

Australian/New Zealand Standard™

Structural steel welding

Part 1: Welding of steel structures



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.
This Standard was published on 25 November 2014.

The following are represented on Committee WD-003:

Australasian Corrosion Association
Australian Chamber of Commerce and Industry
Australian Industry Group
Australian Steel Institute
Austroads
Bureau of Steel Manufacturers of Australia
Energy Networks Association
Engineers Australia
New Zealand Heavy Engineering Research Association
New Zealand Non-Destructive Testing Association
Steel Reinforcement Institute of Australia
University of Sydney
Welding Technology Institute of Australia

Keeping Standards up-to-date

Standards are living documents which reflect progress in science, technology and systems. To maintain their currency, all Standards are periodically reviewed, and new editions are published. Between editions, amendments may be issued. Standards may also be withdrawn. It is important that readers assure themselves they are using a current Standard, which should include any amendments which may have been published since the Standard was purchased.

Detailed information about joint Australian/New Zealand Standards can be found by visiting the Standards Australia Web Site at www.standards.org.au or Standards New Zealand web site at www.standards.govt.nz and looking up the relevant Standard in the on-line catalogue.

For more frequent listings or notification of revisions, amendments and withdrawals, Standards Australia and Standards New Zealand offer a number of update options. For information about these services, users should contact their respective national Standards organization.

We also welcome suggestions for improvement in our Standards, and especially encourage readers to notify us immediately of any apparent inaccuracies or ambiguities. Please address your comments to the Chief Executive of Standards Australia or the New Zealand Standards Executive at the address shown on the back cover.

This Standard was issued in draft form for comment as DR AS/NZS 1554.1.

Australian/New Zealand Standard™

Structural steel welding

Part 1: Welding of steel structures

Originated in Australia as AS CA8—1933.
Originated in New Zealand, in part, as NZS 4701:1981.
Previous edition AS/NZS 1554.1:2011.
Ninth edition 2014.
Reissued incorporating Amendment No. 1 (September 2015).
Reissued incorporating Amendment No. 2 (September 2017).

COPYRIGHT

© Standards Australia Limited

© The Crown in right of New Zealand, administered by the New Zealand Standards Executive

All rights are reserved. No part of this work may be reproduced or copied in any form or by any means, electronic or mechanical, including photocopying, without the written permission of the publisher, unless otherwise permitted under the Copyright Act 1968 (Australia) or the Copyright Act 1994 (New Zealand).

ISBN 978 1 74342 893 1

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.

CONTENTS

	<i>Page</i>
SECTION 1 SCOPE AND GENERAL	
1.1 SCOPE.....	5
1.2 EXCLUSIONS.....	6
1.3 INNOVATION	6
1.4 NORMATIVE REFERENCES	6
1.5 DEFINITIONS AND SYMBOLS	6
1.6 WELD CATEGORIES	7
1.7 MANAGEMENT OF QUALITY.....	7
1.8 SAFETY	8
SECTION 2 MATERIALS OF CONSTRUCTION	
2.1 PARENT MATERIAL.....	9
2.2 BACKING MATERIAL	9
2.3 WELDING CONSUMABLES	9
SECTION 3 DETAILS OF WELDED CONNECTIONS	
3.1 GENERAL.....	11
3.2 BUTT WELDS	11
3.3 FILLET WELDS	12
3.4 COMPOUND WELDS	17
3.5 SEAL WELDS.....	18
3.6 PLUG WELDS	19
3.7 SLOT WELDS.....	19
3.8 COMBINING STEEL SECTIONS	19
SECTION 4 QUALIFICATION OF PROCEDURES AND PERSONNEL	
4.1 QUALIFICATION OF WELDING PROCEDURE.....	21
4.2 METHODS FOR QUALIFYING A WELDING PROCEDURE.....	23
4.3 PREQUALIFIED WELDING PROCEDURES.....	24
4.4 PORTABILITY OF QUALIFIED WELDING PROCEDURES	24
4.5 PREQUALIFIED JOINT PREPARATIONS	24
4.6 QUALIFICATION OF WELDING CONSUMABLES.....	32
4.7 QUALIFICATION OF WELDING PROCEDURE BY TESTING	40
4.8 EXTENSION OF QUALIFICATION	45
4.9 COMBINATION OF PROCESSES	45
4.10 RECORDS OF TESTS	45
4.11 REQUALIFICATION OF WELDING PROCEDURES	45
4.12 QUALIFICATION OF WELDING PERSONNEL	49

