

AS/NZS 1554.4:2004

AS/NZS 1554.4

Australian/New Zealand Standard™

Structural steel welding

Part 4: Welding of high strength quenched and tempered steels



AS/NZS 1554.4:2004

This Joint Australian/New Zealand Standard was prepared by Joint Technical Committee WD-003, Welding of Structures. It was approved on behalf of the Council of Standards Australia on 16 December 2003 and on behalf of the Council of Standards New Zealand on 5 March 2004. It was published on 24 March 2004.

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Australian/New Zealand Standard™

Structural steel welding

Part 4: Welding of high strength quenched and tempered steels

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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee WD-003, Welding of Structures, to supersede AS/NZS 1554.4:1995.

The objective of this Standard is to provide rules for the welding of a wide range of steel constructions, using high strength quenched and tempered steel parent material.

The objective of this edition is to update the Standard and bring it in line with the latest edition of AS/NZS 1554.1, *Structural steel welding*, Part 1: *Welding of steel structures*.

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 three categories of welds with three 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 more than one category, 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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STANDARDS AUSTRALIA/STANDARDS NEW ZEALAND

Australian/New Zealand Standard**Structural steel welding****Part 4: Welding of high strength quenched and tempered steels**

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), including pulsed mode.
- (d) Gas tungsten-arc welding (GTAW or TIG).
- (e) Flux-cored arc welding (FCAW).
- (f) Electroslag (including consumable guide) welding (ESW) (see Note).
- (g) Electro gas welding (EGW) (see Note).

NOTE: These processes may not be suitable for welding quenched and tempered steels in all cases (see WTIA Technical Note 15).

The Standard is limited to the welding of quenched and tempered steel parent material complying with Clause 2.1.

The Standard applies to the welding of steelwork in structures complying with appropriate Standards. Where 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 limited by Item (ii) below, or with the directly equivalent fatigue provisions of other application Standards.

The Standard applies to welded joints that are—

- (i) not subject to fatigue conditions; or
- (ii) subject to fatigue conditions; and—
 - (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, (Category SP weld, see Clause 1.5.2); or

- (C) the stress range in the welded joint is greater than 80% of the permissible stress range for stress Category B of AS 3990, or exceeds the stress range permitted for detail Category 112 of AS 4100 or NZS 3404.1 (Category FP weld, see Clause 1.5.2), but does not exceed the maximum stress ranges permitted for these categories.

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

NOTES:

- 1 Further information on this Standard, which the drafting committee could not incorporate, is given in WTIA Technical Note 11.
- 2 Complementary codes that facilitate design and fabrication of high strength quenched and tempered steels include the following:
 - (a) American Institute of Steel Construction Specification for the Design, Fabrication and Erection of Structural Steel for Buildings.
 - (b) American Association of State Highway and Transportation Officials, Standard Specifications for Highway Bridges.
 - (c) American Railway Engineering Association Specifications for Steel Railway Bridges.
- 3 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.
- 4 In catering for structures subject to fatigue conditions as well as statically loaded structures, the Standard provides three categories of welds with three differing levels of weld quality assurance, associated with the different types of service to which the welds are subjected. The intention is for designer to elect the category suited to the severity of the service and nominate this on the drawings, where a structure contains more than one category, this will ensure that appropriate levels of supervision and inspection will be applied to the relevant parts of the structure.

1.2 EXCLUSIONS

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

- (1) Oxy-fuel gas welding (GW).
- (2) Resistance welding (RW).
- (3) Friction welding (FW).
- (4) Thermit welding (TW).

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

The Standard does not cover the design of welded connections and permissible stresses in welds, nor the production, rectification or repair of 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 three 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 three weld categories shall be designated as follows:

- (a) *GP (general purpose)*—to be generally be selected where —
 - (i) the weld is essentially statically loaded and designed to meet the appropriate requirements of AS 4100 or NZS 3404.1;
 - (ii) the weld is stressed to 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 for 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)*—to be generally be selected where —
 - (i) the weld is essentially statically loaded and designed to meet the appropriate requirements of AS 4100 or NZS 3404.1;
 - (ii) the weld is stressed to 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 Clause 1.1.
- (c) *FP (Fatigue purposes)*—to be only be selected where the weld is subjected to high levels of dynamic loading where the stress ranges exceed detail Category 112 of AS 4100 or NZS 3404.1; or where they exceed 80% of the permissible stress range for Category B of AS 3990.

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).

NOTE: Fabricators may find it useful to refer to AS/NZS ISO 3834 and its part where fabrication activities require the approval of the principal or the inspecting authority, or where the fabrication of large, complex or critical structures is being undertaken.

1.8 SAFETY

1.8.1 Safety equipment and procedures

Welding shall be carried out in accordance with the relevant requirements of AS 1470, AS 1674.1, AS 1674.2, AS/NZS 1336, AS/NZS 1337, AS/NZS 1338.1 and AS/NZS 2865.

1.8.2 Welding equipment

Welding plant and equipment shall comply with the relevant sections of the appropriate regulations, and the relevant requirements of AS 1966.1, AS 1966.2, AS 2799, AS/NZS 1995 and IEC 60974-1.

1.8.3 Other hazards

The fabricator shall identify and manage any other risks and hazards from welding that are not covered by Clauses 1.8.1 and 1.8.2. In particular, due consideration shall be given to the control of emitted fumes, especially when welding through paints, primers and other surface coatings.

NOTES:

- 1 Guidance on the management of risk is given in AS/NZS 4360.
- 2 Further guidance on safety precautions is given in WTIA Technical Notes 7 and 22.

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 800 MPa;
- (b) be selected in accordance with Appendix B; and
- (c) comply with AS 3597, ISO 4950-3, ASTM A 514, ASTM A 517, or equivalent.

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.

Parent materials not identified to a Standard nominated in Item (c) above may be used provided one of the following requirements are met:

- (i) Testing of the material to determine compliance with any of the grade types in the Standards nominated in Item (c) above has been carried out to the satisfaction of the principal.
- (ii) A comparison of supplied test certificated with the requirements of any of the grade types in the Standards nominated in Item (c) above has been performed to the satisfaction of the principal.

NOTE: Impact tests in addition to those prescribed by the Standards in Item (c) above may be required to establish compliance with Appendix B, Paragraph B4.3.3.

2.2 BACKING MATERIAL

Permanently attached steel backing material shall have a weldability of 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 1553.2 (see Clause 4.5.1).

Electrodes or filler wires for processes other than manual metal-arc welding shall comply with AS 1858.2, AS 2203.1 or AS/NZS 2717.1, as applicable (see Clause 4.6.1).

Electrodes that do not comply with the above Standards may be used, provided 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 and other matter that is deleterious to satisfactory operation of the weld metal. Any coating on the electrodes or filler wires shall be continuous and firmly adherent. Any recommendations of the manufacturer shall be followed, including covering protection during storage and use, and conditioning and pretreatment of electrodes and filler wires prior to use.

NOTE: See WTIA Technical Note 3 for 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 1858.2. Where the manufacturer makes specific recommendations covering conditioning and pre-treatment of flux prior to use, such recommendations shall be followed.

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

Flux that is fused in the welding process shall not be re-used.

2.3.4 Shielding gas

Gas and gas mixtures used for shielding during gas metal-arc welding and flux-cored arc welding shall be of a welding grade complying with the requirements of AS 4882, and 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 Design stresses

Where welded joints are to be welded in accordance with this Standard, the maximum stresses in the joints shall not exceed the maximum values given in the appropriate design Standards.

3.1.3 Drawings

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

- (a) Specification and grade of parent metal.
- (b) Nominal tensile strength of weld metal.
- (c) Location, type, size and effective length of the 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) Details of seal welds, if such welds are required.
- (h) Type and extent of inspection, including any special inspection requirements.
- (i) Relevant design Standard.
- (j) Any special requirements that could affect welding operations.

3.2 BUTT WELDS

3.2.1 Size of weld

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

The size of incomplete penetration butt welds 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 complete penetration butt welds shall be the thickness of the thinner part.

3.2.2.2 *Incomplete penetration butt weld*

The design throat thickness of incomplete penetration butt welds 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 $\theta < 60^\circ$, $D - 3$ 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 welds may be correspondingly reduced.

3.2.3 Effective length

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

3.2.4 Effective area

The effective area of butt welds 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.

For Category GP welds and Category SP welds, the transition slope between parts shall not exceed 1:1. For Category FP welds, the transition slope between parts shall not exceed 4:1. However, the fatigue provisions of AS 3990, AS 4100, NZS 3404.1 and other design codes may require a lesser slope or a curved transition between the parts.

3.3 FILLET WELDS

3.3.1 Size of weld

The size of fillet welds shall be the leg length as defined by AS 2812.

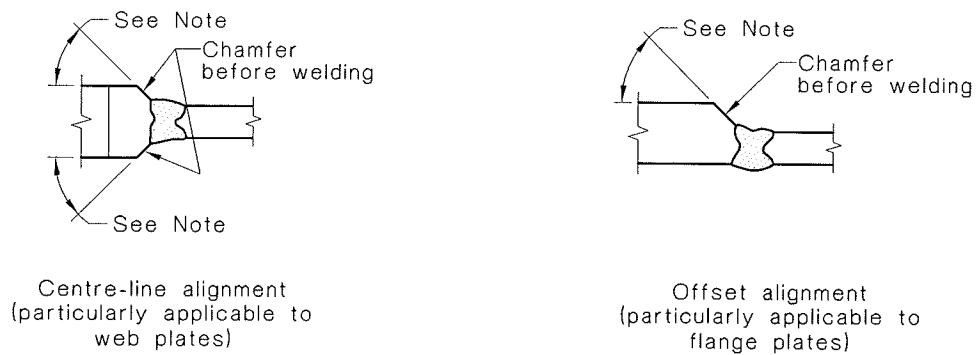
The preferred sizes of fillet welds less than 15 mm are 2, 3, 4, 5, 6, 8, 10 and 12 mm.

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.

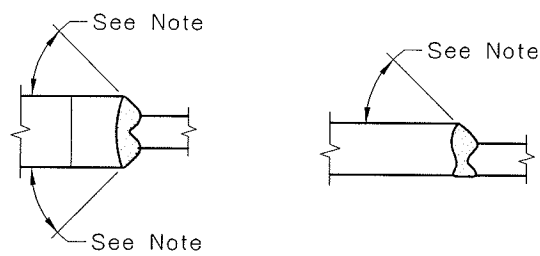
3.3.2 Design throat thickness

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

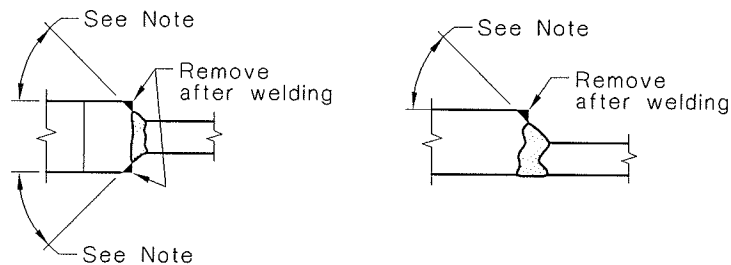
For deep penetration fillet welds made by fully automatic arc welding processes, provided that it can be demonstrated by means of a macro test on a production weld that the required penetration has been achieved, an increase in design throat thickness shall be allowed as shown in Figure 3.3.2. Where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



(i) Transition by chamfering thicker part

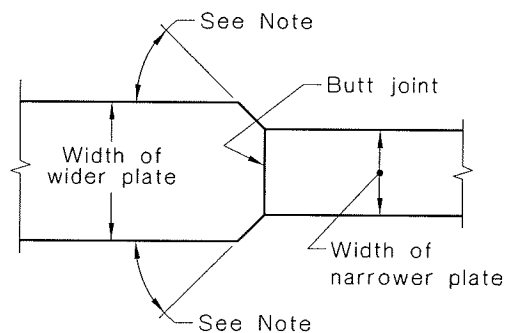


(ii) Transition by sloping weld surface



(iii) Transition by sloping weld surface and chamfering

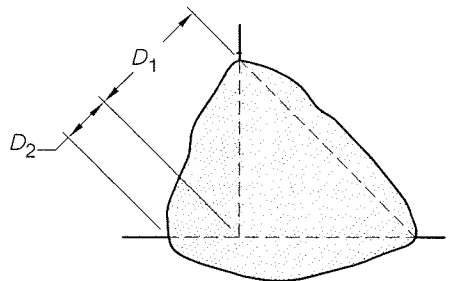
(a) Transition of butt joints in parts of unequal thickness



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

NOTE: Transition slopes shall comply with Clause 3.2.5.

