cadmium (marked in accordance with the requirements of Supplementary Requirements S8) are not subjected to the requirements of 8.1.5 (see Appendix X2).

8.1.5.1 Special Requirement, Grades 2HM and 7M — Preparation of Grades 2HM and 7M nuts for hardness test and the hardness test itself shall be performed with consideration to (1) protect legibility of markings; (2) minimize exterior dimensional changes; and (3) maintain thread fit.

8.2 Proof Load Test:

8.2.1 Requirements — All nuts shall be capable of withstanding the proof loads specified in Table 3 and Table 4. However, nuts manufactured to dimensions and configurations other than those covered by ANSI B 1.1, ANSI B 1.13M, ANSI B 18.2.2, and B 18.2.4.6M are not subject to the proof load test.

8.2.2 Number of Tests:

8.2.2.1 The manufacturer shall test the number of nuts specified in 8.1.2.1 following all production heat treatments. Nuts that would require a proof load in excess of 160 000 lb/f or 705 kN may be furnished on the basis of minimum hardness requirements. Testing of nuts requiring a proof load in excess of 160 000 lb/f or 705 kN is covered in Supplementary Requirements S1 and S4.

8.2.3 Test Method — The test shall be run using a threaded mandrel or a test bolt in accordance with Specification A 962/A 962M.

8.3 Cone Proof Load Test:

8.3.1 Requirements — This test shall be performed only when visible surface discontinuities become a matter of issue between the manufacturer and the purchaser. Nuts in the size range $\frac{1}{4}$ to $1\frac{1}{2}$ in. inclusive and M6 to M36 inclusive shall be proof load tested. Nuts not in this size range and all types of Grade 8 nuts are not subject to this

test. Also, nuts manufactured to dimensions and configurations other than those covered by Specification A 962/A 962M, ANSI B 1.1, ANSI B 1.13M, ANSI B 18.2.2, and ANSI B 18.2.4.6M are not subject to the cone proof load test. The cone proof load applied shall be determined in accordance with the Cone Proof Load requirements in Specification A 962/A 962M (tables or formulae or both) based upon the proof stresses shown in Table 5 and Table 6 of Specification A 194/A 194M.

8.3.2 Number of Tests — The manufacturer shall sample and test the number of nuts specified in 8.1.2.1. The lot shall be considered acceptable if the sample nut(s) withstand(s) application of the cone proof load without failure.

9. Dimensions

9.1 Nuts shall be hexagonal in shape, and in accordance with the dimensions for the hex or heavy hex series, as required, by ANSI B 18.2.2 and ANSI B 18.2.4.6M. Unless otherwise specified, the American National Standard Heavy Hex Series shall be used and nuts shall be either double chamfered or have a machined or forged washer face, at the option of the manufacturer, and, conform to the angularity requirements of ANSI B 18.2.2 and ANSI B 18.2.4.6M.

9.2 Unless otherwise specified, threads shall be in accordance with ANSI B 1.1 or ANSI B 1.13M, and shall be gaged in accordance with ANSI B 1.2 and ANSI B 1.13M as described in 9.2.1 and 9.2.2.

9.2.1 Nuts up to and including 1 in. nominal size shall be UNC Series Class 2B fit. Metric nuts up to and including M24 nominal size shall be coarse thread series tolerance 6H.

9.2.2 Nuts over 1 in. nominal size shall be either UNC Series Class 2B fit or 8 UN Series Class 2B fit. Unless otherwise specified, the 8 UN series shall be furnished. Metric nuts over M24 nominal size shall be coarse thread series tolerance 6H.

10. Workmanship, Finish, and Appearance

10.1 Nuts shall be free of defects and shall be good commercial finish.

10.2 If visible surface imperfections in size $\frac{1}{4}$ through $1\frac{1}{2}$ in. and M6 through M36 and in any grade other than Grade 8 become a matter of issue between the manufacturer and the purchaser, the cone proof load test described in 8.3 shall be employed.

10.3 If a scale-free bright finish is required, this shall be specified on the purchase order.

11. Retests

11.1 Provisions for retests by the purchaser and his representative are specified in Supplementary Requirement S2.

12. Certification

12.1 The producer of nuts shall furnish a certification to the purchaser or his representative showing the results of the chemical analysis, macroetch examination (Carbon and Alloy Steels Only), mechanical tests, and the minimum tempering temperature for nuts of Grades 2H, 2HM, 3, 4, 6, 6F, 7, and 7M.

12.2 Certification shall also include at least the following:

12.2.1 A statement that the fasteners were manufactured, sampled, tested and inspected in accordance with the specification and any supplementary requirements or other requirements designated in the purchase order or contract and was found to meet those requirements.

12.2.2 The specification number, year date, and identification symbol.

13. Product Marking

13.1 All nuts shall bear the manufacturer's identification mark.

13.2 Nuts shall be legibly marked on one face to indicate the grade and process of the manufacturer, as presented in Table 7. Marking of wrench flats or bearing surfaces is not permitted unless agreed upon between manufacturer and purchaser.

13.3 For purposes of identification marking, the manufacturer is considered the organization that certifies the fastener was manufactured, sampled, tested, and inspected in accordance with the specification and the results have been determined to meet the requirements of this specification.

14. Keywords

14.1 bolting; chemical analysis; coated; marking on fasteners; plated

TABLE 1
CHEMICAL REQUIREMENTS [NOTES (1), (2), AND (3)]

Grade Symbol	Material	UNS Number	Carbon, %	Manganese, %	Phosphorus, %	Sulfur, % [Note (4)]	Silicon, %	Chromium, %	Nickel, %	Molybdenum, %	Titanium, %	Columbium and Tantalum, %	Nitrogen, %	Other Elements, %
1 2, 2HM, and 2H	Carbon	...	0.15 min	1.00	0.040	0.050	0.40	...	...	...	...	...	...	...
4	Carbon	...	0.40 min	1.00	0.040	0.050	0.40	...	...	...	...	...	...	...
3	Carbon, molybdenum	...	0.40–0.50	0.70–0.90	0.035	0.040	0.15–0.35	...	...	0.20–0.30	...	...	...	...
6	Type 501	...	0.10 min	1.00	0.040	0.030	1.00	4.0–6.0	...	0.40–0.65	...	...	...	...
6F	Type 410	S41000	0.15	1.00	0.040	0.030	1.00	11.5–13.5	...	...	...	...	...	...
6F	Type 416	S41600	0.15	1.25	0.060	0.15 min	1.00	12.0–14.0	...	...	...	...	...	...
6F	Type 416 Se	S41623	0.15	1.25	0.060	0.060	1.00	12.0–14.0	...	...	...	...	...	Selenium 0.15 min
7, 7M	Type 4140/ 4142/ 4145, 4140H, 4142H, 4145H	...	0.37–0.49	0.65–1.10	0.035	0.04	0.15–0.35	0.75–1.20	...	0.15–0.25	...	...	...	...
8, 8A 8C, 8CA	Type 304 Type 347	S30400 S34700	0.08 0.08	2.00 2.00	0.045 0.045	0.030 0.030	1.00 1.00	18.0–20.0 17.0–19.0	8.0–11.0 9.0–12.0	...	...	...	...	...
8M, 8MA 8T, 8TA	Type 316 Type 321	S31600 S32100	0.08 0.08	2.00 2.00	0.045 0.045	0.030 0.030	1.00 1.00	16.0–18.0 17.0–19.0	10.0–14.0 9.0–12.0	2.00–3.00	...	...	...	...
8F, 8FA 8F, 8FA	Type 303 Type 303 Se	S30300 S30323	0.15 0.15	2.00 2.00	0.20 0.20	0.15 min 0.06	1.00 1.00	17.0–19.0 17.0–19.0	8.0–10.0 8.0–10.0	...	...	...	...	...
8P, 8PA	Type 305 with re- stricted carbon	S30500	0.08	2.00	0.045	0.030	1.00	17.0–19.0	11.0–13.0	...	...	...	...	Selenium 0.15 min
8N, 8NA 8LN, 8LNA 8MN, 8MNA	Type 304N Type 304LN Type 316N	S30451 S30453 S31651	0.08 0.030 0.08	2.00 2.00 2.00	0.045 0.045 0.045	0.030 0.030 0.030	1.00 1.00 1.00	18.0–20.0 18.0–20.0 16.0–18.0	8.0–11.0 8.0–11.0 10.0–13.0	...	...	...	0.10–0.16 0.10–0.16 0.10–0.16	...

TABLE 1
CHEMICAL REQUIREMENTS [NOTES (1), (2), AND (3)] (CONT'D)

Grade Symbol	Material	UNS Number	Carbon, %	Manganese, %	Phosphorus, %	Sulfur, % [Note (4)]	Silicon, %	Chromium, %	Nickel, %	Molybdenum, %	Titanium, %	Columbium and Tantalum, %	Nitrogen, %	Other Elements, %
8MLN, 8MLNA	Type 316N	S31653	0.030	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	...	...	0.01–0.16	...
8R, 8RA [Note (5)]	XM19	S20910	0.06	4.0–6.0	0.045	0.030	1.00	20.5–23.5	11.5–13.5	1.50–3.00	...	0.10–0.30	0.20–0.40	Vanadium, 0.10–0.30
8S, 8SA	...	S21800	0.10	7.0–9.0	0.060	0.030	3.5–4.5	16.0–18.0	8.0–9.0	...	...	...	0.08–0.18	...
8MLCuN, 8MLCuNA	S31254	S31254	0.020	1.00	0.030	0.010	0.80	19.5–20.5	17.5–18.5	6.0–6.5	...	...	0.18–0.22	Copper, 0.50–1.00
9C, 9CA	N08367	N08367	0.030	2.00	0.040	0.030	1.00	20.0–22.0	23.5–25.5	6.0–7.0	...	...	0.18–0.25	Copper 0.75
16	Chromium Molyb- denum Vanadium	...	0.36–0.47	0.45–0.70	0.035	0.040	0.15–0.35	0.80–1.15	...	0.50–0.65	...	...	...	Vanadium 0.25–0.35 Aluminum [Note (2)] 0.015

NOTES:

- (1) The intentional addition of Bi, Se, Te, and Pb is not permitted except for Grades 6F, 8F, and 8FA, in which Se is specified and required.
(2) Total aluminum, soluble and insoluble.
(3) Maximum, unless minimum or range is indicated.
(4) Because of the degree to which sulfur segregates, product analysis for sulfur over 0.060% max is not technologically appropriate.
(5) As described in Specification A 276.

TABLE 2
HARDNESS REQUIREMENTS

Grade and Type	Completed Nuts			Sample Nut After Treatment As in 8.1.5	
	Brinell Hardness	Rockwell Hardness		Brinell Hardness, min	Rockwell Hardness B Scale, min
		C Scale	B Scale		
1	121 min	...	70 min	121	70
2	159 to 352	...	84 min	159	84
2H to 1½ in. or M36, incl	248 to 327	24 to 35	...	179	89
2H over 1½ in. or M36	212 to 327	38 max	95 min	147	79
2HM and 7M	159 to 235	...	84 to 99	159	84
3, 4, 7, and 16	248 to 327	24 to 35	...	201	94
6 and 6F	228 to 271	20 to 28	...	...	...
8, 8C, 8M, 8T, 8F, 8P, 8N, 8MN, 8LN, 8MLN, 8MLCuN, and 9C	126 to 300	32 max	60 min	...	...
8A, 8CA, 8MA, 8TA, 8FA, 8PA, 8NA, 8MNA, 8LNA, 8MLNA, and 8MLCuNA and 9CA	126 to 192	...	60 to 90	...	...
8R, 8RA, 8S, and 8SA	183 to 271	25 max	88 min	...	...

TABLE 3
PROOF LOAD USING THREADED MANDREL — INCH SERIES

Nominal Size, in.	Threads per Inch	Stress Area, in. ²	Proof Load, lbf [Note (1)]					
			Grade 1		Grades 2, 2HM, 6, 6F, 7M		Grades 2H, 3, 4, 7, 16	
			Heavy Hex [Note (2)]	Hex [Note (3)]	Heavy Hex [Note (4)]	Hex [Note (5)]	Heavy Hex [Note (6)]	Hex [Note (7)]
1/4	20	0.0316	4 130	3 820	4 770	4 300	5 570	4 770
5/16	18	0.0524	6 810	6 290	7 860	7 070	9 170	7 860
3/8	16	0.0774	10 080	9 300	11 620	10 460	13 560	11 620
7/16	14	0.1063	13 820	12 760	15 940	14 350	18 600	15 940
1/2	13	0.1419	18 450	17 030	21 280	19 160	24 830	21 280
9/16	12	0.182	23 660	21 840	27 300	24 570	31 850	27 300
5/8	11	0.226	29 380	27 120	33 900	30 510	39 550	33 900
3/4	10	0.334	43 420	40 080	50 100	45 090	58 450	50 100
7/8	9	0.462	60 060	55 440	69 300	62 370	80 850	69 300
1	8	0.606	78 780	72 720	90 900	81 810	106 000	90 900
1 1/8	8	0.790	102 700	94 800	118 500	106 700	138 200	118 500
1 1/4	8	1.000	130 000	120 000	150 000	135 000	175 000	150 000
1 3/8	8	1.233	160 200	148 000	185 000	166 500	215 800	185 000
1 1/2	8	1.492	194 000	170 040	223 800	201 400	261 100	223 800

All Types of Grades 8, 9C, and 9CA					
Nominal Size, in.	Threads per Inch	Stress Area, in. ²	Heavy Hex [Note (8)]	Hex [Note (9)]	
1/4	20	0.0316	2 540	2 380	
5/16	18	0.0524	4 190	3 930	
3/8	16	0.0774	6 200	5 810	
7/16	14	0.1063	8 500	7 970	
1/2	13	0.1419	11 350	10 640	
9/16	12	0.182	14 560	13 650	
5/8	11	0.226	18 080	16 950	
3/4	10	0.334	26 720	25 050	
7/8	9	0.462	36 960	34 650	
1	8	0.606	48 480	45 450	
1 1/8	8	0.790	63 200	59 250	
1 1/4	8	1.000	80 000	75 000	
1 3/8	8	1.233	98 640	92 450	
1 1/2	8	1.492	119 360	111 900	

GENERAL NOTE: Proof loads are not design loads.

NOTES:

- (1) See limit for proof load test in 8.2.2.1. The proof load for jam nuts shall be 46% of the tabulated load.
- (2) Based on proof stress of 130 000 psi.
- (3) Based on proof stress of 120 000 psi.
- (4) Based on proof stress of 150 000 psi.
- (5) Based on proof stress of 135 000 psi.
- (6) Based on proof stress of 175 000 psi.
- (7) Based on proof stress of 150 000 psi.
- (8) Based on proof stress of 80 000 psi.
- (9) Based on proof stress of 75 000 psi.

TABLE 4
PROOF LOAD USING THREADED MANDREL — METRIC

Nominal Size, mm	Threads Pitch	Stress Area mm ²	Proof Load, kN ^A					
			Grade 1		Grades 2, 2HM, 6, 6F, 7M		Grades 2H, 3, 4, 7, 16	
			Heavy Hex ^B	Hex ^C	Heavy Hex ^D	Hex ^E	Heavy Hex ^F	Hex ^G
M6	1.0	20.1	18.0	16.6	20.8	18.7	29.2	20.8
M8	1.25	36.6	32.8	30.2	37.9	34.0	44.1	37.9
M10	1.50	58.0	51.9	47.9	60.0	53.9	69.9	60.0
M12	1.75	84.3	75.5	69.5	87.3	78.4	101.6	87.3
M14	2.0	115.0	102.9	94.9	119.0	107.0	138.6	119.0
M16	2.0	157.0	140.5	129.5	162.5	146.0	189.2	162.5
M20	2.5	245.0	219.3	202.1	253.6	227.8	295.2	253.6
M22	2.5	303.0	271.2	249.9	313.6	281.8	365.1	313.6
M24	3.0	353.0	315.9	291.2	365.4	328.3	425.4	365.4
M27	3.0	459.0	411.0	378.7	475.1	426.9	553.4	475.1
M30	3.5	561.0	502.1	462.8	580.6	521.7	676.0	580.6
M36	4.0	817.0	731.2	674.0	845.6	759.8	984.5	845.6

All Types of Grades 8, 9C, and 9CA					
Nominal Size, mm	Thread Pitch	Stress Area, mm ²	Heavy Hex ^H	Hex ^I	
M6	1.0	20.1	11.1	10.4	
M8	1.25	36.6	20.1	18.8	
M10	1.50	58.0	31.9	29.9	
M12	1.75	84.3	46.4	43.4	
M14	2.0	115.0	63.3	59.2	
M16	2.0	157.0	86.4	80.9	
M20	2.5	245.0	134.8	126.2	
M22	2.5	303.0	166.7	156.0	
M24	3.0	353.0	194.2	181.8	
M27	3.0	459.0	252.5	236.4	
M30	3.5	561.0	308.6	288.9	
M36	4.0	817.0	449.4	420.8	

NOTE 1 — Proof loads are not design loads.

^A See limit for proof load test in 8.2.2.1. The proof load for jam nuts shall be 46% of the tabulated load.

^B Based on proof stress of 895 MPa.

^C Based on proof stress of 825 MPa.

^D Based on proof stress of 1035 MPa.

^E Based on proof stress of 930 MPa.

^F Based on proof stress of 1205 MPa.

^G Based on proof stress of 1035 MPa.

^H Based on proof stress of 550 MPa.

^I Based on proof stress of 515 MPa.

TABLE 5
PROOF STRESS USING 120° HARDENED STEEL CONE — INCH

Proof Stress – psi, Minimum			
Type	Grade 1	Grades 2, 2HM, 6, 6F & 7M	Grades 2H 3, 4, 7, & 16
Hex	120 000	135 000	150 000
Heavy Hex	130 000	150 000	175 000

TABLE 6
PROOF STRESS USING 120° HARDENED STEEL CONE — METRIC

Proof Stress – MPa, Minimum			
Type	Grade 1	Grades 2, 2HM, 6, 6F & 7M	Grades 2H 3, 4, 7, & 16
Hex	825	930	1035
Heavy Hex	895	1035	1205

TABLE 7
MARKING OF NUTS

Grade and Type	Nuts Hot-Forged or Cold-Punched	Nuts Machined from Bar Stock	Nuts Manufactured in Accordance with 6.6
1	1	1B	...
2	2	2B	...
2H [Note (1)]	2H	2HB	...
2HM [Note (1)]	2HM	2HMB	...
3	3	3B	...
4	4	4B	...
4L [Note (2)]	4L	4BL	...
6	6	6B	...
6F	6F	6FB	...
7	7	7B	...
7L [Note (2)]	7L	7BL	...
7M [Note (1)]	7M	7MB	...
8	8	8B	8A
8C	8C	8CB	8CA
8M	8M	8MB	8MA
8T	8T	8TB	8TA
8F	8F	8FB	8FA
8P	8P	8PB	8PA
8N	8N	8NB	8NA
8MN	8MN	8MNB	8MNA
8R	8R	8RB	8RA
8S	8S	8SB	8SA
8LN	8LN	8LNB	8LNA
8MLN	8MLN	8MLNB	8MLNA
8MLCuN	8MLCuN	8MLCuNB	8MLCuNA
9C	9C	9CB	9CA
16	16	16B	

NOTES:

(1) The letters H and M indicate heat-treated nuts (see Section 6).

(2) See Supplementary Requirement S3.

TABLE 8
PROOF LOAD TESTING OF STRAIN HARDENED NUTS USING THREADED MANDREL — INCH SERIES

Proof Load, lbf [Note (1)]						
Nominal Size, in.	Threads per Inch	Stress Area, in. ²	Grade 8M (strain hardened)	Grade 8M (strain hardened)	All Other Types of Grade 8 (strain hardened)	All Other Types of Grade 8 (strain hardened)
			Heavy Hex [Note (2)]	Hex [Note (3)]	Heavy Hex [Note (4)]	Hex [Note (2)]
$\frac{1}{4}$	20	0.0316	3 480	3 160	3 950	3 480
$\frac{5}{16}$	18	0.0523	5 760	5 240	6 550	5 760
$\frac{3}{8}$	16	0.0774	8 510	7 740	9 675	8 510
$\frac{7}{16}$	14	0.1063	11 690	10 630	13 290	11 690
$\frac{1}{2}$	13	0.1419	15 610	14 190	17 740	15 610
$\frac{9}{16}$	12	0.182	20 020	18 200	22 750	20 020
$\frac{5}{8}$	11	0.226	24 860	22 600	28 250	24 860
$\frac{3}{4}$	10	0.334	36 740	33 400	41 750	36 740
$\frac{7}{8}$	9	0.462	46 200	41 580	53 130	46 200
1	8	0.606	60 600	54 540	69 690	60 600
$1\frac{1}{8}$	8	0.790	75 050	67 150	82 950	75 050
$1\frac{1}{4}$	8	1.000	95 000	85 000	105 000	95 000
$1\frac{3}{8}$	8	1.233	110 970	98 640	123 300	110 970
$1\frac{1}{2}$	8	1.492	134 280	119 360	149 200	134 280

GENERAL NOTE: Proof loads are not design loads.

NOTES:

- (1) The proof load for jam nuts shall be 46% of the tabulated value.
 (2) Based on proof stress of 110 000 psi up to $\frac{3}{4}$ in.; 100 000 psi $\frac{7}{8}$ to 1 in.; 95 000 psi $1\frac{1}{8}$ to $1\frac{1}{4}$ in.; 90 000 psi $1\frac{3}{8}$ to $1\frac{1}{2}$ in.
 (3) Based on proof stress of 100 000 psi up to $\frac{3}{4}$ in.; 90 000 psi $\frac{7}{8}$ to 1 in.; 85 000 psi $1\frac{1}{8}$ to $1\frac{1}{4}$ in.; 80 000 psi $1\frac{3}{8}$ to $1\frac{1}{2}$ in.
 (4) Based on proof stress of 125 000 psi up to $\frac{3}{4}$ in.; 115 000 psi $\frac{7}{8}$ to 1 in.; 105 000 psi $1\frac{1}{8}$ to $1\frac{1}{4}$ in.; 100 000 psi $1\frac{3}{8}$ to $1\frac{1}{2}$ in.

TABLE 9
PROOF LOAD TESTING OF STRAIN HARDENED NUTS USING THREADED MANDREL — METRIC

Proof Load, kN ^A						
Nominal Size, mm	Thread Pitch	Stress Area, mm ²	Grade 8M (strain hardened)	Grade 8M (strain hardened)	All Other Types of Grade 8 (strain hardened)	All Other Types of Grade 8 (strain hardened)
			Heavy Hex ^B	Hex ^C	Heavy Hex ^D	Hex ^B
M6	1.0	20.1	15.3	13.9	17.3	15.3
M8	1.25	36.6	27.8	25.3	31.3	27.8
M10	1.50	58.0	44.1	40.0	49.9	44.1
M12	1.75	84.3	64.1	58.2	72.5	64.1
M14	2.0	115.0	87.4	79.4	98.9	87.4
M16	2.0	157.0	119.3	108.3	135.0	119.3
M20	2.5	245.0	186.2	169.0	210.9	186.2
M22	2.5	303.0	209.0	187.9	240.9	209.0
M24	3.0	353.0	243.5	218.9	280.6	243.5
M27	3.0	459.0	300.6	268.5	332.7	300.6
M30	3.5	561.0	367.5	328.2	406.7	367.5
M36	4.0	817.0	506.5	449.4	563.7	506.5

NOTE 1 — Proof loads are not design loads.

^A The proof load for jam nuts shall be 46% of the tabulated value.

^B Based on proof stress of 760 MPa up to M20 mm; 690 MPa M22 to M24 mm; 655 MPa M27 to M30; and 620 MPa for M36.

^C Based on proof stress of 690 MPa up to M20 mm; 620 MPa M22 to M24 mm; 585 MPa M27 to M30; and 550 MPa for M36.

^D Based on proof stress of 860 MPa up to M20 mm; 795 MPa M22 to M24 mm; 725 MPa M27 to M30 mm; and 690 MPa for M36.

TABLE 10
PROOF LOAD FOR LARGE HEAVY HEX NUTS — INCH [NOTE (1)]

Nominal Size, in.	Threads per Inch	Stress Area, in. ²	Proof Load, lbf [Note (2)]		
			Grade 1 Heavy Hex	Grades 2, 2HM, 6, 6F, 7M Heavy Hex	Grades 2H, 3, 4, 7, 16 Heavy Hex
1 ⁵ / ₈	8	1.78	231 400	267 000	311 500
1 ³ / ₄	8	2.08	270 400	312 000	364 000
1 ⁷ / ₈	8	2.41	313 300	361 500	421 800
2	8	2.77	360 100	415 500	484 800
2 ¹ / ₄	8	3.56	462 800	534 000	623 000
2 ¹ / ₂	8	4.44	577 200	666 000	777 000
2 ³ / ₄	8	5.43	705 900	814 500	950 250

NOTES:

(1) ANSI B18.2.2 in the size range over 1¹/₂ in. provides dimensions only for heavy hex nuts. Refer to 8.3.1.

(2) Proof loads for nuts of larger dimensions or other thread series may be calculated by multiplying the thread stress area times the proof stress in the notes to Table 3 or Table 8. The proof load for jam nuts shall be 46% of the tabulated load.

TABLE 11
PROOF LOAD FOR LARGE HEAVY HEX NUTS — METRIC⁴

Nominal Size, mm	Thread Pitch	Stress Area, mm ²	Proof Load, kN ⁵		
			Grade 1 Heavy Hex	Grades 2, 2HM, 6, 6F, 7M Heavy Hex	Grades 2H, 3, 4, 7, 16 Heavy Hex
M42	4.5	1120	1002.4	1159.2	1349.6
M48	5	1470	1315.7	1521.4	1771.4
M56	5.5	2030	1816.9	2101.0	2446.2
M64	6	2680	2398.6	2773.8	3229.4
M72	6	3460	3096.7	3581.1	4169.3

⁴ ANSI B18.2.4.6M in the size range over M36 provides dimensions only for heavy hex nuts. Refer to 8.3.1.

⁵ Proof loads for nuts of larger dimensions or other thread series may be calculated by multiplying the thread stress area times the proof stress in the notes to Table 4 or Table 9. The proof load for jam nuts shall be 46% of the tabulated load.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Strain-Hardened Austenitic Steel Nuts

S1.1 Strain hardened Grades 8, 8C, 8T, 8M, 8F, 8P, 8N, or 8MN nuts may be specified. When Supplementary Requirement S1 is invoked in the order, nuts shall be machined from cold drawn bars or shall be cold forged to shape. No subsequent heat treatment shall be performed on the nuts. Nuts made in accordance with this requirement shall be proof load tested in accordance with 8.2.2.1 and shall withstand the proof load specified in Table 8 and Table 9. Testing nuts requiring proof loads over 160 000 lbf or 705 kN is only required when Supplementary Requirement S4 is invoked. The hardness limits of Table 2 do not apply to strain hardened nuts. Nuts made in accordance with this requirement shall be marked with the Grade symbol underlined.

S2. Retests by Purchaser's Representative

S2.1 The purchaser's representative may select two nuts per keg (200 lb unit [90 kg]) for sizes $\frac{5}{8}$ in. and M16 and smaller, one nut per keg for sizes over $\frac{5}{8}$ in. and M16 up to and including $1\frac{1}{2}$ in. and M36, and one nut per every two kegs for sizes larger than $1\frac{1}{2}$ in. and M36, which shall be subjected to the tests specified in Section 8.

S3. Low-Temperature Requirements for Grade 4, Grade 7 or Grade 7M Nuts

S3.1 When low-temperature requirements are specified for Grade 4 or Grade 7 nuts, the Charpy test procedures and requirements as defined in Specification A 320/A 320M for Grade L7 shall apply. When low-temperature requirements are specified for Grade 7M nuts, the Charpy test procedures and requirements as defined in Specification A 320/A 320M for Grade L7M shall apply. Depending on the size of nuts, separate test samples of the same heat may be required and shall be processed through heat treatment with the nuts for which the test is to apply. Impact testing is not required when the bar stock or nut is smaller than $\frac{5}{8}$ in. [16 mm] in diameter.

S3.2 An "L" shall be added to the marking, as shown in Table 7, for nuts so tested.

S4. Proof Load Tests of Large Nuts

S4.1 Proof load testing of nuts requiring proof loads of over 160 000 lbf or 705 kN is required. Testing shall be performed in accordance with 8.2 to the loads required in Table 10 and Table 11. The maximum load will be based entirely on the equipment available.

S5. Control of Product by Heat Number

S5.1 When control of nuts by actual heat analysis is required and this supplementary requirement is specified, the manufacturer shall identify the completed nuts in each shipment by the actual heat number. When this supplementary requirement is specified, a certificate including the results of the actual production tests of each test lot together with the heat chemical analysis shall be furnished by the manufacturer.

S6. Grain Size Requirements for Non H Grade Austenitic Steels Used Above 1000°F

S6.1 For design metal temperatures above 1000°F [540°C], the material shall have a grain size of No. 7 or coarser as determined in accordance with Test Methods E 112. The grain size so determined shall be reported on the Certificate of Test.

S7. Coating on Nuts

S7.1 It is the purchaser's responsibility to specify in the purchase order all information required by the coating facility. Examples of such information may include but are not limited to the following:

S7.1.1 Reference to the appropriate coating specification and type, thickness, location, modification to dimensions, and hydrogen embrittlement relief.

S7.1.2 Reference to Specifications A 153/A 153M, B 695, B 696, B 766, F 1941, Test Method F 1940, or other standards.

S8. Marking Coated Nuts

S8.1 Nuts coated with zinc shall have an asterisk (*) marked after the grade symbol. Nuts coated with cadmium shall have a plus sign (+) marked after the grade symbol.

APPENDICES

(Nonmandatory Information)

X1. STRAIN HARDENING OF AUSTENITIC STEELS

X1.1 Strain hardening is the increase in strength and hardness that results from plastic deformation below the recrystallization temperature (cold work). This effect is produced in austenitic stainless steels by reducing oversized bars to the desired final size by cold drawing or other process. The degree of strain hardening achievable in any alloy is limited by its strain hardening characteristics. In addition, the amount of strain hardening that can be produced is further limited by the variables of the process, such as the total amount of crosssection reduction, die angle and bar size. In large diameter bars, for example, plastic deformation will occur principally in the outer regions of the bar, so that the increased strength and hardness due to strain hardening is achieved predominantly near the surface of the bar. That is, the smaller the bar,

the greater the penetration of strain hardening. Thus, the mechanical properties of a given strain hardened fastener are dependent not just on the alloy, but also on the size of bar from which it is machined.

X2. COATINGS AND APPLICATION LIMITS

X2.1 Use of coated fasteners at temperatures above approximately one-half the melting point (Fahrenheit or Celsius) of the coating is not recommended unless consideration is given to the potential for liquid and solid metal embrittlement, or both. The melting point of elemental zinc is approximately 780°F [415°C]. Therefore, application of zinc coated fasteners should be limited to temperatures less than 390°F [210°C]. The melting point of cadmium is approximately 600°F [320°C]. Therefore, application of cadmium coated fasteners should be limited to temperatures less than 300°F [160°C].

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SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, CHROMIUM-MANGANESE-SILICON



SA-202/SA-202M



(Identical with ASTM Specification A 202/A 202M-93.)

1. Scope

1.1 This specification covers chromium-manganese-silicon alloy steel plates, intended particularly for welded boilers and other pressure vessels.

1.2 Material under this specification is available in two grades having strength levels as follows:

Grade	Tensile Strength, ksi [MPa]
A	75-95 [515-655]
B	85-110 [585-760]

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements; however, current practice normally limits the maximum thickness of plates furnished under this specification to 2 in. [50 mm].

1.4 Grade A is suitable for rivets and when so used the bars shall be subject to the requirements for rolled bars specified in Specification A 31, except for the chemical and mechanical requirements.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents. Therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

2. Referenced Documents

2.1 ASTM Standards:

- A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels
- A 31 Specification for Steel Rivets and Bars for Rivets, Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the basis of purchase that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

- 3.3.1** Vacuum treatment,
- 3.3.2** Additional or special tension testing,
- 3.3.3** Impact testing, and
- 3.3.4** Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice* — The steel shall be killed.

5. Heat Treatment

5.1 Plates are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1.

7. Mechanical Requirements

7.1 *Tension Test Requirements* — The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

TABLE 1
CHEMICAL REQUIREMENTS

Elements	Composition, %	
	Grade A	Grade B
Carbon, max ^A	0.17	0.25
Manganese:		
Heat analysis	1.05–1.40	1.05–1.40
Product analysis	0.97–1.52	0.97–1.52
Phosphorus, max ^A	0.035	0.035
Sulfur, max ^A	0.035	0.035
Silicon:		
Heat analysis	0.60–0.90	0.60–0.90
Product analysis	0.54–0.96	0.54–0.96
Chromium:		
Heat analysis	0.35–0.60	0.35–0.60
Product analysis	0.31–0.64	0.31–0.64

^A Applies to both heat and product analyses.

TABLE 2
TENSILE REQUIREMENTS

	Grade A	Grade B
	ksi [MPa]	ksi [MPa]
Tensile strength	75–95 [515–655]	85–110 [585–760]
Yield strength, min ^B	45 [310]	47 [325]
Elongation in 8 in. [200 mm], min, %	16 ^A	15 ^A
Elongation in 2 in. [50 mm], min, %	19	18

^A See Specification A 20/A 20M for elongation adjustments.

^B Determined by either the 0.2% offset method or the 0.5% extension-under-load method.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Those which are considered suitable for use with this specification are listed below by title.

- | | |
|--|---|
| S1. Vacuum Treatment, | S8. Ultrasonic Examination in accordance with |
| S2. Product Analysis, | Specification A 435/A 435M, |
| S3. Simulated Post-Weld Heat Treatment of | S9. Magnetic Particle Examination, |
| Mechanical Test Coupons, | S11. Ultrasonic Examination in accordance with |
| S4.1 Additional Tension Test, | Specification A 577/A 577M, |
| S5. Charpy V-Notch Impact Test, | S12. Ultrasonic Examination in accordance with |
| S6. Drop Weight Test, | Specification A 578/A 578M, and |
| S7. High-Temperature Tension Test, | S14. Bend Test. |

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SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, NICKEL



SA-203/SA-203M



[Identical with ASTM Specification A 203/A 203M-97(R03).]

1. Scope

1.1 This specification covers nickel-alloy steel plates intended primarily for welded pressure vessels.

1.2 Plates under this specification are available with four strength levels and two nickel compositions as follows:

Grade	Nominal Nickel Content %	Yield Strength, min, ksi [MPa]	Tensile Strength, min, ksi [MPa]
A	2.25	37 [255]	65 [450]
B	2.25	40 [275]	70 [485]
D	3.50	37 [255]	65 [450]
E	3.50	40 [275]	70 [485]
F	3.50		
2 in. [50 mm] and under		55 [380]	80 [550]
Over 2 in. [50 mm]		50 [345]	75 [515]

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements. However, current practice normally limits the maximum thickness of plates furnished under this specification as follows:

Grade	Maximum Thickness, in. [mm]
A	6[150]
B	6[150]
D	4[100]
E	4[100]
F	4[100]

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents. Therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

2. Referenced Documents

2.1 ASTM Standards:

- A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels
- A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates
- A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates
- A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of imperfections, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the basis of purchase that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

- 3.3.1** Vacuum treatment,
- 3.3.2** Additional or special tension testing,
- 3.3.3** Impact testing, and
- 3.3.4** Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 *Steelmaking Practice* — The steel shall be killed and shall conform to the fine grain size requirement of Specification A 20/A 20M.

5. Heat Treatment

5.1 All plates shall be thermally treated as follows:

5.1.1 All plates of Grades A, B, D, and E shall be normalized except as permitted by 5.1.1.1.

5.1.1.1 If approved by the purchaser for Grades A, B, D, and E, cooling rates faster than air cooling are permissible for improvement of the toughness, provided the plates are subsequently tempered at not less than 1100°F [595°C] for not less than 1/2 h.

5.1.2 All plates of Grade F shall be heat treated by heating into the austenitic range, quenching in water, and tempering at not less than 1100°F [595°C] for not less than 1/2 h.

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

7. Mechanical Properties

7.1 *Tension Test Requirements* — The material as represented by the tension test specimens shall conform to the requirements shown in Table 2.

7.1.1 For plates that have been heat treated in accordance with 5.1.1.1 or 5.1.2, and have a nominal thickness of 3/4 in. [20 mm] and under, the 1 1/2 in. (40 mm) wide rectangular specimen may be used for the tension test, and the elongation may be determined in a 2 in. [50 mm] gage length that includes the fracture and that shows the greatest elongation. When this specimen is used, the elongation shall be not less than 23%.

7.2 *Impact Test Requirements:*

7.2.1 Plates of Grades A, B, D, and E that have been heat treated in accordance with 5.1.1.1 shall be Charpy V-notch impact tested. The impact test shall meet 20 ft-lbf [27 J]. The test temperature and orientation shall be a matter of agreement between the purchaser and supplier.

7.2.2 Grade F plates shall be impact tested in accordance with Supplementary Requirement S5 in Specification A 20/A 20M.

8. Keywords

8.1 alloy steel plate; nickel alloy steel; pressure containing parts; pressure vessel steels; steel plates; steel plates for pressure vessel applications

TABLE 1
CHEMICAL REQUIREMENTS

Elements	Composition, %			
	Grade A	Grade B	Grade D	Grades E and F
Carbon, max ^A :				
Up to 2 in. [50 mm] in thickness	0.17	0.21	0.17	0.20
Over 2 in. to 4 in. [100 mm] incl. in thickness	0.20	0.24	0.20	0.23
Over 4 in. [100 mm] in thickness	0.23	0.25	...	...
Manganese, max:				
Heat analysis:				
2 in. [50 mm] and under	0.70	0.70	0.70	0.70
Over 2 in. [50 mm]	0.80	0.80	0.80	0.80
Product analysis				
2 in. [50 mm] and under	0.78	0.78	0.78	0.78
Over 2 in. [50 mm]	0.88	0.88	0.88	0.88
Phosphorus, max ^A	0.035	0.035	0.035	0.035
Sulfur, max ^A	0.035	0.035	0.035	0.035
Silicon:				
Heat analysis	0.15–0.40	0.15–0.40	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45	0.13–0.45	0.13–0.45
Nickel:				
Heat analysis	2.10–2.50	2.10–2.50	3.25–3.75	3.25–3.75
Product analysis	2.03–2.57	2.03–2.57	3.18–3.82	3.18–3.82

^A Applies to both heat and product analyses.TABLE 2
TENSILE REQUIREMENTS

	Grades A and D		Grades B and E		Grade F	
	ksi	[MPa]	ksi	[MPa]	ksi	[MPa]
Tensile strength						
2 in. [50 mm] and under	65–85	[450–585]	70–90	[485–620]	80–100	[550–690]
Over 2 in. [50 mm]	65–85	[450–585]	70–90	[485–620]	75–95	[515–655]
Yield strength, min						
2 in. [50 mm] and under	37	[255]	40	[275]	55	[380]
Over 2 in. [50 mm]	37	[255]	40	[275]	50	[345]
Elongation in 8 in. [200 mm] min, % ^A	19		17		...	
Elongation in 2 in. [50 mm] min, % ^{A,B}	23		21		20	

^A See Specification A20/A 20M for elongation adjustments.^B See 7.1.1.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Those which are considered suitable for use with this specification are listed below by title.

- | | |
|---|---|
| S1. Vacuum Treatment, | S8. Ultrasonic Examination in accordance with Specification A 435/A 435M, |
| S2. Product Analysis, | S9. Magnetic Particle Examination, |
| S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons, | S11. Ultrasonic Examination in accordance with Specification A 577/A 577M, |
| S4.1 Additional Tension Test, | S12. Ultrasonic Examination in accordance with Specification A 578/A 578M, |
| S5. Charpy V-Notch Impact Test, | S14. Bend Test, and |
| S6. Drop Weight Test, | S17. Vacuum Carbon-Deoxidized Steel. |
| S7. High-Temperature Tension Test, | |

SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, MOLYBDENUM



SA-204/SA-204M



[Identical with ASTM Specification A 204/A 204M-03(R07).]

1. Scope

1.1 This specification covers molybdenum-alloy steel plates, intended particularly for welded boilers and other pressure vessels.

1.2 Plates under this specification are available in three grades having different strength levels as follows:

Grade	Tensile Strength, ksi [MPa]
A	65–85 [450–585]
B	70–90 [485–620]
C	75–95 [515–655]

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements; however, current practice normally limits the maximum thickness of plates furnished under this specification as follows:

Grade	Maximum Thickness, in. [mm]
A	6 [150]
B	6 [150]
C	4 [100]

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

2. Referenced Documents

2.1 ASTM Standards:

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Plates supplied to this product specification shall conform to Specification A 20/A 20M, which outlines the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for ordering information that should be complied with when purchasing plates to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available where additional control, testing, or examination is required to meet end use requirements.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1 — For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plates from coil are described in Specification A 20/A 20M.

3.6 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed.

5. Heat Treatment

5.1 Plates $1\frac{1}{2}$ in. [40 mm] and under in thickness are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved or both.

5.2 Plates over $1\frac{1}{2}$ in. [40 mm] in thickness shall be normalized.

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements given in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

7. Mechanical Requirements

7.1 *Tension Test Requirements*—The plates, as represented by the tension-test specimens, shall conform to the requirements given in Table 2.

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %		
	Grade A	Grade B	Grade C
Carbon, max (A):			
Up to 1 in. [25 mm] incl, in thickness	0.18	0.20	0.23
Over 1 in. to 2 in. [50 mm] incl, in thickness	0.21	0.23	0.26
Over 2 in. to 4 in. [100 mm] incl, in thickness	0.23	0.25	0.28
Over 4 in. [100 mm] in thickness	0.25	0.27	0.28
Manganese, max:			
Heat analysis	0.90	0.90	0.90
Product analysis	0.98	0.98	0.98
Phosphorous, max (A)	0.035	0.035	0.035
Sulfur, max (A)	0.035	0.035	0.035
Silicon:			
Heat analysis	0.15–0.40	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45	0.13–0.45
Molybdenum:			
Heat analysis	0.45–0.60	0.45–0.60	0.45–0.60
Product analysis	0.41–0.64	0.41–0.64	0.41–0.64

NOTE:

(A) Applies to both heat and product analyses.

TABLE 2
TENSILE REQUIREMENTS

	Grade A		Grade B		Grade C	
	ksi	[MPa]	ksi	[MPa]	ksi	[MPa]
Tensile strength	65–85	450–585	70–90	485–620	75–95	515–655
Yield strength, min (A)	37	255	40	275	43	295
Elongation in 8 in. [200 mm], min, % (B)	19		17		16	
Elongation in 2 in. [50 mm], min, % (B)	23		21		20	

NOTES:

(A) Determined by either the 0.2% offset method or the 0.5% extension-under-load method.

(B) See Specification A 20/A 20M for elongation adjustment.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 20/A 20M. Those that are considered suitable for use with this specification are listed in this section by title.

- | | |
|--|---|
| S1. Vacuum Treatment, | S8. Ultrasonic Examination in Accordance With |
| S2 Product Analysis, | Specification A 435/A 435M, |
| S3. Simulated Post-Weld Heat Treatment of | S9. Magnetic Particle Examination, |
| Mechanical Test Coupons, | S11. Ultrasonic Examination in Accordance With |
| S4.1 Additional Tension Test, | Specification A 577/A 577M, |
| S5. Charpy V-Notch Impact Test, | S12. Ultrasonic Examination in Accordance With |
| S6. Drop Weight Test, | Specification A 578/A 578M, and |
| S7. High-Temperature Tension Test, | S17. Vacuum Carbon-Deoxidized Steel. |

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SPECIFICATION FOR SEAMLESS CARBON-MOLYBDENUM ALLOY-STEEL BOILER AND SUPERHEATER TUBES



SA-209/SA-209M



[Identical with ASTM Specification A 209/A 209M-03(R07).]

1. Scope

1.1 This specification covers several grades of minimum-wall-thickness, seamless, carbon-molybdenum alloy-steel, boiler and superheater tubes.

1.2 This specification covers tubes $\frac{1}{2}$ to 5 in. [12.7 to 127 mm] inclusive, in outside diameter and 0.035 to 0.500 in. [0.9 to 12.7 mm], inclusive, in minimum wall thickness.

1.3 An optional supplementary requirement is provided and, when desired, shall be so stated in the order.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

2. Referenced Documents

2.1 ASTM Standards:

A 1016/A 1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

3. General Requirements

3.1 Product furnished under this specification shall conform to the requirements of Specification A 1016/A 1016M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification

A 1016/A 1016M constitutes nonconformance with this specification. In case of conflict with the requirements of this specification and Specification A 1016/A 1016M, this specification shall prevail.

4. Materials and Manufacture

4.1 Steelmaking Practice — The steel shall be killed.

4.2 The tubes shall be made by the seamless process and shall be either hot-finished or cold-finished, as specified.

4.3 Heat Treatment — Hot-finished tubes shall be heat treated at a temperature of 1200°F [650°C] or higher. Cold-finished tubes shall, after the final cold finishing, be heat treated at a temperature of 1200°F [650°C] or higher, or tubing may be furnished in the full-annealed, isothermal annealed, or normalized and tempered condition. If furnished in the normalized and tempered condition, the minimum tempering temperature shall be 1200°F [650°C].

5. Chemical Composition

5.1 The steel shall conform to the requirements given in Table 1.

5.2 Product Analysis

5.2.1 An analysis shall be made by the manufacturer of one billet or one tube from each heat. The chemical composition thus determined, shall conform to the requirements given in Table 1.

5.2.2 If the original test for product analysis fails, retests of two additional billets or tubes shall be made. Both retests for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (see 7.1) shall be rejected or, at

the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes that do not meet the requirements of the specification shall be rejected.

6. Mechanical Properties

6.1 Tensile Requirements

6.1.1 The material shall conform to the requirements given in Table 2.

6.1.2 Table 3 gives the computed minimum elongation values for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined by the following equation:

$$E = 48t + 15.00 \quad [E = 1.87t + 15.00] \quad (1)$$

where:

E = elongation in 2 in. [50 mm], %, and,
 t = actual thickness of specimen, in. [mm].

6.2 Hardness Requirements — The tubes shall have a hardness not exceeding the values given in Table 4.

6.3 Number of Tests

6.3.1 Tension Test — One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (see 7.2).

6.3.2 Flattening Test — One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flaring test, from each lot (see 7.1).

6.3.3 Flaring Test — One flaring test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (see 7.1).

6.3.4 Hardness Test — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (see 7.2).

7. Sampling

7.1 Flattening, Flaring, and Product Analysis — For flattening, flaring, and product analysis requirements, the

term *lot* applies to all tubes prior to cutting of the same nominal size and wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat that are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes given in Table 5.

7.2 Tension and Hardness Tests — For tension and hardness tests, the term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat that are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

8. Forming Operations

8.1 Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws. Superheater tubes when properly manipulated shall stand all forging, welding, and bending operations necessary for application without developing defects.

9. Product Marking

9.1 In addition to the marking prescribed in Specification A 1016/A 1016M, the marking shall include whether the tube is hot-finished or cold-finished.

10. Keywords

10.1 boiler tubes; carbon-molybdenum; seamless steel tube; steel tube; superheater tubes

TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS

Element	Composition, %		
	Grade T1	Grade T1a	Grade T1b
Carbon	0.10–0.20	0.15–0.25	0.14 max
Manganese	0.30–0.80	0.30–0.80	0.30–0.80
Phosphorus, max	0.025	0.025	0.025
Sulfur, max	0.025	0.025	0.025
Silicon	0.10–0.50	0.10–0.50	0.10–0.50
Molybdenum	0.44–0.65	0.44–0.65	0.44–0.65

TABLE 2
TENSILE REQUIREMENTS

	Grade T1	Grade T1b	Grade T1a
Tensile strength, min, ksi [MPa]	55 [380]	53 [365]	60 [415]
Yield strength, min, ksi [MPa]	30 [205]	28 [195]	32 [220]
Elongation in 2 in. or 50 mm, min, %	30	30	30
For longitudinal strip tests a deduction shall be made for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{5}{16}$ in. [8 mm] from the basic minimum elongation of the following percentage	1.50 ⁴	1.50 ⁴	1.50 ⁴
When standard round 2 in. or 50 mm gage length or smaller proportionally sized specimen with the gage length equal to 4D (four times the diameter) is used	22	22	22

⁴ Table 3 gives the computed minimum values.

TABLE 3
COMPUTED MINIMUM VALUES

Wall Thickness		Elongation in 2 in. or 50 mm, min, % ⁴
in.	mm	
$\frac{5}{16}$ (0.312)	8	30
$\frac{9}{32}$ (0.281)	7.2	29
$\frac{1}{4}$ (0.250)	6.4	27
$\frac{7}{32}$ (0.219)	5.6	26
$\frac{3}{16}$ (0.188)	4.8	24
$\frac{5}{32}$ (0.156)	4	22
$\frac{1}{8}$ (0.125)	3.2	21
$\frac{3}{32}$ (0.094)	2.4	20
$\frac{1}{16}$ (0.062)	1.6	18

⁴ Calculated elongation requirements shall be rounded to the nearest whole number.

TABLE 4
HARDNESS REQUIREMENTS

	Brinell Hardness Number (Tubes 0.200 in. [5.1 mm] and over in Wall Thickness), HBW	Rockwell Hardness Number (Tubes less than 0.200 in. [5.1 mm] in Wall Thickness), HRB
Grade T1	146	80
Grade T1a	153	81
Grade T1b	137	77

TABLE 5
NUMBER OF TUBES IN A LOT HEAT TREATED BY THE CONTINUOUS PROCESS

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in. [5.1 mm] and over in wall thickness	not more than 50 tubes
2 in. [50.8 mm] and over in outside diameter and under 0.200 in. [5.1 mm] in wall thickness	not more than 75 tubes
Less than 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified by the purchaser in the inquiry, contract, or order.

S1. Surface Condition

S1.1 If pickling or shot blasting, or both, are required, this shall be specifically stated in the order. Details of this supplemental requirement shall be agreed upon between the manufacturer and the purchaser.

SUMMARY OF CHANGES

The Committee has identified the location of selected changes to this specification since the last issue, which may impact the use of this specification.

(1) Revised and re-formatted extensively to adopt the new general requirements specification and conform to the

guidelines for form and style. The mandatory hydrostatic test, unless the nondestructive electric test is specified by purchaser was changed to the mandatory nondestructive electric test unless the hydrostatic test is specified by purchaser per Specification A 1016/A 1016.

SPECIFICATION FOR SEAMLESS MEDIUM-CARBON STEEL BOILER AND SUPERHEATER TUBES



SA-210/SA-210M

(Identical with ASTM Specification A 210/A 210M-95 except for editorial differences in Table 2.)

1. Scope

1.1 This specification covers minimum-wall-thickness, seamless medium-carbon steel, boiler tubes and boiler flues, including safe ends (Note 1), arch and stay tubes, and superheater tubes.

NOTE 1 — This type is not suitable for safe ending by forge welding.

1.2 The tubing sizes and thicknesses usually furnished to this specification are $\frac{1}{2}$ in. to 5 in. [12.7 to 127 mm] in outside diameter and 0.035 to 0.500 in. [0.9 to 12.7 mm], inclusive, in minimum wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.4 When these products are to be used in applications conforming to ISO Recommendations for Boiler Construction, the requirements of Specification A 520, shall supplement and supersede the requirements of this specification.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

2. Referenced Documents

2.1 ASTM Standards:

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

A 520 Specification for Supplementary Requirements for Seamless and Electric-Resistance-Welded Carbon Steel Tubular Products for High-Temperature Service Conforming to ISO Recommendations for Boiler Construction

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, metres, or number of lengths),

3.1.2 Name of material (seamless tubes),

3.1.3 Grade,

3.1.4 Manufacture (hot-finished or cold-finished),

3.1.5 Size (outside diameter and minimum wall thickness),

3.1.6 Length (specific or random),

3.1.7 Optional requirements (Sections 7 and 10),

3.1.8 Test report required (see Certification Specification of Specification A 450/A 450M),

3.1.9 Specification designation, and

3.1.10 Special requirements

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

5. Manufacture

5.1 *Steelmaking Practice* — The steel shall be killed.

5.2 The tubes shall be made by the seamless process and shall be either hot-finished or cold-finished, as specified.

6. Heat Treatment

6.1 Hot-finished tubes need not be heat treated. Cold-finished tubes shall be given a subcritical anneal, a full anneal, or a normalizing heat treatment after the final cold-finishing process.

7. Surface Condition

7.1 If pickling or shot blasting or both are required, this shall be specifically stated in the order.

8. Chemical Composition

8.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

8.2 When a grade is ordered under this specification, supplying an alloy grade that specifically requires the addition of any element other than those listed for the ordered grade in Table 1 is not permitted.

9. Product Analysis

9.1 When requested on the purchase order, a product analysis shall be made by the supplier from one tube or billet per heat. The chemical composition thus determined shall conform to the requirements specified.

9.2 If the original test for product analysis fails, retests of two additional billets or tubes shall be made. Both retests for the elements in question shall meet the requirements of the specification; otherwise, all remaining material in the heat or lot (Note 2) shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes which do not meet the requirements of the specification shall be rejected.

NOTE 2 — For flattening and flaring requirements, the term “lot” applies to all tubes prior to cutting of the same nominal size and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as prescribed in Table 2.

NOTE 3 — For tensile and hardness test requirements, the term “lot” applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

10. Tensile Requirements

10.1 The material shall conform to the requirements as to tensile properties prescribed in Table 3.

10.2 Table 4 gives the computed minimum elongation values for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined by the following equation:

$$E = 48t + 15.00 \quad [E = 1.87t + 15.00]$$

where:

E = elongation in 2 in. or 50 mm, %, and

t = actual thickness of specimen, in. [mm].

11. Hardness Requirements

11.1 The tubes shall have a hardness not exceeding the following: 79 HRB or 143 HB for Grade A-1, 89 HRB or 179 HB for Grade C.

12. Mechanical Tests Required

12.1 Tension Test — One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (Note 3).

12.2 Flattening Test — One flattening test shall be made on specimens from each end of one finished tube from each lot (Note 2), but not the one used for the flaring test. Tears or breaks occurring at the 12 or 6 o'clock positions on Grade C tubing with sizes of 2.375 in. [60.3 mm] in outside diameter and smaller shall not be considered a basis for rejection.

12.3 Flaring Test — One flaring test shall be made on specimens from each end of the one finished tube from each lot (Note 2,) but not the one used for the flattening test.

12.4 Hardness Test — Brinell or Rockwell hardness test shall be made on specimens from two tubes from each lot (Note 3).

12.5 Hydrostatic or Nondestructive Electric Test — Each tube shall be subjected to the hydrostatic, or, instead of this test, a nondestructive electric test may be used when specified by the purchaser.

13. Forming Operations

13.1 When inserted in the boiler, tubes shall stand expanding and beading without showing cracks or flaws. When properly manipulated, superheater tubes shall stand all forging, welding and bending operations necessary for application without developing defects.

14. Product Marking

14.1 In addition to the marking prescribed in Specification A 450/A 450M, the marking shall indicate whether the tube is hot-finished or cold-finished.

15. Keywords

15.1 boiler tubes; carbon; seamless steel tube; steel tube; superheater tubes

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %	
	Grade A-1	Grade C
Carbon ^A , max	0.27	0.35
Manganese	0.93 max	0.29–1.06
Phosphorus, max	0.035	0.035
Sulfur, max	0.035	0.035
Silicon, min	0.10	0.10

^A For each reduction of 0.01% below the specified carbon maximum, an increase of 0.06% manganese above the specified maximum will be permitted up to a maximum of 1.35%.

TABLE 2
NUMBER OF TUBES IN A LOT HEAT TREATED BY THE CONTINUOUS PROCESS

Size of Tube	Size of Lot
2 in. (50.8 mm) and over in diameter and 0.200 in. (5.1 mm) and over in wall thickness	not more than 50 tubes
2 in. (50.8 mm) and over in outside diameter and under 0.200 in. (5.1 mm) in wall thickness	not more than 75 tubes
Less than 2 in. (50.8 mm) but over 1 in. (25.4 mm) in outside diameter or over 1 in. in outside diameter and under 0.200 in. (5.08 mm) in wall thickness	not more than 75 tubes
1 in. (25.4 mm) or less in outside diameter	not more than 125 tubes

TABLE 3
TENSILE REQUIREMENTS

	Grade A-1	Grade C
Tensile strength, min, ksi [MPa]	60 [415]	70 [485]
Yield strength, min, ksi [MPa]	37 [255]	40 [275]
Elongation in 2 in. or 50 mm, min, %	30	30
For longitudinal strip tests, a deduction shall be made for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness under $\frac{5}{16}$ in. [8 mm] from the basic minimum elongation of the following percentage points	1.50 ^A	1.50 ^A
When standard round 2 in. or 50 mm gage length or smaller proportionally sized specimen with the gage length equal to 4D (four times the diameter) is used	22	20

^A See Table 4 for the computed minimum values.

TABLE 4
COMPUTED MINIMUM ELONGATION VALUES⁴

Wall Thickness, in. [mm]	Elongation in 2 in. or 50 mm, min, %
$\frac{5}{16}$ (0.312) [8]	30
$\frac{9}{32}$ (0.281) [7.2]	28
$\frac{1}{4}$ (0.250) [6.4]	27
$\frac{7}{32}$ (0.219) [5.6]	26
$\frac{3}{16}$ (0.188) [4.8]	24
$\frac{5}{32}$ (0.156) [4]	22
$\frac{1}{8}$ (0.125) [3.2]	21
$\frac{3}{32}$ (0.094) [2.4]	20
$\frac{1}{16}$ (0.062) [1.6]	18
0.062 to 0.035 [1.6 to 0.9], excl	17
0.035 to 0.022 [0.9 to 0.6], excl	16
0.022 to 0.015 [0.6 to 0.4], incl	16

⁴ Calculated elongation requirements shall be rounded to the nearest whole number.

SPECIFICATION FOR SEAMLESS FERRITIC AND AUSTENITIC ALLOY-STEEL BOILER, SUPERHEATER, AND HEAT-EXCHANGER TUBES



SA-213/SA-213M

(Identical with ASTM Specification A 213/A 213M-08 except for the additional H grade heat treatment requirements in 6.2.)

(10)

1. Scope

1.1 This specification covers seamless ferritic and austenitic steel boiler, superheater, and heat-exchanger tubes, designated Grades T5, TP304, etc. These steels are listed in Tables 1 and 2.

1.2 Grades containing the letter, H, in their designation, have requirements different from those of similar grades not containing the letter, H. These different requirements provide higher creep-rupture strength than normally achievable in similar grades without these different requirements.

1.3 The tubing sizes and thicknesses usually furnished to this specification are $\frac{1}{8}$ in. [3.2 mm] in inside diameter to 5 in. [127 mm] in outside diameter and 0.015 to 0.500 in. [0.4 to 12.7 mm], inclusive, in minimum wall thickness or, if specified in the order, average wall thickness. Tubing having other diameters may be furnished, provided such tubes comply with all other requirements of this specification.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Documents

2.1 ASTM Standards:

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

A 1016/A 1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E 112 Test Methods for Determining Average Grain Size

3. Terminology

3.1 Definitions — For definitions of terms used in this specification, refer to Terminology A 941.

4. Ordering Information

4.1 It shall be the responsibility of the purchaser to specify all requirements that are necessary for products under this specification. Such requirements to be considered include, but are not limited to, the following:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (seamless tubes),

4.1.3 Grade (Tables 1 and 2),

4.1.4 Condition (hot finished or cold finished),

4.1.5 Controlled structural characteristics (see 6.3),

4.1.6 Size (outside diameter and minimum wall thickness, unless average wall thickness is specified),

4.1.7 Length (specific or random),

4.1.8 Hydrostatic Test or Nondestructive Electric Test (see 10.1),

4.1.9 Specification designation and year of issue,

4.1.10 Increased sulfur (for machinability, see Note B, Table 1, and 15.3), and

4.1.11 Special requirements and any supplementary requirements selected.

5. General Requirements

5.1 Product furnished to this specification shall conform to the requirements of Specification A 1016/A 1016M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 1016/A 1016M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 1016/A 1016M, this specification shall prevail.

6. Materials and Manufacture

6.1 *Manufacture and Condition* — Tubes shall be made by the seamless process and shall be either hot finished or cold finished, as specified. Grade TP347HFG shall be cold finished.

6.2 Heat Treatment:

6.2.1 *Ferritic Alloy and Ferritic Stainless Steels* — The ferritic alloy and ferritic stainless steels shall be reheated for heat treatment in accordance with the requirements of Table 3. Heat treatment shall be carried out separately and in addition to heating for hot forming.

6.2.2 *Austenitic Stainless Steels* — All austenitic tubes shall be furnished in the heat-treated condition, and shall be heat treated in accordance with the requirements of Table 3. Other than for Grades S30815, S30942, S31035, S31272, S33228, and H Grades, seamless tubing immediately following hot forming may be individually quenched in water or rapidly cooled by other means, provided that the temperature of the tubes after hot forming is not less than the minimum specified solution temperature (direct quenched). For H grades, as well as Grades S30815, S30942, S31035, S31272, and S33228, the tubes shall be reheated to the specified solution treatment temperature for the required time before quenching.

6.3 If any controlled structural characteristics are required, these shall be so specified in the order as to be a guide as to the most suitable heat treatment.

7. Chemical Composition

7.1 Composition Requirements:

7.1.1 The alloy steels shall conform to the chemical requirements given in Table 1.

7.1.2 The stainless steels shall conform to the chemical requirements given in Table 2.

7.2 Product Analysis:

7.2.1 An analysis of either one billet or one tube shall be made from each heat. The chemical composition thus determined shall conform to the requirements specified.

7.2.2 If the original test for product analysis fails, retests of two additional billets or tubes shall be made. Both retests, for the elements in question, shall meet the requirements of the specification; otherwise all remaining material in the heat shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes that do not meet the requirements of the specification shall be rejected.

8. Grain Size

8.1 Grain size shall be as given in Table 3, as determined in accordance with Test Methods E 112.

8.2 Grain size determinations, to demonstrate compliance with 8.1, shall be made on one end of one finished tube from each lot. See 14.1.

9. Mechanical Properties

9.1 Tensile Requirements:

9.1.1 The material shall conform to the requirements as to tensile properties given in Table 4.

9.1.2 Table 5 gives the computed minimum elongation values for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values shown in Table 5, the minimum elongation value shall be determined by the following equations. For Grades T23, T24, T91, T92, T122, T911, and S44400: $E = 32t + 10.00$ [$E = 1.25t + 10.00$]. For Grade T36: $E = 32t + 5.0$ [$E = 1.25t + 5.0$]. For all other ferritic alloy grades: $E = 48t + 15.00$ [$E = 1.87t + 15.00$].

where:

E = elongation in 2 in. [50 mm], %, and
 t = actual thickness of specimen, in. [mm]

9.1.3 One tension test shall be made on a specimen from one tube for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes. See 14.2.

9.2 Hardness Requirements:

9.2.1 The material shall conform to the hardness requirements given in Table 4. See 14.2.

9.2.2 Brinell, Vickers, or Rockwell hardness tests shall be made on specimens from two tubes from each lot. See 14.2.

9.3 *Flattening Test* — One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flaring test, from each lot. See 14.1.

9.4 *Flaring Test* — One flaring test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot. See 14.1.

9.5 Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in inside diameter or thinner than 0.015 in. [0.4 mm] in thickness.

10. Hydrostatic or Nondestructive Electric Test

10.1 Each tube shall be subjected to the nondestructive electric test or the hydrostatic test. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

11. Forming Operations

11.1 Tubes, when inserted in a boiler or tube sheet, shall stand expanding and beading without showing cracks or flaws. Superheater tubes when properly manipulated shall stand all forging, welding, and bending operations necessary for application without developing defects. See Note 1.

NOTE 1 — Certain of the ferritic steels covered by this specification will harden if cooled rapidly from above their critical temperature. Some will air harden, that is, become hardened to an undesirable degree when cooled in air from high temperatures, particularly chromium-containing steels with chromium of 4% and higher. Therefore, operations that involve heating such steels above their critical temperatures, such as welding, flanging, and hot bending, should be followed by suitable heat treatment.

12. Permissible Variations from the Specified Wall Thickness

12.1 Permissible variations from the specified minimum wall thickness shall be in accordance with Specification A 1016/A 1016M.

12.2 Permissible variations from the specified average wall thickness are $\pm 10\%$ of the specified average wall thickness.

13. Surface Condition

13.1 Ferritic alloy cold-finished steel tubes shall be free of scale and suitable for inspection. A slight amount of oxidation is not considered scale.

13.2 Ferritic alloy hot-finished steel tubes shall be free of loose scale and suitable for inspection.

13.3 Stainless steel tubes shall be pickled free of scale. When bright annealing is used, pickling is not necessary.

13.4 Any special finish requirement shall be subject to agreement between the supplier and the purchaser.

14. Sampling

14.1 For flattening, flaring, and grain size requirements, the term lot applies to all tubes, prior to cutting, of the same size (see 4.1.6) that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat that are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace or when the heat-treated condition is obtained directly by quenching after hot forming, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as prescribed in Table 6.

14.2 For tensile and hardness test requirements, the term lot applies to all tubes prior to cutting, of the same size (see 4.1.6) that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat that are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, or when the heat-treated condition is obtained directly by quenching after hot forming, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed; or all tubes of the same size and heat, hot formed and quenched in the same production run, except as prescribed in 9.1.3.

15. Product Marking

15.1 In addition to the marking prescribed in Specification A 1016/A 1016M, the marking shall include: the condition, hot finished or cold finished; and the wall designation, minimum wall or average wall.

15.2 For the austenitic stainless steels having a grain size requirement (see Table 3) the marking shall also include the heat number and heat-treatment lot identification.

15.3 When either T2 or T12 are ordered with higher sulfur contents as permitted by Note B of Table 1, the marking shall include the letter, S, following the grade designation: T2S or T12S.

16. Keywords

16.1 alloy steel tubes; austenitic stainless steel; boiler tubes; ferritic stainless steel; heat exchanger tubes; high-temperature applications; seamless steel tubes; steel tubes; superheater tubes; temperature service applications-high

TABLE 1 CHEMICAL COMPOSITION LIMITS, %^A, FOR LOW ALLOY STEEL

UNS Grade	Designation	Composition, %														Other Elements
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Vanadium	Boron	Niobium	Nitrogen	Aluminum	Tungsten	
T2	K11547	0.10-0.20	0.30-0.61	0.025	0.025 ^B	0.10-0.30	...	0.50-0.81	0.44-0.65	...	...	...	...	...	...	...
T5	K41545	0.15	0.30-0.60	0.025	0.025	0.50	...	4.00-6.00	0.45-0.65	...	...	...	...	...	...	...
T5b	K51545	0.15	0.30-0.60	0.025	0.025	1.00-2.00	...	4.00-6.00	0.45-0.65	...	...	...	...	...	...	...
T5c	K41245	0.12	0.30-0.60	0.025	0.025	0.50	...	4.00-6.00	0.45-0.65	...	...	...	...	...	...	Ti 4xC-0.70
T9	K90941	0.15	0.30-0.60	0.025	0.025	0.25-1.00	...	8.00-10.00	0.90-1.10	...	...	...	...	...	...	...
T11	K11597	0.05-0.15	0.30-0.60	0.025	0.025	0.50-1.00	...	1.00-1.50	0.44-0.65	...	...	...	...	...	...	...
T12	K11562	0.05-0.15	0.30-0.61	0.025	0.025 ^B	0.50	...	0.80-1.25	0.44-0.65	...	...	...	...	...	...	...
T17	K12047	0.15-0.25	0.30-0.61	0.025	0.025	0.15-0.35	...	0.80-1.25	...	0.15	...	...	...	...	...	...
T21	K31545	0.05-0.15	0.30-0.60	0.025	0.025	0.50-1.00	...	2.65-3.35	0.80-1.06	...	...	...	...	...	...	...
T22	K21590	0.05-0.15	0.30-0.60	0.025	0.025	0.50	...	1.90-2.60	0.87-1.13	...	...	...	...	...	...	...
T23	K40712	0.04-0.10	0.10-0.60	0.030	0.010	0.50	...	1.90-2.60	0.05-0.30	0.20-0.30	0.0005-0.006	0.02-0.08	0.03	0.030	1.45-1.75	...
T24	K30736	0.05-0.10	0.30-0.70	0.020	0.010	0.15-0.45	...	2.20-2.60	0.90-1.10	0.20-0.30	0.0015-0.007	...	0.012	0.02	...	Ti 0.06-0.10
T36	K21001	0.10-0.17	0.80-1.20	0.030	0.025	0.25-0.50	1.00-1.30	0.30	0.25-0.50	0.02	...	0.015-0.045	0.02	0.050	...	Cu 0.50-0.80
T91	K90901	0.07-0.14	0.30-0.60	0.020	0.010	0.20-0.50	0.40	8.0-9.5	0.85-1.05	0.18-0.25	...	0.06-0.10	0.030-0.070	0.02	...	Ti 0.01 Zr 0.01
T92	K92460	0.07-0.13	0.30-0.60	0.020	0.010	0.50	0.40	8.5-9.5	0.30-0.60	0.15-0.25	0.001-0.006	0.04-0.09	0.030-0.070	0.02	1.5-2.00	Ti 0.01 Zr 0.01
T122	K91271	0.07-0.14	0.70	0.020	0.010	0.50	0.50	10.0-11.5	0.25-0.60	0.15-0.30	0.0005-0.005	0.04-0.10	0.040-0.100	0.02	1.50-2.50	Cu 0.30-1.70
T911	K91061	0.09-0.13	0.30-0.60	0.020	0.010	0.10-0.50	0.40	8.5-9.5	0.90-1.10	0.18-0.25	0.0003-0.006	0.06-0.10	0.040-0.090	0.02	0.90-1.10	Ti 0.01 Zr 0.01

^A Maximum, unless range or minimum is indicated. Where ellipses (...) appear in this table, there is no requirement, and analysis for the element need not be determined or reported.

^B It is permissible to order T2 and T12 with a sulfur content of 0.045 max. See 15.3.

TABLE 2 CHEMICAL COMPOSITION LIMITS, %⁴, FOR AUSTENITIC AND FERRITIC STAINLESS STEEL

Grade	UNS Designation	Composition											Other Elements
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen ^g	Niobium	Titanium	
TP201	S20100	0.15	5.5-7.5	0.060	0.030	1.00	16.0-18.0	3.5-5.5	...	0.25	...	...	...
TP202	S20200	0.15	7.5-10.0	0.060	0.030	1.00	17.0-19.0	4.0-6.0	...	0.25	...	...	...
XM-19	S20910	0.06	4.0-6.0	0.045	0.030	1.00	20.5-23.5	11.5-13.5	1.50-3.00	0.20-0.40	0.10-0.30	...	V 0.10-0.30
^c	S21500	0.06-0.15	5.5-7.0	0.045	0.030	0.20-1.00	14.0-16.0	9.0-11.0	0.80-1.20	...	0.75-1.25	...	B 0.003-0.009, V 0.15-0.40
^c	S25700	0.02	2.00	0.025	0.010	6.5-8.0	8.0-11.5	22.0-25.0	0.50	...	...	...	...
TP304	S30400	0.08	2.00	0.045	0.030	1.00	18.0-20.0	8.0-11.0	...	...	...	...	...
TP304L	S30403	0.035 ^d	2.00	0.045	0.030	1.00	18.0-20.0	8.0-12.0	...	...	...	...	...
TP304H	S30409	0.04-0.10	2.00	0.045	0.030	1.00	18.0-20.0	8.0-11.0	...	...	...	...	...
^c	S30432	0.07-0.13	1.00	0.040	0.010	0.30	17.0-19.0	7.5-10.5	...	0.05-0.12	0.30-0.60	...	Al 0.003-0.030, B 0.001-0.010, Cu 2.5-3.5
^c	S30434	0.07-0.14	2.00	0.040	0.010	1.00	17.5-19.5	9.0-12.0	...	...	0.10-0.40 ^e	0.10-0.25 ^e	B 0.001-0.004 Cu 2.50-3.50
TP304N	S30451	0.08	2.00	0.045	0.030	1.00	18.0-20.0	8.0-11.0	...	0.10-0.16	...	...	...
TP304LN	S30453	0.035 ^d	2.00	0.045	0.030	1.00	18.0-20.0	8.0-11.0	...	0.10-0.16	...	...	...
^c	S30615	0.016-0.24	2.00	0.030	0.030	3.2-4.0	17.0-19.5	13.5-16.0	...	...	...	...	Al 0.8-1.5
^c	S30815	0.05-0.10	0.80	0.040	0.030	1.40-2.00	20.0-22.0	10.0-12.0	...	0.14-0.20	...	...	Ce 0.03-0.08
TP309S	S30908	0.08	2.00	0.045	0.030	1.00	22.0-24.0	12.0-15.0	...	...	...	...	...
TP309H	S30909	0.04-0.10	2.00	0.045	0.030	1.00	22.0-24.0	12.0-15.0	...	...	...	...	...
TP309Cb	S30940	0.08	2.00	0.045	0.030	1.00	22.0-24.0	12.0-16.0	...	...	10xC-1.10	...	...
TP309Hcb	S30941	0.04-0.10	2.00	0.045	0.030	1.00	22.0-24.0	12.0-16.0	...	...	10xC-1.10	...	...
...	S30942	0.03-0.10	2.00	0.040	0.030	1.00	21.0-23.0	14.5-16.5	...	0.10-0.20	0.50-0.80	...	B-0.001-0.005
^c	S31002	0.02	2.00	0.020	0.015	0.15	24.0-26.0	19.0-22.0	0.10	0.10	...	...	...
TP310S	S31008	0.08	2.00	0.045	0.030	1.00	24.0-26.0	19.0-22.0	...	...	...	...	...
TP310H	S31009	0.04-0.10	2.00	0.045	0.030	1.00	24.0-26.0	19.0-22.0	...	...	...	...	...
...	S31035	0.04-0.10	0.60	0.030	0.015	0.40	21.5-23.5	23.5-26.5	...	0.15-0.30	0.30-0.60	...	W 2.0-4.0 Co 1.0-2.0 Cu 2.0-3.5 B 0.002-0.008
TP310Cb	S31040	0.08	2.00	0.045	0.030	1.00	24.0-26.0	19.0-22.0	...	...	10xC-1.10	...	...
TP310Hcb	S31041	0.04-0.10	2.00	0.045	0.030	1.00	24.0-26.0	19.0-22.0	...	...	10xC-1.10	...	...
TP310HcbN	S31042	0.04-0.10	2.00	0.045	0.030	1.00	24.0-26.0	19.0-22.0	...	0.15-0.35	0.20-0.60	...	...
TP310MoLN	S31050	0.025	2.00	0.020	0.030	0.40	24.0-26.0	21.0-23.0	2.00-3.00	0.10-0.16	...	...	...
^c	S31060	0.05-0.10	1.00	0.040	0.030	0.50	22.0-24.0	10.0-12.5	...	0.18-0.25	...	...	Ce + La 0.025-0.070 B 0.001-0.010
^c	S31254	0.020	1.00	0.030	0.010	0.80	19.5-20.5	17.5-18.5	6.0-6.5	0.18-0.22	...	...	Cu 0.50-1.00
^c	S31272	0.08-0.12	1.50-2.00	0.030	0.015	0.30-0.70	14.0-16.0	14.0-16.0	1.00-1.40	...	...	0.30-0.60	B 0.004-0.008 Cu 0.50-1.50
^c	S31277	0.020	3.00	0.030	0.010	0.50	20.5-23.0	26.0-28.0	6.5-8.0	0.30-0.40	...	...	...
TP316	S31600	0.08	2.00	0.045	0.030	1.00	16.0-18.0	10.0-14.0	2.00-3.00	...	...	...	...
TP316L	S31603	0.035 ^d	2.00	0.045	0.030	1.00	16.0-18.0	10.0-14.0	2.00-3.00	...	...	...	...
TP316H	S31609	0.04-0.10	2.00	0.045	0.030	1.00	16.0-18.0	11.0-14.0	2.00-3.00	...	...	...	...
TP316Ti	S31635	0.08	2.00	0.045	0.030	0.75	16.0-18.0	10.0-14.0	2.00-3.00	0.10	...	5X (C + N)- 0.70	...
TP316N	S31651	0.08	2.00	0.045	0.030	1.00	16.0-18.0	10.0-13.0	2.00-3.00	0.10-0.16	...	...	...
TP316LN	S31653	0.035 ^d	2.00	0.045	0.030	1.00	16.0-18.0	10.0-13.0	2.00-3.00	0.10-0.16	...	...	...
TP317	S31700	0.08	2.00	0.045	0.030	1.00	18.0-20.0	11.0-15.0	3.0-4.0	...	...	...	...
TP317L	S31703	0.035	2.00	0.045	0.030	1.00	18.0-20.0	11.0-15.0	3.0-4.0	...	...	...	...

TABLE 2 CHEMICAL COMPOSITION LIMITS, %^A, FOR AUSTENITIC AND FERRITIC STAINLESS STEEL (CONT'D)

UNS Designation	Composition											Other Elements	
	Grade	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen ^d	Niobium		Titanium
TP317LM TP317LMN ^c TP321	S31725	0.03	2.00	0.045	0.030	1.00	18.0-20.0	13.5-17.5	4.0-5.0	0.20	...	...	Cu 0.75
	S31726	0.03	2.00	0.045	0.030	1.00	17.0-20.0	13.5-17.5	4.0-5.0	0.10-0.20	...	...	Cu 0.75
	S32050	0.030	1.50	0.035	0.020	1.00	22.0-24.0	20.0-23.0	6.0-6.8	0.21-0.32	...	...	Cu 0.40
	S32100	0.08	2.00	0.045	0.030	1.00	17.0-19.0	9.0-12.0	...	...	...	5(C + N)-0.70	...
TP321H ^c	S32109	0.04-0.10	2.00	0.045	0.030	1.00	17.0-19.0	9.0-12.0	...	...	...	4(C + N)-0.70	...
	S32615	0.07	2.00	0.045	0.030	4.8-6.0	16.5-19.5	19.0-22.0	0.30-1.50	...	...	...	Cu 1.50-2.50
TP33228 ^c	S33228	0.04-0.08	1.00	0.020	0.015	0.30	26.0-28.0	31.0-33.0	...	...	0.60-1.00	...	Ce 0.05-0.10, Al 0.025
TP347 ^c TP347H TP347HFG TP347LN	S34565	0.030	5.0-7.0	0.030	0.010	1.00	23.0-25.0	16.0-18.0	4.0-5.0	0.40-0.60	0.10	...	...
	S34700	0.08	2.00	0.045	0.030	1.00	17.0-20.0	9.0-13.0	...	...	10xC-1.10	...	...
	S34709	0.04-0.10	2.00	0.045	0.030	1.00	17.0-19.0	9.0-13.0	...	...	8xC-1.10	...	...
	S34710	0.06-0.10	2.00	0.045	0.030	1.00	17.0-19.0	9.0-13.0	...	...	8xC-1.10	...	...
TP347LN	S34751	0.005-0.020	2.00	0.045	0.030	1.00	17.0-19.0	9.0-12.0	...	0.06-0.10	0.20-0.50 ^f	...	...
TP348	S34800	0.08	2.00	0.045	0.030	1.00	17.0-19.0	9.0-13.0	...	...	^g	...	Co 0.20, Ta 0.10
TP348H	S34809	0.04-0.10	2.00	0.045	0.030	1.00	17.0-19.0	9.0-13.0	...	...	^h	...	Co 0.20, Ta 0.10
...	S35045	0.06-0.10	1.50	0.045	0.015	1.00	25.0-29.0	32.0-37.0	...	...	...	0.15-0.60	Al 0.15-0.60
XM-15 ...	S38100	0.08	2.00	0.030	0.030	1.50-2.50	17.0-19.0	17.5-18.5	...	...	...	...	...
	S38815	0.030	2.00	0.040	0.020	5.5-6.5	13.0-15.0	15.0-17.0	0.75-1.50	...	...	...	Cu 0.75-1.50
TP444	S44400	0.03	1.00	0.040	0.030	1.00	17.5-19.5	ⁱ	1.75-2.50	0.035	...	^j	Al 0.30

^A Maximum, unless a range or minimum is indicated. Where ellipses (...) appear in this table, there is no minimum and analysis for the element need not be determined or reported.^B The method of analysis for Nitrogen shall be a matter of agreement between the purchaser and the producer.^C For these alloys, there is no common grade designation. The UNS number uniquely identifies these alloys.^D For small diameter or thin walls, or both, where many drawing passes are required, a carbon maximum of 0.040% is necessary in Grades TP304L, TP304LN, TP316L, and TP316LN.^E Grade S30434 shall have (Ti + 1/2 Nb) of not less than 2 times and not more than 4 times the carbon content.^F Grade TP347LN shall have an Nb content of not less than 15 times the carbon content.^G Grade TP348 shall have an Nb + Ta content of not less than 10 times the carbon content and not more than 1.10%.^H Grade TP348H shall have an Nb + Ta content of not less than 8 times the carbon content and not more than 1.10%.^I Grade TP444 shall have Ni + Cu = 1.00 max.^J Grade TP444 shall have Ti + Nb = 0.20 + 4(C + N)-0.80.

TABLE 3 HEAT TREATMENT AND GRAIN SIZE REQUIREMENTS⁴

Grade	UNS Number	Heat Treat Type	Austenitizing/ Solutioning Temperature, min or range °F[°C]	Cooling Media	Subcritical Annealing or Tempering Temperature, min or range °F [°C]	ASTM Grain Size No. ⁸
Ferritic Alloy Steels						
T2	K11547	full or isothermal anneal normalize and temper subcritical anneal	... ... ...	... ... ...	... ... 1200 to 1350 [650 to 730]	... ... ...
T5	K41545	full or isothermal anneal normalize and temper	... ...	...	... 1250 [675]	... ...
T5b	K51545	full or isothermal anneal normalize and temper	... ...	...	... 1250 [675]	... ...
T5c	K41245	subcritical anneal	...	air or furnace	1350 [730] ^C	...
T9	S50400	full or isothermal anneal normalize and temper	... ...	... ...	... 1250 [675]	... ...
T11	K11597	full or isothermal anneal normalize and temper	... ...	... ...	... 1200 [650]	... ...
T12	K11562	full or isothermal anneal normalize and temper subcritical anneal	... ... ...	... ... ...	... ... 1200 to 1350 [650 to 730]	... ... ...
T17	K12047	full or isothermal anneal normalize and temper	... ...	... ...	... 1200 [650]	... ...
T21	K31545	full or isothermal anneal normalize and temper	... ...	...	... 1250 [675]	... ...
T22	K21590	full or isothermal anneal normalize and temper	... ...	... ...	... 1250 [675]	... ...
T23	K40712	normalize and temper	1900-1975 [1040-1080]	...	1350-1470[730-800]	...
T24	K30736	normalize and temper	1800-1975 [980-1080]	...	1350-1470 [730-800]	...
T36	K21001	normalize and temper	1650 [900]	^D	1100 [595]	...
T91	K90901	normalize and temper	1900-1975 [1040-1080]	...	1350-1470 [730-800]	...
T92	K92460	normalize and temper	1900-1975 [1040-1080]	...	1350-1470 [730-800]	...
T122	K91261	normalize and temper	1900-1975 [1040-1080]	...	1350-1470 [730-800]	...
T911	K91061	normalize and temper	1900-1975 [1040-1080]	^E	1365-1435 [740-780]	...
Austenitic Stainless Steels						
TP201	S20100	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
TP202	S20200	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
XM-19	S20910	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
...	S21500	solution treatment	1900[1040] ^{F,G}	water or other rapid cool	...	...
...	S25700	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
...	S30150	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
TP304	S30400	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
TP304L	S30403	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
TP304H	S30409	solution treatment	1900[1040]	water or other rapid cool	...	7
...	S30432	solution treatment	2000[1100] ^F	water or other rapid cool	...	...
...	S30434	solution treatment	2120[1160]	water or other rapid cool	...	...
TP304N	S30451	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
TP304LN	S30453	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
...	S30615	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
...	S30815	solution treatment	1920[1050]	water or other rapid cool	...	...
TP309S	S30908	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
TP309H	S30909	solution treatment	1900[1040]	water or other rapid cool	...	7
TP309Cb	S30940	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
TP309HCB	S30941	solution treatment	1900[1040] ^H	water or other rapid cool	...	7
...	S30942	solution treatment	2120[1160]	water or other rapid cool	...	6
...	S31002	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
TP310S	S31008	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
TP310H	S31009	solution treatment	1900[1040]	water or other rapid cool	...	7
...	S31035	solution treatment	2160-2280 [1180-1250]	water or other rapid cool	...	7
TP310Cb	S31040	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
TP310HCB	S31041	solution treatment	1900[1040] ^H	water or other rapid cool	...	7
TP310HCBN	S31042	solution treatment	1900[1040] ^{F,H}	water or other rapid cool	...	7
...	S31060	solution treatment	1975-2160 [1080-1180] ^F	water or other rapid cool	...	7
...	S31254	solution treatment	2100[1150]	water or other rapid cool	...	...
...	S31272	solution treatment	1920[1050]	water or other rapid cool	...	...
...	S31277	solution treatment	2050[1120] ^F	water or other rapid cool	...	...
TP316	S31600	solution treatment	1900[1040] ^F	water or other rapid cool	...	...

TABLE 3 HEAT TREATMENT AND GRAIN SIZE REQUIREMENTS^A (CONT'D)

Grade	UNS Number	Heat Treat Type	Austenitizing/ Solutioning Temperature, min or range °F[°C]	Cooling Media	Subcritical Annealing or Tempering Temperature, min or range °F [°C]	ASTM Grain Size No. ^B
TP316L	S31603	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP316H	S31609	solution treatment	1900 [1040]	water or other rapid cool	...	7
TP316Ti	S31635	solution treatment	1900 [1040]	water or other rapid cool	...	...
TP316N	S31651	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP316LN	S31653	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP317	S31700	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP317L	S31703	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
...	S31725	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
...	S32050	solution treatment	2100 [1150] ^F	water or other rapid cool	...	...
TP321	S32100	solution treatment	1900 [1040] ^{F,H}	water or other rapid cool	...	...
TP321H	S32109	solution treatment	cold worked: 2000 [1090] hot rolled: 1925 [1050] ^H	water or other rapid cool	...	7
...	S32615	solution treatment	1900 [1040] ^F	water or other rapid cool	...	3 or finer
...	S32716	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
...	S33228	solution treatment	2050 [1120]	water or other rapid cool	...	...
...	S34565	solution treatment	2050-2140 [1120-1170]	water or other rapid cool	...	...
TP347	S34700	solution treatment	1900 [1040] ^{F,H}	water or other rapid cool	...	...
TP347H	S34709	solution treatment	cold worked: 2000 [1100] hot rolled: 1925 [1050] ^H	water or other rapid cool	...	7
TP347HFG	S34710	solution treatment, ^I	2150 [1175] ^F	water or other rapid cool	...	7-10
TP347LN	S34751	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP348	S34800	solution treatment	1900 [1040] ^{F,H}	water or other rapid cool	...	...
TP348H	S34809	solution treatment	cold worked: 2000 [1100] hot rolled: 1925 [1050] ^H	water or other rapid cool	...	7
...	S35045	solution treatment	2000 [1100] ^F	still air cool or faster	...	...
XM-15	S38100	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
...	S38815	solution treatment	1950 [1065] ^F	water or other rapid cool	...	...
Ferritic Stainless Steels						
TP444	S44400	subcritical anneal	...	...	1400 [760]	...

^A Where ellipses (...) appear in this table there is no requirement.

^B ASTM Grain Size No. listed, or coarser, unless otherwise indicated.

^C Approximately, to achieve properties.

^D Accelerated air cooling or liquid quenching shall be permitted for Class 2.

^E Accelerated cooling from the normalizing temperature shall be permitted for section thicknesses greater than 3 in. [75 mm].

^F Quenched in water or rapidly cooled by other means, at a rate sufficient to prevent re-precipitation of carbides, as demonstrable by the capability of tubes, heat treated by either separate solution annealing or by direct quenching, passing Practices A 262, Practice E. The manufacturer is not required to run the test unless it is specified on the purchase order (see Supplementary Requirement S4). Note that Practices A 262 requires the test to be performed on sensitized specimens in the low-carbon and stabilized types and on specimens representative of the as-shipped condition for other types. In the case of low-carbon types containing 3% or more molybdenum, the applicability of the sensitizing treatment prior to testing shall be a matter for negotiation between the seller and the purchaser.

^G A maximum solution treating temperature of 2100 °F [1150 °C] is recommended for UNS S21500.

^H A solution treating temperature above 1950 °F [1065 °C] may impair resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in the indicated grades. When specified by the purchaser, a lower temperature stabilization or resolution anneal shall be used subsequent to the higher-temperature solution anneal prescribed in this table.

^I Solution treatment shall be preceded by a softening heat treatment prior to cold-working. The softening temperature shall be at least 90 °F [50 °C] higher than the solution heat treatment temperature, which shall be at 2150 °F [1180 °C] minimum.

TABLE 4 TENSILE AND HARDNESS REQUIREMENTS

Grade	UNS Designation	Tensile Strength, min. ksi [MPa]	Yield Strength, min. ksi [MPa]	Elongation in 2 in. or 50 mm, min, % ^{A,B}	Hardness, Max	
					Brinell/Vickers	Rockwell
<i>Low Alloy Steels:</i>						
T5b	K51545	60 [415]	30 [205]	30	179 HBW/190HV	89 HRB
T9	K90941	60 [415]	30 [205]	30	179 HBW/190HV	89 HRB
T12	K11562	60 [415]	32 [220]	30	163 HBW/170 HV	85 HRB
T23	K40712	74 [510]	58 [400]	20	220 HBW/230 HV	97 HRB
T24	K30736	85 [585]	60 [415]	20	250 HBW/265 HV	25 HRC
T36 Class 1	K21001	90 [620]	64 [440]	15	250 HBW/265 HV	25 HRC
T36 Class 2	K21001	95.5 [660]	66.5 [460]	15	250 HBW/265 HV	25 HRC
T91	K90901	85 [585]	60 [415]	20	250 HBW/265 HV	25 HRC
T92	K92460	90 [620]	64 [440]	20	250 HBW/265 HV	25 HRC
T122	K91271	90 [620]	58 [400]	20	250 HBW/265 HV	25 HRC
T911	K91061	90 [620]	64 [440]	20	250 HBW/265 HV	25 HRC
All other low alloy grades		60 [415]	30 [205]	30	163 HB/170 HV	85 HRB
<i>Austenitic Stainless Steels:</i>						
TP201	S20100	95 [655]	38 [260]	35	219 HBW/230 HV	95 HRB
TP202	S20200	90 [620]	45 [310]	35	219 HBW/230 HV	95 HRB
XM-19	S20910	100 [690]	55 [380]	35	250 HBW/265 HV	25 HRC
...	S21500	78 [540]	33 [230]	35	192 HBW/200 HV	90 HRB
...	S25700	78 [540]	35 [240]	50	217 HBW	95 HRB
TP304	S30400	75 [515]	30 [205]	35	192 HBW/200 HV	90 HRB
TP304L	S30403	70 [485]	25 [170]	35	192 HBW/200 HV	90 HRB
TP304H	S30409	75 [515]	30 [205]	35	192 HBW/200 HV	90 HRB
...	S30432	86 [590]	34 [235]	35	219 HBW/230 HV	95 HRB
...	S30434	73 [500]	30 [205]	35	192 HBW/200 HV	90 HRB
TP304N	S30451	80 [550]	35 [240]	35	192 HBW/200 HV	90 HRB
TP304LN	S30453	75 [515]	30 [205]	35	192 HBW/200 HV	90 HRB
...	S30615	90 [620]	40 [275]	35	192 HBW/200 HV	90 HRB
...	S30815	87 [600]	45 [310]	40	217 HBW	95 HRB
TP309S	S30908	75 [515]	30 [205]	35	192 HBW/200 HV	90 HRB

TABLE 4 TENSILE AND HARDNESS REQUIREMENTS (CONT'D)

Grade	UNS Designation	Tensile Strength, min. ksi [MPa]	Yield Strength, min. ksi [MPa]	Elongation in 2 in. or 50 mm, min, % ^{A,B}	Hardness, Max	
					Brinell/Vickers	Rockwell
TP309H	S30909	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP309Cb	S30940	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP309HCb	S30941	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
...	S30942	86 [590]	34 [235]	35	219 HBW/ 230 HV	95 HRB
...	S31002	73 [500]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP310S	S31008	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP310H	S31009	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
...	S31035	95 [655]	45 [310]	40	220 HBW/ 230 HV	96 HRB
TP310Cb	S31040	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP31010HCb	S31041	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP310HCbN	S31042	95 [655]	43 [295]	30	256 HBW	100 HRB
TP310MoLN	S31050					
T ≤ 0.25 in. [6 mm]		84 [580]	39 [270]	25	217 HBW	95 HRB
t > 0.25 in. [6 mm]		78 [540]	37 [255]	25	217 HBW	95 HRB
...	S31060	87 [600]	41 [280]	40	217 HBW	95 HRB
...	S31254					
T ≤ 0.187 in. [5 mm]		98 [675]	45 [310]	35	220 HBW/ 230 HV	96 HRB
T > 0.187 in. [5 mm]		95 [655]	45 [310]	35	220 HBW/ 230 HV	96 HRB
...	S31272	65 [450]	29 [200]	35	217 HBW	95 HRB
...	S31277	112 [770]	52 [360]	40	241 HBW	100 HRB
TP316	S31600	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP316L	S31603	70 [485]	25 [170]	35	192 HBW/ 200 HV	90 HRB
TP316H	S31609	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP316Ti	S31635	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP316N	S31651	80 [550]	35 [240]	35	192 HBW/ 200 HV	90 HRB
TP317	S31700	75 [515]	30 [205]	34	192 HBW/ 200 HV	90 HRB
TP317L	S31703	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
...	S31725	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
...	S32050	98 [675]	48 [330]	40	256 HBW	100 HRB
TP321	S32100	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB

TABLE 4 TENSILE AND HARDNESS REQUIREMENTS (CONT'D)

Grade	UNS Designation	Tensile Strength, min. ksi [MPa]	Yield Strength, min. ksi [MPa]	Elongation in 2 in. or 50 mm, min, % ^{A,B}	Hardness, Max	
					Brinell/Vickers	Rockwell
TP321H	S32109	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
...	S32615	80 [550]	32 [220]	25	192 HBW/ 200 HV	90 HRB
...	S32716	80 [550]	35 [240]	35	192 HBW/ 200 HV	90 HRB
...	S33228	73 [500]	27 [185]	30	192 HBW/ 200 HV	90 HRB
...	S34565	115 [790]	60 [415]	35	241 HBW	100 HRB
TP347	S34700	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP347H	S34709	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP347HFG	S34710	80 [550]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP347LN	S34751	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP348	S34800	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP348H	S34809	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
...	S35045	70 [485]	25 [170]	35	192 HBW/ 200 HV	90 HRB
XM-15	S38100	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
...	S38815	78 [540]	37 [255]	30	256 HBW	100 HRB
<i>Ferritic Stainless Steels</i>						
TP444	S44400	60 [415]	40 [275]	20	217 HBW/ 230 HV	96 HRB

^A When standard round 2 in. or 50 mm gage length or smaller proportionally sized specimens with gage length equal to 4D (4 times the diameter) is used, the minimum elongation shall be 22% for all low alloy grades except T23, T24, T91, T92, T122, and T911; and except for TP444.

^B For longitudinal strip tests, a deduction from the basic minimum elongation values of 1.00% for TP444, T23, T24, T91, T92, T122, and T911, and of 1.50% for all other low alloy grades for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{5}{16}$ in. [8 mm] shall be made.

TABLE 5
COMPUTED MINIMUM VALUES [NOTE (1)]

Wall Thickness		Elongation in 2 in. or 50 mm, Min., %		
		S44400, T23, T24, T91, T92, T122, and T911	T 22	All Other Ferritic Grades
in.	mm			
$\frac{5}{16}$ [0.312]	8	20	15	30
$\frac{9}{32}$ [0.281]	7.2	19	14	29
$\frac{1}{4}$ [0.250]	6.4	18	13	27
$\frac{7}{32}$ [0.219]	5.6	17	12	26
$\frac{3}{16}$ [0.188]	4.8	16	11	24
$\frac{5}{32}$ [0.156]	4	15	10	23
$\frac{1}{8}$ [0.125]	3.2	14	9	21
$\frac{3}{32}$ [0.094]	2.4	13	8	20
$\frac{1}{16}$ [0.062]	1.6	12	7	18
0.062 to 0.035, excl.	1.6 to 0.9	12	7	17
0.035 to 0.022, excl.	0.9 to 0.6	11	6	17
0.022 to 0.015 incl.	0.6 to 0.4	11	6	16

NOTE:

(1) Calculated elongation requirements shall be rounded to the nearest whole number.

TABLE 6
NUMBER OF TUBES IN A LOT HEAT TREATED BY THE
CONTINUOUS PROCESS OR BY DIRECT QUENCH
AFTER HOT FORMING

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in. [5.1 mm] and over in wall thickness	not more than 50 tubes
2 in. [50.8 mm] and over in outside diameter and under 0.200 in. [5.1 mm] in wall thickness	not more than 75 tubes
Less than 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order.

S1. Stress-Relieved Annealed Tubes

S1.1 For use in certain corrosives, particularly chloride where stress corrosion may occur, tubes in Grades TP304L, TP316L, TP321, TP347, and TP348 may be specified in the stress-relieved annealed condition.

S1.2 When stress-relieved tubes are specified, tubes shall be given a heat treatment at 1500 to 1650°F [815 to 900°C] after roll straightening. Cooling from this temperature range may be either in air or by slow cooling. No mechanical straightening is permitted after the stress-relief treatment.

S1.3 Straightness of the tubes shall be a matter of negotiation between the purchaser and supplier.

S2. Stabilizing Heat Treatment

S2.1 Subsequent to the solution anneal required in Section 6, Grades TP309HCb, TP310HCb, TP310HCbN, TP321, TP321H, TP347, TP347H, TP348, and TP348H shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S3. Unstraightened Tubes

S3.1 When the purchaser specifies tubes unstraightened after final heat treatment (such as coils), the minimum yield strength of Table 4 shall be reduced by 5 ksi [35 MPa].

S3.2 On the certification, and wherever the grade designation for unstraightened tubing appears, it shall be identified with the suffix letter “U” (for example, 304-U, 321-U, etc.).

S4. Intergranular Corrosion Test

S4.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE S4.1 — Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S4.2 A stabilization heat treatment in accordance with Supplementary Requirement S2 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium, particularly in their H versions.

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SPECIFICATION FOR ELECTRIC-RESISTANCE-WELDED CARBON STEEL HEAT-EXCHANGER AND CONDENSER TUBES



SA-214/SA-214M

(Identical with ASTM Specification A 214/A 214M-90a except for editorial differences in 7.2.)

1. Scope

1.1 This specification covers minimum-wall-thickness, electric-resistance-welded, carbon steel tubes to be used for heat exchangers, condensers, and similar heat-transfer apparatus.

1.2 The tubing sizes usually furnished to this specification are to 3 in. [76.2 mm] in outside diameter, inclusive. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.4 The purchaser shall specify in the order the outside diameter and minimum wall thickness. The inside diameter shall not be specified.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

2. Referenced Document

2.1 *ASTM Standard:*
A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

3. General Requirements

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (electric-resistance-welded tubes),

4.1.3 Size (outside diameter and minimum wall thickness),

4.1.4 Length (specific or random),

4.1.5 Optional requirements (Section 8 and 10.5),

4.1.6 Test report required (see Certification Section of Specification A 450/A 450M),

4.1.7 Specification designation, and

4.1.8 Special requirements.

5. Manufacture

5.1 Tubes shall be made by electric-resistance welding.

6. Heat Treatment

6.1 After welding, all tubes shall be heat treated at a temperature of 1650°F [900°C] or higher and followed by cooling in air or in the cooling chamber of a controlled atmosphere furnace. Cold drawn tubes shall be heat treated

after the final cold-draw pass at a temperature of 1200°F [650°C] or higher.

7. Chemical Composition

7.1 The steel shall conform to the following requirements as to chemical composition:

Carbon, max, %	0.18
Manganese, %	0.27–0.63
Phosphorus, max, %	0.035
Sulfur, max, %	0.035

7.2 Supplying an alloy grade of steel that specifically requires the addition of any element other than those listed in 7.1 is not permitted.

8. Product Analysis

8.1 When requested on the purchase order, a product analysis shall be made by the supplier from one tube per 250 pieces; or when tubes are identified by heat, one tube per heat shall be analyzed. The chemical composition thus determined shall conform to the requirements specified.

8.2 If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock, or tubes shall be made. Both retests, for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (Note) shall be rejected or, at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes which do not meet the requirements of the specification shall be rejected.

NOTE — A lot consists of 250 tubes.

9. Hardness Requirements

9.1 The tubes shall have a hardness number not exceeding 72 HRB.

10. Mechanical Tests Required

10.1 *Flattening Test* — One flattening test shall be made on specimens from each of two tubes from each lot (Note) or fraction thereof.

10.2 *Flange Test* — One flange test shall be made on specimens from each of two tubes from each lot (Note) or fraction thereof.

10.3 *Reverse Flattening Test* — One reverse flattening test shall be made on a specimen from each 1500 ft [450 m] of finished tubing.

10.4 *Hardness Test* — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot. The term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

10.5 *Hydrostatic or Nondestructive Electric Test* — Each tube shall be subjected to either the hydrostatic or the nondestructive electric test. The purchaser may specify which test is to be used.

11. Surface Condition

11.1 The finished tubes shall be free of scale. A slight amount of oxidation shall not be considered as scale.

12. Product Marking

12.1 In addition to the marking prescribed in Specification A 450/A 450M, the letters “ERW” shall be legibly stenciled on each tube, or marked on a tag attached to the bundle or box in which the tubes are shipped.

12.2 The manufacturer’s name or symbol may be placed permanently on each tube by rolling or light stamping before normalizing. If a single stamp is placed on the tube by hand, this mark should not be less than 8 in. [200 mm] from one end of the tube.

SPECIFICATION FOR STEEL CASTINGS, CARBON, SUITABLE FOR FUSION WELDING FOR HIGH-TEMPERATURE SERVICE



SA-216/SA-216M

(Identical with ASTM Specification A 216/A 216M-07 except for the addition of 2.3 and editorial differences in 2.1 and 10.1.)

1. Scope

1.1 This specification covers carbon steel castings for valves, flanges, fittings, or other pressure-containing parts for high-temperature service and of quality suitable for assembly with other castings or wrought-steel parts by fusion welding.

1.2 Three grades, WCA, WCB, and WCC, are covered in this specification. Selection will depend upon design and service conditions, mechanical properties, and the high temperature characteristics.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 ASTM Standards:

A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts

A 985/A 985M Specification for Steel Investment Castings General Requirements, for Pressure-Containing Parts

E 165 Test Method for Liquid Penetrant Examination

E 709 Guide for Magnetic Particle Examination

2.2 Manufacturers' Standardization Society of the Valve and Fittings Industry Standard:

SP 55 Steel Castings for Valve, Flanges, and Fittings, and Other Components (Visual Method)

2.3 ASME Standard:

ASME Boiler and Pressure Vessel Code, Section IX, Welding and Brazing Qualifications

3. General Conditions for Delivery

3.1 Except for investment castings, castings furnished to this specification shall conform to the requirements of Specification A 703/A 703M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 703/A 703M, this specification shall prevail.

3.2 Steel investment castings furnished to this specification shall conform to the requirements of Specification A 985/A 985M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 985/A 985M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 985/A 985M, Specification A 985/A 985M shall prevail.

4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 Grade of steel,

4.1.3 Options in the specification,

4.1.4 Whether the castings are to be produced using the investment casting process, and

4.1.5 The supplementary requirements desired including the standards of acceptance.

5. Heat Treatment

5.1 All castings shall receive a heat treatment proper to their design and chemical composition.

5.2 Castings shall be furnished in the annealed, or normalized, or normalized and tempered condition unless Supplementary Requirement S15 is specified.

5.3 Heat treatment shall be performed after castings have been allowed to cool below the transformation range.

6. Temperature Control

6.1 Furnace temperatures for heat treating shall be effectively controlled by pyrometer.

7. Chemical Composition

7.1 The steel shall be in accordance with the requirements as to chemical composition prescribed in Table 1.

8. Tensile Requirements

8.1 Steel used for the castings shall be in accordance with the requirements as to tensile properties prescribed in Table 2.

9. Quality

9.1 The surface of the casting shall be examined visually and shall be free of adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Method SP-55 or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

9.2 When additional inspection is desired, Supplementary Requirements S4, S5, and S10 may be ordered.

9.3 The castings shall not be peened, plugged, or impregnated to stop leaks.

10. Repair by Welding

10.1 Repairs shall be made using procedures and welders qualified under ASME Section IX.

10.2 Weld repairs shall be inspected to the same quality standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S4 specified, weld repairs shall be inspected by magnetic particle examination to the same standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S5 specified, weld repairs on castings that have leaked on hydrostatic test, or on castings in which the depth of any cavity prepared for repair welding exceeds 20% of the wall thickness or 1 in. [25 mm], whichever is smaller, or on castings in which any cavity prepared for welding is greater than approximately 10 in.² [65 cm²], shall be radiographed to the same standards that are used to inspect the castings.

10.3 Castings containing any repair weld that exceeds 20% of the wall thickness or 1 in. [25 mm], whichever is smaller, or that exceeds approximately 10 in.² [65 cm²] in area, or that was made to correct hydrostatic test defects, shall be stress relieved or heat treated after welding. This mandatory stress relief or heat treatment shall be in accordance with the procedure qualification used.

11. Keywords

11.1 carbon steel; high temperature; pressure-containing parts; steel castings

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %		
	Grade WCA UNS J02502	Grade WCB UNS J03002	Grade WCC UNS J02503
Carbon, max	0.25 ^A	0.30 ^B	0.25 ^C
Manganese, max	0.70 ^A	1.00 ^B	1.20 ^C
Phosphorus, max	0.04	0.04	0.04
Sulfur, max	0.045	0.045	0.045
Silicon, max	0.60	0.60	0.60
Specified residual elements:			
Copper, max	0.30	0.30	0.30
Nickel, max	0.50	0.50	0.50
Chromium, max	0.50	0.50	0.50
Molybdenum, max	0.20	0.20	0.20
Vanadium, max	0.03	0.03	0.03
Total of these specified residual elements, max ^D	1.00	1.00	1.00

^A For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.04% manganese above the specified maximum will be permitted up to a maximum of 1.10%.

^B For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.04% Mn above the specified maximum will be permitted up to a maximum of 1.28%.

^C For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.04% manganese above the specified maximum will be permitted to a maximum of 1.40%.

^D Not applicable when Supplementary Requirement S11 is specified.

TABLE 2
TENSILE REQUIREMENTS

	Grade WCA	Grade WCB	Grade WCC
Tensile strength, ksi [MPa]	60 to 85 [415 to 585]	70 to 95 [485 to 655]	70 to 95 [485 to 655]
Yield strength, ^A min, ksi [MPa]	30 [205]	36 [250]	40 [275]
Elongation in 2 in. [50 mm], min, % ^B	24	22	22
Reduction of area, min, %	35	35	35

^A Determine by either 0.2% offset method or 0.5% extension-under-load method.

^B When ICI test bars are used in tensile testing as provided for in Specification A 703/A 703M, the gage length to reduced section diameter ratio shall be 4 to 1.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 703/A 703M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in Specification A 703/A 703M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Unspecified Elements

S2. Destruction Tests

S3. Bend Test

S4. Magnetic Particle Inspection

S5. Radiographic Inspection

S10. Examination of Weld Preparation

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Guide E 709 or Test Method E 165.

S11. Carbon Equivalent

S11.1 When specified on the order, the maximum carbon equivalent shall be:

Grade	Carbon Equivalent, max
WCA	0.50
WCB	0.50
WCC	0.55

S11.2 Carbon equivalent (*CE*) shall be determined as follows:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

S15. Quench and Temper Heat-Treatment

S16. Requirements for Carbon Steel Castings for Hydrofluoric Acid Alkylation Service

S16.1 Castings shall be provided in the normalized or normalized and tempered heat-treated condition.

S16.2 The maximum carbon equivalent shall be as follows:

Maximum specified section thickness less

than or equal to 1 in. [25 mm]

Maximum specified section thickness

greater than 1 in. [25 mm]

CE maximum

0.43

0.45

S16.3 Determine the carbon equivalent (*CE*) as follows:

$$CE = C + \frac{Mn}{6} + \frac{(Cr + Mo + V)}{5} + \frac{(Ni + Cu)}{15}$$

S16.4 Vanadium and niobium maximum content based upon heat analysis shall be:

NOTE 1 — Niobium = columbium

Maximum vanadium

Maximum niobium

Maximum vanadium plus niobium

0.02 wt%

0.02 wt%

0.03 wt%

S16.5 The sum of the nickel and copper contents, based upon heat analysis, shall not exceed 0.15 wt%.

S16.6 The minimum carbon content shall be 0.18 wt%. The maximum carbon content shall be as required for the appropriate grade.

S16.7 Welding consumables for repair welds shall be of the low-hydrogen type. E60XX electrodes shall not be used and the resulting weld chemistry shall meet the same chemistry requirements as the base metal.

S16.8 In addition to the requirements for product marking in the specification, an “HF-N” stamp or marking shall be provided on each casting to identify that the casting complies with this supplementary requirement.

SPECIFICATION FOR STEEL CASTINGS, MARTENSITIC STAINLESS AND ALLOY, FOR PRESSURE-CONTAINING PARTS, SUITABLE FOR HIGH-TEMPERATURE SERVICE



SA-217/SA-217M



(Identical with ASTM Specification A 217/A 217M-07.)

1. Scope

1.1 This specification covers martensitic stainless steel and alloy steel castings for valves, flanges, fittings, and other pressure-containing parts (Note 1) intended primarily for high-temperature and corrosive service (Note 2).

1.2 One grade of martensitic stainless steel and nine grades of ferritic alloy steel are covered. Selection will depend on design and service conditions, mechanical properties, and the high-temperature and corrosion-resistant characteristics (Note 3).

NOTE 1 — Carbon steel castings for pressure-containing parts are covered by Specification A 216/A 216M. Low alloy quench-and-tempered grades equivalent to Specification A 217/A 217M grades may be found in both Specifications A 352/A 352M and A 487/A 487M.

NOTE 2 — The grades covered by this specification represent materials that are generally suitable for assembly with other castings or wrought steel parts by fusion welding. It is not intended to imply that these grades possess equal degrees of weldability; therefore, it is the responsibility of the purchaser to establish for himself a suitable welding technique. Since these grades possess varying degrees of suitability for high-temperature and corrosion-resistant service, it is also the responsibility of the purchaser to determine which grade shall be furnished, due consideration being given to the requirements of the applicable construction codes.

NOTE 3 — The committee formulating this specification has included nine grades of materials that are considered to represent basic types of ferritic alloy steels suitable for valves, flanges, fittings, and other pressure-containing parts. Additional alloy steels that may better fulfill certain types of service will be considered for inclusion in this specification by the committee as the need becomes apparent.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining

values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A 217 and SI units for materials ordered to Specification A 217M.

2. Referenced Documents

2.1 ASTM Standards:

- A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service
- A 352/A 352M Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service
- A 487/A 487M Specification for Steel Castings Suitable for Pressure Service
- A 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel
- A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts
- A 802/A 802M Practice for Steel Castings, Surface Acceptance Standards, Visual Examination
- A 985/A 985M Specification for Steel Investment Castings General Requirements, for Pressure-Containing Parts
- E 165 Test Method for Liquid Penetrant Examination
- E 709 Guide for Magnetic Particle Examination

3. General Conditions for Delivery

3.1 Except for investment castings, castings furnished to this specification shall conform to the requirements of Specification A 703/A 703M including any supplementary

requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 703/A 703M, this specification shall prevail.

3.2 Steel investment castings furnished to this specification shall conform to the requirements of Specification A 985/A 985M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 985/A 985M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 985/A 985M, Specification A 985/A 985M shall prevail.

4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 Grade of steel,

4.1.3 Options in the specification,

4.1.4 Whether the castings are to be produced using the investment casting process, and

4.1.5 The supplementary requirements desired including the standards of acceptance.

5. Heat Treatment

5.1 All castings shall receive a heat treatment proper to their design and chemical composition.

5.2 Castings shall be furnished in the normalized and tempered conditions; Grades WC1, WC4, WC5, WC6, and CA15 shall be tempered at 1100°F [595°C] min; Grades WC9, C5, C12, and WC11 shall be tempered at 1250°F [675°C] min; Grade C12A shall be normalized at 1900–1975°F [1040–1080°C] and tempered at 1350–1470°F [730–800°C].

5.3 Heat treatment shall be performed after castings have been allowed to cool below the transformation range.

6. Chemical Composition

6.1 The steel shall be in accordance with the requirements as to chemical composition prescribed in Table 1 (Note 4).

NOTE 4 — The role of alloying elements in the development of Grade C12A has been extensively investigated. V and Cb contribute to precipitation strengthening by forming fine and coherent precipitation of M(C,N)X

carbo-nitrides in the ferrite matrix. V also precipitates as VN during tempering or during creep. The two elements are more effective in combination. Therefore, the addition of strong nitride-forming elements, those with a stronger affinity for nitrogen than Cb and V, as deoxidation agents, interferes with these high-temperature strengthening mechanisms.

7. Tensile Requirements

7.1 Steel used for the castings shall be in accordance with the requirements as to tensile properties prescribed in Table 2.

8. Quality

8.1 The surface of the casting shall be examined visually and shall be free of adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Practice A 802/A 802M or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities. When methods involving high temperature are used in the removal of discontinuities, castings shall be preheated to at least the minimum temperatures in Table 3.

8.2 When additional inspection is desired, Supplementary Requirements S4, S5, and S10 may be ordered.

8.3 The castings shall not be peened, plugged, or impregnated to stop leaks.

9. Repair by Welding

9.1 Repairs shall be made using procedures and welders qualified under Practice A 488/A 488M.

9.2 Weld repaired Grade C12A castings shall be post-weld heat treated at 1350–1470°F [730–800°C].

9.3 Weld repairs shall be inspected to the same quality standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S4 specified, weld repairs shall be inspected by magnetic particle examination to the same standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S5 specified, weld repairs on castings that have leaked on hydrostatic test, or on castings in which the depth of any cavity prepared for repair welding exceeds 20% of the wall thickness or 1 in. [25 mm], whichever is smaller, or on castings in which any cavity prepared for welding is greater than approximately 10 in.² [65 cm²], shall be radiographed to the same standards that are used to inspect the castings.

9.4 Weld repairs shall be considered major in the case of a casting that has leaked on hydrostatic test, or when

the depth of the cavity prepared for welding exceeds 20% of the wall thickness or 1 in. [25 mm], whichever is smaller, or when the extent of the cavity exceeds approximately 10 in.² [65 cm²]. All castings with major repair welds shall be thermally stress relieved or completely reheat-treated. This mandatory stress relief or reheat-treatment shall be in accordance with the qualified procedure used. Major

repairs shall be inspected to the same quality standards that are used to inspect the castings.

10. Keywords

10.1 alloy steel; high temperature; martensitic stainless steel; pressure containing; steel castings

TABLE 1
CHEMICAL REQUIREMENTS

		Composition, %									
Grade Identification Symbol UNS Number	Carbon Molybdenum	Nickel		Nickel		Chromium		Chromium		Chromium	
		WC1 J12524	WC4 J12082	WC5 J22000	WC6 J12072	WC9 J21890	WC11 J11872	C5 J42045	C12 J82090	Chromium Molybdenum Vanadium	Chromium Molybdenum Vanadium
Carbon	0.25	0.05–0.20	0.05–0.20	0.05–0.20	0.05–0.20	0.05–0.18	0.15–0.21	0.20	0.20	0.08–0.12	0.15
Manganese	0.50–0.80	0.50–0.80	0.50–0.80	0.40–0.70	0.50–0.80	0.40–0.70	0.50–0.80	0.40–0.70	0.35–0.65	0.30–0.60	1.00
Phosphorus	0.04	0.04	0.04	0.04	0.04	0.04	0.020	0.04	0.04	0.030	0.040
Sulfur	0.045	0.045	0.045	0.045	0.045	0.045	0.015	0.045	0.045	0.010	0.040
Silicon	0.60	0.60	0.60	0.60	0.60	0.60	0.30–0.60	0.75	1.00	0.20–0.50	1.50
Nickel	...	0.70–1.10	...	0.60–1.00	...	...	...	...	...	0.40	1.00
Chromium	...	0.50–0.80	0.50–0.80	0.50–0.90	1.00–1.50	2.00–2.75	1.00–1.50	4.00–6.50	8.00–10.00	8.0–9.5	11.5–14.0
Molybdenum	0.45–0.65	0.45–0.65	0.45–0.65	0.90–1.20	0.45–0.65	0.90–1.20	0.45–0.65	0.45–0.65	0.90–1.20	0.85–1.05	0.50
Columbium	...	...	...	...	...	...	...	...	...	0.060–0.10	...
Nitrogen	...	...	...	...	...	...	...	...	...	0.030–0.070	...
Vanadium	...	...	...	...	...	...	...	...	...	0.18–0.25	...
Specified Residual Elements											
Aluminum	...	...	...	...	...	...	0.01	...	...	0.02	...
Copper	0.50	0.50	0.50	0.50	0.50	0.50	0.35	0.50	0.50	...	...
Nickel	0.50	...	...	...	0.50	0.50	0.50	0.50	0.50	...	...
Chromium	0.35	...	...	...	...	...	...	...	...	...	...
Titanium	...	...	...	...	...	...	...	...	...	0.01	...
Tungsten	0.10	0.10	0.10	0.10	0.10	0.10	...	0.10	0.10	...	...
Vanadium	...	...	...	...	...	...	0.03	...	...	...	...
Zirconium	...	...	...	...	...	...	...	...	...	0.01	...
Total content of these residual elements	1.00	0.60	0.60	0.60	1.00	1.00	1.00	1.00	1.00	...	...

NOTE — All values are maximum unless otherwise indicated.

TABLE 2
TENSILE REQUIREMENTS

Grade	Tensile Strength, ksi [MPa]	Yield Strength, ^A min, ksi [MPa]	Elongation in 2 in. [50 mm], min, % ^B	Reduction of Area, min, %
WC1	65 [450] to 90 [620]	35 [240]	24	35
WC4, WC5, WC6, WC9	70 [485] to 95 [655]	40 [275]	20	35
WC11	80 [550] to 105 [725]	50 [345]	18	45
C5, C12	90 [620] to 115 [795]	60 [415]	18	35
C12A	85 [585] to 110 [760]	60 [415]	18	45
CA15	90 [620] to 115 [795]	65 [450]	18	30

^A Determine by either 0.2% offset method or 0.5% extension-under-load method.

^B When ICI test bars are used in tensile testing as provided for in Specification A 703/A 703M, the gage length to reduced section diameter ratio shall be 4 to 1.

TABLE 3
MINIMUM PREHEAT TEMPERATURES

Grade	Thickness, in. [mm]	Minimum Preheat Temperature, °F [°C]
WC1	$\frac{5}{8}$ and under	50 [10]
	Over $\frac{5}{8}$ [15.9]	250 [120]
WC4	All	300 [150]
WC5	All	300 [150]
WC6	All	300 [150]
WC9	All	400 [200]
WC11	All	300 [150]
C5	All	400 [200]
C12	All	400 [200]
C12A	All	400 [200]
CA15	All	400 [200]

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 703/A 703M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in Specification A 703/A 703M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Unspecified Elements**S2. Destruction Tests****S3. Bend Tests****S4. Magnetic Particle Inspection****S5. Radiographic Inspection****S10. Examination of Weld Preparation**

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Test Method E 165 or Guide E 709.

S13. Hardness Test**S21. Heat Treatment Furnace Record****S22. Heat Treatment****S51. Mandatory Postweld Heat Treatment**

S51.1 All castings with repair welds shall receive a mandatory thermal stress relief or complete reheat treatment in accordance with the qualified procedure after all weld repairs.

SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, MANGANESE-VANADIUM-NICKEL



SA-225/SA-225M



[Identical with ASTM Specification A 225/A 225M-03(R07).]

1. Scope

1.1 This specification covers manganese-vanadium-nickel alloy steel plates intended primarily for welded layered pressure vessels.

1.2 Plates under this specification are available in two grades having different strength levels as follows:

Grade	Tensile Strength, ksi [MPa]
C	105–135 [725–930]
D	
3 in. [75 mm] and under	80–105 [550–725]
Over 3 in. [75 mm]	75–100 [515–690]

1.3 The maximum thickness of plates is limited only by the capacity of the chemical composition to meet the specified mechanical property requirements; however, current mill practice normally limits Grade C to 0.58 in. [15 mm] maximum and Grade D to 6 in. [150 mm] maximum.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 ASTM Standards:

- A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels
- A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates
- A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Plates supplied to this product specification shall conform to Specification A 20/A 20M, which outlines the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/ 20M also establishes the rules for ordering information that should be complied with when purchasing plates to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available where additional control, testing, or examination is required to meet end use requirements.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1 — For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plates from coil are described in Specification A 20/A 20M.

3.6 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 *Steelmaking Practice* — The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

5. Heat Treatment

5.1 Grade D plates of all thicknesses and Grade C plates of thicknesses over 2 in. [50 mm] shall be normalized.

5.2 Grade C plates 2 in. [50 mm] and under in thickness are usually supplied in the as-rolled condition. The plates may be ordered normalized or stress-relieved, or both.

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements given in Table 1, unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

7. Mechanical Properties

7.1 *Tension Test* — The plates, as represented by the tension test specimens, shall conform to the requirements given in Table 2.

7.2 For plates with a nominal thickness of $\frac{3}{4}$ in. [20 mm] and under, the $1\frac{1}{2}$ in. [40 mm] wide rectangular specimen may be used and the elongation determined in a 2 in. [50 mm] gage length that includes the fracture and that shows the greatest elongation.

TABLE 1
CHEMICAL REQUIREMENTS

Elements	Composition, %	
	Grade C	Grade D
Carbon, max (A)	0.25	0.20
Manganese, max:		
Heat analysis	1.60	1.70
Product analysis	1.72	1.84
Phosphorus, max (A)	0.035	0.035
Sulfur, max (A)	0.035	0.035
Silicon:		
Heat analysis	0.15–0.40	0.10–0.50
Product analysis	0.13–0.45	0.08–0.56
Vanadium:		
Heat analysis	0.13–0.18	0.10–0.18
Product analysis	0.11–0.20	0.08–0.20
Nickel:		
Heat analysis	0.40–0.70	0.40–0.70
Product analysis	0.37–0.73	0.37–0.73

NOTE:

(A) Applies to both heat and product analyses.

TABLE 2
TENSILE REQUIREMENTS

	Grade C		Grade D	
	ksi	MPa	ksi	MPa
Tensile strength				
All thicknesses	105–135	725–930		
3 in. [75 mm] and under			80–105	550–725
Over 3 in. [75 mm]			75–100	515–690
Yield strength, min (A)				
All thicknesses	70	485	60	415
3 in. [75 mm] and under			55	380
Over 3 in. [75 mm]				
Elongation in 8 in. [200 mm], min, % (B)			...	
Elongation in 2 in. [50 mm], min, % (B)	20		19	
Elongation in 5D, min, % (B)			17	

NOTES:

(A) Determined by either the 0.2% offset method or the 0.5% extension-under-load method.

(B) See Specification A 20/A 20M for elongation adjustment.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 20/A 20M. Those that are considered suitable for use with this specification are listed below by title.

- | | |
|---|---|
| S1. Vacuum Treatment, | S8. Ultrasonic Examination in Accordance With Specification A 435/A 435M, |
| S2. Product Analysis, | S9. Magnetic Particle Examination, |
| S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons, | S11. Ultrasonic Examination in Accordance With Specification A 577/A 577M, |
| S4.1 Additional Tension Test, | S12. Ultrasonic Examination in Accordance With Specification A 578/A 578M, and |
| S5. Charpy V-Notch Impact Test, | S17. Vacuum Carbon-Deoxidized Steel. |
| S6. Drop Weight Test, | |
| S7. High-Temperature Tension Test, | |

SPECIFICATION FOR CHROMIUM-VANADIUM ALLOY STEEL SPRING WIRE



SA-231/SA-231M

(Identical with ASTM Specification A 231/A 231M-96 except that certification requirements in para. 13.1 are mandatory.)

1. Scope

1.1 This specification covers round chromium-vanadium alloy steel spring wire having properties and quality intended for the manufacture of springs used at moderately elevated temperatures. This wire shall be either in the annealed and cold-drawn or oil-tempered condition as specified by the purchaser.

1.2 The values stated in either SI (metric) units or inch-pound units are to be regarded separately as standard. The values stated in each system are not exact equivalents; therefore, each system must be used independent of the other.

2. Referenced Documents

2.1 ASTM Standards:

- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- A 752 Specification for General Requirements for Wire Rods and Coarse Round Wire, Alloy Steel
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

2.2 ANSI Standard:

- B 32.4M Preferred Metric Sizes for Round, Square, Rectangle, and Hexagon Metal Products

2.3 Military Standard:

- MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

2.4 Federal Standard:

- Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.5 AIAG Standard:

- AIAGB-5 02.00 Primary Metals Identification Tag Application Standard

3. Ordering Information

3.1 Orders for material under this specification should include the following information for each ordered item:

- 3.1.1** Quantity (mass);
- 3.1.2** Name of material (chromium-vanadium alloy steel wire);
- 3.1.3** Wire diameter (Table 1 and Table 2);
- 3.1.4** Packaging (Section 14);
- 3.1.5** Cast or heat analysis report (if requested) (5.2);
- 3.1.6** Certification and test report (Section 13); and
- 3.1.7** ASTM designation and date of issue.

NOTE 1 — A typical ordering description is as follows: 20,000 kg oil-tempered chromium-vanadium alloy steel wire, size 6.00 mm in 150 kg coils to ASTM A 231M dated_____, or for inch-pound units, 40 000 lb oil-tempered chromium-vanadium alloy steel spring wire, size 0.250 in. in 350 lb coils to ASTM A 231 dated_____.

4. Materials and Manufacture

4.1 The steel may be made by any commercially accepted steel-making process. The steel may be either ingot cast or strand cast.

4.2 The finished wire shall be free from detrimental pipe and undue segregation.

5. Chemical Composition

5.1 The steel shall conform to the requirements as to chemical composition specified in Table 3.

5.2 Cast or Heat Analysis — Each cast or heat of steel shall be analyzed by the manufacturer to determine the

percentage of elements prescribed in Table 3. This analysis shall be made from a test specimen preferably taken during the pouring of the cast or heat. When requested, this shall be reported to the purchaser and shall conform to the requirements of Table 3.

5.3 Product Analysis (formerly Check Analysis) — An analysis may be made by the purchaser from finished wire representing each cast or heat of steel. The chemical composition thus determined, as to elements required or restricted, shall conform to the product (check) analysis requirements specified in Table 5 of Specification A 752.

5.4 For referee purposes, Test Methods, Practices, and Terminology A 751 shall be used.

6. Mechanical Properties

6.1 Annealed and Cold Drawn — When purchased in the annealed and cold-drawn condition, the wire shall have been given a sufficient amount of cold working to meet the purchaser's coiling requirements and shall be in a suitable condition to respond properly to heat treatment. In special cases the hardness, if desired, shall be stated in the purchase order.

6.2 Oil Tempered — When purchased in the oil-tempered condition, the tensile strength and minimum percent reduction of area, sizes 2.50 mm or 0.105 in. and coarser, of the wire shall conform to the requirements as shown in Table 1 or Table 2.

6.2.1 Number of Tests — One test specimen shall be taken for each ten coils, or fraction thereof, in a lot. Each cast or heat in a given lot shall be tested.

6.2.2 Location of Tests — Test specimens shall be taken from either end of the coil.

6.2.3 Test Method — The tension test shall be made in accordance with Test Methods and Definitions A 370.

6.3 Wrap Test:

6.3.1 Oil tempered or cold drawn wire 4.00 mm or 0.162 in. and smaller in diameter shall wind on itself as an arbor without breakage. Larger diameter wire up to and including 8.00 mm or 0.312 in. in diameter shall wrap without breakage on a mandrel twice the wire diameter. The wrap test is not applicable to wire over 8.00 mm or 0.312 in. in diameter.

6.3.2 Number of Tests — One test specimen shall be taken for each ten coils, or fraction thereof, in a lot. Each cast or heat in a given lot shall be tested.

6.3.3 Location of Test — Test specimens shall be taken from either end of the coil.

6.3.4 Test Method — The wrap test shall be made in accordance with Supplement IV of Test Methods and Definitions A 370.

7. Metallurgical Properties

7.1 Surface Condition:

7.1.1 The surface of the wire as received shall be free of rust and excessive scale. No serious die marks, scratches, or seams may be present. Based upon examination of etched end specimen, seams shall not exceed 3.5% of the wire diameter, or 0.25 mm or 0.010 in., whichever is the smaller as measured on a transverse section.

7.1.2 Number of Tests — One test specimen shall be taken for each ten coils, or fraction thereof, in a lot. Each cast or heat in a given lot shall be tested.

7.1.3 Location of Test — Test specimens shall be taken from either or both ends of the coil.

7.1.4 Test Method — The surface shall be examined after etching in a solution of equal parts of hydrochloric acid and water that has been heated to approximately 80° C. Test ends shall be examined using 10× magnification. Any specimen which shows questionable seams of borderline depth shall have a transverse section taken from the unetched area, properly mounted and polished and examined to measure the depth of the seam.

8. Dimensions and Permissible Variations

8.1 The permissible variations in the diameter of the wire shall be as specified in Table 4 or Table 5.

9. Workmanship and Appearance

9.1 Annealed and Cold Drawn — The wire shall not be kinked or improperly cast. To test for cast, a few convolutions of wire shall be cut loose from the coil and placed on a flat surface. The wire shall lie flat on itself and not spring up nor show a wavy condition.

9.2 Oil Tempered — The wire shall be uniform in quality and temper and shall not be wavy or crooked.

9.3 Each coil shall be one continuous length of wire properly coiled. Welds made prior to cold drawing are permitted. If unmarked welds are unacceptable to the purchaser, special arrangements should be made with the manufacturer at the time of the purchase.

9.4 Appearance — The surface shall be smooth and free of defects such as seams, pits, die marks, and other defects tending to impair the use of the wire for springs. Any additional surface requirements must be negotiated at the time of entry of the order.

10. Retests

10.1 If any test specimen exhibits obvious defects or shows the presence of a weld, it may be discarded and another specimen substituted.

11. Inspection

11.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified in this specification. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification when such inspections and tests are deemed necessary to assure that the material conforms to prescribed requirements.

12. Rejection and Rehearing

12.1 Unless otherwise specified, any rejection based on tests made in accordance with this specification shall be reported to the manufacturer as soon as possible so that an investigation may be initiated.

12.2 The material must be adequately protected and correctly identified in order that the manufacturer may make a proper investigation.

13. Certification

13.1 A manufacturer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. A report of the test results shall be furnished.

13.2 The certification shall include the specification number, year date of issue, and revision letter, if any.

14. Packaging, Marking, and Loading for Shipment

14.1 The coil mass, dimensions, and the method of packaging shall be as agreed upon between the manufacturer and purchaser.

14.2 The size of the wire, purchaser's order number, ASTM Specification number, heat number, and name or mark of the manufacturer shall be marked on a tag securely attached to each coil of wire.

14.3 Unless otherwise specified in the purchaser's order, packing, marking, and loading for shipments shall be in accordance with those procedures recommended by Practices A 700.

14.4 For Government Procurement:

14.4.1 Packaging, packing, and marking of material for military procurement shall be in accordance with the requirements of MIL-STD-163, Level A, Level C, or commercial as specified in the contract or purchase order. Marking for shipment of material for civil agencies shall be in accordance with Fed. Std. No. 123.

14.5 Bar Coding — In addition to the previously-stated identification requirements, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with AIAG B-5 02.00, Primary Metals Identification Tag Application. The bar code may be applied to a substantially affixed tag.

15. Keywords

15.1 alloy; chromium-vanadium; spring; wire

TABLE 1
TENSILE REQUIREMENTS, SI UNITS ^A

Diameter, ^B mm	Tensile Strength, MPa		Reduction of Areas, Min., %
	Min.	Max.	
0.50	2060	2260	^C
0.55	2050	2240	^C
0.60	2030	2220	^C
0.65	2010	2200	^C
0.70	2000	2160	^C
0.80	1980	2140	^C
0.90	1960	2120	^C
1.00	1940	2100	^C
1.10	1920	2080	^C
1.20	1900	2060	^C
1.40	1860	2020	^C
1.60	1820	1980	^C
1.80	1800	1960	^C
2.00	1780	1930	^C
2.20	1750	1900	^C
2.50	1720	1860	45
2.80	1680	1830	45
3.00	1660	1800	45
3.50	1620	1760	45
4.00	1580	1720	40
4.50	1560	1680	40
5.00	1520	1640	40
5.50	1480	1620	40
6.00	1460	1600	40
6.50	1440	1580	40
7.00	1420	1560	40
8.00	1400	1540	40
9.00	1380	1520	40
10.00	1360	1500	40
11.00	1340	1480	40
12.00	1320	1460	40

^A Tensile strength values for intermediate diameters may be interpolated.

^B Preferred sizes. For a complete list, refer to ANSI B 32.4M, Preferred Metric Sizes for Round, Square, Rectangle, and Hexagon Metal Products.

^C The reduction of area test is not applicable to wire diameters under 2.34 mm.

TABLE 2
TENSILE REQUIREMENTS, INCH-POUND UNITS ^A

Diameter, ^B in.	Tensile Strength, ksi		Reduction of Areas, Min., %
	Min.	Max.	
0.020	300	325	^C
0.032	290	315	^C
0.041	280	305	^C
0.054	270	295	^C
0.062	265	290	^C
0.080	255	275	^C
0.105	245	265	45
0.135	235	255	45
0.162	225	245	40
0.192	220	240	40
0.244	210	230	40
0.283	205	225	40
0.312	203	223	40
0.375	200	220	40
0.438	195	215	40
0.500	190	210	40

^A Tensile strength values for intermediate diameters may be interpolated.

^B Preferred sizes. For a complete list, refer to ANSI B 32.4M, Preferred Metric Sizes for Round, Square, Rectangle, and Hexagon Metal Products.

^C The reduction of area test is not applicable to wire diameters under 0.092 in.

TABLE 3
CHEMICAL REQUIREMENTS

Element	Analysis, %
Carbon	0.48-0.53
Manganese	0.70-0.90
Phosphorus	0.040 max.
Sulfur	0.040 max.
Silicon	0.15-0.35
Chromium	0.80-1.10
Vanadium	0.15 min.

TABLE 4
PERMISSIBLE VARIATIONS IN WIRE DIAMETER,
SI UNITS ^A

Diameter, mm	Permissible Variations, plus and Minus, mm	Permissible Out- of Round, mm
To 0.70, incl.	0.02	0.02
Over 0.70 to 2.00, incl.	0.03	0.03
Over 2.00 to 9.00, incl.	0.05	0.05
Over 9.00	0.08	0.08

^A For purposes of determining conformance with this specification, all specified limits are absolute as defined in Practice E 29.

TABLE 5
PERMISSIBLE VARIATIONS IN WIRE DIAMETER,
INCH-POUND UNITS ^A

Diameter, in.	Permissible Variations, Plus and Minus, mm	Permissible Out- of Round, mm
0.020 to 0.028, incl.	0.0008	0.0008
Over 0.028 to 0.075, incl.	0.001	0.001
Over 0.075 to 0.375, incl.	0.002	0.002
Over 0.375 to 0.500, incl.	0.003	0.003

^A For purposes of determining conformance with this specification, all specified limits are absolute as defined in Practice E 29.

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SPECIFICATION FOR CHROMIUM-VANADIUM ALLOY STEEL VALVE SPRING QUALITY WIRE



SA-232/SA-232M



(Identical with ASTM Specification A 232/A 232M-91.)

1. Scope

1.1 This specification covers the highest quality of round chromium-vanadium alloy steel valve spring wire, uniform in quality and temper, intended for the manufacture of valve springs and other springs requiring high-fatigue properties when used at moderately elevated temperatures. This wire shall be either in the annealed and cold-drawn or oil-tempered condition as specified by the purchaser.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the inch-pound units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independent of the other.

2. Referenced Documents

2.1 ASTM Standards:

- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

2.2 ANSI Standard:

- B32.4 Preferred Metric Sizes for Round, Square, Rectangle, and Hexagon Metal Products

2.3 Federal Standard:

- Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.4 Military Standard:

- MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

3. Ordering Information

3.1 Orders for material under this specification should include the following information for each ordered item:

- 3.1.1** Quantity (mass),
- 3.1.2** Name of material (chromium-vanadium alloy steel valve spring quality wire),
- 3.1.3** Dimensions (Table 1 and Section 8),
- 3.1.4** Condition (Section 6),
- 3.1.5** Packaging (Section 14),
- 3.1.6** Heat analysis report, if requested (Section 5.2),
- 3.1.7** Certification or test report, or both, if specified (Section 13), and
- 3.1.8** ASTM designation and year of issue.

NOTE 1 — A typical ordering description is as follows: 20 000 kg oil-tempered chromium-vanadium alloy steel valve spring quality wire, size 6.00 mm in 150 kg coils to ASTM A 232/A 232M dated _____, or for inch-pound units, 40 000 lb oil-tempered chromium-vanadium alloy steel valve spring quality wire, size 0.250 in. in 350-lb coils to ASTM A 232/A 232M dated _____.

4. Materials and Manufacture

4.1 The steel may be made by any commercially accepted steel making process. The steel may be either ingot cast or strand cast.

4.2 The finished wire shall be free from detrimental pipe and undue segregation.

5. Chemical Requirements

5.1 The steel shall conform to the requirements for chemical composition specified in Table 2.

5.2 Heat Analysis — Each heat of steel shall be analyzed by the manufacturer to determine the percentage of elements prescribed in Table 2. This analysis shall be made

from a test specimen preferably taken during the pouring of the heat. When requested, this shall be reported to the purchaser and shall conform to the requirement of Table 2.

5.3 Product Analysis — An analysis may be made by the purchaser from finished wire representing each heat of steel. The average of all the separate determinations made shall be within the limits specified in the analysis column. Individual determinations may vary to the extent shown in the product analysis tolerance column, except that the several determinations of a single element in any one heat shall not vary both above and below the specified range.

5.4 For referee purposes, Test Methods, Practices and Terminology A 751 shall be used.

6. Mechanical Requirements

6.1 Annealed and Cold Drawn — When purchased in the annealed and cold-drawn condition, the wire shall have been given a sufficient amount of cold working to meet the purchaser's coiling requirements and shall be in a suitable condition to respond properly to heat treatment. In special cases the hardness, if desired, shall be stated in the purchase order.

6.2 Oil Tempered — When purchased in the oil-tempered condition, the tensile strength and minimum percent reduction of area, sizes 2.50 mm [0.105 in.] and coarser, of the wire shall conform to the requirements prescribed in Table 1.

6.2.1 Number of Tests — One test specimen shall be taken for each five coils, or fraction thereof, in a lot. Each heat in a given lot shall be tested.

6.2.2 Location of Tests — Test specimens shall be taken from either end of the coil.

6.2.3 Test Method — The tension test shall be made in accordance with Test Methods and Definitions A 370.

6.3 Wrap Test:

6.3.1 Oil-tempered or cold-drawn wire 4.00 mm [0.162 in.] and smaller in diameter shall wind on itself as an arbor without breakage. Larger diameter wire up to and including 8.00 mm [0.312 in.] in diameter shall wrap without breakage on a mandrel twice the wire diameter. The wrap test is not applicable to wire over 8.00 mm [0.312 in.] in diameter.

6.3.2 Number of Tests — One test specimen shall be taken for each five coils or fraction thereof, in a lot. Each heat in a given lot shall be tested.

6.3.3 Location of Test — Test specimens shall be taken from either end of the coil.

6.3.4 Test Method — The wrap test shall be made in accordance with Test Methods and Definitions A 370.

7. Metallurgical Requirements

7.1 Surface Condition:

7.1.1 The surface of the wire as received shall be free of imperfections such as pits, die marks, scratches, seams, and other defects tending to impair the fatigue value of the springs.

7.1.2 Number of Tests — One test specimen shall be taken from each end of every coil.

7.1.3 Test Method — The surface shall be examined after etching in a solution of equal parts of hydrochloric acid and water that has been heated to approximately 80°C for a sufficient length of time to remove up to approximately 1% of the diameter of the wire. Test ends shall be examined using 10× magnification.

7.2 Decarburization:

7.2.1 Transverse sections of the wire properly mounted, polished, and etched shall show no completely decarburized (carbon-free) areas when examined at a magnification of 100 diameters. Partial decarburization shall not exceed a depth of 0.025 mm [0.001 in.] on wire 5.00 mm [0.192 in.] and smaller or 0.038 mm [0.0015 in.] on larger than 5.00 mm [0.192 in.].

7.2.2 To reveal the decarburization more accurately in the untempered wire, the specimen shall be hardened and tempered before microscopical examination. Prior to hardening, the specimen shall be filed flat on one side enough to reduce the diameter at least 20%. The subsequent mounted specimen shall show the flattened section, as well as the original wire edge. Any decarburization on this flattened section shall necessitate a new specimen for examination.

7.2.3 Number of Tests — One test specimen shall be taken for each five coils, or fraction thereof, in a lot. Each in a given lot shall be tested.

7.2.4 Location of Tests — Test specimens may be taken from either end of the coil.

8. Dimensions and Permissible Variations

8.1 The permissible variations in the diameter of the wire shall be specified in Table 3.

8.2 Number of Tests — One test specimen shall be taken from each end of every coil.

9. Workmanship, Finish, and Appearance

9.1 Annealed and Cold Drawn — The wire shall not be kinked or improperly cast. To test for cast, a few convolutions of wire shall be cut loose from the coil and placed on a flat surface. The wire shall lie substantially flat on itself and not spring up nor show a wavy condition.

9.2 Oil Tempered—The wire shall be uniform in quality and temper and shall not be wavy or crooked.

9.3 Each coil shall be one continuous length of wire properly coiled and firmly tied.

9.4 No welds are permitted in the finished product and any welds made during processing must be removed.

10. Retests

10.1 If any test specimen exhibits obvious defects it may be discarded and another specimen substituted.

11. Inspection

11.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified in this specification. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification when such inspections and tests are deemed necessary to assure that the material conforms to prescribed requirements.

12. Rejection and Rehearing

12.1 Unless otherwise specified, any rejection based on tests made in accordance with these specifications shall be reported to the manufacturer as soon as possible so that an investigation may be initiated.

12.2 The material must be adequately protected and correctly identified in order that the manufacturer may make a proper investigation.

13. Certification

13.1 When specified in the purchase order or contract, a manufacturer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

13.2 The certification shall include the specification number, year date of issue, and revision letter, if any.

14. Packaging, Marking, and Loading for Shipment

14.1 The coil mass, dimensions, and the method of packaging shall be agreed upon between the manufacturer and purchaser.

14.2 The size of the wire, purchaser's order number, ASTM specification number, heat number, and name or mark of the manufacturer shall be marked on a tag securely attached to each coil of wire.

14.3 Unless otherwise specified in the purchaser's order, packaging, marking, and loading for shipments shall be in accordance with those procedures recommended by Practice A 700.

14.4 For Government Procurement—Packaging, packing, and marking of material for military procurement shall be in accordance with the requirements of MIL-STD-163, Level A, Level C, or commercial as specified in the contract or purchase order. Marking for shipment of material for civil agencies shall be in accordance with Fed. Std. No. 123.

TABLE 1
TENSILE REQUIREMENTS^A
SI Units

Diameter ^B mm	MPa, min	MPa, max	Reduction of Area, min, %
0.50	2060	2260	C
0.55	2050	2240	C
0.60	2030	2220	C
0.65	2010	2200	C
0.70	2000	2160	C
0.80	1980	2140	C
0.90	1960	2120	C
1.00	1940	2100	C
1.10	1920	2080	C
1.20	1900	2060	C
1.40	1860	2020	C
1.60	1820	1980	C
1.80	1800	1960	C
2.00	1780	1930	C
2.20	1750	1900	C
2.50	1720	1860	45
2.80	1680	1830	45
3.00	1660	1800	45
3.50	1620	1760	45
4.00	1580	1720	40
4.50	1560	1680	40
5.00	1520	1640	40
5.50	1480	1620	40
6.00	1460	1600	40
6.50	1440	1580	40
7.00	1420	1560	40
8.00	1400	1540	40
9.00	1380	1520	40
10.00	1360	1500	40
11.00	1340	1480	40
12.00	1320	1460	40
Inch-Pound Units			
Diameter, in.	ksi, min	ksi, max	Reduction of Area, min, %
0.020	300	325	C
0.032	290	315	C
0.041	280	305	C
0.054	270	295	C
0.062	265	290	C
0.080	255	275	C
0.105	245	265	45
0.135	235	255	45
0.162	225	245	40
0.192	220	240	40
0.244	210	230	40
0.283	205	225	40
0.312	203	223	40
0.375	200	220	40
0.438	195	215	40
0.500	190	210	40

^A Tensile strength values for intermediate diameters may be interpolated.

^B Preferred sizes. For a complete list, refer to ANSI B32.4.

^C The reduction of area test is not applicable to wire under 2.50 mm [0.105 in.] in diameter.

TABLE 2
CHEMICAL REQUIREMENTS

	Analysis, %	Product Analysis Tolerance, %
Carbon	0.48–0.53	±0.02
Manganese	0.70–0.90	±0.03
Phosphorus	0.020 max	+0.005
Sulfur	0.035 max	+0.005
Silicon	0.15–0.35	±0.02
Chromium	0.80–1.10	±0.05
Vanadium	0.15 min	–0.01

TABLE 3
PERMISSIBLE VARIATIONS IN WIRE DIAMETER^A
SI Units

Diameter, mm	Permissible Variations, plus and minus, mm	Permissible Out-of-Round, mm
to 2.0, incl	0.02	0.02
Over 2.0 to 4.00, incl	0.03	0.03
Over 4.00 to 9.00, incl	0.04	0.04
Over 9.00	0.05	0.05

Inch-Pound

Diameter, in.	Permissible Variations, plus and minus, in.	Permissible Out-of-Round, in.
0.020 to 0.075, incl	0.0008	0.0008
Over 0.075 to 0.148, incl	0.001	0.001
Over 0.148 to 0.375, incl	0.0015	0.0015
Over 0.375 to 0.500, incl	0.002	0.002

^A For purposes of determining conformance with this specification, all specified limits are absolute as defined in Practice E 29.

SPECIFICATION FOR PIPING FITTINGS OF WROUGHT CARBON STEEL AND ALLOY STEEL FOR MODERATE AND HIGH-TEMPERATURE SERVICE



SA-234/SA-234M



(Identical with ASTM Specification A 234/A 234M-07.)

1. Scope

1.1 This specification covers wrought carbon steel and alloy steel fittings of seamless and welded construction covered by the latest revision of ASME B16.9, B16.11, MSS-SP-79, MSS-SP-83, and MSS-SP-95. These fittings are for use in pressure piping and in pressure vessel fabrication for service at moderate and elevated temperatures. Fittings differing from these ASME and MSS standards shall be furnished in accordance with Supplementary Requirement S58 of Specification A 960/A 960M.

1.2 Optional supplementary requirements are provided for fittings where a greater degree of examination is desired. When desired, one or more of these supplementary requirements may be specified in the order.

1.3 This specification does not cover cast welding fittings or fittings machined from castings. Cast steel welding fittings are governed by Specifications A 216/A 216M and A 217/A 217M.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable “M” specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 In addition to those reference documents listed in Specification A 960/A 960M, the following list of standards apply to this specification.

2.2 ASTM Standards:

A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service

A 217/A 217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service

A 960/A 960M Specification for Common Requirements for Wrought Steel Piping Fittings

2.3 ASME Standards:

B16.9 Steel Butt-Welding Fittings

B16.11 Forged Steel Fittings, Socket Welding and Threaded

2.4 ASME Boiler and Pressure Vessel Code:

Section V Nondestructive Examination

Section VIII, Division 1, Pressure Vessels

Section IX Welding Qualifications

2.5 MSS Standards:

MSS-SP-25 Standard Marking System for Valves, Fittings, Flanges, and Unions

MSS-SP-79 Socket Welding Reducer Inserts

MSS-SP-83 Steel Pipe Unions, Socket-Welding and Threaded

MSS-SP-95 Swage(d) Nipples and Bull Plugs

2.6 ASNT Standard:

SNT-TC-1A Recommended Practice for Nondestructive Testing Personnel Qualification and Certification

3. Ordering Information

3.1 See Specification A 960/A 960M.

4. General Requirements

4.1 Product furnished to this specification shall conform to the requirements of Specification A 960/A 960M,

including any supplementary requirements that are indicated in the purchase order. Failure to comply with the requirements of Specification A 960/A 960M constitutes non-conformance with this specification. In case of a conflict between the requirements of this specification and Specification A 960/A 960M, this specification shall prevail.

5. Materials

5.1 The material for fittings shall consist of killed steel, forgings, bars, plates, seamless or fusion-welded tubular products with filler metal added and shall conform to the chemical requirements of Table 1. Unless otherwise specified for carbon steel plates, the steel may be made to either coarse grain or fine grain practice. Grade WP9 shall be made to fine grain practice.

5.2 A starting material specification that specifically requires the addition of any element beyond those listed for the materials in Table 1 for the applicable grade of material is not permitted. This does not preclude the use of deoxidizers or the judicious use of elements for grain size control.

6. Manufacture

6.1 Forging or shaping operations may be performed by hammering, pressing, piercing, extruding, upsetting, rolling, bending, fusion welding, machining, or by a combination of two or more of these operations. The forming procedure shall be so applied that it will not produce injurious imperfections in the fittings.

NOTE 1 — Fittings NPS 4 and under may be machined from hot-forged or rolled, cold-sized, and straightened bar stock having the chemical composition of the Grade in Table 1 and the mechanical properties of the Grade in Table 2. Heat treatment shall be in accordance with Section 7. All caps machined from bar stock shall be examined by liquid penetrant or magnetic particle in accordance with S52 or S53 in Specification A 960/A 960M.

6.2 All welds including welds in tubular products from which fittings are made shall be (1) made by welders, welding operators, and welding procedures qualified under the provisions of ASME Section IX, (2) heat treated in accordance with Section 7 of this specification, and (3) radiographically examined throughout the entire length of each weld in accordance with Article 2, ASME Section V with acceptance limits in accordance with Paragraph UW-51 of ASME Section VIII, Division 1 of the ASME Boiler & Pressure Vessel Code. In place of radiographic examination, welds may be ultrasonically examined in accordance with Appendix 12 of Section VIII. The NDE of welds in Grades WPB, WPC, WP1, WP11 Class 1, WP11 Class 2, WP11 Class 3, WP12 Class 1, WP12 Class 2, and WPR may be performed either prior to or after

forming. NDE of welds in Grades WP5, WP9, WP91, WP911, WP22 Class 1, and WP22 Class 3 shall be done after forming.

6.3 Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

6.4 The welded joints of the fittings shall be finished in accordance with the requirements of Paragraph UW-35(a) of ASME Section VIII, Division 1.

6.5 All butt-weld tees manufactured by cold-forming method(s) shall be liquid penetrant or magnetic particle examined by one of the methods specified in Supplementary Requirement S52 or S53 in Specification A 960/A 960M. This examination shall be performed after final heat treat. Only the side wall area of the tees need be examined. This area is defined by a circle that covers the area from the weld bevel of the branch outlet to the center line of the body or run. Internal and external surfaces shall be examined when size permits accessibility. No cracks shall be permitted. Other imperfections shall be treated in accordance with Section 13 on Surface Quality. After the removal of any crack, the tee(s) shall be re-examined by the original method. Acceptable tees shall be marked with the symbol PT or MT, as applicable, to indicate compliance.

6.6 Stubends may be produced with the entire lap added by the welding of a ring, made from plate or bar of the same alloy grade and composition, to the outside of a straight section of pipe, provided the weld is double welded, is a full penetration joint, satisfies the requirements of 6.2 for qualifications and 7.3.3 for post weld heat treatment.

7. Heat Treatment

7.1 Heat Treatment Procedures — Fittings, after forming at an elevated temperature, shall be cooled to a temperature below the critical range under suitable conditions to prevent injurious defects caused by too rapid cooling, but in no case more rapidly than the cooling rate in still air. Heat treatment temperatures specified are metal (part) temperatures. Heat-treated fittings shall be treated according to paragraph 7 in Specification A 960/A 960M.

7.2 WPB, WPC, and WPR Fittings:

7.2.1 Hot-formed WPB, WPC, and WPR fittings upon which the final forming operation is completed at a temperature above 1150°F [620°C] and below 1800°F [980°C] need not be heat treated provided they are cooled in still air.

7.2.2 Hot-formed or forged WPB, WPC, and WPR fittings finished at temperature in excess of 1800°F [980°C] shall subsequently be annealed, normalized, or normalized

and tempered. Hot-forged fittings NPS 4 or smaller need not be heat treated.

7.2.3 WPB, WPC, and WPR fittings over NPS 12, produced by locally heating a portion of the fitting stock to any temperature for forming, shall be subsequently annealed, normalized, or normalized and tempered. Fittings such as elbows, tees, header tees, reducers and lap joint stub ends with a carbon content less than 0.26%, NPS 12 and under, shall not require heat treatment after forming a locally heated portion of the fitting.

7.2.4 Cold-formed WPB, WPC, and WPR fittings, upon which the final forming operation is completed at a temperature below 1150°F [620°C], shall be normalized, or shall be stress relieved at 1100 to 1275°F [595 to 690°C].

7.2.5 WPB, WPC, and WPR fittings produced by fusion welding and having a nominal wall thickness at the welded joint of $\frac{3}{4}$ in. [19 mm] or greater shall be post-weld heat treated at 1100 to 1250°F [595 to 675°C], or in accordance with 7.2.6.

7.2.6 At the option of the manufacturer, WPB and WPC fittings produced by any of the methods in Section 6 may be annealed, normalized, or normalized and tempered.

7.3 Fittings Other than WPB, WPC, and WPR:

7.3.1 Fittings of Grades WP1, WP11 Class 1, WP11 Class 2, WP11 Class 3, WP12 Class 1, WP12 Class 2, WP22 Class 1, WP22 Class 3, WP5, and WP9 shall be furnished in the full-annealed, isothermal-annealed, or normalized and tempered condition. If normalized and tempered, the tempering temperature for WP11 Class 1, WP11 Class 2, WP11 Class 3, WP12 Class 1, and WP12 Class 2 shall not be less than 1150°F [620°C]; for Grades WP5, WP9, WP22 Class 1, and WP22 Class 3 the tempering temperature shall not be less than 1250°F [675°C].

7.3.2 Fittings of Grades WP1, WP12 Class 1, or WP12 Class 2 either hot formed or cold formed may be given a final heat treatment at 1200°F [650°C] instead of the heat treatment specified in 7.3.1.

7.3.3 Fittings in all thicknesses produced by fusion welding after the heat treatment specified in 7.3.1 shall be post-weld heat treated at a temperature not less than prescribed above for tempering except that Grade WP1 is required to be post-weld heat treated only when the nominal wall thickness at the welded joint is $\frac{1}{2}$ in. [13 mm] or greater.

7.3.4 Except when Supplementary Requirement S1 is specified by the purchaser, Grade WP91 shall be normalized at 1900°F [1040°C] minimum, and 1975°F [1080°C] maximum, and tempered in the temperature range of 1350°F [730°C] to 1470°F [800°C] as a final heat treatment.

7.3.5 Grade WP911 shall be normalized in the temperature range of 1900 to 1975°F [1040 to 1080°C], and

tempered in the temperature range of 1365 to 1435°F [740 to 780°C] as a final heat treatment.

7.4 WPB and WPC Fittings Made from Bar — Cold-finished bars reduced in cross-sectional area more than 10% by cold drawing or cold rolling are not acceptable for use in the manufacture of these fittings unless the bars have been either stress relieved in the temperature range of 1100 to 1250°F [595 to 675°C], normalized, normalized and tempered, or fully annealed. Mechanical testing must be performed subsequent to the final heat-treating operation.

7.5 Liquid quenching followed by tempering shall be permitted for all grades when approved by the purchaser. Minimum tempering temperature shall be 1100°F [595°C] for WPB, WPC, and WPR, 1150°F [620°C] for Grades WP1, WP11 Class 1, WP11 Class 2, WP11 Class 3, WP12 Class 1, and WP12 Class 2 and 1250°F [675°C] for Grades WP5, WP9, WP22 Class 1, and WP22 Class 3, and 1350°F [730°C] for Grade WP91 and WP911.

8. Chemical Composition

8.1 The chemical composition of each cast or heat used shall be determined and shall conform to the requirements of the chemical composition for the respective materials listed in Table 1. The ranges as shown have been expanded to include variations of the chemical analysis requirements that are listed in the various specifications for the starting materials (pipe, tube, plate, bar, and forgings) normally used in the manufacturing of fittings to this specification.

8.2 The steel shall not contain any unspecified elements for the ordered grade to the extent that it conforms to the requirements of another grade for which that element is a specified element having a required minimum content.

8.3 Weld metal used in the construction of carbon-steel fittings shall be mild steel analysis No. A1 of Table QW-442, Section IX of the ASME Boiler and Pressure Vessel Code, No. A2 may be used for Grade WPCW.

8.4 The molybdenum and chromium content of the deposited weld metal of alloy steel fittings shall be within the same percentage range as permitted for the base metal.

9. Tensile Requirements

9.1 The tensile properties of the fitting material shall conform to the requirements listed in Table 2.

9.1.1 Specimens cut either longitudinally or transversely shall be acceptable for the tension test.

9.1.2 While Table 2 specifies elongation requirements for both longitudinal and transverse specimens, it is not the intent that both requirements apply simultaneously.

Instead, it is intended that only the elongation requirement that is appropriate for the specimen used be applicable.

9.2 One tension test shall be made on each heat of material and in the same condition of heat treatment as the finished fittings it represents. The sample thickness shall not vary more than $\frac{1}{4}$ in. [6 mm] from the fitting wall thickness it represents.

9.3 When cold-formed fittings are furnished, samples of the raw material shall be normalized or stress relieved as required in 7.2.4. Tension tests conducted on these heat-treated samples shall be considered to be the tensile properties of the cold-formed fittings.

9.4 Records of the tension tests shall be certification that the material of the fitting meets the tensile requirements of this specification provided the heat treatments are the same. If the raw material was not tested, or the fitting is not in the same condition of heat treatment, the fitting manufacturer shall perform the required test on material representative of the finished fitting from each heat of starting material.

10. Hardness

10.1 Fittings shall be capable of meeting the following hardness requirements, if tested:

10.1.1 Fittings of Grades WP5, WP9, and WPR — 217 HB maximum.

10.1.2 Fittings of Grade WP91 and WP911 — 248 HB maximum.

10.1.3 Fittings of all other grades — 197 HB maximum.

10.2 When actual hardness testing of the fittings is required, see Supplementary Requirement S57 in Specification A 960/A 960M.

11. Hydrostatic Tests

11.1 See Specification A 960/A 960M.

12. Dimensions

12.1 Butt-welding fittings and butt-welding short radius elbows and returns purchased in accordance with this specification shall conform to the dimensions and tolerances given in the latest revision of ASME B16.9. Steel socket-welding and threaded fittings purchased in accordance with this specification shall conform to the sizes, shapes, dimensions, and tolerances specified in the latest revision of ASME B16.11, MSS-SP-79, or MSS-SP-83.

12.2 Fittings of size or shape differing from these standards, but meeting all other requirements of this specification may be furnished in accordance with Supplementary Requirement S58 in Specification A 960/A 960M.

13. Surface Quality

13.1 See Specification A 960/A 960M.

14. Repair by Welding

14.1 See Specification A 960/A 960M.

15. Inspection

15.1 See Specification A 960/A 960M.

15.2 Other tests, when required by agreement, shall be made from material of the lots covered in the order.

16. Rejection and Rehearing

16.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly in writing. In case of dissatisfaction with the results of the tests, the producer or supplier may make claim for a rehearing.

16.2 Fittings that develop defects in shopworking or application operations may be rejected. Upon rejection, the manufacturer shall be notified promptly in writing.

17. Certification

17.1 Test reports are required for all fittings covered by this specification. Each test report shall include the following information:

17.1.1 Chemical analysis results, Section 8 (Table 1). When the amount of an element is less than 0.02%, the analysis for that element may be reported as “<0.02 %.”

17.1.2 Tensile property results, Section 9 (Table 2), report the yield strength and ultimate strength in ksi [MPa] and elongation in percent,

17.1.3 Hardness acceptable in accordance with Section 10,

17.1.4 Type heat treatment, if any, Section 7,

17.1.5 Seamless or welded,

17.1.6 Starting material, specifically pipe, plate, etc.,

17.1.7 Statement regarding radiographic or ultrasonic examination, 6.2,

17.1.8 Any supplemental testing required by the purchase order,

17.1.9 Statement that the fitting was manufactured, sampled, tested, and inspected in accordance with the specification, and was found to meet the requirements, and

17.1.10 The specification number, year of issue, revision letter (if any), grade and class of the fittings.

18. Product Marking

18.1 All fittings shall have the prescribed information stamped or otherwise suitably marked on each fitting in accordance with the Standard Marking System for Valves, Fittings, Flanges and Unions (MSS-SP-25, latest edition).

18.2 The prescribed information for butt-welding fittings shall be: The manufacturer's name or trademark (see Note 2), schedule number or nominal wall thickness designation, size, fitting designation in accordance with Annex A1 and the heat number or manufacturer's heat identification.

NOTE 2 — For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component complies with this specification.

18.3 The prescribed information for threaded or socket-welding fittings shall be: The manufacturer's name or trademark (see Note 2), pressure class or schedule number and fitting designation in accordance with Annex A1, and the

heat number or the manufacturer's heat identification.

18.4 Specification number, year of issue and revision letter are not required to be marked on fittings.

18.5 Bar Coding — In addition to the requirements in 18.1, 18.2, 18.3 and 18.4, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small fittings, the bar code may be applied to the box or a substantially applied tag.