SECTION 5 WORKMANSHIP

5.1	PREPARATION OF EDGES FOR WELDING	54
5.2	ASSEMBLY	54
5.3	PREHEATING AND INTER-RUN CONTROL	56
5.4	WELDING UNDER ADVERSE WEATHER CONDITIONS	62
5.5	TACK WELDS	62
5.6	WELD DEPTH-TO-WIDTH RATIO	62
5.7	CONTROL OF DISTORTION AND RESIDUAL STRESS	63
5.8	BACKGOUGING AND REPAIR OF DEFECTS IN WELDS	64
5.9	TEMPORARY ATTACHMENTS	65
5.10	ARC STRIKES	65
5.11	CLEANING OF FINISHED WELDS	65
5.12	DRESSING OF BUTT WELDS	65

SECTION 6 QUALITY OF WELDS

6.1	CATEGORIES OF WELDS	66
6.2	METHODS OF INSPECTION AND PERMISSIBLE LEVELS OF IMPERFECTIONS	66
6.3	RADIOGRAPHY	71
6.4	ULTRASONIC EXAMINATION	72
6.5	MAGNETIC PARTICLE EXAMINATION	73
6.6	LIQUID PENETRANT EXAMINATION	73
6.7	WELD DEFECTS	73
6.8	REPORTING	73

SECTION 7 INSPECTION

7.1	GENERAL	74
7.2	QUALIFICATIONS OF INSPECTORS	74
7.3	VISUAL INSPECTION OF WORK	74
7.4	NON-DESTRUCTIVE EXAMINATION OTHER THAN VISUAL	75

APPENDICES

A	NORMATIVE REFERENCED DOCUMENTS	76
B	BRITTLE FRACTURE	79
C	TYPICAL FORMS FOR WELDING PROCEDURES	84
D	MATTERS FOR RESOLUTION	87
E	WELDED JOINT AND PROCESS IDENTIFICATION	88
F	WELD PROCEDURE REQUIREMENTS ASSOCIATED WITH CHANGES TO THE WELDING CONSUMABLE CLASSIFICATION SYSTEM	107
G	TYPICAL MATERIAL GROUPS FOR COMMON STEELS	111
H	SELECTION OF MATERIALS FOR THE AVOIDANCE OF LAMELLAR TEARING	113

BIBLIOGRAPHY	116
--------------------	-----

STANDARDS AUSTRALIA/STANDARDS NEW ZEALAND

Australian/New Zealand Standard
Structural steel welding

Part 1: Welding of steel structures

SECTION 1 SCOPE AND GENERAL**1.1 SCOPE**

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

- (a) Manual metal-arc welding (MMAW).
- (b) Submerged arc welding (SAW).
- (c) Gas metal-arc welding (GMAW or MIG), including pulsed mode.
- (d) Gas tungsten-arc welding (GTAW or TIG).
- (e) Flux-cored arc welding (FCAW).
- (f) Electroslag (including consumable guide) welding (ESW).
- (g) 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 $\theta < 60^\circ$, $D - 3$ mm; or
 - (ii) where $\theta \geq 60^\circ$, D ;

where

D = depth of preparation

θ = angle of preparation

- (c) For incomplete penetration butt welds made by a fully automatic arc welding process, provided that it can be demonstrated by means of a macro test on a production weld that the required penetration has been achieved, a design throat thickness up to the depth of penetration. 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 $t_{\text{thinner}}/3$. 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 Clause 5.2.3).