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

3.3.3 Effective length

The effective length of fillet welds 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 the 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 an intermittent fillet weld shall have an effective length of not less than 40 mm.

3.3.4 Effective area

The effective area of fillet welds 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 fillet welds, including the first run of multi-run fillet welds but not fillet welds 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 (LEG LENGTH) OF
FILLET WELDS

millimetres	
Thickness of thickest part (t)	Size of fillet weld
≤ 3	$2t/3^*$
$>3 \leq 7$	3^*
$>7 \leq 10$	4^*
$>10 \leq 15$	5
>15	6

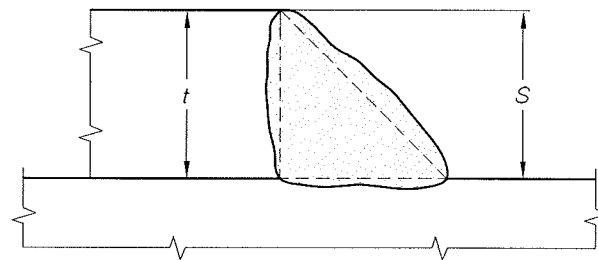
* These values may need to be increased to comply with some design Standards.

3.3.6 Maximum size of fillet welds along edges

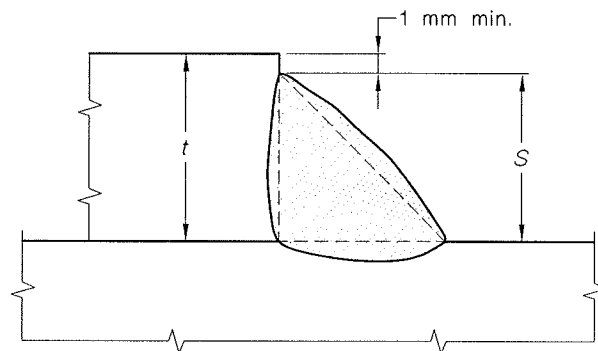
The maximum size of fillet welds along edges of material shall be—

- (a) for material with a thickness of less than 6 mm (see Figure 3.3.6(a)), the thickness of the material;

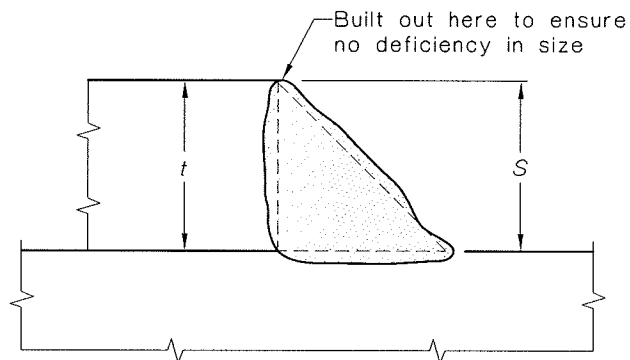
- (b) for material with thickness of not less than 6 mm (see Figure 3.3.6(b)), the thickness of the material minus 1 mm; or
- (c) for material with a thickness of not less than 6 mm, where the weld is designated on the drawing to be built out to obtain the design throat thickness (see Figure 3.3.6(c)),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



(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

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.

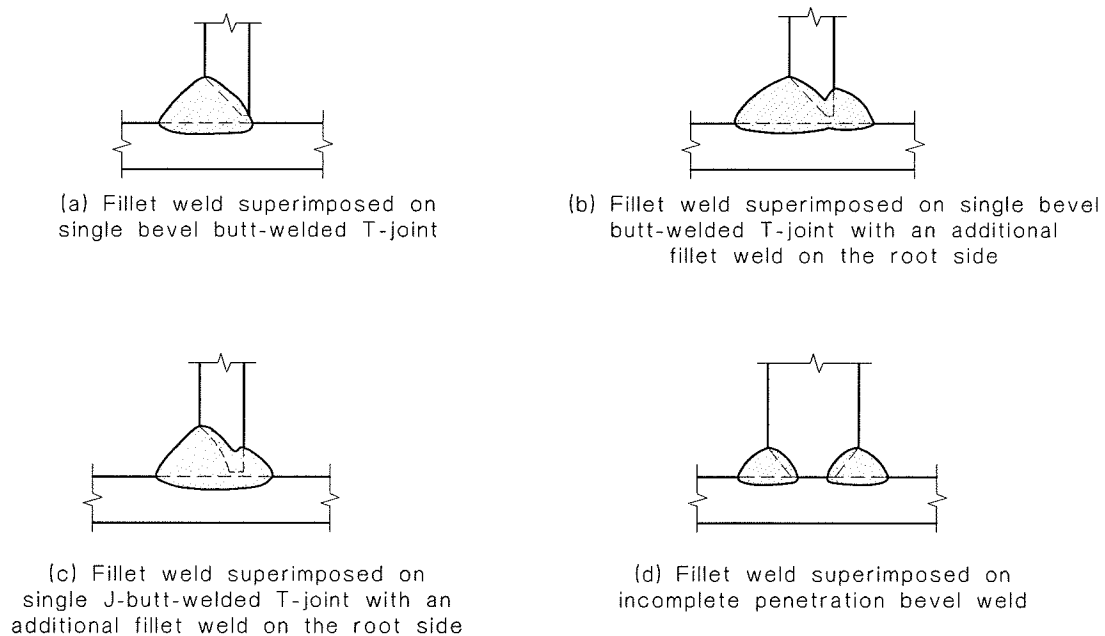


FIGURE 3.4.1 COMPOUND WELDS

3.4.2 Design throat thickness (*DTT*)

3.4.2.1 Compound welds with complete penetration in T-joints

The *DTT* of compound welds with complete penetration in T-joints 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

The *DTT* of compound welds with incomplete penetration shall be as shown in Figure 3.4.2.2, where *DTT* is the shortest distance from the root of the incomplete penetration weld to the face of the fillet weld 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.

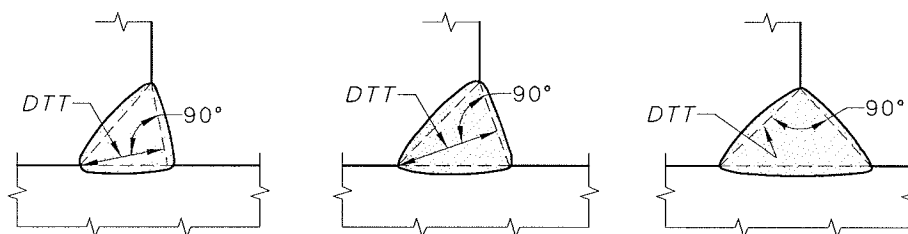


FIGURE 3.4.2.2 DESIGN THROAT THICKNESS OF COMPOUND WELDS WITH INCOMPLETE PENETRATION WELDS

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 Clause 3.3.5, unless a larger weld is specifically required.

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

Where seal welding is required, the procedure shall be specified clearly on the drawings or other documents (see Clause 3.1.3).

3.6 PLUG WELDS

The diameter of the hole for plug welds 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; or
 - (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 plug welds 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 greater 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; or
 - (ii) 2.25 times the thickness of the member.

The ends of slots shall be semicircular or 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).

SECTION 4 QUALIFICATION OF PROCEDURES AND PERSONNEL

4.1 QUALIFICATION OF WELDING PROCEDURE

4.1.1 General

The welding procedure (that is, 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 specified by Clause 4.11, and made available to the welder during fabrication.

Procedures involving joining of quenched and tempered steels to structural steels listed in AS/NZS 1554.1 shall be carried out in accordance with AS/NZS 1554.1, except that—

- (a) controlled hydrogen consumables are to be used; and
- (b) preheat and heat input requirements of both this Standard and AS/NZS 1554.1 are to be observed. (See WTIA Technical Note 15.)

The welding procedure 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 complete penetration and incomplete penetration 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 except that 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 single-run fillet welds, qualification shall cover the size of the fillet used for the qualification test and single-run fillets that are below the size qualified for the positions shown in Table 4.1.3.
 - (ii) For multi-run fillet welds, qualification shall cover the size of the fillet used for qualification and 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 requires procedure qualification 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 METHOD OF QUALIFICATION OF 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 materials are prequalified in accordance with Clause 2.1;
- (c) the consumables are prequalified in accordance with Clause 4.6;
- (d) the workmanship and welding techniques, including the preheat and inter-run temperature requirements, comply with this Standard; and
- (e) 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 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 principal; 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 the welding processes and consumables 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, Appendix E, 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.

Joint preparations for connections butt-welded from one side, complying with the details shown in Figure 4.5.5.1 for circular and unequal-width rectangular hollow sections and in Figure 4.5.5.2 for equal-width rectangular hollow sections, 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 4.5.5.3 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 4.5.5.4 for circular and unequal-width rectangular hollow sections and in Figure 4.5.5.2 for equal-width rectangular hollow sections, shall be deemed prequalified for all processes, provided that the joint preparations for butt welds conform to the appropriate Table E1 or E4, Appendix E.

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°, the welding procedure shall be qualified in accordance with Clause 4.2 before welding commences; and
 - (ii) not less than 30°, 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

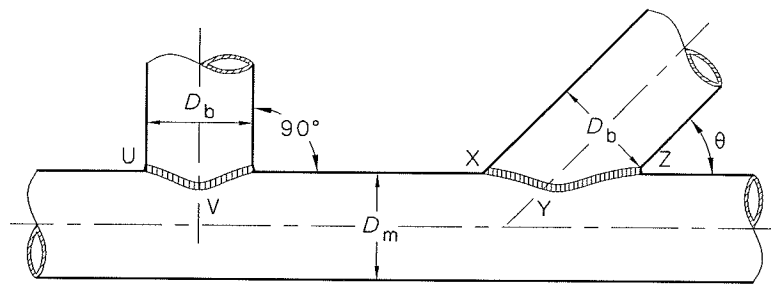
- (b) *Partially or fully flattened* Where the end of a circular hollow section member is partially flattened to a suitable shape, Items (a)(i) and (a)(ii) above shall apply and, for applications of Item (a)(ii), the diameter of the flattened portion of the section shall be measured in a plane perpendicular 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 4.5.5.5.

4.5.5.5 *End-to-surface connections of rectangular hollow sections*

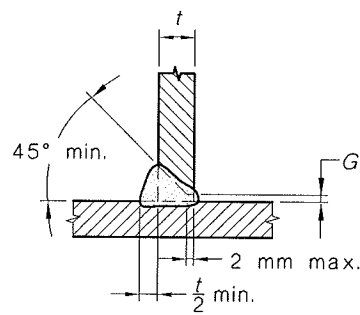
For end-to-surface connections of rectangular hollow sections, the following shall also apply, as appropriate:

- (a) *Angle of intersection not less than 30°* 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°, 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°* 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°, 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.

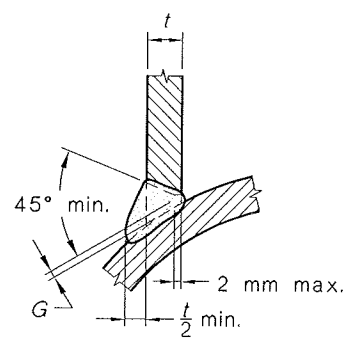


NOTE: Any value of D_b/D_m is permissible.

