AS/NZS 1554.1:2014

(Incorporating Amendment Nos 1 and 2)

AS/NZS 1554.1:2014

Australian/New Zealand Standard™

Structural steel welding

Part 1: Welding of steel structures

STANDARDS Australia

STANDARDS NEW ZEALAND PAEREWA AOTEAROA

AS/NZS 1554.1:2014

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 24 September 2014 and on behalf of the Council of Standards New Zealand on 12 September 2014.
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(Incorporating Amendment Nos 1 and 2)

Australian/New Zealand Standard™

Structural steel welding

Part 1: Welding of steel structures

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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 1554.1:2011.

This Standard incorporates Amendment No. 1 (September 2015) and Amendment No. 2 (September 2017). The changes required by the Amendment are indicated in the text by a marginal bar and amendment number against the clause, note, table, figure or part thereof affected.

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

This edition incorporates the following major changes to the 2011 edition:

(a) *Revision of the following Clauses*:

1.1 (new Note), 2.3.1, 2.3.3, 3.1.2.2 (new), 4.1.1 (Note 2 revised), 4.1.4, 4.2(b) and Note 1, 4.2 (d) (correction), 4.3, 4.5.5.1, 4.5.5.3, 4.6.1.1(e)(iii), 4.6.1.2 (new Note), 4.7.1, 4.7.7, 4.8, 4.12.1, 4.12.2.3, 5.2.4, 5.3.4, 5.3.5 (title), 6.2.2, 6.3.3 (Note added), 6.4.3 (Note added), 6.7 (Note 2 revised), 6.8 (new Note), 7.2(e) (new), F2.2, F4, Appendix H (new).

(b) *Revision of the following Tables*:

4.1.3, 4.6.1(A), 4.6.1(B), 4.6.1(C), 4.6.2, 4.7.1 (Notes 1, 3 and 4 revised), 4.11(A) (item deleted and Item (i) revised), 4.12.2(B) (Note 1), 5.2.4 (new), 5.3.4, 6.2.2, E4 (items renumbered, root gap revised), G1.

(c) *Revision of the following Figures*:

4.5.5.1 (Note 2 and the title revised), 4.5.5.3 (Note 2 revised), 4.5.5.4 (title revised).

This 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.

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

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

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

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SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

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

(a) Manual metal-arc welding (MMAW).

(b) Submerged arc welding (SAW).

(c) Gas metal-arc welding (GMAW or MIG), including pulsed mode.

(d) Gas tungsten-arc welding (GTAW or TIG).

(e) Flux-cored arc welding (FCAW).

(f) Electroslag (including consumable guide) welding (ESW).

(g) Electrogas welding (EGW).

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

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

Welded joints complying with the above Standards are the following:

(i) Those that are not subject to fatigue conditions.

(ii) Those that are subject to fatigue conditions, where—

   (A) the stress range in the welded joint complies with the permissible stress range of stress categories C, D, E or F of AS 3990, or weld categories lower than or equal to detail category 112 of AS 4100 or NZS 3404.1; or

   (B) the stress range in the welded joint is not greater than 80% of the permissible stress range of stress category B of AS 3990.

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

NOTES:

1 Further information on this Standard, is given in WTIA Technical Note 11.

2 GMAW includes waveform controlled welding such as ‘synergic’, ‘programmable’, and ‘microprocessor controlled’ processes (e.g. pulsed spray transfer or controlled short circuit transfer).

1.2 EXCLUSIONS

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

(a) Oxyacetylene welding (OAW).

(b) Friction welding (FW).

(c) Thermit welding (TW).

(d) Resistance welding (RW).

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

This Standard does not apply to underwater welding.

This Standard does not cover the design of welded connections or permissible stresses in welds, or the production, rectification or repair of castings.

NOTES:

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

2 For guidance on underwater welding the user should refer to ISO 15614-10, ISO 15618-1 or ISO 15618-2, as appropriate.

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.

1.4 NORMATIVE REFERENCES

Documents referenced for normative purposes are listed in Appendix A.

NOTE: Documents referenced for informative purposes are listed in the Bibliography.

1.5 DEFINITIONS AND SYMBOLS

1.5.1 Definitions

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

1.5.1.1 *Fabricator*

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

1.5.1.2 *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.

1.5.1.3 *Inspector*

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

1.5.1.4 *May*

Indicates the existence of an option.

1.5.1.5 *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.

1.5.1.6 *Shall*

Indicates that a statement is mandatory.

1.5.1.7 *Should*

Indicates a recommendation.

1.5.2 Symbols

For the purposes of this Standard, the symbols given in AS 1101.3 shall apply.

1.6 WELD CATEGORIES

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

The two weld categories shall be designated as follows:

(a) *GP (general purpose)*—GP to be generally 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 of that category, may be considered as Category GP welds, provided the requirements of the design Standard are satisfied and the principal has agreed.

(b) *SP (structural purpose)*—SP to be generally 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 of the scope of this Standard, as described in Clause 1.1.

1.7 MANAGEMENT OF QUALITY

1.7.1 Quality management

Fabricators shall ensure that all welding and related activities, see Clause 1.7.2, are managed under a suitable quality management system.

Such a system should generally comply with the requirements of AS/NZS ISO 3834 series, particularly where fabrication activities require the approval of the principal or inspecting authority, or where the fabrication of large, complex or critical structures is being undertaken.

1.7.2 Basic welding requirements

The basis of this Standard is that a weld shall—

(a) be made in accordance with a qualified welding procedure;

(b) be carried out by a welder suitably qualified to carry out such a procedure;

(c) be carried out under the supervision of a welding supervisor who is employed by or contracted to the fabricator; and

(d) comply with the appropriate requirements of this Standard.

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

1.8 SAFETY

1.8.1 Safety equipment and procedures

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

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

1.8.2 Welding equipment

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

AS 60974.1, AS 2799, AS/NZS 1995.

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 ISO 31000.

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 500 MPa;

(b) be selected in accordance with the provisions of Appendix B; and

(c) comply with AS 1397, AS 1450, AS 1548, AS 2074, AS/NZS 1163, AS/NZS 1594, AS/NZS 1595, AS/NZS 3678, AS/NZS 3679.1 or AS/NZS 3679.2, as appropriate.

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

With the exception of quenched and tempered steels, parent materials not identified to a Standard nominated in Item (c) above may be used, provided one of the following requirements is 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 certificates 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.

NOTES:

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

2 Impact tests, in addition to those prescribed by the Standards in Item (c) above, may be required to establish compliance with Paragraph B4.3.4, Appendix B.

A1 | **‘Text deleted’**

2.2 BACKING MATERIAL

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

Temporary backing material of any type may be used for welds, provided 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 4855 or AS/NZS 4857, as applicable (see Clause 4.6.1).

Electrodes or filler wires for processes other than manual metal-arc welding shall comply with AS/NZS ISO 14171, AS/NZS 1167.2, AS/NZS 14341, AS/NZS ISO 17632, or ISO 636, 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 or other matter deleterious either to satisfactory operation or to the weld metal. Any coating on the electrodes or filler wires shall be continuous and firmly adherent. Any recommendations of the manufacturer, covering protection during storage and use, conditioning and pretreatment of electrodes or filler wires prior to use, shall be followed.

NOTE: 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/NZS ISO 14174. Where the manufacturer makes specific recommendations covering conditioning and pretreatment 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 shall be such that the flux remains in a satisfactory condition for re-use.

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

2.3.4 Shielding gas

A gas or gas mixture used for shielding during arc welding shall be of a welding grade complying with the requirements of AS 4882, and shall be suitable for the intended application.

SECTION 3 DETAILS OF WELDED CONNECTIONS

3.1 GENERAL

3.1.1 Permissible weld types

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

3.1.2 Design stresses

3.1.2.1 *General*

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 AS 3990, AS 4100 or NZS 3404.1, as applicable. See Appendix D, Item (a).

3.1.2.2 *Parent material through-thickness loading*

Joints whose function is to transmit stress normal to the surface of a connected part, especially when the thickness of the branch member or the required weld size is 20 mm or greater, shall be given special attention during design, parent material selection and detailing (see Appendix H). Joint details that minimize stress intensity on parent materials subject to stress in the through-thickness direction shall be used where practical. Specifying weld sizes larger than necessary shall be avoided.

NOTES:

1 Where stress in the through-thickness direction is unavoidable, it may be necessary to specify parent metal with guaranteed minimum through-thickness tensile properties, i.e. 'Z' steels.

2 Guidance on the avoidance of lamellar tearing is available in Appendix H and WTIA Technical Note 6.

3.1.3 Drawings

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

(a) Specification and grade of the parent metal.

(b) Nominal tensile strength of the weld metal.

(c) Location, type, size of welds, and the effective length of welds.

(d) Whether welds are to be made in the shop or at the site.

(e) Weld category.

(f) Details of non-standard welds.

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

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

3.2.2 Design throat thickness

3.2.2.1 *Complete penetration butt weld*

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

3.2.2.2 *Incomplete penetration butt weld*

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

(a) For prequalified incomplete penetration butt welds, except as otherwise provided in Item (c) below, as shown in Table E2, Appendix E.

(b) For non-prequalified incomplete penetration butt welds, except as provided in Item (c) below—

(i) where $\theta < 60°$, $D - 3$ mm; or

(ii) where $\theta \geq 60°$, 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. See Appendix D, Item (b).

NOTE: Where such penetration is achieved, the size of the weld may be correspondingly reduced.

3.2.3 Effective length

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

3.2.4 Effective area

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

3.2.5 Transition of thickness or width

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

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

Butt-welded T-joints may have a small fillet weld superimposed on each welded face not exceeding the lesser of 6 mm or $t_{thinner}/3$. Larger fillet welds are not permitted unless a compound joint (see Clause 3.4) has been specified by the designer.

3.3 FILLET WELDS

3.3.1 Size of weld

The size of a fillet weld 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 a fillet weld shall be as shown in Table E3, Appendix E.

For deep penetration fillet welds made by fully automatic arc welding processes, provided that it can be demonstrated by means of a macro test on a production weld that the required penetration has been achieved, an increase in design throat thickness shall be allowed as shown in Figure 3.3.2. See Appendix D, Item (b).

NOTE: Where such penetration is achieved, the size of the weld may be correspondingly reduced.

3.3.3 Effective length

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

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

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

3.3.4 Effective area

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

3.3.5 Minimum size of fillet welds

The minimum size of a fillet weld, including the first run of a multi-run fillet weld, other than a fillet weld used to reinforce a butt weld, shall conform to Table 3.3.5 except that the size of the weld do not need to exceed the thickness of the thinner part joined (see also
A2 Clause 5.2.3).

TABLE 3.3.5

MINIMUM SIZE (LEG LENGTH) OF FILLET WELDS

millimetres

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

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

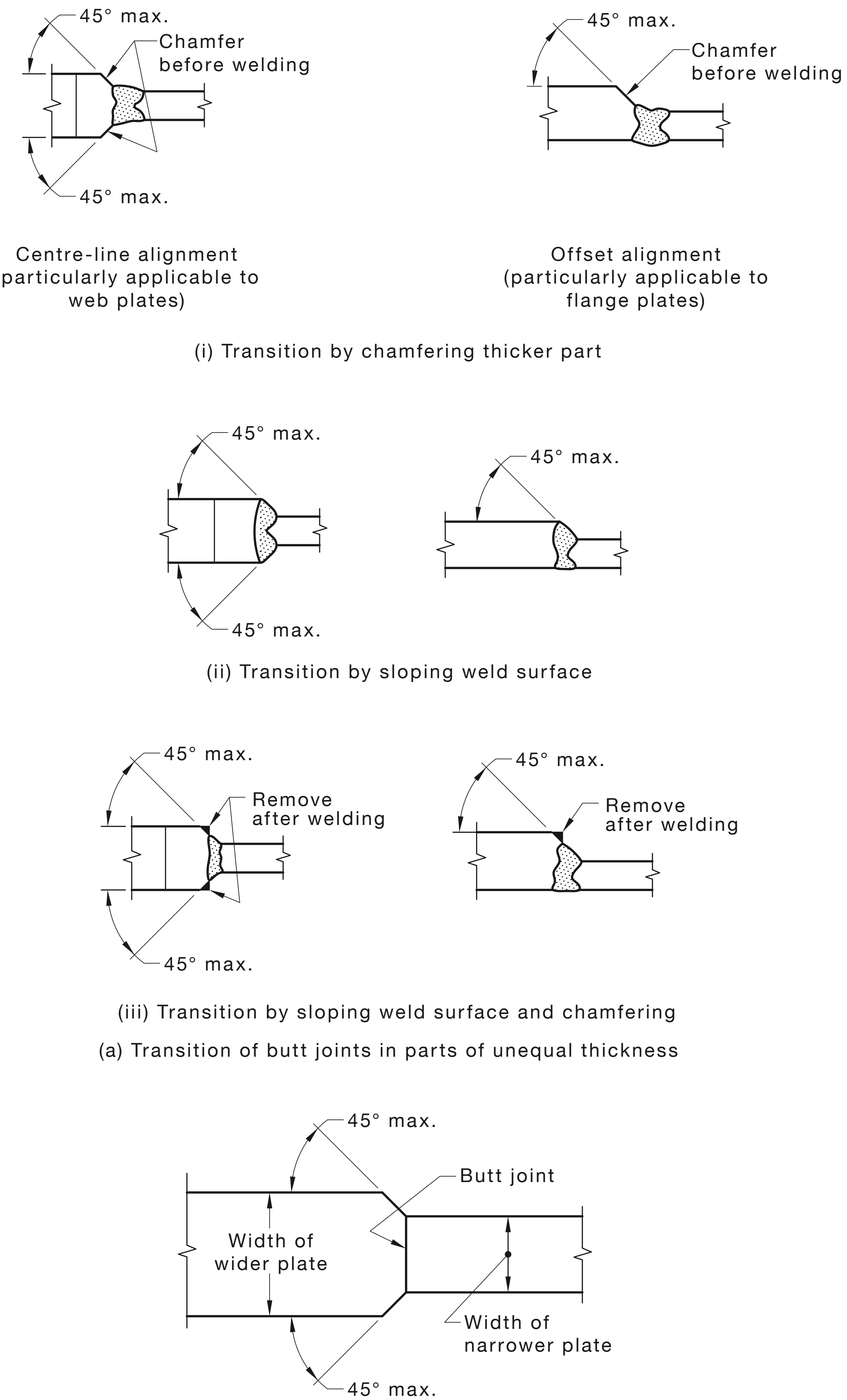
3.3.6 Maximum size of fillet welds along edges

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

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

(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.



(i) Transition by chamfering thicker part

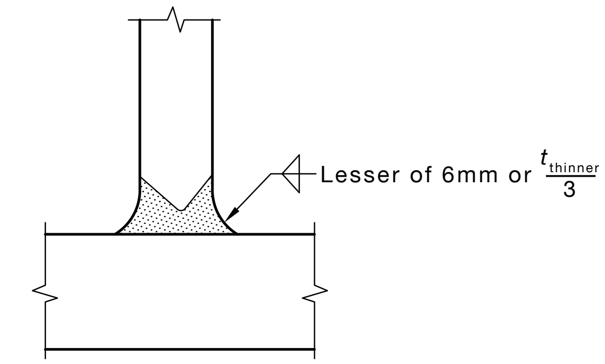
(ii) Transition by sloping weld surface

(iii) Transition by sloping weld surface and chamfering

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

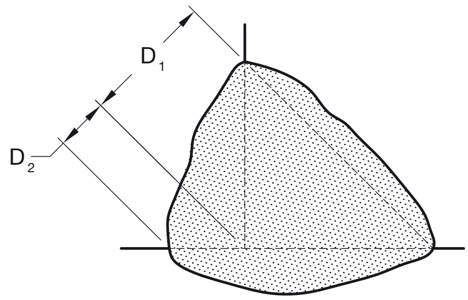
(b) Transition of butt joints in parts of unequal width, by chamfering the wider part

FIGURE 3.2.5 (in part) TRANSITION OF THICKNESSES OR WIDTHS FOR BUTT WELDS SUBJECT TO TENSION



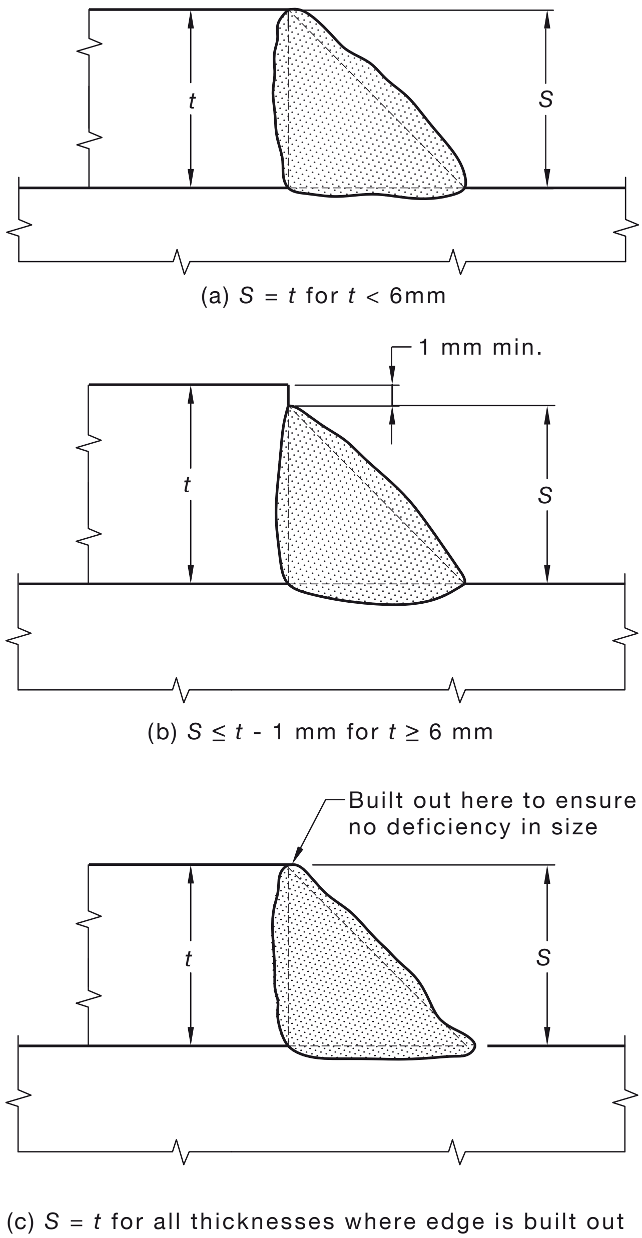
(c) Transition of parts in T-joints

FIGURE 3.2.5 (in part) 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



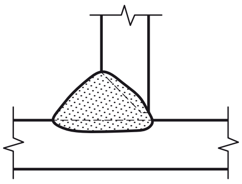
LEGEND:
S = size of fillet weld
t = thickness of part joined

FIGURE 3.3.6 MAXIMUM SIZE OF FILLET WELDS ALONG EDGES

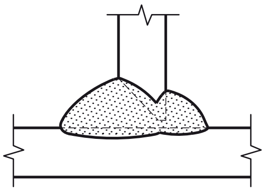
3.4 COMPOUND WELDS

3.4.1 Description

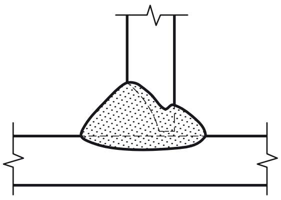
A compound weld is a butt-welded T-joint with a fillet weld superimposed on one or both faces. Details of typical compound welds are shown in Figure 3.4.1.



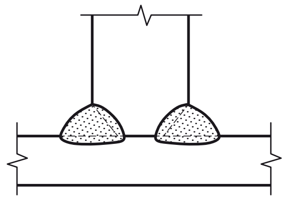
(a) Fillet weld superimposed on single bevel butt-welded T-joint



(b) Fillet weld superimposed on single bevel butt-welded T-joint with an additional fillet weld on the root side



(c) Fillet weld superimposed on single J-butt-welded T-joint with an additional fillet weld on the root side



(d) Fillet weld superimposed on incomplete penetration bevel weld

FIGURE 3.4.1 COMPOUND WELDS

3.4.2 Design throat thickness (*DTT*)

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

The *DTT* of compound welds with complete penetration welds in the T-joint shall be the thickness of the part that butts against the face of the other part.

3.4.2.2 *Compound welds with incomplete penetration welds*

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

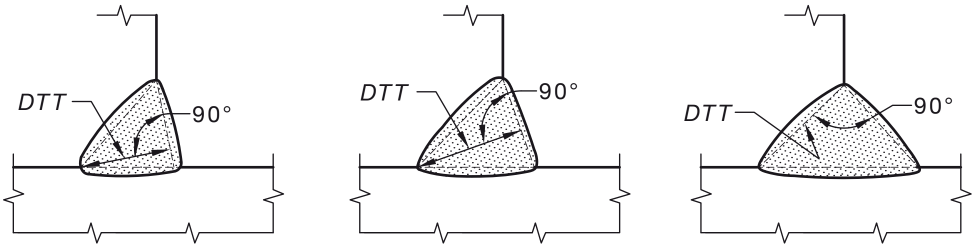


FIGURE 3.4.2.2 DESIGN THROAT THICKNESS OF COMPOUND WELDS WITH INCOMPLETE PENETRATION WELDS

3.5 SEAL WELDS

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

Seal welds shall be made in accordance with a qualified welding procedure. See Appendix D, Item (c).