A2 |

TABLE 3.3.5
MINIMUM SIZE (LEG LENGTH)
OF FILLET WELDS

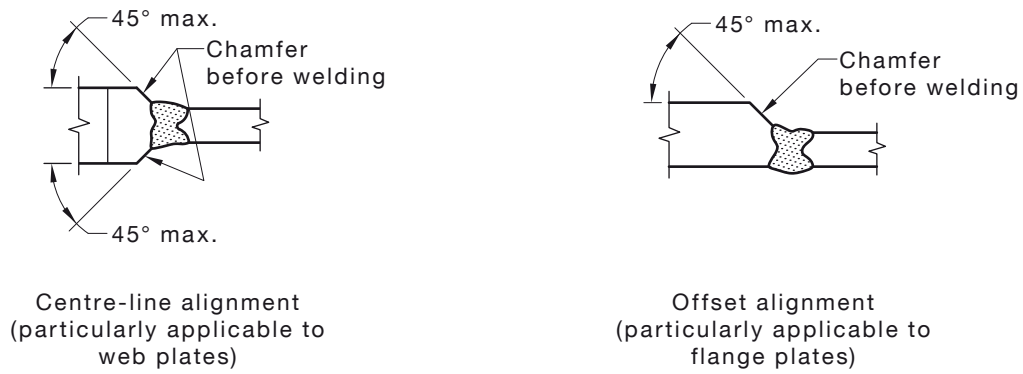
millimetres	
Thickness of thickest part (<i>t</i>)	Minimum size of fillet weld
≤3	$2t/3^*$
>3 ≤7	3*
>7 ≤10	4*
>10 ≤15	5
>15	6

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

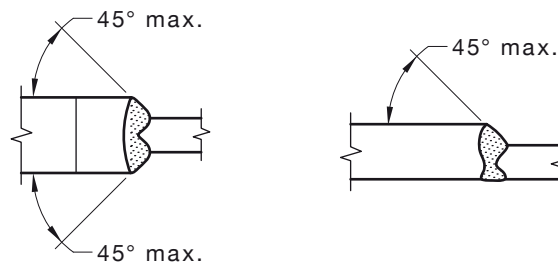
3.3.6 Maximum size of fillet welds along edges

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

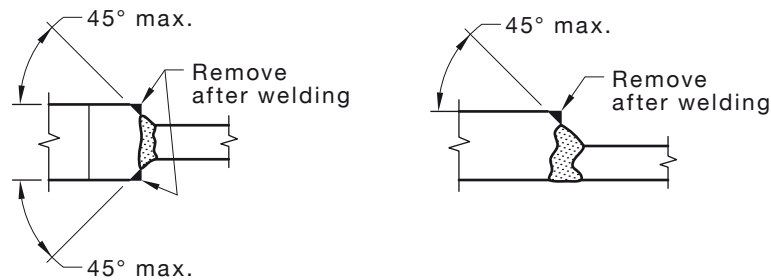
- (a) for material with a thickness of less than 6 mm [see Figure 3.3.6(a)], the thickness of the material;
- (b) for material with thickness of not less than 6 mm [see Figure 3.3.6(b)], the thickness of the material minus 1 mm; or
- (c) for material with a thickness of not less than 6 mm, where the 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

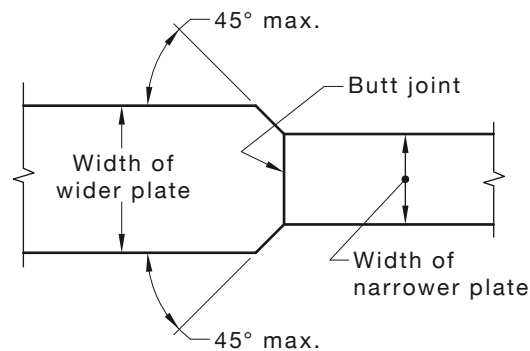


(ii) Transition by sloping weld surface



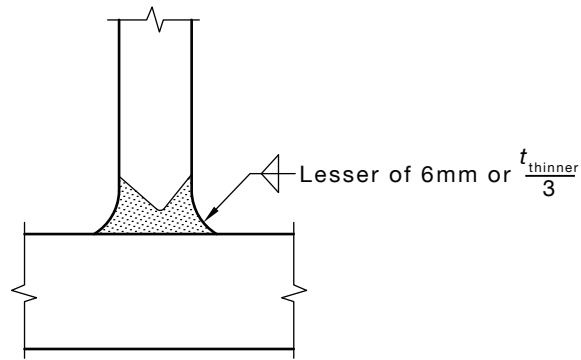
(iii) Transition by sloping weld surface and chamfering