(a) Butt-welded connections

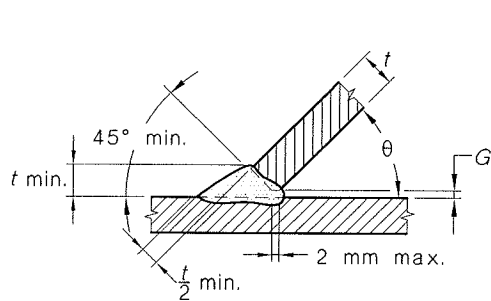


SECTION U

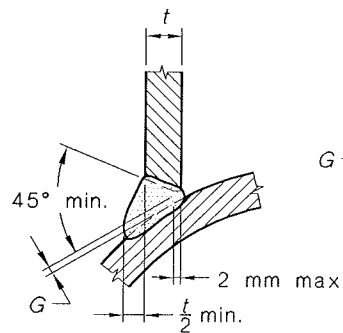


SECTION V

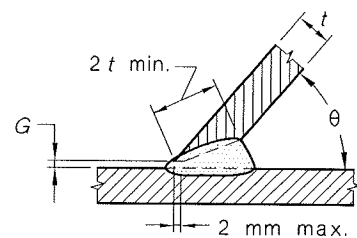
(b) Butt-welded right-angled connections



SECTION X



SECTION Y



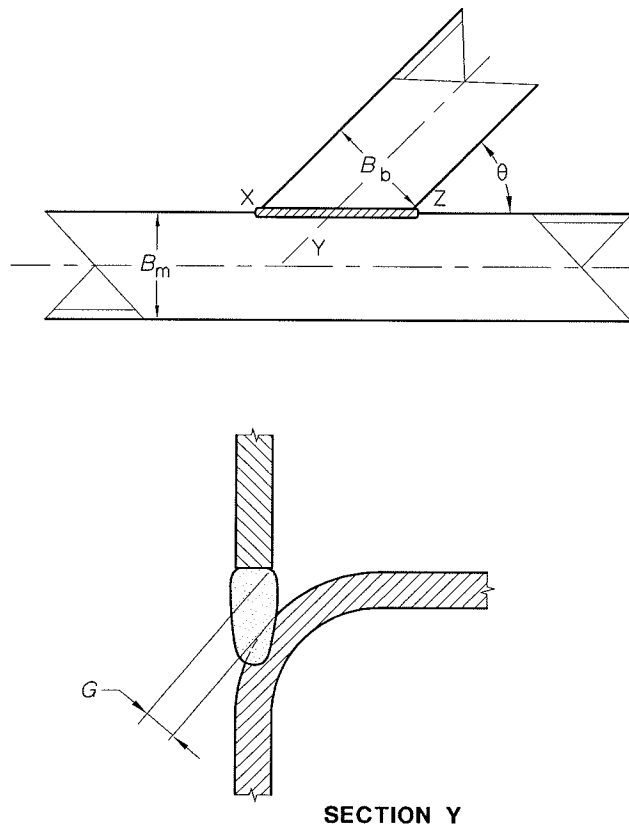
SECTION Z

(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 as drawn apply to circular hollow sections.
- 4 Only Sections U, X and Z apply to unequal-width rectangular hollow sections.
- 5 For Section Y, see Figure 4.5.5.2 for equal-width rectangular hollow sections.
- 6 For rectangular hollow sections, welds should not be started or stopped at corners.

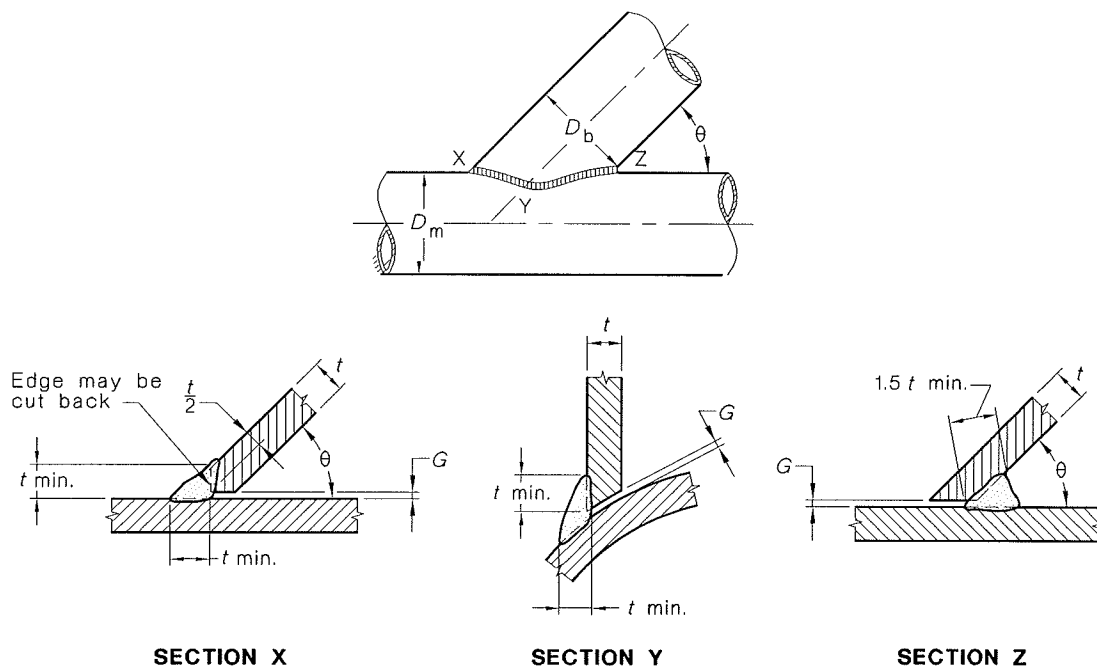
FIGURE 4.5.5.1 PREQUALIFIED BUTT WELDS FOR CIRCULAR AND UNEQUAL-WIDTH RECTANGULAR HOLLOW SECTIONS



NOTES:

- 1 $\theta \geq 30^\circ$.
- 2 The values for width of root gap (G) are given in Table E4, Appendix E.
- 3 Placing pieces of metal in the root gap for bridging the gap is not permitted.
- 4 Sections X and Z are the same as Sections X and Z of Figures 4.5.5.1 and 4.5.5.3.
- 5 For unequal-width rectangular hollow sections, see Figure 4.5.5.1.

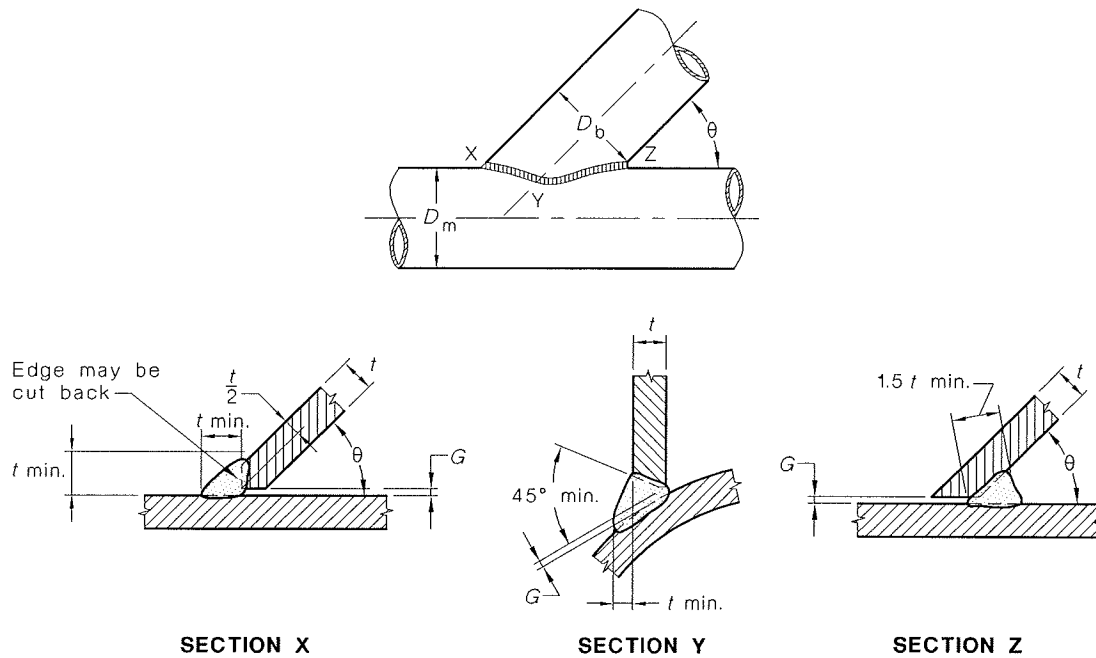
FIGURE 4.5.5.2 PREQUALIFIED BUTT WELDS FOR EQUAL-WIDTH RECTANGULAR HOLLOW SECTIONS



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 as drawn apply to circular hollow sections.
- 4 Only Sections X and Z apply to unequal-width rectangular hollow sections.
- 5 For Section Y, see Figure 4.5.5.2 for equal-width rectangular hollow sections (see Clause 4.5.5.5(c)).

FIGURE 4.5.5.3 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 as drawn apply to circular hollow sections.
- 4 Only Sections X and Z apply to unequal-width rectangular hollow sections.
- 5 For Section Y, see Figure 4.5.5.2 for equal-width rectangular hollow sections (see Clause 4.5.5.5(c)).

FIGURE 4.5.5.4 PREQUALIFIED COMBINATION OF FILLET AND BUTT WELDS INCLUDING COMPOUND BUTT AND FILLET WELD

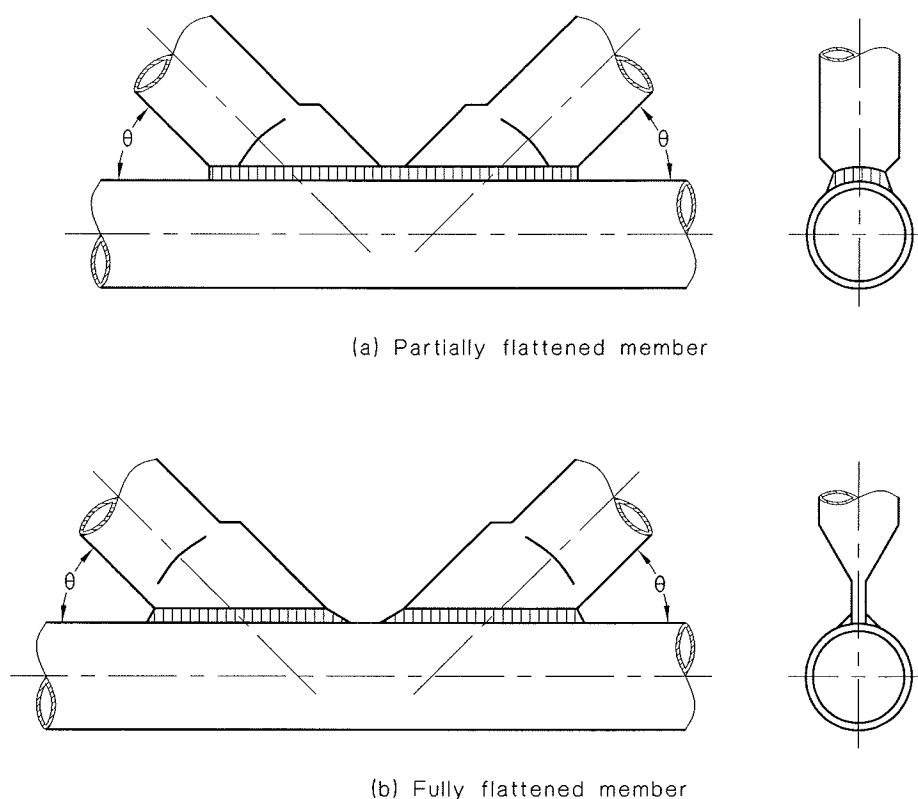


FIGURE 4.5.5.5 FLATTENED CIRCULAR HOLLOW SECTION JOINTS

4.6 QUALIFICATION OF WELDING CONSUMABLES

4.6.1 Prequalified welding consumables

4.6.1.1 General

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

- (a) The consumables are matched with the steel type in compliance with Table 4.6.1(A);
- (b) The consumables are used within the welding parameter ranges specified by the manufacturer of the consumables;
- (c) Either—
 - (i) the impact test temperature of the consumables, as specified in the relevant Standard for the consumables, is the lower of -30°C or 20° colder than the design service temperature (see Paragraph B3, Appendix B); or
 - (ii) a fracture mechanics assessment has been conducted on the weld metal (see Paragraph B5, Appendix B).

NOTE: Lower strength hydrogen controlled welding consumables may be used in fillet weld configurations where design permits.

Where consumables are not prequalified in accordance with the above items, but the fabricator can produce relevant properly documented data of satisfactory prior experience in the use of the consumables with a qualified 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 Use of lower strength consumables

Consumables having a tensile strength lower than the strength deemed prequalified for each steel type listed in Table 4.6.1(A) may be used, provided that—

- (a) the use of lower strength consumables is permitted by the designer and shown on the drawings;
- (b) the consumables are prequalified for other lower strength steel types, either within Table 4.6.1(A) or AS/NZS 1554.1;
- (c) the consumables are hydrogen controlled and classified H10 or lower; and
- (d) either the impact test temperature of the consumables complies with Clause 4.6.1.1(c), or a fracture mechanics assessment has been conducted on the weld metal (see Paragraph B5, Appendix B).