19. Keywords

19.1 pipe fittings—steel; piping applications; pressure containing parts; pressure vessel service; temperature service applications—elevated

TABLE 1
CHEMICAL REQUIREMENTS

Grade and Marking Symbol ^A	Composition, %									
	Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Chromium	Molybdenum	Nickel	Copper	Others
WPB ^{B,C,D,E,F}	0.30 max	0.29–1.06	0.050	0.058	0.10 min	0.40 max	0.15 max	0.40 max	0.40 max	Vanadium 0.08 max
WPC ^{B,C,D,E,F}	0.35 max	0.29–1.06	0.050	0.058	0.10 min	0.40 max	0.15 max	0.40 max	0.40 max	Vanadium 0.08 max
WP1	0.28 max	0.30–0.90	0.045	0.045	0.10–0.50	...	0.44–0.65	...	...	...
WP12 CL1, WP12 CL2	0.05–0.20	0.30–0.80	0.045	0.045	0.60 max	0.80–1.25	0.44–0.65	...	...	...
WP11 CL1	0.05–0.15	0.30–0.60	0.030	0.030	0.50–1.00	1.00–1.50	0.44–0.65	...	...	...
WP11 CL2, WP11 CL3	0.05–0.20	0.30–0.80	0.040	0.040	0.50–1.00	1.00–1.50	0.44–0.65	...	...	...
WP22 CL1, WP22 CL3	0.05–0.15	0.30–0.60	0.040	0.040	0.50 max	1.90–2.60	0.87–1.13	...	...	...
WP5 CL1, WP5 CL3	0.15 max	0.30–0.60	0.040	0.030	0.50 max	4.0–6.0	0.44–0.65	...	...	...
WP9 CL1, WP9 CL3	0.15 max	0.30–0.60	0.030	0.030	1.00 max	8.0–10.0	0.90–1.10	...	...	...
WPR	0.20 max	0.40–1.06	0.045	0.050	...	...	...	1.60–2.24	0.75–1.25	...
WP91	0.08–0.12	0.30–0.60	0.020	0.010	0.20–0.50	8.0–9.5	0.85–1.05	0.40 max	...	Vanadium 0.18–0.25 Columbium 0.06–0.10 Nitrogen 0.03–0.07 Aluminum 0.02 max ^G Titanium 0.01 max ^G Zirconium 0.01 max ^G Vanadium 0.18–0.25 Columbium 0.060–0.10 Nitrogen 0.04–0.09 Aluminum 0.02 max ^G Boron 0.0003–0.006 Tungsten 0.90–1.10 Titanium 0.01 max ^G Zirconium 0.01 max ^G
WP911	0.09–0.13	0.30–0.60	0.020	0.010	0.10–0.50	8.5–9.5	0.90–1.10	0.40 max	...	...

NOTE 1 — All requirements are maximum unless otherwise indicated.

NOTE 2 — Where an ellipsis (. . .) appears in this table, there is no requirement.

^A When fittings are of welded construction, the grade and marking symbol shown above shall be supplemented by letter "W".

^B Fittings made from bar or plate may have 0.35 max carbon.

^C Fittings made from forgings may have 0.35 max carbon and 0.35 max silicon with no minimum.

^D For each reduction of 0.01% below the specified carbon maximum, an increase of 0.06% manganese above the specified maximum will be permitted, up to a maximum of 1.35%.

^E The sum of Copper, Nickel, Chromium, and Molybdenum shall not exceed 1.00%.

^F The sum of Chromium and Molybdenum shall not exceed 0.32%.

^G Applies both to heat and product analyses.

TABLE 2
TENSILE REQUIREMENTS

Grade and Marking Symbol	WPB	WPC, WP11 CL2, WP12 CL2	WP1	WP11 CL1, WP22 CL1, WP5 CL1, WP9 CL1	WPR	WP11 CL3, WP22 CL3, WP5 CL3, WP9 CL3	WP91	WP911	WP12 CL1
Tensile strength, range ksi [MPa]	60–95 [415–655]	70–95 [485–655]	55–80 [380–550]	60–85 [415–585]	63–88 [435–605]	75–100 [520–690]	85–110 [585–760]	90–120 [620–840]	60–85 [415–585]
Yield strength, min, ksi [MPa] (0.2% offset or 0.5% extension-under-load)	35 [240]	40 [275]	30 [205]	30 [205]	46 [315]	45 [310]	60 [415]	64 [440]	32 [220]
Elongation Requirements									
Grades									
All Grades except WPR, WP91, and WP911				WPR		WP91		WP911	
Longitudinal				Transverse		Longitudinal		Transverse	
Elongation:									
Standard round specimen, or small proportional specimen, min % in 4 D				22		14		20	
Rectangular specimen for wall thickness $\frac{5}{16}$ in. [7.94 mm] and over, and for all small sizes tested in full section; min % in 2 in. [50 mm]				30		20 ^A		28	
Rectangular specimen for wall thickness less than $\frac{5}{16}$ in. [7.94 mm]; min % in 2 in. [50 mm] ($\frac{1}{2}$ in. [12.7 mm] wide specimen)				B		B		B	

NOTE — Where an ellipsis (. . .) appears in this table, there is no requirement.

^A WPB and WPC fittings manufactured from plate shall have a minimum elongation of 17%.^B For each $\frac{1}{32}$ in. [0.79 mm] decrease in wall thickness below $\frac{5}{16}$ in. [7.94 mm], a deduction of 1.5% for longitudinal and 1.0% for transverse from the values shown above is permitted. The following table gives the minimum value for various wall thicknesses.

Wall Thickness		Grades			
		All Grades except WPR, WP91, and WP911		WPR	WP91 and WP911
in.	[mm]	Longitudinal	Transverse	Longitudinal	Longitudinal
$\frac{5}{16}$ (0.312)	7.94	30.0	20.0	28.0	20
$\frac{9}{32}$ (0.281)	7.14	28.5	19.0	26.5	19
$\frac{1}{4}$ (0.250)	6.35	27.0	18.0	25.0	18
$\frac{7}{32}$ (0.219)	5.56	25.5	...	23.5	17
$\frac{3}{16}$ (0.188)	4.76	24.0	...	22.0	16
$\frac{5}{32}$ (0.156)	3.97	22.5	...	20.5	15
$\frac{1}{8}$ (0.125)	3.17	21.0	...	19.0	14
$\frac{3}{32}$ (0.094)	2.38	19.5	...	17.5	13
$\frac{1}{16}$ (0.062)	1.59	18.0	...	16.0	12

NOTE — This table gives the computed minimum % elongation value for each $\frac{1}{32}$ in. [0.79 mm] decrease in wall thickness. Where the wall thickness lies between two values above, the minimum elongation value is determined by the following equations:

Direction of Test

Longitudinal
Transverse

Equation

 $E = 48t + 15.00$
 $E = 32t + 10.00$

where:

 E = elongation in 2 in. or [50 mm], %, and
 t = actual thickness of specimen, in. [mm].

SUPPLEMENTARY REQUIREMENTS

These requirements shall not be considered unless specified in the order, in which event, the supplementary requirements specified shall be made at the place of manufacture, unless otherwise agreed upon, at the purchaser's expense. The test specified shall be witnessed by the purchaser's inspector before shipment of material, if so specified in the order.

S1. Alternative Heat Treatment—Grade WP91

S1.1 Grade WP91 shall be normalized in accordance with 7.3.4 and tempered at a temperature, to be specified by the purchaser, less than 1350°F [730°C]. It shall be the purchaser's responsibility to subsequently temper the entire fitting in the temperature range of 1350°F [730°C] to 1470°F [800°C] as a final heat treatment. All mechanical tests shall be made on material heat treated in accordance with 7.3.4. The certification shall reference this supplementary requirement indicating the actual tempering temperature applied. The notation "S1" shall be included with the required marking of the fitting.

S2. Restricted Vanadium Content

S2.1 The vanadium content of the fittings shall not exceed 0.03%.

S3. Carbon Equivalent

S3.1 For grades WPB and WPC, the maximum carbon equivalent (C.E.), based on heat analysis and the following formula, shall be 0.50.

$$\text{C.E.} = \text{C} + \frac{\text{Mn}}{6} + \frac{\text{Cr} + \text{Mo} + \text{V}}{5} + \frac{\text{Ni} + \text{Cu}}{15}$$

S3.2 A lower maximum carbon equivalent may be agreed upon between the purchaser and the supplier.

S3.3 The C.E. shall be reported on the test report.

ANNEX

(Mandatory Information)

A1. FITTING DESIGNATION FOR MARKING PURPOSES

TABLE A1.1
FITTING DESIGNATION FOR MARKING PURPOSES

Grade	Class	Construction	Mandatory Marking
WPB	...	W (Welded construction)	WPBW ^A
		S (Seamless construction)	WPB
WPC	...	W (Welded construction)	WPCW ^A
		S (Seamless construction)	WPC
WP1	...	W (Welded construction)	WP1W ^A
		S (Seamless construction)	WP1
WP12	CL1	W (Welded construction)	WP12 CL1W ^A
		S (Seamless construction)	WP12 CL1
	CL2	W (Welded construction)	WP12 CL2W ^A
		S (Seamless construction)	WP12 CL2
WP11	CL1	W (Welded construction)	WP11 CL1W ^A
		S (Seamless construction)	WP11 CL1
	CL2	W (Welded construction)	WP11 CL2W ^A
		S (Seamless construction)	WP11 CL2
	CL3	W (Welded construction)	WP11 CL3W ^A
		S (Seamless construction)	WP11 CL3
WP22	CL1	W (Welded construction)	WP22 CL1W ^A
		S (Seamless construction)	WP22 CL1
	CL3	W (Welded construction)	WP22 CL3W ^A
		S (Seamless construction)	WP22 CL3
WP5	CL1	W (Welded construction)	WP5 CL1W ^A
		S (Seamless construction)	WP5 CL1
	CL3	W (Welded construction)	WP5 CL3W ^A
		S (Seamless construction)	WP5 CL3
WP9	CL1	W (Welded construction)	WP9 CL1W ^A
		S (Seamless construction)	WP9 CL1
	CL3	W (Welded construction)	WP9 CL3W ^A
		S (Seamless construction)	WP9 CL3
WPR	...	W (Welded construction)	WPRW ^A
		S (Seamless construction)	WPR
WP91	...	W (Welded construction)	WP91W ^A
		S (Seamless construction)	WP91

^A Add "U" to marking if welds are ultrasonic inspected in lieu of radiography.

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SPECIFICATION FOR CHROMIUM AND CHROMIUM-NICKEL STAINLESS STEEL PLATE, SHEET, AND STRIP FOR PRESSURE VESSELS AND FOR GENERAL APPLICATIONS



SA-240/SA-240M



(Identical with ASTM Specification A 240/A 240M-04)

1. Scope

1.1 This specification covers chromium, chromium-nickel, and chromium-manganese-nickel stainless steel plate, sheet, and strip for pressure vessels and for general applications.

1.2 The values stated in either inch-pound units or SI units are to be regarded separately as standard. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.3 This specification is expressed in both inch-pound and SI units. However, unless the order specifies the applicable “M” specification designation (SI units), the material shall be furnished in inch-pound units.

2. Referenced Documents

2.1 ASTM Standards:

- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip
- A 923 Test Methods for Detecting Detrimental Intermetallic Phase in Wrought Duplex Austenitic/Ferritic Stainless Steels
- E 112 Test Methods for Determining Average Grain Size
- E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 SAE Standard:

- J 1086 Practice for Numbering Metals and Alloys (UNS)

3. General Requirements

3.1 The following requirements for orders for material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 480/A 480M.

- 3.1.1** Definitions,
- 3.1.2** General requirements for delivery,
- 3.1.3** Ordering information,
- 3.1.4** Process,
- 3.1.5** Special tests,
- 3.1.6** Heat treatment,
- 3.1.7** Dimensions and permissible variations,
- 3.1.8** Workmanship, finish and appearance,
- 3.1.9** Number of tests/test methods,
- 3.1.10** Specimen preparation,
- 3.1.11** Retreatment,
- 3.1.12** Inspection,
- 3.1.13** Rejection and reheating,
- 3.1.14** Material test report,
- 3.1.15** Certification, and
- 3.1.16** Packaging, marking, and loading.

4. Chemical Composition

4.1 The steel shall conform to the requirements as to chemical composition specified in Table 1, and shall conform to applicable requirements specified in Specification A 480/A 480M.

5. Mechanical Properties

5.1 The material shall conform to the mechanical properties specified in Table 2.

5.2 When specified by the purchaser, Charpy impact tests shall be performed in accordance with Supplementary Requirement S1.

6. Materials for High-Temperature Service

6.1 The austenitic *H* Types shall conform to an average grain size of ASTM No. 7 or coarser as measured by Test Methods E 112.

6.2 Supplementary Requirement S2 shall be invoked when non-H grade austenitic stainless steels are ordered for ASME Code applications for service above 1000°F [540°C].

6.3 Grade S31060, unless otherwise specified in the purchase order, shall conform to an average grain size of ASTM No. 7 or coarser, as measured by Test Methods E 112.

TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS, %^A

UNS Designation ^B	Type ^C	Carbon ^D	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Copper	Other Elements ^{E, F}
Austenitic (Chromium-Nickel) (Chromium-Manganese-Nickel)												
N08020	...	0.07	2.00	0.045	0.035	1.00	19.00–21.00	32.0–38.0	2.00–3.00	...	3.0–4.0	Cb 8 × C min, 1.10 max
N08367	...	0.030	2.00	0.040	0.030	1.00	20.0–22.0	23.5–25.5	6.0–7.0	0.18–0.25	0.75	Fe ^H 39.5 min
N08800	800 ^G	0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	...	...	0.75	Al 0.15–0.60
N08810	800 ^H	0.05–0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	...	...	0.75	Ti 0.15–0.60
N08811	...	0.06–0.10	1.50	0.040	0.015	1.00	19.0–23.0	30.0–35.0	...	...	0.75	Fe ^H 39.5 min
N08904	904L ^G	0.020	2.00	0.045	0.035	1.00	19.0–23.0	23.0–28.0	4.0–5.0	0.10	1.0–2.0	Al 0.15–0.60
N08926	...	0.020	2.00	0.030	0.010	0.50	19.0–21.0	24.0–26.0	6.0–7.0	0.15–0.25	0.5–1.5	Ti 0.15–0.60
S31277	...	0.020	3.00	0.030	0.010	0.50	20.5–23.0	26.0–28.0	6.5–8.0	0.30–0.40	0.50–1.50	Fe ^H 39.5 min
S20100	201	0.15	5.5–7.5	0.060	0.030	1.00	16.0–18.0	3.5–5.5	...	0.25	...	Al 0.15–0.60
S20103	...	0.03	5.5–7.5	0.045	0.030	0.75	16.0–18.0	3.5–5.5	...	0.25	...	Fe ^H 39.5 min
S20153	...	0.03	6.4–7.5	0.045	0.015	0.75	16.0–17.5	4.0–5.0	...	0.10–0.25	1.00	Al 0.15–0.60
S20161	...	0.15	4.0–6.0	0.040	0.040	3.0–4.0	15.0–18.0	4.0–6.0	...	0.08–0.20	...	Ti 0.15–0.60
S20200	202	0.15	7.5–10.0	0.060	0.030	1.00	17.0–19.0	4.0–6.0	...	0.25	...	Fe ^H 39.5 min
S20400	...	0.030	7.0–9.0	0.040	0.030	1.00	15.0–17.0	1.50–3.00	...	0.15–0.30	...	Ti 0.15–0.60
S20910	XM-19 ^J	0.06	4.0–6.0	0.040	0.030	0.75	20.5–23.5	11.5–13.5	1.50–3.00	0.20–0.40	...	Al ^I 0.15–0.60
S21400	XM-31 ^J	0.12	14.0–16.0	0.045	0.030	0.30–1.00	17.0–18.5	1.0	...	0.35 min	...	Cb 0.10–0.30
S21600	XM-17 ^J	0.08	7.5–9.0	0.045	0.030	0.75	17.5–22.0	5.0–7.0	2.00–3.00	0.25–0.50	...	V 0.10–0.30
S21603	XM-18 ^J	0.03	7.5–9.0	0.045	0.030	0.75	17.5–22.0	5.0–7.0	2.00–3.00	0.25–0.50	...	...
S21800	...	0.10	7.0–9.0	0.060	0.030	3.5–4.5	16.0–18.0	8.0–9.0	...	0.08–0.18	...	...
S24000	XM-29 ^J	0.08	11.5–14.5	0.060	0.030	0.75	17.0–19.0	2.3–3.7	...	0.20–0.40	...	...
S30100	301	0.15	2.00	0.045	0.030	1.00	16.0–18.0	6.0–8.0	...	0.10	...	...
S30103	301L ^G	0.03	2.00	0.045	0.030	1.00	16.0–18.0	6.0–8.0	...	0.20	...	...
S30153	301LN	0.03	2.00	0.045	0.030	1.00	16.0–18.0	6.0–8.0	...	0.07–0.20	...	...
S30200	302	0.15	2.00	0.045	0.030	0.75	17.0–19.0	8.0–10.0	...	0.10	...	...
S30400	304	0.08	2.00	0.045	0.030	0.75	18.0–20.0	8.0–10.5	...	0.10	...	...
S30403	304L	0.030	2.00	0.045	0.030	0.75	18.0–20.0	8.0–10.5	...	0.10	...	...
S30409	304H	0.04–0.10	2.00	0.045	0.030	0.75	18.0–20.0	8.0–10.5	...	...	...	...
S30415	...	0.04–0.06	0.80	0.045	0.030	1.00–2.00	18.0–20.0	9.0–10.0	...	0.12–0.18	...	Ce 0.03–0.08
S30451	304N	0.08	2.00	0.045	0.030	0.75	18.0–20.0	8.0–10.5	...	0.10–0.16	...	...
S30452	XM-21 ^J	0.08	2.00	0.045	0.030	0.75	18.0–20.0	8.0–10.5	...	0.16–0.30	...	...
S30453	304LN	0.030	2.00	0.045	0.030	0.75	18.0–20.0	8.0–10.5	...	0.10–0.16	...	...
S30500	305	0.12	2.00	0.045	0.030	0.75	17.0–19.0	10.5–13.0	...	...	...	...
S30600	...	0.018	2.00	0.020	0.020	3.7–4.3	17.0–18.5	14.0–15.5	0.20	...	0.50	...
S30601	...	0.015	0.50–0.80	0.030	0.013	5.00–5.60	17.0–18.0	17.0–18.0	0.20	0.050	0.35	...
S30615	...	0.16–0.24	2.00	0.030	0.030	3.2–4.0	17.0–19.5	13.5–16.0	...	...	...	Al 0.8–1.5
S30815	...	0.05–0.10	0.80	0.040	0.030	1.40–2.00	20.0–22.0	10.0–12.0	...	0.14–0.20	...	Ce 0.03–0.08
S30908	309S	0.08	2.00	0.045	0.030	0.75	22.0–24.0	12.0–15.0	...	...	...	...
S30909	309H ^G	0.04–0.10	2.00	0.045	0.030	0.75	22.0–24.0	12.0–15.0	...	...	...	...
S30940	309Cb ^G	0.08	2.00	0.045	0.030	0.75	22.0–24.0	12.0–16.0	...	...	...	Cb 10 × C min, 1.10 max
S30941	309HCb ^G	0.04–0.10	2.00	0.045	0.030	0.75	22.0–24.0	12.0–16.0	...	...	...	Cb 10 × C min, 1.10 max
S31008	310S	0.08	2.00	0.045	0.030	1.50	24.0–26.0	19.0–22.0	...	...	...	...

TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS, %^A (CONT'D)

UNS Designation ^B	Type ^C	Carbon ^D	Manganese	Phos- phorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Copper	Other Elements ^{E, F}
Austenitic (Chromium-Nickel) (Chromium-Manganese-Nickel) (Cont)												
S31009	310H ^G	0.04–0.10	2.00	0.045	0.030	0.75	24.0–26.0	19.0–22.0	...	...	...	...
S31040	310Cb ^G	0.08	2.00	0.045	0.030	1.50	24.0–26.0	19.0–22.0	...	...	...	Cb 10 × C min, 1.10 max
S31041	310HCb ^G	0.04–0.10	2.00	0.045	0.030	0.75	24.0–26.0	19.0–22.0	...	...	...	Cb 10 × C min, 1.10 max
S31050	310MoLN ^G	0.020	2.00	0.030	0.010	0.50	24.0–26.0	20.5–23.5	1.60–2.60	0.09–0.15	...	Ce + La 0.025– 0.070 B 0.001– 0.010
S31060	...	0.05–0.10	1.00	0.040	0.030	0.50	22.0–24.0	10.0–12.5	...	0.18–0.25	...	...
S31254	...	0.020	1.00	0.030	0.010	0.80	19.5–20.5	17.5–18.5	6.0–6.5	0.18–0.22	0.50–1.00	...
S31266	...	0.030	2.00–4.00	0.035	0.020	1.00	23.0–25.0	21.0–24.0	5.2–6.2	0.35–0.60	1.00–2.50	W 1.50–2.50
S31600	316	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10	...	...
S31603	316L	0.030	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10	...	...
S31609	316H	0.04–0.10	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	...	...	Ti 5 × (C + N)
S31635	316Ti ^G	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10	...	min, 0.70 max Cb 10 × C min, 1.10 max
S31640	316Cb ^G	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10	...	...
S31651	316N	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10–0.16	...	...
S31653	316LN	0.030	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10–0.16	...	...
S31700	317	0.08	2.00	0.045	0.030	0.75	18.0–20.0	11.0–15.0	3.0–4.0	0.10	...	...
S31703	317L	0.030	2.00	0.045	0.030	0.75	18.0–20.0	11.0–15.0	3.0–4.0	0.10	...	...
S31725	317LM ^G	0.030	2.00	0.045	0.030	0.75	18.0–20.0	13.5–17.5	4.0–5.0	0.20	...	...
S31726	317LMN ^G	0.030	2.00	0.045	0.030	0.75	17.0–20.0	13.5–17.5	4.0–5.0	0.10–0.20	...	...
S31753	317LN ^G	0.030	2.00	0.045	0.030	0.75	18.0–20.0	11.0–15.0	3.0–4.0	0.10–0.22	...	...
S32050	...	0.030	1.50	0.035	0.020	1.00	22.0–24.00	20.0–23.00	6.0–6.8	0.21–0.32	0.40	...
S32100	321	0.08	2.00	0.045	0.030	0.75	17.0–19.0	9.0–12.0	...	0.10	...	Ti 5 × (C + N) min, 0.70 max Ti 4 × (C + N) min, 0.70 max
S32109	321H	0.04–0.10	2.00	0.045	0.030	0.75	17.0–19.0	9.0–12.0	...	...	...	...
S32615	...	0.07	2.00	0.045	0.030	4.8–6.0	16.5–19.5	19.0–22.0	0.30–1.5	...	1.50–2.50	...
S32654	...	0.020	2.00–4.00	0.030	0.005	0.50	24.0–25.0	21.0–23.0	7.0–8.0	0.45–0.55	0.30–0.60	...
S33228	...	0.04–0.08	1.00	0.020	0.015	0.03	26.0–28.0	31.0–33.0	...	...	...	Ce 0.05–0.10 Cb 0.6–1.0 Al 0.025
S33400	334 ^G	0.08	1.00	0.030	0.015	1.00	18.0–20.0	19.0–21.0	...	...	...	Al 0.15–0.60 Ti 0.15–0.60
S34565	...	0.030	5.0–7.0	0.030	0.010	1.00	23.0–25.0	16.0–18.0	4.0–5.0	0.40–0.60	...	Cb 0.10
S34700	347	0.08	2.00	0.045	0.030	0.75	17.0–19.0	9.0–13.0	...	...	...	Cb 10 × C min, 1.00 max
S34709	347H	0.04–0.10	2.00	0.045	0.030	0.75	17.0–19.0	9.0–13.0	...	...	...	Cb 8 × C min, 1.00 max
S34800	348	0.08	2.00	0.045	0.030	0.75	17.0–19.0	9.0–13.0	...	...	...	Cb + Ta 10 × C min, 1.00 max Ta 0.10 max Co 0.20

TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS, %^A (CONT'D)

UNS Designation ^B	Type ^C	Carbon ^D	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Copper	Other Elements ^{E, F}
Austenitic (Chromium-Nickel) (Chromium-Manganese-Nickel) (Cont'd)												
S34809	348H	0.04–0.10	2.00	0.045	0.030	0.75	17.0–19.0	9.0–13.0	...	...	...	Cb + Ta 8 × C min, 1.00 max Ta 0.10 max Co 0.20
S35045	...	0.06–0.10	1.50	0.045	0.015	1.00	25.0–29.0	32.0–37.0	...	...	0.75	Al 0.15–0.60 Ti 0.15–0.60
S35135	...	0.08	1.00	0.045	0.015	0.60–1.00	20.0–25.0	30.0–38.0	4.0–4.8	...	0.75	Ti 0.40–1.00
S35315	...	0.04–0.08	2.00	0.040	0.030	1.20–2.00	24.0–26.0	34.0–36.0	...	0.12–0.18	...	Ce 0.03–0.08
S38100	XM-15 ^J	0.08	2.00	0.030	0.030	1.50–2.50	17.0–19.0	17.5–18.5	...	...	...	...
S38815	...	0.030	2.00	0.040	0.020	5.5–6.5	13.0–15.0	13.0–17.0	0.75–1.50	...	0.75–1.50	Al 0.30
Duplex (Austenitic-Ferritic)												
S31200	...	0.030	2.00	0.045	0.030	1.00	24.0–26.0	5.5–6.5	1.2–2.0	0.14–0.20	...	...
S31260	...	0.03	1.00	0.030	0.030	0.75	24.0–26.0	5.5–7.5	2.5–3.5	0.10–0.30	0.20–0.80	W 0.10–0.50
S31803	...	0.030	2.00	0.030	0.020	1.00	21.0–23.0	4.5–6.5	2.5–3.5	0.08–0.20	...	...
S32001	...	0.030	4.0–6.0	0.040	0.030	1.00	19.5–21.5	1.00–3.00	0.60	0.05–0.17	1.00	...
S32003	...	0.030	2.00	0.030	0.020	1.00	19.5–22.5	3.0–4.0	1.50–2.00	0.14–0.20	...	...
S32101	...	0.040	4.0–6.0	0.040	0.030	1.00	21.0–22.0	1.35–1.70	0.10–0.80	0.20–0.25	0.10–0.80	...
S32205	2205 ^G	0.030	2.00	0.030	0.020	1.00	22.0–23.0	4.5–6.5	3.0–3.5	0.14–0.20	...	...
S32304	2304 ^G	0.030	2.50	0.040	0.030	1.00	21.5–24.5	3.0–5.5	0.05–0.60	0.05–0.20	0.05–0.60	...
S32520	...	0.030	1.50	0.035	0.020	0.80	24.0–26.0	5.5–8.0	3.0–4.0	0.20–0.35	0.50–2.00	...
S32550	255 ^G	0.04	1.50	0.040	0.030	1.0	24.0–27.0	4.5–6.5	2.9–3.9	0.10–0.25	1.50–2.50	...
S32750	2507 ^G	0.030	1.20	0.035	0.020	0.80	24.0–26.0	6.0–8.0	3.0–5.0	0.24–0.32	0.50	...
S32760 ^K	...	0.030	1.00	0.030	0.010	1.00	24.0–26.0	6.0–8.0	3.0–4.0	0.20–0.30	0.50–1.00	W 0.50–1.00
S32900	329	0.08	1.00	0.040	0.030	0.75	23.0–28.0	2.5–5.0	1.00–2.00	...	...	...
S32906	...	0.030	0.80–1.50	0.030	0.030	0.50	28.0–30.0	5.8–7.5	1.50–2.60	0.30–0.40	0.80	...
S32950	...	0.030	2.00	0.035	0.010	0.60	26.0–29.0	3.5–5.2	1.00–2.50	0.15–0.35	...	...
Ferritic or Martensitic (Chromium)												
S32803	...	0.015	0.50	0.020	0.0035	0.55	28.0–29.0	3.0–4.0	1.80–2.50	0.020 (C + N) 0.030	...	Cb 12 × (C + N) min, 0.15–0.50
S40500	405	0.08	1.00	0.040	0.030	1.00	11.5–14.5	0.60	...	...	...	Al 0.10–0.30
S40900 ^L	409 ^L	...	...	...	...	...	...	...	...	...	...	...
S40910	...	0.030	1.00	0.040	0.020	1.00	10.5–11.7	0.50	...	0.030	...	Ti 6 × (C + N) min, 0.50 max; Cb 0.17
S40920	...	0.030	1.00	0.040	0.020	1.00	10.5–11.7	0.50	...	0.030	...	Ti 8 × (C + N) min, Ti 0.15–0.50; Cb 0.10
S40930	...	0.030	1.00	0.040	0.020	1.00	10.5–11.7	0.50	...	0.030	...	(Ti + Cb) [0.08 + 8 × (C + N)] min, 0.75 max; Ti 0.05 min
S40945	...	0.030	1.00	0.040	0.030	1.00	10.5–11.7	0.50	...	0.030	...	Cb 0.18–0.40
S40975	...	0.030	1.00	0.040	0.030	1.00	10.5–11.7	0.50–1.00	...	0.030	...	Ti 0.05–0.20
S40977	...	0.030	1.50	0.040	0.015	1.00	10.5–12.5	0.30–1.00	...	0.030	...	Ti 6 × (C + N) min, 0.75 max
S41000	410	0.08–0.15	1.00	0.040	0.030	1.00	11.5–13.5	0.75	...	...	...	...

TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS, %^A (CONT'D)

UNS Designation ^B	Type ^C	Carbon ^D	Manganese	Phos- phorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Copper	Other Elements ^{E, F}
Ferritic or Martensitic (Chromium) (Cont')												
S41003	...	0.03	1.50	0.040	0.030	1.00	10.5–12.5	1.50	...	0.030	...	...
S41008	410S	0.08	1.00	0.040	0.030	1.00	11.5–13.5	0.60	...	...	...	... 9 × (C + N)
S41045	...	0.030	1.00	0.040	0.030	1.00	12.0–13.0	0.50	...	0.030	...	min, 0.60 max
S41050	...	0.04	1.00	0.045	0.030	1.00	10.5–12.5	0.60–1.10	...	0.10	...	...
S41500 ^M	...	0.05	0.50–1.00	0.030	0.030	0.60	11.5–14.0	3.5–5.5	0.50–1.00	...	...	...
S42035	...	0.08	1.00	0.045	0.030	1.00	13.5–15.5	1.0–2.5	0.2–1.2	...	...	Ti 0.30–0.50
S42900	429 ^G	0.12	1.00	0.040	0.030	1.00	14.0–16.0	...	...	...	...	...
S43000	430	0.12	1.00	0.040	0.030	1.00	16.0–18.0	0.75	...	...	...	...
S43035	439	0.030	1.00	0.040	0.030	1.00	17.0–19.0	0.50	...	0.030	...	Ti [0.20 + 4 (C + N)] min, 1.10 max; Al 0.15 max
S43400	434	0.12	1.00	0.040	0.030	1.00	16.0–18.0	...	0.75–1.25	...	...	...
S43600	436	0.12	1.00	0.040	0.030	1.00	16.0–18.0	...	0.75–1.25	...	...	Cb 5 × C min, 0.80 max
S43932	...	0.030	1.00	0.040	0.030	1.00	17.0–19.0	0.50	...	0.030	...	(Ti + Cb) [0.20 + 4 (C + N)] min, 0.75 max; Al 0.15
S43940	...	0.030	1.00	0.040	0.015	1.00	17.5–18.5	...	...	...	...	Ti 0.10–0.60 Cb [0.30 + {3 × C}] min
S44400	444	0.025	1.00	0.040	0.030	1.00	17.5–19.5	1.00	1.75–2.50	0.035	...	(Ti + Cb) [0.20 + 4 (C + N)] min, 0.80 max
S44500	...	0.020	1.00	0.040	0.012	1.00	19.0–21.0	0.60	...	0.03	0.30–0.60	Cb 10 × (C + N) – 0.80
S44626	XM-33 ^J	0.06	0.75	0.040	0.020	0.75	25.0–27.0	0.50	0.75–1.50	0.04	0.20	Ti 0.20–1.00; Ti 7 (C + N) min
S44627	XM-27 ^J	0.010 ^H	0.40	0.020	0.020	0.40	25.0–27.5	0.50	0.75–1.50	0.015 ^N	0.20	Cb 0.05–0.20 (Ni + Cu) 0.50 max

TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS, %^A (CONT'D)

UNS Designation ^B	Type ^C	Carbon ^D	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Copper	Other Elements ^{E, F}
Ferritic or Martensitic (Chromium) (Con't)												
S44635	...	0.025	1.00	0.040	0.030	0.75	24.5–26.0	3.5–4.5	3.5–4.5	0.035	...	(Ti + Cb) [0.20 + 4 (C + N)] min, 0.80 max
S44660	...	0.030	1.00	0.040	0.030	1.00	25.0–28.0	1.0–3.50	3.0–4.0	0.040	...	(Ti + Cb) 0.20 – 1.00, Ti + Cb 6 x (C + N) min (C + N) 0.025 (Ti + Cb) 0.20–1.00, (Ti + Cb) 6 x
S44700	...	0.010	0.30	0.025	0.020	0.20	28.0–30.0	0.15	3.5–4.2	0.020	0.15	(C + N) 0.025
S44735	...	0.030	1.00	0.040	0.030	1.00	28.0–30.0	1.00	3.6–4.2	0.045	...	(Ti + Cb) 0.20–1.00, (Ti + Cb) 6 x
S44800	...	0.010	0.30	0.025	0.020	0.20	28.0–30.0	2.00–2.50	3.5–4.2	0.020	0.15	(C + N) min (C + N) 0.025
S46800	...	0.030	1.00	0.040	0.030	1.00	18.0–20.0	0.50	...	0.030	...	Ti 0.07–0.30 Cb 0.10–0.60 (Ti + Cb) [0.20 + 4 (C + N)] min, 0.80 max

^A Maximum, unless range or minimum is indicated.

^B Designation established in accordance with Practice E 527 and SAE J 1086.

^C Unless otherwise indicated, a grade designation originally assigned by the American Iron and Steel Institute (AISI).

^D Carbon analysis shall be reported to nearest 0.01 % except for the low-carbon types, which shall be reported to nearest 0.001 %.

^E The terms Columbium (Cb) and Niobium (Nb) both relate to the same element.

^F When two minimums or two maximums are listed for a single type, as in the case of both a value from a formula and an absolute value, the higher minimum or lower maximum shall apply.

^G Common name, not a trademark, widely used, not associated with any one producer.

^H Iron shall be determined arithmetically by difference of 100 minus the sum of the other specified elements.

^I (Al + Ti) 0.85–1.20.

^J Naming system developed and applied by ASTM.

^K Cr + 3.3 Mo + 16 N = 40 min.

^L S40900 (Type 409) has been replaced by S40910, S40920, and S40930. Unless otherwise specified in the ordering information, an order specifying S40900 or Type 409 shall be satisfied by any one of S40910, S40920, or S40930 at the option of the seller. Material meeting the requirements of S40910, S40920, or S40930, may at the option of the manufacturer be certified as S40900.

^M Plate version of CA-6NM.

^N Product (check or verification analysis) tolerance over the maximum limit for C and N in XM-27 shall be 0.002%.

TABLE 2
MECHANICAL TEST REQUIREMENTS

UNS Designation	Type ^A	Tensile		Yield		Elongation in 2 in. or 50 mm, Min., %	Hardness, Max. ^C		Cold Bend ^D
		Strength, Min.		Strength ^B Min.			Brinell	Rockwell B	
		ksi	MPa	ksi	MPa				
Austenitic (Chromium-Nickel) (Chromium-Manganese-Nickel)									
N08820	...	80	550	35	240	30 ^E	217	95	not required
N08367									
Sheet and Strip		100	690	45	310	30	...	100	not required
Plate		95	655	45	310	30	241	...	not required
N08800	800 ^F	75	520	30 ^G	205 ^G	30 ^H	...	...	not required
N08810	800H ^F	65	450	25 ^G	170 ^H	30	...	...	not required
N08811	...	65	450	25	170	30	...	...	not required
N08904	904L ^F	71	490	31	220	35	...	90	not required
N08926	...	94	650	43	295	35	...	...	not required
S20100	201-1 ^I	75	515	38	260	40	217	95	...
S20100	201-2 ^I	95	655	45	310	40	241	100	...
S20103	201L ^F	95	655	38	260	40	217	95	not required
S20153	201LN ^F	95	655	45	310	45	241	100	not required
S20161	...	125	860	50	345	40	255	25 ^J	not required
S20200	202	90	620	38	260	40	241	...	...
S20400	...	95	655	48	330	35	241	100	not required
S30100	301	75	515	30	205	40	217	95	not required
S30103	301L ^F	80	550	32	220	45	241	100	not required
S30153	301LN ^F	80	550	35	240	45	241	100	not required
S30200	302	75	515	30	205	40	201	92	not required
S30400	304	75	515	30	205	40	201	92	not required
S30403	304L	70	485	25	170	40	201	92	not required
S30409	304H	75	515	30	205	40	201	92	not required
S30415	...	87	600	42	290	40	217	95	not required
S30451	304N	80	550	35	240	30	217	95	not required
S30453	304LN	75	515	30	205	40	217	95	not required
S30500	305	70	485	25	170	40	183	88	not required
S30600	...	78	540	35	240	40	...	...	...
S30601	...	78	540	37	255	30	...	...	not required
S30615	...	90	620	40	275	35	217	95	not required
S30815	...	87	600	45	310	40	217	95	...
S30908	309S	75	515	30	205	40	217	95	not required
S30909	309H ^F	75	515	30	205	40	217	95	not required
S30940	309Cb ^F	75	515	30	205	40	217	95	not required
S30941	309HCb ^F	75	515	30	205	40	217	95	not required
S31008	310S	75	515	30	205	40	217	95	not required
S31009	310H ^F	75	515	30	205	40	217	95	not required
S31040	310Cb ^F	75	515	30	205	40	217	95	not required
S31041	310HCb ^F	75	515	30	205	40	217	95	not required
S31060	...	87	600	41	280	40	217	95	not required
S31254									
Sheet and Strip		100	690	45	310	35	223	96	not required
Plate		95	655	45	310	35	223	96	not required
S31266	...	109	750	61	420	35	...	...	not required
S31277	...	112	770	52	360	40	...	...	not required
S31600	316	75	515	30	205	40	217	95	not required
S31603	316L	70	485	25	170	40	217	95	not required
S31609	316H	75	515	30	205	40	217	95	not required
S31635	316Ti ^F	75	515	30	205	40	217	95	not required
S31640	316Cb ^F	75	515	30	205	30	217	95	not required
S31651	316N	80	550	35	240	35	217	95	not required
S31653	316LN	75	515	30	205	40	217	95	not required
S31700	317	75	515	30	205	35	217	95	not required
S31725	317LM ^F	75	515	30	205	40	217	95	not required
S31726	...	80	550	35	240	40	223	96	not required
S31703	317L	75	515	30	205	40	217	95	not required
S31753	317LN	80	550	35	240	40	217	95	not required
S32050	...	98	675	48	330	40	250	...	not required
S32100	321	75	515	30	205	40	217	95	not required
S32109	321H	75	515	30	205	40	217	95	not required
S32615 ^K	...	80	550	32	220	25	...	...	not required
S32654	...	109	750	62	430	40	250	...	not required

TABLE 2
MECHANICAL TEST REQUIREMENTS (CONT'D)

UNS Designation	Type ^A	Tensile Strength, Min.		Yield Strength ^B Min.		Elongation in 2 in. or 50 mm, Min., %	Hardness, Max. ^C		Cold Bend ^D
		ksi	MPa	ksi	MPa		Brinell	Rockwell B	
Austenitic (Chromium-Nickel) (Chromium-Manganese-Nickel)									
S33228	...	73	500	27	185	30	217	95	not required
S33400	334 ^F	70	485	25	170	30	...	92	not required
S34565	...	115	795	60	415	35	241	100	not required
S34700	347	75	515	30	205	40	201	92	not required
S34709	347H	75	515	30	205	40	201	92	not required
S34800	348	75	515	30	205	40	201	92	not required
S34809	348H	75	515	30	205	40	201	92	not required
S35045	...	70	485	25	170	35	...	...	not required
S35135	...	...	...	...	...	...	...	...	...
Sheet and Strip	...	80	550	30	205	30	...	...	not required
Plate	...	75	515	30	205	30	...	...	not required
S35315	...	94	650	39	270	40	217	95	not required
S38100	XM-15 ^L	75	515	30	205	40	217	95	not required
S38815	...	78	540	37	255	30	...	...	not required
S30452	XM-21 ^L	...	...	...	...	...	...	...	...
Sheet and Strip	...	90	620	50	345	30	241	100	not required
Plate	...	85	585	40	275	30	241	100	not required
S31050	310MoLN ^F	...	...	...	...	...	...	...	...
	<i>t</i> ≤ 0.25 in.	84	580	39	270	25	217	95	not required
	<i>t</i> > 0.25 in.	78	540	37	255	25	217	95	not required
S21600	XM-17 ^J	...	...	...	...	...	...	...	...
Sheet and Strip	...	100	690	60	415	40	241	100	not required
Plate	...	90	620	50	345	40	241	100	not required
S21603	XM-18 ^L	...	...	...	...	...	...	...	...
Sheet and Strip	...	100	690	60	415	40	241	100	not required
Plate	...	90	620	50	345	40	241	100	not required
S20910	XM-19 ^L	...	...	...	...	...	...	...	...
Sheet and Strip	...	105	725	60	415	30	241	100	not required
Plate	...	100	690	55	380	35	241	100	not required
S24000	XM-29 ^L	...	...	...	...	...	...	...	...
Sheet and Strip	...	100	690	60	415	40	241	100	not required
Plate	...	100	690	55	380	40	241	100	not required
S21400	XM-31 ^L	...	...	...	...	...	...	...	...
Sheet	...	125	860	70	485	40	...	...	not required
Strip	...	105	725	55	380	40	...	...	not required
S21800	...	95	655	50	345	35.0	241	100	not required
Duplex (Austenitic-Ferritic)									
S31200	...	100	690	65	450	25	293	31 ^J	not required
S31260	...	100	690	70	485	20	290	...	...
S31803	...	90	620	65	450	25	293	31 ^J	not required
S32001	...	90	620	65	450	25	...	25 ^J	not required
S32003	...	90	620	65	450	25	293	31 ^J	not required
S32101	...	90	620	65	450	25	293	31 ^J	not required
	<i>t</i> ≤ 0.25 in. [6.4 mm]	101	700	77	530	30	290	...	not required
	<i>t</i> > 0.25 in. [6.4 mm]	95	650	65	450	30	290	...	not required
S32205	2205 ^F	95	655	65	450	25	293	31 ^J	not required
S32304	2304 ^F	87	600	58	400	25	290	32 ^J	not required
S32520	...	112	770	80	550	25	310	...	not required
S32550	255 ^F	110	760	80	550	15	302	32 ^J	not required
S32750	2507 ^F	116	795	80	550	15	310	32 ^J	not required
S32760	...	108	750	80	550	25	270	...	not required
S32900	329	90	620	70	485	15	269	28 ^J	not required
S32906	...	...	...	...	...	...	...	...	...
	<i>t</i> < 0.4 in. [1.0 mm]	116	800	94	650	25	310	32 ^J	not required
	<i>t</i> ≥ 0.4 in. [1.0 mm]	109	750	80	550	25	310	32 ^J	not required
S32950 ^M	...	100	690	70	485	15	293	32 ^J	not required

TABLE 2
MECHANICAL TEST REQUIREMENTS (CONT'D)

UNS Designation	Type ^A	Tensile Strength, Min.		Yield Strength ^B Min.		Elongation in 2 in. or 50 mm, Min., %	Hardness, Max. ^C		Cold Bend ^D
		ksi	MPa	ksi	MPa		Brinell	Rockwell B	
Ferritic or Martensitic (Chromium)									
S32803	...	87	600	72	500	16	241	100	not required
S40500	405	60	415	25	170	20	179	88	180
S40900 ^N	409 ^N								
S40910	...	55	380	25	170	20	179	88	180
S40920	...	55	380	25	170	20	179	88	180
S40930	...	55	380	25	170	20	179	88	180
S40945	...	55	380	30	205	22	...	80	180
S40975	...	60	415	40	275	20	197	92	180
S40977	...	65	450	41	280	18	180	88	not required
S41000	410	65	450	30	205	20	217	96	180
S41003	...	66	455	40	275	18	223	20 ^J	not required
S41008	410S	60	415	30	205	22 ^O	183	89	180
S41045	...	55	380	30	205	22	...	80	180
S41050	...	60	415	30	205	22	183	89	180
S41500	...	115	795	90	620	15	302	32 ^J	not required
S42035	...	80	550	55	380	16	180	88	not required
S42900	429 ^F	65	450	30	205	22 ^M	183	89	180
S43000	430	65	450	30	205	22 ^M	183	89	180
S43035	439	60	415	30	205	22	183	89	180
S43400	434	65	450	35	240	22	...	89	180
S43600	436	65	450	35	240	22	...	89	180
S43932	...	60	415	30	205	22	183	89	180
S43940	...	62	430	36	250	18	180	88	not required
S44400	...	60	415	40	275	20	217	96	180
S44500	...	62	427	30	205	22	...	83	180
S44626	XM-33 ^L	68	470	45	310	20	217	96	180
S44627	XM-27 ^L	65	450	40	275	22	187	90	180
S44635	...	90	620	75	515	20	269	28 ^J	180
S44660	...	85	585	65	450	18	241	100	180
S44700	...	80	550	60	415	20	223	20 ^J	180
S44735	...	80	550	60	415	18	255	25 ^J	180
S44800	...	80	550	60	415	20	223	20 ^J	180
S46800	...	60	415	30	205	22	...	90	180

^A Unless otherwise indicated, a grade designation originally assigned by the American Iron and Steel Institute (AISI).

^B Yield strength shall be determined by the offset method at 0.2% in accordance with Test Methods and Definitions A 370. Unless otherwise specified (see Specification A 480/A 480M, paragraph 4.1.11, Ordering Information), an alternative method of determining yield strength may be based on total extension under load of 0.5%.

^C Either Brinell or Rockwell B Hardness is permissible.

^D Bend test are not required for chromium steels (ferritic or martensitic) thicker than 1 in. [25 mm] or for any austenitic or duplex (austenitic-ferritic) stainless steels regardless of thickness.

^E Elongation for thickness, less than 0.015 in. (0.38 mm) shall be 20% minimum, in 1 in. (25.4 mm).

^F Common name, not a trademark, widely used, not associated with any one producer.

^G Yield strength requirements shall not apply to material under 0.020 in. (0.50 mm) in thickness.

^H Not applicable for thickness under 0.010 in. (0.25 mm).

^I Type 201 is generally produced with a chemical composition balanced for rich side (Type 201-1) or lean side (Type 201-2) austenite stability depending on the properties required for specific applications.

^J Rockwell C scale.

^K For S32615, the grain size as determined in accordance with the Test Methods E 112, Comparison Method, Plate II, shall be No. 3 or finer.

^L Naming system developed and applied by ASTM.

^M Prior to Specification A 240-89b, the tensile value for S32950 was 90 ksi.

^N S40900 (Type 409) has been replaced by S40910, S40920, and S40930. Unless otherwise specified in the ordering information, an order specifying S40900 or Type 409 shall be satisfied by any one of S40910, S40920, or S40930 at the option of the seller. Material meeting the requirements of S40910, S40920, or S40930, may at the option of the manufacturer be certified as S40900.

^O Material 0.050 in (1.27 mm) and under in thickness shall have a minimum elongation of 20%.

SUPPLEMENTARY REQUIREMENTS

A supplementary requirement shall apply only when specified in the purchase order.

S1. Charpy Impact Testing of Plate

S1.1 Charpy impact tests shall be conducted in accordance with Test Methods and Definitions A 370.

S1.2 *Number of Tests* — One impact test (3 specimens) shall be made from one plate per heat treatment lot in the final heat treated condition.

S1.3 *Orientation of Test Specimens* — Unless specified as transverse specimens (long axis of the specimen transverse to the final rolling direction, root of the notch perpendicular to the rolling face) on the purchase order, the orientation of the specimens shall be longitudinal (long axis of the specimen parallel to the final rolling direction, root of the notch perpendicular to the rolling face). The manufacturer is permitted to test transverse specimens provided that such tests meet the acceptance criteria applicable to longitudinal specimens. Unless otherwise specified on the purchase order, the specimens shall be taken so as to include the mid-thickness of the product.

S1.4 *Test Temperature* — The purchaser shall specify the test temperature. The manufacturer is permitted to test specimens at a temperature lower than that specified by the purchaser, provided that such tests shall meet the acceptance criteria applicable to specimens tested at the specified temperature (see Note).

NOTE — Test Methods A 923, Method B, applicable to some duplex (austenitic-ferritic) stainless steels as listed in Test Methods A 923, uses a Charpy impact test for the purpose of determining the absence of detrimental intermetallic phases. Method B specifies a test temperature and acceptance criterion, expressed as impact energy, for each type of steel covered. It may be economical for the Charpy impact tests performed

on duplex stainless steels covered in both Specification A 240 and Test Methods A 923 to be performed at the lower of the temperatures specified by this supplementary requirement and Test Methods A 923 Method B, with measurement of both lateral expansion and impact energy.

S1.5 *Acceptance Limit* — Unless otherwise specified on the purchase order, each of the three specimens tested shall show a lateral expansion opposite the notch of not less than 0.015 in. [0.38 mm].

S1.6 *Records* — The recorded results shall include the specimen orientation, specimen size, test temperature, absorbed energy values (if required), and lateral expansion opposite the notch.

S2. Materials for High-Temperature Service

S2.1 Unless an H grade has been ordered, this supplementary requirement shall be specified for ASME Code applications for service above 1000°F [540°C].

S2.2 The user is permitted to use an austenitic stainless steel as the corresponding H grade when the material meets all requirements of the H grade including chemistry, annealing temperature, and grain size (see Section 6).

S2.3 The user is permitted to use an L grade austenitic stainless steel for service above 1000°F [540°C], subject to the applicable allowable stress table of the ASME Code, when the material meets all requirements of this specification and the grain size is ASTM No. 7 or coarser as determined in accordance with Test Method E 112. The grain size shall be reported on a Certified Test Report.

SUMMARY OF CHANGES

The Committee has highlighted those changes that impact the use of this specification. This section may also include descriptions of changes or reasons for changes, or both.

(1) In Table 2, HBN and HRB for S20100, S30451, and S30453, were reconciled with those in Specification A 666, annealed condition.

(2) Added new alloy UNS S31277 to Tables 1 and 2.

(3) Added UNS S32906 to Tables 1 and 2.

(4) Added UNS S32101 to Tables 1 and 2.

(5) Added a new duplex stainless steel (S32003) to Tables 1 and 2.

SPECIFICATION FOR WELDED AUSTENITIC STEEL BOILER, SUPERHEATER, HEAT-EXCHANGER, AND CONDENSER TUBES



SA-249/SA-249M

(Identical with ASTM Specification A 249/A 249M-04a except that Supplementary Requirement S5 has been deleted and S9 is mandatory when 100% joint efficiency is required.)

1. Scope

1.1 This specification covers nominal-wall-thickness welded tubes and heavily cold worked welded tubes made from the austenitic steels listed in Table 1, with various grades intended for such use as boiler, superheater, heat exchanger, or condenser tubes.

1.2 Grades TP304H, TP309H, TP309HCb, TP310H, TP310HCb, TP316H, TP321H, TP347H, and TP348H are modifications of Grades TP304, TP309S, TP309Cb, TP310S, TP310Cb, TP316, TP321, TP347, and TP348, and are intended for high-temperature service such as for superheaters and reheaters.

1.3 The tubing sizes and thicknesses usually furnished to this specification are $\frac{1}{8}$ in. [3.2 mm] in inside diameter to 12 in. [304.8 mm] in outside diameter and 0.015 to 0.320 in. [0.4 to 8.1 mm], inclusive, in wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.4 Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.5 Optional supplementary requirements are provided and, when one or more of these are desired, each shall be so stated in the order.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply

unless the “M” designation of this specification is specified in the order.

1.7 The following safety hazards caveat pertains only to the test method described in the Supplementary Requirements of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* A specific warning statement is given in Supplementary Requirement S7, Note S7.1.

2. Referenced Documents

2.1 ASTM Standards:

- A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
- A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip
- A 1016/A 1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes
- E 112 Test Methods for Determining Average Grain Size
- E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing
- E 273 Practice for Ultrasonic Examination of the Weld Zone of Welded Pipe and Tubing
- E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 ASME Boiler and Pressure Vessel Code: Section VIII

2.3 Other Standard:

- SAE J1086 Practice for Numbering Metals and Alloys (UNS)

3. Ordering Information

3.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to, the following:

3.1.1 Quantity (feet, metres, or number of lengths),

3.1.2 Name of material welded tubes (WLD) or heavily cold worked tubes (HCW),

3.1.3 Grade (Table 1),

3.1.4 Size (outside diameter and nominal wall thickness),

3.1.5 Length (specific or random),

3.1.6 Optional requirements (13.6),

3.1.7 Test report required (see Certification Section of Specification A 1016/A 1016M),

3.1.8 Specification designation, and

3.1.9 Special requirements and any supplementary requirements selected.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 1016/A 1016M, unless otherwise provided herein.

5. Manufacture

5.1 The welded (WLD) tubes shall be made from flat-rolled steel by an automatic welding process with no addition of filler metal.

5.1.1 Subsequent to welding and prior to final heat treatment, the tubes shall be cold worked either in both weld and base metal or in weld metal only. The method of cold working may be specified by the purchaser. When cold drawn, the purchaser may specify the minimum amount of reduction in cross-sectional area or wall thickness, or both.

5.1.2 Heavily cold worked (HCW) tubes shall be made by applying cold working of not less than 35% reduction in both wall and weld to a welded tube prior to the final anneal. No filler metal shall be used in the making of the weld. Prior to cold working, the weld shall be 100% radiographically inspected in accordance with the requirements of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, latest revision, Paragraph UW-51.

6. Heat Treatment

6.1 All material shall be furnished in the heat-treated condition in accordance with the requirements of Table 2.

6.2 A solution annealing temperature above 1950°F [1065°C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in TP309HCb, TP310HCb, TP321, TP321H, TP347, TP347H, TP348, and TP348H. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the initial high temperature solution anneal (see Supplementary Requirement S4).

7. Chemical Composition

7.1 The heat analysis shall conform to the requirements as to chemical composition given in Table 1.

8. Product Analysis

8.1 An analysis of either one length of flat-rolled stock or one tube shall be made for each heat. The chemical composition thus determined shall conform to the requirements given in Section 7.

8.2 A product analysis tolerance of Table A1.1 in Specification A 480/A 480M shall apply. The product analysis tolerance is not applicable to the carbon content for material with a specified maximum carbon of 0.04% or less.

8.3 If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock or tubes shall be made. Both retests for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (Note 1) shall be rejected or, at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes that do not meet the requirements of the specification shall be rejected.

NOTE 1 — For flattening and flange requirements, the term lot applies to all tubes prior to cutting of the same nominal size and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as prescribed in Table 3.

NOTE 2 — For tension and hardness test requirements, the term lot applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, annealed in the same furnace at the same temperature, time at heat, and furnace speed.

9. Tensile Requirements

9.1 The material shall conform to the tensile properties prescribed in Table 4.

10. Hardness Requirements

10.1 The tubes shall have a Rockwell hardness number not exceeding the values specified in Table 4.

11. Reverse-Bend Test Requirement

11.1 A section 4 in. [100 mm] minimum in length shall be split longitudinally 90° on each side of the weld. The sample shall then be opened and bent around a mandrel with a maximum thickness of four times the wall thickness, with the mandrel parallel to the weld and against the original outside surface of the tube. The weld shall be at the point of maximum bend. There shall be no evidence of cracks, or of overlaps resulting from the reduction in thickness of the weld areas by cold working. When the geometry or size of the tubing make it difficult to test the sample as a single piece, the sample may be sectioned into smaller pieces provided a minimum of 4 in. of weld is subjected to reverse bending.

NOTE 3 — The reverse bend test is not applicable when the specified wall is 10 % or more of the specified outside diameter, or the wall thickness is 0.134 in. [3.4 mm] or greater, or the outside diameter size is less than 0.375 in. [9.5 mm]. Under these conditions the reverse flattening test of Specification A 1016/A 1016M shall apply.

12. Grain Size Requirement

12.1 The grain size of Grades TP309H, TP309HCb, TP310H and TP310HCb, as determined in accordance with Test Methods E 112, shall be No. 6 or coarser.

12.2 The grain size of Grades TP304H, TP316H, TP321H, TP347H and TP348H, as determined in accordance with Test Methods E112, shall be No. 7 or coarser.

13. Mechanical Tests and Grain Size Determinations Required

13.1 Tension Test — One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (Note 2).

13.2 Flattening Test — One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flange test, from each lot (Note 1).

13.3 Flange Test — One flange test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (Note 1).

13.4 Reverse-Bend Test — One reverse-bend test shall be made on a specimen from each 1500 ft [450 m] of finished tubing.

13.5 Hardness Test — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (Note 2).

13.6 Hydrostatic or Nondestructive Electric Test — Each tube shall be subjected to either the hydrostatic or the nondestructive electric test. The purchaser may specify which test is to be used.

13.7 Grain Size — Grain size determinations on grades TP309H, TP309HCb, TP310H and TP310HCb shall be made on the same number of tubes as prescribed for the flattening test.

13.8 Heavily cold worked tubes (HCW) shall be capable of passing the weld decay test listed in Supplementary S7 with a weld metal to base metal loss ratio of 0.90 to 1.10. The test is not required unless S7 is specified in the purchase order.

14. Permissible Variations in Dimensions

14.1 Dimensional tolerances other than wall thickness tolerances shall be in accordance with Specification A 1016/A 1016M. Wall thickness tolerances shall be $\pm 10\%$ of nominal wall for all tubing sizes.

14.2 The wall thickness of the weld shall not exceed the wall thickness measured 90° from the weld by more than 6% of the specified wall thickness or 0.004 in. [0.1 mm], whichever is greater.

14.2.1 Requirements of 14.2 are not applicable when any of the following apply:

14.2.1.1 When the specified wall thickness exceeds 12% of the specified outside diameter;

14.2.1.2 When the specified wall thickness exceeds 0.165 in. [4.2 mm];

14.2.1.3 When the specified OD exceeds 3 in. [76.2 mm]; or

14.2.1.4 When the specified minimum yield strength given in Table 4 for the specified grade is 35 ksi [240 MPa] or greater.

15. Workmanship, Finish, and Appearance

15.1 Finished tubes shall have smooth ends free of burrs and shall not deviate from straightness by more than 0.030 in. [0.8 mm] in 3 ft [900 mm] of length.

16. Surface Condition

16.1 The tubes, after final heat treatment, shall be chemically descaled or pickled free of scale. When bright annealing is used, pickling or chemical descaling is not necessary.

17. Forming Operations

17.1 Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws.

All tubes, when properly manipulated, shall be able to stand expanding and beading without showing cracks and flaws, and also shall stand all forging, welding, and bending operations necessary for application without developing defects.

18. Product Marking

18.1 In addition to the marking prescribed in Specification A 1016/A 1016M, the marking for Grades TP304H, TP309H, TP309HCb, TP310H, TP310HCb, TP316H,

TP321H, TP347H, and TP348H shall also include the heat number and the heat-treatment lot identification.

19. Keywords

19.1 austenitic stainless steel; boiler tubes; condenser tube; heat exchanger tube; high temperature applications; steel tube; superheater tubes; temperature service applications, high; welded steel tube and heavily cold worked (HCW) tubes

TABLE 1
CHEMICAL REQUIREMENTS, %^A

Grade	UNS Designation ^B	Composition, %									
		Carbon	Manganese	Phosphorous	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen ^C	Other
TP201	S20100	0.15	5.50–7.5	0.060	0.030	1.00	16.0–18.0	3.5–5.5	...	0.25	...
TP202	S20200	0.15	7.5–10.0	0.060	0.030	1.00	17.0–19.0	4.0–6.0	...	0.25	...
TPXM-19	S20910	0.06	4.0–6.0	0.045	0.030	1.00	20.5–23.5	11.5–13.5	1.50–3.00	0.20–0.40	Cb 0.10–0.30 V 0.10–0.30
TPXM-29	S24000	0.08	11.5–14.5	0.060	0.030	1.00	17.0–19.0	2.3–3.7	...	0.20–0.40	...
TP304	S30400	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...
TP304L ^D	S30403	0.030	2.00	0.045	0.030	1.00	18.0–20.0	8.0–12.0	...	...	...
TP304H	S30409	0.04–0.10	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...
...	S30415	0.04–0.06	0.80	0.045	0.030	1.00–2.00	18.0–19.0	9.0–10.0	...	0.12–0.18	Ce 0.03–0.08
TP304N	S30451	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	0.10–0.16	...
TP304LN ^D	S30453	0.030	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	0.10–0.16	...
TP305	S30500	0.12	2.00	0.045	0.030	1.00	17.0–19.0	11.0–13.0	...	...	...
...	S30615	0.16–0.24	2.00	0.030	0.030	3.2–4.0	17.0–19.5	13.5–16.0	...	...	...
...	S30815	0.05–0.10	0.80	0.040	0.030	1.40–2.00	20.0–22.0	10.0–12.0	...	0.14–0.20	Ce 0.03–0.08
TP309S	S30908	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	...	...	...
TP309H	S30909	0.04–0.10	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	...	...	...
TP309Cb	S30940	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–16.0	...	...	Cb 10xC-1.10
TP309HCb	S30941	0.04–0.10	2.00	0.045	0.030	1.00	22.0–24.0	12.0–16.0	...	...	Cb 10xC-1.10
TP310S	S31008	0.08	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	...	...	...
TP310H	S31009	0.04–0.10	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	...	...	...
TP310Cb	S31040	0.08	2.00	0.045	0.030	1.00	14.0–26.0	18.0–22.0	...	...	Cb 10xC-1.10
TP310HCb	S31041	0.04–0.10	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	...	...	Cb 10xC-1.10
...	S31050	0.030	2.00	0.030	0.015	0.40	24.0–26.0	21.0–23.0	2.00–3.00	0.10–0.16	...
...	S31254	0.020	1.00	0.030	0.010	0.80	19.5–20.5	17.5–18.5	6.0–6.5	0.18–0.25	0.50–1.00
...	S31277	0.020	3.00	0.030	0.010	0.50	20.5–23.0	26.0–28.0	6.5–8.0	0.30–0.40	0.50–1.50
TP316	S31600	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...
TP316L ^D	S31603	0.030	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...

TABLE 1
CHEMICAL REQUIREMENTS, %^A (CONT'D)

Grade	UNS Designation ^B	Composition, %										
		Carbon	Manganese	Phosphorous	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen ^C	Copper	Other Elements
TP316H	S31609	0.04–0.10	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...
TP316N	S31651	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	0.10–0.16	...	...
TP316LN ^D	S31653	0.030	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	0.10–0.16	...	...
TP317	S31700	0.08	2.00	0.045	0.030	1.00	18.0–20.0	11.0–15.0	3.0–4.0	...	...	...
TP317L	S31703	0.030	2.00	0.045	0.030	1.00	18.0–20.0	11.0–15.0	3.0–4.0	...	...	...
...	S31725	0.030	2.00	0.045	0.030	1.00	18.0–20.0	13.5–17.5	4.0–5.0	0.20	...	...
...	S31726	0.030	2.00	0.045	0.030	1.00	17.0–20.0	14.5–17.5	4.0–5.0	0.10–0.20	...	...
...	S32050	0.030	1.50	0.035	0.020	1.00	22.0–24.0	20.0–23.0	6.0–6.8	0.21–0.32	0.40	...
TP321	S32100	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	0.10	...	Ti 5(C+N)–0.70
TP321H	S32109	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	0.10	...	Ti 5(C+N)–0.70
...	S32654	0.020	2.0–4.0	0.030	0.005	0.50	24.0–25.0	21.0–23.0	7.0–8.0	0.45–0.55	0.30–0.60	...
...	S33228	0.04–0.08	1.00	0.020	0.015	0.30	26.0–28.0	31.0–33.0	...	...	...	Cb 0.60–1.00 Ce 0.05–0.10 Al 0.025
...	S34565	0.030	5.0–7.0	0.030	0.010	1.00	23.0–25.0	16.0–18.0	4.0–5.0	0.40–0.60	...	Cb 0.10
TP347	S34700	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	...	...	Cb 10xC-1.10
TP347H	S34709	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	...	...	Cb 8xC-1.10
TP348	S34800	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	...	...	(Cb+Ta) 10xC-1.10 Ta 0.10 Co 0.20
TP348H	S34809	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	...	...	(Cb+Ta) 8xC-1.10 Ta 0.10 Co 0.20
...	S35045	0.06–0.10	1.50	0.045	0.015	1.00	25.0–29.0	32.0–37.0	...	...	0.75	Al 0.15–0.60 Ti 0.15–0.60
TPXM-15	S38100	0.08	2.00	0.030	0.030	1.50–2.50	17.0–19.0	17.5–18.5	...	...	...	...
...	S38815	0.030	2.00	0.040	0.020	5.5–6.5	13.0–15.0	15.0–17.0	0.75–1.50	...	0.75–1.50	Al 0.30 max.
...	N08367	0.030	2.00	0.040	0.030	1.00	20.0–22.0	23.5–25.5	6.0–7.0	0.18–0.25	0.75	...
...	N08926	0.020	2.00	0.030	0.010	0.50	19.0–21.0	24.0–26.0	6.0–7.0	0.15–0.25	0.50–1.50	...
...	N08904	0.020	2.00	0.040	0.030	1.00	19.0–23.0	23.0–28.0	4.0–5.0	0.10	1.00–2.00	...

^A Maximum, unless otherwise indicated.

^B New designation established in accordance with Practice E 527 and SAE J1086.

^C The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

^D For small diameter or thin walls, or both, where many drawing passes are required, a carbon maximum of 0.040% is necessary in Grades TP304L and TP316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall are those less than 0.049 in. [1.2 mm] in minimum wall thickness.

TABLE 2
HEAT TREATMENT REQUIREMENTS

Grade	UNS Number	Solutioning Temperature, Min or Range	Quenching Method
All grades not individually listed below	...	1900°F [1040°C]	^A
...	S30815	1920°F [1050°C]	^B
TP309HCB	S30941	1900°F [1040°C] ^C	^B
TP310H	S31009	1900°F [1040°C]	^B
TP310HCB	S31041	1900°F [1040°C] ^C	^B
...	S31254	2100°F [1150°C]	^B
...	S31277	2050°F [1120°C]	^B
TP316H	S31609	1900°F [1040°C]	^B
TP321	S32100	1900°F [1040°C] ^C	^B
TP321H	S32109	2000°F [1100°C] ^C	^B
...	S32654	2100°F [1150°C]	^B
...	S33228	2050°F [1120°C]	^B
...	S34565	2050°F [1120°C]	^B
		2140°F [1170°C]	^B
TP347	S34700	1900°F [1040°C] ^C	^B
TP347H	S34709	2000°F [1100°C] ^C	^B
TP348	S34800	1900°F [1040°C] ^C	^B
TP348H	S34809	2000°F [1100°C] ^C	^B
...	S35045	2000°F [1100°C]	^D
...	S38815	1950°F [1065°C]	^B
...	N08367	2025°F [1110°C]	^B
...	N08904	2000°F [1100°C]	^B
...	N08926	2010°F [1105°C]	^B

^A Quenched in water or rapidly cooled by other methods, at a rate sufficient to prevent reprecipitation of carbides, as demonstrated by the capability of passing Practices A 262, Practice E. The manufacturer is not required to run the test unless it is specified on the purchase order (See Supplementary Requirement S6). Note that Practices A 262 requires the test to be performed on sensitized specimens in the low carbon and stabilized types and on specimens representative of the as-shipped condition of the other types. In the case of low carbon types containing 3% or more molybdenum, the applicability of the sensitizing treatment prior to testing shall be a matter for negotiation between the seller and purchaser.

^B Quenched in water or rapidly cooled by other methods.

^C A solution treating temperature above 1950°F [1065°C] may impair resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in the indicated grades. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the higher-temperature solution anneal prescribed in this table (See Supplementary Requirement S4).

^D Cooled in still air, or faster.

TABLE 3
NUMBER OF TUBES IN A LOT HEAT TREATED BY
THE CONTINUOUS PROCESS

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in. [5.1 mm] and over in wall thickness	Not more than 50 tubes
Less than 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter or over 1 in. [25.4 mm] in outside diameter and under 0.200 in. [5.1 mm] in wall thickness	Not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	Not more than 125 tubes

TABLE 4
TENSILE AND HARDNESS REQUIREMENTS⁴

Grade	UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, %	Rockwell Hardness Number, max
TP201	S20100	95 [655]	38 [260]	35	B95
TP202	S20200	90 [620]	38 [260]	35	B95
TPXM-19	S20910	100 [690]	55 [380]	35	C25
TPXM-29	S24000	100 [690]	55 [380]	35	B100
...	S24565	115 [795]	60 [415]	35	B100
TP304	S30400	75 [515]	30 [205]	35	B90
TP304L	S30403	70 [485]	25 [170]	35	B90
TP304H	S30409	75 [515]	30 [205]	35	B90
...	S30415	87 [600]	42 [290]	35	B96
TP304N	S30451	80 [550]	35 [240]	35	B90
TP304LN	S30453	75 [515]	30 [205]	35	B90
TP305	S30500	75 [515]	30 [205]	35	B90
...	S30615	90 [620]	40 [275]	35	B95
...	S30815	87 [600]	45 [310]	35	B95
TP309S	S30908	75 [515]	30 [205]	35	B90
TP309H	S30909	75 [515]	30 [205]	35	B90
TP309Cb	S30940	75 [515]	30 [205]	35	B90
TP309HCb	S30941	75 [515]	30 [205]	35	B90
TP310S	S31008	75 [515]	30 [205]	35	B90
TP310H	S31009	75 [515]	30 [205]	35	B90
TP310Cb	S31040	75 [515]	30 [205]	35	B90
TP310HCb	S31041	75 [515]	30 [205]	35	B90
...	S31050:				
	t ≤ 0.25 in.	84 [580]	39 [270]	25	B95
	t > 0.25 in.	78 [540]	37 [255]	25	B95
...	S31254:				
	t ≤ 0.187 in. [5.00 mm]	98 [675]	45 [310]	35	B100
	t > 0.187 in. [5.00 mm]	95 [655]	45 [310]	35	B100
...	S31277	112 [770]	52 [360]	40	B100
TP316	S31600	75 [515]	30 [205]	35	B90
TP316L	S31603	70 [485]	25 [170]	35	B90
TP316H	S31609	75 [515]	30 [205]	35	B90
TP316N	S31651	80 [550]	35 [240]	35	B90
TP316LN	S31653	75 [515]	30 [205]	35	B90
TP317	S31700	75 [515]	30 [205]	35	B90
TP317L	S31703	75 [515]	30 [205]	35	B90
...	S31725	75 [515]	30 [205]	35	B90
...	S31726	80 [550]	35 [240]	35	B90
...	S32050	98 [675]	48 [330]	40	
TP321	S32100	75 [515]	30 [205]	35	B90
TP321H	S32109	75 [515]	30 [205]	35	B90
...	S32654	109 [750]	62 [430]	35	B100
...	S33228	73 [500]	27 [185]	30	B90
TP347	S34700	75 [515]	30 [205]	35	B90
TP347H	S34709	75 [515]	30 [205]	35	B90
TP348	S34800	75 [515]	30 [205]	35	B90
TP348H	S34809	75 [515]	30 [205]	35	B90
...	S35045	70 [485]	25 [170]	35	B90
TPXM-15	S38100	75 [515]	30 [205]	35	B90
...	S38815	78 [540]	37 [255]	30	B100
...	N08367				
	t ≤ 0.187	100 [690]	45 [310]	30	100
	t > 0.187	95 [655]	45 [310]	30	100
...	N08904	71 [490]	31 [215]	35	B90
...	N08926	94 [650]	43 [295]	35	B100

⁴ Not applicable to tubes less than $\frac{1}{8}$ in. [3.2 mm] in outside diameter or having wall thickness below 0.015 in. [0.4 mm], or both. The tensile properties of such small diameter or thin wall tubes shall be a matter of agreement between the manufacturer and the purchaser.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order.

S1. Stress-Relieved Annealed Tubes

S1.1 For use in certain corrosives, particularly chlorides where stress corrosion may occur, tubes in Grades TP304L, TP316L, TP321, TP347, and TP348 may be specified in the stress-relieved annealed condition. Details of these supplemental requirements shall be agreed upon by the manufacturer and the purchaser.

S1.2 When stress-relieved tubes are specified, tubes shall be given a heat treatment at 1550 to 1650°F [845 to 900°C] after roll straightening. Cooling from this temperature range may be either in air or by slow cooling. No mechanical straightening is permitted after the stress-relief treatment.

S1.3 Straightness of the tubes shall be a matter of negotiation between the purchaser and manufacturer.

S2. Minimum Wall Tubes

S2.1 When specified by the purchaser, tubes shall be furnished on a minimum wall basis. Such tubes shall satisfy the minimum wall thickness requirements of Specification A 1016/A 1016M rather than the nominal wall requirements of this specification. In addition to the marking required by Section 18, the tubing shall be marked S2.

S3. Air Underwater Pressure Test

S3.1 When specified, the tubing shall be examined by the air underwater pressure test.

S4. Stabilizing Heat Treatment

S4.1 Subsequent to the solution anneal required in Section 6, Grades TP309HCb, TP310HCb, TP321, TP321H, TP347, TP347H, TP348, and TP348H shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S5. DELETED

S6. Intergranular Corrosion Test

S6.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE S6.1 — Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S6.2 A stabilization heat treatment in accordance with Supplementary Requirement S4 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium, particularly in their H versions.

S7. Weld Decay Test

S7.1 This test is not applicable to alloys with a nickel content $\geq 19.0\%$ or a molybdenum content $\geq 4.00\%$, or both.

S7.2 When specified by the purchase order, one sample from each lot of tubing (Note 2) shall be subjected to testing in a boiling mixture of 50% reagent grade hydrochloric acid and 50% water.

S7.3 Approximately 2 in. long samples shall be prepared from a production length of tubing. Shorter, 1 in. samples may be used for small diameter ($\frac{1}{2}$ in. and below) tubing. Split the sample longitudinally to allow for easy micrometer measurements. The sample may be one piece which contains the weld and at least 90° of base-metal to one side of the weld. Alternately, the sample may be two separate pieces with one containing the weld and a similar size section from the balance of the tube opposite the weld consisting of 100% base metal. Remove all burrs and sharp edges by lightly grinding. Remove dust and grease by cleaning with soap and water or other suitable solvents. Then, place sample(s) in the flask. It is not recommended to test more than four samples together, or to mix alloy types.

S7.4 Prepare the hydrochloric acid solution by slowly adding reagent grade (approximately 37%) hydrochloric acid to an equal volume of distilled water. (**Warning**—Protect eyes and use rubber gloves when handling acid. Mixing shall be done under a hood and testing shall be run under a hood.)

S7.5 The test container shall be a 1-L Erlenmeyer flask equipped with ground-glass joints and an Ahlin condenser. The volume of the solution shall be approximately 700 mL.

S7.6 Measure the thickness of the tube at five locations along the weld area and at five locations along the base-metal section. In both cases, take measurements at approximately equal longitudinal intervals along the section

lengths. Make these measurements with a sharp pointed micrometer accurate to at least 0.001 in. The micrometer must be suitable for measuring the small features in the surface after testing. Typical pin micrometers have tapered anvils with a tip radius of less than 0.015 in.

S7.7 Immerse the samples into the solution. Add boiling chips and bring to a boil. Allow the chips to remain boiling throughout the test. The time of testing shall be that which is required to remove 40 to 60% of the original base-metal thickness (usually 2 h or less). If more than 60% of the base-metal thickness remains, the sample may be removed after 24 h.

S7.8 At the end of the test period, remove the samples from the solution, rinse with distilled water, and dry.

S7.9 After exposure to the test solution, repeat the tube-thickness measurement as in S7.6. If the thinning is not uniform across the width of the weld, then two sets of weld-metal measurement are required. One set of measurements is to be taken along the centerline of the weld. The second set of measurements is to be taken in the thinnest area of the weld.

S7.10 Calculate the corrosion ratio, R , for both sections of the weld as follows in eq (1):

$$R = \frac{W_o - W}{B_o - B} \quad (1)$$

where:

- W_o = average weld-metal thickness before the test,
- W = average weld-metal thickness after the test,
- B_o = average base-metal thickness before the test, and
- B = average base-metal thickness after the test

S7.10.1 A corrosion ratio of 1.25 or less for the thinnest section of the weld is permissible. Other criteria, such as a ratio of 1.00 or less, may be specified upon agreement between the producer and the purchaser.

S8. Special Applications

S8.1 For special applications, such as hydraulic expansion of tubes into tube sheets, there shall be no dimensional indication of the weld. Tubes ordered to this requirement shall bear the additional marking of NB.

S9. Additional Testing of Welded Tubing per ASME Request

S9.1 Each tube shall be subjected to an ultrasonic inspection employing Practices E 273 or E 213 with the rejection criteria referenced in Specification A 1016/A 1016M.

S9.2 If Practice E 273 is employed, a 100% volumetric inspection of the entire length of each tube shall also be performed using one of the nondestructive electric tests permitted by Specification A 1016/A 1016M.

S9.3 The test methods described in the supplement may not be capable of inspecting the end portions of tubes. This condition is referred to as end effect. This portion, as determined by the manufacturer, shall be removed and discarded.

S9.4 In addition to the marking prescribed in Specification A 1016/A 1016M, "S9" shall be added after the grade designation.

SPECIFICATION FOR ELECTRIC-RESISTANCE- WELDED FERRITIC ALLOY-STEEL BOILER AND SUPERHEATER TUBES



SA-250/SA-250M

(Identical with ASTM Specification A 250/A 250M-05(R09) except that Supplementary Requirement S1 is mandatory when 100% weld joint efficiency is required.)

1. Scope

1.1 This specification covers several grades, designated T1, T1a, T1b, T2, T11, T12 and T22, of minimum-wall-thickness, electric-resistance-welded, carbon-molybdenum and chromium-molybdenum alloy-steel, boiler and superheater tubes.

1.2 The tubing sizes and thicknesses usually furnished to this specification are $\frac{1}{2}$ to 5 in. [12.7 to 127 mm] in outside diameter and 0.035 to 0.320 in. [0.9 to 8.1 mm], inclusive, in minimum wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.4 An optional supplementary requirement is provided for non-destructive examination for certain ASME applications.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Documents

2.1 ASTM Standards:

A 1016/A 1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 273 Practice for Ultrasonic Examination of the Weld Zone of Welded Pipe and Tubing

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, metres, or number of lengths),

3.1.2 Name of material (electric-resistance-welded tubes),

3.1.3 Grade (Table 1),

3.1.4 Size (outside diameter or minimum wall thickness),

3.1.5 Length (specific or random),

3.1.6 Optional requirement (7.3.6),

3.1.7 Test report required (see Certification Section of Specification A 1016/A 1016M),

3.1.8 Specification designation, and

3.1.9 Special requirements and any supplementary requirements selected.

4. General Requirements

4.1 Product furnished under this specification shall conform to the applicable requirements of Specification A 1016/A 1016M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 1016/A 1016M constitutes nonconformance with this

specification. In case of conflicts with the requirements of this specification and Specification A 1016/A 1016M, this specification shall prevail.

5. Materials and Manufacture

5.1 The steel shall be killed.

5.2 The tubes shall be made by electric-resistance welding.

5.3 Heat Treatment

5.3.1 After welding, or when cold finished, after the final cold-drawing pass, all tubes shall be heat treated and, except as provided in 5.3.2, furnished in the full annealed, isothermal annealed, normalized, or normalized and tempered condition at the option of the manufacturer. If furnished in the normalized and tempered condition, the minimum tempering temperature shall be 1200°F [650°C], except T22 shall be tempered at 1250°F [676°C] minimum.

5.3.2 When grades T1, T1a, T1b, and T2 are cold finished, the tubes may, at the option of the manufacturer, be heat treated after the final cold-drawing pass at a temperature of 1200°F or higher, provided one of the heat treatments specified in 5.3.1 was applied after welding.

6. Chemical Composition

6.1 The steel shall conform to the requirements given in Table 1.

6.2 Product Analysis

6.2.1 An analysis of either one length of flat-rolled stock or one tube shall be made on each heat. The chemical composition thus determined shall conform to the requirements given in Table 1.

6.2.2 If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock or tubes shall be made. Both retests for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (See 8.1) shall be rejected or, at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes that do not meet the requirements of the specification shall be rejected.

7. Mechanical Requirements

7.1 Tensile Requirements

7.1.1 The material shall conform to the requirements as to tensile properties given in Table 2.

7.1.2 Table 3 gives the computed minimum elongation values for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values given in Table 3, the minimum elongation value shall be determined by the following equation:

$$E = 48t + 15.00 \quad [E = 1.87t + 15.00]$$

where:

E = elongation in 2 in. [50 mm] %, and

t = actual thickness of specimen, in. [mm].

7.2 Hardness Requirements — The tubes shall have a hardness not exceeding the values given in Table 4.

7.3 Mechanical Tests Required

7.3.1 Tension Test — One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (See 8.2).

7.3.2 Flattening Test — One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flange test, from each lot (See 8.1).

7.3.3 Flange Test — One flange test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (See 8.1).

7.3.4 Reverse Flattening Test — One reverse flattening test shall be made on a specimen from each 1500 ft [450 m] of finished tubing.

7.3.5 Hardness Test — Brinell and Rockwell hardness tests shall be made on specimens from two tubes from each lot (See 8.2).

7.3.6 Hydrostatic or Nondestructive Electric Tests — Each tube shall be subjected to either the hydrostatic or the nondestructive electric test. The purchaser may specify which is to be used.

8. Sampling

8.1 For flattening and flange requirements, the term *lot* applies to all tubes prior to cutting of the same specified outside diameter and specified wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat that are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes given in Table 5.

8.2 For tensile and hardness test requirements, the term *lot* applies to all tubes prior to cutting, of the same specified outside diameter and specified wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only

those tubes of the same size and the same heat that are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

9. Forming Operations

9.1 Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws. Superheater tubes when properly manipulated shall stand

all forging, welding, and bending operations necessary for application without developing defects.

10. Product Marking

10.1 In addition to the marking prescribed in Specification A 1016/A 1016M, the marking shall include the words “Electric Resistance-Welded Steel.”

11. Keywords

11.1 boiler tube; resistance welded steel tube; steel tube, alloy; superheater tube; welded steel tube

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %						
	Grade T1	Grade T1a	Grade T1b	Grade T2	Grade T11	Grade T12	Grade T22
Carbon	0.10–0.20	0.15–0.25	0.14 max	0.10–0.20	0.05–0.15	0.05–0.15	0.15 max
Manganese	0.30–0.80	0.30–0.80	0.30–0.80	0.30–0.61	0.30–0.60	0.30–0.61	0.30–0.60
Phosphorus, max	0.025	0.025	0.025	0.025	0.025	0.030	0.025
Sulfur, max	0.025	0.025	0.025	0.020	0.020	0.020	0.020
Silicon	0.10–0.50	0.10–0.50	0.10–0.50	0.10–0.30	0.50–1.00	0.50 max	0.50 max
Molybdenum	0.44–0.65	0.44–0.65	0.44–0.65	0.44–0.65	0.44–0.65	0.44–0.65	0.87–1.13
Chromium	...	...	...	0.50–0.81	1.00–1.50	0.80–1.25	1.90–2.60

TABLE 2
TENSILE REQUIREMENTS

Grade	T1	T1a	T1b	T2	T11	T12	T22
Tensile strength, min, ksi [MPa]	55 [380]	60 [415]	53 [365]	60 [415]	60 [415]	60 [415]	60 [415]
Yield strength, min, ksi [MPa]	30 [205]	32 [220]	28 [195]	30 [205]	30 [205]	32 [220]	30 [205]
Elongation in 2 in. or 50 mm, min, %	30	30	30	30	30	30	30
For longitudinal strip tests a deduction shall be made for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{5}{16}$ in. [8 mm] from the basic minimum elongation of the following percentage points	1.50 ^A	1.50 ^A	1.50 ^A	1.50 ^A	1.50 ^A	1.50 ^A	1.50 ^A

^A See Table 3 for the computed minimum values.

TABLE 3
MINIMUM ELONGATION VALUES

Wall Thickness		Elongation in 2 in. or 50 mm, min, % ⁴
in.	mm	Grades T1, T1a, T1b, T2, T11, T12, and T22
$\frac{5}{16}$ (0.312)	8	30
$\frac{9}{32}$ (0.281)	7.2	29
$\frac{1}{4}$ (0.250)	6.4	27
$\frac{7}{32}$ (0.219)	5.6	26
$\frac{3}{16}$ (0.188)	4.8	24
$\frac{5}{32}$ (0.156)	4	22
$\frac{1}{8}$ (0.125)	3.2	21
$\frac{3}{32}$ (0.094)	2.4	20
$\frac{1}{16}$ (0.062)	1.6	18

⁴ Calculated elongation requirements shall be rounded to the nearest whole number.

TABLE 4
HARDNESS REQUIREMENTS

Grade	Brinell Hardness Number (Tubes 0.200 in. [5.1 mm] and Over in Wall Thickness), HBW	Rockwell Hardness Number (Tubes Less Than 0.200 in. [5.1 mm] in Wall Thickness), HRB
T1	146	80
T1a	153	81
T1b	137	77
T2	163	85
T11	163	85
T12	163	85
T22	163	85

TABLE 5
**NUMBER OF TUBES IN A LOT HEAT TREATED BY
THE CONTINUOUS PROCESS**

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in out- side diameter and 0.200 in. [5.1 mm] and over in wall thickness	Not more than 50 tubes
Less than 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter or over 1 in. [25.4 mm] in outside diameter and under 0.200 in. [5.1 mm] in wall thickness	Not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	Not more than 125 tubes

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements may become a part of the specification when specified in the inquiry or invitation to bid, and purchase order or contract. These requirements shall not be considered, unless specified in the order and the necessary tests shall be made at the mill.

S1. Additional Testing of Welded Tubing for 100% Joint Efficiency in Certain ASME Applications

S1.1 Where this supplement is specified in the purchase order, in certain ASME applications it is permissible to use 100% joint efficiency for the longitudinal weld, provided the following additional requirements are met:

S1.1.1 Each tube shall be subjected to an ultrasonic inspection employing Practices E 273 or E 213 with the rejection criteria referenced in Specification A 1016/A 1016M.

S1.1.2 If Practice E 273 is employed, a 100% volumetric inspection of the entire length of each tube shall also be performed using one of the non-destructive electric tests permitted by Specification A 1016/A 1016M.

S1.1.3 The test methods described in the supplement may not be capable of inspecting the end portions of tubes. This condition is referred to as end effect. This portion, as determined by the manufacturer, shall be removed and discarded.

S1.1.4 In addition to the marking prescribed in Specification A 1016/A 1016M, "S1" shall be added after the grade designation.

SPECIFICATION FOR STAINLESS CHROMIUM STEEL-CLAD PLATE



SA-263



(Identical with ASTM Specification A 263-09.)

(a)

1. Scope

1.1 This specification covers plate of a carbon steel or low-alloy steel base to which is integrally and continuously bonded on one or both sides a layer of stainless chromium steel. The material is generally intended for pressure vessel use.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

2. Referenced Documents

2.1 ASTM Standards:

- A 6/A 6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling
- A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels
- A 240/A 240M Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip
- A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

2.2 Other Standards:

- ASME Code Boiler and Pressure Vessel Code, Section IX, Welding Qualifications

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 This material is considered as single-clad or double-clad stainless chromium-steel plate, depending on whether one or both sides are covered.

3.1.2 alloy cladding — the stainless chromium steel component of the composite plate.

3.1.3 base metal (backing steel) — component to which the alloy cladding is applied, usually the greater percentage of the composite plate.

3.1.4 integrally and continuously bonded — a condition in which the alloy cladding and base metal are brought together to form a metallurgical bond at essentially the entire interface of the two metals by means other than those processes that do not produce a homogeneous composite plate.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to, the following:

4.1.1 Quantity (weight or number of pieces).

4.1.2 Cladding alloy specification (UNS or ASTM Specification A 240/A 240M) and whether cladding is for corrosion allowance only.

4.1.3 Base metal specification.

4.1.4 Bond integrity Class (1, 3, or 5; see Section 13).

4.1.5 Dimensions including the minimum or nominal thicknesses of the cladding alloy and the backing steel, or of the total composite and if more or less restrictive thickness tolerances apply.

4.1.6 Product analysis, if required (see Section 10). Specify whether applicable to the cladding alloy, backing steel, or both.

4.1.7 Mechanical properties including shear test if required (see Sections 7, 8, and 9).

4.1.8 Finish (see Section 12).

4.1.9 Restrictions, if required, on repair by welding (see Section 14).

4.1.10 Additions to the specification or special requirements.

4.2 In addition to the basic requirements of this specification and the backing steel specification, certain supplementary requirements are available when necessary to meet end use requirements. These include:

4.2.1 Nondestructive examination,

4.2.2 Impact testing, and

4.2.3 Simulated Post-Weld Heat Treatment of Mechanical Test Coupons (SPWHT).

4.3 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

4.4 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

5. Materials and Manufacture

5.1 Process:

5.1.1 The steel shall be made by the open-hearth, electric-furnace, or basic-oxygen processes, or by secondary processes whereby steel made from these primary processes is remelted using, but not limited to electroslog remelting or vacuum-arc remelting processes.

5.1.2 The alloy-cladding metal may be metallurgically bonded to the base metal by any method that will produce a clad steel that will conform to the requirements of this specification.

5.2 Heat Treatment — Unless otherwise specified or agreed upon between the purchaser and the manufacturer, all plates shall be furnished in the normalized, tempered, normalized and tempered, or quenched and tempered condition as permitted by the backing steel specification. Stress relieving of the composite plate by heating subcritically is permitted, provided the temperature is 75°F (40°C) or more below the minimum tempering temperature (when tempered).

6. Chemical Composition

6.1 The composite plate shall conform to any desired combination of alloy-cladding metal and base metal as

described in 6.2 and 6.3 and as agreed upon between the purchaser and the manufacturer.

6.2 Alloy Cladding Metal — The alloy-cladding metal specified shall conform to the requirements as to chemical composition prescribed for the respective chromium steel in Specification A 240/A 240M.

6.3 Base Metal — The base metal shall be carbon steel or low-alloy steel conforming to the ASTM specifications for steels for pressure vessels or other as agreed by the purchaser and the manufacturer. The base metal shall conform to the chemical requirements of the specification to which it is ordered.

7. Mechanical Properties

7.1 Tensile Requirements:

7.1.1 The tensile properties shall be determined by a tension test of the composite plate for clad plates that meet all of the following conditions.

(1) The nominal composite gage is less than or equal to 1½ in. (38 mm).

(2) The specified minimum tensile strength of the base steel is less than or equal to 70 000 psi (485 MPa).

(3) The specified minimum yield strength of the base steel is less than or equal to 40 000 psi (275 MPa).

The tensile properties thus determined shall be not less than the minimum and not more than 5000 psi (35 MPa) over the maximum prescribed in the specification for the base steel used. All other tensile test requirements of the specification for the base steel shall be met.

7.1.2 The tensile properties shall be determined by a tension test of the base steel only for clad plates that meet one of the following conditions. The properties thus determined shall meet all of the tensile test requirements for the base steel.

(1) The composite gage is greater than 1½ in. (38 mm).

(2) The specified minimum tensile strength of the base steel is greater than 70 000 psi (485 MPa).

(3) The specified minimum yield strength of the base steel is greater than 40 000 psi (275 MPa).

7.1.3 If the cladding is for corrosion allowance only, the cladding need not be included in the tensile test. The tensile properties thus determined shall meet the base steel requirements.

7.2 Tests for strength of the bond, when required, must be specified by the purchaser and shall consist of one of the following.

7.2.1 Shear Strength — When required by the purchaser, the minimum shear strength of the alloy cladding and base metals shall be 20 000 psi (140 MPa). The shear test, when specified, shall be made in the manner indicated

in Fig. 1. The minimum cladding thickness for shear testing shall be 0.075 in. (1.9 mm) exclusive as ordered. Testing for shear strength for clad plates with minimum cladding thickness of 0.075 in. (1.9 mm) or less shall be permitted upon agreement between the purchaser and the manufacturer.

7.2.2 Bond Strength — As an alternative to the shear strength test provided in 7.2.1, or when agreed upon by the purchaser and the manufacturer, or both, three bend tests shall be made with the alloy cladding in compression to determine the quality of the bond. These bend tests shall be made in the manner of the tension tests indicated in Fig. 2 and shall be bent through an angle of 180° to the bend diameters provided for in either Specification A 6/A 6M or Specification A 20/A 20M, Appendix X4 or equivalent, as applicable. At least two of the three tests shall show not more than 50% separation on both edges of the bent portion. Greater separation shall be cause for rejection.

7.3 Methods and practices relating to mechanical testing required by this specification shall be in accordance with the Test Methods and Definitions of A 370.

8. Number of Tests and Retests

8.1 One or more tension tests, as required by the specifications for the base metal and, when specified, one shear test or three bond bend tests shall be made representing each plate as rolled. Each specimen shall be in the final condition of heat treatment required for the plate, including any SPWHT if required.

8.2 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

9. Test Specimens

9.1 The tension test specimens from plate shall conform to the requirements prescribed in the specifications for the base metal.

9.2 Bend test specimens for the alternative bond strength tests shall be taken at right angles to longitudinal axis of the plate.

9.3 When required by the purchaser, the shear test specimen should be taken near a corner of the plate, parallel to its longitudinal axis, or other location that is representative of the final product.

9.4 For plates $1\frac{1}{2}$ in. (38 mm) and under in thickness tension test specimens shall be full thickness of the material except as specified in 7.1.2 and 7.1.3.

9.5 For plates over $1\frac{1}{2}$ in. (38 mm) in thickness, tension tests shall be of the form shown in Fig. 3 and shall be

of all base steel conforming to the requirements of the specification for the base steel.

9.6 The bend test specimen used for bond strength determination shall be $1\frac{1}{2}$ in. (38 mm) wide by not more than $\frac{3}{4}$ in. (19 mm) in thickness and shall be machined to the form and dimensions shown in Fig. 2, or may be machined with both edges parallel. In reducing the thickness of the specimen, both the alloy cladding and the base steel shall be machined so as to maintain the same ratio of clad metal to base steel as is maintained in the plate, except that the thickness of the clad metal need not be reduced below $\frac{1}{8}$ in. (3.1 mm). The sides of the bend test specimen used for bond strength determination may have the corners rounded to a radius not over $\frac{1}{16}$ in. (1.6 mm) for plates, 2 in. (50 mm) and under in thickness, and not over $\frac{1}{8}$ in. (3.1 mm) for plates over 2 in. (50 mm) in thickness.

10. Product Analysis

10.1 Product analysis may be required for the cladding alloy on the finished product. Chemical analysis may be accomplished by wet chemical or instrumental procedures. If wet chemical procedures are used, millings may be taken only when the composite plate thickness is sufficient to permit obtaining millings without danger of contamination from the adjacent layer. If spectrometric procedures are used, the sample shall be exposed on the center line of the cladding when there is sufficient cladding thickness available so that there is no contamination from the adjacent base metal.

10.2 If product analysis is specified by the purchaser for the cladding alloy, it shall be made from drillings or millings taken from the final piece or a broken test specimen. For wet chemical analysis, in order to avoid contamination by the base plate metal, millings of cladding samples shall be taken from the test coupon by removal and discard of all the base metal plate material, plus 40% of the cladding thickness from the bonded side, not to exceed $\frac{1}{16}$ in. (1.6 mm). The material shall be chemically cleaned and sufficient millings shall be taken to represent the full cross-section of the remainder. If there is insufficient cladding thickness available to spectrographically expose on the center line of the cladding without contamination, 50% of the cladding shall be removed and the sample exposed on this surface.

10.3 Methods and practices relating to chemical analysis required by this specification shall be in accordance with the Test Methods, Practices, and Terminology of A 751.

10.4 Results of the product analysis shall conform to the requirements of Section 7 of Specification A 480/A 480M.

10.5 Results of the product analysis for the backing steel when required shall conform to the requirements of Section 7 of Specification A 20/A 20M.

11. Permissible Variations

11.1 Permissible variations except for thickness shall be in accordance with Specification A 20/A 20M.

11.2 Minimum thickness of the alloy cladding metal and of the backing steel, or of the total composite plate shall be as required by purchase order documents when ordered to minimum thicknesses.

11.3 Permissible variation in thickness when ordered to nominal thicknesses shall be 0.01 in. (0.3 mm) under each for backing steel or total composite, and 0.03 in. (0.8 mm) under for the alloy cladding.

11.4 Permissible variations for excess thickness of the total composite shall be the greater of 0.125 in. (3 mm) or 10% of the total composite thickness ordered and may occur in either backing steel, cladding, or both, provided the minimum for each is met.

11.5 More restrictive or less restrictive permissible variations may be agreed upon by the purchaser and the manufacturer.

12. Workmanship, Finish, and Appearance

12.1 The material shall be free of injurious defects, shall have a workmanlike appearance, and shall conform to the designated finish.

12.2 Plate alloy surfaces shall be blasted (descaled by means such as sand or stainless grit, shot or wire, or equivalent), pickled, blast-cleaned and pickled, or 100% conditioned.

13. Bond Quality

13.1 The cladding metal shall be integrally and continuously bonded to the base metal.

13.2 Inspection:

13.2.1 Clad plates less than $\frac{3}{8}$ in. (10 mm) total minimum composite thickness shall be visually inspected for bond integrity prior to shipment.

13.2.2 Clad plates $\frac{3}{8}$ in. (10 mm) and thicker total minimum composite thickness, and when specified by the purchaser, clad plates less than $\frac{3}{8}$ in. (10 mm) total minimum composite thickness, shall be ultrasonically inspected for bond integrity prior to shipment in accordance with the Procedures and Methods of Specification A 578/A 578M.

13.2.3 Areas of non-bond detected visually shall be explored ultrasonically to determine the extent of the condition in accordance with 13.2.2. For purposes of defining

non-bond, the cladding shall be interpreted to be unbonded when there is complete loss of back reflection accompanied by an echo indication from the plane of the interface of the clad and backing steel. Areas within 1 in. (25 mm) of a cut edge on the plate that contain indications exceeding 50% of the back reflection at the bond interface shall be considered to be unbonded.

13.2.4 Extent of ultrasonic examination shall be at the discretion of the manufacturer and sufficient enough to provide the quality level required by the purchaser. Plates may be ordered with 100% coverage (Supplementary Requirements S12).

13.3 Quality Levels:

13.3.1 Class 1 — No single unbonded area exceeding 1 in. (25 mm) in its longest dimension with total unbonded area not to exceed 1% of the total clad surface area.

13.3.2 Class 3 — No single unbonded area exceeding 3 in. (75 mm) in its longest dimension with total unbonded area not to exceed 3% of the total clad surface area.

13.3.3 Class 5 — No single unbonded area exceeding 9 in.² (58 cm²) with total unbonded area not to exceed 5% of the total clad surface area.

13.3.4 The class to be supplied should be listed on the purchase order. When none has been specified, plates shall be furnished as Class 5 at the option of the manufacturer.

14. Repair of Cladding by Welding

14.1 The material manufacturer may repair defects in cladding by welding provided the following requirements are met:

14.1.1 When specified in the purchase order, prior approval shall be obtained from the purchaser.

14.1.2 The welding procedure and the welders or welding operators shall be qualified in accordance with Section IX of the ASME Code.

14.1.3 The defective area shall be removed and the area prepared for repair shall be examined by a magnetic particle method or a liquid penetrant method to ensure all defective area has been removed. Method of test and acceptance standard shall be as agreed upon between the purchaser and the manufacturer.

14.1.4 The repair weld shall be deposited in accordance with a welding procedure and welding materials suitable for the cladding material. The surface condition of the repaired area shall be restored to a condition similar to the rest of the cladding.

14.1.5 The repaired area shall be examined by a liquid penetrant method.

14.1.6 The location and extent of the weld repairs together with the repair procedure and examination results shall be transmitted as a part of the certification.

14.2 All repairs in Alloy Type 410 and any repairs to Type 410S penetrating into the backing steel shall be stress relieved to eliminate residual stresses unless otherwise agreed upon.

15. General Requirements for Delivery

15.1 Material furnished under this specification shall conform to the applicable requirements of Specification A 20/A 20M.

16. Certification

16.1 The chemical analysis of the base metal and the alloy cladding shall be certified to the purchaser by the clad plate manufacturer.

16.2 The results of the tests in Section 7 and any other tests required by the purchase order shall be reported to the purchaser.

16.3 Compliance with the clad quality level of 13.3 shall be certified. Reports shall include the results of ultrasonic inspection when Supplementary Requirement S12 is specified.

17. Product Marking

17.1 Except as specified in 17.2, plates shall be marked in accordance with the requirements of Specification A 20/A 20M for the backing steel and the type number of the alloy cladding metal and this specification number.

17.2 For double-clad material or for material under $\frac{1}{4}$ in. (6.35 mm) in thickness, the marking shall be legibly stenciled instead of stamped.

18. Keywords

18.1 alloy cladding; backing steel; bond strength; carbon steel; clad steel plate; low-alloy steel; pressure vessel; shear strength; stainless chromium steel

FIG. 1 TEST SPECIMEN AND METHOD OF MAKING SHEAR TEST OF CLAD PLATE

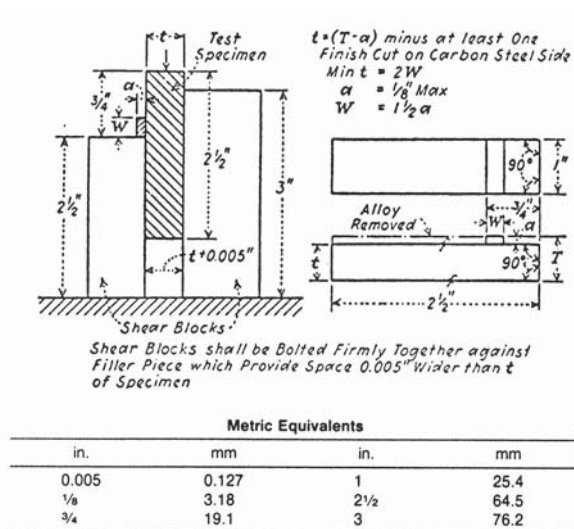
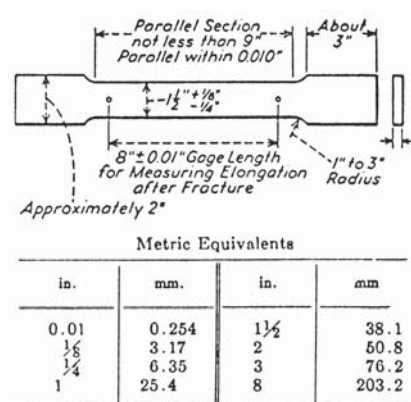


FIG. 2 STANDARD RECTANGULAR TENSION TEST SPECIMEN WITH 8 IN. GAGE LENGTH

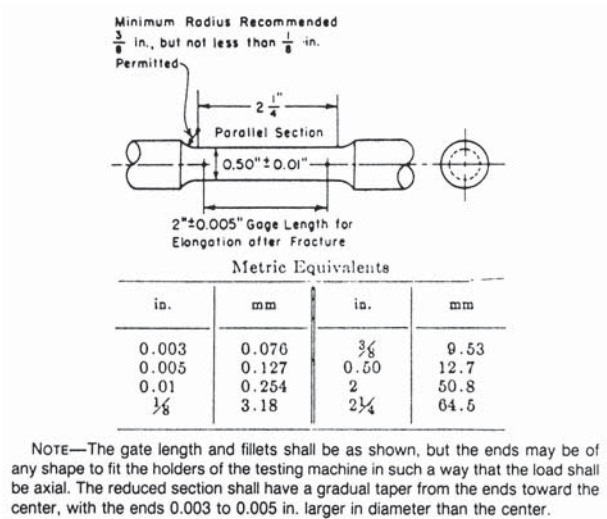


NOTE 1—When necessary, it is permissible to use a narrower specimen, but in such a case the reduced portion shall be not less than 1 in. in width.

NOTE 2—Punch marks for measuring elongation after fracture shall be made on the flat or on the edge of the specimen and within the parallel section; either a set of nine punch marks 1 in. apart, or one or more sets of 8-in. punch marks may be used.

NOTE 3—The dimension t is the thickness of the test specimen as provided for in the applicable material specifications.

FIG. 3 STANDARD ROUND TENSION TEST SPECIMEN WITH 2 IN. GAGE LENGTH



SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified on the order. A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

S2. Product Analysis**S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons****S5. Charpy V-Notch Impact Test****S12. Ultrasonic Examination in Accordance With Specification A 578/A 578M**

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SPECIFICATION FOR STAINLESS CHROMIUM-NICKEL STEEL-CLAD PLATE



SA-264



(Identical with ASTM Specification A 264-09)

(a)

1. Scope

1.1 This specification covers plate of a carbon steel or low-alloy steel base to which is integrally and continuously bonded on one or both sides a layer of stainless chromium-nickel steel. The material is generally intended for pressure vessel use.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

2. Referenced Documents

2.1 ASTM Standards:

- A 6/A 6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling
- A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels
- A 240/A 240M Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip
- A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

2.2 Other Standards:

- ASME Code Boiler and Pressure Vessel Code, Section IX, Welding Qualifications

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 This material is considered as single-clad or double-clad corrosion-resisting chromium-nickel steel plate, depending on whether one or both sides are covered.

3.1.2 *alloy cladding* — the stainless chromium-nickel steel component of the composite plate.

3.1.3 *base metal (backing steel)* — component to which the alloy cladding is applied, usually the greater percentage of the composite plate and usually consisting of carbon or low-alloy steel.

3.1.4 *integrally and continuously bonded* — the process by which the alloy cladding and base metal are brought together to form a metallurgical bond at essentially the entire interface of the two metals by means other than those processes that do not produce a homogeneous composite plate.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to, the following:

4.1.1 Quantity (weight or number of pieces).

4.1.2 Cladding alloy specification, (UNS or ASTM Specification A 240/A 240M and whether cladding is for corrosion allowance only),

4.1.3 Base metal specification.

4.1.4 Bond integrity Class (1, 3, or 5).

4.1.5 Dimensions including the minimum or nominal thickness of the cladding alloy, and the backing steel, or of the total composite plate and if more or less restrictive thickness tolerances apply.

4.1.6 Product analysis, if required (see Section 10). Specify whether applicable to the cladding alloy, backing steel or both.

4.1.7 Mechanical properties, including shear test if required.

4.1.8 Finish (see Section 12).

4.1.9 Restrictions, if required, on repair by welding (see Section 14).

4.1.10 Additions to the specification or special requirements.

4.1.11 Corrosion testing if applicable.

4.2 In addition to the basic requirements of this specification and the backing steel specification, certain supplementary requirements are available when necessary to meet end use requirements. These include:

4.2.1 Nondestructive examination,

4.2.2 Impact testing, and

4.2.3 Simulated Post-Weld Heat Treatment of Mechanical Test Coupons (SPWHT).

4.3 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

4.4 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4.5 Special tests.

5. Materials and Manufacture

5.1 Process:

5.1.1 The steel shall be made by the open-hearth, electric-furnace, or basic-oxygen processes, or by secondary processes whereby steel made from these primary processes is remelted using, but not limited to electroslag remelting or vacuum-arc remelting processes.

5.1.2 The alloy-cladding metal may be metallurgically bonded to the base metal by any method that will produce a clad steel that will conform to the requirements of this specification.

5.2 Heat Treatment:

5.2.1 Unless otherwise specified or agreed upon between the purchaser and the manufacturer, all austenitic stainless steel clad plates shall be given a heat treatment consisting of heating to the proper temperature for the solution of the chromium carbides in the cladding followed by individual air cooling. For base metals of air-hardening low-alloy steels the above heat treatment shall be followed by a tempering treatment.

5.2.2 Duplex stainless steel clad plates shall be provided in a heat treated condition as agreed upon between the purchaser and the manufacturer.

5.2.3 When plates are to be cold formed, or when otherwise required by the base metal specification, the purchaser may specify that such plates, following solution annealing, be heat treated for grain refinement of the base metal by normalizing and either air cooled or water quenched as appropriate. In the case of clad plate manufactured without hot rolling, the base metal and alloy cladding components may be heat treated separately as appropriate prior to bonding.

6. Chemical Composition

6.1 The composite plate may conform to any desired combination of alloy-cladding metal and base metal as described in 6.2 and 6.3 and as agreed upon between the purchaser and the manufacturer.

6.2 Alloy Cladding Metal — The alloy-cladding metal specified shall conform to the requirements as to chemical composition prescribed for the respective chromium-nickel or duplex steel in Specification A 240/A 240M.

6.3 Base Metal — The base metal shall be carbon steel or low-alloy steel conforming to the ASTM specifications for steel for pressure vessels, or other, as agreed by the purchaser and the manufacturer. The base metal shall conform to the chemical requirements of the specification to which it is ordered.

7. Mechanical Properties

7.1 Tensile Requirements:

7.1.1 The tensile properties shall be determined by a tension test of the composite plate for clad plates that meet all of the following conditions.

(1) The composite gage is less than or equal to 1½ in. (38 mm).

(2) The specified minimum tensile strength of the base steel is less than or equal to 70 000 psi (485 MPa).

(3) The specified minimum yield strength of the base steel is less than or equal to 40 000 psi (275 MPa).

(4) The tensile properties thus determined shall be not less than the minimum and not more than 5000 psi (35 MPa) over the maximum prescribed in the specification for the base steel used. All other tensile test requirements of the specification for the base steel shall be met.

7.1.2 The tensile properties shall be determined by a tension test of the base steel only for clad plates that meet one of the following conditions. The properties thus determined shall meet all of the tensile test requirements for the base steel.

- (1) The composite gage is greater than $1\frac{1}{2}$ in. (38 mm).
- (2) The specified minimum tensile strength of the base steel is greater than 70 000 psi (485 MPa).
- (3) The specified minimum yield strength of the base steel is greater than 40 000 psi (275 MPa).

7.1.3 If the cladding is for corrosion allowance only, the cladding need not be included in the tensile test. The tensile properties thus determined shall meet the base steel requirements.

7.2 Tests for strength of the bond, when required, must be specified by the purchaser and shall consist of one of the following.

7.2.1 Shear Strength — When required by the purchaser, the minimum shear strength of the alloy cladding and base metals shall be 20 000 psi (140 MPa). The shear test, when specified, shall be made in the manner indicated in Fig. 1. The minimum cladding thickness for shear testing shall be 0.075 in. (1.9 mm), exclusive as ordered. Testing for shear strength for clad plates with minimum cladding thickness of 0.075 in. (1.9 mm) or less shall be permitted upon agreement between the purchaser and the manufacturer.

7.2.2 Bond Strength — As an alternative to the shear strength test provided in 7.2.1, or when agreed upon by the purchaser and the manufacturer, or both, three bend tests shall be made with the alloy cladding in compression to determine the quality of the bond. These bend tests shall be made in the manner of the tension tests indicated in Fig. 2 and shall be bent through an angle of 180° to the bend diameters provided for in either Specification A 6/A 6M or Specification A 20/A 20M, Appendix X4 or equivalent, as applicable. At least two of the three tests shall show not more than 50% separation on both edges of the bent portion. Greater separation shall be cause for rejection.

7.3 Methods and practices relating to mechanical testing required by this specification shall be in accordance with the Test Methods and Definitions of A 370.

8. Number of Tests and Retests

8.1 One or more tension tests, as required by the specifications for the base metal and when specified, one shear test or three bond bend tests shall be made, representing each plate as rolled. Each specimen shall be in the final condition of heat treatment required for the plate, including any SPWHT if required.

8.2 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

9. Test Specimens

9.1 The tension test specimens from plate shall conform to the requirements prescribed in the specifications for the base metal.

9.2 Bend test specimens for the alternative bond strength tests, shall be taken at right angles to its longitudinal axis.

9.3 When required by the purchaser, the shear test specimen should be taken near a top or bottom corner of the plate as rolled, parallel to its longitudinal axis, or other location that is representative of the final product.

9.4 For plates $1\frac{1}{2}$ in. (38 mm) and under in thickness, tension test specimens shall be the full thickness of the material, except as specified in 7.1.2 and 7.1.3.

9.5 For plates over $1\frac{1}{2}$ in. (38 mm) in thickness, tension tests shall be of the form shown in Fig. 3 and shall be of all base steel conforming to the requirements of the specification for the base steel.

9.6 The bend test specimen used for bond strength determination shall be $1\frac{1}{2}$ in. (38 mm) wide by not more than $\frac{3}{4}$ in. (19 mm) in thickness and shall be machined to the form and dimensions shown in Fig. 2, or may be machined with both edges parallel. In reducing the thickness of the specimen, both the alloy cladding and the base steel shall be machined so as to maintain the same ratio of clad metal to base steel as is maintained in the plate, except that the thickness of the clad metal need not be reduced below $\frac{1}{8}$ in. (3.1 mm). The sides of the bend test specimen used for bond strength determination may have the corners rounded to a radius not over $\frac{1}{16}$ in. (1.6 mm) for plates, 2 in. (50 mm) and under in thickness, and not over $\frac{1}{8}$ in. (3.1 mm) for plates over 2 in. (50 mm) in thickness.

10. Product Analysis

10.1 Product analysis may be required for the cladding alloy on finished product. Chemical analysis may be accomplished by wet chemical or instrumental procedures. If wet chemical procedures are used, millings may be taken only when the composite plate thickness is sufficient to permit obtaining millings without danger of contamination from the adjacent layer. If spectrometric procedures are used, the sample shall be exposed on the center line of the cladding when there is sufficient cladding thickness available so that there is no contamination from the adjacent base metal.

10.2 If product analysis is specified by the purchaser for the cladding alloy, it shall be made on a sample taken from the finished product or a broken test specimen. For wet chemical analysis, in order to avoid contamination by

the base plate metal, millings of cladding samples shall be taken from the test coupon by removal and discard of all the base metal plus 40% of the cladding thickness from the bonded side, not to exceed $\frac{1}{16}$ in. (1.6 mm). The material shall be cleaned and sufficient millings taken to represent the full cross-section of the remainder. If there is insufficient cladding thickness available to spectrographically expose on the center line of the cladding without contamination, 50% of the cladding shall be removed and the sample exposed on this surface.

10.3 The results of the product analysis shall conform to the requirements of Section 7 of Specification A 480/A 480M.

10.4 Methods and practices relating to chemical analysis required by this specification shall be in accordance with the Test Methods, Practices, and Definitions of A 751.

10.5 Results of the product analysis for the backing steel when required shall conform to the requirements of Section 7 of Specification A 20/A 20M.

11. Permissible Variations

11.1 Permissible variations except for thickness shall be in accordance with Specification A 20/A 20M.

11.2 Minimum thickness of the alloy cladding metal and of the backing steel, or of the total composite plate shall be as required by purchase order documents when ordered to minimum thicknesses.

11.3 Permissible variation in thickness when ordered to nominal thicknesses shall be 0.01 in. (0.3 mm) under each for backing steel or total composite, and 0.03 in. (0.8 mm) under for the alloy cladding.

11.4 Permissible variations for excess thickness of the total composite shall be the greater of 0.125 in. (3 mm) or 10% of the total composite thickness ordered and may occur in either backing steel, cladding, or both, provided the minimum for each is met.

11.5 More restrictive or less restrictive permissible variations may be agreed upon by the purchaser and the manufacturer.

12. Workmanship, Finish, and Appearance

12.1 The material shall be free of injurious defects, shall have a workmanlike appearance, and shall conform to the designated finish.

12.2 Plate alloy surfaces shall be blasted (descaled by means of sand or stainless grit, shot, or wire), pickled, blast-cleaned and pickled, or 100% conditioned.

13. Bond Quality

13.1 The cladding metal shall be integrally and continuously bonded to the base metal.

13.2 Inspection:

13.2.1 Clad plates less than $\frac{3}{8}$ in. (10 mm) total minimum composite thickness shall be visually inspected for bond integrity prior to shipment.

13.2.2 Clad plates $\frac{3}{8}$ in. (10 mm) and thicker total minimum composite thickness, and when specified by the purchaser, clad plates less than $\frac{3}{8}$ in. (10 mm) total minimum composite thickness, shall be ultrasonically inspected for bond integrity prior to shipment in accordance with the Procedures and Methods of Specification A 578/A 578M.

13.2.3 Areas of non-bond detected visually shall be explored ultrasonically to determine the extent of the condition in accordance with 13.2.2. For purposes of defining non-bond, the cladding shall be interpreted to be unbonded when there is complete loss of back reflection accompanied by an echo indication from the plane of the interface of the clad and backing steel. Areas within 1 in. (25 mm) of a cut edge on the plate that contain indications exceeding 50% of the back reflection at the bond interface shall be considered to be unbonded.

13.2.4 Extent of ultrasonic examination shall be at the discretion of the manufacturer and sufficient enough to provide the quality level required by the purchaser. Plates may be ordered with 100% coverage (Supplementary Requirement S12).

13.3 Quality Levels:

13.3.1 Class 1 — No single unbonded area exceeding 1 in. (25 mm) in its longest dimension with total unbonded area not to exceed 1% of the total clad surface area.

13.3.2 Class 3 — No single unbonded area exceeding 3 in. (75 mm) in its longest dimension with total unbonded area not to exceed 3% of the total clad surface area.

13.3.3 Class 5 — No single unbonded area exceeding 9 in.² (58 cm²) with total unbonded area not to exceed 5% of the total clad surface area.

13.3.4 The class to be supplied should be listed on the purchase order. When none has been specified, plates shall be furnished as Class 5 at the option of the manufacturer.

14. Repair of Cladding by Welding

14.1 The material manufacturer may repair defects in cladding by welding provided the following requirements are met:

14.1.1 When specified in the purchase order, prior approval shall be obtained from the purchaser.

14.1.2 The welding procedure and the welders or welding operators shall be qualified in accordance with Section IX of the ASME Code.

14.1.3 The defective area shall be removed and the area prepared for repair shall be examined by a liquid penetrant method to ensure that all of the defective area has been removed. Method of test and acceptance standard shall be as agreed upon between the purchaser and the manufacturer.

14.1.4 The repair weld shall be deposited in accordance with a welding procedure and welding materials suitable for the cladding material. The surface condition of the repaired area shall be restored to a condition similar to the rest of the cladding.

14.1.5 The repaired area shall be examined by a liquid penetrant method.

14.1.6 The location and extent of the weld repairs together with the repair procedure and examination results shall be transmitted as a part of the certification.

15. General Requirements for Delivery

15.1 Material furnished under this specification shall conform to the applicable requirements of Specification A 20/A 20M.

16. Certification

16.1 The chemical analysis of the base metal and the alloy cladding shall be certified to the purchaser by the clad plate manufacturer.

16.2 The results of the tests in Section 7 and any other tests required by the purchase order shall be reported to the purchaser.

16.3 Compliance with the clad quality level of 13.3 shall be certified. Reports shall include the results of ultrasonic inspection when Supplementary Requirement S12 is specified.

17. Product Marking

17.1 Except as specified in 17.2, plates shall be marked in accordance with the requirements of Specification A 20/A 20M for the backing steel and the type number of the alloy cladding metal and this specification number.

17.2 For double-clad material or for material under $\frac{1}{4}$ in. (6.35 mm) in thickness, the marking specified in 17.1 shall be legibly stenciled instead of stamped.

18. Keywords

18.1 alloy cladding; backing steel; bond strength; carbon steel; clad steel plate; low-alloy steel; pressure vessel; shear strength; stainless chromium-nickel steel

FIG. 1 TEST SPECIMEN AND METHOD OF MAKING SHEAR TEST OF CLAD PLATE

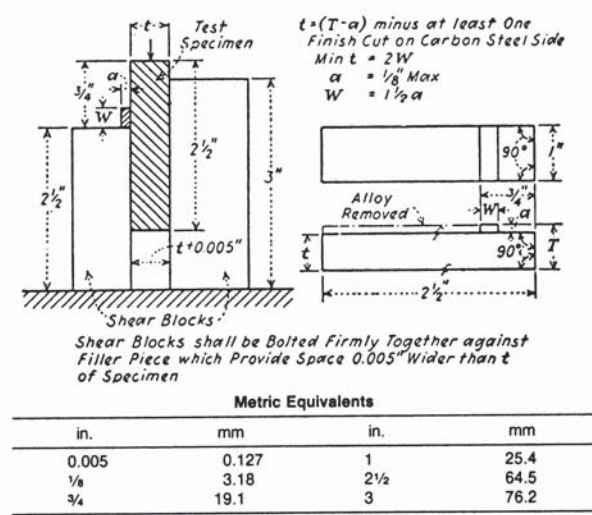


FIG. 2 STANDARD RECTANGULAR TENSION TEST SPECIMEN WITH 8 IN. GAGE LENGTH

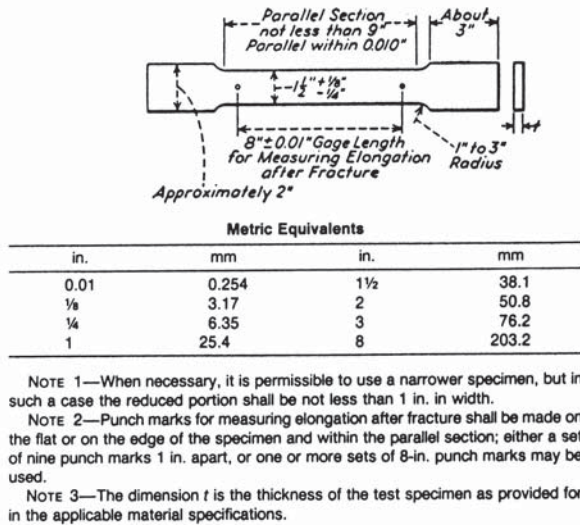
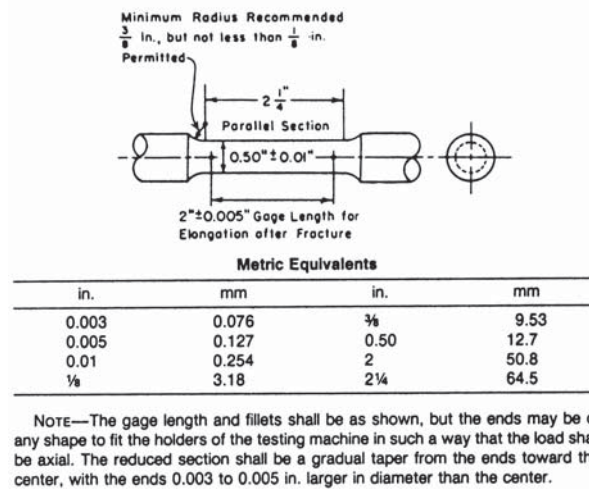


FIG. 3 STANDARD ROUND TENSION TEST SPECIMEN WITH 2 IN. GAGE LENGTH



SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified on the order. A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

S2. Product Analysis

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons

S5. Charpy V-Notch Impact Test

S12. Ultrasonic Examination in Accordance With Specification A 578/A 578M S1

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SPECIFICATION FOR NICKEL AND NICKEL-BASE ALLOY-CLAD STEEL PLATE



SA-265



(Identical with ASTM Specification A 265-09.)

(a)

1. Scope

1.1 This specification covers plate of a carbon steel or low-alloy steel base to which is integrally and continuously bonded on one or both sides a layer of nickel or nickel-base alloy. The material is generally intended for pressure vessel use but may be used in other structural applications where corrosion resistance of the alloy is of prime importance.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

2. Referenced Documents

2.1 ASTM Standards:

- A 6/A 6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling
- A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- B 127 Specification for Nickel-Copper Alloy (UNS N04400) Plate, Sheet, and Strip
- B 162 Specification for Nickel Plate, Sheet, and Strip
- B 168 Specification for Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025, N06045, and N06696) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Plate, Sheet, and Strip

- B 333 Specification for Nickel-Molybdenum Alloy Plate, Sheet, and Strip
- B 409 Specification for Nickel-Iron-Chromium Alloy Plate, Sheet, and Strip
- B 424 Specification for Ni-Fe-Cr-Mo-Cu Alloy (UNS N08825 and UNS N08221) Plate, Sheet, and Strip
- B 443 Specification for Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) and Nickel-Chromium-Molybdenum-Silicon-Alloy (UNS N06219) Plate, Sheet, and Strip
- B 463 Specification for UNS N08020 Alloy Plate, Sheet, and Strip
- B 575 Specification for Low-Carbon Nickel-Chromium-Molybdenum, Low-Carbon Nickel-Chromium-Molybdenum-Copper, Low-Carbon Nickel-Chromium-Molybdenum-Tantalum, and Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy Plate, Sheet, and Strip
- B 582 Specification for Nickel-Chromium-Iron-Molybdenum-Copper Alloy Plate, Sheet, and Strip
- B 625 Specification for UNS N08925, UNS N08031, UNS N08932, UNS N08926, UNS N08354, and UNS R20033 Plate, Sheet, and Strip

2.2 Other Standards:

ASME Code Boiler and Pressure Vessel Code, Section IX, Welding Qualifications

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 This material is considered as single-clad or double-clad nickel or nickel-base alloy clad steel plate, depending on whether one or both sides are covered.

3.1.2 The term plate as used in this specification applies to material $\frac{3}{16}$ in. (2.73 mm) and over in thickness, and over 10 in. (254 mm) in width.

3.1.3 alloy cladding — the nickel or nickel-base alloy component of the composite plate.

3.1.4 base metal (backing steel) — component to which the alloy cladding is applied, usually the greater percentage of the composite plate and usually consisting of carbon or low-alloy steel.

3.1.5 integrally and continuously bonded — the process by which the alloy cladding and base metal are brought together to form a metallurgical bond at essentially the entire interface of the two metals by means other than those processes that do not produce a homogeneous composite plate.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to the following:

4.1.1 Quantity (weight or number of pieces).

4.1.2 Heat treatment, if required (see Section 5).

4.1.3 Dimensions, including the thickness of the cladding alloy and the backing steel, or of the total composite plate and if more or less restrictive thickness tolerances apply.

4.1.4 Cladding alloy specification (see Section 6).

4.1.5 Base metal specification (see Section 6).

4.1.6 Product analysis, if required. Specify whether applicable to the cladding alloy, backing steel, or both (see Section 10).

4.1.7 Mechanical Properties (see Sections 7, 13, and 14).

4.1.8 Restrictions, if required, on repair by welding (see Section 14).

4.1.9 Additions to the specification or special requirements.

4.1.10 Corrosions tests, if required.

4.2 In addition to the basic requirements of this specification and the backing steel specification, certain supplementary requirements are available when necessary to meet the end use requirements. These include:

4.2.1 Nondestructive examination,

4.2.2 Impact testing, and

4.2.3 Simulated Post-Weld Heat Treatment of Mechanical Test Coupons (SPWHT).

4.3 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed

requirements in Specification A 20/A 20M. If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4.4 Special tests.

5. Materials and Manufacture

5.1 Process:

5.1.1 The steel shall be made by the open-hearth, electric-furnace (with separate degassing and refining optional), or basic-oxygen processes, or by secondary processes whereby steel made from these primary processes is remelted using, but not limited to electroslog remelting or vacuum arc remelting processes.

5.1.2 The cladding metal may be metallurgically bonded to the base metal by any method that will produce a clad steel that will conform to the requirements of this specification.

5.2 Heat Treatment — Unless a specific heat treatment is required by the cladding material or base steel specification, or unless otherwise agreed upon by the purchaser and manufacturer, the clad plate shall be furnished in a condition that is appropriate for the cladding alloy, base metal, or both.

6. Chemical Composition

6.1 The composite plate may conform to any desired combination cladding metal and base metal as described in 6.2 and 6.3, and as agreed upon between the purchaser and the manufacturer.

6.2 Cladding Metal — The nickel or nickel-base alloy cladding metal specified shall conform to the requirements as to chemical composition prescribed for the respective metal in Specifications B 127, B 162, B 168, B 333, B 409, B 424, B 443, B 463, B 575, B 582, and B 625, or other nickel-base alloy as agreed upon by the purchaser and manufacturer.

6.3 Base Metal — The base metal shall be carbon steel or low-alloy steel conforming to the ASTM specifications for steels for either pressure vessels or general structural applications, or other, as agreed upon by the purchaser and manufacturer. The base metal shall conform to the chemical requirements of the specification to which it is ordered.

7. Mechanical Properties

7.1 Tensile Requirements:

7.1.1 The tensile properties shall be determined by a tension test of the composite plate for clad plates that meet all of the following conditions.

(1) The nominal composite gage is less than or equal to $1\frac{1}{2}$ in. (38 mm).

(2) The specified minimum tensile strength of the base steel is less than or equal to 70 000 psi (485 MPa).

(3) The specified minimum yield strength of the base steel is less than or equal to 40 000 psi (275 MPa).

(4) The tensile properties thus determined shall not be less than the minimum and not more than 5000 psi (35 MPa) over the maximum prescribed in the specification for the base steel used. All other tensile test requirements of the specification for the base steel shall be met.

7.1.2 The tensile properties shall be determined by a tension test of the base steel only for clad plates that meet one of the following conditions. The properties thus determined shall meet all of the tensile test requirements for the base steel.

(1) The composite gage is greater than $1\frac{1}{2}$ in. (38 mm).

(2) The specified minimum tensile strength of the base steel is greater than 70 000 psi (485 MPa).

(3) The specified minimum yield strength of the base steel is greater than 40 000 psi (275 MPa).

7.1.3 If the cladding is for corrosion allowance only, the cladding need not be included in the tensile test. The tensile properties thus determined shall meet the base steel requirements.

7.2 Test for strength of the bond, when required, must be specified by the purchaser and shall consist of one of the following.

7.2.1 Shear Strength — When required by the purchaser, the minimum shear strength of the alloy cladding and base metals shall be 20 000 psi (140 MPa). The shear test, when specified, shall be made in the manner indicated in Fig. 1. The minimum cladding thickness for shear testing shall be 0.075 in. (1.9 mm) exclusive as ordered. Testing for shear strength for clad plates with minimum cladding thickness of 0.075 in. (1.9 mm) or less shall be permitted upon agreement between the purchaser and the manufacturer.

7.2.2 Bond Strength — As an alternative to the shear strength test provided in 7.2.1 or when agreed upon by the purchaser and the manufacturer, or both, three bend tests shall be made with the alloy cladding in compression to determine the quality of the bond. These bend tests shall be made in the manner of the tension tests indicated in Fig. 2 and shall be bent through an angle of 180° to the bend diameters provided for in either Specification A 6/A 6M or Specification A 20/A 20M (Appendix X4, or equivalent), as applicable. At least two of the three tests shall show not more than 50% separation on both edges of the bent portion. Greater separation shall be cause for rejection.

7.3 Methods and practices relating to mechanical testing required by this specification shall be in accordance with the Test Methods and Definitions of A 370.

8. Number of Tests and Retests

8.1 One or more tension tests, as required by the specifications for the base metal and when specified, one shear test or three bond bend tests shall be made, representing each plate as rolled. Each specimen shall be in the final condition of heat treatment required for the plate, including any SPWHT if required.

8.2 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

9. Test Specimens

9.1 The tension test specimens shall conform to the requirements prescribed in the specifications for the base metal.

9.2 Bend test specimens for the alternative bond strength tests shall be taken at right angles to its longitudinal axis.

9.3 When required by the purchaser, the shear test specimen shall be taken near a top or bottom corner of the plate as rolled, parallel to its longitudinal axis, or other location that is representative of the final product.

9.4 For plates $1\frac{1}{2}$ in. (38 mm) and under in thickness, tension test specimens shall be the full thickness of the material, except as specified in 7.1.2 and 7.1.3.

9.5 For plates over $1\frac{1}{2}$ in. (38 mm) in thickness, tension tests shall be of the form shown in Fig. 3 and shall be of all base steel conforming to the requirements of the specification for the base steel.

9.6 The bend test specimen used for bond strength determination shall be $1\frac{1}{2}$ in. (38 mm) by not more than $\frac{3}{4}$ in. (19 mm) in thickness and shall be machined to the form and dimensions shown in Fig. 2, or may be machined with both edges parallel. In reducing the thickness of the specimen, both the alloy cladding and the base steel shall be machined so as to maintain the same ratio of clad metal to base steel as is maintained in the plate, except that the thickness of the clad material need not be reduced below $\frac{1}{8}$ in. (3.1 mm). The sides of the bend test specimen used for bond strength determination may have the corners rounded to a radius not over $\frac{1}{16}$ in. (1.6 mm) for plates, 2 in. (50 mm) and under in thickness, and not over $\frac{1}{8}$ in. (3.1 mm) for plates over 2 in. (50 mm) in thickness.

10. Product Analysis

10.1 Product analysis may be required for the cladding alloy on finished product. Chemical analysis may be accomplished by wet chemical or instrumental procedures. If wet chemical procedures are used, millings may be taken

only when the composite plate thickness is sufficient to permit obtaining millings without danger of contamination from the adjacent layer. If spectrometric procedures are used, the sample shall be exposed on the center line of the cladding when there is sufficient cladding thickness available so that there is no contamination from the adjacent base metal.

10.2 If product analysis is specified by the purchaser for the cladding alloy, it shall be made on a sample taken from the finished product or a broken test specimen. For wet chemical analysis, in order to avoid contamination by the base plate metal, millings of cladding samples shall be taken from the test coupon by removal and discard of all the base metal plus 40% of the cladding thickness from the bonded side, not to exceed $\frac{1}{16}$ in. (1.6 mm). The material shall be cleaned and sufficient millings taken to represent the full cross-section of the remainder. If there is insufficient cladding thickness available to spectrographically expose on the center line of the cladding without contamination, 50% of the cladding shall be removed and the sample exposed on this surface.

10.3 The results of the product analysis shall conform to the requirements of standards referenced in Section 2.

10.4 Methods and practices relating to chemical analysis required by this specification shall be in accordance with the Test Methods, Practices, and Terminology of A 751.

10.5 Results of the product analysis for the backing steel when required shall conform to the requirements of Section 7 of Specification A 20/A 20M or A 6/A 6M, as applicable.

11. Permissible Variations

11.1 Permissible variations except for thickness shall be in accordance with Specification A 20/A 20M or A 6/A 6M as applicable based on the backing specification.

11.2 Minimum thickness of the alloy cladding metal and of the backing steel, or of the total composite plate shall be as required by purchase order documents when ordered to minimum thickness.

11.3 Permissible variation in thickness when ordered to nominal thicknesses shall be 0.01 in. (0.3 mm) under each for backing steel or total composite, and 0.03 in. (0.8 mm) under for the alloy cladding.

11.4 Permissible variations for excess thickness of the total composite shall be the greater of 0.125 in. (3 mm) or 10% of the total composite thickness ordered and may occur in either backing steel, cladding, or both, provided the minimum for each is met.

11.5 More restrictive or less restrictive permissible variations may be agreed upon by the purchaser and the manufacturer.

12. Workmanship Finish, and Appearance

12.1 The material shall be free of injurious defects and shall have a workmanlike appearance.

12.2 Unless otherwise specified, the clad surface may be supplied as-rolled, blasted (descaled by means of sand, grit, shot or wire followed by pickling), or 100% conditioned.

13. Bond Quality

13.1 The cladding metal shall be integrally and continuously bonded to the base metal.

13.2 Inspection:

13.2.1 Clad plates less than $\frac{3}{8}$ in. (10 mm) total minimum composite thickness shall be visually inspected for bond integrity prior to shipment.

13.2.2 Clad plates $\frac{3}{8}$ in. (10 mm) and thicker total minimum composite thickness, and when specified by the purchaser, clad plates less than $\frac{3}{8}$ in. (10 mm) total minimum composite thickness, shall be ultrasonically inspected for bond integrity prior to shipment in accordance with the Procedures and Methods of Specification A 578/A 578M.

13.2.3 Areas of non-bond detected visually shall be explored ultrasonically to determine the extent of the condition in accordance with 13.2.2. For purposes of defining non-bond, the cladding shall be interpreted to be unbonded when there is complete loss of back reflection accompanied by an echo indication from the plane of the interface of the clad and backing steel. Areas within 1 in. (25 mm) of a cut edge on the plate that contain indications exceeding 50% of the back reflection at the bond interface shall be considered to be unbonded.

13.2.4 Extent of ultrasonic examination shall be at the discretion of the manufacturer and sufficient enough to provide the quality level required by the purchaser. Plates may be ordered with 100% coverage (see Supplementary Requirement S12).

13.3 Quality Levels:

13.3.1 Class 1 — No single unbonded area exceeding 1 in. (25 mm) in its longest dimension with total unbonded area not to exceed 1% of the total clad surface area.

13.3.2 Class 3 — No single unbonded area exceeding 3 in. (75 mm) in its longest dimension with total unbonded area not to exceed 3% of the total clad surface area.

13.3.3 Class 5 — No single unbonded area exceeding 9 in.² (58 cm²) with total unbonded area not to exceed 5% of the total clad surface area.

13.3.4 The class to be supplied shall be listed on the purchase order. When none has been specified, plates shall be furnished as Class 5 at the option of the manufacturer.

14. Repair of Cladding by Welding

14.1 The material manufacturer may repair defects in cladding by welding provided the following requirements are met:

14.1.1 When specified in the purchase order, prior approval shall be obtained from the purchaser.

14.1.2 The welding procedure and the welders or welding operators shall be qualified in accordance with Section IX of the ASME Code.

14.1.3 The defective area shall be removed and the area prepared for repair shall be examined by a liquid penetrant method to ensure all defective area has been removed. Method of test and acceptance standard shall be as agreed upon between the purchaser and the manufacturer.

14.1.4 The repair weld shall be deposited in accordance with a welding procedure and welding materials suitable for the cladding material. The surface condition of the repaired area shall be restored to a condition similar to the rest of the cladding.

14.1.5 The repaired area shall be examined by a liquid penetrant method in accordance with 14.1.3.

14.1.6 The location and extent of the weld repairs together with the repair procedure and examination results shall be transmitted as a part of the certification.

15. General Requirements for Delivery

15.1 Material furnished under this specification shall conform to the applicable requirements of Specification A 6/A 6M or A 20/A 20M as appropriate for the backing metal.

15.2 In the event of conflicts between this specification and the general delivery requirement specification for the backing steel, this specification shall apply.

16. Certification

16.1 The chemical analysis of the base metal and the alloy cladding shall be certified to the purchaser by the clad plate manufacturer.

16.2 The results of the tests in Section 7 and any other tests required by the purchase order shall be reported to the purchaser.

16.3 Compliance with the clad quality level of 13.3 shall be certified. Reports shall include the results of ultrasonic inspection when Supplementary Requirement S12 is specified.

17. Product Marking

17.1 Except as specified in 17.2, plates shall be marked in accordance with the requirements of Specification A 6/A 6M or A 20/A 20M for the backing steel as applicable, the cladding alloy designation, and this specification number.

17.2 For double-clad material or for material under $\frac{3}{8}$ in. (6.35 mm) nominal in thickness or for clad plates provided with conditioned surfaces, the marking specified in 17.1 shall be legibly stenciled instead of stamped when the material is shipped with the alloy surface up.

18. Keywords

18.1 alloy cladding; bond strength; carbon steel; clad steel plate; low-alloy steel; nickel; nickel-base alloy

TABLE 1
WEIGHTS FOR COMPONENT MATERIALS

	Density		Weight per Square Foot for Material 1 in. (25.4 mm) in Thickness, lb
	lb/in. ³	g/cm ³	
Steel	0.283	7.83	40.80
Nickel	0.321	8.88	46.22
Nickel-copper alloy	0.319	8.83	45.94
Nickel-chromium-iron alloy	0.307	8.49	44.21

FIG. 1 TEST SPECIMEN AND METHOD OF MAKING SHEAR TEST OF CLAD PLATE

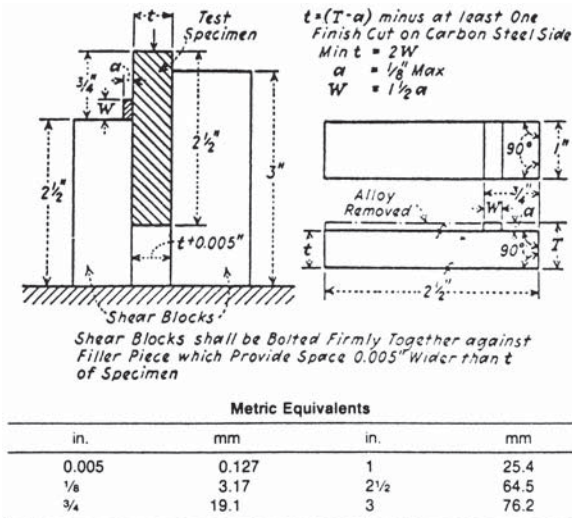
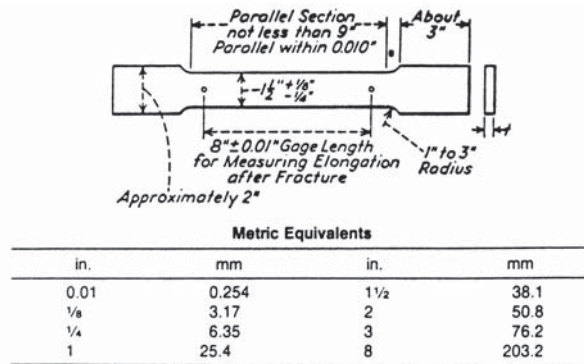


FIG. 2 STANDARD RECTANGULAR TEST SPECIMENS WITH 8 IN. GAGE LENGTH

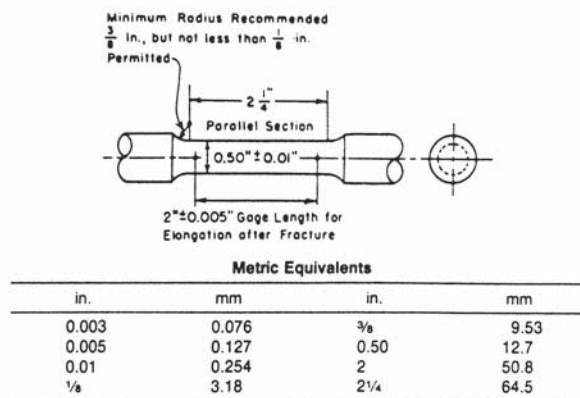


NOTE 1—When necessary, it is permissible to use a narrower specimen, but in such a case the reduced portion shall be not less than 1 in. in width.

NOTE 2—Punch marks for measuring elongation after fracture shall be made on the flat or on the edge of the specimen and within the parallel section; either a set of nine punch marks 1 in. apart, or one or more sets of 8-in. punch marks may be used.

NOTE 3—The dimension t is the thickness of the test specimen as provided for in the applicable material specifications.

FIG. 3 STANDARD ROUND TENSION TESTS SPECIMEN WITH 2 IN. GAGE LENGTH



NOTE—The gage length and fillets shall be as shown, but the ends may be of any shape to fit the holders of the testing machine in such a way that the load shall be axial. The reduced section shall have a gradual taper from the ends toward the center, with the ends 0.003 to 0.005 in. larger in diameter than the center.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified on the order. A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

S2. Product Analysis

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons

S5. Charpy V-Notch Impact Test

S12. Ultrasonic Examination in Accordance With Specification A 578/A 578M

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SPECIFICATION FOR CARBON STEEL FORGINGS FOR PRESSURE VESSEL COMPONENTS



SA-266/SA-266M



[Identical with ASTM Specification A 266/A 266M-03a(R08)]

1. Scope

1.1 This specification covers four grades of carbon steel forgings for boilers, pressure vessels, and associated equipment.

NOTE 1 — Designations have been changed as follows:

Current	Formerly
Grade 1	Class 1
Grade 2	Class 2
Grade 3	Class 3
Grade 4	Class 4

1.2 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.3 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as the standard. Within the text and tables, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.4 Unless the order specifies the applicable “M” specification designation, the material shall be furnished to the inch-pound units.

2. Referenced Documents

2.1 ASTM Standards:

- A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 788 Specification for Steel Forgings, General Requirements

E 112 Test Methods for Determining the Average Grain Size

E 165 Test Method for Liquid Penetrant Examination

E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

2.2 Other Standard:

ASME Boiler and Pressure Vessel Code, Section IX, Welding Qualifications

3. Ordering Information and General Requirements

3.1 In addition to the ordering information required by Specification A 788, the purchaser shall include with the inquiry and order a detailed drawing, sketch, or written description of the forging.

3.2 Material supplied to this specification shall conform to the requirements of Specification A 788, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A 788, the requirements of this specification shall prevail.

3.4 For hubbed flanges and tube sheets ordered for ASME Boiler and Pressure Vessel Code application, Supplementary Requirement S12 of Specification A 788 shall be specified in addition to Supplementary Requirement S8 of this specification.

4. Materials and Manufacture

4.1 The steel shall be made in accordance with the Melting Process Section of Specification A 788. A sufficient discard shall be made to secure freedom from injurious pipe and undue segregation.

4.2 The material shall be forged as close as practical to the specified shape and size.

4.3 The finished product shall be a hot-worked forging as defined by Specification A 788.

5. Machining

5.1 Surfaces shall be machined as designated by the purchaser. Unmachined surfaces shall be sufficiently free of scale to permit inspection.

5.2 Machining may be performed either prior to or after heat treatment at the option of the manufacturer unless specified in accordance with Supplementary Requirement S1.

6. Heat Treatment

6.1 After forging and before reheating for heat treatment, the forgings shall be cooled in such a manner as to prevent injury and to accomplish transformation.

6.2 All forgings shall be annealed, normalized, or normalized and tempered, but alternatively may be liquid quenched and tempered when mutually agreed upon between the manufacturer and the purchaser. When tempering is performed, it shall be at a subcritical temperature, but no less than 1100°F [595°C].

6.3 A multiple stage austenitizing procedure may be used whereby the forging is first fully austenitized and liquid quenched, followed by reheating within the intercritical temperature range to partially reaustenitize, and again liquid quenched. On completion of the austenitizing/quenching cycles, tempering at a temperature between 1100°F [595°C] and the lower critical temperature shall follow.

NOTE 2 — Although liquid quenching from the austenitizing temperatures is more effective in enhancing impact properties, air cooling from the austenitizing temperatures is also beneficial and may be used instead of the normalizing procedure in 6.2.

7. Chemical Composition

7.1 Heat Analysis — The heat analysis obtained from sampling in accordance with Specification A 788 shall comply with Table 1 except that the additional features of Supplementary Requirements S11 and S12 shall also apply as individually specified in the ordering information.

7.2 Product Analysis — The purchaser may use the product analysis provision of Specification A 788 to obtain a product analysis from a forging representing each heat or multiple heat.

8. Mechanical Properties

8.1 General Requirements — Except when otherwise specified in accordance with Supplementary Requirement S2, the material shall conform to the requirements for mechanical properties prescribed in Table 2 when tested in accordance with the latest issue of Test Methods and Definitions A 370. The largest obtainable tension test specimen as specified in Test Methods and Definitions A 370 shall be used.

8.1.1 Except when otherwise specified in accordance with Supplementary Requirement S2, the longitudinal axis of the specimens shall be parallel to the direction of major working of the forging. For upset-disc forgings, the longitudinal axis of the test specimen shall be in the tangential direction.

8.1.1.1 The longitudinal axis of the specimen shall be located midway between the parallel surfaces of the test extension if added to the periphery of disks or midway between the center and surface of solid forgings. For hollow forgings, the longitudinal axis of the specimens shall be located midway between the center and outer surfaces of the wall. When separately forged test blocks are employed as defined in 8.1.3, the tension test specimens shall be taken from a location that represents the midwall of the heaviest section of the production forgings. When specimens are required from opposite ends, they shall be taken from the diagonal corners of an axial plane.

8.1.2 Except as specified herein, tests for acceptance shall be made after heat treatment has been completed. When the ends of the cylindrical forgings are closed in by reforging, the cylindrical forgings may be annealed, normalized, or normalized and tempered and tested prior to reforging. After reforging, the entire forging shall be reheat-treated in the same manner and at the same temperature range as employed when the forging was heat-treated prior to certification testing.

8.1.3 When mutually agreed upon between manufacturer and purchaser, test specimens may be machined from a specially forged block suitably worked and heat treated with the production forgings. Such a special block shall be obtained from an ingot, slab, or billet from the same heat used to make the forgings it represents. This block shall receive essentially the same type of hot working and forging reduction as the production forgings; however, a longitudinally forged bar with dimensions not less than T by T by $3T$ may be used to represent a ring forging. The dimension T shall be representative of the heaviest effective cross section of the forging. For quenched and tempered forgings for which tests are required at both ends by 8.2.2.3 and 8.2.2.4, separately forged test blocks are not allowed.

NOTE 3 — In using separately forged test blocks, attention is drawn to the effect of mass differences between the production forgings and the test blocks.

8.2 Specific Requirements — The number and location of tests are based on forging length, weight, and heat treatment, and shall be as prescribed below. The length and weight to be used for this purpose shall be the shipped length and weight of forgings produced individually or the aggregate shipped length and weight of all pieces cut from a multiple forging.

8.2.1 Annealed, Normalized, or Normalized and Tempered Steel Forgings:

8.2.1.1 For forgings weighing 5000 lb [2250 kg] or less at the time of heat treatment, one tension test shall be taken from one forging per heat in each heat-treatment charge. When heat treatment is performed in continuous-type furnaces with suitable temperature controls and equipped with recording pyrometers so that complete heat-treatment records are available, a tempering charge may be considered as any continuous run not exceeding an 8 h period.

8.2.1.2 For forgings and forged bars weighing over 5000 lb [2250 kg] at the time of heat treatment, one tension test shall be taken from each forging.

8.2.2 Quenched and Tempered Forgings:

8.2.2.1 For quenched and tempered forgings weighing 5000 lb [2250 kg] or less at the time of heat treatment, but not exceeding 12 ft [3.7 m] in length, one tension test shall be taken from one forging per heat in each heat-treatment charge. When heat treatment is performed in continuous-type furnaces with suitable temperature controls and equipped with recording pyrometers so that complete heat-treatment records are available, a tempering charge may be considered as any continuous run not exceeding an 8-h period.

8.2.2.2 For quenched and tempered forgings and forged bars weighing over 5000 lb [2250 kg] to 10 000 lb [4500 kg] at the time of heat treatment, but not exceeding 12 ft [3.7 m] in length, one tension test shall be taken from each forging.

8.2.2.3 For quenched and tempered forgings and forged bars that exceed 12 ft [3.7 m] in length, one tension test shall be taken from each end of each forging.

8.2.2.4 For quenched and tempered forgings and forged bars weighing more than 10 000 lb [4500 kg] at the time of heat treatment, two tension test specimens shall be taken from each forging. These shall be offset 180° from each other except that if the length of the forging, excluding test prolongations, exceeds 12 ft [3.7 m], then one specimen shall be taken from each end of the forging.

9. Repair Welding

9.1 Repair welding of forgings is permissible only at the option of the purchaser. If repair welding is performed,

welders and weld procedures shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

10. Certification

10.1 In addition to the mandatory certification requirements of Specification A 788, the heat treatment cycle data shall be included.

11. Product Marking

11.1 Each forging shall be identified in accordance with the Marking Section of Specification A 788. In addition, the forging shall be marked following the grade designation by the letter “A” for annealed, “N” for normalized, “NT” for normalized and tempered, and “S” for liquid quenched and tempered, as applicable.

12. Keywords

12.1 pressure vessel service; steel forgings—carbon

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %		
	Grades 1 and 2	Grade 3	Grade 4
Carbon, max	0.30	0.35	0.30
Manganese	0.40–1.05	0.80–1.35	0.80–1.35
Phosphorus, max	0.025	0.025	0.025
Sulfur, max	0.025	0.025	0.025
Silicon	0.15–0.35	0.15–0.35	0.15–0.35

TABLE 2
TENSILE REQUIREMENTS

	Grade 1	Grades 2 and 4	Grade 3
Tensile strength, min, ksi [MPa]	60–85 [415–585]	70–95 [485–655]	75–100 [515–690]
Yield strength (0.2% offset), min, ksi [MPa]	30 [205]	36 [250]	37.5 [260]
Elongation in 2 in. or 50 mm, min, %	23	20	19
Reduction of area, min, %	38	33	30

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon between the manufacturer and the purchaser.

S1. Rough Turning and Boring

S1.1 The position of the rough turning and boring in the sequence of manufacturing operations shall be as specified by the purchaser.

S2. Alternative Tension Test Orientation

S2.1 In lieu of the requirements of Section 8, the longitudinal axis of the test specimens shall be transverse to the direction of major working of the forging. The results shall conform with requirements of Table 2, with the exception of the ductility limits that shall be as follows:

Grade	1	2 and 4	3
Elongation in 2 in. [50 mm], min, %	20	19	18
Reduction of area, min, %	30	25	25

S3. Hydrostatic Test

S3.1 A hydrostatic pressure test shall be applied. The details of the test, including its position in the sequence of manufacturing operations, shall be specified.

S4. Magnetic Particle Examination

S4.1 All accessible surfaces of the finished forging shall be examined by a magnetic particle method. The method shall be in accordance with Test Method A 275/A 275 M. Acceptance limits shall be as agreed upon between the manufacturer and the purchaser.

S5. Liquid Penetrant Examination

S5.1 After forgings have been heat treated by liquid quenching and tempering, all accessible surfaces shall be inspected for quench cracks by the liquid penetrant method in accordance with Test Method E 165 as an alternative to magnetic particle examination.

S6. Macroetch Test

S6.1 A sample forging shall be sectioned and etched to show flow lines and internal imperfections. The test shall be conducted in accordance with Method E 381. Details of the test shall be agreed upon between the manufacturer and the purchaser.

S7. Product Analysis

S7.1 A product analysis in accordance with Section 7 shall be made from one randomly selected forging representing each size and shape of forging on the order. If the analysis fails to comply, each forging shall be checked or the lot rejected. All results shall be reported to the purchaser.

S8. Specimen Location on Forged Hubs

S8.1 Forged hubs to be butt-welded to shells shall be forged in such a manner as to provide in the hub the full minimum tensile strength and elongation specified for the material, in a direction parallel to the axis of the vessel. A tension specimen (subsize if necessary) shall be taken in this direction and as close to the finished hub outside diameter as practical.

S9. Hardness

S9.1 The purchaser may check the Brinell hardness of the forging at any location on the surface of the forging, and the hardness shall be within the following limits:

Grade	Brinell Hardness Limits
1	121 to 170
2 and 4	137 to 197
3	156 to 207

S10. Grain Size

S10.1 The austenitic grain size of the steel shall be 1 to 5 as determined using Test Methods E 112.

S11. Restriction on Residual Elements (Applicable to Heat Analysis)

S11.1 Nickel, chromium, and molybdenum shall be determined and shall not exceed the following limits:

Nickel	0.25% max
Chromium	0.20% max
Molybdenum	0.08% max

S12. Restriction on Carbon (Applicable to Grade I)

S12.1 The carbon content shall be 0.30% max.

S13. Impact Tests

S13.1 Charpy impact tests shall be made. The number and location of the tests, minimum properties, and test temperatures shall be specified.

S13.2 The specimens shall be machined and tested in accordance with Test Methods and Definitions A 370.

S13.3 Retests may be conducted in accordance with Section 10 of Specification A 788.

S14. Individual Forging

S14.1 Forgings, whether identical or not, shall be produced individually. They shall not be forged in multiples and separated prior to or after heat treatment.

S14.2 The shape and size of individual forgings shall be agreed upon between the manufacturer and the purchaser by means of a forging drawing or the purchase order.

S15. Carbon Equivalency

S15.1 The heat analysis including the residual element restrictions of S1 in Specification A 788 shall be limited such that the carbon equivalent shall not exceed 0.45 for Grade 1 or 0.50 for Grade 2 or 4 when calculated in accordance with the following formula:

$$CE = \% C + \frac{\% Mn}{6} + \frac{\% Cr + \% Mo + \% V}{5} + \frac{\% Ni + \% Cu}{15}$$

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SPECIFICATION FOR SEAMLESS AND WELDED FERRITIC AND MARTENSITIC STAINLESS STEEL TUBING FOR GENERAL SERVICE



SA-268/SA-268M



(Identical with ASTM Specification A 268/A 268M-05a.)

1. Scope

1.1 This specification covers a number of grades of nominal-wall-thickness, stainless steel tubing for general corrosion-resisting and high-temperature service. Most of these grades are commonly known as the “straight-chromium” types and are characterized by being ferromagnetic. Two of these grades, TP410 and UNS S41500 (Table 1), are amenable to hardening by heat treatment, and the high-chromium, ferritic alloys are sensitive to notch-brittleness on slow cooling to ordinary temperatures. These features should be recognized in the use of these materials. Grade TP439 is used primarily for hot-water tank service and does not require post-weld heat treatment to prevent attack of the heat affected zone.

1.2 An optional supplementary requirement is provided, and when desired, shall be so stated in the order.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

2. Referenced Documents

2.1 ASTM Standards:

- A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip
- A 763 Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels

A 1016/A 1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 273 Practice for Ultrasonic Examination of the Weld Zone of Welded Pipe and Tubing

3. Terminology

3.1 Lot Definitions:

3.1.1 For flange and flaring requirements, the term lot applies to all tubes, prior to cutting, of the same nominal size and wall thickness that are produced from the same heat of steel. If final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat that are heat treated in the same furnace charge. If the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as given in Table 2.

3.1.2 For tensile and hardness test requirements, the term lot applies to all tubes, prior to cutting, of the same nominal diameter and wall thickness that are produced from the same heat of steel. If final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat that are heat treated in the same furnace charge. If the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered

under this specification. Such requirements may include, but are not limited to, the following:

- 4.1.1 Quantity (feet, metres, or number of lengths),
- 4.1.2 Name of material (seamless or welded tubes),
- 4.1.3 Grade (Table 1),
- 4.1.4 Size (outside diameter and nominal wall thickness),
- 4.1.5 Length (specific or random),
- 4.1.6 Optional requirements (hydrostatic or nondestructive electric test, Section 16),
- 4.1.7 Test report required (Certification Section of Specification A 1016/A 1016M),
- 4.1.8 Specification designation,
- 4.1.9 Intergranular corrosion test, and
- 4.1.10 Special requirements.

5. General Requirements

5.1 Material furnished under this specification shall conform to the applicable requirements of Specification A 1016/A 1016M unless otherwise provided herein.

6. Manufacture

6.1 The tubes shall be made by the seamless or welded process with no filler metal added.

7. Heat Treatment

7.1 As a final heat treatment, tubes shall be reheated to a temperature of 1200°F [650°C] or higher and cooled (as appropriate for the grade) to meet the requirements of this specification.

7.2 The martensitic grade UNS S41500 shall be reheated to a temperature of 950°F [510°C] or higher and cooled as appropriate to meet the requirements of this specification.

8. Chemical Composition

8.1 The steel shall conform to the chemical requirements prescribed in Table 1.

9. Product Analysis

9.1 An analysis of either one billet or one length of flatrolled stock or one tube shall be made from each heat. The chemical composition thus determined shall conform to the requirements specified.

9.2 The product analysis tolerance of the Chemical Requirements Table of A 480/A 480M shall apply. The

product analysis tolerance is not applicable to the carbon content for material with a specified maximum carbon of 0.04% or less.

9.3 If the original test for product analysis fails, retests of two additional billets, lengths of flat-rolled stock or tubes shall be made. Both retests for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets, lengths of flat-rolled stock or tubes which do not meet the requirements of the specification shall be rejected.

10. Tensile Requirements

10.1 The material shall conform to the tensile properties prescribed in Tables 3 and 4.

11. Hardness Requirements

11.1 The tubes shall have a hardness number not to exceed those prescribed in Table 5.

12. Permissible Variations in Dimensions

12.1 Variations in outside diameter, wall thickness, and length from those specified shall not exceed the amounts prescribed in Table 6.

12.2 The permissible variations in outside diameter given in Table 6 are not sufficient to provide for ovality in thin-walled tubes, as defined in the Table. In such tubes, the maximum and minimum diameters at any cross section shall deviate from the nominal diameter by no more than twice the permissible variation in outside diameter given in Table 6; however, the mean diameter at that cross section must still be within the given permissible variation.

12.3 When the specified wall is 2% or less of the specified outside diameter, the method of measurement is in accordance with the agreement between the purchaser and the manufacturer (see Note 1).

NOTE 1 — Very thin wall tubing may not be stiff enough for the outside diameter to be accurately measured with a point contact test method, such as with the use of a micrometer or caliper. When very thin walls are specified, “go” – “no go” ring gages are commonly used to measure diameters of 1½ in. [38.1 mm] or less. A0.002 in. [0.05 mm] additional tolerance is usually added on the “go” ring gage to allow clearance for sliding. On larger diameters, measurement is commonly performed with a pi tape. Other test methods such as optical test methods may also be considered.

13. Surface Condition

13.1 All tubes shall be free of excessive mill scale, suitable for inspection. A slight amount of oxidation will

not be considered as scale. Any special finish requirements shall be subject to agreement between the manufacturer and the purchaser.

14. Mechanical Tests Required

14.1 Tension Tests — One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes.

14.2 Flaring Test (for Seamless Tubes) — One test shall be made on specimens from one end of one tube from each lot of finished tubes. The minimum expansion of the inside diameter shall be 10%. For tubes over 8 in. [203.2 mm] in outside diameter, or tubes with wall thickness $\frac{3}{8}$ in. [9.52 mm] and over, the flattening test may be performed instead of the flaring test unless the flaring test is specified in the purchase order.

14.3 Flange Test (for Welded Tubes) — One test shall be made on specimens from one end of one tube from each lot of finished tubes. For tubes over 8 in. [203.2 mm] in outside diameter, or tubes with wall thickness $\frac{3}{8}$ in. [9.52 mm] and over, the flattening test may be performed instead of the flange test unless the flange test is specified in the purchase order.

14.4 Hardness Test — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot.

14.5 When more than one heat is involved, the tension, flaring, flanging, and hardness test requirements shall apply to each heat.

14.6 Reverse Flattening Test — For welded tubes, one reverse flattening test shall be made on a specimen from each 1500 ft [450 m] of finished tubing.

15. Intergranular Corrosion Test

15.1 If intergranular corrosion testing is specified in the purchase order, the test shall be made in accordance with Practices A 763, using samples prepared as agreed upon between the seller and the purchaser.

16. Hydrostatic or Nondestructive Electric Test

16.1 Each tube, seamless or welded, shall be subjected to the nondestructive electric test or the hydrostatic test. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

17. Product Marking

17.1 In addition to the marking described in Specification A 1016/A 1016M, the marking shall indicate whether the tubing is seamless or welded.

