

Steel pipes and tubes for pressure purposes: carbon and carbon manganese steel with specified elevated temperature properties —

**Part 1: Specification for seamless and
electric resistance welded including
induction welded tubes**

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Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Iron and Steel Standards Committee (ISM/-) to Technical Committee ISM/73, upon which the following bodies were represented:

- Associated Offices Technical Committee
- BEAMA Ltd. (Power Generation Association)
- British Compressed Air Society
- British Gas plc
- British Steel Industry
- Electricity Supply Industry in England and Wales
- Engineering Equipment and Materials Users' Association
- High Pressure Pipework Consultative Committee
- Lloyds Register of Shipping
- Process Plant Association
- Seamless Steel Tube Association
- Water Tube Boilermakers' Association
- Welding Institute
- Coopted members

The following bodies were also represented in the drafting of the standard, through sub-committees and panels:

- British Fluid Power Association
- British Forging Industry Association
- British industrial Truck Association
- British Welded Steel Tube Association
- Confederation of British Industry
- Energy Industries Council
- Coopted member

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Foreword

BS 3602-1:1987 has been prepared under the direction of the Iron and Steel Standards Committee. It supersedes BS 3602-1:1978, which is withdrawn.

This standard is one of a series specifying requirements for steel pipes and tubes for pressure purposes. Other standards in the series are as follows.

BS 3601, *Specification for steel pipes and tubes for pressure purposes: carbon steel with specified room temperature properties.*

BS 3602, *Specification for steel pipes and tubes for pressure purposes: carbon and carbon manganese steel with specified elevated temperature properties.*

BS 3603, *Specification for steel pipes and tubes for pressure purposes: carbon and alloy steel with specified low temperature properties.*

BS 3604, *Specification for steel pipes and tubes for pressure purposes: ferritic alloy steel with specified elevated temperature properties.*

BS 3605, *Specification for seamless and welded austenitic stainless steel pipes and tubes for pressure purposes.*

Part 1 takes account of current production procedures for seamless and welded tubes as well as grades of carbon and carbon manganese steel now in common industrial use. Requirements for tubes manufactured by the submerged arc welding process are given in BS 3602-2.

The steels covered by this standard are generally regarded as being weldable. However, care should be taken and welding should be in accordance with the appropriate British Standards for welding, e.g. BS 2633.

The main technical differences between this edition and the previous edition are that steel grade 460 is not included in this edition and changes have been made to the chemical analysis and the mechanical properties of the other grades at room temperature and elevated temperature to take into account current steelmaking practice. For example, the minimum specified tensile strength of grade 410, included in the previous edition, has been increased to 430 N/mm² and the grade designation has been changed accordingly in this edition to 430.

In a number of cases, changes have been made to the tolerances of tubes and tolerances for seamless tubes and cold finished electric resistance, including induction welded tubes specified by inside diameter and thickness, are included.

The designation of steel tubes in this standard and their nearest equivalent designations in ISO 2604-II and 2604-III are shown in appendix A for information purposes.

This Part of BS 3602 is aligned as far as possible with corresponding material requirements and test procedures now agreed for incorporation in documents by the International Organization for Standardization (ISO).

The specified elevated temperature yield or proof stress values are those derived from national data by the procedure described in BS 3920. Additionally, provision is made for the application of the related procedure for verifying that a product consistently meets specified levels of elevated temperature values.

Estimated average stress rupture values (taken from ISO/TR 7468) are shown in appendix C.

It is recommended that the results of elevated temperature tests should, together with information on the product thickness, the room temperature tensile properties and the chemical composition of the material, be sent to Secretariat of ISO/TC17/SC18, British Standards Institution, 3 York Street, Manchester M2 2AT, UK, so that, for future revisions of this standard, minimum elevated temperature proof stress values can be derived from a continuously updated data bank.

Impact test values are not specified in this standard but if the purchaser requires an impact test to be carried out then it is recommended that the Charpy impact test should be carried out in accordance with BS 131-2.

The appropriate British Standard for the design and construction of boilers, pressure vessels, pipework, etc. should be consulted for requirements relating to the application and permissible design stress for products made to this standard.

Purchasers ordering to this standard are advised to specify in their purchasing contract that the supplier operates a quality system in compliance with BS 5750-2 to assure themselves that products claimed to comply with BS 3602-1 consistently achieve the required level of quality.

It is outside the scope of this standard to specify formal qualifications for personnel engaged in testing but it is emphasized that the operation of all equipment should be supervised by competent, trained personnel.

For the purpose of this standard, no difference is intended in the meaning between “pipe” and “tube” though idiomatic use prefers sometimes the one and sometimes the other.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 16, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

This British Standard specifies requirements for plain end, seamless and electric resistance welded, including induction welded, carbon and carbon manganese steel tubes suitable for pressure purposes.

Tubes manufactured in accordance with this standard have specified room temperature properties and specified proof stress values at elevated temperatures.

In addition to the definitive requirements this specification requires the items detailed in 2.1 to be documented. It also requires options selected by the purchaser from those detailed in 2.2 to be documented. For compliance with this standard both the definitive requirements and the documented items have to be satisfied.

This standard provides for two categories of room temperature test procedure, designated category 1 and category 2 (see clause 11).

NOTE 1 The range of diameters and thicknesses appropriate to this standard is given in appendix B. However, it may be convenient to select from the discrete sizes given in the following standards.

- a) BS 3600:1976, Table 1.
- b) BS 1600-2:1970 (completely interchangeable with ANSI B36.10M and ANSI B36.19M).
- c) BS 3600:1976, Table 4 (for use with compression couplings).

Tubes of diameters and thicknesses not covered by the above standards are also available.

NOTE 2 The titles of the publications referred to in this standard are listed on the inside back cover.

2 Information to be supplied by the purchaser and options to be documented

2.1 Information to be supplied by the purchaser

The following information shall be supplied by the purchaser and shall be fully documented:

- a) the designation of the tubes, i.e. the number and part of this British Standard, the method of tube manufacture, the grade of steel and the category of test as specified in clause 3, e.g. BS 3602-1:HFS 430:Cat. 1;
- b) the tube outside diameter and thickness for electric resistance welded tubes or the outside or inside diameter and thickness for seamless tubes and cold finished electric resistance welded tubes (see 10.2);
- c) the tube length if exact (see 10.4);
- d) the quantity in metres or number of lengths.

2.2 Options to be documented

A number of options are permitted by this standard as listed below and the purchaser shall identify the options required. Both the definitive requirements specified throughout this standard and the following documented items shall be satisfied before a claim of compliance with this standard can be made and verified. In the event that the purchaser does not indicate his requirements at the time of enquiry or order the manufacturer shall select the options where appropriate.