4.6.2 Qualification of welding consumables by testing

Where welding consumables are not prequalified in accordance with Clause 4.6.1, they shall be qualified. This may be accomplished in conjunction with a procedure qualification test in accordance with Clause 4.7.1. Where the mechanical properties of the transverse butt tensile test meet the minimum requirements of Table 4.6.2, and the weld metal hardness complies with Clause 4.7.8, the consumables shall be deemed qualified for that procedure.

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 (c) 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.

NOTE: 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 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 (see Clause 4.7.8) and the HAZ hardness test (see 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 test pieces that are 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 tests

Macro tests shall be carried out in accordance with AS 2205.5.1.

Specimens shall comply with the requirements of Clauses 5.6 and 6.2 and Table 6.2, 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, 6.3(A) and 6.3(B).

TABLE 4.6.1(A)
PREQUALIFIED WELDING CONSUMABLES

Steel type (see Notes 1 and 2)	Manual metal-arc consumable to AS/NZS 1553.2 (see Notes 3 and 4)	Gas metal-arc consumable to AS/NZS 2717.1 (see Notes 4 and 5)	Gas tungsten-arc AS/NZS 1167.2	Flux-cored arc to AS 2203.1 (see Notes 4, 5 and 6)	Submerged-arc consumables to AS 1858.2 (see Notes 4, 5 and 6)
8	E5515-Z E5516-Z E5518-Z E6215-Z E6216-Z E6218-Z	W559H-Z W629H-Z	—	W55XY.ZH W62XY.ZH	W55XY.ZH W62XY.ZH
9	E6915-Z E6916-Z E6918-Z E7615-Z E7616-Z E7618-Z	W699H-Z W769H-Z W839H-Z	—	W69XY.ZH W76XY.ZH W83XY.ZH	W69XY.ZH W76XY.ZH W83XY.ZH
10	E7615-Z E7616-Z E7618-Z E8315-Z E8316-Z E8318-Z	W769H-Z W839H-Z	—	W76XY.ZH W83XY.ZH	W76XY.ZH W83XY.ZH

NOTES:

- 1 The allocation of steel type numbers to particular steels is given in Table 4.6.1(B).
- 2 Steel types 1 to 7 are identified in AS/NZS 1554.1.
- 3 Consumables with a higher impact grading than that shown are also acceptable.
- 4 The letter 'Z' stands for any chemical composition.
- 5 The letter 'H' denotes controlled hydrogen.
- 6 The letter 'X' represents impact energy values. The letter 'Y' designates condition of heat treatment.

TABLE 4.6.1(B)
**ASSOCIATION OF STEEL TYPE NUMBERS
TO PARTICULAR STEELS**

Steel type	Specification and grade numbers of parent metal			
	AS 3597	ISO 4950-3	ASTM A 514	ASTM A 517
8	500	E460 E500 E550	—	—
9	600	E620	—	—
10	700 700 PV	E690	All grades	All grades

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

Steel type (see Table 4.6.1(B))	Weld metal	
	Tensile strength (see Note 1) MPa	Charpy-V impact property (see Note 2 and 3)
8	550	27 J at -40°C
9	690	27 J at -50°C
10	760	27 J at -50°C

NOTES:

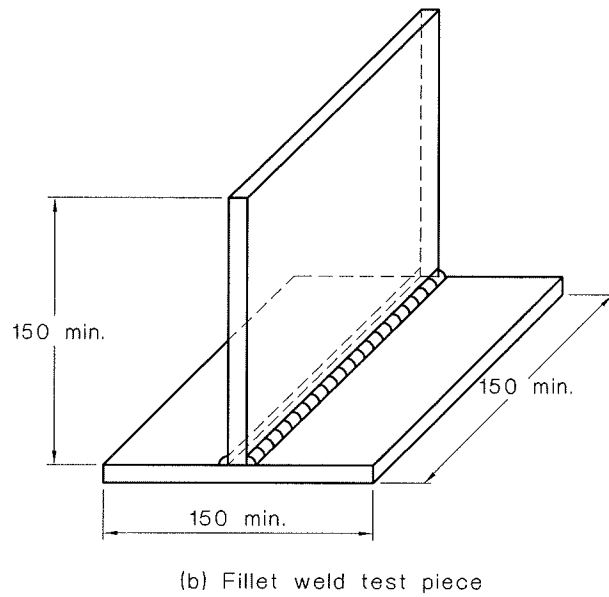
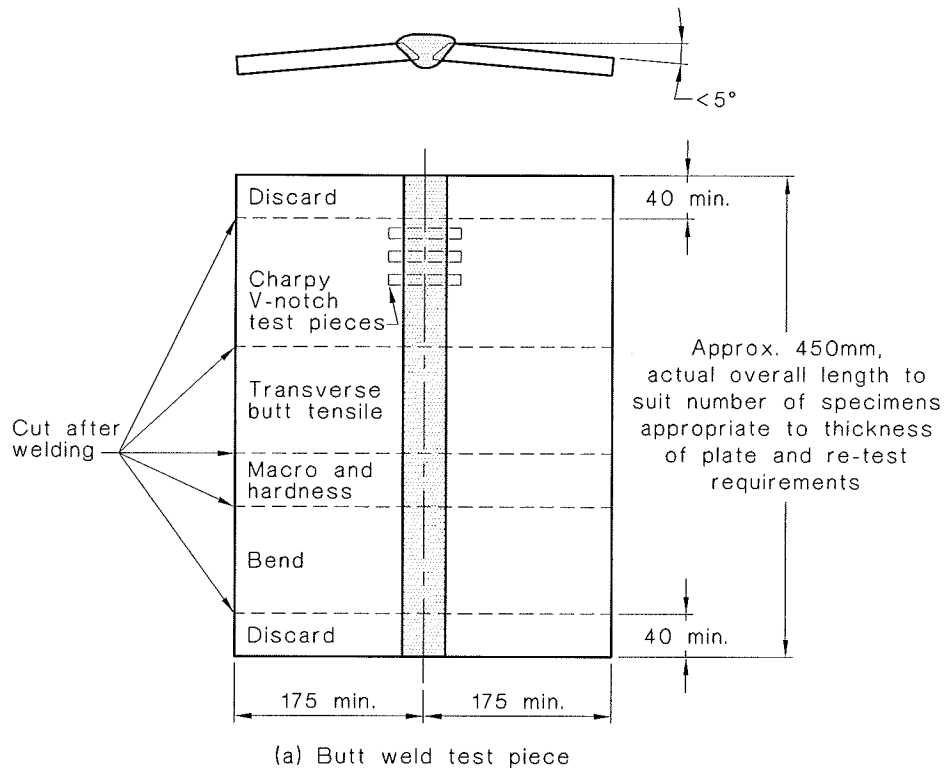
- 1 Fracture of the tensile test specimen outside the weld zone with a tensile strength not less than the minimum specified for the parent material is permitted.
- 2 Impact requirements are for the computed average values for the three test specimens.
- 3 The Charpy-V test temperature shall be the lower of the relevant temperature given in Table 4.6.2 and that specified in Clause 4.6.1.1(c).

TABLE 4.7.1
REQUIRED EXTENT OF TESTING

Weld category	Consumables	Preparation	Test required						
			Butt welds				Fillet welds		
			Macro (see Clause 4.7.4 and Note 1)	Tensile (see Clause 4.7.5 and Note 1)	Bend (see Clause 4.7.6 and Note 1)	Charpy V (see Clause 4.7.7 and Note 1)	Comparison (see Clause 4.7.8)	HAZ in accordance with Note 2 (see Clause 4.7.9)	Hardness Macro (see Clause 4.7.4) HAZ in accordance with Note 2 (see Clause 4.7.9)
SP and FP	Prequalified, conforming to Table 4.6.1(A)	Prequalified, conforming to Tables E1 to E4	1	Nil	Nil	Nil	Nil	1	1
		Other preparations	1	Nil	2 side or 1 face and 1 root	Nil	Nil	1	1
	Not prequalified	Prequalified, conforming to Tables E1 to E4	1	1	2 side or 1 face and 1 root	3	1	1	1
		Other preparations	2	1	2 side or 1 face and 1 root	3	1	1	2
GP	Prequalified, conforming to Table 4.6.1(A)	Prequalified, conforming to Tables E1 to E4	Nil	Nil	Nil	Nil	Nil	1	Nil
	Any other condition		1	Nil	Nil	Nil	Nil	1	1

NOTES:

- 1 Where the welding procedure for a fillet weld requires qualification because either the preheat temperature does not comply with Clause 5.3, or the welding consumable is not prequalified, the butt weld test piece shown in Figure 4.7.2 is used in the qualification tests.
- 2 Hardness tests are required only to qualify the welding procedure, where the preheat temperatures do not comply with Clause 5.3.



DIMENSIONS IN MILLIMETRES

FIGURE 4.7.2 FORM AND DIMENSIONS OF WELD TEST PIECES

4.7.5 Transverse butt tensile tests

Transverse butt tensile tests shall be carried out in accordance with AS 2205.2.1.

Specimens shall comply with the requirements of Table 4.6.2.

4.7.6 Bend tests

Bend tests shall be carried out in accordance with AS 2205.3.1, using a former having a diameter of 6.7 times the thickness of the specimen. The free space between supports at the end of the test should be equal to 8.9 times the thickness of the specimen.

On the completion of the test, the dimension of any crack or other defect in the weld or the heat-affected zone shall be not greater 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 cause for rejection.

4.7.7 Charpy impact tests

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 welded side.

The specimen shall comply with Table 4.6.2.

4.7.8 Hardness comparison tests between parent metal and weld metal

Hardness comparison tests between 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 tests for weld-heat-affected zones

Hardness tests for weld-heat-affected zones shall be carried out in accordance with AS 2205.6.1.

The hardness of the heat-affected zone shall be not greater than 450 HV 10.

4.7.10 Retests

Where any one specimen of 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 any of the failures 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 for Category SP may be employed without further qualification for Category GP. Procedures qualified for Category FP may be employed without further qualification for Category SP and Category GP.

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.

NOTE: A change in pulse parameters includes a change in pulse waveform (Item (q) of Table 4.11(A)) and implies that the welding machine and machine program used to qualify the welding procedure be identified on the welding procedure and used to produce the qualified production welds unless it can be demonstrated that pulse parameters remain unchanged.

4.12 QUALIFICATION OF WELDING PERSONNEL

4.12.1 Welding supervisor

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

The welding supervisor shall ensure that all welding is carried out in accordance with the plans, the specifications, any other documents and the requirements of this Standard.

The welding supervisor shall have a minimum of three years experience in the fabrication of welded structures and shall comply with one or more of the following:

- (a) Hold a Welding Supervisor's Certificate in accordance with AS 2214, AS 1796 Certificate No. 10, or a New Zealand Institute of Welding Supervisor's Certificate.
- (b) Hold an International Institute of Welding qualification at the level of International Welding Specialist (IWS), International Welding Technologist (IWT) or International Welding Engineer IWE diploma.
- (c) Hold a New Zealand Institute of Welding Certificate in welding engineering.
- (d) Hold a postgraduate certificate, diploma or degree in welding engineering from a recognized university or an approved technical college.
- (e) Have served an apprenticeship in an appropriate metal trade; and during or subsequent thereto, has had five years' experience in the fabrication of welded steel structures and is able to satisfy the principal of sufficient technical knowledge and suitability for the work under the conditions of employment.
- (f) Has at least seven years' experience in the fabrication of welded steel structures and is able to satisfy the principal of sufficient technical knowledge and suitability for the work under the conditions of employment.
- (g) Hold a diploma or a certificate in engineering or metallurgy from an approved technical college; or is a graduate in engineering or metallurgy of a recognized university and, is able to satisfy the principal of sufficient technical knowledge and suitability for the work under the conditions of employment.

- (h) Has equivalent qualifications acceptable to the principal.

NOTE: Guidance on the minimum technical knowledge requirements for Items (e), (f), (g) and (h) is provided in AS 2214.

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 the 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 new employer shall qualify the welder who has changed employment.
- (iii) There is some specific reason to question the welder's ability.

