

Australian/New Zealand Standard™

Structural steel welding

Part 1: Welding of steel structures



S t a n d a r d s Australia



STANDARDS
NEW ZEALAND
Pāheke Aotearoa

AS/NZS 1554.1:2000

This Joint Australian/New Zealand Standard was prepared by Joint Technical Committee WD/3, Welding of Structures. It was approved on behalf of the Council of Standards Australia on 9 June 2000 and on behalf of the Council of Standards New Zealand on 3 July 2000. It was published on 2 September 2000.

The following interests are represented on Committee WD/3:

Association of Consulting Engineers Australia
Australian Chamber of Commerce and Industry
Australian Industry Group
Australian Institution of Steel Construction
AUSTROADS
Bureau of Steel Manufacturers of Australia
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This Standard was issued in draft form for comment as DR 98630.

Australian/New Zealand Standard™

Structural steel welding

Part 1: Welding of steel structures

Originated in Australia as AS CA8—1933.
Originated in New Zealand, in part, as NZS 4701:1981 and NZS 4704:1994.
Previous edition AS/NZS 1554.1:1995.
Sixth edition 2000.

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Jointly published by Standards Australia International Ltd, GPO Box 5420, Sydney, NSW 2001 and Standards New Zealand, Private Bag 2439, Wellington 6020

ISBN 0 7337 3483 9

PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee WD/3, Welding of Structures, to supersede AS/NZS 1554.1—1995, NZS 4701:1981, *Metal-arc welding of steel structures*, and NZS 4704:1994, *Structural steel welding—Welding of steel structures*.

The objective of this Standard is to provide rules for the welding of a wide range of steel constructions and while it is expected that its main use will be for statically loaded welds, it applies also to some welds subject to fatigue. Although this Standard has been specifically prepared for steel structures, it may be usefully applied to machine frames and other types of steel constructions.

This edition incorporates the following major changes to the 1995 edition, some of which were included in Amendment 1 to the 1995 edition:

(a) *Additions to the following clauses:*

1.6 (the Note), 1.7(c), 2.1 (the Note), 4.1.2, 4.4, 4.5.5, 4.5.5.5(c), 4.6.1.1(h), 5.2.2 (last paragraph).

(b) *Additions to the following tables:*

6.2.2 (Note 3), 7.1 (Notes 1, 2 and 4)

(c) *Amendments to the following clauses:*

4.2(c), 4.3(d), 4.5.4, 4.7.4, 4.12, 5.7.2, 5.11, 6.3.3, 6.4.1, 6.4.3, 6.7, B5, C.

(d) *Amendments to the following figures:*

B1, B2.

(e) *Amendments to the following tables:*

4.6.1(A), 4.6.1(B), 4.6.1(C), 4.6.2, 4.7.1, 4.11(A), 4.11(C), 5.3.4(A), B1.

In Tables E1 to E4, the Note on gas metal-arc now states that globular transfer mode may be used with CO₂.

In Table E1—

- (i) for joint identification B–C 2d, the preparation detail position for gas metal-arc, spray transfer in Column 7 is 'F' (instead of 'All'); and
- (ii) for joint identifications B–C 5, T–C 5 and C–C 5, the preparation detail angle θ for flux-cored arc, self-shielded and gas-shielded in Column 6 includes an additional angle 60 for V.

(f) Deletion of Clause 3.1.2 of the 1995 edition on design requirements.

The Standard requires that weld preparations, welding consumables and welding procedures be qualified before commencement of welding. Prequalified joint preparations, welding consumables and welding procedures are also given in the Standard.

The Standard, in catering for structures subject to fatigue conditions as well as statically loaded structures, provides two categories of welds with two differing levels of weld quality assurance associated with the different types of service to which the welds are subjected. The intention is that the designer should select the category suited to the severity of the service and nominate this on the drawings. Where a structure contains both categories, this nomination of appropriate categories will ensure that appropriate levels of supervision and inspection will be applied to the relevant parts of the structure.

Statements expressed in mandatory terms in notes to tables and figures are deemed to be requirements of this Standard.

The terms 'normative' and 'informative' have been used in this Standard to define the application of the appendix to which they apply. A 'normative' appendix is an integral part of a Standard, whereas an 'informative' appendix is only for information and guidance.

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Australian/New Zealand Standard
Structural steel welding

Part 1: Welding of steel structures

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard specifies requirements for the welding of steel structures made up of combinations of steel plate, sheet or sections, including hollow sections and built-up sections, or castings and forgings, by the following processes:

- (a) Manual metal-arc welding (MMAW).
- (b) Submerged arc welding (SAW).
- (c) Gas metal-arc welding (GMAW or MIG), including pulsed mode.
- (d) Gas tungsten-arc welding (GTAW or TIG).
- (e) Flux-cored arc welding (FCAW).
- (f) Electroslag (including consumable guide) welding (ESW).
- (g) Electro gas welding (EGW).

The Standard is limited to the welding of steel parent material with a specified minimum yield strength not exceeding 500 MPa.

The Standard applies specifically to the welding of steelwork in structures complying with AS 3990, AS 4100, AS/NZS 4600 or NZS 3404.1. Where the proportions of welded joints in these structures are governed by dynamic loading conditions, the Standard applies only to those welded joints that comply with the fatigue provisions of AS 3990, AS 4100 or NZS 3404.1, as limited by Item (ii) below, or the directly equivalent fatigue provisions of other application Standards.

Welded joints complying with the above requirements are those that are —

- (i) not subject to fatigue conditions; or
- (ii) subject to fatigue conditions, where—
 - (A) the stress range in the welded joint complies with the permissible stress range of stress categories C, D, E or F of AS 3990, or weld categories lower than or equal to detail category 112 of AS 4100 or NZS 3404.1; or
 - (B) the stress range in the welded joint is not more than 80% of the permissible stress range of stress category B of AS 3990.

In addition to the abovementioned structures the Standard applies to the welding of cranes, hoists and other dynamically loaded structures, the welding of road and pedestrian bridges and the welding of steelwork in applications other than structural.

NOTE: Further information on this Standard, which the drafting committee could not incorporate, is given in WTIA Technical Note 11.

1.2 EXCLUSIONS

The Standard does not apply to the welding of structures by the following processes:

- (a) Oxyacetylene welding (OAW).
- (b) Friction welding (FW).
- (c) Thermit welding (TW).
- (d) Resistance welding (RW).

NOTE: Resistance welds in structures complying with AS/NZS 4600 should be made in accordance with AWS C1.1 or AWS C1.3, as appropriate.

The Standard does not apply to the welding of pressure vessels and pressure piping.

The Standard does not cover the design of welded connections or permissible stresses in welds, nor the production, rectification or repair of castings.

NOTE: Refer to AS 1988 for the welding of steel castings.

1.3 INNOVATION

Any alternative materials, welding processes, consumables, methods of construction or testing that give equivalent results to those specified, but do not comply with the specific requirements of this Standard or are not mentioned in it, are not necessarily prohibited.

The Joint Standards Australia/Standards New Zealand Committee on welding of structures can act in an advisory capacity concerning equivalent suitability, but specific approval remains the prerogative of the inspecting authority.

1.4 REFERENCED DOCUMENTS

The documents referred to in this Standard are listed in Appendix A.

1.5 DEFINITIONS

For the purpose of this Standard, the symbols and definitions given in AS 1101.3 and AS 2812 and those below apply.

1.5.1 Fabricator

The person or organization responsible for the welding of the structure during fabrication or erection.

1.5.2 Inspecting authority

The authority having statutory powers to control the design and erection of buildings or structures.

NOTE: Where the structure is not subject to statutory jurisdiction, the principal is deemed to be the inspecting authority.

1.5.3 Inspector

A person employed by or acceptable to the inspecting authority or principal for the purpose of inspecting welding in accordance with this Standard.

1.5.4 May

Indicates the existence of an option.

1.5.5 Principal

The purchaser or owner of the structure being fabricated or erected, or a nominated representative.

NOTE: The nominated representative should be suitably qualified to deal with the technical issues of this Standard.

1.5.6 Shall

Indicates that a statement is mandatory.

1.5.7 Should

Indicates a recommendation.

1.6 WELD CATEGORIES

The Standard provides two categories of welds based on the type of application (see Clause 6.1), which in turn necessitates two levels of quality assurance (i.e. inspection and acceptance of weld imperfections) suitable for different weld applications and service conditions.

The two weld categories shall be designated as follows:

- (a) *GP (general purpose)* Category GP should generally be selected where —
- (i) the weld is essentially statically loaded and designed to meet the appropriate requirements of AS 4100, AS/NZS 4600 or NZS 3404.1;
 - (ii) the weld is stressed not more than 50% of the relevant maximum permissible stress as specified in AS 3990; or
 - (iii) the welding application is other than structural.

NOTE: Welds nominated as Category SP, but not complying with the requirements of that category, may be considered as Category GP welds, provided the requirements of the design Standard are satisfied and the principal has agreed.

- (b) *SP (structural purpose)* Category SP should generally be selected where —
- (i) the weld is essentially statically loaded and designed to meet the appropriate requirements of AS 4100, AS/NZS 4600 or NZS 3404.1;
 - (ii) the weld is stressed more than 50% of the relevant maximum permissible stress as specified in AS 3990; or
 - (iii) the weld is subject to dynamic loading within the limits specified in Clauses 1.1 and 1.2.

1.7 BASIC WELDING REQUIREMENTS

The basis of this Standard is that a weld shall—

- (a) be made in accordance with a qualified welding procedure;
- (b) be carried out by a welder suitably qualified to carry out such a procedure;
- (c) be carried out under the supervision of a welding supervisor who is employed by or contracted to the fabricator; and
- (d) comply with the appropriate requirements of this Standard.

For certain conditions prescribed herein, the welding procedure is deemed to be prequalified and may not require full qualification testing (see Clause 4.3 and Table 4.7.1).

1.8 SAFETY**1.8.1 Safety equipment and procedures**

Welding shall be carried out in accordance with the relevant requirements of the following Standards:

AS 1470, AS 1674.1, AS 1674.2, AS 2865, AS/NZS 1336, AS/NZS 1337, AS/NZS 1338.1.

1.8.2 Welding equipment

Welding plant and equipment shall comply with the relevant sections of appropriate regulations, and the following relevant Standards:

AS 1966.1, AS 1966.2, AS 2799, AS/NZS 1995, IEC 60974-1.

NOTE: For further guidance on safety precautions, refer to WTIA Technical Note 7, or HERA Report R7-42.

SECTION 2 MATERIALS OF CONSTRUCTION

2.1 PARENT MATERIAL

The parent material to be welded shall—

- (a) be of a grade with a specified minimum yield strength not exceeding 500 MPa;
- (b) be selected in accordance with the provisions of Appendix B; and
- (c) comply with the following Standards as appropriate:

AS 1163, AS 1397, AS 1450, AS 1548, AS 2074, AS/NZS 1594, AS/NZS 1595, AS/NZS 3678, AS/NZS 3679.1, AS/NZS 3679.2, NZS 3415.

NOTE: Any steel type from any Standard above may be welded to any other steel type from any Standard above, provided the requirements of this Standard are met for each of the steels.

With the exception of quenched and tempered steels, other weldable steels with a specified minimum yield strength not exceeding 500 MPa may be used after the establishment and qualification of welding procedures in accordance with this Standard.

NOTE: For high-strength quenched and tempered steels, see AS/NZS 1554.4.

2.2 BACKING MATERIAL

Permanently attached steel backing material shall have a weldability not less than that of the parent material.

Temporary backing material of any type may be used for welds, provided that the finished weld complies with the requirements of this Standard.

2.3 WELDING CONSUMABLES

2.3.1 Electrodes and filler wires

Electrodes for manual metal-arc welding shall comply with AS/NZS 1553.1 or AS/NZS 1553.2, as applicable (see Clause 4.6.1).

Electrodes or filler wires for processes other than manual metal-arc welding shall comply with AS 1858.1, AS 2203.1 AS/NZS 1167.2 or AS/NZS 2717.1, as applicable (see Clause 4.6.1).

Electrodes that do not comply with these Standards may be used, provided that they are qualified in accordance with the requirements of Clause 4.6.2.

2.3.2 Care of electrodes and filler wires

Electrodes and filler wires shall be stored in their original packets, cans or cartons in a dry place adequately protected from the weather. Filler wires shall be dry, smooth and free from corrosion or other matter deleterious either to satisfactory operation or to the weld metal. Any coating on the electrodes or filler wires shall be continuous and firmly adherent. Any recommendations of the manufacturer, covering protection during storage and use, conditioning and pretreatment of electrodes or filler wires prior to use, shall be followed.

NOTE: WTIA Technical Note 3 contains recommendations for the storage and conditioning of arc welding consumables.

2.3.3 Flux

Flux for submerged arc welding shall be stored in accordance with AS 1858.1. Where the manufacturer makes specific recommendations covering conditioning and pretreatment of flux prior to use, such recommendations shall be followed.

Where flux is reused, flux-recycling systems shall include suitable sieves and magnetic particle separators and shall be such that the flux remains in a satisfactory condition for reuse.

Flux fused in the welding process shall not be reused.

2.3.4 Shielding gas

A gas or gas mixture used for shielding in arc welding shall be of a welding grade having a dewpoint of not warmer than -35°C and shall be suitable for the intended application.

SECTION 3 DETAILS OF WELDED CONNECTIONS

3.1 GENERAL

3.1.1 Permissible weld types

Welded connections may be made by butt, fillet, plug or slot welds, or by a combination of these.

3.1.2 Drawings

Drawings or other documents that give details of welded connections shall specify the following:

- (a) Specification and grade of the parent metal.
- (b) Nominal tensile strength of the weld metal.
- (c) Location, type, size of welds, and the effective length of welds.
- (d) Whether welds are to be made in the shop or at the site.
- (e) Weld category.
- (f) Details of non-standard welds.
- (g) Where seal welds are required, details of such welds.
- (h) Type and extent of inspection, including any special inspection requirements.
- (i) Relevant design Standard.
- (j) Any special requirements that would affect welding operations.

3.2 BUTT WELDS

3.2.1 Size of weld

The size of a complete penetration butt weld shall be the thickness of the thinner part. The size of a complete penetration T-joint or corner joint butt weld shall be the thickness of the part that butts against the face of the other part.

The size of an incomplete penetration butt weld shall be the minimum depth to which the weld extends from its face into the joint, exclusive of reinforcement. Where the joint contains two welds, the size shall be the combined depths.

3.2.2 Design throat thickness

3.2.2.1 *Complete penetration butt weld*

The design throat thickness of a complete penetration butt weld shall be the thickness of the thinner part.

3.2.2.2 *Incomplete penetration butt weld*

The design throat thickness of an incomplete penetration butt weld shall be as follows:

- (a) For prequalified incomplete penetration butt welds, except as otherwise provided in Item (c) below, as shown in Table E2, Appendix E.
- (b) For non-prequalified incomplete penetration butt welds, except as provided in Item (c) below—
 - (i) where $\theta < 60^\circ$, $D - 3 \text{ mm}$; or

- (ii) where $\theta \geq 60^\circ$, D ;

where

D = depth of preparation

θ = angle of preparation.

- (c) For incomplete penetration butt welds made by a fully automatic arc welding process, provided that it can be demonstrated by means of a macro test on a production weld that the required penetration has been achieved, a design throat thickness up to the depth of penetration. Where such penetration is achieved, the size of the weld may be correspondingly reduced.

3.2.3 Effective length

The effective length of the butt weld shall be the length of a continuous full-size weld.

3.2.4 Effective area

The effective area of a butt weld shall be the product of the effective length and the design throat thickness.

3.2.5 Transition of thickness or width

Butt-welded joints between parts of different thicknesses or parts of unequal widths that are subject to tension shall have a smooth transition between the surfaces or the edges. The transition shall be made by chamfering the thicker part or by sloping the weld surfaces or by any combination of these as shown in Figure 3.2.5.

The transition slope between the parts shall be not steeper than 1:1. However, the fatigue provisions of AS 3990, AS 4100, NZS 3404.1 and other design codes may require a lesser slope than this or a curved transition between the parts.

3.3 FILLET WELDS

3.3.1 Size of weld

The size of a fillet weld shall be the lengths of the sides lying along the legs of a triangle inscribed within the cross-section of the weld (see Table E3, Appendix E). Where these lengths are equal, the size shall be given by a single dimension.

The preferred sizes of fillet welds less than 15 mm are 2, 3, 4, 5, 6, 8, 10 and 12 mm.

Where there is a root gap, the size shall be given by the lengths of the legs of the inscribed triangle, reduced by the amount shown in Table E3, Appendix E.

3.3.2 Design throat thickness

The design throat thickness (DTT) of a fillet weld shall be as shown in Table E3, Appendix E.

For deep penetration fillet welds made by fully automatic arc welding processes, provided that it can be demonstrated by means of a macro test on a production weld that the required penetration has been achieved, an increase in design throat thickness shall be allowed as shown in Figure 3.3.2. Where such penetration is achieved, the size of the weld may be correspondingly reduced.

3.3.3 Effective length

The effective length of a fillet weld shall be the overall length of the full-size fillet, including end returns. Where the weld is full size throughout its length, no reduction in effective length shall be made for either the start or crater of the weld.

Where the effective length of a fillet weld is less than four times the size of the weld, the size of the weld for design calculation purposes shall be reduced to 25% of the effective length.

Any segment of intermittent fillet weld shall have an effective length of not less than 40 mm.

3.3.4 Effective area

The effective area of a fillet weld shall be the product of the effective length and the design throat thickness.

3.3.5 Minimum size of fillet welds

The minimum size of a fillet weld, including the first run of a multirun fillet weld, other than a fillet weld used to reinforce a butt weld, shall conform to Table 3.3.5 except that the size of the weld need not exceed the thickness of the thinner part joined (see also Clause 5.3).

TABLE 3.3.5
MINIMUM SIZE OF FILLET WELDS

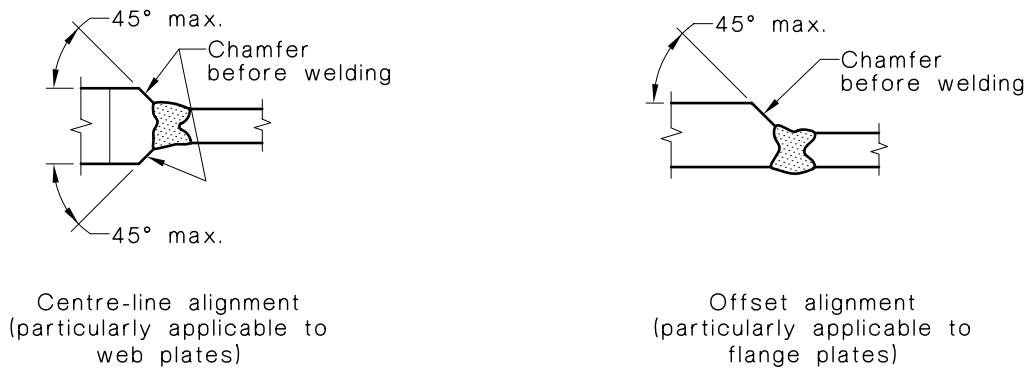
millimetres	
Thickness of thickest part (<i>t</i>)	Minimum size of fillet weld
≤3	2 <i>t</i> /3*
>3 ≤7	3*
>7 ≤10	4*
>10 ≤15	5
>15	6

* These values may need to be increased to comply with some design Standards.

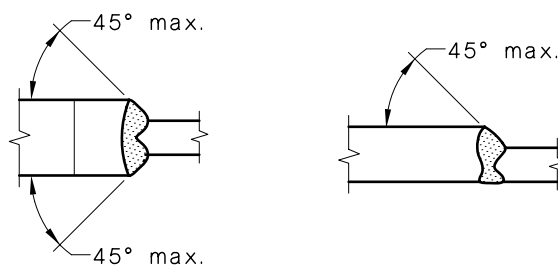
3.3.6 Maximum size of fillet welds along edges

The maximum size of a fillet weld along edges of material shall be—

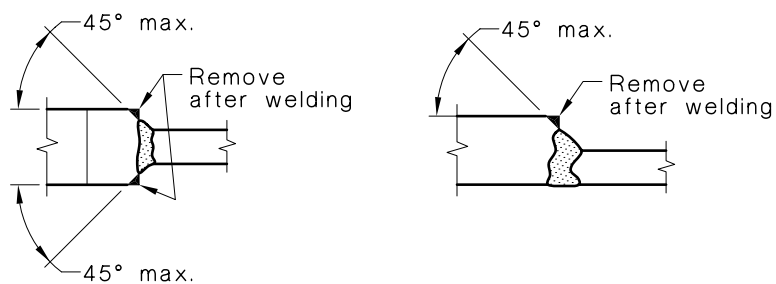
- (a) for material with a thickness of less than 6 mm (see Figure 3.3.6(a)), the thickness of the material; or
- (b) for material with thickness of not less than 6 mm (see Figure 3.3.6(b)), the thickness of the material minus 1 mm; or
- (c) for material with a thickness or not less than 6 mm, where the weld is designated on the drawing to be built out to obtain the design throat thickness (see Figure 3.3.6(c)), the thickness of the material.



(i) Transition by chamfering thicker part

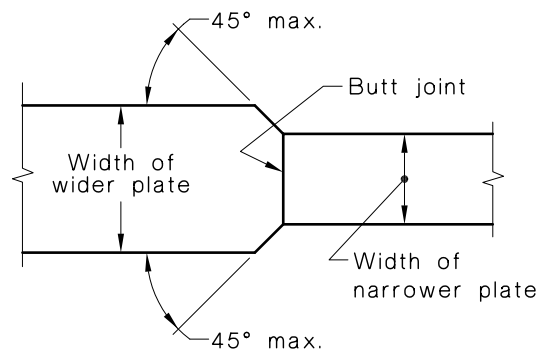


(ii) Transition by sloping weld surface



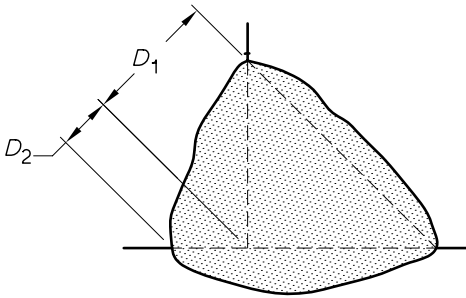
(iii) Transition by sloping weld surface and chamfering

(a) Transition of butt joints in parts of unequal thickness



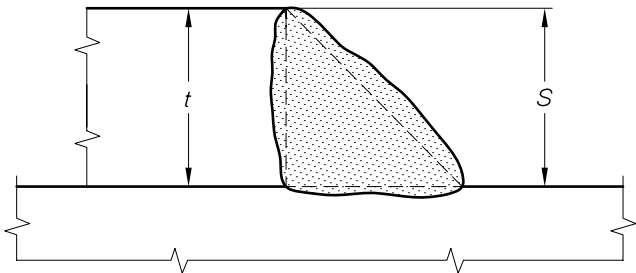
(b) Transition of butt joints in parts of unequal width, transition by chamfering wider part

FIGURE 3.2.5 TRANSITION OF THICKNESSES OR WIDTHS FOR BUTT WELDS SUBJECT TO TENSION

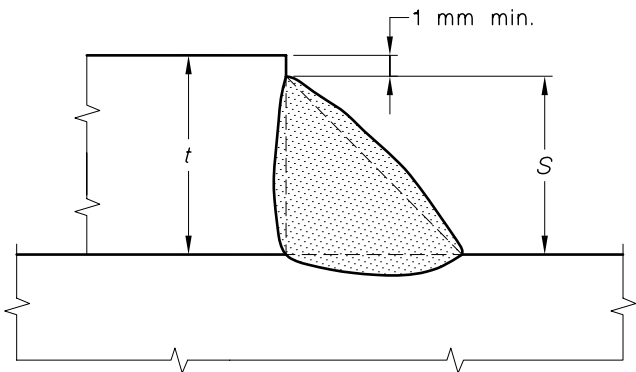


NOTE: $DTT = D_1 + 0.85 D_2$, where DTT is the design throat thickness for deep penetration fillet welds made by a fully automatic process.