18. Keywords

18.1 ferritic stainless steel; seamless steel tube; stainless steel tube; steel tube; welded steel tube

TABLE 1
CHEMICAL REQUIREMENTS

		Composition, %																
Grade	UNS Designation	Carbon		Manganese		Phosphorous		Sulfur		Silicon	Nickel	Chromium	Molybdenum	Aluminum	Copper	Nitrogen	Titanium	Columbium
		Max		Max		Max		Max										
....	S32803	0.015 ^C	0.5	0.020	0.005	0.50	3.0–4.0	28.0–29.0	1.8–2.5	...	...	0.020 max	...	...	...	...	...	0.15–0.50 ^F
TP405	S40500	0.08	1.00	0.040	0.030	1.00	0.50 max	11.5–14.5	...	0.10–0.30	...	...	...	...	...	...	...	...
....	S40800	0.08	1.00	0.045	0.045	1.00	0.80 max	11.5–13.0	...	...	...	...	...	...	...	12 × C min; 1.10 max	...	...
TP409	S40900	0.08	1.00	0.045	0.030	1.00	0.50 max	10.5–11.7	...	...	...	...	...	...	...	6 × C min; 0.75 max	...	...
....	S40977	0.03	1.50	0.040	0.015	1.00	0.30–1.00	10.50–12.50	...	...	...	0.030 max	...	...	...	...	...	...
TP410	S41000	0.15	1.00	0.040	0.030	1.00	...	11.5–13.5	...	...	...	...	...	...	...	...	...	...
....	S41500 ^B	0.05	0.5–1.0	0.03	0.03	0.60	3.5–5.5	11.5–14.0	0.5–1.0	...	...	...	...	...	...	...	...	...
....	S42035	0.08	1.00	0.045	0.030	1.00	1.0–2.5	13.5–15.5	0.2–1.2	...	...	...	...	...	...	0.30–0.50	...	...
TP429	S42900	0.12	1.00	0.040	0.030	1.00	...	14.0–16.0	...	...	...	...	...	...	...	...	...	...
TP430	S43000	0.12	1.00	0.040	0.030	1.00	...	16.0–18.0	...	...	...	...	...	...	...	...	...	...
TP439	S43035	0.07	1.00	0.040	0.030	1.00	0.50 max	17.00–19.00	...	0.15 max	...	0.04 max	0.20 + 4 (C + N) min; 1.10 max	...	...	...	...	...
TP430 Ti	S43036	0.10	1.00	0.040	0.030	1.00	0.75 max	16.00–19.50	...	...	...	...	5 × C min; 0.75 max	...	...	...	...	...
....	S43932	0.030	1.00	0.040	0.030	1.00	0.50	17.0–19.0	...	0.15 max	...	0.030 max	(Ti + Cb) = 0.20 + 4 (C + N) min; 0.75 max	...	...	...	...	(3 × %C + 0.30) min
....	S43940	0.03	1.00	0.040	0.015	1.00	...	17.50–18.50	...	...	...	...	0.10–0.60	...	...	...	...	...
TP443	S44300	0.20	1.00	0.040	0.030	1.00	0.75 max	18.0–23.0	...	...	0.90–1.25	...	...	...	...	...	...	...
18Cr-2Mo	S44400	0.025	1.00	0.040	0.030	1.00	1.00 max	17.5–19.5	1.75–2.50	...	...	0.035 max	(Ti + Cb) = 0.20 + 4 (C + N) min; 0.80 max	...	...	...	...	...
TP446-1	S44600	0.20	1.50	0.040	0.030	1.00	0.75 max	23.0–27.0	...	...	...	0.25	...	...	...	...	...	...
TP446-2 ^A	S44600	0.12	1.50	0.040	0.030	1.00	0.50 max	23.0–27.0	...	...	...	0.25	...	...	...	...	...	...
TPXM-33 ^A	S44626	0.06	0.75	0.040	0.020	0.75	0.50 max	25.0–27.0	0.75–1.50	...	0.20 max	0.040 max	7 × (C + N) but no less than 0.20 min; 1.00 max	...	...	...	...	...
TPXM-27	S44627	0.01 ^A	0.40	0.02	0.02	0.40	0.5 ^D max	25.0–27.5	0.75–1.50	...	0.2 max	0.015 max	...	...	...	...	...	0.05–0.20
25-4-4	S44635	0.025	1.00	0.040	0.030	0.75	3.5–4.5	24.5–26.0	3.5–4.5	...	...	0.035 max	(Ti + Cb) = 0.20 + 4 (C + N) min; 0.80 max	...	...	...	...	...

TABLE 1
CHEMICAL REQUIREMENTS (CONT'D)

Grade	UNS Designation	Composition, %																	
		Carbon		Manganese		Phosphorous		Sulfur		Silicon		Nickel	Chromium	Molybdenum	Aluminum	Copper	Nitrogen	Titanium	Columbium
		Max		Max		Max		Max		Max									
26-3-3	S44660	0.030	1.00	0.040	0.030	1.00	1.0-3.50	25.0-28.0	3.0-4.0	...	...	0.040 max (Ti + Cb) = 0.20-1.00 and 6 x (C + N) min	...	...	...	...	...	...
29-4	S44700	0.010	0.30	0.025	0.020	0.20	0.15 max	28.0-30.0	3.5-4.2	...	0.15 max	0.020 ^E	...	...	...	...	...	...
...	S44735	0.030	1.00	0.040	0.030	1.00	1.00 max	28.00-30.00	3.60-4.20	...	...	0.045 max (Ti + Cb) = 0.20-1.00 and 6 x (C + N) min	...	...	...	...	...	...
29-4-2	S44800	0.010	0.30	0.025	0.020	0.20	2.0-2.5	28.0-30.0	3.5-4.2	...	0.15 max	0.020 ^E	...	...	...	...	...	...
TP468	S46800	0.030	1.00	0.040	0.030	1.00	0.50	18.00-20.00	...	...	...	0.030 max 0.07-0.30	...	...	...	0.10-0.60 (Ti + Cb) = 0.20 + 4 (C + N) min; 0.80 max	...	...

^A For small diameter or thin walls, or both, tubing, where many drawing passes are required, a carbon maximum of 0.015% is necessary. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes as those less than 0.049 in. [1.2 mm] in average wall thickness (0.040 in. [1 mm] in minimum wall thickness).

^B Plate version of CA6NM.

^C Carbon plus nitrogen = 0.30 max.

^D Nickel plus copper.

^E Carbon plus nitrogen = 0.025% max.

^F Cb/(C + N) = 12 min.

TABLE 2
NUMBER OF TUBES IN A LOT HEAT TREATED BY THE CONTINUOUS PROCESS

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in. [5.1 mm] and over in wall thickness	Not more than 50 tubes
Less than 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter or over 1 in. [25.4 mm] in outside diameter and under 0.200 in. [5.1 mm] in wall thickness	Not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	Not more than 125 tubes

TABLE 3
TENSILE REQUIREMENTS

Grade and UNS Designation	Tensile Strength, Min, ksi [MPa]	Yield Strength, Min, ksi [MPa]	Elongation ^{A,B} in 2 in. or 50 mm, Min, %
TP405 S40500	60 [415]	30 [205]	20
... S40800	55 [380]	30 [205]	20
TP410 S41000	60 [415]	30 [205]	20
TP429, TP430, and TP430 Ti S42900, S43000, and S43036	60 [415]	35 [240]	20
TP443 S44300	70 [485]	40 [275]	20
TP446-1 S44600	70 [485]	40 [275]	18
TP446-2 S44600	65 [450]	40 [275]	20
TP409 S40900	55 [380]	25 [170]	20
TP439 S43035	60 [415]	30 [205]	20
S43932	60 [415]	30 [205]	20
... S41500	115 [795]	90 [620]	15
TPXM-27 S44627	65 [450]	40 [275]	20
TPXM-33 S44626	68 [470]	45 [310]	20
18Cr-2Mo S44400	60 [415]	40 [275]	20
29-4 and 29-4-2 S44700 and S44800	80 [550]	60 [415]	20
26-3-3 S44660	85 [585]	65 [450]	20
25-4-4 S44635	90 [620]	75 [515]	20
... S44735	75 [515]	60 [415]	18
28-2-3.5 S32803	87 [600]	72 [500]	16
S40977	65 [450]	41 [280]	18
S43940	62 [430]	36 [250]	18
S42035	80 [550]	55 [380]	16
TP468 S46800	60 [415]	30 [205]	22

^A For tubing smaller than $\frac{1}{2}$ in. [12.7 mm] in outside diameter, the elongation values given for strip specimens in Table 2 shall apply. Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in outside diameter or with walls thinner than 0.015 in. [0.4 mm].

^B For longitudinal strip tests a deduction of 0.90% for TP446-1 and S44735 and 1.00% for all other grades shall be made from the basic minimum elongation for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{7}{16}$ in. [8 mm]. The following table gives the computed minimum values:

TABLE 4
MINIMUM ELONGATION VALUES

Wall Thickness		Elongation ⁴ in 2 in. or 50 mm, Min, %		
in.	mm	TP446-1 and S44735	S41500	All Other Grades
$\frac{5}{16}$ [0.312]	8	18	15	20
$\frac{9}{32}$ [0.281]	7.2	17	14	19
$\frac{1}{4}$ [0.250]	6.4	16	14	18
$\frac{7}{32}$ [0.219]	5.6	15	13	17
$\frac{3}{16}$ [0.188]	4.8	14	12	16
$\frac{5}{32}$ [0.156]	4	13	11	15
$\frac{1}{8}$ [0.125]	3.2	13	11	14
$\frac{3}{32}$ [0.094]	2.4	12	10	13
$\frac{1}{16}$ [0.062]	1.6	11	9	12
0.062–0.035, excl	1.6–0.9	10	8	12
0.035–0.022, excl	0.9–0.6	10	8	11
0.022–0.015, incl	0.6–0.4	10	8	11

⁴ Calculated elongation requirements shall be rounded to the nearest whole number.

NOTE — The above table gives the computed minimum values for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined by the following equation:

Grade	Equation
TP446-1 and S44735	$E = 28.8t + 9.00$ [$E = 1.13t + 9.00$]
S41500	$E = 24t + 7.5$
All other grades	$E = 32t + 10.00$ [$E = 1.25t + 10.00$]

where:

E = elongation in 2 in. or 50 mm, %.

t = actual thickness of specimen, in. [mm].

TABLE 5
HARDNESS REQUIREMENTS

Grade	UNS Designation	Brinell Hardness, Max	Rockwell Hardness, B Scale, Max
TP405	S40500	207	95
...	S40800	207	95
TP410	S41000	207	95
TP429, TP430, and TP430 Ti	S42900, S43000, and S43036	190	90
TP443	S44300	207	95
TP446-1 and TP446-2	S44600	207	95
TP409	S40900	207	95
TP439	S43035 ^A	190	90
...	S43932	190	90
...	S41500	295 ^B	32
TPXM-33 and TPXM-27	S44626 and S44627	241	100
18Cr-2Mo	S44400	217	95
29-4 and 29-4-2	S44700 and S44800	207	100
26-3-3	S44660	265	25 ^B
25-4-4	S44635	270	27 ^B
...	S44735	...	100
28-2-3.5	S32803	240	100
...	S40977	180	88
...	S43940	180	88
...	S42035	180	88

^A Editorially corrected October 2000.

^B Rockwell hardness, C scale.

TABLE 6
PERMISSIBLE VARIATIONS IN DIMENSIONS

Group	Size, Outside Diameter, in. [mm]	Permissible Variations in Outside Diameter, in. [mm]	Permissible Variations in Wall Thickness, ^A %	Permissible Variations in Cut Length, in. ^B [mm]		Thin-Walled Tubes ^C
				Over	Under	
1	Up to 1/2 [12.7], excl	±0.005 [0.13]	±15	1/8 [3]	0	...
2	1/2 to 1 1/2 [12.7 to 38.1], excl	±0.005 [0.13]	±10	1/8 [3]	0	Less than 0.065 in. [1.6 mm] nominal
3	1 1/2 to 3 1/2 [38.1 to 88.9], excl	±0.010 [0.25]	±10	3/16 [5]	0	Less than 0.095 in. [2.4 mm] nominal
4	3 1/2 to 5 1/2 [88.9 to 139.7], excl	±0.015 [0.38]	±10	3/16 [5]	0	Less than 0.150 in. [3.8 mm] nominal
5	5 1/2 to 8 [139.7 to 203.2], incl	±0.030 [0.76]	±10	3/16 [5]	0	Less than 0.150 in. [3.8 mm] nominal

^A When tubes as ordered require wall thicknesses 3/4 in. [19 mm] or over, or an inside diameter 60% or less of the outside diameter, a wider variation in wall thickness is required. On such sizes a variation in wall thickness of 12.5% over or under will be permitted. For tubes less than 1/2 in. [12.7 mm] in inside diameter which cannot be successfully drawn over a mandrel, the wall thickness may vary ±15% from that specified.

^B These tolerances apply to cut lengths up to and including 24 ft [7.3 m]. For lengths greater than 24 ft [7.3 m], the above over tolerances shall be increased by 1/8 in. [3 mm] for each 10 ft [3 m] or fraction thereof over 24 ft, or 1/2 in. [13 mm], whichever is lesser.

^C Ovality provisions of 12.2 apply.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order.

S1. Air-Underwater Pressure Test

S1.1 When specified, the tubing shall be examined by the air underwater pressure test.

S2. Additional Testing of Welded Tubing for 100% Joint Efficiency in Certain ASME Applications (see Note S2.1)

NOTE S2.1 — When specified, the special testing in this supplement is intended for special ASME applications. It is not mandatory for all ASME applications.

S2.1 Where this supplement is specified in the purchase order, in certain ASME applications it is permissible to use 100% joint efficiency for the longitudinal weld, provided the following additional requirements are met:

S2.1.1 Each tube shall be subjected to an ultrasonic inspection employing Practices E 273 or E 213 with the rejection criteria referenced in Specification A 1016/A 1016M.

S2.1.2 If Practice E 273 is employed, a 100% volumetric inspection of the entire length of each tube shall also be performed using one of the non-destructive electric tests permitted by Specification A 1016/A 1016M.

S2.1.3 The test methods described in the supplement may not be capable of inspecting the end portions of tubes. This condition is referred to as end effect. This portion, as determined by the manufacturer, shall be removed and discarded.

S2.1.4 In addition to the marking prescribed in Specification A 1016/A 1016M, “S2” shall be added after the grade designation.

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TEST METHOD FOR MAGNETIC PARTICLE EXAMINATION OF STEEL FORGINGS



SA-275/SA-275M



(Identical with ASTM Specification A 275/A 275M-06.)

1. Scope

1.1 This test method covers a procedure for magnetic particle examination of steel forgings. The procedure will produce consistent results upon which acceptance standards can be based. This standard does not contain acceptance standards or recommended quality levels.

1.2 Only direct current or rectified alternating (full or half wave) current shall be used as the electric power source for any of the magnetizing methods. Alternating current is not permitted because its capability to detect subsurface discontinuities is very limited and therefore unsuitable.

1.2.1 Portable battery powered electromagnetic yokes are outside the scope of this test method.

NOTE 1 — Guide E 709 may be utilized for magnetic particle examination in the field for machinery components originally manufactured from steel forgings.

1.3 The minimum requirements for magnetic particle examination shall conform to practice standards of Practice E 1444. If the requirements of this test method are in conflict with the requirements of Practice E 1444, the requirements of this test method shall prevail.

1.4 This specification and the applicable material specifications are expressed in both inch-pound units and SI units. However, unless the order specifies the applicable “M” specification designation [SI units], the material shall be furnished to inch-pound units.

1.5 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish*

appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:

E 709 Guide for Magnetic Particle Examination
E 1444 Practice for Magnetic Particle Testing

2.2 Other Document:

Recommended Practice No. SNT-TC-1A, Supplement B-Magnetic Particle Method

3. Terminology

3.1 Definitions:

3.1.1 indication — the visual magnetic particle buildup resulting from leakage fields in the magnetic field.

3.1.2 linear indication — an indication in which the length is at least three times the width. The minimum length of indications to be considered linear shall be $\frac{1}{16}$ in. [1.6 mm].

3.1.3 magnetic flux — the product of the magnetic induction and the area of a surface (or cross section) when the magnetic induction is uniformly distributed and normal to the plane of the surface. The concept that the magnetic field is flowing along the lines of force suggests that these lines are therefore “flux” lines, and they are called magnetic flux.

3.1.4 magnetic particle method of examination — a method for detecting discontinuities on or near the surface in suitably magnetized materials, which employs finely divided magnetic particles that tend to congregate in regions of leakage fields.

3.1.5 nonrelevant indications — indications produced by leakage fields. However, the conditions causing them are present by design or accident, or other features of the

part having no relation to the damaging flaws being sought. The term signifies that such an indication has no relation to the discontinuities that might constitute defects.

4. Basis of Application

4.1 When in accordance with the requirements of the inquiry, contract, order, or specifications, forgings are furnished subject to magnetic particle examination, the manufacturer and the purchaser shall be in agreement concerning the following:

4.1.1 The locations on the forgings that are to be subjected to magnetic particle examination.

4.1.2 The type, size, number, location, and orientation of indications that are to be considered injurious.

4.1.3 The method of application of magnetic particles, demagnetization requirements and magnetic field strengths.

4.2 In cases where large undercuts in the forgings are to be taken by the purchaser, the manufacturer shall be given the privilege (when the design permits) of machining slots or grooves in the rough-machined forging to explore the internal conditions prior to shipping.

4.3 Acceptance standards.

5. Personnel Requirements

5.1 Personnel performing the magnetic particle examination to this test method shall be qualified and certified in accordance with a written procedure conforming to Recommended Practice No. SNT-TC-1A or another national standard that is acceptable to both the purchaser and the supplier.

6. Stage of Inspection

6.1 Unless otherwise specified by the purchaser, acceptance inspection shall be performed on a forging in the final machined surface condition and final thermally treated condition (including stress relief) or within 0.030 in. [0.8 mm] of the final machined surface.

7. Magnetizing Apparatus

7.1 Rectified alternating (full or half wave) or direct-current electric power sources may be used. When current is passed through the part itself, the equipment shall consist of contacting or clamping elements with sufficient surface area and clamping pressure to allow the required current to flow without damaging (burning) the part being examined.

7.2 Portable electromagnetic (ac-dc) yokes may be used in the dc mode as a magnetizing apparatus, provided the

sensitivity to detect crack-like defects is demonstrated to be at least equivalent to that of the direct-magnetization method.

7.2.1 Portable battery powered electromagnetic yokes are not included in the scope of this standard.

8. Magnetic Particles

8.1 The inspection medium shall consist of finely divided ferromagnetic particles, which may be suspended in a suitable liquid medium, or used in dry powder form.

8.2 The size and shape of the particles, and their magnetic properties, both individually and collectively, are important (see Section 11).

9. Surface Preparation

9.1 The sensitivity of the magnetic particle examination will depend to a considerable extent upon the condition of the surface being tested. Defects may be satisfactorily revealed on shot-blasted or otherwise cleaned forged surfaces, or on surfaces having small amounts of heat-treating scale without any special surface preparation; however, loose scale must be removed. To reveal fine defects, the surfaces to be inspected should be smooth machined to at least a 250 μ in. [6.35 μ m] finish.

9.2 The surfaces shall be free of grease, oils, or other substances to which the particles may adhere.

9.3 Rough surfaces hamper the mobility of magnetic powders due to mechanical trapping which in turn produces false indications. Such areas should be surface ground. If grinding is impractical, a paper tape overlay (as described in 14.1.1.2) may eliminate the problem.

10. Methods of Magnetization

10.1 The forging may be magnetized either by passing current through the piece or by inducing a magnetic field by means of a central conductor or by coils.

10.1.1 Continuous Method — In the continuous method, the inspection medium is applied to the surface under inspection while the current is still flowing. The current source generates high amperage current in pulses of up to 1-s duration. The duration of this flow shall allow at least three pulses of current or in the case where machines supply continuous current flow a minimum shot of $\frac{1}{5}$ to $\frac{1}{2}$ -s duration should be applied.

10.1.2 Surge Method — In the surge method a high-magnetizing force is applied and then reduced to a lower continuous value, which is maintained during application of the inspection medium.

10.2 At least two separate examinations shall be carried out on each area. The second examination shall be with the lines of magnetic flux approximately perpendicular to those used for the first examination in that area. A different means of magnetizing may be used for the second examination. Magnetizing in more than one direction cannot be accomplished simultaneously.

NOTE 2 — An exception to the above rule is overall sequential multi-vector magnetization whereby several magnetizing circuits are provided for sequentially magnetizing a part in multiple directions depending upon the locations of the current connectors. By this technique, flaws of any orientation can be detected with a single application of magnetic particles.

10.3 The two general types of magnetization with regard to direction are longitudinal and circular, as follows:

10.3.1 Longitudinal — When a forging is magnetized longitudinally, the magnetic flux lines are usually parallel to the axis of the piece. A longitudinally magnetized piece always has definite poles readily detectable by compass or magnetometer. Longitudinal magnetization is usually accomplished by placing the forging within a solenoid, often formed by wrapping cable around the piece (Fig. 1). For special applications, magnetic yokes can be used (Fig. 2) when requirements of 7.2 are met.

10.3.2 Circular — Circular magnetization is obtained by passing a current directly through the piece (Fig. 3), or induced through a conductor (Fig. 4), or conductors threaded (Fig. 5) through an opening in the piece. Localized circular magnetization may be obtained by passing current through the local areas by use of prod-type contacts (Fig. 6).

10.4 The magnetic field is confined almost entirely to the piece and there may be no external manifestation of the magnetized condition. Indications will appear strongest in the direction perpendicular to the direction of the magnetic field.

10.5 Field Strength — The minimum field strength that will reveal and permit classification of all objectionable defects shall be used. The maximum field strengths practical are the ones just below the point at which excessive adherence of the particles begins to occur over the surface being inspected.

10.5.1 Coil Magnetization — When coil magnetization is used, the magnetic field strength is directly proportional to the current (ampere-turns if a coil or solenoid is used) and inversely proportional to the thickness of the section being inspected.

10.5.1.1 Longitudinal Magnetization — For encircling coils (Fig. 1), the turns of the coil shall be kept closely together. The field strength decreases as distance from the coil increases and long parts must be magnetized in sections. If the area to be inspected extends beyond 6 in. [150 mm] on either side of the coils, the adequacy of the

field shall be demonstrated by the use of field indicators (see 10.5.6).

(1) *Small Forgings* — Magnetizing force shall be 35 000 ampere-turns divided by the sum of 2 plus the “length over diameter” ratio of the test part. For example, a part 10 in. [250 mm] long by 2 in. [50 mm] in outside diameter has an L/D ratio of 5. Therefore, $35\,000/(2 + 5) = 5000$ ampere-turns; if a 5-turn coil is used, the current required is $5000/5$ or 1000 A. This formula provides an adequate field strength on small parts having an L/D ratio of 4 or greater. For parts having a smaller L/D ratio, adequate field strengths shall be demonstrated by the use of a field indicator (see 10.5.6). The graph in Fig. 7 may be used to determine the ampere-turns required for each L/D relationship.

(2) *Large Forgings* — For large forgings the magnetizing force shall be in the range from 1200 to 4500 ampere-turns. A field indicator (see 10.5.6) shall be used to demonstrate the presence of an adequate field strength over the area to be inspected.

10.5.1.2 Circular Magnetization (Fig. 5) — For circular magnetization with through coils, use the current with amperage as specified in 10.5.2 divided by the number of turns in the coil.

10.5.2 Direct Magnetization — When current is passed directly through the part to be examined, the current shall be between 100 and 900 A per inch [4 and 35 A per millimetre] of diameter or cross section (per inch or millimetre of greatest width in a plane at right angles to current flow). For hollow parts this would be wall thickness when cables are clamped to the wall. Suggested current for diameters or sections up to 5 in. [125 mm] are 600 to 900 A per inch [25 to 35 A per millimetre]; for diameters or sections between 5 and 10 in. [125 to 250 mm], 400 to 600 A per inch [15 to 25 A per millimetre]; and 100 to 400 A per inch [4 to 15 A per millimetre] for outside diameters or sections over 10 in. [250 mm]. If it is not practical to obtain these current levels for diameters over 10 in. [250 mm], the presence of an adequate field strength shall be demonstrated using a field indicator. In all other instances the adequacy of the magnetizing force shall be demonstrated by means of a field indicator (see 10.5.6). When large parts have been examined by clamping contacts to the wall thickness the adequacy of the field in the circumferential direction shall also be determined by the field indicator.

10.5.3 Prod Magnetization — When prods are used to circularly magnetize a local area, the field strength is directly proportional to the amperage used but also varies with the prod spacing and thickness of section being inspected.

10.5.3.1 A magnetizing force of 75 to 100 A per linear inch [3 to 4 A per millimetre] of prod spacing shall

be used for material under $\frac{3}{4}$ in. [20 mm] thick, and 100 to 125 A per linear inch [4 to 5 A per millimetre] of prod spacing shall be used for material $\frac{3}{4}$ in. [20 mm] and over in thickness.

10.5.3.2 Prod spacing shall be a maximum of 8 in. [200 mm]. Prod spacing less than 3 in. [75 mm] usually is not feasible due to banding of the particles around the prods. Care shall be taken to prevent local overheating or burning of the surface being examined. Steel- or aluminum-tipped prods or copper-brush-type prods rather than solid copper-tipped prods are recommended where the magnetizing voltage is over 25 V open circuit (bad contact) in order to avoid copper penetration. Permanent magnetic leeches may be used as a pair or in conjunction with a prod. Leeches should not be used in excess of 1500 A because loss of magnetization occurs.

10.5.3.3 A remote control switch, which may be built into the prod handles, shall be provided to permit the current to be turned on after the prods have been properly positioned and to turn it off before the prods are removed in order to prevent arcing.

10.5.3.4 *Examination Coverage* — Examinations shall be conducted with sufficient overlap to assure 100% coverage at the established sensitivity.

10.5.3.5 *Direction of Magnetization* — At least two separate examinations shall be carried out on each area. The prods shall be placed so that the lines of flux during one examination are approximately perpendicular to the lines of flux during the other.

10.5.4 Indirect circular magnetization of the bores of shaft forgings (Fig. 4) shall be performed using a current of 100 to 125 A per inch [4 to 5 A per millimetre] of bore diameter.

10.5.5 A suitable instrument such as an ammeter shall be used to measure the specified or agreed upon current.

10.5.6 A magnetic particle field indicator (Fig. 8) where necessary shall be used to establish adequacy of the magnetic field. The magnetizing current shall be sufficient to develop the pattern in the indicator clearly.

10.5.6.1 The magnetic particle field indicator shall be used by positioning the indicator on the forging being examined while applying the required current and ferromagnetic particles. The production of a pattern (usually a cross) of discernible ferromagnetic particles indicates that adequate field strength has been generated in the forging being examined.

10.5.7 *Yoke Magnetization* — When electromagnetic yokes are used to magnetize a local area, a longitudinal field is formed between the poles.

10.5.7.1 *Equipment* — Yokes may be of the fixed or articulated leg types.

10.5.7.2 *Yoke Qualification* — Permitted direct-current electromagnetic yokes shall have a lifting power of at least 40 lbf [175 N] at a pole spacing of 3 to 6 in. [75 to 150 mm].

10.5.7.3 *Direction of Magnetization* — At least two separate examinations shall be carried out on each area. In the second examination, the lines of magnetic flux shall be approximately perpendicular to those used for the first examination in that area.

10.5.7.4 *Pole Spacing* — Pole spacing shall be limited to 2 to 8 in. [50 to 200 mm].

10.5.7.5 *Inspection Area* — Inspection area is limited to a maximum distance of one quarter of the pole spacing on either side of a line joining the two poles. Overlapping of pole spacing shall be at least 1 in. [25 mm].

11. Application of Particles

11.1 While the forging is properly magnetized, the particles may be applied by one of the following methods:

11.1.1 *Dry Method* — In the dry method the particles shall be applied from a hand shaker (such as a shaker can), mechanical shaker, bulb blower, or mechanical blower. The use of the shaker shall be limited to flat and nearly horizontal surfaces, whereas the blowers may be used on vertical or overhead surfaces. The powder shall be applied evenly on the surface of the forging. The color of the dry powder should be chosen to provide suitable contrast. Too much powder is disadvantageous as it masks the patterns.

11.1.2 Care shall be exercised in blowing off excess powder so as not to disturb the indications.

11.2 Wet Methods:

11.2.1 *Oil* — The material for the wet method is usually supplied in concentrate form, and the inspection medium shall be prepared by mixing the concentrate with a suitable light oil. The liquid recommended for the inspection vehicle is a well refined, light, petroleum distillate having a relatively high flash point. The approximate characteristics of a suitable liquid are as follows:

API gravity	46
Viscosity, SUS	31
Flash point (Tag Open Cup), °F [°C]	155 to 175 [65 to 80]
Initial boiling point, °F [°C]	390 [200]
End point, °F [°C]	490 [255]
Color, Saybolt	25

A suspension of from 1 to 2% solid material by volume shall generally be used. The inspection medium shall be flowed or sprayed over the area being inspected. The color of the particles should be chosen to provide suitable contrast.

11.2.2 *Water* — Magnetic particles suspended in clean water, or clean water with suitable wetting agents

may be used. Suspension of from 2 to 2½% solid material by volume shall generally be used.

11.3 Fluorescent Method — Fluorescent magnetic particle inspection is a variation of the wet method. A concentrate, similar to that used in the wet method, shall be used, except that the magnetic particle shall be coated with material that fluoresces when activated by “black” light.

11.3.1 The same procedure specified when mixing the wet medium shall be followed, except that the suspension shall contain 0.1 to 0.7% of solid material by volume when petroleum distillate or water is used.

11.3.2 The vehicle shall not be fluorescent.

11.3.3 If fluorescent particles are used, the examination shall be conducted in a darkened area using “black light,” and the light intensity shall be at least 1000 $\mu\text{W}/\text{cm}^2$ at a distance of 15 in. from the lamp. The “black light” shall emit ultraviolet radiation of a wavelength within the range from 3300 to 3900 Å. The particles shall emit a brilliant fluorescence when subjected to this light. The bulb shall be allowed to warm up for a minimum of 5 min prior to its use in examination.

12. Demagnetization

12.1 When specified, parts shall be sufficiently demagnetized after inspection so that the residual field will not interfere with future welding or machining operations, magnetic instruments used in the proximity of the part, or so that leakage fields will not occur in areas of dynamic contact surfaces.

12.2 When direct current is used, demagnetizing may usually be accomplished by repeatedly reversing and progressively decreasing the magnetizing current. The initial field strength used during demagnetization shall be equal to or greater than the original magnetizing force. When the current has been reduced to the vanishing point, the part should be practically demagnetized. Direct current is recommended for demagnetizing large parts.

12.3 When alternating current is used, it is necessary merely to decrease the magnetizing current in small steps or continuously to a very low current.

12.4 Demagnetization will not be necessary if the piece is to be subject to an austenitizing treatment prior to future use or machining.

13. Interpretation and Evaluation of Indications

13.1 The following shall not be used as a standard for rejection or acceptance of a part, but may be used as an aid in interpreting and evaluating indications obtained. Examples of discontinuities and reference photographs of magnetic particle indications may be found in Guide E 709.

13.2 Factors that must be considered in interpreting an indication as to its cause are as follows:

13.2.1 Appearance of the indication.

13.2.2 Direction and shape of the indication.

13.2.3 Type of material from which the part is made.

13.2.4 Processing history of the part, type of machining, heat treatment, etc.

13.2.5 Past experience with similar parts based on destructive tests such as sectioning, etching, fracturing, chipping, grinding, etc.

13.3 The indications may be grouped into three broad classes:

13.3.1 Surface defects that produce sharp, distinct, clear-cut, tightly adhering patterns. These may generally be interpreted from characteristic indications as follows:

13.3.1.1 Laminar Defects — give strong indications which are parallel to the surface.

13.3.1.2 Forging Laps and Folds — are indications that may not be very heavy, and are not straight. They follow metal flow lines.

13.3.1.3 Flakes — (thermal ruptures caused by entrapped hydrogen) can occur in areas that have been machined away. They are characterized by irregular, scattered indications.

13.3.1.4 Heat-Treating Crack — indications are strong and occur at corners, notches, and changes of section.

13.3.1.5 Shrinkage Crack — indications are very strong and sharp, usually continuous with few branches, and occur at changes of section.

13.3.1.6 Grinding Crack — indications usually occur in groups at right angles to the direction of grinding.

13.3.1.7 Etching or Plating Cracks — produce strong indications in a direction perpendicular to residual stresses.

13.3.2 Subsurface defects produce less distinct or fuzzy patterns which are broad rather than sharp, and are less tightly held. They generally produce the following characteristic indications:

13.3.2.1 Stringers of Nonmetallic Inclusions — often have strong indications like surface seams but are usually discontinuous or short and occur in groups. These indications follow the grain flow in forgings. The indications show only when the defects are near the surface.

13.3.2.2 Large Nonmetallics — produce indications ranging from sharp to diffuse, which may occur anywhere in a section.

13.3.2.3 Cracks in Underbeads of Welds — produce indications that occur in broad diffuse patterns.

13.3.2.4 Forging Bursts — produce irregular and diffuse indications.

13.3.3 Nonrelevant or “false” indications are generally confusing but can usually be identified, as follows:

13.3.3.1 Magnetic Writing — indications are fuzzy and will be destroyed by demagnetization. These indications are caused by contact with other steel or magnets while magnetized.

13.3.3.2 Changes in Section — are indications that are broad and fuzzy and caused by concentration of magnetic field in gear teeth, fillets, keyways, etc.

13.3.3.3 Edge of Weld — indications are caused by change of magnetic properties due to diffusion. These indications are not tightly adherent.

13.3.3.4 Flow Lines — are large groups of parallel indications that occur particularly in forgings examined by means of excessive currents.

13.3.4 Any indication that is believed to be nonrelevant shall be regarded as unacceptable until the indication is either eliminated by surface conditioning or it is reexamined by the same or other nondestructive means and demonstrated to be nonrelevant.

14. Report of Indications

14.1 Record the size, number, and location of all linear indications. Use sketches to show location, direction, and

frequency of indications. The report shall indicate the type of magnetization and location of contacts.

14.1.1 Permanent Recording of Data:

14.1.1.1 A permanent record of the indications may be made by carefully covering the surface with transparent, adhesive-backed, cellophane tape. The tape is then removed with the particle indication adhering to it. The tape may then be placed on white paper or cardboard and photographed or otherwise reproduced.

14.1.1.2 If a more accurate reproduction of the indication is desired the following technique may be used. Once an indication has been detected using the normal examining technique, remove the accumulated powder and place a piece of white paper tape with a gloss surface and a gum adhesive backing over the area containing the indication; reapply the current and dust the tape surface with the powder. Immediately the particles will collect over the discontinuity, and with the current still passing through the test piece, spray the tape surface with a thin coating of acrylic lacquer. Terminate the current flow and remove the tape; this will leave an exact replica of the powder buildup adhering to it.

15. Acceptance Standards

15.1 The standards for acceptance of defects detected by magnetic particle examination shall be as specified in the applicable ASTM product specification, contract, or order.

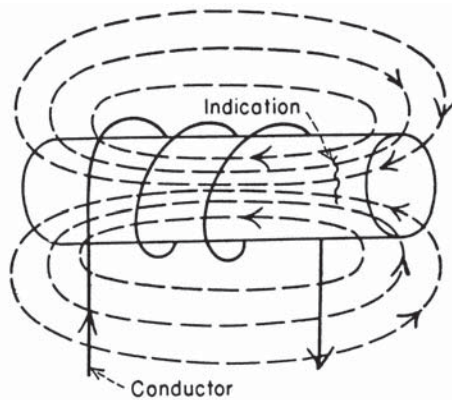
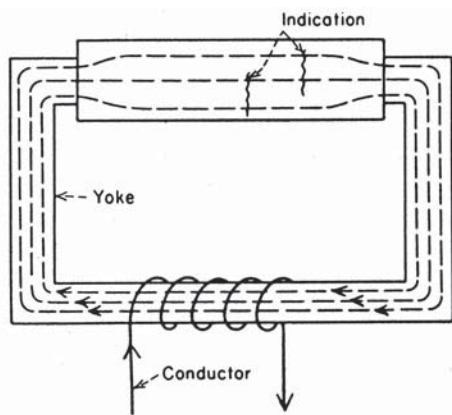
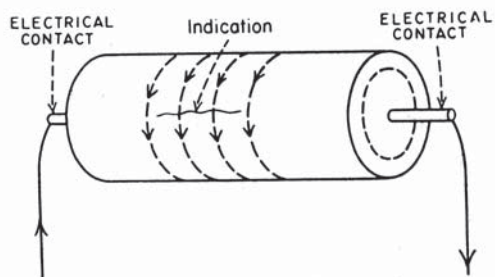
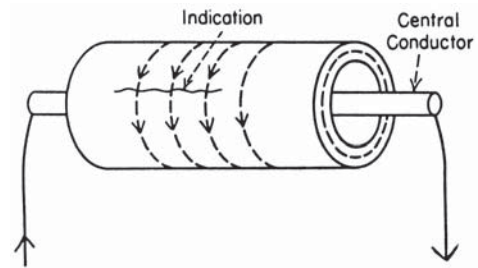
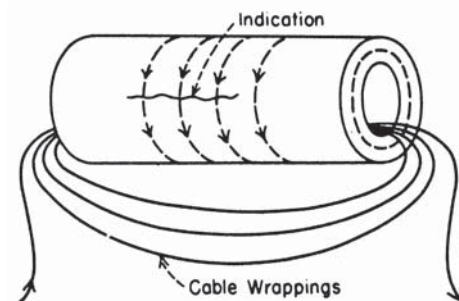
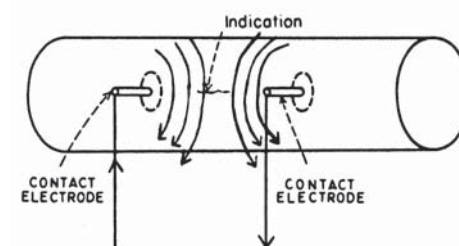
FIG. 1 LONGITUDINAL
MAGNETIZATIONFIG. 2 LONGITUDINAL
MAGNETIZATION, WITH YOKEFIG. 3 CIRCULAR MAGNETIZATION,
CURRENT DIRECTLY THROUGH FORGINGFIG. 4 CIRCULAR MAGNETIZATION,
CURRENT THROUGH A CONDUCTORFIG. 5 CIRCULAR MAGNETIZATION,
CURRENT THROUGH CONDUCTORS
THREADED THROUGH FORGINGFIG. 6 CIRCULAR MAGNETIZATION WITH
"PROD" TYPE CONTACT ELECTRODES

FIG. 7 LONGITUDINAL MAGNETIZATION

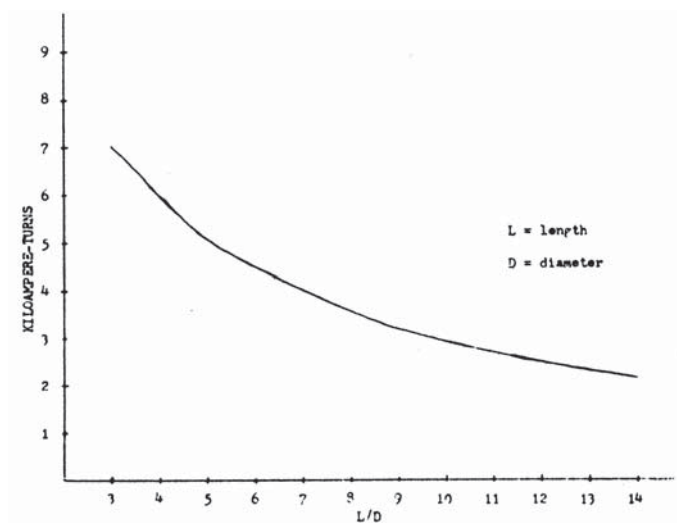
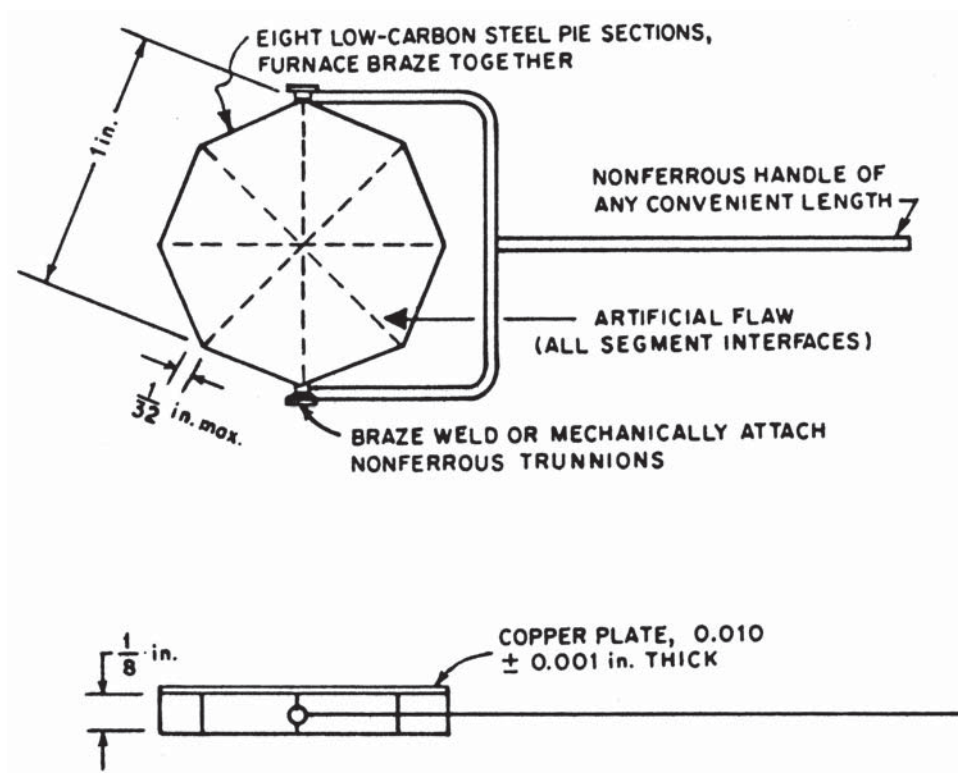


FIG. 8 MAGNETIC PARTICLE FIELD INDICATOR



SPECIFICATION FOR STAINLESS STEEL BARS AND SHAPES



SA-276



(Identical with ASTM Specification A 276-97.)

1. Scope

1.1 This specification covers hot-finished or cold-finished bars except bars for reforging (Note 1). It includes rounds, squares, and hexagons, and hot-rolled or extruded shapes, such as angles, tees, and channels in the more commonly used types of stainless steels. The free-machining types (Note 2), for general corrosion resistance and high-temperature service, are covered in a separate specification.

NOTE 1 —For bars for reforging, see Specification A 314.

NOTE 2 —For free-machining stainless bars designed especially for optimum machinability, see Specification A 582/A 582M.

NOTE 3 —There are standards covering high nickel, chromium, austenitic corrosion, and heat resisting alloy materials. These standards are under the jurisdiction of ASTM Subcommittee B02.07 and may be found in Annual Book of ASTM Standards, Vol. 02.04.

1.2 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 ASTM Standards:

- A 314 Specification for Stainless Steel Billets and Bars for Forging
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 484/A 484M Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings
- A 582/A 582M Specification for Free-Machining Stainless Steel Bars
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 Other Document:

- SAE J1086 Recommended Practice for Numbering Metals and Alloys

3. Ordering Information

3.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include but are not limited to the following:

3.1.1 Quantity (weight or number of pieces);

3.1.2 Name of material: stainless steel;

3.1.3 Form (bars, angles, etc.);

3.1.4 Condition (Section 5.1);

3.1.5 Finish (Section 4 of Specification A 484/A 484M);

3.1.6 Surface preparation of shapes (Section 4 of Specification A 484/A 484M);

3.1.7 Applicable dimensions including size, thickness, width, and length;

3.1.8 Cross section (round, square, etc.);

3.1.9 Type or UNS designation (Table 1);

3.1.10 ASTM designation and date of issue; and

3.1.11 Whether bars are to be rolled as bars or cut from strip or plate.

3.1.12 Test for magnetic permeability when specified by customer purchase order when ordering Types 201 and 205.

3.1.13 Special requirements.

NOTE 4 —A typical ordering description is as follows: 5,000 lb (2268 kg) Stainless Steel Bars, Annealed and Centerless Ground, 1½ in. (38.10 mm) Round, 10 to 12 ft (3.05 to 3.66 m) in length, Type 304, ASTM Specification A 276 dated_____, End use: machined valve parts.

4. General Requirements

4.1 In addition to the requirements of this specification, all requirements of the current edition of Specification A 484/A 484M shall apply. Failure to comply with the

general requirements of Specification A 484/A 484M constitutes nonconformance to this specification.

5. Manufacture

5.1 Condition:

5.1.1 Bars shall be furnished in one of the following conditions listed in the Mechanical Requirements table:

5.1.1.1 *Condition A* — Annealed.

5.1.1.2 *Condition H* — Hardened and tempered at a relatively low temperature.

5.1.1.3 *Condition T* — Hardened and tempered at a relatively high temperature.

5.1.1.4 *Condition S* — Strain Hardened—Relatively light cold work.

5.1.1.5 *Condition B* — Relatively severe cold work.

6. Chemical Composition

6.1 The steel shall conform to the requirements for chemical composition specified in Table 1.

6.2 Methods and practices relating to chemical analysis required by this specification shall be in accordance with Test Methods, Practices, and Terminology A 751.

7. Mechanical Properties Requirements

7.1 The material shall conform to the mechanical test requirements specified in Table 2.

7.2 The martensitic grades shall be capable of meeting the hardness requirements after heat treating as specified in Table 3.

7.3 Hardness measurements, when required, shall be made at a location midway between the surface and the center of the cross section.

8. Magnetic Permeability

8.1 When required by the purchase order, the magnetic permeability of Types 201 and 205 in the annealed condition shall not exceed 1.2 as tested by a Severn-type indicator.

9. Certification

9.1 Upon request of the purchaser in the contract or order, the producer's certification that the material was manufactured and tested in accordance with this specification, together with a certified report of the test results shall be furnished at the time of the shipment.

10. Keywords

10.1 austenitic stainless steel; austenitic-ferritic duplex stainless steel; ferritic stainless steel; martensitic stainless steel; stainless steel bars; stainless steel shapes.

TABLE 1
CHEMICAL REQUIREMENTS^A

UNS Designation ^B	Type	Composition, %							Other Elements		
		Carbon	Manganese	Phosphorous	Sulfur	Silicon	Chromium	Nickel		Molybdenum	Nitrogen
Austenitic Grades											
S20100	201	0.15	5.50–7.50	0.060	0.030	1.00	16.00–18.00	3.50–5.50	...	0.25	...
S20161	...	0.15	4.00–6.00	0.040	0.040	3.00–4.00	15.00–18.00	4.00–6.00	...	0.08–0.20	...
S20200	202	0.15	7.50–10.00	0.060	0.030	1.00	17.00–19.00	4.00–6.00	...	0.25	...
S20500	205	0.12–25	14.00–15.50	0.060	0.030	1.00	16.50–18.00	1.00–1.70	...	0.32–0.40	...
S20910	XM–19	0.06	4.00–6.00	0.040	0.030	1.00	20.50–23.50	11.50–13.50	1.50–3.00	0.20–0.40	Cb 0.10–0.30, V 0.10–0.30
S21800	...	0.10	7.00–9.00	0.060	0.030	3.50–4.50	16.00–18.00	8.00–9.00	...	0.08–0.18	...
S21900	XM–10	0.08	8.00–10.00	0.060	0.030	1.00	19.00–21.50	5.50–7.50	...	0.15–0.40	...
S21904	XM–11	0.04	8.00–10.00	0.060	0.030	1.00	19.00–21.50	5.50–7.50	...	0.15–0.40	...
S24000	XM–29	0.08	11.50–14.50	0.060	0.030	1.00	17.00–19.00	2.25–3.75	...	0.20–0.40	...
S24100	XM–28	0.15	11.00–14.00	0.060	0.030	1.00	16.50–19.00	0.50–2.50	...	0.20–0.45	...
S24565	...	0.030	5.0–7.0	0.030	0.010	1.00	23.00–25.00	16.0–18.0	4.0–5.0	0.4–0.6	Cb 0.10
S28200	...	0.15	17.00–19.00	0.045	0.030	1.00	17.00–19.00	...	0.75–1.25	0.40–0.60	Cu 0.75–1.25
S30200	302	0.15	2.00	0.045	0.030	1.00	17.00–19.00	8.00–10.00	...	0.10	...
S30215	302B	0.15	2.00	0.045	0.030	2.00–3.00	17.00–19.00	8.00–10.00	...	...	...
S30400	304	0.08	2.00	0.045	0.030	1.00	18.00–20.00	8.00–10.50	...	0.10	...
S30403	304L ^C	0.030	2.00	0.045	0.030	1.00	18.00–20.00	8.00–12.00	...	0.10	...
S30451	304N	0.08	2.00	0.045	0.030	1.00	18.00–20.00	8.00–10.50	...	0.10–0.16	...
S30452	XM–21	0.08	2.00	0.045	0.030	1.00	18.00–20.00	8.00–10.50	...	0.16–0.30	...
S30453	304LN	0.03	2.00	0.045	0.030	1.00	18.00–20.00	8.00–12.00	...	0.10–0.16	...
S30454	...	0.03	2.00	0.045	0.030	1.00	18.00–20.00	8.00–12.00	...	0.16–0.30	...
S30500	305	0.12	2.00	0.045	0.030	1.00	17.00–19.00	10.50–13.00	...	...	...
S30800	308	0.08	2.00	0.045	0.030	1.00	19.00–21.00	10.00–12.00	...	...	...
S30815	...	0.10	0.80	0.040	0.030	1.40–2.00	20.00–22.00	10.00–12.00	...	0.14–0.20	Ce 0.03–0.08
S30900	309	0.20	2.00	0.045	0.030	1.00	22.00–24.00	12.00–15.00	...	...	...
S30908	309S	0.08	2.00	0.045	0.030	1.00	22.00–24.00	12.00–15.00	...	...	...
S30940	309Cb	0.08	2.00	0.045	0.030	1.00	22.00–24.00	12.00–16.00	...	0.10	Cb+Ta 10×C–1.10
S31000	310	0.25	2.00	0.045	0.030	1.50	24.00–26.00	19.00–22.00	...	...	...
S31008	310S	0.08	2.00	0.045	0.030	1.50	24.00–26.00	19.00–22.00	...	...	...
S31040	310Cb	0.08	2.00	0.045	0.030	1.50	24.00–26.00	19.00–22.00	...	0.10	Cb+Ta 10×C–1.10
S31254	...	0.020	1.00	0.030	0.010	0.80	19.50–20.50	17.50–18.50	6.00–6.50	0.18–0.22	Cu 0.50–1.00
S31400	314	0.25	2.00	0.045	0.030	1.50–3.00	23.00–26.00	19.00–22.00	...	...	...
S31600	316	0.08	2.00	0.045	0.030	1.00	16.00–18.00	10.00–14.00	2.00–3.00	0.10	...
S31603	316L ^C	0.030	2.00	0.045	0.030	1.00	16.00–18.00	10.00–14.00	2.00–3.00	0.10	...
S31635	316Ti	0.08	2.00	0.045	0.030	1.00	16.00–18.00	10.00–14.00	2.00–3.00	0.10	Ti 5×(C+N)–0.70
S31640	316Cb	0.08	2.00	0.045	0.030	1.00	16.00–18.00	10.00–14.00	2.00–3.00	0.10	Cb+Ta 10×C–1.10

TABLE 1
CHEMICAL REQUIREMENTS^A (CONT'D)

UNS Designation ^B	Type	Composition, %							Other Elements		
		Carbon	Manganese	Phosphorous	Sulfur	Silicon	Chromium	Nickel		Molybdenum	Nitrogen
Austenitic-Ferritic Grades											
S31651	316N	0.08	2.00	0.045	0.030	1.00	16.00–18.00	10.00–14.00	2.00–3.00	0.10–0.16	...
S31653	316LN	0.030	2.00	0.045	0.030	1.00	16.00–18.00	10.00–14.00	2.00–3.00	0.10–0.16	Cu 0.16–0.30
...	S31654	0.03	2.00	0.045	0.030	1.00	16.00–18.00	10.00–14.00	2.00–3.00	...	...
S31700	317	0.08	2.00	0.045	0.030	1.00	18.00–20.00	11.00–15.00	3.00–4.00	0.10	...
S31725	...	0.03	2.00	0.045	0.030	1.00	18.00–20.00	13.50–17.50	4.0–5.0	0.10	Cu 0.75
S31726	...	0.03	2.00	0.045	0.030	1.00	17.00–20.00	13.50–17.50	4.0–5.0	0.10–0.20	Cu 0.75
S32100	321	0.08	2.00	0.045	0.030	1.00	17.00–19.00	9.00–12.00	...	...	Ti 5×(C+N)–0.70 ^D
...	S32550	0.04	1.50	0.040	0.030	1.00	24.0–27.0	4.50–6.50	2.9–3.9	0.10–0.25	Cu 1.50–2.50
S34700	347	0.08	2.00	0.045	0.030	1.00	17.00–19.00	9.00–13.00	...	...	Cb+Ta 10×C min
S34800	348	0.08	2.00	0.045	0.030	1.00	17.00–19.00	9.00–13.00	...	...	Cb+Ta 10×C min,
											Ta 0.10 Co 0.20
S31100	XM-26	0.06	1.00	0.040	0.030	1.00	25.00–27.00	6.00–7.00	...	...	Ti 0.25
S31803	...	0.030	2.00	0.030	0.020	1.00	21.00–23.00	4.50–6.50	2.50–3.50	0.08–0.20	...
S32304	...	0.030	2.50	0.040	0.030	1.00	21.50–24.50	3.00–5.50	0.05–0.60	0.05–0.20	Cu 0.05–0.60
S32760 ^E	...	0.030	1.00	0.030	0.010	1.00	24.00–26.00	6.00–8.00	3.00–4.00	0.20–0.30	Cu 0.05–1.00
											W 0.50–1.00
Ferritic Grades											
S40500	405	0.08	1.00	0.040	0.030	1.00	11.50–14.50	...	...	...	Al 0.10–0.30
S42900	429	0.12	1.00	0.040	0.030	1.00	14.00–16.00	...	...	...	...
S43000	430	0.12	1.00	0.040	0.030	1.00	16.00–18.00	...	...	...	...
S44400	...	0.025	1.00	0.040	0.030	1.00	17.5–19.5	1.00	1.75–2.50	0.035	Ti+Cb 0.20+4× (C+N)–0.80
S44600	446	0.20	1.50	0.040	0.030	1.00	23.00–27.00	...	...	0.25	...
S44627	XM-27 ^F	0.010 ^G	0.40	0.020	0.020	0.40	25.00–27.50	0.50 max.	0.75–1.50	0.015 ^G	Cu 0.20
S44700	...	0.010	0.30	0.025	0.020	0.20	28.00–30.00	0.15 max.	3.50–4.20	0.020	Cb 0.05–0.20 C+N 0.025
S44800	...	0.010	0.30	0.025	0.020	0.20	28.00–30.00	2.00–2.50	3.50–4.20	0.020	Cu 0.15 C+N 0.25 Cu 0.15

TABLE 1
CHEMICAL REQUIREMENTS^A (CONT'D)

UNS Designation ^B	Type	Composition, %									
		Carbon	Manganese	Phosphorous	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Other Elements
Martensitic Grades											
S40300	403	0.15	1.00	0.040	0.030	0.50	11.50–13.00	...	...	...	...
S41000	410	0.15	1.00	0.040	0.030	1.00	11.50–13.50	...	...	...	...
S41040	XM-30	0.18	1.00	0.040	0.030	1.00	11.50–13.50	...	...	...	Cb 0.05–0.30
S41400	414	0.15	1.00	0.040	0.030	1.00	11.50–13.50	1.25–2.50	...	...	...
S41500	^H	0.05	0.50–1.00	0.030	0.030	0.60	11.50–14.00	3.50–5.50	0.50–1.00	...	...
S42000	420	over 0.15	1.00	0.040	0.030	1.00	12.00–14.00	...	...	...	...
S42010	...	0.15–0.30	1.00	0.040	0.030	1.00	13.50–15.00	0.35–0.85	0.40–0.85	...	...
S43100	431	0.20	1.00	0.040	0.030	1.00	15.00–17.00	1.25–2.50	...	...	...
S44002	440A	0.60–0.75	1.00	0.040	0.030	1.00	16.00–18.00	...	0.75	...	...
S44003	440B	0.75–0.95	1.00	0.040	0.030	1.00	16.00–18.00	...	0.75	...	...
S44004	440C	0.95–1.20	1.00	0.040	0.030	1.00	16.00–18.00	...	0.75	...	...
S50400	9	0.15	0.30–0.60	0.030	0.030	0.75–1.00	8.00–10.00	...	0.90–1.10	...	...

NOTES

^A Maximum, unless range or minimum is indicated.

^B Designations established in accordance with Practice E 527 and SAE J1086.

^C For some applications, the substitution of Type 304L for Type 304, or Type 316L for Type 316 may be undesirable because of design, fabrication, or service requirements. In such cases, the purchaser should so indicate on the order.

^D Nitrogen content is to be reported for this grade.

^E % Cr + 3.3 × % Mo + 16 × % N ≥ 40.

^F Nickel plus copper shall be 0.50 % max.

^G Product analysis tolerance over the maximum limit for carbon and nitrogen shall be 0.002 %.

^H Wrought version of CA 6NM.

TABLE 2
MECHANICAL REQUIREMENTS

Type	Condition	Finish	Diameter or Thickness, in. (mm)	Tensile Strength, Min.		Yield Strength, ^A Min.		Elongation in 2 in. (50 mm), ^B or 4D Min., ^B %	Reduction of Area, ^C Min., %	Brinell Hardness, ^D Max.
				ksi	MPa	ksi	MPa			
Austenitic Grades										
201, 202	A	hot-finished or cold-finished	all	75	515	40	275	40	45	...
S20161	A	hot-finished or cold-finished	all	125	860	50	345	40	40	255
205	A	hot-finished or cold-finished	all	100	690	60	414	40	50	...
XM-19	A	hot-finished or cold-finished	all	100	690	55	380	35	55	...
As hot-rolled		hot-finished or cold-finished	up to 2 (50.8), incl.	135	930	105	725	20	50	...
			over 2 to 3 (50.8 to 76.2), incl.	115	795	75	515	25	50	...
			over 3 to 8 (76.2 to 203.2), incl.	100	690	60	415	30	50	...
S21800	A	hot-finished or cold-finished	all	95	655	50	345	35	55	241
XM-10, XM-11	A	hot-finished or cold-finished	all	90	620	50	345	45	60	...
XM-29	A	hot-finished or cold-finished	all	100	690	55	380	30	50	...
XM-28	A	hot-finished or cold-finished	all	100	690	55	380	30	50	...
S24565	A	hot-finished or cold-finished	all	115	795	60	415	35	40	...
S28200	A	hot-finished or cold-finished	all	110	760	60	410	35	55	...
302, 302B, 304, 304LN, 305, 308, 309, 309S, 309Cb, 310, 310S, 310Cb, 314, 316, 316LN, 316Cb, 316Ti, 317, 321, 347, 348	A	hot-finished	all	75 ^E	515	30 ^F	205	40 ^G	50	...
			up to 1/2 (12.70) incl.	90	620	45	310	30	40	...
			over 1/2 (12.70)	75 ^E	515	30 ^F	205	30	40	...
304L, 316L	A	hot-finished or cold-finished	all	70	485	25	170	40 ^G	50	...
			up to 1/2 (12.70) incl.	90	620	45	310	30	40	...
			over 1/2 (12.70)	70	485	25	170	30	40	...

TABLE 2
MECHANICAL REQUIREMENTS (CONT'D)

Type	Condition	Finish	Diameter or Thickness, in. (mm)	Tensile Strength, Min.		Yield Strength, ^A		Elongation in 2 in. (50 mm) ^B or 4D Min. ^B %	Reduction of Area, ^C Min., %	Brinell Hardness, ^D Max.
				ksi	MPa	ksi	MPa			
Austenitic Grades (Cont'd)										
304N, 316N	A	hot-finished or cold-finished	all	80	550	35	240	30	...	...
	B	cold-finished	up to ¾ (19.05) incl.	125	860	100	690	12	35	...
202, 302, 304, 304N, 316, 316N	S	cold-finished	over ¾ (19.05) to 1 (25.40)	115	795	80	550	15	35	...
			over 1 (25.40) to 1¼ (31.75)	105	725	65	450	20	35	...
			over 1¼ (31.75) to 1½ (38.10)	100	690	50	345	24	45	...
			over 1½ (38.10) to 1¾ (44.45)	95	655	45	310	28	45	...
			up to 2 (50.8) incl.	95	650	75	515	25	40	...
XM-21, S30454, S31654	A	hot-finished or cold-finished	over 2 to 2½ (50.8 to 63.5) incl.	90	620	65	450	30	40	...
			over 2½ to 3 (63.5 to 76.2) incl.	80	550	55	380	30	40	...
			all	90	620	50	345	30	50	...
XM-21, S30454, S31654	B	cold-finished	up to 1 (25.40) incl.	145	1000	125	860	15	45	...
			over 1 (25.40) to 1¼ (31.75)	135	930	115	795	16	45	...
			over 1¼ (31.75) to 1½ (38.10)	135	895	105	725	17	45	...
			over 1½ (38.10) to 1¾ (44.45)	125	860	100	690	18	45	...
S30815	A	hot-finished or cold-finished	all	87	600	45	310	40	50	...
S31254	A	hot-finished or cold-finished	all	95	650	44	300	35	50	...
S31725	A	hot-finished or cold-finished	all	75	515	30	205	40	...	...
S31726	A	hot-finished or cold-finished	all	80	550	35	240	40	...	...

TABLE 2
MECHANICAL REQUIREMENTS (CONT'D)

Type	Condition	Finish	Diameter or Thickness, in. (mm)	Tensile Strength, Min.		Yield Strength, ^A Min.		Elongation in 2 in. (50 mm) ^B or 4D Min. ^B %	Reduction of Area, ^C Min., %	Brinell Hardness, ^D Max.
				ksi	MPa	ksi	MPa			
Austenitic-Ferritic Grades										
XM-26	A	hot-finished or cold-finished	all	90	620	65	450	20	55	...
S31803	A	hot-finished or cold-finished	all	90	620	65	448	25	...	290
S32304	A	hot-finished	all	87	600	58	400	25	...	290
S32550	A	cold-finished	all	110	760	80	550	15	...	302
S32760	A	hot-finished or cold-finished	all	109	750	80	550	25	...	290
S32760	S	cold-finished	all	125	860	105	720	16	...	335
Ferritic Grades										
405 ^F	A	hot-finished	all	...	...	...	...	...	...	207
429	A	cold-finished	all	...	...	...	...	...	...	217
		hot-finished	all	70	480	40	275	20	45	...
430	A	cold-finished	all	70	480	40	275	16	45	...
		hot-finished or cold-finished	all	60	415	30	207	20	45	...
S44400	A	hot-finished	all	60	415	45	310	20	45	217
446, XM-27	A	cold-finished	all	60	415	45	310	16	45	217
		hot-finished	all	65	450	40	275	20	45	219
S44700	A	cold-finished	all	65	450	40	275	16	45	219
		hot-finished	all	70	480	55	380	20	40	...
S44800	A	cold-finished	all	75	520	60	415	15	30	...
		hot-finished	all	70	480	55	380	20	40	...
		cold-finished	all	75	520	60	415	15	30	...

TABLE 2
MECHANICAL REQUIREMENTS (CONT'D)

Type	Condition	Finish	Diameter or Thickness, in. (mm)	Tensile Strength, Min.		Yield Strength, ^A Min.		Elongation in 2 in. (50 mm) ^B or 4D Min., ^B %	Reduction of Area, ^C Min., %	Brinell Hardness, ^D Max.
				ksi	MPa	ksi	MPa			
Martensitic Grades										
403, 410	A	hot-finished	all	70	480	40	275	20	45	...
		cold-finished	all	70	480	40	275	16	45	...
403, 410	T	hot-finished	all	100	690	80	550	15	45	...
		cold-finished	all	100	690	80	550	12	40	...
XM-30	T	hot-finished	all	125	860	100	690	13	45	302
		cold-finished	all	125	860	100	690	12	35	...
403, 410	H	hot-finished	all	120	830	90	620	12	40	...
		cold-finished	all (rounds only)	120	830	90	620	12	40	...
XM-30	A	hot-finished	all	70	480	40	275	13	45	235
		cold-finished	all	70	480	40	275	12	35	...
414	A	hot-finished or cold-finished	all	...	...	...	...	...	...	298
414	T	hot-finished or cold-finished	all	115	790	90	620	15	45	...
S41500	T	hot-finished or cold-finished	all	115	795	90	620	15	45	295
		cold-finished								
420	A	hot-finished	all	...	...	...	...	...	...	241
S42010	A	cold-finished	all	...	...	...	...	...	...	255
		hot-finished or cold-finished	all	...	...	...	...	...	...	235
431	...	cold-finished	all	...	...	...	...	...	...	255
	A	hot-finished or cold-finished	all	...	...	...	...	...	...	285
440A, 440B, and 440C	A	hot-finished	all	...	...	...	...	...	...	...
		cold-finished	all	...	...	...	...	...	...	269
9 (S50400)	A	hot-finished or cold-finished	all	60	415	30	207	30	45	285
		cold-finished	all	100	690	80	550	14	35	179
	T	hot-finished or cold-finished	all	...	...	...	...	...	...	241

NOTES

^A Yield strength shall be determined by the 0.2% offset in accordance with Test Methods and Definitions A 370. An alternative method of determining yield strength may be used based on total extension under load of 0.5%.

^B For some specific products, it may not be practicable to use a 2 in. or 50 mm gage length. The use of sub-size test specimens, when necessary, is permissible in accordance with Test Methods and Definitions A 370.

^C Reduction of area does not apply on flat bars $\frac{3}{16}$ in. (4.76 mm) and under in thickness as this determination is not generally made in this product size.

^D Or equivalent Rockwell hardness.

^E For extruded shapes of all Cr-Ni grades of Condition A, the yield strength shall be 25 ksi (170 MPa) min., and tensile strength shall be 70 ksi (480 MPa) min.

^F Material shall be capable of being heat treated to a maximum Brinell hardness of 250 when oil quenched from 1750°F (953°C).

^G For shapes having section thickness of $\frac{1}{2}$ in. (12.5 mm) or less, 30% min., elongation is acceptable.

TABLE 3 RESPONSE TO HEAT TREATMENT

Type ^A	Heat Treatment Temperature ^B °F (°C), Min.	Quenchant	Hardness HRC, Min.
403	1750 (955)	Air	35
410	1750 (955)	Air	35
414	1750 (955)	Oil	42
420	1825 (995)	Air	50
S42010	1850 (1010)	Oil	48
431	1875 (1020)	Oil	40
440A	1875 (1020)	Air	55
440B	1875 (1020)	Oil	56
440C	1875 (1020)	Air	58

NOTES

^A Samples for testing shall be in the form of a section not exceeding $\frac{3}{8}$ in. (9.50 mm) in thickness.

^B Temperature tolerance is $\pm 25^{\circ}\text{F}$ (14°C).

SPECIFICATION FOR GRAY IRON CASTINGS FOR PRESSURE-CONTAINING PARTS FOR TEMPERATURES UP TO 650°F (350°C)



SA-278/SA-278M

[Identical with ASTM Specification A 278/A 278M-01(R06) except for an editorial change to 5.1.1 and a change to 16.1 making certification mandatory.]

1. Scope

1.1 This specification covers gray iron for castings suitable for pressure-containing parts for use at temperatures up to 650°F (350°C).

1.2 Classes of Iron:

1.2.1 Castings of all classes are suitable for use up to 450°F (230°C). For temperatures above 450°F and up to 650°F, only Class 40, 45, 50, 55, and 60 castings are suitable.

1.2.2 Castings of all classes are suitable for use up to 230°C. For temperatures above 230°C and up to 350°C, only Class 275, 300, 325, 350, 380, and 415 castings are suitable.

2. Referenced Documents

2.1 ASTM Standards:

A 644 Terminology Relating to Iron Castings
E 8 Test Methods for Tension Testing of Metallic Materials

3. Terminology

3.1 Definitions of many terms common to gray iron castings may be found in Terminology A 644.

4. Classification

4.1 Classification by tensile strength.

4.1.1 Castings ordered to this specification are classified based upon the minimum tensile strength of the iron in ksi, in English units. Class 25 has a minimum specified tensile strength of 25 ksi.

4.1.2 Castings ordered to this specification are classified based upon the minimum tensile strength of the iron

in MPa, in Metric units. Class 150 has a minimum specified tensile strength of 150 MPa.

5. Ordering Information

5.1 Orders for material in this specification should include the following information:

5.1.1 Specification designation and year date,

5.1.2 Class of iron required and service temperature,

5.1.3 Quantity,

5.1.4 Heat Treatment:

5.1.4.1 Whether or not heat treatment is required for Class 40, 45, 50, 55, and 60 castings to be used at temperatures at 450°F or less (see 6.2),

5.1.4.2 Whether or not heat treatment is required for Class 275, 300, 325, 350, 380, and 415 castings to be used at temperatures at 230°C or less (see 6.2),

5.1.5 The size of separately cast test bar to be poured (see Section 9 and Table 1),

5.1.6 The size of test specimen to be machined from test bars C or S, and

5.1.7 Special requirements.

6. Materials and Manufacture

6.1 Castings intended for use above 450°F (230°C) shall be stress-relieved by placing them in a suitable furnace at a temperature not exceeding 400°F (200°C) and heating them uniformly to the temperatures and for the times specified in Table 2. The heating and cooling rates shall be uniform and shall not be more than 400°F/h (250°C/h) for castings of 1 in. (25 mm) maximum section.

For heavier sections the maximum heating and cooling rates in degrees Fahrenheit per hour shall be 400 divided by the maximum section thickness.

6.2 Heat Treatment and Cooling Rate:

6.2.1 Castings of Class Nos. 45, 50, 55, and 60, which are to be used at temperatures below 450°F, may be heat treated in accordance with 6.1 or they shall be cooled in the mold to 500°F at an average rate of not more than 100°F/h for castings up to 1 in. in section. For heavier sections the maximum cooling rate in degrees Fahrenheit per hour shall be 100 divided by the maximum section thickness.

6.2.2 Castings of Class Nos. 275, 300, 325, 350, 380, and 415, which are to be used at temperatures below 230°C, may be heat treated in accordance with 6.1 or they shall be cooled in the mold to 250°C at an average rate of not more than 50°C/h for castings up to 25 mm in section. For heavier sections the maximum cooling rate in degrees Celsius per hour shall be 1250 divided by the maximum section thickness.

7. Chemical Composition

7.1 Carbon Equivalent:

7.1.1 Class 40, 45, 50, 55, and 60 castings intended for service above 450°F (230°C) shall have a maximum carbon equivalent of 3.8% as calculated from the equation $CE = \%C + 0.3 (\%Si + \%P)$. The maximum phosphorus and sulfur contents shall be 0.25% and 0.12%, respectively.

7.1.2 Class 275, 300, 325, 350, 380, and 415 castings intended for service above 230°C shall have a maximum carbon equivalent of 3.8% as calculated from the equation $CE = \%C + 0.3 (\%Si + \%P)$. The maximum phosphorus and sulfur contents shall be 0.25% and 0.12%, respectively.

7.2 The chemical analysis for total carbon shall be made on either chilled cast pencil-type specimens or thin wafers approximately $\frac{1}{32}$ in. thick cut from test coupons. Drillings shall not be used because of attendant loss of graphite.

8. Tensile Requirements

8.1 Iron used in supplying castings to this specification shall conform to the tensile requirements prescribed in Table 3 and Table 4.

9. Test Bars

9.1 Separately cast test bars having the dimensions shown in Table 1 shall be poured from the same lot as the castings represented. The size of the test bar to be poured shall be selected by the purchaser using Table 5. In the

event no choice is made, the selection will be made by the manufacturer.

9.2 Separately cast test bars shall be heat treated in the same furnace together with the castings represented.

9.3 At the option of the manufacturer, test coupons may be removed from the casting at a location agreed upon between the manufacturer and purchaser.

9.4 Castings weighing in excess of 2000 lb may be represented either by separately cast test bars (9.1) or by integrally cast test bars having a cooling rate closely approximating that of the controlling section of the casting.

9.5 For castings weighing in excess of 10 000 lb or having a controlling section greater than 2 in., test bars may be removed from the casting or integral projections having a cross section no less than the controlling section. The minimum tensile strength requirement for tension tests performed on either of these test bars shall be 80% of the specified class.

10. Molding and Pouring Test Bars

10.1 The test bars shall be cast in dried siliceous sand molds maintained at approximately room temperature. A suitable design for a mold is shown in Fig. 1.

11. Workmanship, Finish, and Appearance

11.1 All castings shall be made in a workmanlike manner and shall conform to the dimensions on drawings furnished by the purchaser. If the pattern is supplied by the purchaser without drawings, the dimensions of the casting shall be as predicted by the pattern.

11.2 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order.

12. Sampling

12.1 A lot shall consist of one of the following:

12.1.1 All the metal poured from a single heating in a batch type melting furnace,

12.1.2 All the metal from two or more batch type melting furnaces poured into a single ladle or single casting, or

12.1.3 All the metal poured from a continuous melting furnace for a given period of time between changes in charge, processing conditions, or aim-for chemistry or 4 h, whichever is the shorter period.

12.1.3.1 The purchaser may agree to extend the 4 h time period to 8 h if the manufacturer can demonstrate sufficient process control to warrant such an extension.

13. Tension Test Specimens

13.1 Tension test specimens A and B in Fig. 2 shall be machined from test bars A and B in Table 1, respectively.

13.2 The purchaser shall specify whether test specimen B or C is to be machined from test bar C. If no choice is made, the manufacturer shall make the selection.

13.3 The size of the test specimen to be machined from test bar S shall be as agreed upon between the manufacturer and purchaser.

14. Number of Tests and Retests

14.1 One tension test shall be performed on each lot in accordance with Test Method E 8 and conform to the tensile requirements specified.

14.2 If the results of a valid test fail to conform to the requirements of this specification, two retests shall be made. If either retest fails to meet the specification requirements, the castings represented by these test specimens shall be rejected.

14.3 If, after testing, a test specimen shows evidence of a defect, the results of the test may be invalidated and another made on a specimen from the same lot.

15. Repair

15.1 Any repairs performed on castings produced to this specification shall be agreed upon between the manufacturer and purchaser.

16. Certification

16.1 The manufacturer shall furnish his certification stating that the material was manufactured, sampled, tested, and inspected in accordance with this specification including the year date. The certification shall also include the results of all tests performed.

16.2 A signature is not required on the certification. However, the document shall clearly identify the organization submitting the certification and the authorized agent of the manufacturer who certified the test results. Notwithstanding the absence of a signature, the organization submitting the certification is responsible for its content.

17. Inspection

17.1 All tests and inspections required by this specification shall be performed by the manufacturer or other reliable sources whose services have been contracted for by the manufacturer. Complete records of all tests and inspections shall be maintained by the manufacturer and shall be available for review by the purchaser.

18. Rejection and Rehearing

18.1 Castings which fail to conform to the requirements specified when inspected or tested by the purchaser or his agent may be rejected. Rejection shall be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the test results, the manufacturer or supplier may make claim for a rehearing.

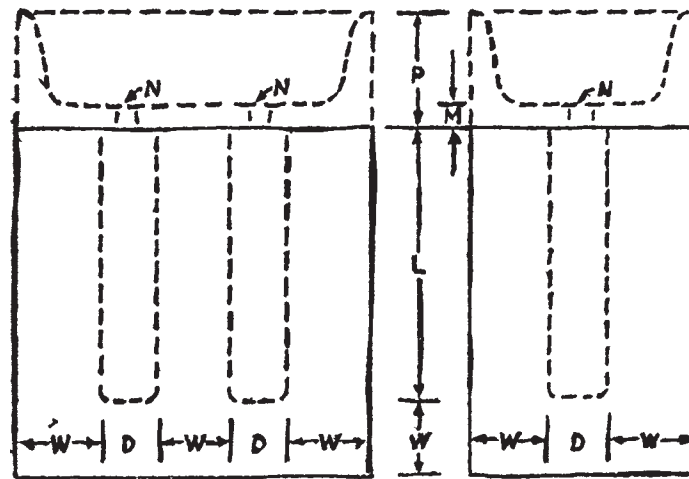
19. Product Marking

19.1 Castings shall have the name of the manufacturer, or his recognized trademark, and the class of iron to which it conforms, cast or indelibly stamped on a surface indicated by the purchaser or in such a position as not to injure the usefulness of the casting.

20. Keywords

20.1 elevated temperature service; gray iron castings; pressure containing parts

FIG. 1 SUITABLE DESIGN AND DIMENSIONS FOR MOLD FOR SEPARATELY CAST CYLINDRICAL TEST BARS FOR GRAY IRON



Number of test bars in a single mold—2 suggested.

L—see Table 1.

D—see Table 1.

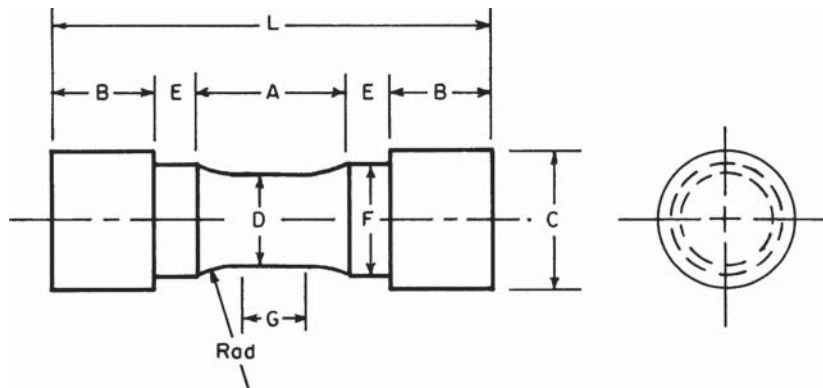
W—not less than diameter, D.

P—2 in. (50-mm) suggested

N— $\frac{5}{16}$ in. (8-mm) in diameter, suggested

M—1.5 N, suggested

FIG. 2 TENSION-TEST SPECIMENS



Dimensions, in. (mm)	Tension Test Specimen A	Tension Test Specimen B	Tension Test Specimen C
G—Length of parallel, min	0.50 (13)	0.75 (20)	1.25 (32)
D—Diameter	0.500 ± 0.010 (13 \pm 0.25)	0.750 ± 0.015 (20 \pm 0.4)	1.25 ± 0.025 (32 \pm 0.5)
R—Radius of fillet, min	1 (25)	1 (25)	2 (50)
A—Length of reduced section, min	$1\frac{1}{4}$ (32)	$1\frac{1}{2}$ (38)	$2\frac{1}{4}$ (57)
L—Overall length, min	$3\frac{3}{4}$ (95)	4 (100)	$6\frac{3}{8}$ (160)
C—Diameter of end section, approximate	$\frac{7}{8}$ (22)	$1\frac{1}{4}$ (32)	$1\frac{7}{8}$ (47)
E—Length of shoulder, min	$\frac{1}{4}$ (6)	$\frac{1}{4}$ (6)	$\frac{5}{16}$ (8)
F—Diameter of shoulder	$\frac{5}{8} \pm \frac{1}{64}$ (16 \pm 0.5) A	$\frac{15}{16} \pm \frac{1}{64}$ (25 \pm 0.5) A	$1\frac{7}{16} \pm \frac{1}{64}$ (36 \pm 0.5) A
B—Length of end section			

^A Optional to fit holders on testing machine. If threaded, root diameter shall not be less than dimension F.

TABLE 1
DIAMETERS AND LENGTHS OF CAST TEST BARS

Test Bar	As-Cast Diameter, in. (mm)			Length, in. (mm)	
	Nominal (Mid-Length)	Minimum (Bottom)	Maximum (Top)	Minimum (Specified)	Maximum (Recommended)
A	0.88 (23)	0.85 (22)	0.96 (25)	5.0 (125)	6.0 (150)
B	1.20 (33)	1.14 (32)	1.32 (36)	7.0 (175)	9.0 (150)
C	2.00 (54)	1.90 (53)	2.10 (58)	6.0 (150)	10.0 (255)
S ^A					

^A All dimensions of Test Bar S shall be as agreed upon by the manufacturer and the purchaser.

TABLE 2
STRESS RELIEVING REQUIREMENTS

Class	Metal Temperature, °F (°C)	Holding Time, h ^A	
		B	B
40, 45, 50, 55, 60 (275, 300, 325, 350, 380, 415)	1050 to 1200 (565 to 650)	2 (2 min) ^B	12 (12 max) ^B

^A In no case shall the holding time be less than 1 h/in. of maximum metal section, or in excess of 12 h max, dependent upon which governs.

^B In no case shall the holding time be less than 1 h/in. for every 25 mm metal section or in excess of 12 h max, depending upon which governs.

TABLE 4
TENSILE REQUIREMENTS (SI)

Class	Tensile Strength, min, MPa
No. 150	150
No. 175	175
No. 200	200
No. 225	225
No. 250	250
No. 275	275
No. 300	300
No. 325	325
No. 350	350
No. 380	380
No. 415	415

TABLE 3
TENSILE REQUIREMENTS

Class	Tensile Strength, min, ksi
No. 20	20
No. 25	25
No. 30	30
No. 35	35
No. 40	40
No. 45	45
No. 50	50
No. 55	55
No. 60	60

TABLE 5
SEPARATELY CAST TEST BARS FOR USE WHEN A SPECIFIC CORRELATION HAS NOT BEEN ESTABLISHED BETWEEN THE TEST BAR AND THE CASTING

Thickness of the Wall of the Controlling Section of the Casting, in. (mm)	Test Bar
Under 0.25 (6)	S
0.25 to 0.50 (6 to 12)	A
0.51 to 1.00 (13 to 25)	B
1.01 to 2 (25 to 50)	C
Over 2 (50)	S

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SPECIFICATION FOR LOW AND INTERMEDIATE TENSILE STRENGTH CARBON STEEL PLATES



SA-283/SA-283M



[Identical with ASTM Specification A 283/A 283M-03(R07).]

1. Scope

1.1 This specification covers four grades (A, B, C, and D) of carbon steel plates of structural quality for general application.

1.2 When the steel is to be welded, a welding procedure suitable for the grade of steel and intended use or service is to be utilized. See Appendix X3 of Specification A 6/A 6M for information on weldability.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exactly equivalents, therefore each system is to be used independently of the other, without combining values in any way.

1.4 For plate produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results, of Specification A 6/A 6M apply.

1.5 This specification contains notes or footnotes, or both, that provide explanatory material. Such notes and footnotes, excluding those in tables and figures do not contain any mandatory requirements.

2. Referenced Document

2.1 *ASTM Standard:*
A 6/A 6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling

3. General Requirements for Delivery

3.1 Plates furnished under this specification shall conform to the requirements of the current edition of Specification A 6/A 6M, for the specific date ordered, unless a conflict exists in which case this specification shall prevail.

3.2 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from a coil. The processor directly controls, or is responsible for, the operation involved in the processing of a coil into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1 — For plates produced from coil and furnished without heat treatment or with stress relieving only, two test results are to be reported for each qualifying coil. Additional requirements regarding plate produced from coil are described in Specification A 6/A 6M.

4. Process

4.1 The steel shall be made by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace.

5. Chemical Requirements

5.1 The heat analysis shall conform to the requirements prescribed in Table 1.

5.2 The steel shall conform on product analysis to the requirements prescribed in Table 1, subject to the product analysis tolerances in Specification A 6/A 6M.

6. Tensile Requirements

6.1 Material as represented by the test specimens shall conform to the requirements as to tensile properties prescribed in Table 2.

TABLE 1
CHEMICAL REQUIREMENTS

Elements	Heat Analysis, %			
	Grade A	Grade B	Grade C	Grade D
Carbon, max	0.14	0.17	0.24	0.27
Manganese, max	0.90	0.90	0.90	0.90
Phosphorus, max	0.035	0.035	0.035	0.035
Sulfur, max	0.04	0.04	0.04	0.04
Silicon				
Plates 1½ in. [40 mm] and under, max	0.40	0.40	0.40	0.40
Plates over 1½ in. [40 mm]	0.15–0.40	0.15–0.40	0.15–0.40	0.15–0.40
Copper, min % when copper is specified	0.20	0.20	0.20	0.20

TABLE 2
TENSILE REQUIREMENTS^A

	Grade A	Grade B	Grade C	Grade D
Tensile strength, ksi [MPa]	45–60 [310–415]	50–65 [345–450]	55–75 [380–515]	60–80 [415–550]
Yield point, min, ksi [MPa]	24 [165]	27 [185]	30 [205]	33 [230]
Elongation in 8 in. [200 mm], min, % ^B	27	25	22	20
Elongation in 2 in. [50 mm], min, % ^B	30	28	25	23

^A See Specimen Orientation under the Tension Tests section of Specification A6/A 6M.

^B For plates wider than 24 in. [600 mm], the elongation requirement is reduced two percentage points. See elongation requirement adjustments in the Tension Tests section of Specification A 6/A 6M.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirement shall not apply unless specified in the order or contract. Standardized supplementary requirements for use at the option of the purchaser are listed in Specification A 6/A 6M. Those that are considered suitable for use with this specification are listed by title:

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S8. Ultrasonic Examination, and

S15. Reduction of Area

S97. Limitation on Rimmed or Capped Steel

S97.1 The steel shall be other than rimmed or capped.

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SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON STEEL, LOW- AND INTERMEDIATE-TENSILE STRENGTH



SA-285/SA-285M



[Identical with ASTM Specification A 285/A 285M-03(R07).]

1. Scope

1.1 This specification covers carbon steel plates of low- and intermediate-tensile strengths which may be made by killed, semi-killed, capped, or rimmed steel practices at the producer's option. These plates are intended for fusion-welded pressure vessels.

1.2 Plates under this specification are available in three grades having different strength levels as follows:

Grade	Tensile Strength, ksi (MPa)
A	45–65 [310–450]
B	50–70 [345–485]
C	55–75 [380–515]

1.3 The maximum thickness of plates under this specification, for reasons of internal soundness, is limited to a maximum thickness of 2 in. [50 mm] for all grades.

NOTE 1 — For killed carbon steels only refer to the following ASTM specifications:

A 299/A 299M, Pressure Vessel Plates, Carbon Steel, Manganese-Silicon
A 515/A 515M Pressure Vessel Plates, Carbon Steel, for Intermediate and Higher-Temperature Service

A 516/A 516M Pressure Vessel Plates, Carbon Steel, for Moderate and Lower-Temperature Service

1.4 For plates produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results, of Specification A 20/A 20M apply.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated

in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 ASTM Standard:

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

3. General Requirements and Ordering Information

3.1 Plates supplied to this product specification shall conform to Specification A 20/A 20M, which outlines the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for ordering information that should be complied with when purchasing plates to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available where additional control, testing, or examination is required to meet end use requirements.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 Coils are excluded from qualification to this specification until they are processed into finished plate. Plates produced from coil means plates that have been cut to

individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 2 — For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plate produced from coil are described in Specification A 20/A 20M.

3.6 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Heat Treatment

4.1 Plates are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

5. Chemical Composition

5.1 The steel shall conform to the requirements as to chemical composition as given in Table 1.

6. Mechanical Properties

6.1 Tension Test — The plates, as represented by the tension test specimens, shall conform to the requirements given in Table 2.

TABLE 1
CHEMICAL REQUIREMENTS

Elements	Composition, %		
	Grade A	Grade B	Grade C
Carbon, max ^A	0.17	0.22	0.28
Manganese, max			
Heat analysis	0.90	0.90	0.90
Product analysis	0.98	0.98	0.98
Phosphorus, max ^A	0.035	0.035	0.035
Sulfur, max ^A	0.035	0.035	0.035

^A Applies to both heat and product analysis.

TABLE 2
TENSILE REQUIREMENTS

	Grade A		Grade B		Grade C	
	ksi	[MPa]	ksi	[MPa]	ksi	[MPa]
Tensile strength	45–65	[310–450]	50–70	[345–485]	55–75	[380–515]
Yield strength, min ^A	24	[165]	27	[185]	30	[205]
Elongation in 8 in. or [200 mm], min, % ^B		27		25		23
Elongation in 2 in. or [50 mm], min, % ^B		30		28		27

^A Determined by either the 0.2% offset method or the 0.5% extension-under-load method.

^B See Specification A 20/A 20M for elongation adjustment.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 20/A 20M. Those that are considered suitable for use with this specification are listed below by title.

- S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons.**
- S4. Additional Tension Test.**

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

Also listed below are additional optional supplementary requirements suitable for this specification.

S57. Copper-Bearing

S57.1 The copper content, by heat analysis shall be 0.20–0.35% and by product analysis 0.18–0.37%.

S58. Restricted Copper

S58.1 The maximum incidental copper content by heat analysis shall not exceed 0.25%.

SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON STEEL, MANGANESE-SILICON



SA-299/SA-299M



(Identical with ASTM Specification A 299/A 299M-04.)

1. Scope

1.1 This specification covers manganese-silicon carbon steel plates for use in welded boilers and other pressure vessels.

1.2 Plates under this specification are produced in two grades. The specified minimum the yield strength decreases on thicknesses over 1 in. [25 mm].

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements; however, current practice normally limits the maximum thickness of plates furnished under this specification to 8 in. [200 mm].

1.4 For plates produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results, of Specification A 20/A 20M apply.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 ASTM Standards:
A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

3. General Requirements and Ordering Information

3.1 Plates supplied to this product specification shall conform to Specification A 20/A 20M, which outlines the

testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of defects, marking, loading, and so forth.

3.2 Specification A 20/A 20M also establishes the rules for the ordering information that should be complied with when purchasing plates to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available where additional control, testing, or examination is required to meet end use requirements.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1 — For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plates from coil are described in Specification A 20/A 20M.

3.6 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 Steelmaking Practice — The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

5. Heat Treatment

5.1 Plates 2 in. [50 mm] and under in thickness are normally supplied in the as-rolled condition. Plates may be ordered normalized or stress relieved, or both.

5.2 Plates over 2 in. [50 mm] in thickness shall be normalized.

6. Chemical Composition

6.1 The steel shall conform to the requirements given in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

7. Mechanical Properties

7.1 Tension Test Requirements — The plates, as represented by the tension test specimens, shall conform to the requirements given in Table 2.

8. Keywords

8.1 carbon steel plate; pressure containing parts; pressure vessel steels; steel plates; steel plates for pressure vessel applications

TABLE 1
CHEMICAL REQUIREMENTS

Elements	Composition, %
†Carbon, max ^A :	
1 in. [25 mm] and under	
Grade A	0.26
Grade B	0.28
Over 1 in. [25 mm]	
Grade A	0.28
Grade B	0.30
Manganese:	
1 in. [25 mm] and under	
Heat analysis	0.90 to 1.40
Product analysis	0.84 to 1.52
Over 1 in. [25 mm]	...
Heat analysis	0.90 to 1.50
Product analysis	0.84 to 1.62
Phosphorus, max ^A	0.035
Sulfur, max ^A	0.035
Silicon:	
Heat analysis	0.15 to 0.40
Product analysis	0.13 to 0.45

† Editorially corrected.

^A Applies to both heat and product analyses.

TABLE 2
TENSILE REQUIREMENTS

	Grade A	Grade B
Tensile strength, ksi	75–95 [515–655]	80–100 [550–690]
[MPa]		
Yield strength, min, ^A ksi [MPa]:		
1 in. [25 mm] and under	42 [290]	47 [325]
Over 1 in. [25 mm]	40 [275]	45 [310]
Elongation in 8 in.	16	16
[200 mm], min, % ^B		
Elongation in 2 in.	19	19
[50 mm], min, % ^B		

^A Determined by either the 0.2% offset method or the 0.5% extension-under-load method.

^B See the Elongation Requirements Adjustment subsection in the Tension Tests sections of Specification A 20/A 20M.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 20/A 20M. Those that are considered suitable for use with this specification are listed below by title.

- | | |
|---|---|
| S1. Vacuum Treatment, | S8. Ultrasonic Examination in Accordance With Specification A 435/A 435M, |
| S2. Product Analysis, | S9. Magnetic Particle Examination, |
| S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons, | S11. Ultrasonic Examination in Accordance With Specification A 577/A 577M, |
| S4. Additional Tension Test, | S12. Ultrasonic Examination in Accordance With Specification A 578/A 578M, |
| S5. Charpy V-Notch Impact Test, | S17. Vacuum Carbon-Deoxidized Steel. |
| S6. Drop Weight Test, | |
| S7. High-Temperature Tension Test, | |

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SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, MANGANESE-MOLYBDENUM AND MANGANESE-MOLYBDENUM-NICKEL



SA-302/SA-302M



[Identical with ASTM Specification A 302/A 302M-03(R07)]

1. Scope

1.1 This specification covers manganese-molybdenum and manganese-molybdenum-nickel alloy steel plates intended particularly for welded boilers and other pressure vessels.

1.2 Plates under this specification are available in four grades having different strength levels as follows:

Grade	Tensile Strength, ksi [MPa]	Type
A	75–95 [515–655]	Mn-Mo
B	80–100 [550–690]	Mn-Mo
C	80–100 [550–690]	Mn-Mo-Ni
D	80–100 [550–690]	Mn-Mo-Ni

1.3 The maximum thickness of plates is limited only by the capacity of the chemical composition to meet the specified mechanical property requirements. The minimum thickness is limited to 0.25 in. [6.5 mm].

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 ASTM Standard:

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

3. General Requirements and Ordering Information

3.1 Plates supplied to this product specification shall conform to Specification A 20/A 20M which outlines the

testing and retesting methods and procedures, permissible variations in dimensions, and mass, quality and repair of defects, marking, loading, and so forth.

3.2 Specification A 20/A 20M also establishes the rules for ordering information that should be complied with when purchasing plates to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available where additional control, testing, or examination is required to meet end use requirements.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operation involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1 — For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plates from coil are described in Specification A 20/A 20M.

3.6 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 *Steelmaking Practice* — The steel shall be killed and shall conform to the fine grain size requirement of Specification A 20/A 20M.

5. Heat Treatment

5.1 Plates 2 in. [50 mm] and under in thickness are normally supplied in the as-rolled condition. Plates may be ordered normalized or stress relieved, or both.

5.2 Plates over 2 in. [50 mm] in thickness shall be normalized.

5.3 When normalizing plates 4 in. [100 mm] or over in thickness, the cooling rate may be accelerated by air blasting or liquid quenching to obtain mechanical properties comparable to those developed by normalizing plates in the lesser thicknesses.

5.4 If approved by the purchaser, for plates less than 4 in. [100 mm] in thickness, cooling rates faster than those obtained by cooling in air are permissible for improvement of toughness, provided the plates are subsequently tempered in the temperature range from 1100 to 1300°F [595 to 705°C].

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

7. Mechanical Properties

7.1 *Tension Test Requirements* — The plates as represented by the tension test specimens shall conform to the requirements given in Table 2.

7.1.1 For accelerated cooled plates with a nominal thickness of $\frac{3}{4}$ in. [20 mm] or less, the $1\frac{1}{2}$ in. [40 mm] wide rectangular specimen may be used for the tension test, and the elongation may be determined in a 2 in. [50 mm] gage length that includes the fracture and that shows the greatest elongation.

8. Keywords

8.1 alloy steel plate; pressure containing parts; pressure vessel steels; steel plates; steel plates for pressure vessel applications

TABLE 1
CHEMICAL REQUIREMENTS

Elements	Composition, %			
	Grade A	Grade B	Grade C	Grade D
Carbon, max ⁴ :				
Up to 1 in. [25 mm], incl, in thickness	0.20	0.20	0.20	0.20
Over 1 to 2 in. [50 mm], incl	0.23	0.23	0.23	0.23
Over 2 in. [50 mm] in thickness	0.25	0.25	0.25	0.25
Manganese:				
Heat analysis	0.95–1.30	1.15–1.50	1.15–1.50	1.15–1.50
Product analysis	0.87–1.41	1.07–1.62	1.07–1.62	1.07–1.62
Phosphorus, max ⁴	0.035	0.035	0.035	0.035
Sulfur, max ⁴	0.035	0.035	0.035	0.035
Silicon:				
Heat analysis	0.15–0.40	0.15–0.40	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45	0.13–0.45	0.13–0.45
Molybdenum:				
Heat analysis	0.45–0.60	0.45–0.60	0.45–0.60	0.45–0.60
Product analysis	0.41–0.64	0.41–0.64	0.41–0.64	0.41–0.64
Nickel:				
Heat analysis	...	...	0.40–0.70	0.70–1.00
Product analysis	...	...	0.37–0.73	0.67–1.03

⁴ Applies to both heat and product analysis.

TABLE 2
TENSILE REQUIREMENTS

	Grade A	Grade B	Grade C	Grade D
Tensile strength, ksi [MPa]	75–95 [515–655]	80–100 [550–690]	80–100 [550–690]	80–100 [550–690]
Yield strength, min, ksi [MPa]	45 [310]	50 [345]	50 [345]	50 [345]
Elongation in 8 in. [200 mm], min, % ⁴	15	15	17	17
Elongation in 2 in. [50 mm], min, % ⁴	19	18	20	20

⁴ See Specification A 20/A 20M for elongation adjustment.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 20/A 20M. Those that are considered suitable for use with this specification are listed below by title.

- | | |
|---|--|
| S1. Vacuum Treatment, | S8. Ultrasonic Examination in Accordance With Specification A 435/A 435M, |
| S2. Product Analysis, | S9. Magnetic Particle Examination, |
| S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons, | S11. Ultrasonic Examination in Accordance With Specification A 577/A 577M, |
| S4.1 Additional Tension Test, | S12. Ultrasonic Examination in Accordance With Specificaion A 578/A 578M, and |
| S5. Charpy V-Notch Impact Test, | S17. Vacuum Carbon-Deoxidized Steel. |
| S6. Drop Weight Test, | |
| S7. High-Temperature Tension Test, | |

SPECIFICATION FOR CARBON STEEL BOLTS AND STUDS, 60 000 PSI TENSILE STRENGTH



SA-307

(Identical with ASTM Specification A 307-07b except for the deletion of private label distributor from para. 13.1.1.)

(10)

1. Scope

1.1 This specification covers the chemical and mechanical requirements of three grades of carbon steel bolts and studs in sizes $\frac{1}{4}$ in. through 4 in. The fasteners are designated by “Grade” denoting tensile strength and intended use, as follows:

Grade	Description
Grade A	Bolts and studs having a minimum tensile strength of 60 ksi and intended for general applications,
Grade B	Bolts and studs having a tensile strength of 60 to 100 ksi and intended for flanged joints in piping systems with cast iron flanges, and
Grade C	Replaced by Specification F 1554 Gr. 36

1.1.1 The term studs includes stud stock, sometimes referred to as threaded rod.

1.2 This specification does not cover requirements for machine screws, thread cutting/forming screws, mechanical expansion anchors or similar externally threaded fasteners.

1.3 Suitable nuts are covered in Specification A 563. Unless otherwise specified, the grade and style of nut for each grade of fastener, of all surface finishes, shall be as follows:

Fastener Grade and Size	Nut Grade and Style ^A
A $\frac{1}{4}$ to $1\frac{1}{2}$ in.	A, hex
A over $1\frac{1}{2}$ to 4 in.	A, heavy hex
B $\frac{1}{4}$ to 4 in.	A, heavy hex

^A Nuts of other grades and styles having specified proof load stresses (Specification A 563, Table 3) greater than the specified grade and style of nut are also suitable.

1.4 The values stated in inch-pound units are to be regarded as the standard.

1.5 Supplementary Requirement S1 of an optional nature is provided, which describes additional restrictions

to be applied when bolts are to be welded. It shall apply only when specified in the inquiry, order, and contract.

1.6 Terms used in this specification are defined in Terminology F 1789 unless otherwise defined herein.

2. Referenced Documents

2.1 ASTM Standards:

A 563 Specification for Carbons and Alloy Steel Nuts
 A 706/A 706M Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement
 A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
 B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
 D 3951 Practice for Commercial Packaging
 F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets
 F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection
 F 1554 Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength
 F 1789 Terminology for F16 Mechanical Fasteners
 F 2329 Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners

2.2 ASME Standards:

B 1.1 Unified Screw Threads
 B 18.2.1 Square and Hex Bolts and Screws
 B 18.24 Part Identifying Number (PIN) Code System

3. Ordering Information

3.1 Orders for externally threaded fasteners (including nuts and accessories) under this specification shall include the following:

3.1.1 ASTM designation and year of issue,

3.1.2 Name of product, bolts or studs; and bolt head style, that is, hex or heavy hex,

3.1.3 Grade, that is, A, or B. If no grade is specified, Grade A is furnished.

3.1.4 Quantities (number of pieces by size including nuts),

3.1.5 Fastener size and length,

3.1.6 *Washers* — Quantity and size (separate from bolts),

3.1.7 *Zinc Coating* — Specify the zinc-coating process required, for example, hot-dip, mechanically deposited, or no preference (see 4.5).

3.1.8 *Other Finishes* — Specify other protective finish, if required.

3.1.9 Specify if inspection at point of manufacture is required,

3.1.10 Specify if certified test report is required (see 8.2), and

3.1.11 Specify additional testing (8.3) or special requirements.

3.1.12 For establishment of a part identifying system, see ASME B18.24.

4. Materials and Manufacture

4.1 Steel for bolts and studs shall be made by the openhearth, basic-oxygen, or electric-furnace process.

4.2 Bolts shall be produced by hot or cold forging of the heads or machining from bar stock.

4.3 *Heat Treatment:*

4.3.1 Cold headed fasteners with head configurations other than hex shall be stress relief annealed.

4.3.2 Stress relieving of hex head fasteners shall be at the manufacturer's option.

4.4 Bolt and stud threads shall be rolled or cut.

4.5 *Zinc Coatings, Hot-Dip and Mechanically Deposited:*

4.5.1 When zinc-coated fasteners are required, the purchaser shall specify the zinc-coating process, for example hot dip, mechanically deposited, or no preference.

4.5.2 When hot-dip is specified, the fasteners shall be zinc-coated by the hot-dip process in accordance with the requirements of Specification F 2329.

4.5.3 When mechanically deposited is specified, the fasteners shall be zinc-coated by the mechanical-deposition process in accordance with the requirements of Class 55 of Specification B 695.

4.5.4 When no preference is specified, the supplier may furnish either a hot-dip zinc coating in accordance with Specification F 2329, or a mechanically deposited zinc coating in accordance with Specification B 695, Class 55. Threaded components (bolts and nuts) shall be coated by the same zinc-coating process and the supplier's option is limited to one process per item with no mixed processes in a lot.

5. Chemical Composition

5.1 Grade A and B bolts and studs shall have a heat analysis conforming to the requirements specified in Table 1 based on the steel producer's heat analysis.

5.2 The purchaser shall have the option of conducting product analyses on finished bolts in each lot, which shall conform to the product analysis specified in Table 1.

5.3 In case of conflict or for referee purposes, the product analysis shall take precedence.

5.4 Bolts and studs are customarily furnished from stock, in which case individual heats of steel cannot be identified.

5.5 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted for Grade B bolts and studs.

5.6 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A 751.

6. Mechanical Properties

6.1 Grades A and B bolts and studs shall conform to the hardness specified in Table 2.

6.2 Grade A and B bolts and studs 1½ in. in diameter or less, other than those excepted in 6.4, shall be tested full size and shall conform to the requirements for tensile strength specified in Table 3.

6.3 Grade A and B bolts and studs larger than 1½ in. in diameter, other than those excepted in 6.4, shall preferably be tested full size and when equipment of sufficient capacity is available and shall conform to the requirements for tensile strength specified in Table 3. When equipment of sufficient capacity for full-size bolt testing is not available, or when the length of the bolt makes full-size testing impractical, machined specimens shall be tested and shall conform to the requirements specified in Table 4.

6.4 Grades A and B bolts and studs less than three diameters in length or bolts with drilled or undersize heads are not subject to tensile tests.

6.5 In the event that bolts are tested by both full size and by machine test specimen methods, the full-size test

shall govern if a controversy between the two methods exists.

6.6 For bolts and studs on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence in the event that there is controversy over low readings of hardness tests.

7. Dimensions

7.1 Unless otherwise specified, threads shall be the Coarse Thread Series as specified in the latest issue of ASME B1.1, and shall have a Class 2A tolerance.

7.2 Unless otherwise specified, Grade A bolts shall be hex bolts with dimensions as given in the latest issue of ASME B18.2.1. Unless otherwise specified, Grade B bolts shall be heavy hex bolts with dimensions as given in the latest issue of ASME B18.2.1.

7.3 Unless otherwise specified, bolts and studs to be used with nuts or tapped holes which have been tapped oversize, in accordance with Specification A 563, shall have Class 2A threads before hot-dip or mechanically deposited zinc coating. After zinc coating the maximum limit of pitch and major diameter shall not exceed the Class 2A maximum limit by more than the following amounts:

Diameter, in.	Oversize Limit, in (mm) ^A
$\frac{1}{4}$	0.016
$\frac{5}{16}, \frac{3}{8}$	0.017
$\frac{7}{16}, \frac{1}{2}$	0.018
$\frac{9}{16}$ to $\frac{3}{4}$, incl	0.020
$\frac{7}{8}$	0.022
1.0 to $1\frac{1}{4}$, incl	0.024
$1\frac{3}{8}, 1\frac{1}{2}$	0.027
$1\frac{3}{4}$ to 4.0, incl	0.050

^A These values are the same as the overtapping required for zinc-coated nuts in Specification A 563.

7.4 The gaging limit for bolts and studs shall be verified during manufacture or use by assembly of a nut tapped as nearly as practical to the amount oversize shown above. In case of dispute, a calibrated thread ring gage of that same size (Class X tolerance, gage tolerance plus) shall be used. Assembly of the gage, or the nut described above, must be possible with hand effort following application of light machine oil to prevent galling and damage to the gage. These inspections, when performed to resolve disputes, shall be performed at the frequency and quality described in Table 5.

8. Number of Tests and Retests

8.1 The requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests

of individual shipments of material are not ordinarily contemplated. Individual heats of steel are not identified in the finished product.

8.2 When specified in the order, the manufacturer shall furnish a test report certified to be the last completed set of mechanical tests for each stock size in each shipment.

8.3 When additional tests are specified on the purchase order, a lot, for purposes of selecting test samples, shall consist of all material offered for inspection at one time that has the following common characteristics:

8.3.1 One type of item,

8.3.2 One nominal size, and

8.3.3 One nominal length of bolts and studs.

8.4 From each lot, the number of tests for each requirement shall be as follows:

Number of Pieces in Lot	Number of Samples
800 and under	1
801 to 8 000	2
8 001 to 22 000	3
Over 22 000	5

8.5 If any machined test specimen shows defective machining it shall be discarded and another specimen substituted.

8.6 Should any sample fail to meet the requirements of a specified test, double the number of samples from the same lot shall be tested, in which case all of the additional samples shall meet the specification.

9. Test Methods

9.1 Grades A and B bolts and studs shall be tested in accordance with Test Methods F 606.

9.2 Standard square and hex head bolts only shall be tested by the wedge tension method except as noted in 6.4. Fracture shall be in the body or threads of the bolt without any fracture at the junction of the head and body. Other headed bolts shall be tested by the axial tension method.

9.3 Speed of testing as determined with a free running crosshead shall be a maximum of 1 in./min for the tensile strength tests of bolts.

10. Inspection

10.1 If the inspection described in 10.2 is required by the purchaser it shall be specified in the inquiry, order, or contract.

10.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer's works that concern the manufacture of the material ordered. The

manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser's representative shall be made before shipment, and shall be conducted as not to interfere unnecessarily with the operation of the works.

11. Responsibility

11.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser.

12. Rejection and Rehearing

12.1 Disposition of nonconforming lots shall be in accordance with Guide F 1470, specifically sections on disposition of nonconforming lots, suppliers option, and purchasers option.

13. Product Marking

13.1 Grades A and B Bolts and Studs:

13.1.1 Bolt heads and one end of studs shall be marked with a unique identifier by the manufacturer to identify the manufacturer. Additional marking required by the manufacturer for his own use shall be at the option of the manufacturer.

13.1.2 In addition to the requirements of 13.1, all bolt heads, one end of studs $\frac{3}{8}$ in. and larger, and whenever feasible studs less than $\frac{3}{8}$ in. shall be marked with a grade marking a follows:

Grade	Marking
A	307A
B	307B

13.1.3 All markings shall be located on the top of the bolt head or stud end and shall be raised or depressed at the option of the manufacturer.

14. Packaging and Package Marking

14.1 Packaging:

14.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

14.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

14.2 Package Marking:

14.2.1 Each shipping unit shall include or be plainly marked with the following information:

14.2.1.1 ASTM designation and grade,

14.2.1.2 Size,

14.2.1.3 Name and brand or trademark of the manufacturer,

14.2.1.4 Number of pieces,

14.2.1.5 Purchase order number,

14.2.1.6 Country of origin.

15. Keywords

15.1 bolts; carbon steel; steel; studs

TABLE 1
CHEMICAL REQUIREMENTS FOR GRADES A
AND B BOLTS AND STUDS

	Heat Analysis	Product Analysis
Carbon, max.	0.29	0.33
Manganese, max.	1.20	1.25
Phosphorus, max.	0.04	0.041
Sulfur, max.		
Grade A	0.15	^A
Grade B	0.05	0.051

NOTE:

^A Resulturized steel is not subject to rejection based on product analysis for sulfur

TABLE 2
HARDNESS REQUIREMENTS FOR BOLTS AND STUDS

Grade	Length, in.	Hardness ^A			
		Brinell		Rockwell B	
		Min.	Max.	Min.	Max.
A	Less than 3 × dia ^B	121	241	69	100
	3 × dia and longer	...	241	...	100
B	Less than 3 × dia ^B	121	212	69	95
	3 × dia and longer	...	212	...	95

NOTES:

^A As measured anywhere on the surface or through the cross section.

^B Also bolts with drilled or undersize heads. These sizes and bolts with modified heads shall meet the minimum and maximum hardness as hardness is the only requirement.

TABLE 3
TENSILE REQUIREMENTS FOR FULL-SIZE BOLTS AND STUDS

Bolt Size, in.	Threads Per Inch	Stress Area, ^A in. ²	Tensile Strength, lbf ^B		
			Grade A, min. ^C	Grade B	
				min. ^D	max. ^D
1/4	20	0.0318	1,900	1,900	3,180
5/16	18	0.0524	3,100	3,100	5,240
3/8	16	0.0775	4,650	4,650	7,750
7/16	14	0.1063	6,350	6,350	10,630
1/2	13	0.1419	8,500	8,500	14,190
9/16	12	0.182	11,000	11,000	18,200
5/8	11	0.226	13,550	13,550	22,600
3/4	10	0.334	20,050	20,050	33,400
7/8	9	0.462	27,700	27,700	46,200
1	8	0.606	36,350	36,350	60,600
1 1/8	7	0.763	45,800	45,800	76,300
1 1/4	7	0.969	58,150	58,150	96,900
1 3/8	6	1.155	69,300	69,300	115,500
1 1/2	6	1.405	84,300	84,300	140,500
1 3/4	5	1.90	114,000	114,000	190,000
2	4 1/2	2.50	150,000	150,000	250,000
2 1/4	4 1/2	3.25	195,000	195,000	325,000
2 1/2	4	4.00	240,000	240,000	400,000
2 3/4	4	4.93	295,800	295,800	493,000
3	4	5.97	358,200	358,200	597,000
3 1/4	4	7.10	426,000	426,000	710,000
3 1/2	4	8.33	499,800	499,800	833,000
3 3/4	4	9.66	579,600	579,600	966,000
4	4	11.08	664,800	664,800	1,108,000

NOTES:

^A Area calculated from the equation:

$$A_s = 0.7854 [D - (0.9743/n)]^2$$

where:

A_s = stress area,
 D = nominal diameter of bolt, and
 n = threads per inch.

^B 1 lbf = 4.448 N.^C Based on 60 ksi (414 MPa).^D Based on 60–100 ksi (414–690 MPa).

TABLE 4
TENSILE REQUIREMENTS FOR MACHINED SPECIMENS

	Grade A	Grade B
Tensile strength, ksi	60 min.	60–100
Yield point, min. ksi	...	...
Elongation in 2 in. min., %	18	18

TABLE 5
SAMPLE SIZES AND ACCEPTANCE NUMBERS FOR
INSPECTION OF HOT-DIP OR MECHANICALLY
DEPOSITED ZINC-COATED THREADS

Lot Size	Sample Size ^A	Acceptance Number
2 to 90	13	1
91 to 150	20	2
151 to 280	32	3
281 to 500	50	5
501 to 1,200	80	7
1,201 to 3,200	125	10
3,201 to 10,000	200	14
10,001 and over	315	21

NOTE:

^A Inspect all bolts in the lot if the lot size is less than the sample size.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified in the purchase order or contract.

S1. Bolts Suitable for Welding

S1.1 The material described in this section is intended for welding. This supplemental section, by additional chemical composition restrictions and by a carbon equivalent formula, provides assurance of weldability by chemical composition control.

S1.2 Welding technique is of fundamental importance when bolts produced to this supplementary section are welded. It is presupposed that suitable welding procedures for the steel being welded and the intended service will be selected.

S1.3 All of the requirements of this supplemental section apply in addition to all of the chemical, mechanical, and other requirements of the base specification, Specification A 307 for Grade B.

S1.4 Because of the embrittling effects of welding temperatures on cold-forged steel, this supplemental section is limited to hot-forged bolts, or, if not forged, then to bolts produced from hot-rolled bars without forging or threaded bars, bars studs, or stud bolts produced from hot-rolled bars without forging. Cold-forged bolts, or cold-drawn threaded bars, if they are given a thermal treatment by heating to a temperature of not less than 1500°F (815°C) and air-cooled are also suitable.

S1.5 Chemical Requirements:

S1.5.1 Heat Chemical Analysis — Material conforming to the following additional analysis limitations shall be used to manufacture the product described in this supplementary requirement.

Carbon	0.30%, max
Manganese	1.00%, max
Phosphorus	0.04%, max
Sulfur	0.05%, max
Silicon	0.50%, max

S1.5.2 Carbon Equivalent (Source — Specification A 706/A 706M) — In addition to the heat chemical analysis requirements in S1.5.1, the heat analysis shall be such as to provide a carbon equivalent (CE) not exceeding 0.55 when calculated as follows:

$$CE = \%C + \frac{\%Mn}{6} + \frac{\%Cu}{40} + \frac{\%Ni}{20} + \frac{\%Cr}{10} - \frac{\%Mo}{50} - \frac{\%V}{10}$$

S1.6 Analysis Reports — If requested on the order or contract, the chemical composition of each heat of steel used and the calculated carbon equivalent for each heat shall be reported to the purchaser.

S1.7 Product (Check) Verification Analysis — Chemical analyses when made by the purchaser or a representative on bolts from each heat of steel, shall not exceed the values specified in S1.5.2 by more than the following amounts:

	%
Carbon	+0.03
Manganese	+0.06
Phosphorus	+0.008
Sulfur	+0.008
Silicon	+0.05

S2. Permanent Manufacturer's Identification

S2.1 Replaced by Specification F 1554.

S3. Permanent Grade Identification

S3.1 Replaced by Specification F 1554.

SPECIFICATION FOR COLD-DRAWN, STRESS-RELIEVED CARBON STEEL BARS SUBJECT TO MECHANICAL PROPERTY REQUIREMENTS



SA-311/SA-311M

[Identical to ASTM Specification A 311/A 311M-04(R10) except for deletion of 5.1.11, revision of Note A to Table 1 and an editorial change to 5.1.9. Certification has been made mandatory in 11.1.]

1. Scope

1.1 This specification covers two classes, nine grades, and four conditions of stress-relieved cold-drawn carbon steel bars produced to mechanical property requirements. One class, B, is cold drawn with higher than normal (heavy) drafts to provide higher strength levels, and four grades provide improved machinability.

1.2 Supplementary Requirements, S1 through S6, of an optional nature are provided.

1.3 The values stated in inch-pound units or SI units are to be regarded as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents, therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 ASTM Standards:

- A 29/A 29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished, General Requirements for
- A 108 Specification for Steel Bar, Carbon and Alloy, Cold-Finished
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- E 527 Practice for Numbering Metals and Alloys (UNS)

3. Terminology

3.1 Definitions:

3.1.1 stress relieving — heating to a suitable temperature, holding long enough to reduce residual stresses, and

then cooling slowly enough to minimize the development of new residual stresses.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 heavy draft — Using higher than normal drafts (approximately 10% through 35% reduction), followed by stress relieving, produces higher tensile and yield strengths provided an appropriate composition is used; for example, medium carbon with normal or higher manganese content.

4. Classification

4.1 The bars are furnished in the following classes and grades, and in the conditions shown in 6.4.

4.1.1 Class A — Normal-draft cold-drawn and stress-relieved rounds, squares, hexagons, and flats in the following grades:

Grades	UNS Designations
1018	G10180
1035	G10350
1045	G10450
1050	G10500
1541	G15410
1117	G11170
1137	G11370
1141	G11410
1144	G11440

4.1.2 Class B — Heavy-draft cold-drawn and stress-relieved rounds and hexagons in the following grades:

Grades	UNS Designations
1045	G10450
1050	G10500
1541	G15410
1141	G11410
1144	G11440

5. Ordering Information

5.1 Orders for material under this specification should include the following information as required to adequately describe the desired material:

- 5.1.1** Quantity (weight [mass] or number of pieces),
- 5.1.2** Name of material (carbon steel bars, cold drawn, stress relieved),
- 5.1.3** Condition 8.3,
- 5.1.4** Cross-sectional shape,
- 5.1.5** Size,
- 5.1.6** Length,
- 5.1.7** Class and grade,
- 5.1.8** Report of heat analysis, tensile properties Section 11,
- 5.1.9** Specification designation A 311 or A 311M,
- 5.1.10** Application,
- 5.1.11** DELETED
- 5.1.12** Supplementary requirements, if any, and
- 5.1.13** Additional requirements, if any.

NOTE 1 — A typical ordering description is as follows: 10000 lb carbon steel bars, cold drawn, stress relieved turned and polished, round 2.0 in. (50.8 mm) Diameter, 10 to 12 ft (3048 to 3658 mm) long, Class B, Grade 1050, (UNS G10500), fine grain, test reports required, ASTM A 311/A 311M dated _____, hydraulic cylinder piston rods. [5000 kg carbon steel bars, cold drawn, stress relieved turned and polished round 50 mm diameter, 3050 to 3650 mm long, Class B, Grade 1050 (UNS G10500), fine grain, test reports required, ASTM A 311M dated _____, hydraulic cylinder piston rods.]

6. Materials and Manufacture

6.1 Melting Practice — The steel shall be made by one or more of the following primary processes: open-hearth, basic-oxygen, or electric-furnace. The primary melting may incorporate separate degassing or refining and may be followed by secondary melting using electroslag remelting or vacuum arc remelting. Where secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

6.2 Cold Working:

6.2.1 Class A bars shall be cold drawn using normal drafting practices.

6.2.2 Class B bars shall be cold drawn using heavy (higher than normal) drafting practices.

6.3 Thermal Treatment — After cold drawing, the bars shall be stress relieved at a temperature of not less than 550°F [288°C] to meet the mechanical requirements specified in Table 2.

6.4 Condition — The bars shall be furnished in the following cold finish conditions, as specified:

6.4.1 Cold drawn, stress relieved;

6.4.2 Cold drawn, stress relieved, turned, and polished;

6.4.3 Cold drawn, stress relieved, turned, ground, and polished; and

6.4.4 Cold drawn, stress relieved, ground, and polished.

NOTE 2 — When turned bars are specified, turning may be performed prior to cold-drawing.

7. Chemical Composition

7.1 Composition — The cast or heat analysis shall conform to the chemical composition requirements specified in Table 1 for the grade ordered.

8. Mechanical Properties

8.1 Requirements — The bars shall conform to the requirements listed in Table 2.

8.2 Number of Tests — At least one tension test shall be made on each lot. A lot shall consist of bars of the same size from the same heat which have been stress relieved in the same stationary furnace charge. For continuous type of treatment, a lot shall consist of 25 tons [25 Mg] or less of the same size of each heat, treated in the same cycle.

8.3 Specimens — Tension test specimens shall be taken longitudinally in accordance with and from the locations specified in Test Methods and Definitions A 370.

8.4 Test Methods — Tension tests shall be made in accordance with Test Methods and Definitions A 370. The yield strength shall be determined at 0.2% offset or at 0.005 in./in. [0.005 mm/mm] of gage length, total extension under load.

9. Workmanship, Finish, and Appearance

9.1 Surface Finish — Unless otherwise specified, the bars shall have a commercial bright smooth surface finish consistent with the cold finishing operations specified in 6.4.

9.2 Bars that are thermal treated after cold finishing may have a discolored or oxidized surface.

9.3 Oiling — The bars shall be given a surface coating of oil or other rust inhibitor to protect against rust during shipment.

9.4 Workmanship — The bars shall be free of pipe, cracks, and flakes. Within the limits of good manufacturing and inspection practices, the bars shall be free of injurious seams, laps, segregation, or other imperfections that, due to their nature, degree, or extent, will interfere with the use of the material in machining or fabrication of suitable parts.

10. General Requirements

10.1 Material furnished under this specification shall conform to the requirements of the current edition of Specification A 29/A 29M and/or Specification A 108 unless otherwise stated.

11. Certification and Test Reports

11.1 A manufacturer's certification that the material was manufactured and tested in accordance with this specification together with a report of the heat analysis and tension test results shall be furnished at the time of shipment. The report shall include the name of the manufacturer, ASTM designation and year date and revision letter, if any, class and grade, heat number, size, and grain size (if requested).

12. Keywords

12.1 carbon steel bars; cold finished steel bars; steel bars

TABLE 1
CHEMICAL REQUIREMENTS
(CAST OR HEAT ANALYSIS)⁴

UNS Designation	Grade	Carbon, %	Manganese, %	Phosphorus, max %	Sulfur, %
G10180	1018	0.15–0.20	0.60–0.90	0.040	0.050 max
G10350	1035	0.32–0.38	0.60–0.90	0.040	0.050 max
G10450	1045	0.43–0.50	0.60–0.90	0.040	0.050 max
G10500	1050	0.48–0.55	0.60–0.90	0.040	0.050 max
G15410	1541	0.36–0.44	1.35–1.65	0.040	0.050 max
G11170	1117	0.14–0.20	1.00–1.30	0.040	0.08–0.13
G11370	1137	0.32–0.39	1.35–1.65	0.040	0.08–0.13
G11410	1141	0.37–0.45	1.35–1.65	0.040	0.08–0.13
G11440	1144	0.40–0.48	1.35–1.65	0.040	0.24–0.33

⁴ The intentional addition of Bi, Se, Te, and Pb is not permitted.

TABLE 2
MECHANICAL REQUIREMENTS

UNS No.	Grade Designation	Diameter, Thickness, or Distance Between Parallel Faces, in. [mm]	Tensile Strength, min., ksi [MPa]	Yield Strength, min., ksi [MPa]	Elongation in 2 in. [50 mm], min., %	Reduction of Area, min., %
Class A — Normal Draft Cold Drawn and Stress Relieved Annealed						
G10180	1018	Up to 7⁄8 [20], incl	70 [485]	60 [415]	18	40
		Over 7⁄8 [20] to 1¼ [30], incl	65 [450]	55 [380]	16	40
		Over 1¼ [30] to 2 [50], incl	60 [415]	50 [345]	15	35
		Over 2 [50] to 3 [75], incl	55 [380]	45 [310]	15	35
G10350	1035	Up to 7⁄8 [20], incl	85 [590]	75 [520]	13	35
		Over 7⁄8 [20] to 1¼ [30], incl	80 [550]	70 [485]	12	35
		Over 1¼ [30] to 2 [50], incl	75 [520]	65 [450]	12	35
		Over 2 [50] to 3 [75], incl	70 [485]	60 [415]	10	30
G10450	1045	Up to 7⁄8 [20], incl	95 [655]	85 [585]	12	35
		Over 7⁄8 [20] to 1¼ [30], incl	90 [620]	80 [550]	11	30
		Over 1¼ [30] to 2 [50], incl	85 [585]	75 [520]	10	30
		Over 2 [50] to 3 [75], incl	80 [550]	70 [485]	10	30
G10500 and G15410	1050 and G1541	Up to 7⁄8 [20], incl	100 [690]	90 [620]	11	35
		Over 7⁄8 [20] to 1¼ [30], incl	95 [655]	85 [585]	11	30
		Over 1¼ [30] to 2 [50], incl	90 [620]	80 [550]	10	30
		Over 2 [50] to 3 [75], incl	85 [585]	75 [520]	10	30
G11170	1117	Up to 7⁄8 [20], incl	75 [520]	65 [450]	15	40
		Over 7⁄8 [20] to 1¼ [30], incl	70 [485]	60 [415]	15	40
		Over 1¼ [30] to 2 [50], incl	65 [450]	55 [380]	13	35
		Over 2 [50] to 3 [75], incl	60 [415]	50 [345]	12	30
G11370 and G11410	1137 and 1141	Up to 7⁄8 [20], incl	95 [655]	90 [620]	11	35
		Over 7⁄8 [20] to 1¼ [30], incl	90 [620]	85 [585]	11	30
		Over 1¼ [30] to 2 [50], incl	85 [585]	80 [550]	10	30
		Over 2 [50] to 3 [70], incl	80 [550]	75 [520]	10	30
G11440	1144	Up to 7⁄8 [20], incl	105 [725]	95 [655]	10	30
		Over 7⁄8 [20] to 1¼ [30], incl	100 [690]	90 [620]	10	30
		Over 1¼ [30] to 2 [50], incl	95 [655]	85 [585]	10	25
		Over 2 [50] to 3 [70], incl	90 [620]	80 [550]	10	20
		Over 3 [70] to 4½ [115], incl	85 [585]	75 [520]	10	20
Class B — Heavy Draft Cold Drawn and Stress Relieved Annealed						
UNS No.	Grade Designation	In. [mm], Round or Hexagon ⁴	Tensile Strength, min., ksi [MPa]	Yield Strength, min., ksi [MPa]	Elongation in 2 in. [50 mm], min., %	Reduction of Area, min., %
G10450	1045	Up to 7⁄8 [20], incl	115 [795]	100 [690]	10	25
		Over 7⁄8 [20] to 1¼ [30], incl	115 [795]	100 [690]	10	25
		Over 1¼ [30] to 2 [50], incl	115 [795]	100 [690]	10	25
		Over 2 [50] to 3 [75], incl	115 [795]	100 [690]	9	25
		Over 3 [75] to 4 [102], incl	105 [725]	90 [620]	7	20
G10500	1050	Up to 7⁄8 [20], incl	115 [795]	100 [690]	8	25
G15410	1541	Over 7⁄8 [20] to 1¼ [30], incl	115 [795]	100 [690]	8	25
G11410	1141	Over 1¼ [30] to 2 [50], incl	115 [795]	100 [690]	8	25
and		Over 2 [50] to 3 [75], incl	115 [795]	100 [690]	8	20
G11440	1144	Over 3 [75] to 4½ [115], incl	115 [795]	100 [690]	7	20

⁴ Maximum size for hexagons is $1\frac{1}{2}$ in. [40 mm].

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry or order. Details of these requirements shall be agreed upon between the manufacturer and the purchaser.

S1. Special Surface

S1.1 When inspection standards more restrictive than visual inspection are required, special surface may be specified.

S2. Restricted Cast or Heat Analysis

S2.1 When required, the purchaser may specify restrictive cast or heat analysis limits on one or more elements. The degree of restriction and the number of elements so restricted are both subject to agreement between the manufacturer and the purchaser.

S3. Restricted Decarburization

S3.1 The purchaser may specify a maximum affected depth of decarburization when required for special applications, subject to agreement between the manufacturer and the purchaser.

S4. Nonmetallic Inclusion Requirements (Microscopical)

S4.1 When nonmetallic inclusion requirements are specified, the samples for testing shall be taken on a longitudinal direction midway between the center and the surface of the material. The area of the sample to be examined

should be agreed upon between the purchaser and the manufacturer, and the test specimen should be hardened by heating and quenched before being polished to avoid pits. The rating of the inclusion count should also be agreed upon and be based upon examination at a magnification of 100 diameters. Resulfurized steels are not subject to inclusion ratings.

S5. Restricted Incidental Elements

S5.1 The purchaser may specify limiting maximum requirements for copper, nickel, chromium, or molybdenum subject to agreement between the manufacturer and the purchaser.

S6. Grain Size

S6.1 The steel shall conform to either the coarse austenitic grain size (except as stated in S6.2), or the fine austenitic grain size requirement of Specification A 29/A 29M.

S6.2 Certain elements, or combinations of elements, such as manganese, sulfur, and lead tend to produce grain refinement and it is technically inappropriate to ensure coarse grain size as measured by the McQuaid-Ehn test on high manganese, high sulfur, and leaded steels such as 1144, 1151, and 11L41.

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SPECIFICATION FOR SEAMLESS AND WELDED AUSTENITIC STAINLESS STEEL PIPES



SA-312/SA-312M

(Identical with ASTM Specification A 312/A 312M-01a except for the deletion of 5.2, revision to 6.2 to add “H” Grade heat treatment requirements and editorial differences in 7.1 and Table 1 and an editorial correction to the Cr and Ni percent chemical composition for UNS S31002 in Table 1.)

1. Scope

1.1 This specification covers seamless, straight-seam welded, and heavily cold worked welded austenitic stainless steel pipe intended for high-temperature and general corrosive service.

NOTE 1— When the impact test criterion for a low-temperature service would be 15 ft-lbf [20 J] energy absorption or 15 mils [0.38 mm] lateral expansion, some of the austenitic stainless steel grades covered by this specification are accepted by certain pressure vessel or piping codes without the necessity of making the actual test. For example, Grades TP304, TP304L, and TP347 are accepted by the ASME Pressure Vessel Code, Section VIII Division 1, and by the Chemical Plant and Refinery Piping Code, ANSI B31.3, for service at temperatures as low as -425°F [-250°C] without qualification by impact tests. Other AISI stainless steel grades are usually accepted for service temperatures as low as -325°F [-200°C] without impact testing. Impact testing may, under certain circumstances, be required. For example, materials with chromium or nickel content outside the AISI ranges, and for material with carbon content exceeding 0.10%, are required to be impact tested under the rules of ASME Section VIII Division 1 when service temperatures are lower than -50°F [-45°C].

1.2 Grades TP304H, TP309H, TP309HCb, TP310H, TP310HCb, TP316H, TP321H, TP347H, and TP348H are modifications of Grades TP304, TP309Cb, TP309S, TP310Cb, TP310S, TP316, TP321, TP347, and TP348, and are intended for high-temperature service.

1.3 Optional supplementary requirements are provided for pipe where a greater degree of testing is desired. These supplementary requirements call for additional tests to be made and, when desired, one or more of these may be specified in the order.

1.4 Table X1.1 lists the standardized dimensions of welded and seamless stainless steel pipe as shown in ANSI B36.19. These dimensions are also applicable to heavily cold worked pipe. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification.

1.5 Grades TP321 and TP321H have lower strength requirements for pipe manufactured by the seamless process in nominal wall thicknesses greater than $\frac{3}{8}$ in. [9.5 mm].

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

NOTE 2— The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as “nominal diameter,” “size,” and “nominal size.”

2. Referenced Documents

2.1 ASTM Standards:

- A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes
- A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
- A 999/A 999M Specification for General Requirements for Alloy and Stainless Steel Pipe
- E 112 Test Methods for Determining the Average Grain Size

E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings
E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 ANSI Standards:

B1.20.1 Pipe Threads, General Purpose
B36.10 Welded and Seamless Wrought Steel Pipe
B36.19 Stainless Steel Pipe

2.3 ASME Standard:

ASME Boiler and Pressure Vessel Code: Section VIII

2.4 AWS Standard:

A5.9 Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Electrodes

2.5 Other Standard:

SAE J1086 Practice for Numbering Metals and Alloys (UNS)

2.6 Other Standard:

SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing

3. Terminology

3.1 Definitions:

3.1.1 The definitions in Specification A 999/A 999M and Terminology A 941 are applicable to this specification.

4. Ordering Information

4.1 Orders for material to this specification should include the following, as required, to describe the desired material adequately:

4.1.1 Quantity (feet, centimetres, or number of lengths),

4.1.2 Name of material (austenitic steel pipe),

4.1.3 Process (seamless (SML) or welded (WLD) or heavily cold worked (HCW),

4.1.4 Grade (Table 1),

4.1.5 Size (NPS or outside diameter and schedule number or average wall thickness),

4.1.6 Length (specific or random) (Section 13),

4.1.7 End finish (Section on Ends of Specification A 999/A 999M),

4.1.8 Optional requirements (product analysis, see Section 8; hydrostatic or nondestructive electric test, see Section 12),

4.1.9 Test report required (Certification Section of Specification A 999/A 999M),

4.1.10 Specification number, and

4.1.11 Special requirements or any supplementary requirements selected, or both.

5. General Requirements

5.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 999/A 999M unless otherwise provided herein.

5.2 DELETED

6. Materials and Manufacture

6.1 Manufacture:

6.1.1 The pipe shall be manufactured by one of the following processes:

6.1.2 *Seamless (SML) pipe* shall be made by a process that does not involve welding at any stage of production.

6.1.3 *Welded (WLD) pipe* shall be made using an automatic welding process with no addition of filler metal during the welding process.

6.1.4 *Heavily cold-worked (HCW) pipe* shall be made by applying cold working of not less than 35% reduction in thickness of both wall and weld to a welded pipe prior to the final anneal. No filler shall be used in making the weld. Prior to cold working, the weld shall be 100% radiographically inspected in accordance with the requirements of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, latest revision, Paragraph UW-51.

6.1.5 Welded pipe and HCW pipe of NPS 14 and smaller shall have a single longitudinal weld. Welded pipe and HCW pipe of a size larger than NPS 14 shall have a single longitudinal weld or shall be produced by forming and welding two longitudinal sections of flat stock when approved by the purchaser. All weld tests, examinations, inspections, or treatments shall be performed on each weld seam.

6.1.6 At the option of the manufacturer, pipe shall be either hot finished or cold finished.

6.1.7 The pipe shall be free of scale and contaminating exogenous iron particles. Pickling, blasting, or surface finishing is not mandatory when pipe is bright annealed. The purchaser is permitted to require that a passivating treatment be applied to the finished pipe.

6.2 Heat Treatment— All pipe shall be furnished in the heat-treated condition in accordance with the requirements of Table 2. Other than for Grades S33228, S30815, S31272 and the “H” grades, seamless pipe immediately following hot forming may be individually quenched in water or rapidly cooled by other means, provided that the temperature of the pipes after hot forming is not less than the minimum specified solution treatment temperature. For H Grades, as well as Grades S33228, S30815, and S31272, the pipes shall be reheated to the specified solution treatment temperature for the required time before quenching.

6.3 Grain Size:

6.3.1 The grain size of Grade UNS S32615, as determined in accordance with Test Methods E 112, shall be No. 3 or finer.

6.3.2 The grain size of grades TP309H, TP309HCb, TP310H and TP310HCb, as determined in accordance with Test Methods E 112, shall be No. 6 or coarser.

6.3.3 The grain size of grades 304H, 316H, 321H, 347H, and 348H, as determined in accordance with Test Methods E 112, shall be No. 7 or coarser.

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

8. Product Analysis

8.1 At the request of the purchaser, an analysis of one billet or one length of flat-rolled stock from each heat, or two pipes from each lot shall be made by the manufacturer. A lot of pipe shall consist of the following number of lengths of the same size and wall thickness from any one heat of steel:

NPS Designator	Lengths of Pipe in Lot
Under 2	400 or fraction thereof
2 to 5	200 or fraction thereof
6 and over	100 or fraction thereof

8.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Section 7.

8.3 If the analysis of one of the tests specified in 8.1 does not conform to the requirements specified in Section 7, an analysis of each billet or pipe from the same heat or lot may be made, and all billets or pipe conforming to the requirements shall be accepted.

9. Permitted Variations in Wall Thickness

9.1 In addition to the implicit limitation of wall thickness for seamless pipe imposed by the limitation on weight in Specification A 999/A 999M, the wall thickness for seamless and welded pipe at any point shall be within the tolerances specified in Table 3, except that for welded pipe the weld area shall not be limited by the 'Over' tolerance. The wall thickness and outside diameter for inspection for compliance with this requirement for pipe ordered by NPS and schedule number is shown in Table X1.1.

10. Tensile Requirements

10.1 The tensile properties of the material shall conform to the requirements prescribed in Table 4.

11. Mechanical Tests, Grain Size Determinations, and Weld Decay Tests Required

11.1 Transverse or Longitudinal Tension Test — One tension test shall be made on a specimen for lots of not more than 100 pipes. Tension tests shall be made on specimens from two tubes for lots of more than 100 pipes.

NOTE 3 — The term "lot," for mechanical tests, applies to all pipe of the same diameter and wall thickness (or schedule) which are produced from the same heat of steel and subjected to the same finishing treatment: (1) in a continuous heat-treatment furnace, (2) in a batch-type heat-treatment furnace, equipped with recording pyrometers and automatically controlled within a 50°F [30°C] range, or (3) by direct quenching after hot forming, the larger of: (a) Each 200 ft [60 m] or fraction thereof or, (b) That pipe heat treated in the same batch furnace charge.

11.2 Flattening Test — For material heat treated in a batch-type furnace, flattening tests shall be made on 5% of the pipe from each heat-treated lot. For material heat treated by the continuous process, or by direct quenching after hot forming this test shall be made on a sufficient number of pipe to constitute 5% of the lot, but in no case less than two lengths of pipe.

11.2.1 For welded pipe a transverse-guided face bend test of the weld may be conducted instead of a flattening test in accordance with the method outlined in the steel tubular product supplement of Test Methods and Definitions A 370. The ductility of the weld shall be considered acceptable when there is no evidence of cracks in the weld or between the weld and the base metal after bending. Test specimens from 5% of the lot shall be taken from the pipe or test plates of the same material as the pipe, the test plates being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

11.3 Grain Size — Grain size determinations on Grades TP309H, TP309HCb, TP310H, TP310HCb, and UNS S32615 shall be made on the same number of tubes as prescribed for the flattening test.

11.4 HCW pipe shall be capable of passing the weld decay tests listed in Supplementary S9 with a weld metal to base metal loss ratio of 0.90 to 1.1. The test is not required to be performed unless S9 is specified in the purchase order.

12. Hydrostatic or Nondestructive Electric Test

12.1 Each pipe shall be subjected to the nondestructive electric test or the hydrostatic test. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

12.2 The hydrostatic test shall be in accordance with Specification A 999/A 999M, unless specifically exempted under the provisions of 12.3.

12.3 For pipe whose dimensions equal or exceed NPS 10, the purchaser, with the agreement of the manufacturer,

may waive the hydrostatic test requirement when in lieu of such test the purchaser performs a system test. Each length of pipe furnished without the completed manufacturer's hydrostatic test shall include with the mandatory markings the letters "NH."

12.4 Nondestructive Electric Test:

Nondestructive electric tests shall be in accordance with Specification A 999/A 999M.

13. Lengths

13.1 Pipe lengths shall be in accordance with the following regular practice:

13.1.1 Unless otherwise agreed upon, all sizes from NPS $\frac{1}{8}$ to and including NPS 8 are available in a length up to 24 ft (Note 4) with the permissible range of 15 to 24 ft (Note 4). Short lengths are acceptable and the number and minimum length shall be agreed upon between the manufacturer and the purchaser.

NOTE 4 — This value(s) applies when the inch-pound designation of this specification is the basis of purchase. When the "M" designation of this specification is the basis of purchase, the corresponding metric value(s) shall be agreed upon between the manufacturer and the purchaser.

13.1.2 If definite cut lengths are desired, the lengths required shall be specified in the order. No pipe shall be under the specified length and not more than $\frac{1}{4}$ in. [6 mm] over that specified.

13.1.3 No jointers are permitted unless otherwise specified.

14. Workmanship, Finish, and Appearance

14.1 The finished pipes shall be reasonably straight and shall have a workmanlike finish. Imperfections may be removed by grinding, provided the wall thicknesses are not decreased to less than that permitted in Section 9 of Specification A 999/A 999M.

15. Repair by Welding

15.1 For welded pipe whose diameter equals or exceeds NPS 6, and whose nominal wall thickness equals or exceeds 0.200, weld repairs made with the addition of compatible filler metal may be made to the weld seam with the same procedures specified for plate defects in the section on Repair by Welding of Specification A 999/A 999M.

15.2 Weld repairs of the weld seam shall not exceed 20% of the seam length.

15.3 Weld repairs shall be made only with the gas tungsten-arc welding process using the same classification of bare filler rod qualified to the most current AWS Specification A5.9 as the grade of stainless steel pipe being

repaired and as shown in Table 5. Alternatively, subject to approval by the purchaser, weld repairs shall be made only with the gas tungsten-arc welding process using a filler metal more highly alloyed than the base metal when needed for corrosion resistance or other properties.

15.4 Pipes that have had weld seam repairs with filler metal shall be uniquely identified and shall be so stated and identified on the certificate of tests. When filler metal other than that listed in Table 5 is used, the filler metal shall be identified on the certificate of tests.

16. Certification

16.1 In addition to the information required by Specification A 999/A 999M, the certification shall state whether or not the material was hydrostatically tested. If the material was nondestructively tested, the certification shall so state and shall show which standard practice was followed and what reference discontinuities were used.

17. Marking

17.1 In addition to the marking specified in Specification A 999/A 999M, the marking shall include the NPS (nominal pipe size) or outside diameter and schedule number or average wall thickness, heat number, and NH when hydrotesting is not performed and ET when eddy-current testing is performed or UT when ultrasonic testing is performed. The marking shall also include the manufacturer's private identifying mark, the marking requirement of 12.3, if applicable, and whether seamless (SML), welded (WLD), or heavily cold-worked (HCW). For Grades TP304H, TP316H, TP321H, TP347H, TP348H, and S30815, the marking shall also include the heat number and heat-treatment lot identification. If specified in the purchase order, the marking for pipe larger than NPS 4 shall include the weight.

18. Government Procurement

18.1 Scale Free Pipe for Government Procurement:

18.1.1 When specified in the contract or order, the following requirements shall be considered in the inquiry, contract or order, for agencies of the U.S. Government where scale free pipe or tube is required. These requirements shall take precedence if there is a conflict between these requirements and the product specifications.

18.1.2 The requirements of Specification A 999/A 999M for pipe and Specification A 450/A 450M for tubes shall be applicable when pipe or tube is ordered to this specification.

18.1.3 Pipe and tube shall be one of the following grades as specified herein:

Grade	UNS Designation
TP304	S30400
TP304L	S30403
TP304N	S30451
TP316	S31600
TP316L	S31603
TP316N	S31651
TP317	S31700
TP317L	S31703
TP321	S32100
TP347	S34700

18.1.4 Part Number:

Example: ASTM A 312/A 312M Pipe 304 NPS 12 SCH 40S SMLS

Specification Number	ASTM A 312
Pipe	P
Grade	304
NPS	12
Wall	0.375
SMLS OR WELDED	SML

18.1.4.1

Specification Number	ASTM A 312
Tube	T
Grade	304
Outside Diameter	0.250
Wall	0.035
SMLS OR WELDED	WLD

18.1.5 Ordering Information — Orders for material under this specification shall include the following in addition to the requirements of Section 4:

18.1.5.1 Pipe or tube,

18.1.5.2 Part number,

18.1.5.3 Ultrasonic inspection, if required,

18.1.5.4 If shear wave test is to be conducted in two opposite circumferential directions,

18.1.5.5 Intergranular corrosion test, and

18.1.5.6 Level of preservation and packing required.

19. Keywords

19.1 austenitic stainless steel; seamless steel pipe; stainless steel pipe; steel pipe; welded steel pipe

TABLE 1
CHEMICAL REQUIREMENTS

Grade	UNS Designation ⁴	Composition, % ^g										
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Titanium	Columbium	Tantalum, max.
Aluminum	Cerium	Boron	Vanadium	Copper	Nitrogen ^c	Copper	Vanadium	Cerium	Boron	Aluminum	Aluminum	Aluminum
...	S20400	0.030	7.0-9.0	0.045	0.030	1.00	15.0-17.0	1.50-3.00	...	...	...	...
TPXM-19	S20910	0.06	4.0-6.0	0.045	0.030	1.00	20.5-23.5	11.5-13.5	...	...	...	...
TPXM-10	S21900	0.08	8.0-10.0	0.045	0.030	1.00	19.0-21.5	5.5-7.5	...	...	...	...
TPXM-11	S21904	0.04	8.0-10.0	0.045	0.030	1.00	19.0-21.5	5.5-7.5	...	...	...	...
TPXM-29	S24000	0.08	11.5-14.5	0.060	0.030	1.00	17.0-19.0	2.3-3.7	...	...	...	...
TP304	S30400	0.08	2.00	0.045	0.030	1.00	18.0-20.0	8.0-11.0	...	...	...	...
TP304L	S30403	0.035 ^d	2.00	0.045	0.030	1.00	18.0-20.0	8.0-13.0	...	...	...	...
TP304H	S30409	0.04-0.10	2.00	0.045	0.030	1.00	18.0-20.0	8.0-11.0	...	...	...	...
...	S30415	0.04-0.06	0.80	0.045	0.030	1.00-2.00	18.0-19.0	9.0-10.0	...	...	...	...
TP304N	S30451	0.08	2.00	0.045	0.030	1.00	18.0-20.0	8.0-11.0	...	...	...	...
TP304LN	S30453	0.035	2.00	0.045	0.030	1.00	18.0-20.0	8.0-12.0	...	...	...	...
...	S30600	0.018	2.00	0.02	0.02	3.7-4.3	17.0-18.5	14.0-15.5	0.20	...	...	...
...	S30615	0.16-0.24	2.00	0.030	0.03	3.2-4.0	17.0-19.5	13.5-16.0	13.5-16.0	...	...	...
...	S30815	0.05-0.10	0.80	0.040	0.030	1.40-2.00	20.0-22.0	10.0-12.0	...	...	...	...
TP309S	S30908	0.08	2.00	0.045	0.030	1.00	22.0-24.0	12.0-15.0	0.75	...	...	...
TP309H	S30909	0.04-0.10	2.00	0.045	0.030	1.00	22.0-24.0	12.0-15.0	...	...	...	...
TP309Cb	S30940	0.08	2.00	0.045	0.030	1.00	22.0-24.0	12.0-16.0	0.75	...	...	...
TP309HCb	S30941	0.04-0.10	2.00	0.045	0.030	1.00	22.0-24.0	12.0-16.0	0.75	...	...	...
TP310S	S31002	0.015	2.00	0.020	0.015	0.15	24.0-26.0	19.0-22.0	0.10	...	...	...
TP310H	S31008	0.08	2.00	0.045	0.030	1.00	24.0-26.0	19.0-22.0	0.75	...	...	...
TP310Cb	S31009	0.04-0.10	2.00	0.045	0.030	1.00	24.0-26.0	19.0-22.0	...	...	...	...
TP310H	S31040	0.08	2.00	0.045	0.030	1.00	24.0-26.0	19.0-22.0	0.75	...	...	...
TP310HCb	S31041	0.04-0.10	2.00	0.045	0.030	1.00	24.0-26.0	19.0-22.0	0.75	...	...	...
...	S31050	0.025	2.00	0.020	0.015	0.4	24.0-26.0	20.5-23.5	1.6-2.6	...	...	...
...	S31254	0.020	1.00	0.030	0.010	0.80	19.5-20.5	17.5-18.5	6.0-6.5	...	...	...
TP316	S31272	0.08-0.12	1.5-2.00	0.030	0.015	0.25-0.75	14.0-16.0	14.0-16.0	1.00-1.40	0.30-0.60	...	...
TP316L	S31600	0.08	2.00	0.045	0.030	1.00	16.0-18.0	11.0-14.0 ^e	2.00-3.00	...	...	...
TP316H	S31603	0.035 ^d	2.00	0.045	0.030	1.00	16.0-18.0	10.0-14.0	2.00-3.00	...	...	...
...	S31609	0.04-0.10	2.00	0.045	0.030	1.00	16.0-18.0	11.0-14.0 ^e	2.00-3.00	...	...	...
TP316N	S31635	0.08	2.00	0.045	0.030	0.75	16.0-18.0	10.0-12.0	2.00-3.00	...	...	...
TP316LN	S31651	0.08	2.00	0.045	0.030	1.00	16.0-18.0	11.0-14.0 ^e	2.00-3.00	...	...	...
TP317	S31700	0.08	2.00	0.045	0.030	1.00	18.0-20.0	11.0-14.0	3.0-4.0	...	...	...
TP317L	S31703	0.035	2.00	0.045	0.030	1.00	18.0-20.0	11.0-15.0	3.0-4.0	...	...	...
...	S31725	0.03	2.00	0.040 ^f	0.030	1.00	18.0-20.0	13.5-17.5	4.0-5.0	...	...	...
...	S31726	0.03	2.00	0.040 ^f	0.030	1.00	17.0-20.0	14.5-17.5	4.0-5.0	...	...	...
TP321	S32100	0.08	2.00	0.045	0.030	1.00	17.0-19.0	9.0-12.0	...	...	...	...
TP321H	S32109	0.04-0.10	2.00	0.045	0.030	1.00	17.0-19.0	9.0-12.0	...	...	...	...

TABLE 1
CHEMICAL REQUIREMENTS (CONT'D)

Grade	UNS Designation ^A	Composition, % ^B																
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Titanium	Columbium	Tantalum, max.	Nitrogen ^C	Vanadium	Copper	Cerium	Boron	Aluminum
...	S32615	0.07	2.00	0.045	0.030	4.8–6.0	16.5–19.5	19.0–22.0	0.30–1.50	...	...	...	...	...	1.50–2.50	...	...	...
...	S32654	0.020	2.0–4.0	0.030	0.005	0.50	24.0–25.0	21.0–23.0	7.0–8.0	...	...	...	0.45–0.55	...	0.30–0.60	...	...	...
...	S33228	0.04–0.08	1.00	0.020	0.015	0.30	26.0–28.0	31.0–33.0	...	...	0.60–1.00	...	...	...	...	0.05–0.10	...	0.025
...	S34565	0.03	5.0–7.0	0.030	0.010	1.00	23.0–25.0	16.0–18.0	4.0–5.0	...	0.10	...	0.40–0.60	...	...	...	...	...
TP347	S34700	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	...	J	...	...	...	...	...	...	...
TP347H	S34709	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	...	J	...	...	...	...	...	...	...
	0.005–									0.20–								
TP347LN	S34751	0.020	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	...	0.50 ^{F, K}	...	0.06–0.10	...	...	...	...	...
TP348	S34800	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	...	J	0.10	...	...	...	...	...	...
TP348H	S34809	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	...	J	0.10	...	...	...	...	...	...
...	S35045	0.06–0.10	1.50	...	0.015	1.00	25–29.0	32.0–37.0	...	0.15–0.60	...	...	...	...	0.75	...	...	0.15–0.60
...	S35315	0.04–0.08	2.00	0.040	0.030	1.20–2.00	24.0–26.0	34.0–36.0	...	...	...	...	0.12–0.18	...	...	0.03–0.08	...	...
TPXM-15	S38100	0.08	2.00	0.030	0.030	1.50–2.50	17.0–19.0	17.5–18.5	...	...	...	...	...	...	...	...	...	...
...	N08367	0.030	2.00	0.040	0.030	1.00	20.00–22.00	23.5–25.5	6.00–7.00	...	...	...	0.18–0.25	...	0.75	...	...	...
...	N08904	0.020	2.00	0.040	0.030	1.00	19.0–23.0	23.0–28.0	4.0–5.0	...	...	...	0.10	...	1.00–2.00	...	...	...
...	N08926	0.020	2.00	0.030	0.010	0.50	24.0–26.0	19.0–21.0	6.0–7.0	...	...	...	0.15–0.25	...	0.50–1.50	...	...	...

^A New designation established in accordance with Practice E 527 and SAE J1086.

^B Maximum, unless otherwise indicated.

^C The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

^D For small diameter or thin walls or both, where many drawing passes are required, a carbon maximum of 0.040% is necessary in grades TP304L and TP316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes as those less than 0.049 in. [1.20 mm] in average wall thickness (0.044 in. [1.10 mm] in minimum wall thickness).

^E For welded TP316, TP316N, TP316LN, and TP316H pipe, the nickel range shall be 10.0–14.0%.

^F For welded pipe, the phosphorus maximum shall be 0.045%.

^G The titanium content shall be not less than five times the carbon content and not more than 0.70%.

^H The titanium content shall be not less than four times the carbon content and not more than 0.60%.

^I The columbium content shall be not less than ten times the carbon content and not more than 1.00%.

^J The columbium content shall be not less than eight times the carbon content and not more than 1.0%.

^K Grade S34751 shall have a columbium (niobium) plus tantalum content of not less than 15 times the carbon content.

TABLE 2
ANNEALING REQUIREMENTS

Grade or UNS Designation ^A	Heat Treating Temperature ^B	Cooling/Testing Requirements
All grades not individually listed below:	1900°F [1040°C]	<i>C</i>
TP321H, TP347H, TP348H		
Cold finished	2000°F [1100°C]	<i>D</i>
Hot finished	1925°F [1050°C]	<i>D</i>
TP304H, TP316H		
Cold finished	1900°F [1040°C]	<i>D</i>
Hot finished	1900°F [1040°C]	<i>D</i>
TP309H, TP309HCB, TP310H, TP310HCB		
Cold finished	1900°F [1040°C]	<i>D</i>
Hot finished	1900°F [1040°C]	<i>D</i>
S30600	2010–2140°F [1100–1170°C]	<i>D</i>
S30815, S31272	1920°F [1050°C]	<i>D</i>
S31254, S32654	2100°F [1150°C]	<i>D</i>
S33228	2050–2160°F [1120–1180°C]	<i>D</i>
S34565	2050–2140°F [1120–1170°C]	<i>D</i>
S35315	2010°F [1100°C]	<i>D</i>
N08367	2025°F [1110°C]	<i>D</i>
N08904	2000°F [1100°C]	<i>D</i>
N08926	2010°F [1100°C]	<i>D</i>

^A New designation established in accordance with Practice E 527 and SAE J1086.

^B Minimum, unless otherwise stated.

^C Quenched in water or rapidly cooled by other means, at a rate sufficient to prevent reprecipitation of carbides, as demonstrable by the capability of passing Practices A 262, Practice E. The manufacturer is not required to run the test unless it is specified on the purchase order (see Supplementary Requirement S7). Note that Practices A 262 requires the test to be performed on sensitized specimens in the low-carbon and stabilized types and on specimens representative of the as-shipped condition for other types. In the case of low-carbon types containing 3% or more molybdenum, the applicability of the sensitizing treatment prior to testing shall be a matter for negotiation between the seller and the purchaser.

^D Quenched in water or rapidly cooled by other means.

TABLE 3
PERMITTED VARIATIONS IN WALL THICKNESS

NPS Designator	Tolerance, % from Nominal	
	Over	Under
1/8 to 2 1/2 incl., all <i>t/D</i> ratios	20.0	12.5
3 to 18 incl., <i>t/D</i> up to 5% incl.	22.5	12.5
3 to 18 incl., <i>t/D</i> > 5%	15.0	12.5
20 and larger, welded, all <i>t/D</i> ratios	17.5	12.5
20 and larger, seamless, <i>t/D</i> up to 5% incl.	22.5	12.5
20 and larger, seamless, <i>t/D</i> > 5%	15.0	12.5

where:

t = Nominal Wall Thickness

D = Ordered Outside Diameter

TABLE 4
TENSILE REQUIREMENTS

Grade	UNS Designation	Tensile Strength, Min. ksi [MPa]	Yield Strength, Min. ksi [MPa]
...	S20400	95 [635]	48 [330]
TPXM-19	S20910	100 [690]	55 [380]
TPXM-10	S21900	90 [620]	50 [345]
TPXM-11	S21904	90 [620]	50 [345]
TPXM-29	S24000	100 [690]	55 [380]
TP304	S30400	75 [515]	30 [205]
TP304L	S30403	70 [485]	25 [170]
TP304H	S30409	75 [515]	30 [205]
...	S30415	87 [600]	42 [290]
TP304N	S30451	80 [550]	35 [240]
TP304LN	S30453	75 [515]	30 [205]
...	S30600	78 [540]	35 [240]
...	S30615	90 [620]	40 [275]
...	S30815	87 [600]	45 [310]
TP309S	S30908	75 [515]	30 [205]
TP309H	S30909	75 [515]	30 [205]
TP309Cb	S30940	75 [515]	30 [205]
TP309HCb	S30941	75 [515]	30 [205]
...	S31002	73 [500]	30 [205]
TP310S	S31008	75 [515]	30 [205]
TP310H	S31009	75 [515]	30 [205]
TP310Cb	S31040	75 [515]	30 [205]
TP310HCb	S31041	75 [515]	30 [205]
...	S31050:		
t ≤ 0.25 in.		84 [580]	39 [270]
t > 0.25 in.		78 [540]	37 [255]
...	S31254:		
t ≤ 0.187 in. [5.00 mm]		98 [675]	45 [310]
t > 0.187 in. [5.00 mm]		95 [655]	45 [310]
...	S31272	65 [450]	29 [200]
TP316	S31600	75 [515]	30 [205]
TP316L	S31603	70 [485]	25 [170]
TP316H	S31609	75 [515]	30 [205]
...	S31635	75 [515]	30 [205]
TP316N	S31651	80 [550]	35 [240]
TP316LN	S31653	75 [515]	30 [205]
TP317	S31700	75 [515]	30 [205]
TP317L	S31703	75 [515]	30 [205]
...	S31725	75 [515]	30 [205]
...	S31726	80 [550]	35 [240]
TP321	S32100:		
Welded		75 [515]	30 [205]
Seamless:			
≤ 3/8 in.		75 [515]	30 [205]
> 3/8 in.		70 [485]	25 [170]
TP321H	S32109:		
Welded		75 [515]	30 [205]
Seamless:			
≤ 3/16 in.		75 [515]	30 [205]
> 3/16 in.		70 [480]	25 [170]
...	S32615	80 [550]	32 [220]
...	S32654	109 [750]	62 [430]
...	S33228	73 [500]	27 [185]
...	S34565	115 [795]	60 [415]
TP347	S34700	75 [515]	30 [205]
TP347H	S34709	75 [515]	30 [205]
TP347LN	S34751	75 [515]	30 [205]
TP348	S34800	75 [515]	30 [205]
TP348H	S34809	75 [515]	30 [205]
...	S35045	70 [485]	25 [170]
...	S35315	94 [650]	39 [270]

TABLE 4
TENSILE REQUIREMENTS (CONT'D)

Grade	UNS Designation	Tensile Strength, Min. ksi [MPa]	Yield Strength, Min. ksi [MPa]
TPXM-15	S38100	75 [515]	30 [205]
...	N08367:		
t ≤ 0.187		100 [690]	45 [310]
t > 0.187		95 [655]	45 [310]
...	N08904	71 [490]	31 [215]
...	N08926	94 [650]	43 [295]
Elongation in 2 in. or 50 mm (or 4D), Min., %:		Longitudinal	Transverse
All Grades except S31050 and S32615		35	25
S32615, S31050		25	...
N08367		30	...

TABLE 5
PIPE AND FILLER METAL SPECIFICATION

Pipe		Filler Metal	
Grade	UNS Designation	AWS A5.9 Class	UNS Designation
TP304	S30400	ER308	S30800, W30840
TP304L	S30403	ER308L	S30883, W30843
TP304N	S30451	ER308	S30880, W30840
TP304LN	S30453	ER308L	S30883, W30843
TP304H	S30409	ER308	S30880, W30840
TP309Cb	S30940	...	...
TP309S	S30908	...	...
TP310Cb	S31040	...	...
TP310S	S31008	...	...
...	S31272	...	...
TP316	S31600	ER316	S31680, W31640
TP316L	S31603	ER316L	S31683, W31643
TP316N	S31651	ER316	S31680, W31640
TP316LN	S31653	ER316L	S31683, W31643
TP316H	S31609	ER316H	S31680, W31640
TP321	S32100	ER321	S32180, W32140
...	...	ER347	S34780, W34740
TP347	S34700	ER347	S34780, W34740
TP348	S34800	ER347	S34780, W34740
TPXM-19	S22100	ER209	S20980, W32240
TPXM-29	S28300	ER240	S23980, W32440
...	N08367	...	N06625
...	S20400	ER209	S20980, W32240
...	N08926	...	N06625

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 For all pipe NPS 5 and larger in nominal size there shall be one product analysis made of a representative sample from one piece for each ten lengths or fraction thereof from each heat of steel.

S1.2 For pipe smaller than NPS 5 there shall be one product analysis made from ten lengths per heat of steel or from 10% of the number of lengths per heat of steel, whichever number is smaller.

S1.3 Individual lengths failing to conform to the chemical requirements specified in Section 7 shall be rejected.

S2. Transverse Tension Tests

S2.1 There shall be one transverse tension test made from one end of 10% of the lengths furnished per heat of steel. This applies only to pipe NPS 8 and larger.

S2.2 If a specimen from any length fails to conform to the tensile properties specified that length shall be rejected.

S3. Flattening Test

S3.1 The flattening test of Specification A 999/A 999M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A 999/A 999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free

of injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S5. Radiographic Examination

S5.1 The entire length of weld in each double welded pipe shall be radiographically examined, using X-radiation, in accordance with Paragraph UW-51 of Section VIII Division 1 of the ASME Boiler and Pressure Vessel Code. In addition to the marking required by Section 13 each pipe shall be marked "RT" after the specification and grade. Requirements of S5 shall be required in the certification.

S6. Stabilizing Heat Treatment

S6.1 Subsequent to the solution anneal required in 6.2, Grades TP309HCb, TP310HCb, TP321, TP321H, TP347, TP347H, TP348, and TP348H shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S7. Intergranular Corrosion Test

S7.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE S7.1 — Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S7.2 A stabilization heat treatment in accordance with Supplementary Requirement S6 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium, particularly in their H versions.

S8. Minimum Wall Pipe

S8.1 When specified by the purchaser, pipe shall be furnished on a minimum wall basis. The wall of such pipe shall not fall below the thickness specified. In addition to the marking required by Section 17, the pipe shall be marked S8.

S9. Weld Decay Test

S9.1 When specified in the purchase order, one sample from each lot of pipe shall be subject to testing in a boiling solution of 50% reagent grade hydrochloric acid and 50% water.

S9.2 The sample, of approximately 2 in. [50 mm] length, shall be prepared from a production length of pipe. Depending on the size of the pipe, it is permitted to section the sample longitudinally to allow it to fit in the Erlenmeyer flask. As a minimum, the tested sample shall include the entire weld and adjacent area and the full length of base metal 180° across from the weld. All burrs and sharp edges shall be removed by light grinding. Dust and grease shall be removed by cleaning with soap and water or other suitable solvents.

S9.3 The hydrochloric acid solution shall be prepared by slowly adding reagent grade (approximately 37%) hydrochloric acid to an equal volume of distilled water.

Warning — Protect eyes and use rubber gloves when handling acid. Mixing and testing shall be performed in a protective enclosure.

S9.4 The test container shall be a 1-L Erlenmeyer flask equipped with ground-glass joints and an Ahline condenser. The volume of the solution shall be approximately 700 mL.