NOTE: Where seal welding is required, Clause 3.1.3 specifies that the procedure be specified clearly on the drawings or other documents.

3.6 PLUG WELDS

The diameter of the hole for a plug weld shall be as follows:

(a) Not less than the sum of 8 mm plus the thickness of the part containing the hole.

(b) Not more than the greater of—

  (i) the sum of 11 mm plus the thickness of the part containing the hole; and

  (ii) 2.25 times the thickness of the member.

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

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

The depth of the filling of plug welds shall be as set out in Table 3.6.

TABLE 3.6

DEPTH OF FILLING OF PLUG WELDS

Material thickness (t) mm	Depth of filling mm
≤16	T
>16 ≤32	≥16
>32	≥t/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; and

  (ii) 2.25 times the thickness of the member.

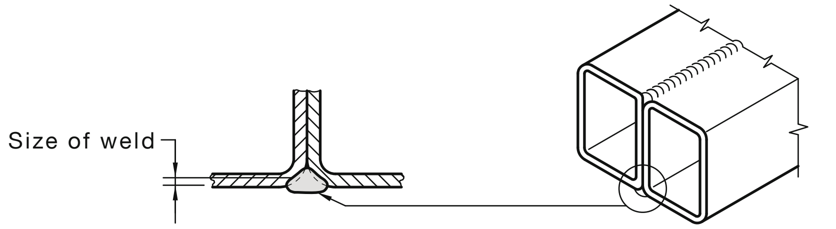
The ends of the slot shall be semicircular or shall have the corners rounded to a radius of not less than the thickness of the part containing it, except for those ends that extend to the edge of the part.

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

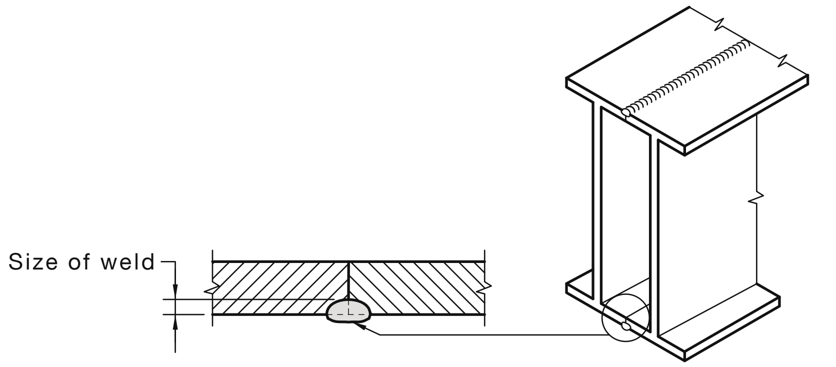
The effective area of a slot weld shall be as for a fillet weld of the same size and effective length. Where a slot weld is made by completely or partially filling the slot (i.e. not made with a fillet weld around the perimeter of the slot), the effective area shall be as for plug welds (see Clause 3.6).

3.8 COMBINING STEEL SECTIONS

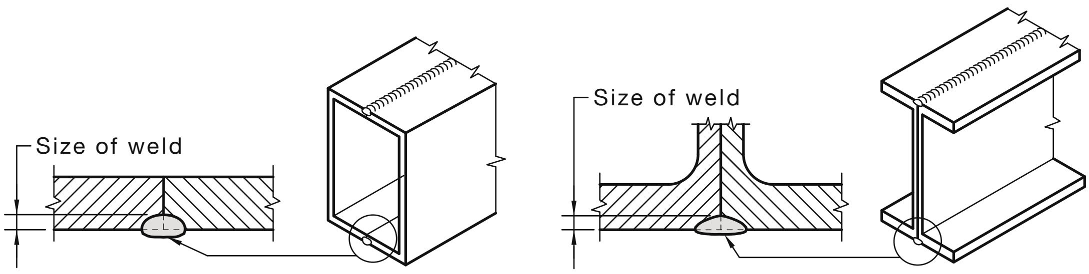
The size of welds made for the purpose of combining steel sections to form composite members (see Figure 3.8) shall be not less than 3 mm.



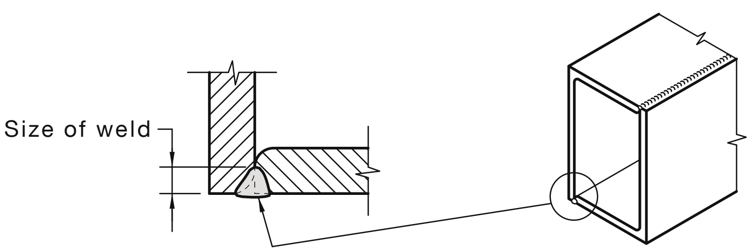
(a) Hollow sections



(b) Beams or columns



(c) Channels



(d) Angles

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

SECTION 4 QUALIFICATION OF PROCEDURES AND PERSONNEL

4.1 QUALIFICATION OF WELDING PROCEDURE

4.1.1 General

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

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

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

The welding 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 for PQR and WPS welding procedure sheets are shown in Appendix C.

2 For New Zealand, where the specification requires fabrication to NZS 3404.1 the welding procedures are required to be 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 apply:

(a) For welding processes MMAW, SAW, GMAW, GTAW and FCAW, a procedure qualification of a butt weld that has been welded from only the one side on a single-V or a single-U preparation shall qualify for single-sided butt welds in both plate and pipe.

(b) A procedure qualification for any prequalified butt-welded joint listed in Table E1, E2 or E4, Appendix E, shall qualify all other welding positions listed for that joint and angle of preparation (θ) used without further testing. A change in welding direction between vertical 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 bevel butt weld that has been welded from only the one side shall qualify for welding a double bevel butt weld and a single bevel butt weld that has been welded on both sides.

(e) 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.

(f) A procedure qualification on a single-J butt weld that has been welded from only the one side shall qualify for welding a double-J butt weld and a single-J butt weld that has been welded on both sides.

(g) 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.

(h) A procedure qualification on a double bevel butt weld shall also qualify for welding a single bevel butt weld that has been welded on both sides.

(i) 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.

(j) A procedure qualification on a double-J butt weld shall also qualify for welding a single-J butt weld that has been welded on both sides.

(k) 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.

   (iii) For T butt joints between non-equal thickness members, the thickness limitation applicable to the prepared member abutting the non-prepared member shall apply.

   NOTE: When applying these thickness limitations, an adjustment to the minimum preheat temperature may be required (see Clause 5.3.4).

4.1.3 Fillet welds

For fillet welds, the following apply:

(a) The procedure qualification of a fillet weld using processes on either plate or pipe shall qualify for fillet welds on both plate and pipe.

(b) The procedure qualification of a fillet weld shall be based on the fillet weld size (leg length), not material thicknesses, as follows:

   (i) For a single-run fillet weld, qualification shall cover the size of the fillet used for the qualification test and all single-run fillets below the size qualified for the positions shown in Table 4.1.3.

   (ii) For multi-run fillets, qualification shall cover the size of the fillet used for qualification and all larger multi-run fillets for the positions shown in Table 4.1.3. When applying this qualification for single-run and multi-run fillets, consideration shall be given to the pre-heat requirements for combined thicknesses of T1, T2 and T3, and the pre-heat requirements for the combined thicknesses shall be shown on the welding procedure specification (WPS) and on the procedure qualification record (PQR).

(c) A change in welding direction between vertical up and vertical down shall require separate qualification.

   NOTE: Single-run and multi-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
PA or 1F (flat)	PA or 1F only
PB, PC or 2F (horizontal)	PA, PB, PC, PD, PE, 1F, 2F and 4F (overhead)
PF, PG or 3F (vertical)	PF, PG or 3F in direction of welding only
PD, PE or 4F (overhead)	PA, PB, PC, PD, PE, 1F, 2F and 4F

NOTE: Welding positions are defined in AS 3545.

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 H-L045 (5G) or J-L045 (6G) fixed position.

4.2 METHODS FOR QUALIFYING A WELDING PROCEDURE

A welding procedure shall be qualified [see Appendix D, Items (d) and (e)] 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. A completed welding procedure sheet (WPS), together with records of tests carried out constitutes documentary evidence of prior experience. All WPSs shall meet the requirements of essential variables of AS/NZS 1554.1. The following are deemed to comply with this requirement:

  (i) Procedure qualifications established in accordance with this and previous editions of this Standard.

  (ii) Qualifications and evidence of successful usage of procedures qualified in accordance with other application Standards (e.g. AS/NZS 3992) provided that the parent materials comply with Appendix B, were welded with consumables complying with Clause 2.3, and the level of imperfections complies with Clause 6.2.

  NOTES:

  1 A sample WPS is shown in Appendix C.

  2 Evidence of compliance with Clause 6.2 can be established via records of non-destructive examinations of a volumetric nature.

  3 Due to changes in the welding consumable classifications systems used in Australia and New Zealand, reference should be made to Appendix F for guidance on the extension of weld procedure qualification. Weld procedures qualified using consumables classified under the former systems remain valid and may continue to be used without further qualification where consumable equivalence can be established.

(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.

  NOTE: 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 preparation, 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

4.3.1 Complying conditions

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 Clauses 4.3.2 and 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 and Table 4.7.1, 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: For the purpose of this requirement, a digital or scanned image is considered to be the equivalent of a photograph.

4.3.2 Non-complying conditions

Welding procedures utilizing self-shielded flux-cored consumables in combination with other consumable types shall be deemed non-compliant with Clause 4.6 and require qualification (see Clause 4.7).

4.4 PORTABILITY OF QUALIFIED WELDING PROCEDURES

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

(a) the original qualification tests were carried out in accordance with this Standard or other acceptable national or international Standards, and were fully documented;

(b) the second fabricator has adequate equipment and facilities and demonstrates successful welding of welder qualification tests or a macro test using the procedure;

(c) the application of the welding procedure is acceptable to both fabricators and the 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 that are used comply with the recommendations of the consumables manufacturer.

4.5.2 Prequalified complete penetration butt welds

Joint preparations for prequalified complete penetration butt welds conforming to a preparation listed in Table E1, Appendix E, shall be deemed prequalified. Provided 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 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/NZS 1163 or AS 1450, and in addition complying with one of the processes specified in Table E4, Appendix E.

Typical joint preparations for connections butt-welded from one side are shown in Figure 4.5.5.1(A) for circular and unequal-width rectangular hollow sections and in Figure 4.5.5.1(B) for equal-width rectangular hollow sections.

The connections shown in Figure 4.5.5.1(B) shall be deemed prequalified for all appropriate processes.

4.5.5.2 *Fillet welds*

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

4.5.5.3 *Combination of fillet and butt welds*

Joint preparations for combinations of fillet welds and butt welds, complying with the details shown in Figure 4.5.5.3 for circular and unequal-width rectangular hollow sections and Figure 4.5.5.1(B) for equal-width rectangular hollow sections, shall be deemed prequalified for all processes, provided the joint preparations for butt welds conform to Table E1 or E2 or E4, Appendix E, as applicable.

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* as follows:

(i) Where the end of the section is not flattened and the sections intersect at an angle of less than 30°, the welding procedure shall be qualified in accordance with Clause 4.2 before welding commences.

(ii) Where the end of the section is not flattened and the sections intersect at an angle of 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 the application of Item (a)(ii), the diameter of the flattened portion of the section shall be measured in a plane perpendicular to the axis of the main section, the plane being taken at the point of intersection of the axis of the branch section with the surface of the main section.

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

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

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

(a) *Angle of intersection not less than 30°* 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:

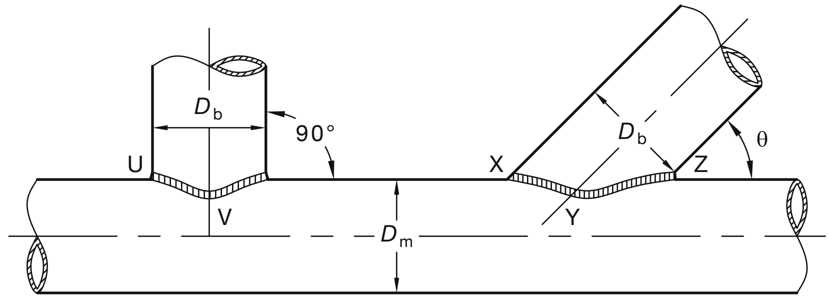
(i) A butt weld shall be used throughout.

(ii) A fillet weld shall be used throughout.

(iii) A combination of fillet and butt welds shall be used throughout.

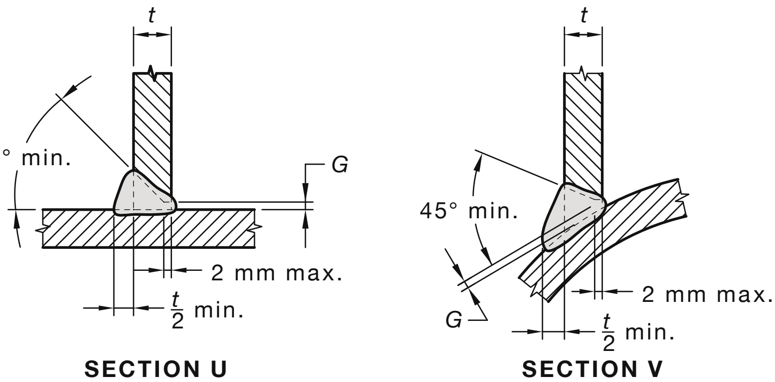
(b) *Angle of intersection less than 30°* Where the end of a rectangular hollow section member is welded to the surface of another rectangular hollow section member of greater width, with the axes of the members intersecting at an angle of less than 30°, the welding procedure shall be qualified in accordance 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.

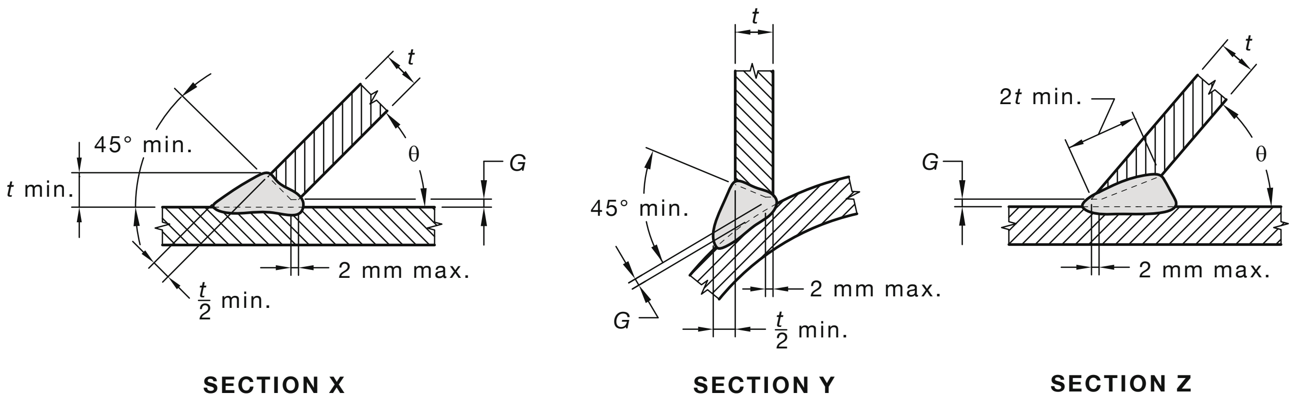


NOTE: Any value of D_b / D_m is permissible.

(a) Butt-welded connections



(b) Butt-welded right-angled connections



(c) Butt-welded acute-angled connections

NOTES:

1 $\theta \geq 30°$.

2 The values for width of root gap (G) shall be established using suitable weld procedure qualifications tests.

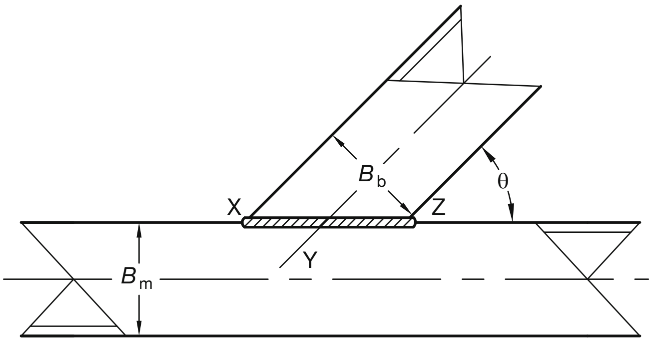
3 These sections, as drawn, apply to circular hollow sections.

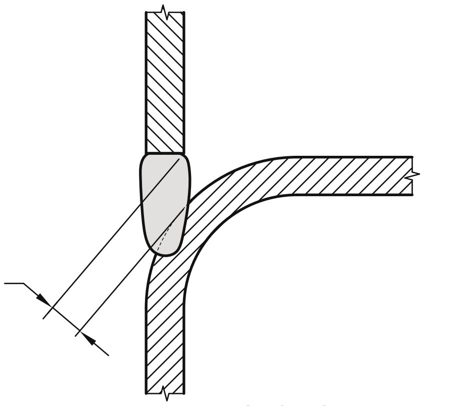
4 Only Sections U, X and Z apply to unequal-width rectangular hollow sections.

5 For Section Y, see Figure 4.5.5.1(B) 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(A) TYPICAL BUTT WELDS FOR CIRCULAR AND UNEQUAL-WIDTH RECTANGULAR HOLLOW SECTIONS





NOTES:

1 $\theta \geq 30°$.

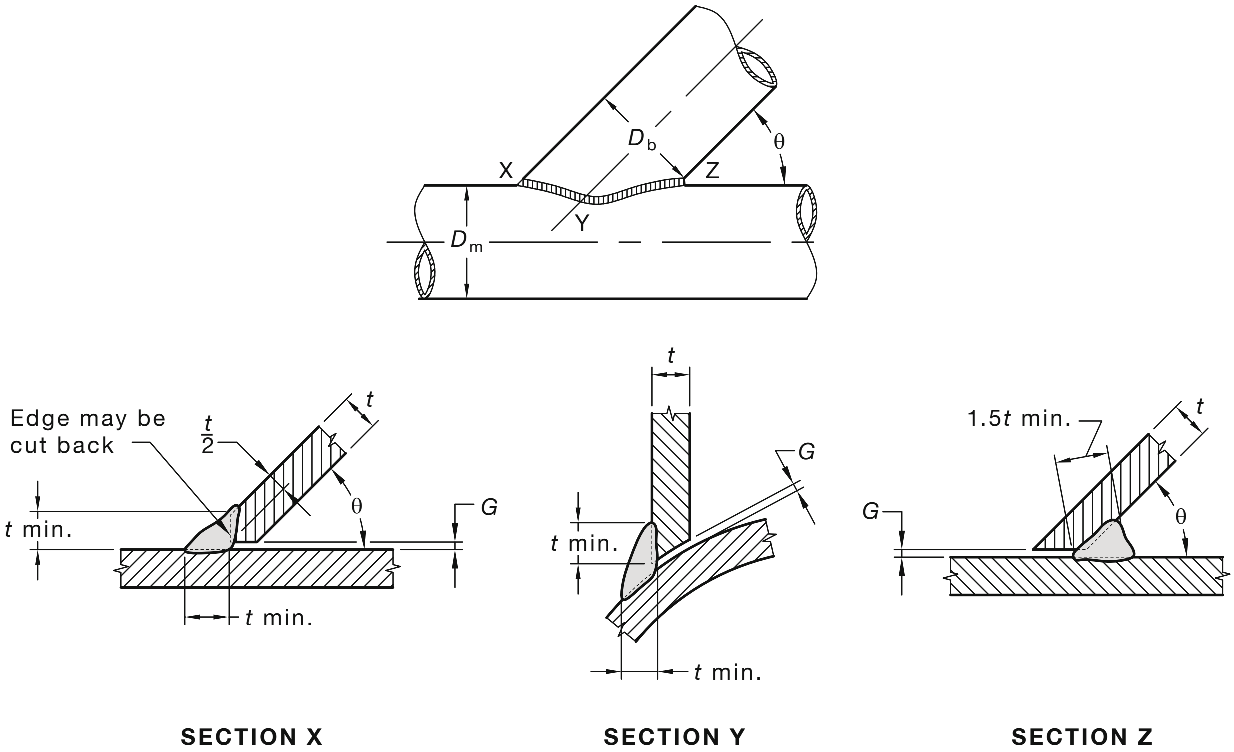
2 The values for width of root gap (G) are given in Table E4, Appendix E.

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(A) and 4.5.5.2.

5 For unequal-width rectangular hollow sections, see Figure 4.5.5.1(A).

FIGURE 4.5.5.1(B) PREQUALIFIED BUTT WELDS FOR EQUAL-WIDTH RECTANGULAR HOLLOW SECTIONS



NOTES:

1 $\theta \geq 30°$.