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



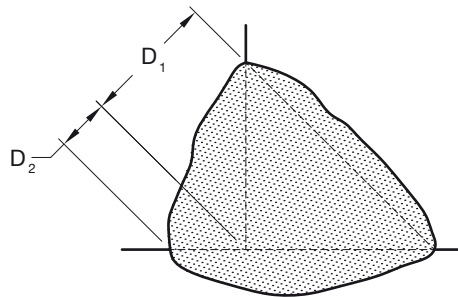
(b) Transition of butt joints in parts of unequal width, by chamfering the wider part

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



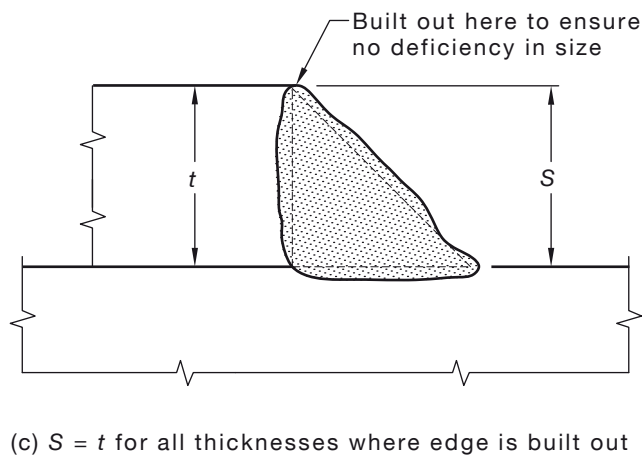
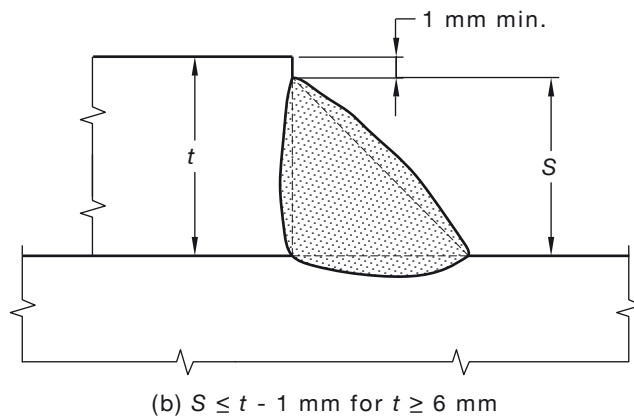
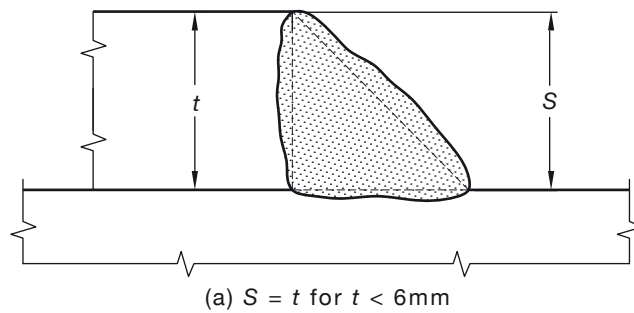
(c) Transition of parts in T-joints

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.