S9.5 The thickness of the weld and the base metal 180° from the weld shall be measured near both ends of the sample. These measurements shall be made with a micrometer with an anvil shape suitable for measuring the thickness with an accuracy to at least 0.001 in. [0.025 mm].

S9.6 The sample sections, both weld and base metal, shall be immersed in the flask containing the solution. Boiling chips shall be added and the solution brought to

a boil. Boiling shall be maintained through the duration of the test. The time of testing shall be that which is required to remove 40 to 60% of the original base metal thickness (usually 2 h or less). If more than 60% of the base metal thickness remains, it is permitted to terminate the test after 24 h.

S9.7 At the end of the test period, the samples shall be removed from the solution, rinsed with distilled water, and dried.

S9.8 The thickness measurements as in S9.5 shall be repeated. The anvil shape of the micrometer used shall be suitable for measuring the minimum remaining thickness with an accuracy to at least 0.001 in. [0.025 mm].

S9.9 The corrosion ratio, R , shall be calculated as follows:

$$R = (W_o - W) / (B_o - B)$$

where:

W_o = average weld-metal thickness before the test

W = average weld-metal thickness after the test

B_o = average base-metal thickness before the test, and

B = average base-metal thickness after the test

S9.9.1 The corrosion ratio for HCW pipe shall be as specified in 11.4.

S9.9.2 The corrosion ratio shall be 1.25 or less, or as further restricted in the purchase order, when the weld decay test is specified for welded (WLD) pipe.

$$R = (W_o - W) / (B_o - B)$$

where:

W_o = average weld-metal thickness before the test

W = average weld-metal thickness after the test

B_o = average base-metal thickness before the test, and

B = average base-metal thickness after the test

S9.9.1 The corrosion ratio for HCW pipe shall be as specified in 11.4.

S9.9.2 The corrosion ratio shall be 1.25 or less, or as further restricted in the purchase order, when the weld decay test is specified for welded (WLD) pipe.

APPENDIX

(Nonmandatory Information)

X1. DIMENSIONS OF WELDED AND SEAMLESS STAINLESS STEEL PIPE

X1.1 Table X1.1 is based on Table 1 of the American National Standard for stainless steel pipe (ANSI B36.19).

TABLE X1.1
DIMENSIONS OF WELDED AND SEAMLESS STAINLESS STEEL PIPE

NPS Designator	Outside Diameter		Nominal Wall Thickness							
			Schedule 5S ^A		Schedule 10S ^A		Schedule 40S		Schedule 80S	
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
1/8	0.405	10.29	...	...	0.049	1.24	0.068	1.73	0.095	2.41
1/4	0.540	13.72	...	...	0.065	1.65	0.088	2.24	0.119	3.02
3/8	0.675	17.15	...	...	0.065	1.65	0.091	2.31	0.126	3.20
1/2	0.840	21.34	0.065	1.65	0.083	2.11	0.109	2.77	0.147	3.73
3/4	1.050	26.67	0.065	1.65	0.083	2.11	0.113	2.87	0.154	3.91
1.0	1.315	33.40	0.065	1.65	0.109	2.77	0.133	3.38	0.179	4.55
1 1/4	1.660	42.16	0.065	1.65	0.109	2.77	0.140	3.56	0.191	4.85
1 1/2	1.900	48.26	0.065	1.65	0.109	2.77	0.145	3.68	0.200	5.08
2	2.375	60.33	0.065	1.65	0.109	2.77	0.154	3.91	0.218	5.54
2 1/2	2.875	73.03	0.083	2.11	0.120	3.05	0.203	5.16	0.276	7.01
3	3.500	88.90	0.083	2.11	0.120	3.05	0.216	5.49	0.300	7.62
3 1/2	4.000	101.60	0.083	2.11	0.120	3.05	0.226	5.74	0.318	8.08
4	4.500	114.30	0.083	2.11	0.120	3.05	0.237	6.02	0.337	8.56
5	5.563	141.30	0.109	2.77	0.134	3.40	0.258	6.55	0.375	9.52
6	6.625	168.28	0.109	2.77	0.134	3.40	0.280	7.11	0.432	10.97
8	8.625	219.08	0.109	2.77	0.148	3.76	0.322	8.18	0.500	12.70
10	10.750	273.05	0.134	3.40	0.165	4.19	0.365	9.27	0.500 ^B	12.70 ^B
12	12.750	323.85	0.156	3.96	0.180	4.57	0.375 ^B	9.52 ^B	0.500 ^B	12.70 ^B
14	14.000	355.60	0.156	3.96	0.188 ^B	4.78 ^B	...	...	...	...
16	16.000	406.40	0.165	4.19	0.188 ^B	4.78 ^B	...	...	...	...
18	18.000	457.20	0.165	4.19	0.188 ^B	4.78 ^B	...	...	...	...
20	20.000	508.00	0.188	4.78	0.218 ^B	5.54 ^B	...	...	...	...
22	22.000	558.80	0.188	4.78	0.218 ^B	5.54 ^B	...	...	...	...
24	24.000	609.60	0.218	5.54	0.250	6.35	...	...	...	...
30	30.000	762.00	0.250	6.35	0.312	7.92	...	...	...	...

NOTE 1: The decimal thickness listed for the respective pipe sizes represents their nominal or average wall dimensions.

^A Schedules 5S and 10S wall thicknesses do not permit threading in accordance with the American National Standard for Pipe Threads (ANSI B1.20.1).

^B These do not conform to the American National Standard for Welded and Seamless Wrought Steel Pipe (ANSI B36.10–1979).

SPECIFICATION FOR ALLOY STEEL AND STAINLESS STEEL BOLTING MATERIALS FOR LOW-TEMPERATURE SERVICE



SA-320/SA-320M

(Identical with ASTM Specification A 320/A 320M-07 except for editorial clarification of exemption of carbide solution treated austenitic material from impact test requirements in 6.2.1.1.) (10)

1. Scope

1.1 This specification covers alloy steel bolting materials for pressure vessels, valves, flanges, and fittings for low-temperature service. The term “bolting material” as used in this specification covers rolled, forged, or strain hardened bars, bolts, screws, studs, and stud bolts. The bars shall be hotwrought. The material may be further processed by centerless grinding or by cold drawing. Austenitic stainless steel may be solution annealed or annealed and strain-hardened. When strain hardened austenitic stainless steel is ordered, the purchaser should take special care to ensure that Appendix X1 is thoroughly understood.

1.2 Several grades are covered, including both ferritic and austenitic steels designated L7, B8, etc. Selection will depend on design, service conditions, mechanical properties, and low-temperature characteristics. The mechanical requirements of Table 1 indicate the diameters for which the minimum mechanical properties apply to the various grades and classes, and Table 2 stipulates the requirements for Charpy impact energy absorption. The manufacturer should determine that the material can conform to these requirements before parts are manufactured. For example, when Grade L43 is specified to meet the Table 2 impact energy values at -150°F [-101°C], additional restrictions (such as procuring a steel with lower P and S contents than might normally be supplied) in the chemical composition for AISI 4340 are likely to be required.

NOTE 1 — The committee formulating this specification has included several grades of material that have been rather extensively used for the present purpose. Other compositions will be considered for inclusion by the committee from time to time as the need becomes apparent. Users should note that hardenability of some of the grades mentioned may restrict the maximum size at which the required mechanical properties are obtainable.

1.3 Nuts for use with this bolting material are covered in Section 10 and the nut material shall be impact tested.

1.4 Supplementary Requirements (S1, S2, and S3) of an optional nature are provided. They shall apply only when specified in the inquiry, contract and order.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable “M” specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 ASTM Standards:

- A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 962/A 962M Specification for Common Requirements for Steel Fasteners or Fastener Materials, or Both, Intended for Use at Any Temperature from Cryogenic to the Creep Range
- E 566 Practice for Electromagnetic (Eddy-Current) Sorting of Ferrous Metals
- F 436 Specification for Hardened Steel Washers

F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets

2.2 ANSI Standards:

B1.1 Screw Threads

B18.22.1 Plain Washers

3. Ordering Information

3.1 It is the purchaser's responsibility to specify in the purchase order all information necessary to purchase the needed materials. Examples of such information include, but are not limited to, the following:

3.1.1 Quantity and size,

3.1.2 Heat-treated condition, that is, for the austenitic stainless steels, solution-treated (Class 1); solution-treated after finishing (Class 1A); and annealed and strain-hardened (Class 2),

3.1.3 Description of items required (bars, bolts, screws, or studs),

3.1.4 Nuts and washers, if required by the purchaser, in accordance with Section 10, and

3.1.5 Special requirements, in accordance with 5.1.1, 5.1.2, 5.1.3, and 12.1.

4. Common Requirements

4.1 Material and fasteners supplied to this specification shall conform to the requirements of Specification A 962/A 962M. These requirements include methods, finish, thread dimensions, marking certification, optional supplementary requirements, and others. Failure to comply with the requirements of Specification A 962/A 962M constitutes nonconformance with this specification. In case of conflict between the requirements in this specification and Specification A 962/A 962M, this specification shall prevail.

4.2 For L7M bolting, the final heat treatment, which may be the tempering operation if conducted at 1150°F [620°C] minimum, shall be done after machining and forming operations, including thread rolling and any type of cutting.

5. Materials and Manufacture

5.1 Heat Treatment:

5.1.1 The bolting material shall be allowed to cool to room temperature after rolling or forging. Grades L7, L7A, L7B, L7C, L7M, L43, L1, L70, L71, L72, and L73 shall be reheated to above the upper critical temperature and liquid quenched and tempered. Grades B8, B8C, B8M,

B8T, B8F, B8P, B8LN, and B8MLN shall receive a carbide solution treatment. Products made from such material are described as Class 1. This shall consist of holding the material for a sufficient time at a temperature at which the chromium carbide will go into solution and then cooling in air or in a liquid medium at a rate sufficient to prevent reprecipitation of the carbide. Material thus treated is described as Class 1. If specified in the purchase order, material shall be solution treated in the finished condition; material so treated is described as Class 1A.

5.1.2 When increased mechanical properties are desired, the austenitic bolting materials shall be solution annealed and strain hardened if specified in the purchase order; material so treated is identified as Class 2.

5.1.3 If scale-free bright finish is required, this shall be specified in the purchase order.

5.1.4 For L7M bolting, the final heat treatment, which may be the tempering or stress-relieving operation conducted at 1150°F [620°C] minimum, shall be done after machining or rolling of the threads and any type of cutting.

6. Mechanical Requirements

6.1 Tensile Properties:

6.1.1 The material as represented by the tension specimens shall conform to the requirements as to tensile properties prescribed in Table 1 at room temperature after heat treatment (see 5.1.1). Alternatively, Class 2 Strain Hardened Headed Fasteners shall be tested full size after strain hardening to determine tensile strength and yield strength and shall conform to the requirements prescribed in Table 1. Should the results of full size tests conflict with results of tension specimen tests, full size test results shall prevail.

6.1.2 Number of Tests:

6.1.2.1 For heat-treated bars, one tension test and one impact test consisting of three specimens shall be made for each diameter of each heat represented in each tempering charge. In the continuous type treatment, a charge shall be defined as 6000 lb [2700 kg].

6.1.2.2 For studs, bolts, screws, etc., one tension test and one set of three impact specimens shall be made for each diameter of each heat involved in the lot. Each lot shall consist of the following:

Diameter, in. [mm]	Lot Size, lb [kg]
1⅛ [30] and under	1500 [680] or fraction thereof
Over 1⅛ [30] to 1¾ [45], incl	4500 [2040] or fraction thereof
Over 1¾ [45] to 2½ [65], incl	6000 [2700] or fraction thereof
Over 2½ [65]	100 pieces or fraction thereof

6.1.2.3 Full Size Specimens, Headed Fasteners — Headed fasteners 1½ in. in body diameter and smaller, with body length three times the diameter or longer, and which

are produced by upsetting or forging (hot or cold) shall be subjected to full size testing in accordance with 6.1.3. This testing shall be in addition to tensile testing as specified in 6.1.1. The lot size shall be shown in 6.1.2.2. Failure shall occur in the body or threaded sections with no failure, or indications of failure, such as cracks, at the junction of the head and shank.

6.1.3 Full Size Fasteners, Wedge Tensile Testing — When applicable, see 6.1.2.3. Headed fasteners shall be wedge tested full size in accordance with Annex A3 of Test Methods and Definitions A 370 and shall conform to the tensile strength shown in Table 1. The minimum full size breaking strength (lbf) for individual sizes shall be as follows:

$$T_s = UTS \times A_s \quad (1)$$

where:

T_s = Wedge tensile strength
 UTS = Tensile strength specified in Table 1, and
 A_s = Stress area, square inches, as shown in ANSI B1.1 or calculated as follows:

$$A_s = 0.785 (D - (0.974/n))^2 \quad (2)$$

where:

D = Nominal thread size, and
 n = The number of threads per inch

6.2 Impact Properties:

6.2.1 Requirements:

- (10) **6.2.1.1** Impact tests are required for the grades shown in Table 3. Class 1, 1A and 2 austenitic steels for temperatures above -325°F [-200°C]; Class 1 and 1A austenitic Grades B8, B8A, B8P, B8PA, B8C, B8CA, B8LN, and B8LNA above -425°F [-255°C]; and ferritic or austenitic bolting $\frac{1}{2}$ in. [12.5 mm] and smaller, are exempt from impact testing, unless Supplementary Requirement S1 is specified in the purchase order (see 1.4). All other material furnished under this specification shall be tested. Material of Grades L7, L7A, L7B, L7C, L7M, L43, L70, L71, L72, and L73 shall show a minimum impact energy absorption of 20 ft · lbf [27 J] and of Grade L1 a minimum impact energy absorption of 40 ft · lbf [54 J] at the test temperature when tested by the procedure specified in the applicable portions of Sections 19 to 28 of Test Methods and Definitions A 370. The temperature of the coolant used for chilling the test specimens shall be controlled within $\pm 3^{\circ}\text{F}$ [1.5°C]. Test temperatures for ferritic grades are listed in Table 3. Exceptions to this requirement are permissible, and the impact tests may be made at specified temperatures different than those shown in Table 3, provided the test temperature is at least as low as the intended service temperature and the bolting is suitably marked to identify the reported test temperature.

When impact testing is required for austenitic grades, test criteria shall be agreed upon between the supplier and purchaser.

6.2.1.2 The impact test requirements for standard and subsize Charpy test specimens are prescribed in Table 2.

6.2.2 Number of Tests:

6.2.2.1 The test requirements for heat-treated bars are given in 6.1.2.1.

6.2.2.2 For test requirements on studs, bolts, screws, etc., see 6.1.2.2.

6.2.2.3 Impact tests are not required to be made on heat-treated bars, bolts, screws, studs, and stud bolts $\frac{1}{2}$ in. [12.5 mm] and under in diameter.

6.2.3 Test Specimens — For sections 1 in. [25 mm] or less in diameter, test specimens shall be taken at the axis; for sections over 1 in. [25 mm] in diameter, midway between the axis and the surface.

6.3 Hardness Requirements:

6.3.1 The hardness shall conform to the requirements prescribed in Table 1. Hardness testing shall be performed in accordance with either Specification A 962/A 962M or with Test Methods F 606.

6.3.2 The maximum hardness of Grade L7M shall be 235 HB or 99 HRB (conversion in accordance with Table Number 2B of Test Methods and Definitions A 370). Minimum hardness shall not be less than 200 HB or 93 HRB. Conformance to this hardness shall be ensured by testing each bolt or stud by Brinell or Rockwell B methods in accordance with 6.3.1.

6.3.2.1 The use of 100% electromagnetic testing for hardness as an alternative to 100% indentation hardness testing is permissible when qualified by sampling using indentation hardness testing. Each lot tested for hardness electromagnetically shall be 100% examined in accordance with Practice E 566. Following electromagnetic testing for hardness, a random sample of a minimum of 100 pieces in each purchase lot (as defined in 6.1.2.2) shall be tested by indentation hardness methods. All samples must meet hardness requirements to permit acceptance of the lot. If any one sample is outside of the specified maximum or minimum hardness, the lot shall be rejected and either reprocessed and resampled, or tested 100% by indentation hardness methods.

6.3.2.2 In the event a controversy exists relative to minimum strength, tension tests shall prevail over hardness readings. Products which have been tested and found acceptable shall have a line under the grade symbol.

7. Chemical Composition

7.1 Each alloy shall conform to the chemical composition requirements prescribed in Table 4.

8. Workmanship, Finish, and Appearance

8.1 Bolts, screws, studs, and stud bolts shall be pointed and shall have a workmanlike finish.

9. Retests

9.1 If the results of the mechanical tests of any test lot do not conform to the requirements specified, the manufacturer may retreat such lot not more than twice, in which case two additional tension tests and one additional impact test consisting of three specimens shall be made from such lot, all of which shall conform to the requirements specified.

10. Nuts and Washers

10.1 Bolts, studs, and stud bolts of Grades L7, L7A, L7B, L7C, L43, L1, L70, L71, L72, and L73 shall be equipped with ferritic alloy nuts conforming to Grade 4 or Grade 7 of Specification A 194/A 194M or a grade of steel similar to the studs. Grade 7M nuts at a hardness not exceeding 235 HB (or equivalent) shall be used with Grade L7M bolts, studs, and stud bolts. All nut materials, including those which may be supplied under Specification A 194/A 194M, shall be subject to the impact requirements of this specification in the following manner: impact tests shall be made on test specimens taken from the bar or plate from the heat of steel used for manufacturing the nuts, and heat treated with the nut blanks.

10.2 Bolts, studs, and stud bolts of Grades B8, B8C, B8T, B8P, B8F, B8M, B8LN, and B8MLN shall be equipped with austenitic alloy nuts conforming to Grades 8, 8C, 8T, 8F, 8M, 8LN, and 8MLN for Specification A 194/A 194M. Impact tests are not required for Grades 8F, 8M, 8T, and 8MLN for temperatures above -325°F [-200°C] and for Grades 8, 8P, 8C, and 8LN above -425°F [-255°C].

10.3 If the purchaser requires nuts with a Charpy impact energy absorption of not less than 20 ft · lbf [27 J] at temperatures below -150°F [-100°C], he may require that the nuts conform to Grades 8, 8C, 8M, 8P, 8T, 8F, 8LN, or 8MLN of Specification A 194/A 194M.

10.4 Washers for use with ferritic steel bolting shall conform to Specification F 436.

10.5 Washers for use with austenitic steel bolting shall be made of austenitic steel as agreed upon between the manufacturer and purchaser.

10.6 Washer dimensions shall be in accordance with requirements of ANSI B18.22.1, unless otherwise specified in the purchase order.

11. Threads

11.1 Where practical, all threads shall be formed after heat treatment. Class 1A, Grades B8A, B8CA, B8MA, B8PA, B8FA, B8TA, B8LNA, and B8MLNA are to be solution-treated in the finished condition.

12. Product Marking

12.1 The identification symbol shall be as shown in Table 4. In the case of Class 2, Grades B8, B8C, B8M, B8P, B8F, and B8T strain hardened as provided in Table 1, a line shall be stamped under the grade symbol in order to distinguish it from Class 1 and Class 1A bolting which has not been strain hardened. In the case of Class 1A, the marking B8A, B8CA, B8MA, B8PA, B8FA, B8TA, B8LNA, and B8MLNA identifies the material as being in the solution-treated condition in the finished state. Grade L7M which has been 100% evaluated in conformance with this specification shall have a line under the grade symbol to distinguish it from L7M produced to previous revisions not requiring 100% hardness testing.

12.2 For bolting materials, including threaded bars, that are furnished bundled and tagged or boxed, the tags and boxes shall carry the grade symbol for the material identification and the manufacturer's identification mark or name.

12.3 Nuts from materials that have been impact tested shall be marked with the letter "L."

12.4 For purposes of identification marking, the manufacturer is considered the organization that certifies the fastener was manufactured, sampled, tested, and inspected in accordance with the specification and the results have been determined to meet the requirements of this specification.

13. Keywords

13.1 additional elements; austenitic stainless steel; bolts — steel; chromium-molybdenum steel; fasteners — steel; markings on fittings; nickel-chromium-molybdenum alloy steel; pressure vessel service; stainless steel bolting material; starting material; steel bars — alloy; steel bolting material; steel flanges; steel valves; temperature service applications — low

TABLE 1
MECHANICAL REQUIREMENTS

Class and Grade, Diameter, in [mm]	Heat Treatment	Minimum Tempering Temperature °F [°C]	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa] (0.2% offset)	Elongation in 2 in. or 50 mm min, %	Reduction of Area, min, %	Hardness max
Ferritic Steels							
L7, L7A, L7B, L7C, L70, L71, L72, L73 2½ [65] and under ^A	quenched and tempered	1100 [593]	125 [860]	105 [725]	16	50	...
L43 4 [100] and under ^A	quenched and tempered	1100 [593]	125 [860]	105 [725]	16	50	...
L7M 2½ [65] and under ^A	quenched and tempered	1150 [620]	100 [690]	80 [550]	18	50	235 HB ^B or 99 HRB
L1 1 [25] and under ^A	quenched and tempered	125 [860]	125 [860]	105 [725]	16	50	...
Austenitic Steels^C							
Class 1: B8, B8C, B8M, B8P, B8F, B8T, B8LN, B8MLN, all diameters	carbide solution treated	75 [515]	75 [515]	30 [205]	30	50	223 HB ^D or 96 HRB
Class 1A: B8A, B8CA, B8MA, B8PA, B8FA, B8TA, B8LNA, B8MLNA, all diameters	carbide solution treated in the fin- ished condition	75 [515]	75 [515]	30 [205]	30	50	192 HB or 90 HRB
Class 2: B8, B8C, B8P, B8F, B8T: ¾ [20] and under	carbide solution treated and strain hardened	125 [860]	125 [860]	100 [690]	12	35	321 HB or 35 HRC
over ¾ to 1 [20 to 25], incl		115 [795]	115 [795]	80 [550]	15	30	321 HB or 35 HRC
over 1 to 1¼ [25 to 32], incl		105 [725]	105 [725]	65 [450]	20	35	321 HB or 35 HRC
over 1¼ to 1½ [32 to 40], incl ^A		100 [690]	100 [690]	50 [345]	28	45	321 HB or 35 HRC
Class 2: B8M: ¾ [20] and under	carbide solution treated and strain hardened	110 [760]	110 [760]	95 [655]	15	45	321 HB or 35 HRC
over ¾ to 1 [20 to 25], incl		100 [690]	100 [690]	80 [550]	20	45	321 HB or 35 HRC
over 1 to 1¼ [25 to 32], incl		95 [655]	95 [655]	65 [450]	25	45	321 HB or 35 HRC
over 1¼ to 1½ [32 to 40], incl ^A		90 [620]	90 [620]	50 [345]	30	45	321 HB or 35 HRC

^A These upper diameter limits were established on the basis that these were the largest sizes commonly available that consistently met specification property limits. They are not intended as absolute limits beyond which bolting materials could no longer be certified to the specification.

^B To meet the tensile requirements, the Brinell hardness shall not be less than 200 HB or 93 HRB.

^C Class 1 products are made from solution-treated material. Class 1A products are solution treated in the finished condition for corrosion resistance; heat treatment is critical for enhancing this physical property and meeting the mechanical property requirements. Class 2 products are made from solution-treated material that has been strain hardened. Austenitic steels in the strain-hardened condition may not show uniform properties throughout the cross section, particularly in sizes over ¾ in. [20 mm] in diameter.

^D For sizes ¾ in. [20 mm] in diameter and smaller, a maximum hardness of 241 HB (100 HRB) is permitted.

TABLE 2
IMPACT ENERGY ABSORPTION REQUIREMENTS

Size of Specimen, mm	Minimum Impact Value Required for Average of Each Set of Three Specimens, ft · lbf [J]	Minimum Impact Value Permitted for One Specimen Only of a Set, ft · lbf [J]
All Grades Except L1 ⁴		
10 by 10	20 [27]	15 [20]
10 by 7.5	16 [22]	12 [16]
Grade L1		
10 by 10	40 [54]	30 [41]
10 by 7.5	32 [44]	24 [32]

⁴ See 6.2.1.1 for permitted exemptions.

TABLE 3
RECOMMENDED TEST TEMPERATURE
FOR STOCK PARTS

Grade	Test Temperature	
	°F	°C
L7M, L70, L71, L72, L73	−100	−73
L7, L7A, L7B, L7C	−150	−101
L43	−150	−101
L1	−100	−73

TABLE 4
CHEMICAL REQUIREMENTS (COMPOSITION, %)^A

Ferritic Steels									
Type	L7, L7M, L70		L7A, L71	L7B, L72	L7C, L73		L43	L1	
Description	Chromium-Molybdenum ^B		Carbon-Molybdenum (AISI 4037)	Chromium-Molybdenum (AISI 4137)	Nickel-Chromium-Molybdenum (AISI 8740)		Nickel-Chromium-Molybdenum (AISI 4340)	Low-Carbon Boron	
	Range, %	Product Variation, %	Range, %	Product Variation, %	Range, %	Product Variation, %	Range, %	Product Variation, %	Product Variation, %
Carbon	0.38–0.48 ^C	0.02	0.35–0.40	0.02	0.38–0.43	0.02	0.38–0.43	0.02	0.17–0.24
Manganese	0.75–1.00	0.04	0.70–0.90	0.03	0.75–1.00	0.04	0.60–0.85	0.03	0.70–1.40
Phosphorus, max	0.035	0.005 over	0.035	0.005 over	0.035	0.005 over	0.035	0.005 over	0.035
Sulfur, max	0.040	0.005 over	0.040	0.005 over	0.040	0.005 over	0.040	0.005 over	0.050
Silicon	0.15–0.35	0.02	0.15–0.35	0.02	0.15–0.35	0.02	0.15–0.35	0.02	0.15–0.30
Nickel	...	...	...	...	0.40–0.70	0.03	1.65–2.00	0.05	...
Chromium	0.80–1.10	0.05	0.80–1.10	0.05	0.40–0.60	0.03	0.70–0.90	0.03	...
Molybdenum	0.15–0.25	0.02	0.15–0.25	0.02	0.20–0.30	0.02	0.20–0.30	0.02	...
Boron	...	...	...	...	...	...	...	...	0.001–0.003
Austenitic Steels, Classes 1, 1A, and 2 ^D									
Type	B8, B8A		B8C, B8CA						
Grade	S30400(304)		S34700(347)						
UNS Designation	Product Variation, %		Product Variation, %		Range, %				
	Range, %	Over or Under	Range, %	Over or Under					
Carbon, max	0.08	0.01 over	0.08	0.01 over					
Manganese, max	2.00	0.04 over	2.00	0.04 over					
Phosphorus, max	0.045	0.010 over	0.045	0.010 over					
Sulfur, max	0.030	0.005 over	0.030	0.005 over					
Silicon, max	1.00	0.05 over	1.00	0.05 over					
Nickel	8.0–11.0	0.15	9.0–12.0	0.15					
Chromium	18.0–20.0	0.20	17.0–19.0	0.20					
Columbium + tantalum	...	...	10 X carbon content, min – 1.10 max	...					

TABLE 4
CHEMICAL REQUIREMENTS (COMPOSITION, %)^A (CONT'D)

Austenitic Steels, Classes 1, 1A, and 2 ^D									
Type	B8P, B8PA			B8F, B8FA			B8M, B8MA		
Grade	B8T, B8TA			B8P, B8PA			B8F, B8FA		
UNS Designation	S32100(321)			S30500			S30300(303)		
	Range, %	Product Variation, %		Range, %	Product Variation, %		Range, %	Product Variation, %	
		Over or Under	Over or Under		Over or Under	Over or Under		Over or Under	Over or Under
Carbon, max	0.08	0.01 over	0.01 over	0.08	0.01 over	0.01 over	0.15	0.01 over	0.01 over
Manganese, max	2.00	0.04 over	0.04 over	2.00	0.04 over	0.04 over	2.00	0.04 over	0.04 over
Phosphorus, max	0.045	0.010 over	0.010 over	0.045	0.010 over	0.010 over	0.20	0.010 over	0.010 over
Sulfur	0.030, max	0.005 over	0.005 over	0.030, max	0.005 over	0.020	0.15, min	0.030, max	0.005 over
Silicon, max	1.00	0.05 over	0.05 over	1.00	0.05 over	0.05 over	1.00	0.05 over	0.05 over
Nickel	9.0–12.0	0.15	0.15	10.5–13.0	0.15	0.10	8.0–10.0	10.0–14.0	0.15
Chromium	17.0–19.0	0.20	0.20	17.0–19.0	0.20	0.20	17.0–19.0	16.0–18.0	0.20
Molybdenum	...	...	...	...	...	...	...	2.00–3.00	0.10
Selenium	...	...	...	...	...	...	0.15–0.35	...	...
Titanium	5 × carbon content, min	0.05 under	...	...	...	...	...	...	...

Austenitic Steels, Classes 1, 1A									
Type	B8LN, B8LNA			B8MLN, B8MLNA			S31653		
Grade	B8LN, B8LNA			B8MLN, B8MLNA			S31653		
UNS Designation	Range, %	Product Variation, %		Range, %	Product Variation, %		Range, %	Product Variation, %	
		Over or Under	Over or Under		Over or Under	Over or Under		Over or Under	Over or Under
Carbon, max	0.030	0.005 over	0.005 over	0.030	0.005 over	0.005 over	0.030	0.005 over	0.005 over
Manganese, max	2.00	0.04 over	0.04 over	2.00	0.04 over	0.04 over	2.00	0.04 over	0.04 over
Phosphorus, max	0.045	0.010 over	0.010 over	0.045	0.010 over	0.010 over	0.045	0.010 over	0.010 over
Sulfur, max	0.030	0.005 over	0.005 over	0.030	0.005 over	0.005 over	0.030	0.005 over	0.005 over
Silicon, max	1.00	0.05 over	0.05 over	1.00	0.05 over	0.05 over	1.00	0.05 over	0.05 over
Nickel	8.0–10.5	0.15	0.15	10.0–14.0	0.15	0.15	10.0–14.0	0.15	0.15
Chromium	18.0–20.0	0.20	0.20	16.0–18.0	0.20	0.20	16.0–18.0	0.20	0.20
Molybdenum	...	...	...	2.00–3.00	...	...	2.00–3.00	0.10	0.10
Nitrogen	0.10–0.16	0.01	0.01	0.10–0.16	0.01	0.01	0.10–0.16	0.01	0.01

^A The intentional addition of Bi, Se, Te, and Pb is not permitted except for Grade B8F, in which selenium is specified and required.

^B Typical steel compositions used for this grade include 4140, 4142, 4145, 4140H, 4142H, and 4145H.

^C For the L7M grade, a minimum carbon content of 0.28% is permitted provided that the required tensile properties are met in the section sizes involved; the use of AISI 4130 or 4130H is allowed.

^D Class 1 are made from solution-treated material. Class 1A products (B8A, B8CA, B8MA, B8PA, B8FA, and B8TA) are solution-treated in the finished condition. Class 2 products are solution-treated and strain-hardened.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, and order.

S1. Impact Properties

S1.1 When impact properties are desired for austenitic steel grades exempt from testing under 6.2.1, test shall be made as agreed between the manufacturer and the purchaser.

NOTE S2.1 — Grades L7, L7A, L7B will generally have difficulty meeting the minimum value at -150°F [-101°C]. Grade L43 may be preferred.

S2. Lateral Expansion

S2.1 When lateral expansion measurements for ferritic steels are required in addition to the energy absorption requirements of 6.2.1.1, the minimum value for each specimen of a set must be .015 in. [0.38 mm]. The test temperature shall be specified by the purchaser and agreed upon by the producer.

S3. Hardness Testing of Class 2 Bolting Materials for ASME Applications

S3.1 The maximum hardness shall be Rockwell C 35 immediately under the thread roots. The hardness shall be taken on a flat area at least $\frac{1}{8}$ in. [3 mm] across, prepared by removing threads. No more material than necessary shall be removed to prepare the flat area. Hardness determinations shall be made at the same frequency as tensile tests.

APPENDIX

(Nonmandatory Information)

X1. STRAIN HARDENING OF AUSTENITIC STEELS

X1.1 Strain hardening is the increase in strength and hardness that results from plastic deformation below the recrystallization temperature (cold work). This effect is produced in austenitic stainless steels by reducing oversized bars or wire to the desired final size by cold drawing or other process. The degree of strain hardening achievable in any alloy is limited by its strain hardening characteristics. In addition, the amount of strain hardening that can be produced is further limited by the variables of the process, such as the total amount of cross-section reduction, die angle, and bar size. In large diameter bars, for example, plastic deformation will occur principally in the outer regions of the bar, so that the increased strength and hardness due to strain hardening is achieved predominantly

near the surface of the bar. That is, the smaller the bar, the greater the penetration of strain hardening.

X1.2 Thus, the mechanical properties of a given strain hardened fastener are dependent not just on the alloy, but also on the size of bar from which it is machined. The minimum bar size that can be used, however, is established by the configuration of the fastener, so that the configuration can affect the strength of the fastener.

X1.3 For example, a stud of a particular alloy and size may be machined from a smaller diameter bar than a bolt of the same alloy and size because a larger diameter bar is required to accommodate the head of the bolt. The stud, therefore, is likely to be stronger than the same size bolt in a given alloy.

SPECIFICATION FOR STRUCTURAL BOLTS, STEEL, HEAT TREATED, 120/105 ksi MINIMUM TENSILE STRENGTH



SA-325

(Identical with ASTM Specification A 325-07a except for the deletion of the term “private label distributor” in 15.1 and 15.5.)

1. Scope

1.1 This specification covers two types of quenched and tempered steel heavy hex structural bolts having a minimum tensile strength of 120 ksi for sizes 1.0 in. and less and 105 ksi for sizes over 1.0 to 1½ in., inclusive.

1.2 The bolts are intended for use in structural connections. These connections are covered under the requirements of the Specification for Structural Joints Using ASTM A 325 or A 490 Bolts, approved by the Research Council on Structural Connections, endorsed by the American Institute of Steel Construction and by the Industrial Fastener Institute.

1.3 The bolts are furnished in sizes ½ to 1½ in., inclusive. They are designated by type, denoting chemical composition as follows:

Type	Description
Type 1	Medium carbon, carbon boron, or medium carbon alloy steel
Type 2	Withdrawn in November 1991
Type 3	Weathering steel

NOTE 1 — Bolts for general applications, including anchor bolts, are covered by Specification A 449. Also refer to Specification A 449 for quenched and tempered steel bolts and studs with diameters greater than 1½ in. but with similar mechanical properties.

NOTE 2 — A complete metric companion to Specification A 325 has been developed — Specification A 325M; therefore, no metric equivalents are presented in this specification.

1.4 This specification is applicable to heavy hex structural bolts only. For bolts of other configurations and thread lengths with similar mechanical properties, see Specification A 449.

1.5 Terms used in this specification are defined in Terminology F 1789.

1.6 The following safety hazard caveat pertains only to the test methods portion, Section 10, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

- A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
- A 449 Specification for Hex Cap Screws, Bolts and Studs, Steel, Heat Treated, 120/105/90 ksi Minimum Tensile Strength, General Use
- A 490 Specification for Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength
- A 563 Specification for Carbons and Alloy Steel Nuts
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
- D 3951 Practice for Commercial Packaging
- F 436 Specification for Hardened Steel Washers
- F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets
- F 788/F 788M Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series
- F 959 Specification for Compressible-Washer-Type Direct Tension Indicators for Use with Structural Fasteners
- F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection
- F 1789 Terminology for F16 Mechanical Fasteners

F 2329 Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners
 G 101 Guide for Estimating the Atmospheric Corrosion Resistance of Low-Alloy Steels

2.2 ASME Standards:

B1.1 Unified Screw Threads

B18.2.6 Fasteners for Use in Structural Applications

B18.24 Part Identification Number (PIN) Code System Standard for B18 Fastener Products

3. Ordering Information

3.1 Orders for heavy hex structural bolts under this specification shall include the following:

3.1.1 Quantity (number of pieces of bolts and accessories).

3.1.2 Size, including nominal bolt diameter, thread pitch, and bolt length.

3.1.3 Name of product, heavy hex structural bolts.

3.1.4 When bolts threaded full length are required, Supplementary Requirement S1 shall be specified.

3.1.5 Type of bolt: Type 1 or 3. When type is not specified, either Type 1 or Type 3 shall be furnished at the supplier's option.

3.1.6 ASTM designation and year of issue.

3.1.7 Other components such as nuts, washers, and compressible washer-type direct-tension indicators, if required.

3.1.7.1 When such other components are specified to be furnished, also state "Nuts, washers, and direct tension indicators, or combination thereof, shall be furnished by lot number."

3.1.8 Zinc Coating — Specify the zinc coating process required, for example, hot dip, mechanically deposited, or no preference (see 4.3).

3.1.9 Other Finishes — Specify other protective finish, if required.

3.1.10 Test reports, if required (see Section 13).

3.1.11 Supplementary or special requirements, if required.

3.1.12 For establishment of a part identifying system, see ASME B18.24.

NOTE 3 — A typical ordering description follows: 1000 pieces 1 $\frac{1}{8}$ -7 UNC in. dia \times 4 in. long heavy hex structural bolt, Type 1 ASTM A 325-02, each with one hardened washer, ASTM F 436 Type 1, and one heavy hex nut, ASTM A 563 Grade DH. Each component hot-dip zinc-coated. Nuts lubricated.

3.2 Recommended Nuts:

3.2.1 Nuts conforming to the requirements of Specification A 563 are the recommended nuts for use with

Specification A 325 heavy hex structural bolts. The nuts shall be of the class and have a surface finish for each type of bolt as follows:

Bolt Type and Finish	Nut Class and Finish
1, plain (noncoated)	A 563-C, C3, D, DH, DH3, plain
1, zinc coated	A 563-DH, zinc coated
3, plain	A 563-C3, DH3, plain

3.2.2 Alternatively, nuts conforming to Specification A 194/A 194M Gr. 2H are considered a suitable substitute for use with Specification A 325 Type 1 heavy hex structural bolts.

3.2.3 When Specification A 194/A 194M Gr. 2H zinc-coated nuts are supplied, the zinc coating, overtapping, lubrication, and rotational capacity testing shall be in accordance with Specification A 563.

3.3 Recommended Washers:

3.3.1 Washers conforming to Specification F 436 are the recommended washers for use with Specification A 325 heavy hex structural bolts. The washers shall have a surface finish for each type of bolt as follows:

Bolt Type and Finish	Washer Finish
1, plain (uncoated)	Plain (uncoated)
1, zinc coated	Zinc coated
3, plain	Weathering steel, plain

3.4 Other Accessories:

3.4.1 When compressible washer type direct tension indicators are specified to be used with these bolts, they shall conform to Specification F 959 Type 325.

4. Materials and Manufacture

4.1 Heat Treatment:

4.1.1 Type 1 bolts produced from medium carbon steel shall be quenched in a liquid medium from the austenitizing temperature. Type 1 bolts produced from medium carbon steel to which chromium, nickel, molybdenum, or boron were intentionally added shall be quenched only in oil from the austenitizing temperature.

4.1.2 Type 3 bolts shall be quenched only in oil from the austenitizing temperature.

4.1.3 Type 1 bolts, regardless of the steel used, and Type 3 bolts shall be tempered by reheating to not less than 800°F.

4.2 Threading — Threads shall be cut or rolled.

4.3 Zinc Coatings, Hot-Dip and Mechanically Deposited:

4.3.1 When zinc-coated fasteners are required, the purchaser shall specify the zinc coating process, for example, hot dip, mechanically deposited, or no preference.

4.3.2 When hot-dip is specified, the fasteners shall be zinc-coated by the hot-dip process and the coating shall conform to the coating weight/thickness and performance requirements of Specification F 2329.

4.3.3 When mechanically deposited is specified, the fasteners shall be zinc-coated by the mechanical deposition process and the coating shall conform to the coating weight/thickness and performance requirements of Class 55 of Specification B 695.

4.3.4 When no preference is specified, the supplier shall furnish either a hot-dip zinc coating in accordance with Specification F 2329, or a mechanically deposited zinc coating in accordance with Specification B 695, Class 55. Threaded components (bolts and nuts) shall be coated by the same zinc-coating process and the supplier's option is limited to one process per item with no mixed processes in a lot.

4.4 Lubrication — When zinc-coated nuts are ordered with the bolts, the nuts shall be lubricated in accordance with Specification A 563, Supplementary Requirement S1, to minimize galling.

4.5 Secondary Processing:

4.5.1 If any processing, which can affect the mechanical properties or performance of the bolts, is performed after the initial testing, the bolts shall be retested for all specified mechanical properties and performance requirements affected by the reprocessing.

4.5.2 When the secondary process is heat treatment, the bolts shall be tested for all specified mechanical properties. Hot dip zinc-coated bolts shall be tested for all specified mechanical properties and rotational capacity. If zinc-coated nuts are relubricated after the initial rotational capacity tests, the assemblies shall be retested for rotational capacity.

5. Chemical Composition

5.1 Type 1 bolts shall be plain carbon steel, carbon boron steel, alloy steel or alloy boron steel at the manufacturer's option, conforming to the chemical composition specified in Table 1.

5.2 Type 3 bolts shall be weathering steel and shall conform to one of the chemical compositions specified in Table 2. The selection of the chemical composition, A, B, C, D, E, or F, shall be at the option of the bolt manufacturer. See Guide G 101 for methods of estimating the atmospheric corrosion resistance of low alloy steels.

5.3 Product analyses made on finished bolts representing each lot shall conform to the product analysis requirements specified in Tables 1 and 2, as applicable.

5.4 Heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted for bolts.

5.5 Compliance with 5.4 shall be based on certification that heats of steel having any of the listed elements intentionally added were not used to produce the bolts.

5.6 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A 751.

6. Mechanical Properties

6.1 Hardness — The bolts shall conform to the hardness specified in Table 3.

6.2 Tensile Properties:

6.2.1 Except as permitted in 6.2.2 for long bolts and 6.2.3 for short bolts, sizes 1.00 in. and smaller having a length of $2\frac{1}{4}D$ and longer, and sizes larger than 1.00 in. having a length of $3D$ and longer, shall be wedge tested full size and shall conform to the minimum wedge tensile load and proof load or alternative proof load specified in Table 4. The load achieved during proof load testing shall be equal to or greater than the specified proof load.

6.2.2 When the length of the bolt makes full-size testing impractical, machined specimens shall be tested and shall conform to the requirements specified in Table 5. When bolts are tested by both full-size and machined specimen methods, the full-size test shall take precedence.

6.2.3 Sizes 1.00 in. and smaller having a length shorter than $2\frac{1}{4}D$ down to $2D$, inclusive, that cannot be wedge tensile tested shall be axially tension tested full size and shall conform to the minimum tensile load and proof load or alternate proof load specified in Table 4. Sizes 1.00 in. and smaller having a length shorter than $2D$ that cannot be axially tensile tested shall be qualified on the basis of hardness.

6.2.4 For bolts on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence in the event of low hardness readings.

6.3 Rotational Capacity Test:

6.3.1 Definition — The rotational capacity test is intended to evaluate the presence of a lubricant, the efficiency of the lubricant, and the compatibility of assemblies as represented by the components selected for testing.

6.3.2 Requirement — Zinc-coated bolts, zinc-coated washers, and zinc-coated and lubricated nuts tested full size in an assembled joint or tension measuring device, in accordance with 10.2, shall not show signs of failure when subjected to the nut rotation in Table 6. The test shall be performed by the responsible party (see Section 14) prior

to shipment after zinc coating and lubrication of nuts (see 10.2 and Note 5).

6.3.3 Acceptance Criterion — The bolt and nut assembly shall be considered as non-conforming if the assembly fails to pass any one of the following specified requirements:

6.3.3.1 Inability to install the assembly to the nut rotation in Table 6.

6.3.3.2 Inability to remove the nut after installing to the rotation specified in Table 6.

6.3.3.3 Shear failure of the threads as determined by visual examination of bolt and nut threads following removal.

6.3.3.4 Torsional or torsional/tension failure of the bolt. Elongation of the bolt, in the threads between the nut and bolt head, is to be expected at the required rotation and is not to be classified as a failure.

7. Dimensions

7.1 Head and Body:

7.1.1 The bolts shall conform to the dimensions for heavy hex structural bolts specified in ASME B18.2.6.

7.1.2 The thread length shall not be changed except as provided in Supplementary Requirement S1. Bolts with thread lengths other than those required by this specification shall be ordered under Specification A 449.

7.2 Threads:

7.2.1 Uncoated — Threads shall be the Unified Coarse Thread Series as specified in ASME B1.1, and shall have Class 2A tolerances.

7.2.2 Coated — Unless otherwise specified, zinc-coated bolts to be used with zinc-coated nuts or tapped holes that are tapped oversize, in accordance with Specification A 563, shall have Class 2A threads before hot-dip or mechanically deposited zinc coating. After zinc coating, the maximum limits of pitch and major diameter shall not exceed the Class 2A limit by more than the following amounts:

Nominal Bolt Diameter (in.)	Oversize Limit, in. ^A	
	Hot Dip Zinc	Mechanical Zinc
$\frac{1}{2}$	0.018	0.012
$\frac{9}{16}, \frac{5}{8}, \frac{3}{4}$	0.020	0.013
$\frac{7}{8}$	0.022	0.015
1 to $1\frac{1}{4}$	0.024	0.016
$1\frac{3}{8}, 1\frac{1}{2}$	0.027	0.018

^AHot-dip zinc nuts are tapped oversize after coating, and mechanical zinc-coated nuts are tapped oversize before coating.

7.2.3 The gaging limit for bolts shall be verified during manufacture. In case of dispute, a calibrated thread ring gage of the same size as the oversize limit in 7.2.2 (Class X tolerance, gage tolerance plus) shall be used to verify compliance. The gage shall assemble with hand effort following application of light machine oil to prevent galling and damage to the gage. These inspections, when performed to resolve controversy, shall be conducted at the frequency specified in the quality assurance provisions of ASME B18.2.6.

8. Workmanship

8.1 The allowable limits, inspection, and evaluation of the surface discontinuities, quench cracks, forging cracks, head bursts, shear bursts, seams, folds, thread laps, voids, tool marks, nicks, and gouges shall be in accordance with Specification F 788/F 788M (See Note 4).

NOTE 4 — Specification F 788/F 788M nor Guide F 1470 guarantee 100% freedom from head bursts. Sampling is designed to provide a 95% confidence level of freedom from head bursts in any test lot. Head bursts, within the limits in Specification F 788/F 788M, are unsightly but do not affect mechanical properties or functional requirements of the bolt.

9. Number of Tests and Retests

9.1 Testing Responsibility:

9.1.1 Each lot shall be tested by the manufacturer prior to shipment in accordance with the lot identification control quality assurance plan in 9.2 through 9.5.

9.1.2 When bolts are furnished by a source other than the manufacturer, the Responsible Party as defined in 14 shall be responsible for assuring all tests have been performed and the bolts comply with the requirements of this specification (see 4.5).

9.2 Purpose of Lot Inspection — The purpose of a lot inspection program is to ensure that each lot conforms to the requirements of this specification. For such a plan to be fully effective it is essential that secondary processors, distributors, and purchasers maintain the identification and integrity of each lot until the product is installed.

9.3 Lot Method — All bolts shall be processed in accordance with a lot identification-control quality assurance plan. The manufacturer, secondary processors, and distributors shall identify and maintain the integrity of each production lot of bolts from raw-material selection through all processing operations and treatments to final packing and shipment. Each lot shall be assigned its own lot-identification number, each lot shall be tested, and the inspection test reports for each lot shall be retained.

9.4 Lot Definition — A lot shall be a quantity of uniquely identified heavy hex structural bolts of the same nominal

size and length produced consecutively at the initial operation from a single mill heat of material and processed at one time, by the same process, in the same manner so that statistical sampling is valid. The identity of the lot and lot integrity shall be maintained throughout all subsequent operations and packaging.

9.5 Number of Tests — The minimum number of tests from each lot for the tests specified below shall be as follows:

Tests	Number of Tests in Accordance With
Hardness, tensile strength, proof load, and rotational capacity	Guide F 1470
Coating weight/thickness	The referenced coating specification ^A
Surface discontinuities	Specification F 788/F 788M
Dimensions and thread fit	ASME B18.2.6

^A Guide F 1470 applies if the coating specification does not specify a testing frequency.

10. Test Methods

10.1 Tensile, Proof Load, and Hardness:

10.1.1 Tensile, proof load, and hardness tests shall be conducted in accordance with Test Methods F 606.

10.1.2 Tensile strength shall be determined using the Wedge or Axial Tension Testing Method of Full Size Product Method or the Machined Test Specimens Method depending on size and length as specified in 6.2.1-6.2.4. Fracture on full-size tests shall be in the body or threads of the bolt without a fracture at the junction of the head and body.

10.1.3 Proof load shall be determined using Method 1, Length Measurement, or Method 2, Yield Strength, at the option of the manufacturer.

10.2 Rotational Capacity — The zinc-coated bolt shall be placed in a steel joint or tension measuring device and assembled with a zinc-coated washer and a zinc-coated and lubricated nut with which the bolt is intended to be used (see Note 5). The nut shall have been provided with the lubricant described in the last paragraph of the Manufacturing Processes section of Specification A 563. The joint shall be one or more flat structural steel plates or fixture stack up with a total thickness, including the washer, such that 3 to 5 full threads of the bolt are located between the bearing surfaces of the bolt head and nut. The hole in the joint shall have the same nominal diameter as the hole in the washer. The initial tightening of the nut shall produce a load in the bolt not less than 10% of the specified proof load. After initial tightening, the nut position shall be marked relative to the bolt, and the rotation shown in

Table 6 shall be applied. During rotation, the bolt head shall be restrained from turning. After the tightening rotation has been applied, the assembly shall be taken apart and examined for compliance with 6.3.3.

NOTE 5 — Rotational capacity tests shall apply only to matched assembly lots that contain one A 325 bolt, one A 563 lubricated nut, and one F 436 washer that have been zinc coated in accordance with either Specifications F 2329 or B 695. Both the bolt and nut components of the matched assembly shall be zinc coated using the same process.

11. Inspection

11.1 If the inspection described in 11.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.

11.2 The purchaser's representative shall have free entry to all parts of the manufacturer's works, or supplier's place of business, that concern the manufacture or supply of the material ordered. The manufacturer or supplier shall afford the purchaser's representative all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser's representative shall be made before shipment, and shall be conducted as not to interfere unnecessarily with the operation of the manufacturer's works or supplier's place of business.

12. Rejection and Rehearing

12.1 Disposition of nonconforming bolts shall be in accordance with the Guide F 1470 section titled "Disposition of Nonconforming Lots."

13. Certification

13.1 When specified on the purchase order, the manufacturer or supplier, whichever is the responsible party as defined in Section 14, shall furnish the purchaser a test reports that includes the following:

13.1.1 Heat analysis, heat number, and a statement certifying that heats having the elements listed in 5.4 intentionally added were not used to produce the bolts,

13.1.2 Results of hardness, tensile, and proof load tests,

13.1.3 Results of rotational capacity tests. This shall include the test method used (solid plate or tension measuring device); and the statement "Nuts lubricated" for zinc-coated nuts when shipped with zinc-coated bolts,

13.1.4 Zinc coating measured coating weight/thickness for coated bolts,

13.1.5 Statement of compliance of visual inspection for surface discontinuities (Section 8),

13.1.6 Statement of compliance with dimensional and thread fit requirements,

13.1.7 Lot number and purchase order number,

13.1.8 Complete mailing address of responsible party, and

13.1.9 Title and signature of the individual assigned certification responsibility by the company officers.

13.2 Failure to include all the required information on the test report shall be cause for rejection.

14. Responsibility

14.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser.

15. Product Marking

15.1 *Manufacturer's Identification* — All Type 1 and 3 bolts shall be marked by the manufacturer with a unique identifier to identify the manufacturer.

15.2 *Grade Identification:*

15.2.1 Type 1 bolts shall be marked “A 325.”

15.2.2 Type 3 bolts shall be marked “A 325” with the “A 325” underlined. The use of additional distinguishing marks to indicate that the bolts are weathering steel shall be at the manufacturer's option.

15.3 *Marking Location and Methods* — All marking shall be located on the top of the bolt head and shall be either raised or depressed at the manufacturer's option.

15.4 *Acceptance Criteria* — Bolts which are not marked in accordance with these provisions shall be considered nonconforming and subject to rejection.

15.5 Type and manufacturer's identification shall be separate and distinct. The two identifications shall preferably be in different locations and, when on the same level, shall be separated by at least two spaces.

16. Packaging and Package Marking

16.1 *Packaging:*

16.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

16.1.2 When zinc coated nuts are included on the same order as zinc coated bolts, the bolts and nuts shall be shipped in the same container.

16.1.3 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

16.2 *Package Marking:*

16.2.1 Each shipping unit shall include or be plainly marked with the following information:

16.2.1.1 ASTM designation and type,

16.2.1.2 Size,

TABLE 1
CHEMICAL REQUIREMENTS FOR TYPE 1 BOLTS

Element	Carbon Steel	
	Heat Analysis	Product Analysis
Carbon	0.30–0.52	0.28–0.55
Manganese, min	0.60	0.57
Phosphorus, max	0.040	0.048
Sulfur, max	0.050	0.058
Silicon	0.15–0.30	0.13–0.32

Element	Carbon Boron Steel	
	Heat Analysis	Product Analysis
Carbon	0.30–0.52	0.28–0.55
Manganese, min	0.60	0.57
Phosphorus, max	0.040	0.048
Sulfur, max	0.050	0.058
Silicon	0.10–0.30	0.08–0.32
Boron	0.0005–0.003	0.0005–0.003

Element	Alloy Steel	
	Heat Analysis	Product Analysis
Carbon	0.30–0.52	0.28–0.55
Manganese, min	0.60	0.57
Phosphorus, max	0.035	0.040
Sulfur, max	0.040	0.045
Silicon	0.15–0.35	0.13–0.37
Alloying Elements	^A	^A

Element	Alloy Boron Steel	
	Heat Analysis	Product Analysis
Carbon	0.30–0.52	0.28–0.55
Manganese, min	0.60	0.57
Phosphorus, max	0.035	0.040
Sulfur, max	0.040	0.045
Silicon	0.15–0.35	0.13–0.37
Boron	0.0005–0.003	0.0005–0.003
Alloying Elements	^A	^A

^A Steel, as defined by the American Iron and Steel Institute, shall be considered to be alloy when the maximum of the range given for the content of alloying elements exceeds one or more of the following limits: Manganese, 1.65%; silicon, 0.60%; copper, 0.60% or in which a definite range or a definite minimum quantity of any of the following elements is specified or required within the limits of the recognized field of constructional alloy steels: aluminum, chromium up to 3.99%, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any other alloying elements added to obtain a desired alloying effect.

16.2.1.3 Name and brand or trademark of the manufacturer,

16.2.1.4 Number of pieces,

16.2.1.5 Lot number; when nuts, washers or direct tension indicators, or combination thereof, are ordered with A 325 heavy hex structural bolts, the shipping unit shall be marked with the lot number in addition to the marking

required by the applicable product specification,

16.2.1.6 Purchase order number, and

16.2.1.7 Country of origin.

17. Keywords

17.1 bolts; carbon steel; steel; structural; weathering steel

TABLE 2
CHEMICAL REQUIREMENTS FOR TYPE 3 HEAVY HEX STRUCTURAL BOLTS

Element	Composition, %					
	Type 3 Bolts ^A					
	A	B	C	D	E	F
Carbon:						
Heat analysis	0.33–0.40	0.38–0.48	0.15–0.25	0.15–0.25	0.20–0.25	0.20–0.25
Product analysis	0.31–0.42	0.36–0.50	0.14–0.26	0.14–0.26	0.18–0.27	0.19–0.26
Manganese:						
Heat analysis	0.90–1.20	0.70–0.90	0.80–1.35	0.40–1.20	0.60–1.00	0.90–1.20
Product analysis	0.86–1.24	0.67–0.93	0.76–1.39	0.36–1.24	0.56–1.04	0.86–1.24
Phosphorus:						
Heat analysis	0.035 max.	0.06–0.12	0.035 max.	0.035 max.	0.035 max.	0.035 max.
Product analysis	0.040 max.	0.06–0.125	0.040 max.	0.040 max.	0.040 max.	0.040 max.
Sulfur:						
Heat analysis	0.040 max.	0.040 max.	0.040 max.	0.040 max.	0.040 max.	0.040 max.
Product analysis	0.045 max.	0.045 max.	0.045 max.	0.045 max.	0.045 max.	0.045 max.
Silicon:						
Heat analysis	0.15–0.35	0.30–0.50	0.15–0.35	0.25–0.50	0.15–0.35	0.15–0.35
Product analysis	0.13–0.37	0.25–0.55	0.13–0.37	0.20–0.55	0.13–0.37	0.13–0.37
Copper:						
Heat analysis	0.25–0.45	0.20–0.40	0.20–0.50	0.30–0.50	0.30–0.60	0.20–0.40
Product analysis	0.22–0.48	0.17–0.43	0.17–0.53	0.27–0.53	0.27–0.63	0.17–0.43
Nickel:						
Heat analysis	0.25–0.45	0.50–0.80	0.25–0.50	0.50–0.80	0.30–0.60	0.20–0.40
Product analysis	0.22–0.48	0.47–0.83	0.22–0.53	0.47–0.83	0.27–0.63	0.17–0.43
Chromium:						
Heat analysis	0.45–0.65	0.50–0.75	0.30–0.50	0.50–1.00	0.60–0.90	0.45–0.65
Product analysis	0.42–0.68	0.47–0.83	0.27–0.53	0.45–1.05	0.55–0.95	0.42–0.68
Vanadium:						
Heat analysis	<i>B</i>	<i>B</i>	0.020 min.	<i>B</i>	<i>B</i>	<i>B</i>
Product analysis	<i>B</i>	<i>B</i>	0.010 min.	<i>B</i>	<i>B</i>	<i>B</i>
Molybdenum:						
Heat analysis	<i>B</i>	0.06 max.	<i>B</i>	0.10 max.	<i>B</i>	<i>B</i>
Product analysis	<i>B</i>	0.07 max.	<i>B</i>	0.11 max.	<i>B</i>	<i>B</i>
Titanium:						
Heat analysis	<i>B</i>	<i>B</i>	<i>B</i>	0.05 max.	<i>B</i>	<i>B</i>
Product analysis	<i>B</i>	<i>B</i>	<i>B</i>	0.06 max.	<i>B</i>	<i>B</i>

NOTES:

^A A, B, C, D, E, and F are classes of material used for Type 3 bolts. Selection of a class shall be at the option of the bolt manufacturer.

^B These elements are not specified or required.

TABLE 3
HARDNESS REQUIREMENTS FOR BOLTS

Bolt Size, in.	Bolt Length, in.	Brinell		Rockwell C	
		Min.	Max.	Min.	Max.
$\frac{1}{2}$ to 1, incl.	Less than 2D ^A	253	319	25	34
	2D and over	...	319	...	34
$1\frac{1}{8}$ to $1\frac{1}{2}$, incl.	Less than 3D ^A	223	286	19	30
	3D and over	...	286	...	30

NOTE:

^A Sizes 1.00 in. and smaller having a length shorter than 2D and sizes larger than 1.00 in. having a length shorter than 3D are subject only to minimum and maximum hardness.

D = Nominal diameter or thread size.

TABLE 4
TENSILE LOAD REQUIREMENTS FOR FULL SIZE BOLTS

Bolt Size, Threads per Inch and Series Designation	Stress Area, ^A in. ²	Tensile Load, ^B Min., lbf	Proof Load, ^B Length Measurement Method	Alternative Proof Load, ^B Yield Strength Method
Column 1	Column 2	Column 3	Column 4	Column 5
$\frac{1}{2}$ -13 UNC	0.142	17,050	12,050	13,050
$\frac{5}{8}$ -11 UNC	0.226	27,100	19,200	20,800
$\frac{3}{4}$ -10 UNC	0.334	40,100	28,400	30,700
$\frac{7}{8}$ -9 UNC	0.462	55,450	39,250	42,500
1-8 UNC	0.606	72,700	51,500	55,750
$1\frac{1}{8}$ -7 UNC	0.763	80,100	56,450	61,800
$1\frac{1}{4}$ -7 UNC	0.969	101,700	71,700	78,500
$1\frac{3}{8}$ -6 UNC	1.155	121,300	85,450	93,550
$1\frac{1}{2}$ -6 UNC	1.405	147,500	104,000	113,800

NOTES:

^A The stress area is calculated as follows:

$$As = 0.7854 [D - (0.9743/n)]^2$$

where:

As = stress area, in.²,
D = nominal bolt size, and
n = threads per inch.

^B Loads tabulated are based on the following:

Bolt Size, in.	Column 3	Column 4	Column 5
$\frac{1}{2}$ to 1, incl.	120,000 psi	85,000 psi	92,000 psi
$1\frac{1}{8}$ to $1\frac{1}{2}$, incl.	105,000 psi	74,000 psi	81,000 psi

TABLE 5 TENSILE STRENGTH REQUIREMENTS FOR SPECIMENS MACHINED FROM BOLTS

Bolt Diameter, in.	Tensile Strength, min, psi (MPa)	Yield Strength, min, psi (MPa)	Elongation, in 4D, min, %	Reduction of Area, min, %
$\frac{1}{2}$ to 1, incl.	120 000 (825)	92 000 (635)	14	35
Over 1 to $1\frac{1}{2}$	105 000 (725)	81 000 (560)	1435	...

TABLE 6
ROTATIONAL CAPACITY TEST FOR ZINC-COATED BOLTS

Bolt Length, in.	Nominal Nut Rotation, degrees (Turn)
Up to and including 4 × dia	240 ($\frac{2}{3}$)
Over 4 × dia, but not exceeding 8 × dia	360 (1)
Over 8 × dia, but not exceeding 12 × dia	420 ($1\frac{1}{6}$)
Over 12 × dia	Test not applicable

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order. Details of these supplementary requirements shall be agreed upon in writing between the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Bolts Threaded Full Length

S1.1 Bolts with nominal lengths equal to or shorter than four times the nominal bolt diameter shall be threaded full length. Bolts need not have a shoulder, and the distance from the underhead bearing surface to the first complete (full form) thread, as measured with a GO thread ring gage,

assembled by hand as far as the thread will permit, shall not exceed the length of $2\frac{1}{2}$ threads for bolt sizes 1 in. and smaller, and $3\frac{1}{2}$ threads for bolt sizes larger than 1 in.

S1.2 Bolts shall be marked in accordance with Section 15, except that the symbol shall be “A 325 T” instead of “A 325.”

SPECIFICATION FOR SEAMLESS AND WELDED STEEL PIPE FOR LOW-TEMPERATURE SERVICE



SA-333/SA-333M

(Identical with ASTM Specification A 333/A 333M-04a except for the deletion of 12.3 that conflicts with 15.)

1. Scope

1.1 This specification covers nominal (average) wall seamless and welded carbon and alloy steel pipe intended for use at low temperatures. Several grades of ferritic steel are included as listed in Table 1. Some product sizes may not be available under this specification because heavier wall thicknesses have an adverse effect on low-temperature impact properties.

1.2 Supplementary Requirement S1 of an optional nature is provided. This shall apply only when specified by the purchaser.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

NOTE 1 — The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as “nominal diameter,” “size,” and “nominal size.”

2. Referenced Documents

2.1 ASTM Standards:

- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 671 Specification for Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures
- A 999/A 999M Specification for General Requirements for Alloy and Stainless Steel Pipe
- E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required, to describe the material adequately:

3.1.1 Quantity (feet, centimeters, or number of lengths),

3.1.2 Name of material (seamless or welded pipe),

3.1.3 Grade (Table 1),

3.1.4 Size (NPS or outside diameter and schedule number of average wall thickness),

3.1.5 Length (specific or random) (Section 9), (see the Permissible Variations in Length section of Specification A 999/A 999M),

3.1.6 End finish (see the Ends section of Specification A 999/A 999M),

3.1.7 Optional requirements (see the Heat Analysis requirement in the Chemical Composition section of A 999/A 999M, the Repair by Welding section, and the section on Nondestructive Test Requirements),

3.1.8 Test report required (see the Certification section of Specification A 999/A 999M),

3.1.9 Specification designation, and

3.1.10 Special requirements or exceptions to this specification.

4. Materials and Manufacture

4.1 Manufacture — The pipe shall be made by the seamless or welding process with the addition of no filler metal in the welding operation. Grade 4 shall be made by the seamless process.

NOTE 2 — For electric-fusion-welded pipe, with filler metal added, see Specification A 671.

4.2 Heat Treatment:

4.2.1 All seamless and welded pipe, other than Grades 8 and 11, shall be treated to control their microstructure in accordance with one of the following methods:

4.2.1.1 Normalize by heating to a uniform temperature of not less than 1500°F [815°C] and cool in air or in the cooling chamber of an atmosphere controlled furnace.

4.2.1.2 Normalize as in 4.2.1.1, and, at the discretion of the manufacturer, reheat to a suitable tempering temperature.

4.2.1.3 For the seamless process only, reheat and control hot working and the temperature of the hot-finishing operation to a finishing temperature range from 1550 to 1750°F [845 to 945°C] and cool in air or in a controlled atmosphere furnace from an initial temperature of not less than 1550°F [845°C].

4.2.1.4 Treat as in 4.2.1.3 and, at the discretion of the manufacturer, reheat to a suitable tempering temperature.

4.2.1.5 Seamless pipe of Grades 1, 6, and 10 may be heat treated by heating to a uniform temperature of not less than 1500°F [815°C], followed by quenching in liquid and reheating to a suitable tempering temperature, in place of any of the other heat treatments provided for in 4.2.1.

4.2.2 Grade 8 pipe shall be heat treated by the manufacturer by either of the following methods:

4.2.2.1 Quenched and Tempered — Heat to a uniform temperature of 1475 ± 25°F [800 ± 15°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; quench by immersion in circulating water. Reheat until the pipe attains a uniform temperature within the range from 1050 to 1125°F [565 to 605°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air or water quench at a rate no less than 300°F [165°C]/h.

4.2.2.2 Double Normalized and Tempered — Heat to a uniform temperature of 1650 ± 25°F [900 ± 15°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air. Reheat until the pipe attains a uniform temperature of 1450 ± 25°F [790 ± 15°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air. Reheat to a uniform temperature within the range from 1050 to 1125°F [565 to 605°C]; hold at this temperature for a minimum time of 1 h/in. [2 min/mm] of thickness but in no case less than 15 min; cool in air or water quench at a rate not less than 300°F [165°C]/h.

4.2.3 Whether to anneal Grade 11 pipe is per agreement between purchaser and supplier. When Grade

11 pipe is annealed, it shall be normalized in the range of 1400 to 1600°F [760 to 870°C].

4.2.4 Material from which test specimens are obtained shall be in the same condition of heat treatment as the pipe furnished. Material from which specimens are to be taken shall be heat treated prior to preparation of the specimens.

4.2.5 When specified in the order the test specimens shall be taken from full thickness test pieces which have been stress relieved after having been removed from the heat-treated pipe. The test pieces shall be gradually and uniformly heated to the prescribed temperature, held at that temperature for a period of time in accordance with Table 2, and then furnace cooled at a temperature not exceeding 600°F [315°C]. Grade 8 shall be cooled at a minimum rate of 300°F [165°C]/h in air or water to a temperature not exceeding 600°F [315°C].

5. Chemical Composition

5.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

5.2 When Grades 1, 6, or 10 are ordered under this specification, supplying an alloy grade that specifically requires the addition of any element other than those listed for the ordered grade in Table 1 is not permitted. However, the addition of elements required for the deoxidation of the steel is permitted.

6. Product Analysis

6.1 At the request of the purchaser, an analysis of one billet or two samples of flat-rolled stock from each heat or of two pipes from each lot shall be made by the manufacturer. A lot of pipe shall consist of the following:

NPS Designator	Length of Pipe in Lot
Under 2	400 or fraction thereof
2 to 6	200 or fraction thereof
Over 6	100 or fraction thereof

6.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative and shall conform to the requirements specified.

6.3 If the analysis of one of the tests specified in 6.1 does not conform to the requirements specified, an analysis of each billet or pipe from the same heat or lot may be made, and all billets or pipe conforming to the requirements shall be accepted.

7. Tensile Requirements

7.1 The material shall conform to the requirements as to tensile properties prescribed in Table 3.

8. Impact Requirements

8.1 For Grades 1, 3, 4, 6, 7, 9, and 10, the notched-bar impact properties of each set of three impact specimens, including specimens for the welded joint in welded pipe with wall thicknesses of 0.120 in. [3 mm] and larger, when tested at temperatures in conformance with 14.1 shall be not less than the values prescribed in Table 4. The impact test is not required for Grade 11.

8.1.1 If the impact value of one specimen is below the minimum value, or the impact values of two specimens are less than the minimum average value but not below the minimum value permitted on a single specimen, a retest shall be allowed. The retest shall consist of breaking three additional specimens and each specimen must equal or exceed the required average value. When an erratic result is caused by a defective specimen, or there is uncertainty in test procedures, a retest will be allowed.

8.2 For Grade 8 each of the notched bar impact specimens shall display a lateral expansion opposite the notch of not less than 0.015 in. [0.38 mm].

8.2.1 When the average lateral expansion value for the three impact specimens equals or exceeds 0.015 in. [0.38 mm] and the value for one specimen is below 0.015 in. [0.38 mm] but not below 0.010 in. [0.25 mm], a retest of three additional specimens may be made. The lateral expansion of each of the retest specimens must equal or exceed 0.015 in. [0.38 mm].

8.2.2 Lateral expansion values shall be determined by the procedure in Test Methods and Definitions A 370.

8.2.3 The values of absorbed energy in foot-pounds and the fracture appearance in percentage shear shall be recorded for information. A record of these values shall be retained for a period of at least 2 years.

9. Lengths

9.1 If definite lengths are not required, pipe may be ordered in single random lengths of 16 to 22 ft (Note 3) with 5% 12 to 16 ft (Note 3), or in double random lengths with a minimum average of 35 ft (Note 3) and a minimum length of 22 ft (Note 3) with 5% 16 to 22 ft (Note 3).

NOTE 3 — This value(s) applies when the inch-pound designation of this specification is the basis of purchase. When the “M” designation of this specification is the basis of purchase, the corresponding metric value(s) shall be agreed upon between the manufacturer and purchaser.

10. Workmanship, Finish, and Appearance

10.1 The pipe manufacturer shall explore a sufficient number of visual surface imperfections to provide reasonable assurance that they have been properly evaluated with respect to depth. Exploration of all surface imperfections

is not required but may be necessary to ensure compliance with 10.2.

10.2 Surface imperfections that penetrate more than $12\frac{1}{2}\%$ of the nominal wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with such defects shall be given one of the following dispositions:

10.2.1 The defect may be removed by grinding provided that the remaining wall thickness is within specified limits.

10.2.2 Repaired in accordance with the repair welding provisions of 10.5.

10.2.3 The section of pipe containing the defect may be cut off within the limits of requirements on length.

10.2.4 The defective pipe may be rejected.

10.3 To provide a workmanlike finish and basis for evaluating conformance with 10.2, the pipe manufacturer shall remove by grinding the following:

10.3.1 Mechanical marks, abrasions and pits, any of which imperfections are deeper than $\frac{1}{16}$ in. [1.6 mm], and

10.3.2 Visual imperfections commonly referred to as scabs, seams, laps, tears, or slivers found by exploration in accordance with 10.1 to be deeper than 5% of the nominal wall thickness.

10.4 At the purchaser's discretion, pipe shall be subject to rejection if surface imperfections acceptable under 10.2 are not scattered, but appear over a large area in excess of what is considered a workmanlike finish. Disposition of such pipe shall be a matter of agreement between the manufacturer and the purchaser.

10.5 When imperfections or defects are removed by grinding, a smooth curved surface shall be maintained, and the wall thickness shall not be decreased below that permitted by this specification. The outside diameter at the point of grinding may be reduced by the amount so removed.

10.5.1 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In case of dispute, the measurement determined by use of the mechanical caliper shall govern.

10.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A 999/A 999M.

10.7 The finished pipe shall be reasonably straight.

11. General Requirements

11.1 Material furnished to this specification shall conform to the applicable requirements of the current edition

of Specification A 999/A 999M unless otherwise provided herein.

12. Mechanical Testing

12.1 Sampling — For mechanical testing, the term “lot” applies to all pipe of the same nominal size and wall thickness (or schedule) that is produced from the the same heat of steel and subjected to the same finishing treatment in a continuous furnace. If the final heat treatment is in a batch-type furnace, the lot shall include only those pipes that are heat treated in the same furnace charge.

12.2 Transverse or Longitudinal Tensile Test and Flattening Test — For material heat treated in a batch-type furnace, tests shall be made on 5% of the pipe from each lot. If heat treated by the continuous process, tests shall be made on a sufficient number of pipe to constitute 5% of the lot, but in no case less than 2 pipes.

12.3 DELETED

12.4 Impact Test — One notched bar impact test, consisting of breaking three specimens, shall be made from each heat represented in a heat-treatment load on specimens taken from the finished pipe. This test shall represent only pipe from the same heat and the same heat-treatment load, the wall thicknesses of which do not exceed by more than $\frac{1}{4}$ in. [6.3 mm] the wall thicknesses of the pipe from which the test specimens are taken. If heat treatment is performed in continuous or batch-type furnaces controlled within a 50°F [30°C] range and equipped with recording pyrometers so that complete records of heat treatment are available, then one test from each heat in a continuous run only shall be required instead of one test from each heat in each heat-treatment load.

12.5 Impact Tests (Welded Pipe) — On welded pipe, additional impact tests of the same number as required in 12.3 or 12.4 shall be made to test the weld.

12.6 Specimens showing defects while being machined or prior to testing may be discarded and replacements shall be considered as original specimens.

12.7 Results obtained from these tests shall be reported to the purchaser or his representative.

13. Specimens for Impact Test

13.1 Notched bar impact specimens shall be of the simple beam, Charpy-type, in accordance with Test Methods E 23, Type A with a V notch. Standard specimens 10 by 10 mm in cross section shall be used unless the material to be tested is of insufficient thickness, in which case the largest obtainable subsize specimens shall be used. Charpy specimens of width along the notch larger than 0.394 in.

[10 mm] or smaller than 0.099 in. [2.5 mm] are not provided for in this specification.

13.2 Test specimens shall be obtained so that the longitudinal axis of the specimen is parallel to the longitudinal axis of the pipe while the axis of the notch shall be perpendicular to the surface. On wall thicknesses of 1 in. [25 mm] or less, the specimens shall be obtained with their axial plane located at the midpoint; on wall thicknesses over 1 in. [25 mm], the specimens shall be obtained with their axial plane located $\frac{1}{2}$ in. [12.5 mm] from the outer surface.

13.3 When testing welds the specimen shall be, whenever diameter and thickness permit, transverse to the longitudinal axis of the pipe with the notch of the specimen in the welded joint and perpendicular to the surface. When diameter and thickness do not permit obtaining transverse specimens, longitudinal specimens in accordance with 13.2 shall be obtained; the bottom of the notch shall be located at the weld joint.

14. Impact Test

14.1 Except when the size of the finished pipe is insufficient to permit obtaining subsize impact specimens, all material furnished to this specification and marked in accordance with Section 16 shall be tested for impact resistance at the minimum temperature for the respective grades as shown in Table 5.

14.1.1 Special impact tests on individual lots of material may be made at other temperatures as agreed upon between the manufacturer and the purchaser.

14.1.2 When subsize Charpy impact specimens are used and the width along the notch is less than 80% of the actual wall thickness of the original material, the specified Charpy impact test temperature for Grades 1, 3, 4, 6, 7, 9, and 10 shall be lower than the minimum temperature shown in Table 5 for the respective grade. Under these circumstances the temperature reduction values shall be by an amount equal to the difference (as shown in Table 6) between the temperature reduction corresponding to the actual material thickness and the temperature reduction corresponding to the Charpy specimen width actually tested. Appendix X1 shows some examples of how the temperature reductions are determined.

14.2 The notched bar impact test shall be made in accordance with the procedure for the simple beam, Charpy-type test of Test Methods E 23.

14.3 Impact tests specified for temperatures lower than 70°F [20°C] should be made with the following precautions. The impact test specimens as well as the handling tongs shall be cooled a sufficient time in a suitable container so that both reach the desired temperature. The temperature shall be measured with thermocouples, thermometers, or

any other suitable devices and shall be controlled within 3°F [2°C]. The specimens shall be quickly transferred from the cooling device to the anvil of the Charpy impact testing machine and broken with a time lapse of not more than 5 s.

15. Hydrostatic or Nondestructive Electric Test

15.1 Each pipe shall be subjected to the nondestructive electric test or the hydrostatic test. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

15.2 The hydrostatic test shall be in accordance with Specification A 999/A 999M.

15.3 *Nondestructive Electric Test*— Nondestructive electric tests shall be in accordance with Specification A 999/A 999M, with the following addition.

15.3.1 If the test signals were produced by visual imperfections (listed in 15.3.2), the pipe may be accepted based on visual examination, provided the imperfection is less than 0.004 in. (0.1 mm) or 12½% of the specified wall thickness (whichever is greater).

15.3.2 *Visual Imperfections:*

- 15.3.2.1** Scratches,
- 15.3.2.2** Surface roughness,
- 15.3.2.3** Dings,
- 15.3.2.4** Straightener marks,
- 15.3.2.5** Cutting chips,
- 15.3.2.6** Steel die stamps,

15.3.2.7 Stop marks, or

15.3.2.8 Pipe reducer ripple.

16. Product Marking

16.1 Except as modified in 16.1.1, in addition to the marking prescribed in Specification A 999/A 999M, the marking shall include whether hot finished, cold drawn, seamless or welded, the schedule number and the letters “LT” followed by the temperature at which the impact tests were made, except when a lower test temperature is required because of reduced specimen size, in which case, the higher impact test temperature applicable to a full-size specimen should be marked.

16.1.1 When the size of the finished pipe is insufficient to obtain subsize impact specimens, the marking shall not include the letters “LT” followed by an indicated test temperature unless Supplementary Requirement S1 is specified.

16.1.2 When the pipe is furnished in the quenched and tempered condition, the marking shall include the letters “QT,” and the heat treatment condition shall be reported to the purchaser or his representative.

17. Keywords

17.1 low; low temperature service; seamless steel pipe; stainless steel pipe; steel pipe; temperature service applications

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %								
	Grade 1 ^A	Grade 3	Grade 4	Grade 6 ^A	Grade 7	Grade 8	Grade 9	Grade 10	Grade 11
Carbon, max	0.30	0.19	0.12	0.30	0.19	0.13	0.20	0.20	0.10
Manganese	0.40–1.06	0.31–0.64	0.50–1.05	0.29–1.06	0.90 max	0.90 max	0.40–1.06	1.15–1.50	0.60 max
Phosphorus, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.035	0.025
Sulfur, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.015	0.025
Silicon	...	0.18–0.37	0.08–0.37	0.10 min	0.13–0.32	0.13–0.32	...	0.10–0.35	0.35 max
Nickel	...	3.18–3.82	0.47–0.98	...	2.03–2.57	8.40–9.60	1.60–2.24	0.25 max	35.0–37.0
Chromium	...	...	0.44–1.01	...	...	...	...	0.15 max	0.50 max
Copper	...	...	0.40–0.75	...	...	...	0.75–1.25	0.15 max	...
Aluminum	...	...	0.04–0.30	...	...	...	...	0.06 max	...
Vanadium, max	...	...	...	...	...	...	...	0.12	...
Columbium, max	...	...	...	...	...	...	...	0.05	...
Molybdenum, max	...	...	...	...	...	...	...	0.05	0.50 max
Cobalt	...	...	...	...	...	...	...	...	0.50 max

^A For each reduction of 0.01% carbon below 0.30%, an increase of 0.05% manganese above 1.06% would be permitted to a maximum of 1.35% manganese.

TABLE 2
STRESS RELIEVING OF TEST PIECES

Metal Temperature ^{A,B}				Minimum Holding Time, h/in. [min/mm] of Thickness
Grades 1, 3, 6, 7, and 10		Grade 4 ^C		
°F	°C	°F	°C	
1100	600	1150	620	
1050	565	1100	600	1 [2.4]
1000	540	1050	565	2 [4.7]
				3 [7.1]

^A For intermediate temperatures, the holding time shall be determined by straight-line interpolation.

^B Grade 8 shall be stress relieved at 1025 to 1085°F [550 to 585°C], held for a minimum time of 2 h for thickness up to 1.0 in. [25.4 mm], plus a minimum of 1 h for each additional inch [25.4 mm] of thickness and cooled at a minimum rate of 300°F [165°C]/h in air or water to a temperature not exceeding 600°F [315°C].

^C Unless otherwise specified, Grade 4 shall be stress relieved at 1150°F [620°C].

TABLE 3
TENSILE REQUIREMENTS

	Grade 1		Grade 3		Grade 4		Grade 6		Grade 7		Grade 8		Grade 9		Grade 10		Grade 11	
	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa
Tensile strength, min	55 000	380	65 000	450	60 000	415	60 000	415	65 000	450	100 000	690	63 000	435	80 000	550	65 000	450
Yield strength, min	30 000	205	35 000	240	35 000	240	35 000	240	35 000	240	75 000	515	46 000	315	65 000	450	35 000	240
Elongation in 2 in. or 50 mm (or 4D), min, %:	35	25	30	20	30	16.5	30	16.5	30	22	22	...	28	...	22	...	18 ^A	
Basic minimum elongation for walls $\frac{5}{16}$ in. [8 mm] and over in thickness, strip tests, and for all small sizes tested in full section	28	20	22	14	22	12	22	12	22	14	16	...	...	...	16	...	...	...
When standard round 2 in. or 50 mm gage length or proportionally smaller size test specimen with the gage length equal to 4D (4 times the diameter) is used	1.75 ^B	1.25 ^B	1.50 ^B	1.00 ^B	1.50 ^B	1.00 ^B	1.50 ^B	1.00 ^B	1.50 ^B	1.00 ^B	1.25 ^B	...	1.50 ^B	...	1.25 ^B	...	...	...
For strip tests, a deduction for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{5}{16}$ in. [8 mm] from the basic minimum elongation of the following percentage																		

^A Elongation of Grade 11 is for all walls and small sizes tested in full section.

^B The following table gives the calculated minimum values.

TABLE 3
TENSILE REQUIREMENTS (CONT'D)

Wall Thickness		Elongation in 2 in. or 50 mm, min, % ^c															
in.	mm	Grade 1		Grade 3		Grade 4		Grade 6		Grade 7		Grade 8		Grade 9		Grade 10	
		Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse
5/16 (0.312)	8	35	25	30	20	30	16	30	16	30	22	22	...	28	...	22	...
9/32 (0.281)	7.2	33	24	28	19	28	15	28	15	28	21	21	...	26	...	21	...
1/4 (0.250)	6.4	32	23	27	18	27	15	27	15	27	20	20	...	25	...	20	...
7/32 (0.219)	5.6	30	...	26	...	26	...	26	...	26	...	...	...	24	...	18	...
3/16 (0.188)	4.8	28	...	24	...	24	...	24	...	24	...	...	...	22	...	17	...
5/32 (0.156)	4	26	...	22	...	22	...	22	...	22	...	...	...	20	...	16	...
1/8 (0.125)	3.2	25	...	21	...	21	...	21	...	21	...	...	...	19	...	15	...
3/32 (0.094)	2.4	23	...	20	...	20	...	20	...	20	...	...	...	18	...	13	...
1/16 (0.062)	1.6	21	...	18	...	18	...	18	...	18	...	...	...	16	...	12	...

^c Calculated elongation requirements shall be rounded to the nearest whole number.

NOTE — The preceding table gives the computed minimum elongation values for each 1/32 in. [0.80 mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value is determined by the following equation:

Grade	Direction of Test	Equation
1	Longitudinal	$E = 56t + 17.50 [E = 2.19t + 17.50]$
	Transverse	$E = 40t + 12.50 [E = 1.56t + 12.50]$
3	Longitudinal	$E = 48t + 15.00 [E = 1.87t + 15.00]$
	Transverse	$E = 32t + 10.00 [E = 1.25t + 10.00]$
4	Longitudinal	$E = 48t + 15.00 [E = 1.87t + 15.00]$
	Transverse	$E = 32t + 6.50 [E = 1.25t + 6.50]$
6	Longitudinal	$E = 48t + 15.00 [E = 1.87t + 15.00]$
	Transverse	$E = 32t + 6.50 [E = 1.25t + 6.50]$
7	Longitudinal	$E = 48t + 15.00 [E = 1.87t + 15.00]$
	Transverse	$E = 32t + 11.00 [E = 1.25t + 11.00]$
8 and 10	Longitudinal	$E = 40t + 9.50 [E = 1.56t + 9.50]$
	Longitudinal	$E = 48t + 13.00 [E = 1.87t + 13.00]$

where:

E = elongation in 2 in. or 50 mm, in %, and
 t = actual thickness of specimen, in. [mm].

TABLE 4
IMPACT REQUIREMENTS FOR GRADES 1, 3, 4, 6, 7, 9, AND 10

Size of Specimen, mm	Minimum Average Notched Bar Impact Value of Each Set of Three Specimens ^A		Minimum Notched Bar Impact Value of One Specimen Only of a Set ^A	
	ft-lbf	J	ft-lbf	J
10 by 10	13	18	10	14
10 by 7.5	10	14	8	11
10 by 6.67	9	12	7	9
10 by 5	7	9	5	7
10 by 3.33	5	7	3	4
10 by 2.5	4	5	3	4

^A Straight line interpolation for intermediate values is permitted.

TABLE 5
IMPACT TEMPERATURE

Grade	Minimum Impact Test Temperature	
	°F	°C
1	−50	−45
3	−150	−100
4	−150	−100
6	−50	−45
7	−100	−75
8	−320	−195
9	−100	−75
10	−75	−60

TABLE 6
IMPACT TEMPERATURE REDUCTION

Specimen Width Along Notch or Actual Material Thickness		Temperature Reduction, Degrees Colder ^A	
in.	mm	°F	°C
0.394	10 (standard size)	0	0
0.354	9	0	0
0.315	8	0	0
0.295	7.5 ($\frac{3}{4}$ std. size)	5	3
0.276	7	8	4
0.262	6.67 ($\frac{2}{3}$ std. size)	10	5
0.236	6	15	8
0.197	5 ($\frac{1}{2}$ std. size)	20	11
0.158	4	30	17
0.131	3.33 ($\frac{1}{3}$ std. size)	35	19
0.118	3	40	22
0.099	2.5 ($\frac{1}{4}$ std. size)	50	28

^A Straight line interpolation for intermediate values is permitted.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchase in the contract or order.

S1. Subsize Impact Specimens

S1.1 When the size of the finished pipe is insufficient to permit obtaining subsize impact specimens, testing shall be a matter of agreement between the manufacturer and the purchaser.

APPENDIX

(Nonmandatory Information)

X1. DETERMINATION OF TEMPERATURE REDUCTIONS

X1.1 Under the circumstances stated in 14.1.2, the impact test temperature specified in Table 5 must be lowered. The following examples are offered to describe the application of the provisions of 14.1.2.

X1.1.1 When subsize specimens are used (see 10.1) and the width along the notch of the subsize specimen is 80% or greater of the actual wall thickness of the original material, the provisions of 14.1.2 do not apply.

X1.1.1.1 For example, if the actual wall thickness of pipe was 0.200 in. [5.0 mm] and the width along the notch of the largest subsize specimen obtainable is 0.160 in. [4 mm] or greater, no reduction in test temperature is required.

X1.1.2 When the width along the subsize specimen notch is less than 80% of the actual wall thickness of the pipe, the required reduction in test temperature is computed by taking the difference between the temperature reduction values shown in Table 6 for the actual pipe thickness and the specimen width used.

X1.1.2.1 For example, if the pipe were 0.262 in. [6.67 mm] thick and the width along the Charpy specimen notch was 3.33 mm ($\frac{1}{3}$ standard size), the test temperature would have to be lowered by 25°F [14°C]. That is, the temperature reduction corresponding to the subsize specimen is 35°F [19°C]; the temperature reduction corresponding to the actual pipe thickness is 10°F [5°C]; the difference between these two values is the required reduction in test temperature.

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SPECIFICATION FOR SEAMLESS AND WELDED CARBON AND ALLOY-STEEL TUBES FOR LOW- TEMPERATURE SERVICE



SA-334/SA-334M



[Identical with ASTM Specification A 334/A 334M-04a(R10).]

1. Scope

1.1 This specification covers several grades of minimum-wall-thickness, seamless and welded, carbon and alloy-steel tubes intended for use at low temperatures. Some product sizes may not be available under this specification because heavier wall thicknesses have an adverse affect on low-temperature impact properties.

1.2 Supplementary Requirement S1 of an optional nature is provided. This shall apply only when specified by the purchaser.

NOTE 1 — For tubing smaller than $\frac{1}{2}$ in. [12.7 mm] in outside diameter, the elongation values given for strip specimens in Table 1 shall apply. Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in outside diameter and with a wall thickness under 0.015 in. [0.4 mm].

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

2. Referenced Documents

2.1 ASTM Standards:

- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 1016/A 1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required to describe the desired material adequately:

- 3.1.1** Quantity (feet, metres, or number of lengths),
- 3.1.2** Name of material (seamless or welded tubes),
- 3.1.3** Grade (Table 1),
- 3.1.4** Size (outside diameter and minimum wall thickness),
- 3.1.5** Length (specific or random),
- 3.1.6** Optional requirements (other temperatures, Section 14; hydrostatic or electric test, Section 16),
- 3.1.7** Test report required, (Certification Section of Specification A 1016/A 1016M),
- 3.1.8** Specification designation, and
- 3.1.9** Special requirements and any supplementary requirements selected.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 1016/A 1016M, unless otherwise provided herein.

5. Materials and Manufacture

5.1 The tubes shall be made by the seamless or automatic welding process with no addition of filler metal in the welding operation.

6. Heat Treatment

6.1 All seamless and welded tubes, other than Grades 8 and 11, shall be treated to control their microstructure in accordance with one of the following methods:

6.1.1 Normalize by heating to a uniform temperature of not less than 1550°F [845°C] and cool in air or in the cooling chamber of an atmosphere controlled furnace.

6.1.2 Normalize as in 10.1.1, and, at the discretion of the manufacturer, reheat to a suitable tempering temperature.

6.1.3 For the seamless process only, reheat and control hot working and the temperature of the hot-finishing operation to a finishing temperature range from 1550 to 1750°F [845 to 955°C] and cool in a controlled atmosphere furnace from an initial temperature of not less than 1550°F [845°C].

6.1.4 Treat as in 6.1.3 and, at the discretion of the manufacturer, reheat to a suitable tempering temperature.

6.2 Grade 8 tubes shall be heat treated by the manufacturer by either of the following methods.

6.2.1 *Quenched and Tempered* — Heat to a uniform temperature of 1475 ± 25°F [800 ± 15°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; quench by immersion in circulating water. Reheat until the pipe attains a uniform temperature within the range from 1050 to 1125°F [565 to 605°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air or water quench at a rate no less than 300°F [165°C]/h.

6.2.2 *Double Normalized and Tempered* — Heat to a uniform temperature of 1650 ± 25°F [900 ± 15°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air. Reheat until the pipe attains a uniform temperature of 1450 ± 25°F [790 ± 15°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air. Reheat to a uniform temperature within the range from 1050 to 1125°F [565 to 605°C]; hold at this temperature for a minimum time of 1 h/in. [2 min/mm] of thickness but in no case less than 15 min; cool in air or water quench at a rate not less than 300°F [165°C]/h.

6.3 Material from which impact specimens are obtained shall be in the same condition of heat treatment as the finished tubes.

6.4 Whether to anneal Grade 11 tubes is per agreement between purchaser and supplier. When Grade 11 tubes are annealed they shall be normalized in the range of 1400 to 1600°F [760 to 870°C].

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

7.2 When Grades 1 or 6 are ordered under this specification, supplying an alloy grade that specifically requires the addition of any element other than those listed for the ordered grade in Table 1 is not permitted. However, the addition of elements required for the deoxidation of the steel is permitted.

8. Product Analysis

8.1 An analysis of either one billet or one length of flat-rolled stock or one tube shall be made for each heat. The chemical composition thus determined shall conform to the requirements specified.

8.2 If the original test for product analysis fails, retests of two additional billets, lengths of flat-rolled stock, or tubes shall be made. Both retests, for the elements in question, shall meet the requirements of the specification; otherwise all remaining material in the heat or lot shall be rejected or, at the option of the manufacturer, each billet, length of flat-rolled stock, or tube may be individually tested for acceptance. Billets, lengths of flat-rolled stock, or tubes which do not meet the requirements of the specification shall be rejected.

9. Sampling

9.1 For flattening, flare, and flange requirements, the term *lot* applies to all tubes prior to cutting of the same nominal size and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as prescribed in Table 2.

9.2 For tensile and hardness test requirements, the term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat and furnace speed.

10. Tensile Requirements

10.1 The material shall conform to the requirements as to tensile properties prescribed in Table 3.

11. Hardness Requirements

11.1 The tubes shall have a hardness number not exceeding those prescribed in Table 4.

12. Impact Requirements

12.1 For Grades 1, 3, 6, 7 and 9, the notched-bar impact properties of each set of three impact specimens, including specimens for the welded joint in welded pipe with wall thicknesses of 0.120 in. [3 mm] and larger, when tested at temperatures in conformance with 14.1 shall be not less than the values prescribed in Table 5. The impact test is not required for Grade 11.

12.1.1 If the impact value of one specimen is below the minimum value, or the impact values of two specimens are less than the minimum average value but not below the minimum value permitted on a single specimen, a retest shall be allowed. The retest shall consist of breaking three additional specimens and each specimen must equal or exceed the required average value. When an erratic result is caused by a defective specimen, or there is uncertainty in test procedures, a retest will be allowed.

12.2 For Grade 8 each of the notched bar impact specimens shall display a lateral expansion opposite the notch not less than 0.015 in. [0.38 mm].

12.2.1 When the average lateral expansion value for the three impact specimens equals or exceeds 0.015 in. [0.38 mm] and the value for one specimen is below 0.015 in. [0.38 mm] but not below 0.010 in. [0.25 mm], a retest of three additional specimens may be made. The lateral expansion of each of the retest specimens must equal or exceed 0.015 in. [0.38 mm].

12.2.2 Lateral expansion values shall be determined in accordance with Test Methods and Definitions A 370.

12.2.3 The values of absorbed energy in foot-pounds and the fracture appearance in percentage shear shall be recorded for information. A record of these values shall be retained for a period of at least 2 years.

13. Mechanical Tests

13.1 Tension Test — One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes.

13.2 Flattening Test — One flattening test shall be made on specimens from each end of one finished tube of each lot but not the one used for the flare or flange test.

13.3 Flare Test (Seamless Tubes) — One flare test shall be made on specimens from each end of one finished tube of each lot, but not the one used for the flattening test.

13.4 Flange Test (Welded Tubes) — One flange test shall be made on specimens from each end of one finished tube of each lot, but not the one used for the flattening test.

13.5 Reverse Flattening Test — For welded tubes, one reverse flattening test shall be made on a specimen from each 1500 ft [460 m] of finished tubing.

13.6 Hardness Test — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot.

13.7 Impact Tests — One notched-bar impact test, consisting of breaking three specimens, shall be made from each heat represented in a heat-treatment load on specimens taken from the finished tube. This test shall represent only tubes from the same heat, which have wall thicknesses not exceeding by more than $\frac{1}{4}$ in. [6.3 mm] the wall thicknesses of the tube from which the test specimens are taken. If heat treatment is performed in continuous or batch-type furnaces controlled within a 50°F [30°C] range and equipped with recording pyrometers which yield complete heat-treatment records, then one test from each heat in a continuous run only shall be required instead of one test from each heat in each heat-treatment load.

13.8 Impact Tests (Welded Tubes) — On welded tube, additional impact tests of the same number as required in 13.7 shall be made to test the weld.

13.9 Specimens showing defects while being machined or prior to testing may be discarded and replacements shall be considered as original specimens.

14. Specimens for Impact Test

14.1 Notched-bar impact specimens shall be of the simple beam, Charpy-type, in accordance with Test Methods E 23, Type A, with a V notch. Standard specimens 10 by 10 mm in cross section shall be used unless the material to be tested is of insufficient thickness, in which case the largest obtainable subsize specimens shall be used. Charpy specimens of width along the notch larger than 0.394 in. [10 mm] or smaller than 0.099 in. [2.5 mm] are not provided for in this specification.

14.2 Test specimens shall be obtained so that the longitudinal axis of the specimen is parallel to the longitudinal axis of the tube while the axis of the notch shall be perpendicular to the surface. On wall thicknesses of 1 in. [25 mm] or less, the specimens shall be obtained with their axial plane located at the midpoint; on wall thicknesses over 1 in. [25 mm], the specimens shall be obtained with their axial plane located $\frac{1}{2}$ in. [12.5 mm] from the outer surface.

14.3 When testing welds the specimen shall be, whenever diameter and thickness permits, transverse to the longitudinal axis of the tube with the notch of the specimen

in the welded joint and perpendicular to the surface. When diameter and thickness does not permit obtaining transverse specimens, longitudinal specimens in accordance with 14.2 shall be obtained. The bottom of the notch shall be located at the weld joint.

15. Impact Test

15.1 Except when the size of the finished tube is insufficient to permit obtaining subsize impact specimens, all material furnished under this specification and marked in accordance with Section 17 shall be tested for impact resistance at the temperature for the respective grades as prescribed in Table 6.

15.1.1 Special impact tests on individual lots of material may be made at other temperatures if agreed upon between the manufacturer and the purchaser.

15.2 The notched-bar impact test shall be made in accordance with the procedure for the simple beam, Charpy-type of test of Test Methods E 23.

15.3 Impact tests specified for temperatures lower than +70°F [20°C] should be made with the following precautions. The impact test specimens as well as the handling tongs shall be cooled a sufficient time in a suitable container so that both reach the desired temperature. The temperature shall be measured with thermocouples, thermometers, or any other suitable devices and shall be controlled within ±3°F [2°C]. The specimens shall be quickly transferred from the cooling device to the anvil of the Charpy impact testing machine and broken with a time lapse of not more than 5 s.

15.4 When subsize Charpy impact specimens are used and the width along the notch is less than 80% of the actual wall thickness of the original material, the specified Charpy

impact test temperature for Grades 1, 3, 6, 7, and 9 shall be lower than the minimum temperature shown in Table 6 for the respective grade. Under these circumstances the temperature reduction values shall be by an amount equal to the difference (as shown in Table 7) between the temperature reduction corresponding to the actual material thickness and the temperature reduction corresponding to Charpy specimen width actually tested. The appendix shows some examples of how the temperature reductions are determined.

16. Hydrostatic or Nondestructive Electric Test

16.1 Each tube shall be subjected to the nondestructive electric test or the hydrostatic test in accordance with Specification A 1016/A 1016M. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

17. Product Marking

17.1 Except as modified in 16.1.1, in addition to the marking prescribed in Specification A 1016/A 1016M, the marking shall include whether hot-finished, cold-drawn, seamless, or welded, and the letters "LT" followed by the temperature at which the impact tests were made, except when a lower test temperature is required because of reduced specimen size, in which case, the higher impact test temperature applicable to a full-size specimen should be marked.

17.1.1 When the size of the finished tube is insufficient to obtain subsize impact specimens, the marking shall not include the letters LT followed by an indicated test temperature unless Supplementary Requirement S1 is specified.

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %						
	Grade 1 [Note (1)]	Grade 3	Grade 6 [Note (1)]	Grade 7	Grade 8	Grade 9	Grade 11
Carbon, max	0.30	0.19	0.30	0.19	0.13	0.20	0.10
Manganese	0.40–1.06	0.31–0.64	0.29–1.06	0.90 max	0.90 max	0.40–1.06	0.60 max
Phosphorus, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Sulfur, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Silicon	...	0.18–0.37	0.10 min	0.13–0.32	0.13–0.32	...	0.35 max
Nickel	...	3.18–3.82	...	2.03–2.57	8.40–9.60	1.60–2.24	35.0–37.0
Chromium	...	...	...	...	...	...	0.50 max
Copper	...	...	...	...	...	0.75–1.25	...
Cobalt	...	...	...	...	...	...	0.50 max
Molybdenum	...	...	...	...	...	...	0.50 max

NOTE:

(1) For each reduction of 0.01% carbon below 0.30%, an increase of 0.05% manganese above 1.06% will be permitted to a maximum of 1.35% manganese.

TABLE 2
HEAT-TREATMENT LOT

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in. [5.1 mm] and over in wall thickness	not more than 50 tubes
Under 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter, or over 1 in. [25.4 mm] in outside diameter and under 0.200 in. [5.1 mm] in thickness	not more than 75 tubes
1 in. [25.4 mm] or under in outside diameter	not more than 125 tubes

TABLE 3
TENSILE REQUIREMENTS

	Grade 1		Grade 3		Grade 6		Grade 7		Grade 8		Grade 9		Grade 11	
	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa
Tensile Strength, min	55	380	65	450	60	415	65	450	100	690	63	435	65	450
Yield Strength, min	30	205	35	240	35	240	35	240	75	520	46	315	35	240
Elongation in 2 in. or 50 mm (or 4D), min, %:														
Basic minimum elongation for walls $\frac{5}{16}$ in. [8 mm] and over in thickness, strip tests, and for all small sizes tested in full section	35		30		30		30		22		28		18 [Note (1)]	
When standard round 2 in. or 50 mm gage length or proportionally smaller size specimen with the gage length equal to 4D (4 times the diameter) is used	28		22		22		22		16		...		...
For strip tests, a deduction for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{5}{16}$ in. [8 mm] from the basic minimum elongation of the following percentage points	1.75 [Note (2)]		1.50 [Note (2)]		1.50 [Note (2)]		1.50 [Note (2)]		1.25 [Note (2)]		1.50 [Note (2)]		...	

NOTES:

(1) Elongation of Grade 11 is for all walls and for small sizes tested in full section.

(2) The following table gives the calculated minimum values:

Wall Thickness		Elongation in 2 in. or 50 mm, min % [Note (1)]					
in.	mm	Grade 1	Grade 3	Grade 6	Grade 7	Grade 8	Grade 9
$\frac{5}{16}$ (0.312)	8	35	30	30	30	22	28
$\frac{9}{32}$ (0.281)	7.2	33	28	28	28	21	26
$\frac{1}{4}$ (0.250)	6.4	32	27	27	27	20	25
$\frac{7}{32}$ (0.219)	5.6	30	26	26	26	18	24
$\frac{3}{16}$ (0.188)	4.8	28	24	24	24	17	22
$\frac{5}{32}$ (0.156)	4	26	22	22	22	16	20
$\frac{1}{8}$ (0.125)	3.2	25	21	21	21	15	19
$\frac{3}{32}$ (0.094)	2.4	23	20	20	20	13	18
$\frac{1}{16}$ (0.062)	1.6	21	18	18	18	12	16

NOTE:

(1) Calculated elongation requirements shall be rounded to the nearest whole number.

NOTE: The above table gives the computed minimum elongation values for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value is determined by the following equations.

Grade	Equation [Note (3)]
1	$E = 56t + 17.50$ [$E = 2.19t + 17.50$]
3	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]
6	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]
7	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]
8	$E = 40t + 9.50$ [$E = 1.56t + 9.50$]
9	$E = 48t + 13.00$ [$E = 1.87t + 13.00$]

where:

 E = elongation in 2 in. or 50 mm, %, and t = actual thickness of specimen, in. [mm].

TABLE 4
MAXIMUM HARDNESS NUMBER

Grade	Rockwell	Brinell
1	B 85	163
3	B 90	190
6	B 90	190
7	B 90	190
8	...	...
11	B 90	190

TABLE 5
IMPACT REQUIREMENTS FOR GRADES 1, 3, 6, 7, AND 9

Size of Specimen, mm	Minimum Average Notched Bar Impact Value of Each Set of Three Specimens [Note (1)]		Minimum Notched Bar Impact Value of One Specimen Only of a Set [Note (1)]	
	ft·lbf	J	ft·lbf	J
10 by 10	13	18	10	14
10 by 7.5	10	14	8	11
10 by 6.67	9	12	7	9
10 by 5	7	9	5	7
10 by 3.33	5	7	3	4
10 by 2.5	4	5	3	4

NOTE:

(1) Straight line interpolation for intermediate values is permitted.

TABLE 6
IMPACT TEMPERATURE

Grade	Impact Test Temperature	
	°F	°C
1	−50	−45
3	−150	−100
6	−50	−45
7	−100	−75
8	−320	−195
9	−100	−75

TABLE 7
IMPACT TEMPERATURE REDUCTION

Specimen Width Along Notch or Actual Material Thickness [Note (1)]		Temperature Reduction, Degrees Colder	
Inches	Millimeters	°F	°C
0.394	10 (standard size)	0	0
0.354	9	0	0
0.315	8	0	0
0.295	7.5 ($\frac{3}{4}$ standard size)	5	3
0.276	7	8	4
0.262	6.67 ($\frac{2}{3}$ standard size)	10	5
0.236	6	15	8
0.197	5 ($\frac{1}{2}$ standard size)	20	11
0.158	4	30	17
0.131	3.33 ($\frac{1}{3}$ standard size)	35	19
0.118	3	40	22
0.099	2.5 ($\frac{1}{4}$ standard size)	50	28

NOTE:

(1) Straight line interpolation for intermediate values is permitted.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified by the purchaser in the inquiry, contract, or order.

S1. Nonstandard Test Specimens

S1.1 When the size of the finished tube is insufficient to permit obtaining subsize impact specimens, testing shall be a matter of agreement between the manufacturer and the purchaser.

APPENDIX

(Nonmandatory Information)

X1. DETERMINATION OF TEMPERATURE REDUCTIONS

X1.1 Under the circumstances stated in 15.4, the impact test temperatures specified in Table 6 must be lowered. The following examples are offered to describe the application of the provisions of 15.4.

X1.1.1 When subsize specimens are used (see 14.1) and the width along the notch of the subsize specimen is 80% or greater of the actual wall thickness of the original material, the provisions of 15.4 do not apply.

X1.1.1.1 For example, if the actual wall thickness of pipe was 0.200 in. [5.0 mm] and the width along the notch of the largest subsize specimen obtainable is 0.160 in. [4 mm] or greater, no reduction in test temperature is required.

X1.1.2 When the width along the subsize specimen notch is less than 80% of the actual wall thickness of the pipe, the required reduction in test temperature is computed by taking the difference between the temperature reduction values shown in Table 7 for the actual pipe thickness and the specimen width used.

X1.1.2.1 For example, if the pipe were 0.262 in. [6.67 mm] thick and the width along the Charpy specimen notch was 3.33 mm ($\frac{1}{3}$ standard size), the test temperature would have to be lowered by 25°F [14°C] (that is, the temperature reduction corresponding to the subsize specimen is 35°F [19°C], the temperature reduction corresponding to the actual pipe thickness is 10°F [5°C]; the difference between these two values is the required reduction in test temperature).

SPECIFICATION FOR SEAMLESS FERRITIC ALLOY-STEEL PIPE FOR HIGH-TEMPERATURE SERVICE



SA-335/SA-335M

(Identical with ASTM Specification A 335/A 335M-06 except for the addition of hardness requirements for P23 and P911 in 9.3 and 14.2.1, and the correction of the UNS numbers for P9 and P91.)

1. Scope

1.1 This specification covers nominal wall and minimum wall seamless ferritic alloy-steel pipe intended for high-temperature service. Pipe ordered to this specification shall be suitable for bending, flanging (vanstoning), and similar forming operations, and for fusion welding. Selection will depend upon design, service conditions, mechanical properties, and high-temperature characteristics.

1.2 Several grades of ferritic steels (see Note 1) are covered. Their compositions are given in Table 1.

NOTE 1 — Ferritic steels in this specification are defined as low- and intermediate-alloy steels containing up to and including 10% chromium.

1.3 Supplementary requirements (S1 to S7) of an optional nature are provided. These supplementary requirements call for additional tests to be made, and when desired, shall be so stated in the order together with the number of such tests required.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

NOTE 2 — The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as “nominal diameter,” “size,” and “nominal size.”

2. Referenced Documents

2.1 ASTM Standards:

A 999/A 999M Specification for General Requirements for Alloy and Stainless Steel Pipe

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation

E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

E 527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

E 570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

2.2 ASME Standard:

B36.10M Welded and Seamless Wrought Steel Pipe

2.3 Other Documents:

SNT-TC-1A Recommended Practice for Nondestructive Personnel Qualification and Certification

SAE J 1086 Practice for Numbering Metals and Alloys (UNS)

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, metres, or number of lengths),

3.1.2 Name of material (seamless alloy steel pipe),

3.1.3 Grade (Table 1),

3.1.4 Manufacture (hot-finished or cold-drawn),

3.1.5 Size using one of the following:

3.1.5.1 NPS and schedule number,

3.1.5.2 Outside diameter and nominal wall thickness,

3.1.5.3 Outside diameter and minimum wall thickness,

3.1.5.4 Inside diameter and nominal wall thickness, and

3.1.5.5 Inside diameter and minimum wall thickness.

3.1.6 Length (specific or random),

3.1.7 End finish (Ends Section of Specification A 999/A 999M),

3.1.8 Optional requirements (Section 8, 12 and 13 of this specification. See the Sections on Hydrostatic Test Requirements and Permissible Variation in Weight for Seamless Pipe in Specification A 999/A 999M),

3.1.9 Test report required (Certification Section of Specification A 999/A 999M),

3.1.10 Specification designation, and

3.1.11 Special requirements or any supplementary requirements selected, or both.

4. General Requirements

4.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 999/A 999M, unless otherwise provided herein.

5. Materials and Manufacture

5.1 Pipe may be either hot finished or cold drawn with the finishing treatment as required in 5.3.

5.2 *Grade P2 and P12* — The steel shall be made by coarse-grain melting practice. Specific limits, if any, on grain size or deoxidation practice shall be a matter of agreement between the manufacturer and purchaser.

5.3 Heat Treatment:

5.3.1 All pipe shall be reheated for heat treatment and heat treated in accordance with the requirements of Table 2.

NOTE 3 — It is recommended that the temperature for tempering should be at least 100°F [50°C] above the intended service temperature; consequently, the purchaser should advise the manufacturer if the service temperature is to be over 1100°F [600°C].

NOTE 4 — Certain of the ferritic steels covered by this specification will harden if cooled rapidly from above their critical temperature. Some will air harden, that is, become hardened to an undesirable degree when cooled in air from high temperatures. Therefore, operations involving heating such steels above their critical temperatures, such as welding, flanging, and hot bending, should be followed by suitable heat treatment.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

7. Workmanship, Finish, and Appearance

7.1 The pipe manufacturer shall explore a sufficient number of visual surface imperfections to provide reasonable assurance that they have been properly evaluated with respect to depth. Exploration of all surface imperfections is not required but may be necessary to ensure compliance with 7.2.

7.2 Surface imperfections that penetrate more than $12\frac{1}{2}\%$ of the nominal wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with such defects shall be given one of the following dispositions:

7.2.1 The defect may be removed by grinding provided that the remaining wall thickness is within specified limits.

7.2.2 Repaired in accordance with the repair welding provisions of 7.6.

7.2.3 The section of pipe containing the defect may be cut off within the limits of requirements on length.

7.2.4 Rejected.

7.3 To provide a workmanlike finish and basis for evaluating conformance with 7.2, the pipe manufacturer shall remove by grinding the following:

7.3.1 Mechanical marks, abrasions (see Note 5) and pits, any of which imperfections are deeper than $\frac{1}{16}$ in. [1.6 mm].

NOTE 5 — Marks and abrasions are defined as cable marks, dings, guide marks, roll marks, ball scratches, scores, die marks, and the like.

7.3.2 Visual imperfections, commonly referred to as scabs, seams, laps, tears, or slivers, found by exploration in accordance with 7.1 to be deeper than 5% of the nominal wall thickness.

7.4 At the purchaser's discretion, pipe shall be subject to rejection if surface imperfections acceptable under 7.2 are not scattered, but appear over a large area in excess of what is considered a workmanlike finish. Disposition of such pipe shall be a matter of agreement between the manufacturer and the purchaser.

7.5 When imperfections or defects are removed by grinding, a smooth curved surface shall be maintained, and the wall thickness shall not be decreased below that permitted by this specification. The outside diameter at the point of grinding may be reduced by the amount so removed.

7.5.1 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In case of dispute, the measurement determined by use of the mechanical caliper shall govern.

7.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A 999/A 999M.

7.6.1 After weld repair, Grades P23, P91, P92, and P122 shall be heat treated at 1350-1470°F [730-800°C].

7.6.2 After weld repair, Grade P911 shall be heat treated at 1365-1435°F [740-780°C].

7.7 The finished pipe shall be reasonably straight.

8. Product Analysis

8.1 At the request of the purchaser, an analysis of two pipes from each lot shall be made by the manufacturer. A lot (see Note 6) of pipe shall consist of the following:

NPS Designator	
Under 2	400 or fraction thereof
2 to 5	200 or fraction thereof
6 and over	100 or fraction thereof

NOTE 6 — A lot shall consist of the number of lengths specified in 8.1 of the same size and wall thickness from any one heat of steel.

8.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Table 1.

8.3 For grade P 91 the carbon content may vary for the product analysis by -0.01% and $+0.02\%$ from the specified range as per Table 1.

8.4 If the analysis of one of the tests specified in 8.1 does not conform to the requirements specified in 6.1, an analysis of each billet or pipe from the same heat or lot may be made, and all billets or pipe conforming to the requirements shall be accepted.

9. Tensile and Hardness Requirements

9.1 The tensile properties of the material shall conform to the requirements prescribed in Table 3.

9.2 Table 4 lists elongation requirements.

9.3 Pipe of Grades P91, P92, P911, P122, and P36 shall have a hardness not exceeding 250 HB/265 HV [25 HRC]. Hardness of P23 shall not exceed 220 HB (RB 97).

9.4 Table 5 gives the computed minimum elongation values for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values above, the minimum elongation value is determined by the following formula:

Direction of Test	Equation
Longitudinal, all grades except P23, P91, P92, P122, and P911	$E = 48t + 15.00$ $[E = 1.87t + 15.00]$
Transverse, all grades except P23, P91, P92, P122, and P911	$E = 32t + 10.00$ $[E = 1.25t + 10.00]$
Longitudinal, P23, P91, P92, P122, and P911	$E = 32t + 10.00$ $[E = 1.25t + 10.00]$
Longitudinal, P36	$E = 32t + 5.0$ $[E = 1.25t + 5.0]$

where

E = elongation in 2 in. or 50 mm, % and

t = actual thickness of specimens, in. [mm]

10. Permissible Variations in Diameter

10.1 For pipe ordered to NPS [DN] or outside diameter, variations in outside diameter shall not exceed those specified in Table 6.

10.2 For pipe ordered to inside diameter, the inside diameter shall not vary more than $\pm 1\%$ from the specified inside diameter.

11. Permissible Variations in Wall Thickness

11.1 In addition to the implicit limitation of wall thickness for pipe imposed by the limitation on weight in Specification A 999/A 999M, the wall thickness for pipe at any point shall be within the tolerances specified in Table 7. The minimum wall thickness and outside diameter for inspection for compliance with this requirement for pipe ordered by NPS [DN] and schedule number is shown in ASME B36.10M.

12. Hydrostatic Test

12.1 Each length of pipe shall be subjected to the hydrostatic test, except as provided for in 12.2 or 12.3.

12.2 Unless otherwise specified in the purchase order, each length of pipe shall, at the option of the manufacturer, be subjected to the nondestructive electric test as shown in Section 13 in lieu of the hydrostatic test.

12.3 When specified by the purchaser, pipe shall be furnished without hydrostatic test and without nondestructive examination.

12.4 When specified by the purchaser, pipe shall be furnished with both the hydrostatic test and a nondestructive examination having been performed.

13. Nondestructive Examination

13.1 When selected by the manufacturer or when specified in the order, as an alternative to the hydrostatic test

(12.2), or when specified in the purchase order in addition to the hydrostatic test (12.4), each pipe shall be examined by a nondestructive examination method in accordance with Practice E 213, Practice E 309 or Practice E 570. The range of pipe sizes that may be examined by each method shall be subject to the limitations in the scope of the respective practices.

13.2 The following information is for the benefit of the user of this specification:

13.2.1 The reference standards defined in 13.8 are convenient standards for standardization of nondestructive examination equipment. The dimensions of these standards should not be construed as the minimum size imperfection detectable by such equipment.

13.2.2 Ultrasonic examination can be performed to detect both longitudinally and transversely oriented discontinuities. It should be recognized that different techniques should be employed to detect differently oriented imperfections. The examination may not detect short, deep imperfections.

13.2.3 The eddy current examination referenced in this specification has the capability to detect significant discontinuities, especially of the short abrupt type.

13.2.4 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented discontinuities. It should be recognized that different techniques should be employed to detect differently oriented imperfections.

13.2.5 The hydrostatic test of Section 12 has the capability to find imperfections of a size that permit the test fluid to leak through the pipe wall so that it may be either visually seen or detected by a loss of fluid pressure. This test may not detect very tight, through-wall imperfections, or imperfections that extend into the wall without complete penetration.

13.2.6 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular products.

13.3 *Time of Examination:*

13.3.1 Nondestructive examination for specification acceptance shall be performed after all mechanical processing, heat treatments and straightening operations. This requirement does not preclude additional testing at earlier stages in the processing.

13.4 *Surface Conditions:*

13.4.1 All surfaces shall be clean and free of scale, dirt, grease, paint, or other foreign material that could interfere with interpretation of test results. The methods

used for cleaning and preparing the surfaces for examination shall not be detrimental to the base metal or the surface finish.

13.4.2 Excessive surface roughness or deep scratches can produce signals that interfere with the test (see 13.10.2.3).

13.5 *Extent of Examination:*

13.5.1 The relative motion of the pipe and the transducer(s), coil(s), or sensor(s) shall be such that the entire pipe surface is scanned, except for end effects as noted in 13.5.2.

13.5.2 The existence of end effects is recognized, and the extent of such effects shall be determined by the manufacturer, and, if requested, shall be reported to the purchaser. Other nondestructive tests may be applied to the end areas, subject to agreement between the purchaser and the manufacturer.

13.6 *Operator Qualifications* — The test unit operator shall be certified in accordance with SNT-TC-1A, or an equivalent, recognized and documented standard.

13.7 *Test Conditions:*

13.7.1 For examination by the ultrasonic method, the minimum nominal transducer frequency shall be 2.25 MHz.

13.7.2 For eddy current testing, the excitation coil frequency shall be 10 kHz, or less.

13.8 *Reference Standards:*

13.8.1 Reference standards of convenient length shall be prepared from a length of pipe of the same grade, size (NPS or outside diameter and schedule or wall thickness), surface finish and heat treatment condition as the pipe to be examined.

13.8.2 For ultrasonic testing, the reference notches shall be any one of the three common notch shapes shown in Practice E 213, at the option of the manufacturer. The depth of the notch shall not exceed $12\frac{1}{2}\%$ of the specified nominal wall thickness of the pipe or 0.004 in. (0.1 mm), whichever is greater. The length of the notch shall be at least twice the diameter of the transducer(s). The width of the notch shall not exceed the depth.

13.8.3 For eddy current testing, the reference standard shall contain, at the option of the manufacturer, any one of the following discontinuities:

13.8.3.1 *Drilled Hole* — The reference standard shall contain three or more holes, equally spaced circumferentially around the pipe and longitudinally separated by a sufficient distance to allow distinct identification of the signal from each hole. The holes shall be drilled radially and completely through the pipe wall, with care being taken to avoid distortion of the pipe while drilling. The hole diameter shall vary with NPS as follows

NPS Designator	Hole Diameter
$\frac{1}{2}$	0.039 in. [1 mm]
above $\frac{1}{2}$ to $1\frac{1}{4}$	0.055 in. [1.4 mm]
above $1\frac{1}{4}$ to 2	0.071 in. [1.8 mm]
above 2 to 5	0.087 in. [2.2 mm]
above 5	0.106 in. [2.7 mm]

13.8.3.2 Transverse Tangential Notch — Using a round tool or file with a $\frac{1}{4}$ in. (6.4 mm) diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. Said notch shall have a depth not exceeding $12\frac{1}{2}\%$ of the specified nominal wall thickness of the pipe or 0.004 in. (0.1 mm), whichever is greater.

13.8.3.3 Longitudinal Notch — A notch 0.031 in. or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the pipe, to have a depth not exceeding $12\frac{1}{2}\%$ of the specified nominal wall thickness of the pipe or 0.004 in. (0.1 mm), whichever is greater. The length of the notch shall be compatible with the testing method.

13.8.4 For flux leakage testing, the longitudinal reference notches shall be straight-sided notches machined in a radial plane parallel to the pipe axis. For wall thickness less than $\frac{1}{2}$ in. (12.7 mm), outside and inside notches shall be used; for wall thicknesses equal to or greater than $\frac{1}{2}$ in., only an outside notch shall be used. Notch depth shall not exceed $12\frac{1}{2}\%$ of the specified nominal wall thickness or 0.004 in. (0.1 mm), whichever is greater. Notch length shall not exceed 1 in. (25.4 mm), and the width shall not exceed the depth. Outside and inside notches shall have sufficient separation to allow distinct identification of the signal from each notch.

13.8.5 More or smaller reference discontinuities, or both, may be used by agreement between the purchaser and the manufacturer.

13.9 Standardization Procedure:

13.9.1 The test apparatus shall be standardized at the beginning and end of each series of pipes of the same size (NPS or diameter and schedule or wall thickness), grade and heat treatment condition, and at intervals not exceeding 4 h during the examination of such pipe. More frequent standardizations may be performed at the manufacturer's option or may be required upon agreement between the purchaser and the manufacturer.

13.9.2 The test apparatus shall also be standardized after any change in test system settings, change of operator, equipment repair, or interruption due to power loss, shutdown or operator breaks.

13.9.3 The reference standard shall be passed through the test apparatus at same speed and test system settings as the pipe to be tested.

13.9.4 The signal-to-noise ratio for the reference standard shall be 2.5 to 1 or greater and the reference signal amplitude for each discontinuity shall be at least 50% of full scale of the display.

13.9.5 If upon any standardization, the reference signal amplitude has decreased by 25% (2 db), the test apparatus shall be considered out of standardization. The test system settings may be changed, or the transducer(s), coil(s) or sensor(s) adjusted, and the unit restandardized, but all pipe tested since the last acceptable standardization must be retested.

13.10 Evaluation of Imperfections:

13.10.1 Pipes producing a signal equal to or greater than the signal produced by the reference standard shall be positively identified and they shall be separated from the acceptable pipes. The area producing the signal may be reexamined.

13.10.2 Such pipes shall be subject to one of the following three dispositions:

13.10.2.1 The pipes may be rejected without further examination, at the discretion of the manufacturer.

13.10.2.2 The pipes shall be rejected, but may be repaired, if the test signal was produced by imperfections which cannot be identified, or was produced by cracks or crack-like imperfections. These pipes may be repaired by grinding (in accordance with 7.2.1), welding (in accordance with 7.6) or sectioning (in accordance with 7.2.3). To be accepted, a repaired pipe must pass the same nondestructive examination by which it was rejected, and it must meet the remaining wall thickness requirements of this specification.

13.10.2.3 Such pipes may be evaluated in accordance with the provisions of Section 7, if the test signals were produced by visual imperfections such as those listed below:

- (1) Scratches,
- (2) Surface roughness,
- (3) Dings,
- (4) Straightener marks,
- (5) Cutting chips,
- (6) Steel die stamps,
- (7) Stop marks, or
- (8) Pipe reducer ripple.

14. Mechanical Tests Required

14.1 Transverse or Longitudinal Tension Test and Flattening Test, Hardness Test, or Bend Test — For material heat treated in a batch-type furnace, tests shall be made on 5% of the pipe from each treated lot (see Note 7). For small lots, at least 1 pipe shall be tested. For material heat treated by the continuous process, tests shall be made on

a sufficient number of pipe to constitute 5% of the lot (see Note 7), but in no case less than 2 pipe.

NOTE 7 — The term “lot” applies to all pipe of the same nominal size and wall thickness (or schedule) which is produced from the same heat of steel and subjected to the same finishing treatment in a continuous furnace; when final heat treatment is in a batch-type furnace, the lot shall include only that pipe which is heat treated in the same furnace charge.

14.2 Hardness Test:

14.2.1 For pipe of Grades P23, P91, P92, P122, P911, and P36, Brinell, Vickers, or Rockwell hardness tests shall be made on a specimen from each lot (see Note 7).

14.3 Bend Test:

14.3.1 For pipe whose diameter exceeds NPS 25 and whose diameter to wall thickness ratio is 7.0 or less shall be subjected to the bend test instead of the flattening test. Other pipe whose diameter equals or exceeds NPS 10 may be given the bend test in place of the flattening test subject to the approval of the purchaser.

14.3.2 The bend test specimens shall be bent at room temperature through 180° without cracking on the outside of the bent portion. The inside diameter of the bend shall be 1 in. [25 mm].

14.3.3 Test specimens for the bend test specified in 14.3 shall be cut from one end of the pipe and, unless otherwise specified, shall be taken in a transverse direction. One test specimen shall be taken as close to the outer surface as possible and another from as close to the inner surface as possible. The specimens shall be either $\frac{1}{2}$ by $\frac{1}{2}$ in. [12.5 by 12.5 mm] in section or 1 by $\frac{1}{2}$ in. [25 by 12.5 mm] in section with the corners rounded to a radius not over $\frac{1}{16}$ in. [1.6 mm] and need not exceed 6 in. [150 mm] in length. The side of the samples placed in tension during the bend shall be the side closest to the inner and outer surface of the pipe, respectively.

15. Certification

15.1 In addition to the information required by Specification A 999/A 999M, the certification shall state whether or not the pipe was hydrostatically tested. If the pipe was nondestructively examined, the certification shall so state and shall show which practice was followed and what reference discontinuities were used. In addition, the test method information as given in Table 8 shall be appended to the specification number and grade shown on the certification.

16. Product Marking

16.1 In addition to the marking prescribed in Specification A 999/A 999M, the marking shall include the length,

an additional symbol “S”, if the pipe conforms to any of the Supplementary Requirements S1 to S6, the schedule number, if the pipe is ordered to a schedule number, and the heat number or manufacturer’s number by which the heat can be identified. Furthermore, the marking designated in Table 8 to indicate the test method(s) shall be included. Marking may be by stenciling, stamping, or rolling. Pipe that has been weld repaired in accordance with 7.6 shall be marked “WR.”

17. Government Procurement

17.1 Scale Free Pipe:

17.1.1 When specified in the contract or order, the following requirements shall be considered in the inquiry contract or order, for agencies of the U.S. Government where scale free pipe is required. These requirements shall take precedence if there is a conflict between these requirements and the product specification.

17.1.2 The requirements of Specification A 999/A 999M for pipe shall be applicable when pipe is ordered to this specification.

17.1.3 Pipe shall be one of the following grades as specified herein:

Grade	UNS Designation
P11	K11597
P22	K21590
P5	K41545

17.1.4 Part Number:

17.1.4.1 Pipe shall be ordered to nominal pipe size and schedule specified in ASME B36.10M

Example: A 335/A 335M Pipe P-11 NPS 12 Sch 40

Specification Number	ASTM A 335/A 335M
Pipe	P
Grade	P-11
NPS	12
Wall	0.375

17.1.4.2

Specification Number	ASTM A 335/A 335M
Tube	T
Grade	P-11
Outside Diameter	0.250
Wall	0.035

17.1.5 Ordering Information — Orders for material under this specification shall include the following in addition to the requirements of Section 3:

17.1.5.1 Pipe or tube,

17.1.5.2 Part number,

17.1.5.3 Ultrasonic inspection, if required,

17.1.5.4 If shear wave test is to be conducted in two opposite circumferential directions, and

17.1.5.5 Level of preservation and packing required.

18. Keywords

18.1 alloy steel pipe; high temperature service; seamless steel pipe; steel pipe; temperature service applications

TABLE 1
CHEMICAL REQUIREMENTS

Grade	UNS Designation ^A	Composition, %							
		Carbon	Manganese	Phosphorus, Max.	Sulfur, Max.	Silicon	Chromium	Molybdenum	Others
P1	K11522	0.10–0.20	0.30–0.80	0.025	0.025	0.10–0.50	...	0.44–0.65	...
P2	K11547	0.10–0.20	0.30–0.61	0.025	0.025	0.10–0.30	0.50–0.81	0.44–0.65	...
P5	K41545	0.15 max.	0.30–0.60	0.025	0.025	0.50 max.	4.00–6.00	0.45–0.65	...
P5b	K51545	0.15 max.	0.30–0.60	0.025	0.025	1.00–2.00	4.00–6.00	0.45–0.65	...
P5c	K41245	0.12 max.	0.30–0.60	0.025	0.025	0.50 max.	4.00–6.00	0.45–0.65	... ^B
P9	S50400	0.15 max.	0.30–0.60	0.025	0.025	0.25–1.00	8.00–10.00	0.90–1.10	...
P11	K11597	0.05–0.15	0.30–0.60	0.025	0.025	0.50–1.00	1.00–1.50	0.44–0.65	...
P12	K11562	0.05–0.15	0.30–0.61	0.025	0.025	0.50 max.	0.80–1.25	0.44–0.65	...
P15	K11578	0.05–0.15	0.30–0.60	0.025	0.025	1.15–1.65	...	0.44–0.65	...
P21	K31545	0.05–0.15	0.30–0.60	0.025	0.025	0.50 max.	2.65–3.35	0.80–1.06	...
P22	K21590	0.05–0.15	0.30–0.60	0.025	0.025	0.50 max.	1.90–2.60	0.87–1.13	...
P23	K41650	0.04–0.10	0.10–0.60	0.030 max.	0.010 max.	0.50 max.	1.90–2.60	0.05–0.30	V 0.20–0.30 Cb 0.02–0.08 B 0.0005–0.006 N 0.030 max. Al 0.030 max. W 1.45–1.75
P36	K21001	0.10–0.17	0.80–1.20	0.030 max.	0.025 max.	0.25–0.50	0.30 max.	0.25–0.50	Ni 1.00–1.30 Cu 0.050–0.080 Cb 0.015–0.045 V 0.02 max. N 0.02 max. Al 0.050 max.
P91	K91560	0.08–0.12	0.30–0.60	0.020	0.010	0.20–0.50	8.00–9.50	0.85–1.05	V 0.18–0.25 N 0.030–0.070 Ni 0.40 max. Al 0.02 max. Cb 0.06–0.10 Ti 0.01 max. Zr 0.01 max.
P92	K92460	0.07–0.13	0.30–0.60	0.020	0.010	0.50 max.	8.50–9.50	0.30–0.60	V 0.15–0.25 N 0.03–0.07 Ni 0.40 max. Al 0.02 max. Cb 0.04–0.09 W 1.5–2.00 B 0.001–0.006 Ti 0.01 max. Zr 0.01 max.
P122	K92930	0.07–0.14	0.70 max.	0.020	0.010	0.50 max.	10.00–11.50	0.25–0.60	V 0.15–0.30 W 1.50–2.50 Cu 0.30–1.70 Cb 0.04–0.10 B 0.0005–0.005 N 0.040–0.100 Ni 0.50 max. Al 0.020 max. Ti 0.01 max. Zr 0.01 max.
P911	K91061	0.09–0.13	0.30–0.60	0.020 max.	0.010 max.	0.10–0.50	8.50–9.50	0.90–1.10	V 0.18–0.25 Ni 0.40 max. Cb 0.060–0.10 B 0.0003–0.006 N 0.04–0.09 Al 0.02 max. W 0.90–1.10 Ti 0.01 max. Zr 0.01 max.

NOTES:

^A New designation established in accordance with Practice E 527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).

^B Grade P5c shall have a titanium content of not less than 4 times the carbon content and not more than 0.70%; or a columbium content of 8 to 10 times the carbon content.

TABLE 2
HEAT TREATMENT REQUIREMENTS⁴

Grade	Heat Treat Type	Normalizing Temperature, Min. or Range °F [°C]	Cooling Media	Subcritical Annealing or Tempering Temperature, Min. or Range °F [°C]
P1	Full or isothermal anneal	...	...	...
	Normalize and temper	...	...	1200 [650]
	Subcritical anneal	...	...	1200–1300 [650–705]
P2	Full or isothermal anneal	...	...	...
	Normalize and temper	...	...	1250 [675]
	Subcritical anneal	...	...	1200–1300 [650–705]
P5	Full or isothermal anneal	...	...	...
	Normalize and temper	...	...	1250 [675]
P5b	Full or isothermal anneal	...	...	...
	Normalize and temper	...	...	1250 [675]
P5c	Subcritical anneal	...	...	1325–1375 [715–745]
P9	Full or isothermal anneal	...	...	...
	Normalize and temper	...	...	1250 [675]
P11	Full or isothermal anneal	...	...	...
	Normalize and temper	...	...	1200 [650]
P12	Full or isothermal anneal	...	...	...
	Normalize and temper	...	...	1200 [650]
	Subcritical anneal	...	...	1200–1300 [650–705]
P15	Full or isothermal anneal	...	...	...
	Normalize and temper	...	...	1200 [650]
P21	Full or isothermal anneal	...	...	...
	Normalize and temper	...	...	1250 [675]
P22	Full or isothermal anneal	...	...	...
	Normalize and temper	...	...	1250 [675]
P23	Normalize and temper	1900–1975 [1040–1080]	air or accelerated cooling	1350–1470 [730–800]

TABLE 2
HEAT TREATMENT REQUIREMENTS^A (CONT'D)

Grade	Heat Treat Type	Normalizing Temperature, Min. or Range °F [°C]	Cooling Media	Subcritical Annealing or Tempering Temperature, Min. or Range °F [°C]
P36	Normalize and temper ^B	1650 [900]	...	1100 [595]
P91	Normalize and temper	1900–1975 [1040–1080]	...	1350–1470 [730–800] ^C
	Quench and temper ^D	1900–1975 [1040–1080]	...	1350–1470 [730–800]
P92	Normalize and temper	1900–1975 [1040–1080]	...	1350–1470 [730–800]
P122	Normalize and temper	1900–1975 [1040–1080]	...	1350–1470 [730–800]
P911	Normalize and temper	1900–1975 [1040–1080]	^E	1365–1435 [740–780]

^A Where ellipsis (...) appear in this table there is no requirement.

^B Alternatively, Grade P36, Class 2 shall be cooled from the austenitizing temperature by accelerated cooling in air or by liquid quenching.

^C Except when Supplementary Requirement S7 is specified by the purchaser.

^D When mutually agreed upon between the manufacturer and the purchaser, quenching and tempering shall be permitted for thicknesses greater than 3 in. [75 mm].

^E Accelerated cooling from the normalizing temperature shall be permitted for section thickness greater than 3 in. [75 mm].

TABLE 3
TENSILE REQUIREMENTS

	Grade							
	P1, P2	P12	P23	P91	P92, P911 P36 Class 1	P122	P36 Class 2	All Others
Tensile Strength, min.:								
ksi	55	60	74	85	90	90	95.5	60
MPa	380	415	510	585	620	620	660	415
Yield strength, min.:								
ksi	30	32	58	60	64	58	66.5	30
MPa	205	220	400	415	440	400	460	205

TABLE 4
ELONGATION REQUIREMENTS

	Elongation Requirements				
	All Grades Except P23, P36, P91, P92, P122, and P911		P23, P91, P92, P122, and P911		P36
	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal
Elongation in 2 in. or 50 mm (or $4D$), min., %:					
Basic minimum elongation for wall $\frac{5}{16}$ in. [8 mm] and over in thickness, strip tests, and for all small sizes tested in full section	30	20	20	...	15
When standard round 2 in. or 50 mm gage length or proportionally smaller size specimen with the gage length equal to $4D$ (4 times the diameter) is used	22	14	20	13	...
For strip tests a deduction for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{5}{16}$ in. [8 mm] from the basic minimum elongation of the following percentage points shall be made	1.50 ^A	1.00 ^A	1.00 ^A	...	1.00 ^A

NOTE:

^A Table 5 gives the calculated minimum values.

TABLE 5
CALCULATED MINIMUM ELONGATION VALUES

Wall Thickness		Elongation in 2 in. or 50 mm, min., %			
		All Grades Except P23, P36, P91, P92, P122, and P911		P23, P91, P92, P122, and P911	P36
				Longitudinal	Longitudinal
in.	mm	Longitudinal	Transverse	Longitudinal	Longitudinal
$\frac{5}{16}$ (0.312)	8	30	20	20	15
$\frac{9}{32}$ (0.281)	7.2	28	19	19	14
$\frac{1}{4}$ (0.250)	6.4	27	18	18	13
$\frac{7}{32}$ (0.219)	5.6	26	...	17	12
$\frac{3}{16}$ (0.188)	4.8	24	...	16	11
$\frac{5}{32}$ (0.156)	4	22	...	15	10
$\frac{1}{8}$ (0.125)	3.2	21	...	14	9
$\frac{3}{32}$ (0.094)	2.4	20	...	13	8
$\frac{1}{16}$ (0.062)	1.6	18	...	12	7

TABLE 6
PERMISSIBLE VARIATIONS IN OUTSIDE DIAMETER

NPS [DN] Designator	Over		Under	
	in.	mm	in.	mm
$\frac{1}{8}$ to $1\frac{1}{2}$ [6 to 40], incl.	$\frac{1}{64}$ (0.015)	0.40	$\frac{1}{64}$ (0.015)	0.40
Over $1\frac{1}{2}$ to 4 [40 to 100], incl.	$\frac{1}{32}$ (0.031)	0.79	$\frac{1}{32}$ (0.031)	0.79
Over 4 to 8 [100 to 200], incl.	$\frac{1}{16}$ (0.062)	1.59	$\frac{1}{32}$ (0.031)	0.79
Over 8 to 12 [200 to 300], incl.	$\frac{3}{32}$ (0.093)	2.38	$\frac{1}{32}$ (0.031)	0.79
Over 12 [300]	$\pm 1\%$ of the specified outside diameter			

TABLE 7
PERMITTED VARIATIONS IN WALL THICKNESS

NPS [DN] Designator	Tolerance, % from Specified	
	Over	Under
$\frac{1}{8}$ to $2\frac{1}{2}$ [6 to 65] incl., all t/D ratios ^A	20.0	12.5
Above $2\frac{1}{2}$ [65], t/D $\leq 5\%$ ^A	22.5	12.5
Above $2\frac{1}{2}$ [65], t/D $> 5\%$ ^A	15.0	12.5

TABLE 8
**TEST METHOD INFORMATION FOR CERTIFICATION
AND MARKING**

Hydrostatic	Nondestructive	Marking
YES	NO	Test Pressure
NO	YES	NDE
NO	NO	NH
YES	YES	Test Pressure/NDE

NOTE:

^At = Specified Wall Thickness; D = Specified Outside Diameter.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical composition requirements shall be rejected.

S2. Transverse Tension Tests

S2.1 A transverse tension test shall be made on a specimen from one end or both ends of each pipe NPS 8 and over. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails to meet the required tensile properties (tensile, yield, and elongation), that length shall be rejected subject to retreatment in accordance with Specification A 999/A 999M and satisfactory retest.

S3. Flattening Test

S3.1 The flattening test of Specification A 999/A 999M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A 999/A 999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound. The bend test of 13.2 shall be substituted for the flattening test for pipe whose diameter exceeds NPS 25 and whose diameter to wall thickness ratio is 7.0 or less.

S4. Metal Structure and Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free from injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified,

the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

NOTE S4.1 — Pending development of etching methods applicable to the product covered by this specification, it is recommended that the Recommended Practice for a Standard Macro Etch Test for Routine Inspection of Iron and Steel, described in the *Metals Handbook*, Am. Soc. for Metals, 1948 edition, p. 389, be followed.

S5. Photomicrographs

S5.1 When requested by the purchaser and so stated in the order, the manufacturer shall furnish one photomicrograph at 100 diameters from a specimen of pipe in the as-finished condition for each individual size and wall thickness from each heat, for pipe NPS 3 and over. Such photomicrographs shall be suitably identified as to pipe size, wall thickness, and heat. No photomicrographs for the individual pieces purchased shall be required except as specified in Supplementary Requirement S6. Such photomicrographs are for information only, to show the actual metal structure of the pipe as finished.

S6. Photomicrographs for Individual Pieces

S6.1 In addition to the photomicrographs required in accordance with Supplementary Requirement S5, the purchaser may specify that photomicrographs shall be furnished from each end of one or more pipes from each lot of pipe NPS 3 and larger in the as-finished condition. The purchaser shall state in the order the number of pipes to be tested from each lot. When photomicrographs are required on each length, the photomicrographs from each lot of pipe in the as-finished condition which may be required under Supplementary Requirement S5 may be omitted. All photo-micrographs required shall be properly identified as to heat number, size, and wall thickness of pipe from which the section was taken. Photomicrographs shall be further identified to permit association of each photomicrograph with the individual length of pipe it represents.

S7. Alternative Heat Treatment — Grade P91

S7.1 Grade P91 shall be normalized in accordance with Table 2 and tempered at a temperature, to be specified by the purchaser, less than 1350°F [730°C]. It shall be purchaser's responsibility to subsequently temper at

1350-1470°F [730-800°C] minimum. All mechanical tests shall be made on material heat treated in accordance with Table 2. The certification shall reference this supplementary requirement indicating the tempering temperature applied. The notation "S7" shall be included with the required marking of the pipe.

SPECIFICATION FOR ALLOY STEEL FORGINGS FOR PRESSURE AND HIGH-TEMPERATURE PARTS



SA-336/SA-336M



(Identical with ASTM Specification A 336/A 336M-07.)

1. Scope

1.1 This specification covers ferritic steel forgings for boilers, pressure vessels, high-temperature parts, and associated equipment.

1.2 Forgings made of steel grades listed in Specification A 335/A 335M, may also be ordered under this specification. The chemical, tensile, heat treatment, and marking requirements of Specification A 335/A 335M shall apply, except the forging shall conform to the chemical requirements of Tables 1 and 2 of Specification A 335/A 335M only with respect to heat analysis. On check analysis they may deviate from these limits to the extent permitted in Table 1 of this specification.

Current	Formerly
Grade F1	Class F1
Grade F11, Class 2	Class F11
Grade F11, Class 3	Class F11A
Grade F11, Class 1	Class F11B
Grade F12	Class F12
Grade F5	Class F5
Grade F5A	Class F5A
Grade F9	Class F9
Grade F6	Class F6
Grade F21 Class 1	Class F21A
Grade F21, Class 3	Class F21
Grade F22, Class 1	Class F22A
Grade F22, Class 3	Class F22
Grade F91	Class F91
Grade F3V	Class F3V
Grade F22V	Class F22V

1.3 Supplementary Requirements S1 to S9 are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.4 Unless the order specifies the applicable “M” specification designation, the material shall be furnished to the inch-pound units.

1.5 Specification A 336/A 336M formerly included austenitic steel forgings, which are now found in Specification A 965/A 965M.

1.6 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as standards. Within the text and tables, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 ASTM Standards:

- A 275/A 275M Practice for Magnetic Particle Examination of Steel Forgings
- A 335/A 335M Specification for Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 788/A 788M Specification for Steel Forgings, General Requirements
- A 965/A 965M Specification for Steel Forgings, Austenitic, for Pressure and High Temperature Parts
- E 165 Test Method for Liquid Penetrant Examination

2.2 Other Standard:

ASME Boiler and Pressure Vessel Code Section III, Nuclear Facility Components and Section IX, Welding Qualifications

3. Ordering Information and General Requirements

3.1 In addition to the ordering information required by Specification A 788/A 788M, the purchaser should include with the inquiry and order the following information:

3.1.1 A drawing or sketch that shows test locations when the testing is in accordance with 8.1.1.3.

3.1.2 The intended use of forgings if 5.1 is applicable.

3.2 Material supplied to this specification shall conform to the requirements of Specification A 788/A 788M, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A 788/A 788M, the requirements of this specification shall prevail.

3.4 For hubbed flanges and tube sheets ordered for ASME Boiler and Pressure Vessel Code application, Supplementary Requirement S12 of Specification A 788/A 788M shall be specified.

3.5 For Section III, Part NB of the ASME Boiler and Pressure Vessel Code application, Supplementary Requirement S3 shall be specified.

4. Melting and Forging

4.1 In addition to the melting and forging requirements of Specification A 788/A 788M, which may be supplemented by Supplementary Requirement S8, the following conditions apply:

4.1.1 A sufficient discard shall be made to secure freedom from injurious pipe and undue segregation.

5. Machining

5.1 Forged pressure vessels for steam power service shall have the inner surface machined or ground. Unfired pressure vessels shall have the inner surfaces sufficiently free of scale to permit inspection.

5.2 When rough machining is performed, it may be done either before or after heat treatment.

6. Heat Treatment

6.1 Except as permitted in 6.1.1 for Grade F22V, the steel forgings shall be annealed or normalized and tempered but alternatively may be liquid quenched and tempered when mutually agreed upon between the manufacturer and the purchaser. For all grades, normalizing or liquid quenching shall be followed by tempering at a subcritical temperature.

6.1.1 Grade F22V forgings shall be normalized and tempered or liquid quenched and tempered at the manufacturer's option.

6.1.1.1 For Grade F22V forgings the minimum austenizing temperature shall be 1650°F [900°C].

6.1.2 For Grade F91 and F911 forgings the austenizing temperature shall be in the range of 1900 to 1975°F [1040 to 1080°C].

6.1.3 Except for the following grades, the minimum tempering temperature shall be 1100°F [595°C]:

Grade	Tempering Temperature Minimum or Range, °F [°C]
F6	1150 [620]
F11, Class 2	1150 [620]
F11, Class 3	1150 [620]
F11, Class 1	1150 [620]
F5	1250 [675]
F9	1250 [675]
F21, Class 1	1250 [675]
F3V, F3VCb	1250 [675]
F22, Class 1	1250 [675]
F22V	1250 [675]
F91	1350-1470 [730-800]
F911	1365-1435 [740-780]
F22, Class 3	1250 [675]

7. Chemical Composition

7.1 Heat Analysis — The heat analysis obtained from sampling in accordance with Specification A 788/A 788M and shall comply with Table 2.

7.2 Product Analysis — The manufacturer shall use the product analysis provision of Specification A 788/A 788M to obtain a product analysis from a forging representing each heat or multiple heat. The product analysis for columbium and calcium for Grade F22V shall conform to the requirements of Table 2 of this specification. Boron is not subject to product analysis. The purchaser may also make this determination in accordance with Specification A 788/A 788M.

8. Mechanical Properties

8.1 General Requirements — The material shall conform to the requirements for mechanical properties prescribed in Table 1. The largest obtainable tension test specimen as specified in Test Methods and Definitions A 370 shall be used.

8.1.1 Except as required in 3.4, for annealed, normalized, and tempered or quenched and tempered forgings, the longitudinal axis of the specimens shall be parallel to the direction of major working of the forging, except when Supplementary Requirement S2 is specified. For upset disk forgings, the longitudinal axis of the test specimen shall be in the tangential direction.

8.1.1.1 Except as provided for liquid quenched and tempered forgings in 8.1.1.3, the longitudinal axis of

the specimen shall be located midway between the parallel surfaces of the test extension if added to the periphery of disks or midway between the center and surface of solid forgings. For hollow forgings, the longitudinal axis of the specimens shall be located midway between the center and outer surfaces of the wall. When separately forged test blocks are employed, as defined in 8.1.3, the tension test specimens shall be taken from a location that represents the midwall of the heaviest section of the production forgings. When specimens are required from opposite ends, they shall be taken from the diagonal corners of an axial plane. Alternatively, and when specified by the purchaser, the specimens shall be taken in accordance with Supplementary Requirement S3.

8.1.1.2 For liquid quenched and tempered forgings, the test specimens shall have their longitudinal axis at least $\frac{1}{4} T$ of the maximum heat-treated thickness from any surface and with the mid-length of the specimens at least one T from any second surface. This is normally referred to as $\frac{1}{4} T \times T$, where T is the maximum heat-treated thickness. A thermal buffer may be used to adhere to the above condition.

8.1.1.3 For liquid quenched and tempered forgings with prior purchaser approval, test specimens may be taken at a depth (t) corresponding to the distance from the area of significant stress to the nearest heat-treated surface and at least twice this distance ($2t$) from any second surface. However, the test depth shall not be nearer to one heat-treated surface than $\frac{3}{4}$ in. [19 mm] and to the second treated surface than $1\frac{1}{2}$ in. [38 mm]. This method of test specimen location normally (known as tx2t testing) applies to thick and complex pressure vessel components where the testing in accordance with 8.1.1.2 is not practical. Sketches showing the proposed exact test locations shall be approved by the purchaser when this method is used.

8.1.2 Except as specified in this specification, tests for acceptance shall be made after heat treatment has been completed in accordance with Section 6. When the ends of the cylindrical forgings are closed in by reforging, the cylindrical forgings may be normalized and tempered or annealed and tested before reforging. After reforging, the entire forging shall be re-heat treated in the same manner and at the same temperature range as employed when the forging was heat treated before certification testing.

8.1.3 When mutually agreed upon between the manufacturer and the purchaser, test specimens may be machined from a specially forged block suitably worked and heat treated with the production forgings. Such a special block shall be obtained from an ingot, slab, or billet from the same heat used to make the forgings it represents. This block shall receive essentially the same type of hot-working and forging reduction as the production forgings; however, a longitudinally forged bar with dimensions not less than

$T \times T \times 3T$ may be used to represent a ring forging. The dimension T shall be representative of the heaviest effective cross section of the forging. For quenched and tempered forgings for which tests are required at both ends by 8.2.2.3 and 8.2.2.4, separately forged test blocks are not allowed.

NOTE 1 — In using separately forged test blocks, attention is drawn to the effect of mass differences between the production forgings and the test blocks. This can be particularly significant when forgings are either normalized and tempered or quenched and tempered.

8.2 Number and Location of Tests — The number and location of tests are based on forging length, weight, and heat treatment and shall be as prescribed below. The length and weight to be used for this purpose shall be the shipped length and weight of forgings produced individually or the aggregate shipped length and weight of all pieces cut from a multiple forging.

8.2.1 Annealed or Normalized and Tempered Forgings:

8.2.1.1 For forgings weighing 5000 lb [2250 kg] or less at the time of heat treatment, one tension test shall be taken from one forging per heat, per heat treatment charge. When heat treatment is performed in continuous type furnaces with suitable temperature controls and equipped with recording pyrometers so that complete heat treatment records are available, a tempering charge may be considered as any continuous run not exceeding an 8 h period.

8.2.1.2 For forgings and forged bars weighing over 5000 lb [2250 kg] at the time of heat treatment, one tension test shall be taken from each forging.

8.2.2 Quenched and Tempered Forgings:

8.2.2.1 For quenched and tempered forgings weighing 5000 lb [2250 kg] or less at the time of heat treatment, but not exceeding 12 ft [3.7 m] in length, one tension test shall be taken from one forging per heat, per heat treatment charge. When heat treatment is performed in continuous type furnaces with suitable temperature controls and equipped with recording pyrometers so that complete heat treatment records are available, a tempering charge may be considered as any continuous run not exceeding an 8 h period.

8.2.2.2 For quenched and tempered forgings and forged bars weighing over 5000 to 10 000 lb [2250 to 4500 kg] at the time of heat treatment, but not exceeding 12 ft [3.7 m] in length, one tension test shall be taken from each forging.

8.2.2.3 Quenched and tempered forgings that exceed 12 ft [3.7 m] in length shall be tension tested at both ends of the forging under test.

8.2.2.4 For quenched and tempered forgings and forged bars weighing more than 10 000 lb [4500 kg] at the time of heat treatment, two tension test specimens shall

be taken from each forging. These shall be offset 180° from each other except that if the length of the forging, excluding test prolongations, exceeds 12 ft [3.7 m], then one specimen shall be taken from each end of the forging.

8.3 Notch Toughness Requirements—Grades F3V, F3VCb, and F22V:

8.3.1 Impact test specimens shall be Charpy V-notch, as shown in Test Methods and Definitions A 370. The usage of subsize specimens due to material limitations must have prior purchaser approval.

8.3.2 The Charpy V-notch test specimens shall be obtained as required for tension tests in 8.1 and 8.2. One set of three Charpy V-notch specimens shall be taken from each tensile specimen location.

8.3.3 The longitudinal axis and mid-length of impact specimen shall be located similarly to the longitudinal axis of the tension test specimens. The axis of the notch shall be normal to the nearest heat treated surface of the forging.

8.3.4 The Charpy V-notch tests shall meet a minimum energy absorption value of 40 ft•lbf [54 J] average of three specimens. One specimen only in one set may be below 40 ft•lbf [54 J] and it shall meet a minimum value of 35 ft•lbf [48 J].

8.3.5 The impact test temperature shall be not warmer than 0°F [−18°C].

9. Workmanship, Finish, and Appearance

9.1 When forgings have been heat treated by quenching and tempering, all accessible surfaces shall subsequently

be examined for quench cracks by the magnetic particle method in accordance with Test Method A 275/A 275M.

10. Repair Welding

10.1 Repair welding of forgings may be permitted but only at the option of the purchaser. Such repair welds shall be made in accordance with the ASME Boiler and Pressure Vessel Code, Section IX.

11. Marking

11.1 In addition to the marking requirements of Specification A 788/A 788M, the specification marking shall be followed by the letter A for annealed, N for normalized and tempered, or Q for liquid quenched and tempered as applicable.

12. Test Reports

12.1 The certification requirements of Specification A 788/A 788M shall apply.

13. Keywords

13.1 chromium alloy steel; chromium-molybdenum steel; pressure containing parts; pressure vessel service; steel forgings—alloy; temperature service applications—high

TABLE 1
TENSILE REQUIREMENTS

	Ferritic Steels																	
	Grade																	
	F1	F11, Class 2	F11, Class 3	F11, Class 1	F12	F5	F5A	F9	F6	F21, Class 3	F21, Class 1	F22, Class 3	F22, Class 1	F91	F911	F3V	F3VCh	F22V
Tensile strength, psi [MPa]	70,000–95,000 [485–660]	70,000–95,000 [485–660]	75,000–100,000 [515–690]	60,000–85,000 [415–585]	70,000–95,000 [485–660]	60,000–85,000 [415–585]	80,000–105,000 [550–725]	85,000–110,000 [585–760]	85,000–110,000 [585–760]	75,000–100,000 [515–690]	60,000–85,000 [415–585]	75,000–100,000 [515–585]	60,000–85,000 [415–585]	85,000–110,000 [585–760]	90,000–120,000 [620–830]	85,000–110,000 [585–760]	85,000–110,000 [585–760]	85,000–110,000 [585–760]
Yield strength, min, psi [MPa]	40,000 [275]	40,000 [275]	45,000 [310]	30,000 [205]	40,000 [275]	36,000 [250]	50,000 [345]	55,000 [380]	55,000 [380]	45,000 [310]	30,000 [205]	45,000 [310]	30,000 [205]	60,000 [415]	64,000 [440]	60,000 [415]	60,000 [415]	60,000 [415]
Elongation in 2 in. or 50 mm, min, %	20	20	18	20	20	20	19	20	18	19	20	19	20	20	20	18	18	18
Reduction of area, min, %	40	40	40	45	40	40	35	40	35	40	45	40	45	40	40	45	45	45

TABLE 2
CHEMICAL REQUIREMENTS

Composition, %									
Ferritic Steels									
Grade									
Element	F1	F11, Classes 2 and 3	F11, Class 1	F12	F5 [Note (1)]	F5A [Note (1)]	F9	F6	
Carbon	0.20–0.30	0.10–0.20	0.05–0.15	0.10–0.20	0.15 max	0.25 max	0.15 max	0.12 max	
Manganese	0.30–0.80	0.30–0.80	0.30–0.60	0.30–0.80	0.30–0.60	0.60 max	0.30–0.60	1.00 max	
Phosphorus, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	
Sulfur, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	
Silicon	0.20–0.35	0.50–1.00	0.50–1.00	0.10–0.60	0.50 max	0.50 max	0.50–1.00	1.00 max	
Nickel	...	...	...	...	...	...	...	...
Chromium	...	1.00–1.50	1.00–1.50	0.80–1.10	4.0–6.0	4.0–6.0	8.0–10.0	0.50 max	
Molybdenum	0.40–0.60	0.45–0.65	0.44–0.65	0.45–0.65	0.45–0.65	0.45–0.65	0.90–1.10	11.5–13.5	
								...	

Grade									
Element	F21, Classes 1 and 3	F22, Classes 1 and 3	F3V	F3Vcb	F22V				
Carbon	0.05–0.15	0.05–0.15	0.10–0.15	0.10–0.15	0.11–0.15				
Manganese	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60				
Phosphorus, max	0.025	0.025	0.020	0.020	0.015				
Sulfur, max	0.025	0.025	0.020	0.010	0.010				
Silicon	0.50 max	0.50 max	0.10 max	0.10 max	0.10 max				
Nickel	...	...	...	...	...
Chromium	2.7–3.3	2.00–2.50	2.7–3.3	2.7–3.3	2.25 max				
Molybdenum	0.80–1.10	0.90–1.10	0.90–1.10	0.90–1.10	2.00–2.50				
Vanadium	...	...	0.20–0.30	0.20–0.30	0.90–1.10				
Copper	...	...	0.20–0.30	0.20–0.30	0.25–0.35				
Nitrogen	...	...	...	0.015–0.070	0.07 max				
Columbium	...	...	...	...	...

Element	Grade F91	Grade F911	F3V	F3Vcb	F22V				
Carbon	0.08–0.12	0.09–0.13	0.10–0.15	0.10–0.15	0.11–0.15				
Manganese	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60				
Phosphorus, max	0.025	0.020	0.020	0.020	0.015				
Sulfur, max	0.025	0.010	0.020	0.010	0.010				
Silicon	0.20–0.50	0.10–0.50	0.10 max	0.10 max	0.10 max				
Nickel	0.40 max	0.40 max	...	0.25 max	0.25 max				
Chromium	8.0–9.5	8.5–9.5	2.7–3.3	2.7–3.3	2.00–2.50				
Molybdenum	0.85–1.05	0.90–1.10	0.90–1.10	0.90–1.10	0.90–1.10				
Vanadium	0.18–0.25	0.18–0.25	0.20–0.30	0.20–0.30	0.25–0.35				
Columbium	0.06–0.10	0.06–0.10	...	0.015–0.070	0.07 max				
Nitrogen	0.03–0.07	0.04–0.09	...	...	...	
Aluminum	0.02 max. [Note (2)]	0.02 max. [Note (2)]	...	...	...	
Boron	...	0.0003–0.006	0.001–0.003	...	0.0020 max				
Tungsten	...	0.90–1.10	...	...	...	
Titanium	0.01 max [Note (2)]	0.01 max [Note (2)]	0.015–0.035	0.015 max	0.030 max				
Copper	...	...	...	0.25 max	0.20 max				
Calcium	...	...	...	0.0005–0.0150	0.015 max [Note (3)]				
Zirconium	0.01 max. [Note (2)]	0.01 max. [Note (2)]	...	...	...	

NOTES:

- (1) The present Grade F5A (0.25%, maximum carbon) previous to 1955 was assigned the identification symbol F5. Identification symbol F5 has been assigned to the 0.15%, maximum, carbon grade to be consistent with ASTM specifications for other products such as pipe, tubing, bolting, welding, fittings, etc.
- (2) Applies to both heat and product analyses.
- (3) For Grade F22V, rare earth metals (REM) may be added in place of calcium subject to agreement between the producer and the purchaser. In that case the total amount of REM shall be determined and reported.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, and order. Details of these supplementary requirements shall be agreed upon between the manufacturer and the purchaser.

S1. Rough Turning and Boring

S1.1 The position of the rough turning and boring in the sequence of manufacturing operations shall be specified.

S2. Transverse Tension Test

S2.1 Instead of test specimens taken in accordance with 8.1.1, the longitudinal axis of the test specimens shall be transverse to the direction of major working of the forging. The results shall conform with requirements of Table 1, with the exception of the ductility limits which shall be as prescribed in Table S2.1.

S3. Alternative Test Specimen Requirements

S3.1 The test requirements for materials of the ASME Boiler and Pressure Code, Section III, Article NB-2223.3, shall be used in place of that specified in 8.1.1.1.

S4. Hydrostatic Test

S4.1 A hydrostatic pressure test shall be applied. The details of the test, including its position in the sequence of manufacturing operations, shall be specified.

S6. Liquid Penetrant Examination

S6.1 After forgings have been heat treated by quenching and tempering, all accessible surfaces shall be inspected for quench cracks by the liquid penetrant method in accordance with Test Method E 165 as an alternative to magnetic particle examination.

S7. Marking

S7.1 Forgings shall be marked at a location indicated by the purchaser in the purchase order or drawing.

S8. Forging Requirements

S8.1 Large drum forgings shall be made from solid cast ingots, punched, bored, or trepanned, or from hollow

ingots cast in metal molds. The walls of the hollowed or hollow ingots shall be reduced in thickness at least one-half by forging on mandrels.

S8.2 Drum forgings with one solid closed end may be hollow forged in closed dies or on a draw bench provided the metal is worked thoroughly.

S8.3 Drum forgings, either with open ends or one solid closed end, may also be produced by hot extrusion provided the metal is worked thoroughly.

S8.4 Small drum forgings may be made as solid forgings, subsequently bored, provided the purchaser agrees to this method of forging. The cross-sectional area of the solid forgings shall have a reduction by forging from that of the ingot in the ratio of not less than 3:1.

S8.5 Small sections or component parts of pressure vessels, which are to be subsequently assembled to form drums, may be made by expanding on a mandrel under a press or hammer, by hot extrusion or by ring rolling methods, provided the wall thickness is reduced at least one-half in the process.

S8.6 Heads or covers shall be forged as disks, upset from blocks cut from ingots or billets. The length of block before upsetting shall be at least twice the thickness of the as-forged head or cover.

S9. Individual Forging

S9.1 Forgings, whether identical or not identical, shall be produced individually. They shall not be forged in multiple and separated prior to or after heat treatment.

S9.2 The shape and size of individual forgings shall be agreed between the manufacturer and the purchaser by means of a forging drawing or the purchase order.

TABLE S1.1
DUCTILITY LIMITS

	Grade																		
	F11, F1		F11, Class 2	F11, Class 3	F11, Class 2	F12	F5	F5A	F9	F6	F21, Class 3	F21, Class 1	F22, Class 3	F22, Class 1	F3V	F46	F22V	F91	F911
Elongation in 2 in. or 50 mm, min, %	20	18	18	19	18	19	19	18	18	18	19	18	20	17	40	17	19	16	
Reduction of area, min, %	30	35	30	40	25	35	35	35	35	35	35	25	35	35	50	35	40	30	

SPECIFICATION FOR CARBON AND LOW-ALLOY STEEL FORGINGS, REQUIRING NOTCH TOUGHNESS TESTING FOR PIPING COMPONENTS



SA-350/SA-350M

(Identical with ASTM Specification A 350/A 350M-02b except for the deletion of 6.1.2 and 14.1, revision to 14.2.5, and test reports have been made mandatory.)

