

Australian/New Zealand Standard™

Structural steel welding

Part 6: Welding stainless steels for structural purposes



AS/NZS 1554.6:2012

This Joint Australian/New Zealand Standard was prepared by Joint Technical Committee WD-003, Welding of Structures. It was approved on behalf of the Council of Standards Australia on 16 February 2012 and on behalf of the Council of Standards New Zealand on 9 May 2012.

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Australian/New Zealand Standard™

Structural steel welding

Part 6: Welding stainless steels for structural purposes

Originated as AS/NZS 1554.6:1994.
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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 1554.6:1994.

The objective of this Standard is to provide rules for the welding of a wide range of stainless steel fabrications (other than pressure vessels and pressure piping), and it applies to statically and dynamically loaded welds.

The objective of this revision is to substantially update the Standard to reflect changes in structural welding since the publication of the original edition in 1994. As this is a major revision, changes from the previous edition are not indicated in this Preface.

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 this Standard.

Strength capacity of welds is not covered in this Standard and designers are referred to relevant design codes or specifications for this purpose.

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

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

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STANDARDS AUSTRALIA/STANDARDS NEW ZEALAND

Australian/New Zealand Standard Structural steel welding

Part 6: Welding stainless steels for structural purposes

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard specifies requirements for the welding of stainless steel structures made up of combinations of stainless steel plate, sheet, 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).
- (d) Gas tungsten arc welding (GTAW).
- (e) Flux cored arc welding (FCAW).
- (f) Plasma arc welding (PAW).

The Standard applies to the welding of steelwork in structures complying with appropriate Standards. Where welded joints are governed by dynamic loading conditions, the Standard applies to those welded joints that comply with the fatigue provisions of the relevant application Standards.

The Standard prescribes materials of construction, weld preparations and weld qualities, surface finish, qualification of welding procedures and welding personnel, and fabrication and inspection requirements for welds related to all stainless steel fabrication including aesthetic, hygienic or other non-structural applications.

NOTE: GMAW includes waveform controlled welding such as "synergic", "programmable", and "microprocessor controlled" processes' e.g. pulsed spray transfer, controlled short circuit transfer.

1.2 EXCLUSIONS

The Standard does not cover the selection of grades to suit the corrosion requirements, although an informative appendix is included. The Standard does not cover the design of welded connections or permissible stresses in welds, nor the production, rectification or repair of castings.

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

NOTE: For further guidance on welding of stainless steel, refer to AWS D1.6, WTIA Technical Note 13, WRC Bulletin 519 and ASSDA Reference Manual. For guidance on selection to suit corrosion requirements, refer to AS/NZS 4673.

1.3 INNOVATION

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

The joint Australian/New Zealand Standards Committee WD-003, Welding of Structures, can act in an advisory capacity concerning equivalent suitability, but specific approval remains the prerogative of the inspecting authority.

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

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

1.5.1 Fabricator

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

1.5.2 Inspecting authority

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

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

1.5.3 Inspector

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

1.5.4 May

Indicates the existence of an option.

1.5.5 Principal

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

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

1.5.6 Shall

Indicates a requirement.

1.5.7 Should

Indicates a recommendation.

1.6 WELD CATEGORIES AND SURFACE FINISHES

NOTE: For guidance on the selection of weld categories and surface finishes, see Appendix B.

1.6.1 Weld categories

The Standard provides six categories of welds based on the type of application. These involve the selection of one of three levels of internal imperfections combined with one of three classes of surface imperfections (see Section 6).

1.6.2 Surface finishes

The Standard provides three grades of surface finish based on the type of application (see Section 6).

1.6.3 Welds subject to dynamic loading

For welds subject to levels of dynamic loading where AS 4100 and NZS 3404.1 require detail category 112 or lower, weld imperfections shall meet the requirements of category 1B in accordance with Section 6 of this Standard.

Where detail categories greater than 112 are applicable, weld imperfections shall meet the requirements of category FA in accordance with Section 6, and transition of thickness or width for butt welds shall comply with Clause 3.2.5.

NOTE: Category FA may be suitable for austenitic stainless steel structures designed in accordance with the guidelines of AS/NZS 4673 Appendix F.

1.7 MANAGEMENT OF QUALITY

1.7.1 Quality management

Fabricators shall ensure that all welding and related activities prescribed within Clause 1.7.2 and this Standard are managed under a suitable quality management system.

Such a system should generally comply with the requirements of AS/NZS ISO 3834 and its parts, 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 HEAT TREATMENT

Postweld heat treatment (PWHT) is not normally required or necessary for austenitic, ferritic or ferritic-austenitic (duplex) stainless steels. Martensitic stainless steels generally require pre and post weld heat treatment. Ferritics generally cannot and should not be heat treated. Heat treatment of these grades is not covered by this Standard.

Where required, heat treatment should be carried out in accordance with the manufacturer's instructions for the grade specified.

It is important to note that heat treatments used for carbon steels can be highly detrimental to both the corrosion and mechanical properties of stainless steels.

NOTE: Expert advice should be sought where dissimilar metal joints are to be heat-treated. Refer to AS 4458 for information on PWHT.

1.9 SAFETY

1.9.1 Welding safety

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

1.9.2 Welding equipment

Welding plant and equipment shall comply with all the relevant sections of appropriate regulations, and the relevant requirements of AS 1966.1, AS 1966.2, AS 2799, AS/NZS 1995 and AS 60974.1.

1.9.3 Pickling and passivation

Both pickling and passivation use acids that can be damaging to health and the environment. For Australia, requirements of the relevant hazardous substances legislation promulgated by the regulatory authorities shall be followed. For New Zealand, requirements of the Environmental Risk Management Authority (ERMA) shall be followed.

NOTE: Pickling treatments also passivate the surface during washing.

1.9.4 Other hazards

The fabricator shall identify and manage any other risks and hazards from welding that are not covered by Clauses 1.9.1 and 1.9.2. Due consideration shall be given to the control and dispersal of emitted fumes including when welding through surface coatings, and the safe handling and disposal of surface treatment chemicals including pickling and passivation pastes.

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, and the ASSDA Reference Manual.

SECTION 2 MATERIALS OF CONSTRUCTION

2.1 GENERAL

The grades of materials and welding consumables given in this Standard shall be traceable to the manufacturer.

2.2 PARENT MATERIAL

The parent material to be welded shall be of any one of the following groups:

- (a) Austenitic stainless steels.
- (b) Ferritic stainless steels.
- (c) Martensitic stainless steels.
- (d) Duplex (ferritic-austenitic) stainless steels.

The selection of the appropriate alloy grade for any application is the responsibility of the principal. Alternative grades shall only be acceptable with permission of the principal.

NOTES:

- 1 Precipitation hardening grades are not included but may be dealt with under the innovation provisions (see Clause 1.3).
- 2 For guidance on the welding of dissimilar stainless steel to structural carbon steel joints see Appendix H.

2.3 BACKING MATERIAL

Permanently attached backing material shall be of the same grade as the structure unless otherwise agreed with the principal. Where permanent backing is exposed to corrosive media it shall be seal welded to the structure.