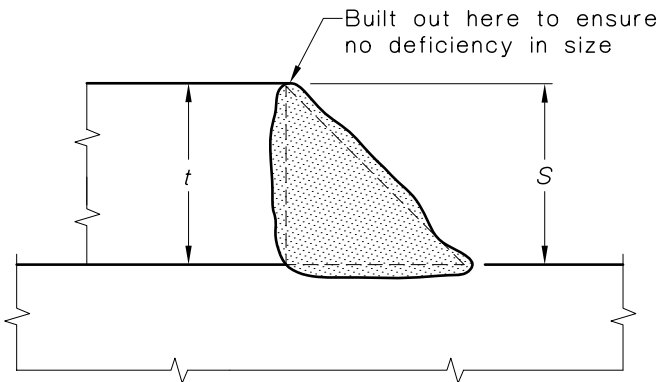
FIGURE 3.3.2 DEEP PENETRATION FILLET WELD



(a) $S = t$ for $t < 6\text{ mm}$



(b) $S \leq t - 1\text{ mm}$ for $t \geq 6\text{ mm}$



(c) $S = t$ for all thicknesses where edge is built out

LEGEND:
 S = size of fillet weld
 t = thickness of part joined

FIGURE 3.3.6 MAXIMUM SIZE OF FILLET WELDS ALONG EDGES

3.4 COMPOUND WELDS

3.4.1 Description of compound weld

A compound weld is a butt welded T-joint with a fillet weld superimposed on one or both faces. Details of typical compound welds are shown in Figure 3.4.1.

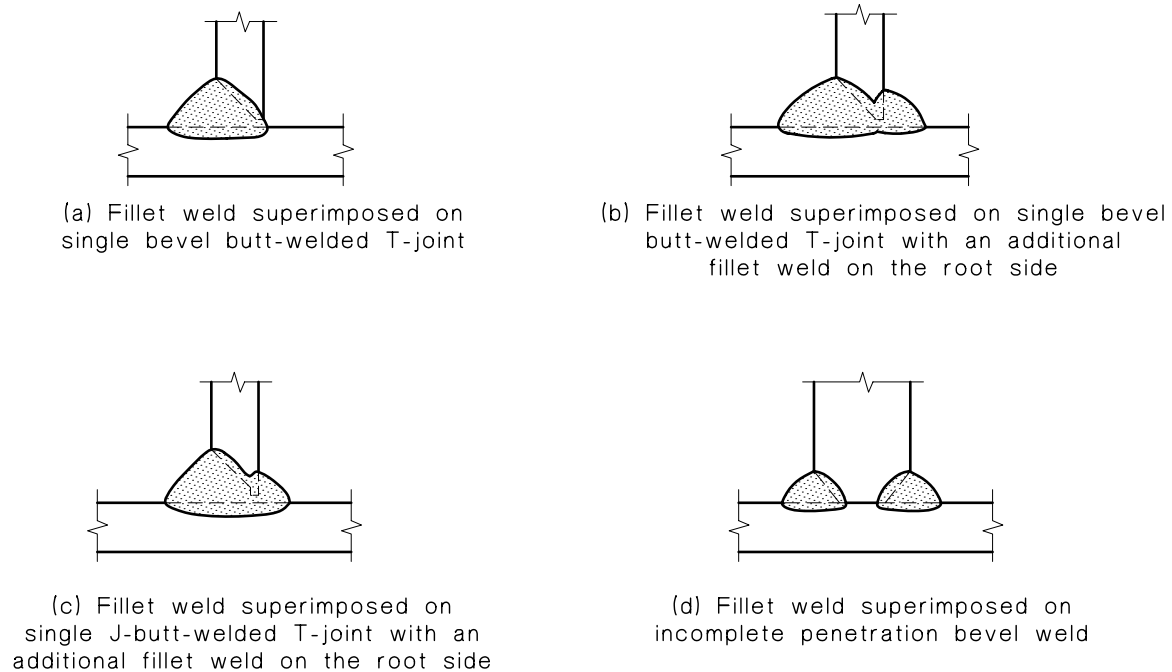


FIGURE 3.4.1 COMPOUND WELDS

3.4.2 Design throat thickness (DTT)

3.4.2.1 Compound welds with complete penetration welds in the T-joint

The DTT shall be the thickness of the part that butts against the face of the other part.

3.4.2.2 Compound welds with incomplete penetration welds

The DTT shall be as shown in Figure 3.4.2.2, where DTT is the shortest distance from the root of the incomplete penetration welds to the face of the fillet welds as determined by the largest inscribed triangle in the total weld cross-section, with a maximum value equal to the thickness of the part that butts against the face of the other part to form the T-joint.

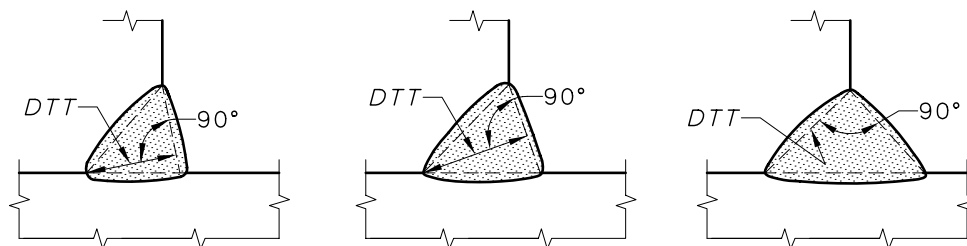


FIGURE 3.4.2.2 DESIGN THROAT THICKNESS OF COMPOUND WELDS WITH INCOMPLETE PENETRATION WELDS

3.5 SEAL WELDS

Seal welds shall be single run fillet or incomplete penetration butt welds, as applicable. The size of seal welds shall comply with Clauses 3.3.5 and 3.8, unless a larger weld is specifically required.

Seal welds shall be made in accordance with a qualified welding procedure.

NOTE: Where seal welding is required, such a procedure has to be specified clearly on the drawings or other documents (see Clause 3.1.2).

3.6 PLUG WELDS

The diameter of the hole for a plug weld shall be—

- (a) not less than the sum of 8 mm plus the thickness of the part containing the hole; and
- (b) not more than the greater of—
 - (i) the sum of 11 mm plus the thickness of the part containing the hole; and
 - (ii) 2.25 times the thickness of the member.

The centre-to-centre spacing between plug welds shall be not less than four times the diameter of the hole.

The effective area of a plug weld shall be the nominal cross-sectional area of the hole in the plane of the faying or contact surface.

The depth of the filling of plug welds shall be as follows:

Material thickness (<i>t</i>) mm	Depth of filling mm
≤16	<i>T</i>
>16 ≤32	≥16
>32	≥ <i>t</i> /2

3.7 SLOT WELDS

The length of the slot for slot welds shall be not more than 10 times the thickness of the part containing it. The width of the slot for slot welds shall be—

- (a) not less than the sum of 8 mm plus the thickness of the part containing the slot; and
- (b) not more than the greater of—
 - (i) the sum of 11 mm plus the thickness of the part containing the slot; and
 - (ii) 2.25 times the thickness of the member.

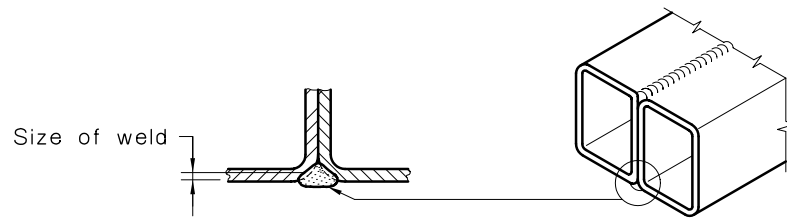
The ends of the slot shall be semicircular or shall have the corners rounded to a radius of not less than the thickness of the part containing it, except for those ends that extend to the edge of the part.

The minimum spacing of lines of slot welds in a direction transverse to their length shall be four times the width of the slot. The minimum centre-to-centre spacing in a longitudinal direction on any line shall be two times the length of the slot.

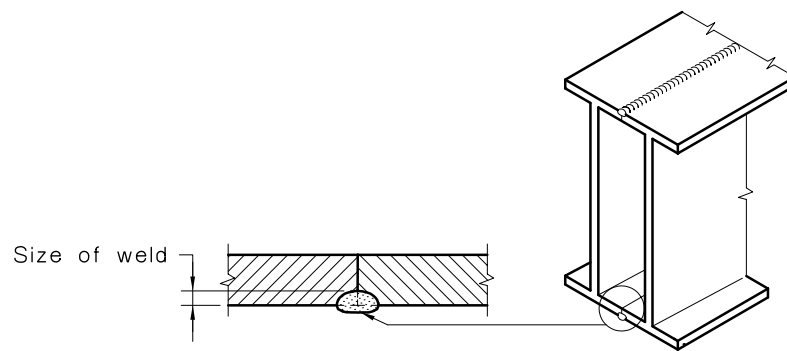
The effective area of a slot weld shall be as for a fillet weld of the same size and effective length. Where a slot weld is made by completely or partially filling the slot (i.e. not made with a fillet weld around the perimeter of the slot), the effective area shall be as for plug welds (see Clause 3.6).

3.8 COMBINING STEEL SECTIONS

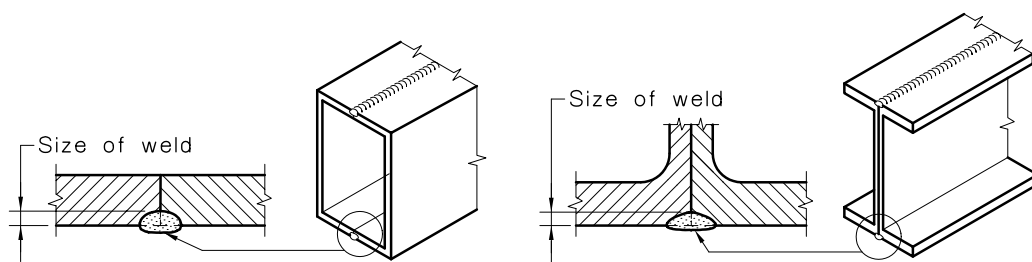
The size of welds made for the purpose of combining steel sections to form composite members (see Figure 3.8) shall be not less than 3 mm.



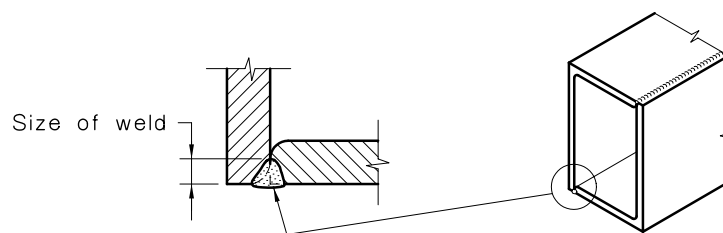
(a) Hollow sections



(b) Beams or columns



(c) Channels



(d) Angles

FIGURE 3.8 WELDING OF ROLLED SECTIONS TO FORM BUILT-UP MEMBERS

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SECTION 4 QUALIFICATION OF PROCEDURES AND PERSONNEL

4.1 QUALIFICATION OF WELDING PROCEDURE

4.1.1 General

The welding procedure (i.e. the weld preparation, the welding consumables and the welding parameters) shall be qualified before welding of either the structure or the component commences.

The fabricator shall establish a welding procedure and list the applicable parameters in a document known as the welding procedure qualification record (also known as PQR or WPQR), which shall be held as a record and shall be available for examination.

A welding procedure specification shall be developed from the PQR, based on the limits of the essential variables of Clause 4.11, and made available to the welder during fabrication.

The welding procedures may be approved on the welding procedure sheets by a representative of the principal, who shall have, as a minimum, the qualification of a welding supervisor in accordance with Clause 4.12.1 or welding inspector (see Clause 7.2).

NOTES:

- 1 Forms suitable as PQR and WPS welding procedure sheets are shown in Appendix C.
- 2 For New Zealand, NZS 3404.1 requires the welding procedures to have been approved by the principal, prior to the commencement of welding.

4.1.2 Butt welds

For butt welds, the following also apply:

- (a) For welding processes MMAW, SAW, GMAW, GTAW and FCAW, a procedure qualification of a butt weld that has been welded from only the one side on a single-V or a single-U preparation shall qualify for single sided butt welds in both plate and pipe.
- (b) A procedure qualification for any prequalified butt-welded joint listed in Table E1, E2 or E4, Appendix E, shall qualify all other welding positions listed for that joint and angle of preparation (θ) used without further testing. A change in welding direction between vertically up and vertical down shall require separate qualification.
- (c) A procedure qualification on a single-V butt weld that has been welded from only the one side shall qualify for welding a double-V butt weld and a single-V butt weld that has been welded on both sides.
- (d) A procedure qualification on a single-U butt weld that has been welded from only the one side shall qualify for welding a double-U butt weld and a single-U butt weld that has been welded on both sides.
- (e) A procedure qualification on a double-V butt weld shall also qualify for welding a single-V butt weld that has been welded on both sides.
- (f) A procedure qualification on a double-U butt weld shall also qualify for welding a single-U butt weld that has been welded on both sides.
- (g) Thickness limitations for butt welds shall comply with the following:
 - (i) For material with a thickness of less than 36 mm, Item (o) of Table 4.11(A) applies.
 - (ii) For material with a thickness of not less than 36 mm, no upper limit applies.

4.1.3 Fillet welds

For fillet welds, the following also apply:

- (a) The procedure qualification of a fillet weld using processes on either plate or pipe shall qualify for fillet welds on both plate and pipe.
- (b) The procedure qualification of a fillet weld shall be based on the fillet weld size (leg length), not material thicknesses, as follows:
 - (i) For a single-run fillet weld, qualification shall cover the size of the fillet used for the qualification test and all single-run fillets below the size qualified for the positions shown in Table 4.1.3.
 - (ii) For multi-run fillets, qualification shall cover the size of the fillet used for qualification and all larger multi-run fillets for the positions shown in Table 4.1.3. When applying this qualification for single-run and multi-run fillets, consideration shall be given to the pre-heat requirements for combined thicknesses of T1, T2 and T3, and the pre-heat requirements for the combined thicknesses shall be shown on the welding procedure specification (WPS) and on the procedure qualification record (PQR).
- (c) A change in welding direction between vertical up and vertical down shall require separate qualification.

NOTE: Single run and multiple run fillet welds may be qualified on opposite sides of the same test plates.

TABLE 4.1.3
PROCEDURE QUALIFICATION FOR FILLET WELDS
ON PLATE OR PIPE—POSITIONS QUALIFIED

Weld position	Position qualified
1F (flat)	1F only
2F (horizontal)	1F, 2F and 4F (overhead)
3F (vertical)	3F only
4F (overhead)	1F, 2F and 4F

4.1.4 Qualification of multiple welding positions

Where a test piece involves welding in more than one position, the test piece qualifies the welding procedures for those positions, provided a macro is taken from each position to be qualified.

NOTE: This can be achieved by welding a pipe test piece in the 5G or 6G fixed position.

4.2 METHODS FOR QUALIFYING A WELDING PROCEDURE

A welding procedure shall be qualified by one of the following methods:

- (a) A prequalified procedure in accordance with Clause 4.3.
- (b) Production of documentary evidence of relevant prior experience by the fabricator.

NOTE: A completed welding procedure sheet such as that shown in Appendix C, together with records of any tests carried out as required by the application Standard to which the procedure was qualified, constitutes documentary evidence of prior experience.

- (c) Production of a suitable length of test piece of the same joint type, material type, material thickness and edge preparation as the component, upon which the procedures are to be applied, and testing it in accordance with Clause 4.7 where the type of joint allows such testing. The test piece may be made as a production test piece.
- (d) Preparation of a special test piece, such as shown in Figure 4.7.2, which simulates as closely as practicable the weld penetration, material type and direction of rolling, material thickness, edge preparation, welding conditions, including welder access and conditions of restraint to be used in production, and testing it in accordance with Clause 4.7.
- (e) Destructive testing of a prototype joint, structure or component.
- (f) A welding procedure qualified by another fabricator, see Clause 4.4.

4.3 PREQUALIFIED WELDING PROCEDURES

Welding procedures shall be deemed to be prequalified, where—

- (a) the joint preparations are prequalified in accordance with Clause 4.5;
- (b) the consumables are prequalified in accordance with Clause 4.6;
- (c) the workmanship and welding techniques, including the preheat and inter-run temperature requirements, comply with this Standard; and
- (d) where Table 4.7.1 requires the weld to be tested, there is documentary evidence of a satisfactory macro test in accordance with Clause 4.7.4, including a satisfactory macro or a sketch or photograph of it, showing the position number, the sequence of runs, the minimum leg length, the throat thickness and the scale of the sketch.

NOTE: A digital or scanned image is considered to be the equivalent of a photograph for the purpose of this requirement.

4.4 PORTABILITY OF QUALIFIED WELDING PROCEDURES

A welding procedure qualified by one fabricator shall be valid for use by a second fabricator, provided that—

- (a) the original qualification tests were carried out in accordance with this Standard or other acceptable national or international Standards, and were fully documented;
- (b) the second fabricator has adequate equipment and facilities and demonstrates successful welding of welder qualification tests or a macro test using the procedure;
- (c) the application of the welding procedure is acceptable to both fabricators and the purchaser; and
- (d) the welding procedure identifies the original and second fabricator.

4.5 PREQUALIFIED JOINT PREPARATIONS

4.5.1 General

The joint preparations prescribed in Clauses 4.5.2, 4.5.3 and 4.5.4 shall be deemed prequalified, provided that the welding processes and consumables used comply with the recommendations of the consumables manufacturer.

4.5.2 Prequalified complete penetration butt welds

Joint preparations for prequalified complete penetration butt welds conforming to a preparation listed in Table E1, Appendix E, shall be deemed prequalified. Provided that each preparation complies with the requirements of Table E1 for double-V, double bevel, double-U and double-J welds, preparations of unequal depth shall be deemed prequalified also.

NOTE: For additional requirements for hollow sections, see Clause 4.5.5.

Complete penetration butt welds that are to be welded from both sides using these prequalified preparations shall have the roots of the weld gouged out by suitable means to sound metal, before welding is started on the second side, unless evidence is produced by macro etching that complete fusion can be obtained without such gouging.

4.5.3 Prequalified incomplete penetration butt welds

Joint preparations for prequalified incomplete penetration butt welds that conform to a preparation listed in Table E2, Appendix E, shall be deemed prequalified. Provided that each preparation complies with the requirements of Table E2, Appendix E, for double-V, double bevel, double-U or double-J welds, preparations of unequal depth shall be deemed prequalified also.

4.5.4 Prequalified fillet welds

Joint preparations for prequalified fillet welds conforming to a preparation listed in Table E3 shall be deemed prequalified. Welding positions shall comply with AS 3545 (see also Table 4.5.4).

NOTES:

- 1 For additional requirements for fillet welds for hollow sections, see Clause 4.5.5.
- 2 Single run and multiple run fillet welds may be qualified on opposite sides of the same test plates.

TABLE 4.5.4
PROCEDURE QUALIFICATION FOR FILLET WELDS ON PLATE
OR PIPE, AND SIZE QUALIFIED

Fillet Size	Number of welds per procedure	Macro etch samples	Sizes qualified	
			Material thickness	Fillet size
Single-run maximum size to be used in qualification	One	See Table 4.7.1	Unlimited	Maximum test size single-run and smaller
Multi-run minimum size to be used in qualification	One	See Table 4.7.1	Unlimited	Minimum test size multi-run and larger

4.5.5 Additional requirements for welds in hollow section members

4.5.5.1 Complete penetration butt welds

Joint preparations for complete penetration butt welds in hollow sections that conform to one of the following shall be deemed prequalified:

- (a) Joints welded from both sides and complying with one of the processes specified in Table E1, Appendix E.
- (b) Joints welded from one side with sections complying with AS 1163 or AS 1450, and in addition complying with one of the processes specified in Table E4, Appendix E.

Also, the joint preparations shown in Figure 4.5.5.1 for connections butt welded from one side shall be deemed prequalified for all appropriate processes.

4.5.5.2 Fillet welds

Joint preparations for fillet welds conforming to Table E3, Appendix E, shall be deemed prequalified for all processes. In addition, the joint preparations shown in Figure 4.5.5.2 for fillet-welded connections shall be deemed prequalified for all appropriate processes.

4.5.5.3 Combination of fillet and butt welds

Joint preparations for combinations of fillet welds and butt welds complying with the details shown in Figure 4.5.5.3 shall be deemed prequalified for all processes, provided that the joint preparations for butt welds conform to the appropriate Table E1 or E4.

4.5.5.4 Circular hollow section connections

Where a weld connects the end of one circular hollow section member to the surface of another circular hollow section member, the following shall also apply, as appropriate:

- (a) *Not flattened* Where the end of the section is not flattened and the sections intersect at an angle of —
- (i) less than 30 degrees, the welding procedure shall be qualified in accordance with Clause 4.2 before welding commences; and
 - (ii) not less than 30 degrees, the joint shall comply with the following additional requirements:

Type of weld	Usage
Butt throughout	Used in any joint
Fillet throughout	Used only where diameter of smaller member is less than one-third of that of larger member
Combination of butt and fillet with gradual transitions between them	Used in any joint

- (b) *Partially or fully flattened* Where the end of a circular hollow section member is partially flattened to a suitable shape, Items (a)(i) and (a)(ii) above shall apply and, for the application of Item (a)(ii), the diameter of the flattened portion of the section shall be measured in a plane perpendicular to the axis of the main section, the plane being taken at the point of intersection of the axis of the branch section with the surface of the main section.

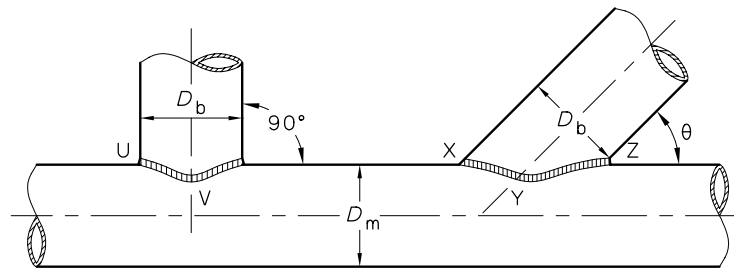
The flattening of the section shall be made over the minimum length practicable. The change of shape shall be gradual, with no evidence of splitting or cracking in the flattened portion. Typical flattened circular hollow section joints are shown in Figure 4.5.5.4.

4.5.5.5 End-to-surface connections of rectangular hollow sections

For end-to-surface connections of rectangular hollow sections, the following shall also apply, as appropriate:

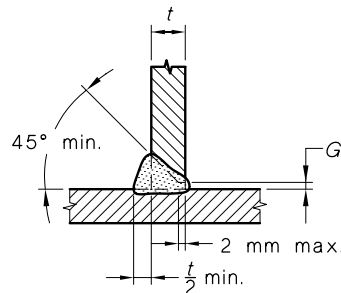
- (a) *Angle of intersection not less than 30 degrees* Where the end of a rectangular hollow section member is welded to the surface of another rectangular hollow section member of greater width, with the axes of the members intersecting at an angle of not less than 30 degrees, the joint shall comply with one of the following additional requirements:
- (i) A butt weld is used throughout.
 - (ii) A fillet weld is used throughout.
 - (iii) A combination of fillet and butt welds is used throughout.
- (b) *Angle of intersection less than 30 degrees* Where the end of a rectangular hollow section member is welded to the surface of another rectangular hollow section member of greater width, with the axes of the members intersecting at an angle of less than 30 degrees, the welding procedure shall be qualified in accordance with Clause 4.2 before welding commences.

- (c) *Equal width rectangular hollow sections* Where the end of a rectangular hollow section member is welded to the surface of another rectangular hollow section member of equal width, the welding procedure shall be qualified in accordance with Clause 4.2 before welding commences.

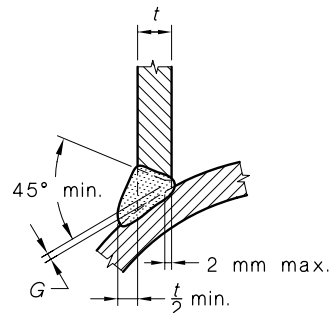


NOTE: Any value of D_b/D_m is permissible.