- a) whether the steelmaking process used has to be reported [see 4.2 and 15.2 a)];
- b) whether a product analysis is required [see 6.2 and 15.2 b)];
- c) whether selected chemical elements additional to those specified are to be reported [see 6.3 and 15.2 c)];
- d) the final supply condition of the tubes (see clause 7);
- e) whether the upper limit for the dressing of surface imperfections will be less than the specification value (see 9.8);
- f) whether the tube tolerances are required to suit compression couplings (see 10.3);
- g) whether lengths other than random lengths are required (see 10.4);
- h) whether the method of leak tightness test to be carried out on test category 2 tubes up to and including 180 mm o.d. is the hydraulic test or the eddy current test [see 12.4 and 15.2 e)];
- i) whether the hydraulic test, if specified, is to be carried out at a pressure in excess of 140 bar¹⁾ and the pressure required [see 13.3 and 15.2 e)];
- j) whether additional non-destructive testing is required (see 13.6);
- k) whether verification of elevated temperature proof stress values is required (see 13.7);
- l) whether verification of elevated temperature proof stress values by testing is required and the temperature selected from Table 5 at which this is to be carried out (see 13.7.2);
- m) whether the tubes are to be supplied uncoated or with the manufacturer's normal mill coating (see 16);
- n) whether marking requirements in accordance with BS 5383 are required (see 17.1 and 17.4).

¹⁾ 1 bar = 10⁵ N/m² = 100 kPa.

3 Designation

The tubes shall be designated by the number, and Part of this British Standard, i.e. BS 3602-1 and from Table 1, by one of the references which indicates the method of manufacture (see clause 5) and the appropriate grade of steel (see Table 2), and the test category (see clause 11).

Table 1 — Method of manufacture of tube, reference and steel grades applicable

Method of manufacture	Reference	Steel grades applicable		
Hot finished seamless	HFS	360	430	500 Nb
Cold finished seamless	CFS	360	430	500 Nb
Electric resistance welded	ERW	360	430	—
Cold finished electric resistance welded	CEW	360	430	—
Tubes intended for compression couplings (see 10.2) shall have the letters CC added to the designation. Example. BS 3602-1:CFS 430:Cat. 1 designates cold finished seamless tube made from steel grade 430 tested to category 1. The designations for tubes in this standard and their nearest equivalent designations in ISO 2604-II and ISO 2604-III are listed in appendix A for information.				

4 Manufacture of the steel

4.1 General

The steelmaking process within the provisions of 4.2 and the deoxidation practice within the provisions of 4.3 shall be at the option of the steel manufacturer.

4.2 Steelmaking process

The steel shall be produced by an electric or one of the basic oxygen processes. If he so requires [see 2.2 a)] the purchaser shall be informed of the steelmaking process used.

4.3 Deoxidation

Steels for seamless tubes shall be fully killed. Steels for welded tubes shall be either semi-killed or fully killed.

5 Manufacture of the product

The tubes shall be manufactured by one of the following processes.

- a) *Seamless*. The tubes shall be manufactured by a seamless process and shall be hot finished or cold finished (see note 1).

- b) *Electric resistance welded*. The tubes shall be manufactured from hot or cold flat rolled strip, longitudinally welded continuously by the passage of an electric current across the abutting edges or along the edges prior to closure under welding pressure without the addition of filler metal. They shall be as-welded, hot finished or cold finished. The finished tubes shall not include welds used for joining lengths of the hot or cold, flat-rolled strip, prior to tube forming (see note 1).

For tubes of both test categories ultrasonic or other suitable non-destructive testing method shall be used for continuous examination of the weld area (see note 4).

- NOTE 1 The terms “as-welded”, “hot finished” and “cold finished” apply to the condition of the tube before heat treatment, if required, in accordance with clause 7.
- NOTE 2 Electric resistance welded tubes cover those produced by both high frequency and low frequency techniques using either direct contact or induction.
- NOTE 3 The range of dimensions and tolerances in which tubes are available is dependent upon the method of manufacture. The thicknesses available are also dependent upon the diameter. The dimensional limits generally applicable to this standard are shown in appendix B and the tolerances in clause 10.
- NOTE 4 Non-destructive testing of the weld area is made for the purpose of quality control during manufacture by a method and at a place chosen by the manufacturer.

6 Chemical analysis

6.1 Ladle analysis

The steel shall show on ladle analysis the composition given in Table 2 appropriate to the steel grade specified.

6.2 Product analysis

If a product analysis for acceptance purposes is required by the purchaser this shall be stated in the enquiry and order [see 2.2 b)].

When an analysis on the product is carried out, the permitted deviations given in Table 3 shall apply to the specified ladle analysis in Table 2.

The number of samples to be taken shall be one per cast. The samples shall be taken either from the test pieces used for the verification of the mechanical properties or from the whole thickness of the tube at the same location as for the mechanical test samples.

In cases of dispute the methods for chemical analysis shall be in accordance with British Standard Handbook 19 or BS 6200-3 as appropriate.

Table 2 — Chemical composition and mechanical properties at room temperature

Steel	Method of manufacture	Chemical composition (ladle analysis) (see notes 1 and 2)										Mechanical properties at room temperatures (see note 3)						
		C	Si		Mn		P	S	Al (total)	Nb		R_m		R_e min. for thickness (in mm)			A	Bend test bar diameter
		max.	min.	max.	min.	max.	max.	max.	max.	min.	max.	min.	max.	≤ 16	> 16 ≤ 40	< 40 ≤ 65 ^a	min.	
360	Seamless	0.17	0.10	0.35	0.30	0.80	0.035	0.035	.06	—	—	360	500	235	225	215	25	4a (see note 3)
	Welded	0.17	—	0.35	0.30	0.80	0.035	0.035	.06	—	—	360	500	235	—	—	25	—
430	Seamless	0.21	0.10	0.35	0.40	1.20	0.035	0.035	.06	—	—	430	570	275	265	255	22	4a (see note 3)
	Welded	0.21	—	0.35	0.40	1.20	0.035	0.035	.06	—	—	430	570	275	—	—	22	—
500 Nb	Seamless	0.22	0.15	0.35	1.00	1.50	0.035	0.030	.06	0.015	0.10	500	650	355	345	335	21	5a (see note 3)
NOTE 1 Elements not quoted in this table are not intentionally added other than for the purpose of finishing the heat. All reasonable precautions are taken to prevent the addition of such elements from scrap or other materials used in the manufacture, but residual elements may be present provided that the mechanical properties and applicability are not adversely affected.																		
NOTE 2 For permissible deviations on product analysis, see Table 3.																		
NOTE 3 R_m is the tensile strength. R_e is the yield strength. For acceptance purposes either the upper yield stress R_eH or the 0.5 % proof stress (total elongation) $R_{t0.5}$ may be used (see 13.1.2). A is the percentage elongation after fracture on a gauge length of $L_0 = 5.65 \sqrt{S_0}$ (where S_0 is the original cross-sectional area of the gauge length). a is the thickness of the test piece.																		
^a For thicknesses over 65 mm, properties are subject to agreement between the supplier and the purchaser.																		

6.3 Content of elements

If required by the purchaser [see 2.2 c)] the content of elements, selected by the purchaser, in addition to those specified in Table 2 shall be reported.

NOTE The purchaser may require, for example, to know the content of elements relating to weldability.