Temporary backing bars, especially those made of copper, shall contain an appropriate groove and weld parameters shall be modified to avoid copper pick-up in the weld.

2.4 WELDING CONSUMABLES

2.4.1 Electrodes and filler metals

Electrodes or filler metals having chemical composition complying with the following Standards are prequalified where they are matched with the steel types in accordance with Table 4.6.1.

- AS/NZS 1167.2;
- AS/NZS 4854;
- AS/NZS ISO 14343;
- AS/NZS ISO 17633;
- ANSI/AWS A5.4;
- ANSI/AWS A5.9;
- ANSI/AWS A5.22.

When requested by the principal (see Appendix G), the fabricator shall provide the manufacturer's certification that filler metals meet the requirements of the classification of grade and minimum ferrite numbers (FN) for all-weld-metal test.

NOTE: For filler metals according to AWS A5.22 and AWS A5.9, certification should indicate a ferrite number for the all-weld-metal of at least 3.0FN.

2.4.2 Care of electrodes and filler metals

Electrodes and filler wires shall be stored in a warm dry place adequately protected from any damage that will hinder the intended use and quality of the deposited weld. Where special protection during storage and use is recommended by the manufacturer, electrodes and filler wires they shall be stored and used in accordance with the recommended conditions. Filler wires shall be dry, smooth and free from corrosion or other matter deleterious either to satisfactory operation or to the weld metal. If the electrodes or filler wires are coated, the coating shall be continuous and firmly adherent. Where the manufacturer makes specific recommendations covering conditioning and pretreatment of electrodes prior to use, such recommendations shall be followed. Off cut material shall not be used as filler material.

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

2.4.3 Flux

Flux for submerged arc welding shall be kept dry and stored in accordance with the manufacturer's instructions. 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 that is fused in the welding process shall not be re-used.

NOTE: Flux for submerged arc welding should be selected to prevent loss of chromium or increase of carbon content in the weld.

2.4.4 Shielding, backing or purging gas

Gas and gas mixtures used for shielding, backing or purging shall be of a welding grade complying with the requirements of AS 4882 and suitable for the intended application.

SECTION 3 DETAILS OF WELDED CONNECTIONS

3.1 GENERAL

3.1.1 Permissible weld types

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

3.1.2 Drawings

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

- (a) Specification, grade and thickness of parent metal.
- (b) Location, type, size, and effective length of all welds.
- (c) Whether welds are to be made in the shop or at the site.
- (d) Weld category and surface finish.
- (e) Surface treatment.
- (f) Details of non-standard welds.
- (g) Where seal welds are required, details of such welds.
- (h) Type and extent of inspection, including any special inspection requirements.
- (i) 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 butt weld for a 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*

For stress calculations, 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*

For stress calculations, the design throat thickness of an incomplete penetration butt weld shall be as follows:

- (a) Prequalified incomplete penetration butt weld except as otherwise provided in Item (c) below, as shown in Table D2, Appendix D.
- (b) Non-prequalified incomplete penetration butt weld except as provided in Item (c) below—
 - (i) where $\theta < 60^\circ$: $D - 3 \text{ mm}$; or
 - (ii) where $\theta \geq 60^\circ$: D .

where

D = depth of preparation

θ = angle of preparation.

- (c) For an incomplete penetration butt weld 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, an increase in the design throat thickness up to the depth of penetration shall be allowed. Where such penetration is achieved, the size of the weld may be correspondingly reduced.

NOTE: Incomplete penetration butt welds may not be suitable for some corrosion applications.

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.

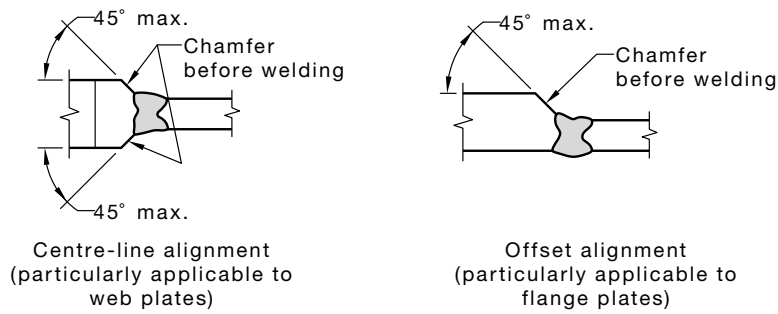
3.2.5 Transition of thickness or width

Butt-welded joints between axially aligned parts of different thickness or unequal width that are subject to tension or to fatigue loads 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.

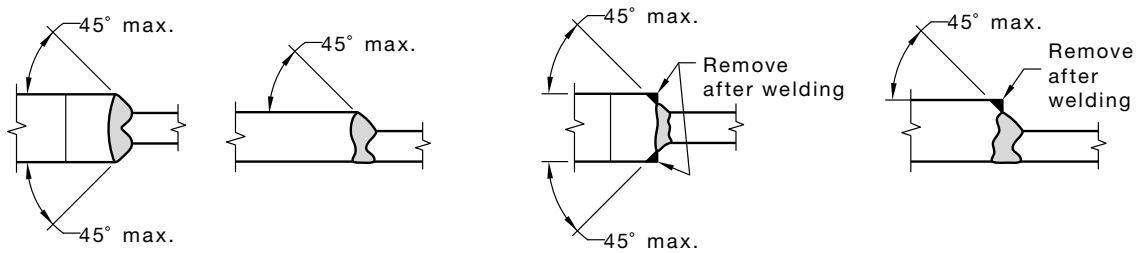
The transition slope between the parts subject to tensile stress shall not be steeper than 1:1. However, fatigue or other design considerations may require a lesser slope than this or a curved transition between the parts.

For category FA welds, the transition slope between the parts shall not exceed 4:1. Butt-welded T-joints may have a small fillet weld superimposed on each welded face not exceeding the lesser of 6 mm or $\frac{t_{\text{thinner}}}{3}$.

Larger fillet welds are not permitted unless a compound joint (see Clause 3.4) has been specified by the designer.



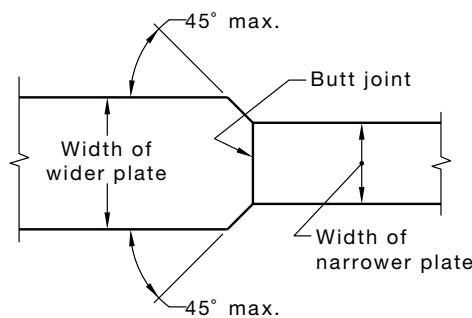
(i) Transition by chamfering thicker part



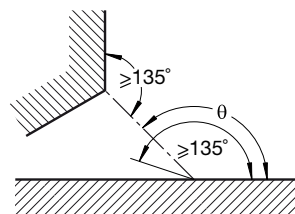
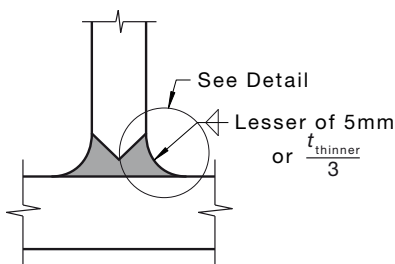
(ii) Transition by sloping weld surface

(iii) Transition by sloping weld surface and chamfering

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



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



NOTE: For category FA welds, the toe should have an external angle $\theta \geq 135^\circ$.
If the weld makes an angle $\theta < 135^\circ$ at either toe, the weld is to blend with a minimum radius of 5mm.
Undercut is not permitted.