(a) Butt-welded connections

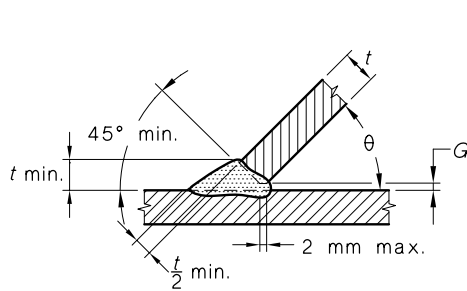


SECTION U

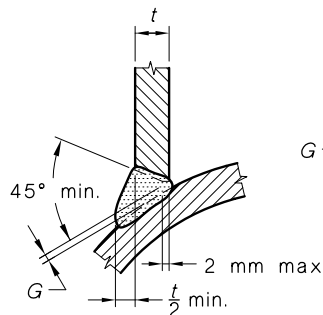


SECTION V

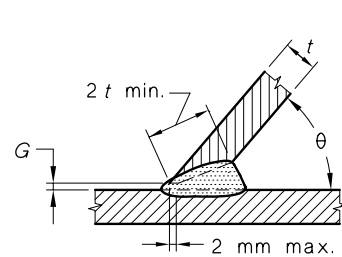
(b) Butt-welded right-angled connections



SECTION X



SECTION Y



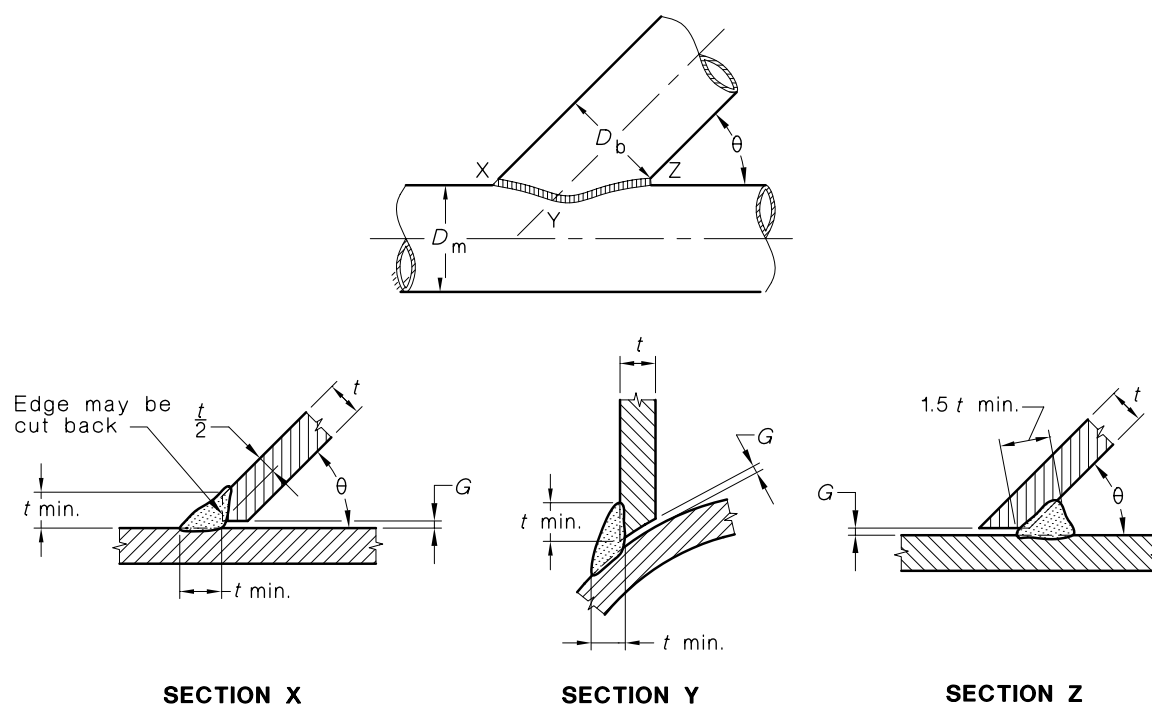
SECTION Z

(c) Butt-welded acute-angled connections

NOTES:

- 1 $\theta \geq 30^\circ$.
- 2 The values for width of root gap (G) are given in Table E4, Appendix E.
- 3 These sections apply to circular hollow sections.
- 4 Only Sections U, X and Z apply to unequal-width rectangular hollow sections.
- 5 These details may not apply to equal-width rectangular hollow sections (see Clause 4.5.5.5(c)).

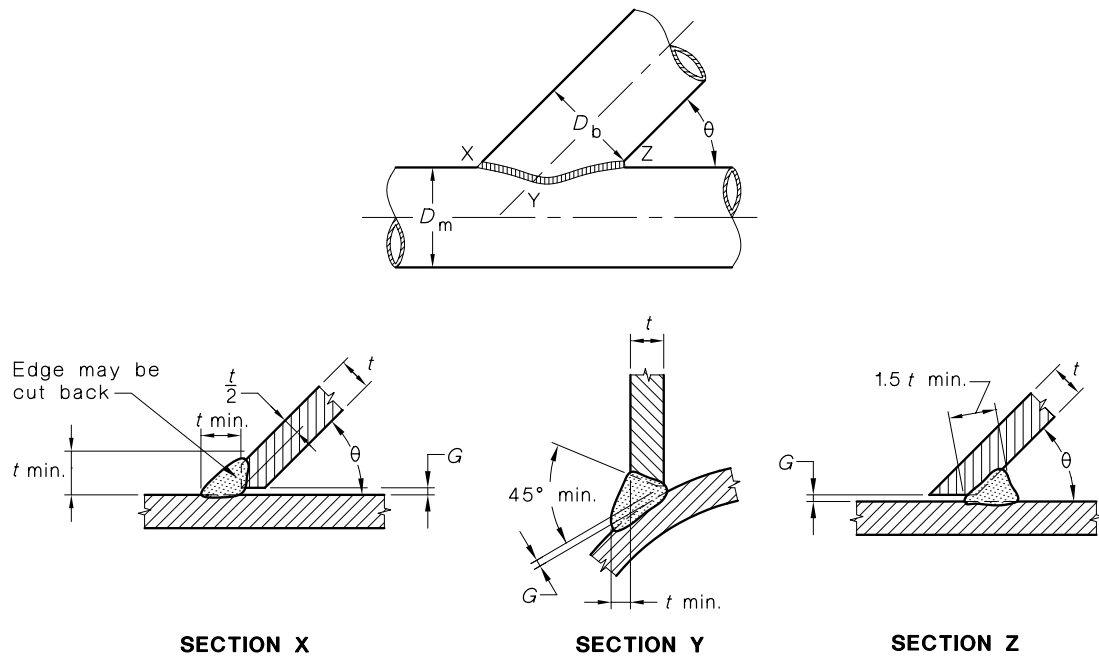
FIGURE 4.5.5.1 PREQUALIFIED BUTT WELDS



NOTES:

- 1 $\theta \geq 30^\circ$.
- 2 The values for width of root gap (G) are given in Table E4, Appendix E.
- 3 These sections apply to circular hollow sections.
- 4 Only sections X and Z apply to unequal-width rectangular hollow sections.
- 5 These details may not apply to equal-width rectangular hollow sections (see Clause 4.5.5.5(c)).

FIGURE 4.5.5.2 PREQUALIFIED FILLET WELDS



NOTES:

- 1 $\theta \geq 30^\circ$.
- 2 The values for width of root gap (G) are given in Table E4, Appendix E.
- 3 These sections apply to circular hollow sections.
- 4 Only Sections X and Z apply to unequal-width rectangular hollow sections.
- 5 These details may not apply to equal-width rectangular hollow sections (see Clause 4.5.5.5(c)).

FIGURE 4.5.5.3 PREQUALIFIED COMBINATION OF FILLET AND BUTT WELDS INCLUDING COMPOUND BUTT AND FILLET WELD

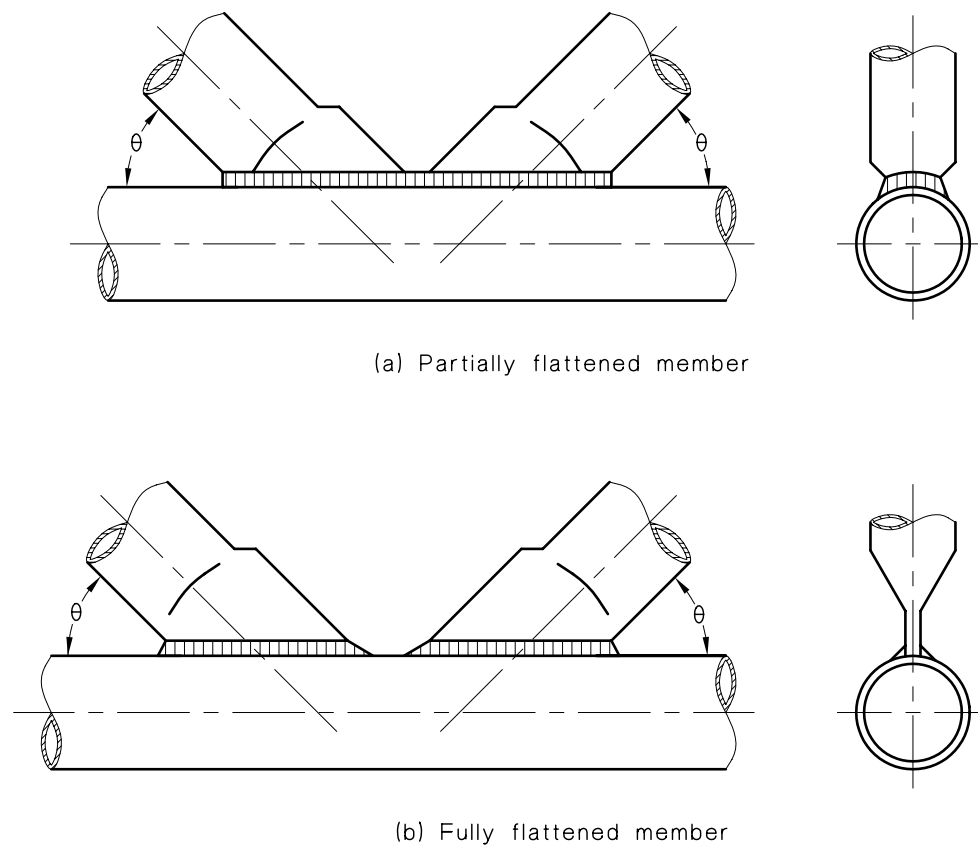


FIGURE 4.5.5.4 FLATTENED CIRCULAR HOLLOW SECTION JOINTS

4.6 QUALIFICATION OF WELDING CONSUMABLES

4.6.1 Prequalified welding consumables

4.6.1.1 General

Welding consumables shall be deemed prequalified and require no qualification testing, where they comply with the following requirements:

- Consumables are matched with the steel type in compliance with Table 4.6.1(A);
- Consumables are used within the welding parameter ranges specified by the manufacturer of the consumables;
- Electrodes for manual metal-arc welding conform to Columns 2 and 3 of Table 4.6.1(A).
- Consumables for submerged arc and flux-cored arc welding conform to Columns 4 and 5 of Table 4.6.1(A), provided that for L0 grade steels the maximum arc energy is limited to 5 kJ/mm and for L15 grade or L20 grade steels the maximum arc energy is limited to 2.5 kJ/mm.
- Consumables for gas metal-arc welding conform to Column 6 of Table 4.6.1(A).
- Consumables for gas-tungsten arc welding conform to Column 7 of Table 4.6.1(A).

- (g) Consumables for automatic and semi-automatic processes (submerged arc, flux-cored arc, gas metal-arc) have Lloyds' or other ship classification societies' approvals as shown in Columns 8, 9 and 10 of Table 4.6.1(A), with the following limitations regarding arc energy:
 - (i) For consumables with S, M, or SM grading—
 - (A) for multirun butt welds or any fillet weld in L0 grade steel, 5 kJ/mm max.; or
 - (B) for multirun butt welds or any fillet weld in L15 or L20 grade steels, 2.5 kJ/mm max.
 - (ii) For consumables with T grading, no limitation on arc energy for single run or two-run technique.
 - (iii) For consumables with TM grading, no limitation on arc energy for single run or multirun technique.
- (h) The impact test temperature of the consumables, as specified in the relevant Standard for the consumables, is not warmer than the design service temperature (see Clause B3, Appendix B).

Where consumables are not prequalified in accordance with the above items, but the fabricator can produce relevant data, properly documented, of satisfactory prior experience in the use of the consumables with a particular procedure, the data shall be taken as sufficient evidence for deeming the consumable prequalified for that procedure (see Clause 4.2(b)).

4.6.1.2 *Weather-resistant steels*

For applications of weather-resistant steels, where the weld metal is required to have the characteristics of resistance to atmospheric corrosion and colouring similar to those of the parent material, the following consumables shall be deemed prequalified:

- (a) For single-run fillet welds and butt welds made with a single run or a single run each side and where the welds are made with no weave, welding consumables selected in accordance with Table 4.6.1(A).
- (b) For single-run fillet welds and butt welds made with a single run or a single-run each side and where weaving is used during the run, welding consumables selected in accordance with Table 4.6.1(C).
- (c) For capping runs on multirun fillet or butt welds, welding consumables selected in accordance with Table 4.6.1(C).
- (d) For runs other than capping runs on multirun fillet or butt welds, welding consumables selected in accordance with Table 4.6.1(A).

TABLE 4.6.1(A)
PREQUALIFIED WELDING CONSUMABLES

(See Notes below)

1	2	3	4	5	6	7	8	9	10
Steel type (see Table 4.6.1(B))	Manual metal-arc (AS/NZS 1553.1)		Submerged arc (AS 1858.1)	Flux-cored arc (AS 2203.1)	Gas metal-arc (AS/NZS 2717.1)	Gas tungsten-arc (AS/NZS 1167.2)	Ship classification societies' approval		
	Classifi- cation	Grade	Classifi- cation	Classifi- cation	Classification	Classification	S, M or SM Grade multi-run	T Grade two-run	TM Grade two-run and multi-run
1	E41XX E48XX	0 and 1	W40XY W50XY	W40XX.X W50XX.X	W50X	R1	1M 1S 1SM	1T	1TM
2	E41XX E48XX	2	W402Y W502Y	W402X.X W502X.X	W502	—	2M 2S 2SM	2T	2TM
3	E41XX E48XX	3	W403Y W503Y	W403X.X W503X.X	W503	—	3M 3S 3SM	3T	3TM
4	E41XX E48XX	0 and 1	W40XY W50XY	W40XX.X W50XX.X	W50X	—	1YM 1YSM 1YS	1YT	1YTM
5	E41XX E48XX	2	W402Y W502Y	W402X.X W502X.X	W502	—	2YM 2YSM 2YS	2YT	2YTM
6	E41XX E48XX	3	W403Y W503Y	W403X.X W503X.X	W503	—	3YM 3YSM 3YS	3YT	3YTM
7A	E48XX	0 and 1	W50XY	W50X	W50X	—	1YM 1YSM 1YS	1YT	1YTM
7B	E48XX	2	W502Y	W502X.X	W502	—	2YM 2YSM 2YS	2YT	2YTM
7C	E48XX	1	W503Y	W503X.X	W503	—	3YM 3YSM 3YS	3YT	3YTM
8	See Note 6	—	See Note 7	W55XY.ZH W62XY.ZH	W559H-Z W629H-Z	—	—	—	—

NOTES:

- 1 The allocation of steel type numbers to particular steels is given in Table 4.6.1(B).
- 2 Consumables with a higher impact grading than that shown are also acceptable.
- 3 The letter 'H' denotes controlled hydrogen.
The letter 'X' represents impact energy values.
The letter 'Y' designates condition of heat treatment.
The letter 'Z' stands for any chemical composition.
- 4 Consumables are prequalified for use with weathering steels (WR, HW) of AS/NZS 1594, AS/NZS 3678, AS/NZS 3679.1 and AS/NZS 3679.2 where similar weathering properties are not required. Where matching weathering properties are required, refer to Table 4.6.1(C).
- 5 For steel types 4, 5 and 6 (except steel to AS/NZS 3678—400), consumables of the E4IXX, W40XY or W40XX.X type will equal or exceed the specified minimum yield strength of the material and will usually give a tensile strength of not less than 95% of the specified tensile strength of the parent material.
For steel to AS/NZS 3678—400, consumables of the E4IXX, W40XY or W40XX.X type shall require qualification.
- 6 AS/NZS 1553.2, Classifications: E5515-Z, E5516-Z, E5518-Z, E6215-Z, E6216-Z, E6218-Z.
- 7 AS 1858.2, Classifications: W55XY.ZH, W62XY.ZH.

TABLE 4.6.1(B)
ASSOCIATION OF STEEL TYPE NUMBERS TO AUSTRALIAN AND
NEW ZEALAND STEELS

Steel type	Specification and grade of parent metal									
	AS 1163	AS 1397	AS 1450	AS 1548	AS/NZS 1594	AS/NZS 1595	AS 2074	AS/NZS 3678 AS/NZS 3679.2	AS/NZS 3679.1	NZS 3415
1	C250	G250 G300	C200 H200 C250 H250	7-430 7-460	HA1 HA3 HA4N HA200 HA250 HA250/1 HU250 HA300 HA300/1 HU300 HA1006 HA1010 HA1016 HXA1016	All grades	C2 C3 C7A-1	200 250 300 A1006 XK1016	250 300	Fe 430A
2	C250 L0	—	—	7-430L0 7-460L0	—	—	—	—	250 L0 300 L0	Fe 430C
3	—	—	—	7-430L20 7-430L40 7-430L50 7-460L20 7-460L40 7-460L50	XF300	—	—	250L15 300L15	250 L15 300 L15	Fe 430D
4	C350	G350	C350 H350	5-490 7-490	HA350 HA400 HW350	—	C1 C4-1 C4-2 C7A-2	350 WR350 400	350 400	Fe 510A Fe 510B
5	C350 L0	—	—	7-490L0	—	—	—	WR350 L0	350 L0 400 L0	Fe 510C
6	—	—	—	5-490L20 5-490L40 5-490L50 7-490L20 7-490L40 7-490L50	XF400	—	—	350 L15 400 L15	350 L15 400 L15	Fe 510D
7A	C450	G450	C450	—	—	—	—	450	—	—
7B	C450 L0	—	—	—	—	—	—	—	—	—
7C	—	—	—	—	—	—	—	450 L15	—	—
8	—	—	—	—	XF500	—	—	—	—	—

TABLE 4.6.1(C)
PREQUALIFIED WELDING CONSUMABLES WITH
SIMILAR WEATHERING RESISTANCE

Steel grade	Consumables (see Note)	
	Manual metal-arc (AS/NZS 1553.2)	Flux-cored arc (AS 2203.1)
AS/NZS 1594— HW350 AS/NZS 3678— WR350 AS/NZS 3678— WR350 L0	E4815-C1L	W50XX.Ni1
	E4816-C1L	W55XX.Ni1
	E4818-C1L	W50XX.Ni2
	E4815-C2L	W55XX.Ni2
	E4816-C2L	W50XX.Ni3
	E4818-C2L	W55XX.Ni3
	E5516-C1	
	E5518-C1	
	E5516-C2	
	E5518-C2	

NOTE: Any listed consumables may be used with any listed steel grade.

4.6.2 Qualification of welding consumables by testing

Where welding consumables are not prequalified in accordance with Clause 4.6.1, they may be qualified in conjunction with a procedure qualification test in accordance with Clause 4.7. Where the mechanical properties of the transverse butt tensile test meet the minimum requirements shown in Table 4.6.2 and the weld metal hardness complies with Clause 4.7.8, the consumables shall be deemed qualified for that procedure.

TABLE 4.6.2
TRANSVERSE BUTT TENSILE TEST AND CHARPY-V IMPACT PROPERTIES

Steel type (see Table 4.6.1(B) and Note 1)	Minimum tensile strength, MPa	Charpy-V impact properties (see Note 2)			
		Manual metal- arc	Automatic and semi-automatic (see Note 4)		Temperature, °C (see Note 5)
			Average energy, J (see Note 3)	Minimum energy, J	
1	430	TNR	TNR	TNR	TNR
2	430	40	23	35	0
3	430	40	23	35	−15
4	500	TNR	TNR	TNR	TNR
5	500	47	26	40	0
6	500	47	26	40	−15
7A	500	TNR	TNR	TNR	TNR
7B	500	47	26	40	0
7C	500	47	26	40	−15
8	550	47	26	40	−15

NOTES TO TABLE 4.6.2:

- 1 Fracture of the tensile test specimen outside the weld zone with a tensile strength of not less than the minimum specified for the parent material is permitted.
- 2 TNR = Testing not required.
- 3 For manual metal-arc electrodes, the impact requirements are for the computed average values for the three test specimens.
- 4 For automatic and semi-automatic consumables, the impact requirements are for the minimum computed average values of the three test specimens plus the allowable minimum of any single specimen.
- 5 The Charpy-V test temperature shall be the lower of the relevant temperature given in Table 4.6.2 and the design service temperature (see Appendix B) as specified in Clause 4.6.1.1(h).

4.7 QUALIFICATION OF WELDING PROCEDURE BY TESTING

4.7.1 Method of qualification

Where the welding procedure to be used is not qualified in accordance with Items (a), (b) or (e) of Clause 4.2, it shall be qualified by producing a suitable test piece in accordance with either Item (c) or (d) of Clause 4.2 and subjecting the weld in the as-welded condition to the tests specified in Table 4.7.1.

Where the weld complies with the relevant test requirements of Clause 4.7, the welding procedure shall be accepted as qualified.

NOTES:

- 1 Where the welding procedure for a fillet weld requires qualification because the preheat temperature does not comply with Clause 5.3, the butt weld test piece shown in Figure 4.7.2(a) is used in the qualification tests.
- 2 Instructions for the qualification of welding procedures on steels not listed in Clause 2.1 or Table 4.6.1(B) are not specifically provided for by this Standard. Thus, such instructions should be agreed between the fabricator and principal. It is recommended that the fabricator should treat such joints as if they had been welded with non-prequalified welding consumables. The tests listed within the appropriate section of this Table should be performed, including the hardness comparison test (Clause 4.7.8) and the HAZ hardness test (Clause 4.7.9). In addition, where the design service temperature is not more than 5°C, it is also recommended that parent plate charpy tests be taken, to ensure compliance with Appendix B, in particular Table B1.

4.7.2 Preparation of special test piece

Where required, a special test piece shall be prepared in accordance with Figure 4.7.2, as appropriate. Under certain circumstances, such as an unusual joint configuration, it may be necessary to prepare two test pieces for different purposes, one as shown in Figure 4.7.2 for testing the weld metal and the other for closely simulating the configuration of the joint for testing the weld penetration.

4.7.3 Dimensions of test pieces

The dimensions of the test piece that is obtained either from the same joint type as the component being welded (see Clause 4.2(c)) or from a run-on or run-off piece welded in production or from the special test piece shown in Figure 4.7.2 shall be sufficient to allow preparation of the required number of test specimens for the tests.

4.7.4 Macro test

The macro test shall be carried out in accordance with AS 2205.5.1.

The specimen shall comply with the requirements of Clauses 5.6 and 6.2 and Table 6.2.2, as appropriate. Unless it can be proved otherwise for the remainder of the test plate (e.g. by radiographic testing, by ultrasonic testing, by further macro testing), internal imperfections revealed by the test piece shall be assumed to run the full length of the weld and assessed in accordance with Tables 6.2.1 and 6.2.2.

4.7.5 Transverse butt tensile test

The transverse butt tensile test shall be carried out in accordance with AS 2205.2.1.

The specimen shall comply with the requirements given in Table 4.6.2.