Table 3 — Permitted deviations of the product analysis from the specified ladle analysis

Element	Upper limit of range in which the specified maximum for ladle analysis falls	Permitted deviations from specified limits	
		Greater than maximum	Less than maximum
	Up to and including, %	%	%
Carbon	0.25	0.03	—
Silicon	0.50	0.05 ^a	0.05 ^a
Manganese	2.0	0.10 ^a	0.10 ^a
Phosphorus	0.050	0.005	—
Sulphur	0.050	0.005	—
Niobium	0.10	0.005 ^a	0.005 ^a
Aluminium	0.06	0.005	—

^a The deviations apply either above the specified maximum or below the specified minimum but both deviations shall not be applied to different samples from the same cast.

Table 4 — Tube manufacturing processes and final supply conditions

Manufacturing process	Final supply conditions
Electric resistance welded (ERW)	Hot finished — not heat treated As welded — normalized ^a Cold finished — normalized ^a
Hot finished seamless (HFS), grades 360 and 430	Hot finished — not heat treated Hot finished — normalized ^a
Cold finished seamless (CFS), grades 360 and 430	Cold finished — normalized ^a
Hot finished seamless (HFS), grade 500 Nb	Hot finished — normalized ^b
Cold finished seamless (CFS), grade 500 Nb	Cold finished — normalized ^b

^a Normalizing carried out in the temperature range 880 to 940 °C.

^b Normalizing carried out in the temperature range 900 to 960 °C.

7 Final supply condition

7.1 Except as provided for in 7.2, the final supply condition applicable to each manufacturing process shall be as given in Table 4. Unless otherwise specified by the purchaser [see 2.2 d)] on the order, the manufacturer shall have the option of supplying tube in any of the applicable supply conditions given in Table 4.

7.2 If the tubes are required for subsequent manipulation and when acceptable to the purchaser, the manufacturer may deliver the tubes in a condition other than the final supply condition given in Table 4.

NOTE The manufacturer should inform the purchaser of the heat treatment necessary to give the required properties (see also 8.1 and 12.2.3).

8 Mechanical properties

8.1 Mechanical properties at room temperature

The mechanical properties at room temperature²⁾ to be obtained on test pieces selected prepared and tested in accordance with clauses 12 and 13 shall be as specified in Table 2.

NOTE If heat treatments different from, or additional to, the normal reference heat treatment (which may have an adverse effect on the mechanical properties) are to be carried out after the delivery of the tubes, the purchaser may request, at the time of enquiry and order, additional mechanical tests on samples that have been given heat treatments different from or additional to, those given in Table 4. The heat treatment of the samples and the mechanical properties to be obtained from tests on them should be agreed between the purchaser and the manufacturer at the time of enquiry and order.

8.2 Elevated temperature minimum 0.2 % proof stress values

The elevated temperature minimum 0.2 % proof stress values shall be as specified in Table 5 when sampled as described in 12.6 and tested or verified as described in 13.7.

NOTE The values are not normally subject to verification.

8.3 Stress rupture properties

Stress rupture properties shall not be subject to verification.

NOTE For tubes complying with this standard the estimated average stress rupture values are shown in appendix C and can be used for design purposes.

8.4 Flattening test properties

8.4.1 When tested in accordance with 13.2.2 the ring shall withstand being flattened without showing cracks or flaws in the metal except as specified in 8.4.2 until the distance between the platens, H , is equal to or less than the value calculated using the constant specified.

8.4.2 Test pieces are normally tested without preparation of the cut edges and in this condition cracks originating at the edges of the test piece which are less than 6 mm long and which do not penetrate through the wall shall be deemed not to affect compliance with this standard.

8.5 Bend test properties

NOTE Not applicable to electric resistance welded tube, including induction welded tube.

8.5.1 When tested in accordance with 13.2.3, the test piece shall not show any crack or flaw except as specified in 8.5.2.

8.5.2 Test pieces are normally tested without preparation of the cut edges and in this condition cracks originating at the edges of the test pieces which are less than 6 mm long and which do not penetrate the thickness of the piece shall be deemed not to affect compliance with this standard.

9 Visual inspection and appearance

9.1 Visual inspection shall be carried out on the external and internal surfaces. In the case of the internal surface, the tube shall be viewed from each end.

NOTE 1 Visual inspection should be carried out in suitable lighting.

NOTE 2 It is recognized that the ability to visually examine the inner surface from the tube ends is limited in the case of small diameter tubes.

9.2 The tubes shall be free from such defects as can be established by visual inspection and testing in accordance with this standard (see 12.3).

9.3 The tubes shall have a finish and a surface condition which permits surface imperfections or marks requiring dressing to be identified.

NOTE Any special requirements for surface condition should be agreed between the purchaser and the manufacturer at the time of enquiry and order.

Table 5 — Minimum 0.2 % proof stress (R_p 0.2) values at elevated temperatures (see note)

Steel grade	R_p 0.2 min. at a temperature of									
	20 °C	50 °C	100 °C	150 °C	200 °C	250 °C	300 °C	350 °C	400 °C	450 °C
	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²
360	212	207	198	187	170	150	132	120	112	108
430	255	248	239	224	202	180	164	151	143	137
500 Nb	343	333	313	291	267	244	222	203	188	177

NOTE Values at 20 °C and 50 °C are included for information and are not subject to verification. Values except those at 50 °C, which have been obtained by interpolation, are based on tests carried out in accordance with BS 3688-1 at the specified strain rate of 0.001 to 0.003 per min. Values at 20 °C differ therefore from the corresponding minimum values given in Table 1 as the significantly higher strain rate for room temperature testing results in higher proof stress values.

²⁾ In cases of dispute, room temperature is to be taken as 20 °C ± 5 °C.

9.4 It shall be permissible to dress by grinding or machining surface marks and imperfections such as scabs, seams, tears, laps, slivers or gouges provided that the thickness of the tube after dressing does not fall below the nominal thickness by more than the tolerance specified in this standard.

9.5 Surface imperfections which encroach on the minimum wall thickness shall be considered defects and shall be deemed not to comply with this standard.

9.6 All dressed areas shall blend smoothly into the contour of the tube.

9.7 The manufacturer shall explore by grinding a sufficient number of surface marks and imperfections identified during visual inspection to provide assurance that these have been evaluated to ensure compliance with **9.8**.

9.8 The manufacturer shall, subject to the limitations given in **9.9**, dress surface imperfections found by exploration in accordance with **9.7** to be deeper than 5 % of the nominal thickness or 3 mm whichever is the lesser but not less than 0.5 mm. The purchaser shall have the option to specify an upper limit of 1.5 mm instead of 3 mm [see **2.2 e**].

9.9 If surface imperfections acceptable under **9.8** are not scattered and appear over a large area in excess of what is considered to be an acceptable surface condition then tubes shall be rejected or alternatively subjected to dressing as agreed at the time of the order.

9.10 The tubes shall not deviate from straightness by more than 1 in 600 at the centre of the length.

9.11 The ends shall be cut nominally square with the axis of the tube and shall be free from excessive burrs.

10 Tolerances

10.1 General

The maximum tolerances on the dimensions of the tubes shall be as specified in **10.2** and **10.4** or, if specified by the purchaser on his order [see **2.2 f**], as specified in **10.3** and **10.4**.

10.2 Outside or inside diameter, thickness and size of weld upset

The tolerances on outside or inside diameter shall, include ovality and those on thickness shall include eccentricity.

a) Hot finished seamless (HFS)

Tubes specified by outside diameter and thickness shall be subject to the following tolerances.