1. Scope

1.1 This specification covers several grades of carbon and low-alloy steel forged or ring-rolled flanges, forged fittings and valves intended primarily for low-temperature service and requiring notch toughness testing. They are made to specified dimensions, or to dimensional standards, such as the ASME and API Specifications referenced in Section 2. Although this specification covers some piping components machined from rolled bar and seamless tubular materials (see 5.3.3), it does not cover raw material produced in these product forms.

1.2 No limitation on size is intended beyond the ability of the manufacturer to obtain the specified requirements. However, Class 3 of Grade LF787 is only available in the quenched-and-precipitation heat treated condition.

1.3 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified by the purchaser in the order.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable “M” specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

NOTE 1 — Refer to Test Methods and Definitions A 370 for notes on significance of notched-bar impact testing.

2. Referenced Documents

2.1 ASTM Standards:

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 788 Specification for Steel Forgings, General Requirements

A 961 Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications

2.2 ASME Standards:

B 16.5 Steel Pipe Flanges and Flanged Fittings

B 16.9 Factory-Made Wrought Steel Butt-Welding Fittings

B 16.10 Face-to-Face and End-to-End Dimensions of Ferrous Valves

B 16.11 Forged Steel Fittings, Socket-Welding and Threaded

B 16.30 Unfired Pressure Vessel Flange Dimensions

B 16.34 Valves-Flanged, Threaded, and Welding End

B 16.47 Large Diameter Steel Flanges

2.3 ASME Boiler and Pressure Vessel Code:

Section IX Welding Qualifications

2.4 AWS Standards:

A 5.1 Mild Steel Covered Arc-Welding Electrodes

A 5.5 Low-Alloy Steel Covered Arc-Welding Electrodes

2.5 API Standards:

600 Steel Gate Valves with Flanged or Butt-Welding Ends

602 Compact Design Carbon Steel Gate Valves for Refinery Use

605 Large Diameter Carbon Steel Flanges

3. Ordering Information

3.1 It is the purchaser's responsibility to specify in the purchase order information necessary to purchase the

needed material. In addition to the ordering information guidelines in Specification A 961, orders should include the following information:

3.1.1 Additional requirements (see Table 1 footnotes).

4. General Requirements

4.1 Product furnished to this specification shall conform to the requirements of Specification A 961, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 961 constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 961, this specification shall prevail.

5. Manufacture

5.1 Melting Process — The steel shall be produced by any of the following primary processes: open-hearth, basic oxygen, electric-furnace, or vacuum-induction melting (VIM). The primary melting may incorporate separate degassing or refining, and may be followed by secondary melting using electroslog remelting (ESR), or vacuum-arc remelting (VAR).

5.1.1 The steel shall be fully killed, fine-grain practice.

5.1.2 The molten steel may be vacuum treated prior to or during pouring of the ingot.

5.2 Discard — A sufficient discard shall be made to secure freedom from injurious piping and undue segregation.

5.3 Forging Process:

5.3.1 Material for forgings shall consist of ingots, or forged, rolled, or strandcast blooms, billets, slabs, or bars.

5.3.2 The finished product shall be a forging as defined in the Terminology section of Specification A 788.

5.3.3 Except for flanges of all types, hollow, cylindrically-shaped parts may be machined from rolled bar or seamless tubular materials provided that the axial length of the part is approximately parallel to the metal flow lines of the stock. Other parts, excluding flanges of all types, may be machined from hot-rolled or forged bar up through and including NPS 4. Elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

5.4 Heat Treatment:

5.4.1 After hot working and before reheating for heat treatment, the forging shall be allowed to cool substantially below the transformation range.

5.4.2 Forgings of grades other than Grade LF787 shall be furnished in the normalized, or in the normalized and tempered, or in the quenched and tempered condition described by the following procedures:

5.4.2.1 Normalize — Heat to a temperature that produces an austenitic structure, holding sufficient time to attain uniform temperature throughout. Cool uniformly in still air.

5.4.2.2 Normalize and Temper — Subsequent to normalize, reheat to 1100°F [590°C] minimum, holding at temperature a minimum of 30 min/in. [30 min/25 mm] of maximum thickness, but in no case less than 30 min. Cool in still air.

5.4.2.3 Quench and Temper — The procedure for quenching shall consist of either (1) fully austenitizing the forgings followed by quenching in a suitable liquid medium or (2) using a multiple stage procedure whereby the forging is first fully austenitized and rapidly cooled, then reheated to partially reaustenitize, followed by quenching in a suitable liquid medium. All quenched forgings shall be tempered by reheating to a temperature between 1100°F [590°C] and the lower transformation temperature, holding at temperature a minimum of 30 min/in. [30 min/25 mm] of maximum thickness but in no case less than 30 min. Cool in still air.

5.4.3 Grade LF787 forgings shall be furnished in either the normalized-and-precipitation heat treated condition or in the quenched-and-precipitation heat treated condition. The heat treatment procedures shall be as follows:

5.4.3.1 Normalized-and-Precipitation Heat Treated — Heat to a temperature in the range from 1600 to 1725°F [870 to 940°C], hold at the temperature for a time sufficient to attain uniform temperature throughout, soak at the temperature for not less than $\frac{1}{2}$ h, and remove from the furnace and cool in air. Subsequently, heat to a temperature in the range from 1000 to 1200°F [540 to 650°C], soak at the temperature for not less than $\frac{1}{2}$ h, and cool at any convenient rate.

5.4.3.2 Quenched-and-Precipitation Heat Treated — Heat to a temperature in the range from 1600 to 1725°F [879 to 940°C], hold at the temperature for a time sufficient to attain uniform temperature throughout, soak at the temperature for not less than $\frac{1}{2}$ h and quench in a suitable liquid medium by immersion; reheat to a temperature in the range from 1000 to 1225°F [540 to 665°C], hold at the temperature for not less than $\frac{1}{2}$ h, and cool at any convenient rate.

6. Chemical Composition

6.1 Heat Analysis:

6.1.1 A chemical heat analysis in accordance with Specification A 961 shall be made and conform to the

requirements as to chemical composition prescribed in Table 1. Lead steels shall not be permitted.

6.1.2 DELETED

6.2 Product Analysis:

6.2.1 The purchaser may make a product analysis on products supplied to this specification in accordance with Specification A 961.

7. Mechanical Properties

7.1 Tension Tests:

7.1.1 Requirements — The material shall conform to requirements for tensile properties in Table 2.

7.1.1.1 The test specimen shall be obtained from a rough or finished forging, or prolongation thereof. For forgings under 10 000 lbs, at time of heat treatment, it may be obtained from separately forged test blanks from the same heat of steel as the production forgings. The test blank shall be reduced by forging in a manner similar to that for the products represented, and shall receive approximately the same hot working and reduction and the same heat treatment as the finished products represented. The test material shall be treated in the same furnace at the same time as the forging it represents, subject to the requirements of 7.1.2.1.

7.1.1.2 The test specimen shall represent all forgings from the same heat and heat-treatment load whose maximum thicknesses do not exceed the thickness of the test forging or blank by more than $\frac{1}{4}$ in. [6 mm].

7.1.2 Number of Tests — One tension test at room temperature shall be made in accordance with 7.1.1.2 from each heat in each heat-treatment load.

7.1.2.1 If heat treatment is performed in either a continuous or a batch-type furnace controlled within $\pm 25^\circ\text{F}$ [$\pm 14^\circ\text{C}$] of the required heat-treatment temperature and equipped with recording pyrometers so that complete records of heat treatment are available and if the same heat-treating cycles are used on the forgings represented by the tension test, then one tension test from each heat shall be required, instead of one tension test from each heat in each heat treatment load in accordance with 7.1.1.2.

7.1.3 Test Locations and Orientations — The test specimen shall be removed from the heaviest section of the forging or test blank, at locations described in 7.1.3.1, 7.1.3.2, 7.1.3.5 or as close to these locations as practical, subject to forging size and geometry.

7.1.3.1 For forgings or test blanks having a maximum heat-treated thickness, T , of 2 in. [50 mm] or less, the longitudinal axis of the test specimen shall be taken at mid-thickness and its mid-length shall be at least 2 in. [50 mm] from a second heat treated surface, exclusive of the

T dimension surfaces. (This is normally referred to as $\frac{1}{2} T$ by 2 in. [50 mm]).

7.1.3.2 For forgings or test blanks having a maximum heat-treated thickness, T , greater than 2 in. [50 mm], the central axis of the test specimen shall be taken at least $\frac{1}{4} T$ from the nearest heat-treated surface and at least T or 4 in. [100 mm], whichever is less, from any second heat-treated surface. For quenched and tempered forgings, the midlength of the test specimen shall be at least T from any second heat-treated surface. See Fig. 1 for test specimen location in separately forged test blanks for quenched and tempered forgings.

7.1.3.3 Metal Buffers — The required distances from heat treated surfaces may be obtained with metal buffers instead of integral expansions. Buffer material may be carbon or low alloy steel, and shall be joined to the forging with a partial penetration weld that seals the buffered surface. Specimens shall be located at $\frac{1}{2}$ in. [13 mm] minimum from the buffered surface of the forging. Buffers shall be removed and the welded areas subjected to magnetic particle test to assure freedom from cracks unless the welded areas are completely removed by subsequent machining.

7.1.3.4 The test specimen shall have its longitudinal axis located parallel to the direction of major working of the forging or test blank.

7.1.3.5 With prior purchaser approval, tests may be taken at a depth (t) corresponding to the distance from the area of significant loading to the nearest heat treated surface and at least twice this distance ($2t$) from any second surface. However, the test depth shall not be nearer to one treated surface than $\frac{3}{4}$ in. [19 mm] and to the second treated surface than $1\frac{1}{2}$ in. [38 mm]. This method of test location would normally apply to contour-forged parts, or parts with thick cross-sectional areas where $\frac{1}{4} T \times T$ testing (7.1.3.2) is not practical. Sketches showing the exact test locations shall be approved by the purchaser when this method is used.

7.1.4 Test Method — Testing shall be performed in accordance with Test Methods and Definitions A 370. The test specimen shall be as large as is practicable and shall be machined to the form and dimensions of Fig. 5 of Test Methods and Definitions A 370. When seamless tubular materials are used, testing shall be performed on longitudinal specimens in accordance with Annex A2, Steel Tubular Products, of Test Methods and Definitions A 370.

7.2 Impact Test:

7.2.1 Requirements — The material shall conform to the requirements for impact properties in Table 3 when tested at the applicable standard temperature in Table 4 within the limits of 7.2.4.2 and 7.2.4.3. When subsize specimens are used, the impact energy values obtained

shall conform to Table 5 at energy values proportional to standard size. Exceptions to this requirement are permissible when Supplementary Requirement S1 is specified by the purchaser. Impact tests may be made at temperatures different from those in Table 4, provided that the test temperature is at least as low as the intended service temperature, and that the forging is suitably marked to identify the reported test temperature.

7.2.1.1 The test specimens shall be machined from material obtained as in 7.1.

7.2.2 Number of Tests — Three specimens shall constitute one test set. There shall be the same number of test sets as tension tests in 7.1.2.

7.2.3 Test Locations and Orientations — The test specimen shall be located and oriented as described in 7.1.3. The area under the notch of the impact test specimen shall be used to locate the specimen with respect to the second heat-treated surface. The base of the notch shall be perpendicular to the nearest heat-treated surface.

7.2.4 Test Method — The notched bar impact test shall be made in accordance with the procedure for the Charpy V-notch type test as described in Test Methods and Definitions A 370.

7.2.4.1 Standard size specimens shown in Fig. 11 of Test Methods and Definitions A 370 shall be used for the impact test. Where the material is of insufficient thickness, or the shape of the forging precludes standard size, the largest obtainable subsize specimen described in Test Methods and Definitions A 370 shall be used.

7.2.4.2 Where subsize specimens are used and represent forged material with thicknesses equal to or greater than 0.394 in. [10 mm], and where the largest obtainable specimen has a width along the notch of at least 8 mm, such specimen shall be tested at the temperature in Table 4. Where the largest obtainable specimen has a width along the notch less than 8 mm, the temperature for testing shall be lower than the temperature in Table 4 by the amount shown in Table 6 for the actual specimen width tested.

7.2.4.3 Where subsize specimens are used and represent forged material with thicknesses less than 0.394 in. [10 mm], and where the largest obtainable specimen has a width along the notch of at least 80% of the forging thickness, the specimen shall be tested at the temperature in Table 4. Where the largest obtainable specimen has a width along the notch of less than 80% of the material thickness, the temperature for testing shall be lower than the temperature in Table 4 by an amount equal to the difference (referring to Table 6) between the temperature reduction corresponding to the thickness of the material represented, and the temperature reduction corresponding to the specimen width actually tested.

7.3 Hardness Test:

7.3.1 Except when only one forging is produced, a minimum of two forgings shall be hardness tested per batch or continuous run as defined in 7.1.2.1 to ensure that hardness of the forgings does not exceed 197 HB after heat treatment for mechanical properties. The hardness measurements shall be made in accordance with Test Methods and Definitions A 370. When only one forging is produced, it shall be hardness tested to ensure that it meets the 197 HB maximum of this specification. The purchaser may verify that this requirement has been met by testing at any location on the forging, provided that such testing does not render the forging useless.

8. Hydrostatic Test

8.1 Forgings manufactured under this specification shall be capable of passing a hydrostatic test compatible with the rating of the finished item. Such tests shall be conducted by the manufacturer only when Supplementary Requirement S57 of Specification A 961 is specified.

9. Workmanship, Finish, and Appearance

9.1 Forgings shall conform to the requirements of Specification A 961.

10. Retests

10.1 If any test specimen shows flaws or defective machining, it may be discarded and another specimen substituted.

11. Rework and Retreatment

11.1 If the results of the mechanical tests do not conform to the requirements specified, the manufacturer may reheat treat the forgings represented, and shall retest to the applicable requirements.

11.2 Individually tested forgings meeting all requirements shall be acceptable.

11.3 Repair by Welding — Weld repairs shall be permitted (see Supplementary Requirement S58 of Specification A 961) at the discretion of the manufacturer with the following limitations and requirements:

11.3.1 Repair by welding shall be made using welding procedures and welders qualified in accordance with ASME Section IX of the Code. The weld procedure qualification test shall also include impact tests of the weld metal and heat-affected zone. All impact test specimens shall have the longitudinal axis transverse to the weld and the base of the notch normal to the weld surface. Weld

specimens shall have the notch in weld metal and heat-affected zone specimens shall have the notch in the heat-affected zone. The specimens shall be as large as permitted by the weldment thickness. Where full-size specimens can be obtained and where there is sufficient weldment thickness, the weld specimen shall be taken with one side of the specimen within $\frac{1}{16}$ in. [1.6 mm] of the weld surface. Heat-affected zone impact test specimens shall be taken at the same depth and locations applicable to the forging in 7.1.3.1 and 7.1.3.2. When forgings are thermally treated after repair welding, the weld procedure test plate shall be subjected to the same thermal treatment. The mechanical properties of the weld procedure qualification test shall conform to Section 7.

11.3.2 Defects shall be completely removed by chipping or grinding to sound metal as verified by magnetic particle, or liquid penetrant inspection prior to welding.

11.3.3 For Grade LF1 forgings, and LF2 forgings that are to be only stress-relieved after repair welding, the weld metal shall be deposited using carbon steel electrodes E 7015, E 7016, or E 7018, complying with AWS A 5.1. For Grade LF2 forgings in all other conditions of post-weld heat treatment, the weld metal shall be deposited using low-alloy steel electrodes E 7015-A1; E 7016-A1, or E 7018-A1 complying with AWS 5.5; for Grade LF3 forgings the weld metal shall be deposited using low-alloy steel electrodes E 8016-C2 or E 8018-C2 complying with AWS A 5.5; for Grades LF5, LF9, and LF787 forgings, the weld metal shall be deposited using low-alloy steel electrodes E 8016-C1 or E 8018-C1 complying with AWS A 5.5. For Grade LF6, the electrodes shall be low-hydrogen, E-XX15, E-XX16, or E-XX18 complying with AWS A 5.1 or A 5.5, as applicable.

11.3.4 After repair welding, the area welded shall be completely free of defects as verified by magnetic particle or liquid penetrant inspection.

11.3.5 Forgings repair welded in the normalized, normalized and tempered, or the quenched and tempered conditions shall be stress-relieved after repair welding at 1100°F [590°C] minimum, but not higher than the temperature previously used for tempering the base metal of the same forging, or shall be reheat treated in accordance with 5.4.

11.3.6 When the purchaser specifies Supplementary Requirement S5, the same requirements shall apply to the weld procedure qualification tests.

11.3.7 Repair by welding shall not exceed 10% of the surface area of the forging or $33\frac{1}{3}\%$ of the wall thickness of the finished forging, or $\frac{3}{8}$ in. [9.5 mm], whichever is less, without prior approval of the purchaser.

11.3.8 When approval of the purchaser is obtained, the limitations set forth in 11.3.7 may be exceeded, but all other requirements of 11.3 shall apply.

12. Inspection

12.1 Inspection provisions of Specification A 961 shall apply.

13. Rejection and Rehearing

13.1 Purchaser shall comply with provisions of Specification A 961.

14. Certification

14.1 DELETED

14.2 Test reports are required, they shall include certification that all requirements of this specification have been met, and shall be traceable to the forging represented. The specification designation included on test reports shall include year of issue and revision letter, if any. The manufacturer shall provide the following where applicable:

14.2.1 Type heat treatment, Section 5,

14.2.2 Chemical analysis results, Section 6 (Table 1),

14.2.3 Product analysis results, 6.2 (Table 1),

14.2.4 Tensile property results, Section 7 (Table 2) report the yield strength and ultimate strength, in ksi [MPa], elongation and reduction in area, in percent,

14.2.5 Impact test results, 7.2 (Table 3, Table 4, Table 5, and Table 6), including specimen size if subsize samples were used,

14.2.6 Hardness results, 7.3.1,

14.2.7 Any supplementary testing required by the purchase order, and

14.2.8 If repaired by welding, letter W is to follow the ASTM designation.

15. Product Marking

15.1 In addition to the marking requirements of Specification A 961, manufacturer's name (see Note 2) or symbol shall be permanently marked on each forging.

NOTE 2 — For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification and the results have been determined to meet the requirements of this specification.

15.1.1 If the forgings have been quenched and tempered or quenched-and-precipitation heat treated, the letters QT shall be stamped on the forgings following the ASTM designation.

15.1.2 Forgings repaired by welding shall be marked with the letter W following the ASTM designation.

15.2 If identification stamps are objectionable and detrimental to the forging, and when so stated on the purchase

order, the marks may be painted or stenciled on the forging, or stamped on a metal or plastic tag which shall be securely attached to the forging.

15.3 When test reports are required, additional marks shall be used as necessary to identify the part with the test report.

15.4 If the test temperature is other than the standard temperature specified in Table 4, the mark shall also include the suffix letter S to the grade and class and the test temperature. A prefix 0 to the test temperature shall indicate a less than 0°F [-18°C] value. For example, LF2S 0175 denotes a test temperature of -175°F [-115°C] for an LF2 part.

15.5 Parts meeting all requirements for more than one class may be marked with more than one class such as LF2 CL1/CL2; LF5 CL1/CL2, and so forth.

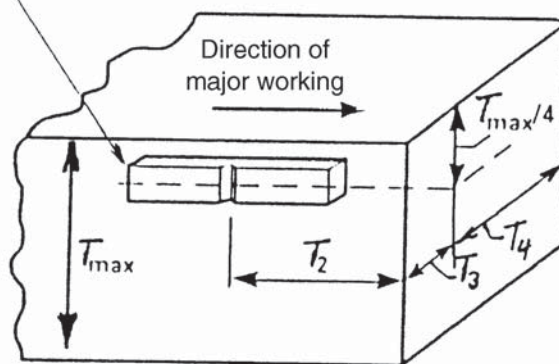
15.6 Bar Coding — In addition to the requirements in 15.1, 15.2, 15.3, 15.4, and 15.5, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

16. Keywords

16.1 carbon equivalent; pipe fittings, steel; piping applications; pressure containing parts; steel flanges; steel forgings, alloy; steel forgings, carbon; steel valves; temperature service applications, low

FIG. 1 TEST SPECIMEN LOCATION FOR QUENCHED AND TEMPERED FORGINGS

Tensile or impact test specimen
(Impact test specimen shown in Fig. 1)



NOTE 1 — For material with thickness T greater than 2 in. [50 mm], $T_2 = T_3 = T_4 \geq T_{\max}$
where:
 T_{\max} = maximum heat treated thickness

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, wt. %						Grade LF787
	Grade LF1	Grade LF2	Grade LF3	Grade LF5	Grade LF6	Grade LF9	
Carbon, max	0.30	0.30	0.20	0.30	0.22	0.20	0.07
Manganese	0.60–1.35	0.60–1.35	0.90 max	0.60–1.35	1.15–1.50	0.40–1.06	0.40–0.70
Phosphorus, max	0.035	0.035	0.035	0.035	0.025	0.035	0.025
Sulfur, max	0.040	0.040	0.040	0.040	0.025	0.040	0.025
Silicon ^A	0.15–0.30	0.15–0.30	0.20–0.35	0.20–0.35	0.15–0.30	...	0.40 max
Nickel	0.40 max ^B	0.40 max ^B	3.3–3.7	1.0–2.0	0.40 max ^B	1.60–2.24	0.70–1.00
Chromium	0.30 max ^{B,C}	0.30 max ^{B,C}	0.30 max ^C	0.30 max ^C	0.30 max ^{B,C}	0.30 max ^C	0.60–0.90
Molybdenum	0.12 max ^{B,C}	0.12 max ^{B,C}	0.12 max ^C	0.12 max ^C	0.12 max ^{B,C}	0.12 max ^C	0.15–0.25
Copper	0.40 max ^B	0.40 max ^B	0.40 max ^C	0.40 max ^C	0.40 max ^B	0.75–1.25	1.00–1.30
Columbium	0.02 max	0.02 max	0.02 max	0.02 max	0.02 max	0.02 max	0.02 min
Vanadium	0.08 max	0.08 max	0.03 max	0.03 max	0.04–0.11	0.03 max	0.03 max
Nitrogen	...	...	...	...	0.01–0.030	...	...

^A When vacuum carbon-deoxidation is required by Supplementary Requirement S4, the silicon content shall be 0.12% maximum.

^B The sum of copper, nickel, chromium, vanadium, and molybdenum shall not exceed 1.00% on heat analysis.

^C The sum of chromium and molybdenum shall not exceed 0.32% on heat analysis.

TABLE 2
TENSILE PROPERTIES AT ROOM TEMPERATURE^A

	Grades							
	LF1 and LF5 Class 1	LF2 Classes 1 and 2	LF3 Classes 1 and 2 LF5 Class 2	LF6		LF9	LF787	
				Class 1	Classes 2 and 3		Class 2	Class 3
Tensile strength, ksi [MPa]	60–85 [415–585]	70–95 [485–655]	70–95 [485–655]	66–91 [455–630]	75–100 [515–690]	63–88 [435–605]	65–85 [450–585]	75–95 [515–655]
Yield strength, min, ksi [MPa] ^{B,C}	30 [205]	36 [250]	37.5 [260]	52 [360]	60 [415]	46 [315]	55 [380]	65 [450]
Elongation:								
Standard round specimen, or small proportional specimen, min % in 4D gage length	25	22	22	22	20	25	20	20
Strip specimen for wall thickness $\frac{5}{16}$ in. (7.94 mm) and over and for all small sizes tested in full sec- tion; min % in 2 in. (50 mm)	28	30	30	30	28	28	28	28
Equation for calculating min elon- gation for strip specimens thinner than $\frac{5}{16}$ in. (7.94 mm); min % in 2 in. (50 mm) t = actual thickness in inches	$48t + 13$	$48t + 15$	$48t + 15$	$48t + 15$	$48t + 13$	$48t + 13$	$48t + 13$	$48t + 13$
Reduction of area, min, %	38	30	35	40	40	38	45	45

^A See 7.3 for hardness tests.

^B Determined by either the 0.2% offset method or the 0.5% extension under load method.

^C For round specimens only.

TABLE 3
CHARPY V-NOTCH ENERGY REQUIREMENTS FOR STANDARD
SIZE [10 by 10 mm] SPECIMENS

Grade	Minimum Impact Energy Required for Average of Each Set of Three Specimens, ft-lbf [J]	Minimum Impact Energy Permitted for One Specimen only of a Set, ft-lbf [J]
LF1 and LF9	13 [18]	10 [14]
LF2, Class 1	15 [20]	12 [16]
LF3, Class 1	15 [20]	12 [16]
LF5, Class 1 and 2	15 [20]	12 [16]
LF787, Classes 2 and 3	15 [20]	12 [16]
LF6, Class 1	15 [20]	12 [16]
LF2, Class 2	20 [27]	15 [20]
LF3, Class 2	20 [27]	15 [20]
LF6, Classes 2 and 3	20 [27]	15 [20]

TABLE 4
STANDARD IMPACT TEST TEMPERATURE FOR
STANDARD SIZE [10 by 10 mm] SPECIMENS

Grade	Test Temperature, °F [°C]
LF1	-20 [-29]
LF2, Class 1	-50 [-46]
LF2, Class 2	0 [-18]
LF3, Classes 1 and 2	-150 [-101]
LF5, Classes 1 and 2	-75 [-59]
LF6, Classes 1 and 2	-60 [-51]
LF6, Class 3	0 [-18]
LF9	-100 [-73]
LF787, Class 2	-75 [-59]
LF787, Class 3	-100 [-73]

TABLE 5
MINIMUM EQUIVALENT ABSORBED ENERGY FT-LBF (J) FOR VARIOUS
SPECIMEN SIZES⁴

Standard Size [10 by 10 mm]	$\frac{3}{4}$ Size [10 by 7.5 mm]	$\frac{2}{3}$ Size [10 by 6.6 mm]	$\frac{1}{2}$ Size [10 by 5 mm]	$\frac{1}{3}$ Size [10 by 3.3 mm]	$\frac{1}{4}$ Size [10 by 2.5 mm]
15 [20]	12 [16]	10 [14]	8 [11]	5 [7]	4 [6]
13 [18]	10 [14]	9 [12]	7 [10]	5 [7]	4 [6]
12 [16]	10 [14]	9 [12]	7 [10]	4 [6]	3 [5]
10 [14]	8 [11]	7 [10]	5 [7]	3 [5]	3 [5]

⁴ Straight-line interpolation for intermediate values is permitted.

TABLE 6
CHARPY IMPACT TEST TEMPERATURE REDUCTION BELOW TABLE 5 TEST
TEMPERATURE WHEN THE SUBSIZE CHARPY IMPACT WIDTH ALONG NOTCH IS
LESS THAN 80% OF THE FORGING THICKNESS

Size of Bar	Thickness of the Material Represented (see 7.2.4.3), or Charpy, Impact Specimen Width Along the Notch ⁴ , in. [mm]	Temperature Reduction, °F [°C]
Standard	0.394 [10]	0 [0]
Standard	0.354 [9]	0 [0]
Standard	0.315 [8]	0 [0]
$\frac{3}{4}$ -size	0.295 [7.5]	5 [3]
$\frac{3}{4}$ -size	0.276 [7]	8 [5]
$\frac{2}{3}$ -size	0.262 [6.67]	10 [6]
$\frac{2}{3}$ -size	0.236 [6]	15 [8]
$\frac{1}{2}$ -size	0.197 [5]	20 [11]
$\frac{1}{2}$ -size	0.158 [4]	30 [17]
$\frac{1}{3}$ -size	0.131 [3.33]	35 [20]
$\frac{1}{3}$ -size	0.118 [3]	40 [22]
$\frac{1}{4}$ -size	0.099 [2.5]	50 [28]

⁴ Straight-line interpolation for intermediate values is permitted.

SUPPLEMENTARY REQUIREMENTS

In addition to any supplementary requirements of Specification A 961, the following supplementary requirements shall apply only when specified by the purchaser in the order:

S1. Other Impact Test Temperatures

S1.1 Impact test temperatures lower or higher than the standard temperature in Table 4 of this specification shall be used.

S1.1.1 When higher test temperatures are employed, the actual test temperature may not be higher than that given in Table S1.1.1.

S1.2 The test temperature shall be specified by the purchaser. When subsize specimens are used, the manufacturer shall adjust the test temperature in accordance with the size restrictions of 7.2.4.2 and 7.2.4.3.

S1.3 The forging shall be marked with the specified test temperature in accordance with 15.4. A lower temperature shall not be marked on the forging because of the use of subsize specimens.

S1.4 The test results shall comply with Table 3 for standard size specimens, and with Table 5 for subsize specimens.

S2. Stress-Relieved Test Specimens

S2.1 The test specimens shall be stress relieved. Stress relieving shall be done after heat treatment in 5.4 and before machining the specimens from the heat-treated test material.

S2.2 The purchaser shall furnish the forging manufacturer with details of the stress-relief treatment desired.

S3. Lateral Expansion

S3.1 Lateral expansion of the Charpy V-notch test in accordance with Section 25 of Test Methods and Definitions A 370 shall be measured and reported.

S4. Vacuum Carbon-Deoxidized Steels

S4.1 Material made to Grades LF1, LF2, LF3, LF5, and LF9 shall be vacuum carbon-deoxidized, in which case the silicon content shall be 0.12% maximum. The test report shall indicate that the steel was vacuum carbon-deoxidized.

S5. Special Impact Test Requirements for Flanges (Note S5.1)

S5.1 Charpy test specimens shall be cut from an actual flange representing each size, heat, and heat-treatment lot. If more than one size flange is represented by the same heat and heat-treatment lot, the maximum size flange shall be considered representative.

S5.2 The number, location, and orientation of the test specimens shall be stated on the order.

S5.3 The test results shall comply with Table 3 for standard size specimens, and with Table 5 for subsize specimens.

NOTE S5.1 — These special requirements should be considered for services when the applied stresses approach the maximum permissible limits of the governing code, or the installation is subject to severe cyclic conditions (7000 or more cycles over the expected life of the installation), or both.

S6. Carbon Equivalent

S6.1 The maximum carbon equivalent based on heat analysis shall be as shown in Table S6.1.

S6.2 Determine the carbon equivalent (CE) as follows:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S6.3 A lower maximum carbon equivalent may be agreed upon between the supplier and the purchaser.

TABLE S1.1.1
MAXIMUM SUPPLEMENTAL TEST
TEMPERATURES

Grade	Maximum Test Temperature, °F (°C)
LF1	−10 [−23]
LF2, Class 1	−35 [−37]
LF3, Classes 1 and 2	−125 [−87]
LF5, Classes 1 and 2	−60 [−51]
LF6, Classes 1 and 2	−40 [−40]
LF9	−80 [−62]
LF787, Class 2	−60 [−51]
LF787, Class 3	−80 [−62]
LF2, Class 2	+10 [−12]
LF6, Class 3	+10 [−12]

TABLE S6.1
MAXIMUM CARBON EQUIVALENT VALUE

Grade	Max. Thickness Less Than or Equal to 2 in.	Max. Thickness Greater Than 2 in.
LF1	0.45	0.46
LF2 CL1 and CL2	0.47	0.48
LF6 CL1	0.45	0.46
LF6 CL2	0.47	0.48

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SPECIFICATION FOR CASTINGS, AUSTENITIC, AUSTENITIC-FERRITIC (DUPLEX), FOR PRESSURE-CONTAINING PARTS



SA-351/SA-351M



(Identical with ASTM Specification A 351/A 351M-00.)

1. Scope

1.1 This specification covers austenitic and austenitic-ferritic (duplex) steel castings for valves, flanges, fittings, and other pressure-containing parts (Note 1).

NOTE 1 — Carbon steel castings for pressure-containing parts are covered by Specification A 216/A 216M, and low-alloy steel castings by Specification A 217/A 217M.

1.2 A number of grades of austenitic and austenitic-ferritic steel castings are included in this specification. Since these grades possess varying degrees of suitability for service at high temperatures or in corrosive environments, it is the responsibility of the purchaser to determine which grade shall be furnished. Selection will depend on design and service conditions, mechanical properties, and high-temperature or corrosion-resistant characteristics, or both.

1.2.1 Because of thermal instability, Grades CE20N, CF3A, CF3MA, and CF8A are not recommended for service at temperatures above 800°F [425°C].

1.2.2 Because of embrittlement phases, Grade CD4MCu is not recommended for service at temperatures above 600°F [316°C].

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 ASTM Standards:

A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service

A 217/A 217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service

A 488/A 488M Practice for Steel Castings, Welding, Qualification of Procedures and Personnel

A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts

E 165 Test Method for Liquid Penetrant Examination

E 709 Guide for Magnetic Particle Examination

2.2 Manufacturers Standardization Society of the Valve and Fittings Industry Standard:

SP-55 Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Components (Visual Method)

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 703/A 703M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 703/A 703M, this specification shall prevail.

3.2 The post weld heat treatment requirements of Supplementary Requirement S11 may be specified when austenitic castings other than HK, HT, or CT15C are to be subjected to severe corrosive service.

4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing).

4.1.2 Grade of steel,

4.1.3 Options in the specification, and

4.1.4 Supplementary requirements desired, including the standards of acceptance.

5. Process

5.1 The steel shall be made by the electric furnace process with or without separate refining such as argon-oxygen decarburization (AOD).

6. Heat Treatment

6.1 All castings shall receive a heat treatment at the temperature specified in Table 1, followed by a quench in water or rapid cool by other means except as noted.

NOTE 2 — Proper heat treatment of these alloys is usually necessary to enhance corrosion resistance and in some cases to meet mechanical properties. Minimum heat-treat temperatures are specified; however, it is sometimes necessary to heat-treat at higher temperatures, hold for some minimum time at temperature and then rapidly cool the castings in order to enhance the corrosion resistance and meet mechanical properties.

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 2.

8. Tensile Properties

8.1 Steel used for the castings shall conform to the requirements as to tensile properties prescribed in Table 3.

9. Quality

9.1 The surface of the casting shall be examined visually and shall be free of adhering sand, scale, cracks, and

hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Method SP 55 or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

9.2 When additional inspection is desired, Supplementary Requirements S5, S6, and S10 may be ordered.

9.3 The castings shall not be peened, plugged, or impregnated to stop leaks.

10. Repair by Welding

10.1 Repairs shall be made using procedures and welders qualified under Practice A 488/A 488M.

10.2 Weld repairs shall be inspected to the same quality standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S5 specified, weld repairs on castings that have leaked on hydrostatic test, or on castings in which the depth of any cavity prepared for repair welding exceeds 20% of the wall thickness or 1 in. [25 mm], whichever is smaller, or on castings in which any cavity prepared for welding is greater than approximately 10 in.² [65 cm²], shall be radiographed to the same standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S6 specified, weld repairs shall be inspected by liquid penetrant examination to the same standards that are used to inspect the castings.

NOTE 3 — When austenitic steel castings are to be used in services where they will be subject to stress corrosion, the purchaser should so indicate in his order and such castings should be solution-heat treated following all weld repairs.

11. Keywords

11.1 austenitic stainless steel; duplex stainless steel; pressure containing parts; stainless steel; steel castings

TABLE 1
HEAT-TREATMENT REQUIREMENTS

Grade	Temperature, min	
	°F	°C
HK30, HK40, HT30, CT15C	as-cast	as-cast
CF3, CF3A, CF8, CF8A, CF3M	1900	1040
CF3MA, CF8M, CF3MN, CG3M, CF10, CF10M, CG8M, CD4MCu, CF10SMnN, CF8C, CF10MC	1950	1065
CD3MWCuN	2010	1100
CN7M, CG6MMN, CE8MN	2050	1120
CK3MCuN, CN3MN, CH8, CH10, CH20, CK20	2100	1150
CE20N ⁴	2225	1220

⁴ Grade shall be quenched in water or the castings may be furnace cooled to 2050°F [1120°C] minimum, held for 15 min minimum and then quenched in water or rapidly cooled by other means.

TABLE 2
CHEMICAL REQUIREMENTS

Element, % (max, except where range is given)	CF3, CF3A	CF8, CF8A	CF3M, CF3MA	CF8M	CF3MN	CF8C	CF10	CF10M (J92901)	CH8	CH10	CH20	CK20	HK30	HK40
Carbon	0.03	0.08	0.03	0.08	0.03	0.08	0.04–0.10	0.04–0.10	0.08	0.04–0.10	0.04–0.20	0.04–0.20	0.25–0.35	0.35–0.45
Manganese	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Silicon	2.00	2.00	1.50	1.50	1.50	2.00	2.00	1.50	1.50	2.00	2.00	1.75	1.75	1.75
Sulfur	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Phosphorus	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Chromium	17.0–21.0	18.0–21.0	17.0–21.0	18.0–21.0	17.0–21.0	18.0–21.0	18.0–21.0	18.0–21.0	22.0–26.0	22.0–26.0	22.0–26.0	23.0–27.0	23.0–27.0	23.0–27.0
Nickel	8.0–12.0	8.0–11.0	9.0–13.0	9.0–12.0	9.0–13.0	9.0–12.0	8.0–11.0	9.0–12.0	12.0–15.0	12.0–15.0	12.0–15.0	19.0–22.0	19.0–22.0	19.0–22.0
Molybdenum	0.50	0.50	2.0–3.0	2.0–3.0	2.0–3.0	0.50	0.50	2.0–3.0	0.50	0.50	0.50	0.50	0.50	0.50
Columbium	...	...	...	...	...	...	...	...	...	...	...	...	...	...
(Niobium)	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Vanadium	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Nitrogen	...	...	...	...	0.10–0.20	...	...	...	...	...	...	...	...	...
Copper	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Tungsten	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Iron	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Note 1 — Tungsten is a new element for Table 2.

TABLE 2
CHEMICAL REQUIREMENTS (CONT'D)

Element, % (max, except where range is given)	HT30	CF10MC	CN7M	CN3MN	CD4MCu	CE8MN	CG6MMN	CG8M	CF10S- MnN	CT15C	CK3MCuN	CE20N	CG3M (J92999)	CD3M- WCuN ⁴
Carbon	0.25–0.35	0.10	0.07	0.03 max	0.04	0.08	0.06	0.08	0.10	0.05–0.15	0.025	0.20	0.03	0.03
Manganese	2.00	1.50	1.50	2.00 max	1.00	1.00	4.00–6.00	1.50	7.00–9.00	0.15–1.50	1.20	1.50	1.50	1.00
Silicon	2.50	1.50	1.50	1.00 max	1.00	1.50	1.00	1.50	3.50–4.50	0.50–1.50	1.00	1.50	1.50	1.00
Sulfur	0.040	0.040	0.040	0.010 max	0.04	0.040	0.030	0.04	0.030	0.03	0.010	0.040	0.04	0.025
Phosphorus	0.040	0.040	0.040	0.040 max	0.04	0.040	0.040	0.04	0.060	0.03	0.045	0.040	0.04	0.030
Chromium	13.0–17.0	15.0–18.0	19.0–22.0	20.0–22.0	24.5–26.5	22.5–25.5	20.50–23.50	18.0–21.0	16.0–18.0	19.0–21.0	19.5–20.5	23.0–26.0	18.0–21.0	24.0–26.0
Nickel	33.0–37.0	13.0–16.0	27.5–30.5	23.5–25.5	4.75–6.00	8.0–11.0	11.50–13.50	9.0–13.0	8.0–9.0	31.0–34.0	17.5–19.5	8.0–11.0	9.0–13.0	6.5–8.5
Molybdenum	0.50	1.75–2.25	2.0–3.0	6.0–7.0	1.75–2.25	3.0–4.5	1.50–3.00	3.0–4.0	...	...	6.0–7.0	0.50	3.0–4.0	3.0–4.0
Columbium	...	...	...	...	...	...	0.10–0.30	...	...	0.50–1.50	...	...	...	...
(Niobium)	...	...	...	...	...	...	0.10–0.30	...	...	...	...	...	...	...
Vanadium	...	...	...	...	...	...	0.10–0.30	...	...	...	...	...	...	...
Nitrogen	...	...	...	0.18–0.26	...	0.10–0.30	0.20–0.40	...	0.08–0.18	...	0.18–0.24	0.08–0.20	...	0.20–0.30
Copper	...	...	3.0–4.0	0.75 max	2.75–3.25	...	...	...	...	...	0.50–1.00	...	...	0.5–1.0
Tungsten	...	...	...	...	...	...	...	...	...	...	...	...	...	0.5–1.0
Iron	...	...	...	...	...	...	...	...	...	...	...	Bal	...	...

Note 1 — Tungsten is a new element for Table 2.

⁴ % Cr + 3.3% Mo + 16% N ≥ 40.⁵ Grade CF8C shall have a columbium content of not less than 8 times the carbon content but not over 1.00%.⁶ Grade CF10MC shall have a columbium content of not less than 10 times the carbon content but not over 1.20%.

TABLE 3
TENSILE REQUIREMENTS

	CF3	CF3A	CF8	CF8A	CF3M	CF3MA	CF8M	CF3MN	CF8C	CF10	CF10M (J92901)	CH8	CH10	CH20	CK20	HK30
Tensile strength, min, ksi [MPa]	70 [485]	77 [530]	70 [485]	77 [530]	70 [485]	80 [550]	70 [485]	75 [515]	70 [485]	70 [485]	70 [485]	65 [450]	70 [485]	70 [485]	65 [450]	65 [450]
Yield Strength, ^A min, ksi [MPa]	30 [205]	35 [240]	30 [205]	35 [240]	30 [205]	37 [255]	30 [205]	37 [255]	30 [205]	30 [205]	30 [205]	28 [195]	30 [205]	30 [205]	28 [195]	35 [240]
Elongation in 2 in. or 50 mm, ^B min, %	35.0	35.0	35.0	35.0	30.0	30.0	30.0	35.0	30.0	35.0	30.0	30.0	30.0	30.0	30.0	10.0
Reduction of area, min, %	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	HK40	HT30	CF10MC	CN7M	CN3MN	CD4MCu	CE8MN	CG6MMN	CG8M	CF10SMnN	CT15C	CK3MCuN	CE20N	CG3M (J92999)	CD3MWCuN	
Tensile strength, min, ksi [MPa]	62 [425]	65 [450]	70 [485]	62 [425]	80 [550]	100 [690]	95 [655]	85 [585]	75 [515]	85 [585]	63 [435]	80 [550]	80 [550]	75 [515]	100 [700]	
Yield Strength, ^A min, ksi [MPa]	35 [240]	28 [195]	30 [205]	25 [170]	38 [260]	70 [485]	65 [450]	42.5 [295]	35 [240]	42.5 [295]	25 [170]	38 [260]	40 [275]	35 [240]	65 [450]	
Elongation in 2 in. or 50 mm, ^B min, %	10.0	15.0	20.0	35.0	35.0	16.0	25.0	30.0	25.0	30.0	20.0	35.0	30.0	25.0	25.0	
Reduction of area, min, %	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

^A Determine by the 0.2% offset method.^B When ICI test bars are used in tensile testing as provided for in Specification A 703/A 703M, the gage length to reduced section diameter ratio shall be 4 to 1.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 703/A 703M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in Specification A 703/A 703M may be used with this specification upon agreement between the manufacturer and purchaser.

S2. Destruction Tests

S5. Radiographic Inspection

S6. Liquid Penetrant Inspection

S10. Examination of Weld Preparation

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Practice E 165 or Practice E 709.

S11. Post Weld Heat Treatment

S11.1 All austenitic castings, except Grades HK, HT, and CT15C, which have been subjected to weld repairs, shall be given a post weld solution heat treatment.

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SPECIFICATION FOR STEEL CASTINGS, FERRITIC AND MARTENSITIC, FOR PRESSURE CONTAINING PARTS, SUITABLE FOR LOW-TEMPERATURE SERVICE



SA-352/SA-352M



(Identical with ASTM Specification A 352/A 352M-06.)

1. Scope

1.1 This specification covers steel castings for valves, flanges, fittings, and other pressure-containing parts intended primarily for low-temperature service.

1.2 Several grades of ferritic steels and one grade of martensitic steel are covered. Selection of analysis will depend on design and service conditions (Note). The temperature shown is the lowest temperature at which the material ordinarily is required to meet the impact requirements of this specification (see Supplementary Requirement S22, Impact Test Temperatures). Users should note that hardenability of some of the grades mentioned may restrict the maximum size at which the required mechanical properties are obtainable (see Appendix X1).

Grade	Unusual Minimum Testing Temperatures, °F [°C]
LCA	-25 [-32]
LCB	-50 [-46]
LCC	-50 [-46]
LC1	-75 [-59]
LC2	-100 [-73]
LC2-1	-100 [-73]
LC3	-150 [-101]
LC4	-175 [-115]
LC9	-320 [-196]
CA6NM	-100 [-73]

NOTE 1 — This specification covers the low-temperature requirements particularly pertinent for ferritic and martensitic steels. Certain of the grades of austenitic steel castings furnished in accordance with Specification A 351/A 351M have been found suitable for low-temperature service down to -300°F [-184°C] and others down to -425°F [-254°C]. These grades may be used when impact tested in accordance with Specification A 352/A 352M with energy levels and temperatures of test mutually agreed upon between the purchaser and the manufacturer. As a guide to

the selection of energy levels and testing temperatures, Appendix X1 should be consulted.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A 352 and SI units for material ordered to Specification A 352M.

2. Referenced Documents

2.1 ASTM Standards:

A 351/A 351M Specification for Castings, Austenitic, for Pressure-Containing Parts
 A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
 A 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel
 A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts
 E 165 Test Method for Liquid Penetrant Examination
 E 709 Guide for Magnetic Particle Examination

2.2 Manufacturers' Standardization Society of the Valve and Fittings Industry Standard:

SP-55 Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Piping Components (Visual Method)

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 703/A 703M

including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 703/A 703M, this specification shall prevail.

4 Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 Grade of steel,

4.1.3 Options in the specification, and

4.1.4 The supplementary requirements desired, including the standards of acceptance.

5 Heat Treatment

5.1 All castings shall receive a heat treatment proper to their design and chemical composition. It should be recognized that liquid quenching of the ferritic grades is normally required to meet the mechanical properties of heavier sections and will greatly enhance the low-temperature properties of thinner sections.

5.2 Ferritic castings shall be furnished in the normalized and tempered or liquid-quenched and tempered condition, except for Grade LC9, which shall be liquid-quenched and tempered. Castings shall be tempered at a minimum of 1100°F [590°C], except Grade LC4, which shall be 1050°F [565°C], and Grade LC9, which shall be tempered in the range of 1050 to 1175°F [565 to 635°C], followed by cooling in air or liquid.

5.3 CA6NM castings shall be heat-treated by heating to 1850°F [1010°C] minimum, and air cooling to 200°F [95°C] maximum before any optional intermediate temper, but shall cool to 100°F [40°C] maximum before the final temper, which shall be between 1050 and 1150°F [565 and 620°C].

5.4 Castings shall be allowed to cool below the transformation range directly after pouring and solidification before they are reheated for normalizing or liquid quenching.

5.5 Temperature Control — Furnace temperature for heat treating shall be controlled by use of pyrometers.

6 Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition for the grade ordered as specified in Table 1.

7 Mechanical Requirements

7.1 Tension Test:

7.1.1 Tensile properties of steel used for the castings shall conform to the requirements specified in Table 1.

7.2 Impact Test:

7.2.1 The notched bar impact properties of the material shall be determined by testing a set of three Charpy V-notch impact specimens for each heat at one of the standard test temperatures shown in Table 1, depending on the intended service temperature (see Appendix X1). The average energy value of the three specimens shall not be less than specified, with not more than one value permitted below the average minimum specified and no value permitted below the minimum specified for a single specimen.

7.2.2 The notched bar impact test shall be made in accordance with Test Methods and Definitions A 370.

7.2.3 Impact test specimens shall be machined to the form and dimensions shown in Test Methods and Definitions A 370, Fig. 11.

8 Quality

8.1 The surface of the casting shall be examined visually and shall be free of adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Method SP-55 or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities. When methods involving high temperature are used in the removal of discontinuities, castings shall be preheated to at least the minimum temperatures in Table 2.

8.2 When additional inspection is desired, Supplementary Requirements S4, S5, and S10, may be ordered.

8.3 The castings shall not be peened, plugged, or impregnated to stop leaks.

9 Repair by Welding

9.1 Repairs shall be made using procedures and welders in accordance with Practice A 488/A 488M.

9.2 Welding of Grade LC9 shall be accomplished using nonmagnetic filler material of AWS classification ENiCrFe-2, and shall require liquid penetrant inspection of the weld (Supplementary Requirement S6) when magnetic particle inspection (Supplementary Requirement S4) is specified for the casting.

9.3 Weld repairs shall be inspected to the same quality standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S4

specified, weld repairs shall be inspected by magnetic particle examination to the same standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S5 specified, weld repairs on castings that have leaked on hydrostatic tests, or on castings in which the depth of any cavity prepared for repair welding exceeds 20% of the wall thickness or 1 in. [25 mm] whichever is smaller, or on castings in which any cavity prepared for welding is greater than approximately 10 in.² [65 cm²] shall be radiographed to the same standards that are used to inspect the castings.

9.4 Castings containing any repair weld that exceeds 20% of the wall thickness, or 1 in. [25 mm], whichever is smaller, or that exceeds approximately 10 in.² [65 cm²] in area, or that was made to correct hydrostatic test defects shall be stress relieved or heat treated after welding. This

mandatory stress relief or heat treatment shall be in accordance with the procedure qualification used. When stress relief is required for Grade LC9, cooling shall be in still air.

10. Product Marking

10.1 All marking shall be on a raised pad using low-stress stamps.

10.2 In addition to the marking required by Specification A 703/A 703M, castings that have been liquid quenched and tempered shall be marked with the letters "QT."

11. Keywords

11.1 alloy steel; carbon steel; ferritic steel; low temperature applications; martensitic stainless steel; pressure containing parts; stainless steel; steel castings

TABLE 1
CHEMICAL, TENSILE, AND IMPACT REQUIREMENTS

Type	Carbon Steel	Carbon Steel	Carbon-Manganese Steel	Carbon-Molybdenum Steel	2½% Nickel Steel	Nickel-Chromium-Molybdenum Steel	3½% Nickel Steel	4½% Nickel Steel	9% Nickel Steel	12½% Chromium-Nickel-Molybdenum Steel
Grade	LCA	LCB ^A	LCC	LC1	LC2	LC2-1	LC3	LC4	LC9	CA6NM
UNS Number	J02504	J03003	J02505	J12522	J22500	J42215	J31550	J41500	J31300	J91540
Element, % (max, except where range is given)										
Carbon	0.25 ^A	0.30	0.25 ^A	0.25	0.25	0.22	0.15	0.15	0.13	0.06
Silicon	0.60	0.60	0.60	0.60	0.60	0.50	0.60	0.60	0.45	1.00
Manganese	0.70 ^A	1.00	1.20 ^A	0.50–0.80	0.50–0.80	0.55–0.75	0.50–0.80	0.50–0.80	0.90	1.00
Phosphorus	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Sulfur	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.03
Nickel	0.50 ^B	0.50 ^B	0.50 ^B	...	2.00–3.00	2.50–3.50	3.00–4.00	4.00–5.00	8.50–10.0	3.5–4.5
Chromium	0.50 ^B	0.50 ^B	0.50 ^B	...	...	1.35–1.85	...	...	0.50	11.5–14.0
Molybdenum	0.20	0.20 ^B	0.20 ^B	...	...	0.30–0.60	...	...	0.20	0.4–1.0
Copper	0.30	0.30 ^B	0.30 ^B	...	...	...	...	...	0.30	...
Vanadium	0.03 ^B	0.03 ^B	0.03 ^B	...	...	...	...	...	0.03	...
Tensile Requirements: ^C										
Tensile strength, ksi [MPa]	60.0–85.0 [415–585]	65.0–90.0 [450–620]	70.0–95.0 [485–655]	65.0–90.0 [450–620]	70.0–95.0 [485–655]	105.0–130.0 [725–895]	70.0–95.0 [485–655]	70.0–95.0 [485–655]	85.0 [585]	110.0–135.0 [760–930]
Yield strength, ^D min, ksi [MPa]	30.0 [205]	35.0 [240]	40.0 [275]	35.0 [240]	40.0 [275]	80.0 [550]	40.0 [275]	40.0 [275]	75.0 [515]	80.0 [550]
Elongation in 2 in. or 50 mm, min, % ^E	24	24	22	24	24	18	24	24	20	15
Reduction of area, min, %	35	35	35	35	35	30	35	35	30	35
Impact Requirements										
Charpy V-Notch ^{C,F}										
Energy value, ft·lbf [J], min value for two specimens and min avg of three specimens	13 [18]	13 [18]	15 [20]	13 [18]	15 [20]	30 [41]	15 [20]	15 [20]	20 [27]	20 [27]
Energy value, ft·lbf [J], min for single specimen	10 [14]	10 [14]	12 [16]	10 [14]	12 [16]	25 [34]	12 [16]	12 [16]	15 [20]	15 [20]
Testing temperature, °F [°C]	–25 [–32]	–50 [–46]	–50 [–46]	–75 [–59]	–100 [–73]	–100 [–73]	–150 [–101]	–175 [–115]	–320 [–196]	–100 [–73]

^A For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.04% manganese above the specified maximum will be permitted up to a maximum of 1.10% for LCA, 1.28% for LCB, and 1.40% for LCC.

^B Specified Residual Elements — The total content of these elements is 1.00% maximum.

^C See 1.2.

^D Determine by either 0.2% offset method or 0.5% extension-under-load method.

^E When ICI test bars are used in tensile testing as provided for in Specification A 703/A 703M, the gage length to reduced section diameter ratio shall be 4 to 1.

^F See Appendix X1.

TABLE 2
MINIMUM PREHEAT TEMPERATURES

Grade	Thickness, in. [mm]	Minimum Preheat Temperature, °F [°C]
LCA	all	50 [10]
LCB	all	50 [10]
LCC	all	50 [10]
LC1	over $\frac{5}{8}$ [15.9]	250 [120]
	$\frac{5}{8}$ and under	50 [10]
LC2	all	300 [150]
LC2-1	all	300 [150]
LC3	all	300 [150]
LC4	all	300 [150]
CA6NM	all	50 [10]

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 703/A 703M. Those which are ordinarily considered suitable for use with this specification are given below together with additional supplementary requirements that are applicable only to this specification. Other supplementary requirements enumerated in A 703/A 703M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Unspecified Elements

S2. Destruction Tests

S4. Magnetic Particle Inspection

S5. Radiographic Inspection

S9. Drop Weight Tests

S10. Examination of Weld Preparation

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Practice E 709 or Practice E 165.

S21. Heat Treatment

S21.1 Castings shall be liquid quenched and tempered.

S22. Impact Test Temperatures

S22.1 When an impact test temperature other than that listed in Table 1 is used, the lowest test temperature at which the material met the impact test requirements shall be stamped with low-stress stamps on a raised pad located immediately ahead of the material symbol; for example,

25 LCB for +25°F [−4°C] and 025 LCB for −25°F [−32°C].

S22.2 Lateral expansion of V-notch specimens shall be measured in accordance with 23.2.3.1 of Test Methods and Definitions A 370, and reported for information.

S23. Carbon Equivalent

S23.1 When specified on the order the maximum carbon equivalent shall be:

Grade	Carbon Equivalent, max
LCA	0.50
LCB	0.50
LCC	0.55

S23.2 Determine carbon equivalent, *CE*, as follows:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

APPENDIX

(Nonmandatory Information)

X1. EXPLANATION OF THE USE OF NOTCHED BAR IMPACT TESTS IN DETERMINING THE ACCEPTABILITY OF STEELS FOR LOW-TEMPERATURE SERVICE

X1.1 Years of experience and test work have shown that some materials, particularly ferritic steels, change from tough to brittle behavior with a decrease in temperature. The transition temperatures and the levels of notch toughness vary with different materials, depending on many factors. When materials are used under conditions where brittle behavior may occur, there is danger that flaws, which would be considered nonhazardous if the material were tough, may propagate to disastrous failure of the equipment.

X1.2 Accordingly, many varieties of tests have been developed in an effort to evaluate the toughness of materials and the conditions under which they will transform from tough to brittle behavior. There are many opinions and shadings of opinion as to which test is most suitable for evaluating the suitability of materials for service at low temperatures; however, as yet, only the Charpy impact test has received sufficient general acceptance and has been used as a basis for purchasing for sufficient time to be included in ASTM standards. Furthermore, this test is required for low-temperature service vessels and piping constructed in accordance with ASME Code for Unfired Pressure Vessels and the American National Standard Code for Pressure Piping (ANSI B31), respectively. These ASTM specifications for materials for low-temperature service are primarily used in piping and pressure vessel construction that are subjected to temperatures lower than ambient; consequently, the notched bar impact test requirements are written to provide material that in quality and by its testing can be validated for use under the construction codes.

X1.3 No assurance is offered that compliance with these requirements will provide a material that will resist brittle failure under all possible conditions of service to as low as the specified impact test temperature. It may eventually be possible that other types of tests will provide greater assurance of material suitability for low-temperature services, but at this time there is insufficient knowledge for agreement and general acceptance of some test other than the Charpy impact test.

X1.4 Attention is directed to the following subjects which have a bearing on the value of Charpy impact tests:

X1.4.1 Much of the original work in the field of notch toughness was done on wrought materials that had definite directional grain flow parallel to the axis of the bar, and the specimens were taken with the longitudinal axis of the specimen parallel to the axis of the bar. It has been well established that the results from impact testing of the same piece of steel may vary considerably, depending upon the orientation of the specimen to the direction of grain flow. Although it is known that specimens taken with their axis transverse to the direction of grain flow will have lower values depending on the amount of cross rolling or forging the material has received, there were insufficient test data to permit specific mandatory requirements on the impact properties of wrought materials determined in any direction other than parallel to the direction of grain flow. Except in special cases this limitation still exists.

X1.4.2 It is acknowledged that notched bar impact tests are of a qualitative rather than a quantitative nature. As yet, except possibly for ship steel, no satisfactory correlation has been possible between tests on small standardization specimens and the behavior of a structural part under any given conditions of loading in service. The required values as determined by the Charpy V-notch impact test are arbitrary values which can be met by carbon and low-alloy constructional steels when tested at temperatures above that where their behavior changes from tough to brittle as judged by this test. The acceptability of this dividing line seems to be justified by service experience on carbon and certain low-alloy steels.

X1.4.3 The literature shows that notched bar impact strengths in constructional steels differ widely in accordance with many variables. Consequently, there is bound to be some discrepancy between an individual test bar and the entire part that it represents. No system of test bar selection can guarantee that every sample would meet minimum requirements. Test bar selection must be a compromise to generally represent the product.

X1.4.4 The committees responsible for these material specifications have had as an objective the selection of test specimens that will represent the properties of the materials, in the form in which they will be used. However, accomplishment of this objective has only partially been realized. At this time it is impossible to select samples for testing that will represent all parts and sizes of the product involved. Particularly in ferritic steels, it is impractical to

remove the test bars from heavy sections over about 4 in. [100 mm] and expect them to show results as high as tests from light sections of the same material. The practical commercial limits on the amount of testing possible, as well as limits to knowledge of what results may be expected

from testing in non-standard locations, have been considered in drafting these specifications. With time and increased knowledge, it may be possible to require more representative testing.

SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, DOUBLE-NORMALIZED AND TEMPERED 9% NICKEL

(a)



SA-353/SA-353M



(Identical with ASTM Specification A 353/A 353M-09.)

1. Scope

1.1 This specification covers double-normalized and tempered 9% nickel steel plates intended particularly for welded pressure vessels for cryogenic service.

1.2 Plates produced under this specification are subject to impact testing at -320°F [-195°C] or at such other temperatures as are agreed upon.

1.3 The maximum thickness of plates is limited only by the capacity of the material to meet the specific mechanical property requirements; however, current mill practice normally limits this material to 2 in. [50 mm] max.

1.4 This material is susceptible to magnetization. Use of magnets in handling after heat treatment should be avoided if residual magnetism would be detrimental to subsequent fabrication or service.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 ASTM Standards:

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 553/A 553M Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered 8 and 9% Nickel

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permitted variations in dimensions, and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 Steelmaking Practice — The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

5. Heat Treatment

5.1 All plates shall be heat treated in accordance with 5.2. Shell plates and other parts, including heads and reinforcing pads that are heated for forming shall be heat treated after forming in accordance with 5.2.

5.2 Heat Treatment Procedure:

5.2.1 First Normalizing Treatment — Heat the plate to a uniform temperature of $1650 \pm 25^\circ\text{F}$ [$900 \pm 15^\circ\text{C}$], hold at that temperature for a minimum of 1 h/in. [2.4 min/mm] of thickness, but in no case less than 15 min, and cool in air.

5.2.2 Second Normalizing Treatment — Reheat the plate to a uniform temperature of $1450 \pm 25^\circ\text{F}$ [$790 \pm 15^\circ\text{C}$], hold at that temperature for a minimum of 1 h/in. [2.4 min/mm] of thickness, but in no case less than 15 min, and cool in air.

5.2.3 Tempering Treatment — Reheat the plate to a uniform temperature within the range from 1050 to 1125°F [565 to 605°C], hold within that temperature range for a minimum of 1 h/in. [2.4 min/mm] of thickness, but in no case less than 15 min, and cool in air or water quench at a rate not less than 300°F/h [165°C/h].

5.2.4 If hot forming is performed after heating to a temperature within the range from 1650 to 1750°F [900 to 955°C] the first normalizing treatment (5.2.1) may be omitted.

5.2.5 When the plates are heat treated by the fabricator, it shall be the fabricator's responsibility to apply the proper heat treatment and to conduct tests it deems necessary to ensure that the specified properties are attained.

6. Chemical Requirements

6.1 The steel shall conform to the chemical composition requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

7. Mechanical Requirements

7.1 Tension Test Requirements — The material as represented by the tension-test specimens shall conform to the requirements specified in Table 2.

7.1.1 Upon agreement between the purchaser and the manufacturer, yield strength may be determined by the extension under load method, using 0.005 in./in. [0.005 mm/mm] total extension.

7.1.2 For nominal plate thicknesses of $\frac{3}{4}$ in. [20 mm] and under, the $1\frac{1}{2}$ in. [40 mm] wide rectangular specimen may be used for the tension test and the elongation may be determined in a 2 in. [50 mm] gage length that includes the fracture and shows the greatest elongation.

7.1.3 One tension test shall be taken from each plate as heat treated.

7.2 Impact Test Requirements:

7.2.1 Charpy V-notch impact tests shall be made in accordance with Specification A 20/A 20M.

7.2.2 The longitudinal axis of the test specimens shall be transverse to the final rolling direction of the plate.

7.2.3 Unless otherwise agreed, tests shall be conducted at -320°F [-195°C].

7.2.4 Each test specimen shall have a lateral expansion opposite the notch of not less than 0.015 in. [0.381 mm].

8. Finish

8.1 Because retained scale may mask surface imperfections, as well as mar the plate surface, plates shall be descaled by the producer after heat treatment. In the case of material to be heat-treated by the purchaser, the plates shall be descaled by the producer prior to shipment.

9. Keywords

9.1 alloy steel; alloy steel plate; pressure containing parts; pressure vessel steels; steel plates; steel plates for pressure vessel applications

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %
Carbon, max ^A	0.13
Manganese, max	
Heat analysis	0.90
Product analysis	0.98
Phosphorus, max ^A	0.015
Sulfur, max ^A	0.015
Silicon:	
Heat analysis	0.15–0.40 ^B
Product analysis	0.13–0.45 ^B
Nickel:	
Heat analysis	8.50–9.50
Product analysis	8.40–9.60

^A Applies to both heat and product analyses.

^B The specified minimum limit does not apply if the total aluminum content is 0.030% or more, or provided that acid soluble aluminum is 0.025% or more.

TABLE 2
TENSILE REQUIREMENTS

Tensile strength, ksi [MPa]	100–120 [690–825]
Yield strength (0.2% offset), min, ksi [MPa] ^A	75 [515]
Elongation in 2 in. [50 mm], min, % ^B	20.0

^A See 7.1.1.

^B See Specification A 20/A 20M for elongation adjustment.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order. A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S4.1 Additional Tension Test,

S6. Drop Weight Test,

**S8. Ultrasonic Examination in Accordance With
Specification A 435/A 435M,**

**S11. Ultrasonic Examination in Accordance With
Specification A 577/A 577M,**

**S12. Ultrasonic Examination in Accordance With
Specification A 578/A 578M, and**

S17. Vacuum Carbon-Deoxidized Steel.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

Also listed below are additional optional Supplementary Requirements S55 and S56 which are suitable for this specification.

S55. Longitudinal Charpy Impact Energy Absorption Requirement

S55.1 The longitudinal Charpy V-notch impact properties shall not be less than 25 ft-lbf [34 J] at the specified temperature.

S55.2 Each impact-test value shall constitute the average value of three specimens, with not more than one value below the specified minimum value of 25 ft-lbf [34 J], but in no case below 20 ft-lbf [27 J] for full size specimens.

S56. Transverse Charpy Impact Energy Absorption Requirement

S56.1 The transverse Charpy V-notch impact properties shall not be less than 20 ft-lbf [27 J] at the specified temperature.

S56.2 Each impact-test value shall constitute the average value of three specimens, with not more than one value below the specified minimum value of 20 ft-lbf [27 J] but in no case below 15 ft-lbf [20 J] for full-size specimens.

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SPECIFICATION FOR QUENCHED AND TEMPERED ALLOY STEEL BOLTS, STUDS, AND OTHER EXTERNALLY THREADED FASTENERS



SA-354

(Identical with ASTM Specification A 354-07a except for the deletion of the term “private label distributor” in 15.1 and 15.3.5.)

1. Scope

1.1 This specification covers the chemical and mechanical requirements of quenched and tempered alloy steel bolts, studs, and other externally threaded fasteners 4 in. and under in diameter for application at normal atmospheric temperatures, where high strength is required and for limited application at elevated temperature (Note 1). Any alloy steel capable of meeting the minimum mechanical and chemical properties set forth in this specification may be used.

NOTE 1 — For bolts, studs, or other externally threaded fasteners, to be used at elevated temperatures, refer to Specification A 193/A 193M.

1.2 Two levels of bolting strength are covered, designated Grades BC and BD. Selection will depend upon design and the stresses and service for which the product is to be used.

NOTE 2 — Quenched and tempered alloy steel bolts for structural steel joints up through 1½ in. in diameter are covered in Specification A 490. Alloy steel bolts, studs, and other externally threaded fasteners (that is, heavy hex-structural bolts over 1½ in., hex bolts, anchor bolts, and countersunk bolts) exhibiting similar mechanical properties to bolts conforming to Specification A 490 shall be covered by Grade BD of this specification.

When bolts of Grade BD of this specification are considered for pretensioned applications in excess of 50% of the bolt tensile strength, the additional requirements of head size, maximum tensile strength, nut size and strength, washer hardness, tests, and inspections contained in Specification A 490 should be carefully considered.

1.3 Nuts are covered in Specification A 563. Unless otherwise specified, the grade and style of nut for each grade of fastener shall be as follows:

Grade of Fastener and Surface Finish	Nut Grade and Style ^A
BC, plain (or with a coating of insufficient thickness to require over-tapped nuts)	C, heavy hex
BC, zinc-coated (or with a coating thickness requiring over-tapped nuts)	DH, heavy hex
BD, all finishes	DH, heavy hex

^A Nuts of other grades and styles having specified proof load stresses (Specification A 563, Table 3) greater than the specified grade and style of nut are suitable.

1.4 The values stated in inch-pound units are to be regarded as the standard.

1.5 Terms used in this specification are defined in Terminology F 1789 unless otherwise defined herein.

2. Referenced Documents

2.1 ASTM Standards:

- A 193/A 193M Specification for Alloy-Steel and Stainless Steel Bolting Materials for High Temperature or High Pressure Service and Other Special Purpose Applications
- A 490 Specification for Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength
- A 563 Specification for Carbons and Alloy Steel Nuts
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
- D 3951 Practice for Commercial Packaging
- F 436 Specification for Hardened Steel Washers
- F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets
- F 788/F 788M Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series

F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection
 F 1789 Terminology for F16 Mechanical Fasteners
 F 2329 Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners

2.2 ASME Standards:

B1.1 Unified Screw Threads
 B18.2.1 Square and Hex Bolts and Screws, Inch Series
 B18.24 Part Identifying Number (PIN) Code System Standard for B18 Fastener Products

3. Ordering Information

3.1 Orders for bolts and studs (including nuts and accessories) under this specification shall include the following:

- 3.1.1 ASTM designation and year of issue,
- 3.1.2 Name of product (that is, bolt or stud),
- 3.1.3 Grade (that is, BC or BD),
- 3.1.4 Quantities (number of pieces by size, including nuts),
- 3.1.5 Size and length,
- 3.1.6 *Washers* — Specify quantity and size (separate from bolts) (4.3),
- 3.1.7 *Zinc Coating* — When zinc-coated Grade BC fasteners are required, specify the zinc-coating process required, for example hot-dip, mechanically deposited, or no preference (see 4.4).
- 3.1.8 *Other Finishes* — Specify other protective finish, if required.
- 3.1.9 Specify if inspection at point of manufacture is required,
- 3.1.10 Specify if Certification (Section 14) is required, and
- 3.1.11 Specify additional testing (Section 9) or special requirements.
- 3.1.12 For establishment of a part identifying system, see ASME B18.24.

4. Materials and Manufacture

4.1 The steel shall be made by the open-hearth, electric-furnace, or basic-oxygen process.

4.2 All fasteners shall be heat-treated. At the option of the manufacturer, heat treatment may be performed on the raw material, during the manufacturing operations, or after final machining. Heat treatment shall consist of quenching in a liquid medium (except Grade BD sizes 1½ in. and smaller shall be quenched in oil) from above the transformation temperature and then tempering by reheating to

a temperature of not less than 800°F (427°C) for Grade BC and for Grade BD.

4.3 When used, suitable hardened washers shall be quenched and tempered (non-carburized) in accordance with Specification F 436.

4.4 Zinc Coatings, Hot-Dip and Mechanically Deposited:

4.4.1 When zinc-coated fasteners are required, the purchaser shall specify the zinc coating process, for example, hot-dip, mechanically deposited, or no preference.

4.4.2 When “hot-dip” is specified, the fasteners shall be zinc coated by the hot-dip process in accordance with the requirements of Specification F 2329.

4.4.3 When mechanically deposited is specified, the fasteners shall be zinc-coated by the mechanical-deposition process in accordance with the requirements of Class 55 of Specification B 695.

4.4.4 When no preference is specified, the supplier may furnish either a hot-dip zinc coating in accordance with Specification F 2329, or a mechanically deposited zinc coating in accordance with Specification B 695, Class 55. Threaded components (bolts and nuts) shall be coated by the same zinc-coating process and the supplier’s option is limited to one process per item with no mixed processes in a lot.

NOTE 3 — When the intended application requires that assembled tension exceeds 50% of minimum bolt proof load, an anti-galling lubricant may be needed. Application of such a lubricant to nuts and a test of the lubricant efficiency are provided in Supplementary Requirement S1 of Specification A 563 and should be specified when required.

4.5 Zinc-coated bolts and nuts shall be shipped in the same container unless specifically requested otherwise by the purchaser.

NOTE 4 — Research conducted on bolts of similar material and manufacture indicates that hydrogen-stress cracking or stress cracking corrosion may occur on hot-dip galvanized Grade BD bolts.

5. Chemical Composition

5.1 All fasteners shall be made from alloy steel conforming to the chemical composition requirements in accordance with Table 1. The steel shall contain sufficient alloying elements to qualify it as an alloy steel.

NOTE 5 — Steel is considered to be alloy, by the American Iron and Steel Institute, when the maximum of the range given for the content of alloying elements exceeds one or more of the following limits: manganese, 1.65%; silicon, 0.60%; copper, 0.60%; or in which a definite range or a definite minimum quantity of any of the following elements is specified or required within the limits of the recognized field of constructional alloy steels: aluminum, chromium up to 3.99%, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any other alloying elements added to obtain a desired alloying effect.

5.2 Product analysis may be made by the purchaser from finished material representing each lot of fasteners. The chemical composition thus determined shall conform to the requirements given in Table 1. Choice of alloy steel composition necessary to ensure meeting the specified mechanical requirements shall be made by the manufacturer and shall be reported to the purchaser for information purposes only.

5.3 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted.

5.4 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A 751.

6. Mechanical Properties

6.1 Fasteners shall not exceed the maximum hardness specified in Table 2. Fasteners less than three diameters in length and studs less than four diameters in length shall have hardness values not less than the minimum nor more than the maximum hardness limits required in Table 2, as hardness is the only requirement.

6.2 Fasteners $1\frac{3}{8}$ in. in diameter or less for Grade BC and $1\frac{1}{4}$ in. in diameter or less for Grade BD, other than those excepted in 6.1, shall be tested full size and shall conform to the tensile strength and either the proof load or the yield strength requirements in accordance with Table 3.

6.3 Fasteners larger than $1\frac{3}{8}$ in. in diameter for Grade BC and fasteners larger than $1\frac{1}{4}$ in. in diameter for Grade BD, other than those excepted in 6.1, shall preferably be tested full size and when so tested, shall conform to the tensile strength and either the proof load or yield strength requirements in accordance with Table 3. When equipment of sufficient capacity for full-size testing is not available, or when the length of the fastener makes full-size testing impractical, machined specimens shall be tested and shall conform to the requirements in accordance with Table 4. In the event that fasteners are tested by both full-size and by the machined test specimen methods, the full-size test shall govern if a controversy between the two methods exists.

6.4 For fasteners on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence in the event that there is controversy over low readings of hardness tests.

7. Dimensions

7.1 Bolts — Unless otherwise specified, the bolts shall be Hex Head with dimensions conforming to the latest issue of ASME B18.2.1.

7.2 Studs — Studs shall have dimensions conforming to those specified by the purchaser.

7.3 Threads:

7.3.1 Unless otherwise specified, threads shall be the Unified National Coarse Thread Series as specified in B1.1, and shall have Class 2A tolerances.

7.3.2 When specified, threads shall be the Unified National Fine Thread Series, 8-Pitch Thread Series for sizes over 1 in. or 14-Pitch UNS on 1 in. size as specified in ANSI B1.1 and shall have Class 2A tolerances.

7.3.3 Unless otherwise specified, bolts and studs to be used with nuts or tapped holes that have been tapped oversize, in accordance with Specification A 563, shall have Class 2A threads before hot dip or mechanically deposited zinc coating. After zinc coating, the maximum limit of pitch and major diameter may exceed the Class 2A limit by the following amount:

Diameter, in.	Oversize Limit, in. (mm) ^A
$\frac{1}{4}$	0.016
$\frac{5}{16}, \frac{3}{8}$	0.017
$\frac{7}{16}, \frac{1}{2}$	0.018
$\frac{9}{16}$ to $\frac{3}{4}$, incl	0.020
$\frac{7}{8}$	0.022
1.0 to $1\frac{1}{4}$, incl	0.024
$1\frac{3}{8}$ to $1\frac{1}{2}$	0.027
$1\frac{3}{4}$ to 4.0, incl	0.050

^A These values are the same as the overtapping required for zinc-coated nuts in Specification A 563.

8. Workmanship

8.1 Surface discontinuity limits shall be in accordance with Specification F 788/F 788M.

9. Number of Tests

9.1 Testing Responsibility:

9.1.1 Each lot shall be tested by the manufacturer prior to shipment in accordance with the lot identification control quality assurance plan in 9.2 through 9.6.

9.1.2 When fasteners are furnished by a source other than the manufacturer, the responsible party as defined in 12.1 shall be responsible for ensuring that all tests have been performed and the fasteners comply with the requirements of this specification.

9.2 Purpose of Lot Inspection — The purpose of a lot inspection program is to ensure that each lot conforms to the requirements of this specification. For such a plan to be fully effective it is essential that secondary processors, distributors, and purchasers maintain the identification and integrity of each lot until the product is installed.

9.3 Lot Processing — All fasteners shall be processed in accordance with a lot identification-control quality assurance plan. The manufacturer, secondary processors, and distributors shall identify and maintain the integrity of each lot of fasteners from raw-material selection through all processing operations and treatments to final packing and shipment. Each lot shall be assigned its own lot-identification number, each lot shall be tested, and the inspection test reports for each lot shall be retained.

9.4 Lot Definition — A lot is a quantity of a uniquely identified fastener product of the same nominal size and length produced consecutively at the initial operation from a single mill heat of material and heat treatment lot and processed at one time, by the same process, in the same manner so that statistical sampling is valid. The identity of the lot is maintained throughout all subsequent operations and packaging.

9.5 Number of Tests — The minimum number of tests from each production lot for the tests specified below shall be in accordance with Guide F 1470.

Hardness	Coating Weight/Thickness
Tensile	Workmanship (Surface Discontinuities Section 8)
Proof Load	

9.5.1 The number of tests for dimensional and thread fit compliance shall be in accordance with the quality assurance provisions of the referenced dimensional standards.

9.6 If any test specimen shows defective machining it may be discarded and another specimen substituted.

10. Test Methods

10.1 Test methods shall be conducted in accordance with Test Methods F 606.

10.2 Proof load, rather than yield strength determination is preferred and shall be the arbitration method for fasteners 1¼ in. and under in diameter.

10.3 Hexagon bolts shall be tested by the wedge tension method. Fracture shall be in the body or threads of the bolt without any fracture at the junction of the head and body.

10.3.1 At the option of the manufacturer, the yield strength test (Method 2, Yield Strength paragraph of Test Methods F 606) and the wedge tension test (Wedge Tension Testing of Full-Size Product paragraph, both from the Test Method section of Test Methods F 606) may be accomplished concurrently to satisfy 10.2 and 10.3.

10.4 Studs and bolts other than those in 10.3 shall be tested by the axial tension method.

10.4.1 At the option of the manufacturer, the yield strength test and the axial tension test may be accomplished concurrently to satisfy 10.2 and 10.4.

10.5 The speed of testing determined with a free running crosshead shall be a maximum of ⅛ in. (3.2 mm)/min for the bolt proof load (or yield strength) determination and a maximum of 1 in. (25.4 mm)/min for the tensile strength determination.

11. Inspection

11.1 If the inspection described in 11.2 is required by the purchaser, it shall be specified in the inquiry and contract or purchase order.

11.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser's representative shall be made before shipment, and shall be conducted as not to interfere unnecessarily with the operation of the works.

12. Responsibility

12.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser.

13. Rejection and Rehearing

13.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

14. Certification

14.1 When specified on the purchase order, the manufacturer or supplier, whichever is the responsible party in accordance with Section 12, shall furnish the purchaser a test report which includes the following:

14.1.1 Product description, grade, quantity, ASTM Specification Number and issue date,

14.1.2 Alloy grade (AISI, SAE, UNS, etc.), heat analysis, and heat number, and type of quench,

14.1.3 Results of hardness, tensile, and proof load tests, as applicable,

14.1.4 Statement of compliance to Protective Coating Specification (if applicable),

14.1.5 Statement of compliance with the surface discontinuity requirements of Specification F 788/F 788M,

14.1.6 Statement of compliance dimensionally,

14.1.7 Report, describe, or illustrate manufacturer's markings and their location,

14.1.8 Lot number, purchase order number, and date shipped,

14.1.9 Country of origin, and

14.1.10 Title and signature of the individual assigned certification responsibility by the company officers, with complete mailing address.

14.2 Failure to include all the required information on the test report shall be cause for rejection.

15. Product Marking

15.1 *Manufacturers Identification* — All products shall be marked by the manufacturer with a unique identifier to identify the manufacturer.

15.2 Grade Identification:

15.2.1 All Grade BC products shall be marked "BC."

15.2.2 All Grade BD products shall be marked "BD." In addition to the "BD" marking, the product may be marked with 6 radial lines 60° apart if manufactured from alloy steel conforming to the requirements of this specification.

15.3 Marking Location and Methods:

15.3.1 Bolts shall be marked on the top of the bolt head.

15.3.2 Where studs have both coarse and fine threads, all markings shall appear on the coarse thread end or, if preferred, the manufacturer's identification shall appear on the fine thread end and the grade marking on the coarse thread end.

15.3.3 Continuous thread studs may be marked on either end.

15.3.4 All markings may be raised or depressed at the manufacturer's option.

15.3.5 Grade and manufacturer's identification shall be separate and distinct. The two identifications shall preferably be in different locations and when on the same level shall be separated by at least two spaces.

16. Packaging and Package Marking

16.1 Packaging:

16.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

16.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

16.2 Package Marking:

16.2.1 Each shipping unit shall include or be plainly marked with the following information:

16.2.1.1 ASTM designation and grade,

16.2.1.2 Size,

16.2.1.3 Name and brand or trademark of the manufacturer,

16.2.1.4 Number of pieces,

16.2.1.5 Purchase order number, and

16.2.1.6 Country of origin.

17. Keywords

17.1 alloy steel; bolts; steel; studs

TABLE 1
CHEMICAL REQUIREMENTS

Element	Heat Analysis, %	Product Analysis, %
Carbon:		
For sizes through 1½ in.	0.30 to 0.53	0.28 to 0.55
For sizes larger than 1½ in.	0.35 to 0.53	0.33 to 0.55
Phosphorus, max.	0.035	0.040
Sulfur, max.	0.040	0.045

TABLE 2
HARDNESS REQUIREMENTS
FOR FULL-SIZE FASTENERS

Size, in.	Grade	Hardness			
		Brinell		Rockwell C	
		Min.	Max.	Min.	Max.
¼ to 2½	BC	255	331	26	36
Over 2½	BC	235	311	22	33
¼ to 2½	BD	311	363	33	39
Over 2½	BD	293	363	31	39

TABLE 3
TENSILE REQUIREMENTS FOR ALL FULL-SIZE FASTENERS — INCH-POUND UNITS

Bolt Size, in.	Threads Per Inch	Stress Area, ^A in. ²	Grade BC			Grade BD		
			Tensile Strength, Min., lbf ^B	Proof Load, Min., lbf ^C	Yield Strength (0.2% offset), Min., lbf ^D	Tensile Strength, Min., lbf ^E	Proof Load, Min., lbf ^F	Yield Strength (0.2% offset), Min., lbf ^G
1	2	3	4	5	6	7	8	9
1/4	20	0.0318	4,000	3,350	3,450	4,750	3,800	4,100
1/4	28	0.0364	4,550	3,820	3,950	5,450	4,350	4,700
5/16	18	0.0524	6,550	5,500	5,700	7,850	6,300	6,800
5/16	24	0.0580	7,250	6,090	6,300	8,700	6,950	7,500
3/8	16	0.0775	9,700	8,150	8,450	11,650	9,300	10,075
3/8	24	0.0878	11,000	9,220	9,550	13,200	10,500	11,400
7/16	14	0.1063	13,300	11,150	11,600	15,950	12,750	13,850
7/16	20	0.1187	14,840	12,470	12,900	17,800	14,200	15,400
1/2	13	0.1419	17,750	14,900	15,450	21,300	17,050	18,500
1/2	20	0.1599	19,990	16,790	17,400	24,000	19,200	20,750
9/16	12	0.182	22,750	19,100	19,850	27,300	21,850	23,600
9/16	18	0.203	25,400	21,400	22,100	30,400	24,400	26,350
5/8	11	0.226	28,250	23,750	24,650	33,900	27,100	29,400
5/8	18	0.256	32,000	26,800	27,900	38,400	30,700	33,250
3/4	10	0.334	41,750	35,050	36,400	50,100	40,100	43,400
3/4	16	0.373	46,600	39,100	40,650	56,000	44,800	48,450
7/8	9	0.462	57,750	48,500	50,350	69,300	55,450	60,100
7/8	14	0.509	63,600	53,400	55,450	76,400	61,100	66,150
1	8	0.606	75,750	63,650	66,050	90,900	72,700	78,800
1	12	0.663	82,900	69,700	72,250	99,400	79,600	86,150
1	14 UNS	0.679	84,900	71,300	74,400	101,900	81,500	88,250
1 1/8	7	0.763	95,400	80,100	83,150	114,450	91,550	99,200
1 1/8	8	0.790	96,750	82,950	86,200	118,500	94,800	102,700
1 1/8	12	0.856	107,000	89,800	93,300	128,400	102,700	111,250
1 1/4	7	0.969	121,150	101,750	105,600	145,350	116,300	126,000
1 1/4	8	1.000	125,000	105,000	109,000	150,000	120,000	130,000
1 1/4	12	1.073	134,100	112,600	116,950	161,000	128,800	139,450
1 1/8	6	1.155	144,400	121,300	125,900	173,250	138,600	150,200
1 1/8	8	1.233	154,150	129,450	134,400	185,000	148,000	160,300
1 3/8	12	1.315	164,400	138,100	143,300	197,200	157,800	170,950
1 1/2	6	1.405	175,650	147,550	153,150	210,750	168,600	182,500
1 1/2	8	1.492	186,500	156,650	162,250	233,800	175,050	194,000
1 1/2	12	1.581	197,600	166,000	172,300	237,200	189,700	205,500
1 3/4	5	1.90	237,500	199,500	207,100	285,000	228,000	247,000
1 3/4	8	2.08	260,000	218,400	226,700	312,000	249,600	270,000
2	4 1/2	2.50	312,500	262,500	272,500	375,000	300,000	325,000
2	8	2.77	346,250	290,850	301,950	415,000	332,400	360,000
2 1/4	4 1/2	3.25	406,250	341,250	354,250	487,000	390,000	422,500
2 1/4	8	3.56	445,000	373,800	388,050	534,000	422,200	462,800
2 1/2	4	4.00	500,000	420,000	436,000	600,000	480,000	520,000
2 1/2	8	4.44	550,000	466,200	483,950	666,000	532,800	577,200
2 3/4	4	4.93	566,950	468,350	488,050	690,200	517,650	566,950
2 3/4	8	5.43	624,450	515,850	537,550	750,200	570,150	624,450
3	4	5.97	686,550	567,150	591,050	835,800	626,850	686,550
3	8	6.51	748,650	618,450	644,500	911,400	683,550	748,650
3 1/4	4	7.10	816,500	674,500	702,900	994,000	745,500	816,500
3 1/4	8	7.69	884,350	730,550	761,300	1,076,600	807,650	884,350
3 1/2	4	8.33	957,950	791,350	824,650	1,166,200	874,650	957,950
3 1/2	8	8.96	1,030,400	851,200	887,050	1,254,400	940,800	1,030,400
3 3/4	4	9.66	1,110,900	917,700	956,350	1,352,400	1,014,300	1,110,900
3 3/4	8	10.34	1,199,100	983,300	1,023,650	1,447,600	1,085,700	1,189,100
4	4	11.08	1,274,200	1,052,600	1,096,900	1,551,200	1,163,400	1,274,200
4	8	11.81	1,358,200	1,122,000	1,169,200	1,653,400	1,240,050	1,358,150

NOTES:

^A Stress Area, in.² = 0.7854 [$D - 0.9743/n$]² where D = nominal diameter in inches and n = threads per inch.^B Based on 125,000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 115,000 psi for sizes over 2 1/2 to 4 in., inclusive.^C Based on 105,000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 95,000 psi for sizes over 2 1/2 to 4 in., inclusive.^D Based on 109,000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 99,000 psi for sizes over 2 1/2 to 4 in., inclusive.^E Based on 150,000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 140,000 psi for sizes over 2 1/2 to 4 in., inclusive.^F Based on 120,000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 105,000 psi for sizes over 2 1/2 to 4 in., inclusive.^G Based on 130,000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 115,000 psi for sizes over 2 1/2 to 4 in., inclusive.

TABLE 4
MECHANICAL REQUIREMENTS FOR MACHINED SPECIMENS

Grade	Size, in.	Tensile Strength, Min., psi	Yield Strength (0.2% offset), Min., psi	Elongation in 2 in. Min., %	Reduction of Area, Min., %
BC	$\frac{1}{4}$ to $2\frac{1}{2}$, incl.	125,000	109,000	16	50
BC	Over $2\frac{1}{2}$	115,000	99,000	16	45
BD	$\frac{1}{4}$ to $2\frac{1}{2}$, incl.	150,000	130,000	14	40
BD	Over $2\frac{1}{2}$	140,000	115,000	14	40

SUPPLEMENTARY REQUIREMENTS

S1. Marking

S1.1 Studs that are continuously threaded with the same class of thread shall be marked on each end with the marking in accordance with Section 15.

S1.2 Marking small sizes (customarily less than 0.375 in. (9.525 mm) may not be practical. Consult the producer for the minimum size that can be marked.

SPECIFICATION FOR ELECTRIC-FUSION-WELDED AUSTENITIC CHROMIUM-NICKEL ALLOY STEEL PIPE FOR HIGH-TEMPERATURE SERVICE



SA-358/SA-358M

(Identical with ASTM Specification A 358/A 358M-01 except for clarified heat treatment requirements in 6.3.1, the deletion of 6.3.2.2 for HT-O pipe and 6.3.2.3 for HT-SO pipe, editorial differences in 1.2, 2.2, and the following additional requirements.)

All products furnished under this SA specification are intended for application under the rules of Section III or Section VIII-1 of the ASME Boiler and Pressure Vessel Code. Manufacture of such products is limited to manufacturers who hold the appropriate ASME Certificate of Authorization and Certification Mark. In addition to conforming to this specification, the manufacturer shall meet all applicable requirements of Section III or Section VIII-1 if applicable of the Code. The plate used to fabricate the pipe shall conform to SA-240. The joints shall be full penetration butt welds as obtained by double welding or by other means which will obtain the same quality of deposited and weld metal on the inside and outside. Welds using metal backing strips which remain in place are excluded. The product is subject to all requirements of Section III or Section VIII-1 if applicable of the Code including welding, heat treatment, nondestructive examination, authorized inspection at the point of manufacture, and application of the Certification Mark.

The applicable ASME Partial Data Report Form signed by an Authorized Inspector and a certified mill test report shall be furnished for each lot of pipe. The term "lot" applies to all pipe of the same mill heat of material and wall thickness which is heat treated in one furnace charge. For pipe that is not heat treated, or that is heat treated in a continuous furnace, a lot shall consist of each 200 ft (61 m) or fraction thereof of all pipe of the same mill heat material and wall thickness subjected to the same heat treatment. For pipe that is heat treated in a batch-type furnace that is automatically controlled within a 50°F range and is equipped with recording pyrometers so that the heating records are available, a lot may be defined the same as for continuous furnaces. Each length of pipe shall be marked in such a manner as to identify each such piece with the lot and the certified mill test report.

1. Scope

1.1 This specification covers electric-fusion-welded austenitic chromium-nickel alloy steel pipe suitable for corrosive or high-temperature service, or both.

NOTE 1 — The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

1.2 This specification covers thirty-seven grades of alloy steel as indicated in Table 1. The selection of the proper alloy and requirements for heat treatment shall be at the discretion of the purchaser, dependent on the service conditions to be encountered.

1.3 Five classes of pipe are covered as follows:

1.3.1 Class 1 — Pipe shall be double welded by processes employing filler metal in all passes and shall be completely radiographed.

1.3.2 Class 2 — Pipe shall be double welded by processes employing filler metal in all passes. No radiography is required.

1.3.3 Class 3 — Pipe shall be single welded by processes employing filler metal in all passes and shall be completely radiographed.

1.3.4 Class 4 — Same as Class 3 except that the weld pass exposed to the inside pipe surface may be made without the addition of filler metal (see 6.2.2.1 and 6.2.2.2).

1.3.5 Class 5 — Pipe shall be double welded by processes employing filler metal in all passes and shall be spot radiographed.

1.4 Supplementary requirements covering provisions ranging from additional testing to formalized procedures for manufacturing practice are provided. Supplementary Requirements S1 through S6 are included as options to be specified when desired.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

2. Referenced Documents

2.1 ASTM Standards:

- A 240/A 240M Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels
- A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
- A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip
- A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
- A 999/A 999M Specification for General Requirements for Alloy and Stainless Steel Pipe
- E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 ASME Boiler and Pressure Vessel Code:

Section I, Rules for Construction of Power Boilers
Section IX, Welding and Qualifications

2.3 AWS Specifications:

- A 5.22 Flux Cored Arc Welding
- A 5.30 Consumable Weld Inserts for Gas Tungsten Arc Welding
- A 5.4 Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes
- A 5.9 Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes
- A 5.11 Nickel and Nickel-Alloy Covered Welding Electrodes
- A 5.14 Nickel and Nickel-Alloy Bare Welding Rods and Electrodes

2.4 Other Standard:

SAE J1086 Practice for Numbering Metals and Alloys (UNS)

3. Terminology

3.1 Definitions:

3.1.1 The definitions in Specification A 999/A 999M and Terminology A 941 are applicable to this specification.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

- 4.1.1** Quantity (feet, metres, or number of lengths),
- 4.1.2** Name of material (electric-fusion-welded pipe),
- 4.1.3** Grade (Table 1),
- 4.1.4** Class (see 1.3),
- 4.1.5** Size (outside diameter and nominal wall thickness),
- 4.1.6** Length (specific or random),
- 4.1.7** End finish (Section on Ends of Specification A 999/A 999M),
- 4.1.8** Authorization for repair of plate defects by welding and subsequent heat treatment without prior approval if such is intended (see 9.3),
- 4.1.9** Specification designation,
- 4.1.10** Special requirements,
- 4.1.11** Statement invoking requirements of 16.4 if such is intended,
- 4.1.12** Circumferential weld permissibility (see Section 16),
- 4.1.13** Supplementary Requirements (S1 through S6),
- 4.1.14** Applicable ASME Code if known,
- 4.1.15** For ASME Code Section III applications, the service classification intended, and
- 4.1.16** Certification requirements (see Section on Certification of Specification A 999/A 999M).

5. General Requirements

5.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 999/A 999M unless otherwise provided herein.

6. Materials and Manufacture

6.1 Materials:

6.1.1 The steel plate material shall conform to the requirements of one of the grades of Specification

A 240/A 240M, listed in Table 1, except as provided in 6.3.2.3.

6.2 Welding:

6.2.1 The joints shall be full penetration double-welded or single-welded butt joints employing fusion welding processes as defined under “Definitions,” ASME Boiler and Pressure Vessel Code, Section IX. This specification makes no provision for any difference in weld quality requirements regardless of the weld joint type employed (single or double) in making the weld. Where backing rings or strips are employed, the ring or strip material shall be of the same P-Number (Table QW-422 of Section IX) as the plate being joined. Backing rings or strips shall be completely removed after welding, prior to any required radiography, and the exposed weld surface shall be examined visually for conformance to the requirements of 6.2.3. Welds made by procedures employing backing strips or rings which remain in place are prohibited. Welding procedures and welding operators shall be qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX.

6.2.2 Except as provided in 6.2.2.1 and 6.2.2.2, welds shall be made in their entirety by processes involving the deposition of filler metal.

6.2.2.1 For Class 4 pipe employing multiple passes, the root-pass may be without the addition of filler metal.

6.2.2.2 For Class 4 pipe, the weld surface exposed inside the pipe may result from a single pass made from the inside of the pipe without the addition of filler metal.

6.2.2.3 All single-welded pipe shall be completely radiographed.

6.2.3 The weld surface on either side of the weld may be flush with the base plate or may have a reasonably uniform crown, not to exceed $\frac{1}{8}$ in. [3 mm]. Any weld reinforcement may be removed at the manufacturer’s option or by agreement between the manufacturer and purchaser. The contour of the reinforcement should be reasonably smooth and free from irregularities. The deposited metal shall be fused uniformly into the plate surface. No concavity of contour is permitted unless the resulting thickness of weld metal is equal to or greater than the minimum thickness of the adjacent base metal.

6.2.4 Weld defects shall be repaired by removal to sound metal and rewelding. Subsequent heat treatment and examination (that is, visual, radiographic, and dye penetrant) shall be as required on the original welds.

6.3 Heat Treatment:

6.3.1 For H grades, separate solution heat treatments are required for solution annealing. In process heat treatments are not permitted as a substitute for the separate

solution annealing treatments. Unless otherwise stated in the order, heat-treatment shall consist of heating the material to a minimum temperature of 1900°F [1040°C] except for S31266, S31254, S32654, S32050, and S30815 which shall be heated to a minimum temperature of 2100°F [1150°C], and 1920°F [1050°C] respectively, S24565 which shall be heated to a minimum temperature of 2050°F [1120°C], N08367 which shall be heated to a minimum temperature of 2025°F [1107°C], and N08926 which shall be heat treated to a minimum temperature of 2010°F [1100°C], all treatments being followed by quenching in water or rapidly cooling by other means. N08904 shall be heat treated to a minimum temperature of 2000°F [1095°C] and cooled rapidly. UNS N08810 shall be heated to a minimum temperature of 2050°F [1120°C] and cooled rapidly. UNS N08020 shall be heated in the range from 1800 to 1850°F [982 to 1010°C] and cooled rapidly.

6.3.2 The purchase order shall specify one of the following conditions if the heat-treated condition specified in 6.3.1 is not desired by the purchaser:

6.3.2.1 *A final heat-treatment temperature under 1900°F [1040°C]* — Each pipe supplied under this requirement shall be stenciled with the final heat-treatment temperature in degrees Fahrenheit or degrees Celsius after the suffix “HT.” Controlled structural or special service characteristics may be specified as a guide for the most suitable heat treatment.

6.3.2.2 DELETED

6.3.2.3 DELETED

6.4 A solution annealing temperature above 1950°F [1065°C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in Grades 321, 347, and 348. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the initial high temperature solution anneal (see Supplementary Requirement S5).

7. Chemical Composition

7.1 The chemical composition of the plate shall conform to the requirements of the applicable specification and grade listed in Specification A 240/A 240M.

7.2 The chemical composition of the welding filler metal shall conform to the requirements of the applicable AWS specification for the corresponding grade shown in Table 1, or shall conform to the chemical composition specified for the plate in Specification A 240/A 240M, or shall, subject to purchaser approval, be a filler metal more highly alloyed than the base metal when needed for corrosion resistance or other properties. Use of a filler metal other than that listed in Table 1 or conforming to the

chemical composition specified for the plate in Specification A 240/A 240M shall be reported and the filler metal identified on the certificate of tests. When nitrogen and cerium are specified elements for the ordered grade, the method of analysis for these elements shall be a matter of agreement between the purchaser and the manufacturer.

8. Permissible Variations in Dimensions

8.1 Permissible Variations — The dimensions at any point in a length of pipe shall not exceed the following:

8.1.1 Outside Diameter — Based on circumferential measurement, $\pm 0.5\%$ of the specified outside diameter.

8.1.2 Out-of-Roundness — Difference between major and minor outside diameters, 1%.

8.1.3 Alignment — Using a 10 ft or 3 m straightedge placed so that both ends are in contact with the pipe, $\frac{1}{8}$ in. [3 mm].

8.1.4 Thickness — The minimum wall thickness at any point in the pipe shall not be more than 0.01 in. [0.3 mm] under the nominal thickness.

9. Workmanship, Finish, and Appearance

9.1 The finished pipe shall have a workmanlike finish.

9.2 Repair of Plate Defects by Machining or Grinding — Pipe showing slivers may be machined or ground inside or outside to a depth which shall ensure the removal of all included scale and slivers, providing the wall thickness is not reduced below the specified minimum wall thickness. Machining or grinding shall follow inspection of the pipe as rolled, and shall be followed by supplementary visual inspection.

9.3 Repair of Plate Defects by Welding — Defects which violate minimum wall thickness may be repaired by welding, but only with the approval of the purchaser. Areas shall be suitably prepared for welding with tightly closed defects removed by grinding. Open, clean defects, such as pits or impressions, may require no preparation. All welders, welding operators, and weld procedures shall be qualified to the ASME Boiler and Pressure Vessel Code, Section IX. Unless the purchaser specifies otherwise, pipe required to be heat treated under the provisions of 6.3, shall be heat treated or reheat treated following repair welding. Repaired lengths, where repair depth is greater than $\frac{1}{4}$ of the thickness, shall be pressure tested or repressure tested after repair and heat treatment (if any). Repair welds shall also be examined by suitable non-destructive examination techniques, including any techniques specifically required of the primary weld.

9.4 The pipe shall be free of scale and contaminating iron particles. Pickling, blasting or surface finishing is not

mandatory when pipe is bright annealed. The purchaser may request that a passivating treatment be applied.

10. Heat Analysis

10.1 An analysis of each heat of steel shall be made by the plate manufacturer to determine the percentages of the elements prescribed in Specification A 240/A 240M. The chemical composition thus determined shall conform to the requirements prescribed in Specification A 240/A 240M.

11. Product Analysis

11.1 For each lot of 500 ft [150 m] of pipe or fraction thereof, analysis shall be made by the manufacturer from the finished pipe of the plate and of the weld deposit. Drillings for analysis may be taken from the mechanical test specimens. The results of these analyses shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements of Section 7, subject to the product analysis tolerances of Table 1 in Specification A 480/A 480M.

11.2 If the analysis of one of the tests specified in 9.1 does not conform to the requirements specified in Section 7, analyses shall be made on additional pipe of double the original number from the same lot, each of which shall conform to the requirements specified.

12. Tensile Requirements

12.1 The plate used in making the pipe shall conform to the requirements as to tensile properties of the applicable specifications listed in Table 1. Tension tests made by the plate manufacturer shall qualify the plate material.

12.2 The transverse tension test taken across the welded joint specimen shall have a tensile strength not less than the specified minimum tensile strength of the plate.

13. Transverse Guided-Bend Weld Tests

13.1 Two bend test specimens shall be taken transversely from the pipe. Except as provided in 13.2, one shall be subject to a face guided-bend test and the second to a root guided-bend test. One specimen shall be bent with the inside surface of the pipe against the plunger, and the other with the outside surface against the plunger.

13.2 For wall thicknesses over $\frac{3}{8}$ in. [9.5 mm] but less than $\frac{3}{4}$ in. [19 mm] side-bend tests may be made instead of the face and root-bend tests. For specified wall thicknesses $\frac{3}{4}$ in. [19 mm] and over, both specimens shall be subjected to the side-bend tests. Side-bend specimens shall

be bent so that one of the side surfaces becomes the convex surface of the bend specimen.

13.3 The bend test shall be acceptable if no cracks or other defects exceeding $\frac{1}{8}$ in. [3 mm] in any direction be present in the weld metal or between the weld and the pipe metal after bending. Cracks which originate along the edges of the specimen during testing, and that are less than $\frac{1}{4}$ in. [6.5 mm] measured in any direction shall not be considered.

14. Test Specimens and Methods of Testing

14.1 Transverse tension and bend test specimens shall be taken from the end of the finished pipe; the transverse tension and bend test specimens shall be flattened cold before final machining to size.

14.2 As an alternative to the requirements of 14.1, the test specimens may be taken from a test plate of the same material as the pipe, which is attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

14.3 Tension test specimens shall be made in accordance with Section IX, Part QW, Paragraph QW-150 of the *ASME Boiler and Pressure Vessel Code* and shall be one of the types shown in QW-462.1 of that code.

14.3.1 Reduced-section specimens conforming to the requirements given in QW-462.1(b) may be used for tension tests on all thicknesses of pipe having outside diameter greater than 3 in. [76 mm].

14.3.2 Turned specimens conforming to the requirements of QW-462.1(d) may be used for tension tests.

14.3.2.1 If turned specimens are used as given in 14.3.2.2 and 14.3.2.3, one complete set shall be made for each required tension test.

14.3.2.2 For thicknesses to and including $1\frac{1}{4}$ in. [32 mm], a single turned specimen may be used.

14.3.2.3 For thicknesses over $1\frac{1}{4}$ in. [32 mm], multiple specimens shall be cut through the full thickness of the weld with their centers parallel to the material surface and not over 1 in. [25 mm] apart. The centers of the specimens adjacent to material surfaces shall not exceed $\frac{5}{8}$ in. [16 mm] from the surface.

14.4 The test specimens shall not be cut from the pipe or test plate until after final heat treatment.

15. Mechanical Tests Required

15.1 *Transverse Tension Test* — One test shall be made to represent each lot (see Note 2) of finished pipe.

NOTE 2 — The term “lot” applies to all pipe of the same grade (may include more than one heat of steel) within a $\frac{3}{16}$ in. [4.7 mm] range of thickness and welded to the same weld procedure, and when heat treated,

done so to the same heat-treating procedure and in the same furnace. The maximum lot size shall be 200 linear ft [60 m] of pipe.

15.2 *Transverse Guided-Bend Weld Test* — One test (two specimens) shall be made to represent each lot (Note 2) of finished pipe.

15.3 *Hydrostatic Test* — Each length of pipe shall be subjected to a hydrostatic test in accordance with Specification A 999/A 999M, unless specifically exempted under the provision of 15.4. Pressure shall be held for a sufficient time to permit the inspector to examine the entire length of the welded seam.

15.4 The purchaser, with the agreement of the manufacturer, may complete the hydrostatic test requirement with the system pressure test, which may be lower or higher than the specification test pressure, but in no case shall the test pressure be lower than the system design pressure. Each length of pipe furnished without the completed manufacturer’s hydrostatic test shall include with the mandatory marking the letters “NH.”

16. Radiographic Examination

16.1 For Classes 1, 3, and 4 pipe, all welded joints shall be completely examined by radiography.

16.2 For Class 5 pipe, the welded joints shall be spot radiographed to the extent of not less than 12 in. [300 mm] of radiograph per 50 ft [15 m] of weld.

16.3 For Classes 1, 3, and 4 pipe, radiographic examination shall be in accordance with the requirements of the *ASME Boiler and Pressure Vessel Code*, Section VIII, latest edition, Paragraph UW-51.

16.4 For Class 5 pipe, radiographic examination shall be in accordance with the requirements of the *ASME Boiler and Pressure Vessel Code*, Section VIII, Division 1, latest edition, Paragraph UW-52.

16.5 Radiographic examination may be performed prior to heat treatment.

17. Lengths

17.1 Circumferentially welded joints of the same quality as the longitudinal joints shall be permitted by agreement between the manufacturer and the purchaser.

18. Product Marking

18.1 In addition to the marking prescribed in Specification A 999/A 999M, the markings on each length of pipe shall include the plate material designations as shown in Table 1, the marking requirements of 6.3 and 15.4, and Class 1, 2, 3, or 4, as appropriate (see 1.3).

18.2 Bar Coding — In addition to the requirements in 18.1, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

19. Keywords

19.1 arc welded steel pipe; austenitic stainless steel; chromium-nickel steel; fusion welded steel pipe; high temperature application; steel pipe; temperature service applications; high; welded steel pipe

TABLE 1
PLATE AND FILLER METAL SPECIFICATIONS

Grade	UNS Designation	Material, Type	ASTM Plate Specification No. and Grade	Filler Metal Classification and UNS Designation [Note (1)] for Applicable [Note (2)] AWS Specification											
				A5.4		A5.9		A5.11		A5.14		A5.22		A5.30	
				Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS
.....	N08020	...	A 240 N08020	...	...	...	ENiCrMo-3	W86112	...	ERNiCrMo-3	...	N06625	...	...	...
.....	N08367	...	A 240 N08367	...	...	...	...	...	...	...	...	...	...	...	...
.....	N08800	...	A 240 N08800	...	...	...	...	...	...	...	...	...	...	...	...
.....	N08810	...	A 240 N08810	...	...	...	...	...	...	...	...	...	...	...	...
.....	N08904	...	A 240 N08904	...	...	...	...	...	...	...	...	...	...	...	...
.....	N08926	...	A 240 N08926	...	...	...	ENiCrMo-3	W86112	...	ERNiCrMo-3	...	N06625	...	...	...
.....	S20400	...	A 240 S20400	E209	W32210	ER209	...	...	...	...	...	...	...	...	...
XM-19	S22100	XM-19	A 240 Type XM-19	E209	W32210	ER209	S20980 W32240	...	...	...	...	...	...	...	...
.....	S24585	...	A 240 S24585	...	...	...	...	...	...	...	...	...	...	...	...
XM-29	S28300	XM-29	A 240 Type XM-29	E240	W32410	ER240	S23980 W32440	...	...	...	...	...	...	...	...
304	S30400	304	A 240 Type 304	E308	W30810	ER308	S30880 W30840	...	...	...	...	...	E308T	W30831	IN308 S30880
304L	S30403	304L	A 240 Type 304	E308L	W30813	ER308L	S30883 W30843	...	...	...	...	...	E308LT	W30835	IN308L S30883
304H	S30409	304H	A 240 Type 304H	E308H	W30810	ER308	S30880 W30840	...	...	...	...	...	E308T	W30831	IN308 S30880
.....	S30415	...	A 240 S30415	...	...	...	...	...	...	...	...	...	...	...	...
304N	S30451	304N	A 240 Type 304N	E308	W30810	ER308	S30880 W30840	...	...	...	...	...	E308T	W30831	IN308 S30880
304LN	S30453	304LN	A 240 Type 304LN	E308L	W30813	ER308L	S30883 W30843	...	...	...	...	...	W308LT	W30835	IN308L S30883
.....	S30600	...	A 240 S30600 [Note (3)]	...	...	...	...	...	...	...	...	...	...	...	...
.....	S30815	...	A 240 S30815	...	...	...	...	...	...	...	...	...	...	...	...
309S	S30908	309S	A 240, Type 309S	...	...	...	...	...	...	...	...	...	...	...	...
309Cb	S30940	309Cb	A 240, Type 309Cb	E309Cb	...	...	...	...	...	...	...	...	...	...	...
310S	S31008	310S	A 240, Type 310S	...	...	...	...	...	...	...	...	...	...	...	...
310Cb	S31040	310Cb	A 240, Type 310Cb	E310Cb	...	...	...	...	...	...	...	...	...	...	...
.....	S31254	...	A 240 S31254	...	...	...	ENiCrMo-3	W86112	...	ERNiCrMo-3	...	N06625	...	...	...
.....	S31266	...	A 240 S31266	...	...	...	ENiCrMo-10	W86022	...	ERNiCrMo-10	...	N06022	...	...	...
.....	S31266	...	A 240 S31266	...	...	...	ENiCrMo-13	W86059	...	ERNiCrMo-13	...	N06059	...	...	...
316	S31600	316	A 240 Type 316	E316	W31610	ER316	S31680 W31640	...	...	...	...	...	E316T	W31631	IN316 S31680
316L	S31603	316L	A 240 Type 316L	E316L	W31613	ER316L	S31683 W31643	...	...	...	...	...	E316LT	W31635	IN316L S31683
316H	S31609	316H	A 240 Type 316H	E316H	W31610	ER316H	S31680 W31640	...	...	...	...	...	E316T	W31631	IN316 S31680
316N	S31651	316N	A 240 Type 316N	E316	W31610	ER316	S31680 W31640	...	...	...	...	...	E316T	W31631	IN316 S31680
316LN	S31653	316LN	A 240 Type 316LN	E316L	W31613	ER316L	S31683 W31643	...	...	...	...	...	E316LT	W31635	IN316L S31683
.....	S31725	...	A 240 S31725	...	...	...	...	...	...	...	...	...	...	...	...
.....	S31726	...	A 240 S31726	...	...	...	ENiCrMo-3	W86112	...	ERNiCrMo-3	...	N06625	...	...	...
.....	S32050	...	A 240 S32050	...	...	...	ENiCrMo-3	W86112	...	ERNiCrMo-3	...	N06625	...	...	...
321	S32100	321	A 240 Type 321	E347	W34710	ER321 ER347	S32180 W32140 S34780 W34740	...	...	...	...	...	E347T	W34733	IN348 S34780

TABLE 1
PLATE AND FILLER METAL SPECIFICATIONS (CONT'D)

Grade	UNS Designation	Material, Type	ASTM Plate Specification No. and Grade	Filler Metal Classification and UNS Designation [Note (1)] for Applicable [Note (2)] AWS Specification											
				A5.4		A5.9		A5.11		A5.14		A5.22		A5.30	
				Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS
...	S32654	...	A 240 S32654	...	...	...	...	...	...	...	...	...	...	...	...
...	S34565	...	A 240 S24565	...	...	...	...	...	...	...	...	...	...	...	...
347	S34700	347	A 240 Type 347	E347	W34710	ER347	S34780 W34740	...	...	...	...	E347T	W34733	IN348	S34780
348	S34800	348	A 240 Type 348	E347	W34710	ER347	S34780 W34740	...	...	...	...	E347T	W34733	IN348	S34780

NOTES:

- (1) New designation established in accordance with ASTM E 527 and SAE J1086.
 (2) Choice of American Welding Society specification depends on the welding process used.
 (3) In previous editions, S30600 was incorrectly shown as S01815.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical composition requirements shall be rejected.

S2. Tension and Bend Tests

S2.1 Tension tests (Section 12) and bend tests (Section 13) shall be made on specimens to represent each length of pipe. Failure of any test specimen to meet the requirements shall be cause for the rejection of the pipe length represented.

S3. Penetrant Oil and Powder Examination

S3.1 All welded joints shall be subjected to examination by a penetrant oil and powder method. The details of the method and the disposition of flaws detected shall be a matter for agreement between the purchaser and the manufacturer.

S4. Ferrite Control in Weld Deposits

S4.1 The ferrite content of the deposited weld metal in any length of pipe may be determined. The procedural details pertaining to this subject (that is, welding; plate and weld deposit chemistry; testing equipment and method;

number and location of test sites; and ferrite control limits) shall be a matter for agreement between the purchaser and the manufacturer.

S5. Stabilizing Heat Treatment

S5.1 Subsequent to the heat treatment required in 6.3, Grades 321, 347, and 348 shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S6. Intergranular Corrosion Test

S6.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE S1 — Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S6.2 A stabilization heat treatment in accordance with Supplementary Requirement S5 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium.

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SPECIFICATION FOR CARBON AND FERRITIC ALLOY STEEL FORGED AND BORED PIPE FOR HIGH-TEMPERATURE SERVICE



SA-369/SA-369M



(Identical with ASTM Specification A 369/A 369M-06.)

1. Scope

1.1 This specification covers heavy-wall carbon and alloy steel pipe (Note 1) made from turned and bored forgings and is intended for high-temperature service. Pipe ordered under this specification shall be suitable for bending and other forming operations and for fusion welding. Selection will depend on design, service conditions, mechanical properties and high-temperature characteristics.

NOTE 1 — The use of the word “pipe” throughout the several sections of this specification is used in the broad sense and intended to mean pipe headers, or leads.

NOTE 2 — The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as “nominal diameter,” “size,” and “nominal size.”

1.2 Several grades of ferritic steels are covered. Their compositions are given in Table 1.

1.3 Supplementary requirements (S1 to S6) of an optional nature are provided. These supplementary requirements call for additional tests to be made, and when desired shall be so stated in the order, together with the number of such tests required.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

2. Referenced Documents

2.1 ASTM Standards:

A 999/A 999M Specification for General Requirements for Alloy and Stainless Steel Pipe

E 290 Test Methods for Bend Testing of Material for Ductility

E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

2.2 ASME Boiler and Pressure Vessel Code:
Section IX Welding Qualifications

2.3 ANSI Standard:
B 46.1 Surface Texture

3. Ordering Information

3.1 Orders for material to this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, centimetres, or number of lengths),

3.1.2 Name of material (forged and bored pipe),

3.1.3 Grade (Table 1),

3.1.4 Size (inside diameter and minimum wall thickness),

3.1.5 Length (Permissible Variations in Length Section of Specification A 999/A 999M),

3.1.6 End finish (13),

3.1.7 Optional requirements (Sections 8, Supplementary Requirements S1 to S6; 13.2),

3.1.8 Test report required (Certification Section of Specification A 999/A 999M),

3.1.9 Specification designation, and

3.1.10 Special requirements or exceptions to this specification.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 999/A 999M, unless otherwise provided herein.

5. Materials and Manufacture

5.1 Discard:

5.1.1 A sufficient discard shall be made from each ingot to secure freedom from injurious defects. The steel shall have a homogeneous structure.

5.2 Manufacture:

5.2.1 Material for forging shall consist of ingots or of blooms, billets, or solid-rolled bars forged or rolled from an ingot, and cut to the required length by a process that will not produce injurious defects in the forging.

5.2.2 The material shall be forged (Note 3) by hammering or pressing, and shall be brought as nearly as practicable to the finished shape and size by hot working.

NOTE 3 — The cross-sectional area of the solid forging shall have a reduction by forging or by rolling and forging from that of the ingot in the ratio of not less than 3 to 1.

5.2.3 Unless otherwise specified, the final forging operation shall be followed by a treatment suitable to the grade as specified in 5.4.

5.3 Machining:

5.3.1 All forgings shall have both the inner and outer surfaces machined.

5.3.2 After heat treatment, the pipe shall be machined to a finish with a roughness value no greater than 250 μin . [6.4 μm] arithmetical average deviation (AA), terms as defined in ANSI B 46.1-1962, unless otherwise specified.

5.4 Heat Treatment:

5.4.1 All pipe of the grades shown in Table 1 other than FPA, FPB, FP1, FP2, FP12, FP91, and FP92 shall be reheated and furnished in the full-annealed or normalized and tempered condition. If furnished in the normalized and tempered condition (Note 4), the temperature for tempering shall be 1250°F [680°C] or higher for Grades FP5, FP9, FP21, and FP22, and 1200°F [650°C] or higher for Grades FP36 and FP11.

NOTE 4 — It is recommended that the temperature for tempering should be at least 100°F [50°C] above the intended service temperature; consequently, the purchaser should advise the manufacturer if the service temperature is to be over 1100°F [600°C].

5.4.2 Pipe in Grades FPA and FPB as a final heat treatment shall be either normalized or shall be given a stress relieving treatment at 1200 to 1300°F [650 to 705°C]. Pipe in Grades FP1, FP2, and FP12, as a final heat treatment

shall be given a stress-relieving treatment at 1200 to 1300°F [650 to 705°C].

NOTE 5 — Certain of the ferritic steels covered by this specification tend to harden if cooled rapidly from above their critical temperature. Some will air harden, that is, become hardened to an undesirable degree when cooled in air from high temperatures. Therefore, operations involving heating such steels above their critical temperatures, such as welding, hot-bending and other forming operations, should be followed by suitable heat treatment.

5.4.3 Except when Supplementary Requirement S6 is specified by the purchaser, Grade FP91 shall be normalized and tempered by reheating within the temperature range from 1900 to 1975°F [1040 to 1080°C], followed by air cooling and tempering in the temperature range of 1350 to 1470°F [730 to 800°C].

5.4.4 Except when Supplementary Requirement S6 is specified by the purchaser, Grade FP92 shall be normalized and tempered by reheating within the temperature range of 1900 to 1975°F [1040 to 1080°C], followed by air cooling and tempering in the temperature range of 1350 to 1470°F [730 to 800°C].

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

7. Heat Analysis

7.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the tubular product manufacturer, shall conform to the requirements specified.

7.2 In the case of large ingots poured from two or more heats, the weighted average of the chemical determinations of the several heats, made in accordance with 7.1, shall conform to the requirements specified in Section 6.

8. Product Analysis

8.1 At the request of the purchaser, a product analysis shall be made by the manufacturer on every heat.

8.2 The results of these analyses shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 6.

8.3 If the analysis of one of the tests specified in Section 7 or Section 8 does not conform to the requirements specified in Section 6 an analysis of each billet or pipe from

the same heat may be made, and all billets or pipes conforming to the requirements shall be accepted.

9. Tensile Requirements

9.1 The material shall conform to the requirements as to tensile properties prescribed in Table 2. Tests for acceptance shall be made after final heat treatment of the forging.

10. Mechanical Tests Required

10.1 *Transverse or Longitudinal Tension Test* — One test shall be made on a specimen from one end of one length of pipe representing each heat in each heat-treatment lot.

10.2 *Flattening Test* — For pipe NPS 14 or less, and diameter to wall thickness ratios of more than 7.0, a flattening test shall be carried out in accordance with Specification A 999/A 999M. A test shall be carried out on a specimen taken from one end of each length of pipe.

10.3 *Bend Test* — For pipe larger than NPS 14 or NPS where diameters to wall thickness ratio is 7.0 or less, a bend test shall be carried out in accordance with Test Methods E 290. Unless otherwise specified, the test specimens shall be taken in a transverse direction. The diameter of the pin shall be $\frac{2}{3}t$ for longitudinal specimens or $\frac{1}{3}t$ for transverse specimens, where t is the specimen thickness. The bend test specimens shall be bent at room temperature through 180° without cracking. One bend test shall be taken from one end of each length of pipe.

11. Workmanship

11.1 The pipe shall conform to the sizes and shapes specified by the purchaser.

12. Ends

12.1 Pipe ends shall be machined as specified in the purchase order.

13. Finish

13.1 The finished pipe shall be reasonably straight and shall have a workmanlike finish.

13.2 Repair of defects by welding shall be permitted only subject to the approval of the purchaser. Defects shall be thoroughly chipped or ground out before welding. Only qualified operators and procedures in accordance with the ASME Boiler and Pressure Vessel Code, Section IX, shall be used. Local or full heat treatment in accordance with 5.4 shall follow welding. Local grinding following welding and retreating shall be considered as meeting the requirements of 5.3.

14. Product Marking

14.1 In addition to the marking prescribed in Specification A 999/A 999M, the marking shall include the wall thickness, piece mark, length, and additional symbol “S” if the pipe conforms to the supplementary requirements specified in Supplementary Requirements S1 to S5, and the heat number or the manufacturer’s number by which the heat can be identified. Indentation stamping, instead of stenciling, will be permitted only with the written approval of the purchaser.

TABLE 1
CHEMICAL REQUIREMENTS

Grade	Composition, %			
	FPA	FPB	FP1	FP2
Carbon	0.25 max	0.30 max	0.10–0.20	0.10–0.20
Manganese	0.27–0.93	0.29–1.06	0.30–0.80	0.30–0.61
Phosphorus, max	0.035	0.035	0.025	0.025
Sulfur, max	0.035	0.035	0.025	0.025
Silicon	0.10 min	0.10 min	0.10–0.50	0.10–0.30
Chromium	...	...	...	0.50–0.81
Molybdenum	...	...	0.44–0.65	0.44–0.65
Grade	FP5	FP9	FP11	FP12
Carbon	0.15 max	0.15 max	0.05–0.15	0.05–0.15
Manganese	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.61
Phosphorus, max	0.025	0.030	0.025	0.025
Sulfur, max	0.025	0.030	0.025	0.025
Silicon	0.50 max	0.50–1.00	0.50–1.00	0.50 max
Chromium	4.00–6.00	8.00–10.00	1.00–1.50	0.80–1.25
Molybdenum	0.45–0.65	0.90–1.10	0.44–0.65	0.44–0.65
Grade	FP21	FP22	FP91	FP92
Carbon	0.05–0.15	0.05–0.15	0.08–0.12	0.07–0.13
Manganese	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60
Phosphorus, max	0.025	0.025	0.025	0.020
Sulfur, max	0.025	0.025	0.025	0.010
Silicon	0.50 max	0.50 max	0.20–0.50	0.50 max
Chromium	2.65–3.35	1.90–2.60	8.00–9.50	8.50–9.50
Molybdenum	0.80–1.06	0.87–1.13	0.85–1.05	0.30–0.60
			Others:	W 1.50–2.00
			Ni 0.40 max	V 0.15–0.25
			V 0.18–0.25	Cb 0.04–0.09
			Cb 0.06–0.10	N 0.030–0.070
			N 0.03–0.07	Ni 0.40 max
			Al 0.04 max	Al 0.02 max
			Ti 0.01 max	Ti 0.01 max
			Zr 0.01 max	Zr 0.01 max
				B 0.001–0.006

TABLE 2
TENSILE REQUIREMENTS

Grade	FPA	FPB	FP1, FP2	FP12	FP91	FP92	All Others	
Tensile strength, min; ksi [MPa]	48 [330]	60 [415]	55 [380]	60 [415]	85 [585]	90 [620]	60 [415]	
Yield strength, min; ksi [MPa]	30 [210]	35 [240]	30 [210]	32 [220]	60 [415]	64 [440]	30 [210]	
Grade	Elongation Requirements							
	FPA		FPB		FP91 and FP92		All Others	
	Longitu- dinal	Trans- verse	Longitu- dinal	Trans- verse	Longitu- dinal	Trans- verse	Longitu- dinal	Trans- verse
Elongation in 2 in. or 50 mm, min, %:								
Basic minimum elongation for wall $\frac{5}{16}$ in. [8 mm] and over in thickness, strip tests, and for all small sizes tested in full-section	35	25	30	17	27	18	30	20
When standard round 2 in. or 50 mm gage length test specimen is used	28	20	22	12	20	13	22	14

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Additional Tension Test

S1.1 An additional tension test shall be made on a specimen from one or each end of each pipe. If this supplementary requirement is specified, the number of tests per pipe required shall be specified. If a specimen from any length fails to meet the required tensile properties (tensile, yield, and elongation), that length shall be rejected subject to retreatment in accordance with Specification A 999/A 999M and satisfactory retest.

S2. Additional Flattening or Bend Tests

S2.1 The appropriate flattening or bend test may be made on specimens from both ends of each length of pipe. Crop ends may be used. If the specimen from either end of any length fails to conform to the specific requirement, that length shall be rejected.

S3. Ultrasonic Tests

S3.1 Each pipe shall be ultrasonically tested to determine its soundness throughout the entire length of the pipe. Until suitable standards are established, the basis for rejection of material shall be a matter of agreement between the manufacturer and purchaser.

S4. Hydrostatic Test

S4.1 A hydrostatic pressure test shall be applied as agreed upon by the manufacturer and purchaser.

S5. Metal Structure and Etching Tests

S5.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free of injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S6. Alternative Heat Treatment Grades FP91 and FP92

S6.1 Grades FP91 and FP92 shall be normalized in accordance with 5.4.3 or 5.4.4, respectively, and tempered at a temperature, to be specified by the purchaser, less than 1350°F [730°C]. It shall be the purchaser's responsibility to subsequently temper in the range of 1350 to 1470°F [730 to 800°C]. All mechanical tests shall be made on material heat treated in accordance with 5.4.3 or 5.4.4, respectively. The certification shall reference this supplementary requirement indicating the tempering temperature applied. The notation "S6" shall be included with the required marking of the pipe.

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TEST METHODS AND DEFINITIONS FOR MECHANICAL TESTING OF STEEL PRODUCTS



SA-370



(Identical with ASTM Specification A 370-05)

1. Scope

1.1 These test methods cover procedures and definitions for the mechanical testing of wrought and cast steels, stainless steels, and related alloys. The various mechanical tests herein described are used to determine properties required in the product specifications. Variations in testing methods are to be avoided, and standard methods of testing are to be followed to obtain reproducible and comparable results. In those cases in which the testing requirements for certain products are unique or at variance with these general procedures, the product specification testing requirements shall control.

1.2 The following mechanical tests are described:

	Sections
Tension	5 to 13
Bend	14
Hardness	15
Brinell	16
Rockwell	17
Portable	18
Impact	19 to 28
Keywords	29

1.3 Annexes covering details peculiar to certain products are appended to these test methods as follows:

	Annex
Bar Products	A1.1
Tubular Products	Annex A2
Fasteners	Annex A3
Round Wire Products	Annex A4
Significance of Notched-Bar Impact Testing	Annex A5
Converting Percentage Elongation of Round Specimens to Equivalents for Flat Specimens	Annex A6
Testing Multi-Wire Strand	Annex A7
Rounding of Test Data	Annex A8
Methods for Testing Steel Reinforcing Bars	Annex A9
Procedure for Use and Control of Heat-Cycle Simulation	Annex A10

1.4 The values stated in inch-pound units are to be regarded as the standard.

1.5 When this document is referenced in a metric product specification, the yield and tensile values may be determined in inch-pound (ksi) units then converted into SI (MPa) units. The elongation determined in inch-pound gage lengths of 2 or 8 in. may be reported in SI unit gage lengths of 50 or 200 mm, respectively, as applicable. Conversely, when this document is referenced in an inch-pound product specification, the yield and tensile values may be determined in SI units then converted into inch-pound units. The elongation determined in SI unit gage lengths of 50 or 200 mm may be reported in inch-pound gage lengths of 2 or 8 in., respectively, as applicable.

1.6 Attention is directed to Practices A 880 and E 1595 when there may be a need for information on criteria for evaluation of testing laboratories.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

- A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts
- A 781/A 781M Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use
- A 833 Practice for Indentation Hardness of Metallic Materials by Comparison Hardness Testers
- A 880 Practice for Criteria for Use in Evaluation of Testing Laboratories and Organizations for Examination and Inspection of Steel, Stainless Steel, and Related Alloys
- E 4 Practices for Force Verification of Testing Machines
- E 6 Terminology Relating to Methods of Mechanical Testing
- E 8 Test Methods for Tension Testing of Metallic Materials

- E 8M Test Methods for Tension Testing of Metallic Materials [Metric]
- E 10 Test Method for Brinell Hardness of Metallic Materials
- E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
- E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E 83 Practice for Verification and Classification of Extensometer System
- E 110 Test Method for Indentation Hardness of Metallic Materials by Portable Hardness Testers
- E 190 Test Method for Guided Bend Test for Ductility of Welds
- E 290 Test Method for Bend Testing of Material for Ductility
- E 1595 Practice for Evaluating the Performance of Mechanical Testing Laboratories

2.2 ASME Document:

ASME Boiler and Pressure Vessel Code, Section VIII, Division I, Part UG-8

3. General Precautions

3.1 Certain methods of fabrication, such as bending, forming, and welding, or operations involving heating, may affect the properties of the material under test. Therefore, the product specifications cover the stage of manufacture at which mechanical testing is to be performed. The properties shown by testing prior to fabrication may not necessarily be representative of the product after it has been completely fabricated.

3.2 Improper machining or preparation of test specimens may give erroneous results. Care should be exercised to assure good workmanship in machining. Improperly machined specimens should be discarded and other specimens substituted.

3.3 Flaws in the specimen may also affect results. If any test specimen develops flaws, the retest provision of the applicable product specification shall govern.

3.4 If any test specimen fails because of mechanical reasons such as failure of testing equipment or improper specimen preparation, it may be discarded and another specimen taken.

4. Orientation of Test Specimens

4.1 The terms “longitudinal test” and “transverse test” are used only in material specifications for wrought products and are not applicable to castings. When such reference

is made to a test coupon or test specimen, the following definitions apply:

4.1.1 Longitudinal Test, unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is parallel to the direction of the greatest extension of the steel during rolling or forging. The stress applied to a longitudinal tension test specimen is in the direction of the greatest extension, and the axis of the fold of a longitudinal bend test specimen is at right angles to the direction of greatest extension (Fig. 1, Fig. 2a, and 2b).

4.1.2 Transverse Test, unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is at right angles to the direction of the greatest extension of the steel during rolling or forging. The stress applied to a transverse tension test specimen is at right angles to the greatest extension, and the axis of the fold of a transverse bend test specimen is parallel to the greatest extension (Fig. 1).

4.2 The terms “radial test” and “tangential test” are used in material specifications for some wrought circular products and are not applicable to castings. When such reference is made to a test coupon or test specimen, the following definitions apply:

4.2.1 Radial Test, unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is perpendicular to the axis of the product and coincident with one of the radii of a circle drawn with a point on the axis of the product as a center (Fig. 2a).

4.2.2 Tangential Test, unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is perpendicular to a plane containing the axis of the product and tangent to a circle drawn with a point on the axis of the product as a center (Fig. 2a, 2b, 2c, and 2d).

TENSION TEST

5. Description

5.1 The tension test related to the mechanical testing of steel products subjects a machined or full-section specimen of the material under examination to a measured load sufficient to cause rupture. The resulting properties sought are defined in Terminology E 6.

5.2 In general, the testing equipment and methods are given in Test Methods E 8. However, there are certain exceptions to Test Methods E 8 practices in the testing of steel, and these are covered in these test methods.

6. Terminology

6.1 For definitions of terms pertaining to tension testing, including tensile strength, yield point, yield strength,

elongation, and reduction of area, reference should be made to Terminology E 6.

7. Testing Apparatus and Operations

7.1 Loading Systems — There are two general types of loading systems, mechanical (screw power) and hydraulic. These differ chiefly in the variability of the rate of load application. The older screw power machines are limited to a small number of fixed free running crosshead speeds. Some modern screw power machines, and all hydraulic machines permit stepless variation throughout the range of speeds.

7.2 The tension testing machine shall be maintained in good operating condition, used only in the proper loading range, and calibrated periodically in accordance with the latest revision of Practices E 4.

NOTE 1 — Many machines are equipped with stress-strain recorders for autographic plotting of stress-strain curves. It should be noted that some recorders have a load measuring component entirely separate from the load indicator of the testing machine. Such recorders are calibrated separately.

7.3 Loading — It is the function of the gripping or holding device of the testing machine to transmit the load from the heads of the machine to the specimen under test. The essential requirement is that the load shall be transmitted axially. This implies that the centers of the action of the grips shall be in alignment, insofar as practicable, with the axis of the specimen at the beginning and during the test and that bending or twisting be held to a minimum. For specimens with a reduced section, gripping of the specimen shall be restricted to the grip section. In the case of certain sections tested in full size, nonaxial loading is unavoidable and in such cases shall be permissible.

7.4 Speed of Testing — The speed of testing shall not be greater than that at which load and strain readings can be made accurately. In production testing, speed of testing is commonly expressed: (1) in terms of free running crosshead speed (rate of movement of the crosshead of the testing machine when not under load), (2) in terms of rate of separation of the two heads of the testing machine under load, (3) in terms of rate of stressing the specimen, or (4) in terms of rate of straining the specimen. The following limitations on the speed of testing are recommended as adequate for most steel products:

NOTE 2 — Tension tests using closed-loop machines (with feedback control of rate) should not be performed using load control, as this mode of testing will result in acceleration of the crosshead upon yielding and elevation of the measured yield strength.

7.4.1 Any convenient speed of testing may be used up to one half the specified yield point or yield strength.

When this point is reached, the free-running rate of separation of the crossheads shall be adjusted so as not to exceed $\frac{1}{16}$ in. per min per inch of reduced section, or the distance between the grips for test specimens not having reduced sections. This speed shall be maintained through the yield point or yield strength. In determining the tensile strength, the free-running rate of separation of the heads shall not exceed $\frac{1}{2}$ in. per min per inch of reduced section, or the distance between the grips for test specimens not having reduced sections. In any event, the minimum speed of testing shall not be less than $\frac{1}{10}$ the specified maximum rates for determining yield point or yield strength and tensile strength.

7.4.2 It shall be permissible to set the speed of the testing machine by adjusting the free running crosshead speed to the above specified values, inasmuch as the rate of separation of heads under load at these machine settings is less than the specified values of free running crosshead speed.

7.4.3 As an alternative, if the machine is equipped with a device to indicate the rate of loading, the speed of the machine from half the specified yield point or yield strength through the yield point or yield strength may be adjusted so that the rate of stressing does not exceed 100 000 psi (690 MPa)/min. However, the minimum rate of stressing shall not be less than 10 000 psi (70 MPa)/min.

8. Test Specimen Parameters

8.1 Selection — Test coupons shall be selected in accordance with the applicable product specifications.

8.1.1 Wrought Steels — Wrought steel products are usually tested in the longitudinal direction, but in some cases, where size permits and the service justifies it, testing is in the transverse, radial, or tangential directions (see Fig. 1 and Fig. 2).

8.1.2 Forged Steels — For open die forgings, the metal for tension testing is usually provided by allowing extensions or prolongations on one or both ends of the forgings, either on all or a representative number as provided by the applicable product specifications. Test specimens are normally taken at mid-radius. Certain product specifications permit the use of a representative bar or the destruction of a production part for test purposes. For ring or disk-like forgings test metal is provided by increasing the diameter, thickness, or length of the forging. Upset disk or ring forgings, which are worked or extended by forging in a direction perpendicular to the axis of the forging, usually have their principal extension along concentric circles and for such forgings tangential tension specimens are obtained from extra metal on the periphery or end of the forging. For some forgings, such as rotors, radial tension tests are required. In such cases the specimens are cut or trepanned from specified locations.

8.1.3 Cast Steels — Test coupons for castings from which tension test specimens are prepared shall be in accordance with the requirements of Specifications A 703/A 703M or A 781/A 781M, as applicable.

8.2 Size and Tolerances — Test specimens shall be the full thickness or section of material as-rolled, or may be machined to the form and dimensions shown in Figs. 3–6, inclusive. The selection of size and type of specimen is prescribed by the applicable product specification. Full section specimens shall be tested in 8 in. (200 mm) gage length unless otherwise specified in the product specification.

8.3 Procurement of Test Specimens — Specimens shall be sheared, blanked, sawed, trepanned, or oxygen-cut from portions of the material. They are usually machined so as to have a reduced cross section at mid-length in order to obtain uniform distribution of the stress over the cross section and to localize the zone of fracture. When test coupons are sheared, blanked, sawed, or oxygen-cut, care shall be taken to remove by machining all distorted, cold-worked, or heat-affected areas from the edges of the section used in evaluating the test.

8.4 Aging of Test Specimens — Unless otherwise specified, it shall be permissible to age tension test specimens. The time-temperature cycle employed must be such that the effects of previous processing will not be materially changed. It may be accomplished by aging at room temperature 24 to 48 h, or in shorter time at moderately elevated temperatures by boiling in water, heating in oil or in an oven.

8.5 Measurement of Dimensions of Test Specimens:

8.5.1 Standard Rectangular Tension Test Specimens — These forms of specimens are shown in Fig. 3. To determine the cross-sectional area, the center width dimension shall be measured to the nearest 0.005 in. (0.13 mm) for the 8 in. (200 mm) gage length specimen and 0.001 in. (0.025 mm) for the 2 in. (50 mm) gage length specimen in Fig. 3. The center thickness dimension shall be measured to the nearest 0.001 in. for both specimens.

8.5.2 Standard Round Tension Test Specimens — These forms of specimens are shown in Fig. 4 and Fig. 5. To determine the cross-sectional area, the diameter shall be measured at the center of the gage length to the nearest 0.001 in. (0.025 mm) (see Table 1).

8.6 General — Test specimens shall be either substantially full size or machined, as prescribed in the product specifications for the material being tested.

8.6.1 Improperly prepared test specimens often cause unsatisfactory test results. It is important, therefore, that care be exercised in the preparation of specimens, particularly in the machining, to assure good workmanship.

8.6.2 It is desirable to have the cross-sectional area of the specimen smallest at the center of the gage length to ensure fracture within the gage length. This is provided for by the taper in the gage length permitted for each of the specimens described in the following sections.

8.6.3 For brittle materials it is desirable to have fillets of large radius at the ends of the gage length.

9. Plate-Type Specimen

9.1 The standard plate-type test specimen is shown in Fig. 3. This specimen is used for testing metallic materials in the form of plate, structural and bar-size shapes, and flat material having a nominal thickness of $\frac{3}{16}$ in. (5 mm) or over. When product specifications so permit, other types of specimens may be used.

NOTE 3 — When called for in the product specification, the 8 in. gage length specimen of Fig. 3 may be used for sheet and strip material.

10. Sheet-Type Specimen

10.1 The standard sheet-type test specimen is shown in Fig. 3. This specimen is used for testing metallic materials in the form of sheet, plate, flat wire, strip, band, and hoop ranging in nominal thickness from 0.005 to $\frac{3}{4}$ in. (0.13 to 19 mm). When product specifications so permit, other types of specimens may be used, as provided in Section 9 (see Note 3).

11. Round Specimens

11.1 The standard 0.500 in. (12.5 mm) diameter round test specimen shown in Fig. 4 is used quite generally for testing metallic materials, both cast and wrought.

11.2 Fig. 4 also shows small size specimens proportional to the standard specimen. These may be used when it is necessary to test material from which the standard specimen or specimens shown in Fig. 3 cannot be prepared. Other sizes of small round specimens may be used. In any such small size specimen it is important that the gage length for measurement of elongation be four times the diameter of the specimen (see Note 4, Fig. 4).

11.3 The shape of the ends of the specimens outside of the gage length shall be suitable to the material and of a shape to fit the holders or grips of the testing machine so that the loads are applied axially. Fig. 5 shows specimens with various types of ends that have given satisfactory results.

12. Gage Marks

12.1 The specimens shown in Figs. 3–6 shall be gage marked with a center punch, scribe marks, multiple device,

or drawn with ink. The purpose of these gage marks is to determine the percent elongation. Punch marks shall be light, sharp, and accurately spaced. The localization of stress at the marks makes a hard specimen susceptible to starting fracture at the punch marks. The gage marks for measuring elongation after fracture shall be made on the flat or on the edge of the flat tension test specimen and within the parallel section; for the 8 in. gage length specimen, Fig. 3, one or more sets of 8 in. gage marks may be used, intermediate marks within the gage length being optional. Rectangular 2-in. gage length specimens, Fig. 3, and round specimens, Fig. 4, are gage marked with a double-pointed center punch or scribe marks. One or more sets of gage marks may be used; however, one set must be approximately centered in the reduced section. These same precautions shall be observed when the test specimen is full section.

13. Determination of Tensile Properties

13.1 Yield Point — Yield point is the first stress in a material, less than the maximum obtainable stress, at which an increase in strain occurs without an increase in stress. Yield point is intended for application only for materials that may exhibit the unique characteristic of showing an increase in strain without an increase in stress. The stress-strain diagram is characterized by a sharp knee or discontinuity. Determine yield point by one of the following methods:

13.1.1 Drop of the Beam or Halt of the Pointer Method — In this method, apply an increasing load to the specimen at a uniform rate. When a lever and poise machine is used, keep the beam in balance by running out the poise at approximately a steady rate. When the yield point of the material is reached, the increase of the load will stop, but run the poise a trifle beyond the balance position, and the beam of the machine will drop for a brief but appreciable interval of time. When a machine equipped with a load-indicating dial is used there is a halt or hesitation of the load-indicating pointer corresponding to the drop of the beam. Note the load at the “drop of the beam” or the “halt of the pointer” and record the corresponding stress as the yield point.

13.1.2 Autographic Diagram Method — When a sharp-kneed stress-strain diagram is obtained by an autographic recording device, take the stress corresponding to the top of the knee (Fig. 7), or the stress at which the curve drops as the yield point.

13.1.3 Total Extension Under Load Method — When testing material for yield point and the test specimens may not exhibit a well-defined disproportionate deformation that characterizes a yield point as measured by the drop of the beam, halt of the pointer, or autographic

diagram methods described in 13.1.1 and 13.1.2, a value equivalent to the yield point in its practical significance may be determined by the following method and may be recorded as yield point: Attach a Class C or better extensometer (Note 4 and Note 5) to the specimen. When the load producing a specified extension (Note 6) is reached record the stress corresponding to the load as the yield point (Fig. 8).

NOTE 4 — Automatic devices are available that determine the load at the specified total extension without plotting a stress-strain curve. Such devices may be used if their accuracy has been demonstrated. Multiplying calipers and other such devices are acceptable for use provided their accuracy has been demonstrated as equivalent to a Class C extensometer.

NOTE 5 — Reference should be made to Practice E 83.

NOTE 6 — For steel with a yield point specified not over 80 000 psi (550 MPa), an appropriate value is 0.005 in./in. of gage length. For values above 80 000 psi, this method is not valid unless the limiting total extension is increased.

NOTE 7 — The shape of the initial portion of an autographically determined stress-strain (or a load-elongation) curve may be influenced by numerous factors such as the seating of the specimen in the grips, the straightening of a specimen bent due to residual stresses, and the rapid loading permitted in 7.4.1. Generally, the aberrations in this portion of the curve should be ignored when fitting a modulus line, such as that used to determine the extension-under-load yield, to the curve.

13.2 Yield Strength — Yield strength is the stress at which a material exhibits a specified limiting deviation from the proportionality of stress to strain. The deviation is expressed in terms of strain, percent offset, total extension under load, etc. Determine yield strength by one of the following methods:

13.2.1 Offset Method — To determine the yield strength by the “offset method,” it is necessary to secure data (autographic or numerical) from which a stress-strain diagram with a distinct modulus characteristic of the material being tested may be drawn. Then on the stress-strain diagram (Fig. 9) lay off Om equal to the specified value of the offset, draw mn parallel to OA , and thus locate r , the intersection of mn with the stress-strain curve corresponding to load R , which is the yield-strength load. In recording values of yield strength obtained by this method, the value of offset specified or used, or both, shall be stated in parentheses after the term yield strength, for example:

$$\text{Yield strength (0.2\% offset)} = 52\,000 \text{ psi (360 MPa)} \quad (1)$$

When the offset is 0.2% or larger, the extensometer used shall qualify as a Class B2 device over a strain range of 0.05 to 1.0%. If a smaller offset is specified, it may be necessary to specify a more accurate device (that is, a Class B1 device) or reduce the lower limit of the strain range (for example, to 0.01%) or both. See also Note 9 for automatic devices.

NOTE 8 — For stress-strain diagrams not containing a distinct modulus, such as for some cold-worked materials, it is recommended that the extension under load method be utilized. If the offset method is used for materials without a distinct modulus, a modulus value appropriate for the material being tested should be used: 30 000 000 psi (207 000 MPa) for carbon steel; 29 000 000 psi (200 000 MPa) for ferritic stainless steel; 28 000 000 psi (193 000 MPa) for austenitic stainless steel. For special alloys, the producer should be contacted to discuss appropriate modulus values.

13.2.2 Extension Under Load Method — For tests to determine the acceptance or rejection of material whose stress-strain characteristics are well known from previous tests of similar material in which stress-strain diagrams were plotted, the total strain corresponding to the stress at which the specified offset (see Note 9 and Note 10) occurs will be known within satisfactory limits. The stress on the specimen, when this total strain is reached, is the value of the yield strength. In recording values of yield strength obtained by this method, the value of “extension” specified or used, or both, shall be stated in parentheses after the term yield strength, for example:

$$\text{Yield strength (0.5\% EUL)} = 52\,000 \text{ psi (360 MPa)} \quad (2)$$

The total strain can be obtained satisfactorily by use of a Class B1 extensometer (Note 4, Note 5, and Note 7).

NOTE 9 — Automatic devices are available that determine offset yield strength without plotting a stress-strain curve. Such devices may be used if their accuracy has been demonstrated.

NOTE 10 — The appropriate magnitude of the extension under load will obviously vary with the strength range of the particular steel under test. In general, the value of extension under load applicable to steel at any strength level may be determined from the sum of the proportional strain and the plastic strain expected at the specified yield strength. The following equation is used:

$$\text{Extension under load, in./in. of gage length} = (YS/E) + r \quad (3)$$

where:

YS = specified yield strength, psi or MPa,
 E = modulus of elasticity, psi or MPa, and
 r = limiting plastic strain, in./in.

13.3 Tensile Strength — Calculate the tensile strength by dividing the maximum load the specimen sustains during a tension test by the original cross-sectional area of the specimen.

13.4 Elongation:

13.4.1 Fit the ends of the fractured specimen together carefully and measure the distance between the gage marks to the nearest 0.01 in. (0.25 mm) for gage lengths of 2 in. and under, and to the nearest 0.5% of the gage length for gage lengths over 2 in. A percentage scale reading to 0.5% of the gage length may be used. The elongation is the increase in length of the gage length, expressed as a percentage of the original gage length. In recording elongation values, give both the percentage increase and the original gage length.

13.4.2 If any part of the fracture takes place outside of the middle half of the gage length or in a punched or scribed mark within the reduced section, the elongation value obtained may not be representative of the material. If the elongation so measured meets the minimum requirements specified, no further testing is indicated, but if the elongation is less than the minimum requirements, discard the test and retest.

13.4.3 Automated tensile testing methods using extensometers allow for the measurement of elongation in a method described below. Elongation may be measured and reported either this way, or as in the method described above, fitting the broken ends together. Either result is valid.

13.4.4 Elongation at fracture is defined as the elongation measured just prior to the sudden decrease in force associated with fracture. For many ductile materials not exhibiting a sudden decrease in force, the elongation at fracture can be taken as the strain measured just prior to when the force falls below 10% of the maximum force encountered during the test.

13.4.4.1 Elongation at fracture shall include elastic and plastic elongation and may be determined with autographic or automated methods using extensometers verified over the strain range of interest. Use a class B2 or better extensometer for materials having less than 5% elongation; a class C or better extensometer for materials having elongation greater than or equal to 5% but less than 50%; and a class D or better extensometer for materials having 50% or greater elongation. In all cases, the extensometer gage length shall be the nominal gage length required for the specimen being tested. Due to the lack of precision in fitting fractured ends together, the elongation after fracture using the manual methods of the preceding paragraphs may differ from the elongation at fracture determined with extensometers.

13.4.4.2 Percent elongation at fracture may be calculated directly from elongation at fracture data and be reported instead of percent elongation as calculated in 13.4.1. However, these two parameters are not interchangeable. Use of the elongation at fracture method generally provides more repeatable results.

13.5 Reduction of Area — Fit the ends of the fractured specimen together and measure the mean diameter or the width and thickness at the smallest cross section to the same accuracy as the original dimensions. The difference between the area thus found and the area of the original cross section expressed as a percentage of the original area is the reduction of area.

BEND TEST

14. Description

14.1 The bend test is one method for evaluating ductility, but it cannot be considered as a quantitative means of predicting service performance in bending operations. The severity of the bend test is primarily a function of the angle of bend and inside diameter to which the specimen is bent, and of the cross section of the specimen. These conditions are varied according to location and orientation of the test specimen and the chemical composition, tensile properties, hardness, type, and quality of the steel specified. Test Method E 190 and Test Method E 290 may be consulted for methods of performing the test.

14.2 Unless otherwise specified, it shall be permissible to age bend test specimens. The time-temperature cycle employed must be such that the effects of previous processing will not be materially changed. It may be accomplished by aging at room temperature 24 to 48 h, or in shorter time at moderately elevated temperatures by boiling in water or by heating in oil or in an oven.

14.3 Bend the test specimen at room temperature to an inside diameter, as designated by the applicable product specifications, to the extent specified without major cracking on the outside of the bent portion. The speed of bending is ordinarily not an important factor.

HARDNESS TEST

15. General

15.1 A hardness test is a means of determining resistance to penetration and is occasionally employed to obtain a quick approximation of tensile strength. Table 2, Table 3, Table 4, and Table 5 are for the conversion of hardness measurements from one scale to another or to approximate tensile strength. These conversion values have been obtained from computer-generated curves and are presented to the nearest 0.1 point to permit accurate reproduction of those curves. Since all converted hardness values must be considered approximate, however, all converted Rockwell hardness numbers shall be rounded to the nearest whole number.

15.2 Hardness Testing:

15.2.1 If the product specification permits alternative hardness testing to determine conformance to a specified hardness requirement, the conversions listed in Table 2, Table 3, Table 4, and Table 5 shall be used.

15.2.2 When recording converted hardness numbers, the measured hardness and test scale shall be indicated in parentheses, for example: 353 HB (38 HRC). This means that a hardness value of 38 was obtained using the Rockwell C scale and converted to a Brinell hardness of 353.

16. Brinell Test

16.1 Description:

16.1.1 A specified load is applied to a flat surface of the specimen to be tested, through a hard ball of specified diameter. The average diameter of the indentation is used as a basis for calculation of the Brinell hardness number. The quotient of the applied load divided by the area of the surface of the indentation, which is assumed to be spherical, is termed the Brinell hardness number (HB) in accordance with the following equation:

$$HB = P/[(\pi D/2)(D - \sqrt{D^2 - d^2})] \quad (4)$$

where:

HB = Brinell hardness number,

P = applied load, kgf,

D = diameter of the steel ball, mm, and

d = average diameter of the indentation, mm.

NOTE 11 — The Brinell hardness number is more conveniently secured from standard tables such as Table 6, which show numbers corresponding to the various indentation diameters, usually in increments of 0.05 mm.

NOTE 12 — In Test Method E 10 the values are stated in SI units, whereas in this section kgf/mm units are used.

16.1.2 The standard Brinell test using a 10 mm ball employs a 3000 kgf load for hard materials and a 1500 or 500 kgf load for thin sections or soft materials (see Annex A2 on Steel Tubular Products). Other loads and different size indentors may be used when specified. In recording hardness values, the diameter of the ball and the load must be stated except when a 10 mm ball and 3000 kgf load are used.

16.1.3 A range of hardness can properly be specified only for quenched and tempered or normalized and tempered material. For annealed material a maximum figure only should be specified. For normalized material a minimum or a maximum hardness may be specified by agreement. In general, no hardness requirements should be applied to untreated material.

16.1.4 Brinell hardness may be required when tensile properties are not specified.

16.2 Apparatus — Equipment shall meet the following requirements:

16.2.1 Testing Machine — A Brinell hardness testing machine is acceptable for use over a loading range within which its load measuring device is accurate to $\pm 1\%$.

16.2.2 Measuring Microscope — The divisions of the micrometer scale of the microscope or other measuring devices used for the measurement of the diameter of the indentations shall be such as to permit the direct measurement of the diameter to 0.1 mm and the estimation of the diameter to 0.05 mm.

NOTE 13 — This requirement applies to the construction of the microscope only and is not a requirement for measurement of the indentation, see 16.4.3.

16.2.3 Standard Ball — The standard ball for Brinell hardness testing is 10 mm (0.3937 in.) in diameter with a deviation from this value of not more than 0.005 mm (0.0004 in.) in any diameter. A ball suitable for use must not show a permanent change in diameter greater than 0.01 mm (0.0004 in.) when pressed with a force of 3000 kgf against the test specimen.

16.3 Test Specimen — Brinell hardness tests are made on prepared areas and sufficient metal must be removed from the surface to eliminate decarburized metal and other surface irregularities. The thickness of the piece tested must be such that no bulge or other marking showing the effect of the load appears on the side of the piece opposite the indentation.

16.4 Procedure:

16.4.1 It is essential that the applicable product specifications state clearly the position at which Brinell hardness indentations are to be made and the number of such indentations required. The distance of the center of the indentation from the edge of the specimen or edge of another indentation must be at least two and one-half times the diameter of the indentation.

16.4.2 Apply the load for a minimum of 15 s.

16.4.3 Measure two diameters of the indentation at right angles to the nearest 0.1 mm, estimate to the nearest 0.05 mm, and average to the nearest 0.05 mm. If the two diameters differ by more than 0.1 mm, discard the readings and make a new indentation.

16.4.4 Do not use a steel ball on steels having a hardness over 450 HB nor a carbide ball on steels having a hardness over 650 HB. The Brinell hardness test is not recommended for materials having a hardness over 650 HB.

16.4.4.1 If a ball is used in a test of a specimen which shows a Brinell hardness number greater than the limit for the ball as detailed in 16.4.4, the ball shall be either discarded and replaced with a new ball or remeasured to ensure conformance with the requirements of Test Method E 10.

16.5 Detailed Procedure — For detailed requirements of this test, reference shall be made to the latest revision of Test Method E 10.

17. Rockwell Test

17.1 Description:

17.1.1 In this test a hardness value is obtained by determining the depth of penetration of a diamond point

or a steel ball into the specimen under certain arbitrarily fixed conditions. A minor load of 10 kgf is first applied which causes an initial penetration, sets the penetrator on the material and holds it in position. A major load which depends on the scale being used is applied increasing the depth of indentation. The major load is removed and, with the minor load still acting, the Rockwell number, which is proportional to the difference in penetration between the major and minor loads is determined; this is usually done by the machine and shows on a dial, digital display, printer, or other device. This is an arbitrary number which increases with increasing hardness. The scales most frequently used are as follows:

Scale Symbol	Penetrator	Major Load, kgf	Minor Load, kgf
B	$\frac{1}{16}$ in. steel ball	100	10
C	Diamond brale	150	10

17.1.2 Rockwell superficial hardness machines are used for the testing of very thin steel or thin surface layers. Loads of 15, 30, or 45 kgf are applied on a hardened steel ball or diamond penetrator, to cover the same range of hardness values as for the heavier loads. The superficial hardness scales are as follows:

Scale Symbol	Penetrator	Major Load, kgf	Minor Load, kgf
15T	$\frac{1}{16}$ in. steel ball	15	3
30T	$\frac{1}{16}$ in. steel ball	30	3
45T	$\frac{1}{16}$ in. steel ball	45	3
15N	Diamond brale	15	3
30N	Diamond brale	30	3
45N	Diamond brale	45	3

17.2 Reporting Hardness — In recording hardness values, the hardness number shall always precede the scale symbol, for example: 96 HRB, 40 HRC, 75 HR15N, or 77 HR30T.

17.3 Test Blocks — Machines should be checked to make certain they are in good order by means of standardized Rockwell test blocks.

17.4 Detailed Procedure — For detailed requirements of this test, reference shall be made to the latest revision of Test Methods E 18.

18. Portable Hardness Test

18.1 Although the use of the standard, stationary Brinell or Rockwell hardness tester is generally preferred, it is not always possible to perform the hardness test using such equipment due to the part size or location. In this event, hardness testing using portable equipment as described in Practice A 833 or Test Method E 110 shall be used.

CHARPY IMPACT TESTING

19. Summary

19.1 A Charpy V-notch impact test is a dynamic test in which a notched specimen is struck and broken by a single blow in a specially designed testing machine. The measured test values may be the energy absorbed, the percentage shear fracture, the lateral expansion opposite the notch, or a combination thereof.

19.2 Testing temperatures other than room (ambient) temperature often are specified in product or general requirement specifications (hereinafter referred to as the specification). Although the testing temperature is sometimes related to the expected service temperature, the two temperatures need not be identical.

20. Significance and Use

20.1 Ductile vs. Brittle Behavior — Body-centered-cubic or ferritic alloys exhibit a significant transition in behavior when impact tested over a range of temperatures. At temperatures above transition, impact specimens fracture by a ductile (usually microvoid coalescence) mechanism, absorbing relatively large amounts of energy. At lower temperatures, they fracture in a brittle (usually cleavage) manner absorbing less energy. Within the transition range, the fracture will generally be a mixture of areas of ductile fracture and brittle fracture.

20.2 The temperature range of the transition from one type of behavior to the other varies according to the material being tested. This transition behavior may be defined in various ways for specification purposes.

20.2.1 The specification may require a minimum test result for absorbed energy, fracture appearance, lateral expansion, or a combination thereof, at a specified test temperature.

20.2.2 The specification may require the determination of the transition temperature at which either the absorbed energy or fracture appearance attains a specified level when testing is performed over a range of temperatures.

20.3 Further information on the significance of impact testing appears in Annex A5.

21. Apparatus

21.1 Testing Machines:

21.1.1 A Charpy impact machine is one in which a notched specimen is broken by a single blow of a freely swinging pendulum. The pendulum is released from a fixed height. Since the height to which the pendulum is raised prior to its swing, and the mass of the pendulum are known,

the energy of the blow is predetermined. A means is provided to indicate the energy absorbed in breaking the specimen.

21.1.2 The other principal feature of the machine is a fixture (See Fig. 10) designed to support a test specimen as a simple beam at a precise location. The fixture is arranged so that the notched face of the specimen is vertical. The pendulum strikes the other vertical face directly opposite the notch. The dimensions of the specimen supports and striking edge shall conform to Fig. 10.

21.1.3 Charpy machines used for testing steel generally have capacities in the 220 to 300 ft•lbf (300 to 400 J) energy range. Sometimes machines of lesser capacity are used; however, the capacity of the machine should be substantially in excess of the absorbed energy of the specimens (see Test Methods E 23). The linear velocity at the point of impact should be in the range of 16 to 19 ft/s (4.9 to 5.8 m/s).

21.2 Temperature Media:

21.2.1 For testing at other than room temperature, it is necessary to condition the Charpy specimens in media at controlled temperatures.

21.2.2 Low temperature media usually are chilled fluids (such as water, ice plus water, dry ice plus organic solvents, or liquid nitrogen) or chilled gases.

21.2.3 Elevated temperature media are usually heated liquids such as mineral or silicone oils. Circulating air ovens may be used.

21.3 Handling Equipment — Tongs, especially adapted to fit the notch in the impact specimen, normally are used for removing the specimens from the medium and placing them on the anvil (refer to Test Methods E 23). In cases where the machine fixture does not provide for automatic centering of the test specimen, the tongs may be precision machined to provide centering.

22. Sampling and Number of Specimens

22.1 Sampling:

22.1.1 Test location and orientation should be addressed by the specifications. If not, for wrought products, the test location shall be the same as that for the tensile specimen and the orientation shall be longitudinal with the notch perpendicular to the major surface of the product being tested.

22.1.2 Number of Specimens.

22.1.2.1 A Charpy impact test consists of all specimens taken from a single test coupon or test location.

22.1.2.2 When the specification calls for a minimum average test result, three specimens shall be tested.

22.1.2.3 When the specification requires determination of a transition temperature, eight to twelve specimens are usually needed.

22.2 Type and Size:

22.2.1 Use a standard full size Charpy V-notch specimen (Type A) as shown in Fig. 11, except as allowed in 22.2.2.

22.2.2 Subsize Specimens.

22.2.2.1 For flat material less than $\frac{7}{16}$ in. (11 mm) thick, or when the absorbed energy is expected to exceed 80% of full scale, use standard subsize test specimens.

22.2.2.2 For tubular materials tested in the transverse direction, where the relationship between diameter and wall thickness does not permit a standard full size specimen, use standard subsize test specimens or standard size specimens containing outer diameter (OD) curvature as follows:

(1) Standard size specimens and subsize specimens may contain the original OD surface of the tubular product as shown in Fig. 12. All other dimensions shall comply with the requirements of Fig. 11.

NOTE 14 — For materials with toughness levels in excess of about 50 ft-lbs, specimens containing the original OD surface may yield values in excess of those resulting from the use of conventional Charpy specimens.

22.2.2.3 If a standard full-size specimen cannot be prepared, the largest feasible standard subsize specimen shall be prepared. The specimens shall be machined so that the specimen does not include material nearer to the surface than 0.020 in. (0.5 mm).

22.2.2.4 Tolerances for standard subsize specimens are shown in Fig. 11. Standard subsize test specimen sizes are: 10 × 7.5 mm, 10 × 6.7 mm, 10 × 5 mm, 10 × 3.3 mm, and 10 × 2.5 mm.

22.2.2.5 Notch the narrow face of the standard subsize specimens so that the notch is perpendicular to the 10 mm wide face.

22.3 Notch Preparation — The machining of the notch is critical, as it has been demonstrated that extremely minor variations in notch radius and profile, or tool marks at the bottom of the notch may result in erratic test data. (See Annex A5).

23. Calibration

23.1 Accuracy and Sensitivity — Calibrate and adjust Charpy impact machines in accordance with the requirements of Test Methods E 23.

24. Conditioning — Temperature Control

24.1 When a specific test temperature is required by the specification or purchaser, control the temperature of

the heating or cooling medium within $\pm 2^\circ\text{F}$ (1°C) because the effect of variations in temperature on Charpy test results can be very great.

NOTE 15 — For some steels there may not be a need for this restricted temperature, for example, austenitic steels.

NOTE 16 — Because the temperature of a testing laboratory often varies from 60 to 90°F (15 to 32°C) a test conducted at “room temperature” might be conducted at any temperature in this range.

25. Procedure

25.1 Temperature:

25.1.1 Condition the specimens to be broken by holding them in the medium at test temperature for at least 5 min in liquid media and 30 min in gaseous media.

25.1.2 Prior to each test, maintain the tongs for handling test specimens at the same temperature as the specimen so as not to affect the temperature at the notch.

25.2 Positioning and Breaking Specimens:

25.2.1 Carefully center the test specimen in the anvil and release the pendulum to break the specimen.

25.2.2 If the pendulum is not released within 5 s after removing the specimen from the conditioning medium, do not break the specimen. Return the specimen to the conditioning medium for the period required in 25.1.1.