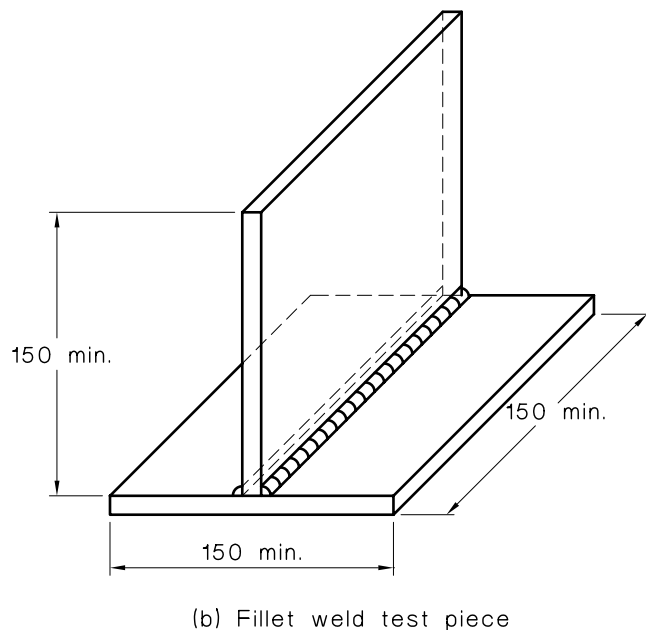
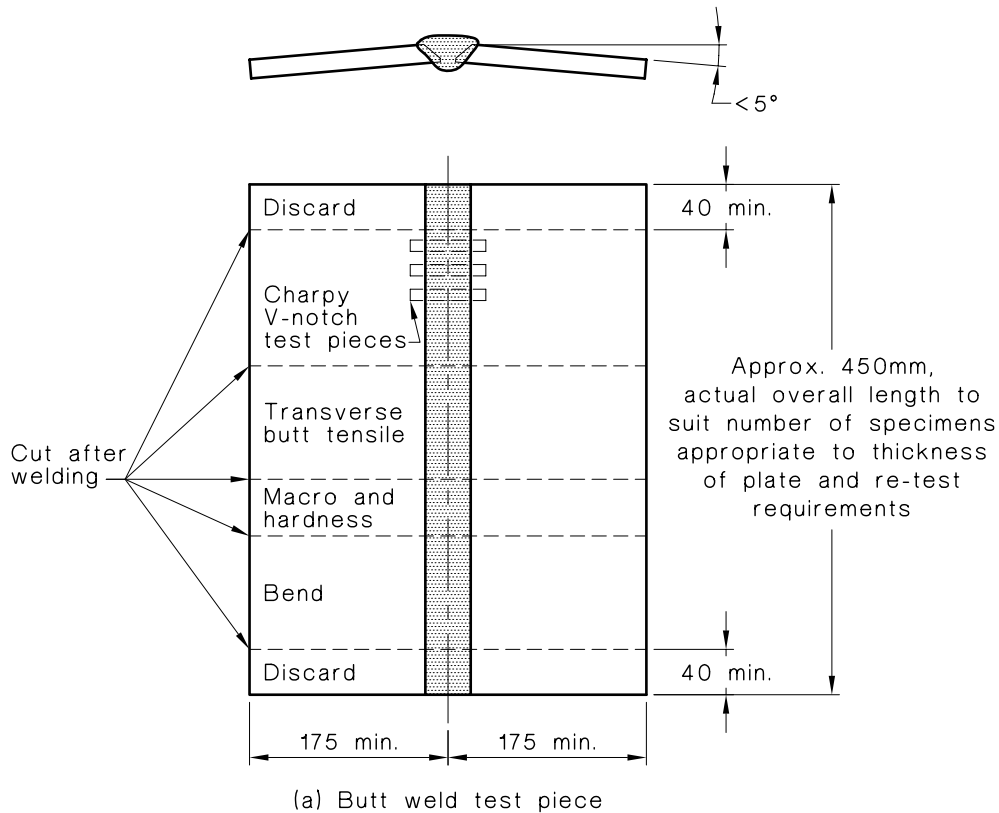
TABLE 4.7.1
EXTENT OF TESTING

Weld category	Consumables	Preparation	Tests required						
			Butt welds						Fillet welds
			Macro (see Clause 4.7.4)	Tensile (see Clause 4.7.5)	Bend (see Clause 4.7.6)	Charpy V (see Clause 4.7.7)	Hardness		Macro (see Clause 4.7.4)
							Comparison (see Clause 4.7.8)	HAZ (see Clause 4.7.9)	
SP	Prequalified, conforming to Table 4.6.1(A) or Table 4.6.1(C)	Prequalified, conforming to Tables E1 to E4, Appendix E	1	Nil	Nil	Nil	Nil	1 (see Note 1)	1
		Other preparations	1	Nil	2 side or 1 face and 1 root	Nil	Nil	1 (see Note 1)	1
	Not prequalified	Prequalified, conforming to Tables E1 to E4, Appendix E	1	1	2 side or 1 face and 1 root	See Note 2	1	1 (see Note 1)	1
		Other Preparations	2	1	2 side or 1 face and 1 root	See Note 2	1	1 (see Note 1)	2
GP	Prequalified, conforming to Table 4.6.1(A) or Table 4.6.1(C)	Prequalified, conforming to Tables E1 to E4, Appendix E	Nil	Nil	Nil	Nil	Nil	1 (see Note 1)	Nil
	Any other condition		1	Nil	Nil	Nil	Nil	1 (see Note 1)	1

NOTES:

6 HAZ hardness tests are required only to qualify welding procedures, where the preheat temperatures do not comply with Clause 5.3.

7 Three tests are required only for L0 and L15 steels, but may also be required for HAZ in accordance with Appendix D.



DIMENSIONS IN MILLIMETRES

FIGURE 4.7.2 FORM AND DIMENSIONS OF WELD TEST PIECES

4.7.6 Bend test

The bend test shall be carried out in accordance with AS 2205.3.1, using a former having a diameter complying with Table 4.7.6.

On the completion of the test, the dimension of any cracks or other defects in the weld or the heat-affected zone shall be not more than 3 mm, measured in any direction at the outer surface of the test specimen. Premature failure at the corners of the test specimen shall not be considered as a cause for rejection.

TABLE 4.7.6
DIAMETER OF FORMER FOR BEND TEST

Minimum specified tensile strength of plate MPa	Diameter of former (<i>D</i>)	Free space between supports at the end of test
≤530	3 <i>T</i>	5.2 <i>T</i>
>530	4 <i>T</i>	6.2 <i>T</i>

LEGEND:

T = thickness of test specimen

4.7.7 Charpy impact test

Charpy impact tests shall be carried out in accordance with AS 2205.7.1. In welds made from two sides, specimens shall be taken from the first side welded.

The specimen shall comply with Table 4.6.2.

4.7.8 Hardness comparison test for parent metal and weld metal

The hardness comparison test for parent metal and weld metal shall be carried out in accordance with AS 1817.

Hardness tests for the qualification of procedures employing consumables not prequalified shall show that the weld metal does not exceed the parent metal hardness by more than 100 HV 10.

4.7.9 Hardness test for weld heat-affected zones

The hardness test for weld heat-affected zones shall be carried out in accordance with AS 2205.6.1.

Except where a higher hardness has been determined in accordance with Appendix B, the hardness of weld heat-affected zones shall be not more than 350 HV 10.

4.7.10 Retests

Where any one specimen of all those tested during a procedure qualification test fails to comply with the test requirements, two retests for that particular type of test specimen may be performed with specimens cut from the same procedure qualification test piece. Both retests shall comply with the test requirements. If the failure is due to cracking in the heat-affected zone or in the weld, the procedure shall be modified and a new procedure test plate shall be prepared.

4.8 EXTENSION OF QUALIFICATION

Procedures qualified to AS/NZS 1554.5 may be employed without further qualification for category SP of this Standard. Similarly, procedures qualified for category SP may be employed without further qualification for category GP of this Standard.

A procedure qualified for use with a carbon or carbon-manganese steel may be employed without further qualification testing on any other carbon or carbon-manganese steel, provided that all of the following apply:

- The specified minimum yield strength of the other steel does not exceed that used in the qualified procedure by more than 51 MPa.
- The steel type number, as given in Table 4.6.1(B), has not increased.

- (c) The Charpy V impact test temperature of the other steel is not colder than that of the steel used in the qualified procedure.
- (d) The preheat group number of the other steel, as given in Table 5.3.4(A), is not greater than that of the steel used in the qualified procedure.
- (e) The chemical composition of the weld metal is not required to match that of the parent metal for weather resistance purpose.

4.9 COMBINATION OF PROCESSES

For complete penetration or incomplete penetration butt joints—

- (a) a different process may be used on each side of the one joint, provided that the preparation on the first side welded conforms to that listed under the process that is being used and the angle of the preparation on the second side conforms to that listed under the applicable process; and
- (b) a combination of processes may be used on the same side of a joint, provided that the preparation conforms to that listed under the process that is being used for the initial portion of the weld.

4.10 RECORDS OF TESTS

The fabricator shall record the results of the qualification tests carried out (e.g. macro, radiography), together with the relevant welding procedure documents, including PQR and WPS. These records shall be kept and made available to those authorized to examine them.

4.11 REQUALIFICATION OF WELDING PROCEDURES

Where a change in an essential variable for a welding procedure exceeds the relevant limits given in Tables 4.11(A) and 4.11(B), the welding procedure shall be requalified in accordance with Table 4.7.1.

Where a change in an essential variable for a welding procedure exceeds the relevant limits given in Table 4.11(C), the welding procedure shall be requalified by a macro test, taken from either a production weld run-off plate or a special test plate welded for the purpose.

TABLE 4.11(A)
CHANGES IN ESSENTIAL VARIABLES REQUIRING REQUALIFICATION FOR
WELDING PROCESSES OTHER THAN ELECTROGAS AND ELECTROSLAG
WELDING

Nature of change		Applicability (see Legend)				
		MMAW	SAW	GMAW	FCAW	GTAW
(a)	A change from one process to another	X	X	X	X	X
(b)	A change in consumable classification, except for a decrease in strength of the filler metal	X	X	X	X	X
(c)	An increase in filler metal strength, but not vice versa	X	X	X	X	X
(d)	A change from a hydrogen-controlled consumable to a non-hydrogen-controlled consumable or any increase in hydrogen classification of the consumable	X	X	—	X	—
(e)	A change from one gas or gas mixture to another gas or gas mixture	—	—	X	X	X
(f)	A change of more than $\pm 7\%$ of the specified mean arc voltage of the electrode used for SAW, GMAW or FCAW or more than $\pm 15\%$ for MMAW or GTAW	X	X	X	X	X
(g)	A change of more than $\pm 10\%$ of the specified mean welding current for the electrode used for SAW, GMAW or FCAW or more than $\pm 15\%$ for MMAW or GTAW	X	X	X	X	X
(h)	A change of more than $\pm 15\%$ of the specified mean speed of travel	—	X	X	X	X
(i)	A change of more than $\pm 25\%$ in the specified number of runs. If the cross-sectional area of the preparation is increased, it is also permissible to increase the number of runs in proportion to the increased area	X	X	X	X	X
(j)	An increase of 25% or more or a decrease of 10% or more in flow rate of the shielding gas	—	—	X	X	X
(k)	A change in position in which welding is done or a change in direction for a vertical weld	X	X	X	X	X
(l)	A change in welding current from a.c. to d.c., or vice versa, or a change in d.c. polarity, or a change in metal transfer across the arc	X	X	X	X	X
(m)	A decrease of more than 20°C in the minimum specified preheat or inter-run temperature	X	X	X	X	X
(n)	For automatic welding, a change in the number of electrodes used in a multiple wire application	—	X	X	X	X
(o)	For butt welds, a change in material thickness outside the range of 0.75 to 1.5 times the thickness of the test plate, see Clause 4.1.2(g)	X	X	X	X	X
(p)	A change in electrical stick-out of more than $\pm 20\%$	—	X	X	X	—
(q)	A change in pulse parameters	—	—	X	X	X
(r)	For fillet welds, a change from single pass to multipass, see Clause 4.1.3	X	X	X	X	X
(s)	For fillet welds, a change in welding position as per Clause 4.5.4	X	X	X	X	X
(t)	For single pass fillets, an increase in leg length over the size reported in the qualification	X	X	X	X	X

LEGEND:

X = Applicable

— = Not applicable.

TABLE 4.11(B)
CHANGES IN ESSENTIAL VARIABLES REQUIRING REQUALIFICATION FOR
ELECTROGAS AND ELECTROSLAG WELDING

(a)	A significant change in filler metal or consumable guide metal composition
(b)	A change in consumable guide metal core cross-sectional area of more than 30%
(c)	A change in fluxing system (e.g. cored electrode, external flux)
(d)	A change in flux composition, including consumable guide coating
(e)	A change in shielding gas composition of any one constituent of more than 5% of the total flow
(f)	A change in welding current of more than 10%
(g)	A change in joint preparation, other than square butt, outside the limits of Clause 4.5
(h)	A change in root gap of more than 6 mm
(i)	A change in joint thickness (T) outside the limits of $0.5T$ to $1.1T$, where T is the thickness used for procedure qualification
(j)	A change in number of electrodes
(k)	A change between alternating current and direct current
(l)	A change in polarity of a direct current
(m)	A change from the qualified process or method of welding to a combination with any other welding process or method
(n)	A change in electrode diameter exceeding 1 mm
(o)	A change in type of moulding shoe, either fixed or movable, from non-fusing solid to water-cooled, and vice versa
(p)	A change of welding position from the qualified position of more than 20 degrees
(q)	A change in voltage of more than 10%, except starting voltage settings
(r)	A change in speed of vertical travel exceeding 20%, except as necessary to compensate for a variation in the joint opening
(s)	A change in spacing of electrodes or consumable guides, except as a consequence of Item (j) above

TABLE 4.11(C)
MINOR CHANGES IN ESSENTIAL VARIABLES REQUIRING
REQUALIFICATION OF WELDING PROCEDURES BY MACRO TEST

Nature of change		Applicability (see Legend)				
		MMAW	SAW	GMAW	FCAW	GTAW
(a)	An increase in the diameter of the electrode	X	—	X	X	—
(b)	A change in electrode diameter of more than one step in the sequence of diameters	—	—	—	—	X
(c)	An increase or decrease in wire diameter of more than one step in the sequence of diameters	—	X	—	—	X
(d)	A change of weld preparation from V-shape to U-shape	X	X	X	X	X
(e)	A change in the shape of any one type of weld preparation more than the tolerance in Clause 5.2 and involving the following:					
(i)	A decrease in the included angle of the weld preparation	X	X	X	X	X
(ii)	A decrease in the root gap of the weld preparation	X	X	X	X	X
(iii)	An increase in the root face of the weld preparation	X	X	X	X	X
(iv)	The omission of backing material	X	X	X	X	X
(f)	A change in electrode geometry beyond the following limits:					
(i)	Longitudinal spacing of arcs of the greater of $\pm 10\%$ and ± 4 mm	—	X	—	—	—
(ii)	Lateral spacing of arcs of the greater $\pm 10\%$ and ± 1.5 mm	—	X	—	—	—
(iii)	Angular rotation of any parallel electrode of $\pm 10\%$	—	X	—	—	—
(iv)	Angle of electrodes:	—	X	—	—	—
	(A) In direction of travel of ± 3 degrees	—	X	—	—	—
	(B) Normal to direction of travel of ± 5 degrees	—	X	—	—	—
(g)	A change in electrical phase sequence between electrodes in multiple electrode welding	—	X	—	—	—

LEGEND:

X = Applicable

— = Not applicable.

4.12 QUALIFICATION OF WELDING PERSONNEL

4.12.1 Welding supervisor

Welding shall be carried out under the supervision of a welding supervisor or a welding coordinator employed by the fabricator.

The welding supervisor shall ensure that all welding is carried out as specified in the plans and specifications or other documents in accordance with this Standard.

The welding supervisor shall comply with one or more of the following:

- (a) Hold a Welding Technology Institute of Australia Welding Supervisor's Certificate in accordance with AS 1796 Certificate No. 10 or AS 2214, or a New Zealand Institute of Welding Supervisor's Certificate, or has equivalent qualifications acceptable to the principal.
- (b) Has served an apprenticeship in an appropriate metal trade and during or subsequent thereto had five years experience in the fabrication of welded steel structures, and is able to satisfy the principal of suitability for the work under the conditions of employment.
- (c) Had at least seven years experience in the fabrication of welded steel structures, and is able to satisfy the principal of suitability for the work under the conditions of employment.
- (d) Holds a diploma or a certificate in engineering or metallurgy of an approved technical college or is a graduate in engineering or metallurgy from a recognized university, and subsequent to obtaining a diploma, certificate or degree had three years experience in the fabrication of welded steel structures.
- (e) Holds a New Zealand Institute of Welding Certificate in Welding Engineering or a postgraduate certificate, diploma or degree in Welding Engineering from a recognized university or an approved technical college.

4.12.2 Welders

Welders shall be suitably qualified to carry out the welding procedures for which they will be employed. The fabricator shall provide evidence acceptable to the principal that the welders are suitably qualified. Such evidence shall be based on welds that closely resemble the joints and their positions to be used in the construction.

If a welder repeatedly produces welds not complying with this Standard, further welding by the welder shall be discontinued, until the welder carries out additional tests and the welds so produced comply with this Standard.

The names of all welders qualified in accordance with this Clause, together with particulars of any tests passed by each, shall be recorded and made available for perusal by the Inspector for the duration of the job.

In addition, the following requirements apply to the qualification of welders:

- (a) Qualifications obtained by welders under appropriate Standards laying down welder qualification tests are acceptable as evidence of their ability. Such evidence shall refer to welding carried out on joints and in positions as close as practicable to the actual joints and positions to be used in construction. Welders qualified to Standards such as AS 1796, AS 2980, AS/NZS 3992, NZS 4711 or ISO 9606-1 shall be deemed to be qualified.
- (b) Welders not already qualified for the welding process and position required by the welding procedure under the conditions of employment shall be required to demonstrate an ability to comply with the appropriate requirements of this Standard by means of a macro test for all welding procedures required on the job.
- (c) Persons operating automatic or semi-automatic equipment and qualified to use a particular process with an approved consumable or combination of consumables shall be considered qualified to use other approved consumables or combinations of consumables with the same process.
- (d) Qualifications established under this Clause with any one of the steels covered by this Standard shall be considered as qualification to weld any other of the steels covered by this Standard.

- (e) Qualifications established in any one position described by this Standard may be extended within the limits of Table 4.12.2.
- (f) Qualifications for welding to a specified welding procedure shall remain valid, provided that it can be shown from records maintained by the organization employing welders that the welders have been employed with reasonable continuity using the relevant welding processes and have continued to produce satisfactory welds as verified by a non-destructive examination.

Reapproval shall be required if any of the following conditions apply:

- (i) Six months or more have elapsed since the welder was employed on the relevant welding processes.
- (ii) The welder changes employment. Under such circumstances, the employer shall qualify the welder who has changed employment.
- (iii) There is some specific reason to question the welder's ability.

TABLE 4.12.2
RANGE OF APPROVAL ACCORDING TO WELDING POSITION
 (See Notes below)

Welding position of approval test piece				Range of approval																						
				Plates										Pipes												
				Butt welds					Fillet welds					Butt welds						Fillet welds						
														Rot- ating	Fixed			Rot- ating	(2)	Fixed						
															0°		90°			45°		0°	90°			
				F	H	VD	VU	OH	F	HV	VD	VU	OH	F	VD	VU	H	6G-VU	6G-VD	F	HV	VD	VU	(3)		
Plates	Butt welds			F	✓	–	–	–	–	X	X	–	–	–	X	–	–	–	–	X	X	–	–	–		
				H	X	✓	–	–	–	X	X	–	–	–	X	–	–	X	–	–	X	X	–	–	–	
				VD	–	–	✓	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	
				VU	X	–	–	✓	–	X	X	–	X	–	X	–	–	–	–	X	X	–	X	–		
				OH	X	X	–	X	✓	X	X	–	X	X	X	–	–	–	–	X	X	–	X	X		
	Fillet welds			F	–	–	–	–	–	✓	–	–	–	–	–	–	–	–	X	–	–	–	–			
				HV	–	–	–	–	–	X	✓	–	–	–	–	–	–	–	X	X	–	–	–			
				VD	–	–	–	–	–	–	–	✓	–	–	–	–	–	–	–	–	–	–	–			
				VU	–	–	–	–	–	X	X	–	✓	–	–	–	–	–	X	X	–	–	–			
				OH	–	–	–	–	–	X	X	–	X	✓	–	–	–	–	–	X	X	–	–	X		
Pipes	Butt welds		Rot- ating	F	X	–	–	–	–	X	X	–	–	–	✓	–	–	–	–	X	X	–	–	–		
				Fixed	0°	VD	–	–	X	–	–	–	–	X	–	–	–	✓	–	–	–	–	–	X	–	–
					VU	X	–	–	X	X	X	X	–	X	X	X	–	✓	–	–	–	X	X	–	X	X
			90°		H	X	X	–	–	–	X	X	–	–	–	X	–	–	✓	–	–	X	X	–	–	–
			45°	6G-VU	X	X	–	X	X	X	X	–	X	X	X	–	X	X	✓	–	X	X	–	X	X	
				6G-VD	–	–	X	–	–	–	–	X	–	–	–	X	–	–	–	✓	–	–	X	–	–	
	Fillet welds		Rot- ating	F	–	–	–	–	–	X	–	–	–	–	–	–	–	–	✓	–	–	–	–			
				(2)	HV	–	–	–	–	–	X	X	–	–	–	–	–	–	–	X	✓	–	–	–		
			Fixed	0°	VD	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	✓	–	–	
					VU	–	–	–	–	–	X	X	–	X	X	–	–	–	–	–	X	X	–	✓	X	

LEGEND:

✓ Indicates the welding position for which the welder is approved in the approval list

X Indicates those welding positions for which the welder is also approved

– Indicates those welding positions for which the welder is not approved.

NOTES:

1 The letters in the table refer to welding positions as defined in Appendix E, except that for vertical welding directions D = down and U = up.

2 Two versions:

(a) Pipe: rotating, axis: horizontal, welds: vertical.

(b) Pipe: fixed, axis: vertical, weld: horizontal vertical.

3 OH, this is an approved position and is covered by the other related tests.

SECTION 5 WORKMANSHIP

5.1 PREPARATION OF EDGES FOR WELDING

5.1.1 General

Surfaces and edges to be welded shall be uniform and free from fins, tears, cracks and other defects that would adversely affect the quality or strength of the weld. Surfaces to be welded and surfaces adjacent to a weld shall also be free from loose or thick scale, slag, rust, grease, paint or other foreign matter that would prevent proper welding. Millscale that withstands vigorous wire brushing may remain. Rust-inhibiting coatings, antisplatter compound and weld-through primers that do not interfere with the welding operation may remain.

5.1.2 Thermal cutting

Surfaces to be incorporated in a weld shall not have a surface rougher than Class 3 as defined in WTIA Technical Note 5.

Surfaces not incorporated in a weld shall comply with AS 3990, AS 4100 or NZS 3404.1, as applicable.

NOTE: WTIA Technical Note 5 gives guidance on cutting conditions, together with replicas of flame-cut surfaces.

5.2 ASSEMBLY

5.2.1 General

The alignment of parts to be welded shall be made as carefully as possible having regard to the normal tolerances associated with the fabrication and erection procedures specified in the application Standard.

5.2.2 Alignment of butt-welded joints

Ends of parts to be joined by butt welds shall be carefully aligned, having regard to the procedure being employed.

Where parts are effectively restrained against bending, due to eccentricity of alignment, any misalignment of the surfaces of plates of equal thickness shall not exceed the lesser of 3 mm and 10% of the thickness of the plates.

Except for electroslog and electrogas processes, the dimensions of butt-welded joints that differ from those shown on the detailed drawings or other documents by more than the tolerances shown in Table 5.2.2 shall be referred to the inspector for approval.

The tolerances for electroslog and electrogas processes shall be determined, before commencement of welding, in accordance with Appendix D.

Root openings wider than those permitted in Table 5.2.2, but not wider than the lesser of 19 mm and twice the thickness of the thinner part, may be corrected by welding to acceptable dimensions, prior to joining of the parts by welding. Root openings wider than the lesser of 19 mm and twice the thickness of the thinner part shall be corrected by welding only with the approval of the principal.

Where the root is to be gouged back to sound metal, the root tolerances given in Table 5.2.2 may be disregarded.

TABLE 5.2.2
ALLOWABLE JOINT TOLERANCES

Dimension	Tolerance
Root face (root not gouged)	± 1.5 mm
Root gap without backing (root not gouged)	± 1.5 mm
Root radius (root not gouged)	+3, -0 mm
Root gap with backing	+6, -1.5 mm
Angle of preparation	+10, -5 degrees

NOTE: For gouged preparations, see Clause 5.2.2.

5.2.3 Alignment of fillet welds and incomplete penetration butt welds

Except for full contact joints, parts to be joined by fillet welds, or by incomplete penetration butt welds parallel to the length of the member, shall be brought into as close a contact as practicable.

The gap between parts shall normally not exceed 5 mm, except in cases involving rolled shapes and plates 75 mm or greater in thickness if, after straightening and on assembly, the gap cannot be closed sufficiently to comply with the requirement. In such cases, a maximum gap of 8 mm is acceptable, provided that a sealing weld or suitable backing material is used to prevent burn through.

Where the separation is 1.5 mm or greater, the size of the fillet weld shall be increased by the amount of the separation or the fabricator shall demonstrate that the required design throat thickness has been obtained.

5.2.4 Separation of a backing material

The separation between the faying surfaces (i.e. two surfaces in contact) of butt-welded material and permanent backing material shall not exceed 1.5 mm.

5.3 PREHEATING AND INTER-RUN CONTROL

5.3.1 General

Control of preheating and inter-run temperature is required for certain combinations of steel grades, material thicknesses and welding conditions. Minimum preheating temperatures related to arc energy input may be determined in accordance with Clause 5.3.4. Excessive preheating should be avoided.

5.3.2 Need for preheating

Where the metal temperature is below the preheating temperature determined from Clause 5.3.4 for the metal being welded and the arc energy employed, the metal shall be preheated to the required temperature and maintained at that temperature while welding is in progress.

5.3.3 Extent of preheating and cooling after welding

Where preheating is required, it shall be applied in such a manner that the parts being welded are at the specified minimum temperature for a distance on both sides of the weld at least equal to the thickness of the parts being welded but not less than 75 mm. The preheat shall be applied in such a manner as will ensure that the full thickness of the materials to be welded are heated to the required temperature.

The rate of cooling from the preheating or interrun temperatures should be uniform and as slow as practicable. Delayed cooling by means of insulation or heat may be desirable in extreme cases or complex joints.