Outside diameter: $\pm 1\%$ with a minimum of ± 0.50 mm.

Thickness:

Thickness to outside diameter ratio	Tolerance on thickness
Up to and including 3 %	$\pm 15\%$
Over 3 % up to and including 10 %	$\pm 12.5\%$

Over 10 %	{	Tubes up to and including 168.3 mm outside diameter	$\pm 12.5\%$
		Tubes over 168.3 mm outside diameter	$\pm 10\%$

Tubes specified by inside diameter and minimum thickness shall be subject to the following tolerances.

NOTE Such tubes are not normally available where the nominal outside diameter is less than 200 mm.

Inside diameter:

≤ 320 mm	$\pm 1.5\%$
> 320 mm	$\pm 1\%$

Thickness:

Thickness to inside diameter ratio	Tolerance on thickness
$\leq 7.5\%$	$\pm 15\%$
$> 7.5\% \leq 15\%$	$\pm 12.5\%$
$> 15\%$	$\pm 10\%$

b) Cold finished seamless (CFS)

Tubes specified by outside or inside diameter and thickness shall be subject to the following tolerances.

Outside diameter: $\pm 0.75\%$ with a minimum of ± 0.50 mm

Thickness: $\pm 7.5\%$

Tubes 200 mm inside diameter and above, specified by the inside diameter and minimum thickness, shall be subject to the following tolerances.

Inside diameter: $+ 0.8$ mm – 1.6 mm

Thickness:

Up to and including 6.5 mm	$+ 15\%$, $- 0\%$
Over 6.5 mm	$+ 10\%$, $- 0\%$

c) Electric resistance welded including induction welded (ERW) (applicable to as welded or hot finished)

The outside diameter and thickness shall be subject to the following tolerances.

Outside diameter: $\pm 1\%$ with a minimum of ± 0.50 mm

Thickness (excluding the weld): $\pm 7.5\%$

The external weld upset (flash) shall be removed completely, i.e. flush with the outside surface of the tube. Where practicable, the internal weld upset shall be trimmed throughout the length of the tube so that its maximum height shall not exceed 8% of the specified thickness or 0.25 mm, whichever is the greater.

d) *Cold finished electric resistance including induction welded (CEW)*

The outside diameter and thickness shall be subject to the following tolerances.

Outside or inside diameter: $\pm 0.75\%$ with a minimum of ± 0.50 mm.

Thickness: $\pm 7.5\%$

10.3 Tubes for use with compression couplings

If specified by the purchaser on his order [see 2.2 f)] tubes shall be supplied to the following tolerances suitable for use with compression couplings.

Outside diameter:

Up to and including 30 mm ± 0.10 mm

Over 30 mm up to and including 38 mm ± 0.15 mm

Over 38 mm up to and including 50 mm ± 0.20 mm

Thickness: $\pm 10\%$

10.4 Length

Unless otherwise specified by the purchaser [see 2.2 g)] tubes shall be supplied as random lengths.

NOTE The actual range of the random lengths may be the subject of agreement between the purchaser and the manufacturer.

Where the length is specified as "exact length" or "cut length" the permissible deviation shall be $+6$ mm, -0 mm for lengths up to and including 6 m. For every 3 m increase in length above 6 m, the plus tolerance shall be increased by 1.5 mm with a maximum of 12.0 mm.

11 Tests

The tubes shall be subjected to the tests specified in Table 6 appropriate to the test category.

The elevated temperature properties shall apply to tubes of both test category 1 and test category 2.

12 Number, selection and preparation of samples and test pieces

12.1 Selection of "batches" for testing purposes

For tubes not heat treated, a batch shall consist only of tubes of the same diameter and thickness and of the same steel cast. For tubes that are heat treated, a batch shall consist only of tubes of the same diameter and thickness and of the same steel cast subjected to the same finishing treatment in a continuous furnace or heat treated in the same furnace charge in a batch-type furnace. If the number of samples specified in this clause, when applied to a particular order, necessitates a number of tubes that includes a fraction, the fraction shall be treated as unity.

12.2 Mechanical tests at room temperature³⁾

12.2.1 For test category 1 the number of tubes on which mechanical tests at room temperature are to be performed shall be 2% of the tubes from each batch.

12.2.2 For test category 2 the number of tubes on which mechanical tests at room temperature are to be performed shall be as follows.

- | | |
|---|--------------------------------|
| a) Up to and including 323.9 mm outside diameter: | 0.5 % of tubes from each batch |
| b) Over 323.9 mm outside diameter: | 1.0 % of tubes from each batch |

12.2.3 Test samples shall be cut from the tube in the final supply condition. If the tubes are to be delivered in a condition different from the specified final heat treatment condition, the test sample shall be in the appropriate reference heat treatment condition given in Table 4.

From the test samples from each tube selected for testing, one test piece shall be prepared for each of the mechanical tests specified in clause 11.

12.2.4 For the tensile test (see 13.1), the dimensions of the test piece shall comply with the appropriate requirements of BS 18.

For welded tubes the tensile test piece shall not include the weld unless the tube is tested in full section.

NOTE For the tensile test, the test piece may be taken longitudinally or transversely at the option of the manufacturer.

12.2.5 For the flattening test (see 13.2.2), a ring not less than 40 mm in length shall be taken from one end of each selected tube.

³⁾ In cases of dispute room temperature is to be taken as 20 ± 5 °C.

12.2.6 For the bend test (see **13.2.3**), the test piece shall be cut circumferentially from one end of each selected tube. The test piece shall not be less than 40 mm wide and of the full thickness of the tube or, for large tubes, a test piece machined from a circumferential strip to a rectangular cross section 40 mm wide by 20 mm thick.

The length of the test piece shall be selected by the manufacturer to suit the equipment on which the test is carried out.

NOTE The edges of the test piece may be rounded to a radius of 1.6 mm.

12.3 Visual inspection

Every tube shall be inspected visually (see clause **9**).

Table 6 — Tests for test category 1 and test category 2

Category 1	Category 2
Visual inspection (see clause 9 and 12.3)	Visual inspection (see clause 9 and 12.3)
Tensile test (see 8.1 , 12.2 and 13.1)	Tensile test (see 8.1 , 12.2 and 13.1)
Flattening test or bend test (see 8.1 , 12.2 and 13.2)	Flattening test or bend test (see 8.1 , 12.2 and 13.2)
Ultrasonic test (see 12.5)	Leak tightness test (see 12.4)

12.4 Leak tightness

All test category 2 tubes shall be subjected to a leak tightness test. This shall be by a hydraulic test in accordance with **13.3** for all tube sizes above 180 mm o.d. For sizes 180 mm o.d. and below, this shall be by either a hydraulic test in accordance with **13.3** or by an eddy current test in accordance with **13.4**, at the discretion of the manufacturer unless otherwise specified by the purchaser [see **2.2 h**]).