NOTES:

- 1 Transition slopes shall comply with Clause 3.2.5.
- 2 These diagrams do not prescribe minimum transition slopes as fatigue considerations may require more gradual transitions.

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

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.

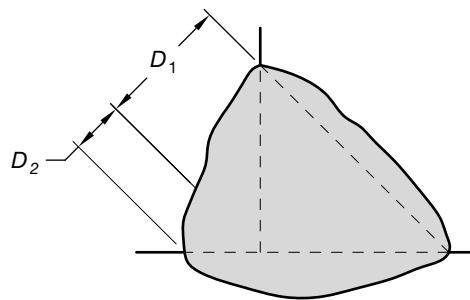
Where there is a root gap, the size shall be given by the lengths of the legs of the inscribed triangle reduced by the amount shown in Table D3.

The size of a fillet weld shall satisfy strength or corrosion requirements (or both).

3.3.2 Design throat thickness

For stress calculations, the design throat thickness of a fillet weld shall be as shown in Table D3, Appendix D.

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



NOTE: $DTT = D1 + 0.85 D2$, where DTT is the design throat thickness for deep penetration fillet welds made by a fully automatic process.

FIGURE 3.3.2 DEEP PENETRATION WELD

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 need not exceed the thickness of the thinner part joined (see also Clause 5.3).

TABLE 3.3.5
MINIMUM SIZE (LEG LENGTH)
OF FILLET WELDS

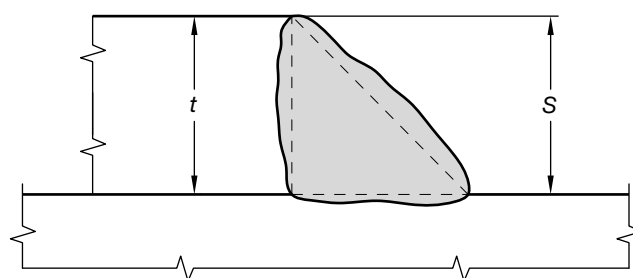
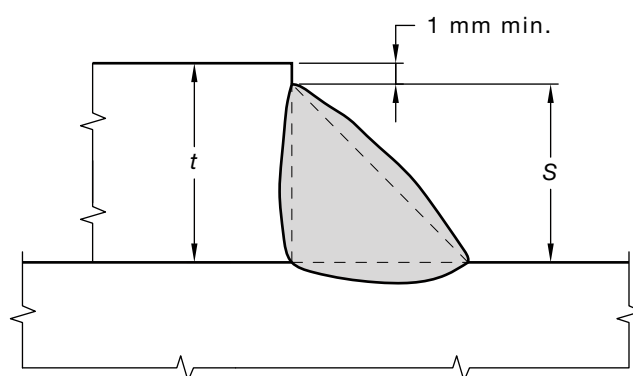
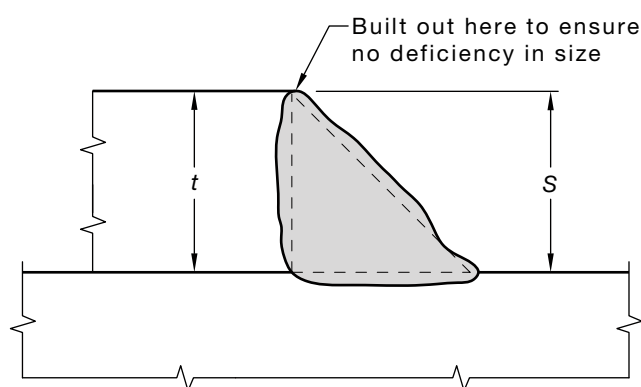
millimetres	
Thickness of thickest part (<i>t</i>)	Minimum size of fillet weld
≤ 3	$2t/3^*$
$>3 \leq 7$	3^*
$>7 \leq 10$	4^*
$>10 \leq 15$	5
>15	6

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

3.3.6 Maximum size of fillet welds along edges

The maximum size of 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.

(a) $S = t$ for $t < 6\text{ mm}$ (b) $S \leq t - 1\text{ mm}$ for $t \geq 6\text{ mm}$ (c) $S = t$ for all thicknesses where edge is built out**LEGEND:** S = size of fillet weld t = thickness of part joined**FIGURE 3.3.6 MAXIMUM SIZE OF FILLET WELDS ALONG EDGES****3.4 COMPOUND WELDS****3.4.1 Description of compound weld**

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

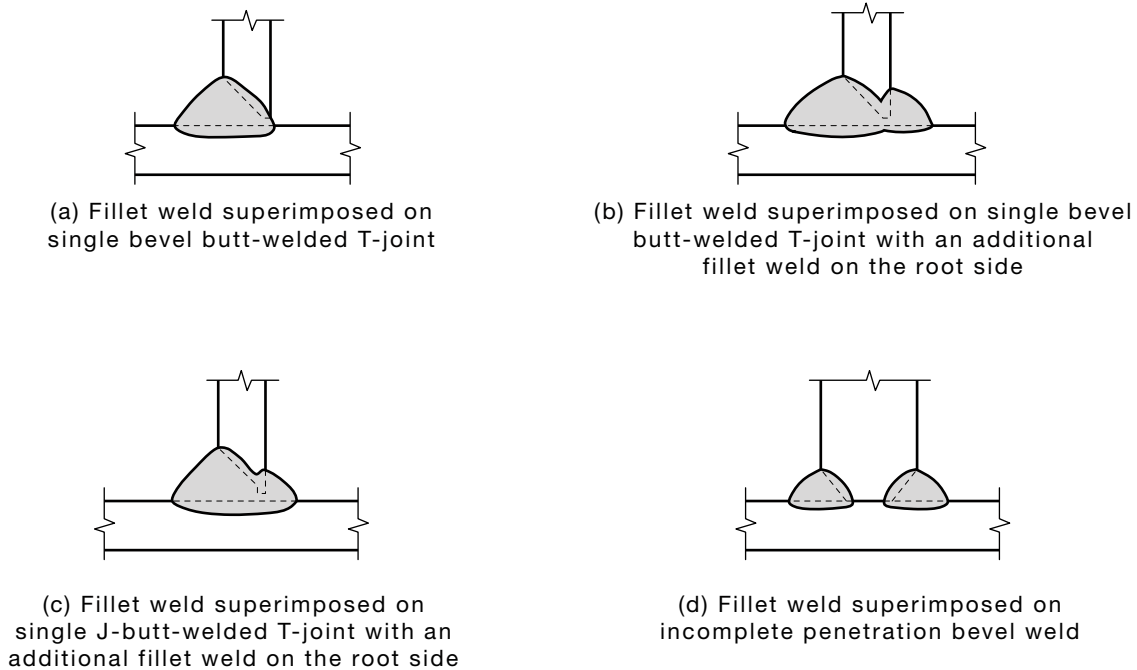


FIGURE 3.4.1 COMPOUND WELDS

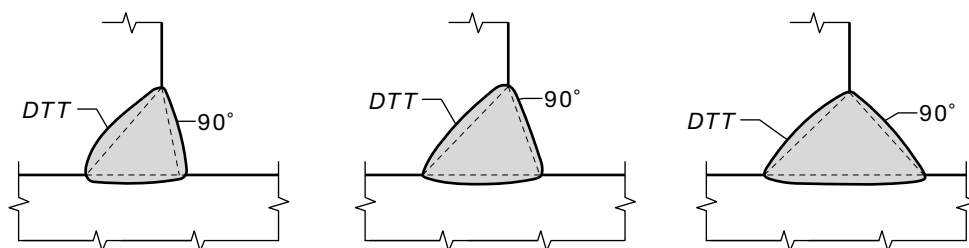
3.4.2 Design throat thickness (DTT)