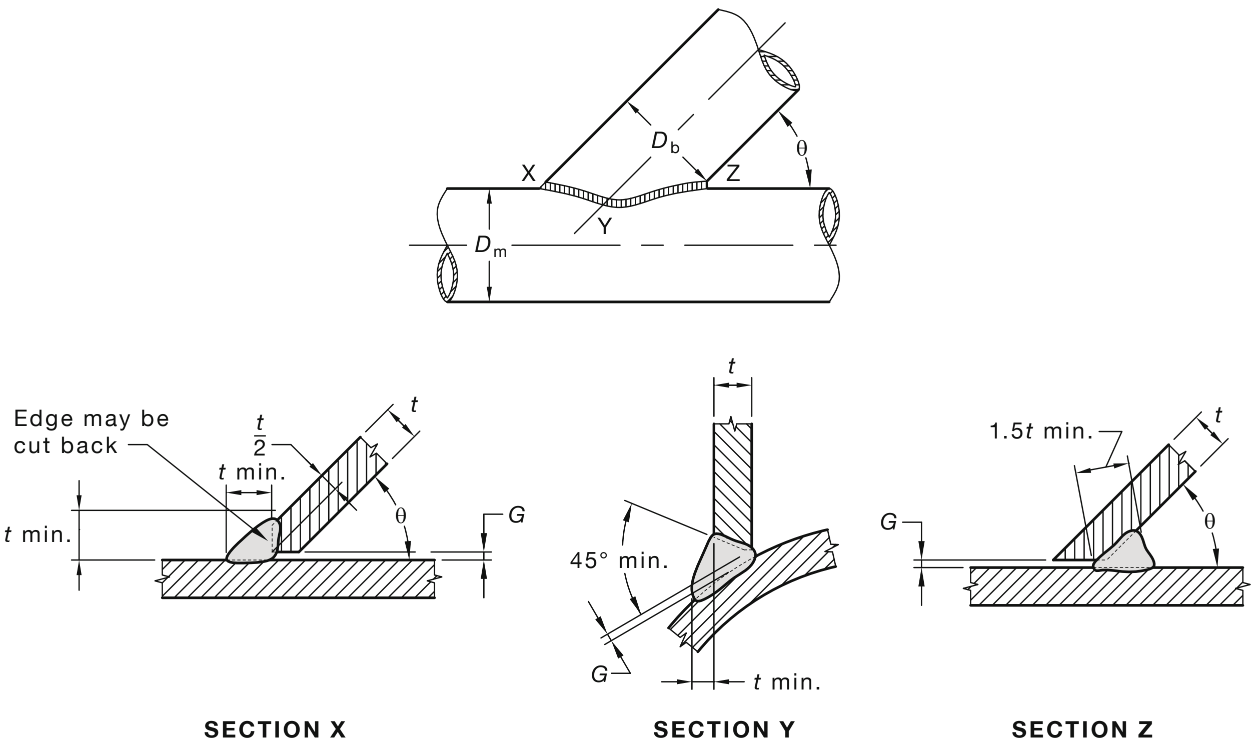
2 The values for width of root gap (*G*) are given in Table E3, Appendix E.

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 4.5.5.1(B) for equal-width rectangular hollow sections [see Clause 4.5.5.5(c)].

FIGURE 4.5.5.2 PREQUALIFIED FILLET WELDS



NOTES:

1 $\theta \geq 30°$.

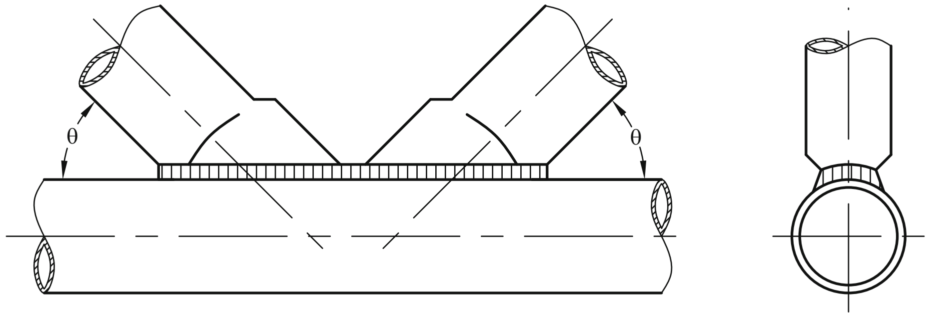
2 The values for width of root gap (*G*) are given in Table E4, Appendix E.

3 These sections apply to circular hollow sections.

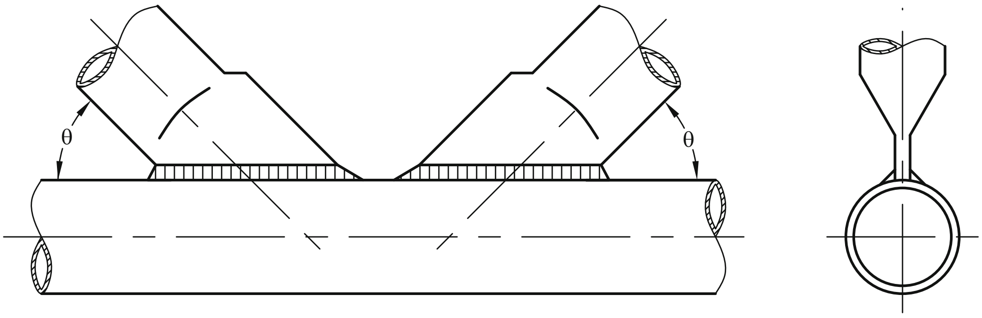
4 Only Sections X and Z apply to unequal-width rectangular hollow sections.

5 These details may not apply to equal-width rectangular hollow sections [see Clause 4.5.5.5(c)].

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



(a) Partially flattened member



(b) Fully flattened member

FIGURE 4.5.5.4 FLATTENED CIRCULAR HOLLOW SECTION JOINTS

4.6 QUALIFICATION OF WELDING CONSUMABLES

4.6.1 Prequalified welding consumables

4.6.1.1 *General*

Welding consumables shall be matched with the steel type in compliance with Table 4.6.1(A) and used within the welding parameter ranges specified by the manufacturer. See Appendix D, Item (f). In addition, the impact test temperature of the consumables (as specified in the relevant Standard for the consumables) shall not be warmer than the design service temperature (see Paragraph B3, Appendix B).

Where welding consumables meet the above requirements and comply with one of the following relevant requirements, they shall be deemed prequalified and require no qualification testing:

(a) Electrodes for manual metal-arc welding conform to Column 2 of Table 4.6.1(A).

(b) Consumables for submerged arc and flux-cored arc welding conform to Columns 3 and 4 of Table 4.6.1(A), provided that for L0 grade steels the maximum arc energy is limited to 5 kJ/mm and for L15, L20, L40, L50, Y20, or Y40 grade steels the maximum arc energy is limited to 2.5 kJ/mm.

(c) Consumables for gas metal-arc welding conform to Column 5 of Table 4.6.1(A).

(d) Consumables for gas-tungsten arc welding conform to Column 6 of Table 4.6.1(A).

(e) Consumables for automatic and semi-automatic processes (submerged arc, flux-cored arc, gas metal-arc) have Lloyds' or other ship classification societies' approval as shown in Columns 7, 8 and 9 of Table 4.6.1(A), with the following limitations regarding arc energy:

  (i) Consumables with S, M or SM grading—

    (A) for multi-run butt welds or any fillet weld in L0 grade steel, 5 kJ/mm max.; or

    (B) for multi-run butt welds or any fillet weld in L15, L20, L40, L50, Y20 or Y40 grade steels, 2.5 kJ/mm max.

  (ii) Consumables with T grading, no limitation on arc energy for single-run or two-run technique.

  (iii) Consumables with both T grading and M grading (i.e. TM grading), no limitation on arc energy for single-run or multi-run technique.

Where a consumable is not prequalified in accordance with Items (a), (b), (c) (d) or (e) above, but the fabricator can produce relevant data, properly documented, 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 qualified for that procedure [see Clause 4.2(b)].

4.6.1.2 *Weather-resistant steels*

For applications of weather-resistant steels listed in Table 4.6.1(C), where the weld metal is required to have the characteristics of resistance to atmospheric corrosion and colouring similar to those of the parent material, the following consumables shall be deemed prequalified:

(a) For single-run fillet welds and butt welds made with a single run or a single run each side and where the welds are made with no weave, welding consumables selected in accordance with Table 4.6.1(A).

(b) For single-run fillet welds and butt welds made with a single run or a single run each side and where weaving is used during the run, welding consumables selected in accordance with Table 4.6.1(C).

(c) For capping runs on multi-run fillet or butt welds, welding consumables selected in accordance with Table 4.6.1(C).

(d) For runs other than capping runs on multi-run fillet or butt welds, welding consumables selected in accordance with Table 4.6.1(A).

NOTE: Guidance on the selection of welding consumables suitable for weathering steel not listed in Table 4.6.1(C) should be sought from the steel manufacturer.

4.6.1.3 *Consumables for designated seismic service*

Welding consumables used to weld S0 steels in designated seismic service meeting all of the following are deemed prequalified:

(a) The welding consumable shall be selected in accordance with Table 4.6.1(A).

(b) The consumable shall comply with the requirements of Clause 4.6.1.1.

(c) The design service temperature shall be warmer than −10°C.

(d) The welding consumable shall have a limitation of 2.5 kJ/mm for maximum arc energy.

(e) The welding consumable shall have a maximum inter-run temperature limit of 300°C.

TABLE 4.6.1(A)

PREQUALIFIED WELDING CONSUMABLES (see Notes 1 to 9)

1	2	3	4	5	6	7	8	9
Steel type [see Table 4.6.1(B)]	**Manual metal-arc (AS/NZS 4855)**	**Submerged arc (AS/NZS ISO 14171)**	**Flux-cored arc (AS/NZS ISO 17632)**	**Gas metal arc (AS/NZS 14341)**	**Gas tungsten arc (AS/NZS 1167.2) (ISO 636)**	**Ship classification societies' approval**		
	Classification					**S, M or SM Grade multi-run**	**T Grade two-run**	**TM Grade two-run and multi-run**
1	A-E35 0 B-E4303 U A-E38 0 B-E4310 A-E42 0 B-E4311 B-E43X6 U B-E43X8 U B-E4319 U B-E4340 U B-E4910-P1 B-E49X5 U B-E49X6 U B-E49X8 U B-E4919 U B-E4924-1 U B-E4903 U	A-S 35 0 A-S 38 0 A-S 42 0 B-S430U B-S490U	A-T35 0 A-T38 0 A-T42 0 B-T430U B-T490U	A-G35 0 A-G38 0 A-G42 0 B-G43 0U B-G49 0U	R1 A-W35 0 A-W38 0 A-W42 0 B-W43 0U B-W49 0U	1M 1S 1SM	1T	1TM
2	A-E35 2 B-E4310 A-E38 2 B-E4311 A-E42 2 B-E43X6 U B-E43X8 U B-E4319 U B-E4910-P1 B-E49X5 U B-E49X6 U B-E49X8 U B-E4919 U B-E4924-1 U	A-S 35 2 A-S 38 2 A-S 42 2 B-S432U B-S492U	A-T35 2 A-T38 2 A-T42 2 B-T432U B-T492U	A-G35 2 A-G38 2 A-G42 2 B-G43 2U B-G49 2U	A-W35 2 A-W38 2 A-W42 2 B-W43 2U B-W49 2U	2M 2S 2SM	2T	2TM

(*continued*)

TABLE 4.6.1(A) (*continued*)

1	2	3	4	5	6	7	8	9
Steel type [see Table 4.6.1(B)]	**Manual metal-arc (AS/NZS 4855)**	**Submerged arc (AS/NZS ISO 14171)**	**Flux-cored arc (AS/NZS ISO 17632)**	**Gas metal arc (AS/NZS 14341)**	**Gas tungsten arc (AS/NZS 1167.2) (ISO 636)**	**Ship classification societies' approval**		
2S	A-E35 3 B-E43X6 U A-E38 3 B-E43X8 U A-E42 3 B-E49X5 U B-E49X6 U B-E49X8 U	A-S 35 3 A-S 38 3 A-S 42 3 B-S433U B-S493U	A-T35 3 A-T38 3 A-T42 3 B-T433U B-T493U	A-G35 3 A-G38 3 A-G42 3 B-G43 3U B-G49 3U	A-W35 3 A-W38 3 A-W42 3 B-W43 3U B-W49 3U	3M 3S 3SM	3T	3TM
3	A-E35 3 B-E4310 U A-E38 3 B-E4311 U A-E42 3 B-E43X6 U B-E43X8 U B-E4910-P1 B-E49X5 U B-E49X6 U B-E49X8 U	A-S 35 3 A-S 38 3 A-S 42 3 B-S433U B-S493U	A-T35 3 A-T38 3 A-T42 3 B-T433U B-T493U	A-G35 3 A-G38 3 A-G42 3 B-G43 3U B-G49 3U	A-W35 3 A-W38 3 A-W42 3 B-W43 3U B-W49 3U	3M 3S 3SM	3T	3TM
4	A-E35 0 B-E4303 U A-E38 0 B-E43X6 U A-E42 0 B-E43X8 U B-E4319 U B-E4340 U B-E4910-P1 B-E49X5 U B-E49X6 U B-E49X8 U B-E4919 U B-E4924-1 U B-E4903 U	A-S 35 0 A-S 38 0 A-S 42 0 B-S430U B-S490U	A-T35 0 A-T38 0 A-T42 0 B-T430U B-T490U	A-G35 0 A-G38 0 A-G42 0 B-G43 0U B-G49 0U	A-W35 0 A-W38 0 A-W42 0 B-W43 0U B-W49 0U	1YM 1YSM 1YS	1YT	1YTM

(*continued*)

TABLE 4.6.1(A) (*continued*)

1	2	3	4	5	6	7	8	9
Steel type [see Table 4.6.1(B)]	**Manual metal-arc (AS/NZS 4855)**	**Submerged arc (AS/NZS ISO 14171)**	**Flux-cored arc (AS/NZS ISO 17632)**	**Gas metal arc (AS/NZS 14341)**	**Gas tungsten arc (AS/NZS 1167.2) (ISO 636)**	**Ship classification societies' approval**		
5	A-E35 2 B-E43X6 U A-E38 2 B-E43X8 U A-E42 2 B-E4319 U B-E4910-P1 B-E49X5 U B-E49X6 U B-E49X8 U B-E4919 U B-E4924-1 U	A-S 35 2 A-S 38 2 A-S 42 2 B-S432U B-S492U	A-T35 2 A-T38 2 A-T42 2 B-T432U B-T492U	A-G35 2 A-G38 2 A-G42 2 B-G43 2U B-G49 2U	A-W35 2 A-W38 2 A-W42 2 B-W43 2U B-W49 2U	2YM 2YSM 2YS	2YT	2YTM
5S	A-F35 3 B-E43X6 U A-E38 3 B-E43X8 U A-E42 3 B-E49X5 U B-E49X6 U B-E49X8 U	A-S 35 3 A-S 38 3 A-S 42 3 B-S433U B-S493U	A-T35 3 A-T38 3 A-T42 3 B-T433U B-T493U	A-G35 3 A-G38 3 A-G42 3 B-G43 3U B-G49 3U	A-W35 3 A-W38 3 A-W42 3 B-W43 3U B-W49 3U	3YM 3YSM 3YS	3YT	3YTM
6	A-E35 3 B-E43X6 U A-E38 3 B-E43X8 U A-E42 3 B-E4910-P1 B-E49X5 U B-E49X6 U B-E49X8 U	A-S 35 3 A-S 38 3 A-S 42 3 B-S433U B-S493U	A-T35 3 A-T38 3 A-T42 3 B-T433U B-T493U	A-G35 3 A-G38 3 A-G42 3 B-G43 3U B-G49 3U	A-W35 3 A-W38 3 A-W42 3 B-W43 3U B-W49 3U	3YM 3YSM 3YS	3YT	3YTM
7A	A-E42 0 B-E49X5 U A-E46 0 B-E49X6 U B-E49X8 U B-E4919 U B-E4924-1 U B-E4924-1 U	A-S 42 0 A-S 46 0 B-S490U	A-T42 0 A-T46 0 B-T490U	A-G42 0 A-G46 0 B-G49 0U	A-W42 0 A-W46 0 B-W49 0U	1YM 1YSM 1YS	1YT	1YTM
7B	A-E42 2 B-E49X5 U A-E46 2 B-E49X6 U B-E49X8 U B-E4919 U B-E4924-1 U	A-S 42 2 A-S 46 2 B-S492U	A-T42 2 A-T46 2 B-T492U	A-G42 2 A-G46 2 B-G49 2U	A-W42 2 A-W46 2 B-W49 2U	2YM 2YSM 2YS	2YT	2YTM

(*continued*)

TABLE 4.6.1(A) (*continued*)

1	2		3	4	5	6	7	8	9
Steel type [see Table 4.6.1(B)]	**Manual metal-arc (AS/NZS 4855)**		**Submerged arc (AS/NZS ISO 14171)**	**Flux-cored arc (AS/NZS ISO 17632)**	**Gas metal arc (AS/NZS 14341)**	**Gas tungsten arc (AS/NZS 1167.2) (ISO 636)**	**Ship classification societies' approval**		
7C	A-E42 3 A-E46 3	B-E49X5 U B-E49X6 U B-E49X8 U	A-S 42 3 A-S 46 3 B-S493U	A-T42 3 A-T46 3 B-T493U	A-G42 3 A-G46 3 B-G49 3U	A-W42 3 A-W46 3 B-W49 3U	3YM 3YSM 3YS	3YT	3YTM
8C	A-E50 3	B-E55X6 U B-E55X8 U (Note 7)	A-S 50 3 B-S553U B-S573U (see Note 9)	A-T50 3 B-T553U B-T573U	A-G50 3 B-G55 3U B-G57 3U	B-W55 3U B-W57 3U	—	—	—

NOTES:

1 The allocation of steel type numbers to particular steels is given in Table 4.6.1(B).

2 Consumables with a higher impact grading than that shown are also acceptable.

3 The letter 'X' represents the positional indicator of the flux covering.

4 Rutile consumables (B-E4312, B4313, B-E4912, B-E4913) meeting Ship Classification Society Grade 2 or 2Y are deemed prequalified for steel types 1, 2, 4 and 5.

5 Consumables are prequalified for use with weathering steels (WR, HW) of AS/NZS 1594, AS/NZS 3678, AS/NZS 3679.1 and AS/NZS 3679.2 where similar weathering properties are not required. Where matching weathering properties are required, refer to Table 4.6.1(C).

6 For steel types 4, 5 and 6 (except steel to AS/NZS 3678—400), consumables of the A-E35, B-E43XX, A-S35, B-S43, A-T35, B-T43, A-G35, B-G43, A-W35 or B-W43 type will equal or exceed the specified minimum yield strength of the material and will usually give a tensile strength of not less than 95% of the specified tensile strength of the parent material. For steel to AS/NZS 3678—400, consumables of the A-E35, B-E43XX, A-S35, B-S43, A-T35, B-T43, A-G35, B-G43, A-W35 or B-W43 type shall require qualification.

7 For steel types 7A, 7B, and 7C, the consumables listed will generally equal or exceed the specific minimum yield strength of the parent material and will usually give a tensile strength of not less than 95% of the specified tensile strength. If matching or over-matching strength is required, consumables prequalified for steel type 8C are prequalified for use on steel type 7A, 7B and 7C.

8 For steel type 8C, consumables complying with AS/NZS 4857 classifications A-E55 3, B-E55XX U and B-E62XX U with guaranteed impact properties at -30°C or colder are prequalified.

9 AS/NZS ISO 26304 classifications: B-SU593U and B-SU623U with guaranteed impact properties at –30°C or colder are also prequalified.

TABLE 4.6.1(B)

ASSOCIATION OF STEEL TYPE NUMBERS TO AUSTRALIAN AND NEW ZEALAND STEELS

Steel type	Specification and grade of parent steel								
	AS/NZS 1163	**AS 1397**	**AS 1450**	**AS 1548**	**AS/NZS 1594**	**AS/NZS 1595**	**AS 2074**	**AS/NZS 3678 AS/NZS 3679.2**	**AS/NZS 3679.1**
1	C250	G250 G300	C200 H200 C250 H250	PT430 PT460	HA1 HA3 HA4N HA200 HA250 HA250/1 HU250 HA300 HA300/1 HU300 HU300/1 HA1016 HA1010 HA1016 HXA1016	CA1010 CA60T CA70T CA85T CA1 CA2 CA3 CA4 CA5SN CA220 CA260 CW300	C2 C3 C4-1 C7A-1	200 250 300 A1006 XK1016	300
2	C250L0	—	—	PT430L0 PT460L0	—	—	—	—	300L0
2S	—	—	—	—	—	—	—	250S0 300S0	300S0
3		—	—	PT430L20 PT430L40 PT460L20 PT460L40 PT460L50	XF300	—	—	250L15 250L20 250Y20 250L40 250Y40 300L15 300L20 300Y20 300L40 300Y40	300L15
4	C350	G350	C350 H350	—	HA350 HA400 HW350	CA350 CA400	C1 C4-2 C7A-2	350 WR350 400	350
5	C350L0	—	—	—	—	—	—	WR350L0	350L0
5S	—	—	—	—	—	—	—	350S0	350S0
6		—	—	PT490 PT490L20 PT490L40 PT490L50	XF400	—	—	350L15 350L20 350Y20 350L40 350Y40 WR350L20 400L15 400L20 400Y20 400L40 400Y40	

(*continued*)

TABLE 4.6.1(B) (*continued*)

Steel type	Specification and grade of parent steel								
	AS/NZS 1163	AS 1397	AS 1450	AS 1548	AS/NZS 1594	AS/NZS 1595	AS 2074	AS/NZS 3678 AS/NZS 3679.2	AS/NZS 3679.1
7A	C450	G450	C450		—	CA450	—	450	—
7B	C450L0	—	—		—	—	—	—	—
7C	—	—	—	PT540 PT540L20 PT540L40 PT540L50	—	—	—	450L15 450L20 450Y20 450L40 450Y40	—
8C	—	—	—	—	XF500	—	—	—	300L0

NOTE: See Appendix G for guidance on the relationship between these steels and material group numbers utilized in other Standards.