5.3.4 Determination of preheating temperature

Preheating and inter-run temperatures shall be determined from Tables 5.3.4(A) and 5.3.4(B) and Figures 5.3.4(A), 5.3.4(B) and 5.3.4(C), in accordance with the following method:

- (a) Select or calculate the weldability group number, using either of the following methods:
 - (i) For a standard steel of known specification, select the weldability group number from Table 5.3.4(A).
 - (ii) For a standard steel type listed in Table 5.3.4(A) of known ladle or heat analysis, calculate the carbon equivalent (CE) using the following equation, add 0.01 to the value, then select the weldability group number from Table 5.3.4(B):

$$CE = C + \frac{Mn}{6} + \frac{(Cr + Mo + V)}{5} + \frac{Ni + Cu}{15} \quad \dots (1)$$

where

CE = Carbon equivalent

C = Carbon content, in percent

Mn = Manganese content, in percent

Cr = Chromium content, in percent

Mo = Molybdenum content, in percent

V = Vanadium content, in percent

Ni = Nickel content, in percent

Cu = Copper content, in percent

NOTE: For other steel types not listed in Table 5.3.4(A), guidance may be obtained from WTIA Technical Note 1.

- (b) Calculate the combined thickness (see Figure 5.3.4(A)).
- (c) Using Figure 5.3.4(A), find the closest curve to the intersection points from Items (a) and (b) above to give the joint weldability index (one of the letters A to L).
- (d) Using the joint weldability index from Item (c) above, obtain the combination of arc energy and minimum preheating temperature from Figure 5.3.4(B) or Figure 5.3.4(C), depending on whether hydrogen controlled or non-hydrogen controlled processes are used.
- (e) The relationship between the arc energy, voltage, current and travel speed is shown in the following equation:

$$Q = \frac{60 E I}{1000 V} \quad \dots (2)$$

where

Q = arc energy, in kilojoules per millimetre

E = arc voltage, measured at the welding head, in volts

I = welding current, in amperes

V = travel speed, in millimetres per minute

NOTE: For pulsed mode welding, use E = average voltage and I = average current in Equation (2) to calculate the minimum arc energy. In cases where the arc energy may need to be limited, such as given in Clause 4.6.1.1, advice should be sought from the welding machine supplier on the calculation of arc energy when using pulsed mode.

To calculate the total arc energy for multi-arc processes, calculate the arc energy for each individual arc using the above equation. The total arc energy for the process is the sum of all arc energies for each individual arc.

Where it is desired to apply preheating temperatures not determined by this method, the welding procedure shall be qualified in accordance with Section 4.

NOTES:

- 1 Guidance on determining preheats for steels not listed in Table 5.3.4(A) can be obtained from WTIA Technical Note 1.
- 2 The preheat prediction methods given herein are designed to minimize the risk of heat-affected zone cold cracking under most fabrication circumstances. The Standard does not address the issue of weld-metal cold cracking. If encountered, weld procedure modifications may be required, including the application of additional preheat beyond that predicted and the use of lower hydrogen consumables. There is evidence that weld-metal cold cracking is more likely to occur with multi-pass welds in restrained plates over 20 mm thick and where high heat input runs are used (i.e. larger weld bead sizes).

TABLE 5.3.4(A)
PREHEAT DETERMINATION

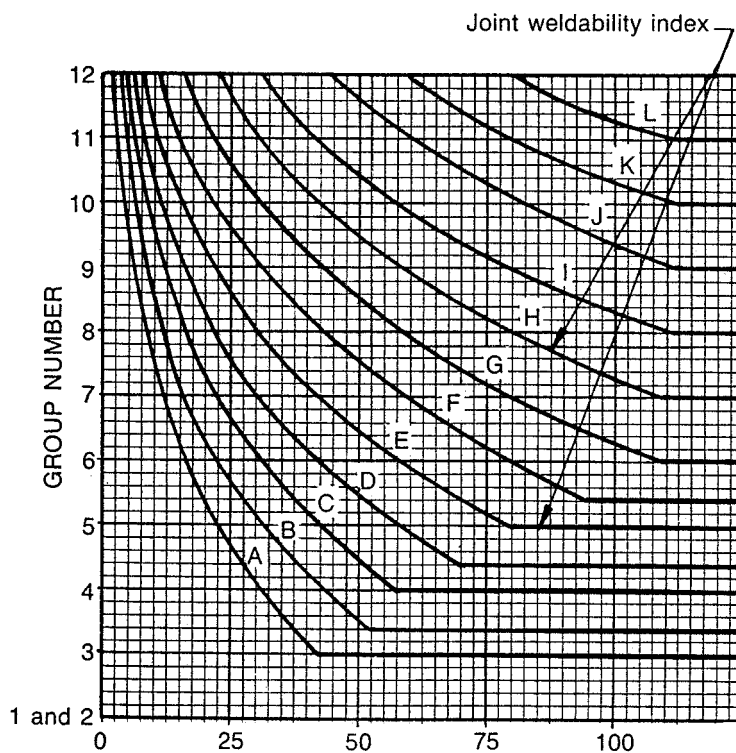
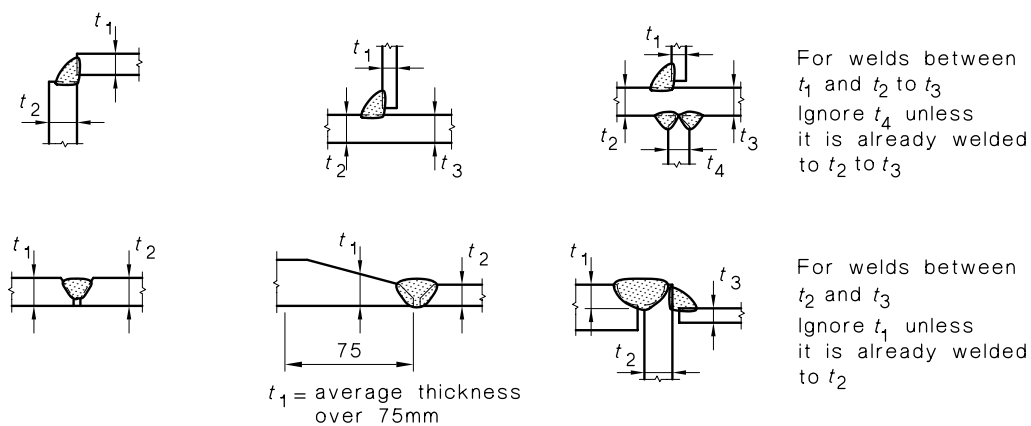
Parent metal		Weldability group number
Standard	Grade (see Note 1)	
AS 1163	C250	1
	C350, C450	3
AS 1397	G250, G300	1
	G350	4
	G450	1
AS 1450	C200, H200	1
	C250, H250	4
	C350, H350	5
	C450	4
AS 1548	5-490	5
	7-430, 7-460	4
	7-490	5
AS/NZS 1594 (see Note 2)	HA1, HA3, HA4, HA200	1
	HA250, HA250/1, HU250	3
	HA300, HA300/1, HU300, XF300	3
	HA350	3
	HW350	5
	HA400, XF400	3
	XF500	4
	HA1006, HA1010	1
	HA1016	3
	HXA1016	4
AS/NZS 1595	All	1
AS 2074	C1	5
	C2	2
	C3	6
	C4-1	5
	C4-2	6
	C7A-1	4
	C7A-2	5
AS/NZS 3678 And AS/NZS 3679.2	200	1
	250, 300	4
	350, WR350, 400, 450	5
	A1006	1
	XK1016	4
AS/NZS 3679.1	250, 300	4
	350, 400	5
NZS 3415	Fe 430	4
	Fe 510	5

NOTES:

- 1 The weldability of each impact tested steel variant is the same as its base steel.
- 2 The weldability group numbers for these AS/NZS 1594 steels is based on the typical maximum carbon equivalent encountered in Australia and New Zealand, rather than the maximum specification limits normally applied.

TABLE 5.3.4(B)
RELATIONSHIP BETWEEN CARBON
EQUIVALENT AND GROUP NUMBER

Carbon equivalent		Group number
	<0.30	1
≥0.30	<0.35	2
≥0.35	<0.40	3
≥0.40	<0.45	4
≥0.45	<0.50	5
≥0.50	<0.55	6
≥0.55	<0.60	7
≥0.60	<0.65	8
≥0.65	<0.70	9
≥0.70	<0.75	10
≥0.75	<0.80	11
≥0.80		12



NOTES:

- 1 Thickness is shown only up to 125 mm for convenience.
- 2 Combined thickness = $t_1 + t_2 + t_3 + t_4$.

FIGURE 5.3.4(A) RELATION OF JOINT WELDABILITY INDEX TO JOINT COMBINED THICKNESS AND GROUP NUMBER

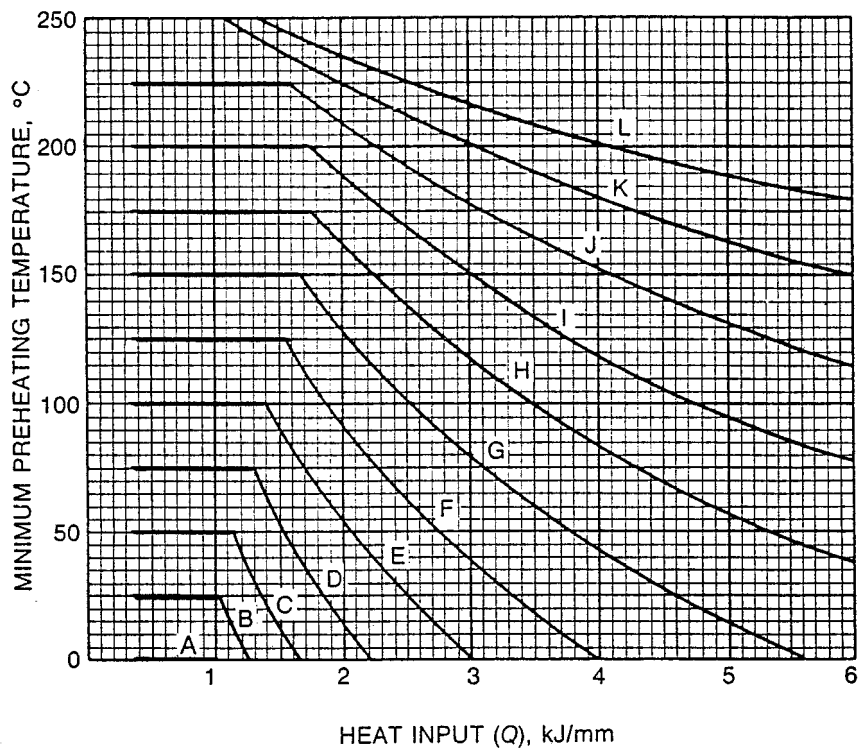


FIGURE 5.3.4(B) PREHEATING DETERMINATION FOR HYDROGEN-CONTROLLED MANUAL METAL-ARC ELECTRODES AND SEMI-AUTOMATIC OR AUTOMATIC PROCESSES

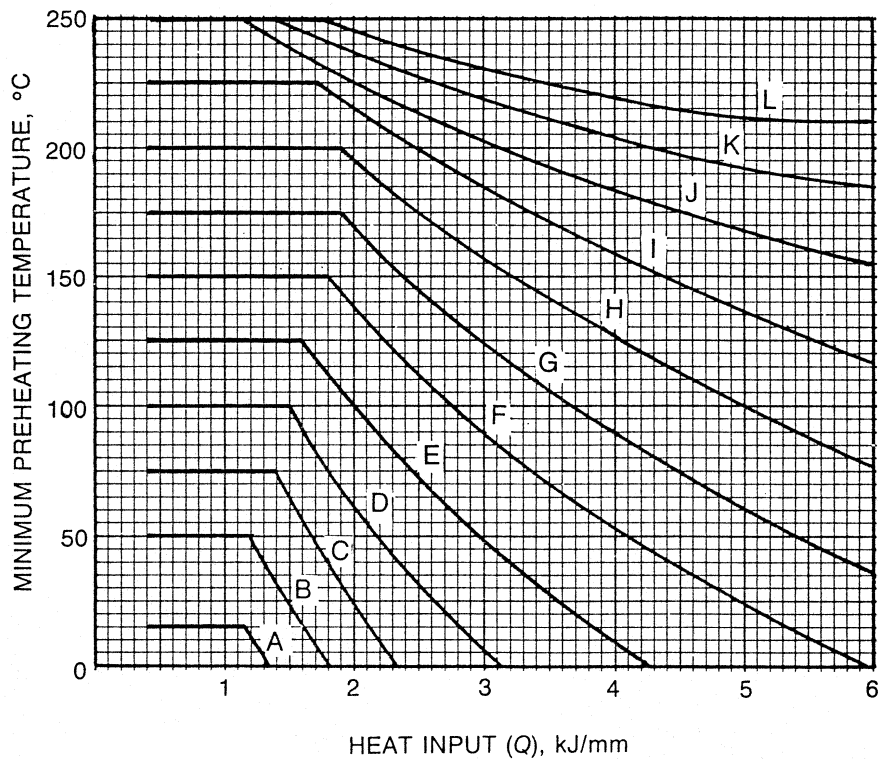


FIGURE 5.3.4(C) PREHEATING DETERMINATION FOR MANUAL METAL-ARC ELECTRODES OTHER THAN HYDROGEN CONTROLLED

5.4 WELDING UNDER ADVERSE WEATHER CONDITIONS

Welding shall not be carried out when the welding surfaces are wet or during periods of high wind, unless the welder and the work are properly protected.

Welding processes requiring an external gas shield shall not be carried out in a draught or wind speed of more than 10 km/h, unless the welding area is suitably protected, so as to reduce the wind speed to less than 10 km/h, or unless a satisfactory welding procedure is established in accordance with Section 4.

Welding and thermal cutting shall not be carried out when the metal temperature is colder than 0°C, unless the welding procedure is qualified in accordance with Section 4.

5.5 TACK WELDS

Tack welds shall—

- (a) be subject to the same quality and workmanship requirements as the final welds, including appropriate temperature controls as given in Clause 5.3;
- (b) if multirun, have cascaded ends; and
- (c) have a length of not less than the lesser of 40 mm and four times the thickness of the thicker part.

5.6 WELD DEPTH-TO-WIDTH RATIO

The depth and the maximum width of the deposited weld metal shall not exceed its width at the surface of the weld (see Figure 5.6); except that this requirement may be waived where the weld depth exceeds the width of the weld at the face, provided the testing of the welding procedure to be used has demonstrated that such welds are free from cracks. This requirement shall not be waived where the maximum width in the cross-section of the weld material deposited exceeds the width of the weld at the surface.

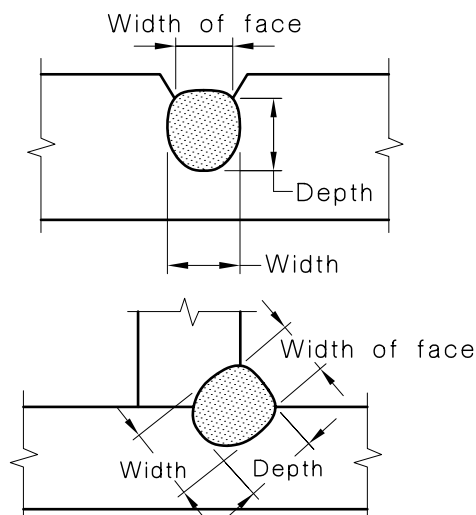


FIGURE 5.6 UNACCEPTABLE WELD RUN IN WHICH DEPTH AND WIDTH EXCEED THE WIDTH OF THE WELD FACE

5.7 CONTROL OF DISTORTION AND RESIDUAL STRESS

5.7.1 General

In the assembly and joining of parts of a structure or built-up members and in the welding of reinforcing parts to members, the procedure and sequence shall be such as will maintain distortion and shrinkage within the required structural limits, guidance on which is given in AS 3990, AS 4100 or NZS 3404.1.

Welding under conditions of severe external shrinkage restraint shall be carried out continuously to completion or to a point that will ensure freedom from cracking, before the joint is allowed to cool below the minimum specified preheating and inter-run temperatures.

5.7.2 Stressed parts

Parts that are stressed shall not be cut or welded, except where the effect of such actions on the flexural, tensile and compressive capacity of the member is considered and the matter is discussed between the fabricator and the principal in accordance with Appendix D, and appropriate safety precautions are taken to prevent damage to or failure of the structure (see the requirements for modification of existing structures in AS 4100 or NZS 3404.1, as appropriate).

5.7.3 Peening

Peening may be used on intermediate weld runs for control of shrinkage stresses in thick welds, to prevent cracking. No peening shall be done on the root or surface layer of the weld or in the base metal at the edges of the weld. Care should be taken to prevent overlapping or cracking of the weld or base metal.

The procedure to be adopted for peening shall be established by the fabricator and approved by the principal, before use, in accordance with Appendix D.

5.7.4 Correction of distortion

Distortion resulting from welding and fabrication may be corrected by mechanical means, by heating or by the controlled application of weld runs. Where flame-heating methods are applied, the following restrictions shall apply:

- (a) Solid water jets may be used for cooling, only if arranged before use in accordance with Appendix D.
- (b) The temperature of steels shall not exceed 600°C.

Improperly fitted parts may be cut apart and rewelded, if arranged in accordance with Appendix D.

5.8 BACKGOUGING AND REPAIR OF DEFECTS IN WELDS

5.8.1 Repair of welds

Where welds are found to have defects as classified by Clause 6.7, either the defects shall be repaired or the entire weld shall be removed and replaced. Repairing or rewelding shall be carried out in accordance with this Standard and the principal shall be advised of all such repairs at the earliest opportunity. A repair weld procedure may be required in such instances.

5.8.2 Removal of weld metal

Removal of the weld metal or portions of the base metal shall be effected by machining, grinding, chipping, oxygen gouging, air-arc gouging or plasma gouging, in such a manner that the remaining weld metal or base metal is not nicked or undercut. Unacceptable portions of the weld shall be removed without substantial removal of the base metal. The surfaces shall be cleaned thoroughly before welding. Oxygen gouged and air-arc gouged surfaces shall be at least cleaned by grinding or machining, to remove all carbon absorption or contamination.

Gouged areas requiring re-welding shall have a root radius of not less than 5 mm and sufficient width to allow the welder reasonable access to reinstate the weld.

Unacceptable undercutting shall be made good by either the deposition of additional weld metal in accordance with this Standard or the removal of the undercut by grinding in accordance with Clause 5.8.3.

NOTE: The use of preheat before air-arc or plasma gouging should be considered. Guidance may be obtained from WTIA Technical Note 5.

5.8.3 Grinding

Grinding shall comply with the following requirements:

- (a) The area ground shall blend smoothly into the surrounding surface, without abrupt changes in contour.
- (b) The grinding shall not extend below the surface of the parent material by more than—
 - (i) for material less than 10 mm thick, 0.5 mm; or
 - (ii) for material not less than 10 mm thick, the lesser of 0.07 times the nominal thickness and 3 mm.

5.8.4 Stop starts

Where stop/starts occur in a length of continuous automatic longitudinal fillet or butt weld, with stress ranges for detail category 112 in accordance with AS 4100 or NZS 3404.1, they shall be repaired by the following procedures:

- (a) Grind the stopped end of the weld, so that it tapers to the root of the joint with a slope of not less than 4:1.
- (b) Restart the weld from the top of the taper slope.
- (c) Grind the repaired weld to a smooth surface, to blend into the profile of the existing weld.

The site of the repair shall be subjected to 100% magnetic particle examination to the requirements of Section 6.

5.9 TEMPORARY ATTACHMENTS

Welds joining temporary attachments to the structure shall be made to the same standards as final welds. All temporary attachments shall be removed, unless otherwise specified on the drawings or other documents. Temporary welds and attachments shall not be allowed on the tension flanges of beams, girders and similar members. When temporary welds or attachments are removed, the surface shall be—

- (a) reinstated to a reasonably smooth condition by grinding or by a combination of welding and grinding;
- (b) checked by magnetic particle examination or other suitable method to ensure soundness; and
- (c) finished to the requirements of Clause 5.8.2.

5.10 ARC STRIKES

Arc strikes outside the area of permanent welds should be avoided on any material. Cracks or blemishes resulting from arc strikes on members, other than those that are essentially statically loaded, shall be ground to a smooth contour in accordance with Clause 5.8.3 and checked by magnetic particle examination.

5.11 CLEANING OF FINISHED WELDS

Slag shall be removed from completed welds. The weld and adjacent base metal shall be cleaned by brushing or other suitable means. Tightly adhering spatter remaining after the cleaning operation is acceptable, unless its removal is required for subsequent non-destructive testing or surface treatment.

Welded joints shall not be painted until after the welding has been completed, inspected and accepted.

5.12 DRESSING OF BUTT WELDS

The surfaces of butt welds that have been dressed flush shall be finished so as to—

- (a) not reduce the thickness of the thinner base metal or weld metal by more than 0.8 mm or 5% of the thickness, whichever is lesser; or
- (b) not leave reinforcement that exceeds 0.8 mm.

Reinforcements shall be removed where welds form part of a faying or contact surface. Any dressing of reinforcements shall blend smoothly with the plate surfaces.

SECTION 6 QUALITY OF WELDS

6.1 CATEGORIES OF WELDS

According to the intended application, welds shall be classified as Category GP or Category SP (see Clause 1.6).

The compliance of completed welds with these categories shall be determined in accordance with the different inspection requirements and different acceptance levels of imperfections for the categories, as given in Clause 6.2.

6.2 METHODS OF INSPECTION AND PERMISSIBLE LEVELS OF IMPERFECTIONS

6.2.1 Methods of inspection of completed welds

Welds shall be inspected in accordance with Clause 7.3 and, where appropriate, Clause 7.4.

In addition, for Category SP butt welds, where radiographic or ultrasonic examination is required by the principal and is specified on the drawings or other documents, examination for the relevant types of imperfections shown in Table 6.2.1 shall be carried out in accordance with Clause 6.3 or 6.4, as appropriate.

NOTE: Table 7.4 contains guidance on the suggested extent of non-destructive examination, which is consistent with the principles on which this Standard is based.

6.2.2 Permissible levels of imperfection

The size, number and spacing of imperfections permitted for the weld categories shall not exceed the relevant levels given in Tables 6.2.1 and 6.2.2.

6.2.3 Adjacent imperfections

6.2.3.1 *Aligned*

Where adjacent imperfections are aligned, they shall be assessed in the manner shown by Figure 6.2.3(a).

6.2.3.2 *Overlapping*

Where there is a horizontal displacement between adjacent imperfections, the effective length (L) shall be as shown in Figure 6.2.3(b).

6.2.3.3 *Overlapping vertical displacement*

Where imperfections occur above each other in the vertical plane of the weld, they shall be assessed in the manner shown by Figure 6.2.3(c).

6.2.4 Interpretation of tests

Where qualification by both a macro test and side-bend tests are required (see Clause 4.7), the bend tests shall be used solely to reveal imperfections not observed in the macro section. Tearing at the ends of imperfections shall not be considered for the purposes of assessing the depth or height of imperfections. Any imperfections observed may be assumed to extend the total length of the weld, unless additional sections are taken to show the extent of the imperfections.

TABLE 6.2.1
PERMISSIBLE LEVELS OF IMPERFECTIONS AS DETERMINED
BY RADIOGRAPHIC OR ULTRASONIC EXAMINATION
FOR WELDS OF CATEGORY SP

Type of imperfection (see Notes 1 to 3)	Thickness of thinner parent metal (<i>t</i>) mm (See Note 4)	Weighting factor					Maximum permissible imperfection level (see Notes 5, 6 and 7)
		Height of imperfection (<i>h</i>), mm					
		≤2	>2 ≤4	>4 ≤10	>10 ≤20	>20	
Cracks	All	Not permitted					
Inclusions, lack of penetration, or lack of fusion:	≤10	2	X	X	X	X	<i>L</i> /5
	>10 ≤20	2	4	X	X	X	<i>L</i> /4
	>20 ≤40	1	2	5	X	X	<i>L</i> /2
	>40	1	2	5	10	X	<i>L</i>
Porosity	All	See Note 8					

LEGEND:

X = Not permitted

L = Weld length under consideration

NOTES:

- For adjacent imperfections, see Clause 6.2.3.
- For the purpose of radiographic examinations and routine ultrasonic examinations, *h* shall to be taken as 2 mm. Where an ultrasonic or a radiographic examination indicates that *h* may be greater than 2 mm, *h* shall be determined by sectioning or vertical ultrasonic sizing in accordance with AS 2207.
- Any imperfections that are suspected of being lamellar tears should be recorded on the NDE report and referred to the principal for consideration.
- See also Clause 3.2.1.
- For any weld length under consideration, the imperfection level shall be calculated by multiplying the length of each imperfection by its weighting factor and adding these weighted lengths to determine a total imperfection level. The total imperfection level shall be less than the maximum permissible imperfection level.
- Any imperfections shall not exceed a height equal to the greater of 2 mm and *t*/20, within a distance of *t* of the end of a weld.
- Where the length of a continuous weld exceeds 1 m, the maximum permissible imperfection level shall not be exceeded in any continuous weld length of 1 m.
- Where continuous or adjacent imperfections cross the division between examination lengths, the examination lengths shall be relocated to include the most severe combination of imperfections.
- Porosity is not considered to be a particularly serious imperfection and is cause for rejection of a weld only where it is present in sufficient quantity to render difficult an inspection for the other imperfections listed in Table 6.2.1. Any such level of porosity shall be recorded and referred to the principal for consideration. For radiographic inspections, porosity levels representing a loss of projected area of more than 2% are permitted. If required, reference may be made to porosity charts in AS 4037, to assist in assessing the appearance of this level of porosity on a radiograph.