25.3 Recovering Specimens — In the event that fracture appearance or lateral expansion must be determined, recover the matched pieces of each broken specimen before breaking the next specimen.

25.4 Individual Test Values:

25.4.1 Impact energy — Record the impact energy absorbed to the nearest ft•lbf (J).

25.4.2 Fracture Appearance:

25.4.2.1 Determine the percentage of shear fracture area by any of the following methods:

(1) Measure the length and width of the brittle portion of the fracture surface, as shown in Fig. 13 and determine the percent shear area from either Table 7 or Table 8 depending on the units of measurement.

(2) Compare the appearance of the fracture of the specimen with a fracture appearance chart as shown in Fig. 14.

(3) Magnify the fracture surface and compare it to a precalibrated overlay chart or measure the percent shear fracture area by means of a planimeter.

(4) Photograph the fractured surface at a suitable magnification and measure the percent shear fracture area by means of a planimeter.

25.4.2.2 Determine the individual fracture appearance values to the nearest 5% shear fracture and record the value.

25.4.3 Lateral Expansion:

25.4.3.1 Lateral expansion is the increase in specimen width, measured in thousandths of an inch (mils), on the compression side, opposite the notch of the fractured Charpy V-notch specimen as shown in Fig. 15.

25.4.3.2 Examine each specimen half to ascertain that the protrusions have not been damaged by contacting the anvil, machine mounting surface, and so forth. Discard such samples since they may cause erroneous readings.

25.4.3.3 Check the sides of the specimens perpendicular to the notch to ensure that no burrs were formed on the sides during impact testing. If burrs exist, remove them carefully by rubbing on emery cloth or similar abrasive surface, making sure that the protrusions being measured are not rubbed during the removal of the burr.

25.4.3.4 Measure the amount of expansion on each side of each half relative to the plane defined by the undeformed portion of the side of the specimen using a gage similar to that shown in Fig. 16 and Fig. 17.

25.4.3.5 Since the fracture path seldom bisects the point of maximum expansion on both sides of a specimen, the sum of the larger values measured for each side is the value of the test. Arrange the halves of one specimen so that compression sides are facing each other. Using the gage, measure the protrusion on each half specimen, ensuring that the same side of the specimen is measured. Measure the two broken halves individually. Repeat the procedure to measure the protrusions on the opposite side of the specimen halves. The larger of the two values for each side is the expansion of that side of the specimen.

25.4.3.6 Measure the individual lateral expansion values to the nearest mil (0.025 mm) and record the values.

25.4.3.7 With the exception described as follows, any specimen that does not separate into two pieces when struck by a single blow shall be reported as unbroken. If the specimen can be separated by force applied by bare hands, the specimen may be considered as having been separated by the blow.

26. Interpretation of Test Result

26.1 When the acceptance criterion of any impact test is specified to be a minimum average value at a given temperature, the test result shall be the average (arithmetic mean) of the individual test values of three specimens from one test location.

26.1.1 When a minimum average test result is specified:

26.1.1.1 The test result is acceptable when all of the below are met:

(1) The test result equals or exceeds the specified minimum average (given in the specification),

(2) The individual test value for not more than one specimen measures less than the specified minimum average, and

(3) The individual test value for any specimen measures not less than two-thirds of the specified minimum average.

26.1.1.2 If the acceptance requirements of 26.1.1.1 are not met, perform one retest of three additional specimens from the same test location. Each individual test value of the retested specimens shall be equal to or greater than the specified minimum average value.

26.2 Test Specifying a Minimum Transition Temperature:

26.2.1 Definition of Transition Temperature — For specification purposes, the transition temperature is the temperature at which the designated material test value equals or exceeds a specified minimum test value.

26.2.2 Determination of Transition Temperature:

26.2.2.1 Break one specimen at each of a series of temperatures above and below the anticipated transition temperature using the procedures in Section 25. Record each test temperature to the nearest 1°F (0.5°C).

26.2.2.2 Plot the individual test results (ft•lbf or percent shear) as the ordinate versus the corresponding test temperature as the abscissa and construct a best-fit curve through the plotted data points.

26.2.2.3 If transition temperature is specified as the temperature at which a test value is achieved, determine the temperature at which the plotted curve intersects the specified test value by graphical interpolation (extrapolation is not permitted). Record this transition temperature to the nearest 5°F (3°C). If the tabulated test results clearly indicate a transition temperature lower than specified, it is not necessary to plot the data. Report the lowest test temperature for which test value exceeds the specified value.

26.2.2.4 Accept the test result if the determined transition temperature is equal to or lower than the specified value.

26.2.2.5 If the determined transition temperature is higher than the specified value, but not more than 20°F (12°C) higher than the specified value, test sufficient samples in accordance with Section 25 to plot two additional curves. Accept the test results if the temperatures determined from both additional tests are equal to or lower than the specified value.

26.3 When subsize specimens are permitted or necessary, or both, modify the specified test requirement according to Table 9 or test temperature according to ASME Boiler and Pressure Vessel Code, Table UG-84.2, or both. Greater energies or lower test temperatures may be agreed upon by purchaser and supplier.

27. Records

27.1 The test record should contain the following information as appropriate:

27.1.1 Full description of material tested (that is, specification number, grade, class or type, size, heat number).

27.1.2 Specimen orientation with respect to the material axis.

27.1.3 Specimen size.

27.1.4 Test temperature and individual test value for each specimen broken, including initial tests and retests.

27.1.5 Test results.

27.1.6 Transition temperature and criterion for its determination, including initial tests and retests.

28. Report

28.1 The specification should designate the information to be reported.

29. Keywords

29.1 bend test; Brinell hardness; Charpy impact test; elongation; FATT (Fracture Appearance Transition Temperature); hardness test; portable hardness; reduction of area; Rockwell hardness; tensile strength; tension test; yield strength

FIG. 1 THE RELATION OF TEST COUPONS AND TEST SPECIMENS TO ROLLING DIRECTION OR EXTENSION
(APPLICABLE TO GENERAL WROUGHT PRODUCTS)

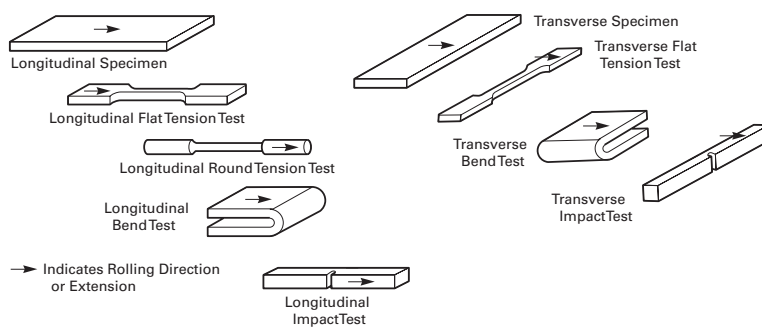


FIG. 2 LOCATION OF LONGITUDINAL TENSION TEST SPECIMENS
IN RINGS CUT FROM TUBULAR PRODUCTS

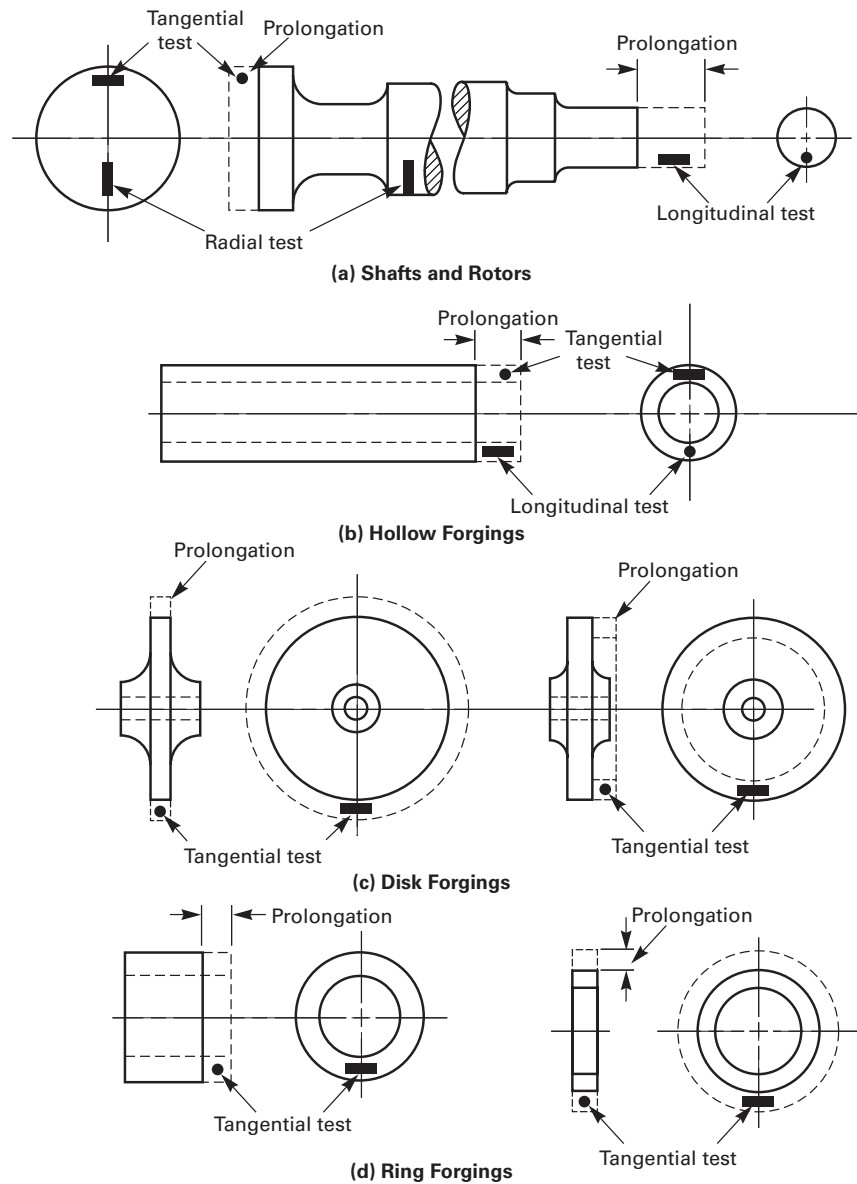
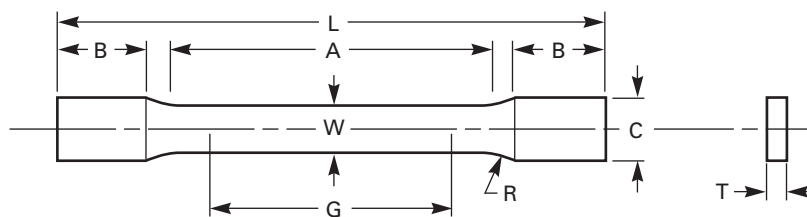


FIG. 3 RECTANGULAR TENSION TEST SPECIMENS



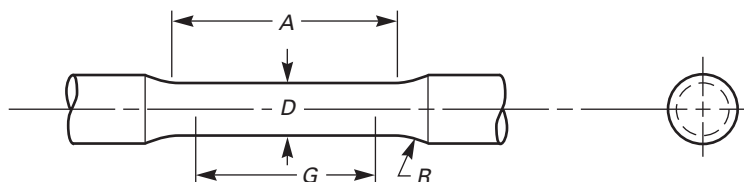
DIMENSIONS

	Standard Specimens				Subsize Specimen	
	Plate-Type, 1½ in. Wide		Sheet-Type, ½ in. Wide		¼ in. Wide	
	in.	mm	in.	mm	in.	mm
G —Gage length (Notes 1 and 2)	8.00 ± 0.01	200 ± 0.25	2.000 ± 0.005	50.0 ± 0.10	1.000 ± 0.003	25.0 ± 0.08
W —Width (Notes 3, 5, and 6)	1½ + ⅛ – ¼	40 + 3 – 6	0.500 ± 0.010	12.5 ± 0.25	0.250 ± 0.002	6.25 ± 0.05
T —Thickness (Note 7)			thickness of material			
R —Radius of fillet, min (Note 4)	½	13	½	13	¼	6
L —Over-all length, min (Notes 2 and 8)	18	450	8	200	4	100
A —Length of reduced section, min	9	225	2¼	60	1¼	32
B —Length of grip section, min (Note 9)	3	75	2	50	1¼	32
C —Width of grip section, approximate (Notes 4, 10, and 11)	2	50	¾	20	⅜	10

NOTES:

- (1) For the 1½ in. (40 mm) wide specimen, punch marks for measuring elongation after fracture shall be made on the flat or on the edge of the specimen and within the reduced section. Either a set of nine or more punch marks 1 in. (25 mm) apart, or one or more pairs of punch marks 8 in. (200 mm) apart may be used.
- (2) For the ½ in. (12.5 mm) wide specimen, gage marks for measuring the elongation after fracture shall be made on the ½ in. (12.5 mm) face or on the edge of the specimen and within the reduced section. Either a set of three or more marks 1.0 in. (25 mm) apart or one or more pairs of marks 2 in. (50 mm) apart may be used.
- (3) For the three sizes of specimens, the ends of the reduced section shall not differ in width by more than 0.004, 0.002 or 0.001 in. (0.10, 0.05 or 0.025 mm), respectively. Also, there may be a gradual decrease in width from the ends to the center, but the width at either end shall not be more than 0.015 in., 0.005 in., or 0.003 in. (0.40, 0.10 or 0.08 mm), respectively, larger than the width at the center.
- (4) For each specimen type, the radii of all fillets shall be equal to each other with a tolerance of 0.05 in. (1.25 mm), and the centers of curvature of the two fillets at a particular end shall be located across from each other (on a line perpendicular to the centerline) within a tolerance of 0.10 in. (2.5 mm).
- (5) For each of the three sizes of specimens, narrower widths (W and C) may be used when necessary. In such cases the width of the reduced section should be as large as the width of the material being tested permits; however, unless stated specifically, the requirements for elongation in a product specification shall not apply when these narrower specimens are used. If the width of the material is less than W , the sides may be parallel throughout the length of the specimen.
- (6) The specimen may be modified by making the sides parallel throughout the length of the specimen, the width and tolerances being the same as those specified above. When necessary a narrower specimen may be used, in which case the width should be as great as the width of the material being tested permits. If the width is 1½ in. (38 mm) or less, the sides may be parallel throughout the length of the specimen.
- (7) The dimension T is the thickness of the test specimen as provided for in the applicable material specifications. Minimum nominal thickness of 1½ in. (40 mm) wide specimens shall be ⅜ in. (5 mm), except as permitted by the product specification. Maximum nominal thickness of ½ in. (12.5 mm) and ¼ in. (6 mm) wide specimens shall be ¾ in. (19 mm) and ¼ in. (6 mm), respectively.
- (8) To aid in obtaining axial loading during testing of ¼ in. (6 mm) wide specimens, the overall length should be as the material will permit.
- (9) It is desirable, if possible, to make the length of the grip section large enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips. If the thickness of ½ in. (13 mm) wide specimens is over ⅜ in. (10 mm), longer grips and correspondingly longer grip sections of the specimen may be necessary to prevent failure in the grip section.
- (10) For standard sheet-type specimens and subsize specimens the ends of the specimen shall be symmetrical with the center line of the reduced section within 0.01 and 0.005 in. (0.25 and 0.13 mm), respectively. However, for steel if the ends of the ½ in. (12.5 mm) wide specimen are symmetrical within 0.05 in. (1.0 mm) a specimen may be considered satisfactory for all but referee testing.
- (11) For standard plate-type specimens the ends of the specimen shall be symmetrical with the center line of the reduced section within 0.25 in. (6.35 mm) except for referee testing in which case the ends of the specimen shall be symmetrical with the center line of the reduced section within 0.10 in. (2.5 mm).

FIG. 4 STANDARD 0.500 IN. (12.5 MM) ROUND TENSION TEST SPECIMEN WITH 2 IN. (50 MM) GAGE LENGTH AND EXAMPLES OF SMALL-SIZE SPECIMENS PROPORTIONAL TO THE STANDARD SPECIMENS



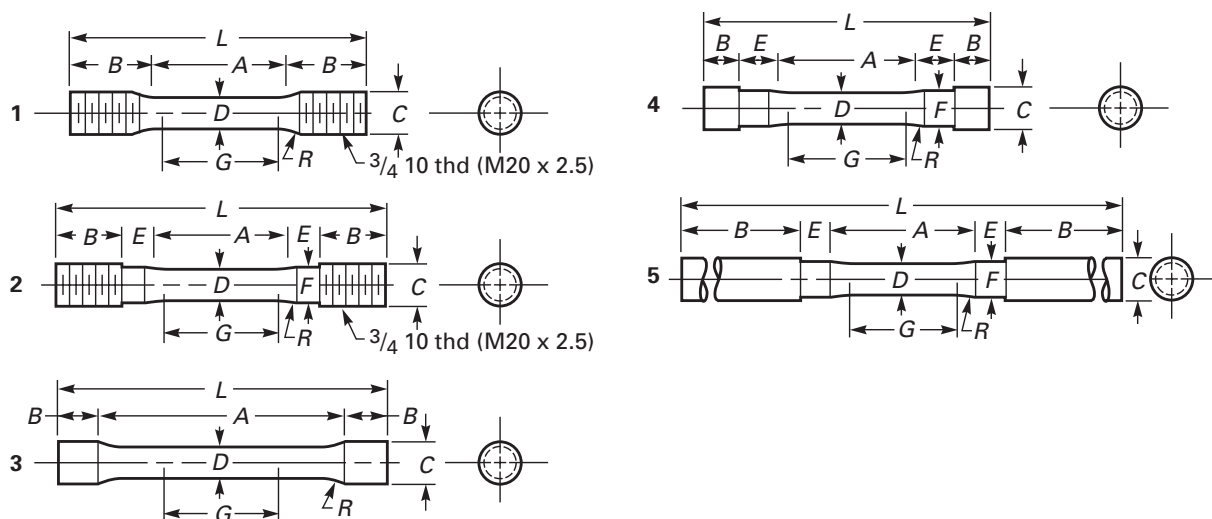
DIMENSIONS

	Standard Specimen		Small-Size Specimens Proportional to Standard							
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
Nominal Diameter	0.500	12.5	0.350	8.75	0.250	6.25	0.160	4.00	0.113	2.50
G—Gage length	2.00± 0.005	50.0± 0.10	1.400± 0.005	35.0± 0.10	1.000± 0.005	25.0± 0.10	0.640± 0.005	16.0± 0.10	0.450± 0.005	10.0± 0.10
D—Diameter (Note 1)	0.500± 0.010	12.5± 0.25	0.350± 0.007	8.75± 0.18	0.250± 0.005	6.25± 0.12	0.160± 0.003	4.00± 0.08	0.113± 0.002	2.50± 0.05
R—Radius of fillet, min	$\frac{3}{8}$	10	$\frac{1}{4}$	6	$\frac{3}{16}$	5	$\frac{5}{32}$	4	$\frac{3}{32}$	2
A—Length of reduced section, min (Note 2)	$2\frac{1}{4}$	60	$1\frac{3}{4}$	45	$1\frac{1}{4}$	32	$\frac{3}{4}$	20	$\frac{5}{8}$	16

NOTES:

- (1) The reduced section may have a gradual taper from the ends toward the center, with the ends not more than 1 percent larger in diameter than the center (controlling dimension).
- (2) If desired, the length of the reduced section may be increased to accommodate an extensometer of any convenient gage length. Reference marks for the measurement of elongation should, nevertheless, be spaced at the indicated gage length.
- (3) The gage length and fillets shall be as shown, but the ends may be of any form to fit the holders of the testing machine in such a way that the load shall be axial (see Fig. 9). If the ends are to be held in wedge grips it is desirable, if possible, to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.
- (4) On the round specimens in Fig. 5 and Fig. 6, the gage lengths are equal to four times the nominal diameter. In some product specifications other specimens may be provided for, but unless the 4-to-1 ratio is maintained within dimensional tolerances, the elongation values may not be comparable with those obtained from the standard test specimen.
- (5) The use of specimens smaller than 0.250 in. (6.25 mm) diameter shall be restricted to cases when the material to be tested is of insufficient size to obtain larger specimens or when all parties agree to their use for acceptance testing. Smaller specimens require suitable equipment and greater skill in both machining and testing.
- (6) Five sizes of specimens often used have diameters of approximately 0.505, 0.357, 0.252, 0.160, and 0.113 in., the reason being to permit easy calculations of stress from loads, since the corresponding cross sectional areas are equal or close to 0.200, 0.100, 0.0500, 0.0200, and 0.0100 in.², respectively. Thus, when the actual diameters agree with these values, the stresses (or strengths) may be computed using the simple multiplying factors 5, 10, 20, 50, and 100, respectively. (The metric equivalents of these fixed diameters do not result in correspondingly convenient cross sectional area and multiplying factors.)

FIG. 5 SUGGESTED TYPES OF ENDS FOR STANDARD ROUND TENSION TEST SPECIMENS



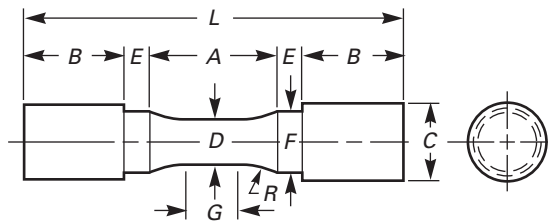
DIMENSIONS

	Specimen 1		Specimen 2		Specimen 3		Specimen 4		Specimen 5	
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
G—Gage length	2.000± 0.005	50.0± 0.10	2.000± 0.005	50.0± 0.10	2.000± 0.005	50.0± 0.10	2.000± 0.005	50.0± 0.10	2.00± 0.005	50.0± 0.10
D—Diameter (Note 1)	0.500± 0.010	12.5± 0.25	0.500± 0.010	12.5± 0.25	0.500± 0.010	12.5± 0.25	0.500± 0.010	12.5± 0.25	0.500± 0.010	12.5± 0.25
R—Radius of fillet, min	$\frac{3}{8}$	10	$\frac{3}{8}$	10	$\frac{1}{16}$	2	$\frac{3}{8}$	10	$\frac{3}{8}$	10
A—Length of reduced section	$2\frac{1}{4}$, min	60, min	$2\frac{1}{4}$, min	60, min	4, ap- proxi- mately	100, ap- proxi- mately	$2\frac{1}{4}$, min	60, min	$2\frac{1}{4}$, min	60, min
L—Overall length, approximate	5	125	$5\frac{1}{2}$	140	$5\frac{1}{2}$	140	$4\frac{3}{4}$	120	$9\frac{1}{2}$	240
B—Grip section (Note 2)	$1\frac{3}{8}$, ap- proxi- mately	35, ap- proxi- mately	1, ap- proxi- mately	25, ap- proxi- mately	$\frac{3}{4}$, ap- proxi- mately	20, ap- proxi- mately	$\frac{1}{2}$, ap- proxi- mately	13, ap- proxi- mately	3, min	75, min
C—Diameter of end section	$\frac{3}{4}$	20	$\frac{3}{4}$	20	$\frac{23}{32}$	18	$\frac{7}{8}$	22	$\frac{3}{4}$	20
E—Length of shoulder and fillet section, approximate	...	...	$\frac{5}{8}$	16	...	...	$\frac{3}{4}$	20	$\frac{5}{8}$	16
F—Diameter of shoulder	...	...	$\frac{5}{8}$	16	...	...	$\frac{5}{8}$	16	$\frac{19}{32}$	15

NOTES:

- (1) The reduced section may have a gradual taper from the ends toward the center with the ends not more than 0.005 in. (0.10 mm) larger in diameter than the center.
- (2) On Specimen 5 it is desirable, if possible, to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.
- (3) The types of ends shown are applicable for the standard 0.500 in. round tension test specimen; similar types can be used for subsize specimens. The use of UNF series of threads ($\frac{3}{4}$ by 16, $\frac{1}{2}$ by 20, $\frac{3}{8}$ by 24, and $\frac{1}{4}$ by 28) is suggested for high-strength brittle materials to avoid fracture in the thread portion.

FIG. 6 STANDARD TENSION TEST SPECIMENS FOR CAST IRON



DIMENSIONS

	Specimen 1		Specimen 2		Specimen 3	
	in.	mm	in.	mm	in.	mm
G—Length of parallel	Shall be equal to or greater than diameter <i>D</i>					
D—Diameter	0.500±0.010	12.5±0.25	0.750±0.015	20.0±0.40	1.25±0.025	30.0±0.60
R—Radius of fillet, min	1	25	1	25	2	50
A—Length of reduced section, min	1¼	32	1½	38	2¼	60
L—Over-all length, min	3¾	95	4	100	6¾	160
B—Grip section, approximate	1	25	1	25	1¾	45
C—Diameter of end section, approximate	¾	20	1⅛	30	1⅞	48
E—Length of shoulder, min	¼	6	¼	6	⅝	8
F—Diameter of shoulder	⅝±⅛	16.0±0.40	1⅝±⅛	24.0±0.40	1⅞±⅛	36.5±0.40

GENERAL NOTE: The reduced section and shoulders (dimensions *A*, *D*, *E*, *F*, *G*, and *R*) shall be shown, but the ends may be of any form to fit the holders of the testing machine in such a way that the load shall be axial. Commonly the ends are threaded and have the dimensions *B* and *C* given above.

FIG. 7 STRESS-STRAIN DIAGRAM SHOWING YIELD POINT CORRESPONDING WITH TOP OF KNEE

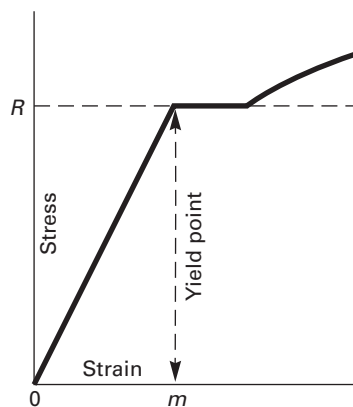


FIG. 8 STRESS-STRAIN DIAGRAM SHOWING YIELD POINT OR YIELD STRENGTH BY EXTENSION UNDER LOAD METHOD

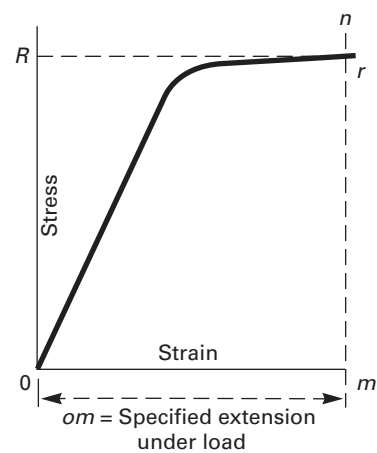


FIG. 9 STRESS-STRAIN DIAGRAM FOR DETERMINATION OF YIELD STRENGTH BY THE OFFSET METHOD

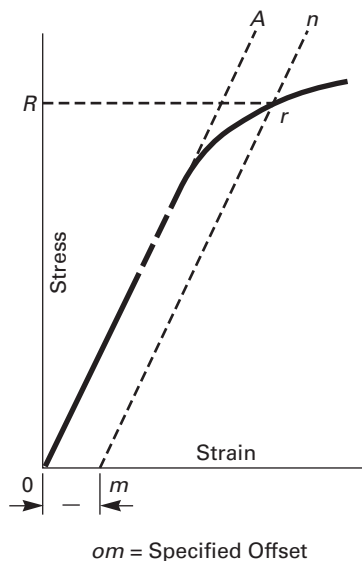
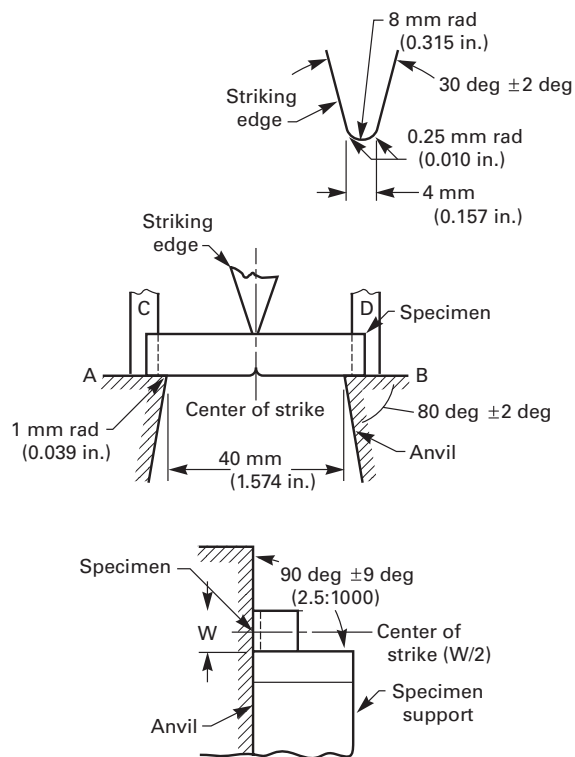


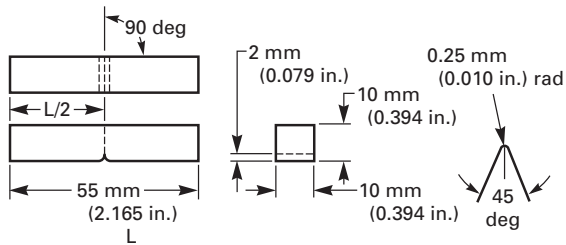
FIG. 10 CHARPY (SIMPLE-BEAM) IMPACT TEST



GENERAL NOTES:

- (a) All dimensional tolerances shall be ± 0.05 mm (0.002 in.) unless otherwise specified.
- (b) A shall be parallel to B within 2:1000 and coplanar with B within 0.05 mm (0.002 in.)
- (c) C shall be parallel to D within 20:1000 and coplanar with D within 0.125 mm (0.005 in.)
- (d) Finish on unmarked parts shall be 4 μ m (125 μ in.).

FIG. 11 CHARPY (SIMPLE-BEAM) IMPACT TEST SPECIMENS

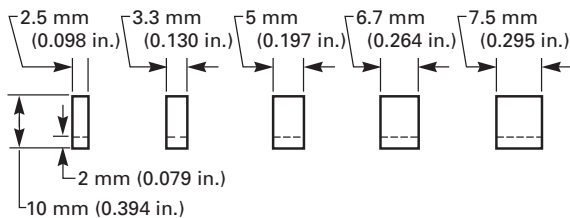


GENERAL NOTES:

(a) Permissible variations shall be as follows:

Notch length to edge	90 deg ± 2 deg
Adjacent sides shall be at	90 deg ± 10 min
Cross-section dimensions	± 0.075 mm (± 0.003 in.)
Length of specimen (L)	+0, -2.5 mm (+0, -0.100 in.)
Centering of notch (L/2)	± 1 mm (± 0.039 in.)
Angle of notch	± 1 deg
Radius of notch	± 0.025 mm (± 0.001 in.)
Notch depth	± 0.025 mm (± 0.001 in.)
Finish requirements	2 μ m (63 μ in.) on notched surface and opposite face; 4 μ m (125 μ in.) on other two surfaces

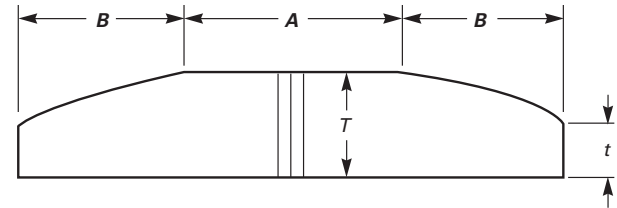
(a) Standard Full Size Specimen



(b) On subsize specimens, all dimensions and tolerances of the standard specimen remain constant with the exception of the width, which varies as shown above and for which the tolerance shall be $\pm 1\%$.

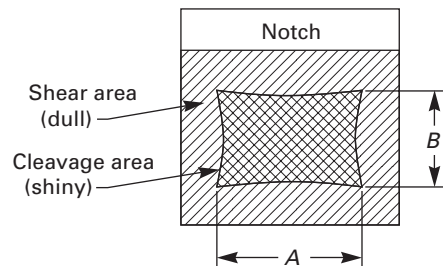
(b) Standard Subsize Specimen

FIG. 12 TUBULAR IMPACT SPECIMEN CONTAINING ORIGINAL OD SURFACE



Dimension	Description	Requirement
A	Machined surface	28 mm minimum
B	Original OD surface	13.5 mm maximum
T	Specimen thickness	Figure 11
t	End thickness	$1/2 T$ minimum

FIG. 13 DETERMINATION OF PERCENT SHEAR FRACTURE



GENERAL NOTES:

(a) Measure average dimensions A and B to the nearest 0.02 in. or 0.5 mm.

(b) Determine the percent shear fracture using Table 7 or Table 8.

FIG. 14 FRACTURE APPEARANCE CHARTS AND PERCENT SHEAR FRACTURE COMPARATOR

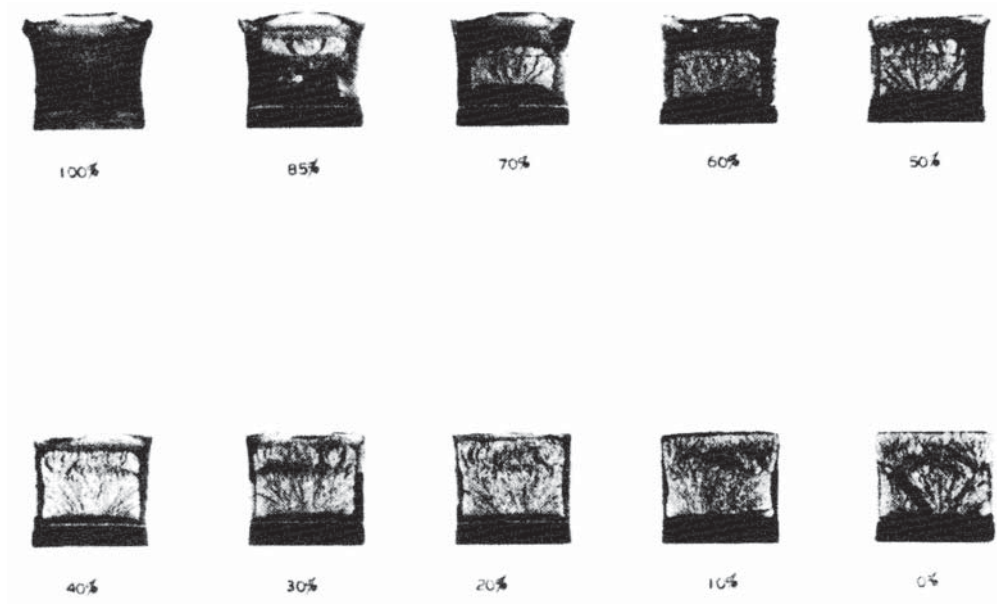
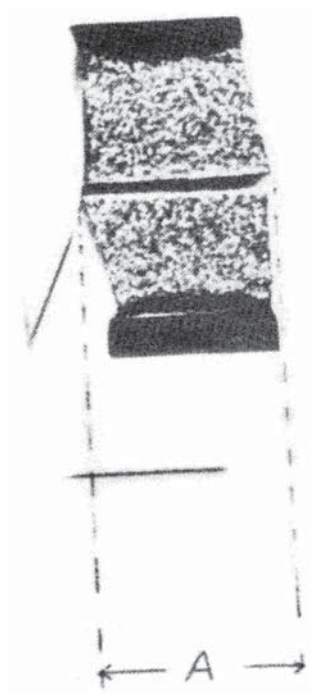
FIG. 15 HALVES OF BROKEN CHARPY V-NOTCH IMPACT SPECIMEN JOINED FOR THE MEASUREMENT OF LATERAL EXPANSION, DIMENSION A 

FIG. 16 LATERAL EXPANSION GAGE FOR CHARPY IMPACT SPECIMENS

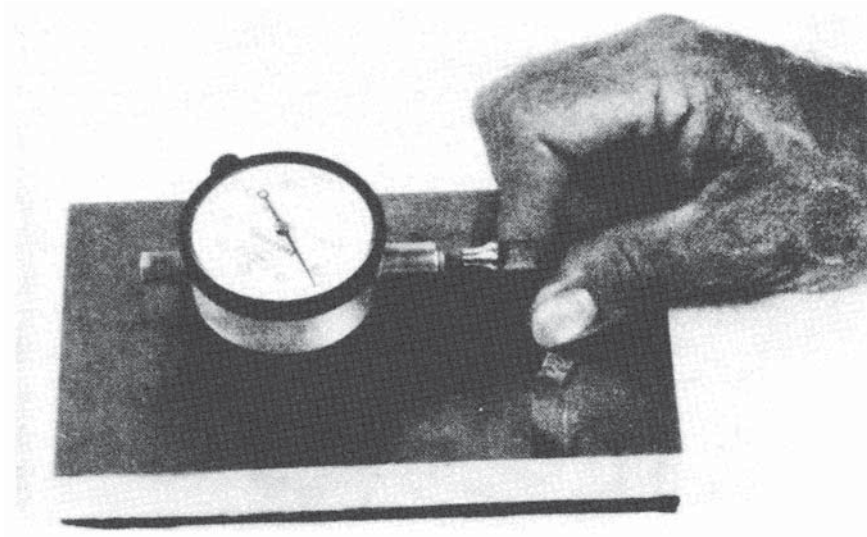
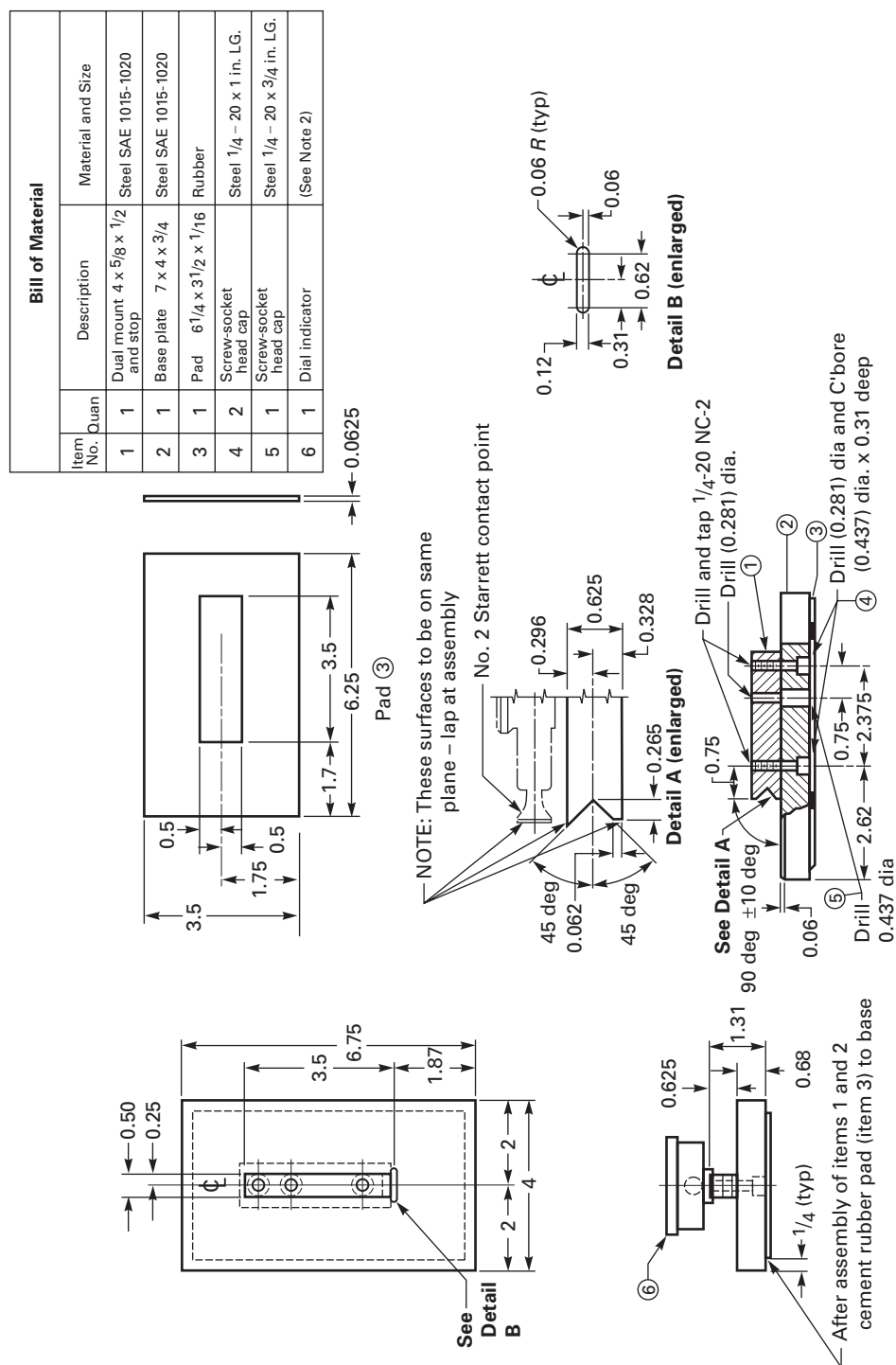


FIG. 17 ASSEMBLY AND DETAILS FOR LATERAL EXPANSION GAGE



NOTES:

- (1) Flash chrome plate items 1 and 2.
(2) Dial indicator – Starrett No. 25-241
range 0.001 – 0.250
back – adjustable bracket
contact point No. 2.

TABLE 1
MULTIPLYING FACTORS TO BE USED FOR VARIOUS DIAMETERS OF ROUND TEST SPECIMENS

Standard Specimen			Small Size Specimens Proportional to Standard					
0.500 in. Round			0.350 in. Round			0.250 in. Round		
Actual Diameter, in.	Area, in. ²	Multiplying Factor	Actual Diameter, in.	Area, in. ²	Multiplying Factor	Actual Diameter, in.	Area, in. ²	Multiplying Factor
0.490	0.1886	5.30	0.343	0.0924	10.82	0.245	0.0471	21.21
0.491	0.1893	5.28	0.344	0.0929	10.76	0.246	0.0475	21.04
0.492	0.1901	5.26	0.345	0.0935	10.70	0.247	0.0479	20.87
0.493	0.1909	5.24	0.346	0.0940	10.64	0.248	0.0483	20.70
0.494	0.1917	5.22	0.347	0.0946	10.57	0.249	0.0487	20.54
0.495	0.1924	5.20	0.348	0.0951	10.51	0.250	0.0491	20.37
0.496	0.1932	5.18	0.349	0.0957	10.45	0.251	0.0495	20.21
							(0.05) (A)	(20.0) (A)
0.497	0.1940	5.15	0.350	0.0962	10.39	0.252	0.0499	20.05
							(0.05) (A)	(20.0) (A)
0.498	0.1948	5.13	0.351	0.0968	10.33	0.253	0.0503	19.89
							(0.05) (A)	(20.0) (A)
0.499	0.1956	5.11	0.352	0.0973	10.28	0.254	0.0507	19.74
0.500	0.1963	5.09	0.353	0.0979	10.22	0.255	0.0511	19.58
0.501	0.1971	5.07	0.354	0.0984	10.16	...	...	...
0.502	0.1979	5.05	0.355	0.0990	10.10	...	...	...
0.503	0.1987	5.03	0.356	0.0995	10.05	...	...	...
				(0.1) (A)	(10.0) (A)			
0.504	0.1995	5.01	0.357	0.1001	9.99	...	...	...
	(0.2) (A)	(5.0) (A)		(0.1) (A)	(10.0) (A)			
0.505	0.2003	4.99	...	...	...	...	...	...
	(0.2) (A)	(5.0) (A)						
0.506	0.2011	4.97	...	...	...	...	...	...
	(0.2) (A)	(5.0) (A)						
0.507	0.2019	4.95	...	...	...	...	...	...
0.508	0.2027	4.93	...	...	...	...	...	...
0.509	0.2035	4.91	...	...	...	...	...	...
0.510	0.2043	4.90	...	...	...	...	...	...

NOTE:

(A) The values in parentheses may be used for ease in calculation of stresses, in pounds per square inch, as permitted in 5 of Fig. 4.

TABLE 2
APPROXIMATE HARDNESS CONVERSION NUMBERS FOR NONAUSTENITIC STEELS (A) (ROCKWELL C TO OTHER
HARDNESS NUMBERS)

Rockwell C Scale, 150 kgf Load, Diamond Penetrator	Vickers Hardness Number	Brinell Hardness, 3000 kgf Load, 10 mm Ball	Knoop Hardness, 500 gf Load and Over	Rockwell A Scale, 60 kgf Load, Diamond Penetrator	Rockwell Superficial Hardness			Approximate Tensile Strength, ksi (MPa)
					15N Scale, 15 kgf Load, Diamond Penetrator	30N Scale 30 kgf Load, Diamond Penetrator	45N Scale, 45 kgf Load, Diamond Penetrator	
68	940	...	920	85.6	93.2	84.4	75.4	...
67	900	...	895	85.0	92.9	83.6	74.2	...
66	865	...	870	84.5	92.5	82.8	73.3	...
65	832	739	846	83.9	92.2	81.9	72.0	...
64	800	722	822	83.4	91.8	81.1	71.0	...
63	772	706	799	82.8	91.4	80.1	69.9	...
62	746	688	776	82.3	91.1	79.3	68.8	...
61	720	670	754	81.8	90.7	78.4	67.7	...
60	697	654	732	81.2	90.2	77.5	66.6	...
59	674	634	710	80.7	89.8	76.6	65.5	351 (2420)
58	653	615	690	80.1	89.3	75.7	64.3	338 (2330)
57	633	595	670	79.6	88.9	74.8	63.2	325 (2240)
56	613	577	650	79.0	88.3	73.9	62.0	313 (2160)
55	595	560	630	78.5	87.9	73.0	60.9	301 (2070)
54	577	543	612	78.0	87.4	72.0	59.8	292 (2010)
53	560	525	594	77.4	86.9	71.2	58.6	283 (1950)
52	544	512	576	76.8	86.4	70.2	57.4	273 (1880)
51	528	496	558	76.3	85.9	69.4	56.1	264 (1820)
50	513	482	542	75.9	85.5	68.5	55.0	255 (1760)
49	498	468	526	75.2	85.0	67.6	53.8	246 (1700)
48	484	455	510	74.7	84.5	66.7	52.5	238 (1640)
47	471	442	495	74.1	83.9	65.8	51.4	229 (1580)
46	458	432	480	73.6	83.5	64.8	50.3	221 (1520)
45	446	421	466	73.1	83.0	64.0	49.0	215 (1480)
44	434	409	452	72.5	82.5	63.1	47.8	208 (1430)
43	423	400	438	72.0	82.0	62.2	46.7	201 (1390)
42	412	390	426	71.5	81.5	61.3	45.5	194 (1340)
41	402	381	414	70.9	80.9	60.4	44.3	188 (1300)
40	392	371	402	70.4	80.4	59.5	43.1	182 (1250)
39	382	362	391	69.9	79.9	58.6	41.9	177 (1220)
38	372	353	380	69.4	79.4	57.7	40.8	171 (1180)
37	363	344	370	68.9	78.8	56.8	39.6	166 (1140)
36	354	336	360	68.4	78.3	55.9	38.4	161 (1110)
35	345	327	351	67.9	77.7	55.0	37.2	156 (1080)
34	336	319	342	67.4	77.2	54.2	36.1	152 (1050)
33	327	311	334	66.8	76.6	53.3	34.9	149 (1030)
32	318	301	326	66.3	76.1	52.1	33.7	146 (1010)
31	310	294	318	65.8	75.6	51.3	32.5	141 (970)
30	302	286	311	65.3	75.0	50.4	31.3	138 (950)
29	294	279	304	64.6	74.5	49.5	30.1	135 (930)
28	286	271	297	64.3	73.9	48.6	28.9	131 (900)
27	279	264	290	63.8	73.3	47.7	27.8	128 (880)
26	272	258	284	63.3	72.8	46.8	26.7	125 (860)
25	266	253	278	62.8	72.2	45.9	25.5	123 (850)
24	260	247	272	62.4	71.6	45.0	24.3	119 (820)
23	254	243	266	62.0	71.0	44.0	23.1	117 (810)
22	248	237	261	61.5	70.5	43.2	22.0	115 (790)
21	243	231	256	61.0	69.9	42.3	20.7	112 (770)
20	238	226	251	60.5	69.4	41.5	19.6	110 (760)

NOTE:

(A) This table gives the approximate interrelationships of hardness values and approximate tensile strength of steels. It is possible that steels of various compositions and processing histories will deviate in hardness-tensile strength relationship from the data presented in this table. The data in this table should not be used for austenitic stainless steels, but have been shown to be applicable for ferritic and martensitic stainless steels. The data in this table should not be used to establish a relationship between hardness values and tensile strength of hard drawn wire. Where more precise conversions are required, they should be developed specially for each steel composition, heat treatment, and part.

TABLE 3
APPROXIMATE HARDNESS CONVERSION NUMBERS FOR NONAUSTENITIC STEELS (A) (ROCKWELL B TO OTHER
HARDNESS NUMBERS)

Rockwell B Scale, 100 kgf Load $\frac{1}{16}$ in. (1.588 mm) Ball	Vickers Hardness Number	Brinell Hardness, 3000 kgf Load, 10 mm Ball	Knoop Hardness, 500 gf Load and Over	Rockwell A Scale, 60 kgf Load, Diamond Penetrator	Rockwell F Scale, 60 kgf Load, $\frac{1}{16}$ in. (1.588 mm) Ball	Rockwell Superficial Hardness			Approximate Tensile Strength ksi (MPa)
						15T Scale, 15 kgf Load, $\frac{1}{16}$ in. (1.588 mm) Ball	30T Scale, 30 kgf Load, $\frac{1}{16}$ in. (1.588 mm) Ball	45T Scale, 45 kgf Load, $\frac{1}{16}$ in. (1.588 mm) Ball	
100	240	240	251	61.5	...	93.1	83.1	72.9	116 (800)
99	234	234	246	60.9	...	92.8	82.5	71.9	114 (785)
98	228	228	241	60.2	...	92.5	81.8	70.9	109 (750)
97	222	222	236	59.5	...	92.1	81.1	69.9	104 (715)
96	216	216	231	58.9	...	91.8	80.4	68.9	102 (705)
95	210	210	226	58.3	...	91.5	79.8	67.9	100 (690)
94	205	205	221	57.6	...	91.2	79.1	66.9	98 (675)
93	200	200	216	57.0	...	90.8	78.4	65.9	94 (650)
92	195	195	211	56.4	...	90.5	77.8	64.8	92 (635)
91	190	190	206	55.8	...	90.2	77.1	63.8	90 (620)
90	185	185	201	55.2	...	89.9	76.4	62.8	89 (615)
89	180	180	196	54.6	...	89.5	75.8	61.8	88 (605)
88	176	176	192	54.0	...	89.2	75.1	60.8	86 (590)
87	172	172	188	53.4	...	88.9	74.4	59.8	84 (580)
86	169	169	184	52.8	...	88.6	73.8	58.8	83 (570)
85	165	165	180	52.3	...	88.2	73.1	57.8	82 (565)
84	162	162	176	51.7	...	87.9	72.4	56.8	81 (560)
83	159	159	173	51.1	...	87.6	71.8	55.8	80 (550)
82	156	156	170	50.6	...	87.3	71.1	54.8	77 (530)
81	153	153	167	50.0	...	86.9	70.4	53.8	73 (505)
80	150	150	164	49.5	...	86.6	69.7	52.8	72 (495)
79	147	147	161	48.9	...	86.3	69.1	51.8	70 (485)
78	144	144	158	48.4	...	86.0	68.4	50.8	69 (475)
77	141	141	155	47.9	...	85.6	67.7	49.8	68 (470)
76	139	139	152	47.3	...	85.3	67.1	48.8	67 (460)
75	137	137	150	46.8	99.6	85.0	66.4	47.8	66 (455)
74	135	135	147	46.3	99.1	84.7	65.7	46.8	65 (450)
73	132	132	145	45.8	98.5	84.3	65.1	45.8	64 (440)
72	130	130	143	45.3	98.0	84.0	64.4	44.8	63 (435)
71	127	127	141	44.8	97.4	83.7	63.7	43.8	62 (425)
70	125	125	139	44.3	96.8	83.4	63.1	42.8	61 (420)
69	123	123	137	43.8	96.2	83.0	62.4	41.8	60 (415)
68	121	121	135	43.3	95.6	82.7	61.7	40.8	59 (405)
67	119	119	133	42.8	95.1	82.4	61.0	39.8	58 (400)
66	117	117	131	42.3	94.5	82.1	60.4	38.7	57 (395)
65	116	116	129	41.8	93.9	81.8	59.7	37.7	56 (385)
64	114	114	127	41.4	93.4	81.4	59.0	36.7	...
63	112	112	125	40.9	92.8	81.1	58.4	35.7	...
62	110	110	124	40.4	92.2	80.8	57.7	34.7	...
61	108	108	122	40.0	91.7	80.5	57.0	33.7	...
60	107	107	120	39.5	91.1	80.1	56.4	32.7	...
59	106	106	118	39.0	90.5	79.8	55.7	31.7	...
58	104	104	117	38.6	90.0	79.5	55.0	30.7	...
57	103	103	115	38.1	89.4	79.2	54.4	29.7	...
56	101	101	114	37.7	88.8	78.8	53.7	28.7	...
55	100	100	112	37.2	88.2	78.5	53.0	27.7	...
54	...	...	111	36.8	87.7	78.2	52.4	26.7	...
53	...	...	110	36.3	87.1	77.9	51.7	25.7	...
52	...	...	109	35.9	86.5	77.5	51.0	24.7	...
51	...	...	108	35.5	86.0	77.2	50.3	23.7	...
50	...	...	107	35.0	85.4	76.9	49.7	22.7	...
49	...	...	106	34.6	84.8	76.6	49.0	21.7	...

TABLE 3
APPROXIMATE HARDNESS CONVERSION NUMBERS FOR NONAUSTENITIC STEELS (A) (ROCKWELL B TO OTHER
HARDNESS NUMBERS) (CONT'D)

Rockwell B Scale, 100- kgf Load $\frac{1}{16}$ -in. (1.588 mm) Ball	Vickers Hardness Number	Brinell Hardness, 3000 kgf Load, 10 mm Ball	Knoop Hardness, 500 gf Load and Over	Rockwell A Scale, 60 kgf Load, Diamond Penetrator	Rockwell F Scale, 60 kgf Load, $\frac{1}{16}$ in. (1.588 mm) Ball	Rockwell Superficial Hardness			Approximate Tensile Strength ksi (MPa)
						15T Scale, 15 kgf Load, $\frac{1}{16}$ in. (1.588 mm) Ball	30T Scale, 30 kgf Load, $\frac{1}{16}$ in. (1.588 mm) Ball	45T Scale, 45 kgf Load, $\frac{1}{16}$ in. (1.588 mm) Ball	
48	105	34.1	84.3	76.2	48.3	20.7	...
47	104	33.7	83.7	75.9	47.7	19.7	...
46	103	33.3	83.1	75.6	47.0	18.7	...
45	102	32.9	82.6	75.3	46.3	17.7	...
44	101	32.4	82.0	74.9	45.7	16.7	...
43	100	32.0	81.4	74.6	45.0	15.7	...
42	99	31.6	80.8	74.3	44.3	14.7	...
41	98	31.2	80.3	74.0	43.7	13.6	...
40	97	30.7	79.7	73.6	43.0	12.6	...
39	96	30.3	79.1	73.3	42.3	11.6	...
38	95	29.9	78.6	73.0	41.6	10.6	...
37	94	29.5	78.0	72.7	41.0	9.6	...
36	93	29.1	77.4	72.3	40.3	8.6	...
35	92	28.7	76.9	72.0	39.6	7.6	...
34	91	28.2	76.3	71.7	39.0	6.6	...
33	90	27.8	75.7	71.4	38.3	5.6	...
32	89	27.4	75.2	71.0	37.6	4.6	...
31	88	27.0	74.6	70.7	37.0	3.6	...
30	87	26.6	74.0	70.4	36.3	2.6	...

NOTE:

(A) This table gives the approximate interrelationships of hardness values and approximate tensile strength of steels. It is possible that steels of various compositions and processing histories will deviate in hardness-tensile strength relationship from the data presented in this table. The data in this table should not be used for austenitic stainless steels, but have been shown to be applicable for ferritic and martensitic stainless steels. The data in this table should not be used to establish a relationship between hardness values and tensile strength of hard drawn wire. Where more precise conversions are required, they should be developed specially for each steel composition, heat treatment, and part.

TABLE 4
APPROXIMATE HARDNESS CONVERSION NUMBERS FOR AUSTENITIC STEELS (ROCKWELL C TO OTHER
HARDNESS NUMBERS)

Rockwell C Scale, 150 kgf Load, Diamond Penetrator	Rockwell A Scale, 60 kgf Load, Diamond Penetrator	Rockwell Superficial Hardness		
		15N Scale, 15 kgf Load, Diamond Penetrator	30N Scale, 30 kgf Load, Diamond Penetrator	45N Scale, 45 kgf Load, Diamond Penetrator
48	74.4	84.1	66.2	52.1
47	73.9	83.6	65.3	50.9
46	73.4	83.1	64.5	49.8
45	72.9	82.6	63.6	48.7
44	72.4	82.1	62.7	47.5
43	71.9	81.6	61.8	46.4
42	71.4	81.0	61.0	45.2
41	70.9	80.5	60.1	44.1
40	70.4	80.0	59.2	43.0
39	69.9	79.5	58.4	41.8
38	69.3	79.0	57.5	40.7
37	68.8	78.5	56.6	39.6
36	68.3	78.0	55.7	38.4
35	67.8	77.5	54.9	37.3
34	67.3	77.0	54.0	36.1
33	66.8	76.5	53.1	35.0
32	66.3	75.9	52.3	33.9
31	65.8	75.4	51.4	32.7
30	65.3	74.9	50.5	31.6
29	64.8	74.4	49.6	30.4
28	64.3	73.9	48.8	29.3
27	63.8	73.4	47.9	28.2
26	63.3	72.9	47.0	27.0
25	62.8	72.4	46.2	25.9
24	62.3	71.9	45.3	24.8
23	61.8	71.3	44.4	23.6
22	61.3	70.8	43.5	22.5
21	60.8	70.3	42.7	21.3
20	60.3	69.8	41.8	20.2

TABLE 5
APPROXIMATE HARDNESS CONVERSION NUMBERS FOR AUSTENITIC STEELS (ROCKWELL B TO OTHER
HARDNESS NUMBERS)

Rockwell B Scale, 100 kgf Load, $\frac{1}{16}$ in. (1.588 mm) Ball	Brinell Indentation Diameter, mm	Brinell Hardness, 3000 kgf Load, 10 mm Ball	Rockwell A Scale, 60 kgf Load, Diamond Penetrator	Rockwell Superficial Hardness		
				15T Scale, 15 kgf Load, $\frac{1}{16}$ in. (1.588 mm) Ball	30T Scale, 30 kgf Load, $\frac{1}{16}$ in. (1.588 mm) Ball	45T Scale, 45 kgf Load, $\frac{1}{16}$ in. (1.588 mm) Ball
100	3.79	256	61.5	91.5	80.4	70.2
99	3.85	248	60.9	91.2	79.7	69.2
98	3.91	240	60.3	90.8	79.0	68.2
97	3.96	233	59.7	90.4	78.3	67.2
96	4.02	226	59.1	90.1	77.7	66.1
95	4.08	219	58.5	89.7	77.0	65.1
94	4.14	213	58.0	89.3	76.3	64.1
93	4.20	207	57.4	88.9	75.6	63.1
92	4.24	202	56.8	88.6	74.9	62.1
91	4.30	197	56.2	88.2	74.2	61.1
90	4.35	192	55.6	87.8	73.5	60.1
89	4.40	187	55.0	87.5	72.8	59.0
88	4.45	183	54.5	87.1	72.1	58.0
87	4.51	178	53.9	86.7	71.4	57.0
86	4.55	174	53.3	86.4	70.7	56.0
85	4.60	170	52.7	86.0	70.0	55.0
84	4.65	167	52.1	85.6	69.3	54.0
83	4.70	163	51.5	85.2	68.6	52.9
82	4.74	160	50.9	84.9	67.9	51.9
81	4.79	156	50.4	84.5	67.2	50.9
80	4.84	153	49.8	84.1	66.5	49.9

TABLE 6
BRINELL HARDNESS NUMBERS (A)
(Ball 10 mm in Diameter, Applied Loads of 500, 1500, and 3000 kgf)

Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number		
	500 kgf Load	1500 kgf Load	3000 kgf Load		500 kgf Load	1500 kgf Load	3000 kgf Load		500 kgf Load	1500 kgf Load	3000 kgf Load		500 kgf Load	1500 kgf Load	3000 kgf Load
2.00	158	473	945	2.60	92.6	278	555	3.20	60.5	182	363	3.80	42.4	127	255
2.01	156	468	936	2.61	91.8	276	551	3.21	60.1	180	361	3.81	42.2	127	253
2.02	154	463	926	2.62	91.1	273	547	3.22	59.8	179	359	3.82	42.0	126	252
2.03	153	459	917	2.63	90.4	271	543	3.23	59.4	178	356	3.83	41.7	125	250
2.04	151	454	908	2.64	89.7	269	538	3.24	59.0	177	354	3.84	41.5	125	249
2.05	150	450	899	2.65	89.0	267	534	3.25	58.6	176	352	3.85	41.3	124	248
2.06	148	445	890	2.66	88.4	265	530	3.26	58.3	175	350	3.86	41.1	123	246
2.07	147	441	882	2.67	87.7	263	526	3.27	57.9	174	347	3.87	40.9	123	245
2.08	146	437	873	2.68	87.0	261	522	3.28	57.5	173	345	3.88	40.6	122	244
2.09	144	432	865	2.69	86.4	259	518	3.29	57.2	172	343	3.89	40.4	121	242
2.10	143	428	856	2.70	85.7	257	514	3.30	56.8	170	341	3.90	40.2	121	241
2.11	141	424	848	2.71	85.1	255	510	3.31	56.5	169	339	3.91	40.0	120	240
2.12	140	420	840	2.72	84.4	253	507	3.32	56.1	168	337	3.92	39.8	119	239
2.13	139	416	832	2.73	83.8	251	503	3.33	55.8	167	335	3.93	39.6	119	237
2.14	137	412	824	2.74	83.2	250	499	3.34	55.4	166	333	3.94	39.4	118	236
2.15	136	408	817	2.75	82.6	248	495	3.35	55.1	165	331	3.95	39.1	117	235
2.16	135	404	809	2.76	81.9	246	492	3.36	54.8	164	329	3.96	38.9	117	234
2.17	134	401	802	2.77	81.3	244	488	3.37	54.4	163	326	3.97	38.7	116	232
2.18	132	397	794	2.78	80.8	242	485	3.38	54.1	162	325	3.98	38.5	116	231
2.19	131	393	787	2.79	80.2	240	481	3.39	53.8	161	323	3.99	38.3	115	230
2.20	130	390	780	2.80	79.6	239	477	3.40	53.4	160	321	4.00	38.1	114	229
2.21	129	386	772	2.81	79.0	237	474	3.41	53.1	159	319	4.01	37.9	114	228
2.22	128	383	765	2.82	78.4	235	471	3.42	52.8	158	317	4.02	37.7	113	226
2.23	126	379	758	2.83	77.9	234	467	3.43	52.5	157	315	4.03	37.5	113	225
2.24	125	376	752	2.84	77.3	232	464	3.44	52.2	156	313	4.04	37.3	112	224
2.25	124	372	745	2.85	76.8	230	461	3.45	51.8	156	311	4.05	37.1	111	223
2.26	123	369	738	2.86	76.2	229	457	3.46	51.5	155	309	4.06	37.0	111	222
2.27	122	366	732	2.87	75.7	227	454	3.47	51.2	154	307	4.07	36.8	110	221
2.28	121	363	725	2.88	75.1	225	451	3.48	50.9	153	306	4.08	36.6	110	219
2.29	120	359	719	2.89	74.6	224	448	3.49	50.6	152	304	4.09	36.4	109	218
2.30	119	356	712	2.90	74.1	222	444	3.50	50.3	151	302	4.10	36.2	109	217
2.31	118	353	706	2.91	73.6	221	441	3.51	50.0	150	300	4.11	36.0	108	216
2.32	117	350	700	2.92	73.0	219	438	3.52	49.7	149	298	4.12	35.8	108	215
2.33	116	347	694	2.93	72.5	218	435	3.53	49.4	148	297	4.13	35.7	107	214
2.34	115	344	688	2.94	72.0	216	432	3.54	49.2	147	295	4.14	35.5	106	213
2.35	114	341	682	2.95	71.5	215	429	3.55	48.9	147	293	4.15	35.3	106	212
2.36	113	338	676	2.96	71.0	213	426	3.56	48.6	146	292	4.16	35.1	105	211
2.37	112	335	670	2.97	70.5	212	423	3.57	48.3	145	290	4.17	34.9	105	210
2.38	111	332	665	2.98	70.1	210	420	3.58	48.0	144	288	4.18	34.8	104	209
2.39	110	330	659	2.99	69.6	209	417	3.59	47.7	143	286	4.19	34.6	104	208
2.40	109	327	653	3.00	69.1	207	415	3.60	47.5	142	285	4.20	34.4	103	207
2.41	108	324	648	3.01	68.6	206	412	3.61	47.2	142	283	4.21	34.2	103	205
2.42	107	322	643	3.02	68.2	205	409	3.62	46.9	141	282	4.22	34.1	102	204
2.43	106	319	637	3.03	67.7	203	406	3.63	46.7	140	280	4.23	33.9	102	203
2.44	105	316	632	3.04	67.3	202	404	3.64	46.4	139	278	4.24	33.7	101	202
2.45	104	313	627	3.05	66.8	200	401	3.65	46.1	138	277	4.25	33.6	101	201
2.46	104	311	621	3.06	66.4	199	398	3.66	45.9	138	275	4.26	33.4	100	200
2.47	103	308	616	3.07	65.9	198	395	3.67	45.6	137	274	4.27	33.2	99.7	199
2.48	102	306	611	3.08	65.5	196	393	3.68	45.4	136	272	4.28	33.1	99.2	198
2.49	101	303	606	3.09	65.0	195	390	3.69	45.1	135	271	4.29	32.9	98.8	198

TABLE 6
BRINELL HARDNESS NUMBERS (A) (CONT'D)
(Ball 10 mm in Diameter, Applied Loads of 500, 1500, and 3000 kgf)

Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number		
	500 kgf Load	1500 kgf Load	3000 kgf Load		500 kgf Load	1500 kgf Load	3000 kgf Load		500 kgf Load	1500 kgf Load	3000 kgf Load		500 kgf Load	1500 kgf Load	3000 kgf Load
2.50	100	301	601	3.10	64.6	194	388	3.70	44.9	135	269	4.30	32.8	98.3	197
2.51	99.4	298	597	3.11	64.2	193	385	3.71	44.6	134	268	4.31	32.6	97.8	196
2.52	98.6	296	592	3.12	63.8	191	383	3.72	44.4	133	266	4.32	32.4	97.3	195
2.53	97.8	294	587	3.13	63.3	190	380	3.73	44.1	132	265	4.33	32.3	96.8	194
2.54	97.1	291	582	3.14	62.9	189	378	3.74	43.9	132	263	4.34	32.1	96.4	193
2.55	96.3	289	578	3.15	62.5	188	375	3.75	43.6	131	262	4.35	32.0	95.9	192
2.56	95.5	287	573	3.16	62.1	186	373	3.76	43.4	130	260	4.36	31.8	95.5	191
2.57	94.8	284	569	3.17	61.7	185	370	3.77	43.1	129	259	4.37	31.7	95.0	190
2.58	94.0	282	564	3.18	61.3	184	368	3.78	42.9	129	257	4.38	31.5	94.5	189
2.59	93.3	280	560	3.19	60.9	183	366	3.79	42.7	128	256	4.39	31.4	94.1	188
4.40	31.2	93.6	187	5.05	23.3	69.8	140	5.70	17.8	53.5	107	6.35	14.0	42.0	84.0
4.41	31.1	93.2	186	5.06	23.2	69.5	139	5.71	17.8	53.3	107	6.36	13.9	41.8	83.7
4.42	30.9	92.7	185	5.07	23.1	69.2	138	5.72	17.7	53.1	106	6.37	13.9	41.7	83.4
4.43	30.8	92.3	185	5.08	23.0	68.9	138	5.73	17.6	52.9	106	6.38	13.8	41.5	83.1
4.44	30.6	91.8	184	5.09	22.9	68.6	137	5.74	17.6	52.7	105	6.39	13.8	41.4	82.8
4.45	30.5	91.4	183	5.10	22.8	68.3	137	5.75	17.5	52.5	105	6.40	13.7	41.2	82.5
4.46	30.3	91.0	182	5.11	22.7	68.0	136	5.76	17.4	52.3	105	6.41	13.7	41.1	82.2
4.47	30.2	90.5	181	5.12	22.6	67.7	135	5.77	17.4	52.1	104	6.42	13.6	40.9	81.9
4.48	30.0	90.1	180	5.13	22.5	67.4	135	5.78	17.3	51.9	104	6.43	13.6	40.8	81.6
4.49	29.9	89.7	179	5.14	22.4	67.1	134	5.79	17.2	51.7	103	6.44	13.5	40.6	81.3
4.50	29.8	89.3	179	5.15	22.3	66.9	134	5.80	17.2	51.5	103	6.45	13.5	40.5	81.0
4.51	29.6	88.8	178	5.16	22.2	66.6	133	5.81	17.1	51.3	103	6.46	13.4	40.4	80.7
4.52	29.5	88.4	177	5.17	22.1	66.3	133	5.82	17.0	51.1	102	6.47	13.4	40.2	80.4
4.53	29.3	88.0	176	5.18	22.0	66.0	132	5.83	17.0	50.9	102	6.48	13.4	40.1	80.1
4.54	29.2	87.6	175	5.19	21.9	65.8	132	5.84	16.9	50.7	101	6.49	13.3	39.9	79.8
4.55	29.1	87.2	174	5.20	21.8	65.5	131	5.85	16.8	50.5	101	6.50	13.3	39.8	79.6
4.56	28.9	86.8	174	5.21	21.7	65.2	130	5.86	16.8	50.3	101	6.51	13.2	39.6	79.3
4.57	28.8	86.4	173	5.22	21.6	64.9	130	5.87	16.7	50.2	100	6.52	13.2	39.5	79.0
4.58	28.7	86.0	172	5.23	21.6	64.7	129	5.88	16.7	50.0	99.9	6.53	13.1	39.4	78.7
4.59	28.5	85.6	171	5.24	21.5	64.4	129	5.89	16.6	49.8	99.5	6.54	13.1	39.2	78.4
4.60	28.4	85.4	170	5.25	21.4	64.1	128	5.90	16.5	49.6	99.2	6.55	13.0	39.1	78.2
4.61	28.3	84.8	170	5.26	21.3	63.9	128	5.91	16.5	49.4	98.8	6.56	13.0	38.9	78.0
4.62	28.1	84.4	169	5.27	21.2	63.6	127	5.92	16.4	49.2	98.4	6.57	12.9	38.8	77.6
4.63	28.0	84.0	168	5.28	21.1	63.3	127	5.93	16.3	49.0	98.0	6.58	12.9	38.7	77.3
4.64	27.9	83.6	167	5.29	21.0	63.1	126	5.94	16.3	48.8	97.7	6.59	12.8	38.5	77.1
4.65	27.8	83.3	167	5.30	20.9	62.8	126	5.95	16.2	48.7	97.3	6.60	12.8	38.4	76.8
4.66	27.6	82.9	166	5.31	20.9	62.6	125	5.96	16.2	48.5	96.9	6.61	12.8	38.3	76.5
4.67	27.5	82.5	165	5.32	20.8	62.3	125	5.97	16.1	48.3	96.6	6.62	12.7	38.1	76.2
4.68	27.4	82.1	164	5.33	20.7	62.1	124	5.98	16.0	48.1	96.2	6.63	12.7	38.0	76.0
4.69	27.3	81.8	164	5.34	20.6	61.8	124	5.99	16.0	47.9	95.9	6.64	12.6	37.9	75.7
4.70	27.1	81.4	163	5.35	20.5	61.5	123	6.00	15.9	47.7	95.5	6.65	12.6	37.7	75.4
4.71	27.0	81.0	162	5.36	20.4	61.3	123	6.01	15.9	47.6	95.1	6.66	12.5	37.6	75.2
4.72	26.9	80.7	161	5.37	20.3	61.0	122	6.02	15.8	47.4	94.8	6.67	12.5	37.5	74.9
4.73	26.8	80.3	161	5.38	20.3	60.8	122	6.03	15.7	47.2	94.4	6.68	12.4	37.3	74.7
4.74	26.6	79.9	160	5.39	20.2	60.6	121	6.04	15.7	47.0	94.1	6.69	12.4	37.2	74.4
4.75	26.5	79.6	159	5.40	20.1	60.3	121	6.05	15.6	46.8	93.7	6.70	12.4	37.1	74.1
4.76	26.4	79.2	158	5.41	20.0	60.1	120	6.06	15.6	46.7	93.4	6.71	12.3	36.9	73.9
4.77	26.3	78.9	158	5.42	19.9	59.8	120	6.07	15.5	46.5	93.0	6.72	12.3	36.8	73.6
4.78	26.2	78.5	157	5.43	19.9	59.6	119	6.08	15.4	46.3	92.7	6.73	12.2	36.7	73.4
4.79	26.1	78.2	156	5.44	19.8	59.3	119	6.09	15.4	46.2	92.3	6.74	12.2	36.6	73.1

TABLE 6
BRINELL HARDNESS NUMBERS (A) (CONT'D)
(Ball 10 mm in Diameter, Applied Loads of 500, 1500, and 3000 kgf)

Brinell Hardness Number				Brinell Hardness Number				Brinell Hardness Number				Brinell Hardness Number			
Diameter of Indentation, mm	500 kgf Load	1500 kgf Load	3000 kgf Load	Diameter of Indentation, mm	500 kgf Load	1500 kgf Load	3000 kgf Load	Diameter of Indentation, mm	500 kgf Load	1500 kgf Load	3000 kgf Load	Diameter of Indentation, mm	500 kgf Load	1500 kgf Load	3000 kgf Load
4.80	25.9	77.8	156	5.45	19.7	59.1	118	6.10	15.3	46.0	92.0	6.75	12.1	36.4	72.8
4.81	25.8	77.5	155	5.46	19.6	58.9	118	6.11	15.3	45.8	91.7	6.76	12.1	36.3	72.6
4.82	25.7	77.1	154	5.47	19.5	58.6	117	6.12	15.2	45.7	91.3	6.77	12.1	36.2	72.3
4.83	25.6	76.8	154	5.48	19.5	58.4	117	6.13	15.2	45.5	91.0	6.78	12.0	36.0	72.1
4.84	25.5	76.4	153	5.49	19.4	58.2	116	6.14	15.1	45.3	90.6	6.79	12.0	35.9	71.8
4.85	25.4	76.1	152	5.50	19.3	57.9	116	6.15	15.1	45.2	90.3	6.80	11.9	35.8	71.6
4.86	25.3	75.8	152	5.51	19.2	57.7	115	6.16	15.0	45.0	90.0	6.81	11.9	35.7	71.3
4.87	25.1	75.4	151	5.52	19.2	57.5	115	6.17	14.9	44.8	89.6	6.82	11.8	35.5	71.1
4.88	25.0	75.1	150	5.53	19.1	57.2	114	6.18	14.9	44.7	89.3	6.83	11.8	35.4	70.8
4.89	24.9	74.8	150	5.54	19.0	57.0	114	6.19	14.8	44.5	89.0	6.84	11.8	35.3	70.6
4.90	24.8	74.4	149	5.55	18.9	56.8	114	6.20	14.7	44.3	88.7	6.86	11.7	35.2	70.4
4.91	24.7	74.1	148	5.56	18.9	56.6	113	6.21	14.7	44.2	88.3	6.86	11.7	35.1	70.1
4.92	24.6	73.8	148	5.57	18.8	56.3	113	6.22	14.7	44.0	88.0	6.87	11.6	34.9	69.9
4.93	24.5	73.5	147	5.58	18.7	56.1	112	6.23	14.6	43.8	87.7	6.88	11.6	34.8	69.6
4.94	24.4	73.2	146	5.59	18.6	55.9	112	6.24	14.6	43.7	87.4	6.89	11.6	34.7	69.4
4.95	24.3	72.8	146	5.60	18.6	55.7	111	6.25	14.5	43.5	87.1	6.90	11.5	34.6	69.2
4.96	24.2	72.5	145	5.61	18.5	55.5	111	6.26	14.5	43.4	86.7	6.91	11.5	34.5	68.9
4.97	24.1	72.2	144	5.62	18.4	55.2	110	6.27	14.4	43.2	86.4	6.92	11.4	34.3	68.7
4.98	24.0	71.9	144	5.63	18.3	55.0	110	6.28	14.4	43.1	86.1	6.93	11.4	34.2	68.4
4.99	23.9	71.6	143	5.64	18.3	54.8	110	6.29	14.3	42.9	85.8	6.94	11.4	34.1	68.2
5.00	23.8	71.3	143	5.65	18.2	54.6	109	6.30	14.2	42.7	85.5	6.95	11.3	34.0	68.0
5.01	23.7	71.0	142	5.66	18.1	54.4	109	6.31	14.2	42.6	85.2	6.96	11.3	33.9	67.7
5.02	23.6	70.7	141	5.67	18.1	54.2	108	6.32	14.1	42.4	84.9	6.97	11.3	33.8	67.5
5.03	23.5	70.4	141	5.68	18.0	54.0	108	6.33	14.1	42.3	84.6	6.98	11.2	33.6	67.3
5.04	23.4	70.1	140	5.69	17.9	53.7	107	6.34	14.0	42.1	84.3	6.99	11.2	33.5	67.0

NOTE:

(A) Prepared by the Engineering Mechanics Section, Institute for Standards Technology.

TABLE 7
PERCENT SHEAR FOR MEASUREMENTS MADE IN INCHES

Dimension B , in.	Dimension A , in.																
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.22	0.24	0.26	0.28	0.30	0.32	0.34	0.36	0.38	0.40
0.05	98	96	95	94	94	93	92	91	90	90	89	88	87	86	85	85	84
0.10	96	92	90	89	87	85	84	82	81	79	77	76	74	73	71	69	68
0.12	95	90	88	86	85	83	81	79	77	75	73	71	69	67	65	63	61
0.14	94	89	86	84	82	80	77	75	73	71	68	66	64	62	59	57	55
0.16	94	87	85	82	79	77	74	72	69	67	64	61	59	56	53	51	48
0.18	93	85	83	80	77	74	72	68	65	62	59	56	54	51	48	45	42
0.20	92	84	81	77	74	72	68	65	61	58	55	52	48	45	42	39	36
0.22	91	82	79	75	72	68	65	61	57	54	50	47	43	40	36	33	29
0.24	90	81	77	73	69	65	61	57	54	50	46	42	38	34	30	27	23
0.26	90	79	75	71	67	62	58	54	50	46	41	37	33	29	25	20	16
0.28	89	77	73	68	64	59	55	50	46	41	37	32	28	23	18	14	10
0.30	88	76	71	66	61	56	52	47	42	37	32	27	23	18	13	9	3
0.31	88	75	70	65	60	55	50	45	40	35	30	25	20	18	10	5	0

GENERAL NOTE: Since this table is set up for finite measurements or dimensions A and B , 100% shear is to be reported when either A or B is zero.

TABLE 8
PERCENT SHEAR FOR MEASUREMENTS MADE IN MILLIMETRES

Dimension <i>B</i> , mm	Dimension <i>A</i> , mm																		
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10
1.0	99	98	98	97	96	96	95	94	94	93	92	92	91	91	90	89	89	88	88
1.5	98	97	96	95	94	93	92	92	91	90	89	88	87	86	85	84	83	82	81
2.0	98	96	95	94	92	91	90	89	88	86	85	84	82	81	80	79	77	76	75
2.5	97	95	94	92	91	89	88	86	84	83	81	80	78	77	75	73	72	70	69
3.0	96	94	92	91	89	87	85	83	81	79	77	76	74	72	70	68	66	64	62
3.5	96	93	91	89	87	85	82	80	78	76	74	72	69	67	65	63	61	58	56
4.0	95	92	90	88	85	82	80	77	75	72	70	67	65	62	60	57	55	52	50
4.5	94	92	89	86	83	80	77	75	72	69	66	63	61	58	55	52	49	46	44
5.0	94	91	88	85	81	78	75	72	69	66	62	59	56	53	50	47	44	41	37
5.5	93	90	86	83	79	76	72	69	66	62	59	55	52	48	45	42	38	35	31
6.0	92	89	85	81	77	74	70	66	62	59	55	51	47	44	40	36	33	29	25
6.5	92	88	84	80	76	72	67	63	59	55	51	47	43	39	35	31	27	23	19
7.0	91	87	82	78	74	69	65	61	56	52	47	43	39	34	30	26	21	17	12
7.5	91	86	81	77	72	67	62	58	53	48	44	39	34	30	25	20	16	11	6
8.0	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0

GENERAL NOTE: Since this table is set up for finite measurements or dimensions *A* and *B*, 100% shear is to be reported when either *A* or *B* is zero.

TABLE 9
CHARPY V-NOTCH TEST ACCEPTANCE CRITERIA FOR VARIOUS SUB-SIZE SPECIMENS

Full Size, 10 by 10 mm		$\frac{3}{4}$ Size, 10 by 7.5 mm		$\frac{2}{3}$ Size, 10 by 6.7 mm		$\frac{1}{2}$ Size, 10 by 5 mm		$\frac{1}{3}$ Size, 10 by 3.3 mm		$\frac{1}{4}$ Size, 10 by 2.5 mm	
ft • lbf	[J]	ft • lbf	[J]	ft • lbf	[J]	ft • lbf	[J]	ft • lbf	[J]	ft • lbf	[J]
40	[54]	30	[41]	27	[37]	20	[27]	13	[18]	10	[14]
35	[48]	26	[35]	23	[31]	18	[24]	12	[16]	9	[12]
30	[41]	22	[30]	20	[27]	15	[20]	10	[14]	8	[11]
25	[34]	19	[26]	17	[23]	12	[16]	8	[11]	6	[8]
20	[27]	15	[20]	13	[18]	10	[14]	7	[10]	5	[7]
16	[22]	12	[16]	11	[15]	8	[11]	5	[7]	4	[5]
15	[20]	11	[15]	10	[14]	8	[11]	5	[7]	4	[5]
13	[18]	10	[14]	9	[12]	6	[8]	4	[5]	3	[4]
12	[16]	9	[12]	8	[11]	6	[8]	4	[5]	3	[4]
10	[14]	8	[11]	7	[10]	5	[7]	3	[4]	2	[3]
7	[10]	5	[7]	5	[7]	4	[5]	2	[3]	2	[3]

ANNEXES

(Mandatory Information)

A1. STEEL BAR PRODUCTS**A1.1 Scope**

A1.1.1 This supplement delineates only those details which are peculiar to hot-rolled and cold-finished steel bars and are not covered in the general section of these test methods.

A1.2 Orientation of Test Specimens

A1.2.1 Carbon and alloy steel bars and bar-size shapes, due to their relatively small cross-sectional dimensions, are customarily tested in the longitudinal direction. In special cases where size permits and the fabrication or service of a part justifies testing in a transverse direction, the selection and location of test or tests are a matter of agreement between the manufacturer and the purchaser.

A1.3 Tension Test

A1.3.1 Carbon Steel Bars — Carbon steel bars are not commonly specified to tensile requirements in the as-rolled condition for sizes of rounds, squares, hexagons, and octagons under $\frac{1}{2}$ in. (13 mm) in diameter or distance between parallel faces nor for other bar-size sections, other than flats, less than 1 in.² (645 mm²) in cross-sectional area.

A1.3.2 Alloy Steel Bars — Alloy steel bars are usually not tested in the as-rolled condition.

A1.3.3 When tension tests are specified, the practice for selecting test specimens for hot-rolled and cold-finished steel bars of various sizes shall be in accordance with Table A1.1, unless otherwise specified in the product specification.

A1.4 Bend Test

A1.4.1 When bend tests are specified, the recommended practice for hot-rolled and cold-finished steel bars shall be in accordance with Table A1.2.

A1.5 Hardness Test

A1.5.1 Hardness Tests on Bar Products — flats, rounds, squares, hexagons and octagons — is conducted on the surface after a minimum removal of 0.015 in. to provide for accurate hardness penetration.

A2. STEEL TUBULAR PRODUCTS**A2.1 Scope**

A2.1.1 This supplement covers test specimens and test methods that are applicable to tubular products and

are not covered in the general section of Test Methods and Definitions A 370.

A2.1.2 Tubular shapes covered by this specification include, round, square, rectangular, and special shapes.

A2.2 Tension Test**A2.2.1 Full-Size Longitudinal Test Specimens:**

A2.2.1.1 As an alternative to the use of longitudinal strip test specimens or longitudinal round test specimens, tension test specimens of full-size tubular sections are used, provided that the testing equipment has sufficient capacity. Snug-fitting metal plugs should be inserted far enough in the end of such tubular specimens to permit the testing machine jaws to grip the specimens properly without crushing. A design that may be used for such plugs is shown in Fig. A2.1. The plugs shall not extend into that part of the specimen on which the elongation is measured (Fig. A2.1). Care should be exercised to see that insofar as practicable, the load in such cases is applied axially. The length of the full-section specimen depends on the gage length prescribed for measuring the elongation.

A2.2.1.2 Unless otherwise required by the product specification, the gage length is 2 in. or 50 mm, except that for tubing having an outside diameter of $\frac{3}{8}$ in. (9.5 mm) or less, it is customary for a gage length equal to four times the outside diameter to be used when elongation comparable to that obtainable with larger test specimens is required.

A2.2.1.3 To determine the cross-sectional area of the full-section specimen, measurements shall be recorded as the average or mean between the greatest and least measurements of the outside diameter and the average or mean wall thickness, to the nearest 0.001 in. (0.025 mm) and the cross-sectional area is determined by the following equation:

$$A = 3.1416t(D - t) \quad (A2.1)$$

where:

A = sectional area, in.²

D = outside diameter, in., and

t = thickness of tube wall, in.

NOTE A2.1 — There exist other methods of cross-sectional area determination, such as by weighing of the specimens, which are equally accurate or appropriate for the purpose.

A2.2.2 Longitudinal Strip Test Specimens:

A2.2.2.1 As an alternative to the use of full-size longitudinal test specimens or longitudinal round test specimens, longitudinal strip test specimens, obtained from strips cut from the tubular product as shown in Fig. A2.2 and machined to the dimensions shown in Fig. A2.3 are used. For welded structural tubing, such test specimens shall be from a location at least 90° from the weld; for other welded tubular products, such test specimens shall be from a location approximately 90° from the weld. Unless otherwise required by the product specification, the gage length is 2 in. or 50 mm. The test specimens shall be tested using grips that are flat or have a surface contour corresponding to the curvature of the tubular product, or the ends of the test specimens shall be flattened without heating prior to the test specimens being tested using flat grips. The test specimen shown as specimen no. 4 in Fig. 3 shall be used, unless the capacity of the testing equipment or the dimensions and nature of the tubular product to be tested makes the use of specimen nos. 1, 2, or 3 necessary.

NOTE A2.2 — An exact formula for calculating the cross-sectional area of specimens of the type shown in Fig. A2.3 taken from a circular tube is given in Test Methods E 8 or E 8M.

A2.2.2.2 The width should be measured at each end of the gage length to determine parallelism and also at the center. The thickness should be measured at the center and used with the center measurement of the width to determine the cross-sectional area. The center width dimension should be recorded to the nearest 0.005 in. (0.127 mm), and the thickness measurement to the nearest 0.001 in.

A2.2.3 Transverse Strip Test Specimens:

A2.2.3.1 In general, transverse tension tests are not recommended for tubular products, in sizes smaller than 8 in. in nominal diameter. When required, transverse tension test specimens may be taken from rings cut from ends of tubes or pipe as shown in Fig. A2.4. Flattening of the specimen may be done either after separating it from the tube as in Fig. A2.4 (a), or before separating it as in Fig. A2.4 (b), and may be done hot or cold; but if the flattening is done cold, the specimen may subsequently be normalized. Specimens from tubes or pipe for which heat treatment is specified, after being flattened either hot or cold, shall be given the same treatment as the tubes or pipe. For tubes or pipe having a wall thickness of less than $\frac{3}{4}$ in. (19 mm), the transverse test specimen shall be of the form and dimensions shown in Fig. A2.5 and either or both surfaces may be machined to secure uniform thickness. Specimens for transverse tension tests on welded steel tubes or pipe to determine strength of welds, shall be located perpendicular to the welded seams with the weld at about the middle of their length.

A2.2.3.2 The width should be measured at each end of the gage length to determine parallelism and also

at the center. The thickness should be measured at the center and used with the center measurement of the width to determine the cross-sectional area. The center width dimension should be recorded to the nearest 0.005 in. (0.127 mm), and the thickness measurement to the nearest 0.001 in. (0.025 mm).

A2.2.4 Round Test Specimens:

A2.2.4.1 When provided for in the product specification, the round test specimen shown in Fig. 4 may be used.

A2.2.4.2 The diameter of the round test specimen is measured at the center of the specimen to the nearest 0.001 in. (0.025 mm).

A2.2.4.3 Small-size specimens proportional to standard, as shown in Fig. 4, may be used when it is necessary to test material from which the standard specimen cannot be prepared. Other sizes of small-size specimens may be used. In any such small-size specimen, it is important that the gage length for measurement of elongation be four times the diameter of the specimen (see Note 4, Fig. 4). The elongation requirements for the round specimen 2-in. gage length in the product specification shall apply to the small-size specimens.

A2.2.4.4 For transverse specimens, the section from which the specimen is taken shall not be flattened or otherwise deformed.

A2.2.4.5 Longitudinal test specimens are obtained from strips cut from the tubular product as shown in Fig. A2.2.

A2.3 Determination of Transverse Yield Strength, Hydraulic Ring-Expansion Method

A2.3.1 Hardness tests are made on the outside surface, inside surface, or wall cross-section depending upon product-specification limitation. Surface preparation may be necessary to obtain accurate hardness values.

A2.3.2 A testing machine and method for determining the transverse yield strength from an annular ring specimen, have been developed and described in A2.3.3–8.1.2.

A2.3.3 A diagrammatic vertical cross-sectional sketch of the testing machine is shown in Fig. A2.6.

A2.3.4 In determining the transverse yield strength on this machine, a short ring (commonly 3 in. (76 mm) in length) test specimen is used. After the large circular nut is removed from the machine, the wall thickness of the ring specimen is determined and the specimen is telescoped over the oil resistant rubber gasket. The nut is then replaced, but is not turned down tight against the specimen. A slight clearance is left between the nut and specimen for the purpose of permitting free radial movement of the specimen as it is being tested. Oil under pressure is then admitted to the interior of the rubber gasket through the pressure

line under the control of a suitable valve. An accurately calibrated pressure gage serves to measure oil pressure. Any air in the system is removed through the bleeder line. As the oil pressure is increased, the rubber gasket expands which in turn stresses the specimen circumferentially. As the pressure builds up, the lips of the rubber gasket act as a seal to prevent oil leakage. With continued increase in pressure, the ring specimen is subjected to a tension stress and elongates accordingly. The entire outside circumference of the ring specimen is considered as the gage length and the strain is measured with a suitable extensometer which will be described later. When the desired total strain or extension under load is reached on the extensometer, the oil pressure in pounds per square inch is read and by employing Barlow's formula, the unit yield strength is calculated. The yield strength, thus determined, is a true result since the test specimen has not been cold worked by flattening and closely approximates the same condition as the tubular section from which it is cut. Further, the test closely simulates service conditions in pipe lines. One testing machine unit may be used for several different sizes of pipe by the use of suitable rubber gaskets and adapters.

NOTE A2.3 — Barlow's formula may be stated two ways:

$$(1) \quad P = 2St/D \quad (A2.2)$$

$$(2) \quad S = PD/2t \quad (A2.3)$$

where:

P = internal hydrostatic pressure, psi,

S = unit circumferential stress in the wall of the tube produced by the internal hydrostatic pressure, psi,

t = thickness of the tube wall, in., and

D = outside diameter of the tube, in.

A2.3.5 A roller chain type extensometer which has been found satisfactory for measuring the elongation of the ring specimen is shown in Fig. A2.7 and Fig. A2.8. Fig. A2.7 shows the extensometer in position, but unclamped, on a ring specimen. A small pin, through which the strain is transmitted to and measured by the dial gage, extends through the hollow threaded stud. When the extensometer is clamped, as shown in Fig. A2.8, the desired tension which is necessary to hold the instrument in place and to remove any slack, is exerted on the roller chain by the spring. Tension on the spring may be regulated as desired by the knurled thumb screw. By removing or adding rollers, the roller chain may be adapted for different sizes of tubular sections.

A2.4 Hardness Tests

A2.4.1 Hardness tests are made either on the outside or the inside surfaces on the end of the tube as appropriate.

A2.4.2 The standard 3000 kgf Brinell load may cause too much deformation in a thin-walled tubular specimen. In this case the 500 kgf load shall be applied, or inside stiffening by means of an internal anvil should be used.

Brinell testing shall not be applicable to tubular products less than 2 in. (51 mm) in outside diameter, or less than 0.200 in. (5.1 mm) in wall thickness.

A2.4.3 The Rockwell hardness tests are normally made on the inside surface, a flat on the outside surface, or on the wall cross-section depending upon the product limitation. Rockwell hardness tests are not performed on tubes smaller than $\frac{5}{16}$ in. (7.9 mm) in outside diameter, nor are they performed on the inside surface of tubes with less than $\frac{1}{4}$ in. (6.4 mm) inside diameter. Rockwell hardness tests are not performed on annealed tubes with walls less than 0.065 in. (1.65 mm) thick or cold worked or heat treated tubes with walls less than 0.049 in. (1.24 mm) thick. For tubes with wall thicknesses less than those permitting the regular Rockwell hardness test, the Superficial Rockwell test is sometimes substituted. Transverse Rockwell hardness readings can be made on tubes with a wall thickness of 0.187 in. (4.75 mm) or greater. The curvature and the wall thickness of the specimen impose limitations on the Rockwell hardness test. When a comparison is made between Rockwell determinations made on the outside surface and determinations made on the inside surface, adjustment of the readings will be required to compensate for the effect of curvature. The Rockwell B scale is used on all materials having an expected hardness range of B0 to B100. The Rockwell C scale is used on material having an expected hardness range of C20 to C68.

A2.4.4 Superficial Rockwell hardness tests are normally performed on the outside surface whenever possible and whenever excessive spring back is not encountered. Otherwise, the tests may be performed on the inside. Superficial Rockwell hardness tests shall not be performed on tubes with an inside diameter of less than $\frac{1}{4}$ in. (6.4 mm). The wall thickness limitations for the Superficial Rockwell hardness test are given in Table A2.1 and Table A2.2.

A2.4.5 When the outside diameter, inside diameter, or wall thickness precludes the obtaining of accurate hardness values, tubular products shall be specified to tensile properties and so tested.

A2.5 Manipulating Tests

A2.5.1 The following tests are made to prove ductility of certain tubular products:

A2.5.1.1 Flattening Test — The flattening test as commonly made on specimens cut from tubular products is conducted by subjecting rings from the tube or pipe to a prescribed degree of flattening between parallel plates (Fig. A2.4). The severity of the flattening test is measured by the distance between the parallel plates and is varied according to the dimensions of the tube or pipe. The flattening test specimen should not be less than $2\frac{1}{2}$ in. (63.5 mm) in length and should be flattened cold to the extent required by the applicable material specifications.

A2.5.1.2 Reverse Flattening Test — The reverse flattening test is designed primarily for application to electric-welded tubing for the detection of lack of penetration or overlaps resulting from flash removal in the weld. The specimen consists of a length of tubing approximately 4 in. (102 mm) long which is split longitudinally 90° on each side of the weld. The sample is then opened and flattened with the weld at the point of maximum bend (Fig. A2.9).

A2.5.1.3 Crush Test — The crush test, sometimes referred to as an upsetting test, is usually made on boiler and other pressure tubes, for evaluating ductility (Fig. A2.10). The specimen is a ring cut from the tube, usually about 2½ in. (63.5 mm) long. It is placed on end and crushed endwise by hammer or press to the distance prescribed by the applicable material specifications.

A2.5.1.4 Flange Test — The flange test is intended to determine the ductility of boiler tubes and their ability to withstand the operation of bending into a tube sheet. The test is made on a ring cut from a tube, usually not less than 4 in. (100 mm) long and consists of having a flange turned over at right angles to the body of the tube to the width required by the applicable material specifications. The flaring tool and die block shown in Fig. A2.11 are recommended for use in making this test.

A2.5.1.5 Flaring Test — For certain types of pressure tubes, an alternate to the flange test is made. This test consists of driving a tapered mandrel having a slope of 1 in 10 as shown in Fig. A2.12 (a) or a 60° included angle as shown in Fig. A2.12 (b) into a section cut from the tube, approximately 4 in. (100 mm) in length, and thus expanding the specimen until the inside diameter has been increased to the extent required by the applicable material specifications.

A2.5.1.6 Bend Test — For pipe used for coiling in sizes 2 in. and under a bend test is made to determine its ductility and the soundness of weld. In this test a sufficient length of full-size pipe is bent cold through 90° around a cylindrical mandrel having a diameter 12 times the nominal diameter of the pipe. For close coiling, the pipe is bent cold through 180° around a mandrel having a diameter 8 times the nominal diameter of the pipe.

A2.5.1.7 Transverse Guided Bend Test of Welds — This bend test is used to determine the ductility of fusion welds. The specimens used are approximately 1½ in. (38 mm) wide, at least 6 in. (152 mm) in length with the weld at the center, and are machined in accordance with Fig. A2.13 for face and root bend tests and in accordance with Fig. A2.14 for side bend tests. The dimensions of the plunger shall be as shown in Fig. A2.15 and the other dimensions of the bending jig shall be substantially as given in this same figure. A test shall consist of a face bend specimen and a root bend specimen or two side bend specimens. A face bend test requires bending with the

inside surface of the pipe against the plunger; a root bend test requires bending with the outside surface of the pipe against the plunger; and a side bend test requires bending so that one of the side surfaces becomes the convex surface of the bend specimen.

(a) Failure of the bend test depends upon the appearance of cracks in the area of the bend, of the nature and extent described in the product specifications.

A3. STEEL FASTENERS

A3.1 Scope

A3.1.1 This supplement covers definitions and methods of testing peculiar to steel fasteners which are not covered in the general section of Test Methods and Definitions A 370. Standard tests required by the individual product specifications are to be performed as outlined in the general section of these methods.

A3.1.2 These tests are set up to facilitate production control testing and acceptance testing with certain more precise tests to be used for arbitration in case of disagreement over test results.

A3.2 Tension Tests

A3.2.1 It is preferred that bolts be tested full size, and it is customary, when so testing bolts to specify a minimum ultimate load in pounds, rather than a minimum ultimate strength in pounds per square inch. Three times the bolt nominal diameter has been established as the minimum bolt length subject to the tests described in the remainder of this section. Sections A3.2.1.1–A3.2.1.3 apply when testing bolts full size. Section A3.2.1.4 shall apply where the individual product specifications permit the use of machined specimens.

A3.2.1.1 Proof Load — Due to particular uses of certain classes of bolts it is desirable to be able to stress them, while in use, to a specified value without obtaining any permanent set. To be certain of obtaining this quality the proof load is specified. The proof load test consists of stressing the bolt with a specified load which the bolt must withstand without permanent set. An alternate test which determines yield strength of a full size bolt is also allowed. Either of the following Methods, 1 or 2, may be used but Method 1 shall be the arbitration method in case of any dispute as to acceptance of the bolts.

A3.2.1.2 Proof Load Testing Long Bolts — When full size tests are required, proof load Method 1 is to be limited in application to bolts whose length does not exceed 8 in. (203 mm) or 8 times the nominal diameter, whichever is greater. For bolts longer than 8 in. or 8 times the nominal diameter, whichever is greater, proof load Method 2 shall be used.

(a) *Method 1, Length Measurement* — The overall length of a straight bolt shall be measured at its true center

line with an instrument capable of measuring changes in length of 0.0001 in. (0.0025 mm) with an accuracy of 0.0001 in. in any 0.001 in. (0.025 mm) range. The preferred method of measuring the length shall be between conical centers machined on the center line of the bolt, with mating centers on the measuring anvils. The head or body of the bolt shall be marked so that it can be placed in the same position for all measurements. The bolt shall be assembled in the testing equipment as outlined in A3.2.1.4, and the proof load specified in the product specification shall be applied. Upon release of this load the length of the bolt shall be again measured and shall show no permanent elongation. A tolerance of ± 0.0005 in. (0.0127 mm) shall be allowed between the measurement made before loading and that made after loading. Variables, such as straightness and thread alignment (plus measurement error), may result in apparent elongation of the fasteners when the proof load is initially applied. In such cases, the fastener may be retested using a 3 percent greater load, and may be considered satisfactory if the length after this loading is the same as before this loading (within the 0.0005 in. tolerance for measurement error).

A3.2.1.3 Proof Load-Time of Loading — The proof load is to be maintained for a period of 10 s before release of load, when using Method 1.

(1) *Method 2, Yield Strength* — The bolt shall be assembled in the testing equipment as outlined in A3.2.1.4. As the load is applied, the total elongation of the bolt or any part of the bolt which includes the exposed six threads shall be measured and recorded to produce a load-strain or a stress-strain diagram. The load or stress at an offset equal to 0.2 percent of the length of bolt occupied by 6 full threads shall be determined by the method described in 13.2.1 of these methods, A 370. This load or stress shall not be less than that prescribed in the product specification.

A3.2.1.4 Axial Tension Testing of Full Size Bolts — Bolts are to be tested in a holder with the load axially applied between the head and a nut or suitable fixture (Fig. A3.1), either of which shall have sufficient thread engagement to develop the full strength of the bolt. The nut or fixture shall be assembled on the bolt leaving six complete bolt threads unengaged between the grips, except for heavy hexagon structural bolts which shall have four complete threads unengaged between the grips. To meet the requirements of this test there shall be a tensile failure in the body or threaded section with no failure at the junction of the body, and head. If it is necessary to record or report the tensile strength of bolts as psi values the stress area shall be calculated from the mean of the mean root and pitch diameters of Class 3 external threads as follows:

$$A_s = 0.7854 [D - (0.9743/n)]^2 \quad (\text{A3.1})$$

where:

A_s = stress area, in.²

D = nominal diameter, in., and

n = number of threads per inch

A3.2.1.5 Tension Testing of Full-Size Bolts with a Wedge — The purpose of this test is to obtain the tensile strength and demonstrate the “head quality” and ductility of a bolt with a standard head by subjecting it to eccentric loading. The ultimate load on the bolt shall be determined as described in A3.2.1.4, except that a 10° wedge shall be placed under the same bolt previously tested for the proof load (see A3.2.1.1). The bolt head shall be so placed that no corner of the hexagon or square takes a bearing load, that is, a flat of the head shall be aligned with the direction of uniform thickness of the wedge (Fig. A3.2). The wedge shall have an included angle of 10° between its faces and shall have a thickness of one-half of the nominal bolt diameter at the short side of the hole. The hole in the wedge shall have the following clearance over the nominal size of the bolt, and its edges, top and bottom, shall be rounded to the following radius:

Nominal Bolt Size, in.	Clearance in Hole, in. (mm)	Radius on Corners of Hole, in. (mm)
$\frac{1}{4}$ to $\frac{1}{2}$	0.030 (0.76)	0.030 (0.76)
$\frac{5}{16}$ to $\frac{3}{4}$	0.050 (1.3)	0.060 (1.5)
$\frac{7}{8}$ to 1	0.063 (1.5)	0.060 (1.5)
$1\frac{1}{8}$ to $1\frac{1}{4}$	0.063 (1.5)	0.125 (3.2)
$1\frac{3}{8}$ to $1\frac{1}{2}$	0.094 (2.4)	0.125 (3.2)

A3.2.1.6 Wedge Testing of HT Bolts Threaded to Head — For heat-treated bolts over 100 000 psi (690 MPa) minimum tensile strength and that are threaded 1 diameter and closer to the underside of the head, the wedge angle shall be 6° for sizes $\frac{1}{4}$ through $\frac{3}{4}$ in. (6.35 to 19.0 mm) and 4° for sizes over $\frac{3}{4}$ in.

A3.2.1.7 Tension Testing of Bolts Machined to Round Test Specimens:

(1) Bolts under $1\frac{1}{2}$ in. (38 mm) in diameter which require machined tests shall preferably use a standard $\frac{1}{2}$ in., (13 mm) round 2 in. (50 mm) gage length test specimen (Fig. 4); however, bolts of small cross-section that will not permit the taking of this standard test specimen shall use one of the small-size-specimens-proportional-to-standard (Fig. 4) and the specimen shall have a reduced section as large as possible. In all cases, the longitudinal axis of the specimen shall be concentric with the axis of the bolt; the head and threaded section of the bolt may be left intact, as in Fig. A3.3 and Fig. A3.4, or shaped to fit the holders or grips of the testing machine so that the load is applied axially. The gage length for measuring the elongation shall be four times the diameter of the specimen.

(2) For bolts $1\frac{1}{2}$ in. and over in diameter, a standard $\frac{1}{2}$ in. round 2 in. gage length test specimen shall be turned

from the bolt, having its axis midway between the center and outside surface of the body of the bolt as shown in Fig. A3.5.

(3) Machined specimens are to be tested in tension to determine the properties prescribed by the product specifications. The methods of testing and determination of properties shall be in accordance with Section 13 of these test methods.

A3.3 Hardness Tests for Externally Threaded Fasteners

A3.3.1 When specified, externally threaded fasteners shall be hardness tested. Fasteners with hexagonal or square heads shall be Brinell or Rockwell hardness tested on the side or top of the head. Externally threaded fasteners with other type of heads and those without heads shall be Brinell or Rockwell hardness tested on one end. Due to possible distortion from the Brinell load, care should be taken that this test meets the requirements of Section 16 of these test methods. Where the Brinell hardness test is impractical, the Rockwell hardness test shall be substituted. Rockwell hardness test procedures shall conform to Section 18 of these test methods.

A3.3.2 In cases where a dispute exists between buyer and seller as to whether externally threaded fasteners meet or exceed the hardness limit of the product specification, for purposes of arbitration, hardness may be taken on two transverse sections through a representative sample fastener selected at random. Hardness readings shall be taken at the locations shown in Fig. A3.6. All hardness values must conform with the hardness limit of the product specification in order for the fasteners represented by the sample to be considered in compliance. This provision for arbitration of a dispute shall not be used to accept clearly rejectable fasteners.

A3.4 Testing of Nuts

A3.4.1 Proof Load — A sample nut shall be assembled on a hardened threaded mandrel or on a bolt conforming to the particular specification. A load axial with the mandrel or bolt and equal to the specified proof load of the nut shall be applied. The nut shall resist this load without stripping or rupture. If the threads of the mandrel are damaged during the test the individual test shall be discarded. The mandrel shall be threaded to American National Standard Class 3 tolerance, except that the major diameter shall be the minimum major diameter with a tolerance of +0.002 in. (0.051 mm).

A3.4.2 Hardness Test — Rockwell hardness of nuts shall be determined on the top or bottom face of the nut. Brinell hardness shall be determined on the side of the nuts. Either method may be used at the option of the manufacturer, taking into account the size and grade of the nuts under test. When the standard Brinell hardness

test results in deforming the nut it will be necessary to use a minor load or substitute a Rockwell hardness test.

A4. ROUND WIRE PRODUCTS

A4.1 Scope

A4.1.1 This supplement covers the apparatus, specimens and methods of testing peculiar to steel wire products which are not covered in the general section of Test Methods A 370.

A4.2 Apparatus

A4.2.1 Gripping Devices — Grips of either the wedge or snubbing types as shown in Fig. A4.1 and Fig. A4.2 shall be used (Note A4.1). When using grips of either type, care shall be taken that the axis of the test specimen is located approximately at the center line of the head of the testing machine (Note A4.2). When using wedge grips the liners used behind the grips shall be of the proper thickness.

NOTE A4.1 — Testing machines usually are equipped with wedge grips. These wedge grips, irrespective of the type of testing machine, may be referred to as the "usual type" of wedge grips. The use of fine (180 or 240) grit abrasive cloth in the "usual" wedge type grips, with the abrasive contacting the wire specimen, can be helpful in reducing specimen slipping and breakage at the grip edges at tensile loads up to about 1000 pounds. For tests of specimens of wire which are liable to be cut at the edges by the "usual type" of wedge grips, the snubbing type gripping device has proved satisfactory.

For testing round wire, the use of cylindrical seat in the wedge gripping device is optional.

NOTE A4.2 — Any defect in a testing machine which may cause nonaxial application of load should be corrected.

A4.2.2 Pointed Micrometer — A micrometer with a pointed spindle and anvil suitable for reading the dimensions of the wire specimen at the fractured ends to the nearest 0.001 in. (0.025 mm) after breaking the specimen in the testing machine shall be used.

A4.3 Test Specimens

A4.3.1 Test specimens having the full cross-sectional area of the wire they represent shall be used. The standard gage length of the specimens shall be 10 in. (254 mm). However, if the determination of elongation values is not required, any convenient gage length is permissible. The total length of the specimens shall be at least equal to the gage length (10 in.) plus twice the length of wire required for the full use of the grip employed. For example, depending upon the type of testing machine and grips used, the minimum total length of specimen may vary from 14 to 24 in. (360 to 610 mm) for a 10 in. gage length specimen.

A4.3.2 Any specimen breaking in the grips shall be discarded and a new specimen tested.

A4.4 Elongation

A4.4.1 In determining permanent elongation, the ends of the fractured specimen shall be carefully fitted together and the distance between the gage marks measured to the nearest 0.01 in. (0.25 mm) with dividers and scale or other suitable device. The elongation is the increase in length of the gage length, expressed as a percentage of the original gage length. In recording elongation values, both the percentage increase and the original gage length shall be given.

A4.4.2 In determining total elongation (elastic plus plastic extension) autographic or extensometer methods may be employed.

A4.4.3 If fracture takes place outside of the middle third of the gage length, the elongation value obtained may not be representative of the material.

A4.5 Reduction of Area

A4.5.1 The ends of the fractured specimen shall be carefully fitted together and the dimensions of the smallest cross section measured to the nearest 0.001 in. (0.025 mm) with a pointed micrometer. The difference between the area thus found and the area of the original cross section, expressed as a percentage of the original area, is the reduction of area.

A4.5.2 The reduction of area test is not recommended in wire diameters less than 0.092 in. (2.34 mm) due to the difficulties of measuring the reduced cross sections.

A4.6 Rockwell Hardness Test

A4.6.1 On heat-treated wire of diameter 0.100 in. (2.54 mm) and larger, the specimen shall be flattened on two parallel sides by grinding before testing. The hardness test is not recommended for any diameter of hard drawn wire or heat-treated wire less than 0.100 in. (2.54 mm) in diameter. For round wire, the tensile strength test is greatly preferred over the hardness test.

A4.7 Wrap Test

A4.7.1 This test is used as a means for testing the ductility of certain kinds of wire.

A4.7.2 The test consists of coiling the wire in a closely spaced helix tightly against a mandrel of a specified diameter for a required number of turns. (Unless other specified, the required number of turns shall be five.) The wrapping may be done by hand or a power device. The wrapping rate may not exceed 15 turns per min. The mandrel diameter shall be specified in the relevant wire product specification.

A4.7.3 The wire tested shall be considered to have failed if the wire fractures or if any longitudinal or transverse cracks develop which can be seen by the unaided eye after the first complete turn. Wire which fails in the first turn shall be retested, as such fractures may be caused

by bending the wire to a radius less than specified when the test starts.

A4.8 Coiling Test

A4.8.1 This test is used to determine if imperfections are present to the extent that they may cause cracking or splitting during spring coiling and spring extension. A coil of specified length is closed wound on an arbor of a specified diameter. The closed coil is then stretched to a specified permanent increase in length and examined for uniformity of pitch with no splits or fractures. The required arbor diameter, closed coil length, and permanent coil extended length increase may vary with wire diameter, properties, and type.

A5. NOTES ON SIGNIFICANCE OF NOTCHED-BAR IMPACT TESTING

A5.1 Notch Behavior

A5.1.1 The Charpy and Izod type tests bring out notch behavior (brittleness versus ductility) by applying a single overload of stress. The energy values determined are quantitative comparisons on a selected specimen but cannot be converted into energy values that would serve for engineering design calculations. The notch behavior indicated in an individual test applies only to the specimen size, notch geometry, and testing conditions involved and cannot be generalized to other sizes of specimens and conditions.

A5.1.2 The notch behavior of the face-centered cubic metals and alloys, a large group of nonferrous materials and the austenitic steels can be judged from their common tensile properties. If they are brittle in tension they will be brittle when notched, while if they are ductile in tension, they will be ductile when notched, except for unusually sharp or deep notches (much more severe than the standard Charpy or Izod specimens). Even low temperatures do not alter this characteristic of these materials. In contrast, the behavior of the ferritic steels under notch conditions cannot be predicted from their properties as revealed by the tension test. For the study of these materials the Charpy and Izod type tests are accordingly very useful. Some metals that display normal ductility in the tension test may nevertheless break in brittle fashion when tested or when used in the notched condition. Notched conditions include restraints to deformation in directions perpendicular to the major stress, or multiaxial stresses, and stress concentrations. It is in this field that the Charpy and Izod tests prove useful for determining the susceptibility of a steel to notch-brittle behavior though they cannot be directly used to appraise the serviceability of a structure.

A5.1.3 The testing machine itself must be sufficiently rigid or tests on high-strength low-energy materials will result in excessive elastic energy losses either upward

through the pendulum shaft or downward through the base of the machine. If the anvil supports, the pendulum striking edge, or the machine foundation bolts are not securely fastened, tests on ductile materials in the range of 80 ft•lbf (108 J) may actually indicate values in excess of 90 to 100 ft•lbf (122 to 136 J).

A5.2 Notch Effect

A5.2.1 The notch results in a combination of multiaxial stresses associated with restraints to deformation in directions perpendicular to the major stress, and a stress concentration at the base of the notch. A severely notched condition is generally not desirable, and it becomes of real concern in those cases in which it initiates a sudden and complete failure of the brittle type. Some metals can be deformed in a ductile manner even down to the low temperatures of liquid air, while others may crack. This difference in behavior can be best understood by considering the cohesive strength of a material (or the property that holds it together) and its relation to the yield point. In cases of brittle fracture, the cohesive strength is exceeded before significant plastic deformation occurs and the fracture appears crystalline. In cases of the ductile or shear type of failure, considerable deformation precedes the final fracture and the broken surface appears fibrous instead of crystalline. In intermediate cases the fracture comes after a moderate amount of deformation and is part crystalline and part fibrous in appearance.

A5.2.2 When a notched bar is loaded, there is a normal stress across the base of the notch which tends to initiate fracture. The property that keeps it from cleaving, or holds it together, is the “cohesive strength.” The bar fractures when the normal stress exceeds the cohesive strength. When this occurs without the bar deforming it is the condition for brittle fracture.

A5.2.3 In testing, though not in service because of side effects, it happens more commonly that plastic deformation precedes fracture. In addition to the normal stress, the applied load also sets up shear stresses which are about 45° to the normal stress. The elastic behavior terminates as soon as the shear stress exceeds the shear strength of the material and deformation or plastic yielding sets in. This is the condition for ductile failure.

A5.2.4 This behavior, whether brittle or ductile, depends on whether the normal stress exceeds the cohesive strength before the shear stress exceeds the shear strength. Several important facts of notch behavior follow from this. If the notch is made sharper or more drastic, the normal stress at the root of the notch will be increased in relation to the shear stress and the bar will be more prone to brittle fracture (see Table A5.1). Also, as the speed of deformation increases, the shear strength increases and the likelihood of brittle fracture increases. On the other hand, by raising

the temperature, leaving the notch and the speed of deformation the same, the shear strength is lowered and ductile behavior is promoted, leading to shear failure.

A5.2.5 Variations in notch dimensions will seriously affect the results of the tests. Tests on E 4340 steel specimens have shown the effect of dimensional variations on Charpy results (see Table A5.1).

A5.3 Size Effect

A5.3.1 Increasing either the width or the depth of the specimen tends to increase the volume of metal subject to distortion, and by this factor tends to increase the energy absorption when breaking the specimen. However, any increase in size, particularly in width, also tends to increase the degree of restraint and by tending to induce brittle fracture, may decrease the amount of energy absorbed. Where a standard-size specimen is on the verge of brittle fracture, this is particularly true, and a double-width specimen may actually require less energy for rupture than one of standard width.

A5.3.2 In studies of such effects where the size of the material precludes the use of the standard specimen, as for example when the material is $\frac{1}{4}$ in. plate, subsize specimens are necessarily used. Such specimens (see Fig. 6 of Test Methods E 23) are based on the Type A specimen of Fig. 4 of Test Methods E 23.

A5.3.3 General correlation between the energy values obtained with specimens of different size or shape is not feasible, but limited correlations may be established for specification purposes on the basis of special studies of particular materials and particular specimens. On the other hand, in a study of the relative effect of process variations, evaluation by use of some arbitrarily selected specimen with some chosen notch will in most instances place the methods in their proper order.

A5.4 Effects of Testing Conditions

A5.4.1 The testing conditions also affect the notch behavior. So pronounced is the effect of temperature on the behavior of steel when notched that comparisons are frequently made by examining specimen fractures and by plotting energy value and fracture appearance versus temperature from tests of notched bars at a series of temperatures. When the test temperature has been carried low enough to start cleavage fracture, there may be an extremely sharp drop in impact value or there may be a relatively gradual falling off toward the lower temperatures. This drop in energy value starts when a specimen begins to exhibit some crystalline appearance in the fracture. The transition temperature at which this embrittling effect takes place varies considerably with the size of the part or test specimen and with the notch geometry.

A5.4.2 Some of the many definitions of transition temperature currently being used are: (1) the lowest temperature at which the specimen exhibits 100% fibrous fracture,

(2) the temperature where the fracture shows a 50% crystalline and a 50% fibrous appearance, (3) the temperature corresponding to the energy value 50% of the difference between values obtained at 100% and 0% fibrous fracture, and (4) the temperature corresponding to a specific energy value.

A5.4.3 A problem peculiar to Charpy-type tests occurs when high-strength, low-energy specimens are tested at low temperatures. These specimens may not leave the machine in the direction of the pendulum swing but rather in a sidewise direction. To ensure that the broken halves of the specimens do not rebound off some component of the machine and contact the pendulum before it completes its swing, modifications may be necessary in older model machines. These modifications differ with machine design. Nevertheless the basic problem is the same in that provisions must be made to prevent rebounding of the fractured specimens into any part of the swinging pendulum. Where design permits, the broken specimens may be deflected out of the sides of the machine and yet in other designs it may be necessary to contain the broken specimens within a certain area until the pendulum passes through the anvils. Some low-energy high-strength steel specimens leave impact machines at speeds in excess of 50 ft (15.3 m)/s although they were struck by a pendulum traveling at speeds approximately 17 ft (5.2 m)/s. If the force exerted on the pendulum by the broken specimens is sufficient, the pendulum will slow down and erroneously high energy values will be recorded. This problem accounts for many of the inconsistencies in Charpy results reported by various investigators within the 10 to 25-ft•lbf (14 to 34 J) range. The Apparatus Section (the paragraph regarding Specimen Clearance) of Test Methods E 23 discusses the two basic machine designs and a modification found to be satisfactory in minimizing jamming.

A5.5 Velocity of Straining

A5.5.1 Velocity of straining is likewise a variable that affects the notch behavior of steel. The impact test shows somewhat higher energy absorption values than the static tests above the transition temperature and yet, in some instances, the reverse is true below the transition temperature.

A5.6 Correlation with Service

A5.6.1 While Charpy or Izod tests may not directly predict the ductile or brittle behavior of steel as commonly used in large masses or as components of large structures, these tests can be used as acceptance tests of identity for different lots of the same steel or in choosing between different steels, when correlation with reliable service behavior has been established. It may be necessary to make the tests at properly chosen temperatures other than room temperature. In this, the service temperature or the transition temperature of full-scale specimens does not give the

desired transition temperatures for Charpy or Izod tests since the size and notch geometry may be so different. Chemical analysis, tension, and hardness tests may not indicate the influence of some of the important processing factors that affect susceptibility to brittle fracture nor do they comprehend the effect of low temperatures in inducing brittle behavior.

A6. PROCEDURE FOR CONVERTING PERCENTAGE ELONGATION OF A STANDARD ROUND TENSION TEST SPECIMEN TO EQUIVALENT PERCENTAGE ELONGATION OF A STANDARD FLAT SPECIMEN

A6.1 Scope

A6.1.1 This method specifies a procedure for converting percentage elongation after fracture obtained in a standard 0.500 in. (12.7 mm) diameter by 2 in. (51 mm) gage length test specimen to standard flat test specimens ½ in. by 2 in. and 1½ in. by 8 in. (38.1 by 203 mm).

A6.2 Basic Equation

A6.2.1 The conversion data in this method are based on an equation by Bertella, and used by Oliver and others. The relationship between elongations in the standard 0.500 in. diameter by 2.0 in. test specimen and other standard specimens can be calculated as follows:

$$e = e_o [4.47(\sqrt{A})/L]^a \quad (\text{A6.1})$$

where:

e_o = percentage elongation after fracture on a standard test specimen having a 2 in. gage length and 0.500 in. diameter

e = percentage elongation after fracture on a standard test specimen having a gage length L and a cross-sectional area A , and

a = constant characteristic of the test material

A6.3 Application

A6.3.1 In applying the above equation the constant a is characteristic of the test material. The value $a = 0.4$ has been found to give satisfactory conversions for carbon, carbon-manganese, molybdenum, and chromium-molybdenum steels within the tensile strength range of 40 000 to 85 000 psi (275 to 585 MPa) and in the hot-rolled, in the hot-rolled and normalized, or in the annealed condition, with or without tempering. Note that the cold reduced and quenched and tempered states are excluded. For annealed austenitic stainless steels, the value $a = 0.127$ has been found to give satisfactory conversions.

A6.3.2 Table A6.1 has been calculated taking $a = 0.4$, with the standard 0.500 in. (12.7 mm) diameter by 2 in. (51 mm) gage length test specimen as the reference

specimen. In the case of the subsize specimens 0.350 in. (8.89 mm) in diameter by 1.4 in. (35.6 mm) gage length, and 0.250 in. (6.35-mm) diameter by 1.0 in. (25.4 mm) gage length the factor in the equation is 4.51 instead of 4.47. The small error introduced by using Table A6.1 for the subsize specimens may be neglected. Table A6.2 for annealed austenitic steels has been calculated taking $a = 0.127$, with the standard 0.500-in. diameter by 2-in. gage length test specimen as the reference specimen.

A6.3.3 Elongation given for a standard 0.500 in. diameter by 2 in. gage length specimen may be converted to elongation for $\frac{1}{2}$ in. by 2 in. or $\frac{1}{2}$ in. by 8 in. (38.1 by 203 mm) flat specimens by multiplying by the indicated factor in Table A6.1 and Table A6.2.

A6.3.4 These elongation conversions shall not be used where the width to thickness ratio of the test piece exceeds 20, as in sheet specimens under 0.025 in. (0.635 mm) in thickness.

A6.3.5 While the conversions are considered to be reliable within the stated limitations and may generally be used in specification writing where it is desirable to show equivalent elongation requirements for the several standard ASTM tension specimens covered in Test Methods A 370, consideration must be given to the metallurgical effects dependent on the thickness of the material as processed.

A7. METHOD OF TESTING MULTI-WIRE STRAND FOR PRESTRESSED CONCRETE

A7.1 Scope

A7.1.1 This method provides procedures for the tension testing of multi-wire strand for prestressed concrete. This method is intended for use in evaluating the strand properties prescribed in specifications for "prestressing steel strands."

A7.2 General Precautions

A7.2.1 Premature failure of the test specimens may result if there is any appreciable notching, cutting, or bending of the specimen by the gripping devices of the testing machine.

A7.2.2 Errors in testing may result if the seven wires constituting the strand are not loaded uniformly.

A7.2.3 The mechanical properties of the strand may be materially affected by excessive heating during specimen preparation.

A7.2.4 These difficulties may be minimized by following the suggested methods of gripping described in A7.4.

A7.3 Gripping Devices

A7.3.1 The true mechanical properties of the strand are determined by a test in which fracture of the specimen

occurs in the free span between the jaws of the testing machine. Therefore, it is desirable to establish a test procedure with suitable apparatus which will consistently produce such results. Due to inherent physical characteristics of individual machines, it is not practical to recommend a universal gripping procedure that is suitable for all testing machines. Therefore, it is necessary to determine which of the methods of gripping described in A7.3.2 to A7.3.8 is most suitable for the testing equipment available.

A7.3.2 *Standard V-Grips with Serrated Teeth (Note A7.1).*

A7.3.3 *Standard V-Grips with Serrated Teeth (Note A7.1), Using Cushioning Material* — In this method, some material is placed between the grips and the specimen to minimize the notching effect of the teeth. Among the materials which have been used are lead foil, aluminum foil, carborundum cloth, bra shims, etc. The type and thickness of material required is dependent on the shape, condition, and coarseness of the teeth.

A7.3.4 *Standard V-Grips with Serrated Teeth (Note A7.1), Using Special Preparation of the Gripped Portions of the Specimen* — One of the methods used is tinning, in which the gripped portions are cleaned, fluxed, and coated by multiple dips in molten tin alloy held just above the melting point. Another method of preparation is encasing the gripped portions in metal tubing or flexible conduit, using epoxy resin as the bonding agent. The encased portion should be approximately twice the length of lay of the strand.

A7.3.5 *Special Grips with Smooth, Semi-Cylindrical Grooves (Note A7.2)* — The grooves and the gripped portions of the specimen are coated with an abrasive slurry which holds the specimen in the smooth grooves, preventing slippage. The slurry consists of abrasive such as Grade 3-F aluminum oxide and a carrier such as water or glycerin.

A7.3.6 *Standard Sockets of the Type Used for Wire Rope* — The gripped portions of the specimen are anchored in the sockets with zinc. The special procedures for socketing usually employed in the wire rope industry must be followed.

A7.3.7 *Dead-End Eye Splices* — These devices are available in sizes designed to fit each size of strand to be tested.

A7.3.8 *Chucking Devices* — Use of chucking devices of the type generally employed for applying tension to strands in casting beds is not recommended for testing purposes.

NOTE A7.1 — The number of teeth should be approximately 15 to 30 per in., and the minimum effective gripping length should be approximately 4 in. (102 mm).

NOTE A7.2 — The radius of curvature of the grooves is approximately the same as the radius of the strand being tested, and is located $\frac{1}{32}$ in. (0.79 mm) above the flat face of the grip. This prevents the two grips from closing tightly when the specimen is in place.

A7.4 Specimen Preparation

A7.4.1 If the molten-metal temperatures employed during hot-dip tinning or socketing with metallic material are too high, over approximately 700°F (370°C), the specimen may be heat affected with a subsequent loss of strength and ductility. Careful temperature controls should be maintained if such methods of specimen preparation are used.

A7.5 Procedure

A7.5.1 Yield Strength — For determining the yield strength use a Class B-1 extensometer (Note A7.3) as described in Practice E 83. Apply an initial load of 10% of the expected minimum breaking strength to the specimen, then attach the extensometer and adjust it to a reading of 0.001 in./in. of gage length. Then increase the load until the extensometer indicates an extension of 1%. Record the load for this extension as the yield strength. The extensometer may be removed from the specimen after the yield strength has been determined.

A7.5.2 Elongation — For determining the elongation use a Class D extensometer (Note A7.3), as described in Practice E 83, having a gage length of not less than 24 in. (610 mm) (Note A7.4). Apply an initial load of 10% of the required minimum breaking strength to the specimen, then attach the extensometer (Note A7.3) and adjust it to a zero reading. The extensometer may be removed from the specimen prior to rupture after the specified minimum elongation has been exceeded. It is not necessary to determine the final elongation value.

A7.5.3 Breaking Strength — Determine the maximum load at which one or more wires of the strand are fractured. Record this load as the breaking strength of the strand.

NOTE A7.3 — The yield-strength extensometer and the elongation extensometer may be the same instrument or two separate instruments. Two separate instruments are advisable since the more sensitive yield-strength extensometer, which could be damaged when the strand fractures, may be removed following the determination of yield strength. The elongation extensometer may be constructed with less sensitive parts or be constructed in such a way that little damage would result if fracture occurs while the extensometer is attached to the specimen.

NOTE A7.4 — Specimens that break outside the extensometer or in the jaws and yet meet the minimum specified values are considered as meeting the mechanical property requirements of the product specification, regardless of what procedure of gripping has been used. Specimens that break outside of the extensometer or in the jaws and do not meet the minimum specified values are subject to retest. Specimens that break between the jaws and the extensometer and do not meet the minimum specified values are subject to retest as provided in the applicable specification.

A8. ROUNDING OF TEST DATA

A8.1 Rounding

A8.1.1 An observed value or a calculated value shall be rounded off in accordance with the applicable product specification. In the absence of a specified procedure, the rounding-off method of Practice E 29 shall be used.

A8.1.1.1 Values shall be rounded up or rounded down as determined by the rules of Practice E 29.

A8.1.1.2 In the special case of rounding the number “5” when no additional numbers other than “0” follow the “5,” rounding shall be done in the direction of the specification limits if following Practice E 29 would cause rejection of material.

A8.1.2 Recommended levels for rounding reported values of test data are given in Table A8.1. These values are designed to provide uniformity in reporting and data storage, and should be used in all cases except where they conflict with specific requirements of a product specification.

NOTE A8.1 — To minimize cumulative errors, whenever possible, values should be carried to at least one figure beyond that of the final (rounded) value during intervening calculations (such as calculation of stress from load and area measurements) with rounding occurring as the final operation. The precision may be less than that implied by the number of significant figures.

A9. METHODS FOR TESTING STEEL REINFORCING BARS

A9.1 Scope

A9.1.1 This annex covers additional details specific to testing steel reinforcing bars for use in concrete reinforcement.

A9.2 Test Specimens

A9.2.1 All test specimens shall be the full section of the bar as rolled.

A9.3 Tension Testing

A9.3.1 Test Specimen — Specimens for tension tests shall be long enough to provide for an 8-in. (200-mm) gage length, a distance of at least two bar diameters between each gage mark and the grips, plus sufficient additional length to fill the grips completely leaving some excess length protruding beyond each grip.

A9.3.2 Gripping Device — The grips shall be shimmed so that no more than $\frac{1}{2}$ in. (13 mm) of a grip protrudes from the head of the testing machine.

A9.3.3 Gage Marks — The 8 in. (200 mm) gage length shall be marked on the specimen using a preset 8 in. (200 mm) punch or, alternately, may be punch marked every 2 in. (50 mm) along the 8 in. (200 mm) gage length, on one of the longitudinal ribs, if present, or in clear spaces

of the deformation pattern. The punch marks shall not be put on a transverse deformation. Light punch marks are desirable because deep marks severely indent the bar and may affect the results. A bullet-nose punch is desirable.

A9.3.4 The yield strength or yield point shall be determined by one of the following methods:

A9.3.4.1 Extension under load using an autographic diagram method or an extensometer as described in 13.1.2 and 13.1.3,

A9.3.4.2 By the drop of the beam or halt in the gage of the testing machine as described in 13.1.1 where the steel tested as a sharp-knead or well-defined type of yield point.

A9.3.5 The unit stress determinations for yield and tensile strength on full-size specimens shall be based on the nominal bar area.

A9.4 Bend Testing

A9.4.1 Bend tests shall be made on specimens of sufficient length to ensure free bending and with apparatus which provides:

A9.4.1.1 Continuous and uniform application of force throughout the duration of the bending operation,

A9.4.1.2 Unrestricted movement of the specimen at points of contact with the apparatus and bending around a pin free to rotate, and

A9.4.1.3 Close wrapping of the specimen around the pin during the bending operation.

A9.4.2 Other acceptable more severe methods of bend testing, such as placing a specimen across two pins free to rotate and applying the bending force with a fix pin, may be used.

A9.4.3 When retesting is permitted by the product specification, the following shall apply:

A9.4.3.1 Sections of bar containing identifying roll marking shall not be used.

A9.4.3.2 Bars shall be so placed that longitudinal ribs lie in a plane at right angles to the plane of bending.

A10. PROCEDURE FOR USE AND CONTROL OF HEAT-CYCLE SIMULATION

A10.1 Purpose

A10.1.1 To ensure consistent and reproducible heat treatments of production forgings and the test specimens that represent them when the practice of heat-cycle simulation is used.

A10.2 Scope

A10.2.1 Generation and documentation of actual production time — temperature curves (MASTER CHARTS).

A10.2.2 Controls for duplicating the master cycle during heat treatment of production forgings. (Heat treating within the essential variables established during A1.2.1).

A10.2.3 Preparation of program charts for the simulator unit.

A10.2.4 Monitoring and inspection of the simulated cycle within the limits established by the ASME Code.

A10.2.5 Documentation and storage of all controls, inspections, charts, and curves.

A10.3 Referenced Documents

A10.3.1 ASME Standards:

ASME Boiler and Pressure Vessel Code Section III, latest edition.

ASME Boiler and Pressure Vessel Code Section VIII, Division 2, latest edition.

A10.4 Terminology

A10.4.1 Definitions:

A10.4.1.1 *master chart* — a record of the heat treatment received from a forging essentially identical to the production forgings that it will represent. It is a chart of time and temperature showing the output from thermocouples imbedded in the forging at the designated test immersion and test location or locations.

A10.4.1.2 *program chart* — the metallized sheet used to program the simulator unit. Time-temperature data from the master chart are manually transferred to the program chart.

A10.4.1.3 *simulator chart* — a record of the heat treatment that a test specimen had received in the simulator unit. It is a chart of time and temperature and can be compared directly to the master chart for accuracy of duplication.

A10.4.1.4 *simulator cycle* — one continuous heat treatment of a set of specimens in the simulator unit. The cycle includes heating from ambient, holding at temperature, and cooling. For example, a simulated austenitize and quench of a set of specimens would be one cycle; a simulated temper of the same specimens would be another cycle.

A10.5 Procedure

A10.5.1 Production Master Charts:

A10.5.1.1 Thermocouples shall be imbedded in each forging from which a master chart is obtained. Temperature shall be monitored by a recorder with resolution sufficient to clearly define all aspects of the heating, holding, and cooling process. All charts are to be clearly identified with all pertinent information and identification required for maintaining permanent records.

A10.5.1.2 Thermocouples shall be imbedded 180° apart if the material specification requires test locations 180° apart.

A10.5.1.3 One master chart (or two if required in accordance with A10.5.3.1) shall be produced to represent essentially identical forgings (same size and shape). Any change in size or geometry (exceeding rough machining tolerances) of a forging will necessitate that a new master cooling curve be developed.

A10.5.1.4 If more than one curve is required per master forging (180° apart) and a difference in cooling rate is achieved, then the most conservative curve shall be used as the master curve.

A10.5.2 Reproducibility of Heat Treatment Parameters on Production Forgings:

A10.5.2.1 All information pertaining to the quench and temper of the master forging shall be recorded on an appropriate permanent record, similar to the one shown in Table A10.1.

A10.5.2.2 All information pertaining to the quench and temper of the production forgings shall be appropriately recorded, preferably on a form similar to that used in A10.5.2.1. Quench records of production forgings shall be retained for future reference. The quench and temper record of the master forging shall be retained as a permanent record.

A10.5.2.3 A copy of the master forging record shall be stored with the heat treatment record of the production forging.

A10.5.2.4 The essential variables, as set forth on the heat treat record, shall be controlled within the given parameters on the production forging.

A10.5.2.5 The temperature of the quenching medium prior to quenching each production forging shall be equal to or lower than the temperature of the quenching medium prior to quenching the master forging.

A10.5.2.6 The time elapsed from opening the furnace door to quench for the production forging shall not exceed that elapsed for the master forging.

A10.5.2.7 If the time parameter is exceeded in opening the furnace door to beginning of quench, the forging shall be placed back into the furnace and brought back up to equalization temperature.

A10.5.2.8 All forgings represented by the same master forging shall be quenched with like orientation to the surface of the quench bath.

A10.5.2.9 All production forgings shall be quenched in the same quench tank, with the same agitation as the master forging.

A10.5.2.10 Uniformity of Heat Treat Parameters — (I) The difference in actual heat treating temperature between production forgings and the master forging used to establish the simulator cycle for them shall not

exceed $\pm 25^{\circ}\text{F}$ ($\pm 14^{\circ}\text{C}$) for the quench cycle. (2) The tempering temperature of the production forgings shall not fall below the actual tempering temperature of the master forging. (3) At least one contact surface thermocouple shall be placed on each forging in a production load. Temperature shall be recorded for all surface thermocouples on a Time Temperature Recorder and such records shall be retained as permanent documentation.

A10.5.3 Heat-Cycle Simulation:

A10.5.3.1 Program charts shall be made from the data recorded on the master chart. All test specimens shall be given the same heating rate above, the AC1, the same holding time and the same cooling rate as the production forgings.

A10.5.3.2 The heating cycle above the AC1, a portion of the holding cycle, and the cooling portion of the master chart shall be duplicated and the allowable limits on temperature and time, as specified in (a)–(c), shall be established for verification of the adequacy of the simulated heat treatment.

(a) *Heat Cycle Simulation of Test Coupon Heat Treatment for Quenched and Tempered Forgings and Bars* — If cooling rate data for the forgings and bars and cooling rate control devices for the test specimens are available, the test specimens may be heat-treated in the device.

(b) The test coupons shall be heated to substantially the same maximum temperature as the forgings or bars. The test coupons shall be cooled at a rate similar to and no faster than the cooling rate representative of the test locations and shall be within 25°F (14°C) and 20 s at all temperatures after cooling begins. The test coupons shall be subsequently heat treated in accordance with the thermal treatments below the critical temperature including tempering and simulated post weld heat treatment.

(c) *Simulated Post Weld Heat Treatment of Test Specimens* (for ferritic steel forgings and bars) — Except for carbon steel (P Number 1, Section IX of the Code) forgings and bars with a nominal thickness or diameter of 2 in. (51 mm) or less, the test specimens shall be given a heat treatment to simulate any thermal treatments below the critical temperature that the forgings and bars may receive during fabrication. The simulated heat treatment shall utilize temperatures, times, and cooling rates as specified on the order. The total time at temperature(s) for the test material shall be at least 80% of the total time at temperature(s) to which the forgings and bars are subjected during postweld heat treatment. The total time at temperature(s) for the test specimens may be performed in a single cycle.

A10.5.3.3 Prior to heat treatment in the simulator unit, test specimens shall be machined to standard sizes that have been determined to allow adequately for subsequent removal of decarb and oxidation.

A10.5.3.4 At least one thermocouple per specimen shall be used for continuous recording of temperature on an independent external temperature-monitoring source. Due to the sensitivity and design peculiarities of the heating chamber of certain equipment, it is mandatory that the hot junctions of control and monitoring thermocouples always be placed in the same relative position with respect to the heating source (generally infrared lamps).

A10.5.3.5 Each individual specimen shall be identified, and such identification shall be clearly shown on the simulator chart and simulator cycle record.

A10.5.3.6 The simulator chart shall be compared to the master chart for accurate reproduction of simulated quench in accordance with A10.5.3.2(a). If any one specimen is not heat treated within the acceptable limits of temperature and time, such specimen shall be discarded and replaced by a newly machined specimen. Documentation of such action and reasons for deviation from the master chart shall be shown on the simulator chart, and on the corresponding nonconformance report.

A10.5.4 Reheat Treatment and Retesting:

A10.5.4.1 In the event of a test failure, retesting shall be handled in accordance with rules set forth by the material specification.

A10.5.4.2 If retesting is permissible, a new test specimen shall be heat treated the same as previously. The

production forging that it represents will have received the same heat treatment. If the test passes, the forging shall be acceptable. If it fails, the forging shall be rejected or shall be subject to reheat treatment if permissible.

A10.5.4.3 If reheat treatment is permissible, proceed as follows: (1) Reheat treatment same as original heat treatment (time, temperature, cooling rate): Using new test specimens from an area as close as possible to the original specimens, repeat the austenitize and quench cycles twice, followed by the tempering cycle (double quench and temper). The production forging shall be given the identical double quench and temper as its test specimens above. (2) Reheat treatment using a new heat treatment practice. Any change in time, temperature, or cooling rate shall constitute a new heat treatment practice. A new master curve shall be produced and the simulation and testing shall proceed as originally set forth.

A10.5.4.4 In summation, each test specimen and its corresponding forging shall receive identical heat treatment or heat treatment; otherwise the testing shall be invalid.

A10.5.5 Storage, Recall, and Documentation of Heat-Cycle Simulation Data — All records pertaining to heat-cycle simulation shall be maintained and held for a period of 10 years or as designed by the customer. Information shall be so organized that all practices can be verified by adequate documented records.

FIG. A2.1 METAL PLUGS FOR TESTING TUBULAR SPECIMENS, PROPER LOCATION OF PLUGS IN SPECIMEN AND OF SPECIMEN IN HEADS OF TESTING MACHINE

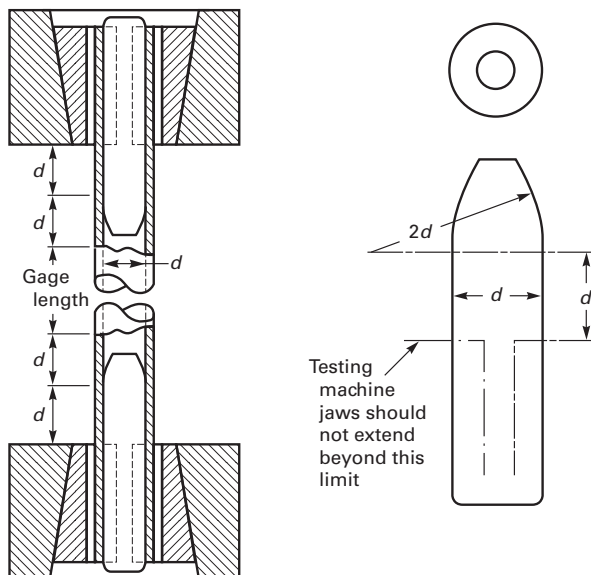
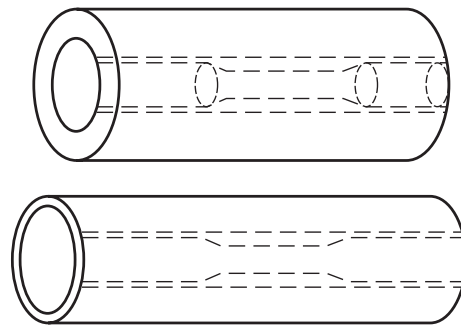
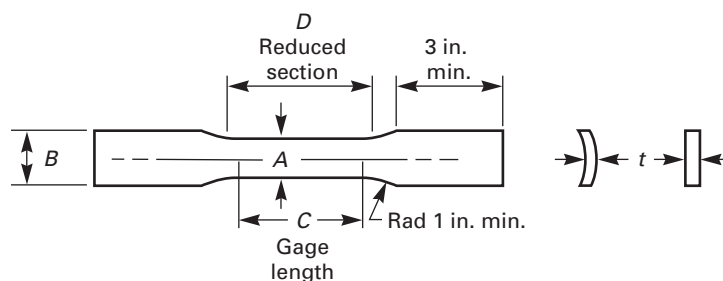


FIG. A2.2 LOCATION OF LONGITUDINAL TENSION — TEST SPECIMENS IN RING CUT FROM TUBULAR PRODUCTS



GENERAL NOTE: The edges of the blank for the specimen shall be cut parallel to each other.

FIG. A2.3 DIMENSIONS AND TOLERANCES FOR LONGITUDINAL STRIP TENSION TEST SPECIMENS FOR TUBULAR PRODUCTS



DIMENSIONS

Specimen No.	Dimensions, in.			
	A	B	C	D
1	$\frac{1}{2} \pm 0.015$	$\frac{11}{16}$ approximately	2 ± 0.005	$2\frac{1}{4}$ min
2	$\frac{3}{4} \pm 0.031$	1 approximately	2 ± 0.005	$2\frac{1}{4}$ min
			4 ± 0.005	$4\frac{1}{2}$ min
3	1 ± 0.062	$1\frac{1}{2}$ approximately	2 ± 0.005	$2\frac{1}{4}$ min
			4 ± 0.005	$4\frac{1}{2}$ min
4	$1\frac{1}{2} \pm \frac{1}{8}$	2 approximately	2 ± 0.010	$2\frac{1}{4}$ min
			4 ± 0.015	$4\frac{1}{2}$ min
			8 ± 0.020	9 min

GENERAL NOTES:

- Cross-sectional area may be calculated by multiplying A and t .
- The dimension t is the thickness of the test specimen as provided for in the applicable material specifications.
- The reduced section shall be parallel within 0.010 in. and may have a gradual taper in width from the ends toward the center, with the ends not more than 0.010 in. wider than the center.
- The ends of the specimen shall be symmetrical with the center line of the reduced section within 0.10 in.
- Metric equivalent: 1 in. = 25.4 mm.
- Specimens with sides parallel throughout their length are permitted, except for referee testing, provided: (a) the above tolerances are used; (b) an adequate number of marks are provided for determination of elongation; and (c) when yield strength is determined, a suitable extensometer is used. If the fracture occurs at a distance of less than 2A from the edge of the gripping device, the tensile properties determined may not be representative of the material. If the properties meet the minimum requirements specified, no further testing is required, but if they are less than the minimum requirements, discard the test and retest.

FIG. A2.4 LOCATION OF TRANSVERSE TENSION TEST SPECIMENS IN RING CUT FROM TUBULAR PRODUCTS

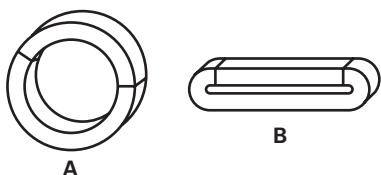
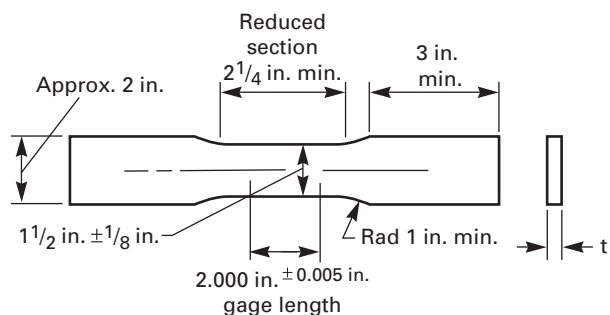


FIG. A2.5 TRANSVERSE TENSION TEST SPECIMEN MACHINED FROM RING CUT FROM TUBULAR PRODUCTS



GENERAL NOTES:

- (a) The dimension t is the thickness of the test specimen as provided for in the applicable material specifications.
- (b) The reduced section shall be parallel within 0.010 in. and may have a gradual taper in width from the ends toward the center, with the ends not more than 0.010 in. wider than the center.
- (c) The ends of the specimen shall be symmetrical with the center line of the reduced section within 0.10 in.
- (d) Metric equivalent: 1 in. = 25.4 mm.

FIG. A2.6 TESTING MACHINE FOR DETERMINATION OF TRANSVERSE YIELD STRENGTH FROM ANNULAR RING SPECIMENS

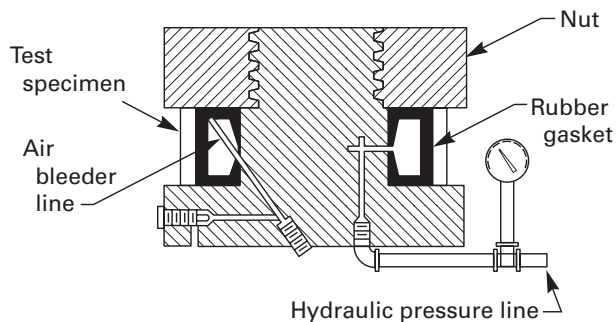


FIG. A2.7 ROLLER CHAIN TYPE EXTENSOMETER, UNCLAMPED

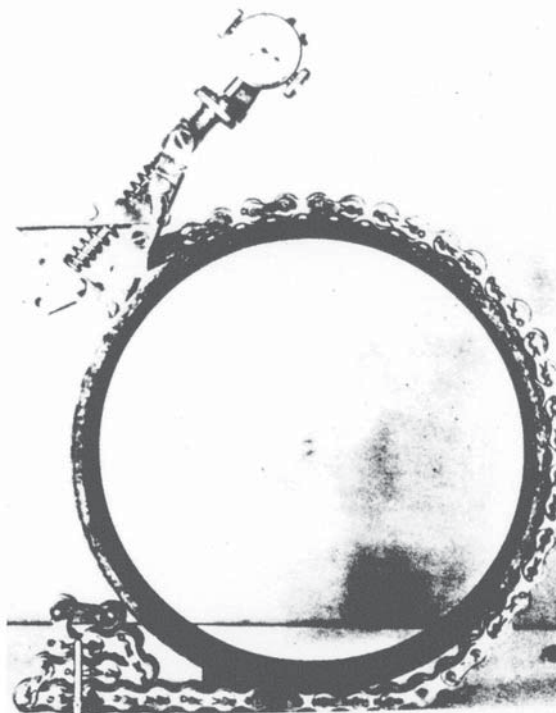


FIG. A2.8 ROLLER CHAIN TYPE EXTENSOMETER, CLAMPED

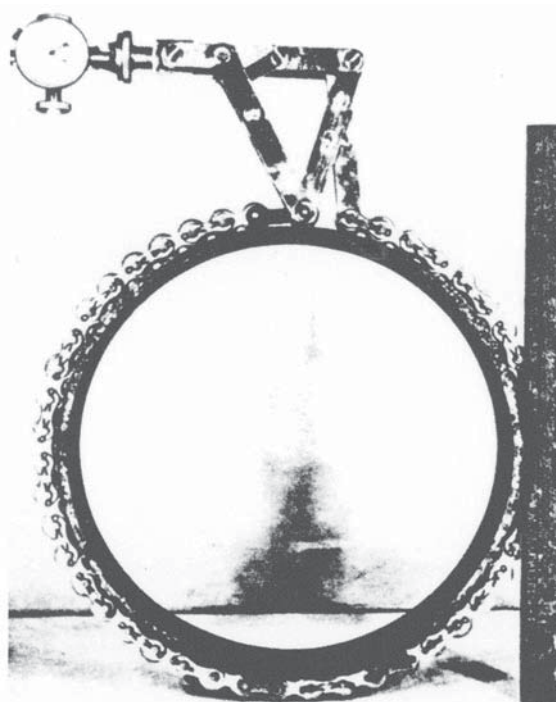


FIG. A2.9 REVERSE FLATTENING TEST

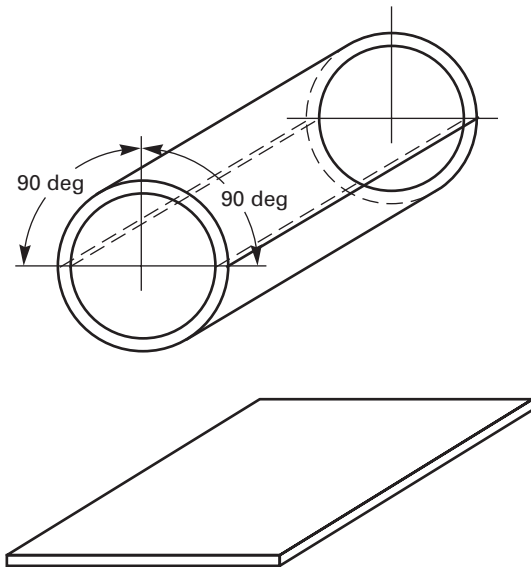


FIG. A2.10 CRUSH TEST SPECIMEN

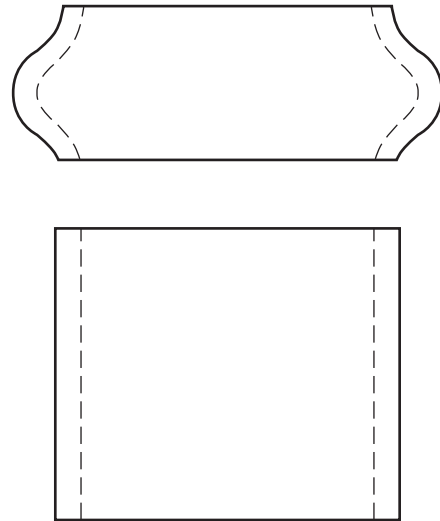
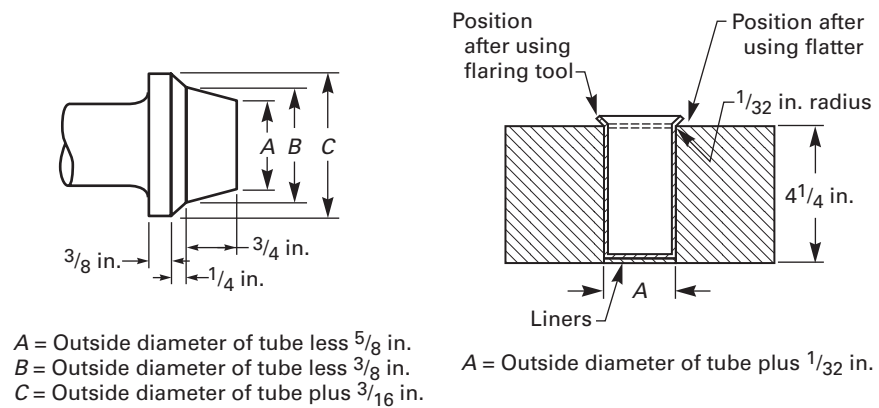


FIG. A2.11 FLARING TOOL AND DIE BLOCK FOR FLANGE TEST



Flaring Tool

Die Block

GENERAL NOTE: Metric equivalent: 1 in. = 25.4 mm.

FIG. A2.12 TAPERED MANDRELS FOR FLARING TEST

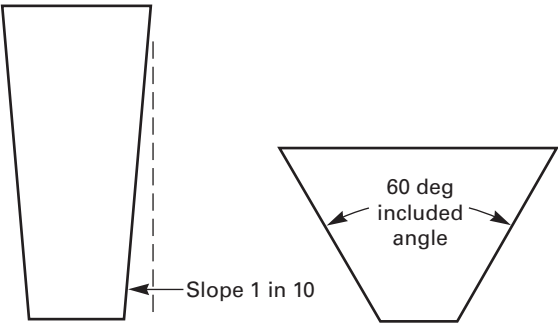
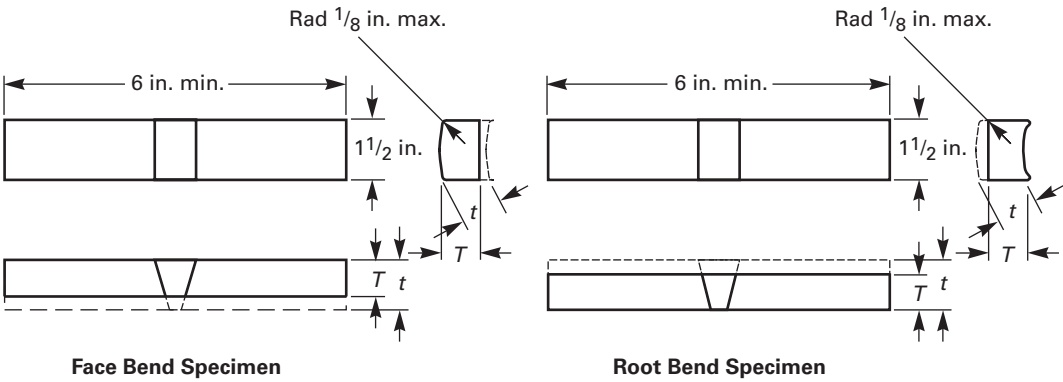


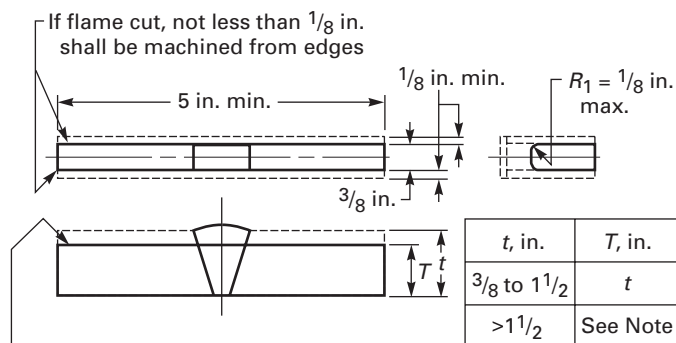
FIG. A2.13 TRANSVERSE FACE- AND ROOT-BEND TEST SPECIMENS



GENERAL NOTE: Metric equivalent: 1 in. = 25.4 mm.

Pipe Wall Thickness (<i>t</i>), in.	Test Specimen Thickness, in.
Up to $\frac{3}{8}$, incl	<i>t</i>
Over $\frac{3}{8}$	$\frac{3}{8}$

FIG. A2.14 SIDE-BEND SPECIMEN FOR FERROUS MATERIALS

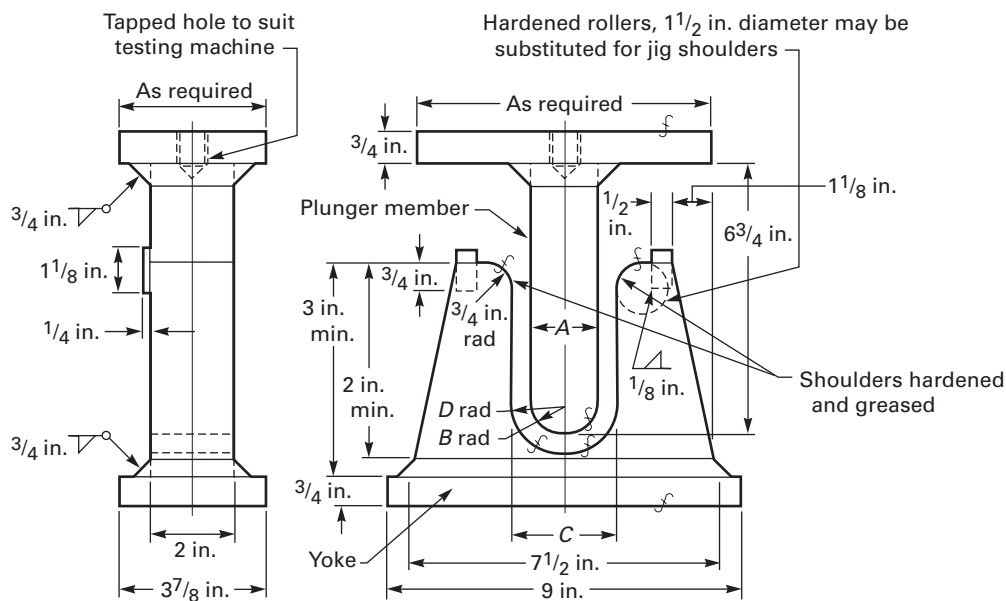


When t exceeds $1 1/2$ use one of the following:

1. Cut along line indicated by arrow. Edge may be flame cut and may or may not be machined.
2. Specimens may be cut into approximately equal strips between $3/4$ in. and $1 1/2$ in. wide for testing or the specimens may be bent at full width (see requirements on jig width in Fig. 32.)

GENERAL NOTE: Metric equivalent: 1 in. = 25.4 mm.

FIG. A2.15 GUIDED-BEND TEST JIG



GENERAL NOTE: Metric equivalent 1 in. = 25.4 mm.

Test Specimen Thickness, in.	A	B	C	D	
$3/8$	$1 1/2$	$3/4$	$2 3/8$	$1 3/16$	
t	$4t$	$2t$	$6t + 1/8$	$3t + 1/16$	
Material					
$3/8$	$2 1/2$	$1 1/4$	$3 3/8$	$1 11/16$	Materials with a specified minimum tensile strength of 95 ksi or greater.
t	$6 2/3 t$	$3 1/3 t$	$8 2/3 t + 1/8$	$4 1/2 t + 1/16$	

FIG. A3.1 TENSION TESTING FULL-SIZE BOLT

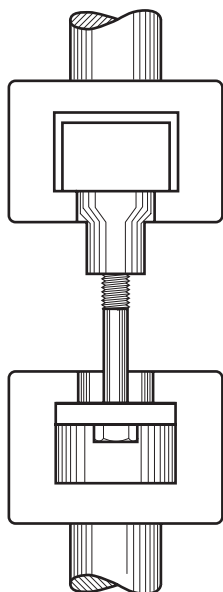


FIG. A3.2 WEDGE TEST DETAIL

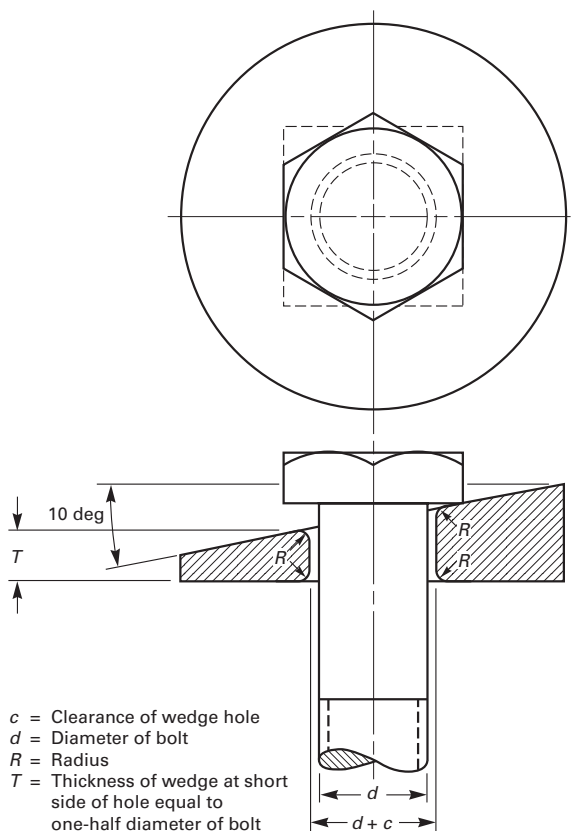
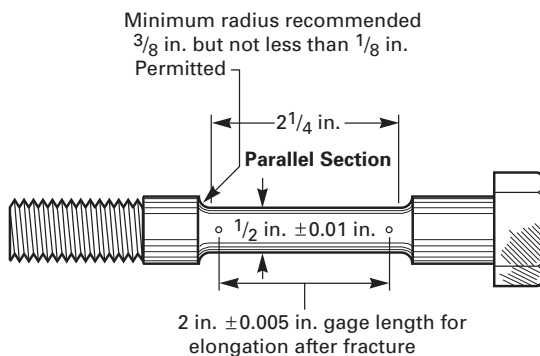
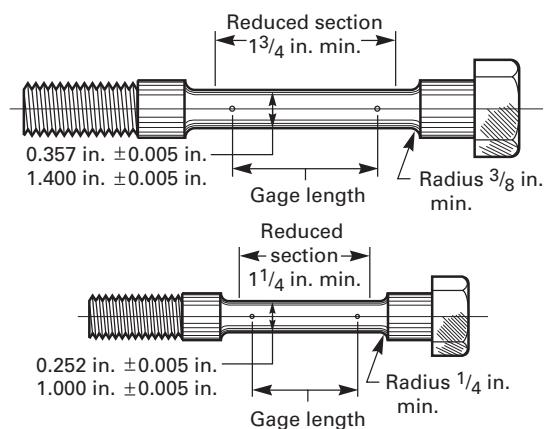


FIG. A3.3 TENSION TEST SPECIMEN FOR BOLT WITH TURNED-DOWN SHANK



GENERAL NOTE: Metric equivalent: 1 in. = 25.4 mm.