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 within the limits of prequalification (see Table 4.6.1(A))	X	X	X	X	X
(c)	An increase in filler metal strength	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 of shielding gas classification outside the limits of AS 4882	—	—	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 outside of that permitted by Clauses 4.1.2 and 4.1.3	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 (see Clause 4.11)	—	—	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°
(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 $\pm 3^\circ$	—	X	—	—	—
(B) Normal to direction of travel of $\pm 5^\circ$	—	X	—	—	—
(g) A change in electrical phase sequence between electrodes in multiple electrode welding	—	X	—	—	—

LEGEND:

X = applicable

— = not applicable

TABLE 4.12.2
RANGE OF WELDER 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		
			Rot- ating	Fixed			Rot- ating	(2)	Fixed			(3)													
																							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	-	-	-		
			0°	VD	-	-	X	-	-	-	-	X	-	-	-	✓	-	-	-	-	-	X	-	-	
			VU	X	-	-	X	X	X	X	-	X	X	X	-	✓	-	-	-	X	X	-	X	X	
		Fixed	90°	H	X	X	-	-	-	X	X	-	-	-	X	-	-	✓	-	-	X	X	-	-	-
			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	X	

LEGEND:

- ✓ welding position for which the welder is approved in the approval list
 X welding positions for which the welder is also approved
 - welding positions for which the welder is not approved.

NOTES:

- 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.
- Horizontal for pipes may be welded in two versions:
 - Pipe: rotating, axis: horizontal, welds: vertical.
 - Pipe: fixed, axis: vertical, weld: horizontal vertical.
- OH—an approved position, which 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 could prevent proper welding. Millscale that withstands vigorous wire brushing, rust-inhibiting coatings, antispatter compound and weld-through primers that do not interfere with weld quality or the welding operation may remain.

5.1.2 Thermal cutting

Surfaces to be incorporated in a weld shall not have a surface roughness greater than Class 3 as defined in WTIA Technical Notes 5 and 15.

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 the parts are effectively restrained against bending because of eccentricity in alignment, the surfaces of plates of equal thickness shall not be out of alignment by more than—

- (a) for Category SP and Category GP welds, the lesser of—
 - (i) 3 mm; or
 - (ii) 10% of the thickness of the plates, unless otherwise approved by the principal.
- (i) for Category FP welds, 5% of the thickness or 1.5 mm, whichever is the lesser.

The method of correction of misalignment in excess of the allowable values shall be determined prior to commencement of welding in accordance with Appendix D.

Except for electroslag 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 the electroslag and electrogas processes shall be determined prior to commencement of welding in accordance with Appendix D.

Root openings wider than those permitted in Table 5.2.2, but not greater than twice the thickness of the thinner part or 19 mm, whichever is the lesser, may be corrected by welding to acceptable dimensions prior to the joining of the parts by welding. Root

openings wider than twice the thickness of the thinner part or 19 mm, whichever is the lesser, 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°

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 3 mm except in cases involving rolled shapes and plates 75 mm or greater in thickness where, after straightening and on assembly, the gap cannot be closed sufficiently to comply with this requirement. In such cases, a maximum gap of 5 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 grade, material thickness and welding condition. 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 and interrune temperature control

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.

Should the actual preheat temperature exceed the maximum inter-run temperature allowed, all welding shall be delayed and the weld allowed to cool until within the specified preheat and inter-run temperature limits.

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 as specified in AS ISO 13916. 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 inter-run 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.

The measurement of preheat and inter-run temperature shall comply with AS ISO 13916.

5.3.4 Determination of preheating temperature

Preheating and inter-run temperatures shall be determined from Table 5.3.4 and Figure 5.3.4, in accordance with the following method:

- (a) Calculate the combined thickness (see Figure 5.3.4).

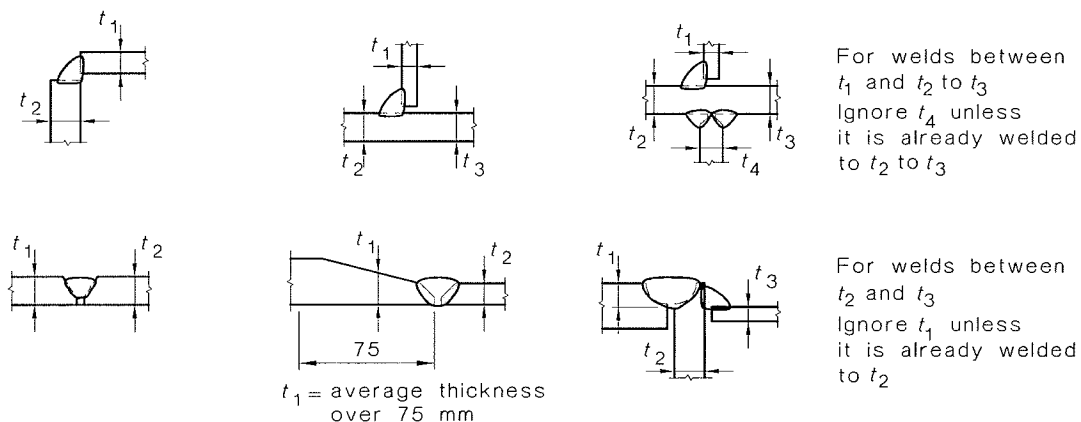


FIGURE 5.3.4 CALCULATION OF COMBINED THICKNESS

- (b) Calculate preheating and interrun temperatures and arc energy in accordance with Table 5.3.4, unless otherwise specified by the material's manufacturer.

TABLE 5.3.4
MINIMUM PREHEAT TEMPERATURES, MAXIMUM INTERRUPT
TEMPERATURES, AND MAXIMUM ARC ENERGY
 (see Note)

Steel grade	Plate combined thickness mm	Preheat temp. (min.) °C	Interrupt temp. (max.) °C	Arc energy (max.) kJ/mm
8, 9 and 10	< 26	Nil	150	2.5
	≥ 26 < 50	50	175	3.5
	≥ 50 < 100	75	200	4.5
	≥ 100	150	220	5.0

NOTE: This Table applies only when the material manufacturer's recommendations are not available. Many current generation group 8, 9 and 10 quenched and tempered steels utilize lean chemistries and lower values of minimum preheat. Guidance may also be obtained from WTIA Technical Note 15.

- (c) The relationship between the arc energy, voltage, current and travel speed is shown in the following equation:

$$Q = \frac{60 E I}{1000 V}$$

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 the above equation to calculate the minimum arc energy. In cases where the arc energy may need to be limited, 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, the arc energy for each individual arc shall be calculated 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.

NOTE: 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).

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 greater than 10 km/h, unless the welding area is suitably protected so as to reduce the wind 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 specified by Clause 5.3;
- (b) have cascaded ends, multi-run;
- (c) have a length of not less than the lesser of 40 mm and four times the thickness of the thicker part; and
- (d) be continuous for the length specified.

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, and 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.

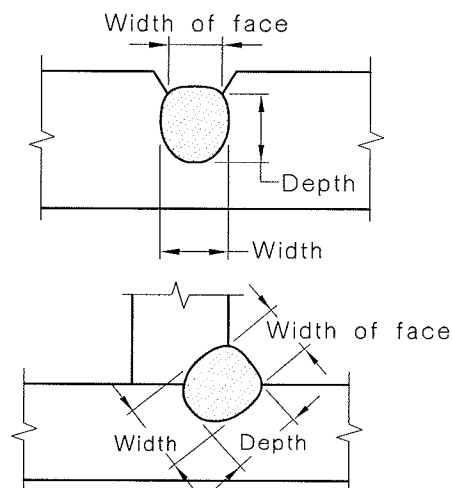


FIGURE 5.6 UNACCEPTABLE WELD RUN IN WHICH DEPTH AND WIDTH EXCEED THE WIDTH OF THE WELD FACE

5.7 CONTROL OF DISTORTION AND RESIDUAL STRESS

5.7.1 General

In the assembly and joining of parts of a structure or of 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.

In the making of welds under conditions of severe external shrinkage restraint, the welding shall be carried 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 interrun temperatures.

5.7.2 Stressed parts

Parts that are stressed shall not be cut or welded, except where—

- (a) the effect of such actions on the flexural, tensile and compressive capacity of the member is considered;
- (b) the matter is discussed between the fabricator and the principal in accordance with Appendix D; and
- (c) appropriate safety precautions are taken to prevent damage to or failure of the structure.

NOTE: 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 prior to use, in accordance with Appendix D.

5.7.4 Correction of distortion

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

- (a) Where solid water jets are used for cooling, their use shall be agreed to in accordance with Item (q), Appendix D.
- (b) The temperature of steels shall not exceed the tempering temperature less 20°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 General

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. A repair weld procedure may be required in such instances.

NOTE: The principal may require that a welding procedure for repairs be qualified and approved.

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 the deposition of additional weld metal in accordance with this Standard or by the removal of the undercut by grinding in accordance with Clause 5.8.3.

NOTE: The use of preheat prior to air-arc gouging should be considered. Guidance may be obtained from WTIA Technical Note 15.

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 the length of continuous automatic longitudinal fillet or butt weld, with stress ranges for detail Category 112 or 125 as specified in AS 4100 or NZS 3404.1, they shall be repaired by the following procedure:

- (a) Grind the stopped end of the weld so that it tapers to the root of the joint with a slope of at least 4:1.
- (b) Restart the weld from the top of the taper slope.
- (c) Grind the repaired weld to a smooth surface.

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

NOTE: In rectangular hollow section joints, welds should not be started or stopped at corners.

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 5.8.3.

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 or other suitable method to ensure soundness.

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

- (a) reducing the thickness of the thinner base metal or weld metal by more than 0.8 mm or 5% of the thickness, whichever is the lesser; or
- (b) leaving reinforcement that exceeds 0.8 mm.

Reinforcements shall be removed where the weld forms part of a faying or contact surface. Any dressing of reinforcement shall blend smoothly into the plate surfaces.

In addition, Category FP welds shall be dressed in accordance with the fatigue requirements of AS 3990, AS 4100 or NZS 3404.1, as appropriate.

SECTION 6 QUALITY OF WELDS

6.1 WELD CATEGORIES

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

The compliance of the 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, with Clause 7.4.

In addition, for Category SP and Category FP 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 6.3 shall be carried out in accordance with Clause 6.3 or Clause 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 that are permitted for the weld categories shall not exceed the relevant levels given in Table 6.2 and Table 6.3.

6.2.3 Adjacent imperfections

6.2.3.1 *Aligned*

Where adjacent imperfections are aligned, they shall be assessed as shown in 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*

Any imperfections occurring one above the other in the vertical plane of the weld shall be assessed as shown in Figure 6.2.3(c).

6.2.4 Interpretation of tests

Where qualification by macro test and side-bend test is required (see Clause 4.7), the bend test 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.

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 Category SP, the technique shall be selected in accordance with the thickness of the material as follows:
 - (i) 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.
 - (ii) 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.

- (b) For Category FP, only method XR2/—shall be used.

6.3.2 IQI sensitivity

IQI sensitivity for each technique shall be as required by 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

Weld category	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
SP	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
FP	XR2/x	13	12	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 6.3(A) or Table 6.3(B), as applicable. Where imperfections in excess of the limits of Table 6.3(A) or 6.3(B) are detected, 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) 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) 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°. 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	Not permitted

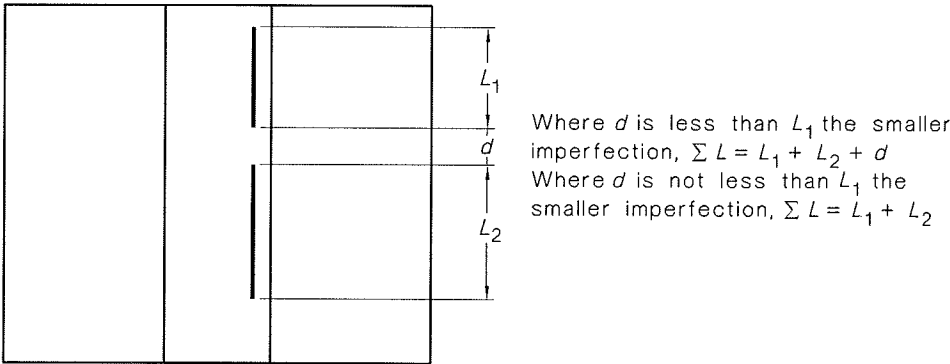
6.4.3 Acceptance limits

The maximum permissible levels of imperfections shall be as given in Tables 6.3(A) and 6.3(B). Where welds fail to meet these criteria they shall be either repaired and retested, or considered defective and dealt with in accordance with Clause 6.7.