TABLE 4.6.1(C)

PREQUALIFIED WELDING CONSUMABLES WITH SIMILAR WEATHER RESISTANCE

Steel grade	Consumables (see Notes)			
	Manual metal-arc (AS/NZS 4855)	Flux-cored arc (AS/NZS ISO 17632)	Gas-metal arc (AS/NZS 14341)	Submerged arc (AS/NZS ISO 14171)
AS/NZS 1594-HW350 AS/NZS 3678-WR350 AS/NZS 3678-WR350L0 AS/NZS 3678-WR350L20	A-E42 2 2Ni A-E46 2 2Ni A-E42 2 3Ni A-E46 3 3Ni B-E49XX N5 B-E55XX N5 B-E49XX N7 B-E55XX N7	A-T42 2 1.5Ni A-T46 2 1.5Ni A-T42 2 2Ni A-T46 2 2Ni A-T42 2 3Ni A-T46 2 3Ni B-T492U N2 B-T552U N2 B-T492U N3 B-T552U N3 B-T492U N5 B-T552U N5 B-T492U N7 B-T552U N7	A-G42 2 3Ni1 A-G46 2 3Ni1 A-G42 2 2Ni2 A-G46 2 2Ni2 B-G492U SN2 B-G552U SN2 B-G492U SN3 B-G552U SN3 B-G492U SN5 B-G552U SN5 B-G492U SN7 B-G552U SN7 B-G492U SN71 B-G552U SN71	A-S2Nil A-S2Nil.5 A-S2Ni2 A-S2Ni3 A-S3Nil.5 B-SUN2 B-SUN21 B-SUN3 B-SUN31 B-SUN5 B-SUN7

NOTES:

1 Any listed consumable may be used with any listed steel grade.

2 Consumables with a higher impact grading than that shown are also acceptable.

3 The letter 'X' represents the flux covering.

4 For submerged arc consumables only the wire composition is shown in the Table. Classifications shall also comply with the relevant strength and impact designations shown in Table 4.6.1(A).

5 Guidance on the selection of welding consumables for weathering steel not listed in this Table should be sought from the steel manufacturer.

4.6.2 Qualification of welding consumables by testing

Where welding consumables are not prequalified in accordance with Clause 4.6.1, they may be qualified in conjunction with a procedure qualification test in accordance with Clause 4.7. Where the mechanical properties of the transverse butt tensile test meet the minimum requirements shown in Table 4.6.2 and the weld metal hardness complies with Clause 4.7.8, the consumables shall be deemed qualified for that procedure (see Clause 4.11).

TABLE 4.6.2

TRANSVERSE BUTT TENSILE TEST AND CHARPY-V IMPACT PROPERTIES

Steel type [see Table 4.6.1(B) and Note 1]	Minimum tensile strength MPa	Charpy-V impact properties		
		All welding processes (see Note 2)		Temperature °C (see Notes 3 and 4)
		Minimum energy J	Average energy J	
1	430	33	47	+20
2	430	33	47	0
2S	430	33	47	−20
3	430	33	47	−20
4	500	33	47	20
5	500	33	47	0
5S	500	33	47	−20
6	500	33	47	−20
7A	500	33	47	20
7B	500	33	47	0
7C	500	33	47	−20
8C	550	33	47	−20

NOTES:

1 Fracture of the tensile test specimen outside the weld zone with a tensile strength of not less than the minimum specified for the parent material is permitted.

2 For all consumables, the impact requirements are for the minimum computed average values of the three test specimens plus the allowable minimum of any single specimen.

3 The Charpy-V test temperature shall be the lower of the relevant temperature given in Table 4.6.2—

(a) for welding consumable qualification the design service temperature (see Appendix B) as specified in Clause 4.6.1.1; and

(b) for parent metal or weld heat affected zone (HAZ) testing (when required) – the permissible service temperature (see Table B1, Appendix B).

4 For steel types 2S and 5S, where the design service temperature (see Appendix B) is colder than 0°C, the impact test temperature shall be at least 20°C colder than the design service temperature.

4.7 QUALIFICATION OF WELDING PROCEDURE BY TESTING

4.7.1 Method of qualification

Where the welding procedure to be used is not qualified in accordance with Items (a), (b) or (e) of Clause 4.2, it shall be qualified by producing a suitable test piece in accordance with either Item (c) or (d) of Clause 4.2. Completed welds shall be visually examined and tested in the as-welded condition as specified in Table 4.7.1. See Appendix D, Items (g) and (h).

Where the weld complies with the relevant test requirements of Clause 4.7 and Table 6.2.2, the welding procedure shall be accepted as qualified.

A1 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 sections of this Standard should be performed, including the hardness comparison test (Clause 4.7.8) and the HAZ hardness test (Clause 4.7.9). In addition, where the design service temperature is not more than 5°C, it is also recommended that parent plate Charpy tests be taken, to ensure compliance with Appendix B, in particular Table B1.

4.7.2 Preparation of special test piece

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

4.7.3 Dimensions of test pieces

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

4.7.4 Macro test

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

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

4.7.5 Transverse butt tensile test

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

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

TABLE 4.7.1

REQUIRED EXTENT OF TESTING

Weld category	Consumables and materials	Preparation	Test required							
			Butt welds						Fillet welds	
			Macro (see Clause 4.7.4 and Notes 1 and 4)	Tensile (see Clause 4.7.5 and Note 1)	Bend (see Clause 4.7.6 and Notes 1, 4 and 5)	Charpy-V (see Clause 4.7.7 and Note 1)	Hardness		Macro (see Clause 4.7.4)	Hardness
							Comparison (see Clause 4.7.8)	HAZ in accordance with Note 2 (see Clause 4.7.9)		HAZ in accordance with Note 2 (see Clause 4.7.9)
SP	Prequalified, conforming to Clause 2.1 and Table 4.6.1(A)	Prequalified, conforming to Tables E1 to E4, Appendix E	1	Nil	Nil	Nil	Nil	1	1	1
		Other preparations	1	Nil	2 side or 1 face and 1 root	Nil	Nil	1	1	1
	Not prequalified (see Note 1)	Prequalified, conforming to Tables E1 to E4, Appendix E	1	1	2 side or 1 face and 1 root	3 (see Note 3)	1	1	1	1
		Other preparations	2	1	2 side or 1 face and 1 root	3 (see Note 3)	1	1	2	1
GP	Prequalified, conforming to Clause 2.1 and Table 4.6.1(A)	Prequalified, conforming to Tables E1 to E4, Appendix E	Nil	Nil	Nil	Nil	Nil	1	Nil	1
	Any other condition		1	Nil	Nil	Nil	Nil	1	1	1

NOTES:

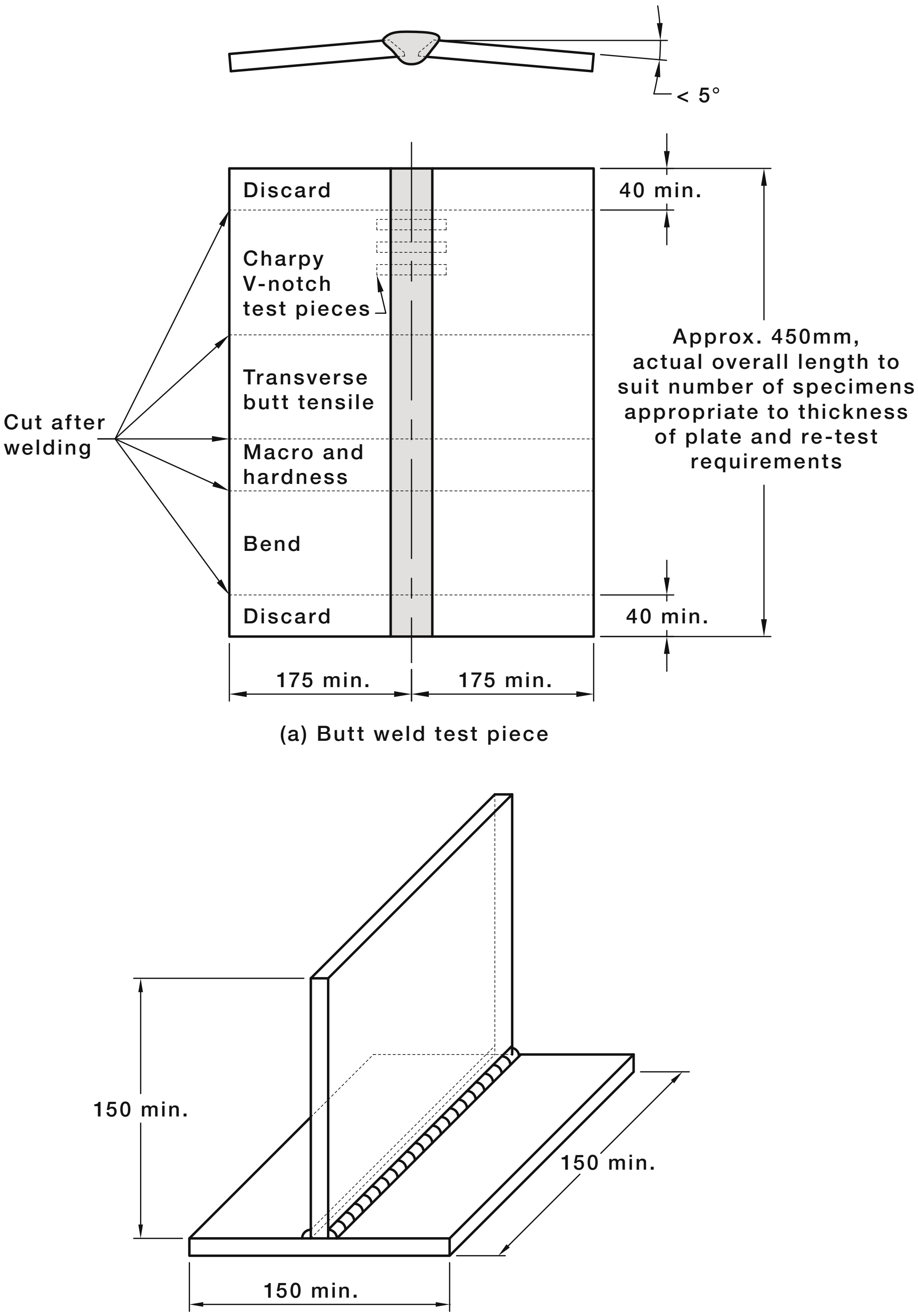
1 For fillet welds, where the welding consumable is not prequalified, in addition to the fillet weld test piece specified, the butt weld test piece shown in Figure 4.7.2 is used in the qualification tests to obtain tensile, bend and impact tests to qualify the use of the consumable.

2 Where the preheat temperatures do not comply with Clause 5.3, hardness tests are required only to qualify the welding procedure.

3 Additional tests may also be required for non-prequalified steels and HAZ in accordance with Clause 2.1 and Appendices B and D.

4 A radiograph (Clause 6.3) may be substituted for a macro test when required to qualify a butt weld procedure or welder (Clause 4.12.2) at the fabricator's discretion. Ultrasonic testing (Clause 6.4) may be used in lieu of radiographic testing for thicknesses ≥10 mm. Where radiographic testing is used, 2 side bend or 1 face and 1 root bend tests are also required to qualify weld procedures and welders using either the GMAW or FCAW (metal cored wire only) processes.

5 Where bend tests are required as part of the weld procedure qualification process, preparations welded as T joints or corner joints should be welded as planar butt joints to permit bend tests to be taken, e.g. use B-C 4a in lieu of T-C 4a or C-C 4a, etc.



(a) Butt weld test piece

(b) Fillet weld test piece

DIMENSIONS IN MILLIMETRES

FIGURE 4.7.2 FORM AND DIMENSIONS OF WELD TEST PIECES

4.7.6 Bend test

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

On the completion of the test, the dimension of any 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.

TABLE 4.7.6

DIAMETER OF FORMER FOR BEND TEST

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

LEGEND:
T = thickness of test specimen

4.7.7 Charpy impact test

A1 **'Text deleted'**

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. In welds made using self-shielded flux cored consumables in combination with other consumable types (see Clause 4.3.2), specimens shall be taken from the zone of intermixing.

The specimen shall comply with Table 4.6.2.

A1 **'Text deleted'**

4.7.8 Hardness comparison test for parent metal and weld metal

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

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

4.7.9 Hardness test for weld-heat-affected zones

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

Except where a greater hardness is permitted in accordance with Appendix D, Item (i), the hardness of weld-heat-affected zones shall be not greater than 350 HV 10.

4.7.10 Retests

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

4.8 EXTENSION OF QUALIFICATION

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

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

(a) Steel type. Either—

  (i) the steel type number, as given in Table 4.6.1(B), has not increased; or

  (ii) for steels certified by the manufacturer as being compliant with more than one grade in Table 4.6.1(B), the welding consumable selected is approved for use for each grade (see Table 4.6.1(A)) and the required minimum preheat has not increased (see Clause 5.3.4).

(b) The Charpy-V impact test temperature of the other steel is not colder than that of the steel used in the qualified procedure.

(c) For other than Clause 4.8(a)(ii), the preheat group number of the other steel, as given in Table 5.3.4(A), is not greater than that of the steel used in the qualified procedure.

(d) The chemical composition of the weld metal is not required to match that of the parent metal for weather resistance purpose.

4.9 COMBINATION OF PROCESSES

For complete penetration or incomplete penetration butt joints—

(a) a different process may be used on each side of the one joint, provided the preparation on the first welded side 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 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. See Appendix D, Item (k).

NOTE: The WPS, PQR and any other supporting documentation may be considered as technical and/or intellectual property of the fabricator and as such, dissemination of this material may be restricted. The extent, type and control of this documentation should be agreed prior to the commencement of the work (see Appendix D).

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 the 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.

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)] (See NOTE)	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 variations given in Table 4.11(D)	—	—	X	X	X
(f) A change of more than ±7% of the specified mean arc voltage of the electrode used for SAW, GMAW or FCAW or more than ±15% for MMAW or GTAW	X	X	X	X	X
(g) A change of more than ±10% of the specified mean welding current for the electrode used for SAW, GMAW or FCAW or more than ±15% for MMAW or GTAW	X	X	X	X	X
(h) A change of more than ±15% of the specified mean speed of travel	—	X	X	X	X
(i) A change of more than ±25% in the specified number of runs. If the cross-sectional area of the preparation is increased or decreased, it is also permissible to adjust the number of runs in proportion to the change in 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 0.5 to 2.0 times the thickness of the thinner test plate, see Clause 4.1.2(k)	X	X	X	X	X
(p) A change in electrical stick-out of more than ±20%	—	X	X	X	—
(q) A change in pulse parameters or waveform (see Clause 4.11)	—	—	X	X	X
(r) For fillet welds, a change from single pass to multi-pass, 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

NOTE: Re-qualification is not required where the change in classification is due to a change in classification Standard and equivalence is established (see Clause 4.2 and Appendix F).

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 0.5*T* to 1.1*T*, 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 shape (see Note)	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 ±10% and ±4 mm	—	X	—	—	—
(ii) Lateral spacing of arcs of the greater ±10% and ±1.5 mm	—	X	—	—	—
(iii) Angular rotation of any parallel electrode of ±10%	—	X	—	—	—
(iv) Angle of electrodes:	—	X	—	—	—
(A) In direction of travel of ±3°	—	X	—	—	—
(B) Normal to direction of travel of ±5°	—	X	—	—	—
(g) A change in electrical phase sequence between electrodes in multiple electrode welding	—	X	—	—	—

LEGEND:
X = applicable
— = not applicable

NOTE: Examples include but are not limited to a change from V-shape to U-shape, a change from V-shape to bevel-shape.

TABLE 4.11(D)

VARIATION FROM CLASSIFICATION PERMITTED FOR MINOR SHIELDING GAS COMPONENTS

Range of minor gas component	Allowed variation of minor gas component	Variation example
≥5 to <50%	±10% relative	16% = 14.4 to 17.6%
<5%	±0.5% absolute	4% = 3.5 to 4.5%

4.12 QUALIFICATION OF WELDING PERSONNEL

4.12.1 Welding supervisor [see Appendix D, Item (l)]

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 drawings, plans, the qualified welding procedure specifications (WPS), any other documents and the requirements of this Standard. The welding procedure specification shall be made available to the welder at the workplace. Checks and tests shall be conducted as necessary prior to assembly, during assembly, during welding, and after welding to ensure that materials and workmanship meet these requirements.

The welding supervisor shall take remedial measures in cases of imperfections.

The welding supervisor may undertake welder qualification tests for those welders under their supervision during the welding of structures. The welding supervisor may also issue and prolong welder qualification test certificates for the welding of structures.

The welding supervisor shall have a minimum of three years' experience in the fabrication of welded structure 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 postgraduate certificate, diploma or degree in welding engineering from a recognized university or an approved technical college.

(e) Have other qualifications or experience acceptable to the principal conforming to the requirements of ISO 14731, with specific technical knowledge and experience in the fabrication of welded steel structures.

NOTES:

1 Guidance on the minimum technical knowledge requirements for Item (e) is provided in AS 2214.

2 For the surveillance of the welding works, the welding supervisor can be assisted by other employees of the fabricator with sufficient welding training or experience. This does not affect the responsibility of the welding supervisor.

4.12.2 Welders [see Appendix D, Item (m)]

4.12.2.1 *General*

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 requirements of Clauses 4.12.2.2 to 4.12.2.4 apply to the qualification of welders.

4.12.2.2 *Qualification via Standards*

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/NZS 2980, AS/NZS 3992 or ISO 9606-1 shall be deemed to be qualified.

4.12.2.3 *Qualification via visual and macro examination*

Welders not already qualified in accordance with Clause 4.12.2.2 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 welding a suitable test piece for all welding procedures required on the job. Each test weld shall have a minimum examination length of 300 mm, be examined visually and by means of a macro test (see also Table 4.7.1 for alternative test methods for butt welds applicable at the fabricator's discretion), and shall satisfy the requirements of Clause 6.2.2.

The welder shall be allowed to remove minor imperfections by grinding, except for the capping run for which only to stop and restart may be ground.

Welder qualifications for welding to a specified welding procedure shall remain valid, provided the following criteria have been met:

(a) It can be shown from records maintained by the organization employing welders that the welders have been employed with reasonable continuity using the relevant welding processes and have continued to produce satisfactory welds as verified by a non-destructive examination (NDE).

(b) The procedure is used within its qualification limits and the following:

 (i) Welder qualifications established in any one position described by this Standard are extended within the limits of Table 4.12.2(A).

 NOTE: The positional qualification limits of the weld procedure are not applicable to welder qualifications.

 (ii) For welds on pipe with an outside diameter d or hollow sections where d is the dimension of the smaller side, the welder is qualified as follows:

  (A) For a test piece with an outside diameter of ≤100 mm, d to $2d$.

  (B) For a test piece with an outside diameter of >100 mm, ≥$0.5d$ to unlimited.

 (iii) 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 [see Table 4.12.2(B)].

 (iv) Welder 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.

4.12.2.4 *Reapproval*

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

(a) Six months or more have elapsed since the welder was employed on the relevant welding processes.

(b) For other than welders qualified to AS/NZS 2980 or ISO 9606-1, the welder changes employment. Under such circumstances, the new employer shall qualify the welder who has changed employment.

(c) There is some specific reason to question the welder's ability.

TABLE 4.12.2(A)

RANGE OF APPROVAL ACCORDING TO WELDING POSITION (see Notes)

Welding position of approval test piece			Range of approval																				
			Plates										Pipes										
			Butt welds					Fillet welds					Butt welds						Fillet welds				
													Rotating	Fixed					Rotating	See Note 2	Fixed		
														0°		90°	45°				0°		90°
			F	H	VD	VU	OH	F	HV	VD	VU	OH	F	VD	VU	H	6G-VU	6G-VD	F	HV	VD	VU	OH (see Note 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	—	—	—
		OH	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

(*continued*)

TABLE 4.12.2(A) (*continued*)

Welding position of approval test piece				Range of approval																				
				Plates										Pipes										
				Butt welds					Fillet welds					Butt welds						Fillet welds				
														Rotating	Fixed					Rotating	See Note 2	Fixed		
															0°		90°	45°				0°		90°
				F	H	VD	VU	OH	F	HV	VD	VU	OH	F	VD	VU	H	6G-VU	6G-VD	F	HV	VD	VU	OH (see Note 3)
Pipes	Butt welds	Rotating	0°	F	X	—	—	—	—	X	X	—	—	—	✓	—	—	—	—	—	X	X	—	—	—
		Fixed		VD	—	—	X	—	—	—	—	X	—	—	—	✓	—	—	—	—	—	—	X	—	—
				VU	X	—	—	X	X	X	X	—	X	X	X	—	✓	—	—	—	X	X	—	X	X
			90°	H	X	X	—	—	—	X	X	—	—	—	X	—	—	✓	—	—	X	X	—	—	—
			45°	6G-VU	X	X	—	X	X	X	X	—	X	X	X	—	X	X	✓	—	X	X	—	X	X
				6G-VD	—	—	X	—	—	—	—	X	—	—	—	X	—	—	—	✓	—	—	X	—	—
	Fillet welds	Rotating		F	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	✓	—	—	—	—
		(See Note 2)		HV	—	—	—	—	—	X	X	—	—	—	—	—	—	—	—	—	X	✓	—	—	—
		Fixed	0°	VD	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	✓	—	—
				VU	—	—	—	—	—	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:

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

2 Horizontal for pipes may be welded in two versions:

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

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

3 OH—an approved position, which is covered by the other related tests.

TABLE 4.12.2(B)

RANGE OF QUALIFICATION FOR WELDING CONSUMABLES

Welding process	Consumable used in the test	Range of qualification			
		Solid wire	Metal core (T15)	Basic core (T4, T5)	Other core
GMAW FCAWgs GTAW	Solid wire	X	X	—	—
	Metal core (T15)	X	X	—	—
FCAW	Basic core (T4, T5)	—	—	X	X
FCAW	Other core	—	—	—	X
SAW	All (see Note 3)	X	X	X	X

LEGEND:

X = welding consumables for which the welder is qualified

— = welding consumables for which the welder is not qualified

FCAWgs = flux cored arc welding—gas shielded

NOTES:

1 Solid wire consumables for the GMAW and GTAW processes include welding consumables classified and complying with AS/NZS 1167.2, AS/NZS 14341 and ISO 636.