3.4.2.1 Complete penetration butt weld

For stress calculations, 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 Incomplete penetration butt weld

For stress calculations, 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.



NOTE: The design throat thickness (DTT) of a weld is the minimum distance from the root of a weld to its face, less any reinforcement. The three sketches above illustrate this concept.

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

3.5 SEAL WELDS

Seal welds shall be made in accordance with a qualified welding procedure. Seal welds shall be single-run fillet or incomplete penetration butt welds as applicable.

NOTES:

- 1 Where seal welding is required, this should be specified clearly on the drawings or other documents (see Clause 3.1.2).
- 2 Seal welds are frequently used in stainless steel fabrication to seal crevices which may act as sites for corrosion.

3.6 PLUG WELDS

The minimum diameter of the hole for a plug weld shall be no less than the thickness of the part containing it plus 8 mm. The maximum diameter shall equal the minimum diameter plus 3 mm or 2.25 times the thickness of the member, whichever is greater.

The minimum centre-to-centre spacing of plug welds shall be four times the diameter of the hole.

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

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

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

3.7 SLOT WELDS

The length of the slot for a slot weld shall not exceed 10 times the thickness of the part containing it. The width of the slot 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 minimum width plus 3 mm; 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 not less than the thickness of the part containing it, except those ends which 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.

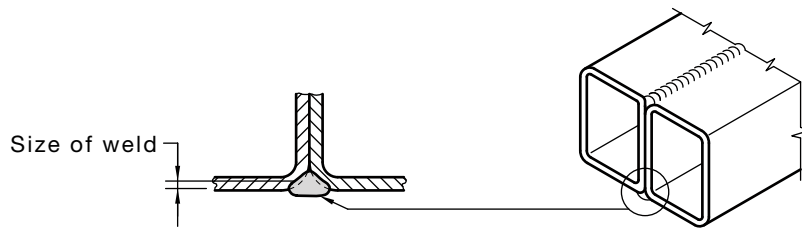
The effective area of a slot weld shall be as for a fillet weld of the same size and effective length.

Where a slot weld is made by completely or partially filling the slot and not made with a fillet weld around the perimeter of the slot, the effective area shall be as for plug welds.

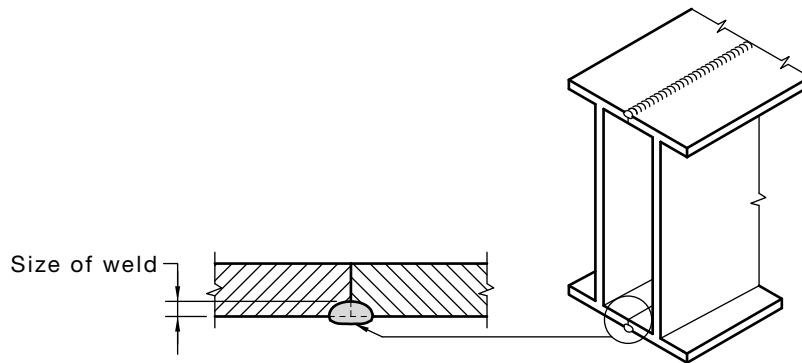
3.8 COMBINING STEEL SECTIONS

The size of welds made for the purpose of combining rolled steel sections shall be taken as shown in Figure 3.8 and shall satisfy strength or corrosion requirements, or both.

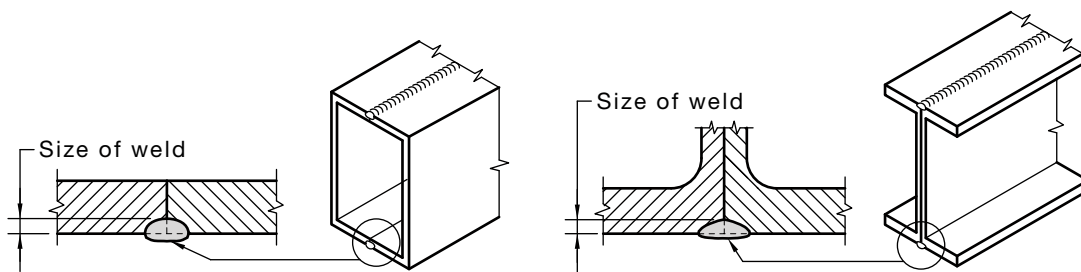
NOTE: Incomplete penetration welds are only allowed where there is no risk of crevice corrosion.



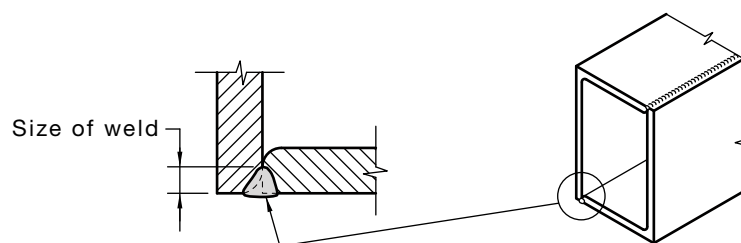
(a) Hollow sections



(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 (that is the weld preparation, the welding consumables and the welding parameters) shall be qualified before welding of either the structure or the component commences.

A welding procedure shall be established and the applicable parameters listed in the welding procedure qualification record PQR, 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).

NOTE: Forms suitable as PQR and welding procedure specification (WPS) are shown in Appendix C.

4.1.2 Butt welds

For complete penetration and incomplete penetration butt welds, the following also apply:

- (a) For welding processes MMAW, SAW, GMAW, GTAW and FCAW, a procedure qualification of a butt weld that has been welded from only the one side on a single-V or a single-U preparation shall qualify for single-sided butt welds in both plate and pipe.
- (b) A procedure qualification for any prequalified butt-welded joint listed in Table D1, D2 or D4, Appendix D, 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 (n) 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 members of non-equal thickness, 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 5.10).