FIG. A3.4 EXAMPLES OF SMALL SIZE SPECIMENS PROPORTIONAL TO STANDARD 2 in. GAGE LENGTH SPECIMEN



GENERAL NOTE: Metric equivalent: 1 in. = 25.4 mm.

FIG. A3.5 LOCATION OF STANDARD ROUND 2 in. GAGE LENGTH TENSION TEST SPECIMEN WHEN TURNED FROM LARGE SIZE BOLT

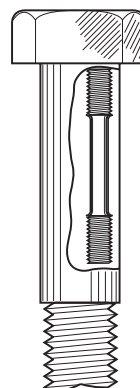
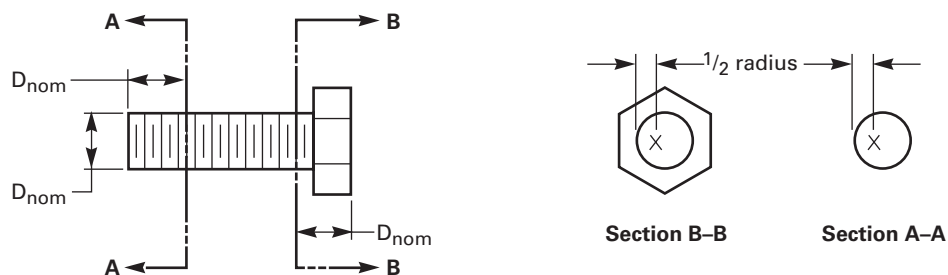


FIG. A3.6 HARDNESS TEST LOCATIONS FOR BOLTS IN A DISPUTE



GENERAL NOTE: X = Location of hardness impressions.

FIG. A4.1 WEDGE-TYPE GRIPPING DEVICE

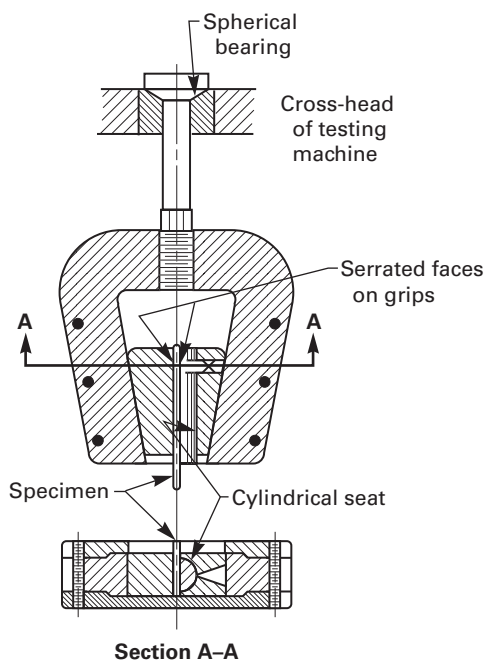


FIG. A4.2 SNUBBING-TYPE GRIPPING DEVICE

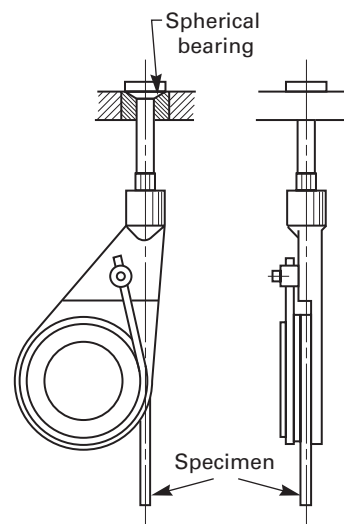


TABLE A1.1
PRACTICES FOR SELECTING TENSION TEST SPECIMENS FOR STEEL BAR PRODUCTS

Thickness, in. (mm)	Width, in. (mm)	Hot-Rolled Bars	Cold-Finished Bars
Flats			
Under $\frac{5}{8}$ (16)	Up to $1\frac{1}{2}$ (38), incl	Full section by 8 in. (203 mm) gage length (Fig. 4).	Mill reduced section to 2 in. (51 mm) gage length and approximately 25% less than test specimen width.
	Over $1\frac{1}{2}$ (38)	Full section, or mill to $1\frac{1}{2}$ in. (38 mm) wide by 8 in. (203 mm) gage length (Fig. 4).	Mill reduced section to 2 in. gage length and $1\frac{1}{2}$ in. wide.
$\frac{5}{8}$ to $1\frac{1}{2}$ (16 to 38), excl	Up to $1\frac{1}{2}$ (38), incl	Full section by 8 in. gage length or machine standard $\frac{1}{2}$ by 2 in. (13 by 51 mm) gage length specimen from center of section (Fig. 5).	Mill reduced section to 2 in. (51 mm) gage length and approximately 25% less than test specimen width or machine standard $\frac{1}{2}$ by 2 in. (13 by 51 mm) gage length specimen from center of section (Fig. 5).
	Over $1\frac{1}{2}$ (38)	Full section, or mill $1\frac{1}{2}$ in. (38 mm) width by 8 in. (203 mm) gage length (Fig. 4) or machine standard $\frac{1}{2}$ by 2 in. gage (13 by 51 mm) gage length specimen from midway between edge and center of section (Fig. 5).	Mill reduced section to 2 in. gage length and $1\frac{1}{2}$ in. wide or machine standard $\frac{1}{2}$ by 2 in. gage length specimen from midway between edge and center of section (Fig. 5).
$1\frac{1}{2}$ (38) and over		Full section by 8 in. (203 mm) gage length, or machine standard $\frac{1}{2}$ by 2 in. (13 by 51 mm) gage length specimen from midway between surface and center (Fig. 5).	Machine standard $\frac{1}{2}$ by 2 in. (13 by 51 mm) gage length specimen from midway between surface and center (Fig. 5).
Rounds, Squares, Hexagons, and Octagons			
Diameter or Distance Between Parallel Faces, in. (mm)	Hot-Rolled Bars		Cold-Finished Bars
Under $\frac{5}{8}$	Full section by 8 in. (203 mm) gage length on machine to subsize specimen (Fig. 5).		Machine to sub-size specimen (Fig. 5).
$\frac{5}{8}$ to $1\frac{1}{2}$ (16 to 38), excl	Full section by 8 in. (203 mm) gage length or machine standard $\frac{1}{2}$ in. by 2 in. (13 by 51 mm) gage length specimen from center of section (Fig. 5).		Machine standard $\frac{1}{2}$ in. by 2 in. gage length specimen from center of section (Fig. 5).
$1\frac{1}{2}$ (38) and over	Full section by 8 in. (203 mm) gage length or machine standard $\frac{1}{2}$ in. by 2 in. (13 by 51 mm) gage length specimen from midway between surface and center of section (Fig. 5).		Machine standard $\frac{1}{2}$ in. by 2 in. (13 by 51 mm) gage length specimen from midway between surface and center of section (Fig. 5)).
Other Bar-Size Sections			
All sizes	Full section by 8 in. (203 mm) gage length or prepare test specimen $1\frac{1}{2}$ in. (38 mm) wide (if possible) by 8 in. (203 mm) gage length.		Mill reduced section to 2 in. (51 mm) gage length and approximately 25% less than test specimen width.

GENERAL NOTE: For bar sections where it is difficult to determine the cross-sectional area by simple measurement, the area in square inches may be calculated by dividing the weight per linear inch of specimen in pounds by 0.2833 (weight of 1 in.³ of steel) or by dividing the weight per linear foot of specimen by 3.4 (weight of steel 1 in. square and 1 ft long).

TABLE A1.2
RECOMMENDED PRACTICE FOR SELECTING BEND TEST SPECIMENS FOR STEEL
BAR PRODUCTS

Flats		
Thickness, in. (mm)	Width, in. (mm)	Recommended Size
Up to $\frac{1}{2}$ (13), incl	Up to $\frac{3}{4}$ (19), incl Over $\frac{3}{4}$ (19)	Full section. Full section or machine to not less than $\frac{3}{4}$ in. (19 mm) in width by thickness of specimen.
Over $\frac{1}{2}$ (13)	All	Full section or machine to 1 by $\frac{1}{2}$ in. (25 by 13 mm) specimen from midway between center and surface.
Rounds, Squares, Hexagons, and Octagons		
Diameter or Distance Between Parallel Faces, in. (mm)	Recommended Size	
Up to $1\frac{1}{2}$ (38), incl Over $1\frac{1}{2}$ (38)	Full section. Machine to 1 by $\frac{1}{2}$ -in. (25 by 13-mm) specimen from midway between center and surface.	

GENERAL NOTES:

- (1) The length of all specimens is to be not less than 6 in. (150 mm).
 (2) The edges of the specimen may be rounded to a radius not exceeding $\frac{1}{16}$ in. (1.6 mm).

TABLE A2.1
WALL THICKNESS LIMITATIONS OF SUPERFICIAL
HARDNESS TEST ON ANNEALED OR DUCTILE
MATERIALS FOR STEEL TUBULAR PRODUCTS (A)
("T" Scale ($\frac{1}{16}$ in. Ball))

Wall Thickness, in. (mm)	Load, kgf
Over 0.050 (1.27)	45
Over 0.035 (0.89)	30
0.020 and over (0.51)	15

NOTE:

- (A) The heaviest load recommended for a given wall thickness is generally used.

TABLE A2.2
WALL THICKNESS LIMITATIONS OF SUPERFICIAL
HARDNESS TEST ON COLD WORKED OR HEAT
TREATED MATERIAL FOR STEEL TUBULAR
PRODUCTS (A)
("N" Scale (Diamond Penetrator))

Wall Thickness, in. (mm)	Load, kgf
Over 0.035 (0.89)	45
Over 0.025 (0.51)	30
0.015 and over (0.38)	15

NOTE:

- (A) The heaviest load recommended for a given wall thickness is generally used.

TABLE A5.1
EFFECT OF VARYING NOTCH DIMENSIONS ON STANDARD SPECIMENS

	High-Energy Specimens, ft • lbf (J)	High-Energy Specimens, ft • lbf (J)	Low-Energy Specimens, ft • lbf (J)
Specimen with standard dimensions	76.0 ± 3.8 (103.0 ± 5.2)	44.5 ± 2.2 (60.3 ± 3.0)	12.5 ± 1.0 (16.9 ± 1.4)
Depth of notch, 0.084 in. (2.13 mm) (A)	72.2 (97.9)	41.3 (56.0)	11.4 (15.5)
Depth of notch, 0.0805 in. (2.04 mm) (A)	75.1 (101.8)	42.2 (57.2)	12.4 (16.8)
Depth of notch, 0.0775 in. (1.77 mm) (A)	76.8 (104.1)	45.3 (61.4)	12.7 (17.2)
Depth of notch, 0.074 in. (1.57 mm) (A)	79.6 (107.9)	46.0 (62.4)	12.8 (17.3)
Radius at base of notch, 0.005 in. (0.127 mm) (B)	72.3 (98.0)	41.7 (56.5)	10.8 (14.6)
Radius at base of notch, 0.015 in. (0.381 mm) (B)	80.0 (108.5)	47.4 (64.3)	15.8 (21.4)

NOTES:

- (A) Standard 0.079 ± 0.002 in. (2.00 ± 0.05 mm).
 (B) Standard 0.010 ± 0.001 in. (0.25 ± 0.025 mm).

TABLE A6.1

CARBON AND ALLOY STEELS — MATERIAL
CONSTANT $a = 0.4$. MULTIPLICATION FACTORS FOR
CONVERTING PERCENT ELONGATION FROM $\frac{1}{2}$ IN.
DIAMETER BY 2 IN. GAGE LENGTH STANDARD
TENSION TEST SPECIMEN TO STANDARD $\frac{1}{2}$ BY 2 IN.
AND $1\frac{1}{2}$ BY 8 IN. FLAT SPECIMENS

Thickness, in.	$\frac{1}{2}$ by 2 in. Specimen	$1\frac{1}{2}$ by 8 in. Specimen	Thickness in.	$1\frac{1}{2}$ by 8 in. Specimen
0.025	0.574	...	0.800	0.822
0.030	0.596	...	0.850	0.832
0.035	0.614	...	0.900	0.841
0.040	0.631	...	0.950	0.850
0.045	0.646	...	1.000	0.859
0.050	0.660	...	1.125	0.880
0.055	0.672	...	1.250	0.898
0.060	0.684	...	1.375	0.916
0.065	0.695	...	1.500	0.932
0.070	0.706	...	1.625	0.947
0.075	0.715	...	1.750	0.961
0.080	0.725	...	1.875	0.974
0.085	0.733	...	2.000	0.987
0.090	0.742	0.531	2.125	0.999
0.100	0.758	0.542	2.250	1.010
0.110	0.772	0.553	2.375	1.021
0.120	0.786	0.562	2.500	1.032
0.130	0.799	0.571	2.625	1.042
0.140	0.810	0.580	2.750	1.052
0.150	0.821	0.588	2.875	1.061
0.160	0.832	0.596	3.000	1.070
0.170	0.843	0.603	3.125	1.079
0.180	0.852	0.610	3.250	1.088
0.190	0.862	0.616	3.375	1.096
0.200	0.870	0.623	3.500	1.104
0.225	0.891	0.638	3.625	1.112
0.250	0.910	0.651	3.750	1.119
0.275	0.928	0.664	3.875	1.127
0.300	0.944	0.675	4.000	1.134
0.325	0.959	0.686	...	...
0.350	0.973	0.696	...	...
0.375	0.987	0.706	...	...
0.400	1.000	0.715	...	...
0.425	1.012	0.724	...	...
0.450	1.024	0.732	...	...
0.475	1.035	0.740	...	...
0.500	1.045	0.748	...	...
0.525	1.056	0.755	...	...
0.550	1.066	0.762	...	...
0.575	1.075	0.770	...	...
0.600	1.084	0.776	...	...
0.625	1.093	0.782	...	...
0.650	1.101	0.788	...	...
0.675	1.110	...	...	...
0.700	1.118	0.800	...	...
0.725	1.126	...	...	...
0.750	1.134	0.811	...	...

TABLE A6.2

ANNEALED AUSTENITIC STAINLESS STEELS —
MATERIAL CONSTANT $a = 0.127$. MULTIPLICATION
FACTORS FOR CONVERTING PERCENT ELONGATION
FROM $\frac{1}{2}$ IN. DIAMETER BY 2 IN. GAGE LENGTH
STANDARD TENSION TEST SPECIMEN TO STANDARD
 $\frac{1}{2}$ BY 2 IN. AND $1\frac{1}{2}$ BY 8 IN. FLAT SPECIMENS

Thickness, in.	$\frac{1}{2}$ by 2 in. Specimen	$1\frac{1}{2}$ by 8 in. Specimen	Thickness, in.	$1\frac{1}{2}$ by 8 in. Specimen
0.025	0.839	...	0.800	0.940
0.030	0.848	...	0.850	0.943
0.035	0.857	...	0.900	0.947
0.040	0.864	...	0.950	0.950
0.045	0.870	...	1.000	0.953
0.050	0.876	...	1.125	0.960
0.055	0.882	...	1.250	0.966
0.060	0.886	...	1.375	0.972
0.065	0.891	...	1.500	0.978
0.070	0.895	...	1.625	0.983
0.075	0.899	...	1.750	0.987
0.080	0.903	...	1.875	0.992
0.085	0.906	...	2.000	0.996
0.090	0.909	0.818	2.125	1.000
0.095	0.913	0.821	2.250	1.003
0.100	0.916	0.823	2.375	1.007
0.110	0.921	0.828	2.500	1.010
0.120	0.926	0.833	2.625	1.013
0.130	0.931	0.837	2.750	1.016
0.140	0.935	0.841	2.875	1.019
0.150	0.940	0.845	3.000	1.022
0.160	0.943	0.848	3.125	1.024
0.170	0.947	0.852	3.250	1.027
0.180	0.950	0.855	3.375	1.029
0.190	0.954	0.858	3.500	1.032
0.200	0.957	0.860	3.625	1.034
0.225	0.964	0.867	3.750	1.036
0.250	0.970	0.873	3.875	1.038
0.275	0.976	0.878	4.000	1.041
0.300	0.982	0.883	...	...
0.325	0.987	0.887	...	...
0.350	0.991	0.892	...	...
0.375	0.996	0.895	...	...
0.400	1.000	0.899	...	...
0.425	1.004	0.903	...	...
0.450	1.007	0.906	...	...
0.475	1.011	0.909	...	...
0.500	1.014	0.912	...	...
0.525	1.017	0.915	...	...
0.550	1.020	0.917	...	...
0.575	1.023	0.920	...	...
0.600	1.026	0.922	...	...
0.625	1.029	0.925	...	...
0.650	1.031	0.927	...	...
0.675	1.034	...	...	...
0.700	1.036	0.932	...	...
0.725	1.038	...	...	...
0.750	1.041	0.936	...	...

TABLE A8.1
RECOMMENDED VALUES FOR ROUNDING TEST DATA

Test Quantity	Test Data Range	Rounded Value (A)
Yield Point,	up to 50 000 psi, excl (up to 50 ksi)	100 psi (0.1 ksi)
Yield Strength,	50 000 to 100 000 psi, excl (50 to 100 ksi)	500 psi (0.5 ksi)
Tensile Strength	100 000 psi and above (100 ksi and above)	1000 psi (1.0 ksi)
	up to 500 MPa, excl	1 MPa
	500 to 1000 MPa, excl	5 MPa
	1000 MPa and above	10 MPa
Elongation	0 to 10%, excl	0.5%
	10% and above	1%
Reduction of Area	0 to 10%, excl	0.5%
	10% and above	1%
Impact Energy	0 to 240 ft • lbf (or 0 to 325 J)	1 ft • lbf (or 1 J) (B)
Brinell Hardness	all values	tabular value (C)
Rockwell Hardness	all scales	1 Rockwell Number

NOTES:

- (A) Round test data to the nearest integral multiple of the values in this column. If the data value is exactly midway between two rounded values, round in accordance with A8.1.1.2.
- (B) These units are not equivalent but the rounding occurs in the same numerical ranges for each. (1 ft • lbf = 1.356 J.)
- (C) Round the mean diameter of the Brinell impression to the nearest 0.05 mm and report the corresponding Brinell hardness number read from the table without further rounding.

TABLE A10.1
HEAT-TREAT RECORD-ESSENTIAL VARIABLES

	Master Forging	Production Forging 1	Production Forging 2	Production Forging 3	Production Forging 4	Production Forging 5
Program chart number						
Time at temperature and actual temperature of heat treatment						
Method of cooling						
Forging thickness						
Thermocouple immersion						
Beneath buffer (yes/no)						
Forging number						
Product						
Material						
Thermocouple location — 0 deg						
Thermocouple location — 180 deg						
Quench tank No.						
Date of heat treatment						
Furnace number						
Cycle number						
Heat treater						
Starting quench medium temperature						
Time from furnace to quench						
Heating rate above 1000°F (538°C)						
Temperature upon removal from quench after 5 min						
Orientation of forging in quench						

SPECIFICATION FOR CARBON AND ALLOY STEEL FORGINGS FOR THIN-WALLED PRESSURE VESSELS



SA-372/SA-372M



[Identical with ASTM Specification A 372/A 372M-03(R08).]

1. Scope

1.1 This specification covers relatively thin-walled forgings (including gas bottles) for pressure vessel use. Three types of carbon steel and six types of alloy steel are included. Provision is made for integrally forging the ends of vessel bodies made from seamless pipe or tubing.

NOTE 1 — When working to the chemical and tensile requirements of this specification, the influence of wall thickness and cooling rate will necessarily eliminate certain forging sizes in each class.

NOTE 2 — Designations have been changed as follows:

Current	Formerly
Grade A	Type I
Grade B	Type II
Grade C	Type III
Grade D	Type IV
Grade E Class 55	Type V Grade 1 Class 55
Grade E Class 65	Type V Grade 1 Class 65
Grade E Class 70	Type V Grade 1 Class 70
Grade F Class 55	Type V Grade 2 Class 55
Grade F Class 65	Type V Grade 2 Class 65
Grade F Class 70	Type V Grade 2 Class 70
Grade G Class 55	Type V Grade 3 Class 55
Grade G Class 65	Type V Grade 3 Class 65
Grade G Class 70	Type V Grade 3 Class 70
Grade H Class 55	Type V Grade 4 Class 55
Grade H Class 65	Type V Grade 4 Class 65
Grade H Class 70	Type V Grade 4 Class 70
Grade J Class 55	Type V Grade 5 Class 55
Grade J Class 65	Type V Grade 5 Class 65
Grade J Class 70	Type V Grade 5 Class 70
Grade K	Type VI
Grade L	Type VII
Grade J Class 110	Type VIII
Grade M Class 85	Type IX Class A
Grade M Class 100	Type IX Class B

1.2 The values stated in either inch-pound or SI [metric] units are to be regarded separately as the standard. Within the text and the tables, the SI units are shown in brackets. The values stated in each system are not exact equivalents;

therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.3 Unless the order specifies the applicable “M” specification designation (SI units), the material shall be furnished to inch-pound units.

2. Referenced Documents

2.1 ASTM Standards:

- A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 388/A 388M Practice for Ultrasonic Examination of Heavy Steel Forgings
- A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe
- A 788 Specification for Steel Forgings, General Requirements
- E 112 Test Methods for Determining the Average Grain Size
- E 165 Practice for Liquid Penetrant Examination
- E 290 Test Method for Semi-Guided Bend Test for Ductility of Metallic Materials
- E 433 Reference Photographs for Liquid Penetrant Inspection

3. Ordering Information and General Requirements

3.1 In addition to the ordering information required by Specification A 788, the purchaser shall include with the inquiry and order a detailed drawing, sketch, or written description of the forging and the areas of significant loading in the forging when required (see 6.4.2.2).

3.2 Material supplied to this specification shall conform to the requirements of Specification A 788, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A 788, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 Melting Practice:

4.1.1 The steel melting procedures of Specification A 788 shall apply except that for Grade M forgings, only steel that has been vacuum treated prior to or during the pouring of the ingot, in order to remove objectionable gases, particularly hydrogen, shall be used.

4.2 Production Methods:

4.2.1 Methods for the production of gas bottles and similar vessels shall include the cupping of slabs or plates, the piercing of billets or plates, and the subsequent drawing of cups so produced. Such semifinished forgings or seamless steel pipe or tubing shall be closed by spinning, swedging, or pressing. In all cases there shall be sufficient discard to ensure soundness in the completed forging.

4.3 Heat Treatment:

4.3.1 At the option of the manufacturer, Grades A, B, C, D and Classes 55, 65, 70 of Grades E, F, G, H, and J forgings shall be normalized, normalized and tempered, or liquid-quenched and tempered.

4.3.2 Grades K, L, M, and Class 110 of Grade J forgings shall be liquid-quenched and tempered.

4.3.3 When normalized forgings are to be tempered, or when forgings have been quenched, they shall be reheated to a subcritical temperature and held for at least $\frac{1}{2}$ h/in. [25 mm] of maximum cross section.

4.3.3.1 Minimum tempering temperatures shall be as follows:

Grades E, F, G, H, J in Classes 55, 65, 70	1100°F [595°C]
Grade K	1100°F [595°C]
Grade L	1000°F [540°C]
Grade J Class 110	1000°F [540°C]
Grade M	1100°F [595°C]

4.3.3.2 If an attachment is welded onto a previously quenched and tempered pressure vessel, the post weld heat treatment temperature of a weldment shall not exceed the prior tempering temperature of the pressure vessel. Fabrication welding of pressure shell is not permitted.

Attachment welding prior to heat treatment is not permitted.

4.3.4 All quenched and tempered forgings shall be subject to magnetic particle examination in accordance with Section 7.

4.3.5 Heat treatment is to be performed after all forming operations.

5. Chemical Composition

5.1 Heat Analysis — The heat analysis obtained from sampling in accordance with Specification A 788 shall comply with Table 1.

5.2 Product Analysis — The purchaser may use the product analysis provision of Specification A 788 to obtain a product analysis from a forging representing each heat or multiple heat.

5.3 Starting material produced to a specification that specifically requires the addition of any element beyond those listed in Table 1 for the applicable grade of material is not permitted. This does not preclude use of deoxidation or inclusion control additions. Supplementary Requirements S1 and S2 of Specification A 788 shall apply.

6. Mechanical Properties

6.1 Mechanical tests for acceptance shall be made after the final heat treatment of the forgings.

6.2 Tension Test — When tested in accordance with Test Methods and Definitions A 370, the material shall conform to the requirements of Table 2. The yield strength shall be determined by the 0.2% offset method.

6.3 Bending Properties — Depending upon the outside diameter, D , and the wall thickness, T , of hollow or bored forgings, a bend test or flattening test will be required.

6.3.1 For bored or hollow forgings with outside diameters of 14 in. [355 mm] or less and with a D/T ratio of more than 10.0, a flattening test is required. This shall be carried out in accordance with Specification A 530/A 530M and Table 3. No breaks or cracks in the test ring are acceptable until the distance between the plates is less than that shown in Table 3.

6.3.2 For bored or hollow forgings with outside diameters over 14 in. [355 mm], or where the D/T ratio is 10.0 or less at the manufacturer's option, the flattening test specified in 6.3.1, or a transverse bend test in accordance with Arrangement C of Test Method E 290 is required. The bend test pin diameter shall be as specified in Table 4. No cracks or ruptures in the test piece are allowable when the test piece is bent through the required angle.

6.4 Orientation and Location of Test Specimens:

6.4.1 Test specimens representing vessel bodies or shells shall be taken from a prolongation of a forging, from test rings that have been heat treated with the forgings they represent, or from a representative forging after heat treatment in accordance with 4.3.

6.4.1.1 Test specimens representing vessel bodies or shells shall be located at a position corresponding to the mid-wall location of the parallel side wall of the heat-treated forging and shall be oriented parallel to the longitudinal axis of the vessel.

6.4.1.2 A test ring shall be in the shape of a right circular cylinder having the same diameter and wall thickness as the cylinders it represents. In addition, the test ring shall be from the same heat of steel and be subjected to the same heat treatment as the cylinders it represents. The method of quenching the test ring must duplicate that of the cylinders; if the cylinders are quenched from the outside only, then the test ring must have its ends closed. The length of test rings that will be liquid quenched must be at least 24 in. [610 mm]. The ends of such test rings may be vented to prevent pressure buildup during heat treating.

6.4.2 Test specimens representing vessel covers or similar components may be taken from a full section prolongation of the cover, from a representative forging, or from an integral prolongation when the part is contour-machined prior to heat treatment.

6.4.2.1 Test specimens taken from full size prolongations or representative forgings shall be located at a position midway between the center and the surface.

6.4.2.2 When forgings are contour-machined prior to heat treatment so that highly stressed surfaces are exposed, the test specimens may be taken at an equal distance (t) from the nearest quenched surface as the highly stressed area, but not less than $\frac{3}{4}$ in. [20 mm]. The location of the specimens from a second surface shall be at least the greater of $1\frac{1}{2}$ in. [40 mm] or $2t$.

6.5 Number of Tests:

6.5.1 Up to 200 like forgings, each with a heat-treated weight of less than 1000 lb [510 kg] when heat treated in a single batch furnace charge, shall have one tension test taken in accordance with 6.4.1 or 6.4.2 to represent each heat. In addition, for hollow or bored forgings, one bend or flattening test shall be taken in accordance with 6.3.

6.5.2 Like forgings, weighing less than 1000 lb [450 kg] each when heat treated in a continuous furnace, shall have one tensile test taken to represent each heat and not more than 200 forgings in any continuous period up to 4 h duration. In addition, bored or hollow forgings shall have one bend or flattening test taken per heat per 200

forgings in any continuous period up to 4 h duration in accordance with 6.3.

6.5.3 For heat-treated forgings weighing 1000 lb [450 kg] or more, one tension test shall be taken in accordance with 6.4.1 or 6.4.2 to represent each heat and not more than ten forgings in a heat-treat lot. In addition, hollow or bored forgings shall have one bend or flattening test, taken in accordance with 6.3, to represent each ten or fewer forgings from the same heat and heat-treatment lot.

6.6 Hardness Testing:

6.6.1 Forgings under 1000 lb [450 kgm] in weight, heat treated in a batch lot of up to 200 pieces (6.5.1) or in a continuous furnace run covering up to 200 pieces in up to four hours production (6.5.2) shall be subject to a uniformity check by Brinell hardness testing, or an equivalent method. For this purpose, 10% of the furnace production shall be sampled and shall meet the minimum hardness specified in Table 2 for the type and shall also be within 20 Brinell points of the hardness of the forging from which the tensile test was taken.

6.6.2 In the event that the test sample does not meet these criteria, the remainder of that production group shall be hardness tested and all of those forgings that fall outside these limits shall be retempered or reheat-treated at the manufacturer's option and retested.

7. Magnetic Particle Examination

7.1 All quenched and tempered forgings shall be subject to magnetic particle examination after heat treatment. The methods used shall be in accordance with Test Method A 275/A 275M.

7.2 Only direct current or rectified alternating (full or half wave) current shall be used as the electric power source for any of the magnetizing methods.

7.3 The forgings shall be free from linear indications indicative of cracks. In case of doubt as to the type of condition giving rise to linear magnetic particle indications, they may be inspected for Type II indications referenced in Reference Photographs E 433 when inspected by the liquid penetrant method in accordance with Practice E 165. Alternatively, some other suitable method for classifying the indications may be used as agreed upon between the manufacturer and the purchaser.

8. Workmanship

8.1 If the thickness of a portion of the wall of a forging is less than that specified, the forgings may be accepted by the purchaser, provided that such irregularity will not require lowering the allowable working pressure below that for which the forging was designed.

9. Repair Welding

9.1 Repair welding shall be permitted when mutually agreed upon between the purchaser and the manufacturer and shall be performed in accordance with all the requirements of the applicable code or rules of construction.

10. Keywords

10.1 alloy steel forgings; carbon steel forgings; gas bottles; pressure vessels; thin wall

**TABLE 1
CHEMICAL REQUIREMENTS**

Elements	Composition, %				Grade D
	Grade A	Grade B	Grade C	Grade E	
Carbon	0.30 max	0.35 max	0.48 max	0.40–0.50	
Manganese	1.00 max	1.35 max	1.65 max	1.40–1.80	
Phosphorus, max	0.025	0.025	0.025	0.025	
Sulfur, max	0.025	0.025	0.025	0.025	
Silicon	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35	
Nickel	...	...	...	...	...
Chromium	...	...	...	...	...
Molybdenum	...	...	...	...	0.17–0.27
	Grade E Classes 55, 65, 70	Grade F Classes 55, 65, 70	Grade G Classes 55, 65, 70	Grade H Classes 55, 65, 70	Grade J Classes 55, 65, 70, 110
Carbon	0.25–0.35	0.30–0.40	0.25–0.35	0.30–0.40	0.35–0.50
Manganese	0.40–0.90	0.70–1.00	0.70–1.00	0.75–1.05	0.75–1.05
Phosphorus, max	0.025	0.025	0.025	0.025	0.025
Sulfur, max	0.025	0.025	0.025	0.025	0.025
Silicon	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35
Nickel	...	...	...	...	...
Chromium	0.80–1.15	0.80–1.15	0.40–0.65	0.40–0.65	0.80–1.15
Molybdenum	0.15–0.25	0.15–0.25	0.15–0.25	0.15–0.25	0.15–0.25
	Grade K	Grade L	Grade M Classes 85 and 100		
Carbon	0.18 max	0.38–0.43	0.23 max		
Manganese	0.10–0.40	0.60–0.80	0.20–0.40		
Phosphorus, max	0.025	0.025	0.020		
Sulfur, max	0.025	0.025	0.020		
Silicon	0.15–0.35	0.15–0.35	0.30 max		
Nickel	2.0–3.3	1.65–2.00	2.8–3.9		
Chromium	1.00–1.80	0.70–0.90	1.50–2.00		
Molybdenum	0.20–0.60	0.20–0.30	0.40–0.60		
Vanadium	...	...	0.08 max		

TABLE 2
MECHANICAL REQUIREMENTS

Type	Tensile Strength, ksi [MPa]	Yield Strength (0.2% Offset), ksi [MPa], min	Elongation in 2 in. [50 mm], min, %	Hardness, HB, min ^A
Grade A	60–85 [415–585]	35 [240]	20	121
Grade B	75–100 [515–690]	45 [310]	18	156
Grade C	90–115 [620–795]	55 [380]	15	187
Grade D	105–130 [725–895]	65 [450]	15	217
Grades E, F, G, H, J (Class 55)	85–110 [545–760]	55 [380]	20	179
Grades E, F, G, H, J (Class 65)	105–130 [725–895]	65 [450]	19	217
Grades E, F, G, H, J (Class 70)	120–145 [825–1000]	70 [485]	18	248
Grade J (Class 110)	135–160 [930–1100]	110 [760]	15	277
Grade K	100–125 [690–860]	80 [550]	20	207
Grade L	155–180 [1070–1240]	135 [930]	12	311
Grade M (Class 85)	105–130 [725–895]	85 [585]	18	217
Grade M (Class 100)	120–145 [825–1000]	100 [690]	16	248

^A When required by 6.6.

TABLE 3
DISTANCE BETWEEN PLATES FOR FLATTENING
TESTS^A

Type	Distance Between Plates, min, in. [mm]
Grade A	0.50 <i>D</i>
Grade B	0.6 <i>D</i>
Grade C	0.65 <i>D</i>
Grade D	0.7 <i>D</i>
Grades E, F, G, H, J (Class 55)	0.7 <i>D</i>
Grades E, F, G, H, J (Class 65)	0.8 <i>D</i>
Grades E, F, G, H, J (Class 70)	0.8 <i>D</i>
Grade J (Class 110)	0.9 <i>D</i>
Grade K	0.8 <i>D</i>
Grade L	0.9 <i>D</i>
Grade M (Class 85)	0.7 <i>D</i>
Grade M (Class 100)	0.8 <i>D</i>

^A *D* = outside diameter.

TABLE 4
MAXIMUM PIN DIAMETERS AND MINIMUM ANGLE
FOR BEND TEST

Type	Pin Diameter	Angle, deg
Grade A	2 <i>t</i>	180
Grade B	2 <i>t</i>	180
Grade C	3 <i>t</i>	180
Grade D	4 <i>t</i>	150
Grades E, F, G, H, J (Class 55)	4 <i>t</i>	150
Grades E, F, G, H, J (Class 65)	4 <i>t</i>	150
Grades E, F, G, H, J (Class 70)	4 <i>t</i>	150
Grade J (Class 110)	6 <i>t</i>	150
Grade K	4 <i>t</i>	150
Grade L	6 <i>t</i>	150
Grade M (Class 85)	4 <i>t</i>	150
Grade M (Class 100)	4 <i>t</i>	150

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser on the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon by the manufacturer and the purchaser.

S1. Grain Size

S1.1 When a grain size range is required, it shall be specified in the ordering information, and shall be determined by an agreed-upon method from Test Methods E 112.

S1.2 Samples for grain size estimation shall be taken from the tension test specimen location.

S2. Rough Machining

S2.1 Rough machining shall be performed in the sequence and manner as specified.

S3. Impact Testing

S3.1 Charpy V-notch test specimens shall be taken from the same location and in the same orientation as tension test specimens. The number of specimens, minimum energy values, and test temperature(s) shall be as specified.

S4. Fracture Toughness

S4.1 Specific fracture toughness requirements are levied by certain sections of the ASME Boiler and Pressure Vessel Code. Forgings in the permitted types shall comply with the applicable code sections.

S4.2 The necessary code references toughness criteria and test temperature data shall be included in the ordering information.

S5. Ultrasonic Examination

S5.1 Ultrasonic examination of forgings shall be carried out in accordance with Practice A 388/A 388M.

S5.2 Acceptance criteria shall be specified and shall be in accordance with the applicable Code or purchaser's specification and shall be included as part of the ordering information.

SPECIFICATION FOR SEAMLESS AUSTENITIC STEEL PIPE FOR HIGH-TEMPERATURE CENTRAL-STATION SERVICE



SA-376/SA-376M

(Identical with ASTM Specification A 376/A 376M-06, except for the deletion of HT-O option from 6.2 and 14.1 and clarification of heat treatment requirements in 6.2.)

1. Scope

1.1 This specification covers seamless austenitic steel pipe intended for high-temperature central-station service. Among the grades covered are five H grades and two nitrogen grades (304N and 316N) that are specifically intended for high-temperature service.

1.2 Optional supplementary requirements (S1 through S10) are provided. These supplementary requirements specify additional tests that will be made only when stated in the order, together with the number of such tests required.

1.3 Grades TP321 and TP321H have lower strength requirements for nominal wall thicknesses greater than $\frac{3}{8}$ in. [9.5 mm].

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

NOTE 1 — The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

2. Referenced Documents

2.1 ASTM Standards:

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

A 999/A 999M Specification for General Requirements for Alloy and Stainless Steel Pipe

E 112 Test Methods for Determining Average Grain Size

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

E 426 Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys

2.2 Other Standards:

SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing

3. Terminology

3.1 Definitions — For definitions of terms used in this specification, refer to Terminology A 941.

4. Ordering Information

4.1 Orders for material to this specification should include the following, as required to describe the desired material adequately:

4.1.1 Quantity (feet, centimetres, or number of lengths),

4.1.2 Name of material (seamless austenitic steel pipe),

4.1.3 Grade (Table 1),

4.1.4 Size (nominal size, or outside diameter and schedule number or average wall thickness),

4.1.5 Lengths (specific or random), (Permissible Variations in Length Section of Specification A 999/A 999M),

4.1.6 End finish (Ends Section of Specification A 999/A 999M),

4.1.7 Optional requirements (Section 9) (see Hydrostatic Test Requirements Section and the Permissible Variation in Weight for Seamless Pipe Section for weighing individual lengths, of Specification A 999/A 999M), (see 10.6, repairing by welding; 14.3, die stamping),

4.1.8 Test report required (Certification Section of Specification A 999/A 999M),

4.1.9 Specification designation, and

4.1.10 Special requirements or any supplementary requirements selected, or both.

5. General Requirements

5.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 999/A 999M unless otherwise provided herein.

6. Materials and Manufacture

6.1 *Manufacture* — At the manufacturer's option, pipe may be either hot finished or cold finished, with a suitable finishing treatment, where necessary.

6.2 Heat Treatment:

6.2.1 All pipe shall be furnished in the heat-treated condition. For H grades, separate solution treatments are required for solution annealing; in process heat treatments are not permitted as a substitute for the separate solution annealing treatments.

6.2.2 As an alternate to final heat treatment in a continuous furnace or batch-type furnace, immediately following hot forming while the temperature of the pipes is not less than the specified minimum solution treatment temperature, pipes may be individually quenched in water or rapidly cooled by other means.

6.2.3 *Grades TP304, TP304N, TP304LN, TP316, TP316N, TP316LN, TP321, TP347, TP348, 16-8-2H, S31725, and S31726* — Unless otherwise stated in the order, heat treatment shall consist of heating to a minimum temperature of 1900°F [1040°C] and quenching in water or rapidly cooling by other means.

6.2.3.1 The purchaser may specify controlled structural or special service characteristics which shall be used as a guide for the most suitable heat treatment. If the final heat treatment is at a temperature under 1900°F [1040°C], each pipe shall be stenciled with the final heat treatment temperature in degrees Fahrenheit or Celsius after the suffix "HT."

6.2.4 *Grades TP304H, TP316H, TP321H, TP347H, TP348H, and 16-8-2H* — If cold working is involved in

processing, the minimum solution-treating temperature for Grades TP321H, TP347H, and TP348H shall be 2000°F [1100°C], for Grades TP304H and TP316H, 1900°F [1040°C], and for Grade 16-8-2H, 1800°F [980°C]. If the material is hot-rolled, the minimum solution-treating temperatures for Grades TP321H, TP347H, and TP348H shall be 1925°F [1050°C], for Grades TP304H and TP316H, 1900°F [1040°C], and for Grade 16-8-2H, 1800°F [980°C].

6.2.5 *Grade S34565* — Heat treatment shall consist of heating to a temperature in the range of 2050°F [1120°C] minimum and 2140°F [1170°C] maximum, and quenching in water or rapidly cooling by other means.

6.3 A solution annealing temperature above 1950°F [1065°C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in TP321, TP321H, TP347, TP347H, TP348, and TP348H. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the initial high temperature solution anneal (see Supplementary Requirement S9).

6.4 The grain size of grades 304H, 316H, 321H, 347H, and 348H as determined in accordance with Test Methods E 112, shall be No. 7 or coarser.

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

8. Product Analysis

8.1 At the request of the purchaser, an analysis of one billet from each heat or two pipes from each lot (Note 2) shall be made by the manufacturer. A lot of pipe shall consist of the following:

NPS Designator	Lengths of Pipe in Lot
Under NPS 2	400 or fraction thereof
NPS 2 to NPS 5, incl	200 or fraction thereof
Over NPS 5	100 or fraction thereof

NOTE 2 — A lot shall consist of the number of lengths specified in 8.1 of the same size and wall thickness from any one heat of steel.

8.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Table 1.

8.3 If the analysis of one of the tests specified in Section 9 does not conform to the requirements specified in Section 7, an analysis of each billet or pipe from the same heat or lot may be made, and all billets or pipe conforming to the requirements shall be accepted.

9. Tensile Requirements

9.1 The material shall conform to the requirements as to tensile properties prescribed in Table 2.

10. Workmanship, Finish, and Appearance

10.1 The pipe manufacturer shall explore a sufficient number of visual surface imperfections to provide reasonable assurance that they have been properly evaluated with respect to depth. Exploration of all surface imperfections is not required but may be necessary to assure compliance with 10.2.

10.2 Surface imperfections that penetrate more than $12\frac{1}{2}\%$ of the nominal wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with such defects shall be given one of the following dispositions:

10.2.1 The defect may be removed by grinding provided that the remaining wall thickness is within specified limits.

10.2.2 Repaired in accordance with the repair welding provisions of 10.6.

10.2.3 The section of pipe containing the defect may be cut off within the limits of requirements on length.

10.2.4 Rejected.

10.3 To provide a workmanlike finish and basis for evaluating conformance with 10.2, the pipe manufacturer shall remove by grinding the following:

10.3.1 Mechanical marks, abrasions (see Note 3), and pits, any of which imperfections are deeper than $\frac{1}{16}$ in. [1.6 mm].

NOTE 3 — Marks and abrasions are defined as cable marks, dings, guide marks, roll marks, ball scratches, scores, die marks, and so forth.

10.3.2 Visual imperfections commonly referred to as scabs, seams, laps, tears, or slivers found by exploration in accordance with 10.1 to be deeper than 5% of the nominal wall thickness.

10.4 At the purchaser's discretion, pipe shall be subject to rejection if surface imperfections acceptable under 10.2 are not scattered, but appear over a large area in excess of what is considered a workmanlike finish. Disposition of such pipe shall be a matter of agreement between the manufacturer and the purchaser.

10.5 When imperfections or defects are removed by grinding, a smooth curved surface shall be maintained, and the wall thickness shall not be decreased below that permitted by this specification. The outside diameter at the point of grinding may be reduced by the amount so removed.

10.5.1 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated

nondestructive testing device of appropriate accuracy. In case of dispute, the measurement determined by use of the mechanical caliper shall govern.

10.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A 999/A 999M.

10.7 The finished pipe shall be reasonably straight.

10.8 The pipe shall be free of scale and contaminating iron particles. Pickling, blasting, or surface finishing is not mandatory when pipe is bright annealed. The purchaser may request that a passivating treatment be applied.

11. Hydrostatic or Nondestructive Electric Test

11.1 Each pipe shall be subjected to the Nondestructive Electric Test or the Hydrostatic Test. Unless specified by the purchaser, either test may be used at the option of the producer.

11.2 *Hydrostatic Test* — Each length of finished pipe shall be subjected to the hydrostatic test in accordance with Specification A 999/A 999M, unless specifically exempted under the provisions of 11.3 and 11.4.

11.3 For pipe sizes NPS 24 and over, the purchaser, with the agreement of the manufacturer, may complete the hydrostatic test requirement with the system pressure test, which may be lower or higher than the specification test pressure, but in no case shall the test pressure be lower than the system design pressure. Each length of pipe furnished without the completed manufacturer's hydrostatic test shall include with the mandatory marking the letters "NH."

11.4 *Nondestructive Examination* — Each pipe shall be examined with a nondestructive test in accordance with Practice E 213 or Practice E 426. Unless specifically called out by the purchaser, the selection of the nondestructive electric test will be at the option of the manufacturer. The range of pipe sizes that may be examined by each method shall be subject to the limitations in the scope of the respective practices.

11.4.1 The following information is for the benefit of the user of this specification:

11.4.1.1 The reference standards defined in 11.10.1 through 11.10.4 are convenient standards for calibration of nondestructive testing equipment. The dimensions of these standards should not be construed as the minimum size imperfection detectable by such equipment.

11.4.1.2 The ultrasonic testing (UT) can be performed to detect both longitudinally and circumferentially oriented defects. It should be recognized that different techniques should be employed to detect differently oriented imperfections. The examination may not detect short, deep, defects.

11.4.1.3 The eddy-current testing (ET) referenced in Practice E 426 has the capability of detecting significant discontinuities, especially the short abrupt type.

11.4.1.4 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

11.5 Time of Examination — Nondestructive testing for specification acceptance shall be performed after all mechanical processing, heat treatments, and straightening operations. This requirement does not preclude additional testing at earlier stages in the processing.

11.6 Surface Condition:

11.6.1 All surfaces shall be free of scale, dirt, grease, paint, or other foreign material that could interfere with interpretation of test results. The methods used for cleaning and preparing the surfaces for examination shall not be detrimental to the base metal or the surface finish.

11.6.2 Excessive surface roughness or deep scratches can produce signals that interfere with the test.

11.7 Extent of Examination:

11.7.1 The relative motion of the pipe and the transducer(s), coil(s), or sensor(s) shall be such that the entire pipe surface is scanned, except as in 6.2.

11.7.2 The existence of end effects is recognized, and the extent of such effects shall be determined by the manufacturer, and, if requested, shall be reported to the purchaser. Other nondestructive tests may be applied to the end areas, subject to agreement between the purchaser and the manufacturer.

11.8 Operator Qualifications — The test unit operator shall be certified in accordance with SNT-TC-1A, or an equivalent recognized and documented standard.

11.9 Test Conditions:

11.9.1 For eddy-current testing, the excitation coil frequency shall be chosen to ensure adequate penetration yet provide good signal-to-noise ratio.

11.9.2 The maximum eddy-current coil frequency used shall be as follows:

On specified walls up to 0.050 in.—100 KHz max
On specified walls up to 0.150 in.—50 KHz max
On specified walls up to 0.150 in.—10 KHz max

11.9.3 Ultrasonic — For examination by the ultrasonic method, the minimum nominal transducer frequency shall be 2.00 MHz and the maximum nominal transducer size shall be 1.5 in.

11.9.3.1 If the equipment contains a reject notice filter setting, this shall remain off during calibration and testing unless linearity can be demonstrated at that setting.

11.10 Reference Standards:

11.10.1 Reference standards of convenient length shall be prepared from a length of pipe of the same grade, size (NPS, or outside diameter and schedule or wall thickness), surface finish, and heat treatment condition as the pipe to be examined.

11.10.2 For Ultrasonic Testing, the reference ID and OD notches shall be any one of the three common notch shapes shown in Practice E 213, at the option of the manufacturer. The depth of each notch shall not exceed $12\frac{1}{2}\%$ of the specified nominal wall thickness of the pipe or 0.004 in., whichever is greater. The width of the notch shall not exceed twice the depth. Notches shall be placed on both the OD and ID surfaces.

11.10.3 For Eddy-Current Testing, the reference standard shall contain, at the option of the manufacturer, any one of the following discontinuities:

11.10.3.1 Drilled Hole — The reference standard shall contain three or more holes, equally spaced circumferentially around the pipe and longitudinally separated by a sufficient distance to allow distinct identification of the signal from each hole. The holes shall be drilled radially and completely through the pipe wall, with care being taken to avoid distortion of the pipe while drilling. One hole shall be drilled in the weld, if visible. Alternately, the producer of welded pipe may choose to drill one hole in the weld and run the calibration standard through the test coils three times with the weld turned at 120° on each pass. The hole diameter shall vary with NPS as follows:

NPS Designator	Hole Diameter
	0.039 in. (1 mm)
above $\frac{1}{2}$ to $1\frac{1}{4}$	0.055 in. (1.4 mm)
above $1\frac{1}{4}$ to 2	0.071 in. (1.8 mm)
above 2 to 5	0.087 in. (2.2 mm)
above 5	0.106 in. (2.7 mm)

11.10.3.2 Transverse Tangential Notch — Using a round tool or file with a $\frac{1}{4}$ in. (6.4 mm) diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. Said notch shall have a depth not exceeding $12\frac{1}{2}\%$ of the specified nominal wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater.

11.10.3.3 Longitudinal Notch — A notch 0.031 in. or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the pipe, to have a depth not exceeding $12\frac{1}{2}\%$ of the specified wall thickness of the pipe or 0.004 in., whichever is greater. The length of the notch shall be compatible with the testing method.

11.10.3.4 More or smaller reference discontinuities, or both, may be used by agreement between the purchaser and the manufacturer.

11.11 Standardization Procedure:

11.11.1 The test apparatus shall be standardized at the beginning and end of each series of pipes of the same size (NPS or diameter and schedule or wall thickness), grade and heat treatment condition, and at intervals not exceeding 4 h. More frequent standardization may be performed at the manufacturer's option or may be required upon agreement between the purchaser and the manufacturer.

11.11.2 The test apparatus shall also be standardized after any change in test system settings; change of operator; equipment repair; or interruption due to power loss, process shutdown, or when a problem is suspected.

11.11.3 The reference standard shall be passed through the test apparatus at the same speed and test system settings as the pipe to be tested.

11.11.4 The signal-to-noise ratio for the reference standard shall be $2\frac{1}{2}$ to 1 or greater. Extraneous signals caused by identifiable causes such as dings, scratches, dents, straightener marks, and so forth, shall not be considered noise. The rejection amplitude shall be adjusted to be at least 50% of full scale of the readout display.

11.11.5 If upon any standardization, the rejection amplitude has decreased by 29% (3 dB) of peak height from the last standardization, the pipe since the last calibration shall be rejected. The test system settings may be changed, or the transducer(s), coil(s) or sensor(s) adjusted, and the unit restandardized, but all pipe tested since the last acceptable standardization must be retested for acceptance.

11.12 Evaluation of Imperfections:

11.12.1 Pipes producing a signal equal to or greater than the lowest signal produced by the reference standard(s) shall be identified and separated from the acceptable pipes. The area producing the signal may be reexamined.

11.12.2 Such pipes shall be rejected if the test signal was produced by imperfections that cannot be identified or was produced by cracks or crack-like imperfections. These pipes may be repaired in accordance with Sections 13 and 14. To be accepted, a repaired pipe must pass the same nondestructive test by which it was rejected, and it must meet the minimum wall thickness requirements of this specification.

11.12.3 If the test signals were produced by visual imperfections such as:

- (1) Scratches,
- (2) Surface roughness,
- (3) Dings,
- (4) Straightener marks,
- (5) Cutting chips,
- (6) Steel die stamps,
- (7) Stop marks, or
- (8) Pipe reducer ripple.

The pipe may be accepted based on visual examination provided the imperfection is less than 0.004 in. (0.1 mm) or $12\frac{1}{2}\%$ of the specified wall thickness (whichever is greater).

11.12.4 Rejected pipe may be reconditioned and retested providing the wall thickness is not decreased to less than that required by this or the product specification. The outside diameter at the point of grinding may be reduced by the amount so removed. To be accepted, retested pipe shall meet the test requirement.

11.12.5 If the imperfection is explored to the extent that it can be identified as non-rejectable, the pipe may be accepted without further test providing the imperfection does not encroach on the minimum wall thickness.

12. Mechanical Tests Required

12.1 Transverse or Longitudinal Tension Test — The tension test shall be performed on 1% of the pipe from each lot.

NOTE 4 — The term "lot" applies to all pipe of the same nominal size and wall thickness (or schedule) which is produced from the same heat of steel and subjected to the same finishing treatment in a continuous furnace or by directly obtaining the heat treated condition by quenching after hot forming. When final heat treatment is in a batch-type furnace, the lot shall include only that pipe which is heat treated in the same furnace charge.

12.2 Flattening Test — For pipe heat treated in a batch-type furnace, the flattening test shall be made on 5% of the pipe from each heat-treated lot (see Note 4). When heat treated by the continuous process or when treated condition is obtained directly by quenching after hot forming, this test shall be made on a sufficient number of pipe to constitute 5% of the lot (Note 4) but in no case less than two pipes.

13. Certification

13.1 In addition to the certification required by Specification A 999/A 999M, the certification for pipe furnished to this specification shall identify each length of pipe which is furnished without the manufacturer's completed hydrostatic test, in accordance with 11.3.

14. Product Marking

14.1 In addition to the marking prescribed in Specification A 999/A 999M, the marking shall include the ANSI schedule number, the heat number or manufacturer's number by which the heat can be identified, and, if applicable,

NH when hydrotesting is not performed and ET when eddy-current testing is performed, or UT when ultrasonic testing is performed.

14.2 If the pipe conforms to any of the supplementary requirements specified in S1 through S10, compliance shall be so indicated by adding the symbol “S” directly followed by the number of the applicable supplementary requirement to the marking prescribed in 14.1.

14.3 No steel indentation stamping shall be done without the purchaser’s consent.

15. Keywords

15.1 austenitic stainless steel; feedwater heater tubes; stainless steel tube; steel tube; welded steel tube

TABLE 1 CHEMICAL REQUIREMENTS

Grade	UNS Designation	Composition, %										Tan- talum	Nitrogen (A)	Others
		Carbon	Manganese, max	Phos- phorus, max	Sulfur, max	Silicon, max	Nickel	Chromium	Molybdenum	Tita- nium	Colum- bium			
TP304	S30400	0.08 max	2.00	0.045	0.030	0.75	8.0–11.0	18.0–20.0	...	...	...	...	...	...
TP304H	S30409	0.04–0.10	2.00	0.045	0.030	0.75	8.0–11.0	18.0–20.0	...	...	...	...	...	...
TP304N	S30451	0.08 max	2.00	0.045	0.030	0.75	8.0–11.0	18.0–20.0	...	...	...	...	0.10–0.16	...
TP304LN	S30453	0.035 max	2.00	0.045	0.030	0.75	8.0–11.0	18.0–20.0	...	...	...	...	0.10–0.16	...
TP316	S31600	0.08 max	2.00	0.045	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	...	...	...	...	...
TP316H	S31609	0.04–0.10	2.00	0.045	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	...	...	...	...	...
TP316N	S31651	0.08 max	2.00	0.045	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	...	...	...	0.10–0.16	...
TP316LN	S31653	0.035 max	2.00	0.045	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	...	...	...	0.10–0.16	...
TP321	S32100	0.08 max	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	...	(B)	...	...	...	...
TP321H	S32109	0.04–0.10	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	...	(C)	...	...	...	...
TP347	S34700	0.08 max	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	...	...	(D)	...	...	...
TP347H	S34709	0.04–0.10	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	...	...	(E)	...	...	...
TP348 (F)	S34800	0.08 max	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	...	...	(D)	0.10	...	Co 0.20 max
TP348H	S34809	0.04–0.10	2.00	0.045	0.030	1.00	9.0–13.0	17.0–19.0	...	...	(E)	...	...	...
16-8-2H	S16800	0.05–0.10	2.00	0.045	0.030	0.75	7.5–9.5	14.5–16.5	1.50–2.00	...	...	...	...	...
...	S31725	0.030 max	2.00	0.045	0.030	0.75	13.5–17.5	18.0–20.0	4.0–5.0	...	...	...	0.20 max	Cu 0.75 max
...	S31726	0.030 max	2.00	0.045	0.030	0.75	14.5–17.5	17.0–20.0	4.0–5.0	...	...	...	0.10–0.20	Cu 0.75 max
...	S34565	0.030 max	5.0–7.0	0.030	0.010	1.0	16.0–18.0	23.0–25.0	4.0–5.0	...	...	...	0.040–0.060	Cb 0.10 max

NOTES:

- (A) The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.
- (B) The titanium content shall be not less than five times the carbon content and not more than 0.70%.
- (C) The titanium content shall be not less than four times the carbon content and not more than 0.70%.
- (D) The columbium content shall be not less than ten times the carbon content and not more than 1.10%.
- (E) The columbium content shall be not less than eight times the carbon content and not more than 1.10%.
- (F) This grade is intended for special purpose applications.

TABLE 2 TENSILE REQUIREMENTS

Grade	Tensile (A) Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm (or 4 <i>D</i>) min, %	
			Longitudinal	Transverse
TP304, TP304H, TP304LN, TP316, TP316H, TP316LN, TP347, TP347H, TP348, TP348H, 16-8-2H, S31725	75 [515]	30 [205]	35	25
TP304N, TP316N, S31726	80 [550]	35 [240]	35	25
S34565	115 [790]	60 [415]	35	30
TP321, TP321H $\leq \frac{3}{8}$ "	75 [515]	30 [205]	35	25
$> \frac{3}{8}$ " (B)	70 [480]	25 [170]	35	25

NOTES:

(A) For grade TP304, NPS 8 or larger, and in schedules 140 and heavier, the required minimum tensile strength shall be 70 ksi [480 MPa].

(B) Prior to the issuance of A 376/A 376M — 88, the tensile and yield strength values were 75 [520] and 30 [210] respectively, for nominal wall greater than $\frac{3}{8}$ in. [9.5 mm].

SUPPLEMENTARY REQUIREMENTS FOR PIPE REQUIRING SPECIAL CONSIDERATION

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical composition requirements shall be rejected.

S2. Transverse Tension Tests

S2.1 A transverse tension test shall be made on a specimen from one end or both ends of each pipe NPS 8 and over in nominal diameter. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails to meet the required tensile properties (tensile, yield, and elongation), that length shall be rejected subject to retreatment in accordance with Specification A 999/A 999M and satisfactory retest.

S3. Flattening Test

S3.1 The flattening test of Specification A 999/A 999M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement that pipe shall be rejected subject to retreatment in accordance with Specification A 999/A 999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free from injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects,

the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S5. Photomicrographs

S5.1 Photomicrographs at 100 diameters may be made from one end of each piece of pipe furnished in sizes 6 in. [152 mm] and larger in the as-furnished condition. Such photomicrographs shall be suitably identified as to pipe size, wall thickness, piece number, and heat. Such photomicrographs are for information only, and shall show the actual metal structure of the pipe as finished.

S6. Ultrasonic Test

S6.1 Each piece of pipe may be ultrasonically tested to determine its soundness throughout the entire length of the pipe. Each piece shall be ultrasonically tested in a circumferential direction in such a manner that the entire piece is scanned by the ultrasonic beam. The calibration standard shall be prepared from a section of pipe which has two notches, one in the inside surface and one in the outside surface. The notches shall be at least $1\frac{1}{2}$ in. [38 mm] long and have a depth of 3% of the wall thickness, or 0.004 in. [0.1 mm], whichever is the greater. Any pipe showing an ultrasonic indication of greater amplitude than the amplitude of the indication from the calibration standard shall be subject to rejection.

S7. Hot Ductility Test for Indicating Weldability

S7.1 A high-temperature ductility test may be made upon each heat of material supplied in heavy-wall pipe sections. An appropriate specimen shall be heated to an initial temperature, cooled 100°F [50°C], then subjected to a tension test, and shall show a minimum reduction of area of 60%. The initial temperature is that temperature 50°F [30°C] below the temperature at which material exhibits zero ductility. Rejection of material shall not be based upon this test.

S8. Retests

S8.1 Upon the purchaser's request, retests shall be made from sections of material removed from any part of the pipe. Failure to meet the requirements stated in this specification shall be cause for rejection.

S9. Stabilization Heat Treatment

S9.1 Subsequent to the solution anneal required in 6.4, Grades TP321, TP321H, TP347, TP347H, TP348, and TP348H shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S10. Intergranular Corrosion Test

S10.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE S10.1 — Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S10.2 A stabilization heat treatment in accordance with Supplementary Requirement S9 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium, particularly in their H versions.

SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, CHROMIUM-MOLYBDENUM



SA-387/SA-387M



(Identical with ASTM Specification A 387/A 387M-06a)

1. Scope

1.1 This specification covers chromium-molybdenum alloy steel plates intended primarily for welded boilers and pressure vessels designed for elevated temperature service.

1.2 Plates are available under this specification in several grades having different alloy contents as follows:

Grade	Nominal Chromium Content, %	Nominal Molybdenum Content, %
2	0.50	0.50
12	1.00	0.50
11	1.25	0.50
22, 22L	2.25	1.00
21, 21L	3.00	1.00
5	5.00	0.50
9	9.00	1.00
91	9.00	1.00

1.3 Each grade except Grades 21L, 22L, and 91 is available in two classes of tensile strength levels as defined in the Tensile Requirements tables. Grades 21L and 22L are available only as Class 1. Grade 91 is available only as Class 2.

NOTE 1 — Grade 911, previously covered by this specification, is now covered by Specification A 1017/A 1017M.

1.4 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents. Therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

2. Referenced Documents

2.1 ASTM Standards:

- A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels
- A 307 Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength
- A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates
- A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates
- A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications
- A 1017/A 1017M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum-Tungsten

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions and weight, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the ordering information that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

- 3.3.1** Vacuum treatment,
- 3.3.2** Additional or special tension testing,
- 3.3.3** Impact testing, and
- 3.3.4** Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M. If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice* — The steel shall be killed.

5. Heat Treatment

5.1 Except for Grade 91, all plates shall be thermally treated either by annealing, normalizing- and -tempering, or, when permitted by the purchaser, accelerated cooling from the austenitizing temperature by air blasting or liquid quenching, followed by tempering. Minimum tempering temperatures shall be as follows:

Grade	Temperature, °F [°C]
2, 12, and 11	1150 [620]
22, 22L, 21, 21L, and 9	1250 [675]
5	1300 [705]

5.1.1 Grade 91 plates shall be normalized at 1900 to 1975°F [1040 to 1080°C] and shall be tempered at 1350 to 1470°F [730 to 800°C].

5.2 Grade 5, 9, 21, 21L, 22, 22L, and 91 plates ordered without the heat treatment required by 5.1 shall be furnished in either the stress-relieved or the annealed condition.

5.3 For plates ordered without the heat treatment required by 5.1, heat treatment of the plates to conform to 5.1 and to Table 2 or Table 3, as applicable, shall be the responsibility of the purchaser.

6. Chemical Requirements

6.1 The steel shall conform to the requirements as to chemical composition shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M for grades other than Grade 11.

7. Metallurgical Structure

7.1 *Austenitic Grain Size* — Grade 2 material shall have a coarse austenitic grain size.

8. Mechanical Requirements

8.1 Tension Test Requirements:

8.1.1 The material as represented by the tension test specimens shall conform to the applicable requirements of Table 2 or Table 3, as specified on the order.

8.1.2 Adjustment of the percentage elongation requirements is permitted in accordance with Specification A 20/A 20M for plates up to $\frac{3}{4}$ in. [20 mm] inclusive, in thickness when an 8 in. [200 mm] gage length is used.

9. Marking

9.1 In addition to the marking required in Specification A 20/A 20M, each plate shall be legibly stamped or stenciled, depending upon the ordered thickness, with the letter *A* for annealed, *N* for normalized and tempered, and *Q* for accelerated cooled and tempered, as applicable.

10. Keywords

10.1 alloy steel; alloy steel plate; pressure containing parts; pressure vessel steels; steel plates; steel plates for pressure vessels

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, % Grade and UNS Number									
	Grade 2 S50460	Grade 12 K11757	Grade 11 K11789	Grade 22 K21590	Grade 22L K21590	Grade 21 K31545	Grade 21L K31545	Grade 5 S50200	Grade 9 K90941	Grade 91 K91560
Carbon:										
Heat analysis	0.05–0.21	0.05–0.17	0.05–0.17	0.05–0.15 [Note (1)]	0.10 max	0.05–0.15 [Note (1)]	0.10 max	0.15 max	0.15 max	0.08–0.12
Product analysis	0.04–0.21	0.04–0.17	0.04–0.17	0.04–0.15 [Note (1)]	0.12 max	0.04–0.15 [Note (1)]	0.12 max	0.15 max	0.15 max	0.06–0.15
Manganese:										
Heat analysis	0.55–0.80	0.40–0.65	0.40–0.65	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60
Product analysis	0.50–0.88	0.35–0.73	0.35–0.73	0.25–0.66	0.25–0.66	0.25–0.66	0.25–0.66	0.25–0.66	0.25–0.66	0.25–0.66
Phosphorus, max:										
Heat analysis	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.030	0.020
Product analysis	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.030	0.025
Sulfur, max:										
Heat analysis	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.030	0.030	0.010
Product analysis	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.030	0.030	0.012
Silicon:										
Heat analysis	0.15–0.40	0.15–0.40	0.50–0.80	0.50 max	0.50 max	0.50 max	0.50 max	0.50 max	1.00 max	0.20–0.50
Product analysis	0.13–0.45	0.13–0.45	0.44–0.86	0.50 max	0.50 max	0.50 max	0.50 max	0.55 max	1.05 max	0.18–0.56
Chromium:										
Heat analysis	0.50–0.80	0.80–1.15	1.00–1.50	2.00–2.50	2.00–2.50	2.75–3.25	2.75–3.25	4.00–6.00	8.00–10.00	8.00–9.50
Product analysis	0.46–0.85	0.74–1.21	0.94–1.56	1.88–2.62	1.88–2.62	2.63–3.37	2.63–3.37	3.90–6.10	7.90–10.10	7.90–9.60
Molybdenum:										
Heat analysis	0.45–0.60	0.45–0.60	0.45–0.65	0.90–1.10	0.90–1.10	0.90–1.10	0.90–1.10	0.45–0.65	0.90–1.10	0.85–1.05
Product analysis	0.40–0.65	0.40–0.65	0.40–0.70	0.85–1.15	0.85–1.15	0.85–1.15	0.85–1.15	0.40–0.70	0.85–1.15	0.80–1.10
Nickel, max:										
Heat analysis	...	...	...	...	...	...	...	...	...	0.40
Product analysis	...	...	...	...	...	...	...	...	...	0.43
Vanadium:										
Heat analysis	...	...	...	...	...	...	...	...	0.04 max	0.18–0.25
Product analysis	...	...	...	...	...	...	...	...	0.05 max	0.16–0.27
Columbium:										
Heat analysis	...	...	...	...	...	...	...	...	...	0.06–0.10
Product analysis	...	...	...	...	...	...	...	...	...	0.05–0.11

TABLE 1
CHEMICAL REQUIREMENTS (CONT'D)

Element	Composition, % Grade and UNS Number									
	Grade 2 S50460	Grade 12 K11757	Grade 11 K11789	Grade 22 K21590	Grade 22L K21590	Grade 21 K31545	Grade 21L K31545	Grade 5 S50200	Grade 9 K90941	Grade 9L K91560
Boron:										
Heat analysis
Product analysis
Nitrogen:										
Heat analysis	0.030—0.070
Product analysis	0.025—0.080
Aluminum, max:										
Heat analysis	0.02
Product analysis	0.02
Titanium, max:										
Heat analysis	0.01
Product analysis	0.01
Zirconium, max:										
Heat analysis	0.01
Product analysis	0.01

NOTE:

(1) The carbon content for plates over 5 in. [125 mm] in thickness is 0.17 max on product analysis.

TABLE 2
TENSILE REQUIREMENTS FOR CLASS 1 PLATES

	Grades 2 and 12	Grade 11	Grades 22, 21, 5, 9, 21L, 22L
Tensile strength, ksi [MPa]	55 to 80 [380 to 550]	60 to 85 [415 to 585]	60 to 85 [415 to 585]
Yield strength, min, ksi [MPa]	33 [230]	35 [240]	30 [205]
Elongation in 8 in. [200 mm], min, % [Note (1)]	18	19	...
Elongation in 2 in. [50 mm], min, % [Note (1)]	22	22	18
Reduction of area, min, %	...	...	45 [Note (2)] 40 [Note (3)]

NOTES:

(1) See Specification A 20/A 20M, elongation adjustments.

(2) Measured on round test specimens.

(3) Measured on flat specimen.

TABLE 3
TENSILE REQUIREMENTS FOR CLASS 2 PLATES [NOTE (1)]

	Grade 2	Grade 11	Grade 12	Grades 22, 21, 5, 9	Grade 91
Tensile strength, ksi [MPa]	70 to 90 [485 to 620]	75 to 100 [515 to 690]	65 to 85 [450 to 585]	75 to 100 [515 to 690]	85 to 110 [585 to 760]
Yield strength, min, ksi [MPa] (0.2% offset)	45 [310]	45 [310]	40 [275]	45 [310]	60 [415]
Elongation in 8 in. [200 mm], min, % [Note (2)]	18	18	19	...	...
Elongation in 2 in. [50 mm], min, % [Note (2)]	22	22	22	18	18
Reduction of area, min, %	...	...	...	45 [Note (3)] 40 [Note (4)]	...

NOTES:

(1) Not applicable to annealed material.

(2) See Specification A 20/A 20M, elongation adjustments.

(3) Measured on round test specimens.

(4) Measured on flat specimen.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

- | | |
|---|---|
| S1. Vacuum Treatment, | S7. High-Temperature Tension Test, |
| S2. Product Analysis, | S8. Ultrasonic Examination in Accordance With Specification A 435/A 435M, |
| S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons, | S9. Magnetic Particle Examination, |
| S4.1 Additional Tension Test, | S11. Ultrasonic Examination in Accordance With Specification A 577/A 577M, |
| S5. Charpy V-Notch Impact Test, | S12. Ultrasonic Examination in Accordance With Specification A 578/A 578M, and |
| S6. Drop Weight Test (for Material 0.625 in. [16 mm] and over in Thickness), | S17. Vacuum Carbon-Deoxidized Steel. |

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

In addition, the following supplementary requirements are suitable for this application. S62 and S63 are applicable for Grades 22 and 21 only.

S53.

When specified by the purchaser, the axis of the tensile and impact test specimens shall come from the mid-thickness of each plate tested, in lieu of midway between the center thickness and the top or bottom surface of the plate.

S60. Restricted Carbon

S60.1 The maximum carbon content of Grade 5 shall be 0.10%.

S62. Temper Embrittlement Factor

S62.1 The composition of the steel, based on heat analysis, shall be restricted in accordance with the following equations:

$$J = (Si + Mn) \times (P + Sn) \times 10^4 \leq 150$$

(Si, Mn, P and Sn in wt. %)

$$Cu \leq 0.20\%$$

$$Ni \leq 0.30\%$$

S62.1.1 Lower values of J, Cu, and Ni can be specified by agreement between purchaser and the supplier.

S62.1.2 When so specified by the purchaser, the maximum value of J shall not exceed 100.

S62.1.3 The values of J shall be reported.

S62.1.4 If the plates are repaired by welding, the composition of the weld deposit shall be restricted in accordance with the following equations:

$$X = (10P + 5Sb + 4Sn + As)/100 \leq 15$$

(P, Sb, Sn and As in ppm)

$$Cu \leq 0.20\%$$

$$Ni \leq 0.30\%$$

S62.1.5 The values of X shall be reported.

S63. Impact Properties After Step Cooling

S63.1 The Charpy V-notch impact properties shall be determined as follows:

S63.1.1 A sufficient amount of Charpy V-notch test specimens shall be taken from the same location from a plate from each heat of steel to construct two transition temperature curves.

S63.1.2 The test specimens for one transition temperature curve shall be given the minimum post weld heat treatment (PWHT) cycle specified by the purchaser.

S63.2 The test specimens for the other transition temperature curve shall be given the PWHT cycle specified in S63.1.2 plus the following step cooling heat treatment:

Hold at 1100°F (593°C) for 1 h, then cool at 10°F (5.6°C)/h to 1000°F (538°C).

Hold at 1000°F (538°C) for 15 h, then cool at 10°F (5.6°C)/h to 975°F (524°C).

Hold at 975°F (524°C) for 24 h, then cool at 10°F (5.6°C)/h to 925°F (496°C).

Hold at 925°F (496°C) for 60 h, then cool at 5°F (2.8°C)/h to 875°F (468°C).

Hold at 875°F (468°C) for 100 h, then cool at 50°F (27.8°C)/h to 600°F (315°C).

Cool in still air.

S63.3 Test the Charpy V-notch test specimens in accordance with Test Methods and Definitions A 370 to determine the 40 ft-lbs (55 J) transition temperature from each transition temperature curve using a set of three test specimens at each test temperature. The test temperatures shall include tests on the upper and lower shelves and a minimum of four intermediate temperatures.

S63.4 The following requirements shall be met.

$$\nu Tr40 + 2.5\Delta \nu Tr40 \leq 50^\circ F$$

$$\nu Tr55 + 2.5\Delta \nu Tr55 \leq 10^\circ C$$

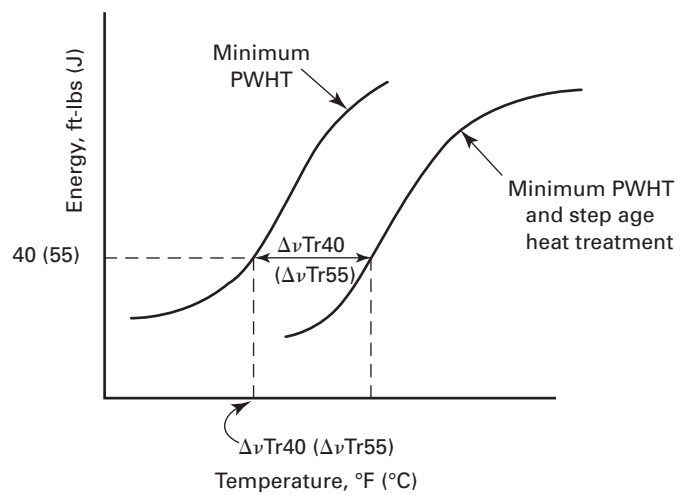
where:

$\nu Tr40$ ($\nu Tr55$) = the 40 ft-lbs (55 J) transition temperature of the material subjected to the minimum PWHT specified by the purchaser

$\Delta \nu Tr40$ ($\Delta \nu Tr55$) = the shift of the 40 ft-lbs (55 J) transition temperature the of the step cooled material. (The 40 ft-lbs (55 J) transition temperature the of the step cooled material minus that of the material subjected to the minimum PWHT only)

S63.5 The 40 ft-lbs (55 J) transition temperatures for the two material conditions shall be reported.

FIG. S1.1 TRANSITION TEMPERATURE CURVES BEFORE AND AFTER STEP COOL HEAT TREATMENT



PRACTICE FOR ULTRASONIC EXAMINATION OF HEAVY STEEL FORGINGS



SA-388/SA-388M



(Identical with ASTM Specification A 388/A 388M-07.)

1. Scope

1.1 This practice covers the examination procedures for the contact, pulse-echo ultrasonic examination of heavy steel forgings by the straight and angle-beam techniques. The straight beam techniques include utilization of the DGS (Distance Gain-Size) method. See Appendix X3.

1.2 This practice is to be used whenever the inquiry, contract, order, or specification states that forgings are to be subject to ultrasonic examination in accordance with Practice A 388/A 388M.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 This specification and the applicable material specifications are expressed in both inch-pound units and SI units. However, unless the order specifies the applicable "M" specification designation [SI units], the material shall be furnished to inch-pound units.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

- A 469/A 469M Specification for Vacuum-Treated Steel Forgings for Generator Rotors
- A 745/A 745M Practice for Ultrasonic Examination of Austenitic Steel Forgings

E 317 Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Instruments and Systems without the Use of Electronic Measurement Instruments

E 428 Practice for Fabrication and Control of Metal, Other than Aluminum Reference, Blocks Used in Ultrasonic Examination

E 1065 Guide for Evaluating Characteristics of Ultrasonic Search Units

2.2 ANSI Standard:

B 46.1 Surface Texture

2.3 Other Document:

Recommended Practice for Nondestructive Personnel Qualification and Certification SNT-TC-1A, (1988 or later)

3. Terminology

3.1 Definitions:

3.1.1 *indication levels (clusters), n*— five or more indications in a volume representing a 2 in. [50 mm] or smaller cube in the forging.

3.1.2 *individual indications, n*— single indications showing a decrease in amplitude as the search unit is moved in any direction from the position of maximum amplitude and which are too small to be considered traveling or planar.

3.1.3 *planar indications, n*— indications shall be considered continuous over a plane if they have a major axis greater than 1 in. [25 mm] or twice the major dimension of the transducer, whichever is greater, and do not travel.

3.1.4 *traveling indications, n*— inductions whose leading edge moves a distance equivalent to 1 in. [25 mm] or more of metal depth with movement of the transducer over the surface of the forging.

4. Ordering Information

4.1 When this practice is to be applied to an inquiry, contract, or order, the purchaser shall so state and shall also furnish the following information:

4.1.1 Designation number (including year date),

4.1.2 Method of establishing the sensitivity in accordance with 8.2.2 and 8.3.3 (Vee- or rectangular-notch),

4.1.2.1 The diameter and test metal distance of the flat-bottom hole and the material of the reference block in accordance with 8.2.2.2,

4.1.3 Quality level for the entire forging or portions thereof in accordance with 11.3, and

4.1.4 Any options in accordance with 1.4, 5.4, 5.5, 6.1, 7.1, 7.2, 8.1.11, 9.1, and 9.2.

5. Apparatus

5.1 An ultrasonic, pulsed, reflection type of instrument shall be used for this examination. The system shall have a minimum capability for examining at frequencies from 1 to 5 MHz. On examining austenitic stainless forgings the system shall have the capabilities for examining at frequencies down to 0.4 MHz.

5.1.1 The ultrasonic instrument shall provide linear presentation (within 5%) for at least 75% of the screen height (sweep line to top of screen). The 5% linearity referred to is descriptive of the screen presentation of amplitude. Instrument linearity shall be verified in accordance with the intent of Practice E 317. Any set of blocks processed in accordance with Practice E 317 or E 428 may be used to establish the specified $\pm 5\%$ instrument linearity.

5.1.2 The electronic apparatus shall contain an attenuator (accurate over its useful range to $\pm 10\%$ (+1 dB) of the amplitude ratio) which will allow measurement of indications beyond the linear range of the instrument.

5.2 *Search Units*, having a transducer with a maximum active area of 1 in.² [650 mm²] with $\frac{3}{4}$ in. [20 mm] minimum to $1\frac{1}{8}$ in. [30 mm] maximum dimensions shall be used for straight-beam scanning (see 8.2); and search units with $\frac{1}{2}$ in. [13 mm] minimum to 1 in. [25 mm] maximum dimensions shall be used for angle-beam scanning (see 8.3).

5.2.1 *Transducers* shall be utilized at their rated frequencies.

5.2.2 Other search units may be used for evaluating and pinpointing indications.

5.3 *Couplants*, having good wetting characteristics such as SAE No. 20 or No. 30 motor oil, glycerin, pine oil, or water shall be used. Couplants may not be comparable to one another and the same couplant shall be used for calibration and examination.

5.4 *Reference Blocks*, containing flat-bottom holes may be used for calibration of equipment in accordance with 5.1.1 and may be used to establish recording levels for straight-beam examination when so specified by the order or contract.

5.5 *DGS Scales*, matched to the ultrasonic test unit and transducer to be utilized, may be used to establish recording levels for straight beam examination, when so specified by the order or contract. The DGS scale range must be selected to include the full thickness cross-section of the forging to be examined. An example of a DGS overlay is found in Appendix X3.

6. Personnel Requirements

6.1 Personnel performing the ultrasonic examinations to this practice shall be qualified and certified in accordance with a written procedure conforming to Recommended Practice No. SNT-TC-1A (1988 or later) or another national standard that is acceptable to both the purchaser and the supplier.

7. Preparation of Forging for Ultrasonic Examination

7.1 Unless otherwise specified in the order or contract, the forging shall be machined to provide cylindrical surfaces for radial examination in the case of round forgings; the ends of the forgings shall be machined perpendicular to the axis of the forging for the axial examination. Faces of disk and rectangular forgings shall be machined flat and parallel to one another.

7.2 The surface roughness of exterior finishes shall not exceed 250 μ in. [6 μ m] unless otherwise shown on the forging drawing or stated in the order or the contract.

7.3 The surfaces of the forging to be examined shall be free of extraneous material such as loose scale, paint, dirt, and so forth.

8. Procedure

8.1 General:

8.1.1 As far as practicable, subject the entire volume of the forging to ultrasonic examination. Because of radii at change of sections and other local configurations, it may be impossible to examine some sections of a forging.

8.1.2 Perform the ultrasonic examination after heat treatment for mechanical properties (exclusive of stress-relief treatments) but prior to drilling holes, cutting keyways, tapers, grooves, or machining sections to contour. If the configuration of the forging required for the treatment for mechanical properties prohibits a subsequent complete

examination of the forging, it shall be permissible to examine prior to treatment for mechanical properties. In such cases, reexamine the forging ultrasonically as completely as possible after heat treatment.

8.1.3 To ensure complete coverage of the forging volume, index the search unit with at least 15% overlap with each pass.

8.1.4 For manual scanning, do not exceed a scanning rate of 6 in./s [150 mm/s].

8.1.5 For automated scanning, adjust scanning speed or instrument repetition rate, or both, to permit detection of the smallest discontinuities referenced in the specification and to allow the recording or signaling device to function. At no time shall the scanning speed exceed the speed at which an acceptable calibration was made.

8.1.6 If possible, scan all sections of forgings in two perpendicular directions.

8.1.7 Scan disk forgings using a straight beam technique from at least one flat face and radially from the circumference, whenever practicable.

8.1.8 Scan cylindrical sections and hollow forgings radially using a straight-beam technique. When practicable, also examine the forging in the axial direction.

8.1.9 In addition, examine hollow forgings by angle-beam technique from the outside diameter surface as required in 8.3.1.

8.1.10 In rechecking or reevaluation by manufacturer or purchaser, use comparable equipment, search units, frequency, and couplant.

8.1.11 Forgings may be examined either stationary or while rotating in a lathe or on rollers. If not specified by the purchaser, either method may be used at the manufacturer's option.

8.2 Straight-Beam Examination:

8.2.1 For straight-beam examination use a nominal $2\frac{1}{4}$ MHz search unit whenever practicable; however, 1 MHz is the preferred frequency for coarse grained austenitic materials and long testing distances. In many instances on examining coarse grained austenitic materials it may be necessary to use a frequency of 0.4 MHz. Other frequencies may be used if desirable for better resolution, penetrability, or detectability of flaws.

8.2.2 Establish the instrument sensitivity by either the reflection, reference-block technique, or DGS method (see Appendix X3 for an explanation of the DGS method).

8.2.2.1 Back-Reflection Technique (Back-Reflection Calibration Applicable to Forgings with Parallel Entry and Back Surfaces) — With the attenuator set at an appropriate level, for example 5 to 1 or 14 dB, adjust the instrument controls to obtain a back reflection approximately 75% of the full-screen height from the opposite

side of the forging. Scan the forging at the maximum amplification setting of the attenuator (attenuator set at 1 to 1). Carry out the evaluation of discontinuities with the gain control set at the reference level. Recalibration is required for significant changes in section thickness or diameter.

NOTE 1 — High sensitivity levels are not usually employed when inspecting austenitic steel forgings due to attendant high level of "noise" or "hash" caused by coarse grain structure.

8.2.2.2 Reference-Block Calibration — The test surface roughness on the calibration standard shall be comparable to, but no better than, the item to be examined. Adjust the instrument controls to obtain the required signal amplitude from the flat-bottom hole in the specified reference block. Utilize the attenuator in order to set up on amplitudes larger than the vertical linearity of the instrument. In those cases, remove the attenuation prior to scanning the forging.

NOTE 2 — When flat-surfaced reference block calibration is specified, adjust the amplitude of indication from the reference block or blocks to compensate for examination surface curvature (an example is given in Appendix X1).

8.2.2.3 DGS Calibration — Prior to use, verify that the DGS overlay matches the transducer size and frequency. Accuracy of the overlay can be verified by reference blocks and procedures outlined in Practice E 317. Overlays are to be serialized to match the ultrasonic transducer and pulse echo testing system that they are to be utilized with.

8.2.2.4 Choose the appropriate DGS scale for the cross-sectional thickness of the forging to be examined. Insert the overlay over the CRT screen, ensuring the DGS scale base line coincides with the sweep line of the CRT screen. Place the probe on the forging, adjust the gain to make the first back-wall echo appear clearly on CRT screen. Using the Delay and Sweep control, shift the screen pattern so that the leading edge of the initial pulse is on zero of the DGS scale and the back-wall echo is on the DGS scale value corresponding to the thickness of the forging. Adjust the gain so the forging back-wall echo matches the height of the DGS reference slope within ± 1 Db. Once adjusted, increase the gain by the Db shown on the DGS scale for the reference slope. Instrument is now calibrated and flaw sizes that can be reliably detected can be directly read from the CRT screen. These flaw sizes are the equivalent flat bottom reflector that can be used as a reference point.

NOTE 3 — The above can be utilized on all solid forgings. Cylindrical hollow forgings, and drilled or bored forgings must be corrected to compensate for attenuation due to the central hole (see Appendix X4).

8.2.3 Recalibration — Any change in the search unit, couplant, instrument setting, or scanning speed from that used for calibration shall require recalibration. Perform a

calibration check at least once every 8 h shift. When a loss of 15% or greater in the gain level is indicated, reestablish the required calibration and reexamine all of the material examined in the preceding calibration period. When an increase of 15% or greater in the gain level is indicated, reevaluate all recorded indications.

8.2.4 During the examination of the forging, monitor the back reflection for any significant reduction in amplitude. Reduction in back-reflection amplitude may indicate not only the presence of a discontinuity but also poor coupling of the search unit with the surface of the forging, nonparallel back-reflection surface, or local variations of attenuation in the forging. Recheck any areas causing loss of back reflection.

8.3 Angle-Beam Examination—Rings and Hollow Forgings:

8.3.1 Perform the examination from the circumference of rings and hollow forgings that have an axial length greater than 2 in. [50 mm] and an outside to inside diameter ratio of less than 2.0 to 1.

8.3.2 Use a 1 MHz, 45° angle-beam search unit unless thickness, OD/ID ratio, or other geometric configuration results in failure to achieve calibration. Other frequencies may be used if desirable for better resolution, penetrability, or detectability of flaws. For angle-beam inspection of hollow forgings up to 2.0 to 1 ratio, provide the transducer with a wedge or shoe that will result in the beam mode and angle required by the size and shape of the cross section under examination.

8.3.3 Calibrate the instrument for the angle-beam examination to obtain an indication amplitude of approximately 75% full-screen height from a rectangular or a 60° V-notch on inside diameter (ID) in the axial direction and parallel to the axis of the forging. A separate calibration standard may be used; however, it shall have the same nominal composition, heat treatment, and thickness as the forging it represents. The test surface finish on the calibration standard shall be comparable but no better than the item to be examined. Where a group of identical forgings is made, one of these forgings may be used as the separate calibration standard. Cut the ID notch depth to 3% maximum of the thickness or 1/4 in. [6 mm], whichever is smaller, and its length approximately 1 in. [25 mm]. Thickness is defined as the thickness of the forging to be examined at the time of examination. At the same instrument setting, obtain a reflection from a similar OD notch. Draw a line through the peaks of the first reflections obtained from the ID and OD notches. This shall be the amplitude reference line. It is preferable to have the notches in excess metal or test metal when possible. When the OD notch cannot be detected when examining the OD surface, perform the examination when practicable (some ID's may be too small to permit examination), as indicated above from both the

OD and ID surfaces. Utilize the ID notch when inspecting from the OD, and the OD notch when inspecting from the ID. Curve wedges or shoes may be used when necessary and practicable.

8.3.4 Perform the examination by scanning over the entire surface area circumferentially in both the clockwise and counter-clockwise directions from the OD surface. Examine forgings, which cannot be examined axially using a straight beam, in both axial directions with an angle-beam search unit. For axial scanning, use rectangular or 60° V-notches on the ID and OD for the calibration. These notches shall be perpendicular to the axis of the forging and the same dimensions as the axial notch.

9. Recording

9.1 Straight-Beam Examination — Record the following indications as information for the purchaser. These recordable indications do not constitute a rejectable condition unless negotiated as such in the purchase order or contract.

9.1.1 For individual indications, report:

9.1.1.1 In the back-reflection technique, individual indications equal to or exceeding 10% of a nominal back reflection from an adjacent area free from indications, and

9.1.1.2 In the reference-block or DGS technique, indications equal to or exceeding 100% of the reference amplitude.

9.1.2 For indications that are planar, traveling, or clustered, determine the location of the edges and the major and minor axes using the half-amplitude (6dB drop) technique and report:

9.1.2.1 The variation in depth or planar area, or both, of traveling indications,

9.1.2.2 The length of major and minor axes of planar indications, and

9.1.2.3 The volume occupied by indication levels and the amplitude range.

9.2 Angle-Beam Examination — Record discontinuity indications equal to or exceeding 50% of the indication from the reference line. When an amplitude reference line cannot be generated, record discontinuity indications equal to or exceeding 50% of the reference notch. These recordable indications do not constitute a rejectable condition unless negotiated as such in the purchase order.

9.3 Report reduction in back reflection exceeding 50% of the original measured in increments of 10%.

9.4 When recording, corrections must be made for beam divergence at the estimated flaw depth (See Guide E 1065).

9.5 Report indication amplitudes in increments of 10%.

10. Report

10.1 Report the following information:

10.1.1 All recordable indications (see Section 9);

10.1.2 For the purpose of reporting the locations of recordable indications, a sketch shall be prepared showing the physical outline of the forging including dimensions of all areas not inspected due to geometric configuration, the purchaser's drawing number, the purchaser's order number, and the manufacturer's serial number, and the axial, radial, and circumferential distribution of recordable ultrasonic indications;

10.1.3 The designation (including year date) to which the examination was performed as well as the frequency used, method of setting sensitivity, type of instrument, surface finish, couplant, and search unit employed; and

10.1.4 The inspector's name or identity and date the examination was performed.

11. Quality Levels

11.1 This practice is intended for application to forgings, with a wide variety of sizes, shapes, compositions, melting processes, and applications. It is, therefore, impracticable to specify an ultrasonic quality level which would be universally applicable to such a diversity of products. Ultrasonic acceptance or rejection criteria for individual forgings should be based on a realistic appraisal of service requirements and the quality that can normally be obtained in the production of the particular type forging.

11.2 Heavy austenitic stainless steel forgings are more difficult to penetrate ultrasonically than similar carbon or low-alloy steel forgings. The degree of attenuation normally increases with section size; and the noise level, generally or in isolated areas, may become too great to permit detection of discrete indications. In most instances, this attenuation results from inherent coarse grained microstructure of these austenitic alloys. For these reasons, the

methods and standards employed for ultrasonically examining carbon and low-alloy steel forgings may not be applicable to heavy austenitic steel forgings. In general, only straight beam inspecting using a back-reflection reference standard is used. However, utilization of Practice A 745/A 745M for austenitic steel forgings can be considered if flat bottom hole reference standards or angle beam examination of these grades are required.

11.3 Acceptance quality levels shall be established between purchaser and manufacturer on the basis of one or more of the following criteria.

11.3.1 *Straight-Beam Examination:*

11.3.1.1 No indications larger than some percentage of the reference back reflection.

11.3.1.2 No indications equal to or larger than the indication received from the flat-bottom hole in a specific reference block or blocks.

11.3.1.3 No areas showing loss of back reflection larger than some percentage of the reference back reflection.

11.3.1.4 No indications per 11.3.1.1 or 11.3.1.2 coupled with some loss of resultant back reflection per 11.3.1.3.

11.3.1.5 No indications exceeding the reference level specified in the DGS method

11.3.2 *Angle-Beam Examination* — No indications exceeding a stated percentage of the reflection from a reference notch or of the amplitude reference line.

11.4 Intelligent application of ultrasonic quality levels involves an understanding of the effects of many parameters on examination results.

12. Keywords

12.1 angle beam examination; back-reflection; DGS; reference-block; straight beam examination; ultrasonic

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order. Details shall be agreed upon by the manufacturer and the purchaser.

S1. Reporting Criteria

S1.1 Reference block calibration shall be performed using at least three holes, spaced to approximate minimum, mean, and maximum thickness as tested, and shall be used to generate a distance amplitude correction (DAC) curve. The following hole sizes apply:

- (a) $\frac{1}{16}$ in. [1.5 mm] flat bottom holes (FBH) for thicknesses less than 1.5 in. [40 mm].
- (b) $\frac{1}{8}$ in. [3 mm] FBH for thicknesses of 1.5-6 in. [40-150 mm] inclusive.
- (c) $\frac{1}{4}$ in. [6 mm] FBH for thicknesses over 6 in. [150 mm].

S1.2 Reporting criteria include:

- (a) All indications exceeding the DAC curve.
- (b) Two or more indications separated by $\frac{1}{2}$ in. [12 mm] or less.

APPENDICES

(Nonmandatory Information)

X1. TYPICAL TUNING LEVEL COMPENSATION FOR THE EFFECTS OF FORGING CURVATURE

X1.1 The curve (Fig. X1.1) was determined for the following test conditions:

Material	nickel-molybdenum-vanadium alloy steel (Specification A 469/A 469M, Class 4)
Instrument	Type UR Reflectoscope
Search unit	1 $\frac{1}{8}$ in. [30 mm] diameter quartz
Frequency	2 $\frac{1}{4}$ MHz
Reference block	ASTM No. 3-0600 (aluminum)
Reflection area of reference curve	0.010 in. ² [6.5 mm ²] in nickel-molybdenum-vanadium alloy steel
Surface finish	250 μ in. [6 μ m], max, roughness

X1.2 To utilize curve, adjust reflectoscope sensitivity to obtain indicated ultrasonic response on ASTM No. 3-0600 reference block for each diameter as shown. A response of 1 in. [25 mm] sweep-to-peak is used for flat surfaces. Use attenuator to obtain desired amplitude, but do testing at 1 to 1 setting.

X2. INDICATION AMPLITUDE COMPENSATION FOR TEST DISTANCE VARIATIONS

X2.1 The curve (Fig. X2.1) has been determined for the following test conditions:

Material	nickel-molybdenum-vanadium alloy steel (Specification A 469/A 469M, Class 4)
Instrument	Type UR Reflectoscope
Search unit	1 $\frac{1}{8}$ in. [30 mm] diameter quartz
Frequency	2 $\frac{1}{4}$ MHz
Couplant	No. 20 oil
Reference block	ASTM No. 3-0600 (aluminum)
Reflection area of reference curve	0.010 in. ² [6.5 mm ²] in nickel-molybdenum-vanadium alloy steel
Surface finish	250 μ in. [6 μ m], max, roughness

X2.2 To utilize curve, establish amplitude from ASTM reference block to coincide with values from Appendix X1.

X3. BACKGROUND INFORMATION ON THE DGS METHODS

X3.1 The overlay in Fig. X3.1 was designed for a 2.0 MHz, 1 in. [25 mm] diameter probe and a maximum test distance of 39.4 in. [1000 mm]. In order to use this overlay, the sweep time base must be accurately calibrated and aligned with the overlay being used. The back reflection is then adjusted to either the RE + 10 dB line or the RE + 20 dB line, based on the thickness being tested; additional gain (10 or 20 dB) is added as designated by the line being used. The RE + 20 line covers a range to approximately 15.7 in. [400 mm] and the RE + 10 line from 15.7 to 39.4 in. [400 to 1000 mm]. At this calibration level, the flaw size is read directly from the screen. Flaw sizes from 0.078 to 1 in. [2 to 25 mm] can be read directly from the overlay.

X4. COMPENSATION FOR CENTER HOLE ATTENUATION ON CYLINDRICAL BORED OR HOLLOW FORGINGS UTILIZING THE DGS METHOD

X4.1 The hole in a cylindrical bored forging causes sound scatter. In these cases, a correction is required which depends on the wall thickness and bore diameter.

X4.1.1 Determine the correction value in dB from the Nomogram (Fig. X4.1). With the gain-dB control, proceed as described in 8.2.2.4 reducing the flaw detector gain by the correction value determined.

FIG. X1.1 TYPICAL COMPENSATION CURVE FOR EFFECTS OF FORGING CURVATURE

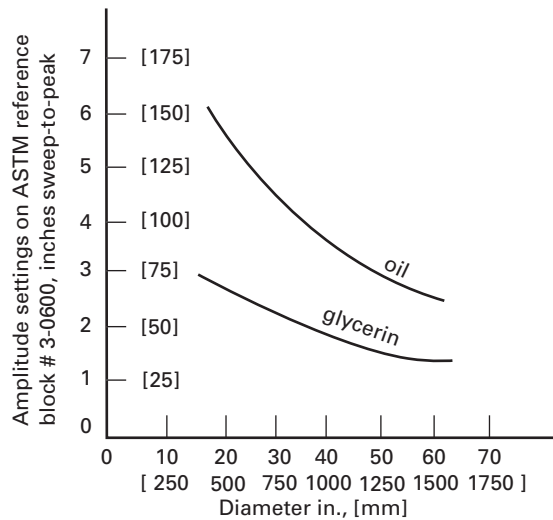


FIG. X2.1 TYPICAL DISTANCE-AMPLITUDE CORRECTION CURVE

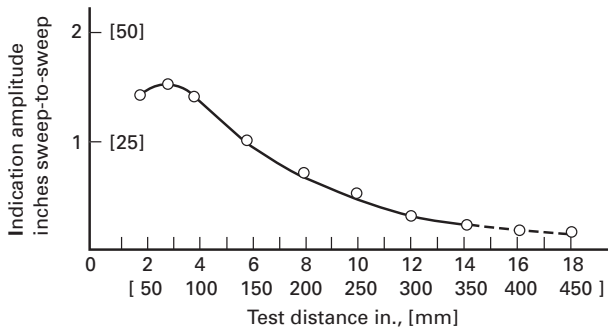


FIG. X3.1 EXAMPLE OF DGS OVERLAY

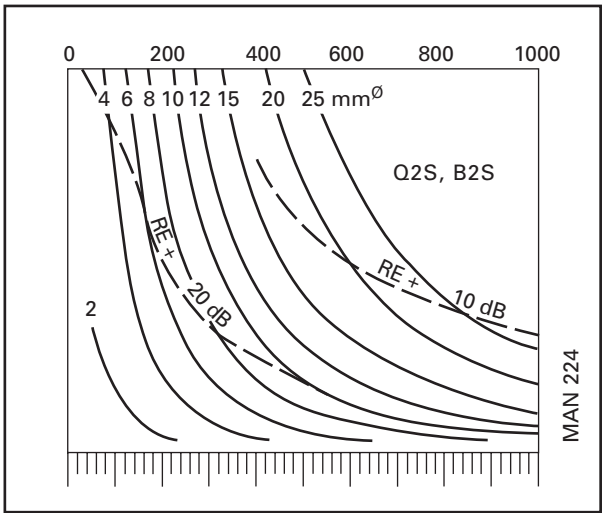
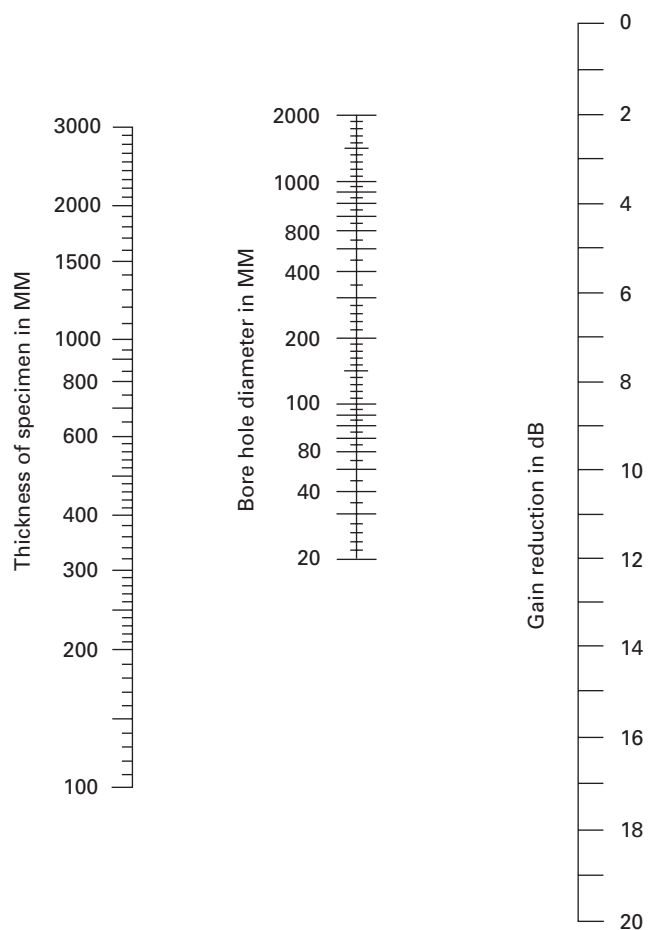


FIG. X4.1 THE INFLUENCE OF A CENTRAL BORE ON THE
BACKWALL ECHO AMPLITUDE OF CYLINDRICAL OR
PLANE PARALLEL FORGINGS



NOTE: Metric units are presented in this figure to be consistent with DGS scales presently available. Conversion to English units would also be acceptable.

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SPECIFICATION FOR FERRITIC DUCTILE IRON PRESSURE-RETAINING CASTINGS FOR USE AT ELEVATED TEMPERATURES



SA-395/SA-395M



[Identical with ASTM Specification A 395/A 395M-99(R09).]

1. Scope

1.1 This specification covers ductile iron castings for pressure-retaining parts for use at elevated temperatures. Castings of all grades are suitable for use up to 450°F. For temperatures above 450°F and up to 650°F, only Grade 60–40–18 castings are suitable (Note 1).

1.2 Valves, flanges, pipe fittings, pumps, and other piping components are generally manufactured in advance and supplied from stock by the manufacturer, jobber, or dealer.

1.3 For supplemental casting requirements, Specification A 834 may be utilized.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance to the specification.

NOTE 1 — For service other than as specified in this section, reference should be made to Specification A 536 for Ductile Iron Castings.

2. Referenced Documents

2.1 ASTM Standards:

- A 247 Test Method for Evaluating the Microstructure of Graphite in Iron Castings
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 536 Specification for Ductile Iron Castings
- A 732/A 732M Specification for Castings, Investment, Carbon and Low Alloy Steel for General Application,

and Cobalt Alloy for High Strength at Elevated Temperatures

- A 834 Specification for Common Requirements for Iron Castings for General Industrial Use
- E 8 Test Methods for Tension Testing of Metallic Materials
- E 10 Test Method for Brinell Hardness of Metallic Materials
- E 186 Reference Radiographs for Heavy-Walled (2 to 4½ in. [51 to 114 mm]) Steel Castings
- E 280 Reference Radiographs for Heavy-Walled (4½ to 12 in. [114 to 305 mm]) Steel Castings
- E 446 Reference Radiographs for Steel Castings up to 2 in. [51 mm] in Thickness
- E 689 Reference Radiographs for Ductile Iron Castings
- E 1806 Practice for Sampling Steel and Iron for Determination of Chemical Composition
- F 1476 Specification for Performance of Gasketed Mechanical Couplings for Use in Piping Applications
- F 1548 Specification for the Performance of Fittings for Use with Gasketed Mechanical Couplings used in Piping Applications

2.2 Manufacturer's Standardization Society of the Valve and Fittings Industry Standard:

- SP 25 Standard Marking Systems for Valves, Flanges, Pipe Fittings, and Unions

3. Classification

3.1 Castings ordered to this specification are classified by grades based on mechanical property requirements, as listed in Table 1. See note following Table 1.

4. Ordering Information

4.1 Orders for material under this specification shall include the following applicable information:

4.1.1 Drawing, catalog number, or part identifications,

4.1.1.1 For grade 65-45-15, drawing indicating critical area(s) of casting (see 7.2.2 and 7.3.2).

4.1.2 Quantity (weight or number of pieces),

4.1.3 ASTM designation and year of issue,

4.1.4 Grade (See Table 1), if a Grade is not specified, the manufacturer shall supply grade 60-40-18.

4.1.5 Heat-treating requirements (see 5.2.1),

4.1.6 Pressure test requirements (see 7.4.3),

4.1.7 Test samples from castings (see 11.1.1 and 12.1.1),

4.1.8 Test coupons size (see 11.2),

4.1.9 Metallographic option (see 12.1.1),

4.1.10 Place of inspection (see 16.1),

4.1.11 Certification requirements (see 17.1),

4.1.12 Identification marking (see 18.2), and

4.1.13 Supplemental Requirements (see 1.4, 7.4.2, S1 and S2).

5. Materials and Manufacture

5.1 The melting method and the nodularizing practice shall be optional with the foundry.

5.2 Except as provided in 5.2.1, all castings Grade 60-40-18 shall be given a ferritizing heat treatment that produces essentially a ferritic structure that contains no massive carbides.

5.2.1 When specified in the purchase order, Grade 60-40-18 castings may be provided in an as-cast condition provided they comply with the requirements of 7.1 and 7.2.1.

5.2.2 Castings supplied in accordance with 5.2.1 may be stress relieved by agreement between the manufacturer and purchaser.

5.3 Castings Grade 65-45-15 may be provided in as-cast condition or heat treated, provided they comply with the requirements of 7.1, 7.2.2, and 7.3.2.

6. Chemical Requirements

6.1 The casting shall conform to the following requirements for chemical composition (Note 2):

Total carbon, min, %	3.00
Silicon, max, %	2.50
Phosphorus, max, %	0.08

6.1.1 The chemical analysis for total carbon shall be made on chilled cast pencil type specimens or from thin

wafers approximately $\frac{1}{32}$ in. [0.8 mm] thick cut from test coupons. Drillings are not reliable because of the probable loss of graphite.

6.1.2 For each reduction of 0.01% below the maximum specified phosphorus content, an increase of 0.08% silicon above the specified maximum will be permitted up to a maximum of 2.75%.

NOTE 2 — Silicon contents above 2.75%, or phosphorus contents above 0.08 % have a tendency to lower the impact resistance of the material. If the carbon content is below 3.00%, excess cementite may form during cooling and if this is not removed during heat treatment, the impact resistance of the material may be lowered.

7. Requirements

7.1 Tensile Properties:

7.1.1 The ductile iron as represented by the test specimens shall conform to the mechanical property requirements in Table 1.

7.2 Hardness:

7.2.1 For Grade 60-40-18, the hardness of the castings and test specimens shall be within the limits in Table 1.

7.2.2 For Grade 65-45-15, the hardness of test specimen and the critical area(s) of the casting, as identified on the casting drawing, shall be within the limits in Table 1. If the grade 65-45-15 casting drawing does not have critical area(s) of the casting identified, all areas of the casting shall be within the hardness limits in Table 1.

7.3 Microstructure:

7.3.1 For Grade 60-40-18, the microstructure of the separately cast test coupon or the casting shall be essentially ferritic and contain no massive carbides, and have a minimum of 90% Type I and Type II Graphite as in Fig. 1 or Plate I of Test Method A 247.

7.3.2 For Grade 65-45-15, the microstructure of the critical areas of the casting, as identified on the casting drawing, shall be 45% pearlitic, maximum, contain no massive carbides, and have a minimum 90% Type I and Type II Graphite as in Fig. 1 or Plate I of Test Method A 247.

7.4 Pressure Test Requirements:

7.4.1 Each pressure retaining Grade 60-40-18 casting shall be tested after machining to the test pressure specified by the applicable standard of ANSI, ASME Boiler and Pressure Vessel Code, or other pertinent code, and shall show no leaks.

7.4.2 Castings Grade 65-45-15 manufactured under this specification shall be capable of passing hydrostatic test(s) compatible with the rating of the finished cast component. Such tests shall be conducted by the casting manufacturer only when Supplementary Requirement S2 is specified.

7.4.3 Castings Grade 60-40-18, ordered under this specification not covered by ANSI standards and ASME Pressure Vessel Code, and castings for special service applications, shall be tested to such pressures as may be agreed upon by the manufacturer and the purchaser.

7.4.4 For castings Grade 60-40-18, it is realized that the foundry may be unable to perform the hydrostatic test prior to shipment, or that the purchaser may wish to defer testing until additional work or machining has been performed on the casting. Castings ordered in the rough state for final machining by the purchaser may be tested hydrostatically prior to shipment by the manufacturer at pressures to be agreed upon with the purchaser. However, the foundry is responsible for the satisfactory performance of the castings under the final hydrostatic test.

8. Workmanship and Finish

8.1 The surface of the casting shall be examined visually and shall be free from adhering sand, scale, cracks, and hot tears. Any other surface discontinuities shall meet visual acceptance standards specified in the order.

9. Repair

9.1 Castings for valves, flanges, pipe fittings, pumps, and other piping components ordered under applicable ANSI standards shall not be repaired by plugging, welding, brazing, or impregnation.

9.2 Castings Grade 60-40-18 not covered in 9.1 which leak on hydrostatic tests may be repaired by plugging, provided the following requirements are met:

9.2.1 No welding or brazing is permitted.

9.2.2 The diameter of the plug shall not exceed the diameter of a standard 2 in. [ISO R2] pipe plug.

9.2.3 The plugs, where practical, shall conform in all dimensions to the standard ISO $\frac{3}{8}$ plugs. In addition, they shall have full thread engagement corresponding to the thickness in the repaired section. Where a tapered plug is impractical because of the excess wall thickness in terms of plug diameter and coincident thread engagement, other types of plugs may be used provided both full engagement and effective sealing against pressure are obtained. Where possible, the ends of the plug should be ground smooth after installation to conform to the inside and outside contours of the wall of the pressure vessel or pressure part.

9.2.4 The material from which the plug is manufactured shall conform in all respects to the materials specifications that apply to the pressure vessel or pressure part.

9.2.5 The area adjacent to the drilled hole shall be examined by radiography, and shall meet the Level 3 acceptance requirements of Reference Radiographs E 689

and supporting Reference Radiographs E 446, E 186, or E 280 as applicable and defined in accordance with Reference Radiographs E 689.

9.2.6 The thickness of any repaired section in relation to the size of the plug used shall not be less than that given in Table 2.

9.2.7 The minimum radius of repaired sections of cylinders or cones in relation to the size of plug used shall not be less than that given in Table 3.

9.2.8 A repaired area may consist of a maximum of three plugs with a spacing such that the ligaments between adjacent plugs shall not be less than listed in Table 4. Other defective areas may also be repaired by plugging provided the minimum ligament between plugs in adjacent areas is not less than twice the distance from the nearest plug, the values for which are listed in Table 4.

9.3 Surface imperfections in castings Grade 60-40-18 other than valves, flanges, pipe fittings, pumps, and other piping components may be repaired by plugging provided the depth of the plug is not greater than 20% of the thickness of the casting section and the diameter of the plug is not greater than its length. Repair of surface defects may not be done on pressure-containing portions of castings. The plug need not be threaded. The conditions of 9.2.1 and 9.2.4 shall also be satisfied.

10. Sampling

10.1 A lot shall consist of one of the following:

10.1.1 All the metal from a single heating in a batch-type melting furnace.

10.1.2 All the metal poured from two or more batch-type melting furnaces into a single ladle or a single casting.

10.1.3 All the metal poured from a continuous melting furnace for a given period of time between changes in charge, processing conditions, or aim-for chemistry, or 8 h, whichever is the shorter period.

11. Test Coupon

11.1 The separately cast test coupons poured from the same lot as the castings they represent from which the tension test specimen is machined shall be cast to the size and shape shown in Fig. 2, Fig. 3, or Fig. 4. Cast coupons shall be identified with the castings they represent. Sectioning procedure for removing test specimens from Y-blocks is shown in Fig. 5.

11.1.1 Test samples may be removed from castings at locations designated on a drawing or as agreed to by manufacturer and purchaser.

11.1.2 Test bars removed from castings shall conform to Fig. 6. The testing diameter shall be $\frac{1}{2}$ in. [12.5 mm] if possible. Smaller diameters shall be utilized if necessary.

11.2 The test coupon size shall be as mutually agreed upon between the manufacturer and purchaser. In the absence of agreement, it shall be the option of the manufacturer.

11.3 The test coupons shall be cast in molds made of suitable core sand having a minimum wall thickness of $1\frac{1}{2}$ in. [38 mm] for the $\frac{1}{2}$ in. [12.5 mm], 1 in. [25 mm] sizes, and 3 in. [75 mm] for the 3 in. [75 mm] size. The coupons shall be left in the mold until they have changed to a black color (approximately 900°F [480°C] or less). The keel block as shown in Fig. 2 or the modified keel block produced from the mold shown in Fig. 4 may be substituted for the 1 in. [25 mm] block shown in Fig. 3.

11.4 When investment castings are made to this specification, the manufacturer may use test specimens cast to size incorporated in the mold with the castings or separately cast to size using the same type of mold and the same thermal conditions that are used to produce the castings. These test specimens shall be made to the dimensions shown in Fig. 1 of Specification A 732/A 732M or Fig. 5 and Fig. 6 of Test Methods and Definitions A 370.

11.5 The manufacturer shall cast a sufficient number of test coupons to provide for each ferritizing anneal. The test coupons shall be heat treated with the castings they represent. Sectioning of the test coupons prior to heat treating is not permitted.

11.6 The metallographic examination shall be made on a test lug from the test coupon shown in Fig. 7 or from a casting; or from a representative test coupon poured with the casting(s). The test coupon shall represent the metal treated with the nodularizing agent.

12. Number of Tests and Retests

12.1 One tension test shall be made from sections cut from the test coupons (Fig. 5) required by Section 11.

12.1.1 Unless otherwise stated in the contract or order for castings, a metallographic examination may be substituted for the tension test when separately cast test coupons are used. When the microstructure option is used, a minimum of one tension test is required from each day's melt and for each heat treatment (see 12.2).

12.2 If any tension test specimen shows obvious defects, another from the same coupon, or from another coupon/or representing the same metal and the same anneal charge, may be tested. If an apparently sound test specimen fails to conform to this specification, castings may be re-annealed, if required, and two retests made. If either retest

fails to conform to this specification, the castings they represent shall be rejected.

13. Tension Test Specimen Preparation

13.1 The standard machined $\frac{1}{2}$ in. [12.5 mm] round tension test specimen with 2 in. [50 mm] gage length as shown in Fig. 6 shall be used except where the $\frac{1}{2}$ in. [12.5 mm] Y-block test coupon is required. In this case, either of the small size specimens, 0.375 or 0.250 in. [9 or 6.5 mm] round as shown in Fig. 6, shall be used.

14. Test Methods

14.1 Chemical analysis shall be made in accordance with Test Method E 1806.

14.2 The yield strength shall be determined in accordance with Test Methods E 8 using one of the following methods:

14.2.1 The 0.2% off-set method, or

14.2.2 Extension under load method where the yield strength may be determined as the stress producing an elongation under load of 0.375%; that is, 0.0075 in. [0.19 mm] in a gage length of 2 in. [50 mm].

14.3 The hardness of the ductile iron as represented by the test specimens and castings shall be determined in accordance with Test Method E 10.

14.4 The percentage of each graphite type shall be determined by manual counting, semi-automatic, or automatic image analysis methods. The sum of all graphite types shall total to 100%.

15. Records

15.1 Records of the chemical composition, mechanical properties, and metallographic examination, when applicable, shall be systematically made and maintained.

16. Inspection

16.1 Unless otherwise specified in the contract or purchase order, the manufacturer shall be responsible for carrying out all the tests and inspection required by this specification.

16.2 The inspector representing the purchaser shall have entry at all time, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacturer of the material ordered. The manufacturer shall afford the inspector all

reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Unless otherwise specified, all tests and inspection shall be made at the place of manufacture or by an approved independent laboratory prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

17. Certification

17.1 When agreed upon in writing by the purchaser and the supplier, a certification shall be made on the basis of acceptance of the material. This shall consist of a copy of the manufacturer's test report or a statement by the supplier accompanied by a copy of the test results, that the material has been sampled, tested, and inspected in accordance with the provisions of this specification. Each certification so furnished shall be signed by an authorized agent of the supplier or manufacturer.

18. Product Marking

18.1 Castings for valves, flanges, pipe fittings, and unions shall be marked for material identification in accordance with the Standard Marking System for Valves, Flanges, Pipe Fittings, and Unions, SP-25. Castings for gasketed mechanical couplings and fittings may be marked in accordance with Specification F 1476 or F 1548 respectively.

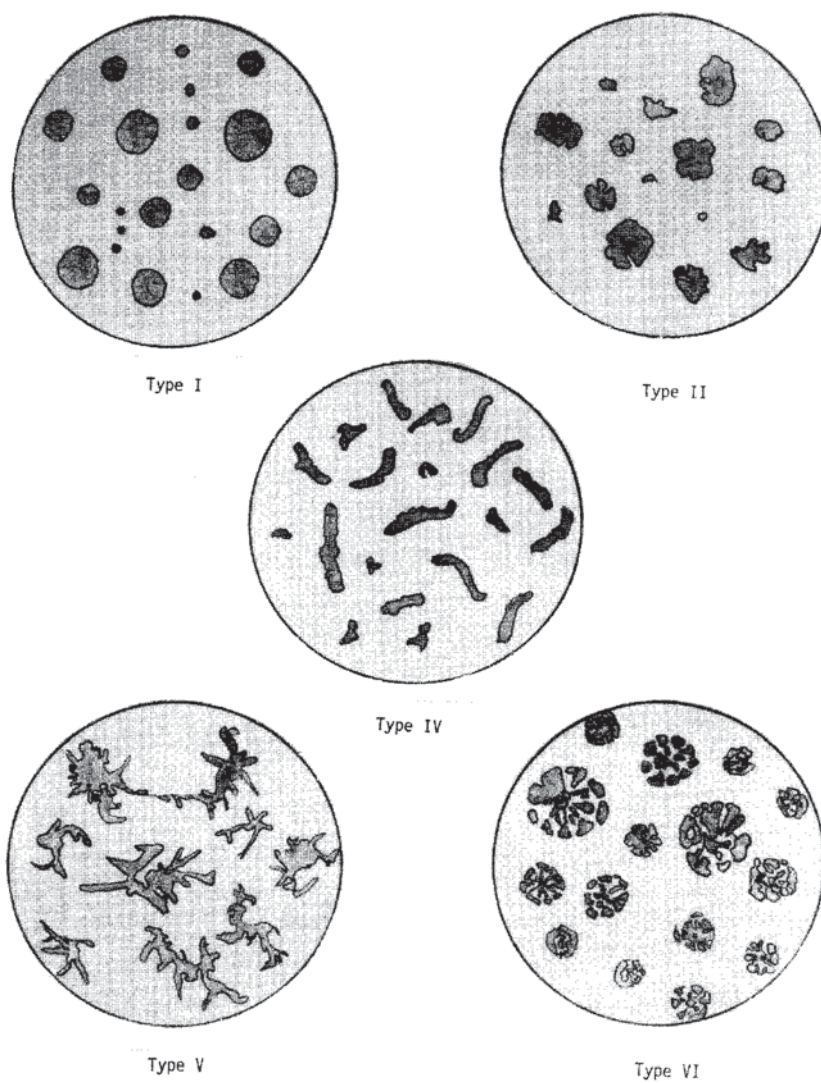
18.2 Castings, other than valves, flanges, pipe fittings, and unions, shall be identified subject to agreement by the manufacturer and the purchaser.

18.3 Marking shall be in such a position as not to injure the usefulness of the castings.

19. Keywords

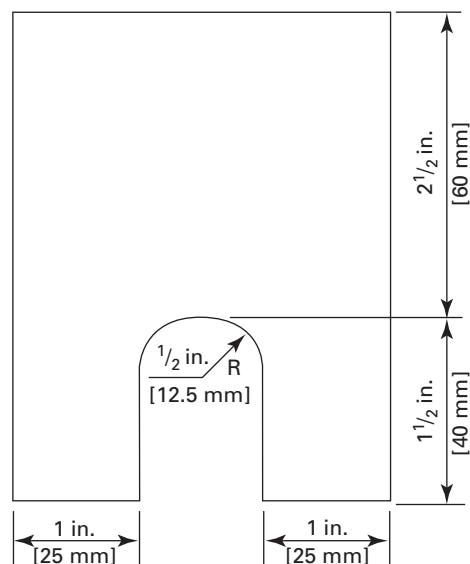
19.1 casting; ductile iron; mechanical properties; pressure-retaining; pressure test; tensile strength; tension testing; yield strength

FIG. 1 SUGGESTED CLASSIFICATION OF GRAPHITE FORM IN DUCTILE CAST IRON



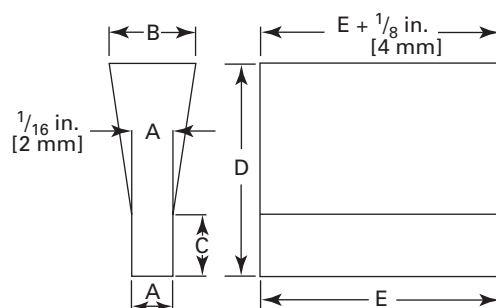
NOTE—Graphite types are identical with Plate 1 of Test Method A 247 and are so identified.

FIG. 2 KEEL BLOCK FOR TEST COUPONS



NOTE: The length of the keel block shall be 6 in. [152 mm]

FIG. 3 Y-BLOCKS FOR TEST COUPONS



"Y" Block Size

	For Castings of Thickness Less Than 1/2 in. [13 mm]	For Castings of Thickness 1/2 in. [13 mm] to 1 1/2 in. [38 mm]	For Castings of Thickness of 1 1/2 in. [38 mm] and Over
Dimensions	in. [mm]	in. [mm]	in. [mm]
A	1/2 [13]	1 [25]	3 [75]
B	1 5/8 [40]	2 3/8 [55]	5 [125]
C	2 [50]	3 [75]	4 [100]
D	4 [100]	6 [150]	8 [200]
E	7 [175]	7 [175]	7 [175]
	approx.	approx.	approx.

FIG. 4 MOLD FOR MODIFIED KEEL BLOCK

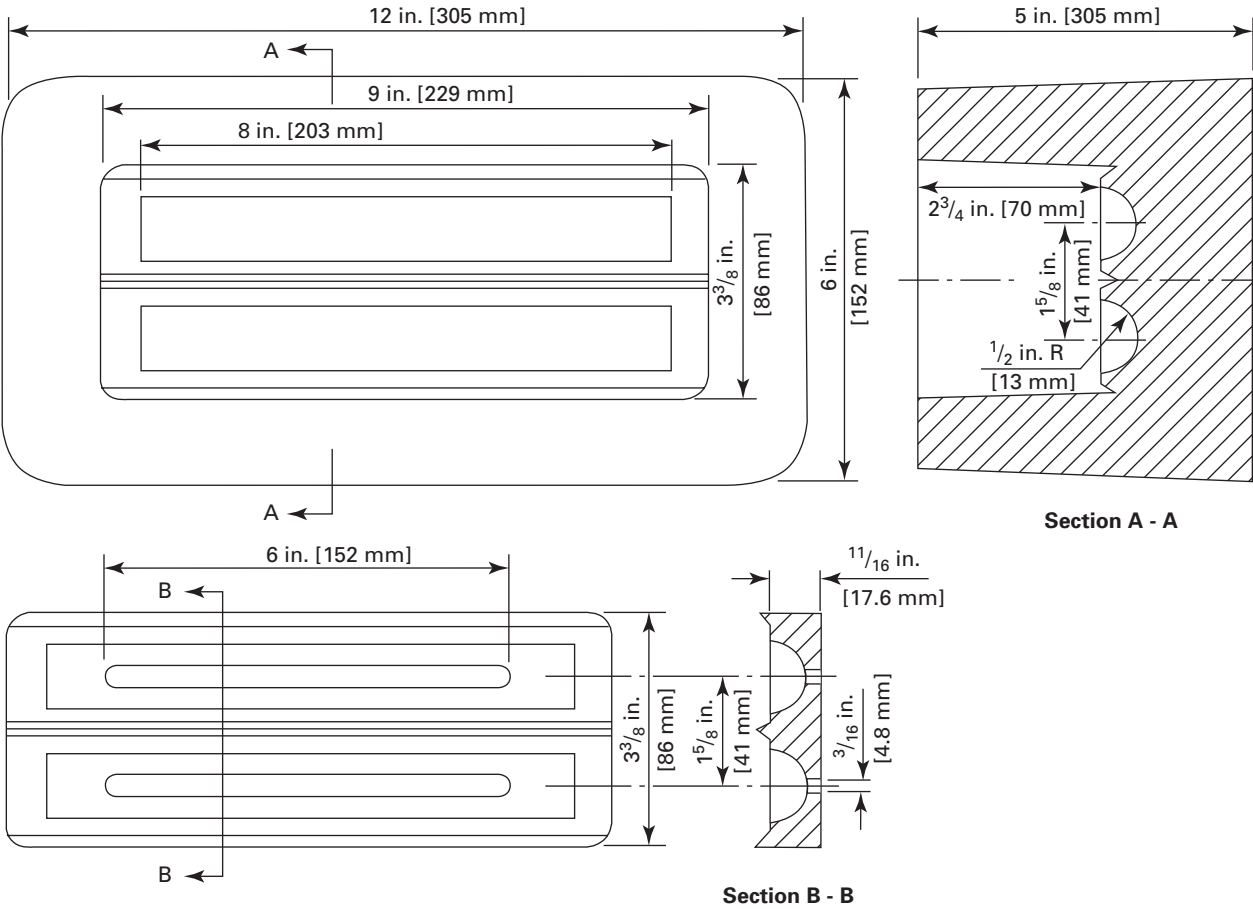


FIG. 5 SECTIONING PROCEDURE FOR Y-BLOCKS

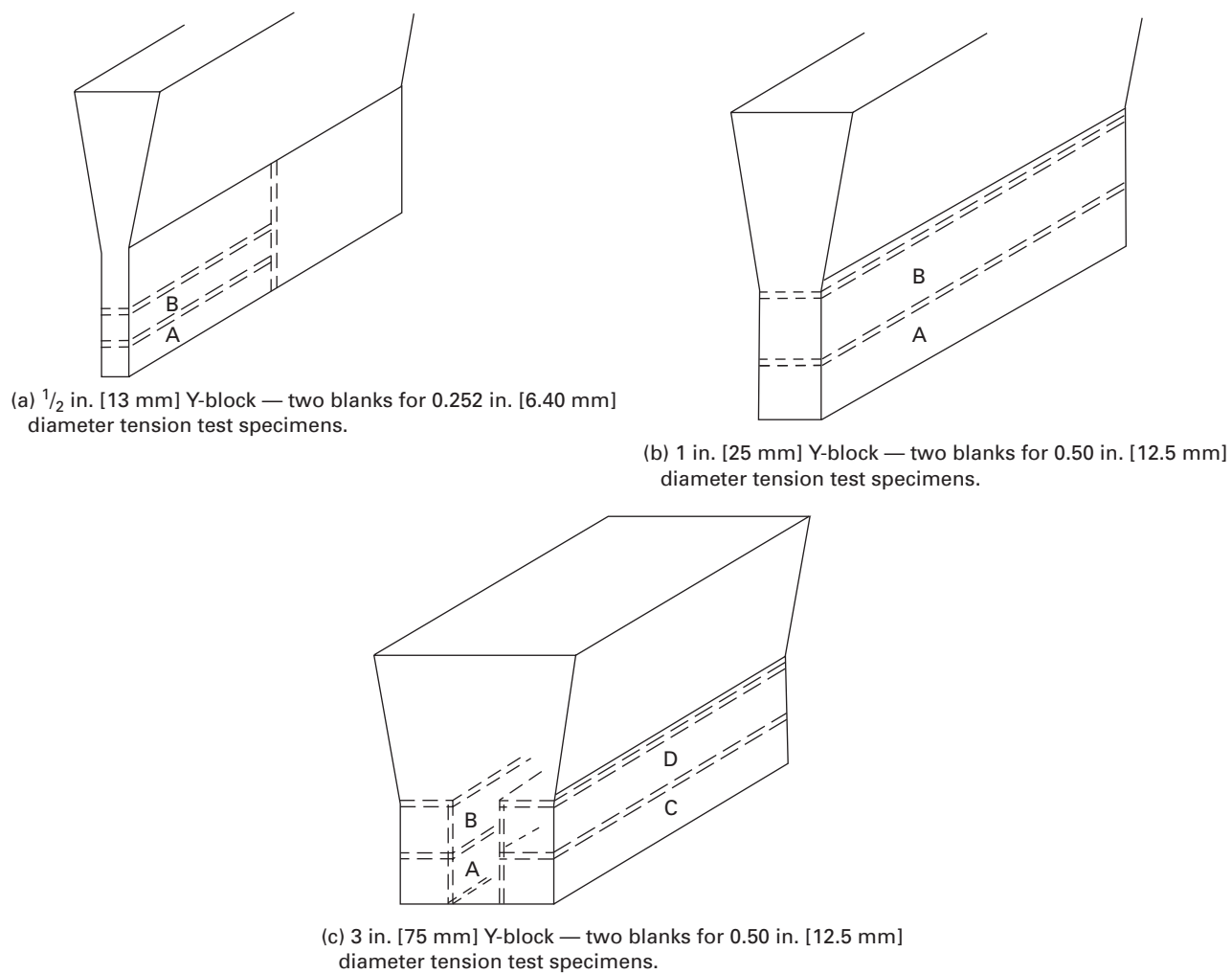
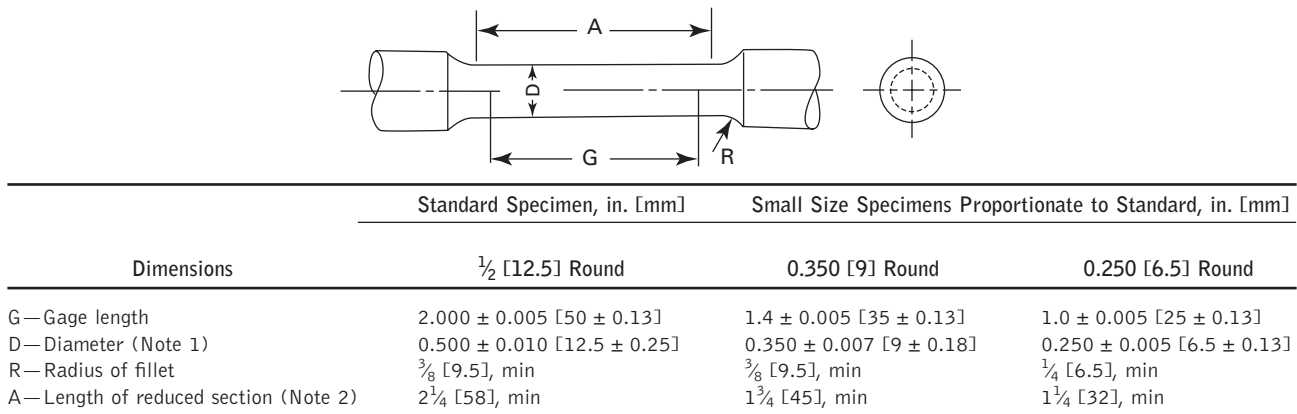


FIG. 6 STANDARD $\frac{1}{2}$ IN. [12.5 MM] ROUND TENSION TEST SPECIMEN WITH 2 IN. [50.0 MM] GAGE LENGTH AND EXAMPLES OF SMALL SIZE SPECIMENS PROPORTIONAL TO THE STANDARD SPECIMEN



NOTES:

- (1) The reduced section may have a gradual taper from the ends toward the center, with the ends not more than 0.005 in. [0.13 mm] larger in diameter than the center on the standard specimen, and not more than 0.003 in. [0.076 mm] larger in diameter than the center on the small size specimens.
- (2) If desired, on the small size specimens the length of the reduced section may be increased to accommodate an extensometer. However, reference marks for measurement of elongation should nevertheless be spaced at the indicated gage length.
- (3) The gage length and fillets shall be as shown, but the ends may be of any form to fit the holders of the testing machine in such a way that the load shall be axial. If the ends are to be held in grips it is desirable, to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.

FIG. 7 TEST COUPONS FOR MICROSCOPICAL EXAMINATION OF DUCTILE IRON

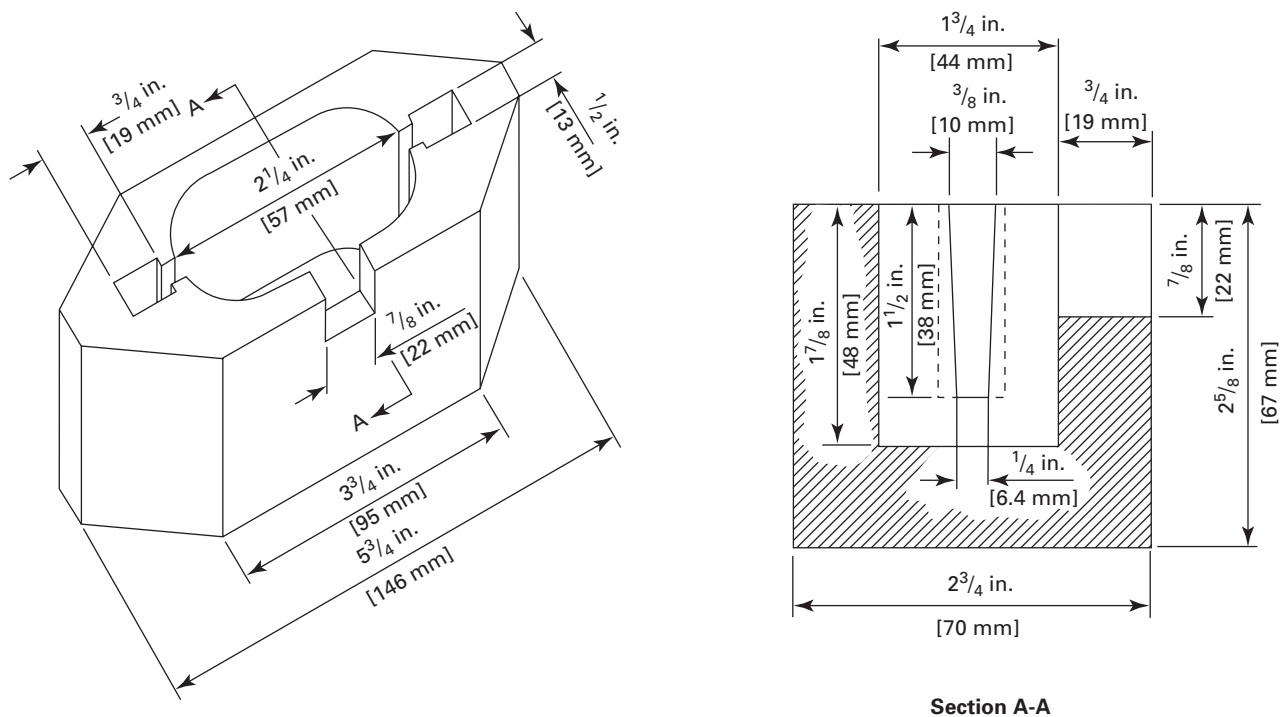


TABLE 1
MECHANICAL PROPERTY REQUIREMENTS

Property	Grade 60-40-18	Grade 65-45-15
Tensile Strength Minimum, psi [MPa]	60 000 [415]	65 000 [450]
Yield Strength Minimum, psi [MPa]	40 000 [275]	45 000 [310]
Elongation in 2 in. Minimum, %	18	15
Hardness HB, 3000 kgf Load	143–187	156–201

NOTE: If a grade is not specified in the ordering information, grade 60–40–18 will be supplied.

TABLE 2
MINIMUM THICKNESS OF REPAIRED SECTIONS

Iron Pipe Size Plug, in.	Minimum Thickness Repaired Section, in. [mm]
$\frac{1}{8}$	$\frac{11}{32}$ [8]
$\frac{1}{4}$	$\frac{7}{16}$ [10]
$\frac{3}{8}$	$\frac{1}{2}$ [13]
$\frac{1}{2}$	$2\frac{1}{32}$ [17]
$\frac{3}{4}$	$\frac{3}{4}$ [19]
1	$1\frac{3}{16}$ [21]
$1\frac{1}{4}$	$\frac{7}{8}$ [23]
$1\frac{1}{2}$	$1\frac{5}{16}$ [24]
2	1 [26]

TABLE 3
MINIMUM RADIUS OF REPAIRED SECTIONS

Iron Pipe Size Plug, in.	Minimum Radius of Cylinder or Cone, in. [mm]
$\frac{1}{8}$	$\frac{9}{16}$ [15]
$\frac{1}{4}$	$1\frac{1}{16}$ [18]
$\frac{3}{8}$	$1\frac{1}{16}$ [28]
$\frac{1}{2}$	$1\frac{1}{4}$ [32]
$\frac{3}{4}$	2 [52]
1	$2\frac{1}{2}$ [64]
$1\frac{1}{4}$	4 [104]
$1\frac{1}{2}$	$5\frac{1}{4}$ [136]
2	$8\frac{1}{8}$ [208]

TABLE 4
MINIMUM LIGAMENT BETWEEN PLUGS^{A,B}

Nominal Plug Diameter, in.	Minimum Ligament Between Plugs, in. [mm]			
	$\frac{1}{8}, \frac{1}{4}, \frac{3}{8}$	$\frac{1}{2}, \frac{3}{4}$	1, $1\frac{1}{4}$	$1\frac{1}{2}, 2$
$\frac{1}{8}, \frac{1}{4}, \frac{3}{8}$	$2\frac{5}{8}$ [67]	$4\frac{1}{8}$ [105]	$6\frac{5}{8}$ [169]	$9\frac{1}{2}$ [242]
$\frac{1}{2}, \frac{3}{4}$	$4\frac{1}{8}$ [105]	$4\frac{1}{8}$ [105]	$6\frac{5}{8}$ [169]	$9\frac{1}{2}$ [242]
1, $1\frac{1}{4}$	$6\frac{5}{8}$ [169]	$6\frac{5}{8}$ [169]	$6\frac{5}{8}$ [169]	$9\frac{1}{2}$ [242]
$1\frac{1}{2}, 2$	$9\frac{1}{2}$ [242]	$9\frac{1}{2}$ [242]	$9\frac{1}{2}$ [242]	$9\frac{1}{2}$ [242]

^A Based on efficiency of 80%.

^B Example: Assume three plugs are required for repair, one $\frac{1}{8}$ in., one $\frac{3}{8}$ in., and one $1\frac{1}{2}$ in. The minimum distance permitted is as follows:

Ligament distance between $\frac{1}{8}$ and $\frac{3}{8}$ in. plugs is $2\frac{5}{8}$ in. [67 mm]

Ligament distance between $\frac{1}{8}$ and $1\frac{1}{2}$ in. plugs is $9\frac{1}{2}$ in. [242 mm]

Ligament distance between $\frac{3}{8}$ and $1\frac{1}{2}$ in. plugs is $9\frac{1}{2}$ in. [242 mm]

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall not apply unless specified in the purchase order.

S1. Casting

S1.1 For Castings Grade 60-40-18, a microstructure test lug is to be cast attached to the casting at the location designated on the casting drawing. The microstructure of the test lug shall be essentially ferritic and contain no massive carbides.

S2. Pressure Test, Casting Grade 65-45-15

S2.1 A hydrostatic test at a pressure agreed upon by the manufacturer and the purchaser shall be applied by the manufacturer.

SPECIFICATION FOR WROUGHT AUSTENITIC STAINLESS STEEL PIPING FITTINGS



SA-403/SA-403M

[Identical to ASTM Specification A 403/A 403M-07 except for the correction of Table 2 Ni minimum for Grade S38815, the deletion of 5.14 and 5.15, clarified heat treatment requirements in 6.1 (Grade S33228) and 6.4, and the deletion of 304/304L/304N in 14.5.]

1. Scope

1.1 This specification covers wrought stainless steel fittings for pressure piping applications.

1.2 Several grades of austenitic stainless steel alloys are included in this specification. Grades are designated with a prefix, WP or CR, based on the applicable ASME or MSS dimensional and rating standards, respectively.

1.3 For each of the WP stainless grades, several classes of fittings are covered, to indicate whether seamless or welded construction was utilized. Class designations are also utilized to indicate the nondestructive test method and extent of nondestructive examination (NDE). Table 1 is a general summary of the fitting classes applicable to all WP grades of stainless steel covered by this specification. There are no classes for the CR grades. Specific requirements are covered elsewhere.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable “M” specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.6 This specification does not apply to cast steel fittings. Austenitic stainless steel castings are covered in Specifications A 351/A 351M, A 743/A 743M, and A 744/A 744M.

2. Referenced Documents

2.1 ASTM Standards:

A 351/A 351M Specification for Castings, Austenitic, for Pressure-Containing Parts

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A 743/A 743M Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application

A 744/A 744M Specification for Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 960/A 960M Specification for Common Requirements for Wrought Steel Piping Fittings

E 112 Test Methods for Determining Average Grain Size

E 165 Test Method for Liquid Penetrant Examination

2.2 ASME Standards:

ASME B16.9 Factory-Made Wrought Steel Butt-Welding Fittings

ASME B16.11 Forged Steel Fittings, Socket-Welding and Threaded

2.3 MSS Standards:

MSS SP-25 Standard Marking System for Valves, Fittings, Flanges, and Unions

MSS SP-43 Standard Practice for Light Weight Stainless Steel Butt-Welding Fittings

MSS SP-79 Socket-Welding Reducer Inserts

MSS SP-83 Steel Pipe Unions, Socket-Welding and Threaded

MSS SP-95 Swage(d) Nipples and Bull Plugs

2.4 ASME Boiler and Pressure Vessel Code:

Section VIII Division I, Pressure Vessels

Section IX, Welding Qualifications

2.5 AWS Standards:

A 5.4 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes

A 5.9 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes

2.6 ASNT:

SNT-TC-1A (1984) Recommended Practice for Nondestructive Testing Personnel Qualification and Certification

3. Common Requirements and Ordering Information

3.1 Material furnished to this specification shall conform to the requirements of Specification A 960/A 960M including any supplementary requirements that are indicated in the purchase order. Failure to comply with the common requirements of Specification A 960/A 960M constitutes nonconformance with this specification. In case of conflict between this specification and Specification A 960/A 960M, this specification shall prevail.

3.2 Specification A 960/A 960M identifies the ordering information that should be complied with when purchasing material to this specification.

4. Material

4.1 The material for fittings shall consist of forgings, bars, plates, or seamless or welded tubular products that conform to the chemical requirements in Table 2. See Table 3 for a list of common names.

4.2 The steel shall be melted by one of the following processes:

4.2.1 Electric furnace (with separate degassing and refining optional),

4.2.2 Vacuum furnace, or

4.2.3 One of the former followed by vacuum or electroslag-consumable remelting.

4.3 If secondary melting is employed, the heat shall be defined as all ingots remelted from a primary heat.

5. Manufacture

5.1 Forming — Forging or shaping operations may be performed by hammering, pressing, piercing, extruding, upsetting, rolling, bending, fusion welding, machining, or by a combination of two or more of these operations. The forming procedure shall be so applied that it will not produce injurious defects in the fittings.

5.2 All fittings shall be heat treated in accordance with Section 6.

5.3 Grade WP fittings ordered as Class S shall be of seamless construction and shall meet all requirements of

ASME B16.9, ASME B16.11, MSS SP-79, MSS SP-83, or MSS SP-95.

5.4 Grade WP fittings ordered as Class W shall meet the requirements of ASME B16.9 and:

5.4.1 Shall have all pipe welds made by mill or the fitting manufacturer with the addition of filler metal radiographically examined throughout the entire length in accordance with the Code requirements stated in 5.5, and,

5.4.2 Radiographic inspection is not required on single longitudinal seam welds made by the starting pipe manufacturer if made without the addition of filler metal; and

5.4.3 Radiographic inspection is not required on longitudinal seam fusion welds made by the fitting manufacturer when all of the following conditions have been met:

5.4.3.1 No addition of filler metal,

5.4.3.2 Only one welding pass per weld seam, and,

5.4.3.3 Fusion welding from one side only.

5.4.4 In place of radiographic examination, welds made by the fitting manufacturer may be ultrasonically examined in accordance with the Code requirements stated in 5.6.

5.5 Grade WP fittings ordered as Class WX shall meet the requirements of ASME B16.9 and shall have all welds, whether made by the fitting manufacturer or the starting material manufacturer, radiographically examined throughout their entire length in accordance with Paragraph UW-51 of Section VIII, Division I, of the ASME Boiler and Pressure Vessel Code.

5.6 Grade WP fittings ordered as Class WU shall meet the requirements of ASME B16.9 and shall have all welds, whether made by the fitting manufacturer or the starting material manufacturer, ultrasonically examined throughout their entire length in accordance with Appendix 12 of Section VIII, Division 1 of ASME Boiler and Pressure Vessel Code.

5.7 The radiography or ultrasonic examination of welds for this class of fittings may be done at the option of the manufacturer, either prior to or after forming.

5.8 Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

5.9 Grade CR fittings shall meet the requirements of MSS SP-43 and do not require nondestructive examination.

5.10 All fittings shall have the welders, welding operators, and welding procedures qualified under the provisions of Section IX of the ASME Boiler and Pressure Vessel Code except that starting pipe welds made without the addition of filler metal do not require such qualification.

5.11 All joints welded with filler metal shall be finished in accordance with the requirements of Paragraph UW-35 (a) of Section VIII, Division I, of the ASME Boiler and Pressure Vessel Code.

5.12 Fittings machined from bar shall be restricted to NPS 4 or smaller. Elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

5.12.1 All caps machined from bar shall be examined by liquid penetrant in accordance with Supplementary Requirement S52 in Specification A 960/A 960M.

5.13 Weld buildup is permitted to dimensionally correct unfilled areas produced during cold forming of stub ends. Radiographic examination of the weld buildup shall not be required provided that all the following steps are adhered to:

5.13.1 The weld procedure and welders or welding operators meet the requirements of 5.10.

5.13.2 Annealing is performed after welding and prior to machining.

5.13.3 All weld surfaces are liquid penetrant examined in accordance with Appendix 8 of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.

5.13.4 Repair of areas in the weld is permitted, but 5.13.1, 5.13.2, and 5.13.3 must be repeated.

5.14 DELETED

5.15 DELETED

5.16 After final heat treatment, all "H-Grade" steel fittings shall have a grain size of 7 or coarser in accordance with Test Methods E 112.

6. Heat Treatment

6.1 All fittings shall be furnished in the heat-treated condition. For H grades, including Grade S33228, separate solution heat treatments are required for solution annealing; in-process heat treatments are not permitted as a substitute for the separate solution annealing treatments. The heat-treat procedure, except for those grades listed in 6.2, shall consist of solution annealing the fittings at a minimum temperature of 1900°F [1040°C] until the chromium carbides go into solution, and then cooling at a sufficient rate to prevent reprecipitation.

6.2 A solution annealing temperature above 1950°F [1065°C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in 321, 321H, 347, and 347H. When specified by the purchaser, a lower temperature stabilization or resolution anneal shall be used subsequent to the initial high-temperature solution anneal (see Supplementary Requirement S2).

6.3 All welding shall be done prior to heat treatment.

6.4 Fittings machined directly from solution-annealed forgings and bar stock that were solution annealed in accordance with 6.1 need not be resolution annealed.

7. Chemical Composition

7.1 The chemical composition of each cast or heat used shall be determined and shall conform to the requirements of the chemical composition for the respective grades of materials listed in Table 2. The ranges as shown have been expanded to include variations of the chemical analysis requirements that are listed in the various specifications for starting materials (pipe, tube, plate, bar, and forgings) normally used in the manufacturing of fittings to this specification. Methods and practices relating to chemical analyses required by this specification shall be in accordance with Test Methods, Practices, and Terminology A 751. Product analysis tolerances in accordance with Specification A 480/A 480M are applicable.

7.2 The steel shall not contain any unspecified elements for the ordered grade to the extent that it conforms to the requirements of another grade for which that element is a specified element having a required minimum content.

7.3 In fittings of welded construction, the alloy content (carbon, chromium, nickel, molybdenum, columbium, and tantalum) of the deposited weld metal shall conform to that required of the base metal or for equivalent weld metal as given in the AWS filler metal specification A5.4 or A5.9 (Type 348 weld metal is listed in AWS A5.9 but not in AWS A5.4). Exceptions are when welding on Types 304L and 304 base metals, the deposited weld metal shall correspond, respectively, to AWS E308L(ER308L) and E308(ER308), when welding on Type 321 base metal, the weld metal shall correspond to AWS Type E347 (ER347 or ER321); and, when welding on S31725, S31726, S31254 or S33228 deposited weld metal shall correspond either to the alloy content of the base metal or to AWS A5.11 E NiCrMo-3 (UNS W86112) (AWS A5.14 Ni Cr Mo-3 (UNS N06625)). On S38815 base metals, the deposited weld metal and filler metal used shall be agreed upon between purchaser and manufacturer.

7.3.1 Supplementary Requirement S1 may be specified where 16-8-2 filler metal is required for joining thick sections of Types 316, 321, or 347 and has adequate corrosion resistance for the intended service.

8. Tensile Properties

8.1 The tensile properties of the fitting material shall conform to the requirements of Table 4. The testing and reporting shall be performed in accordance with Test Methods and Definitions A 370.

8.1.1 Specimens cut either longitudinally or transversely shall be acceptable for the tensile test.

8.1.2 While Table 4 specifies elongation requirements for both longitudinal and transverse specimens, it is not the intent that both requirements apply simultaneously. Instead, it is intended that only the elongation requirement that is appropriate for the specimen used be applicable.

8.2 Records of the tension test made on the starting material shall be certification that the material of the fitting meets the requirements of this specification provided that heat treatments are the same.

8.3 If the raw material was not tested, or if the heat treatment of the raw material was different than the heat treatment of the fitting, the fitting manufacturer shall perform at least one tension test per heat on material representative of the fitting, and in the same condition of heat treatment as the fitting it represents. Qualification of welding procedures shall be in accordance with 5.8.

8.4 If a tension test through the weld is desired, Supplementary Requirement S51 in Specification A 960/A 960M should be specified.

9. Hydrostatic Tests

9.1 Hydrostatic testing is not required by this specification.

9.2 All Grade WP fittings shall be capable of withstanding without failure, leakage, or impairment of serviceability, a test pressure equal to that prescribed for the specified matching pipe or equivalent material.

9.3 All Grade CR fittings, except tees covered in 9.3.1, shall be capable of withstanding without failure, leakage, or impairment of serviceability, a test pressure based on the ratings in MSS SP-43.

9.3.1 Grade CR tees fabricated using intersection welds shall be capable of passing a hydrostatic test based on 70% of the ratings in MSS SP-43.

10. Surface Quality

10.1 Fittings supplied under this specification shall be examined visually. Selected typical surface discontinuities shall be explored for depth. The fittings shall be free from surface discontinuities that penetrate more than 5% of the specified nominal wall thickness, except as defined in 10.3 and 10.4, and shall have a workmanlike finish.

10.2 Surface discontinuities deeper than 5% of the specified nominal wall thickness, except as defined in 10.3 and 10.4, shall be removed by the manufacturer by machining or grinding to sound metal, and the repaired areas shall be well faired. The wall thickness at all points shall be at

least 87½% of the specified nominal wall thickness, and the diameters at all points shall be within the specified limits.

10.3 Surface checks (fish scale) deeper than ¼ in. [0.4 mm] shall be removed.

10.4 Mechanical marks deeper than ⅓ in. [1.6 mm] shall be removed.

10.5 When the removal of a surface discontinuity reduces the wall thickness below 87½% of the specified nominal wall thickness at any point, the fitting shall be subject to rejection or to repair as provided in 10.6.

10.6 Repair by Welding:

10.6.1 Repair of unacceptable imperfections in the base metal is permissible for fittings made to the dimensional standards listed in 1.1 or for other standard fittings made for stock by the manufacturer. Prior approval of the purchaser is required to repair special fittings made to the purchaser's requirements. Welding of unacceptable imperfections in no case shall be permitted when the depth of defect exceeds 33⅓% of the nominal wall thickness or the defect area exceeds 10% of the surface area of the fitting.

10.6.2 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

10.6.3 The composition of the weld deposits shall be in accordance with 7.3 and in accordance with the procedure qualification for the applicable material.

10.6.4 Unacceptable imperfections shall be removed by mechanical means or by thermal cutting or gouging methods. Cavities prepared for welding shall be examined with liquid penetrant in accordance with Practice E 165. No cracks are permitted in the prepared cavities. Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

10.6.5 The weld repair shall be permanently identified with the welder's stamp or symbol in accordance with Section VIII of the ASME Boiler and Pressure Vessel Code.

10.6.6 Weld repair area(s) shall be blended uniformly to the base metal and shall be examined by liquid penetrant in accordance with Practice E 165. No cracks are permitted in the weld or surrounding ½ in. [12.7 mm] of base metal. Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

10.6.7 After weld repair, material shall be heat treated in accordance with Section 6.

10.7 The fittings shall be free of scale and shall be passivated.

11. Dimensions

11.1 For fittings covered by ASME B16.9, ASME B16.11, MSS SP-43, MSS SP-79, MSS SP-83, or MSS SP-95, the sizes, shapes, and dimensions of the fittings shall be as specified in those standards.

11.1.1 Fittings of size or shape differing from these standards, but meeting all other requirements of this specification, may be furnished in accordance with Supplementary Requirement S58 Specification A 960/A 960M.

12. Rejection and Rehearing

12.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the tests, the producer or supplier may make claim for rehearing.

12.2 Fittings that develop defects in shop working or application operations may be rejected. Upon rejection, the manufacturer shall be notified promptly in writing.

13. Test Reports

13.1 Test reports are required for all fittings covered by this specification. Each test report shall include the following information:

13.1.1 The year-date of the specification to which the fitting was furnished,

13.1.2 Heat number or serial number traceable to a heat number,

13.1.3 Chemical analyses for all starting materials,

13.1.4 Mechanical properties of all starting materials,

13.1.5 For construction with filler metal added, weld metal chemical analysis,

13.1.6 For welded fittings, construction method, weld process and procedure specification number,

13.1.7 Heat treatment type,

13.1.8 Results of all nondestructive examinations,

13.1.9 Results of all tests required by Supplementary Requirements and the order, and

13.1.10 Statement that the fitting was manufactured, sampled, tested and inspected in accordance with the specification and was found to meet the requirements.

14. Product Marking

14.1 All fittings shall have the prescribed information stamped or otherwise suitably marked on each fitting in accordance with the latest edition of MSS SP-25. See Table 5 for marking examples of grades and classes.

14.2 Marking paint or ink shall not contain harmful amounts of chlorides, metals, or metallic salt, such as zinc or copper, that cause corrosive attack on heating. On wall thicknesses thinner than 0.083 in. [2.1 mm], no metal impression stamps shall be used. Vibrating pencil marking is acceptable.

14.3 The prescribed information for butt-welding fittings shall be: the manufacturer's name or trademark (see Note 1), schedule number or nominal wall thickness designation, size, grade (see Table 2), class, and the heat number or manufacturer's heat identification. The class S marking need not be added to the material grade for threaded or socket-welded fittings.

14.4 The prescribed information for threaded or socket-welding fittings shall be: the manufacturer's name or trademark (see Note 1), pressure class or schedule number, grade (see Table 2) and class, and heat number or manufacturer's heat identification.

NOTE 1 — For purposes of identification marking, the manufacturer is considered the organization that certifies that the piping component complies with this specification.

14.5 Fittings meeting the chemical and mechanical property requirements of Table 2 and Table 4 for more than one grade designation may be marked with more than one class or grade designation, such as WP304/304H; WP304/304L; WP316/316L, etc.

14.6 Bar Coding — In addition to the requirements in 14.1, 14.2, 14.3, 14.4, and 14.5, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small fittings, the bar code may be applied to the box or a substantially applied tag.

15. Keywords

15.1 austenitic stainless steel; corrosive service applications; pipe fittings; steel; piping applications; pressure containing parts; stainless steel fittings

TABLE 1
FITTING CLASSES FOR WP GRADES

Class	Construction	Nondestructive Examination
S	Seamless	None
W	Welded	Radiography or Ultrasonic
WX	Welded	Radiography
WU	Welded	Ultrasonic

TABLE 2
CHEMICAL REQUIREMENTS

Grade ^A			UNS		Composition, %								
Grade WP	Grade CR	Designation	C ^B	Mn ^B	P ^B	S ^B	Si ^B	Ni	Cr	Mo	Ti	N ₂ C ^C	Others
WP XM-19	CR XM-19	S20910	0.06	4.0–6.0	0.045	0.030	1.00	11.5–13.5	20.5–23.5	1.50–3.00	...	0.20–0.40	^D
WP 304	CR 304	S30400	0.08	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	...	...	...	...
WP 304L	CR 304L	S30403	0.030 ^E	2.00	0.045	0.030	1.00	8.0–12.0	18.0–20.0	...	...	...	...
WP 304H	CR 304H	S30409	0.04–0.10	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	...	...	...	...
WP 304N	CR 304N	S30451	0.08	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	...	...	0.10–0.16	...
WP 304LN	CR 304LN	S30453	0.030	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	...	...	0.10–0.16	...
WP 309	CR 309	S30900	0.20	2.00	0.045	0.030	1.00	12.0–15.0	22.0–24.0	...	...	...	...
WP 310S	CR 310S	S31008	0.08	2.00	0.045	0.030	1.00	19.0–22.0	24.0–26.0	...	...	...	...
WP S31254	CR S31254	S31254	0.020	1.00	0.030	0.010	0.80	17.5–18.5	19.5–20.5	6.0–6.5	...	0.18–0.22	Cu 0.50–1.00
WP 316	CR 316	S31600	0.08	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...
WP 316L	CR 316L	S31603	0.030 ^E	2.00	0.045	0.030	1.00	10.0–14.0 ^F	16.0–18.0	2.00–3.00	...	...	...
WP 316H	CR 316H	S31609	0.04–0.10	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...
WP 316N	CR 316N	S31651	0.08	2.00	0.045	0.030	1.00	10.0–13.0	16.0–18.0	2.00–3.00	...	0.10–0.16	...
WP 316LN	CR 316LN	S31653	0.030	2.00	0.045	0.030	1.00	10.0–13.0	16.0–18.0	2.00–3.00	...	0.10–0.16	...
WP 317	CR 317	S31700	0.08	2.00	0.045	0.030	1.00	11.0–15.0	18.0–20.0	3.0–4.0	...	...	...
WP 317L	CR 317L	S31703	0.030	2.00	0.045	0.030	1.00	11.0–15.0	18.0–20.0	3.0–4.0	...	...	...
WP S31725	CR S31725	S31725	0.030	2.00	0.045	0.030	1.00	13.5–17.5	18.0–20.0	4.0–5.0	...	0.20	...
WP S31726	CR S31726	S31726	0.030	2.00	0.045	0.030	1.00	13.5–17.5	17.0–20.0	4.0–5.0	...	0.10–0.20	...
WP 321	CR 321	S32100	0.08	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	...	^G	...	...
WP 321H	CR 321H	S32109	0.04–0.10	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	...	^H	...	...
WP S33228	CR S33228	S33228	0.04–0.08	1.00	0.020	0.015	0.30	31.0–33.0	26.0–28.0	...	...	...	Ce 0.05–0.10 Al 0.025
WP S34565	CR S34565	S34565	0.030	5.0–7.0	0.030	0.010	1.00	16.0–18.0	23.0–25.0	4.0–5.0	...	0.40–0.60	Cb 0.6–1.0
WP 347	CR 347	S34700	0.08	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	...	...	...	^I
WP 347H	CR 347H	S34709	0.04–0.10	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	...	...	...	^J
WP 348	CR 348	S34800	0.08	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	...	...	...	Cb + Ta = 10 X (C)–1.10 Ta 0.10
WP 348H	CR 348H	S34809	0.04–0.10	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	...	...	...	Co 0.20 Cb + Ta = 8 X (C)–1.10
WP S38815	CR S38815	S38815	0.030	2.00	0.040	0.020	5.5–6.5	15.0–17.0	13.0–15.0	0.75–1.50	...	...	Co 0.20 Cu 0.75–1.50 Al 0.30

TABLE 2
CHEMICAL REQUIREMENTS (CONT'D)

NOTE 1—Where an ellipsis (...) appears in this table, there is no requirement.

NOTES:

- ^A See Section 15 for marking requirements.
- ^B Maximum, unless otherwise indicated.
- ^C The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.
- ^D Columbium 0.10-0.30%; Vanadium, 0.10-0.30%.
- ^E For small diameter or thin walls, or both, where many drawing passes are required, a carbon maximum of 0.040% is necessary in grades TP304L and TP316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes as those less than 0.049 in. [1.24 mm] in average wall thickness.
- ^F On pierced tubing, the nickel may be 11.0-16.0%.
- ^G 5 X (C + N₂) - 0.70.
- ^H 4 X (C + N₂) - 0.70.
- ^I The columbium content shall be not less than ten times the carbon content and not more than 1.10%.
- ^J The columbium content shall be not less than eight times the carbon content and not more than 1.10%.