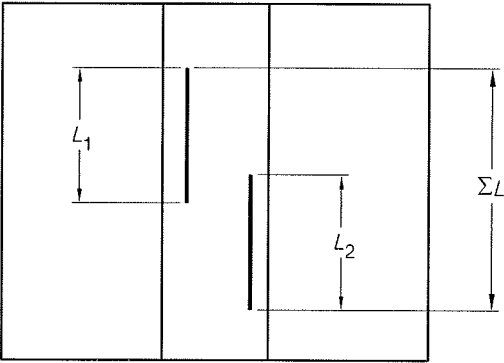
6.5 MAGNETIC PARTICLE EXAMINATION

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

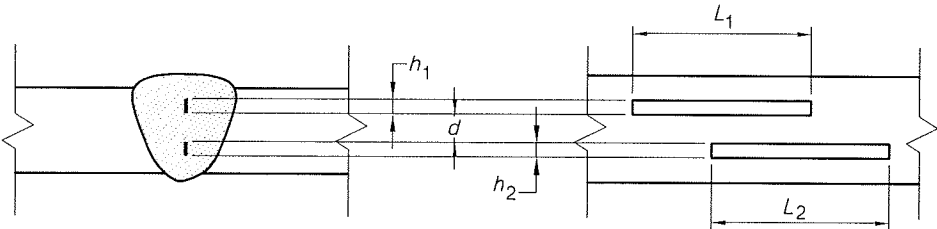
The maximum permissible levels of imperfections shall be as given in Table 6.2.



(a) Aligned imperfections



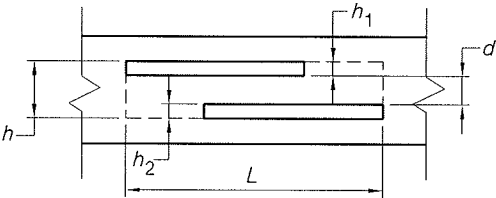
(b) Overlapping imperfections



(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

6.6 LIQUID PENETRANT EXAMINATION

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

The maximum permissible levels of imperfections shall be as given in Table 6.2.

6.7 WELD DEFECTS

Weld imperfections that exceed the levels given in Tables 6.2, 6.3(A) and 6.3(B) 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 on 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.

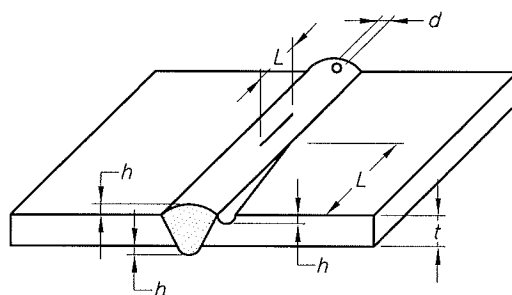
All reports, including calculations for fracture mechanics assessments of defective welds, shall be retained and made available for information purposes.

TABLE 6.2
PERMISSIBLE LEVELS OF IMPERFECTIONS IN BUTT AND FILLET WELDS AS DETERMINED BY VISUAL, MAGNETIC PARTICLE AND LIQUID PENETRANT EXAMINATION OF THE WELD ZONE

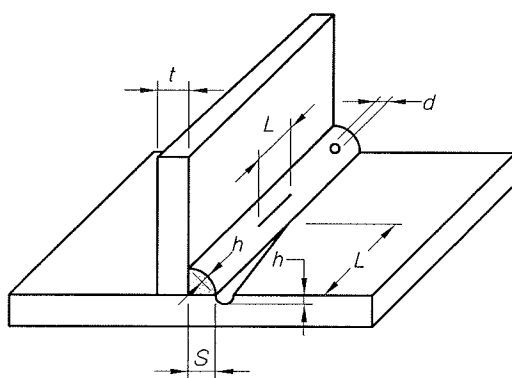
Imperfection		Symbol	Maximum allowable dimension or number of imperfections		
Type	Parameter		GP	SP	FP
Butt welds					
Cracks	Length	l	Crater cracks only	No cracks allowed	
	Cumulative length	Σl	6 mm in 1000 mm weld (crater cracks only)		
Lack of fusion or incomplete penetration	Depth for GP Length for SP		As for undercut depth	l	Where located more than $3t$ from end of weld, $2t/3$, but not greater than 20 mm
				Σl	Where located within $3t$ from end of weld, 3 mm t in $6t$ length, but proportionally less for shorter length
Undercut-continuous	Depth	h	$t/10$, but not greater than 1.5 mm (see Note 3)	$t/20$, but not greater than 1 mm (see Note 3)	Not allowed
Undercut-intermittent	Depth	h	$t/5$, but not greater than 2 mm (see Note 3)	$t/10$, but not greater than 1.5 mm (see Note 3)	Not allowed
Shrinkage grooves Root concavity	—	—	—	As for undercut	Not allowed
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	1 mm max. Smoothly blended at weld toes
Excess penetration	Height (depth)	—	—	As for reinforcement	
Linear misalignment	—	—	—	See Clauses 5.2.2 and 5.2.3	
Overlap	Length	l	$2t$, but not greater than 20 mm	l , but not greater than 10 mm	Not allowed
	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	Smoothly blended
Surface pores	Size of pore	d	Not limited	$t/3$, but not greater than 5 mm	Not allowed
Loss of cross-sectional area (see Note 4)	Number of pores	—	Six per 12t length	Two per 12t length	
	L of A	—	≤ 10 percent	≤ 5 percent	$\leq 3\%$
Fillet welds					
Reinforcement	Height	h	Not limited	For $S \leq 12$ mm 2 mm For $12 \leq S < 25$ mm 3 mm For $S \geq 25$ mm 4 mm	1 mm max. Smoothly blended at weld toes (see Note 6)
Undersize—intermittent (see Note 5)	Leg length	—	$S/5$, but not greater than 4 mm	$S/10$, but not greater than 3 mm	$S/10 \leq 2$ mm
Other surface imperfections	—	—	—	As for butt welds	Not allowed
Loss of cross-sectional area (see Note 4)	L of A	—	—	As for butt welds	$\leq 3\%$

NOTES TO TABLE 6.2:

- 1 For adjacent imperfections, see Clause 6.2.3.
- 2 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.
- 3 Undercut less than 0.5 mm in depth should be disregarded for Category GP and Category SP welds.
- 4 For the calculation of the loss of cross-sectional area, all relevant surface imperfections shall 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.
- 5 The cumulative length of intermittent undersize fillet welds shall not exceed 10% of the length of the weld.
- 6 The angle β between the plane tangential to the weld bead surface at the toe and the plane through the line PQ shall be $\leq 15^\circ$ (see Figure 6.2). Slightly concave welds shall be acceptable, provided the design throat thickness requirements is fulfilled. This requirement also applies for the angle between the tangential planes between multi-run welds.



(a) Buttt weld



(b) Fillet weld

FIGURE 6.2 DIMENSIONS REFERRED TO IN TABLE 6.2

TABLE 6.3(A)
PERMISSIBLE LEVELS OF IMPERFECTIONS AS DETERMINED BY
RADIOGRAPHIC OR ULTRASONIC EXAMINATION
FOR CATEGORY SP WELDS

Type of imperfection (see Notes 1, 2 and 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	L/5
	>10 ≤20	2	4	X	X	X	L/4
	>20 ≤40	1	2	5	X	X	L/2
	>40	1	2	5	10	X	L
Porosity	All	See Notes 8 and 9					

LEGEND:

X = not permitted

L = weld length under consideration

TABLE 6.3(B)
PERMISSIBLE LEVELS OF IMPERFECTIONS AS DETERMINED BY
RADIOGRAPHIC OR ULTRASONIC EXAMINATION
FOR CATEGORY FP WELDS

Type of imperfection (see Notes 1, 2 and 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 (h), mm					
		≤2	>2 ≤4	>4 ≤10	>10 ≤20	>20	
Cracks	All	Not permitted					
Inclusions, lack of penetration, or lack of fusion	≤10	X	X	X	X	X	X
	>10 ≤20	4	8	X	X	X	L/8
	>20 ≤40	2	4	10	X	X	L/4
	>40	2	4	10	20	X	L/2
Porosity	All	See Notes 8 and 9					

LEGEND:

X = not permitted

L = weld length under consideration

NOTES TO TABLES 6.3(A) AND 6.3(B):

- 1 For adjacent imperfections, see Clause 6.2.3.
- 2 For the purpose of radiographic examination or routine ultrasonic examination, h is to be taken as 2 mm. If the ultrasonic or radiographic examination indicates that h may be greater than 2 mm, h is to be determined by sectioning or vertical ultrasonic sizing in accordance with AS 2207.
- 3 Where any imperfection is suspected as being a lamellar tear, it should be recorded on the NDE report and referred to the principal for consideration.
- 4 Also, see Clause 3.2.1.
- 5 For any weld length under consideration, the imperfection level is 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.
- 6 Any imperfection within a distance of t from the end of a weld shall have a height of not more than the greater of 2 mm and $t/20$.
- 7 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.
- 8 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.
- 9 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 the above Table. 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 not exceeding 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.

SECTION 7 INSPECTION

7.1 GENERAL

This Section shall apply 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 one of the following shall be accepted as evidence of these qualifications:

- (a) A Welding Technology Institute of Australia Certificate as a Welding Inspector.
- (b) A Certification Board of Inspection Personnel (CBIP) New Zealand Welding Inspector Certificate.
- (c) A structural welding supervisor certificate in accordance with AS 2214.

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 (Clause 7.3)	Visual examination to Table 6.2	Magnetic particle or liquid penetrant (see Notes 5 and 6)	Radiography or ultrasonics to Table 6.3 (see Note 7)
GP	100	0 to 25	0 to 2	Nil
SP	100	50 to 100	30 to 50	50 to 100
FP	100	100	100	50 to 100

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 of a percentage of the welds, to determine whether the required weld quality (see Table 6.2) has been achieved.
- 4 SP category welds that comply with NZS 3404.1, 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 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

LIST OF 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
1210	Unfired Pressure Vessels (known as the SAA Unfired Pressure Vessels Code)
1336	Recommended practices for eye protection in the industrial environment
1450	Steel tubes for mechanical purposes
1470	Health and safety at work—Principles and practices
1553	Covered electrodes for welding
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
1554.1	Part 1: Welding of steel structures
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
1817.1	Part 1: Test methods
1817.2	Part 2: Verification of testing machines
1817.3	Part 3: Calibration of reference blocks
1858	Electrodes and fluxes for submerged-arc welding
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
1995	Welding cables
2062	Non-destructive testing—Penetrant testing of products and components
2177	Non-destructive testing—Radiography of welded butt joints in metal
2177.1	Part 1: Methods of test
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 of destructive testing of welds in metal
2205.2.1	Method 2.1: Transverse butt tensile test
2205.3.1	Method 3.1: Transverse guided bend test
2205.5.1	Method 5.1: Macro metallographic test for cross-section examination
2205.6.1	Method 6.1: Weld joint hardness test
2205.7.1	Method 7.1: Charpy V-notch impact practice toughness tests
2207	Non-destructive testing—Ultrasonic testing of fusion-welded joints in carbon and low alloy steel

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AS

- 2214 Certification of welding supervisors—Structural steel welding
- 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
- 3597 Structural and pressure vessel steel—Quenched and tempered plate
- 3990 Mechanical equipment—Steelwork
- 4100 Steel Structures
- 4882 Shielding gases for welding

AS ISO

- 13916 Welding—Guide on the measurement of preheating temperature, interpass temperature and preheat maintenance temperature

AS/NZS

- 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
- 4360 Risk management

AS/NZS ISO

- 2717 Welding—Electrodes—Gas metal-arc
- 2717.1 Part 1: Ferritic steel electrodes
- 3834 Quality requirements for welding—Fusion welding for metallic material
- 3834-1 Part 1: Guidelines for selection and use
- 3834-2 Part 2: Comprehensive quality requirements
- 3834-3 Part 3: Standard quality requirements
- 3834-4 Part 4: Elementary quality requirements

NZS

- 3404 Steel structures standard
- 3404.1 Part 1: Steel structure standard
- 4711 Qualification tests for metal-arc welders

ISO

- 4950-3 High yield strength flat steel products
- Part 3: Products supplied in the heat-treated (quenched + tempered) condition

IEC

- 974 Arc welding equipment
- 974-1 Part 1: Welding power sources

ASTM

- A 514 Specification for high-yield strength, quenched and tempered alloy steel plate, suitable for welding
- A 517 Specification for pressure vessel plates, alloy steel, high-strength, quenched and tempered

WTIA [Welding Technology Institute of Australia]

- 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 15—Welding and fabrication of quenched and tempered steels
- Technical Note 22—Welding electrical safety

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, 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 (e.g., snow, ice and frost conditions).

B3.3 Modifications to the basic design temperature

The design service temperature shall be the basic design temperature; except that for parts that are to be subjected to artificial cooling below the basic design service temperature (for example, in refrigerated buildings) it shall be the minimum expected temperature for the part.