4.1.3 Fillet welds

For fillet welds, the following also apply:

- (a) The procedure qualification of a fillet weld using processes on either plate or pipe shall qualify for fillet welds on both plate and pipe.
- (b) The procedure qualification of a fillet weld shall be based on the fillet weld size (leg length), not material thicknesses, as follows:
 - (i) For a single-run fillet weld, qualification shall cover the size of the fillet weld used for the qualification test and all single-run fillet welds below the size qualified as permitted within the ranges of the essential variables of Table 4.11(A) for the positions shown in Table 4.1.3.
 - (ii) For multi-run fillet welds, qualification shall cover the size of the fillet weld used for qualification and all larger multi-run fillet welds 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 PQR.
- (c) A change in welding direction between vertical up and vertical down shall require separate qualification.

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

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

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

4.1.4 Qualification of multiple welding positions

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

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

4.2 METHOD OF QUALIFICATION OF WELDING PROCEDURE

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

- (a) A prequalified procedure in accordance with Clause 4.3.
- (b) Production of documentary evidence of relevant prior experience by the fabricator.
NOTE: A completed welding procedure sheet such as one of those shown in Appendix C, together with records of any tests carried out as required by the application Standard to which the procedure was qualified constitutes documentary evidence of prior experience.
- (c) Production of a suitable length of test piece of the same joint type, material type, material thickness, surface finish, and edge preparation as the component upon which the procedures are to be applied, and testing it in accordance with Clause 4.7 where the type of joint allows such testing. The test piece may be fabricated as a run-on or run-off piece during production.
- (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, surface finish, welding conditions, 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.

All welding procedures shall meet the requirements of essential variables and weld categories of AS/NZS 1554.6.

4.3 PREQUALIFIED WELDING PROCEDURES

Welding procedures shall be deemed to be prequalified where all the following conditions are satisfied:

- (a) The joint preparations are prequalified in accordance with Clause 4.5.
- (b) The consumables are prequalified in accordance with Clause 4.6.
- (c) The workmanship and welding techniques, including the preheat and inter-run temperature requirements and surface finish requirements, comply with this Standard.
- (d) Documentary evidence is available 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, 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.
- (e) Where required by the principal, documentary evidence is available of a satisfactory corrosion test in accordance with Clause 4.7.7.
- (f) Where required by the principal, documentary evidence is available of a satisfactory ferritic content as specified (see Clause 4.7.8).

In addition, requirements for preheat, PWHT and heat input limitation shall be stipulated where appropriate (see Table 5.10). For ferritic grades, any heat input limitation shall be stipulated.

Prequalified welding procedures shall be fully documented.

4.4 PORTABILITY OF QUALIFIED WELDING PROCEDURES

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

- (a) the original qualification tests were carried out in accordance with this Standard or other acceptable national or international Standards, and were fully documented;
- (b) the second fabricator has adequate equipment and facilities and demonstrates successful welding in 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 that the welding processes and consumables used comply with the recommendations of the electrode manufacturer.

NOTES:

- 1 Single sided incomplete penetration butt welds and fillet welds may not be suitable for some corrosion applications due to the presence of the crevice on the reverse side. The approval of the principal should be sought.
- 2 Super duplexes may require a larger root gap for butt welds than that for other types of stainless steels. The steel manufacturer's welding specifications should be followed.

4.5.2 Prequalified complete penetration butt welds

Joint preparations for prequalified complete penetration butt welds conforming to a preparation listed in Table D1, shall be deemed prequalified. Provided that each preparation complies with the requirements of Table D1 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 D2, shall be deemed prequalified. Provided that each preparation complies with the requirements of Table D2, for double-V, double bevel, double-U, and double-J, preparations of unequal depth are prequalified also.

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

4.5.4 Prequalified fillet welds

Joint preparations for prequalified fillet welds conforming to a preparation listed in Table D3, 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 test 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 rolled 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 D1.
- (b) Joints welded from one side and complying with one of the processes specified in Table D4.

Joint preparations for connections butt welded from one side, complying with the details 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, shall be deemed prequalified for all appropriate processes.

4.5.5.2 Fillet welds

Joint preparations for fillet welds conforming to Table D3, 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.

NOTE: Joints in Figure 4.5.5.2 form a crevice which may be unsuitable for corrosion applications. Therefore, the approval of the principal should be sought.

4.5.5.3 Combination of fillet and butt welds

Joint preparations for combinations of fillet 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 that the joint preparations for butt welds conform to Table D1, D2 or D4, as appropriate.

NOTE: Joints in Figure 4.5.5.3 form a crevice, which may be unsuitable for corrosion applications. The approval of the principal should therefore be sought.

4.5.5.4 Circular hollow section connections

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

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

Type of Weld	Usage
Butt throughout, according to Figures 4.5.5.1(A) and (B)	Used in any joint
Fillet throughout, according to Figure 4.5.5.2.	Used only where diameter of smaller members is less than one-third of that of larger member
Combination of butt and fillet with gradual transitions between them, according to Figure 4.5.5.3	Used in any joint

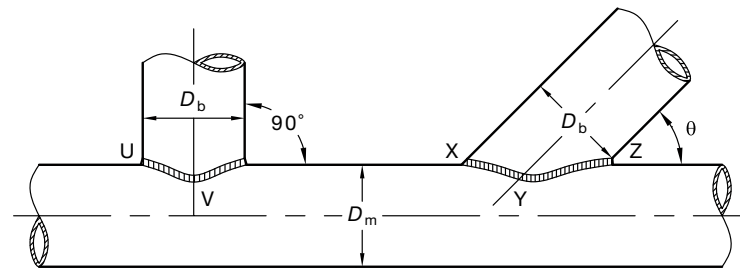
- (b) *Partially or fully flattened* Where the end of a circular hollow section member is partly flattened to a suitable shape, Items (a)(i) and (a)(ii) above shall apply and, for the application of Item (a)(ii), the diameter of the flattened portion of the section shall be measured in a plane perpendicular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

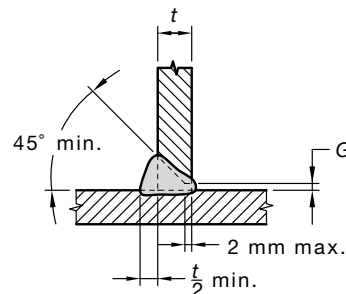
For end-to-surface connections of rectangular hollow sections, the following shall also apply, as appropriate:

- (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 is used throughout.
 - (ii) A fillet weld is used throughout.
 - (iii) A combination of fillet and butt welds is used throughout.
- (b) *Angle of intersection less than 30°* Where the end of a rectangular hollow section member is welded to the surface of another rectangular hollow section member of greater width, with the axes of the members intersecting at an angle of less than 30° , the welding procedure shall be qualified in accordance with Clause 4.2 before welding commences.
- (c) *Equal width rectangular hollow sections* Where the end of a rectangular hollow section member is welded to the surface of another rectangular hollow section member of equal width, the welding procedure shall be qualified in accordance with Clause 4.2 before welding commences.

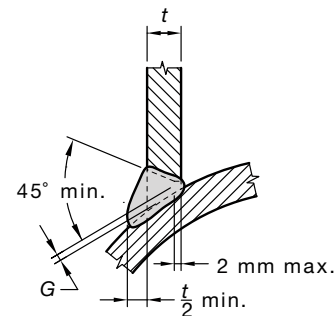


NOTE: Any value of D_b / D_m is permissible.