2 For flux-cored consumables, the usability designations T4, T5 and T15 are defined in AS/NZS ISO 17632.

3 The welder is only qualified for flux cored wires specified by the manufacturer as being suitable for the SAW process.

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.

NOTE: Mill edge plate and coil steels may contain surface discontinuities near the as-rolled edges, and, fabricators should ensure that sufficient edge trim is removed to avoid these areas. Advice should be sought from the product manufacturer regarding the minimum amount of edge trim required.

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 Note 5.

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

NOTES:

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

2 For flame-cut surfaces being incorporated into the weld, it is considered good practice to lightly grind the cut faces to remove the carbide surface layer (see also Clause 5.8.2).

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 the lesser of—

(a) 3 mm; or

(b) 10% of the thickness of the plates, unless otherwise approved by the principal. See Appendix D, Item (n).

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. See Appendix D, Item (o).

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

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

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°

NOTE: For gouged preparations, see Clause 5.2.2.

5.2.3 Alignment of fillet welds and incomplete penetration butt welds

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

The gap between parts shall normally not exceed 5 mm. For 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 the requirement, a maximum gap of 8 mm is acceptable, provided 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 Backing material

5.2.4.1 *Backing thickness*

Permanent steel backing materials shall be of sufficient thickness to prevent melt-through. The recommended minimum nominal thickness of backing bars is shown in Table 5.2.4.

TABLE 5.2.4

RECOMMENDED MINIMUM BACKING THICKNESS

Process	Thickness, mm
GTAW	3
MMAW	5
GMAW	6
FCAW	6
SAW	10

5.2.4.2 *Separation of backing material*

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

5.3 PREHEATING AND INTER-RUN CONTROL

5.3.1 General

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

A1 **'Text deleted'**

NOTE: Excessive preheating should be avoided.

5.3.2 Need for preheating

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

5.3.3 Extent of preheating and cooling after welding

Where preheating is required, it shall be applied in such a manner that the parts being welded are at the specified minimum temperature 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 is heated to the required temperature.

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

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

(a) Select or calculate the weldability group number, using either of the following methods:

(i) For a standard steel of known specification, select the weldability group number from Table 5.3.4(A).

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

$$CE = C + \frac{Mn}{6} + \frac{(Cr + Mo + V)}{5} + \frac{Ni + Cu}{15} \qquad \ldots 5.3.4(1)$$

where

CE = carbon equivalent

C = carbon content, in percent

Mn = manganese content, in percent

Cr = chromium content, in percent

Mo = molybdenum content, in percent

V = vanadium content, in percent

Ni = nickel content, in percent

Cu = copper content, in percent

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

(b) Calculate the combined thickness [see Figure 5.3.4(A)].

(c) Using Figure 5.3.4(A), find the closest curve to the intersection points from Items (a) and (b) above to give the joint weldability index (one of the letters A to L).

(d) Using the joint weldability index from Item (c) above, obtain the combination of arc energy and minimum preheating temperature from Figure 5.3.4(B) or Figure 5.3.4(C), depending on whether hydrogen-controlled or non-hydrogen-controlled processes are used.

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

$$Q = \frac{60\,E\,I}{1000\,V} \qquad \text{. . .5.3.4(2)}$$

where

Q = arc energy, in kilojoules per millimetre

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

I = welding current, in amperes

V = travel speed, in millimetres per minute

NOTE: For pulsed mode welding, use E = average voltage and I = average current in Equation 5.3.4(2) to calculate the minimum arc energy. In cases where the arc energy may need to be limited, such as given in Clause 4.6.1.1, advice should be sought from the welding machine supplier on the calculation of arc energy when using pulsed mode.

To calculate the total arc energy for multi-arc processes, 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.

NOTES:

1 Guidance on determining preheats for steels not listed in Table 5.3.4(A) can be obtained from WTIA Technical Note 1.

2 The preheat prediction methods given herein are designed to minimize the risk of heat-affected zone cold cracking under most fabrication circumstances. This 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).

3 The permitted heat input range (see Clauses 4.11 and 5.3) should be shown on WPS documents and be calculated using low-low-high (amps-volts-welding speed) parameters for the minimum arc energy and high-high-low (amps-volts-welding speed) parameters for the maximum arc energy, i.e.:

$$\text{from } Q_{\min} = \frac{60E_{\min}I_{\min}}{1000V_{\max}} \qquad \text{to } Q_{\max} = \frac{60E_{\max}I_{\max}}{1000V_{\min}}$$

5.3.5 Maximum inter-run temperature

For welded structures subject to seismic loadings where seismic resisting steels [steel groups 2S and 5S, Table 4.6.1(B)] are specified, the maximum inter-run temperature shall be 300°C unless the weld procedure is qualified at a higher inter-run temperature, in which case the higher temperature shall prevail.

TABLE 5.3.4(A)

PREHEAT DETERMINATION

Parent metal		Weldability group number
Standard	**Grade (see Note 1)**	
AS/NZS 1163	C250 C350, C450	1 4
AS 1397	G250 G300, G350 G450	1 5 4
AS 1450	C200, H200 C250, H250 C350, H350 C450	1 4 5 4
AS 1548	PT430, PT460 PT490, PT540	4 5
AS/NZS 1594 (see Note 2)	HA1, HA3, HA4, HA200, HA250/1 HA250, HU250 HA300, HA300/1, HU300, HU300/1, XF300 HA350 HW350 (see Note 2) HA400 XF400 XF500 HA1006, HA1010 HA1016, HXA1016	1 3 3 4 5 4 3 4 1 3
AS/NZS 1595	AllCA1010, CA60T, CA70T, CA85T, CA1 CA2, CA3, CA4, CA5SN, CA220, CA260 CA350 CA400, CA450 CW300	1 1 3 4 5
AS 2074	C1 C2 C3 C4-1 C4-2 C7A-1 C7A-2	5 2 6 5 6 4 5

(*continued*)

TABLE 5.3.4(A) (*continued*)

Parent metal		Weldability group number
Standard	**Grade (see Note 1)**	
AS/NZS 3678 and AS/NZS 3679.2	200	1
	250, 300	4
	350, WR350 (see Note 2), 400, 450	5
	A1006	1
	XK1016	4
AS/NZS 3679.1	300	4
	350	5

NOTES:

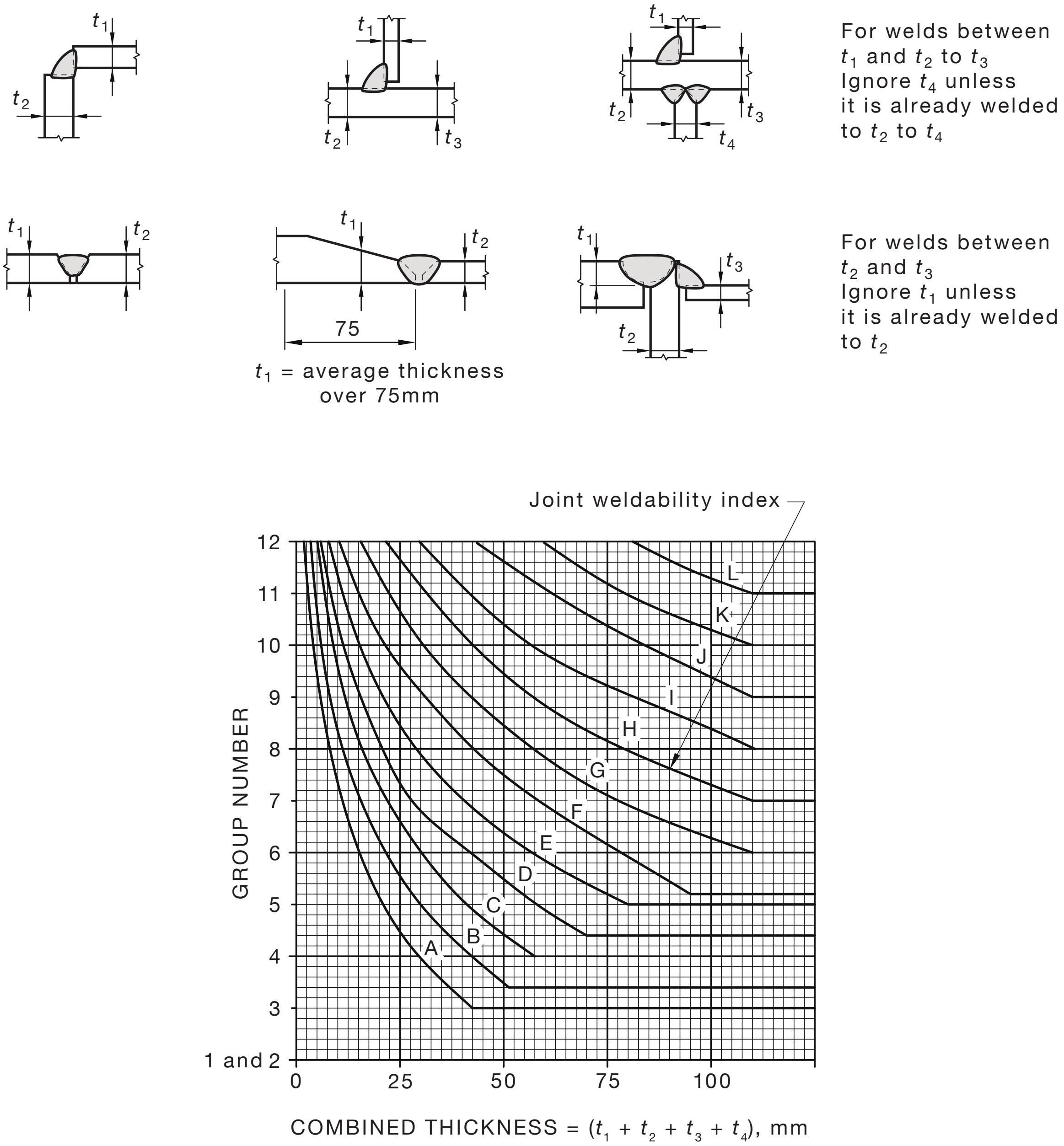
1 The weldability of each impact tested steel variant is the same as its base steel.

2 Weldability Group Number 5 for CW300, HW350 and WR350 steels is based on the typical maximum carbon equivalent encountered in Australia and New Zealand, rather than the maximum specification limits normally applied.

TABLE 5.3.4(B)

RELATIONSHIP BETWEEN CARBON EQUIVALENT AND GROUP NUMBER

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



NOTE: Combined thickness is shown only up to 125 mm for convenience.

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

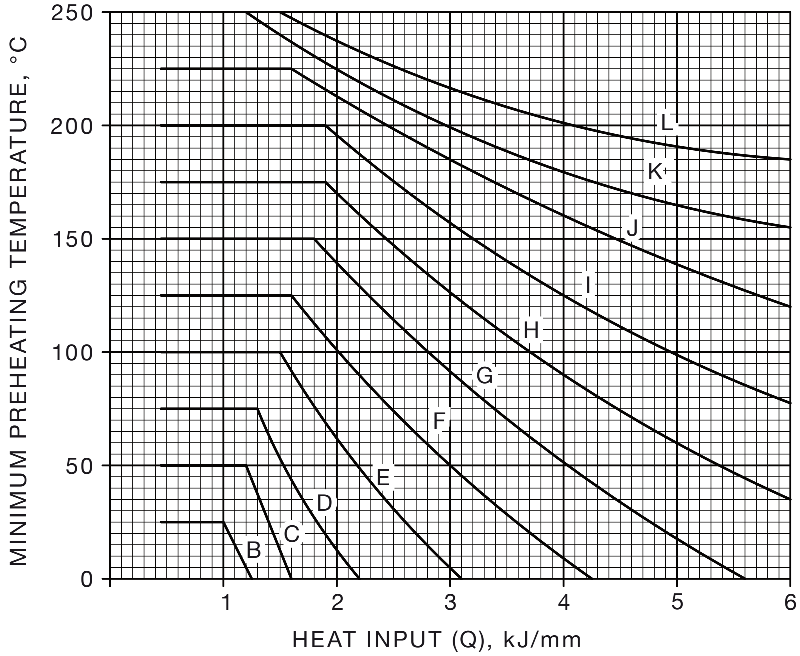


FIGURE 5.3.4(B) PREHEATING DETERMINATION FOR HYDROGEN-CONTROLLED MANUAL METAL-ARC ELECTRODES AND SEMI-AUTOMATIC OR AUTOMATIC PROCESSES

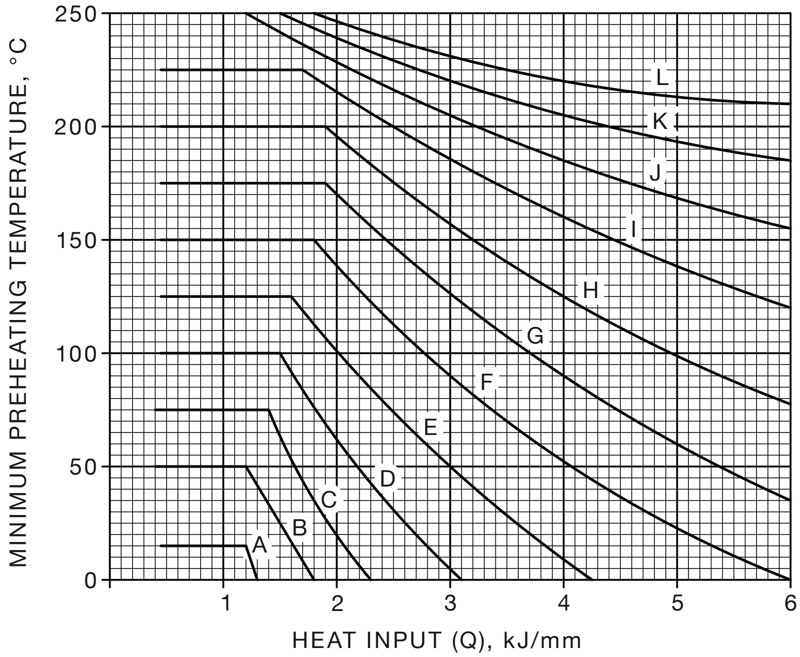


FIGURE 5.3.4(C) PREHEATING DETERMINATION FOR MANUAL METAL-ARC ELECTRODES OTHER THAN HYDROGEN CONTROLLED

5.4 WELDING UNDER ADVERSE WEATHER CONDITIONS

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

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

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

5.5 TACK WELDS

Tack welds shall—

(a) be subject to the same quality and workmanship requirements as the final welds, including appropriate temperature controls as given in Clause 5.3;

(b) if multi-run, have cascaded ends; and

(c) have a length of not less than the lesser of 40 mm and four times the thickness of the thicker part.

5.6 WELD DEPTH-TO-WIDTH RATIO

The depth and the maximum width of the deposited weld metal shall not exceed its width at the surface of the weld (see Figure 5.6), with the following conditions:

(a) 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.

(b) This requirement shall not be waived where the maximum width in the cross-section of the weld material deposited exceeds the width of the weld at the surface.

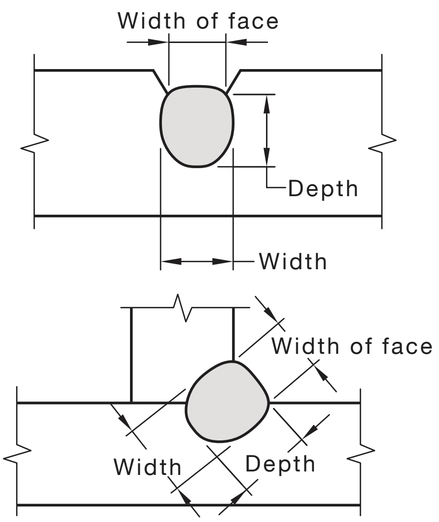


FIGURE 5.6 UNACCEPTABLE WELD RUN IN WHICH DEPTH AND WIDTH EXCEED THE WIDTH OF THE WELD FACE

5.7 CONTROL OF DISTORTION AND RESIDUAL STRESS

5.7.1 General

In the assembly and joining of parts of a structure or built-up members and in the welding of reinforcing parts to members, the procedure and sequence shall be such as will maintain distortion and shrinkage within the required structural limits.

NOTES:

1 Guidance on distortion and shrinkage is given in AS 3990, AS 4100 or NZS 3404.1.

2 The order in which weld joints and/or weld runs are deposited can have an effect on the residual stress, mechanical properties, hardness, corrosion, distortion, ease of welding, likelihood of defects including lamellar tearing, fatigue and final appearance, and so influence the performance of the final joint. For critical joints, bead placement should be carefully considered by the fabricator when developing the welding procedure specification.

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

5.7.2 Stressed parts

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

(a) the effect of such actions on the flexural tensile and compressive capacity of the member is considered;

(b) the matter is the subject of agreement between the fabricator and the principal in accordance with Appendix D, Item (p); 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, before use, in accordance with Appendix D, Item (q).

5.7.4 Correction of distortion

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

(a) Solid water jets may be used for cooling, only if arranged before use in accordance with Appendix D, Item (r).

(b) The temperature of steels shall not exceed 600°C.

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

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 (refer to Table 6.2.2) shall be made good by either the deposition of additional weld metal in accordance with this Standard or the removal of the undercut by grinding in accordance with Clause 5.8.3.

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

5.8.3 Grinding

Grinding shall comply with the following requirements:

(a) The ground area shall blend smoothly into the surrounding surface, without abrupt changes in contour.

(b) The grinding shall not extend below the surface of the parent material by more than—

  (i) for material less than 10 mm thick, 0.5 mm; or

  (ii) for material not less than 10 mm thick, the lesser of 0.07 times the nominal thickness and 3 mm.

5.8.4 Stop starts

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

(a) Grind the stopped end of the weld so that it tapers to the root of the joint with a slope of not less than 4:1.

(b) Restart the weld from the top of the taper slope.

(c) Grind the repaired weld to a smooth surface, to blend into the profile of the existing weld.

The site of the repair shall be subjected to 100% magnetic particle examination in accordance with Clause 6.5.

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 5.8.2.

5.10 ARC STRIKES

Arc strikes outside the area of permanent welds should be avoided on any material. Cracks or blemishes resulting from arc strikes on members, other than those that are essentially statically loaded, shall be ground to a smooth contour in accordance with Clause 5.8.3 and checked by magnetic particle examination in accordance with Clause 6.5.

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. See Appendix D, Item (s).

5.12 DRESSING OF BUTT WELDS

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

(a) not reduce the thickness of the thinner base metal or weld metal by more than 0.8 mm or 5% of the thickness, whichever is lesser; or

(b) not leave reinforcement that exceeds 0.8 mm.

Reinforcements shall be removed where welds form part of a faying or contact surface. Any dressing of reinforcements shall blend smoothly with the plate surfaces. See Appendix D, Item (s).

SECTION 6 QUALITY OF WELDS

6.1 CATEGORIES OF WELDS

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

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

6.2 METHODS OF INSPECTION AND PERMISSIBLE LEVELS OF IMPERFECTIONS

6.2.1 Methods of inspection of completed welds

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

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

NOTE: Table 7.4 includes guidance on the suggested extent of non-destructive examination (NDE), 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 within the weld zone that are permitted for the weld categories shall not exceed the relevant levels given in Tables 6.2.1 and 6.2.2.

Imperfections of parent metal origin are not considered a cause for rejection of the weld.

6.2.3 Adjacent imperfections

6.2.3.1 *Aligned*

Where adjacent imperfections are aligned, they shall be assessed in the manner 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*

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

6.2.4 Interpretation of tests

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

TABLE 6.2.1

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

Type of imperfection (see Notes 1 to 3)	Thickness of thinner parent metal (*t*) mm (see Note 4)	Weighting factor — Height of imperfection (*h*), mm					Maximum permissible imperfection level (see Notes 5, 6, 7 and 8)
		≤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 Note 9					

LEGEND:
X = not permitted
L = weld length under consideration

NOTES:

1 For adjacent imperfections, see Clause 6.2.3.

2 For the purpose of radiographic examinations and routine ultrasonic examinations, *h* shall to be taken as 2 mm. Where an ultrasonic or a radiographic examination indicates that *h* may be greater than 2 mm, *h* shall be determined by sectioning or vertical ultrasonic sizing in accordance with AS 2207.

3 Any imperfections that are suspected of being lamellar tears should be recorded on the NDE report and referred to the principal for consideration.