NOTE 1 The hydraulic leak tightness test is capable of detecting defects of a size and disposition permitting the test fluid to leak through the tube wall. It may not detect through-wall defects that are tight or defects extending an appreciable depth into the tube wall without complete penetration. The test specified in **13.3** should not be regarded as a test of strength since the maximum pressure specified will develop only limited stress in the wall of tubes having low diameter to thickness ratio.

NOTE 2 Both the hydraulic test and the eddy current test may leave a short length at each end of the tube incompletely tested. If specified at the time of enquiry and order the length affected should be determined by the manufacturer and reported to the purchaser. Further, if specified at the time of enquiry and order, the manufacturer may either cut off the untested lengths or test them by an agreed alternative procedure.

⁴⁾ S_0 is the original cross-sectional area of the gauge length.

⁵⁾ In cases of dispute room temperature is taken as $20 \pm 5\text{ }^{\circ}\text{C}$.

12.5 Ultrasonic testing

All tubes to test category 1 shall be ultrasonically tested (see **13.5**).

NOTE Ultrasonic testing may leave a short length at each end of the tube incompletely tested. If specified at the time of the enquiry order, the length affected should be determined by the manufacturer and reported to the purchaser. Further, if specified at the time of the enquiry and order, the manufacturer may either cut off the untested lengths or test them by an agreed alternative procedure.

12.6 Elevated temperature proof stress testing

If elevated temperature testing is carried out (see **13.7**), one test shall be made on each cast using a test piece taken at a position adjacent to the test pieces used for the tensile test at room temperature. If tubes of more than one thickness are to be supplied from one cast, the test piece shall be taken from a tube with the nominally thickest dimension.

NOTE Cast separation is required for all tubes when acceptance tests for verification of the elevated temperature values are required.

13 Test methods

13.1 Tensile test

13.1.1 The tensile test shall be carried out in accordance with BS 18.

13.1.2 The tensile strength R_m , the yield strength R_e and the elongation A shall be determined. For the yield strength, either the upper yield stress R_{eH} or the 0.5 % proof stress (total elongation) $R_{t0.5}$ shall be determined.

The elongation shall be reported with reference to a gauge length of $L_0 = 5.65 \sqrt{S_0}$ ⁴⁾. If other gauge lengths are used, the corresponding percentage elongation on $5.65 \sqrt{S_0}$ shall be obtained by reference to BS 3894-1. In cases of dispute, a gauge length of $5.65 \sqrt{S_0}$ shall be used.

13.2 Flattening or bend test

13.2.1 General. At the option of the manufacturer, and dependent upon the dimensions of the tube and method of manufacture, either a flattening test (see **13.2.2**) or a bend test (see **13.2.3**) shall be carried out.

13.2.2 Flattening test. The test piece shall be flattened at room temperature⁵⁾ between parallel, flat platens until the distance between the platens H (in mm) is not greater than the value given by the following equation:

$$H = \frac{(1 + C)a}{C + a/D}$$

where

a is the specified thickness (in mm);
 D is the specified outside diameter (in mm);
 C is the flattening test constant (see Table 7).

Table 7 — Flattening test constant C

Steel grade	Flattening test constant C
360 seamless	0.09
welded	0.09
430 seamless	0.08
welded	0.08
500 Nb seamless	0.06

For electric resistance welded including induction welded tubes the weld shall be positioned at 90° to the direction of flattening.

13.2.3 Bend test

NOTE The bend test is not applied to electric resistance welded including induction welded tubes.

The test piece shall be bent at room temperature⁶⁾ in the direction of the original curvature through an angle of 180°.

13.3 Hydraulic test

For test category 2 tubes which are hydraulically tested for the verification of leak tightness (see 12.4) the test pressure P (in bar) shall be calculated from the equation:

$$P = \frac{20 Sa}{D}$$

where

D is the specified outside diameter (in mm);
 a is the specified thickness (in mm);
 S is a stress (in N/mm²) which shall be taken as 80 % of the specified minimum yield strength appropriate to thickness at room temperature.

The test shall be carried out at the pressure P or at 140 bar whichever is lower but when 140 bar is lower than P , the purchaser has the option [see 2.2 i)] to specify that the test shall be carried out at a pressure higher than 140 bar but not greater than the value P determined from the equation.

The test pressure shall be maintained sufficiently long for any leakage to be observed visually. Any tube failing to withstand the hydraulic pressure test shall be deemed not to comply with this standard.

13.4 Eddy current testing

For test category 2 tubes that are eddy current tested for verification of leak tightness (see 12.4) the eddy current test and the assessment of results shall be carried out in accordance with appendix E.

13.5 Ultrasonic testing

For test category 1, ultrasonic testing for longitudinal imperfections and assessment of results shall be carried out in accordance with appendix F.

13.6 Additional non-destructive testing

The purchaser has the option to specify additional non-destructive tests. The additional methods of test and the basis of acceptance shall be stated on his enquiry and order [see 2.2 j)].

13.7 Elevated temperature proof stress tests or verification procedure

13.7.1 if the purchaser requires verification of elevated temperature proof stress values, this shall be carried out in accordance with 13.7.2 or 13.7.3 [see 2.2 k)]. The method of verification shall be at the option of the manufacturer unless the purchaser specifies verification in accordance with 13.7.2 on the enquiry and order [see 2.2 l)].

13.7.2 When the purchaser requires verification of elevated temperature proof stress values by testing, the tests shall be carried out in accordance with BS 3688-1 at a temperature selected by the purchaser from Table 5 and specified at the time of enquiry and order [see 2.2 l)].

NOTE The specified strain rate in BS 3688-1 is 0.001 to 0.003 per minute.

13.7.3 For verification of elevated temperature proof stress values without testing, the values shall be verified by the procedure given in BS 3920 (see appendix D).

14 Retests

Should a tube selected for testing fail in any of the tests specified in 13.1, 13.2 or 13.7, the tube and the batch of tubes that it represents shall be deemed not to comply with this standard unless:

- two further tests of the same kind as produced failure are made from the same tube and both these further tests prove satisfactory; or
- the first tube tested is rejected and all the tests specified in 13.1, 13.2 and 13.7 are carried out on two further tubes from the batch and all these tests are satisfactory; or

⁶⁾ Marking BS 3602 on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standard. The accuracy of the claim is therefore solely the responsibility of the person making the claim. Such a declaration is not to be confused with third party certification of conformity, which may also be desirable.

c) if either of the further tests required by a) or b) proves unsatisfactory, the tubes represented are suitably heat treated or re-heat treated and samples are selected and tested in accordance with all the tests specified in **13.1**, **13.2** and **13.7** and all these tests are satisfactory.

15 Test certificate

15.1 A manufacturer's test certificate shall be supplied giving the following information:

- a) the designation (see clause **3**);
- b) the ladle analysis for elements specified in Table 2 for each of the casts used;
- c) the mechanical test results for each of the batches tested;
- d) the purchaser's order number or other appropriate mark [see **17.2(c)**].

15.2 The certificate shall also give the following information where appropriate for options selected by the purchaser (see **2.2**):

- a) the steelmaking process used (see **4.2**);
- b) the product analysis (see **6.2**);
- c) the content of selected elements in addition to those specified in Table 2 (see **6.3**);
- d) the final supply condition (see clause **7**);
- e) for category 2 tubes, the method of verification of leak tightness, either by eddy current or hydraulic and, in the latter case, the pressure applied (see **12.4**);
- f) the elevated temperature test results (see **13.7.2**) or statement of verification of values (see **13.7.3**).