(a) Butt-welded connections

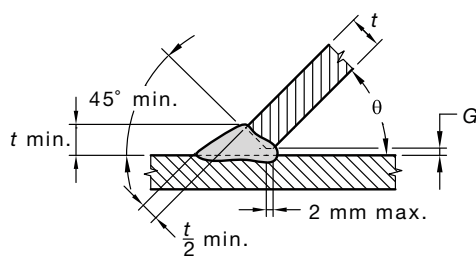


SECTION U

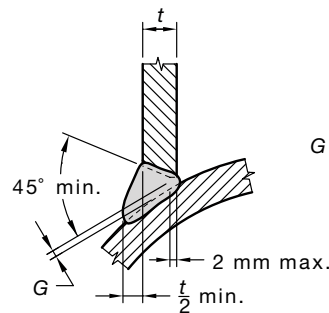


SECTION V

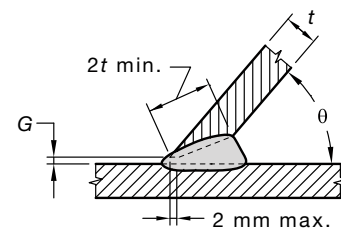
(b) Butt-welded right-angled connections



SECTION X



SECTION Y



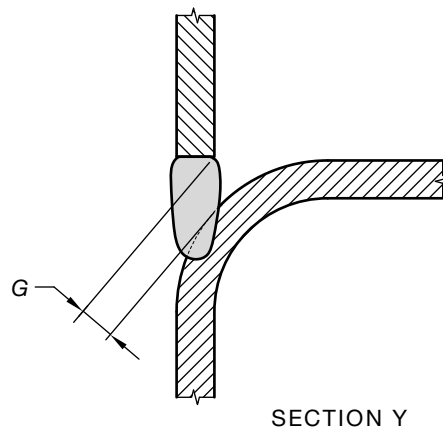
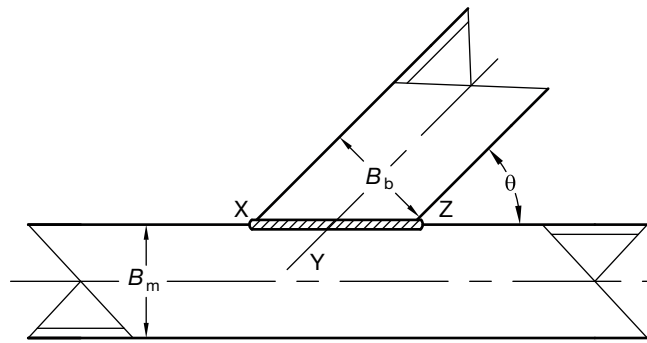
SECTION Z

(c) Butt-welded acute-angled connections

NOTES:

- 1 $\theta \geq 30^\circ$.
- 2 The values for width of root gap (G) are given in Table D4, Appendix D.
- 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) PREQUALIFIED BUTT WELDS FOR CIRCULAR AND UNEQUAL-WIDTH RECTANGULAR HOLLOW SECTIONS

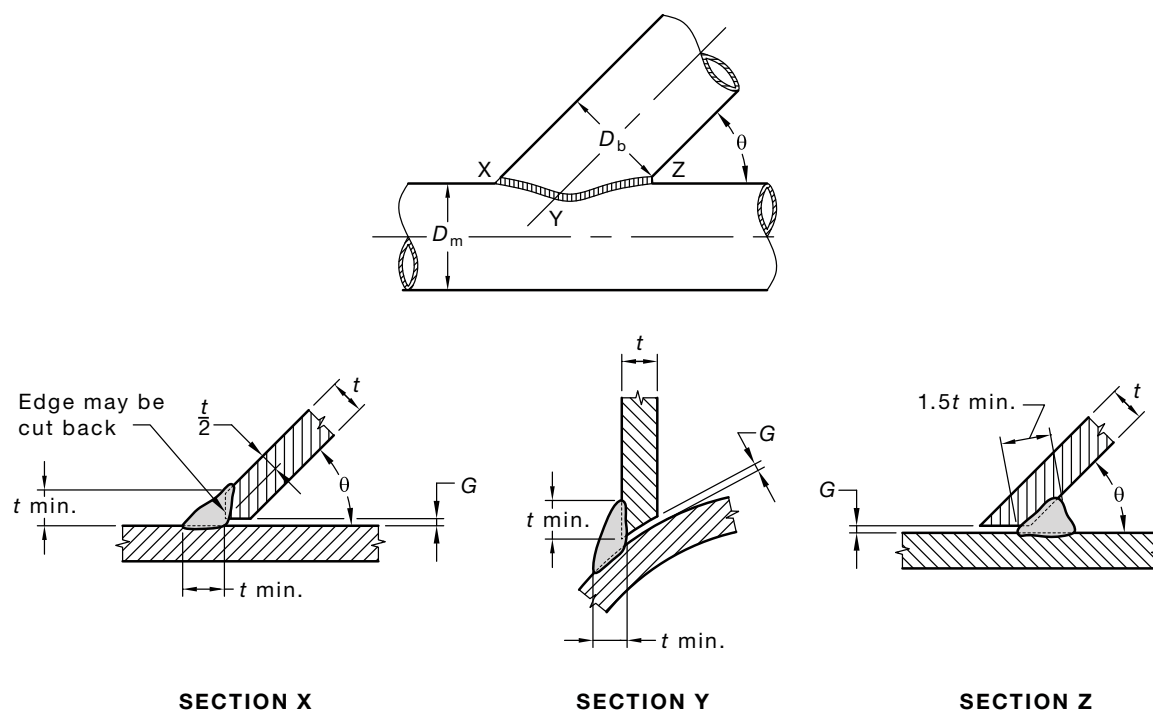


SECTION Y

NOTES:

- 1 $\theta \geq 30^\circ$.
- 2 The values for width of root gap (G) are given in Table D4.
- 3 Placing pieces of metal in the root gap to bridge 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).