4 See also Clause 3.2.1.

5 For any weld length under consideration, the imperfection level shall be calculated by multiplying the length of each imperfection by its weighting factor and adding these weighted lengths to determine a total imperfection level. The total imperfection level shall be less than the maximum permissible imperfection level.

6 Any imperfections shall not exceed a height equal to the greater of 2 mm and *t*/20, within a distance of *t* of the end of a weld.

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 Table 6.2.1. Any such level of porosity shall be recorded and referred to the principal for consideration. For radiographic inspections, porosity levels representing a loss of projected area of not more than 2% are permitted. If required, reference may be made to porosity charts in AS 4037, to assist in assessing the appearance of this level of porosity on a radiograph.

TABLE 6.2.2

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

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

NOTES TO TABLE 6.2.2:

1 For adjacent imperfections, see Clause 6.2.3.

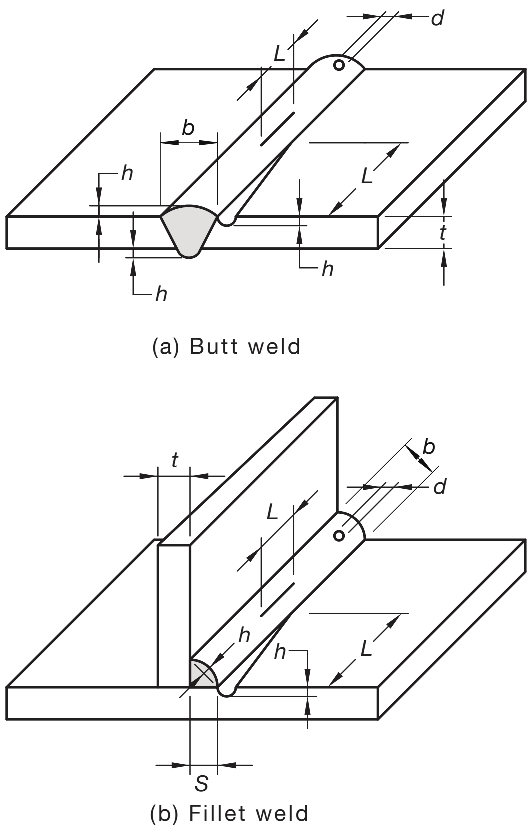
2 Undercut less than 0.5 mm in depth should be disregarded.

3 Where these allowances for overlap and surface pores are detrimental to any surface treatment, they may not be acceptable.

4 For a welding procedure qualification, the assessment of the test piece for compliance with the permissible levels of imperfections should be done with the aid of the macro test specimen. For calculation of the loss of cross-sectional area, internal imperfections are estimated from the macro test specimen.

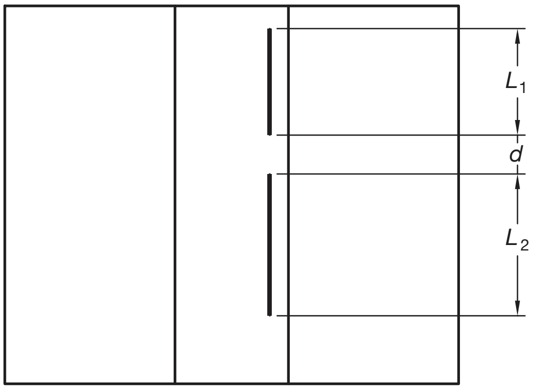
5 For the calculation of the loss of cross-sectional area, all relevant surface imperfections shall be included. Where lack of root fusion is evident, the inspector is required to assess the approximate depth of the imperfection. The macro test specimen from the welding procedure qualification may need examination for this purpose.

6 The cumulative length of intermittent undersize fillet welds shall not exceed 10% of the length of the weld.



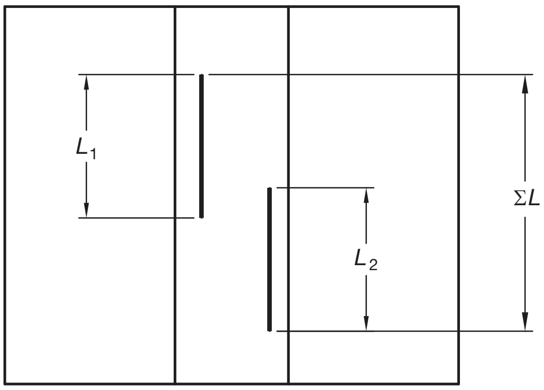
LEGEND:
L = length or maximum dimensions of individual imperfections measured parallel to axis of weld
ΣL = sum of lengths of imperfections in stated weld length
h = height (depth) of imperfection
t = thickness of parent metal (thinner)
b = width of weld face
d = size of pore
S = size of fillet weld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

FIGURE 6.2.2 DIMENSIONS REFERRED TO IN TABLE 6.2.2

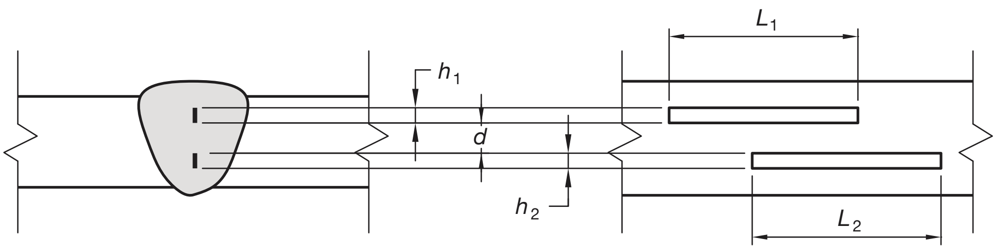


Where d is less than L_1 the smaller imperfection, $\Sigma L = L_1 + L_2 + d$
Where d is not less than L_1 the smaller imperfection, $\Sigma L = L_1 + L_2$

(a) Aligned imperfections



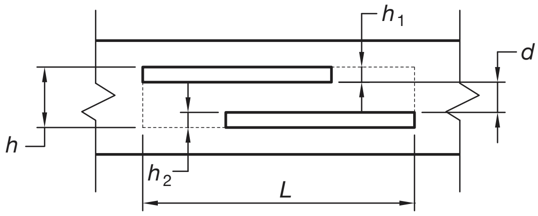
(b) Overlapping imperfections



(i) Cross-section

NOTE: Treat as separate defects.

(ii) Longitudinal section, where $d > 5$mm



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

(iii) Longitudinal section, where $d < 5$mm

(c) Overlapping vertical displacement

FIGURE 6.2.3 ASSESSMENT OF ADJACENT IMPERFECTIONS

6.3 RADIOGRAPHY

6.3.1 Method (see Appendix D)

When required, radiography shall be carried out in accordance with AS 2177, using the following test methods as designated by AS 2177, for which '*z*' is 'S', 'DWS' or 'DWD' as appropriate:

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

(b) For material thicknesses of more than 12 mm, XR2/*z*, GR1/*z* or GR2/*z*.

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

6.3.2 Image quality indicator (IQI) sensitivity

IQI sensitivity for each technique shall comply with Table 6.3.2. The IQI sensitivity shall be measured through the weld using wire type IQI in accordance with AS 2314. At least one IQI should be used with each radiograph.

TABLE 6.3.2

SMALLEST DISCERNIBLE WIRE

Method (see Note 1)	Wire number (see AS 2314)							
	Weld metal thickness, mm							
	≤6	>6 ≤10	>10 ≤12	>12 ≤18	>18 ≤25	>25 ≤35	>35 ≤50	> 50
XR2/*z*	13	12	11	10	9	8	7	See Note 2
GR1/*z* or GR2/*z*	12	11	11	10	9	8	7	See Note 2

NOTES:

1 As designated by AS 2177, for which '*z*' is 'S', 'DWS' OR 'DWD' as appropriate.

2 For thicknesses of more than 50 mm, an IQI sensitivity of 2.0% is required.

6.3.3 Acceptance limits

The maximum permissible levels of imperfections shall be as given in Table 6.2.1. Where imperfections in excess of the limits in Table 6.2.1 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. See Appendix D, Item (v).

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, 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.

(c) Refer to AS 4037 for guidance on minimum spot size.

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 and Appendix D, Items (t) and (u)].

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 thickness 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 level of imperfections shall be as given in Table 6.2.1. Where welds fail to meet the criteria of Table 6.2.1, they shall be either repaired and retested, or considered defective and dealt with in accordance with Clause 6.7. See Appendix D, Item (t) and (v).

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, as appropriate:

(a) Where the two additional spots pass, only the original spot should be repaired and examined.

(b) Where either of the two additional spots fail, the entire weld should be examined, and repaired as appropriate.

(c) Refer to AS 4037 for guidance on minimum spot size.

6.5 MAGNETIC PARTICLE EXAMINATION

Where required, magnetic particle examination shall be carried out in accordance with one of the techniques specified in AS 1171. See Appendix D, Items (t) and (u).

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

6.6 LIQUID PENETRANT EXAMINATION

Where required, penetrant examination shall be carried out in accordance with one of the techniques specified in AS 2062. See Appendix D, Items (t) and (u).

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

6.7 WELD DEFECTS

Weld imperfections that exceed the levels given in Tables 6.2.1 and 6.2.2 shall be classed as defects. However, where it can be demonstrated, by the use of fracture mechanics or other suitable methods of assessment, that the defects will not be injurious to the performance of the structure, such defects do not need to 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 and Appendix D, Item (v)].

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 parent metal origin are not normally considered to be a cause for rejection of the weld. Parent metal discontinuities which interfere with the examination should be reported to the principal and included in the test report.

6.8 REPORTING

Test reports for non-destructive examination shall comply with the appropriate 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. See Appendix D, Item (w).

NOTE: Test reports that may be used for revalidation or prolongation of welder qualification should include WPS number, date welded and welder identification.

SECTION 7 INSPECTION

7.1 GENERAL

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

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

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

7.2 QUALIFICATIONS OF INSPECTORS

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

(a) International Institute of Welding diploma as an IIW Welding Inspector, at the appropriate level.

(b) A Welding Technology Institute of Australia Certificate as a Welding Inspector, at the appropriate level.

(c) A Certification Board of Inspection Personnel (CBIP) New Zealand Welding Inspector.

(d) A certificate as a structural welding supervisor in accordance with AS 2214.

(e) Have other qualifications and experience acceptable to the principal.

NOTES:

1 The inspector should have at least the qualifications required for a welding supervisor.

2 The inspector should be certified as competent to inspect at the level required by the Principal or Inspecting Authority.

3 The inspector should not be involved in the supervision of the welded fabrication.

7.3 VISUAL INSPECTION OF WORK

The inspector shall conduct a visual examination in accordance with the requirements of AS 3978. Aids to visual examination may be used wherever necessary to facilitate the assessment of an imperfection. Inspection aids and measuring devices shall be sufficient to enable the inspector to detect imperfections that could occur on welds and test pieces.

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 either complying with AS 3998 from the Australian Institute of Non-destructive Testing at the appropriate level, or from the CBIP-NZ shall be deemed to be qualified. See Appendix D, Items (t), (x) and (y).

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 3.1.3).

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 (NDE)

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

NOTES:

1 This Table is intended to apply to routine testing of welds, to determine the level of weld quality. Where routine testing reveals imperfections requiring further consideration in accordance with Section 6, Clause 6.7 applies.

2 Where less than 100% of NDE is required, a program for testing should be drawn up by the principal and approved by the design engineer. This program should involve full testing of the first major component or 5% of welds, as appropriate, in order to detect and be able to correct the cause of any major defects on commencement of welding. It should then involve a progressive reduction in frequency of testing, on the basis of achieving compliance with each test. If testing indicates non-compliance, the next 5% of welds or the next major component, as appropriate, should be tested consecutively.

3 Visual means of NDE implies the two following levels of examination:

(a) Visual scanning, to determine that all welds called for in the drawings are included and to detect gross defects.

(b) Visual examination, to examine a percentage of the welds, to determine whether the required weld quality (see Table 6.2.2) has been achieved.

4 In New Zealand 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 their use is usually restricted to repairs (see Clause 6.2.1).

6 Liquid penetrant examination may be used for the inspection of ferromagnetic materials, as an alternative to magnetic particle examination; however, where convenient, magnetic particle examination is preferred.

7 For plates with a thickness of not less than 20 mm, a portion of each multi-pass butt weld should be examined ultrasonically, to determine whether there are any transverse cracks within the weld metal.

APPENDIX A

NORMATIVE REFERENCED DOCUMENTS

(Normative)

AS

1101 Graphical symbols for general engineering
1101.3 Part 3: Welding and non-destructive examination

1171 Non-destructive testing—Magnetic particle testing of ferromagnetic products, components and structures

1397 Continuous hot-dip metallic coated steel sheet and strip—Coatings of zinc and zinc alloyed with aluminium and magnesium

1450 Steel tubes for mechanical purposes

1470 Health and safety at work—Principles and practices

1548 Fine grained, weldable steel plates for pressure equipment

1674 Safety in welding and allied processes
1674.1 Part 1: Fire precautions
1674.2 Part 2: Electrical

1796 Certification of welders and welding supervisors

1817 Metallic materials—Vickers hardness test
1817.1 Part 1: Test methods (ISO 6507-1:1997, MOD)
1817.2 Part 2: Verification of testing machines
1817.3 Part 3: Calibration of reference blocks

2062 Non-destructive testing—Penetrant testing of products and components

2074 Cast steels

2177 Non-destructive testing—Radiography of welded butt joints in metal (series)

2205 Methods for destructive testing of welds in metal
2205.2.1 Method 2.1: Transverse butt tensile test
2205.3.1 Method 3.1: 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 fracture toughness test

2207 Non-destructive testing—Ultrasonic testing of fusion welded joints in carbon and low alloy steel

2214 Certification of welding supervisors—Structural steel welding

2314 Radiography of metals—Image quality indicators (IQI) and recommendations for their use

2799 Resistance welding equipment—Single-phase a.c. transformer type

2812 Welding, brazing and cutting of metals—Glossary of terms

2865 Confined spaces

3545 Welding positions

3978 Non-destructive testing—Visual inspection of metal products and components

3990 Mechanical equipment—Steelwork

AS	
4100	Steel structures
4882	Shielding gases for welding
60974	Arc welding equipment
60974.1	Part 1: Welding power sources (IEC 60974-1:2000, MOD)
AS ISO	
13916	Welding—Guide on the measurement of preheating temperature, interpass temperature and preheat maintenance temperature
AS/NZS	
1163	Cold-formed structural steel hollow sections
1167	Welding and brazing—Filler metals
1167.2	Part 2: Filler metal for welding
1336	Recommended practices for occupational eye protection
1337	Personal eye protection (series)
1338	Filters for eye protectors
1338.1	Part 1: Filters for protection against radiation generated in welding and allied operations
1594	Hot-rolled steel flat products
1595	Cold-rolled, unalloyed, steel sheet and strip
1995	Welding cables
2980	Qualification of welders for fusion welding of steels
3678	Structural steel—Hot-rolled plates, floorplates and slabs
3679	Structural steel
3679.1	Part 1: Hot-rolled bars and sections
3679.2	Part 2: Welded I sections
3992	Pressure equipment—Welding and brazing qualification
4600	Cold-formed steel structures
4855	Welding consumables—Covered electrodes for manual metal arc welding of non-alloy and fine grain steels—Classification
4857	Welding consumables—Covered electrodes for manual metal arc welding of high-strength steels—Classification
14341	Welding consumables—Wire electrodes and weld deposits for gas shielded metal arc welding of non alloy and fine grain steels—Classification (ISO 14341:2010, MOD)
AS/NZS ISO	
14171	Welding consumables—Solid wire electrodes, tubular cored electrodes and electrode/flux combinations for submerged arc welding of non alloy and fine grain steels—Classification
14174	Welding consumables—Fluxes for submerged arc welding and electroslag welding—Classification
17632	Welding consumables—Tubular cored electrodes for gas shielded and non-gas shielded metal arc welding of non-alloy and fine grain steels—Classification (ISO 17632:2004, MOD)

AS/NZS ISO	
26304	Welding consumables—Solid wire electrodes, tubular cored electrodes and electrode-flux combinations for submerged arc welding of high strength steels—Classification
NZS	
3404	Steel structures standard
3404.1	Part 1: Materials, fabrication and construction
ISO	
636	Welding consumables—Rods, wires and deposits for tungsten inert gas welding of non-alloy and fine-grain steels—Classification
9606	Qualification testing of welders—Fusion welding
9606-1	Part 1: Steels
14731	Welding coordination—Tasks and responsibilities

APPENDIX B
BRITTLE FRACTURE
(Normative)

B1 METHODS

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

B2 NOTCH-DUCTILE RANGE METHOD

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

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

B3 DESIGN SERVICE TEMPERATURE

B3.1 General

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

B3.2 Basic design temperature

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

(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.

(b) Critical structures, located where the Bureau of Meteorology records indicate the occurrence of abnormally-low local ambient temperatures for a significant time to cause the temperature of the critical structure to be lowered below the LODMAT temperature, shall have a basic design service temperature equal to such a lowered temperature of the critical structure.

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

B3.3 Modifications to the basic design temperature

The design service temperature shall be the basic design temperature; except that for parts that are to be subjected to artificial cooling below the basic design service temperature (e.g. 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 for the material thickness shall be selected from Table B1, so that the permissible service temperature listed in Table B1 is less than the design service temperature, determined in accordance with Paragraph B3. The permissible service temperatures listed in Table B1 shall be subject to the limitations and modifications specified in Paragraphs B4.2 and B4.3 respectively.

B4.2 Limitations

Table B1 shall only be used without modification for members and components that comply with the fabrication and erection provisions of AS 4100 or NZS 3404.1, and with the provisions of this Standard.

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

B4.3 Modification for certain applications

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

Where a member or component is subjected to an outer bend fibre strain during fabrication of between 1.0% and 10.0%, the permissible service temperatures for each steel type shall be increased by at least 20°C above the value given in Table B1.

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

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

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

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

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

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

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

B4.3.4 *Non-complying conditions*

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

(c) 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.

(d) Three Charpy test specimens shall be taken from the area of maximum strain and tested at the design service temperature.

(e) The impact properties as determined from these tests shall be not less than the minimum specified impact properties for the steel grade under test.

(f) Where the Standard to which the steel complies does not specify minimum impact properties, the average absorbed energy for three 10 mm × 10 mm test specimens shall be not less than 27 J, provided none of them is less than 20 J.

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

B5 FRACTURE ASSESSMENT

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

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

TABLE B1

PERMISSIBLE SERVICE TEMPERATURES ACCORDING TO STEEL TYPE AND THICKNESS

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

NOTES:

1 The permissible service temperature for steels with a L20, L40, L50, Y20 or Y40 designation shall be the colder of the temperature shown in Table B1 and the specified impact test temperature.

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

(Lowest One Day Mean Ambient Temperature)
Based on records 1957-1971
kindly supplied by:
Australian Bureau of Meteorology
prepared by :
Australian Welding Research Association, Feburary 1975

NOTES:

1 The isotherms show the lowest one day mean ambient temperature (LODMAT) in degrees Celsius.

2 Based on records during the years 1957 to 1971 as supplied by the Australian Bureau of Meteorology.

FIGURE B1 LODMAT ISOTHERMS FOR AUSTRALIA

NOTES:
1 The isotherms show the lowest one day mean ambient temperature (LODMAT) in degrees Celsius.
2 Based on records 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

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 Date
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 $\theta°$ 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	Trade name	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	Flow rate	
Purge gas	Flow rate	

Weld run details					**Welding parameters**				
Pass no.	Side	Position	ϕ mm	Trade name	Amperage range	Voltage range	Current and polarity	Travel speed mm/min	Heat input kJ/mm

Technique	Stringer/weave
Single-run or multi-run	Electrical stick-out
Initial cleaning	Backgouge
Inter-run clean	Gouge check

Notes/revisions

Approved by

APPENDIX D

MATTERS FOR RESOLUTION

(Normative)

The following matters of a contractual nature shall be resolved:

(a) Nomination of weld categories (see Clause 1.6) and nominal tensile strength of welds (see Clause 3.1.2).

(b) Increased penetration from fully automatic arc welding processes (see Clauses 3.2.2 and 3.3.2).

(c) Where seal welds are required (see Clause 3.5).

(d) Approval of welding procedures (see Clauses 4.1 and 4.2).

(e) Method of qualification of welding procedure (see Clause 4.2).

(f) Prequalification of consumables (see Clause 4.6.1).

(g) Qualification of non-prequalified steel types (see Clause 4.7.1).

(h) Whether Charpy V-notch impact test is required for heat-affected zone (see Table 4.7.1).

(i) Hardness of heat-affected zone (see Table 4.7.1 and Clause 4.7.9).

(j) Preparation of special test piece (see Clause 4.7.2).

(k) Availability of records, for perusal by inspector (see Clause 4.10).

(l) Qualifications of welding supervisor (see Clause 4.12.1).

(m) Qualifications of welders (see Clause 4.12.2).

(n) Misalignment of plates of equal thickness (see Clause 5.2.2).

(o) Tolerances for butt-welded joints, for electroslag and electrogas (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, ultrasonic examination for the detection of transverse cracks in weld metal, and the value of L as the basis for assessment under Tables 6.2.1 and 7.4 (see Clauses 6.3, 6.4, 6.5, 6.6 and 7.4).

(u) NDE technique and alternatives (see Clauses 6.3.1, 6.4.1, 6.5 and 6.6).

(v) Correction of faulty (defective) welds and cost of weld repair and associated NDE (see Clauses 6.3.3, 6.4.3 and 6.7).