16 Protective coating

The tubes shall be supplied either uncoated or with the manufacturer's normal mill coating at the option of the purchaser [see **2.2 m**)].

NOTE If the purchaser requires additional measures to protect the tubes during delivery or storage, then this should be the subject of agreement between the purchaser and the manufacturer.

17 Marking

17.1 Before dispatch from the manufacturer's works, the tube shall be marked in accordance with **17.2** or, if specified by the purchaser on his order [see **2.2 n**)], in accordance with **17.4**.

17.2 Except as provided for below for tubes that are bundled, each tube shall be legibly marked at one end commencing not more than 300 mm from the end, by stencilling or other indelible marking.

The marking shall consist of the following in the sequence indicated:

- a) the manufacturer's name or identification mark;
- b) the designation⁷⁾ as given in clause **3**, e.g. BS 3602-1:CFS 430:Cat. 1.;
- c) the purchaser's order number or other appropriate mark to identify it with the test certificate.

For tubes that are bundled, the information in a), b) and c) shall be either stamped on one or more metal or other durable tags, or printed on banding clips or straps, which shall be securely attached to each bundle. Not more than one steel grade shall be included in any one bundle.

NOTE If traceability of cast identity is required this should be the subject of an agreement between the purchaser and the manufacturer at the time of enquiry and order.

17.3 The quality of the paint or ink applied shall be such that it shall have a life of at least one year in unheated storage under cover.

The dried film shall contain not more than 250 p.p.m. (0.025 %) of any of the following metals:

lead, tin, copper, zinc.

NOTE For certain applications limits may be required on the levels of sulphur and halogens in the paint. These limits should be the subject of agreement between the supplier and the purchaser.

17.4 If specified by the purchaser on his order [see **2.2 n**)] each tube shall be marked in accordance with BS 5383 and shall include the information specified in **17.2 a)**, **b)** and **c)**.

NOTE Colour coding is an optional additional requirement in BS 5383 and, if required, should be specified by the purchaser on the enquiry and order.

⁷⁾ Marking BS 3602 on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standard. The accuracy of the claim is therefore solely the responsibility of the person making the claim. Such a declaration is not to be confused with third party certification of conformity, which may also be desirable.

Appendix A Designations of steel tubes in BS 3602-1 and the nearest equivalent steel numbers in ISO 2604-II and 2604-III

Table 8 lists the designations for tubes in BS 3602-1:1987 and the nearest equivalent steel numbers in ISO 2604-II and 2604-III.

Table 8 — Designations of steel tubes in BS 3602-1:2604-1987 and the nearest equivalent designations in BS 3602-1:2604-1978 and steel numbers in ISO 2604-II and 2604-III

BS 3602-1:1987	Colour code in accordance with BS 5383	BS 3602-1:1978	ISO 2604:1975-II and ISO 2604:1975-III
HFS 360 Cat 1 CFS 360 Cat 1 ERW 360 Cat 1 CEW 360 Cat 1 HFS 360 Cat 2 CFS 360 Cat 2 ERW 360 Cat 2 CEW 360 Cat 2	White	HFS 360 Cat 1 CFS 360 Cat 1 ERW 360 Cat 1 CEW 360 Cat 1 HFS 360 Cat 2 CFS 360 Cat 2 ERW 360 Cat 2 CEW 360 Cat 2	TS5 Cat IV TS5 Cat IV (cold finished) TW5 Cat IV TW5 Cat IV (cold finished) TS5 Cat II TS5 Cat II (cold finished) TW5 Cat II TW5 Cat II (cold finished)
HFS 430 Cat 1 CFS 430 Cat 1 ERW 430 Cat 1 CEW 430 Cat 1 HFS 430 Cat 2 CFS 430 Cat 2 ERW 430 Cat 2 CEW 430 Cat 2		HFS 410 Cat 1 CFS 410 Cat 1 ERW 410 Cat 1 CEW 410 Cat 1 HFS 410 Cat 2 CFS 410 Cat 2 ERW 410 Cat 2 CEW 410 Cat 2	TS9H Cat IV TS9H Cat IV (cold finished) TW9H Cat IV TW9H Cat IV (cold finished) TS9H Cat II TS9H Cat II (cold finished) TW9H Cat II TW9H Cat II (cold finished)
HFS 500 Nb Cat 1 CFS 500 Nb Cat 1 HFS 500 Nb Cat 2 CFS 500 Nb Cat 2		HFS 490 Nb Cat 1 CFS 490 Nb Cat 1 HFS 490 Nb Cat 2 CFS 490 Nb Cat 2	— — — —

Appendix B Dimensional limits of tubes in relation to the method of manufacture

The range of dimensions shown in Table 9 will cover most applications for which the standard will be used for the tubes supplied to outside diameter and thickness. However tubes to inside diameter and thickness are also available in the seamless and cold finished electric resistance welded ranges.

Table 9 — Dimensional limits of tubes in relation to the method of manufacture

Method of manufacture	Outside diameter	Maximum thickness
	mm	mm
Hot finished seamless (HFS)	33.7 to 1 200	200
Cold finished seamless (CFS)	12.7 to 235	25
Electric resistance welded (ERW)	12.7 to 508	12.7
Cold finished electric resistance welded (CEW)	12.7 to 235	10

Appendix C Estimated average stress rupture values taken from ISO/TR 7468

Estimated average stress rupture values are shown in Table 10 for design purposes.

Table 10 — Estimated average stress rupture values

Steel grade	Rupture time	Estimated average stress for rupture (see note 1) at a temperature of														
		380 °C	390 °C	400 °C	410 °C	420 °C	430 °C	440 °C	450 °C	460 °C	470 °C	480 °C	490 °C	500 °C	510 °C	520 °C
360 and 430	h	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²	N/mm ²
	10 000	213	197	181	166	151	138	125	112	100	89	78	67	57	47	37
	30 000	192	176	161	147	133	120	107	95	84	73	63	52	42	31	—
	50 000	183	167	152	138	125	112	100	88	77	66	56	46*	35*	—	—
	100 000	171*	155*	141*	127*	114*	102*	90*	78*	67*	57*	47*	36*	—	—	—
	150 000	164*	149*	134*	121*	108*	96*	84*	73*	62*	52*	41*	(29)*	—	—	—
	200 000	159*	144*	130*	116*	104*	92*	80*	69*	58*	48*	37*	(23)*	—	—	—
	250 000	155*	140*	126*	113*	101*	89*	77*	66*	55*	45*	34*	—	—	—	—
500 N Nb	10 000	291	266	243	221	200	180	161	143	126	110	96	84	74	65	58
	30 000	262	237	214	192	171	151	132	115	99	86	74	65	57	50	(44)
	50 000	248	223	200	177	156	136	118	102	87	75	65	57	50	(44)	(37)
	100 000	227	203	179	157	136	117	100	85	73	63	55	(47)	(41)	(32)	—
	150 000	215	190	167	144	124	105	89	76	65	56	(49)	(42)	(34)	—	—
	200 000	206*	181*	157*	135*	115*	97*	82*	70*	60*	52*	(44)*	(37)*	—	—	—
	250 000	199*	174*	150*	128*	108*	91*	77*	66*	56*	(48)*	(41)*	(32)*	—	—	—

NOTE 1 Values obtained by extrapolation.