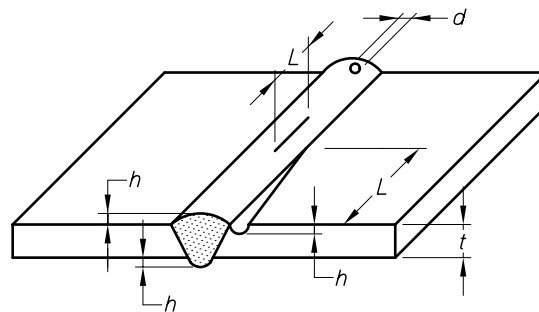
TABLE 6.2.2

**PERMISSIBLE LEVELS OF IMPERFECTIONS IN BUTT AND FILLET WELDS AS
DETERMINED BY VISUAL, MAGNETIC PARTICLE AND LIQUID PENETRANT
EXAMINATION OF THE WELD ZONE (see also Figure 6.2.2)**

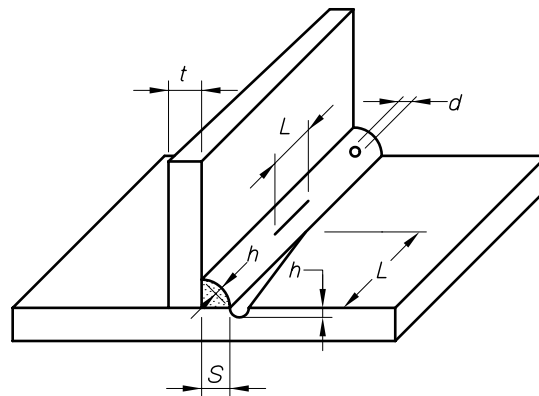
Imperfection (see Note 1)		Symbol	Maximum allowable dimension or number of imperfections	
Type	Parameter		GP	SP
BUTT WELDS				
Cracks	Length	L	Crater cracks only	No cracks allowed
	Cumulative length	ΣL	6 mm in 1000 mm weld (crater cracks only)	
Lack of fusion or incomplete penetration	Length for SP Depth for GP	As for undercut depth	L	Where located more than $3t$ from end of weld, $2t/3$, but not more than 20 mm Where located within $3t$ of end of weld, 3 mm
			ΣL	t in $6t$ length, but proportionally less for shorter length
Undercut-continuous (see Note 2)	Depth	h	$t/10$, but not more than 1.5 mm	$t/20$, but not more than 1 mm
Undercut-intermittent (see Note 2)	Depth	h	$t/5$, but not more than 2 mm	$t/10$, but not more than 1.5 mm
Shrinkage grooves Root concavity	—	—	As for undercut	
Reinforcement (each side)	Height	h	Not limited	For $t \leq 12$ mm, 3 mm For $12 < t \leq 25$ mm, 5 mm For $t > 25$ mm, 6 mm
Excess penetration	Height (depth)	—	As for reinforcement	
Linear misalignment	—	—	See Clauses 5.2.2 and 5.2.3	
Overlap (see Note 3)	Length	L	$2t$, but not more than 20 mm	t , but not more than 10 mm
	Cumulative length	ΣL	60 mm in 300 mm, but proportionately less for shorter lengths	30 mm in 300 mm, but proportionately less for shorter lengths
Toe shape, other than above	—	—	No restriction	Suitable to permit required NDE
Surface pores (see Note 3)	Size of pore	D	Not limited	$t/3$, but not more than 5 mm
	Number of pores	—	Six per $12t$ length	Two per $12t$ length
Loss of cross-sectional area (see Notes 4 and 5)	Loss of area	—	≤10 percent	≤5 percent
FILLET WELDS				
Reinforcement	Height	H	Not limited	For $S \leq 12$ mm, 2 mm For $12 < S \leq 25$ mm, 3 mm For $S > 25$ mm, 4 mm
Undersize-intermittent (see Note 6)	Leg length	—	$S/5$, but not more than 4 mm	$S/10$, but not more than 3 mm
Other surface imperfections	—	—	As for butt welds	
Loss of cross-sectional area (see Note 5)	Loss of area	—	As for butt welds	

NOTES TO TABLE 6.2.2:

- 1 For adjacent imperfections, see Clause 6.2.3.
- 2 Undercut less than 0.5 mm in depth should be disregarded.
- 3 Where these allowances for overlap and surface pores are detrimental to any surface treatment, they may not be acceptable.
- 4 For a welding procedure qualification, the assessment of the test piece for compliance with the permissible levels of imperfections should be done with the aid of the macro test specimen. For calculation of the loss of cross-sectional area, internal imperfections are estimated from the macro test specimen.
- 5 For the calculation of the loss of cross-sectional area, all relevant surface imperfections have to be included. Where lack of root fusion is evident, the inspector is required to assess the approximate depth of the imperfection. The macro test specimen from the welding procedure qualification may need examination for this purpose.
- 6 The cumulative length of intermittent undersize fillet welds shall not exceed 10% of the length of the weld.



(a) Butt weld

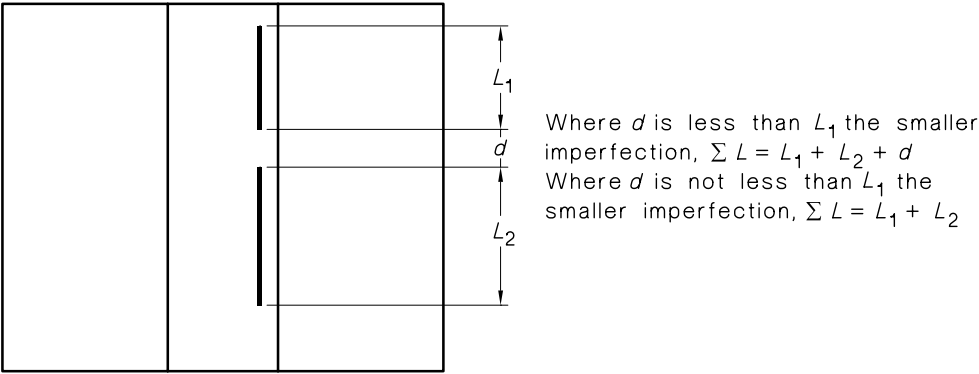


(b) Fillet weld

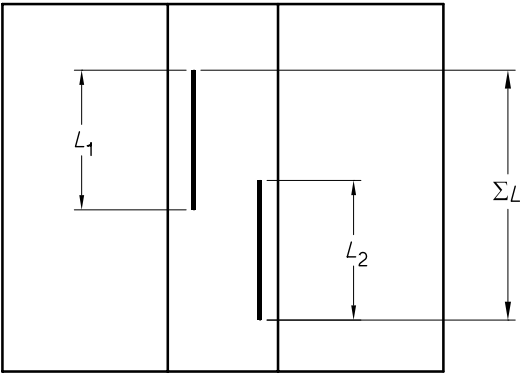
LEGEND:

- L = length or maximum dimensions of an individual imperfection measured parallel to axis of weld
 ΣL = sum of lengths of imperfections in stated weld length
 h = height (depth) of imperfection
 t = thickness of parent metal (thinner)
 d = size of pore
 S = size of fillet weld (see Clause 3.3.1)

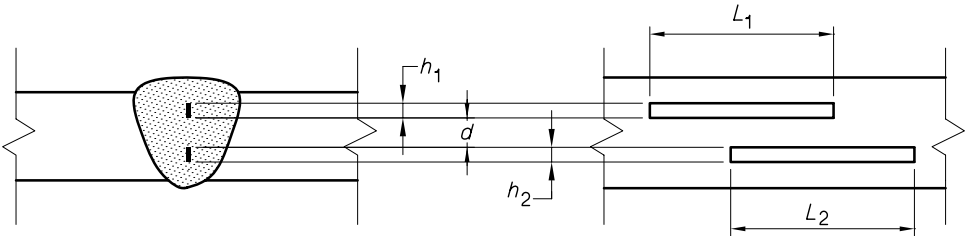
FIGURE 6.2.2 DIMENSIONS REFERRED TO IN TABLE 6.2.2



(a) Aligned imperfections



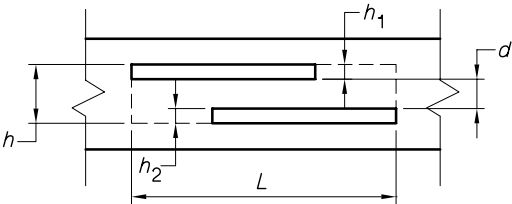
(b) Overlapping imperfections



(i) Cross-section

NOTE: Treat as separate defects.

(ii) Longitudinal section, where $d > 5\text{mm}$



NOTE: Treat as a single defect with dimensions h and L as shown.

(iii) Longitudinal section, where $d \leq 5\text{mm}$

(c) Overlapping vertical displacement

FIGURE 6.2.3 ASSESSMENT OF ADJACENT IMPERFECTIONS

6.3 RADIOGRAPHY

6.3.1 Method

When required, radiography shall be carried out in accordance with AS 2177.1, using the following test methods as designated by AS 2177.1, for which 'z' is 'S', 'DWS' or 'DWD' as appropriate:

- (a) For material thicknesses of not more than 12 mm, XR2/z; except that GR1/z or GR2/z may be used, provided that this is agreed with the principal.
- (b) For material thicknesses of more than 12 mm, XR2/z, GR1/z or GR2/z.

Where materials of different thicknesses are examined, the technique shall be selected according to the thinner plate.

6.3.2 IQI sensitivity

IQI sensitivity for each technique shall comply with Table 6.3.2. The IQI sensitivity shall be measured through the weld using wire type IQI in accordance with AS 2177.2. At least one IQI should be used with each radiograph.

TABLE 6.3.2
SMALLEST DISCERNIBLE WIRE

Method (see Note 1)	Wire number (see AS 2177.2)							
	Weld metal thickness, mm							
	≤6	> 6 ≤10	>10 ≤12	>12 ≤18	>18 ≤25	>25 ≤35	>35 ≤50	> 50
XR2/z	13	12	11	10	9	8	7	See Note 2
GR1/z or GR2/z	12	11	11	10	9	8	7	See Note 2

NOTES:

- 1 As designated by AS 2177.1, for which 'z' is 'S', 'DWS' OR 'DWD' as appropriate.
- 2 For thicknesses of more than 50 mm, an IQI sensitivity of 2.0% is required.

6.3.3 Acceptance limits

The maximum permissible levels of imperfections shall be as given in Table 6.2.1. Where imperfections are detected in excess of the limits in Table 6.2.1, the unacceptable areas shall be repaired and re-radiographed in accordance with this Clause, or by mutual agreement be examined using ultrasonics in accordance with Clause 6.4, in which case, the results of such ultrasonic examination shall be taken as the basis for acceptance. Alternatively, the weld may be considered to be defective and dealt with in accordance with Clause 6.7.

NOTE: Where non-complying welds are detected during a spot examination, two additional spots, each of the same length as the original spot, should be examined. They should comply with the following requirements, as appropriate:

- (a) Where the two additional spots pass, only the original spot should be repaired and re-radiographed.
- (b) Where either of the two additional spots fail, the entire weld should be radiographed or replaced.

6.4 ULTRASONIC EXAMINATION

6.4.1 Method

One of the following shall be carried out:

- (a) An ultrasonic examination complying with AS 2207.

Shear probes shall have a dominant frequency in the range 2.0 MHz to 2.5 MHz, and an essentially square or circular transducer in the size range 15 mm to 22 mm. For plate thicknesses of less than 15 mm, the transducer size may be reduced to 8 mm and frequencies increased to 5 MHz. Compression probes shall have a dominant frequency in the range 4 MHz to 5 MHz, and an essentially square or circular transducer in the size range 10 mm to 20 mm.

Variations to the equipment requirements may be used upon agreement with the principal. Such variations include transducer sizes and frequencies.
- (b) An alternative method of test that is acceptable to the principal (see Clause 1.3).

6.4.2 Evaluation

For welds on material with a thickness of not more than 50 mm, evaluation shall be carried out at Level 2, in accordance with AS 2207. For welds on material with a thicknesses of more than 50 mm, evaluation shall be carried out at Level 3. Planar imperfections should be evaluated at an incident angle of less than 10 degrees. Where this is not possible, additional gain shall be added in accordance with Table 6.4.2. For the purposes of Table 6.4.2, planar imperfections shall be considered to lie along the welding preparation faces. The probe angle shall be the actual measured angle, not the nominal angle.

TABLE 6.4.2
ADDITIONAL GAIN FOR EVALUATION
OF PLANAR IMPERFECTIONS

Angle of incidence, degrees	Additional gain, dB
≤10	0
>10 ≤15	6
>15 ≤20	12
> 20	See note

NOTE: Angles of incidence of more than 20 degrees shall not to be used.

6.4.3 Acceptance limits

The maximum permissible level of imperfections shall be as given in Table 6.2.1. Where welds fail to meet the criteria of Table 6.2.1, they shall be either repaired and retested, or considered defective and dealt with in accordance with Clause 6.7.

6.5 MAGNETIC PARTICLE EXAMINATION

Where required, magnetic particle examination shall be carried out in accordance with one of the techniques specified in AS 1171.

The maximum permissible levels of imperfections shall be as given in Table 6.2.2.

6.6 LIQUID PENETRANT EXAMINATION

Where required, penetrant examination shall be carried out in accordance with one of the techniques specified in AS 2062.

The maximum permissible levels of imperfections shall be as given in Table 6.2.2.

6.7 WELD DEFECTS

Weld imperfections that exceed the levels given in Tables 6.2.1 and 6.2.2 shall be classed as defects. However, where it can be demonstrated by the use of fracture mechanics or other suitable methods of assessment that the defects will not be injurious to the performance of the structure, such defects need not be repaired or rewelded; provided that, for any such defect, such methods of assessment are acceptable to both the principal and the fabricator. (See Paragraph B5, Appendix B).

Repaired welds shall be reinspected to the same level as that originally specified.

NOTES:

- 1 WTIA Technical Note 10 gives guidance on the use of fracture mechanics analyses in the assessment of the effects of imperfections.
- 2 Imperfections of plate origin are not normally considered to be a cause for rejection of the weld.

6.8 REPORTING

Test reports for non-destructive examination shall comply with the appropriate Australian Standard and shall include the following additional information:

- (a) Identity of testing personnel.
- (b) A statement whether the weld complies with the requirements of this Section. If the weld does not comply, the location and extent of the defects shall be given.
- (c) Results of re-tests.

All reports, including calculations for fracture mechanics assessments of defective welds, shall be retained and made available for information purposes.

SECTION 7 INSPECTION

7.1 GENERAL

This Section applies only to inspection by the inspecting authority or the principal.

The inspector shall have access at all reasonable times to all relevant phases of the work, and shall be given reasonable notice in advance of the start of welding operations.

The inspector shall have the opportunity to witness all testing of welding procedures and welder qualification tests that are required.

7.2 QUALIFICATIONS OF INSPECTORS

The inspector shall have had suitable training and experience in the fabrication and inspection of welded structures. The holding of either of the following shall be accepted as evidence of these qualifications:

- (a) A Welding Technology Institute of Australia Certificate, either as a Welding Inspector or as a Structural Welding Supervisor.
- (b) A Certification Board of Inspection Personnel (CBIP) New Zealand Welding Inspector Certificate.

NOTES:

- 1 The inspector should have at least the qualifications required for a welding supervisor.
- 2 The inspector should not be involved in the supervision of the welded fabrication.

7.3 VISUAL INSPECTION OF WORK

Prior to and during welding, the inspector shall inspect the set-up of the work and ensure that—

- (a) welds are in accordance with the drawings;
- (b) the welding is carried out on the specified material with suitable equipment;
- (c) correct procedures are maintained; and
- (d) the work is performed in accordance with the requirements of this Standard.

The inspector shall make a careful and systematic check to ensure that no welds called for in the drawings are omitted. All welds shall receive a full visual inspection in accordance with Section 6.

7.4 NON-DESTRUCTIVE EXAMINATION OTHER THAN VISUAL

Personnel responsible for the interpretation, evaluation and reporting of non-destructive examination shall have qualifications and experience acceptable to the inspecting authority and the principal. Personnel holding appropriate certification from the Australian Institute of Non-destructive Testing or the CBIP-NZ shall be deemed to be qualified.

Where a non-destructive examination is specified, the drawings or other documents shall clearly state the methods to be used and the extent of testing to be carried out (see also Clause 3.1.2).

NOTE: Guidance as to the extent of non-destructive examination is given in Table 7.4.

TABLE 7.4
SUGGESTED EXTENT OF NON-DESTRUCTIVE EXAMINATION

Weld category	Extent of NDE (see Notes 1 and 2), %			
	Visual means (see Notes 3 and 4)		Other means	
	Visual scanning (see Clause 7.3)	Visual examination in accordance with Table 6.2.2	Magnetic particle or liquid penetrant (see Notes 5 and 6)	Radiography or ultrasonics to Table 6.2.1 (see Note 7)
GP	100	5 to 25	0 to 2	Nil
SP	100	10 to 50	0 to 10	0 to 10

NOTES:

- 1 This Table is intended to apply to routine testing of welds, to determine the level of weld quality. Where routine testing reveals imperfections requiring further consideration in accordance with Section 6, Clause 6.7 applies.
- 2 Where less than 100% of NDE is required, a program for testing should be drawn up by the principal and approved by the design engineer. This program should involve full testing of the first major component or 5% of welds, as appropriate, in order to detect and be able to correct the cause of any major defects on commencement of welding. It should then involve a progressive reduction in frequency of testing, on the basis of achieving compliance with each test. If testing indicates non-compliance, the next 5% of welds or the next major component, as appropriate, should be tested consecutively.
- 3 Visual means of NDE implies the two following levels of examination:
 - (a) Visual scanning, to determine that all welds called for in the drawings are included and to detect gross defects.
 - (b) Visual examination, to examine a percentage of the welds, to determine whether the required weld quality (see Table 6.2.2) has been achieved.
- 4 Welds complying with NZS 3404.1 that are category SP or constitute part of a seismic-resisting or associated structural system or are subject to fatigue loading should be subject to a 100% visual examination.
- 5 The use of magnetic particle or liquid penetrant is unusual except for supplementary inspection after visual inspection for the types of structures and applications for which this Standard is intended, and their use is usually restricted to repairs (see Clause 6.2.1).
- 6 Liquid penetrant examination may be used for the inspection of ferromagnetic materials, as an alternative to magnetic particle examination; however, where convenient, magnetic particle examination is preferred.
- 7 For plates with a thickness of not less than 20 mm, a portion of each multipass butt weld should be examined ultrasonically, to determine whether there are any transverse cracks within the weld metal.

APPENDIX A

REFERENCED DOCUMENTS

(Normative)

AS	
1101	Graphical symbols for general engineering
1101.3	Part 3: Welding and non-destructive examination
1163	Structural steel hollow sections
1171	Non-destructive testing—Magnetic particle testing of ferromagnetic products, components and structures
1397	Steel sheet and strip—Hot-dipped zinc-coated or aluminium/zinc-coated
1448	Carbon steels and carbon-manganese steels—Forgings (ruling section 300 mm maximum)
1450	Steel tubes for mechanical purposes
1470	Health and safety at work—Principles and practices
1548	Steel plates for pressure equipment
1674	Safety in welding and allied processes
1674.1	Part 1: Fire precautions
1674.2	Part 2: Electrical
1796	Certification of welders and welding supervisors
1817	Metallic materials—Vickers hardness test
1858	Electrodes and fluxes for submerged-arc welding
1858.1	Part 1: Carbon steels and carbon-manganese steels
1858.2	Part 2: Low and intermediate alloy steels
1966	Electric arc welding power sources
1966.1	Part 1: Transformer type
1966.2	Part 2: Rotary type
1988	Welding of steel castings
2062	Non-destructive testing—Penetrant testing of products and components
2074	Steel castings
2177	Non-destructive testing—Radiography of welded butt joints in metal
2177.1	Part 1: Methods of test
2177	Radiography of welded butt joints in metal
2177.2	Part 2: Image quality indicators (IQI) and recommendations for their use
2203	Cored electrodes for arc-welding
2203.1	Part 1: Ferritic steel electrodes
2205	Methods for destructive testing of welds in metal
2205.2.1	Method 2.1: Transverse butt tensile test
2205.3.1	Method 3.1: Bend tests — Transverse guided bend test
2205.5.1	Method 5.1: Macro metallographic test for cross-section examination
2205.6.1	Method 6.1: Hardness tests — Weld joint hardness test
2205.7.1	Method 7.1: Charpy V-notch impact fracture toughness tests
2207	Non-destructive testing—Ultrasonic testing of fusion welded joints in carbon and low alloy steel

AS	
2214	Certification of welding supervisors—Structural steel welding
2799	Resistance welding equipment—Single-phase a.c. transformer type
2812	Welding, brazing and cutting of metals—Glossary of terms
2865	Safe working in a confined space
2980	Qualification of arc-welders for welding of steels
3545	Welding positions
3990	Mechanical equipment—Steelwork
4037	Pressure equipment—Examination and testing
4100	Steel structures
4458	Pressure equipment—Manufacture
AS/NZS	
1167	Welding and brazing—Filler metals
1167.2	Part 2: Filler metal for welding
1336	Recommended practices for occupational eye protection
1337	Eye protectors for industrial applications
1338	Filters for eye protectors
1338.1	Part 1: Filters for protection against radiation generated in welding and allied operations
1553	Covered electrodes for welding
1553.1	Part 1: Low carbon steel electrodes for manual metal-arc welding of carbon steels and carbon-manganese steels
1553.2	Part 2: Low and intermediate alloy steel electrodes for manual metal-arc welding of carbon steels and low and intermediate alloy steels
1554	Structural steel welding
1554.4	Part 4: Welding of high strength quenched and tempered steels
1554.5	Part 5: Welding of steel structures subject to high levels of fatigue loading
1594	Hot-rolled steel flat products
1595	Cold-rolled, unalloyed, steel sheet and strip
1995	Welding cables
2717	Welding—Electrodes—Gas metal arc
2717.1	Part 1: Ferritic steel electrodes
3678	Structural steel—Hot-rolled plates, floorplates and slabs
3679	Structural steel
3679.1	Part 1: Hot-rolled bars and sections
3679.2	Part 2: Welded I sections
3992	Pressure equipment—Welding and brazing qualification
4600	Cold-formed steel structures
NZS	
3404	Steel structures standard
3404.1	Part 1: Steel structures standard
3415	Hot rolled products of non-alloy structural steels—Technical delivery conditions
4711	Qualification tests for metal-arc welders

AWS	
C1.1	Recommended practices for resistance welding
C1.3	Recommended practices for resistance welding coated low carbon steels
IEC	
60974	Arc welding equipment
60974-1	Part 1: Welding power sources
ISO	
9606	Approval testing of welders—Fusion welding
9606-1	Part 1: Steels
HERA	(New Zealand Heavy Engineering Research Association)
Report R7.42	Avoiding hazards with safe work practices
BS	
7910	Guide on methods for assessing the acceptability of flaws in fusion welded structures
WTIA	
Technical Note 1	—Weldability of steels
Technical Note 3	—Care and conditioning of arc welding consumables
Technical Note 5	—Flame cutting of steels
Technical Note 7	—Health and safety in welding
Technical Note 10	—Fracture mechanics
Technical Note 11	—Commentary on the structural steel welding Standard AS/NZS 1554

APPENDIX B

BRITTLE FRACTURE

(Normative)

B1 METHODS

The steel grade shall be selected by either the notch-ductile range method as specified in Paragraph B2 or using a fracture assessment as specified in Paragraph B5.

B2 NOTCH-DUCTILE RANGE METHOD

The steel grade shall be selected to operate in its notch-ductile temperature range.