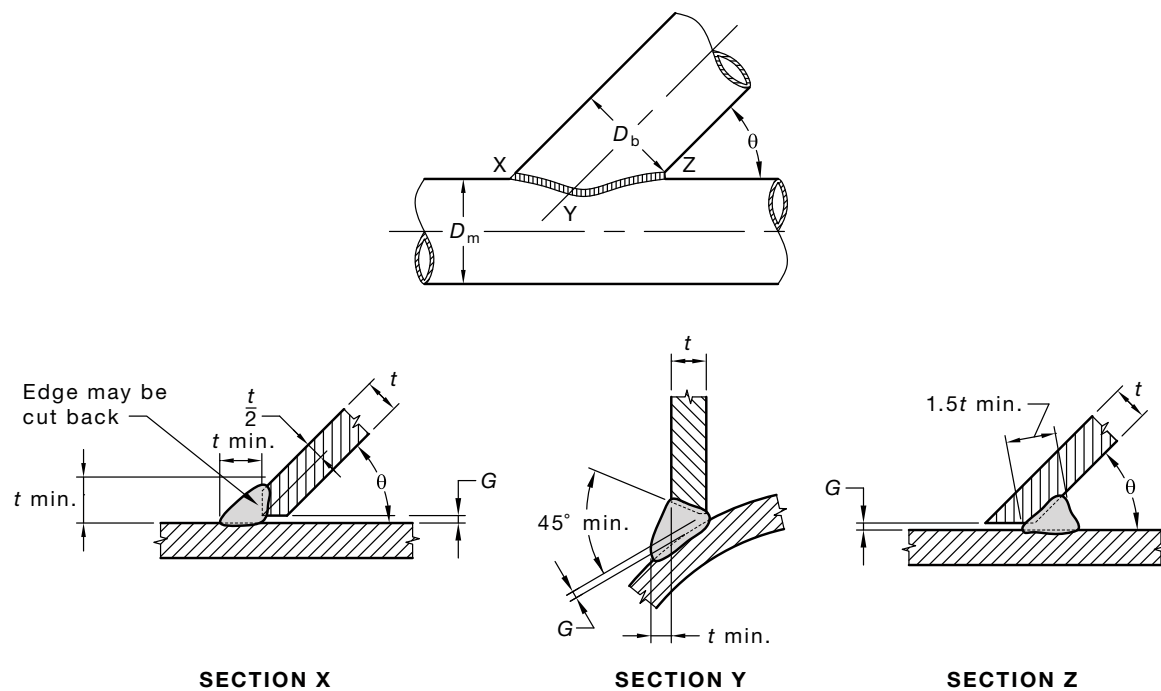
FIGURE 4.5.5.1(B) PREQUALIFIED BUTT WELDS FOR EQUAL-WIDTH RECTANGULAR HOLLOW SECTIONS



NOTES:

- 1 $\theta \geq 30^\circ$.
- 2 The values for width of root gap (G) are given in Table D4.
- 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 (also see Clause 4.5.5.5(c)).

FIGURE 4.5.5.2 PREQUALIFIED FILLET WELDS



NOTES:

- 1 $\theta \geq 30^\circ$.
- 2 The values for width of root gap (G) are given in Table D.
- 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 4.5.5.5I).

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

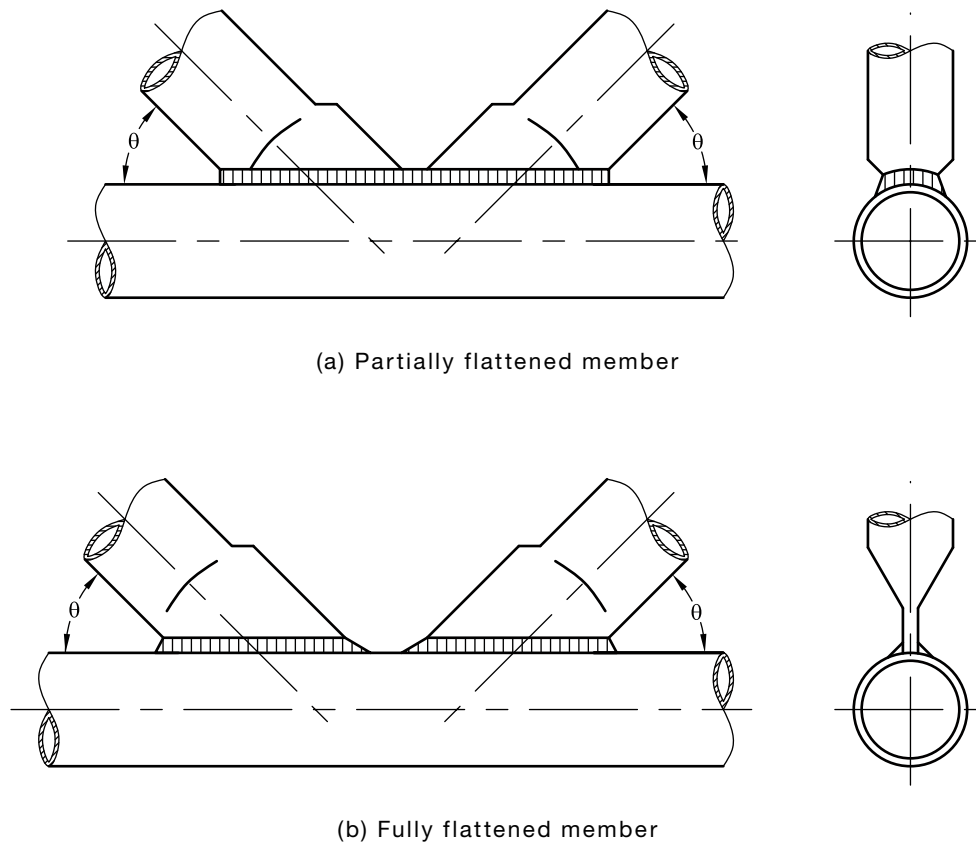


FIGURE 4.5.5.4 FLATTENED CIRCULAR HOLLOW SECTION JOINTS

4.6 QUALIFICATION OF WELDING CONSUMABLES

4.6.1 Filler metals

Where welding consumables are matched with the steel types in compliance with Table 4.6.1, they shall be deemed prequalified and require no qualification testing.

Where a consumable is not prequalified in accordance with Table 4.6.1, it may be qualified in conjunction with a procedure qualification in accordance with Clause 4.7.1. If the weld metal deposited in the test possesses relevant properties specified by the principal, the consumable shall be deemed qualified for that procedure.

NOTE: For further guidance on filler metals for dissimilar metal joints refer to AWS D1.6.

4.6.2 Fluxes

Submerged arc fluxes complying with the following are deemed prequalified. They shall—

- (a) comply with the requirements of flux class 2 or flux class 4 of ISO 14174;
- (b) be specified by the manufacturer as being suitable for the welding of stainless steels; and
- (c) only be used in flux/wire combinations approved by the consumable manufacturer.

4.6.3 Shielding, backing and purging gases

Shielding, backing and purging gases complying with Clause 2.4.4 are deemed prequalified.

Shielding gas that contains hydrogen shall not be used for ferritic, martensitic and duplex stainless steels.

Shielding gas that contains nitrogen shall not be used for austenitic stainless steels.

NOTES:

- 1 Shielding, backing or purging gas should protect the weld area until the temperature of the deposited weld metal drops below 250°C.
- 2 For GMAW, carbon dioxide levels in argon and/or helium based shielding gas should not exceed 5%.
- 3 Purging is required for external attachment welding. For further information on purging, refer to Clause 6.2.3(g) and 6.2.6.