Asterisks and parentheses indicate where values have been obtained by either “extended time” and /or “extended stress” extrapolation, respectively.

Experience suggests that reliable extrapolations may be made covering a range of ± 25 °C about each test temperature, on the basis of a series of tests from at least five casts of steel, the longest test of each series exceeding a certain minimum duration.

The confidence that can be placed upon such values will be related to the extent of extrapolation and for the purposes of this standard, extrapolations exceeding approximately three times the above minimum duration are described as “extended time extrapolations” and marked with an asterisk in the table.

Values may also be obtained by extending the parametric master curves to stresses beyond those at which casts have been tested. such values obtained by “extended stress extrapolation” are enclosed in parentheses. They are subject to greater uncertainty than other values.

NOTE 2 Where carbon and carbon manganese steels have been tempered or stress-relieved for times in excess of 3 h at 620 °C or equivalent times at other temperatures, the average rupture stress should be taken as 10 % lower than the value given.

NOTE 3 The stress rupture values in 10 were derived from data generated by testing stress rupture specimens in air and in some cases at temperatures where significant oxidation of the specimen will have occurred.

Appendix D Procedure for verification of elevated temperature values

As an alternative to verification of individual casts by testing at elevated temperatures, the manufacturer, unless otherwise specified by the purchaser, may verify that his product consistently meets the minimum elevated temperature proof stress values given in the specification for the relevant type of steel by adopting the procedure described in BS 3920.

The basis of the procedure is that the manufacturer compares appropriate data relating to his product with the confidence lines that have been determined from the analysis of a large body of data that have been used to derive the specification minima given in this standard.

Information required for the construction of the lower confidence lines which are necessary for the application of the procedure are given in Table 11 and Table 12.

An example of confidence lines for steel 430 is shown in Figure 1. To achieve the appropriate degree of accuracy however it is necessary to construct the confidence lines on a larger scale. To enable this to be done the co-ordinates of two suitably spaced points on the lines, appropriate to the various grades of steel at each temperature, are given in Table 11 and Table 12.

Table 11 — Parameters for lower confidence lines: steel grades 360 and 430

Temperature °C	0.2 % proof stress at two levels of room temperature tensile strength	
	300 N/mm ²	500 N/mm ²
	N/mm ²	N/mm ²
100	147	262
150	140	245
200	127	221
250	108	199
300	90	183
350	79	169
400	72	161
450	70	153

Table 12 — Parameters for lower confidence lines: steel grade 500 Nb

Temperature °C	0.2 % proof stress at two levels of room temperature tensile strength	
	480 N/mm ²	610 N/mm ²
	N/mm ²	N/mm ²
100	289	351
150	270	325
200	249	297
250	225	275
300	201	255
350	182	238
400	166	224
450	154	213

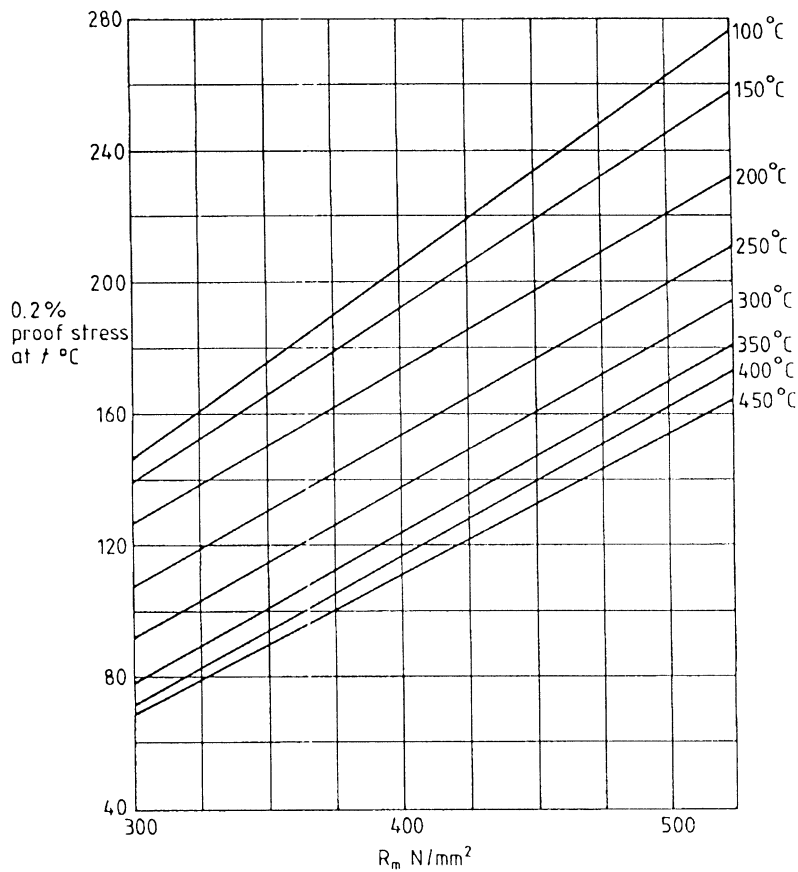


Figure 1 — Example of lower confidence lines (for grade 430)

Table 13 — Drill diameter 10 sizes

Outside diameter	Drill diameter
mm	mm
≤ 25	1.20
> 25 ≤ 45	1.70
> 45 ≤ 65	2.20
> 65 ≤ 100	2.70
> 100 ≤ 140	3.20
> 140 ≤ 180	3.70

Table 14 — Notch dimensions for method B

Depth	12½ % of the specified tube thickness
Minimum depth	0.6 mm
Maximum depth	1.5 mm
Tolerance on depth	± 15 % of notch depth
Width	Not greater than notch depth with a minimum of 0.50 mm
Length	A convenient length selected by the manufacturer for calibration and checking purposes

Appendix E Eddy current testing of tubes for verification of leak tightness

E.1 General

Eddy current testing shall be used only on tube sizes up to and including 180 mm outside diameter. The tubes shall be tested in accordance with BS 3889-2A, with the options of BS 3889-2A as specified in E.2 and E.3 and with the modification to BS 3889-2A as specified in E.4.

E.2 Test procedure

The tubes shall be tested for verification of leak tightness using a concentric coil or a rotating tube/rotating coil eddy current technique as described for methods A and B of BS 3889-2A.

E.3 Reference standards

The equipment shall be calibrated using reference standards prepared in accordance with clause 5.2.4 a) for method A and 5.2.4 b) for method B of BS 3889-2A:1986. The dimensions of the reference hole (method A) and the reference notch (method B) shall be as specified in Table 13 and Table 14 of this standard.