The design service temperature for the steel shall be determined in accordance with Paragraph B3. The appropriate steel type, suitable for the design service temperature and material thickness, shall be selected in accordance with Paragraphs B4.1, B4.2 and B4.3.

B3 DESIGN SERVICE TEMPERATURE

B3.1 General

The design service temperature shall be the estimated lowest metal temperature to be encountered in service or during erection or testing and taken as the basic design temperature as defined in Paragraph B3.2, except as modified in Paragraph B3.3.

B3.2 Basic design temperature

Lowest one-day mean ambient temperature (LODMAT) isotherms for Australia and New Zealand are given in Figures B1 and B2 respectively. The basic design temperature shall be the LODMAT temperature, except that—

- (a) structures that may be subjected to especially-low local ambient temperatures, such as exposed bridges over inland rivers, shall have a basic design service temperature of 5°C cooler than the LODMAT temperature; and
- (b) critical structures, located where the Bureau of Meteorology records indicate the occurrence of abnormally-low local ambient temperatures for a significant time to cause the temperature of the critical structure to be lowered below the LODMAT temperature, shall have a basic design service temperature equal to such a lowered temperature of the critical structure.

NOTE: In special cases, metal temperatures cooler than the LODMAT may occur where there is minimum insulation, minimum heat capacity, minimum radiation shielding or abnormally low local temperatures (such as snow, ice and frost conditions).

B3.3 Modifications to the basic design temperature

The design service temperature shall be the cooler of the following:

- (a) For structures that are subject to artificial cooling, such as structures for refrigerated buildings, the cooler of the basic design temperature and the minimum expected metal temperature for the part concerned.
- (b) Where Item (a) above does not apply, the basic design temperature.

B4 MATERIAL SELECTION

B4.1 Selection of steel type

The steel type for the material thickness shall be selected from Table B1, so that the permissible service temperature listed in Table B1 is less than the design service temperature, determined in accordance with Paragraph B3. The permissible service temperatures listed in Table B1 shall be subject to the limitations and modifications specified in Paragraphs B4.2 and B4.3 respectively.

B4.2 Limitations

Table B1 shall only be used without modification for members and components that comply with the fabrication and erection provisions of AS 4100 and with the provisions of this Standard.

Table B1 may be used without modification for welded members and connection components that are not subjected to more than 1.0% outer bend fibre strain during fabrication. Members and components subjected to greater outer bend fibre strains shall be assessed using the provisions of Paragraph B4.3.

B4.3 Modification for certain applications

B4.3.1 *Steel subject to strain between 1.0% and 10.0%*

Where a member or component is subjected to an outer bend fibre strain during fabrication of between 1% and 10%, the permissible service temperatures for each steel type shall be increased by at least 20°C above the value given in Table B1.

NOTE: Local strain due to weld distortion should be disregarded.

B4.3.2 *Steel subject to a strain of not less than 10%*

Where a member or component is subjected to an outer bend fibre strain during fabrication of not less than 10%, the permissible service temperatures for each steel type shall be increased above the value given in Table B1 by 20°C plus 1°C for every 1.0% increase in outer bend fibre strain above 10%.

NOTE: Local strain due to weld distortion should be disregarded.

B4.3.3 *Post-weld heat-treated members*

Where a member or component has been welded or strained and has been subjected to a post-weld heat-treatment temperature of more than 500°C, but not more than 620°C, the permissible service temperature given in Table B1 shall not be modified.

NOTE: Guidance on appropriate post weld heat treatment may be found in AS 4458.

B4.3.4 *Non-complying conditions*

Steels, for which the permissible service temperature (as modified where applicable) is not known or is warmer than the design service temperature specified by the designer, shall not be used, unless compliance with each of the following requirements is demonstrated:

- (a) A mock-up of the joint or member shall be fabricated from the desired grade of steel, having similar dimensions and strains of not less than that of the service component.
- (b) Three Charpy test specimens shall be taken from the area of maximum strain and tested at the design service temperature.
- (c) The impact properties as determined from these tests shall be not less than the minimum specified impact properties for the steel grade under test.
- (d) Where the Standard to which the steel complies does not specify minimum impact properties, the average absorbed energy for three 10 mm × 10 mm test specimens shall be not less than 27J, provided none of them is less than 20J.

- (e) Where a plate thickness prevents a 10 mm × 10 mm test piece from being used, the standard test thickness closest to the plate thickness shall be used and the minimum value energy absorption requirements shall be reduced proportionally.

B5 FRACTURE ASSESSMENT

A fracture assessment shall be made, using a fracture mechanics analysis coupled with fracture toughness measurements of the steel selected, weld metal and heat-affected zones and non-destructive examination of the welds and their heat-affected zones.

NOTE: For methods of fracture assessment, see BS 7910 and WTIA Technical Note 10.

TABLE B1
PERMISSIBLE SERVICE TEMPERATURES ACCORDING
TO STEEL TYPE AND THICKNESS

Steel type (see Table 4.6.1(B))	Permissible service temperature, °C					
	Thickness, mm					
	≤6	>6≤12	>12≤20	>20≤32	>32≤70	>70
1	−20	−10	0	0	0	5
2	−30	−20	−10	−10	0	0
3	−40	−30	−20	−15	−15	−10
4	−10	0	0	0	0	5
5	−30	−20	−10	0	0	0
6	−40	−30	−20	−15	−15	−10
7A	−10	0	0	0	0	—
7B	−30	−20	−10	0	0	—
7C	−40	−30	−20	−15	−15	—
8	−40	−30	—	—	—	—

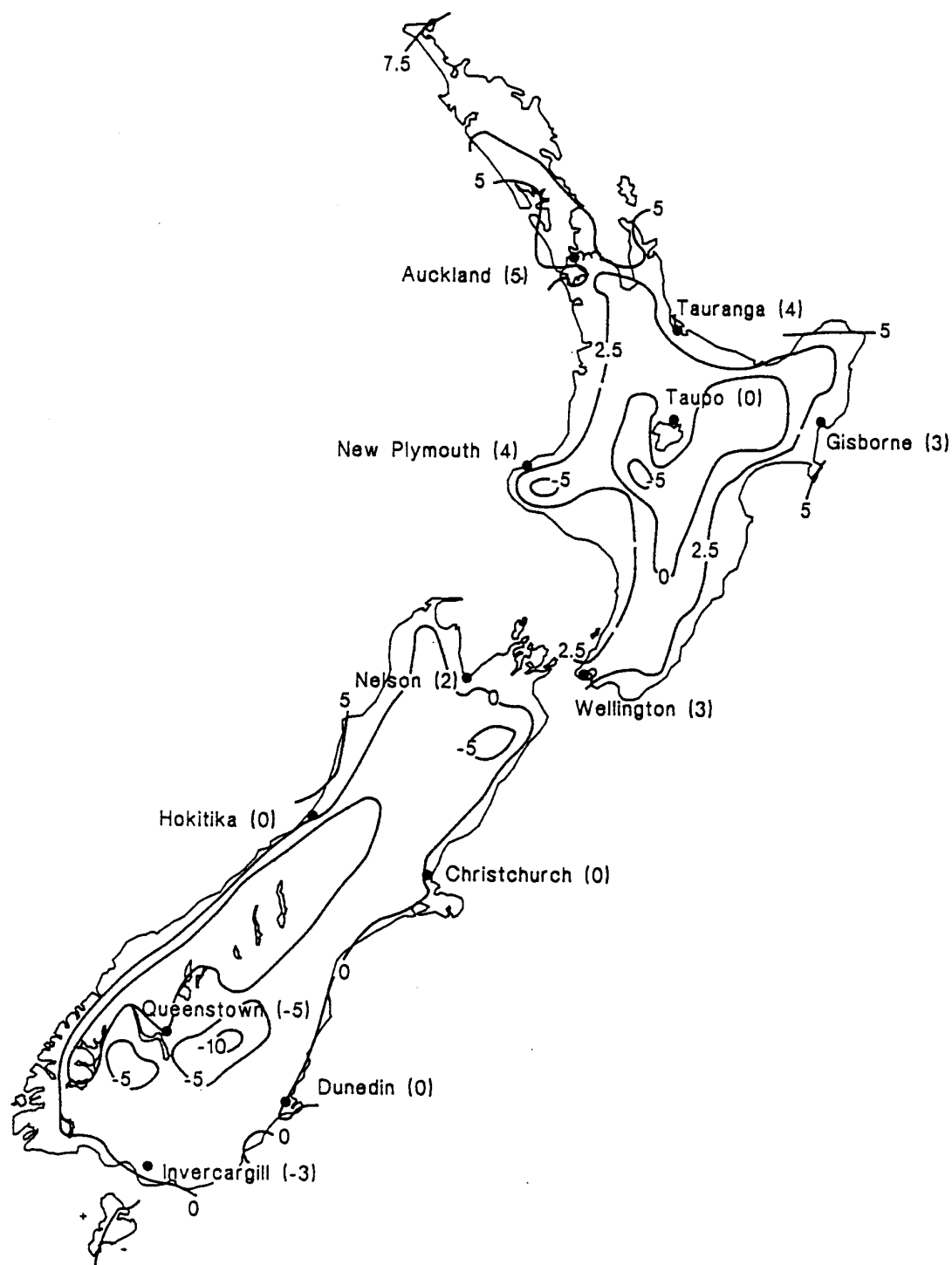
NOTE: This table is based on available statistical data on notch toughness characteristics of steels currently made in Australia or New Zealand. Care should be taken in applying this table to imported steels as verification tests may be required. For a further explanation, see WTIA Technical Note 11.



NOTES:

- 1 The isotherms show the lowest one day mean ambient temperature (LODMAT) in degrees Celsius.
- 2 Based on records during the years 1957 to 1971 as supplied by the Australian Bureau of Meteorology.

FIGURE B1 LODMAT ISOTHERMS FOR AUSTRALIA



NOTES:

- 3 The isotherms show the lowest one day mean ambient temperature (LODMAT) in degrees Celsius.
- 4 Based on records during the years 1930 to 1990 as supplied by the National Institute of Water and Atmosphere Research.
- 5 Where site-specific LODMAT temperatures are available, these should be used in lieu of these temperatures.

FIGURE B2 LODMAT ISOTHERMS FOR NEW ZEALAND

APPENDIX C
TYPICAL FORMS FOR WELDING PROCEDURES
(Informative)

Typical forms for procedure qualification record (PQR) and welding procedure specification (WPS) are given in Tables C1 and C2.

NOTE: These Tables may be copied.

TABLE C1
PROCEDURE QUALIFICATION RECORD

PROCEDURE QUALIFICATION RECORD										
Material spec/grade					To					
Fabricator					PQR no.					
Process					Date qualified					
Welding Standard					Welded by					
Edge preparation					Page					
Weldability group no.					Revision					
Specimen thickness					Date					
Preheat temperature					PWHT					
Inter-run temperature					Hold					
Type and check method					Other					
Run sequence				Joint details						
				Prequal. joint no. To Table Root gap G mm Root face F_r mm Incl. angle θ° Backing						
Specification—Root				Remainder			Flux			
Classification—Root				Remainder						
Shielding gas				Flow rate						
Purge gas				Flow rate						
Weld run details					Welding parameters					
No.	Side	Position	ϕ mm	Tradename	Amperage	Voltage	Current and polarity	Speed mm/min	Heat input kJ/mm	
Technique						Stringer/weave				
Initial cleaning						Electrical stick-out				
Inter-run clean						Backgouge method				
Nozzle size						Backgouge check				
Test results										
Test type	Visual	Macro	Tensile	Bend	Charpy V	Hardness	Other			
Test by										
Report no.										
Result										
Notes/revisions										
Witnessed by					Approved by					

TABLE C2
WELDING PROCEDURE SPECIFICATION

WELDING PROCEDURE SPECIFICATION									
Material specification/grade					to				
Fabricator					WPS no.				
Standard					Date				
Process					PQR no.				
Edge preparation					Page				
Welding direction					Revision		Date		
Range qualified					Positions				
Preheat temperature					PWHT				
Method and check method					Hold				
Inter-run temperature (max.)					Other				
Joint sketch		Run sequence			Joint tolerance				
					Pre-qualified joint no. To Table Root gap G Root fact F_r Included angle θ Backing				
Welding consumables									
Specification—Root		Remainder			Flux				
Classification—Root		Remainder							
Shielding gas		Flowrate							
Purge gas		Flowrate							
Weld run details					Welding parameters				
Pass no.	Side	Position	θ mm	Tradename	Amperage range	Voltage range	Current and polarity	Travel speed mm/min	Heat input kJ/mm
Technique					Stringer/weave				
Single-run or multi-run					Electrical stick-out				
Initial cleaning					Backgouge				
Inter-run clean					Gouge check				
Notes/revisions									
Approved by									

APPENDIX D

MATTERS FOR RESOLUTION

(Normative)

The following matters of a contractual nature shall be resolved:

- (a) Nomination of weld categories and nominal tensile strength of welds (see Clause 3.1.2).
- (b) Increased penetration from fully automatic arc welding processes (see Clauses 3.2.2 and 3.3.2).
- (c) Where seal welds are required (see Clause 3.5).
- (d) Approval of welding procedures (see Clauses 4.1 and 4.2).
- (e) Method of qualification of welding procedure (see Clause 4.2).
- (f) Prequalification of consumables (see Clause 4.6.1).
- (g) Qualification of non-prequalified steel types (see Clause 4.7.1).
- (h) Whether Charpy V-notch impact test is required for heat-affected zone (see Table 4.7.1).
- (i) Hardness of heat-affected zone (see Table 4.7.1 and Clause 4.7.9).
- (j) Preparation of special test piece (see Clause 4.7.2).
- (k) Availability of records, for perusal by inspector (see Clause 4.10).
- (l) Qualifications of welding supervisor (see Clause 4.12.1).
- (m) Qualifications of welders (see Clause 4.12.2).
- (n) Tolerances for butt-welded joints, for electroslog and electrogas (see Clause 5.2.2).
- (o) Welding and cutting under stress (see Clause 5.7.2).
- (p) Peening (see Clause 5.7.3).
- (q) Correction of distortion (see Clause 5.7.4).
- (r) Weld surface quality requirements, to comply with painting specifications (see Clauses 5.11 and 5.12).
- (s) Type and extent of inspection, including requirements for NDE, ultrasonic examination for the detection of transverse cracks in weld metal, and the value of L as the basis for assessment under Tables 6.2.1 and 7.4 (see Clauses 6.3, 6.4, 6.5, 6.6 and 7.4).
- (t) NDE technique and alternatives (see Clauses 6.3.1, 6.4.1, 6.5 and 6.6).
- (u) Correction of faulty (defective) welds and cost of weld repair and associated NDE (see Clauses 6.3.3, 6.4.3 and 6.7).
- (v) Whether a test report is required (see Clause 6.8).
- (w) Qualification of NDE technicians (see Clause 7.4).
- (x) For plates with a thickness of not less than 20 mm, whether a portion of each multipass butt weld should be tested, to determine whether there are any transverse cracks within the weld metal (see Table 7.4).

Where practical, it is recommended that the principal resolve any problems with the fabricator, before work is commenced.

APPENDIX E

WELDED JOINT AND PROCESS IDENTIFICATION

(Normative)

E1 NOTATION FOR JOINT IDENTIFICATION

The notation used for joint identification in the first column of Tables E1 to E4 is the following:

$W-X Y_z$

where

W = joint type identification, as follows:

B = butt joint

C = corner joint

F = fillet joint

H = joint for hollow sections to AS 1163 and AS 1450

T = T joint

X = penetration identification, as follows:

C = complete penetration

P = part (incomplete) penetration

Y = preparation identification, as follows:

1 = square

2 = single-V

3 = double-V

4 = single-bevel

5 = double-bevel

6 = single-U

7 = double-U

8 = single-J

9 = double-J

z = a, b, c or d, to distinguish between diagrams showing variations of the same prequalified joint.

E2 NOTATION FOR DIMENSIONS, POSITIONS AND BACKING MATERIAL

The notation used for dimensions, positions and backing material in Tables E1 to E4 is the following:

D = depth of preparation, in millimetres

DTT = design throat thickness, in millimetres

F = flat position

F_r = width of root face, in millimetres

G	= width of root gap, in millimetres
H	= horizontal position
M	= material of backing as specified
MR	= material of backing as specified, but with backing removed after welding
OH	= overhead position
R	= root radius (the point from which the radius is generated lies on a line projected from the root face), in millimetres
S	= size of weld, in millimetres
S'	= apparent size of weld, in millimetres
t	= plate thickness, in millimetres
V	= vertical position
X	= depth of one preparation in a double-V butt weld, in millimetres
θ	= included angle of preparation, in degrees.

E3 NOTATION FOR PROCESSES

The notation used for welding processes is the following:

EGW	= electrogas welding
ESW	= electroslog welding, including consumable guide
FCAW(C or M)	= flux-cored arc welding with gas shielding, where C indicates shielding with carbon dioxide and M indicates shielding with mixed gases
FCAW(N)	= flux-cored arc welding without gas shielding, where N indicates no gas shielding
GMAW	= gas-shielded metal-arc welding or MIG
GTAW	= gas-shielded tungsten-arc welding or TIG
MMAW	= manual metal-arc welding
SAW	= submerged arc welding

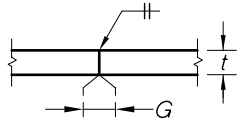
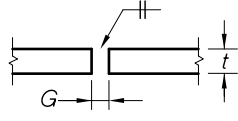
E4 EXAMPLE

Thus, a square corner joint complete penetration butt weld, welded both sides using submerged arc welding, can be described as C-C 1c – SAW.

TABLE E1
PREQUALIFIED COMPLETE PENETRATION BUTT WELD PREPARATIONS

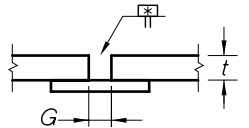
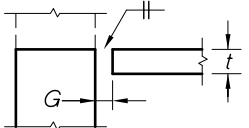
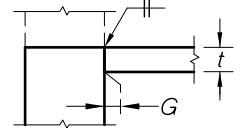
NOTES:

- 1 The notation used is given in Paragraphs E1 to E3.
- 2 For requirements for gouging the roots of the weld, see Clause 4.5.2.
- 3 For dimensional tolerances of weld preparations, see Table 5.2.2.
- 4 Gas metal-arc pulsed-transfer mode may be used for these preparations where average current exceeds 250 A.
- 5 Gas metal-arc welding with globular transfer mode may be used with CO₂ shielding gas.

Joint identification	Joint type	Preparation detail (see Notes 2 and 3)	Manual metal-arc	Submerged arc	Flux-cored arc, self-shielded and gas-shielded	Gas metal-arc, spray transfer (see Notes 4 and 5)	Gas metal-arc, short-circuiting arc transfer or pulsed mode	Electroslag, including consumable guide	Gas-tungsten arc
B-C 1a	Close-joint square butt weld, welded both sides 	t Position G	3 max. All 0	12 max. F 0	6 max. F 0	6 max. F 0			3 max. All 0
B-C 1b	Open-joint square butt weld, welded both sides 	t Position G	6 max. All $t/2$		10 max. All $t/4$		6 max. All $t/2$	20 min. V 25	6 max. All $t/2$

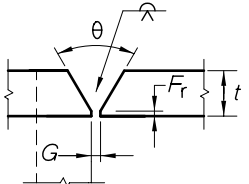
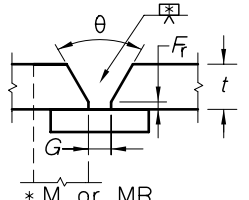
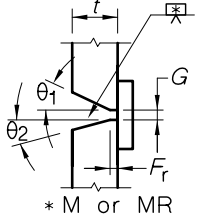
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TABLE E1 (continued)

Joint identification	Joint type	Preparation detail (see Notes 2 and 3)	Manual metal-arc	Submerged arc	Flux-cored arc, self-shielded and gas-shielded	Gas metal-arc, spray transfer (see Notes 4 and 5)	Gas metal-arc, short-circuiting arc transfer or pulsed mode	Electroslag, including consumable guide	Gas-tungsten arc
B-C 1c C-C 1a	Open-joint square butt weld and corner joint, welded one side with backing strip  * M or MR	t Position G	6 max. All t	12 max. F $t/2$	12 max. All t	12 max. F $t/2$	10 max. All $3t/2$	20 min. V 25	
T-C 1a C-C 1b	Open-joint square T-butt weld and corner joint welded both sides 	t Position G	6 max. All $t/2$		10 max. F & H $t/4$		6 max. All 3	20 min. V 25	6 max. All $t/2$
C-C 1c T-C 1b	Close joint square T and corner joint, butt welded both sides 	t Position G	3 All 0	10 max. F 0	6 max. F 0	6 max. F 0			3 max. All 0

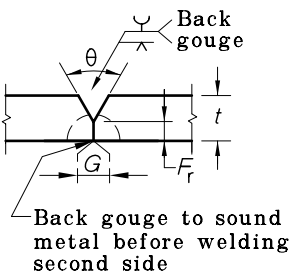
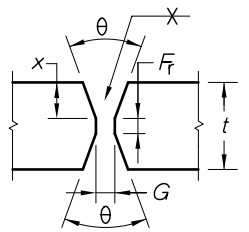
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TABLE E1 (continued)

Joint identification	Joint type	Preparation detail (see Notes 2 and 3)	Manual metal-arc	Submerged arc	Flux-cored arc, self-shielded and gas-shielded	Gas metal-arc, spray transfer (see Notes 4 and 5)	Gas metal-arc, short-circuiting arc transfer or pulsed mode	Electroslag, including consumable guide	Gas-tungsten arc
B-C 2a C-C 2a	Single-V butt weld and corner joint, welded both sides 	t Position G F_r θ	All All 3.5 1.6 60	All F 0 6 60	All See θ 3 3 50 for F, H & OH 60 for V	All F 0 4 50	All See θ 3 0 50 for F, H & OH 60 for V		20 max. All 3 1.5 60
B-C 2b C-C 2b	Single-V butt weld and corner joint, welded one side with backing strip 	t Position G F_r θ	All See θ See θ 0 20 for F & OH: $G = 12$ 30 for F & OH: $G = 9$ 45 for all: $G = 6$	All F See θ 0 30: $G = 6$ 20: $G = 15$	All See θ 6 0 30 for F, H & OH 45 for V	All F 3 1.5 30	All See θ 6 0 30 for F, H & OH 45 for V		
B-C 2c	Single-V butt weld, welded one side with backing strip 	t Position G F_r θ_1 θ_2	20 max. H 5-8 0 45 15		20 max. H 5-8 0 45 15	20 max. H 5-8 0 45 15	20 max. H 5-8 0 45 15		

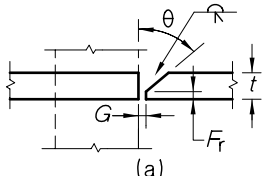
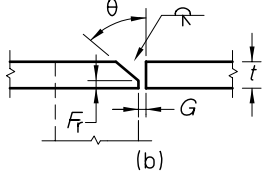
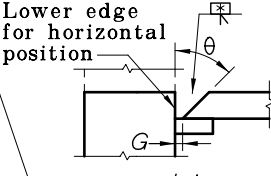
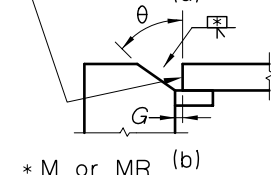
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TABLE E1 (continued)

Joint identification	Joint type	Preparation detail (see Notes 2 and 3)	Manual metal-arc	Submerged arc	Flux-cored arc, self-shielded and gas-shielded	Gas metal-arc, spray transfer (see Notes 4 and 5)	Gas metal-arc, short-circuiting arc transfer or pulsed mode	Electroslag, including consumable guide	Gas-tungsten arc
B-C 2d	Single-V butt weld, welded both sides 	t Position G F_r θ	32 max. All 0 $t/3$ max. 60	32 max. F 0 $\geq 6 \leq t/3$ 60	32 max. All 0 $t/3$ max. 60	32 max. F 0 $t/3$ max. 60	32 max. All 0 $t/3$ max. 60		20 max. All 0 $t/3$ max. 60
B-C 3	Double-V butt weld NOTE: Depth X may range from $\frac{2}{3}(t - F_r)$ to $\frac{1}{3}(t - F_r)$ 	t Position G F_r θ	All All 3.5 1.5 60	All F 0 6 60	All See θ 3 3 50 for F, H & OH 60 for V	All F 0 3 50	All See θ 4 0 50 for F, H & OH 60 for V		20 max. All 3 1.5 60