(w) Whether a 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/NZS 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 = electroslag 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, may be described as C-C 1c–SAW.

TABLE E1

PREQUALIFIED COMPLETE PENETRATION BUTT WELD PREPARATIONS

NOTES:

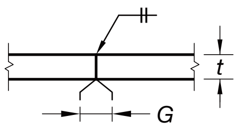
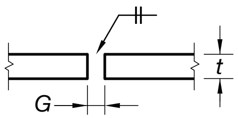
1 Explanation of the notation used is given in Paragraphs E1 to E3.

2 For requirements for gouging the roots of the weld, see Clause 4.5.2.

3 For workmanship tolerances of weld preparations, see Table 5.2.2.

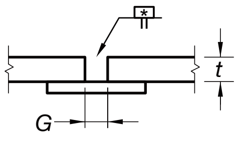
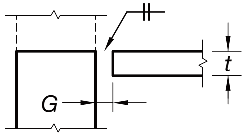
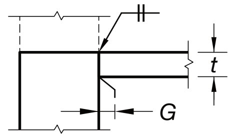
4 Gas metal-arc pulsed-transfer mode may be used for these preparations where average current exceeds 250 A.

5 Gas metal-arc welding with globular transfer mode may be used with CO_2 shielding gas.

Joint identi-fication	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*	3 max.	12 max.	6 max.	6 max.			3 max.
		Position	All	F	F	F			All
		*G*	0	0	0	0			0
B-C 1b	Open-joint square butt weld, welded both sides	*t*	6 max.		10 max.		6 max.	20 min.	6 max.
		Position	All		All		All	V	All
		*G*	*t*/2		*t*/4		*t*/2	25	*t*/2

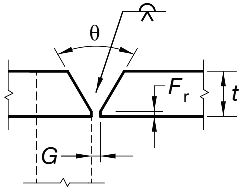
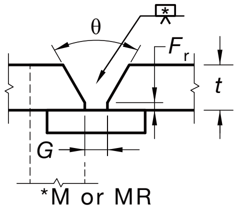
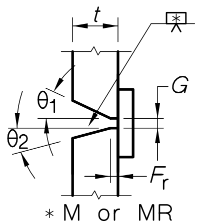
(*continued*)

TABLE E1 (*continued*)

Joint identi-fication	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	n-joint square butt weld and corner joint, welded one side with backing strip  *M or MR	*t* Position *G*	6 max. All *t*	12 max. F *t*/2	12 max. All *t*	12 max. F *t*/2	10 max. All 3*t*/2	20 min. V 25	
T-C 1a C-C 1b	Open-joint square T butt weld and corner joint welded both sides  	*t* Position *G*	6 max. All *t*/2		10 max. F & H *t*/4		6 max. All 3	20 min. V 25	6 max. All *t*/2
C-C 1c T-C 1b	Close joint square T and corner joint, butt welded both sides  	*t* Position *G*	3 All 0	10 max. F 0	6 max. F 0	6 max. F 0			3 max. All 0

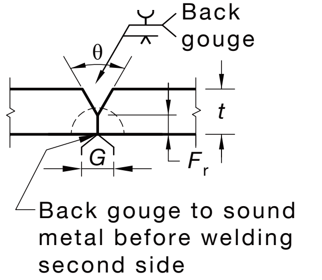
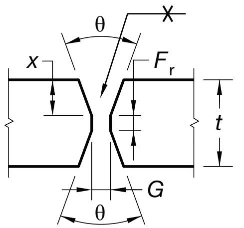
(*continued*)

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 2a C-C 2a	Single-V butt weld and corner joint, welded both sides 	t	All	All	All	All	All		20 max.
		Position	All	F	See θ	F	See θ		All
		G	3.5	0	3	0	3		3
		F_r	1.6	6	3	4	0		1.5
		θ	60	60	50 for F, H & OH 60 for V	50	50 for F, H & OH 60 for V		60
B-C 2b C-C 2b	Single-V butt weld and corner joint, welded one side with backing strip 	t	All	All	All	All	All		
		Position	See θ	F	See θ	F	See θ		
		G	See θ	See θ	6	3	6		
		F_r	0	0	0	1.5	0		
		θ	20 for F & OH: G = 12 30 for F & OH: G = 9 45 for all: G = 6	30: G = 6 20: G = 15	30 for F, H & OH 45 for V	30	30 for F, H & OH 45 for V		
B-C 2c	Single-V butt weld, welded one side with backing strip 	t	20 max.		20 max.	20 max.	20 max.		
		Position	H		H	H	H		
		G	5-8		5-8	5-8	5-8		
		F_r	0		0	0	0		
		θ_1	45		45	45	45		
		θ_2	15		15	15	15		

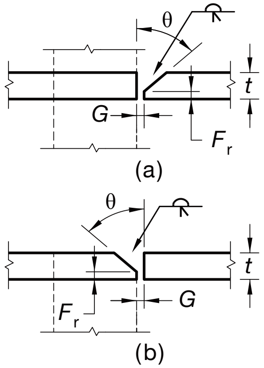
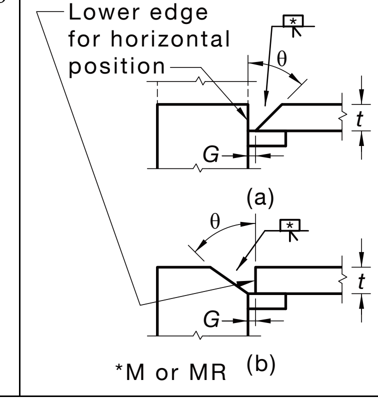
(*continued*)

TABLE E1 (*continued*)

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

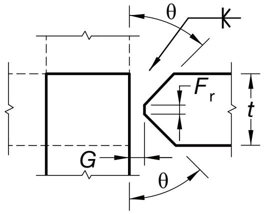
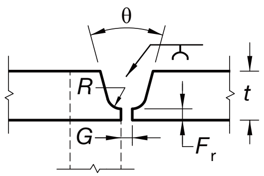
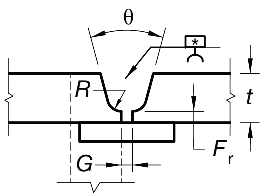
(*continued*)

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 joints, welded both sides 	t Position G F_r θ	All All 3.5 1.5 45	All F & H 0 6 60	All See θ 3 1.5 50 for F, H & OH 60 for V	All F & H 1.5 4 50	All See θ 4 0 50 for F, H & OH 60 for V		20 max. All 3 1.5 60
B-C 4b T-C 4b C-C 4b	Single bevel butt weld, T and corner joints, 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		

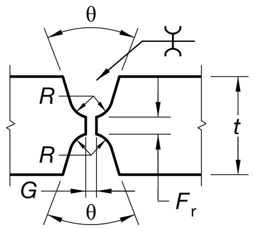
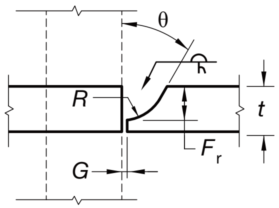
(*continued*)

TABLE E1 (*continued*)

Joint identi-fication	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 joints 	t	All	All	All	All	All		20 max.
		Position	All	F	See θ	F	See θ		All
		G	3.5	0	1.5	0	4		3
		F_r	1.5	6	1.5	3	0		1.5
		θ	45	60	50 for F, H & OH 60 for V	50	50 for F, H & OH 60 for V		60
B-C 6a C-C 6a	Single-U butt weld and corner joint, welded both sides 	t	All	All	All	All	All		All
		Position	See θ	F	All	Flat	All		All
		G	1.5	0	1.5	0	4		1.5
		F_r	1.5	6	1.5	3	0		1.5
		R	6	8	8	8	8		6
		θ	30 for F & OH 45 for all	20	30	30	30		45
B-C 6b C-C 6b	Single-U butt weld and corner joint, welded one side with backing strip  *M or MR	t	All	All	All	All	All		
		Position	See θ	F	All	F	All		
		G	7	2	6	3	6		
		F_r	1.5	1.5	0	1.5	0		
		R	6	8	8	8	8		
		θ	30 for F & OH 45 for all	20	30	30	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	All	All	All	All	All		All
		Position	See θ	F	All	F	All		All
		G	1.5	0	1.5	0	4		1.5
		F_r	1.5	6	3	3	0		1.5
		R	6	8	8	8	8		6
		θ	30 for F & OH 45 for all	20	30	30	30		45
B-C 8a T-C 8a C-C 8a	Singe-J butt weld, T and corner joints, welded both sides 	t	All	All	All	All	All		All
		Position	See θ	F: MMAW or SAW weld on second side	All	F & H	All		All
		G	1.5	0	3	1.5	4		1.5
		F_r	1.5	6	3	4	0		1.5
		R	6	See θ	See θ	8	8		6
		θ	30 for F & OH 45 for all	30: R = 12 45: R = 6	30: R = 10 45: R = 6	45	45		45

(*continued*)

TABLE E1 (*continued*)

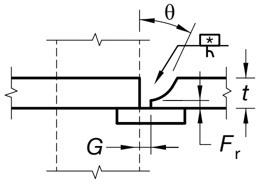
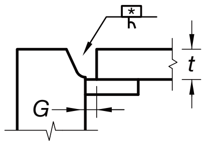
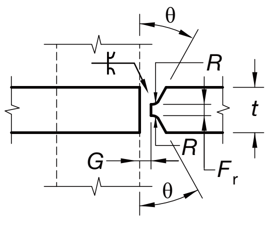
Joint identification	Joint type	Preparation detail (see Notes 2 and 3)	Manual metal-arc	Submerged arc	Flux-cored arc, self-shielded and gas-shielded	Gas metal-arc, spray transfer (see Notes 4 and 5)	Gas metal-arc, short-circuiting arc transfer or pulsed mode	Electroslag, including consumable guide	Gas-tungsten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

TABLE E2

PREQUALIFIED INCOMPLETE PENETRATION BUTT WELD PREPARATIONS

NOTES:

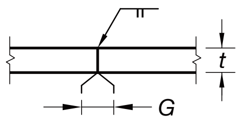
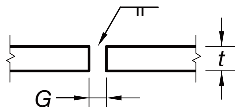
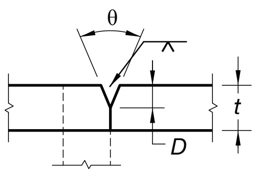
1 Explanation on the notation used is given in Paragraphs E1 to E3.

2 For increased *DTT* for fully automatic process, see Clause 3.2.2.

3 For workmanship tolerances of weld preparations, see Table 5.2.2.

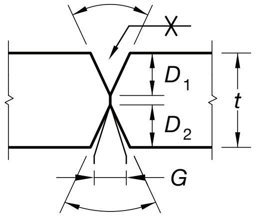
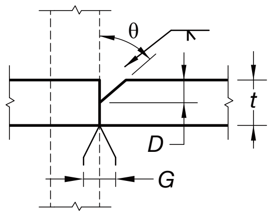
4 Gas metal-arc pulsed-transfer mode may be used for these preparations where average current exceeds 250 A.

5 Gas metal-arc welding with globular transfer mode may be used with CO_2 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 	*T* Position *G* *DTT*	3 max. All 0 0.75*t*	6 max. F 0 0.75*t*	4 max. F & H 0 0.75*t*	3 max. F & H 0 0.75*t*	3 max. All 0 *t*/2	3 max. All 0 0.75*t*
B-P 1b	Open-joint square butt weld, welded one side 	*T* Position *G* *DTT*	6 max. All *t*/2 0.75*t*		8 max. F & H *t*/4 0.75*t*	6 max. F & H *t*/4 0.75*t*	6 max. All *t*/2 *t*/2	6 max. All *t*/2 *t*/2
B-P 2a C-P 2	Close joint single-V butt weld and corner joint, welded one side 	*T* Position *G* *DTT* *θ*	All All 0 See *θ* 45: *DTT* = *D* – 3 60: *DTT* = *D*	All F 0 *D* 60	All See *θ* 0 *D* – 3 50 for F, H & OH 60 for V	All F 0 *D* – 3 50	All See *θ* 0 *D* – 3 50 for F, H & OH 60 for V	20 max. All 0 *D* 60

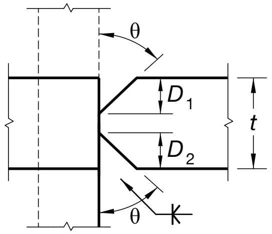
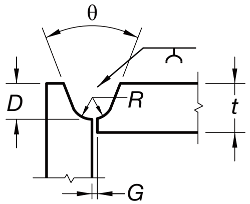
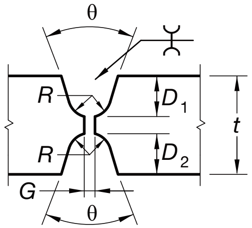
(*continued*)

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 3	Close joint double-V butt weld, welded both sides 	t	All	All	All	All	All	20 max.
		Position	All	F	See θ	F	See θ	All
		G	0	0	0	0	0	0
		DTT	See θ	$D_1 + D_2$	$(D_1 + D_2) - 6$	$(D_1 + D_2) - 6$	$(D_1 + D_2) -6$	$D_1 + D_2$
		θ	45: $(D_1 + D_2) - 6$ 60: $D_1 + D_2$	60	50 for F, H & OH 60 for V	50	50 for F, H & OH 60 for V	70
B-P 4a C-P 4 T-P 4	Close joint single-bevel butt weld, T and corner joint, welded one side 	t	All	All	All	All	All	20 max.
		Position	All	F & H	All	F & H	All	All
		G	0	0	0	0	0	0
		DTT	$D - 3$	D	$D - 3$	$D - 3$	$D - 3$	D
		θ	45	60	45	45	45	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*	All	All	All	All	All	20 max.
		Position	All	F	All	F & H	All	All
		G	0	0	0	0	0	0
		DTT	$(D_1 + D_2) - 6$	$D_1 + D_2$	$(D_1 + D_2) - 6$	$(D_1 + D_2) - 6$	$(D_1 + D_2) - 6$	$D_1 + D_2$
		θ	45	60	45	45	45	60
B-P 6 C-P 6	Single-U butt weld and corner joint, welded one side 	*t*	All	All	All	All	All	20 max.
		Position	All	F	All	F & H	All	All
		G	1.5	0	0	0	0	0
		R	6	6	6	6	6	6
		DTT	*D*	*D*	*D*	*D*	*D*	*D*
		θ	45	20	30	30	30	45
B-P 7	Double-U butt weld, welded both sides 	*t*	All	All	All	All	All	All
		Position	All	F	All	F & H	All	All
		G	1.5	0	0	0	0	0
		R	6	6	6	6	6	6
		DTT	$D_1 + D_2$	$D_1 + D_2$	$D_1 + D_2$	$D_1 + D_2$	$D_1 + D_2$	$D_1 + D_2$
		θ	45	20	30	30	30	45

(*continued*)

TABLE E2 (*continued*)

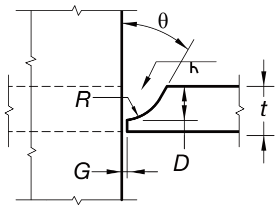
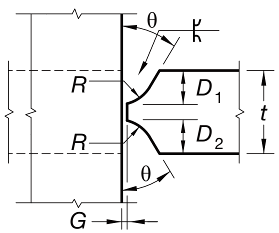
Joint identification	Joint type	Preparation detail (see Notes 2 and 3)	Manual metal-arc	Submerged arc	Flux-cored arc, self-shielded and gas-shielded	Gas metal-arc, spray transfer (see Notes 4 and 5)	Gas metal-arc, short-circuiting arc transfer or pulsed mode	Gas-tungsten arc
B-P 8	Single-J butt weld,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

TABLE E3

PREQUALIFIED FILLET WELD PREPARATIONS

NOTES:

1 Explanation of the notation used is given in Paragraphs E1 to E3.

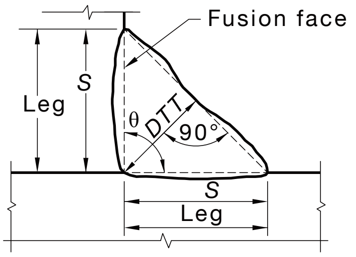
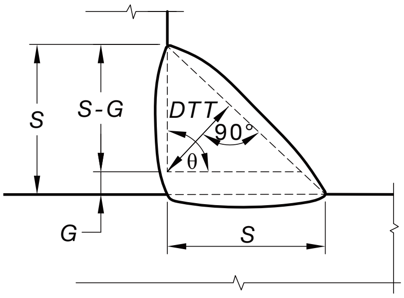
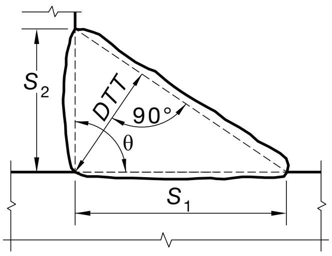
2 For increased *DTT* for fully automatic processes, see Clause 3.3.2.

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 identi-fication	Joint type	Joint description	*DTT* (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*)

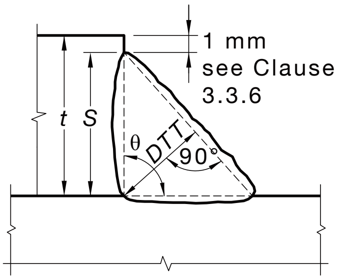
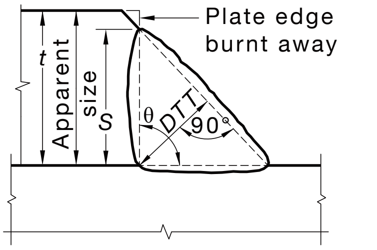
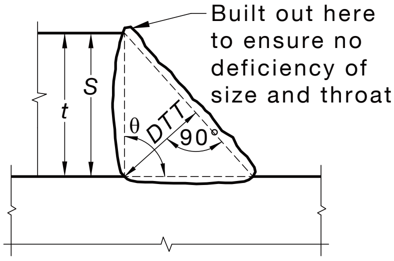
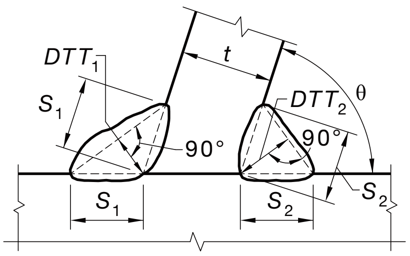
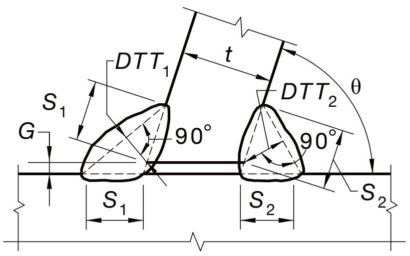
Joint identi-fication	Joint type	Joint description	*DTT* (see Note 2)
F4		Lap joint with unfused edge—applicable for t < 6 $\theta = 90°$	$\frac{S}{\sqrt{2}}$
F5		Lap joint with fused edge—applicable for t < 6 $\theta = 90°$	$\frac{S}{\sqrt{2}}$
F6		Lap joint with built-up edge—applicable to all thicknesses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

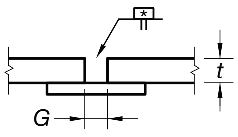
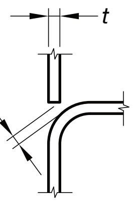
NOTES:

1 Explanation on the notation used is given in Paragraphs E1 to E3.

2 For workmanship tolerances of weld preparations, see Table 5.2.2; except where this Table specifies different tolerances.

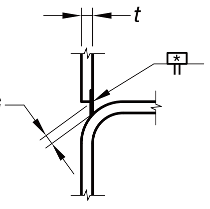
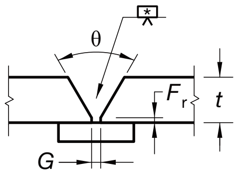
3 Gas metal-arc pulsed-transfer mode may be used for these preparations where average current exceeds 250 A.

4 Gas metal-arc welding with globular transfer mode may be used with CO_2 shielding gas.

Joint identi-fication	Joint type	Preparation detail (see Note 2)	Manual metal-arc	Submerged arc	Flux-cored arc, self-shielded and gas-shielded	Gas metal-arc, spray transfer (see Notes 3 and 4)	Gas metal-arc, short-circuiting arc transfer or pulsed mode	Gas-tungsten arc
H-C 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 1.5*t*	
H-C 1c	Butt weld, equal width brace and chord welded to one side  See Clause 5.2.2 for wide root gaps (*G*)	*t* Position *G*	9 max. F & H *t*/2, 4 mm max.				9 max. F & H *t*/2, 3 mm max.	