B4 MATERIAL SELECTION

B4.1 Selection of steel type

The steel type shall be selected from Table 4.6.1(B). Steels complying with AS 3597 are deemed to have a permissible service temperature of -20°C and other steel types are deemed to have a permissible service temperature of -10°C , provided that this temperature is colder than the design service temperature determined in accordance with Paragraph B3. The permissible service temperature shall be subject to the limitations and modifications specified in Paragraphs B4.2 and B4.3 respectively.

B4.2 Limitations

The permissible service temperature given in Clause B1 shall only be used for members and components that comply with the fabrication and erection provisions of this Standard.

The permissible service temperature may be used 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 5.0%*

Where a member or component is subjected to an outer bend fibre strain during fabrication of between 1% and 5%, the permissible service temperature shall continue to apply, provided that the steel type under consideration is shown to have microalloying additions of boron, titanium and aluminium. Other steel types shall be assessed using the provisions of Paragraph B4.3.3.

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

B4.3.2 *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 deemed permissible service temperature shall not be modified.

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

B4.3.3 *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 $10\text{ mm} \times 10\text{ mm}$ test specimens shall be not less than 40 J, and no results shall be less than 30 J.
- (e) Where a plate thickness prevents a $10\text{ mm} \times 10\text{ mm}$ 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.

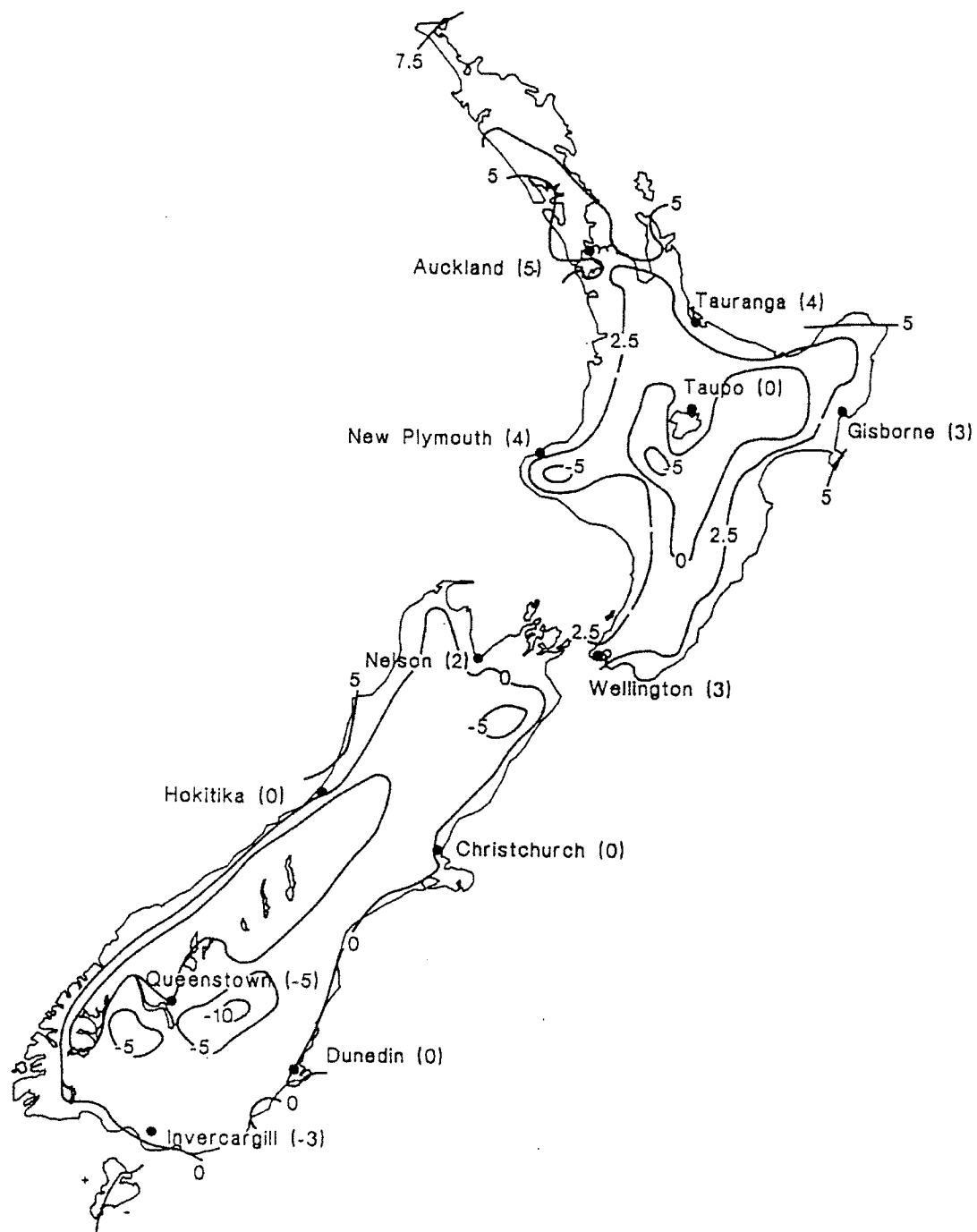
NOTE: For methods of fracture assessment, see BS 7910 and WTIA Technical Note 10.



NOTES:

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

FIGURE B1 LODMAT ISOTHERMS FOR AUSTRALIA



NOTES:

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

FIGURE B2 LODMAT ISOTHERMS FOR NEW ZEALAND

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APPENDIX C
TYPICAL FORMS FOR WELDING PROCEDURES
(Informative)

This Appendix provides typical forms for procedure qualification record (PQR) and welding procedure specification (WPS).

NOTE: These forms may be copied.

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					Qualified position				
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				

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 mm Root face F_r mm 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	ϕ 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

CHECK LIST OF MATTERS FOR DISCUSSION

(Normative)

The following matters of a contractual nature shall be resolved:

- (a) Nomination of weld categories and nominal tensile strength of weld (see Clause 3.1.3).
- (b) Increased penetration from fully automatic arc welding process (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 Clause 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 Clause 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) Misalignment of plates of equal thickness (see Clause 5.2.2).
- (o) Alignment tolerances for butt-welded joints and methods of correction of excessive misalignment (see Clause 5.2.2).
- (p) Welding and cutting under stress (see Clause 5.7.2).
- (q) Peening (see Clause 5.7.3).
- (r) Correction of distortion (see Clause 5.7.4).
- (s) Weld surface quality requirements to comply with painting specifications (see Clauses 5.11 and 5.12).
- (t) Type and extent of inspection including requirements for NDE, and the value of L as the basis for assessment under Table 6.3 (see Clauses 6.3, 6.4, 6.5, 6.6, 7.4.1, and Appendix E).
- (u) NDE technique and alternatives (see Clauses 6.3.1, 6.4.1, 6.5.1, and 6.6.1).
- (v) Correction of faulty (defective) welds and cost of weld repairs and associated NDE (see Clauses 6.3.3, 6.4.3, and 6.7).
- (w) Whether test report is required (see Clause 6.8).
- (x) Qualification of NDE technicians (see Clause 7.4).
- (y) For plates with a thickness of not less than 20 mm, whether a portion of each multi-pass butt weld should be tested, to determine whether there are any transverse cracks within the weld metal (see Table 7.4).

Where practicable, 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:

$W-X Yz$

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	= electrosag 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

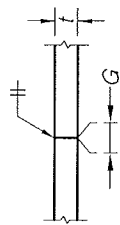
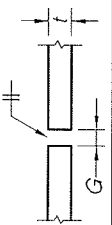
E4 EXAMPLE

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

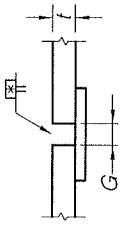
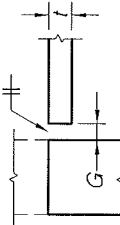
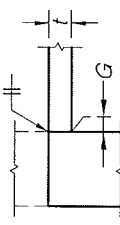
NOTES:

- 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.
- 6 These joint identifications are inappropriate for Category FP procedures.

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 $t/2$

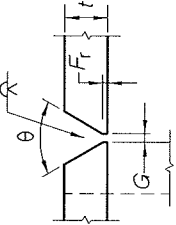
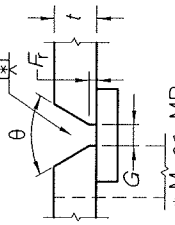
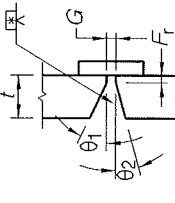
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TABLE E1 (continued)

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 (see Note 6)	Open-joint square butt weld and corner joint, welded one side with backing strip 	<i>t</i> Position <i>G</i>	6 max. All <i>t</i>	12 max. F <i>t/2</i>	12 max. All <i>t</i>	12 max. F <i>t/2</i>	10 max. All <i>3t/2</i>	20 min. V 25	
T-C 1a C-C 1b	Open-joint square T-butt weld and corner joint welded both sides 	<i>t</i> Position <i>G</i>	6 max. All <i>t/2</i>		10 max. F & H <i>t/4</i>		6 max. All 3	20 min. V 25	6 max. All <i>t/2</i>
C-C 1c T-C 1b	Close joint square T and corner joint, butt-welded both sides 	<i>t</i> Position <i>G</i>	3 All 0	10 max. F 0	6 max. F 0	6 max. F 0			3 max. All 0

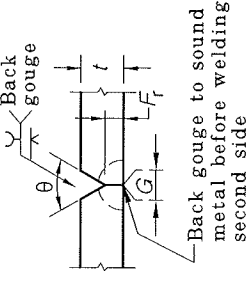
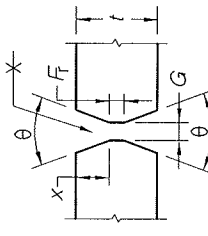
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TABLE E1 (continued)

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 	<i>t</i> Position <i>G</i> <i>F_r</i> 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 (see Note 6)	Single-V butt weld and corner joint, welded one side with backing strip 	<i>t</i> Position <i>G</i> <i>F_r</i> 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 (see Note 6)	Single-V butt weld, welded one side with backing strip 	<i>t</i> Position <i>G</i> <i>F_r</i> 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		

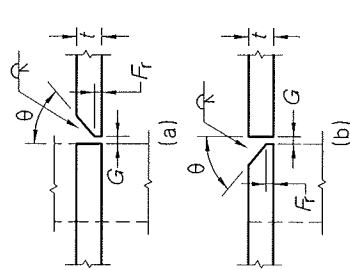
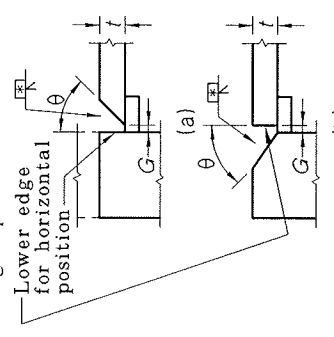
(continued)

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 2d	Single-V butt weld, welded both sides 	t Position G F_r theta	32 max. All 0 t/3 max. 60	32 max. F 0 ≥ 6 ≤ 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 β(t - F_c) to α(t - F_r) 	t Position G F_r theta	All All 3.5 1.5 60	All F 0 6 60	All See theta 3 3 50 for F, H & OH 60 for V	All F 0 3 50	All See theta 4 0 50 for F, H & OH 60 for V		20 max. All 3 1.5 60

(continued)

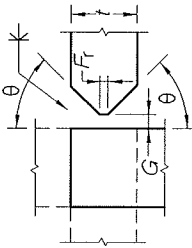
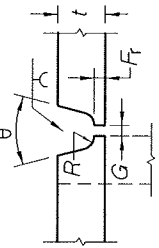
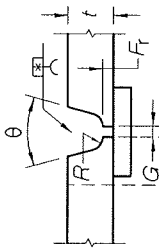
TABLE E1 (continued)

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 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 (see Note 6)	Single bevel butt weld, T and corner joint, welded one side with backing strip 	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: $G = 6$		

* M or MR

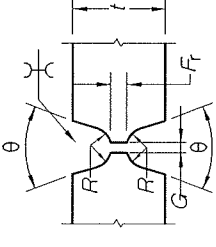
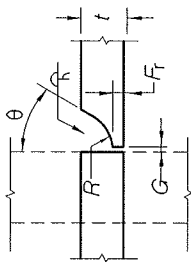
(continued)

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 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 (see Note 6)	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 	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 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	Single-J butt weld, T 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: MMAW or SAW weld on second side 0 6 See 0 30: $R = 12$ 45: $R = 6$	All All 3 3 See 0 30: $R = 10$ 45: $R = 6$	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)