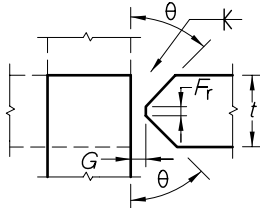
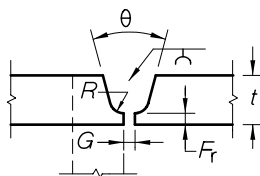
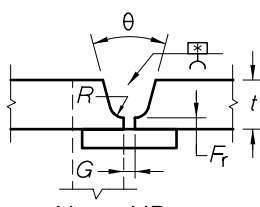
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TABLE E1 (continued)

Joint identification	Joint type	Preparation detail (see Notes 2 and 3)	Manual metal-arc	Submerged arc	Flux-cored arc, self-shielded and gas-shielded	Gas metal-arc, spray transfer (see Notes 4 and 5)	Gas metal-arc, short-circuiting arc transfer or pulsed mode	Electroslag, including consumable guide	Gas-tungsten arc
B-C 4a T-C 4a C-C 4a	Single bevel butt weld, T and corner joint, welded both sides  	t Position G F_r θ	All All 3.5 1.5 45	All F & H 0 6 60	All See θ 3 1.5 50 for F, H & OH 60 for V	All F & H 1.5 4 50	All See θ 4 0 50 for F, H & OH 60 for V		20 max. All 3 1.5 60
B-C 4b T-C 4b C-C 4b	Single bevel butt weld, T and corner joint, welded one side with backing strip   * M or MR (b)	t Position G F_r θ	All See θ See θ 0 20 for F: $G = 11$ (B-C 4b only) 30 for F: $G = 9$ mm 45 for all: $G = 6$ mm	All F & H See θ 0 30 for F: $G = 10$ 45 for H: $G = 6$	All See θ See θ 0 30 for F: $G = 10$ 45 for V, H & OH: $G = 6$	All F & H 5 0 30 for F & H	All See θ See θ 0 30 for F: $G = 10$ 45 for V, H & OH: $G = 6$		

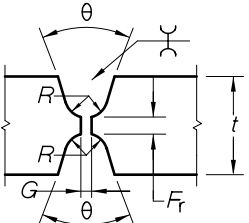
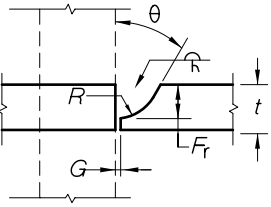
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TABLE E1 (continued)

Joint identification	Joint type	Preparation detail (see Notes 2 and 3)	Manual metal-arc	Submerged arc	Flux-cored arc, self-shielded and gas-shielded	Gas metal-arc, spray transfer (see Notes 4 and 5)	Gas metal-arc, short-circuiting arc transfer or pulsed mode	Electroslag, including consumable guide	Gas-tungsten arc
B-C 5 T-C 5 C-C 5	Double-bevel butt weld, T and corner joint 	t Position G F_r θ	All All 3.5 1.5 45	All F 0 6 60	All See θ 1.5 1.5 50 for F, H & OH 60 for V	All F 0 3 50	All See θ 4 0 50 for F, H & OH 60 for V		20 max. All 3 1.5 60
B-C 6a C-C 6a	Single-U butt weld and corner joint, welded both sides 	t Position G F_r R θ	All See θ 1.5 1.5 6 30 for F & OH 45 for all	All F 0 6 8 20	All All 1.5 1.5 8 30	All Flat 0 3 8 30	All All 4 0 8 30		All All 1.5 1.5 6 45
B-C 6b C-C 6b	Single-U butt weld and corner joint, welded one side with backing strip 	t Position G F_r R θ	All See θ 7 1.5 6 30 for F & OH 45 for all	All F 2 1.5 8 20	All All 6 0 8 30	All F 3 1.5 8 30	All All 6 0 8 30		

(continued)

TABLE E1 (continued)

Joint identification	Joint type	Preparation detail (see Notes 2 and 3)	Manual metal-arc	Submerged arc	Flux-cored arc, self-shielded and gas-shielded	Gas metal-arc, spray transfer (see Notes 4 and 5)	Gas metal-arc, short-circuiting arc transfer or pulsed mode	Electroslag, including consumable guide	Gas-tungsten arc
B-C 7	Double-U butt weld, welded both sides 	<i>t</i> Position <i>G</i> <i>F_r</i> <i>R</i> <i>θ</i>	All See <i>θ</i> 1.5 1.5 6 30 for F & OH 45 for all	All F 0 6 8 20	All All 1.5 3 8 30	All F 0 3 8 30	All All 4 0 8 30		All All 1.5 1.5 6 45
B-C 8a T-C 8a C-C 8a	Singe-J butt weld, T and corner joint, welded both sides 	<i>t</i> Position <i>G</i> <i>F_r</i> <i>R</i> <i>θ</i>	All See <i>θ</i> 1.5 1.5 6 30 for F & OH 45 for all	All F: MMAW or SAW weld on second side 0 6 See <i>θ</i> 30: <i>R</i> = 12 45: <i>R</i> = 6	All All 3 3 See <i>θ</i> 30: <i>R</i> = 10 45: <i>R</i> = 6	All F & H 1.5 4 8 45	All All 4 0 8 45		All All 1.5 1.5 6 45

(continued)

TABLE E1 (continued)

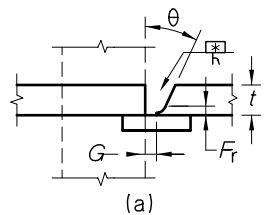
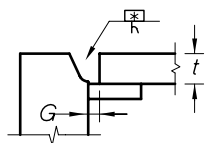
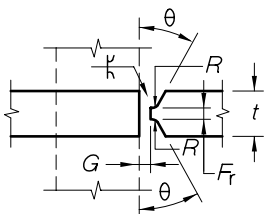
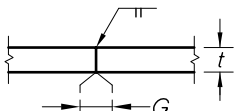
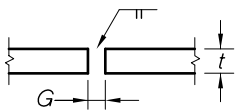
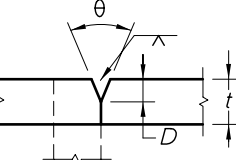
Joint identification	Joint type	Preparation detail (see Notes 2 and 3)	Manual metal-arc	Submerged arc	Flux-cored arc, self-shielded and gas-shielded	Gas metal-arc, spray transfer (see Notes 4 and 5)	Gas metal-arc, short-circuiting arc transfer or pulsed mode	Electroslag, including consumable guide	Gas-tungsten arc
B-C 8b T-C 8b C-C 8b	Single-J butt weld, T and corner joint, welded one side with backing strip  (a)  * M or MR (b)	t Position G F_r R θ	All See θ 7 1.5 6 30 for F & OH 45 for all	All F 6 2 6 30	All F 6 0 6 45	All F 3 3 6 45	20 max. All 6 0 6 45		
B-C 9 T-C 9 C-C 9	Double-J butt weld, T and corner joint 	t Position G F_r R θ	All See θ 1.5 1.5 6 30 for F & OH 45 for all	All F: MMAW or SAW weld on second side 0 6 See θ 30: $R = 12$ 45: $R = 6$	All All 3 3 6 45	All F & H 0 4 8 45	All All 4 0 8 45		All All 1.5 1.5 6 45

TABLE E2
PREQUALIFIED INCOMPLETE PENETRATION BUTT WELD PREPARATIONS

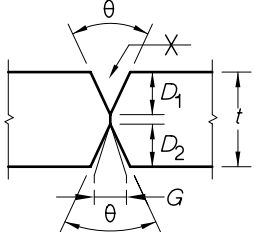
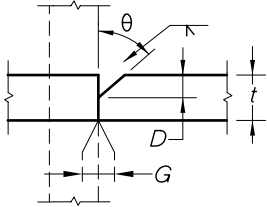
NOTES:

- 1 The notation used is given in Paragraphs E1 to E3.
- 2 For increased *DTT* for fully automatic process, see Clause 3.2.2.
- 3 For dimensional tolerances of weld preparations, see Table 5.2.2.
- 4 Gas metal-arc pulsed-transfer mode may be used for these preparations where average current exceeds 250 A.
- 5 Gas metal-arc welding with globular transfer mode may be used with CO₂ shielding gas.

Joint identification	Joint type	Preparation detail (see Notes 2 and 3)	Manual metal-arc	Submerged arc	Flux-cored arc, self-shielded and gas-shielded	Gas metal-arc, spray transfer (see Notes 4 and 5)	Gas metal-arc, short-circuiting arc transfer or pulsed mode	Gas-tungsten arc
B-P 1a	Close-joint square butt weld, welded one side 	<i>T</i> Position <i>G</i> <i>DTT</i>	3 max. All 0 $0.75t$	6 max. F 0 $0.75t$	4 max. F & H 0 $0.75t$	3 max. F & H 0 $0.75t$	3 max. All 0 $t/2$	3 max. All 0 $0.75t$
B-P 1b	Open-joint square butt weld, welded one side 	<i>T</i> Position <i>G</i> <i>DTT</i>	6 max. All $t/2$ $0.75t$		8 max. F & H $t/4$ $0.75t$	6 max. F & H $t/4$ $0.75t$	6 max. All $t/2$ $t/2$	6 max. All $t/2$ $t/2$
B-P 2a C-P 2	Close joint single-V butt weld and corner joint, welded one side 	<i>T</i> Position <i>G</i> <i>DTT</i> θ	All All 0 See θ 45: $DTT = D - 3$ 60: $DTT = D$	All F 0 <i>D</i> 60	All See θ 0 $D - 3$ 50 for F, H & OH 60 for V	All F 0 $D - 3$ 50	All See θ 0 $D - 3$ 50 for F, H & OH 60 for V	20 max. All 0 <i>D</i> 60

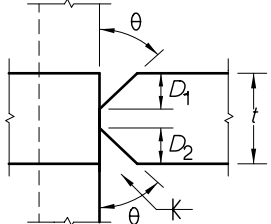
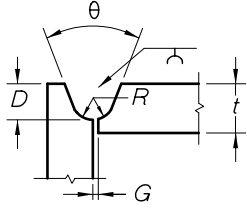
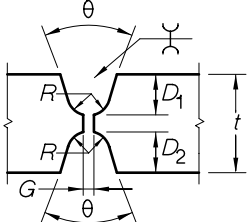
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TABLE E2 (continued)

Joint identification	Joint type	Preparation detail (see Notes 2 and 3)	Manual metal-arc	Submerged arc	Flux-cored arc, self-shielded and gas-shielded	Gas metal-arc, spray transfer (see Notes 4 and 5)	Gas metal-arc, short-circuiting arc transfer or pulsed mode	Gas-tungsten arc
B-P 3	Close joint double-V butt weld, welded both sides 	t Position G DTT θ	All All 0 See θ 45: $(D_1 + D_2) - 6$ 60: $D_1 + D_2$	All F 0 $D_1 + D_2$ 60	All See θ 0 $(D_1 + D_2) - 6$ 50 for F, H & OH 60 for V	All F 0 $(D_1 + D_2) - 6$ 50	All See θ 0 $(D_1 + D_2) - 6$ 50 for F, H & OH 60 for V	20 max. All 0 $D_1 + D_2$ 70
B-P 4a C-P 4 T-P 4	Close joint single-bevel butt weld, T and corner joint, welded one side 	t Position G DTT θ	All All 0 $D - 3$ 45	All F & H 0 D 60	All All 0 $D - 3$ 45	All F & H 0 $D - 3$ 45	All All 0 $D - 3$ 45	20 max. All 0 D 60

(continued)

TABLE E2 (continued)

Joint identification	Joint type	Preparation detail (see Notes 2 and 3)	Manual metal-arc	Submerged arc	Flux-cored arc, self-shielded and gas-shielded	Gas metal-arc, spray transfer (see Notes 4 and 5)	Gas metal-arc, short-circuiting arc transfer or pulsed mode	Gas-tungsten arc
B-P 5 T-P 5 C-P 5	Close joint double-bevel butt weld, T and corner joint 	t Position G DTT θ	All All 0 $(D_1 + D_2) - 6$ 45	All F 0 $D_1 + D_2$ 60	All All 0 $(D_1 + D_2) - 6$ 45	All F & H 0 $(D_1 + D_2) - 6$ 45	All All 0 $(D_1 + D_2) - 6$ 45	20 max. All 0 $D_1 + D_2$ 60
B-P 6 C-P 6	Single-U butt weld and corner joint, welded one side 	t Position G R DTT θ	All All 1.5 6 D 45	All F 0 6 D 20	All All 0 6 D 30	All F & H 0 6 D 30	All All 0 6 D 30	20 max. All 0 6 D 45
B-P 7	Double-U butt weld, welded both sides 	t Position G R DTT θ	All All 1.5 6 $D_1 + D_2$ 45	All F 0 6 $D_1 + D_2$ 20	All All 0 6 $D_1 + D_2$ 30	All F & H 0 6 $D_1 + D_2$ 30	All All 0 6 $D_1 + D_2$ 30	All All 0 6 $D_1 + D_2$ 45

(continued)

TABLE E2 (continued)

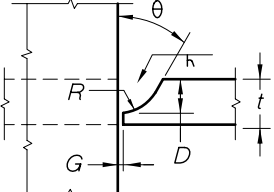
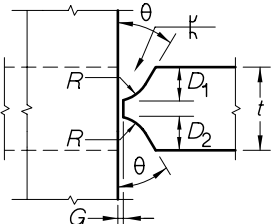
Joint identification	Joint type	Preparation detail (see Notes 2 and 3)	Manual metal-arc	Submerged arc	Flux-cored arc, self-shielded and gas-shielded	Gas metal-arc, spray transfer (see Notes 4 and 5)	Gas metal-arc, short-circuiting arc transfer or pulsed mode	Gas-tungsten arc
B-P 8 T-P 8 C-P 8	Single-J butt weld, T and C joint, welded one side 	t Position G R DTT θ	All All 1.5 10 D 45	All F 0 12 D 20 for B & C joints 45 for T joints	All All 0 10 D 45	All F & H 0 10 D 45	All All 0 10 D 45	20 max. All 0 10 D 45
B-P 9 T-P 9 C-P 9	Double-J butt weld, T and corner joint, welded both sides 	t Position G R DTT θ	All All 1.5 10 $D_1 + D_2$ 45	All F 0 12 $D_1 + D_2$ 20 for B & C joints	All All 0 10 $D_1 + D_2$ 45	All F & H 0 10 $D_1 + D_2$ 45	All All 0 10 $D_1 + D_2$ 45	All All 0 10 $D_1 + D_2$ 45

TABLE E3
PREQUALIFIED FILLET WELD PREPARATIONS

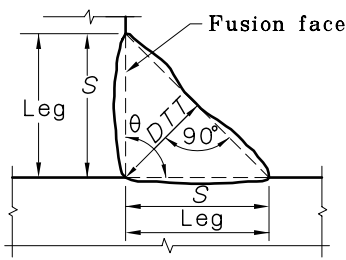
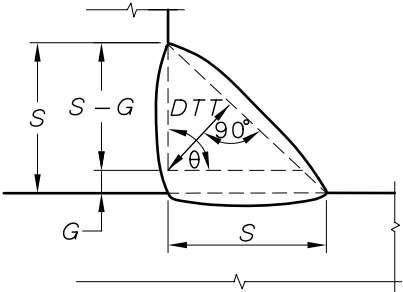
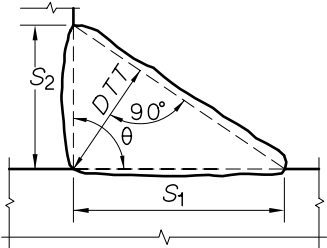
NOTES:

- 1 The notation used is given in Paragraphs E1 to E3.
2 For increased *DTT* for fully automatic processes, see Clause 3.3.2.
3 $DTT = DTT_1 + DTT_2$

$$= S_1 \cos \frac{180 - \theta}{2} + S_2 \cos \frac{\theta}{2}$$

- 4 $DTT = DTT_1 + DTT_2$

$$= \frac{S_1^2 \sin \theta}{\sqrt{\left[\left(S_1 + \frac{G}{\tan \theta} + S_1 \cos \theta \right)^2 + (G + S_1 \sin \theta)^2 \right]}} + \frac{S_2^2 \sin \theta}{\sqrt{\left[\left(S_2 - \frac{G}{\tan \theta} - S_2 \cos \theta \right)^2 + (G + S_2 \sin \theta)^2 \right]}}$$

Joint identification	Joint type	Joint description	<i>DTT</i> (see Note 2)
F1		Fillet weld with equal leg size and no root gap; for gap tolerances, see Clause 5.2.3 $\theta = 90$	$\frac{S}{\sqrt{2}}$
F2		Fillet weld with equal leg size, but with root gap $\theta = 90$	$\frac{(S - G)}{\sqrt{2}}$
F3		Fillet weld with unequal leg size $\theta = 90$	$\frac{S_1 \times S_2}{\sqrt{(S_1^2 + S_2^2)}}$

(continued)

TABLE E3 (continued)

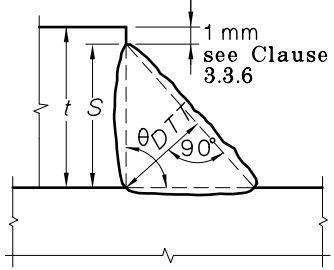
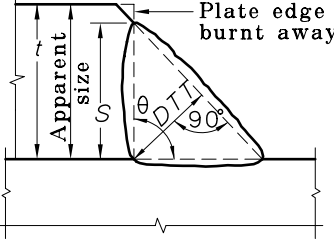
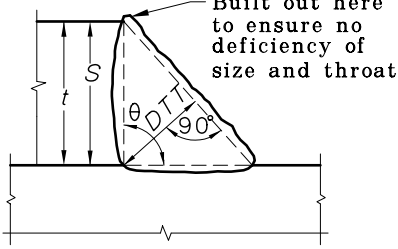
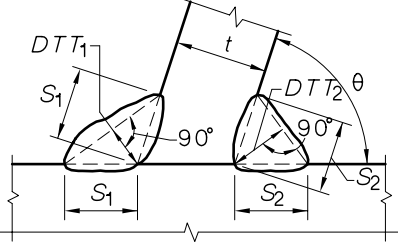
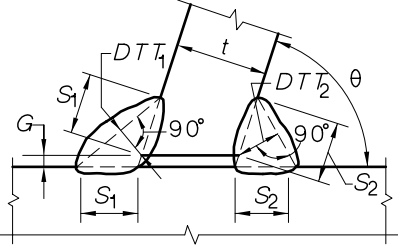
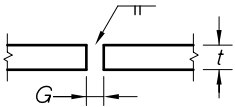
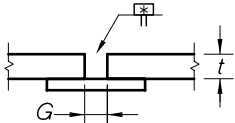
Joint identification	Joint type	Joint description	DTT (see Note 2)
F4		Lap joint with unfused edge— applicable for $t \geq 6$ $\theta = 90$	$\frac{S}{\sqrt{2}}$
F5		Lap joint with fused edge— applicable for $t < 6$ $\theta = 90$	$\frac{S}{\sqrt{2}}$
F6		Lap joint with build-up edge— applicable to all thicknesses $\theta = 90$	$\frac{S}{\sqrt{2}}$
F7		Skewed T-joint with no root gap, welded both sides $\theta = 60$ to 90	(see Note 3)
F8		Skewed T-joint with root gap, welded both sides $\theta = 60$ to 90	(see Note 4)

TABLE E4
PREQUALIFIED COMPLETE PENETRATION BUTT WELD PREPARATIONS
FOR HOLLOW SECTIONS WELDED FROM ONE SIDE

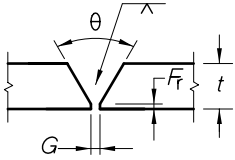
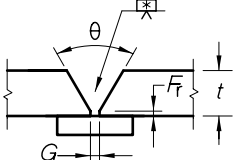
NOTES:

- 1 The notation used is given in Paragraphs E1 to E3.
- 2 For dimensional tolerances of weld preparations, see Table 5.2.2; except where this Table specifies different tolerances.
- 3 Gas metal-arc pulsed-transfer mode may be used for these preparations where average current exceeds 250 A.
- 4 Gas metal-arc welding with globular transfer mode may be use with CO₂ shielding gas.

Joint identification	Joint type	Preparation detail (see Note 2)	Manual metal-arc	Submerged arc	Flux-cored arc, self-shielded and gas-shielded	Gas metal-arc, spray transfer (see Notes 3 and 4)	Gas metal-arc, short-circuiting arc transfer or pulsed mode	Gas-tungsten arc
H-C 1a	Square butt weld, welded one side without backing strip 	t Position G	3 max. All 1.5				3 max. All 1.5	3 max. All 1.5
H-C 1b	Square butt weld, welded one side with backing strip  * M or MR	t Position G	6 max. All t	12 max. F $t/2$	12 max. All t	12 max. F $t/2$	10 max. All $1.5t$	

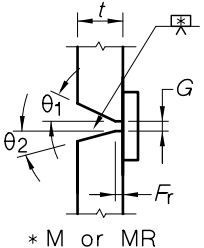
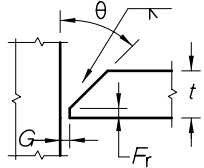
(continued)

TABLE E4 (continued)

Joint identification	Joint type	Preparation detail (see Note 2)	Manual metal-arc	Submerged arc	Flux-cored arc, self-shielded and gas-shielded	Gas metal-arc, spray transfer (see Notes 3 and 4)	Gas metal-arc, short-circuiting arc transfer or pulsed mode	Gas-tungsten arc
H-C 2a	Single-V butt weld, welded one side without sealing run and without backing strip 	t Position G F_r θ	20 max. All 1 to 3 1 to 2.5 60				20 max. All 1 to 3 0 60	20 max. All 2 to 3 0 60
H-C 2b	Single-V butt weld, welded one side with backing strip  * M or MR	t Position G F_r θ	All All 5 to 8 0 60	All F See θ 0 30: $G = 6$ 20: $G = 15$	All All 5 to 8 0 60	All F 5 to 8 0 60	All All 5 to 8 0 60	

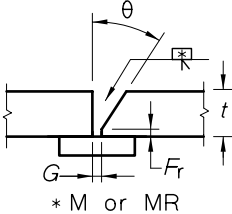
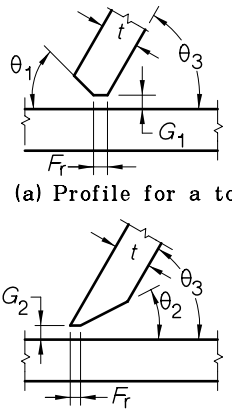
(continued)

TABLE E4 (continued)

Joint identification	Joint type	Preparation detail (see Note 2)	Manual metal-arc	Submerged arc	Flux-cored arc, self-shielded and gas-shielded	Gas metal-arc, spray transfer (see Notes 3 and 4)	Gas metal-arc, short-circuiting arc transfer or pulsed mode	Gas-tungsten arc
H-C 2c	Single-V butt weld, welded one side with backing strip 	t Position G F_r θ_1 θ_2	20 max. H 5 to 8 0 45 15		20 max. H 5 to 8 0 45 15	20 max. H 5 to 8 0 45 15	20 max. H 5 to 8 0 45 15	
H-C 4a	Single bevel butt weld, welded one side 	t Position G F_r θ	20 max. All 2 to 4 1 to 3 45				20 max. All 2 to 4 0 45	20 max. All 1.5 1.5 45

(continued)

TABLE E4 (continued)

Joint identification	Joint type	Preparation detail (see Note 2)	Manual metal-arc	Submerged arc	Flux-cored arc, self-shielded and gas-shielded	Gas metal-arc, spray transfer (see Notes 3 and 4)	Gas metal-arc, short-circuiting arc transfer or pulsed mode	Gas-tungsten arc
H-C 4b	Single bevel butt weld, welded one side with backing strip 	t Position G F_r θ	All All 6 0 45		All All 6 0 45	All F & H 6 0 45	All All 6 0 45	
H-C 4c	Butt welded T-joint, welded one side 	t Position G F_r θ_1 θ_2 θ_3	20 max. All See θ 0 to 1 45 min. > 15 ≤ 25: $G_2 = 5$ > 25 ≤ 40: $G_2 = 3$ > 40: $G_2 = 2$ 30 min.		20 max. All See θ 0 to 1 45 min. > 15 ≤ 20: $G_2 = 12$ > 20 ≤ 25: $G_2 = 9$ > 25 ≤ 30: $G_2 = 6$ > 30 ≤ 40: $G_2 = 3$ 30 min.	20 max. F See θ 0 to 1 45 min. > 15 ≤ 20: $G_2 = 12$ > 20 ≤ 25: $G_2 = 9$ > 25 ≤ 30: $G_2 = 6$ > 30 ≤ 40: $G_2 = 3$ 30 min.	20 max. All See θ 0 to 1 45 min. > 15 ≤ 25: $G_2 = 5$ > 25 ≤ 40: $G_2 = 3$ > 40: $G_2 = 1$ 30 min.	

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