E.4 Assessment of results

The results of the test shall be assessed in accordance with clause 7 of BS 3889-2A:1986, except that 7.3 b) shall be replaced by the following. "Explore the suspect area of the tube by dressing. If the tube thickness within the dressed area remains within the thickness tolerance, either:

- 1) retest the tube using the selected eddy current method in accordance with this appendix and if no signals are obtained that give a trigger/alarm condition the tube shall be deemed to have passed the test; or
- 2) subject the suspect area to magnetic particle inspection in accordance with BS 6072 to ensure that dressing has resulted in complete removal of the imperfection; the tube shall then be deemed to have passed the test.

If the tube thickness within the dressed area does not remain within the thickness tolerance or, if on retesting using the eddy current test method signals are obtained that give a trigger/alarm condition, either:

- 3) cut off the suspect area, the remaining length being deemed to have passed the test; or
- 4) the tube shall be deemed not to have passed the test."

Appendix F Ultrasonic testing of tubes for the detection of longitudinal imperfections

F.1 General

The tube shall be tested in accordance with BS 3889-1 with the options of BS 3889-1 as specified in F.2 and F.3, and with the modification to BS 3889-1 as specified in F.4.

F.2 Test procedure

The tube shall be tested for the detection of imperfections that are oriented predominantly longitudinally to the major axis of the tube in accordance with method A of BS 3889-1. Scanning shall be carried out in both directions of beam travel in accordance with Figure 1 a) of BS 3889-1.

F.3 Reference standards

The equipment shall be calibrated using longitudinal notches parallel to the major axis of the tube, in accordance with clauses 7.1, 7.2.1, 7.2.2 and 7.2.5 of BS 3889-1:1983. The dimensions of the reference notches shall be as given in Table 15 below.

Table 15 — Reference notch dimensions and tolerances

Depth	5 % of specified tube thickness
Minimum depth	0.3 mm
Maximum depth	1.5 mm
Tolerance on depth	± 15 % of notch depth or ± 0.05 mm whichever is the larger
Maximum width	1.5 mm
Length	A convenient length, selected by the manufacturer for calibration and checking purposes

F.4 Assessment of results

F.4.1 Any tube that does not produce signals giving a trigger/alarm condition shall be deemed to have passed the test.

F.4.2 Any tube that produces signals giving a trigger/alarm condition shall be designated "suspect", or, at the manufacturer's option shall be retested on the same automatic equipment as used in the original test.

F.4.3 If, upon retesting, no signal giving a trigger/alarm condition is obtained, the tube shall be deemed to have passed the test. Tubes giving a trigger/alarm condition upon retesting shall be designated “suspect”.

F.4.4 For “suspect” tubes, one or more of the actions specified in items a) to e) shall be taken, or item f) shall apply.

a) The manufacturer shall show to the satisfaction of the purchaser that the trigger/alarm condition arises from a combination of minor imperfections, individually not serious enough to cause a trigger/alarm condition and the tube shall then be deemed to have passed the test.

b) For inside surface defects, the “suspect” area shall be explored by dressing, using an acceptable method and, after checking that the remaining thickness is within tolerance, the suspect area shall be retested by an ultrasonic shear wave method using equipment with the same ultrasonic parameters and calibrated to give the same test sensitivity as used in the original ultrasonic test. If no signals are obtained that give a trigger/alarm condition, the tube shall be deemed to have passed the test.

c) For outside surface defects, the “suspect” area shall be explored by dressing, using an acceptable method, and after checking that the remaining thickness is within tolerance, the “suspect” area shall be retested non-destructively, using the magnetic particle inspection method in accordance with BS 6072 until it can be shown that the imperfection has been completely removed.

The “suspect” area shall then be retested by an ultrasonic shear wave method using equipment with the same ultrasonic parameters and calibrated to give the same test sensitivity as used in the original ultrasonic test. If no signals are obtained that give a trigger/alarm condition, the tube shall be deemed to have passed the test.

d) The surface of the tube shall be dressed using an acceptable method, either completely or locally to include the “suspect” area and, after checking that the thickness is within tolerance, the tube shall be retested on the same automatic equipment as that used in the original test. If no signals are obtained that give a trigger/alarm condition, the tube shall be deemed to have passed the test.

e) The “suspect” area shall be cropped off, the remaining length being deemed to have passed the test.

f) The tube shall be deemed not to have passed the test.

Publications referred to in this standard

BS 18, *Methods for tensile testing of metals*.

BS Handbook 19, *Methods for the sampling and analysis of iron, steel and other ferrous metals*.

BS 131, *Methods for notched bar tests*⁸⁾.

BS 131-2, *The Charpy V-notch impact test on metals*.

BS 1600, *Specification dimensions of steel pipe for the petroleum industry*.

BS 1600-2, *Metric units*.

BS 2633, *Specification for Class I arc welding of ferritic steel pipework for carrying fluids*⁸⁾.

BS 3600, *Specification for dimensions and masses per unit length of welded and seamless steel pipes and tubes for pressure purposes*.

BS 3601, *Specification for steel pipes and tubes for pressure purposes: carbon steel with specified room temperature properties*⁸⁾.

BS 3602, *Specification for steel pipes and tubes for pressure purposes: carbon and carbon manganese steel with specified elevated temperature properties*⁸⁾.

BS 3602-2, *Submerged arc welded tubes*.

BS 3603, *Specification for steel pipes and tubes for pressure purposes: carbon and alloy steel with specified low temperature properties*⁸⁾.

BS 3604, *Specification for steel pipes and tubes for pressure purposes: ferritic alloy steel with specified elevated temperature properties*⁸⁾.

BS 3605, *Specification for seamless and welded austenitic stainless steel pipes and tubes for pressure purposes*⁸⁾.

BS 3688, *Methods for mechanical testing of metals at elevated temperatures*.

BS 3688-1, *Tensile testing*.

BS 3889, *Methods for non-destructive testing of pipes and tubes*.

BS 3889-1, *Methods of automatic ultrasonic testing for the detection of imperfections in wrought steel tubes*.

BS 3889-2A, *Automatic eddy current testing of wrought steel tubes*.

BS 3894, *Method for converting elongation values for steel*.

BS 3894-1, *Carbon and low alloy steels*.

BS 3920, *Specification for procedure for deriving and verifying the minimum elevated temperature yield or proof stress properties of steel products*.

BS 5383, *Specification for material identification of steel, nickel alloy and titanium alloy tubes by continuous character marking and colour coding of steel tubes*.

BS 5750, *Quality systems*⁸⁾.

BS 5750-2, *Specification for manufacture and installation*.

BS 6072, *Method for magnetic particle flaw detection*.

BS 6200, *Sampling and analysis of iron and steel and other ferrous metals*.

BS 6200-3, *Methods of analysis*.

ISO 2604, *Steel products for pressure purposes — Quality requirements*.

ISO 2604-II, *Wrought seamless tubes*.

ISO 2604-III, *Electric resistance and induction — welded tubes*.

ISO/TR 7468, *Summary of average stress rupture properties of wrought steels for boilers and pressure vessels*.

ANSI B36.10M, *Welded and seamless wrought steel pipe*⁹⁾.

ANSI B36.19M, *Stainless steel pipe*⁹⁾.

⁸⁾ Referred to in the foreword only.

⁹⁾ Available from BSI Sales, Linford Wood, Milton Keynes MK 14 6LE.

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