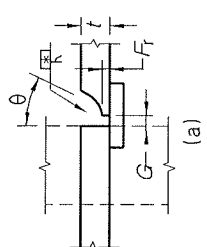
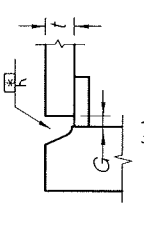
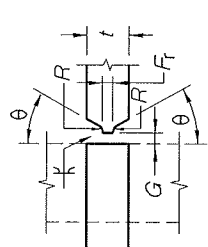
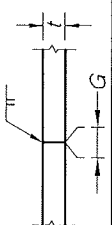
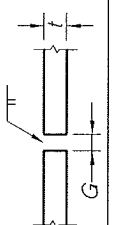
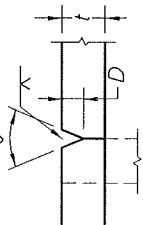
Joint identification	Joint type	Preparation detail (see Notes 2 and 3)	Manual metal-arc	Submerged arc	Flux-cored arc, self-shielded and gas-shielded	Gas metal-arc, spray transfer (see Notes 4 and 5)	Gas metal-arc, short-circuiting arc transfer or pulsed mode	Electroslag, including consumable guide	Gas-tungsten arc
B-C 8b T-C 8b C-C 8b (see Note 6)	Single-J butt weld, T and corner joint, welded one side with backing strip  (a)  (b) * M or MR	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 0 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

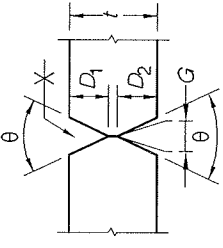
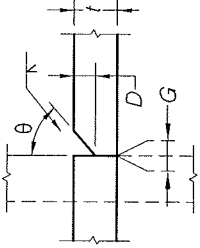
NOTES:

- 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 0.75 <i>t</i>	6 max. <i>F</i> 0 0.75 <i>t</i>	4 max. <i>F</i> & <i>H</i> 0 0.75 <i>t</i>	3 max. <i>F</i> & <i>H</i> 0 0.75 <i>t</i>	3 max. All 0 <i>t</i> /2	3 max. All 0 0.75 <i>t</i>
B-P 1b	Open-joint square butt weld, welded one side 	<i>T</i> Position <i>G</i> <i>DTT</i>	6 max. All <i>t</i> /2 0.75 <i>t</i>		8 max. <i>F</i> & <i>H</i> <i>t</i> /4 0.75 <i>t</i>	6 max. <i>F</i> & <i>H</i> <i>t</i> /4 0.75 <i>t</i>	6 max. All <i>t</i> /2 <i>t</i> /2	6 max. All <i>t</i> /2 <i>t</i> /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> <i>θ</i>	All All 0 See <i>θ</i> 45: <i>DTT</i> = <i>D</i> - 3 60: <i>DTT</i> = <i>D</i>	All <i>F</i> 0 <i>D</i> 60	All See <i>θ</i> 0 <i>D</i> - 3 50 for <i>F</i> , <i>H</i> & <i>OH</i> 60 for <i>V</i>	All <i>F</i> 0 <i>D</i> - 3 50	All See <i>θ</i> 0 <i>D</i> - 3 50 for <i>F</i> , <i>H</i> & <i>OH</i> 60 for <i>V</i>	20 max. All 0 <i>D</i> 60

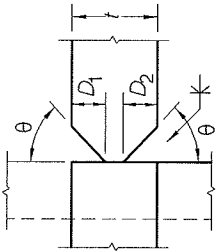
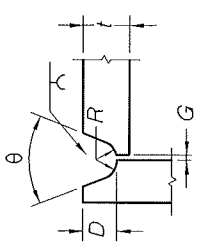
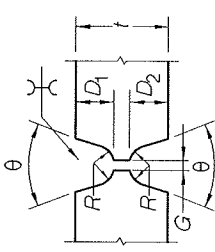
(continued)

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 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 0	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)

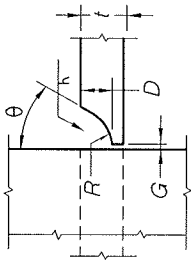
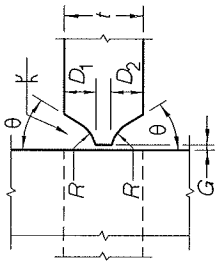
Joint identification	Joint type	Preparation detail (see Notes 2 and 3)	Manual metal-arc	Submerged arc	Flux-cored arc, self-shielded and gas-shielded	Gas metal-arc, spray transfer (see Notes 4 and 5)	Gas metal-arc, short-circuiting arc transfer or pulsed mode	Gas-tungsten arc
B-P 8 T-P 8 C-P 8	Single-J butt weld, T and C joint, welded one side 	t Position G R DTT theta	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 theta	All All 1.5 10 D1 + D2 45	All F 0 12 D1 + D2 20 for B & C joints	All All 0 10 D1 + D2 45	All F & H 0 10 D1 + D2 45	All All 0 10 D1 + D2 45	All All 0 10 D1 + D2 45

TABLE E3
PREQUALIFIED FILLET WELD PREPARATIONS

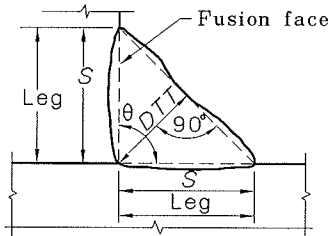
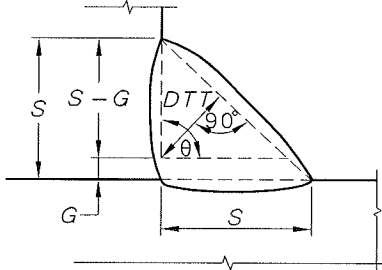
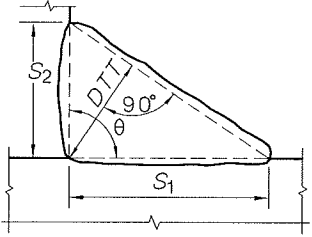
NOTES:

- 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)

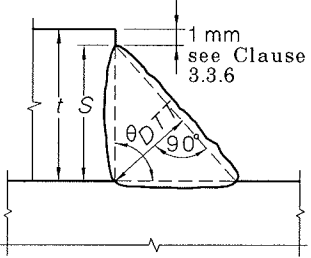
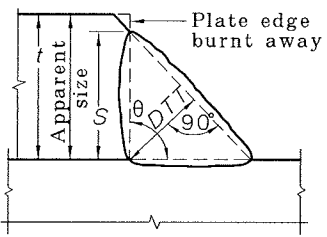
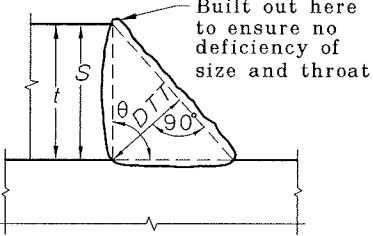
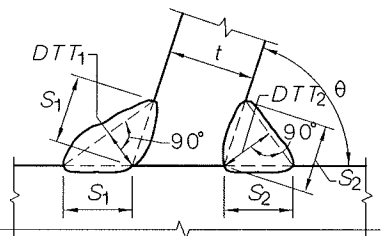
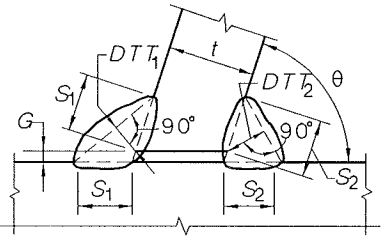
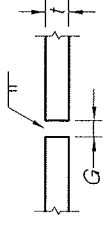
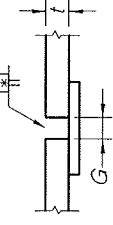
Joint identification	Joint type	Joint description	DTT (see Note 2)
F4		Lap joint with unfused edge— applicable for $t < 6$ $\theta = 90$	$\frac{S}{\sqrt{2}}$
F5		Lap joint with fused edge— applicable for $t < 6$ $\theta = 90$	$\frac{S}{\sqrt{2}}$
F6		Lap joint with build-up edge— applicable to all thicknesses $\theta = 90$	$\frac{S}{\sqrt{2}}$
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

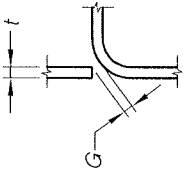
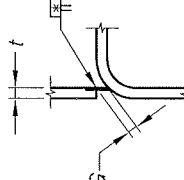
NOTES:

- 1 The notation used is given in Paragraphs E1 to E3.
- 2 The weld preparations in Table E4 are inappropriate for Category FP welds.
- 3 For dimensional tolerances of weld preparations, see Table 5.2.2; except where this Table specifies different tolerances.
- 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 Note 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
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 $1.5t$	

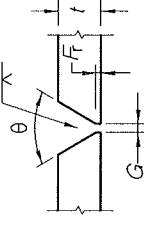
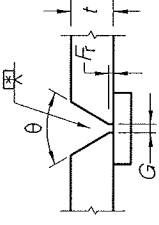
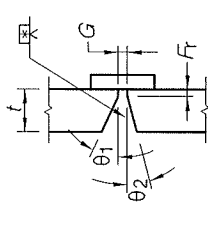
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TABLE E4 (continued)

Joint identification	Joint type	Preparation detail (see Note 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
H-C 1c	Butt weld, equal width brace and chord welded to one side  See Clause 5.2.2 for wide root gaps (<i>G</i>)	<i>t</i> Position <i>G</i>	9 max. F & H 4 mm min.				9 max. F & H 3 mm min.	
H-C 1d	Butt weld, equal width brace and chord welded one side with backing strip  *M or MR	<i>t</i> Position <i>G</i>	9 max. F & H 4 mm min.				9 max. F & H 3 mm min.	

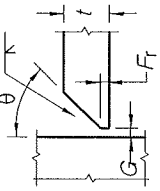
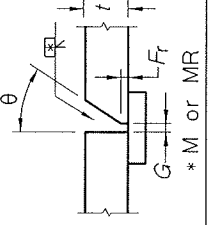
(continued)

TABLE E4 (continued)

Joint identification	Joint type	Preparation detail (see Note 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
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 	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	
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	

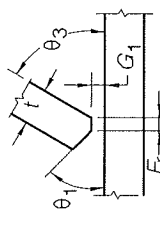
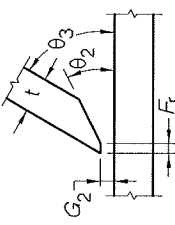
(continued)

TABLE E4 (continued)

Joint identification	Joint type	Preparation detail (see Note 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
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
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	

(continued)

TABLE E4 (continued)

Joint identification	Joint type	Preparation detail (see Note 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
H-C 4c	Butt-welded T-joint, welded one side  (a) Profile for a toe	<i>t</i>	20 max.		20 max.	20 max.	20 max.	
		Position	All		All	F	All	
		<i>G</i>	See 0		See 0	See 0	See 0	
		<i>F_r</i>	0 to 1		0 to 1	0 to 1	0 to 1	
	 (b) Profile for a crotch	<i>0₁</i>	45 min. ≥ 45 ≤ 90: <i>G₁</i> = 2 to 5 > 90: <i>G₁</i> = 0		45 min. ≥ 45 ≤ 90: <i>G₁</i> = 2 to 5 > 90: <i>G₁</i> = 0	45 min. ≥ 45 ≤ 90: <i>G₁</i> = 2 to 5 > 90: <i>G₁</i> = 0	45 min. ≥ 45 ≤ 90: <i>G₁</i> = 2 to 5 > 90: <i>G₁</i> = 0	
		<i>0₂</i>	> 15 ≤ 25: <i>G₂</i> = 5 > 25 ≤ 40: <i>G₂</i> = 3 > 40: <i>G₂</i> = 2		> 15 ≤ 20: <i>G₂</i> = 12 > 20 ≤ 25: <i>G₂</i> = 9 > 25 ≤ 30: <i>G₂</i> = 6 > 30 ≤ 40: <i>G₂</i> = 3	> 15 ≤ 20: <i>G₂</i> = 12 > 20 ≤ 25: <i>G₂</i> = 9 > 25 ≤ 30: <i>G₂</i> = 6 > 30 ≤ 40: <i>G₂</i> = 3	> 15 ≤ 25: <i>G₂</i> = 5 > 25 ≤ 40: <i>G₂</i> = 3 > 40: <i>G₂</i> = 1	
		<i>0₃</i>	30 min.		30 min.	30 min.	30 min.	

NOTES

NOTES

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