TABLE 4.6.1
PREQUALIFIED WELDING CONSUMABLES (see Notes)

Super duplex	S32304/S32101	S31803/S32205	410/420	444	409/410S/430	1.4003	6% Mo	904L	S30815	347	321H	321	317L	317	316Ti	316L	316H	316	310	309	304L	304H	304	To weld to
AUSTENITIC GRADES (11)																								
																								304 ⁽⁵⁾
																								304H
																								304L
																								309
																								310
																								316
																								316H
																								316L
																								316Ti
																								317
																								317L
																								321
																								321H
																								347
																								S30815
																								904L
																								6% Mo

(continued)

TABLE 4.6.1 (continued)

Super duplex	S32304/S32101	S31803/S32205	410/420	444	409/410S/430	1.4003	6% Mo	904L	S30815	347	321H	321	317L	317	316Ti	316L	316H	316	310	309	304L	304H	304	To weld to
FERRITIC GRADES																								
1.4003	316L	316L	316L	309L	309L	316L	316L	316L	309L	309L	309L	309L	309L	309L	309L	309L	309L	309L ⁽⁸⁾						
409/ 410S/ 430	309L	309L	309L	309L	309L	309L	309L	309L	309L	309L	309L	309L	309L	309L	309L	309L	309L	309L	309L	309L				
444	316L	316L	316L	316L	316L	316L	316L	316L	316L	316L	316L	316L	316L	316L	316L	309L	309L	309L	309L ⁽⁶⁾	316L				
MARTENSITIC GRADES																								
410/420	309L	309L	309L	309L	309L	309L	309L	309L	309L	309L	309L	309L	309L	309L	309L	309L	309L	309L	309L	309L				
DUPLEX GRADES																								
S31803/ S32205	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	625	2209	2209	2209	2209			
S32304/ S32101	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	625	2209	2209	2209	2209	2209	2209 ⁽⁷⁾	
Super duplex	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	2209	625	2209	2209	2209	2209	2209	2209	2510
Nickel base	NiCr-3	NiCr-3	NiCr-3	NiCr-3	NiCr-3	NiCr-3	NiCr-3	NiCr-3	NiCr-3	NiCr-3	NiCr-3	NiCr-3	NiCr-3	NiCr-3	NiCr-3	625	625	625	NiCr-3	NiCr-3	NiCr-3	NiCr-3	625	625
Carbon steel ^(10, 13)	309L	309L	309L	309L	310	309L	309L	309LMo	309LMo	309LMo	309LMo	309L	309L	309L	309L	309L	309LMo	309LMo	309LMo	309L	309Mo	309L	309L	309L

NOTES TO TABLE 4.6.1:

- 1 The recommended prequalified consumable for welding one grade to itself, i.e. similar metal welding, is given in bold.
- 2 For dissimilar metals, welding the grade listed at the intersection of the row and column is recommended. Both this grade and the grade in bold on the intersecting row are prequalified, e.g. for welding 316L to 304L, both 308L and 316L are prequalified.
- 3 For parent metals designations, refer to AISI, UNS or SEW designations, as appropriate. For welding consumables designations, refer to AS/NZS 1167.2, AS 4854.3, AS/NZS ISO 14343, ANSI/AWS A5.4 or ANS/AWS A5.9, as appropriate.
- 4 Silicon containing designations in accordance with AS/NZS ISO 14343 are also deemed prequalified, where applicable.
- 5 Also applies to Grades 201, 202, 301 and 302.
- 6 Grade 316L is not prequalified for these dissimilar joints.
- 7 Grade 23 7 LN is also prequalified for Lean Duplex (S32304, S32101) joints.
- 8 Grade 18 8 Mn is also prequalified for 1.4003 joints.
- 9 316L is also prequalified
- 10 For other than 18 8 Mn welding dissimilar carbon to stainless steel joints, austenitic filler metals should have at least 10FN in the all-weld-metal.
- 11 Steel grade 310, 904L and 6% Mo cannot be expected to provide delta ferrite in their welds. Such steels have some tendency to produce solidification cracking. For guidance on avoiding solidification cracking refer to the Appendix F.
- 12 Use of "L" grade fillers in place of standard or "H" grades can be made so long as high temperature requirements are considered. Low carbon content fillers may not be suitable for high temperature applications.
- 13 Grade 18 8 Mn is also prequalified for any dissimilar stainless steel to carbon steel joints.

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 Clause 4.2(a), (b) or (e), it shall be qualified by producing a suitable test piece in accordance with either Clause 4.2(c) or Clause 4.2(d), and subjecting the weld in the condition in which it will enter service to the tests specified in Table 4.7.1.

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

TABLE 4.7.1
EXTENT OF TESTING REQUIRED ON WELDING PROCEDURE TEST PIECE

Weld category	Consumables (see Note 3 and Note 7)*	Preparation	Tests required (see Notes 1, 2 and 3)*				
			Butt welds (see Note 4)*				Fillet welds
			Macro (see Clause 4.7.4 and Note 6 and Note 8)*	Tensile (see Clause 4.7.5)	Bend (see Clause 4.7.6 and Note 5)*	Radiography (see Clause 4.7.9)	Macro (see Clause 4.7.4 and Note 6)*
1A, 1B, 1C and FA	Prequalified conforming to Table 4.6.1	Prequalified conforming to Tables D1 to D4	1	Nil	1 side or 1 face and 1 root (Note 9)	Nil	1
		Other preparations	2	Nil	1 side or 1 face and 1 root	100%	2
	Not prequalified	Prequalified conforming to Tables D1 to D4	1	1	2 side or 1 face and 1 root	100%	1
		Other preparations	2	1	2 side or 1 face and root	100%	2
2A, 2B and 2C	Prequalified conforming to Table 4.6.1	Prequalified conforming to Tables D1 to D4	1	Nil	1 side or 1 face and 1 root (Note 9)	Nil	1
		Other preparations	1	Nil	1 side or 1 face and 1 root	Nil	2
	Not prequalified	Prequalified conforming to Tables D1 to D4	1	Nil	1 side or 1 face and 1 root	Nil	1
		Other preparations	1	Nil	1 side or 1 face and 1 root	Nil	2

* See notes on following page.

NOTES TO TABLE 4.7.1:

- 1 Ferrite content (ferrite numbers) determination, where required by the principal, shall be carried out in accordance with Clause 4.7.8.
- 2 The hardness test of the plate, weld and heat-affected zone may have an effect upon the performance of the joint in testing and service. Where this is regarded as a factor, it is recommended that a hardness survey of the procedure test joint be made. The details of the tests and the acceptance criteria are the subject of agreement in accordance with Appendix G.
- 3 Corrosion testing, where required by the principal, shall be carried out in accordance with Clause 4.7.7.
- 4 Where the weldment is designed for cryogenic application, or if there is a possibility of embrittlement due to welding or other fabrication procedures, a Charpy V test may be specified by the principal. Methods of testing and criteria of acceptance should be agreed between the parties concerned.
- 5 Bend test is not applicable to martensitic grades.
- 6 Where two or more macro tests are required, the specimens shall be separated by a distance of at least 100 mm.
- 7 For austenitic consumables, where required by the principal, electrode manufacturer's certification shall indicate minimum ferrite numbers for the all-weld-metal according to ISO 8249 or ANSI/AWS A4.2. Alternatively, ferrite numbers may be calculated using the filler metal composition according to the Clause 4.7.8.
- 8 When radiography is not required to qualify a weld procedure, at the fabricators discretion, a radiograph may be substituted for a macro test.
- 9 For other than dip transfer in gas metal arc welding, bend tests are not required for austenitic steel grades 304, 304H, 304L, 309, 316, 316H, 316L, 316Ti, 317, 317L, 321, 321H and 347 when heat input and interrun temperature complies with Clause 5.10.