TABLE 3
COMMON NAMES

Grade WP ^A	Grade CR ^A	UNS Designation	Type ^B
WP XM-19	CR XM-19	S20910	XM-19 ^C
WP 304	CR 304	S30400	304
WP 304L	CR 304L	S30403	304L
WP 304H	CR 304H	S30409	304H
WP 304N	CR 304N	S30451	304N
WP 304LN	CR 304LN	S30453	304LN
WP 309	CR 309	S30900	309
WP 310S	CR 310S	S31008	310S
WP S31254	CR S31254	S31254	...
WP 316	CR 316	S31600	316
WP 316L	CR 316L	S31603	316L
WP 316H	CR 316H	S31609	316H
WP 316N	CR 316N	S31651	316N
WP 316LN	CR 316LN	S31653	316LN
WP 317	CR 317	S31700	317
WP 317L	CR 317L	S31703	317L
WP S31725	CR S31725	S31725	317LM ^C
WP S31726	CR S31726	S31726	317LMN ^C
WP 321	CR 321	S32100	321
WP 321H	CR 321H	S32109	321H
WP S33228	CR S33228	S33228	...
WP S34565	CR S34565	S34565	...
WP 347	CR 347	S34700	347
WP 347H	CR 347H	S34709	347H
WP 348	CR 348	S34800	348
WP 348H	CR 348H	S34809	348H

^A Naming system developed and applied by ASTM International.^B Unless otherwise indicated, a grade designation originally assigned by the American Iron and Steel Institute (AISI).^C Common name, not a trademark widely used, not associated with any one producer.TABLE 4
TENSILE REQUIREMENTS

All WP and CR Grades	Yield Strength, min, ksi [MPa]	Tensile Strength, min, ksi [MPa]
304, 304LN, 304H, 309, 310S, 316, 316LN, 316H, 317, 317L, 321, 321H, 347, 347H, 348, 348H, S31725	30 [205]	75 [515]
304L, 316L	25 [170]	70 [485]
304N, 316N, S31726	35 [240]	80 [550]
XM-19	55 [380]	100 [690]
S31254	44 [300]	94 [650] to 119 [820]
S33228	27 [185]	73 [500]
S34565	60 [415]	115 [795]
S38815	37 [255]	78 [540]
Elongation Requirements		
	Longitudinal	Transverse
Standard round specimen, or small proportional specimen, or strip-type specimen, minimum % in 4 <i>D</i> ^A	28	20

^A S38815 Elongation in 2 in. — 30% min.TABLE 5
PRODUCT MARKING EXAMPLES FOR GRADES AND CLASSES

Grade and Class Marking	Description
CR304	Single grade: No classes in CR grades
CR304/304L	Multiple grades, meet chemical and mechanical properties of each
WP304-S	Single grade: seamless
WP304-W	Single grade; welded: RT or UT pipe welds with filler metal and all fitting manufacturer's welds
WP304-WX	Single grade; welded: RT all welds with or without filler metal
WP304-WU	Single grade; welded: UT all welds with or without filler metal
WP304-304L-S	Multiple grades: meet chemical and mechanical properties of each: seamless

SUPPLEMENTARY REQUIREMENTS

One or more of the supplementary requirements described below or appearing in Specification A 960/A 960M may be included in the order or contract. When so included, a supplementary requirement shall have the same force as if it were in the body of the specification. Supplementary requirement details not fully described shall be agreed upon between the purchaser and the supplier.

S1. Special Filler Metal

S1.1 Filler metal shall be AWS Type E16-8-2 or ER 16-8-2 (AWS Specifications A5.4 and A5.9, respectively). Fittings welded with 16-8-2 weld metal shall be marked WP ____ HRW or CR ____ HRW, as appropriate.

given a stabilization heat treatment at 1500 to 1600°F [815 to 870°C] for a minimum of 2h/in. [4.7 min/mm] of thickness and then cooling in the furnace or in air. In addition to the marking required in Section 14, the grade designation symbol shall be followed by the symbol “S2.”

S2. Stabilization Treatment

S2.1 Subsequent to the solution anneal required by 6.2, Grades 321, 321H, 347, 347H, 348, and 348H shall be

SPECIFICATION FOR WELDED LARGE DIAMETER AUSTENITIC STEEL PIPE FOR CORROSIVE OR HIGH-TEMPERATURE SERVICE



SA-409/SA-409M

(Identical with ASTM Specification A 409/A 409M-95a^{e1} except for clarified heat treatment requirements for H grade stainless steels and S30815 editorial corrections in para. 5.3.1, Tables 1, 2, and 3, deletion of 5.3.2.2 and 5.3.2.3 for the non-heat treated pipe provisions, and the inclusion of a grain size requirement in para. 5.1.1 for H grade stainless steels. A requirement for ASME Stamping has been added and additional requirements apply as shown in the subtitle of the specification.)

All products furnished under this SA specification are intended for application under the rules of Section III for Class 3 Piping or for application under the rules of Section VIII-1. Furnishing of such products is limited to manufacturers who hold the appropriate ASME Certification Mark. Weld procedures, welders, and welding machine operators shall be qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX. The product shall meet all applicable requirements of Class 3 piping or Section VIII-1, if applicable including those requirements pertaining to heat treatment and butt welds. Authorized inspection at the point of manufacture and application of the appropriate Certification Mark is required.

The applicable ASME partial data report form, signed by an authorized inspector, and a certified mill test report shall be furnished for each lot of pipe. The term "lot" applies to all pipe of the same mill heat of material and wall thickness which is heat treated in one furnace charge. For pipe which is not heat treated or which is heat treated in a continuous furnace, a lot shall consist of each 200 ft. [61 m] or fraction thereof of all pipe of the same mill heat of material and wall thickness, subjected to the same heat treatment. For pipe which is heat treated in a batch-type furnace which is automatically controlled within a 50°F range and is equipped with recording pyrometer so that the heating records are available, a lot may be defined the same as for continuous furnaces. Each length of pipe shall be marked in such a manner as to identify each such piece with the "lot" and the representative certified mill test report.

1. Scope

1.1 This specification covers straight seam or spiral seam electric-fusion-welded, light-wall, austenitic chromium-nickel alloy steel pipe for corrosive or high-temperature service. The sizes covered are NPS 14 to 30 with extra light (Schedule 5S) and light (Schedule 10S) wall thicknesses. Table X1.1 shows the wall thicknesses of Schedule 5S and 10S pipe. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification.

1.2 Several grades of alloy steel are covered as indicated in Table 1.

1.3 Optional supplementary requirements are provided. These call for additional tests to be made, and when desired shall be stated in the order, together with the number of such tests required.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

NOTE 1—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

2. Referenced Documents

2.1 ASTM Standards:

A 240 Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
 A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe
 E 527 Practice for Numbering Metals and Alloys (UNS)
 E 112 Test Methods for Determining Average Grain Size

2.2 ASME Boiler and Pressure Code:
 Section IX Welding Qualifications

2.3 AWS Standards:
 A 5.22 Flux Cored Arc Welding
 A 5.30 Consumable Weld Inserts for Gas Tungsten Arc Welding
 A 5.4 Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes
 A 5.9 Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes
 A 5.11 Nickel and Nickel-Alloy Covered Welding Electrodes
 A 5.14 Nickel and Nickel-Alloy Bare Welding Rods and Electrodes

3. Ordering Information

3.1 Orders for material to this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, centimeters, or number of lengths),

3.1.2 Name of material (straight seam or spiral seam electric-fusion-welded austenitic steel pipe),

3.1.3 Grade (Table 1),

3.1.4 Size (outside diameter and schedule number, or wall thickness),

3.1.5 Length (specific or random) (Section 11),

3.1.6 End finish (Section on Ends of Specification A 530/A 530M),

3.1.7 Optional requirements (5.2.1 to 5.2.3 removal of weld bead; 5.3.2, special heat treatment; 15.2, nondestructive test; 10.1.1, outside diameter tolerance; 11.2, length circumferentially welded; 12.3, repair by welding and heat treatment subsequent to repair welding; 12.4, sand blasted or pickled; 17.1 Certification; Supplementary Requirements S1 to S6).

3.1.8 Specification designation, and

3.1.9 Special requirements.

4. General Requirements

4.1 Material furnished to this specification shall conform to the applicable requirements of the current edition

of Specification A 530/A 530M, unless otherwise provided herein.

5. Materials and Manufacture

5.1 If a specific type of melting is required by the purchaser it shall be stated on the order.

5.1.1 The grain size for all H grades and S30815 shall be No. 7 or coarser, when determined according to ASTM E 112 Test Methods.

5.2 Welding:

5.2.1 The welds shall be made by the manual or automatic electric-welding process. For manual welding, the operator and procedure shall be qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX. Unless otherwise specified on the purchase order, the pipe may be welded with or without filler metal when the automatic electric-welding process is used.

5.2.2 The weld surface on either side of the weld may be flush with the base plate or may have a reasonably uniform crown, not to exceed $\frac{1}{16}$ in. [2 mm]. Any weld reinforcement may be removed at the manufacturer's option or by agreement between the manufacturer and purchaser. The contour of the reinforcement should be reasonably smooth and free from irregularities. The weld metal shall be fused uniformly into the plate surface. No concavity of contour is permitted unless the resulting thickness of weld metal is equal to or greater than the minimum thickness of the adjacent base metal.

5.2.3 Weld defects, as determined by specified inspection requirements, shall be repaired by removal to sound metal and rewelding.

5.3 Heat Treatment:

5.3.1 Except as provided in 5.3.2, all pipe shall be furnished in the heat-treated condition. For H grades and S30815, separate solution heat treatments are required for solution annealing; in-process heat treatments are not permitted as a substitute for the separate solution annealing treatments. The heat-treatment procedure shall consist of heating the material to a minimum temperature of 1900°F [1040°C], except for S31254 and S30815 which shall be heat treated to 2100°F [1150°C] and 1920°F [1050°C] respectively and for S34565 which shall be heat treated in the range 2050°F [1120°C] to 2140°F [1170°C], all materials to be followed by quenching in water or rapidly cooling by other means.

5.3.2 The purchase order shall specify one of the following conditions if the heat-treated condition specified in 5.3.1 is not desired by the purchaser:

5.3.2.1 A final heat-treatment temperature under 1900°F [1040°C]. Each pipe supplied under this requirement shall be stenciled with the final heat-treatment temperature in degrees Fahrenheit or degrees Celsius after the

suffix “HT”. Controlled structural or special service characteristics may be specified as a guide for the most suitable heat treatment.

5.3.2.2 DELETED

5.3.2.3 DELETED

5.4 A solution annealing temperature above 1950°F [1065°C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in TP321, TP347, and TP348. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the initial high temperature solution anneal (see Supplementary Requirement S5).

6. Chemical Composition

6.1 Each type of stainless steel or alloy shall conform to the requirements as to chemical composition prescribed in Table 1.

6.2 Unless otherwise specified in the purchase order, the chemical composition of the welding filler metal shall conform to the requirements of the applicable AWS specification for the corresponding grade shown in Table 2. Grades with no filler metal classification indicated shall be welded with filler metals producing deposited weld metal having a composition in accordance with the chemical composition specified in Table 1. The method of analysis for nitrogen and cerium shall be a matter of agreement between the purchaser and manufacturer. The purchaser may choose a higher-alloy filler metal when needed for corrosion resistance.

7. Tensile Requirements

7.1 The tensile properties of the plate or sheet used in making the pipe shall conform to the requirements prescribed in Table 3. Certified mill test reports shall be submitted to the pipe manufacturer.

7.2 A transverse tension test taken across the welded joint of the finished pipe shall meet the same minimum tensile strength requirements as the sheet or plate. The weld section on the tension specimen shall be in the the same condition as the finished pipe (with or without bead as specified).

8. Mechanical Tests Required

8.1 Tension Test — One transverse tension test of the weld shall be made on each lot (Note 2) of finished pipe.

NOTE 2—The term “lot” applies to each 200 ft [60 m] or less of pipe of the same NPS and wall thickness (or schedule number) which is produced from the same heat of steel and subjected to the same finishing treatment in a continuous furnace. When final heat treatment is in a batch-type furnace, the lot shall include only that pipe which is heat treated in

the same furnace charge. When no heat treatment is performed following final forming operations, the lot shall include each 200 ft [60 m] or less of pipe of the same NPS and wall thickness (or schedule number) which is produced from the same heat of steel.

8.2 Transverse Guided-Bend Weld Test — One test (two specimens) of the weld shall be made on each lot (Note 2) of finished pipe.

8.3 Pressure or Nondestructive Electric Test — Each length of pipe shall be subjected to a pressure test or a nondestructive electric test as prescribed in Section 5.

9. Permissible Variations in Wall Thickness

9.1 The minimum wall thickness at any point shall not be more than 0.018 in. [0.46 mm] under the specified wall thickness. (This tolerance is slightly more than commercial tolerances on sheet and plate to allow for possible loss of thickness caused by manufacturing operations.)

10. Permissible Variations in Dimensions

10.1 Permissible variations in dimensions shall not exceed the following at any point in each length of pipe.

10.1.1 Specified Diameter — Where the specified wall thickness is less than 0.188 in. [4.8 mm], the actual outside diameter, based on circumferential measurement, shall not vary more than $\pm 0.20\%$ from the specified outside diameter. Where the specified wall thickness is 0.188 in. [4.8 mm] and heavier, the actual outside diameter, based on circumferential measurement, may vary a maximum of $\pm 0.40\%$ from the specified outside diameter. (Outside diameter tolerances closer than shown above may be obtained by agreement between the pipe manufacturer and purchaser.)

10.1.2 Out-of-Roundness — The difference between the major and the minor outside diameter shall not be more than 1.5% of the specified outside diameter.

10.1.3 Alignment (Camber) — Using a 10 ft [3.0 m] straightedge placed so that both ends are in contact with the pipe, the camber shall not be more than $\frac{3}{16}$ in. [4.8 mm].

11. Lengths

11.1 Unless otherwise specified in the purchase order, pipe of NPS 22 or less will be furnished in random lengths of 9 to 12 ft (Note 3). For outside diameters of over NPS 22, the minimum length will be 5 ft (Note 3).

NOTE 3—This value(s) applies when the inch-pound designation of this specification is the basis of purchase. The corresponding metric value(s) shall be agreed upon between the manufacturer and the purchaser.

11.2 When specified by the purchaser, two or more lengths may be circumferentially welded together to produce longer lengths.

11.3 Circumferentially welded joints shall be of the same quality as the longitudinal joints.

12. Workmanship, Finish, and Appearance

12.1 The finished pipe shall have a workmanlike finish.

12.2 *Repair of Defects by Machining or Grinding* — Pipe showing moderate slivers or other surface defects may be machined or ground inside or outside to a depth which will ensure the removal of all defects providing the wall thickness is not reduced below the minimum specified in 9.1.

12.3 *Repair of Defects by Welding* — Defects which violate minimum wall thickness may be repaired by welding, but only with the approval of the purchaser. Areas shall be suitably prepared for welding with tightly closed defects removed by grinding. Open, clean defects, such as pits or impressions, may require no preparation. All welders, welding operators, and weld procedures shall be qualified to the ASME Boiler and Pressure Vessel Code, Section IX. Unless the purchaser specifies otherwise, pipe required to be heat treated under the provisions of 5.3 shall be heat treated or reheat treated following repair welding. Repaired lengths, where repair depth is greater than $\frac{1}{4}$ of the thickness, shall be pressure tested or repressure tested after repair and heat treatment (if any). Repair welds shall also be examined by suitable non-destructive examination techniques, including any techniques specifically required of the primary weld.

12.4 The pipe shall be free of scale and contaminating iron particles. Pickling, blasting, or surface finishing is not mandatory when pipe is bright annealed. The purchaser may request that a passivating treatment be applied.

13. Test Specimens

13.1 Transverse tension and bend test specimens may be taken from a test plate of the same material as the pipe, made by attaching a formed cylinder to the end of the pipe and welding the abutting edges as a continuation and duplication of the seam of the pipe (run-off plate). As an alternative to a formed cylinder, the run-off plate may consist of flat plates with reinforcing bars clamped to the underside to prevent distortion. The run-off plate material shall be of the same heat, preferably shear croppings from the same plate.

13.2 When heat treatment is required, test specimens shall be cut from pipe after the heat treating has been completed, or specimens removed from the pipe prior to heat treating shall be heat treated with the pipe.

14. Transverse Guided-Bend Weld Tests

14.1 Two bend test specimens shall be taken transversely across the weld. One shall be subject to a face guided-bend test and the second to a root guided-bend test. One specimen shall be bent with the inside surface of the pipe against the plunger, and the other with the outside surface against the plunger.

14.2 The bend test shall be acceptable if no cracks or other defects exceeding $\frac{1}{8}$ in. [3 mm] in any direction are present in the weld metal or between the weld and the pipe metal after bending. Cracks which originate along the edges of the specimen during testing, and that are less than $\frac{1}{4}$ in. [6.5 mm] measured in any direction shall not be considered.

15. Pressure Tests

15.1 Where hydrostatic test equipment is not available, the pipe may be air or gas pressure tested with an internal pressure of 100 psi [700 kPa]. The weld and weld area shall be inspected with the use of soap solution or any other prepared solution which will detect the leakage of air or gas from the inside.

15.2 Instead of a pressure test, when mutually agreed upon between the purchaser and manufacturer, the entire weld area of each pipe, including circumferential welds, may be tested by nondestructive testing methods. These methods shall be capable of detecting both surface and subsurface defects.

16. Inspection

16.1 When specified in the purchase order, the pipe may be inspected at the manufacturer's plant by an inspector representing the purchaser. The inspector shall have entry at all times. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

17. Certification

17.1 Upon request of the purchaser in the contract or order, certification in accordance with the provisions of Specification A 530/A 530M shall be furnished. When specified on the purchase order or when a specific type of melting has been specified on the purchase order, the type of melting used shall also be reported to the purchaser or the purchaser's representative.

18. Product Marking

18.1 Each length of pipe manufactured in accordance with this specification shall have the following identifying marking within 12 in. [300 mm] of one end: manufacturer's name or trade-mark, specification number, grade number of the alloy, the manufacturer's heat number, size, and

schedule number. Additional marking requirements for heat treatment are described in Supplementary Requirement S2.

18.2 Marking shall be legibly stenciled with a suitable paint or permanent marking compound, except when otherwise specified by the purchaser.

TABLE 1
CHEMICAL REQUIREMENTS

Grade	UNS Designations ^A	Composition, %									
		Carbon, max	Manganese, max	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Titanium	Columbium
TP304	S30400	0.08	2.00	0.045	0.030	0.75 max	8.00–11.0	18.0–20.0	...	...	...
TP304L	S30403	0.035	2.00	0.045	0.030	0.75 max	8.00–13.0	18.0–20.0	...	...	...
TP309Cb	S30940	0.08	2.00	0.045	0.030	0.75 max	12.0–16.0	22.0–24.0	0.75 max	...	...
											Cu 0.75 max; Cb + Ta 10 × C
TP309S	S30908	0.08	2.00	0.045	0.030	0.75 max	12.0–15.0	22.0–24.0	0.75 max	...	...
TP310Cb	S31040	0.08	2.00	0.045	0.030	0.75 max	19.0–22.0	24.0–26.0	0.75 max	...	...
											Cu 0.75 max; Cb + Ta 10 × C
TP310S	S31008	0.08	2.00	0.045	0.030	0.75 max	19.0–22.0	24.0–26.0	0.75 max	...	...
TP316	S31600	0.08	2.00	0.045	0.030	0.75 max	10.0–14.0	16.0–18.0	2.0–3.0	...	...
TP316L	S31603	0.035	2.00	0.045	0.030	0.75 max	10.0–15.0	16.0–18.0	2.0–3.0	...	...
TP317	S31700	0.08	2.00	0.045	0.030	0.75 max	11.0–14.0	18.0–20.0	3.0–4.0	...	...
TP321	S32100	0.08	2.00	0.045	0.030	0.75 max	9.00–13.0	17.0–20.0	...	...	...
TP347	S34700	0.08	2.00	0.045	0.030	0.75 max	9.00–13.0	17.0–20.0	...	...	...
TP348	S34800	0.08	2.00	0.045	0.030	0.75 max	9.00–13.0	17.0–20.0	...	...	...
...	S31254	0.020	1.00	0.030	0.010	0.80 max	17.5–18.5	19.5–20.5	6.00–6.50	...	...
											Cu 0.50–1.00
...	S30815	0.05–0.10	0.80	0.040	0.030	1.40–2.00	10.0–12.0	20.0–22.0	...	...	...
...	S31725	0.03	2.00	0.045	0.030	0.75 max	13.5–17.5	18.0–20.0	4.0–5.0	...	...
											0.03–0.08
...	S31726	0.03	2.00	0.045	0.030	0.75 max	13.5–17.5	17.0–20.0	4.0–5.0	...	...
											Cu 0.75 max
...	S34565	0.03	5.0–7.0	0.030	0.010	1.00 max	16.0–18.0	23.0–25.0	4.0–5.0	...	...
											N 0.10–0.20
...	N08367	0.03	2.00	0.040	0.030	1.00 max	23.50–25.50	20.00–22.00	6.00–7.00	...	...
											Cu 0.75 max Ni 0.18–0.25

^A New designation established in accordance with ASTM E 527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).

^B The titanium content shall be not less than 5 times the carbon content and not more than 0.70%.

^C The columbium plus tantalum content shall be not less than 10 times the carbon content and not more than 1.0%.

^D The columbium plus tantalum content shall be not less than 10 times the carbon content and not more than 1.0%. The tantalum content shall be 0.10% maximum.

TABLE 2
FILLER METAL SPECIFICATIONS

Filler Metal Classification and UNS Designation ^A for Applicable ^B AWS Specification													
Grade	UNS Designation	A5.4		A5.9		A5.11		A5.14		A5.22		A5.30	
		Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS
TP304	S30400	E308	W30810	ER308	S30880 W30840	...	...	...	...	E308T	W30831	IN308	S30880
TP304L	S30403	E308L	W30813	ER308L	S30883 W30843	...	...	...	...	E308T	W30835	IN308L	S30883
TP309Cb	S30940	E309Cb	W30917	...	...	...	...	...	...	...	...	...	...
TP310Cb	S31040	E310Cb	W31017	...	...	...	...	...	...	...	...	...	...
TP316	S31600	E316	W31610	ER316	S31680 W31640	...	...	...	...	E316T	W31631	IN316	S31680
TP316L	S31603	E316L	W31603	ER316L	S31683 W31643	...	...	...	...	E316LT	W31635	IN316L	S31683
TP317	S31700	E317	W31700	ER317	S31783 W31743	...	...	...	...	E317T	W31731	IN317	S31780
TP321	S32100	E347	W34710	{	S32180	...	...	...	...	E347T	W34733	IN348	S34780
					W32140 S34780 W34740	...	...	...	...
TP347	S34700	E347	W34710	ER347	S34780 W34740	...	...	...	...	E347T	W34733	IN348	S34780
					S34780	...	...	...	...
TP348	S34800	E347	W34710	ER347	S34780 W34740	...	...	...	...	E347T	W34733	IN348	S34780
...	S31254	...	...	...	...	ENiCrMo-3	W86112	ENiCrMo-3	N06625	...	...	...	...
...	S31725	...	...	...	...	ENiCrMo-3	W86112	ENiCrMo-3	N06625	...	...	...	...
...	S31726	...	...	...	...	ENiCrMo-3	W86112	ENiCrMo-3	N06625	...	...	...	...
...	S34565	...	...	...	...	...	...	...	...	...	...	...	...
...	N08367	...	...	...	...	ENiCrMo-3	W86112	ENiCrMo-3	N06625	...	...	...	...

^A New designation established in accordance with Practice E 527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).

^B Choice of American Welding Society specification depends on the welding process used.

TABLE 3
TENSILE REQUIREMENTS

Grade	UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]
TP304	S30400	75 [515]	30 [205]
TP304L	S30403	70 [485]	25 [170]
TP309Cb	S30940	75 [515]	30 [205]
TP309S	S30908	75 [515]	30 [205]
TP310Cb	S31040	75 [515]	30 [205]
TP310S	S31008	75 [515]	30 [205]
TP316	S31600	75 [515]	30 [205]
TP316L	S31603	70 [485]	25 [170]
TP317	S31700	75 [515]	30 [205]
TP321	S32100	75 [515]	30 [205]
TP347	S34700	75 [515]	30 [205]
TP348	S34800	75 [515]	30 [205]
...	S31254	94 [650]	44 [300]
...	S30815	87 [600]	45 [310]
...	S31725	75 [515]	30 [205]
...	S31726	80 [550]	35 [240]
...	S34565	115 [795]	60 [415]
...	N08367		
	t ≤ 0.187	100 [690]	45 [310]
	t > 0.187	95 [655]	45 [310]

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 At the request of the purchaser a product analysis of one coupon representing finished sheet or plate from each heat shall be made by the pipe manufacturer. The drillings for product analysis may be taken from shear crop or test specimens. The results of product analysis shall conform to the requirements in Table 1 and shall be reported to the purchaser.

S2. Radiographic Examination

S2.1 Weld soundness shall be determined through radiographic examination made in accordance with requirements as agreed upon between the pipe manufacturer and purchaser.

S3. Corrosion Requirements

S3.1 Boiling Nitric Acid Test — Except for Grade TP321, coupons representing finished pipe made of nonmolybdenum-bearing material (0.50% and less molybdenum) shall meet the requirement of the boiling nitric acid test conducted according to Practice C of Practices A 262. The condition of the test specimens and the corrosion rates are as follows: Type 347 and Type 348 shall be tested in the sensitized condition (heated for 1 h at 1240°F [675°C]) and the rate of penetration shall not exceed 0.0020 in. [0.05 mm]/month. All other nonmolybdenum-bearing types, except for Grade TP321, shown in Table 1 shall be tested in the annealed and unsensitized condition and the rate of penetration shall not exceed 0.0015 in. [0.04 mm]/month.

S3.2 Acidified Copper Sulfate Test — Coupons representing finished pipe made of molybdenum-bearing material and Type 321 (over 0.50% molybdenum) shall meet the requirements of the copper-copper sulfate-sulfuric acid test (intergranular corrosion test) conducted in accordance with Practice E of Practices A 262. The condition of the

test specimen is as follows: All molybdenum-bearing types shown in Table 1 shall be tested in the annealed and unsensitized condition. Type 321 shall be tested in the sensitized condition (heated for 1 h at 1240°F [675°C]). All specimens shall meet the requirements of the prescribed bend test.

S4. Ferrite Control of Weld Deposits

S4.1 The ferrite content of the deposited weld metal in any length of pipe may be determined. The procedural details pertaining to this subject (that is, welding, plate and weld deposit chemistry, testing equipment and method, number and location of test sites, and ferrite control limits) shall be a matter for agreement between the purchaser and the manufacturer.

S5. Stabilizing Heat Treatment

S5.1 Subsequent to the heat treatment required in 5.3, Grades TP321, TP347, and TP348 shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S6. Intergranular Corrosion Test

S6.1 When specified, material shall pass intergranular corrosion test conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE 4—Practice E requires testing of the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S6.2 A stabilization heat treatment in accordance with Supplementary Requirement S5 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium.

APPENDIX**(Nonmandatory Information)****X1. WALL THICKNESS OF SCHEDULE 5S AND
SCHEDULE 10S****TABLE X1.1 PIPE DIMENSIONS**

NPS Designator	Wall Thickness			
	Schedule 5S		Schedule 10S	
	in.	mm	in.	mm
14	0.156	3.96	0.188	4.78
16	0.165	4.19	0.188	4.78
18	0.165	4.19	0.188	4.78
20	0.188	4.78	0.218	5.54
22	0.188	4.78	0.218	5.54
24	0.218	5.54	0.250	6.35
30	0.250	6.35	0.312	7.92

SPECIFICATION FOR STEEL, SHEET, CARBON, FOR PRESSURE VESSELS



SA-414/SA-414M



(Identical with ASTM Specification A 414/A 414M-07.)

(10)

1. Scope

1.1 This specification covers hot-rolled carbon steel sheet for pressure vessels involving fusion welding or brazing. Welding and brazing technique is of fundamental importance and shall be in accordance with commercial practices.

1.2 The following grades are included in this specification:

Grade	Mechanical Requirements			
	Yield Strength, min		Tensile Strength, min	
	ksi	MPa	ksi	MPa
A	25	170	45	310
B	30	205	50	345
C	33	230	55	380
D	35	240	60	415
E	38	260	65	450
F	42	290	70	485
G	45	310	75	515

1.3 Hot-rolled carbon steel sheet is generally furnished in cut lengths and to decimal thickness only. Coils may be furnished, provided tension test specimens are taken to represent the middle of the slab as required by 5.1.4. The purchaser should recognize this may require cutting the coils to obtain test samples and results in half-size coils. The sheet is furnished to the following size limits:

Thickness, in. [mm]	Width, in. [mm] Over 12 [Over 300]
0.270 to 0.230 [7.0 to 6.0]	sheet (coils only)
Under 0.230 to 0.057 [6.0 to 1.5]	sheet

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining

values from the two systems may result in nonconformance with the specification.

1.5 Tolerances are found in General Requirements Specifications A 568/A 568M and A 635/A 635M. The appropriate General Requirements specification is applied based on the thickness and width of the product ordered.

2. Referenced Documents

2.1 ASTM Standards:

A 568/A 568M Specification for Steel, Sheet, Carbon, Structural, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for
A 635/A 635M Specification for Steel, Sheet and Strip, Heavy-Thickness Coils, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, and High-Strength Low-Alloy with Improved Formability, General Requirements for

3. Ordering Information

3.1 Orders for material under this specification shall include the following information, as required, to describe the material adequately:

3.1.1 Designation or specification number, date of issue, and grade,

3.1.2 Copper bearing steel, when required,

3.1.3 Special requirements, if required,

3.1.4 Condition — pickled (or blast cleaned), if required (material so ordered will be oiled unless ordered dry), and

3.1.5 Dimensions, including type of edges.

3.1.5.1 As agreed upon between the purchaser and the producer, material ordered to this specification will be supplied to meet the appropriate standard or restricted

thickness tolerance table shown in Specification A 568/A 568M or Specification A 635/A 635M.

NOTE 1 — Not all producers are capable of meeting all of the limitations of the thickness tolerance tables in Specification A 568/A 568M or Specification A 635/A 635M. The purchaser should contact the producer regarding possible limitations prior to placing an order.

3.1.6 Cast or heat analysis, or test report request, or both, if required.

NOTE 2 — A typical ordering description is as follows: “ASTM A 414, Grade A, Hot-Rolled Sheet, 0.100 in. [2.54 mm] by 36 in. [914.4 mm] by 96 in. [2438 mm], cut edges.

4. Chemical Requirements

4.1 *Cast or Heat Analysis* — The analysis of the steel shall conform to the requirements prescribed in Table 1.

4.1.1 Unspecified elements may be present. Limits on elements shall be as stated in Table 2.

4.1.1.1 Each of the elements listed in Table 2 shall be included in the report of the heat analysis. When the amount of an element present is less than 0.02%, the analysis may be reported as “<0.02%.”

4.2 *Product, Check, or Verification Analysis* — Analyses may be made by the purchaser from finished material representing each heat.

4.3 *Deoxidation* — For all grades, killed steel is required. See Table 1 and footnotes A and B.

5. Mechanical Property Requirements

5.1 *Tensile Strength:*

5.1.1 *Requirements* — Material as represented by the test specimen shall conform to the tensile requirements specified in Table 3.

5.1.2 *Number of Tests* — Two tensile tests shall be made from the product of each slab as rolled.

5.1.3 *Location and Orientation (see Fig. 1):*

5.1.3.1 Tensile test specimens shall be taken at locations representing the middle and back end of each slab as rolled.

5.1.3.2 Tensile test samples shall be taken from the full thickness of the sheet as rolled.

5.1.3.3 Tensile test specimens shall be taken from a location approximately halfway between the center of the sheet and the edge of the material as-rolled.

5.1.3.4 Tensile test specimens shall be taken with the axis of the test specimen perpendicular to the rolling direction (transverse test).

5.1.4 *Test Method* — Yield strength shall be determined by either the 0.2% offset method or by the 0.5% extension under load method, unless otherwise specified.

6. General Requirements for Delivery

6.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 568/A 568M or Specification A 635/A 635M unless otherwise provided herein.

7. Workmanship

7.1 The material shall be free from injurious defects (see Specifications A 568/A 568M or A 635/A 635M, as appropriate due to thickness).

8. Finish and Appearance

8.1 *Surface Finish:*

8.1.1 Unless otherwise specified, the material shall be furnished without removing the hot-rolled oxide or scale.

8.1.2 When required, the material may be specified to be pickled or blast cleaned.

8.2 *Oiling:*

8.2.1 Unless otherwise specified, the material shall be furnished not oiled.

8.2.2 When specified to be pickled or blast cleaned, the material shall be furnished oiled. When required, pickled or blast-cleaned material may be specified to be furnished dry.

8.3 *Edges* — Unless otherwise specified, mill edges shall be furnished on material that has not had the hot-rolled oxide or scale removed and cut edges shall be furnished on material that has had the hot-rolled oxide or scale removed.

9. Certification and Reports

9.1 The manufacturer or processor shall furnish copies of a test report showing the results of the heat analysis and mechanical property tests made to determine compliance with this specification.

9.2 The report shall include the purchase order number, the specification number and year date, product designation, grade, the heat number, and heat analysis and mechanical properties as indicated by the tension test.

9.3 A signature is not required on the test report. However, the document shall clearly identify the organization submitting the report. Notwithstanding the absence of a signature, the organization submitting the report is responsible for the content of the report.

9.4 A Material Test Report, Certificate of Inspection, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a

counterpart printed in the certifier's facility. The content of the EDI transmitted document must meet the requirements of the invoked ASTM standard and the purchaser and supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

10. Product Marking

10.1 The name or brand of the manufacturer, heat and slab number, specification designation number, and grade shall be legibly and durably marked on each cut length sheet in two places not less than 12 in. [300 mm] from the edges. Cut length sheets, the maximum lengthwise and crosswise, dimensions of which do not exceed 72 in.

[1800 mm], shall be legibly and durably marked in one place approximately midway between the center and a side edge. The manufacturer's test identification number shall be legibly and durably marked on each test specimen. Steel-die marking of sheets is prohibited on material <0.250 in. [6 mm].

10.2 For coil product, the information required in 10.1 shall be legibly and durably marked both on each coil and on a tag affixed to each coil.

11. Keywords

11.1 carbon steel sheet; pressure vessel steels; steel sheet

FIG. 1 LOCATION OF TEST SPECIMENS

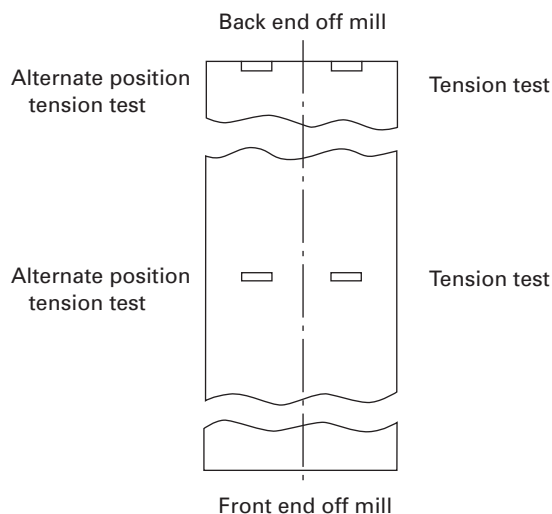


TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition — Weight, % Heat Analysis						
	Grade A	Grade B	Grade C	Grade D	Grade E	Grade F	Grade G
Carbon, max	0.15	0.22	0.25	0.25	0.27	0.31	0.31
Manganese, max	0.90	0.90	0.90	1.20	1.20	1.20	1.35
Phosphorus, max	0.035	0.035	0.035	0.035	0.035	0.035	0.035
Sulfur, max	0.035	0.035	0.035	0.035	0.035	0.035	0.035
Aluminum ⁴	0.02–0.08	0.02–0.08	0.02–0.08	0.02–0.08	0.02–0.08	0.02–0.08	0.02–0.08
Silicon ⁴	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Copper, when copper steel is specified, min	0.20	0.20	0.20	0.20	0.20	0.20	0.20

⁴ The steel shall be considered aluminum-silicon killed when the silicon is between 0.15 and 0.30, otherwise it shall be considered aluminum killed.

TABLE 2
LIMITS ON UNSPECIFIED ELEMENTS (See 4.1.1)

Copper, max % ^A	Heat analysis	0.40
	Product analysis	0.43
Nickel, max % ^A	Heat analysis	0.40
	Product analysis	0.43
Chromium, max % ^{A,B}	Heat analysis	0.30
	Product analysis	0.34
Molybdenum, max % ^{A,B}	Heat analysis	0.12
	Product analysis	0.13
Vanadium, max % ^C	Heat analysis	0.03
	Product analysis	0.04
Columbium, max % ^C	Heat analysis	0.02
	Product analysis	0.03

^A The sum of copper, nickel, chromium, and molybdenum shall not exceed 1.00% on heat analysis. When one or more of these elements are specified, the sum does not apply; in which case, only the individual limits on the remaining unspecified elements will apply.

^B The sum of chromium and molybdenum shall not exceed 0.32% on heat analysis. When one or more of these elements are specified, the sum does not apply; in which case, only the individual limits on the remaining unspecified elements will apply.

^C By agreement, the heat analysis limits for vanadium or columbium, or both, may be increased up to 0.10% and 0.05%, respectively.

TABLE 3
TENSILE REQUIREMENTS

	Grade A	Grade B	Grade C	Grade D	Grade E	Grade F	Grade G
Tensile strength:							
min, ksi [MPa]	45 [310]	50 [345]	55 [380]	60 [415]	65 [450]	70 [485]	75 [515]
max, ksi [MPa]	60 [415]	65 [450]	70 [485]	75 [515]	85 [585]	90 [620]	95 [655]
Yield strength, min, ksi (MPa) ^A	25 [170]	30 [205]	33 [230]	35 [240]	38 [260]	42 [290]	45 [310]
Elongation in 2 in. (50 mm), min, percent:							
Under 0.270 to 0.145 [Under 7.0 to 3.8]	26	24	22	20	18	16	16
Under 0.145 to 0.089 [Under 3.8 to 2.2]	24	22	20	18	16	14	14
Under 0.089 to 0.057 [Under 2.2 to 1.5]	23	21	19	17	15	13	13
Elongation in 8 in. (200 mm), min, percent:							
Under 0.270 to 0.145 [Under 7.0 to 3.8]	20	18	16	14	12	10	10

^A Yield strength determined by the 0.2% offset or 0.5% extension under load methods.

SPECIFICATION FOR PIPING FITTINGS OF WROUGHT CARBON STEEL AND ALLOY STEEL FOR LOW-TEMPERATURE SERVICE



SA-420/SA-420M



(Identical with ASTM Specification A 420/A 420M-04)

1. Scope

1.1 This specification covers wrought carbon steel and alloy steel fittings of seamless and welded construction, covered by the latest revision of ASME B16.9, ASME B16.11, MSS-SP-79, and MSS SP-95. Fittings differing from these ASME and MSSVF standards shall be furnished in accordance with Supplementary Requirement S58 of Specification A 960. These fittings are for use in pressure piping and pressure vessel service at low temperatures.

1.2 Optional supplementary requirements are provided for fittings where a greater degree of examination is desired. When desired, one or more of these supplementary requirements shall be specified in the order.

1.3 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other.

2. Referenced Documents

2.1 In addition to those Referenced Documents listed in Specification A 960, the following list of standards apply to this specification.

2.2 ASTM Standards:

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 960 Specification for Common Requirements for Wrought Steel Piping Fittings

2.3 ASME Standards:

B 16.9 Factory-Made Wrought Steel Butt-Welding Fittings
B 16.11 Forged Steel Fittings, Socket-Welding Threaded Section VIII Division 1, Pressure Vessels

2.4 MSS Standards:

MSS SP-25 Standard Marking System for Valves, Fittings, Flanges, and Unions
MSS SP-79 Socket Welding Reducer Inserts
MSS SP-95 Swage(d) Nipples and Bull Plugs

2.5 ASNT Standard:

ASNT (1984) Recommended Practice No. SNT-TC-1A

3. Ordering Information

3.1 See Specification A 960.

4. General Requirements

4.1 Product furnished to this specification shall conform to the requirements of Specification A 960, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 960 constitutes non-conformance with this specification. In case of conflict between the requirements of this specification and Specification A 960, this specification shall prevail.

5. Material

5.1 The material for fittings shall consist of forgings, bars, plates, seamless or fusion welded tubular products with filler metal added. It shall conform to the chemical requirements in Table 1, and be made by one of the following processes: open-hearth, basic-oxygen, or electric-furnace. The steels shall be made using recognized melting

practices necessary to produce steels that shall meet the impact requirements of this specification.

6. Manufacture

6.1 Forging or forming operations shall be performed by hammering, pressing, piercing, extruding, upsetting, working, bending, fusion-welding, or machining, or by a combination of two or more of these operations. The forming procedure shall be so applied that it will not produce injurious defects in the fittings.

6.2 All welds, including welds in tubular products from which fittings are made, shall be (1) made by welders, welding operators and welding procedures qualified under the provisions of ASME Section IX, (2) heat treated in accordance with Section 7 of this specification, and (3) nondestructively examined throughout the entire length of each weld in accordance with Section 14 of this specification. The radiography of welds shall be done either prior to or after forming at option of manufacturer. Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

6.3 The welded joints of the fittings shall be finished in accordance with the requirements of Paragraph UW-35(a) of Section VIII, Division 1 of ASME Boiler and Pressure Vessel Code.

6.4 All butt-weld tees manufactured by cold-forming methods shall be liquid penetrant or magnetic particle examined by one of the methods specified in Supplementary Requirement S52 or S53 of Specification A 960. This examination shall be performed after final heat treatment by NDE personnel qualified under the provisions of ASNT Recommended Practice No. SNT-TC-1A. Only the side-wall areas of the tee need be examined. This area is defined by a circle that covers the area from the weld bevel of the branch outlet to the centerline of the body or run. Internal and external surfaces shall be examined when size permits accessibility. After the removal of any cracks, the tees shall be re-examined by the original method. Acceptable tees shall be marked with the symbol PT or MT, as applicable, to indicate compliance.

6.5 Stubends may be produced with the entire lap added by the welding of a ring, made from plate or bar of the same alloy grade and composition, to the outside of a straight section of pipe, provided the weld is double welded, is a full penetration joint, satisfies the requirements of 6.2 for qualifications and radiography and 7.1 for post weld heat treatment.

7. Heat Treatment

7.1 All fittings shall be furnished in the normalized, normalized and tempered, annealed, or quenched and tempered condition. All welding shall be completed prior to the austenitizing heat treatment.

7.2 The full thickness of the material from which impact test specimens are to be obtained shall be heat treated with a furnace charge as specified in 10.4.2 or 10.4.3.

7.3 After forming, the fittings shall be allowed to cool below the lower critical before applying one of the heat treatments listed in 7.1.

7.4 When the fittings are to be post-weld heat treated after being welded by the purchaser and when so specified in the order, the test specimens shall be subjected to the same post-weld heat treatment. The purchaser shall use the post-weld heat treatment shown in Table 2, unless otherwise specified in the order.

8. Chemical Composition

8.1 The steel shall conform to requirements of chemical composition for the respective material prescribed in Table 1.

8.2 The steel shall not contain any unspecified elements for the ordered grade to the extent that it then conforms to the requirements of another grade for which that element is a specified element having a required minimum content.

8.3 The chemical composition of weld metal is not required to meet the same limits of the base materials however, the composition of the weld deposit shall be such that it meets the minimum mechanical and impact requirements of this specification. In general, the alloy content shall be similar to that of the base metal but shall not exceed 6% except in the case of fittings of 9% nickel steel.

8.4 A product analysis is optional.

9. Tensile Properties

9.1 The tensile properties of the fittings material shall conform to the requirements for the applicable grade of material as listed in Table 3.

9.2 At least one tension test shall be made on each heat of material and in the same condition of heat treatment as the finished fittings it represents provided that the wall thickness of the fitting and the representative sample thickness do not vary more than $\frac{1}{4}$ in. [6 mm]. At least one tension test per heat of weld metal shall be made after heat treatment in the same manner as the base metal. Results need not be reported unless Supplementary Requirement S51 of Specification A 960 is specified.

9.3 Records of the tension tests shall be certification that the material of the fitting meets the tensile requirements of this specification.

10. Impact Test Properties

10.1 Properties:

10.1.1 The notched bar impact properties of the base metal and weld metal shall conform to the requirements of Table 4 or Table 5 for the applicable grade of material.

10.1.2 Retest – When the average value of the three specimens equals or exceeds the minimum value permitted for a single specimen and the value for more than one specimen is below the required average value, or when the value for one specimen is below the minimum value permitted for a single specimen, a retest of three additional specimens shall be made. The value for each of these retest specimens shall equal or exceed the required average value. When an erratic result is caused by a defective specimen, or there is uncertainty in test procedure, a retest shall be allowed.

10.2 Procedures:

10.2.1 All material furnished under this specification shall be tested for impact resistance at the temperature for the respective grade in Table 6. Exceptions to these requirements are permissible when agreed upon between the purchaser and producer and specified in the order, in that the impact test is acceptable when made at temperatures different from those shown in Table 6, provided the test temperature is at least as low as the intended service temperature, and fittings are suitably marked in accordance with Section 18 to identify the reported test temperature.

10.2.2 The notched-bar impact test shall be made in accordance with the procedure for the simple-beam, Charpy-type test of Test Methods and Definitions A 370. Each impact test shall consist of breaking three specimens.

10.3 Specimens:

10.3.1 Notched-bar impact specimens shall be simple-beam, Charpy-type A with a V-notch in accordance with Test Methods and Definitions A 370. Standard specimens 10 by 10 mm in cross section shall be used unless the material to be tested is of insufficient thickness, in which case the largest obtainable standard subsize impact specimens shall be used. When the size or shape of the finished fittings is insufficient to permit obtaining the smallest standard subsize impact specimens, an impact test by the fitting manufacturer will not be required. The material from which the specimens are taken shall be heat treated with a furnace charge in accordance with 10.4.2 or 10.4.3. Impact tests shall be made from either the raw material from which the fittings are made or from a finished fitting at the option of the manufacturer.

10.3.2 Test specimens shall be obtained so that the longitudinal axis of the specimen is parallel to the longitudinal axis of the fitting while the axis of the “V” shall be perpendicular to the surface. On wall thickness over 1 in.

[25 mm] the specimens shall be obtained with their longitudinal axis located $\frac{1}{2}$ in. [13 mm] from the outer surface.

10.3.3 When testing welds, the notch of the specimen shall be in the welded joint and, where the diameter and wall thickness permit, the longitudinal axis of the specimen shall be transverse to the longitudinal axis of the weld. The axis of the notch shall be perpendicular to the surface.

10.4 Number of Tests:

10.4.1 A notched-bar impact test, consisting of breaking three specimens shall be made. Each test shall represent only such fittings from a heat that do not vary from the thickness of the material from which the test specimens are taken by more than $\frac{1}{4}$ in. [6 mm].

10.4.2 When heat treatment is performed in furnaces not equipped with calibrated recording pyrometers, one impact test shall be made for each heat in each heat-treatment load. Test specimens shall be included with each furnace charge. If this heat treatment is conducted in continuous-type furnaces not equipped with calibrated recording pyrometers, then one test per heat shall be conducted for each 5000 lb or 2550 kg (or less) of product.

10.4.3 When heat treatment is performed in furnaces controlled within a 50°F [28°C] range and equipped with calibrated recording pyrometers so that records of heat treatment are available, then one impact test from each heat is required, provided that all other heat treatments are conducted at the same temperatures and within the same 50°F [28°C] range as the furnace charge that contained the test specimens.

10.4.4 On fittings of welded construction, additional impact tests of the same number as required in 10.4.1 or 10.4.2 shall be made to test the weld metal.

10.4.5 Specimens showing defects while being machined or prior to testing shall be discarded, and replacements shall be considered as original specimens.

10.5 Retreatment:

10.5.1 If the results of impact tests conducted in accordance with 10.4.2 and 10.4.3 fail to conform to the test requirements specified in 10.1, that group of fittings shall be retreated and submitted for test. No group of fittings shall be retreated more than twice.

11. Hydrostatic Tests

11.1 Hydrostatic testing of fittings is not required by this specification.

11.2 All fittings shall be capable of withstanding without failure, leakage, or impairment of their serviceability, a hydrostatic test pressure equal to that prescribed for the specified matching pipe of equivalent material.

12. Dimensions

12.1 Butt-welding fittings and butt-welding short-radius elbows and returns purchased in accordance with this specification shall conform to the dimensions and tolerances given in the latest revision of ASME B16.9. Steel socket-welding and threaded fittings purchased in accordance with this specification shall conform to the sizes, shapes, dimensions, and tolerances specified in the latest revision of ASME B16.11.

12.2 Fittings of size or shape differing from these standards, but meeting all other requirements of the specification, shall be furnished in accordance with Supplementary Requirement S58 of Specification A 960 only by agreement with the purchaser.

13. Surface Quality

13.1 See Specification A 960.

13.2 *Repair by Welding (Base Metal):*

13.2.1 Repair welding, by the manufacturer, is permissible for parts made to dimensional standards such as those of ASME or equivalent standards.

13.2.2 Prior approval of the purchaser shall be required to weld repair special parts made to the purchaser's dimensional requirements.

13.2.3 Welding shall be accomplished with a weld procedure designed to produce low hydrogen in the weldment. Short circuit gas metal arc welding is permissible only with the approval of the purchaser.

13.2.4 The weld repair shall be permanently identified with the welder's stamp or symbol in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

13.2.5 After weld repair, material shall be heat treated in accordance with 7.1.

13.2.6 Tension and impact testing of representative deposited weld metal for each heat shall meet the requirements of 9.2 and 10.1.

14. Radiographic Examination

14.1 All fusion-welded butt joints shall be radiographically examined throughout the entire length in accordance with Paragraph UW-51 of Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code. Instead of radiographic examination, welds made by the manufacturer may be ultrasonically examined in accordance with Appendix 12 of Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code. In general, radiography or ultrasonic examination shall be performed after all forming operations have been completed. Fittings made from fusion-welded

pipe need not be radiographed if the pipe has been radiographed, provided the fitting forming process does not materially affect the weld.

15. Inspection

15.1 All tests and inspections shall be made at the place of manufacture, unless otherwise agreed to.

15.2 Other tests, when required by agreement shall be made from materials of the lots covered in the order.

16. Rejection and Rehearing

16.1 Material that fails to conform to the requirements of this specification shall be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier shall make claim for a rehearing.

16.2 Fittings that develop defects in shop working or application operations shall be rejected. Upon rejection, the manufacturer shall be notified promptly in writing.

17. Certification

17.1 When requested by the purchaser, the manufacturer shall provide a certificate of compliance to this specification. In addition, if requested to provide test reports, the manufacturer shall also provide the following where applicable:

17.1.1 Chemical analysis results, Section 8 (Table 1),

17.1.2 Tensile property results, Section 9 (Table 3) report yield strength and ultimate strength in ksi [MPa] and elongation in percent,

17.1.3 Impact test results, Section 10 (Table 4 and Table 5),

17.1.4 Type heat treatment, Section 7,

17.1.5 Radiographic examination statement, Section 14, and

17.1.6 Any supplemental testing required by the purchase order.

17.2 Certification shall state whether welds have been examined radiographically or ultrasonically.

17.3 Letters of compliance and test results shall state the specification number, year of issue, revision letter (if any), grade and class of the fittings.

18. Product Marking

18.1 All fittings shall have the prescribed information marked on each fitting in accordance with MSS SP-25, latest revision.

18.1.1 Fittings shall be marked by any method which will permanently identify the fittings and not result in sharp discontinuities. Stamping, when used, shall be done with blunt-nosed continuous or blunt-nosed interrupted dot stamps.

18.1.2 When agreed upon between the purchaser and producer, and specified in the order, the markings shall be painted or stenciled on the fitting or stamped on a metal or plastic tag which shall be securely attached to the fitting.

18.2 The prescribed information for butt-welding fittings shall be: the manufacturer's name or trademark (see Note 1), material designation or grade, schedule number or nominal wall thickness designation, and the heat number or manufacturer's heat identification. Fittings containing welds that have been ultrasonically examined instead of radiography shall be marked U after heat identity.

NOTE 1 — For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component complies with this specification.

18.3 The prescribed information for threaded or socket welding fittings shall be: the manufacturer's name or trademark, material designation or grade, pressure class or schedule number, and size.

18.4 When size does not permit complete marking, identification marks shall be omitted in the reverse order of those listed above and in accordance with MSS SP-25.

18.5 The impact test temperature shall also be shown if it is different from the standard test temperature specified in Table 6, for example: WPL-6-60 or WPL3-176.

18.6 Bar Coding — In addition to the requirements in 18.1, 18.2, 18.3, 18.4, and 18.5, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small fittings, the bar code may be applied to the box or a substantially applied tag.

19. Keywords

19.1 pipe fittings; piping applications; pressure containing parts; pressure vessel service; temperature service applications, low

TABLE 1
CHEMICAL REQUIREMENTS

Grade ^A	Composition, %										
	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	Cb	V
WPL6	0.30	0.50–1.35	0.035	0.040	0.15–0.40	0.40	0.30	0.12	0.40	0.02 ^B	0.08
WPL9	0.20	0.40–1.06	0.030	0.030	...	1.60–2.24	...	...	0.75–1.25	...	...
WPL3 ^C	0.20	0.31–0.64	0.05	0.05	0.13–0.37	3.2–3.8	...	...	...	...	...
WPL8 ^D	0.13	0.90	0.030	0.030	0.13–0.37	8.4–9.6	...	...	...	...	...

NOTE 1—All requirements are maximum unless otherwise indicated.

NOTE 2—Where an ellipsis (...) appears in this table, there is no requirement.

^A When fittings are of welded construction, the symbols above shall be supplemented by the letter "W."

^B By agreement, the limit for Columbium may be increased up to 0.05% on heat analysis and 0.06% on product analysis.

^C Fittings made from plate or forgings may have 0.90% max manganese.

^D Fittings made from plate may have 0.98% max manganese.

TABLE 2
POST-WELD HEAT TREATMENT

Grade	Metal Temperature		Minimum Holding Time
	°F	°C	
WPL6	1100–1200	595–650	1 h/in. [25 mm] $\frac{3}{4}$ h min
WPL3	1100–1150	540–620	$\frac{1}{4}$ h/in. [25 mm] 1 h min
WPL8	1050–1100	565–595	$\frac{1}{2}$ h/in. [25 mm] 1 h min
WPL9 ⁴	1025–1085	550–585	1 h/in. [25 mm] 2 h min

⁴ 2 in. [51 mm] thickness and over. The cooling rate shall not be less than 300°F [150°C] per hour down to a temperature of 600°F [315°C].

TABLE 3
TENSILE REQUIREMENTS

Requirement	Grade			
	WPL6	WPL9	WPL3	WPL8
Tensile strength, min ksi [MPa]	60 [415]–85 [585]	63 [435]–88 [610]	65 [450]–90 [620]	100 [690]–125 [865]
Yield strength, min ksi [MPa]	35 [240]	46 [315]	35 [240]	75 [515]

Elongation Requirements	Grades							
	WPL6		WPL9		WPL3		WPL8	
	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse
Standard round specimen, or small proportional specimen, min % in 4 D	22	12	20	...	22	14	16	...
Rectangular specimen for wall thickness $\frac{5}{16}$ in. [7.94 mm] and over, and for all small sizes tested in full section; min % in 2 in. or 50 mm	30	16.5	28	18	30	20	22	...
Rectangular specimen for wall thickness less than $\frac{5}{16}$ in [7.94 mm]; min % in 2 in. or 50 mm ($\frac{1}{2}$ in. [12.7 mm] wide specimen)	A	A	A	A	A	A	A	...

Note 1 — Where an ellipsis (...) appears in this table, there is no requirement.

^A For each $\frac{1}{32}$ in. [0.79 mm] decrease in wall thickness below $\frac{5}{16}$ in. [7.94 mm], a deduction of 1.5% (grades WPL6, WPL9, and WPL3) or 1.25% (WPL8) for longitudinal and 1.0% (grades WPL6, WPL9, and WPL3) for transverse from the values shown above is permitted. The following table gives the minimum value for various wall thicknesses:

Wall Thickness		Grades							
in.	[mm]	WPL6		WPL9		WPL3		WPL8	
		Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse	Longi- tudinal	Trans- verse
$\frac{5}{16}$ (0.312)	[7.94]	30.0	16.5	28.0	18.0	30.0	20.0	22.0	...
$\frac{9}{32}$ (0.281)	[7.14]	28.5	15.5	26.5	17.0	28.5	19.0	20.75	...
$\frac{1}{4}$ (0.250)	[6.35]	27.0	14.5	25.0	16.0	27.0	18.0	19.5	...
$\frac{7}{32}$ (0.219)	[5.56]	25.5	...	23.5	...	25.5	...	18.25	...
$\frac{3}{16}$ (0.188)	[4.76]	24.0	...	22.0	...	24.0	...	17.0	...
$\frac{5}{32}$ (0.156)	[3.97]	22.5	...	20.5	...	22.5	...	15.75	...
$\frac{1}{8}$ (0.125)	[3.17]	21.0	...	19.0	...	21.0	...	14.5	...
$\frac{3}{32}$ (0.094)	[2.38]	19.5	...	17.5	...	19.5	...	13.25	...
$\frac{1}{16}$ (0.062)	[1.59]	18.0	...	16.0	...	18.0	...	12.0	...

NOTE — The preceding table gives the computed minimum elongation value for each $\frac{1}{32}$ in. [0.79 mm] decrease in wall thickness. Where the wall thickness lies between two values above, the minimum elongation value is determined by the following equations:

Direction of Test	Equations			
	WPL6	WPL9	WPL3	WPL8
Longitudinal	$E = 48t + 15.00$	$48t + 13.00$	$E = 48t + 15.00$	$40t + 9.50$
Transverse	$t = 32t + 6.50$	$32t + 8.00$	$E = 32t + 10.00$	...

where:

E = elongation in 2 in. or 50 mm, %, and
 t = actual thickness of specimen, in.

TABLE 4
CHARPY IMPACT REQUIREMENTS FOR WPL6,
WPL9, AND WPL3^A

Size of Specimen, mm	Charpy V-Notch Impact Value Required for Acceptance (Average of Three Specimens)		Minimum Charpy V-Notch Impact Value Without Requiring Retest (One Specimen Only of a Set)	
	ft · lbf	J	ft · lbf	J
10 by 10.0	13	17.6	10	13.6
10 by 7.5	10	13.6	8	10.8
10 by 5.0	7	9.5	5	7.0
10 by 2.5	4	5.4	3	4.1

^A Straight-line interpolation for intermediate values is permitted.

TABLE 5
CHARPY IMPACT REQUIREMENTS FOR WPL8

Size of Specimen, mm	Charpy V-Notch Impact Value Required for Acceptance (Average of Three Specimens)		Minimum Charpy V-Notch Impact Value Without Requiring Retest (One Specimen Only of a Set)	
	ft · lbf	J	ft · lbf	J
10 by 10.0	25.0	33.9	20.0	27.1
10 by 7.5	21.0	28.5	17.0	23.1
10 by 5.0	17.0	23.1	14.0	19.0
10 by 2.5	8.0	10.8	6.0	8.1

TABLE 6
IMPACT TEST TEMPERATURE

Grade	Impact Test Temperature, °F [°C]
WPL6	−50 [−45]
WPL9	−100 [−75]
WPL3	−150 [−100]
WPL8	−320 [−195]

SUPPLEMENTARY REQUIREMENTS

One or more of the supplementary requirements appearing in Specification A 960 may be included in the order or contract. When so included, a supplementary requirement shall have the same force as if it were in the body of the specification. Supplementary requirement details not fully described shall be agreed upon between the purchaser and the supplier.

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SPECIFICATION FOR SEAMLESS AND ELECTRIC-WELDED LOW-ALLOY STEEL TUBES



SA-423/SA-423M



[Identical with ASTM Specification A 423/A 423M-95(R04).]

1. Scope

1.1 This specification covers minimum-wall-thickness, seamless and electric-resistance welded, low-alloy steel tubes for pressure containing parts such as economizers or other applications where corrosion resistance is important.

1.2 The tubing sizes and thicknesses usually furnished to this specification are $\frac{1}{2}$ to 5 in. [12.7 to 127 mm] in outside diameter and 0.035 to 0.500 in. [0.9 to 12.7 mm] inclusive, in minimum wall thicknesses. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than $\frac{1}{4}$ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.4 An optional supplementary requirement is provided and, when desired, shall be so stated in the order.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Document

2.1 ASTM Standard:

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 273 Practice for Ultrasonic Examination of Longitudinal Welded Pipe and Tubing

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

3. Ordering Information

3.1 Orders for material under this specification shall include the following, as required, to describe the desired material adequately;

3.1.1 Quantity (feet, metres, or number of lengths),

3.1.2 Name of material (seamless or electric-resistance welded tubes),

3.1.3 Grade (Table 1),

3.1.4 Manufacture (hot finished or cold finished),

3.1.5 Size (outside diameter and minimum wall thickness)

3.1.6 Length (specific or random),

3.1.7 Optional requirements (hydrostatic or electric test, 13.7),

3.1.8 Test report required (see Certification Section of Specification A 450/A 450M),

3.1.9 Specification designation, and

3.1.10 Special requirements and any supplementary requirements selected.

4. Manufacture

4.1 Tubes made by the seamless process may be hot finished or cold finished.

5. Heat Treatment

5.1 All tubes shall be normalized or given such heat treatment as may be necessary to conform to the requirements of this specification.

6. Chemical Composition

6.1 The steel shall conform to requirements as to chemical composition prescribed in Table 1.

7. Product Analysis

7.1 An analysis of either one billet, one length of flat-rolled stock or one tube shall be made from each heat. The chemical composition thus determined shall conform to the requirements specified.

7.2 If the original test for product analysis fails, retests of two additional billets, lengths of flat-rolled stock, or tubes shall be made. Both retests, for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (Note 1) shall be rejected or, at the option of the producer, each billet, length of flat-rolled stock or tube may be individually tested for acceptance. Billets, lengths of flat-rolled stock or tubes which do not meet the requirements of the specification shall be rejected.

NOTE 1—For flattening, flaring, and flange requirements, the term *lot* applies to all tubes prior to cutting of the same nominal size and wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as prescribed in Table 2.

NOTE 2—For tensile and hardness test requirements, the term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

8. Tensile Requirements

8.1 The material shall conform to the requirements as to tensile properties prescribed in Table 3.

9. Hardness Requirements

9.1 The tubes shall have a hardness number not exceeding 170 HB or 87 HRB.

10. Forming Operations

10.1 Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws.

11. Mechanical Tests Required

11.1 Tension Test — One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension

tests shall be made on specimens from two tubes for lots of more than 50 tubes (Note 2).

11.2 Flattening Test — One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flaring or flanging test, from each lot (Note 1).

11.3 Flaring Test (Seamless Tubes) — One flaring test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (Note 1).

11.4 Flange Test (Welded Tubes) — One flange test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (Note 1).

11.5 Hardness Test — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (Note 2).

11.6 Reverse Flattening Test — For welded tubes, one reverse flattening test shall be made on a specimen from each 1500 ft [460 m] of finished tubing.

11.7 Hydrostatic or Nondestructive Electric Test — Each tube shall be subjected to the hydrostatic test, or, instead of this test, a nondestructive electric test may be used when specified by the purchaser.

12. General Requirements

12.1 Material furnished under this specification should conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

13. Product Marking

13.1 In addition to the marking prescribed in Specification A 450/A 450M, the marking shall include whether hot finished or cold finished, and whether seamless or welded.

14. Keywords

14.1 Seamless steel tube; steel tube; alloy; welded steel tube

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %	
	Grade 1	Grade 2
Carbon, max	0.15	0.15
Manganese, max	0.55	0.50–1.00
Phosphorus	0.06–0.16	0.04 max
Sulfur, max	0.060	0.05
Silicon, min	0.10	. . .
Copper	0.20–0.60	0.30–1.00
Chromium	0.24–1.31	. . .
Nickel	0.20–0.70	0.40–1.10
Molybdenum, min	. . .	0.10

TABLE 2
**NUMBER OF TUBES IN A LOT HEAT TREATED BY
THE CONTINUOUS PROCESS**

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in. [5.1 mm] and over in wall thickness	not more than 50 tubes
Less than 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter or over 1 in. [25.4 mm] in outside diameter and under 0.200 in. [5.1 mm] in wall thickness	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

TABLE 3
TENSILE REQUIREMENTS

Tensile strength, min, ksi [MPa]	60 [415]
Yield strength, min, or 50 mm, ksi [MPa]	37 [255]
Elongation in 2 in. or 50 mm, min, %	25
For longitudinal strip tests a deduction for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{3}{16}$ in. [8 mm] from the basic minimum elongation of the following percentage points shall be made	1.25 ⁴

⁴ Calculated elongation requirements shall be rounded to the nearest whole number.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified by the purchaser in the inquiry, contract, or order. Details of this supplemental requirement shall be agreed upon by the manufacturer and the purchaser.

S1. Surface Condition

S1.1 If pickling or shot-blasting, or both, are required, this shall be specifically stated in the order and shall be done at the purchaser's expense.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements may become a part of the specification when specified in the inquiry or invitation to bid, and purchase order or contract. These requirements shall not be considered unless specified in the order and the necessary tests shall be made at the mill.

S2. Additional Testing of Welded Tubing per ASME Request

S2.1 Each tube shall be subjected to an ultrasonic inspection employing Practices E 273 or E 213 with the rejection criteria referenced in Specification A 450/A 450M.

S2.2 If Practice E 273 is employed, a 100% volumetric inspection of the entire length of each tube shall also be performed using one of the non-destructive electric tests permitted by Specification A 450/A 450M.

S2.3 The test methods described in the supplement may not be capable of inspecting the end portions of tubes. This condition is referred to as end effect. This portion, as determined by the manufacturer, shall be removed and discarded.

S2.4 In addition to the marking prescribed in Specification A 450/A 450M, “S2” shall be added after the grade designation.

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SPECIFICATION FOR CENTRIFUGALLY CAST FERRITIC ALLOY STEEL PIPE FOR HIGH- TEMPERATURE SERVICE



SA-426/SA-426M

(Identical with ASTM Specification A 426/A 426M-07 except for a correction to the molybdenum content for Grade CP91 in Table 1.)

1. Scope

1.1 This specification covers centrifugally cast alloy steel pipe intended for use in high-temperature, high-pressure service.

1.2 Several grades of ferritic steels are covered. Their compositions are given in Table 1.

1.3 Supplementary Requirements S1 through S12 are provided. The supplementary requirements provide for additional tests of an optional nature and when desired shall be so stated in the order (Section 4).

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of each other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 ASTM Standards:

- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 609/A 609M Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof
- A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
- A 999/A 999M Specification for General Requirements for Alloy and Stainless Steel Pipe
- E 94 Guide for Radiographic Examination
- E 165 Test Method for Liquid Penetrant Examination
- E 186 Reference Radiographs for Heavy-Walled (2 to 4½ in. [51 to 114 mm]) Steel Castings

E 208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels

E 280 Reference Radiographs for Heavy-Walled (4½ to 12 in. [114 to 305 mm]) Steel Castings

E 446 Reference Radiographs for Steel Castings Up to 2 in. [51 mm] in Thickness

E 709 Guide for Magnetic Particle Examination

2.2 ANSI Standard:

B46.1 Surface Texture

2.3 ASME Boiler and Pressure Vessel Code:

Section IX Welding Qualifications

3. Ordering Information

3.1 Orders for material under this specification shall include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, centimetres, or number of lengths),

3.1.2 Name of material (centrifugally cast pipe),

3.1.3 Specification number,

3.1.4 Grade (Table 1),

3.1.5 Size (outside or inside diameter and minimum wall thickness),

3.1.6 Length (specific or random) (Section on Permissible Variations in Length of Specification A 999/A 999M),

3.1.7 End finish (Section on Ends of Specification A 999/A 999M),

3.1.8 Optional Requirements S1 through S12 and Section 14.1,

3.1.9 Test report required (Section on Certified Test Report of Specification A 999/A 999M),

3.1.10 Service temperature if over 1000°F [540°C] (Note 1), and

3.1.11 Special requirements or additions to specification.

4. General Requirements for Delivery

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 999/A 999M unless otherwise provided herein.

5. Materials and Manufacture

5.1 Heat-Treatment — The pipe shall be furnished in the normalized and tempered or liquid-quenched and tempered condition (Note 1). The temperature for tempering shall not be less than 1250°F [675°C] except for Grades CP1, CP2, CP11, CP12, and CP15 for which the temperature for tempering shall not be less than 1100°F [595°C]. Grade CP91 shall be normalized at 1900–1975°F (1040–1080°C) and tempered at 1350–1470°F (730–800°C).

5.1.1 Heat treatment shall be performed after the pipe has been allowed to cool below the transformation range. Definition of heat-treatment terms shall be as given in Terminology A 941.

NOTE 1 — Except for Grade CP91, it is recommended that the temperature for tempering should be at least 100°F [55°C] above the intended service temperature. The purchaser shall advise the manufacturer of the service temperature when it is over 1000°F [540°C].

5.2 Machining — The pipe shall be machined on the inner and outer surfaces to a roughness value no greater than 250 μin. [6.35 μm] arithmetical average deviation (AA) from the mean line unless otherwise specified as in ANSI B46.1.

6. Chemical Analysis

6.1 Heat Analysis — An analysis of each heat shall be made by the manufacturer to determine the percentages of elements specified in Table 1. The analysis shall be made on a test sample taken preferable during the pouring of the heat. The chemical composition thus determined shall conform to the requirements specified in Table 1 (Note 2).

NOTE 2 — The role of alloying elements in the development of Grade CP91 has been extensively investigated. V and Nb contribute to precipitation strengthening by forming fine and coherent precipitation of M(C,N)X carbo-nitrides in the ferrite matrix. V also precipitates as VN during tempering or during creep. Therefore, the addition of strong nitride forming elements, those with a stronger affinity for nitrogen than Nb and V, as deoxidation agents, interferes with these high-temperature strengthening mechanisms.

6.2 Product Analysis — A product analysis may be made by the purchaser. The sample for analysis shall be selected so as to be representative of the pipe being analyzed. The chemical composition thus determined shall conform to the requirements of Table 1.

7. Tensile and Hardness Requirements

7.1 Steel used for the castings shall conform to the tensile and hardness requirements specified in Table 2.

8. Permissible Variations in Dimensions

8.1 Thickness — The wall thickness shall not vary over that specified by more than 1/8 in. [3 mm]. There shall be no variation under the specified wall thickness.

9. Number of Tests

9.1 One tension and one hardness test shall be made from each heat.

9.2 If a specimen is machined improperly or if flaws are revealed by machining or during testing, the specimen may be discarded and another substituted from the same heat.

10. Retests

10.1 If the results of the mechanical tests for any heat do not conform to the requirements specified, the castings may be reheat-treated and retested, but may not be re-austenitized more than twice.

11. Test Specimens

11.1 Test coupons from which tension test specimens are prepared shall be removed from heat-treated casting prolongations.

11.2 When agreed upon between the manufacturer and the purchaser, test coupons from which test specimens are prepared shall be cast attached to separate blocks from the same heat as the casting represented. The test blocks shall be heat treated in the same manner as the casting represented.

11.3 Tension test specimens shall be machined to the form and dimensions of the standard round 2 in. [50 mm] gage length specimens shown in Fig. 6 of Test Methods and Definitions A 370.

12. Hydrostatic Test

12.1 Each length of pipe shall be hydrostatically tested in accordance with Specification A 999/A 999M.

12.2 When agreed to between the manufacturer and the purchaser and so stated in the order, the hydrostatic test may be deferred and shall be performed later by the purchaser. Pipe furnished without the hydrostatic test shall include with the mandatory marking the letters "NH." The manufacturer is responsible for the satisfactory performance of the casting when it is tested.

12.3 When certification is required by the purchaser and the hydrostatic test has been omitted, the certification shall clearly state "not hydrostatically tested." The specification number and material grade shown on the certification shall be followed by the letters "NH."

13. Visual Inspection

13.1 The surface of the casting shall be free from cracks and hot tears as determined by visual examination. Other surface imperfections shall be judged in accordance with visual acceptance criteria which may be specified in the order.

14. Rework and Retreatment

14.1 Defects as defined in Section 14 shall be removed and their removal verified by visual inspection of the resultant cavities. Defects that are located by inspecting with supplementary requirements S6, S7, S8, or S9 shall be removed or reduced to an acceptable size.

14.2 If removal of the defect does not infringe upon the minimum wall thickness, the depression may be blended uniformly into the surrounding surface.

14.3 If the cavity resulting from defect removal infringes upon the minimum wall thickness, weld repair

is permitted subject to the purchaser's approval. The composition of the weld rod used shall be suitable for the composition of the metal being welded.

14.3.1 Only welders and procedures qualified in accordance with *ASME Boiler and Pressure Vessel Code*, Section IX, shall be used. All repair welds will be inspected to the same quality standards used to inspect the casting.

14.4 Local or full heat treatment in accordance with tempering temperatures specified in 5.1 shall follow welding.

15. Rejection

15.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the specification based on the inspection and test method as outlined in the specification, the pipe may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

16. Product Marking

16.1 Each length of pipe shall be legibly marked with the manufacturer's name or brand, the specification number and grade. In addition, heat numbers or serial numbers that are traceable to heat numbers shall be marked on each length of pipe.

17. Keywords

17.1 alloy steel, centrifugal; ferritic; high-temperature service; pipe; stainless steel; steel castings

TABLE 1
CHEMICAL REQUIREMENTS

Composition, %									
Grade	UNS Number	Carbon	Man-ganese	Phospho-rus, max	Sulfur, max	Silicon	Chromium	Molybdenum	Other
CP1	J12521	0.25 max	0.30–0.80	0.040	0.045	0.10–0.50	...	0.44–0.65	
CP2	J11547	0.10–0.20	0.30–0.61	0.040	0.045	0.10–0.50	0.50–0.81	0.44–0.65	
CP5	J42045	0.20 max	0.30–0.70	0.040	0.045	0.75 max	4.00–6.50	0.45–0.65	
CP5b	J51545	0.15 max	0.30–0.60	0.040	0.045	1.00–2.00	4.00–6.00	0.45–0.65	
CP9	J82090	0.20 max	0.30–0.65	0.040	0.045	0.25–1.00	8.00–10.00	0.90–1.20	
CP91	J84090	0.08–0.12	0.30–0.60	0.030	0.010	0.20–0.50	8.0–9.5	0.85–1.05	nickel, 0.40 max.; columbium, 0.060–0.10; nitrogen 0.030–0.070; vanadium, 0.18–0.25; aluminum, 0.02 max.; titanium, 0.01 max; zirconium, 0.01 max.
CP11	J12072	0.05–0.20	0.30–0.80	0.040	0.045	0.60 max	1.00–1.50	0.44–0.65	
CP12	J11562	0.05–0.15	0.30–0.61	0.040	0.045	0.50 max	0.80–1.25	0.44–0.65	
CP15	J11522	0.15 max	0.30–0.60	0.040	0.045	0.15–1.65	...	0.44–0.65	
CP21	J31545	0.05–0.15	0.30–0.60	0.040	0.045	0.50 max	2.65–3.35	0.80–1.06	
CP22	J21890	0.05–0.15	0.30–0.70	0.040	0.045	0.60 ma	2.00–2.75	0.90–1.20	
CPCA15	J91150	0.15 max	1.00 max	0.040	0.040	1.50 max	11.5–14.0	0.50 max	

TABLE 2
TENSILE PROPERTIES AND HARDNESS
REQUIREMENTS

Tensile strength, min, psi [MPa]:	
Grade CP1	65 000 [450]
Grades CP11, CP22	70 000 [485]
Grades CP5, CP9, CPCA15	90 000 [620]
Grade CP91	85 000 [585] to 110 000 [760]
All other grades	60 000 [415]
Yield strength, min, psi [MPa]:	
Grade CP1	35 000 [240]
Grades CP11, CP22	40 000 [275]
Grades CP5, CP9	60 000 [415]
Grade CPCA15	65 000 [450]
Grade CP91	60 000 [415]
All other grades	30 000 [205]
Elongation, min, %: ^A	
Grade CP1	24
Grades CP11, CP22	20
Grades CP5, CP9, CP91, CPCA15	18
All other grades	22
Reduction of area, min, %:	
Grades CP1, CP2, CP11, CP12, CP15, CP21, CP22, CP5, CP5b, CP7, CP9	35
Grade CPCA15	30
Grade CP91	45
Hardness, max, HB:	
Grades CP5, CP5b, CP9, CP91, CPCA15	225
All other grades	201

^A Elongation in 2 in. (50 mm) using a standard round specimen, in either the transverse or longitudinal direction.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall be applied only when specified by the purchaser. Details of the supplementary requirements shall be agreed upon between the manufacturer and purchaser. The specified tests shall be performed by the manufacturer prior to shipment of the castings.

S1. Additional Tension Tests

S1.1 Additional tension tests shall be made at a temperature to be specified by the customer, and the properties to be met are a matter of agreement between the purchaser and manufacturer.

S2. Flattening Test

S2.1 The flattening test shall be made on specimens from one or both ends of each length of pipe. If the specimen from any end of any length fails to conform to the requirements of Specification A 999/A 999M, that length shall be rejected.

S3. Photomicrographs

S3.1 The manufacturer shall furnish one photomicrograph at 100 diameters from one specimen of as-finished pipe from each heat in each heat-treatment lot. Such photomicrographs shall be suitable identified as to pipe size, wall thickness, and heat. Such photomicrographs are for information only, to show the actual metal structure of the pipe as furnished. No photo-micrographs for the individual pieces purchased shall be required except as specified in Section S4.

S4. Photomicrographs for Individual Pieces

S4.1 The manufacturer shall furnish photomicrographs from one or both ends of each pipe. All photomicrographs required shall be properly identified as to heat number, size, and wall thickness of pipe from which the section was taken. Photomicrographs shall be further identified to permit association of each photomicrograph with the individual length of pipe it represents.

S5. Metal Structure and Etching Tests

S5.1 Etching tests shall be made on transverse sections from the pipe and shall reveal the macrostructure of the material. Such tests are for information only.

S6. Radiographic Examination

S6.1 The castings shall be examined for internal defects by means of X rays or gamma rays. The inspection procedure shall be in accordance with Guide E 94 and the types

and degrees of discontinuities considered shall be judged by Reference Radio-graphs E 186, E 280, or E 446. The extent of the examination and the basis for acceptance shall be subject to agreement between the manufacturer and the purchaser.

S7. Liquid Penetrant Examination

S7.1 The castings shall be examined for surface discontinuities by means of liquid penetrant inspection. The method of performing the liquid penetrant test shall be in accordance with Practice E 165. The areas to be inspected, the methods and types of liquid penetrants to be used, the developing procedure, and the basis for acceptance shall be as specified on the inquiry or invitation to bid and on the purchase order or contract or both, or as agreed upon between the manufacturer and purchaser.

S8. Magnetic Particle Inspection

S8.1 The castings shall be examined by magnetic particle inspection. The inspection procedure used shall be in accordance with Practice E 709. The extent of examination and the basis for acceptance shall be subject to agreement between the manufacturer and the purchaser.

S9. Ultrasonic Inspection

S9.1 The castings shall be examined ultrasonically in accordance with Practice A 609/A 609M. The extent of the examination and the basis of acceptance shall be subject to agreement between the manufacturer and the purchaser.

S10. Residual Elements

S10.1 An analysis for the elements specified in Table S1 shall be included in those analyses specified in Section 6. The chemical composition thus determined shall conform to the requirements of Table S1.

S11. Charpy Impact Test

S11.1 Charpy impact test properties shall be determined on each heat from a set of three Charpy V-notch specimens.

The test coupons shall be taken as specified for tension specimens in Section 11 and tested at a test temperature agreed upon by the manufacturer and purchaser. The acceptance requirements shall be either energy absorbed or lateral expansion or percent shear area, and shall be that agreed upon by the manufacturer and purchaser. Test specimens shall be prepared as Type A and tested in accordance with Test Methods and Definitions A 370.

S11.2 Absorbed Energy Value, of three specimens shall not be less than that agreed upon by the manufacturer and purchaser, with no more than one value permitted below the minimum average specified and no value permitted below the minimum specified for a single specimen.

S11.3 Lateral Expansion Value, shall be agreed upon by the manufacturer and purchaser.

S11.4 Percent Shear Area, shall be agreed upon by the manufacturer and purchaser.

S12. Drop Weight Test

S12.1 Drop weight test properties shall be determined by preparing and testing either Type P1, P2, or P3 specimens in accordance with Test Method E 208. The test coupons shall be taken as specified for tension specimens in Section 11. The crack starter weld shall be deposited on the surface of the specimen which was nearest to the casting surface. Each test shall consist of at least two specimens tested at a temperature agreed upon by the manufacturer and purchaser. Each specimen shall exhibit a “no break” performance.

TABLE S1
RESIDUAL ELEMENTS

Grade	Copper, max	Nickel, max	Chromium, max	Tungsten, max	Total Contents of These Unspecified Elements, max, %
CP1	0.50	0.50	0.35	0.10	1.00
CP2	0.50	0.50	...	0.10	1.00
CP5	0.50	0.50	...	0.10	1.00
CP5b	0.50	0.50	...	0.10	1.00
CP7	0.50	0.50	...	0.10	1.00
CP9	0.50	0.50	...	0.10	1.00
CP11	0.50	0.50	...	0.10	1.00
CP12	0.50	0.50	...	0.10	1.00
CP15	0.50	0.50	0.35	0.10	1.00
CP21	0.50	0.50	...	0.10	1.00
CP22	0.50	0.50	...	0.10	1.00
CPCA15	0.50	1.00	...	0.10	1.50

SPECIFICATION FOR STRAIGHT-BEAM ULTRASONIC EXAMINATION OF STEEL PLATES



SA-435/SA-435M



[Identical with ASTM Specification A 435/A 435M-90(R07).]

1. Scope

1.1 This specification covers the procedure and acceptance standards for straight-beam, pulse-echo, ultrasonic examination of rolled fully killed carbon and alloy steel plates, $\frac{1}{2}$ in. [12.5 mm] and over in thickness. It was developed to assure delivery of steel plates free of gross internal discontinuities such as pipe, ruptures, or laminations and is to be used whenever the inquiry, contract, order, or specification states that the plates are to be subjected to ultrasonic examination.

1.2 Individuals performing examinations in accordance with this specification shall be qualified and certified in accordance with the requirements of the latest edition of ASNT SNT-TC-1A or an equivalent accepted standard. An equivalent standard is one which covers the qualification and certification of ultrasonic nondestructive examination candidates and which is acceptable to the purchaser.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents, therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Document

2.1 *ASNT Standard:*
SNT-TC-1A

3. Apparatus

3.1 The manufacturer shall furnish suitable ultrasonic equipment and qualified personnel necessary for performing the test. The equipment shall be of the pulse-echo straight beam type. The transducer is normally 1 to $1\frac{1}{8}$ in.

[25 to 30 mm] in diameter or 1 in. [25 mm] square; however, any transducer having a minimum active area of 0.7 in.² [450 mm²] may be used. The test shall be performed by one of the following methods: direct contact, immersion, or liquid column coupling.

3.2 Other search units may be used for evaluating and pinpointing indications.

4. Test Conditions

4.1 Conduct the examination in an area free of operations that interfere with proper functioning of the equipment.

4.2 Clean and smooth the plate surface sufficiently to maintain a reference back reflection from the opposite side of the plate at least 50% of the full scale during scanning.

4.3 The surface of plates inspected by this method may be expected to contain a residue of oil or rust or both. Any specified identification which is removed when grinding to achieve proper surface smoothness shall be restored.

5. Procedure

5.1 Ultrasonic examination shall be made on either major surface of the plate. Acceptance of defects in close proximity may require inspection from the second major surface. Plates ordered in the quenched and tempered condition shall be tested following heat treatment.

5.2 A nominal test frequency of $2\frac{1}{4}$ MHz is recommended. Thickness, grain size, or microstructure of the material and nature of the equipment or method may require a higher or lower test frequency. However, frequencies less than 1 MHz may be used only on agreement with the purchaser. A clear, easily interpreted trace pattern should be produced during the examination.

5.3 Conduct the examination with a test frequency and instrument adjustment that will produce a minimum 50 to a maximum 75% of full scale reference back reflection from the opposite side of a sound area of the plate. While calibrating the instrument, sweep the crystal along the plate surface for a distance of at least 17 or 6 in. [150 mm], whichever is the greater, and note the position of the back reflection. A shift in location of the back reflection during calibration shall be cause for recalibration of the instrument.

5.4 Scanning shall be continuous along perpendicular grid lines on nominal 9 in. [225 mm] centers, or at the manufacturer's option, shall be continuous along parallel paths, transverse to the major plate axis, on nominal 4 in. [100 mm] centers, or shall be continuous along parallel paths parallel to the major plate axis, on 3 in. [75 mm] or smaller centers. A suitable couplant such as water, soluble oil, or glycerin, shall be used.

5.5 Scanning lines shall be measured from the center or one corner of the plate. An additional path shall be scanned within 2 in. [50 mm] of all edges of the plate on the scanning surface.

5.6 Where grid scanning is performed and complete loss of back reflection accompanied by continuous indications is detected along a given grid line, the entire surface area of the squares adjacent to this indication shall be scanned continuously. Where parallel path scanning is performed and complete loss of back reflection accompanied

by continuous indications is detected, the entire surface area of a 9 by 9 in. [225 by 225 mm] square centered on this indication shall be scanned continuously. The true boundaries where this condition exists shall be established in either method by the following technique: Move the transducer away from the center of the discontinuity until the heights of the back reflection and discontinuity indications are equal. Mark the plate at a point equivalent to the center of the transducer. Repeat the operation to establish the boundary.

6. Acceptance Standards

6.1 Any discontinuity indication causing a total loss of back reflection which cannot be contained within a circle, the diameter of which is 3 in. [75 mm] or one half of the plate thickness, whichever is greater, is unacceptable.

6.2 The manufacturer reserves the right to discuss rejectable ultrasonically tested plates with the purchaser with the object of possible repair of the ultrasonically indicated defect before rejection of the plate.

6.3 The purchaser's representative may witness the test.

7. Marking

7.1 Plates accepted in accordance with this specification shall be identified by stamping or stenciling UT 435 adjacent to marking required by the material specification.

SUPPLEMENTARY REQUIREMENTS

The following shall apply only if specified in the order:

- S1.** Instead of the scanning procedure specified by 5.4 and 5.5, and as agreed upon between manufacturer and purchaser, 100% of one major plate surface shall be scanned. Scanning shall be continuous along parallel paths, transverse or parallel to the major plate axis, with not less than 10% overlap between each path.

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SPECIFICATION FOR ALLOY-STEEL TURBINE-TYPE BOLTING MATERIAL SPECIALLY HEAT TREATED FOR HIGH-TEMPERATURE SERVICE



SA-437/SA-437M



(Identical with ASTM Specification A 437/A 437M-06.)

1. Scope

1.1 This specification covers alloy-steel bolting material specially heat treated for high-temperature service, such as steam turbine, gas turbine, and similar uses. This material requires special processing and should not be used in general-purpose applications. The term “bolting material,” as used in this specification, covers rolled or forged bars, bolts, nuts, screws, washers, studs, and stud bolts. The bars shall be hot wrought. The material may be further processed by centerless grinding or by cold drawing.

1.2 The high-temperature properties of the material covered by this specification are dependent upon special heat treatment, which is required. Although the high-temperature properties are not specified, they are implied by control of the chemistry, heat treatment, and room-temperature properties of the material.

NOTE 1— High-temperature tests shall not be required, unless made a matter of agreement between the manufacturer and the purchaser.

1.3 Three levels of bolting strength are covered, designated Grades B4B, B4C, and B4D. Selection will depend on the design and the stresses and service for which the product is to be used.

NOTE 2— When ordering material under this specification, or when incorporating this specification as a reference in any individual specification, the purchaser must designate the steel by identification symbol or analysis, or both, and definitely specify the minimum mechanical properties required as selected from Table 1.

1.4 Supplementary requirements of an optional nature are provided for use at the option of the purchaser. The supplementary requirements shall apply only when specified individually by the purchaser in the purchase order or contract.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable “M” specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 ASTM Standards:

A 962/A 962M Specification for Common Requirements for Steel Fasteners or Fastener Materials, or Both, Intended for Use at Any Temperature from Cryogenic to the Creep Range

3. Common Requirements

3.1 Material and Fasteners supplied to this specification shall conform to the requirements of Specification A 962/A 962M. These requirements include test methods, finish, thread dimensions, marking certification, optional supplementary requirements, and others. Failure to comply with the requirements of Specification A 962/A 962M constitutes nonconformance with this specification. In case of conflict between this specification and Specification A 962/A 962M, this specification shall prevail.

4. Ordering Information

4.1 The inquiry and order should indicate the following:

4.1.1 Specification designation, grade and class, issue date and revision letter,

4.1.2 Quantity (weight or number of pieces),

4.1.3 Description (bars, bolts, nuts, etc.),

4.1.4 Dimensions,

4.1.5 Finish, and

4.1.6 Impact testing of nuts, if required (see Section 9).

5. Discard

5.1 A sufficient discard shall be made from each ingot to ensure freedom from injurious piping and undue segregation.

6. Heat Treatment

6.1 The material Grades B4B and B4C shall be heated to a temperature range of 1875 to 1925°F [1025 to 1050°C] and liquid quenched to below 600°F [316°C]. The material Grades B4B and B4C shall then be uniformly reheated for tempering at a tempering temperature at least 100°F [55°C] higher than the proposed operating temperature but not less than 1150°F [620°C], then air or furnace cooled to room temperature. The material shall be at the tempering temperature for a minimum of 2 h. Double tempering may be used to enhance properties.

6.2 Material Grade B4D shall be heated to a temperature range of 1700 to 1750°F [925 to 954°C] and oil quenched. The material shall then be uniformly reheated or tempered at a temperature of 1200°F [650°C] minimum, followed by air or furnace cooling to room temperature.

6.3 Stress relieving treatment of the bar material is required after any stretcher, roller, or rotary-straightening or cold-finishing operations performed after heat treatment for mechanical properties. Local gagging or press straightening to correct camber limitations in excess of $\frac{1}{4}$ in. in any 5 ft [6 mm in any 1.5 m] shall be followed by a stress relieving heat treatment. The minimum stress relieving temperature shall be 100°F [55°C] below the minimum tempering temperature as shown in 6.1 for Grades B4B and B4C or in 6.2 for Grade B4D.

7. Chemical Composition

7.1 The material shall conform to the requirements as to chemical composition specified in Table 2.

8. Tensile Requirements

8.1 The material shall conform to the requirements as to tensile properties prescribed in Table 1 at room temperature after heat treatment.

8.2 The longitudinal axis of the test specimen shall be parallel to the direction of rolling.

9. Impact Requirements

9.1 The material Grades B4B, B4C, and B4D shall conform to the requirements as to impact properties prescribed in Table 3 at room temperature after heat treatment.

10. Hardness Tests

10.1 The material Grades B4B, B4C, and B4D shall conform to the requirements as to hardness as prescribed in Table 4 and Table 5 at room temperature after heat treatment.

11. Workmanship, Finish, and Appearance

11.1 Standard permissible variations of bars shall be as set forth in Table 6.

12. Nuts and Washers

12.1 When specified by the purchaser, the nuts shall be subject to the impact and tension requirements of this specification. The tests shall be made on test specimens taken from the bar or plate used in the manufacture of the nuts.

13. Threads

13.1 All threads shall be formed after heat treatment.

14. Nondestructive Inspection

14.1 Each bar or forged blank of starting material shall be subjected to NDE following final heat treatment. The method used shall be either the Eddy Current (EC), the Magnetic Particle (MPI) (wet or dry), the Liquid Penetrant (LPI), the Ultrasonic (UT), or the Visual Testing (VT), at the option of the producer. For LPI or MPI, linear indications (those indications longer than $\frac{1}{16}$ in. [1.5 mm] with a length greater than three times their width) are unacceptable.

able. For UT or ET, reject levels for linear indications shall be based on the alarm response from a surface notch with a maximum depth of 0.012 in. [.30 mm] in a calibration bar. Product being subjected to VT shall be pickled prior to inspection. VT indications longer than $\frac{1}{8}$ in. are prohibited.

15. Keywords

15.1 bolts — steel; chromium alloy steel; fasteners — steel; marking on fasteners; nuts — steel; steel bars — alloy; steel bolting material; temperature service applications — high; turbine materials

TABLE 1
TENSILE REQUIREMENTS

Grade	Diameter, in. [mm]	Tensile Strength, min, ksi [MPa]	Yield Strength (0.2% offset) min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, %	Reduction of Area, min, %
B4B	...	145 [1000]	105 [720]	13	30
B4C	...	115 [790]	85 [585]	18	50
B4D	2½ [65] and under	125 [860]	105 [720]	18	50
	over 2½ to 4 [65 to 100]	110 [760]	95 [655]	17	45
	over 4 to 7 [100 to 180]	100 [690]	85 [585]	16	45

TABLE 2
CHEMICAL REQUIREMENTS^A

Element	Grades B4B, B4C ^B		Grade B4D	
	Range, %	Product Variation, %, Over or Under	Range, %	Product Variation, %, Over or Under
Carbon	0.20–0.25	0.02	0.36–0.44	0.02
Manganese	0.50–1.00	0.03	0.45–0.70	0.03
Phosphorus, max	0.025	0.005 over	0.04	0.005 over
Sulfur, max	0.025	0.005 over	0.04	0.005 over
Silicon	0.20–0.50	0.05	0.20–0.35	0.02
Nickel	0.50–1.00	0.03	...	...
Chromium	11.00–12.50	0.15	0.80–1.15	0.05
Molybdenum	0.90–1.25	0.05	0.50–0.65	0.03
Vanadium	0.20–0.30	0.03	0.25–0.35	0.03
Tungsten	0.90–1.25	0.05	...	...
Aluminum, max ^C	0.05	...	0.015	...
Titanium, max	0.05	...	...	...
Tin, max	0.04	...	...	...

^A Steel to which lead has been added shall not be used.

^B UNS S42200.

^C Total, Soluble + Insoluble.

TABLE 3
IMPACT REQUIREMENTS

Grade	Minimum Impact Value, ft · lbf [J]
B4B	10 [14]
B4C	25 [34]
B4D ⁴	25 [34]

⁴ For bars over 5 in. [127 mm] diameter only.

TABLE 4
HARDNESS REQUIREMENTS FOR BOLTS AND STUDS

Grade	Brinell Hardness Number, max
B4B	331
B4C	277
B4D	302

TABLE 5
HARDNESS REQUIREMENTS FOR NUTS AND
WASHERS

Grade	Brinell Hardness Number	Rockwell Hardness Number
B4B	293–341	C 31–37
B4C	229–277	C 21–29
B4D	263–311	C 27–33

TABLE 6
PERMISSIBLE VARIATIONS IN SIZE OF HOT-ROLLED BARS

Specified Size, in. [mm]	Permissible Variations from Specified Size, in. [mm]		Out of Round, in. [mm]
	Over	Under	
$\frac{5}{16}$ [8] and under	0.005 [0.13]	0.005 [0.13]	0.008 [0.20]
Over $\frac{5}{16}$ to $\frac{7}{16}$ [8 to 11], incl	0.006 [0.15]	0.006 [0.15]	0.009 [0.23]
Over $\frac{7}{16}$ to $\frac{5}{8}$ [11 to 16], incl	0.007 [0.18]	0.007 [0.18]	0.010 [0.25]
Over $\frac{5}{8}$ to $\frac{7}{8}$ [16 to 22], incl	0.008 [0.20]	0.008 [0.20]	0.012 [0.30]
Over $\frac{7}{8}$ to 1 [22 to 25], incl	0.009 [0.23]	0.009 [0.23]	0.013 [0.33]
Over 1 to $1\frac{1}{8}$ [25 to 29], incl	0.010 [0.25]	0.010 [0.25]	0.015 [0.38]
Over $1\frac{1}{8}$ to $1\frac{1}{4}$ [29 to 32], incl	0.011 [0.28]	0.011 [0.28]	0.016 [0.41]
Over $1\frac{1}{4}$ to $1\frac{3}{8}$ [32 to 35], incl	0.012 [0.30]	0.012 [0.30]	0.018 [0.46]
Over $1\frac{3}{8}$ to $1\frac{1}{2}$ [35 to 38], incl	0.014 [0.36]	0.014 [0.36]	0.021 [0.53]
Over $1\frac{1}{2}$ to 2 [38 to 50], incl	$\frac{1}{64}$ [0.4]	$\frac{1}{64}$ [0.4]	0.023 [0.58]
Over 2 to $2\frac{1}{2}$ [50 to 65], incl	$\frac{1}{32}$ [0.8]	0	0.023 [0.58]
Over $2\frac{1}{2}$ to $3\frac{1}{2}$ [65 to 90], incl	$\frac{3}{64}$ [1.2]	0	0.035 [0.89]
Over $3\frac{1}{2}$ to $4\frac{1}{2}$ [90 to 115], incl	$\frac{1}{16}$ [1.6]	0	0.046 [1.17]
Over $4\frac{1}{2}$ to $5\frac{1}{2}$ [115 to 140], incl	$\frac{5}{64}$ [2.0]	0	0.058 [1.47]
Over $5\frac{1}{2}$ to $6\frac{1}{2}$ [140 to 165], incl	$\frac{1}{8}$ [3.2]	0	0.070 [1.78]
Over $6\frac{1}{2}$ to $7\frac{1}{2}$ [165 to 190], incl	$\frac{5}{32}$ [4.0]	0	0.085 [2.16]

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order; in which event the specified tests shall be made before shipment of the product.

S1. Non-Destructive Examination

S1.1 NDE is required following all machining and threading. The acceptance criteria of 14.1 shall apply.

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SPECIFICATION FOR HEX CAP SCREWS, BOLTS AND STUDS, STEEL, HEAT TREATED, 120/105/90 ksi MINIMUM TENSILE STRENGTH, GENERAL USE (10)



SA-449

(Identical with ASTM Specification A 449-07b, except for requiring that all mating fastener components be coated by the same zinc-coating process in 5.1.4, the deletion of private label distributor in 16.1 and 16.3.2, and the removal of reference to bolts in para. 6.4.)

1. Scope

1.1 This specification covers quenched and tempered steel hex cap screws, bolts, and studs having a minimum tensile strength of 120 ksi for diameters 1.0 in. and smaller; 105 ksi for diameters over 1.0 in. to 1½ in.; and 90 ksi for diameters 1¾ in. to 3.0 in. inclusive. The term “fasteners” in this specification denotes hex cap screws, bolts, and studs.

1.2 The fasteners are intended for general engineering use.

1.3 The fasteners are furnished in diameters ¼ to 3.0 in. inclusive. They are designated by type denoting chemical composition as follows:

Type	Description
Type 1	Plain carbon steel, carbon boron steel, alloy steel, or alloy boron steel
Type 2	Withdrawn 2003
Type 3	Weathering steel

1.4 Terms used in this specification are defined in Terminology F 1789 unless otherwise defined in this specification.

1.5 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information purposes only.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

A 563 Specification for Carbons and Alloy Steel Nuts

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel

D 3951 Practice for Commercial Packaging

F 436 Specification for Hardened Steel Washers

F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets

F 788/F 788M Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series

F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

F 1789 Terminology for F16 Mechanical Fasteners

F 2329 Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners

G 101 Guide for Estimating the Atmospheric Corrosion Resistance of Low-Alloy Steels

2.2 ASME Standards:

B1.1 Unified Screw Threads

B18.2.1 Square and Hex Bolts and Screws

B18.24 Part Identifying Number (PIN) Code System Standard for B18 Fastener Products

3. Ordering Information

3.1 Orders for fasteners under this specification shall include the following:

3.1.1 Quantity (number of pieces),

3.1.2 Size, including nominal diameter and length,

3.1.3 Name of product,

3.1.4 Type, that is, Type 1, or Type 3 as required,

3.1.5 ASTM designation and year of issue, and

3.1.6 Other components such as nuts and washers if required.

3.1.7 *Hot-Dip or Mechanically Deposited Zinc Coatings* — For hot-dip or mechanically deposited zinc coatings covered by 5.1 and requiring over-tapped nuts, specify the zinc coating process required, that is, hot-dip, mechanically deposited, or no preference (see 5.1).

3.1.8 *Other Coatings* — Specify other protective coating if required (see 5.2).

3.1.9 Specify if inspection at point of manufacture is required.

3.1.10 Test reports if required.

3.1.11 Supplementary or special requirements.

3.1.12 For establishment of a part identifying system, see ASME B18.24.

NOTE 1 — A typical ordering description follows: 1000 pieces $\frac{1}{8}$ in. diameter \times 4.0 in. long hex cap screw, Type 1, ASTM A 449-XX, each with one finished hex nut ASTM A 563, Grade DH. Each component mechanically zinc coated in accordance with B 695, Class 5, Type II.

3.2 Suitable Nuts and Washers:

3.2.1 Suitable nuts are covered in Specification A 563. Unless otherwise specified, the grade and style of nut shall be as follows:

Fastener Size and Surface Finish	Nut Grade and Style ^A
$\frac{1}{4}$ to $1\frac{1}{2}$ in., plain (or with coating of insufficient thickness to require over-tapped nuts)	B, hex
Over $1\frac{1}{2}$ to 3 in., plain (or with coating of insufficient thickness to require over-tapped nuts)	A, heavy hex
$\frac{1}{4}$ to 3 in., zinc-coated (or with a coating thickness requiring over-tapped nuts)	DH, heavy hex
$\frac{1}{4}$ to 3 in., Type 3	C3, DH3, heavy hex

^A Nuts of other grades and styles having specified proof load stresses (Specification A 563, Table 3) greater than the specified grade and style of nuts are suitable.

3.2.2 Unless otherwise specified, washers ordered with fasteners shall be furnished to the requirements of Specification F 436, Type 1 or Specification F 436, Type 3. Washers for A 449 Type 3 fasteners shall conform to Specification F 436 Type 3.

4. Materials and Manufacture

4.1 Heat Treatment:

4.1.1 Type 1 fasteners produced from medium carbon steel shall be quenched in a liquid medium from the austenitizing temperature.

4.1.2 Type 1 fasteners produced from medium carbon steel to which chromium, nickel, molybdenum, or

boron were intentionally added, and Type 3 fasteners, shall be quenched in oil from the austenitizing temperature.

4.1.3 Type 1 and Type 3 fasteners, regardless of the steel used, shall be tempered by reheating to not less than 800°F.

4.2 *Threading* — Threads shall be rolled, cut, or ground.

4.3 *Secondary Processing* — If any processing which can affect the mechanical properties of the fasteners is performed after the initial testing, the fasteners shall be retested for all specified mechanical properties affected by the reprocessing.

5. Protective Coatings

5.1 *Zinc, Hot Dip, and Mechanically Deposited Requiring Over-tapped Nuts:*

5.1.1 When zinc-coated fasteners are required, the purchaser shall specify the zinc-coating process, such as, hot-dip, mechanically deposited, or no preference.

5.1.2 When hot dip is specified, the fasteners shall be zinc coated by the hot-dip process in accordance with the requirements of Specification F 2329.

5.1.3 When mechanically deposited is specified, the fasteners shall be zinc coated by the mechanical deposition process in accordance with the requirements of Class 55 of Specification B 695.

5.1.4 When no preference is specified, the supplier may furnish either a hot-dip zinc coating in accordance with Specification F 2329, or a mechanically deposited zinc coating in accordance with Specification B 695, Class 55. All mating components shall be coated by the same zinc coating process, and the suppliers' option shall be limited to one process per item with no mixed processes in a lot.

NOTE 2 — When the intended application requires that assembled tension exceeds 50% of minimum bolt or stud proof load, an anti-galling lubricant may be needed. Application of such a lubricant to nuts and a test of the lubricant efficiency are provided in Supplementary Requirement S1 of Specification A 563 and should be specified when required.

5.2 Other Coatings:

5.2.1 When other coatings are required, the purchaser shall specify the coating specification, including the classification codes or grade numbers to identify the coating material, thickness, supplemental treatments, or other requirements to define the coating. The fasteners shall be coated in accordance with and conform to the specified coating specification.

5.2.2 When a specification does not apply, the purchaser shall specify the desired coating, coating thickness, supplemental treatments, or other requirements to define the coating.

6. Chemical Composition

6.1 Type 1 fasteners shall be plain carbon steel, carbon boron steel, alloy steel, or alloy boron steels, at the manufacturer's option, conforming to the requirements in Table 1.

6.2 Type 3 fasteners shall be weathering steel and shall conform to one of the chemical compositions specified in Table 2. The selection of the chemical composition, A, B, C, D, E or F, shall be at the option of the manufacturer. See Guide G 101 for methods of estimating the atmospheric corrosion resistance of low alloy steel.

6.3 Product analyses made on finished fasteners representing each lot shall conform to the product analysis requirements specified in Table 1 or Table 2, as applicable.

6.4 Heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted. Compliance shall be based on certification that heats of steel having any of the listed elements intentionally added were not used.

6.5 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A 751.

7. Mechanical Properties

7.1 Hardness — The fasteners shall conform to the hardness specified in Table 3. See Table 3, Note A.

7.2 Tensile Properties:

7.2.1 Except as permitted in 7.2.2 for long fasteners and 7.2.3 for short fasteners, hex cap screws and hex and square head bolts in sizes 1.00 in. and smaller having a length of $2\frac{1}{4}D$ and longer and sizes $1\frac{1}{8}$ to $1\frac{1}{2}$ in. inclusive having a length of 3D and longer shall be wedge tested full size. Bolts with heads other than hex or square shall be axially tested. Both wedge and axially tested hex cap screws and bolts shall conform to the proof load or alternative proof load, and minimum wedge tensile load in Tables 4 and 5, as applicable. The load applied during proof load testing shall be equal to or greater than the proof load in Table 4 or Table 5 as applicable.

7.2.2 Hex cap screws and square head bolts larger than $1\frac{1}{2}$ in. diameter, other than those excepted in 7.2.3, shall preferably be tested full size and when so tested shall conform to the tensile strength and either the specified proof load or yield strength requirements in Tables 4 and 5, as applicable. When equipment of sufficient capacity for full size testing is not available, or when the length of the bolt makes full size testing impractical, machined specimens shall be tested and shall conform to the requirements of Table 6.

7.2.3 Sizes 1.00 in. and smaller having a length shorter than $2\frac{1}{4}D$ down to 2D inclusive, which cannot be

wedge tensile tested shall be axially tension tested full size and shall conform to the minimum tensile load and proof load or alternate proof load specified in Tables 4 and 5. Sizes 1.00 in. and smaller having a length shorter than 2D which cannot be axially tensile tested shall be qualified on the basis of hardness.

7.2.4 Studs 3D and longer shall be axially tension tested full size and shall conform to the tensile and proof load or alternate proof load specified in Table 4 and Table 5, as applicable. When equipment for full size testing is not available, or when the studs are too long for full size testing, machined specimens shall be tested and shall conform to the tensile requirements in Table 6.

7.2.5 If fasteners are subjected to both hardness and tensile tests, the tensile test results shall take precedence in the event of low hardness test results.

7.2.6 If fasteners are subjected to both full size and machined specimen tests, the full size test results shall take precedence if the results of the two methods differ.

8. Dimensions

8.1 Head and Body:

8.1.1 Hex Cap Screws — Unless otherwise specified, hex cap screws shall be furnished with dimensions conforming to ASME B18.2.1.

8.1.2 Bolts — When styles other than specified in 8.1.1 are required, they shall have dimensions conforming to those specified by the purchaser.

8.1.3 Studs — Studs shall have dimensions conforming to those specified by the purchaser.

8.2 Threads:

8.2.1 Uncoated — Unless otherwise specified, uncoated threads shall be the Unified Coarse Thread Series as specified in the latest issue of ASME B1.1, and shall have Class 2A tolerances.

8.2.2 Coated — Unless otherwise specified, zinc-coated bolts, to be used with zinc-coated nuts or tapped holes, which are tapped oversize in accordance with Specification A 563, shall have UNC Class 2A threads before hot-dip or mechanically deposited zinc-coating. After zinc coating, the pitch diameter and major diameter shall not exceed the Class 2A limits by more than the following amounts:

Nominal Diameter (in.)	Oversize Limit, in. ^A	
	Hot-Dip Zinc	Mechanical Zinc
1/4	0.016	0.012
5/16, 3/8	0.017	0.012
7/16, 1/2	0.018	0.012
9/16, 5/8, 3/4	0.020	0.013
7/8	0.022	0.015
1.0 to 1 1/4	0.024	0.016
1 3/8, 1 1/2	0.027	0.018
1 3/4 to 3.0, incl	0.050	0.033

^AHot-dip zinc nuts are tapped oversize after coating and mechanical zinc coated nuts are tapped oversize before coating.

8.2.3 Unless otherwise specified, fasteners electroplated or mechanically coated to 0.0005 in. or less, threads prior to plating shall conform to ASME B1.1 Class 2A and after plating shall not exceed the Class 3A maximum limits, that is, Class 2A plus the allowance.

9. Workmanship, Finish, and Appearance

9.1 Surface discontinuity limits, inspection, and evaluation shall be in accordance with Specification F 788/F 788M.

10. Number of Tests and Retests

10.1 Testing Responsibility:

10.1.1 Each lot shall be tested by the manufacturer prior to shipment in accordance with the lot identification control quality assurance plan in 10.2-10.5.

10.1.2 When fasteners are furnished by a source other than the manufacturer, the responsible party as defined in 15.1 shall be responsible for assuring all tests have been performed and the fasteners comply with the requirements of this specification (see 4.3).

10.2 Purpose of Lot Inspection — The purpose of a lot inspection program is to ensure that each lot conforms to the requirements of this specification. For such a plan to be fully effective, it is essential that secondary processors, distributors, and purchasers maintain the identification and integrity of each lot until the product is installed.

10.3 Lot Processing — All fasteners shall be processed in accordance with a lot identification-control quality assurance plan. The manufacturer, secondary processors, and distributors shall identify and maintain the integrity of each lot from raw material selection through all operations and treatments to final packing and shipment. Each lot shall be assigned its own lot-identification number, each lot shall be tested, and the inspection test reports for each lot shall be retained.

10.4 Lot Definition:

10.4.1 Standard Lot — A lot shall be a quantity of uniquely identified fasteners of the same nominal size and length produced consecutively at the initial operation from a single mill heat of material and processed at one time, by the same processor in the same manner so that statistical sampling is valid. The identity of the lot and lot integrity shall be maintained throughout all subsequent operations and packaging.

10.5 Number of Tests — The minimum number of tests from each lot for the tests specified below shall be as follows:

Tests	Number of Test in Accordance With
Hardness, tensile strength, proof load	Guide F 1470
Coating weight/thickness	The referenced coating specification ^A
Surface discontinuities	Specification F 788/F 788M
Dimensions and thread fit	ASME B18.2.1

^AGuide F 1470 if the coating specification does not specify a testing frequency.

11. Test Methods

11.1 Tensile, proof load, and hardness tests shall be conducted in accordance with Test Methods F 606.

11.2 Tensile strength for hex cap screws and hex and square bolts shall be determined using the wedge or axial tension testing method of full size product method or the machined test specimens method depending on size and length as specified in 7.2.2–7.2.6. Bolts with heads other than hex or square shall be axially tested. Fracture on full size tests shall be in the body or threads of the fastener without a fracture at the junction of the head and body.

11.3 Studs shall be tested by the axial tension method as described in the second paragraph of axial tension testing of full size products in the Test Methods section of Test Methods F 606.

11.4 Proof load shall be determined using Method 1, length measurement, or Method 2, yield strength, at the option of the manufacturer.

12. Inspection

12.1 If the inspection described in 12.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.

12.2 The purchaser's representative shall have free entry to all parts of the manufacturer's works or supplier's place of business that concern the manufacture or supply of

the fasteners. The manufacturer shall afford the purchaser's representative all reasonable facilities to satisfy him that the fasteners are being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser's representative shall be made before shipment, and shall be conducted as not to interfere unnecessarily with the operation of the manufacturer's works or supplier's place of business.

13. Rejection and Rehearing

13.1 Disposition of nonconforming fasteners shall be in accordance with the section on Disposition of Nonconforming Lots of Guide F 1470.

14. Certification

14.1 When specified on the purchase order, the manufacturer or supplier, whichever is the responsible party as defined in Section 15, shall furnish the purchaser test reports which include the following:

14.1.1 Heat analysis, heat number, and a statement certifying that heats having the elements listed in 6.4 intentionally added were not used to produce the fasteners,

14.1.2 Results of hardness, tensile, an proof load tests,

14.1.3 Zinc coating measured coating weight/thickness for coated fasteners,

14.1.4 Statement of compliance with dimensional and thread fit requirements,

14.1.5 Lot number and purchase order number,

14.1.6 Complete mailing address of responsible party, and

14.1.7 Title and signature of the individual assigned certification responsibility by the company officers.

14.2 Failure to include all the required information on the test report shall be cause for rejection.

15. Responsibility

15.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser.

16. Product Marking

16.1 *Manufacturers Identification* — All hex cap screws and bolts and one end of studs $\frac{3}{8}$ in. and larger, and whenever feasible studs smaller than $\frac{3}{8}$ in., shall be marked by the manufacturer with a unique identifier to identify the manufacturer.

16.2 *Type Identification:*

16.2.1 Type 1 hex cap screws and bolts and one end of Type 1 studs $\frac{3}{8}$ in. and larger, and whenever feasible studs smaller than $\frac{3}{8}$ in., shall be marked "A 449."

16.2.2 All Type 3 hex cap screws, bolts, and studs shall be marked to indicate that they are produced from weathering steel. Heads of type 3 hex cap screws and bolts shall be marked "A 449" underlined. Type 3 studs $\frac{3}{8}$ in. and larger, and whenever feasible studs smaller than $\frac{3}{8}$ in., shall be marked "A 449" underlined on at least one end. Studs under $\frac{3}{8}$ in. not marked "A 449" underlined, shall be marked with the use of additional marks to indicate that they are produced from weathering steel.

16.3 *Marking Location and Methods:*

16.3.1 All markings shall be located on the top of a hex cap screw and bolt heads and on one end of studs and shall be either raised or depressed at the manufacturer's option.

16.3.2 Type and manufacturer's identification shall be separate and distinct. The two identifications shall preferably be in different locations and, when on the same level, shall be separated by at least two spaces.

16.4 *Acceptance Criteria* — Fasteners which are not marked in accordance with these provisions shall be considered nonconforming and subject to rejection.

17. Packaging and Package Marking

17.1 *Packaging:*

17.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

17.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

17.2 *Package Marking:*

17.2.1 Each shipping unit shall include or be plainly marked with the following information:

17.2.1.1 ASTM designation and type,

17.2.1.2 Size,

17.2.1.3 Name and brand or trademark of the manufacturer,

17.2.1.4 Number of pieces,

17.2.1.5 Lot number,

17.2.1.6 Purchase order number, and

17.2.1.7 Country of origin.

18. Keywords

18.1 bolts; carbon steel; hex cap screws; steel; studs

TABLE 1
CHEMICAL REQUIREMENTS FOR TYPE 1
FASTENERS

Element	Carbon Steel	
	Heat Analysis	Product Analysis
Carbon	0.30–0.52	0.28–0.55
Manganese, min	0.60	0.57
Phosphorus, max	0.040	0.048
Sulfur, max	0.050	0.058
Silicon	0.15–0.30	0.13–0.32

Element	Carbon Steel	
	Heat Analysis	Product Analysis
Carbon	0.30–0.52	0.28–0.55
Manganese, min	0.60	0.57
Phosphorus, max	0.040	0.048
Sulfur, max	0.050	0.058
Silicon	0.10–0.30	0.08–0.32
Boron	0.0005–0.003	0.0005–0.003

Element	Carbon Steel	
	Heat Analysis	Product Analysis
Carbon	0.30–0.52	0.28–0.55
Manganese, min	0.60	0.57
Phosphorus, max	0.035	0.040
Sulfur, max	0.040	0.045
Silicon	0.15–0.35	0.13–0.37
Alloying Elements	^A	^A

Element	Carbon Steel	
	Heat Analysis	Product Analysis
Carbon	0.30–0.52	0.28–0.55
Manganese, min	0.60	0.57
Phosphorus, max	0.035	0.040
Sulfur, max	0.040	0.045
Silicon	0.15–0.35	0.13–0.37
Boron	0.0005–0.003	0.0005–0.003
Alloying Elements	^A	^A

^A Steel, as defined by the American Iron and Steel Institute, shall be considered to be alloy when the maximum of the range given for the content of alloying elements exceeds one or more of the following limits: manganese, 1.65%; silicon, 0.60%; copper, 0.60% or in which a definite range or a definite minimum quantity of any of the following elements is specified or required within the limits of the recognized field of constructional alloy steels: aluminum, chromium up to 3.99%, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any other alloying elements added to obtain a desired alloying effect.

TABLE 2
CHEMICAL REQUIREMENTS FOR TYPE 3 FASTENERS

Element	Composition, %					
	Type 3 Fasteners ^A					
	A	B	C	D	E	F
Carbon:						
Heat analysis	0.33–0.40	0.38–0.48	0.15–0.25	0.15–0.25	0.20–0.25	0.20–0.25
Product analysis	0.31–0.42	0.36–0.50	0.14–0.25	0.14–0.25	0.18–0.27	0.19–0.25
Manganese:						
Heat analysis	0.90–1.20	0.70–0.90	0.80–1.35	0.40–1.20	0.60–1.00	0.90–1.20
Product analysis	0.86–1.24	0.67–0.93	0.76–1.39	0.36–1.24	0.56–1.04	0.86–1.24
Phosphorus:						
Heat analysis	0.035 max.	0.06–0.12	0.035 max.	0.035 max.	0.035 max.	0.035 max.
Product analysis	0.040 max.	0.06–0.125	0.040 max.	0.040 max.	0.040 max.	0.040 max.
Sulfur:						
Heat analysis	0.040 max.	0.040 max.	0.040 max.	0.040 max.	0.040 max.	0.040 max.
Product analysis	0.045 max.	0.045 max.	0.045 max.	0.045 max.	0.045 max.	0.045 max.
Silicon:						
Heat analysis	0.15–0.35	0.30–0.50	0.15–0.35	0.25–0.50	0.15–0.35	0.15–0.35
Product analysis	0.13–0.37	0.25–0.55	0.13–0.37	0.20–0.55	0.13–0.37	0.13–0.37
Copper:						
Heat analysis	0.25–0.45	0.20–0.40	0.20–0.50	0.30–0.50	0.30–0.60	0.20–0.40
Product analysis	0.22–0.48	0.17–0.43	0.17–0.53	0.27–0.53	0.27–0.53	0.17–0.43
Nickel:						
Heat analysis	0.25–0.45	0.50–0.80	0.25–0.50	0.50–0.80	0.30–0.60	0.20–0.40
Product analysis	0.22–0.48	0.47–0.83	0.22–0.53	0.47–0.83	0.27–0.63	0.17–0.43
Chromium:						
Heat analysis	0.45–0.65	0.50–0.75	0.30–0.50	0.50–1.00	0.60–0.90	0.45–0.65
Product analysis	0.42–0.68	0.47–0.83	0.27–0.53	0.45–1.05	0.55–0.95	0.42–0.68
Vanadium:						
Heat analysis	<i>B</i>	<i>B</i>	0.020 min.	<i>B</i>	<i>B</i>	<i>B</i>
Product analysis	<i>B</i>	<i>B</i>	0.010 min.	<i>B</i>	<i>B</i>	<i>B</i>
Molybdenum:						
Heat analysis	<i>B</i>	0.06 max.	<i>B</i>	0.10 max.	<i>B</i>	<i>B</i>
Product analysis	<i>B</i>	0.07 max.	<i>B</i>	0.11 max.	<i>B</i>	<i>B</i>
Titanium:						
Heat analysis	<i>B</i>	<i>B</i>	<i>B</i>	0.05 max.	<i>B</i>	<i>B</i>
Product analysis	<i>B</i>	<i>B</i>	<i>B</i>	0.06 max.	<i>B</i>	<i>B</i>

NOTES:

^A A, B, C, D, E, and F are classes of material used for Type 3 fasteners. Selection of a class shall be at the option of the bolt manufacturer.

^B These elements are not specified or required.

TABLE 3
HARDNESS REQUIREMENTS FOR HEX CAP SCREWS, BOLTS, AND STUDS

Nominal Diameter, in.	Length, in.	Brinell		Rockwell C	
		Min.	Max.	Min.	Max.
$\frac{1}{4}$ to 1, inclusive	Less than 2D ^A	253	319	25	34
	2D and over	...	319	...	34
Over 1 to 1 $\frac{1}{2}$, inclusive	Less than 3D ^A	223	286	19	30
	3D and over	...	286	...	30
Over 1 $\frac{1}{2}$ to 3, inclusive	Less than 3D ^A	183	235	...	...
	3D and over	...	235	...	...

NOTE:

^A Hex cap screws and bolts larger than 1.00 in. diameter and shorter than 3D and all studs shorter than 3D are subject only to minimum and maximum hardness.

D = Nominal diameter or thread size

TABLE 4
TENSILE LOAD REQUIREMENTS FOR COARSE-THREAD FULL-SIZE HEX CAP SCREWS, BOLTS AND STUDS

Bolt or Stud Diameter, in.	Threads per inch ^A	Stress Area, ^B in. ²	Tensile Load, min, lbf ^C	Proof Load, Length Measurement Method, lbf ^C	Alternative Proof Load, Yield Strength Method (0.2% Offset), min, lbf ^C
Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
1/4	20	0.0318	3 800	2 700	2 900
5/16	18	0.0524	6 300	4 450	4 800
3/8	16	0.0775	9 300	6 600	7 100
7/16	14	0.1063	12 750	9 050	9 800
1/2	13	0.1419	17 050	12 050	13 050
9/16	12	0.182	21 850	15 450	16 750
5/8	11	0.226	27 100	19 200	20 800
3/4	10	0.334	40 100	28 400	30 700
7/8	9	0.462	55 450	39 250	42 500
1	8	0.606	72 700	51 500	55 750
1 1/8	7	0.763	80 100	56 450	61 800
1 1/4	7	0.969	101 700	71 700	78 500
1 3/8	6	1.155	121 300	85 450	93 550
1 1/2	6	1.405	147 500	104 000	113 800
1 3/4	5	1.90	171 000	104 500	110 200
2	4 1/2	2.50	225 000	137 500	145 000
2 1/4	4 1/2	3.25	292 500	178 750	188 500
2 1/2	4	4.00	360 000	220 000	232 000
2 3/4	4	4.93	443 700	271 150	286 000
3	4	5.97	537 300	328 350	346 200

NOTES:

^A For 8 threads per in., sizes 1 1/8 to 1 1/2 in., inclusive, stresses of 105 000 psi, 74 000 psi, and 81 000 psi shall be used for calculating the values in columns 4, 5, and 6 respectively.

^B The stress area is taken from ASME B1.1 which uses the equation below to calculate the values:

$$A_s = 0.7854 [D - (0.9743/n)]^2$$

where:

A_s = stress area, in.²,
 D = nominal diameter, and
 n = threads per inch

^C Values tabulated are based on the following:

Bolt Size, in.	Column 4, psi	Column 5, psi	Column 6, psi
1/4 to 1, incl.	120 000	85 000	92 000
1 1/8 to 1 1/2, incl.	105 000	74 000	81 000
1 3/4 to 3, incl.	90 000	55 000	58 000

TABLE 5
TENSILE LOAD REQUIREMENTS FOR FINE-THREAD FULL-SIZE HEX CAP SCREWS, BOLTS AND STUDS

Bolt or Stud Diameter, in.	Threads per inch	Stress Area, ^A in. ²	Tensile Load, min, lbf ^B	Proof Load, Length Measurement Method, lbf ^B	Alternative Proof Load, Yield Strength Method (0.2% Offset), min, lbf ^B
Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
1/4	28	0.0364	4 350	3 100	3 500
5/16	24	0.0580	6 950	4 950	5 350
3/8	24	0.0878	10 550	7 450	8 100
7/16	20	0.1187	14 500	10 100	10 900
1/2	20	0.1599	19 200	13 600	14 700
9/16	18	0.203	24 350	17 250	18 700
5/8	18	0.256	30 700	21 750	23 500
3/4	16	0.373	44 750	31 700	34 300
7/8	14	0.509	61 100	43 250	46 800
1	12	0.663	79 550	56 350	61 000
1 1/8	12	0.856	89 900	63 350	69 350
1 1/4	12	1.073	112 650	79 400	86 900
1 3/8	12	1.315	138 100	97 300	106 500
1 1/2	12	1.581	166 000	117 000	128 000

^A See footnote B in Table 4.

^B See footnote C in Table 4.

TABLE 6
TENSILE STRENGTH REQUIREMENTS FOR SPECIMENS MACHINED FROM HEX CAP SCREWS, BOLTS AND STUDS

Nominal Diameter, in.	Tensile Strength, min, psi	Yield Strength, min, psi	Elongation in 4 <i>D</i> , min, %	Reduction of Area, min, %
1/4 to 1, incl	120 000	92 000	14	35
Over 1 to 1 1/2, incl	105 000	81 000	14	35
Over 1 1/2 to 3, incl	90 000	58 000	14	35

SUPPLEMENTARY REQUIREMENT

S1. Marking

S1.1 Studs that are continuously threaded with the same class of thread shall be marked on each end with the marking required by Section 16.

S1.2 Marking small sizes (customarily less than 0.375 in.) may not be practical. Consult the producer for the minimum size that can be marked.

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SPECIFICATION FOR GENERAL REQUIREMENTS FOR CARBON, FERRITIC ALLOY, AND AUSTENITIC ALLOY STEEL TUBES



SA-450/SA-450M



(Identical with ASTM Specification A 450/A 450M-96.)

1. Scope

1.1 This specification covers a group of requirements which, with the exceptions of 4.3 and Sections 5, 6, 17, 18, 19, 20, 21, 22, and 23, are mandatory requirements to the following ASTM tubular product specifications:

Title of Specification	ASTM Designation ^A	Title of Specification	ASTM Designation ^A
Seamless Low-Carbon and Carbon-Molybdenum Steel Still Tubes for Refinery Service	A 161	Seamless and Welded Austenitic Stainless Steel Tubing for General Service	A 269
Electric-Resistance-Welded Carbon Steel and Carbon-Manganese Steel Boiler Tubes	A 178/A 178M	Seamless and Welded Austenitic Stainless Steel Sanitary Tubing	A 270
Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes	A 179/A 179M	Seamless Austenitic Chromium-Nickel Steel Still Tubes for Refinery Service	A 271
Seamless Carbon Steel Boiler Tubes for High-Pressure Service	A 192/A 192M	Seamless and Welded Carbon and Alloy-Steel Tubes for Low-Temperature Service	A 334/A 334M
Seamless Cold-Drawn Intermediate Alloy-Steel Heat-Exchanger and Condenser Tubes	A 199/A 199M	Seamless and Electric-Welded Low-Alloy Steel Tubes	A 423/A 423M
Seamless Intermediate Alloy-Steel Still Tubes for Refinery Service	A 200	Electric-Resistance-Welded Coiled Steel Tubing for Gas and Fuel Oil Lines	A 539
Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes	A 209/A 209M	Seamless Cold-Drawn Carbon Steel Feedwater Heater Tubes	A 556/A 556M
Seamless Medium-Carbon Steel Boiler and Superheater Tubes	A 210/A 210M	Electric-Resistance-Welded Carbon Steel Feedwater Heater Tubes	A 557/A 557M
Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes	A 213/A 213M	Welded Austenitic Stainless Steel Feedwater Heater Tubes	A 688/A 688M
Electric-Resistance-Welded Carbon Steel Heat-Exchanger and Condenser Tubes	A 214/A 214M	Seamless Medium-Strength Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes	A 692
Electric-Resistance-Welded Carbon Steel Boiler and Superheater Tubes for High-Pressure Service	A 226/A 226M	Austenitic Stainless Steel Tubing for Breeder Reactor Core Components	A 771
Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes	A 249/A 249M	Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service	A 789/A 789M
Electric-Resistance-Welded Ferritic Alloy-Steel Boiler and Superheater Tubes	A 250/A 250M	Welded Unannealed Ferritic Stainless Steel Tubing	A 791/A 791M
Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing for General Service	A 268/A 268M	Welded Ferritic Stainless Steel Feedwater Heater Tubes	A 803/A 803M
		Seamless, Cold-Drawn Carbon Steel Tubing for Hydraulic System Service	A 822
		Austenitic and Ferritic Stainless Steel Duct Tubes for Breeder Reactor Core Components	A 826
		High-Frequency Induction-Welded, Unannealed Austenitic Steel Condenser Tubes	A 851

^AThese designations refer to the latest issue of the respective specifications.

1.2 One or more of Sections 4.3, 5, 6, 17, 18, 19, 20, 21, 22, and 23 apply when the product specification or purchase order has a requirement for the test or analysis described by these sections.

1.3 In case of conflict between a requirement of the product specification and a requirement of this general requirement specification only the requirement of the product specification need be satisfied.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the “M” designation (SI) of the product specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:*

- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe
- A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- D 3951 Practice for Commercial Packaging
- E 92 Test Method for Vickers Hardness of Metallic Materials
- E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing
- E 273 Practice for Ultrasonic Examination of Longitudinal Welded Pipe and Tubing
- E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation
- E 426 Practice for Electromagnetic (Eddy-Current) Testing of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys
- E 570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

2.2 *Federal Standard:*

- Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products

2.3 *Military Standards:*

- MIL-STD-271 Nondestructive Testing Requirements for Metals
- MIL-STD-792 Identification Marking Requirements for Special Purpose Equipment

2.4 *Steel Structures Painting Council:*

- SSPC-SP6 Surface Preparation Specification No. 6 Commercial Blast Cleaning

2.5 *Other Document:*

- SNT-TC-1A Recommended Practice for Nondestructive Personnel Qualification and Certification

3. Process

3.1 The steel may be made by any process.

3.2 If a specific type of melting is required by the purchaser, it shall be as stated on the purchase order.

3.3 The primary melting may incorporate separate degassing or refining and may be followed by secondary melting, such as electroslog remelting or vacuum-arc remelting. If secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

3.4 Steel may be cast in ingots or may be strand cast. When steel of different grades is sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by an established procedure that positively separates the grades.

4. Chemical Composition

4.1 Samples for chemical analysis, and method of analysis, shall be in accordance with Test Methods, Practices, and Terminology A 751.

4.2 Heat Analysis — An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the tubular product manufacturer, shall conform to the requirements specified in the product specification.

4.2.1 For stainless steels ordered under product specifications referencing this specification of general requirements, the steel shall not contain an unspecified element, other than nitrogen, for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element having a required minimum content. For this requirement, a grade is defined as an alloy described individually and identified by its own UNS designation in a table of chemical requirements within any specification listed within the scope as being covered by this specification.

4.3 Product Analysis — Product analysis requirements and options, if any, are contained in the product specification.

5. Tensile Properties

5.1 The material shall conform to the requirements as to tensile properties prescribed in the individual specification.

5.2 The yield strength corresponding to a permanent offset of 0.2% of the gage length or to a total extension of 0.5% of the gage length under load shall be determined.

5.3 If the percentage of elongation of any test specimen is less than that specified and any part of the fracture is more than $\frac{3}{4}$ in. [19.0 mm] from the center of the gage length, as indicated by scribe marks on the specimen before testing, a retest shall be allowed.

6. Standard Weights

6.1 The calculated weight per foot, based upon a specified minimum wall thickness, shall be determined by the following equation:

$$W = C(D - t)t \quad (1)$$

where:

$C = 10.69$ [0.02466/15],

$W =$ weight, lb/ft [kg/m],

$D =$ specified outside diameter, in. [mm], and

$t =$ specified minimum wall thickness, in. [mm]

6.2 The permissible variations from the calculated weight per foot [kilogram per metre] shall be as prescribed in Table 1.

7. Permissible Variations in Wall Thickness

7.1 Variations from the specified minimum wall thickness shall not exceed the amounts prescribed in Table 2.

7.2 For tubes 2 in. [50.8 mm] and over in outside diameter and 0.220 in. [5.6 mm] and over in thickness, the variation in wall thickness in any one cross section of any one tube shall not exceed the following percentage of the actual mean wall at the section. The actual mean wall is defined as the average of the thickest and thinnest wall in that section.

Seamless tubes $\pm 10\%$
Welded tubes $\pm 5\%$

7.3 When cold-finished tubes as ordered require wall thicknesses $\frac{3}{4}$ in. [19.1 mm] or over, or an inside diameter 60% or less of the outside diameter, the permissible variations in wall thickness for hot-finished tubes shall apply.

8. Permissible Variations in Outside Diameter

8.1 Except as provided in 8.2.1 and 8.3, variations from the specified outside diameter shall not exceed the amounts prescribed in Table 3.

8.2 Thin-wall tubes usually develop significant ovality (out of roundness) during final annealing, or straightening, or both. Thin-wall tubes are defined as those meeting the specified outside diameters and specified wall thicknesses set forth as follows:

Specified Outside Diameter	Specified Wall Thickness
2 in. [50.8 mm] and less	2% or less of specified outside diameter
Greater than 2 in. [50.8 mm]	3% or less of specified outside diameter
All diameters	0.020 in. [0.5 mm] or less

8.2.1 The diameter tolerances of Table 3 are not sufficient to provide for additional ovality expected in thin-wall tubes, and, for such tubes, are applicable only to the *mean* of the extreme (maximum and minimum) outside diameter readings in any one cross section. However, for thin wall tubes the *difference* in extreme outside diameter readings (ovality) in any one cross section shall not exceed the following ovality allowances:

Outside Diameter	Ovality Allowance
1 in. [25.4 mm] and under	0.020 in. [0.5 mm]
Over 1 in. [25.4 mm]	2.0% of specified outside diameter

8.3 For cold-finished seamless austenitic and ferritic/austenitic tubes an ovality allowance is necessary for all sizes less than 2 in. [50.8 mm] outside diameter since they are likely to become out of round during their final heat treatment. In such tubes, the maximum and minimum diameters at any cross section shall deviate from the nominal diameter by no more than ± 0.010 in. [± 0.25 mm]; however, the mean diameter at that cross section must still be within the given permissible variation given in Table 3. In the event of conflict between the provisions of 8.3 and those of 8.2.1, the larger value of ovality tolerance shall apply.

9. Permissible Variations in Length

9.1 Variations from the specified length shall not exceed the amounts prescribed in Table 4.

10. Permissible Variations in Height of Flash on Electric-Resistance-Welded Tubes

10.1 For tubes over 2 in. [50.8 mm] in outside diameter, or over 0.135 in. [3.44 mm] in wall thickness, the flash on the inside of the tubes shall be mechanically removed by cutting to a maximum height of 0.010 in. [0.25 mm] at any point on the tube.

10.2 For tubes 2 in. [50.8 mm] and under in outside diameter and 0.135 in. [3.4 mm] and under in wall thickness, the flash on the inside of the tube shall be mechanically removed by cutting to a maximum height of 0.006 in. [0.15 mm] at any point on the tube.

11. Straightness and Finish

11.1 Finished tubes shall be reasonably straight and have smooth ends free of burrs. They shall have a workmanlike finish. Surface imperfections (Note 1) may be removed by grinding, provided that a smooth curved surface is maintained, and the wall thickness is not decreased to less than that permitted by this or the product specification. The outside diameter at the point of grinding may be reduced by the amount so removed.

NOTE 1—An imperfection is any discontinuity or irregularity found in the tube.

12. Repair by Welding

12.1 Repair welding of base metal defects in tubing is permissible only with the approval of the purchaser and with the further understanding that the tube shall be marked “WR” and the composition of the deposited filler metal shall be suitable for the composition being welded. Defects shall be thoroughly chipped or ground out before welding and each repaired length shall be reheat treated or stress relieved as required by the applicable specification. Each length of repaired tube shall be tested hydrostatically as required by the product specification.

12.2 Repair welding shall be performed using procedures and welders or welding operators that have been qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX.

13. Retests

13.1 If the results of the mechanical tests of any group or lot do not conform to the requirements specified in the individual specification, retests may be made on additional tubes of double the original number from the same group or lot, each of which shall conform to the requirements specified.

14. Retreatment

14.1 If the individual tubes or the tubes selected to represent any group or lot fail to conform to the test requirements, the individual tubes or the group or lot represented may be retreated and resubmitted for test. Not more than two reheat treatments shall be permitted.

15. Test Specimens

15.1 Test specimens shall be taken from the ends of finished tubes prior to upsetting, swaging, expanding, or other forming operations, or being cut to length. They shall be smooth on the ends and free of burrs and flaws.

15.2 If any test specimen shows flaws or defective machining, it may be discarded and another specimen substituted.

16. Method of Mechanical Testing

16.1 The specimens and mechanical tests required shall be made in accordance with Annex A2 of Test Methods and Definitions A 370.

16.2 Specimens shall be tested at room temperature.

16.3 Small or subsize specimens as described in Test Methods and Definitions A 370 may be used only when there is insufficient material to prepare one of the standard specimens. When using small or subsize specimens, the largest one possible shall be used.

17. Flattening Test

17.1 A section of tube not less than 2½ in. [63 mm] in length for seamless and not less than 4 in. [100 mm] in length for welded shall be flattened cold between parallel plates in two steps. For welded tubes, the weld shall be placed 90° from the direction of the applied force (at a point of maximum bending). During the first step, which is a test for ductility, no cracks or breaks, except as provided for in 17.4, on the inside, outside, or end surfaces shall occur in seamless tubes, or on the inside or outside surfaces of welded tubes, until the distance between the plates is less than the value of H calculated by the following equation:

$$H = \frac{(1 + e)t}{e + t/D} \quad (2)$$

where:

- H = distance between flattening plates, in. [mm],
- t = specified wall thickness of the tube, in. [mm],
- D = specified outside diameter of the tube, in. [mm], and
- e = deformation per unit length (constant for a given grade of steel: 0.07 for medium-carbon steel (maximum specified carbon 0.19% or greater), 0.08 for ferritic alloy steel, 0.09 for austenitic steel, and 0.09 for low-carbon steel (maximum specified carbon 0.18% or less)).

During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the tube meet. Evidence of laminated or unsound material, or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

17.2 Surface imperfections in the test specimens before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements.

17.3 Superficial ruptures resulting from surface imperfections shall not be cause for rejection.

17.4 When low D -to- t ratio tubular products are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be cause for rejection if the D to t ratio is less than 10.

18. Reverse Flattening Test

18.1 A section 4 in. [100 mm] in length of finished welded tubing in sizes down to and including $\frac{1}{2}$ in. [12.7 mm] in outside diameter shall be split longitudinally 90° on each side of the weld and the sample opened and flattened with the weld at the point of maximum bend. There shall be no evidence of cracks or lack of penetration or overlaps resulting from flash removal in the weld.

19. Flaring Test

19.1 A section of tube approximately 4 in. [100 mm] in length shall stand being flared with a tool having a 60° included angle until the tube at the mouth of the flare has been expanded to the percentages specified in Table 5 without cracking or showing imperfections rejectable under the provisions of the product specification.

20. Flange Test

20.1 A section of tube shall be capable of having a flange turned over at a right angle to the body of the tube without cracking or showing imperfections rejectable under the provisions of the product specification. The width of the flange for carbon and alloy steels shall be not less than the percentages specified in Table 6. For the austenitic grades, the width of the flange for all sizes listed in Table 6 shall be not less than 15%.

21. Hardness Test

21.1 For tubes 0.200 in. [5.1 mm] and over in wall thickness, either the Brinell or Rockwell hardness test shall be used. When Brinell hardness testing is used, a 10 mm ball with 3000, 1500, or 500 kg load, or a 5 mm ball with 750 kg load may be used, at the option of the manufacturer.

21.2 For tubes less than 0.200 in. [5.1 mm] to and including 0.065 in. [1.7 mm] in wall thickness, the Rockwell hardness test shall be used.

21.3 For tubes less than 0.065 in. [1.7 mm] in wall thickness, the hardness test shall not be required.

21.4 The Brinell hardness test may be made on the outside of the tube near the end, on the outside of a specimen cut from the tube, or on the wall cross section of a

specimen cut from the tube at the option of the manufacturer. This test shall be made so that the distance from the center of the impression to the edge of the specimen is at least 2.5 times the diameter of the impression.

21.5 The Rockwell hardness test may be made on the inside surface, on the wall cross section, or on a flat on the outside surface at the option of the manufacturer.

21.6 For tubes furnished with upset, swaged, or otherwise formed ends, the hardness test shall be made as prescribed in 21.1 and 21.2 on the outside of the tube near the end after the forming operation and heat treatment.

21.7 For welded or brazed tubes, the hardness test shall be made away from the joints.

21.8 When the product specification provides for Vickers hardness, such testing shall be in accordance with Test Method E 92.

22. Hydrostatic Test

22.1 Except as provided in 22.2 and 22.3, each tube shall be tested by the manufacturer to a minimum hydrostatic test pressure determined by the following equation:

$$\text{Inch-Pound Units: } P = 32000 \, t/D \quad (3)$$

$$\text{SI Units: } P = 220.6 \, t/D$$

where:

- P = hydrostatic test pressure, psi or MPa,
- t = specified wall thickness, in. or mm, and
- D = specified outside diameter, in. or mm.

22.1.1 The hydrostatic test pressure determined by eq. (3) shall be rounded to the nearest 50 psi [0.5 MPa] for pressure below 1000 psi [7 MPa], and to the nearest 100 psi [1 MPa] for pressures 1000 psi [7 MPa] and above. The hydrostatic test may be performed prior to cutting to final length, or prior to upsetting, swaging, expanding, bending, or other forming operations, or both.

22.2 Regardless of the determination made by eq. (3), the minimum hydrostatic test pressure required to satisfy these requirements need not exceed the values given in Table 7. This does not prohibit testing at higher pressures at manufacturer's option or as provided in 22.3.

22.3 With concurrence of the manufacturer, a minimum hydrostatic test pressure in excess of the requirements of 22.2 or 22.1, or both, may be stated on the order. The tube wall stress shall be determined by the following equation:

$$S = PD/2t \quad (4)$$

where:

- S = tube wall stress, psi or MPa, and all other symbols as defined in 22.1.

22.4 The test pressure shall be held for a minimum of 5 s.

22.5 If any tube shows leaks during the hydrostatic test, it shall be rejected.

22.6 The hydrostatic test may not be capable of testing the end portion of the pipe. The lengths of pipe that cannot be tested shall be determined by the manufacturer and, when specified in the purchase order, reported to the purchaser.

23. Air Underwater Pressure Test

23.1 When this test is employed, each tube, with internal surface clean and dry, shall be internally pressurized to 150 psi [1000 kPa] minimum with clean and dry compressed air while being submerged in clear water. The tube shall be well-lighted, preferably by underwater illumination. Any evidence of air leakage of the pneumatic couplings shall be corrected prior to testing. Inspection shall be made of the entire external surface of the tube after holding the pressure for not less than 5 s after the surface of the water has become calm. If any tube shows leakage during the air underwater test, it shall be rejected. Any leaking areas may be cut out and the tube retested.

24. Nondestructive Electric Test

24.1 When nondestructive examination is specified by the purchaser or the product specification, each tube shall be examined by a nondestructive examination method in accordance with Practice E 213, Practice E 309 (for ferromagnetic materials), Practice E 426 (for non-magnetic materials), or Practice E 570. Upon agreement, Practice E 273 shall be employed in addition to one of the full periphery tests. The range of tube sizes that may be examined by each method shall be subject to the limitations in the scope of that practice. In case of conflict between these methods and practices and this specification, the requirements of this specification shall prevail.

24.2 The following information is for the benefit of the user of this specification:

24.2.1 Calibration standards for the nondestructive electric test are convenient standards for calibration of nondestructive testing equipment only. For several reasons, including shape, orientation, width, etc., the correlation between the signal produced in the electric test from an imperfection and from calibration standards is only approximate. A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

24.2.2 The ultrasonic examination referred to in this specification is intended to detect longitudinal discontinuities having a reflective area similar to or larger than the calibration reference notches specified in 23.4. The examination may not detect circumferentially oriented imperfections or short, deep defects.

24.2.3 The eddy current examination referenced in this specification has the capability of detecting significant discontinuities, especially of the short abrupt type. Practices E 309 and E 426 contain additional information regarding the capabilities and limitations of eddy-current examination.

24.2.4 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented discontinuities. The provisions of this specification only provide for longitudinal calibration for flux leakage. It should be recognized that different techniques should be employed to detect differently oriented imperfections.

24.2.5 The hydrostatic test referred to in Section 22 is a test method provided for in many product specifications. This test has the capability of finding defects of a size permitting the test fluid to leak through the tube wall and may be either visually seen or detected by a loss of pressure. This test may not detect very tight, through-the-wall defects or defects that extend an appreciable distance into the wall without complete penetration.

24.2.6 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular products.

24.3 *Time of Examination* — Nondestructive examination for specification acceptance shall be performed after all deformation processing, heat treating, welding, and straightening operations. This requirement does not preclude additional testing at earlier stages in the processing.

24.4 *Surface Condition:*

24.4.1 All surfaces shall be free of scale, dirt, grease, paint, or other foreign material that could interfere with interpretation of test results. The methods used for cleaning and preparing the surfaces for examination shall not be detrimental to the base metal or the surface finish.

24.4.2 Excessive surface roughness or deep scratches can produce signals that interfere with the test.

24.5 *Extent of Examination:*

24.5.1 The relative motion of the tube and the transducer(s), coil(s), or sensor(s) shall be such that the entire tube surface is scanned, except for end effects as noted in 24.5.2.

24.5.2 The existence of end effects is recognized, and the extent of such effects shall be determined by the manufacturer, and, if requested, shall be reported to the purchaser. Other nondestructive tests may be applied to the end areas, subject to agreement between the purchaser and the manufacturer.

24.6 Operator Qualifications:

24.6.1 The test unit operator shall be certified in accordance with SNT TC-1-A, or an equivalent documented standard agreeable to both purchaser and manufacturer.

24.7 Test Conditions:

24.7.1 For examination by the ultrasonic method, the minimum nominal transducer frequency shall be 2.0 MHz, and the maximum transducer size shall be 1.5 in. (38 mm).

24.7.2 For eddy current testing, the excitation coil frequency shall be chosen to ensure adequate penetration, yet provide good signal-to-noise ratio.

24.7.2.1 The maximum coil frequency shall be:

Specified Wall Thickness	Maximum Frequency
<0.050 in.	100 KHz
0.050 to 0.150	50
>0.150	10

24.8 References Standards:

24.8.1 Reference standards of convenient length shall be prepared from a length of tube of the same grade, specified size (outside diameter and wall thickness), surface finish and heat treatment condition as the tubing to be examined.

24.8.2 For eddy current testing, the reference standard shall contain, at the option of the manufacturer, any one of the following discontinuities:

24.8.2.1 Drilled Hole — The reference standard shall contain three or more holes, equally spaced circumferentially around the tube and longitudinally separated by a sufficient distance to allow distinct identification of the signal from each hole. The holes shall be drilled radially and completely through the tube wall, with care being taken to avoid distortion of the tube while drilling. The holes shall not be larger than 0.031 in. (0.8 mm) in diameter. As an alternative, the producer may choose to drill one hole and run the calibration standard through the test coil three times, rotating the tube approximately 120° each time. More passes with smaller angular increments may be used, provided testing of the full 360° of the coil is obtained. For welded tubing, if the weld is visible, one of the multiple holes or the single hole shall be drilled in the weld.

24.8.2.2 Transverse Tangential Notch — Using a round tool or file with a $\frac{1}{4}$ in. [6.4 mm] diameter, a notch shall be milled or filed tangential to the surface and transverse to the longitudinal axis of the tube. Said notch shall have a depth not exceeding 12½% of the specified wall thickness of the tube or 0.004 in. [0.1 mm], whichever is greater.

24.8.2.3 Longitudinal Notch — A notch 0.031 in. [0.8 mm] or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the tube, to have a depth not exceeding 12½% of the specified wall thickness of the tube or 0.004 in. [0.1 mm], whichever is greater. The length of the notch shall be compatible with the testing method.

24.8.3 For ultrasonic testing, the reference ID and OD notches shall be any one of the three common notch shapes shown in Practice E 213, at the option of the manufacturer. The depth of notches shall not exceed 12½% of the specified wall thickness of the tube or 0.004 in. [0.1 mm], whichever is greater. The width of the notch shall not exceed two times the depth. For welded tubing, the notch shall be placed in the weld, if the weld is visible.

24.8.4 For flux leakage testing, the longitudinal reference notches shall be straight-sided notches machined in a radial plane parallel to the tube axis on the inside and outside surfaces of the tube. Notch depth shall not exceed 12½% of the specified wall thickness, or 0.004 in. [0.1 mm], whichever is greater. Notch length shall not exceed 1 in. [25 mm], and the width shall not exceed the depth. Outside diameter and inside diameter notches shall have sufficient separation to allow distinct identification of the signal from each notch.

24.8.5 More or smaller reference discontinuities, or both, may be used by agreement between the purchaser and the manufacturer.

24.9 Standardization Procedure:

24.9.1 The test apparatus shall be standardized at the beginning and end of each series of tubes of the same specified size (diameter and wall thickness), grade and heat treatment condition, and at intervals not exceeding 4 h during the examination of such tubing. More frequent standardizations may be performed at the manufacturer's option or may be required upon agreement between the purchaser and the manufacturer.

24.9.2 The test apparatus shall also be standardized after any change in test system settings, change of operator, equipment repair, or interruption due to power loss or shutdown.

24.9.3 The reference standard shall be passed through the test apparatus at the same speed and test system settings as the tube to be tested, except that, at the manufacturer's discretion, the tubes may be tested at a higher sensitivity.

24.9.4 The signal-to-noise ratio for the reference standard shall be 2.5:1 or greater, and the reference signal amplitude for each discontinuity shall be at least 50% of full scale of the display. In establishing the noise level, extraneous signals from identifiable surface imperfections on the reference standard may be ignored. When reject filtering is used during UT testing, linearity must be demonstrated.

24.9.5 If, upon any standardization, the reference signal amplitude has decreased by 29% (3.0 dB), the test apparatus shall be considered out of standardization. The test system settings may be changed, or the transducer(s), coil(s), or sensor(s) adjusted, and the unit restandardized, but all tubes tested since the last acceptable standardization must be retested.

24.10 Evaluation of Imperfections:

24.10.1 Tubing producing a test signal to or greater than the lowest signal produced by the reference standard shall be designated suspect, shall be clearly marked or identified, and shall be separated from the acceptable tubing.

24.10.2 Such suspect tubing shall be subject to one of the following three dispositions:

24.10.2.1 The tubes may be rejected without further examination, at the discretion of the manufacturer.

24.10.2.2 If the test signal was produced by imperfections such as scratches, surface roughness, dings, straightener marks, loose ID bead and cutting chips, steel die stamps, stop marks, tube reducer ripple, or chattered flash trim, the tubing may be accepted or rejected depending on visual observation of the severity of the imperfection, the type of signal it produces on the testing equipment used, or both.

24.10.2.3 If the test signal was produced by imperfections which cannot be identified, or was produced by cracks or crack-like imperfections, the tubing shall be rejected.

24.10.3 Any tubes with imperfections of the types in 24.10.2.2 and 24.10.2.3, exceeding 0.004 in. (0.1 mm) or 12½% of the specified minimum wall thickness (whichever is greater) in depth shall be rejected.

24.10.4 Rejected tubes may be reconditioned and retested providing the wall thickness is not decreased to less than that required by this or the product specification. If grinding is performed, the outside diameter in the area of grinding may be reduced by the amount so removed. To be accepted, reconditioned tubes must pass the nondestructive examination by which they were originally rejected.

25. Inspection

25.1 The inspector representing the purchaser shall have entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All required tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

26. Rejection

26.1 Each length of tubing received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the specification based on the inspection and test method as outlined in the specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

26.2 Material that fails in any of the forming operations or in the process of installation and is found to be defective shall be set aside and the manufacturer shall be notified for mutual evaluation of the material's suitability. Disposition of such material shall be a matter for agreement.

27. Certified Test Report

27.1 When specified in the purchase order or contract, the producer or supplier shall furnish a Certified Test Report certifying that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirements designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the Certified Test Report, but the document shall be dated and shall clearly identify the organization submitting the Report.

NOTE 2—Notwithstanding the absence of a signature or notarization, the organization submitting the Report is responsible for the contents of the Report.

27.2 In addition, the Certified Test Report shall include the following information and test results, when applicable:

27.2.1 Heat Number,

27.2.2 Heat Analysis,

27.2.3 Product Analysis, when specified,

27.2.4 Tensile Properties,

27.2.5 Width of the gage length, when longitudinal strip tension test specimens are used,

27.2.6 Flattening Test acceptable,

27.2.7 Reverse Flattening Test acceptable,

27.2.8 Flaring Test acceptable,

27.2.9 Flange Test acceptable,

27.2.10 Hardness Test values,

27.2.11 Hydrostatic Test pressure,

27.2.12 Non-destructive Electric Test method,

27.2.13 Impact Test results, and

27.2.14 Other test results or information required to be reported by the product specification.

27.3 Test results or information required to be reported by supplementary requirements, or other requirements designated in the purchase order or contract shall be reported, but may be reported in a separate document.

27.4 The Certified Test Report shall include a statement of explanation for the letter added to the specification number marked on the tubes (see 28.3), when all of the requirements of the specification have not been completed. The purchaser must certify that all requirements of the specification have been completed before removal of the letter (that is, X, Y, or Z).

28. Product Marking

28.1 Each length of tube shall be legibly stenciled with the manufacturer's name or brand, the specification number, and grade. The marking need not include the year date of the specification. For tubes less than 1¼ in. [31.8 mm] in diameter and tubes under 3 ft [1 m] in length, the required information may be marked on a tag securely attached to the bundle or box in which the tubes are shipped.

28.2 For austenitic tubes, the marking paint or ink shall not contain any harmful metal, or metal salts, such as zinc, lead, or copper, which cause corrosive attack on heating.

28.3 When it is specified that certain requirements of a specification adopted by the ASME Boiler and Pressure Vessel Committee are to be completed by the purchaser upon receipt of the material, the manufacturer shall indicate that all requirements of the specification have not been completed by a letter such as X, Y, or Z, immediately following the specification number. This letter may be removed after completion of all requirements in accordance with the specification. An explanation of specification requirements to be completed is provided in Section 27.

28.4 Bar Coding — In addition to the requirements in 28.1, 28.2, and 28.3, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

29. Packaging, Marking, and Loading

29.1 When specified on the purchase order, packaging, marking, and loading for shipment shall be in accordance with the procedures of Practices A 700.

30. Government Procurement

30.1 Scale Free Pipe:

30.1.1 When specified in the contract or order, the following requirements shall be considered in the inquiry contract or order, for agencies of the U.S. Government where scale free tube is required. These requirements shall take precedence if there is a conflict between these requirements and the product specification.

30.1.2 Tube shall be ordered to outside diameter (OD) and wall thickness.

30.1.3 Responsibility for Inspection — Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility for ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of the manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to accept the material. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth when such inspections and tests are deemed necessary to ensure that the material conforms to the prescribed requirements.

30.1.4 Sampling for Flattening and Flaring Tests and for Visual and Dimensional Examination — Minimum sampling for flattening and flaring tests and visual and dimensional examination shall be as follows:

Lot Size (pieces per lot)		Sample Size
2 to	8	Entire lot 8
9 to	90	
91 to	150	12
151 to	280	19
281 to	500	21
501 to	1200	27
1201 to	3200	35
3201 to	10 000	38
10 001 to	35 000	46

In all cases, the acceptance number is zero and the rejection number is one. Rejected lots may be screened and resubmitted for visual and dimensional examination. All defective items shall be replaced with acceptable items prior to lot acceptance.

30.1.5 Sampling for Chemical Analysis — One sample for chemical analysis shall be selected from each of two tubes chosen from each lot. A lot shall be all material poured from one heat.

30.1.6 Sampling for Tension and Bend Test — One sample shall be taken from each lot. A lot shall consist of all tube of the same outside diameter and wall thickness manufactured during an 8-h shift from the same heat of steel, and heat treated under the same conditions of temperature and time in a single charge in a batch type furnace, or heat treated under the same condition in a continuous furnace, and presented for inspection at the same time.

30.1.7 Hydrostatic and Ultrasonic Tests — Each tube shall be tested by the ultrasonic (when specified) and hydrostatic tests.

30.1.8 Tube shall be free from heavy oxide or scale. The internal surface of hot finished ferritic steel tube shall be pickled or blast cleaned to a free of scale condition equivalent to the CSA2 visual standard listed in SSPC-SP6. Cleaning shall be performed in accordance with a written procedure that has been shown to be effective. This procedure shall be available for audit.

30.1.9 In addition to the marking in Specification A 530/A 530M, each length of tube $\frac{1}{4}$ in. outside diameter and larger shall be marked with the following listed information. Marking shall be in accordance with FED-STD-183 and MIL-STD-792. (a) Outside diameter, wall thickness, and length (b) Heat or lot identification number.

30.1.10 Tube shall be straight to within the tolerances specified in Table 8.

30.1.11 When specified, each tube shall be ultrasonically examined in accordance with MIL-STD-271, except that the notch depth in the calibration standard shall be 5% of the wall thickness or 0.005 in., whichever is greater. Any tube which produces an indication equal to or greater than 100% of the indication from the calibration standard shall be rejected.

30.1.12 The tube shall be free from repair welds, welded joints, laps, laminations, seams, visible cracks, tears, grooves, slivers, pits, and other imperfections detrimental to the tube as determined by visual and ultrasonic examination, or alternate tests, as specified.

30.1.13 Tube shall be uniform in quality and condition and have a finish conforming to the best practice for standard quality tubing. Surface imperfections such as handling marks, straightening marks, light mandrel and die marks, shallow pits, and scale pattern will not be considered injurious if the imperfections are removable within the tolerances specified for wall thickness or 0.005 in., whichever is greater. The bottom of imperfections shall be visible and the profile shall be rounded and faired-in.

30.1.14 No weld repair by the manufacturer is permitted.

30.1.15 Preservation shall be level A or commercial, and packing shall be level A, B, or commercial, as specified. Level A preservation and level A or B packing shall be in accordance with MIL-STD-163 and commercial preservation and packing shall be in accordance with Practices A 700 or Practice D 3951.

31. Keywords

31.1 alloy steel tube; austenitic stainless steel; carbon steel tube; general delivery; stainless steel tube; steel tube

TABLE 1
PERMISSIBLE VARIATIONS IN WEIGHT PER FOOT⁴

Method of Manufacture	Permissible Variation in Weight per Foot, %	
	Over	Under
Seamless, hot-finished	16	0
Seamless, cold-finished:		
1½ in. [38.1 mm] and under OD	12	0
Over 1½ in. [38.1 mm] OD	13	0
Welded	10	0

⁴ These permissible variations in weight apply to lots of 50 tubes or more in sizes 4 in. [101.6 mm] and under in outside diameter, and to lots of 20 tubes or more in sizes over 4 in. [101.6 mm] in outside diameter.

TABLE 2
PERMISSIBLE VARIATIONS IN WALL THICKNESS⁴

Outside Diameter, in. [mm]	Wall Thickness, %							
	Over 0.095 to 0.150				Over 0.150 to 0.180			
	0.095 [2.4] and Under		[2.4 to 3.8], incl		[3.8 to 4.6], incl		Over 0.180, [4.6]	
	Over	Under	Over	Under	Over	Under	Over	Under
Seamless, Hot-Finished Tubes								
4 [101.6] and under	40	0	35	0	33	0	28	0
Over 4 [101.6]	...	...	35	0	33	0	28	0
Seamless, Cold-Finished Tubes								
	Over				Under			
1½ [38.1] and under	20				0			
Over 1½ [38.1]	22				0			
Welded Tubes								
All sizes	18				0			

⁴ These permissible variations in wall thickness apply only to tubes, except internal-upset tubes, as rolled or cold-finished, and before swaging, expanding, bending, polishing, or other fabricating operations.

TABLE 3
PERMISSIBLE VARIATIONS IN OUTSIDE DIAMETER⁴

Outside Diameter, in. [mm]	Permissible Variations, in. [mm]	
	Over	Under
Hot-Finished Seamless Tubes		
4 [101.6] and under	¼ [0.4]	⅜ [0.8]
Over 4 to 7½ [101.6 to 190.5], incl	¼ [0.4]	¾ [1.2]
Over 7½ to 9 [190.5 to 228.6], incl	¼ [0.4]	⅜ [1.6]
Welded Tubes and Cold-Finished Seamless Tubes		
Under 1 [25.4]	0.004 [0.1]	0.004 [0.1]
1 to 1½ [25.4 to 38.1], incl	0.006 [0.15]	0.006 [0.15]
Over 1½ to 2 [38.1 to 50.8], excl	0.008 [0.2]	0.008 [0.2]
2 to 2½ [50.8 to 63.5], excl	0.010 [0.25]	0.010 [0.25]
2½ to 3 [63.5 to 76.2], excl	0.012 [0.3]	0.012 [0.3]
3 to 4 [76.2 to 101.6], incl	0.015 [0.38]	0.015 [0.38]
Over 4 to 7½ [101.6 to 190.5], incl	0.015 [0.38]	0.025 [0.64]
Over 7½ to 9 [190.5 to 228.6], incl	0.015 [0.38]	0.045 [1.14]

⁴ Except as provided in 8.2 and 8.3, these permissible variations include out-of-roundness. These permissible variations in outside diameter apply to hot-finished seamless, welded and cold-finished seamless tubes before other fabricating operations such as upsetting, swaging, expanding, bending, or polishing.

TABLE 4
PERMISSIBLE VARIATIONS IN LENGTH⁴

Method of Manufacture	Outside Diameter, in. [mm]	Cut Length, in. [mm]	
		Over	Under
Seamless, hot-finished	All sizes	⅜ [5]	0 [0]
Seamless, cold-finished	Under 2 [50.8]	⅜ [3]	0 [0]
	2 [50.8] and over	⅜ [5]	0 [0]
Welded	Under 2 [50.8]	⅜ [3]	0 [0]
	2 [50.8] and over	⅜ [5]	0 [0]

⁴ These permissible variations in length apply to tubes before bending. They apply to cut lengths up to and including 24 ft [7.3 m]. For lengths over 24 ft [7.3 m], the above over-tolerances, of ⅜ in. [3 mm] for each 10 ft [3 m] or fraction thereof over 24 ft or ⅜ in. [3 mm], whichever is lesser.

TABLE 5
FLARING TEST REQUIREMENTS

Ratio of Inside Diameter to Outside Diameter ^A	Minimum Expansion of Inside Diameter, %	
	Carbon, Carbon-Molybdenum, and Austenitic Steels	Other Ferritic Alloy Steels
0.9	21	15
0.8	22	17
0.7	25	19
0.6	30	23
0.5	39	28
0.4	51	38
0.3	68	50

^A In determining the ratio of inside diameter to specified outside diameter, the inside diameter shall be defined as the actual mean inside diameter of the material tested.

TABLE 7
HYDROSTATIC TEST PRESSURES

Outside Diameter of Tube, in. [mm]	Hydrostatic Test Pressure, psi [MPa]
Under 1 [25.4]	1000 [7]
1 to 1½ [25.4 to 38.1], excl	1500 [10]
1½ to 2 [38.1 to 50.8], excl	2000 [14]
2 to 3 [50.8 to 76.2], excl	2500 [17]
3 to 5 [76.2 to 127], excl	3500 [24]
5 [127] and over	4500 [31]

TABLE 8
STRAIGHTNESS TOLERANCES

Specified OD (in.)	Specified wall thickness (in.)	Maximum curvature in any 3 ft (in.)	Maximum curvature in total length (in.)
Up to 5.0, incl.	Over 3% OD to 0.5, incl.	0.030	0.010 × length, ft
Over 5.0 to 8.0, incl.	Over 4% OD to 0.75, incl.	0.045	0.015 × length, ft
Over 8.0 to 12.75, incl.	Over 4% OD to 1.0, incl.	0.060	0.020 × length, ft

TABLE 6
FLANGE REQUIREMENTS

Outside Diameter of Tube, in. [mm]	Width of Flange
To 2½ [63.5], incl	15% of OD
Over 2½ to 3¾ [63.5 to 95.2], incl	12½% of OD
Over 3¾ to 8 [95.2 to 203.2], incl	10% of OD