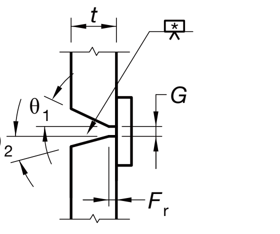
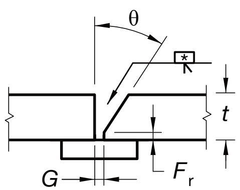
(*continued*)

TABLE E4 (*continued*)

Joint identi-fication	Joint type	Preparation detail (see Note 2)	Manual metal-arc	Submerged arc	Flux-cored arc, self-shielded and gas-shielded	Gas metal-arc, spray transfer (see Notes 3 and 4)	Gas metal-arc, short-circuiting arc transfer or pulsed mode	Gas-tungsten arc
H-C 1d	Butt weld, equal width brace and chord welded one side with backing strip  *M or MR	*t* Position *G*	9 max. F & H 4 mm min.				9 max. F & H 3 mm min.	
H-C 2b	Single-V butt weld, welded one side with backing strip  *M or MR	*t* Position *G* F_r θ	All All 5 to 8 0 60	All F See θ 0 30: G = 6 20: G = 15	All All 5 to 8 0 60	All F 5 to 8 0 60	All All 5 to 8 0 60	

(*continued*)

TABLE E4 (*continued*)

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

APPENDIX F

WELD PROCEDURE REQUIREMENTS ASSOCIATED WITH CHANGES TO THE WELDING CONSUMABLE CLASSIFCATION SYSTEM

(Informative)

F1 GENERAL

Australia and New Zealand have adopted the harmonized ISO welding consumable classification system for the manual metal arc welding (MMAW) and flux-cored arc welding (FCAW) of carbon and other steels. For these steels, the new ISO based consumable classification system brings together two seemingly incompatible systems in common usage:

(a) System A, used in Europe where consumables are classified predominantly by yield strength and the temperature at which 47 J minimum impact energy is guaranteed.

(b) System B, used extensively around the Pacific Rim and North America where consumables are classified by tensile strength and the temperature at which 27 J minimum impact energy is guaranteed.

Australia and New Zealand have generally followed the AWS based system B practice using a tensile strength based classification system with local variations including a 47 J minimum impact energy requirement at the temperature of test as the basis for its consumable classification requirements. For the MMAW process, the system used remained similar to that used by AWS. For the FCAW and other processes, Australia developed its own unique classification systems. With the adoption of the harmonized ISO system, it is expected that usage of AWS based ‘B’ classification system will continue to dominate; however, there will be situations where the European based ‘A’ classification system will be preferred.

To extend the validity of weld procedures qualified under previous classification systems to utilize consumables classified under the harmonized ISO based classification system, the procedure described in this Appendix should be adopted, and where contractually required, agreed between the fabricator and principal prior to the commencement of welding to minimize the need for the fabricator to requalify weld procedures.

It is also recognized that consumables classified under the former Standards systems will remain available in the market and in fabricator’s consumable storage facilities for some time, and these may continue to be used. When welding to this Standard (AS/NZS 1554.1), the fabricator should obtain the new classification from the manufacturer and note the change of classification on both the weld procedure qualification record (PQR) and weld procedure specification (WPS) documents.

For other situations where equivalency cannot be established, the weld procedure should be requalified in accordance with the requirements of this Standard.

F2 SYSTEM CHANGES

F2.1 Strength

Consumable strength designations (ISO uses the term ‘symbol’ rather than ‘designation’) have been realigned for all consumable types and a summary of these changes is given in Table F2.1. These designations are now consistent for all welding processes for which the harmonized ISO system has been applied.

F2.2 Impact resistance

Impact temperature designations have also changed; however, for processes other than MMAW, it is simpler with the designator being more indicative of the temperature of test in a manner similar to that used in the superseded Standards, AS/NZS 2717.1 and AS/NZS 1553.1. Under system B though, only 27 J minimum impact energy is required at the temperature of test unless the consumable classification incorporates the optional ‘U’ designation (47 J minimum impact energy). Consumables bearing the ‘U’ designation have equivalent impact energy requirements to those specified within the former Australasian designation systems.

For MMAW consumables, the situation is more complex as impact energy requirements for system B classified consumables follows the current AWS practice of defining minimum requirements for each electrode class and composition. The system A classification though remains consistent with the method used for other consumables types.

F2.3 Flux designations (MMAW)

Changes to the flux designations (ISO uses the term electrode covering) for MMAW consumables are summarized in Table F2.3. The ISO system B is consistent with AWS designations, which largely means that for most MMAW consumables, the flux type designation will remain unchanged from those used in the superseded AS/NZS 1553.1. The main area of change affects the former type 12 and 13 designations which will now become type 13 although some type 13 consumables with good impact resistance (due to the presence of basic minerals in the flux coating) will most likely be classifiable as a type 03.

F2.4 Usability designations (FCAW)

Flux core and usability were not designated in the former Australasian FCAW classification system thus direct comparison in either system is difficult. Where impact resistance test temperature is known, it can be assumed that, for example, a gas shielded FCAW consumable with a test temperature of −40°C or colder would be a B (basic) designation under system A, or usability designation T5 under the system B (consistent with AWS). For other than metal cored consumables (classed in system A as type M or in system B as T15), other gas-shielded FCAW consumables commonly sold in Australia and New Zealand were the AWS usability designation T1, consistent with the ISO system B T1 usability designation and similar to the P designation of ISO system A.

F2.5 Positional designations

Weld position indicators in the superseded Standard, AS 2203.1, designations used the symbols D for downhand and P for multi-positional. For system A classified consumables, consumables of the former positional class D are equivalent to position designation 3 (including 4) and P are equivalent to designation 1 (including 2 to 5). For system B classified FCAW consumables, the former positional indicator D now uses the symbol 0 and P uses 1, consistent with AWS practice. System A MMAW consumables also utilize this positional designation system. However, for system B MMAW consumables positional characteristics are defined for each coating type, consistent with current Australasian and AWS practice.

F2.6 Weld metal hydrogen

The three-tiered linear weld metal hydrogen designation system used within the harmonized ISO Standards is identical to that currently used in Australasia, these being H5 (very low hydrogen), H10 (low hydrogen) and H15 (medium hydrogen) designations of hydrogen control. No change is required.

F3 EXTENSION OF WELD PROCEDURE QUALIFICATION

Extending the qualification of a weld procedure can be accomplished by carefully considering the changes noted. In most cases extending the procedure qualification will be straightforward particularly if both the trade name and classification of the welding consumable are known.

Where the consumable used to qualify a weld procedure has been identified on the weld procedure using its trade name and classification, the fabricator should append a note on the original procedure qualification record (PQR) noting the change of classification for the welding consumable. For existing welding procedure specification (WPS), a similar notation should also be made on these. For new WPS documents issued, the WPS should include the classification current at the time of issue.

Changes affecting impact resistance designation should also be carefully considered with the former and new rating indicated in the records where there is a variance. Where there is a significant variation in consumable impact rating under ‘system B’, a number of options are available to the fabricator. The consumable used to qualify the procedure may continue to be used for new WPS documents based on the original procedure qualification provided—

(a) they continue to have an impact rating under ‘system A’ equivalent to that shown on the original weld procedure;

(b) they have an equivalent impact rating under the ship classification society system as permitted in Clause 4.6 of this Standard; or

(c) weld metal impact tests establish compliance with the requirements of this Standard.

Alternatively, when the consumable used to qualify a weld procedure has only been identified on the weld procedure using its former classification, identify a welding consumable with an identical classification under the superseded classification system using manufacturer’s literature. Record the trade name of the consumable and its AS/NZS ISO classification on the original PQR and WPS documents as noted above. All new WPS documents should then refer to this modified classification.

For example:

(i) A rutile MMAW consumable is classified to AS/NZS 1553.1 as E4113-2 and has an AWS classification of E6013. Its AS/NZS 4855 classification will be either A-E35 2 RB 1 2 under system A or B-E4303U under system B.

(ii) A gas shielded flux-cored wire is classified to superseded Standard AS 2203.1 as ETP-GMp-W503A CM1 H10. Its AWS classification is E71T-1 MJ H8. Under AS/NZS ISO 17632 it will be classified as either A T42 2 P M 2 H10 or B-T49 2U T1 1 MAKH10.

In all other cases or where equivalence cannot be established, it will be necessary to requalify the weld procedure in accordance with the requirements of this Standard.

F4 OTHER PROCESSES

To establish equivalence with ISO based consumable Standards for the GMAW and SAW process, the procedure is similar to that for the FCAW process. This is largely due to the ISO based classifications for most processes adopting similar strength, impact resistance and hydrogen control designations. Provided that the fabricator has included sufficient information to correctly identify the trade name and previous classification of consumables used to qualify their weld procedures, the procedure tests do not need to be repeated with the adoption of the ISO based classification system.

As with previous examples, the fabricator should append a note on the original procedure qualification report (PQR) noting the change of classification for the welding consumable, with a similar notation being made on WPS documents. For new WPS documents, the WPS should include the classification current at the time of issue.

TABLE F2.1

EQUIVALENT STRENGTH DESIGNATIONS

MMAW			FCAW		
AS/NZS ISO	**AS/NZS 1553**	**AWS**	**AS/NZS ISO 17632**	**AS 2203.1**	**AWS**
A-E35, B-E43XX	E41XX	E60XX	A-T35, B-T43	W40XX	E6X
A-E42, B-E49XX	E48XX	E70XX	A-T42, B-T49	W50XX	E7X
A-E50, B-E55XX	E55XX	E80XX	A-T50, B-T55	W55XX	E8X
A-E55, B-E62XX	E62XX	E90XX	A-T55, B-T62	W62XX	E9X

TABLE F2.3

EQUIVALENT MMAW FLUX DESIGNATIONS

ISO 'system B'	ISO 'system A'	AS/NZS 1553	AWS
03	RB	13	—
10	C, RC	10	10
11	C, RC	11	11
12	R	—	12
13	R	12, 13	13
14	RR	14	14
15	B	15	15
16	B	16	16
18	B	18	18
19	RA	19	19
20	A	20	20
24	RR	24	24
27	A	27	27
28	B	28	28
40	—	99	—
48	B	46, 48	48

NOTE: This Table identifies nearest equivalent designations. Some consumables may have classifications that vary from that shown.

APPENDIX G

TYPICAL MATERIAL GROUPS FOR COMMON STEELS

(Informative)

Table G1 lists the typical material groups for common steels categorized by relevant Standards.

TABLE G1
COMMON STEELS—MATERIAL GROUPS

Grade or specification	Weldability group	ISO/TR 15608	AWS B2.1	AWS D1.1	AS/NZS 3992	ASME IX
			M No.	Group		
AS/NZS 1163						
C250	1	1	I, II	I, II	A1	P1.1
C350	3	1	I, II	I, II	A2	P1.1
C450	3	2	III	III	A2	P1.1
AS 1397						
G250	1	1	I, II	I, II	A1	P1.1
G300	5	1	I, II	I, II	A1	P1.1
G350	5	1	II	II	A2	P1.1
G450	1	2	III	III	A3	P1.1
AS 1450						
C200, H200	1	1	I, II	I, II	A1	P1.1
C250,H250	4	1	I, II	I, II	A1	P1.1
C350, H350	5	1	II	II	A2	P1.1
C450	4	2	III	III	A2	P1.1
AS 1548						
PT430	4	1	I, II	I, II	A1	P1.1
PT460	4	1	II	II	A2	P1.1
PT490	5	1	II	II	A2	P1.1
PT540	5	2	III	III	A2	P1.1
AS/NZS 1594						
HA1, HA3, HA4N, HA200, HA250/1	1	1	I, II	I, II	A1	P1.1
HA250, HU250, HA300, HU300, HA300/1, XF300, HU300/1	3	1	I, II	I, II	A1	P1.1

(continued)

TABLE G1 (*continued*)

Grade or specification	Weldability group	ISO/TR 15608	AWS B2.1	AWS D1.1	AS/NZS 3992	ASME IX
			M No.	Group		
HA350		1	I, II	I, II	A2	P1.1
HW350	5	1	II	II	A2	P1.1
HA400	4	2	II	II	A2	P1.1
XF400	3	2	II	II	A2	P1.1
XF500	4	2	III	III	A3	P1.1
AS/NZS 3678 and AS/NZS 3679.2						
200	1	1	I, II	I, II	A1	P1.1
250	4	1	I, II	I, II	A1	P1.1
300	4	1	II	II	A1	P1.1
350	5	1	II	II	A2	P1.1
WR350	5	3	II	II	A2	P1.1
400	5	2	II	II	A2	P1.1
450	5	2	III	III	A2	P1.1
AS/NZS 3679.1						
300	4	1	II	II	A1	P1.1
350	5	1	II	II	A2	P1.1

NOTES:

1 Only grades with defined strength are shown in this Table.

2 Steels type numbers used in this Standard (not shown) are allocated based on a combination of yield strength and impact properties rather than chemistry and strength as utilised in the other listed Standards.

3 Weldability groups are those allocated within WTIA Technical Note 1 and this Standard.

4 Weldability Group Number 5 allocated to HW350 and WR350 steels is based on the typical maximum carbon equivalent encountered in Australia and New Zealand rather than the maximum specification limits normally applied.

5 ISO/TR 15608 groupings are used in AS/NZS 2980.

6 AWS B2.1 M numbers and groups have been allocated by the relevant AWS B2 committee

7 AWS D1.1 and ASME group numbers shown are for guidance only and have not necessarily been confirmed by either organization.

APPENDIX H

SELECTION OF MATERIALS FOR THE AVOIDANCE OF LAMELLAR TEARING

(Informative)

H1 GENERAL

Lamellar tearing is a weld induced flaw in the material which generally becomes evident during ultrasonic examination. The main risk of tearing is with cruciform, T- and corner joints and with complete penetration welds where high levels of strain are known to occur in the through-thickness direction in the element to which the connection is made. This strain arises from the shrinkage of the weld metal as it cools. It is greatly increased where free movement is restrained by other portions of the structure.

The susceptibility of the material can be determined by measuring the through-thickness ductility as specified in AS/NZS 3678, which is expressed in terms of quality classes identified by Z-values.

NOTE: Further guidance on the avoidance of lamellar tearing is given in WTIA Technical Note 6.

H2 PROCEDURE

The risk of lamellar tearing occurring is minimal if the following condition is satisfied:

$$Z_{Ed} \leq Z_{Rd} \quad \text{. . . H2.1}$$

where

Z_{Ed} = the required design Z-value resulting from the magnitude of strains from restrained metal shrinkage under the weld beads

Z_{Rd} = the available design Z-value for the material according to AS/NZS 3678, i.e. Z15, Z25 or Z35

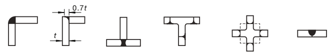
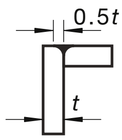
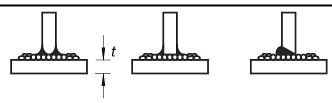
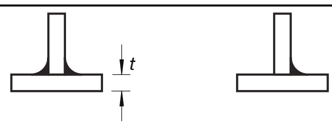
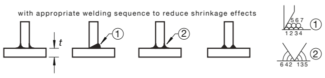
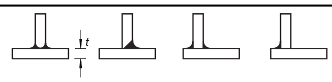
The required design value Z_{Ed} may be determined using—

$$Z_{Ed} = Z_a + Z_b + Z_c + Z_d + Z_e \quad \text{. . . H2.2}$$

in which Z_a, Z_b, Z_c, Z_d and Z_e are as given in Table H2.

TABLE H2

CRITERIA AFFECTING THE TARGET VALUE OF Z_{Ed}
(Adapted from Table 3.2 of EN 1993-1-10:2005 with the permission of CEN)

Item	Subject	Effective weld depth a_{eff} (see Figure H2)		Z_i
(a)	Weld depth relevant for straining from metal shrinkage	$S \leq 7$ mm		$Z_a = 0$
		$7 < S \leq 10$ mm		$Z_a = 3$
		$10 < S \leq 20$ mm		$Z_a = 6$
		$20 < S \leq 30$ mm		$Z_a = 9$
		$30 < S \leq 40$ mm		$Z_a = 12$
		$40 < S \leq 50$ mm		$Z_a = 15$
		$50 < S$		$Z_a = 15$
(b)	Shape and position of welds in T- and cruciform- and corner-connections			$Z_b = -25$
		Corner joints		$Z_b = -10$
		Single run fillet weld $Z_a = 0$ or fillet welds with $Z_a > 1$ with buttering with low strength weld material		$Z_b = -5$
		Multi run fillet welds		$Z_b = 0$
		Partial and full penetration welds		$Z_b = 3$
		Partial and full penetration welds		$Z_b = 5$
		Corner joints		$Z_b = 8$
(c)	Effect of material thickness t on restraint to shrinkage	$t \leq 10$ mm		$Z_c = 2^*$
		$10 < t \leq 20$ mm		$Z_c = 4^*$
		$20 < t \leq 30$ mm		$Z_c = 6^*$
		$30 < t \leq 40$ mm		$Z_c = 8^*$
		$40 < t \leq 50$ mm		$Z_c = 10^*$
		$50 < t \leq 60$ mm		$Z_c = 12^*$
		$60 < t \leq 70$ mm		$Z_c = 15^*$
		$70 < t$		$Z_c = 15^*$
(d)	Remote restraint of shrinkage after welding by other portions of the structure	Low restraint:	Free shrinkage possible (e.g. T-joints)	$Z_d = 0$
		Medium restraint:	Free shrinkage restricted (e.g. diaphragms in box girders)	$Z_d = 3$
		High restraint:	Free shrinkage not possible (e.g. stringers in orthotropic deck plates)	$Z_d = 5$
(e)	Influence of preheating	Without preheating		$Z_e = 0$
		Preheating ≥ 100°C		$Z_e = -8$

* May be reduced by 50% for material stressed, in the through-thickness direction, by compression due to predominantly static loads

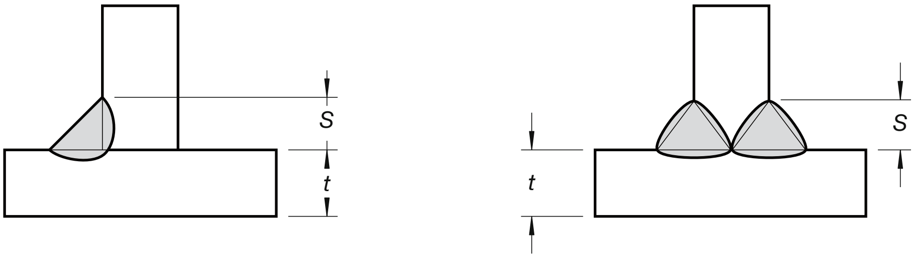


FIGURE H2 EFFECTIVE WELD DEPTH *S* FOR SHRINKAGE

H3 NON-DESTRUCTIVE EXAMINATION

For high risk fabrications, fabricators may find it useful to examine plates to be welded using ultrasonic techniques to establish the location of internal discontinuities such as non-metallic inclusions. This is particularly relevant when the direction of loading is normal to the plate surface (*Z* direction). The ultrasonic sensitivity to be used for parent metal scanning in areas where welds are to be made should comply with AS 2207, i.e. in a discontinuity-free area and using a compression wave probe, the gain on the ultrasonic flaw detector should be set so that the second back echo is displayed at full screen (graticule) height. Where reflectors produce echoes with an amplitude of 25% graticule height or above within 0–25% of the plate thickness, it may be beneficial to place welds away from such areas or to turn the plate over to enable placement of critical welds on the side of the plate furthest from the indications.

Should discontinuities be later detected in the weld heat affected zone it should be remembered that imperfections of parent metal origin are not considered a cause for rejection of the weld (see Clause 6.2.2).

Fabricators and inspectors should be aware that ultrasonic examinations will not typically detect inclusions normally associated with lamellar tearing (e.g. manganese sulphides), and similarly are not an indicator of through-thickness ductility.

BIBLIOGRAPHY

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2203.1 Part 1: Ferritic steel electrodes (superseded)

4037 Pressure equipment—Examination and testing

4458 Pressure equipment—Manufacture

AS/NZS

1553 Covered electrodes for welding
1553.1 Part 1: Low carbon steel electrodes for manual metal-arc welding of carbon steels and carbon-manganese steels (superseded)
1553.2 Part 2: Low and intermediate alloy steel electrodes for manual metal-arc welding of carbon steels and low and intermediate alloy steels (superseded)

1554 Structural steel welding
1554.4 Part 4: Welding of high strength quenched and tempered steels
1554.5 Part 5: Welding of steel structures subject to high levels of fatigue loading

2717 Welding—Electrodes—Gas metal arc
2717.1 Part 1: Ferretic steel electrodes (superseded)

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3834.1 Part 1: Criteria for the selection of the appropriate level of quality requirements
3834.2 Part 2: Comprehensive quality requirements
3834.3 Part 3: Standard quality requirements
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31000 Risk management—Principles and guidelines

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B2.1 Specification for welding procedure and performance qualification

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ISO

15614 Specification and qualification of welding procedures for metallic materials—Welding procedure test
15614-10 Part 10: Hyperbaric dry welding

15618 Qualification testing of welders for underwater welding
15618-1 Part 1: Diver-welders for hyperbaric wet welding
15618-2 Part 2: Diver-welders and welding operators for hyperbaric dry welding

WTIA [Welding Technology Institute of Australia]

Technical Note 1:	Weldability of steels
Technical Note 3:	Care and conditioning of arc welding consumables
Technical Note 5:	Flame cutting of steels
Technical Note 6:	Control of lamellar tearing
Technical Note 7:	Health and safety in welding
Technical Note 10:	Fracture mechanics
Technical Note 11:	Commentary AS/NZS 1554 Structural steel welding
Technical Note 22:	Welding electrical safety

AMENDMENT CONTROL SHEET

AS/NZS 1554.1:2014

Amendment No. 1 (2015)

CORRECTION

SUMMARY: This Amendment applies to Clauses 2.1, 4.7.1, 4.7.7.1, 4.7.7.2 and 5.3.1.

Published on 23 September 2015.

Amendment No. 2 (2017)

CORRECTION

SUMMARY: This Amendment applies to Clause 3.3.5.

Published on 5 September 2017.

NOTES

NOTES

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