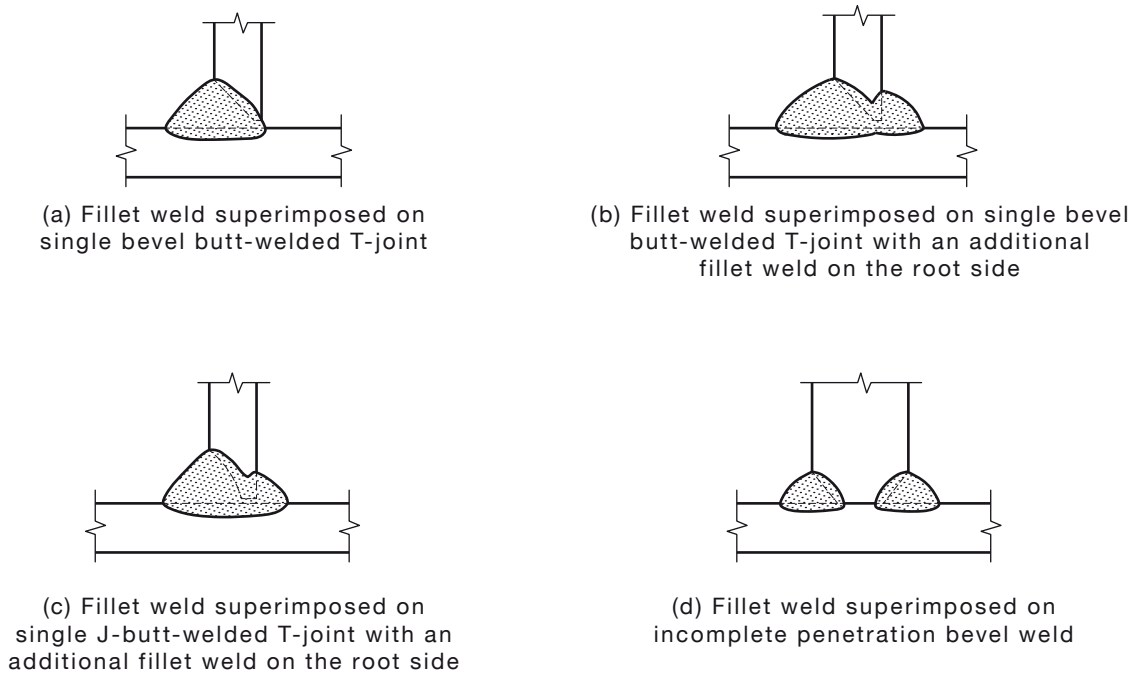


FIGURE 3.4.1 COMPOUND WELDS

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.

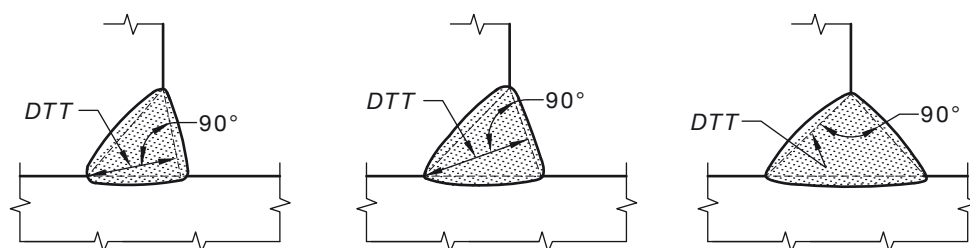


FIGURE 3.4.2.2 DESIGN THROAT THICKNESS OF COMPOUND WELDS WITH INCOMPLETE PENETRATION WELDS

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

3.7 SLOT WELDS

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

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

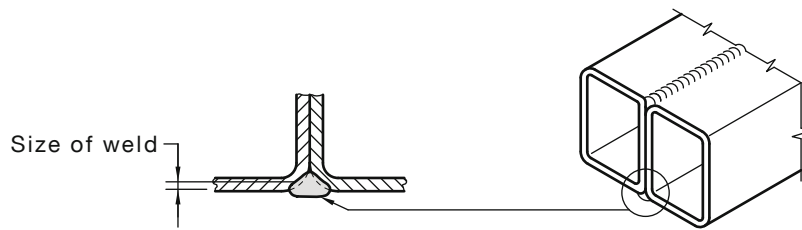
The ends of the slot shall be semicircular or shall have the corners rounded to a radius of not less than the thickness of the part containing it, except for those ends that extend to the edge of the part.

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.

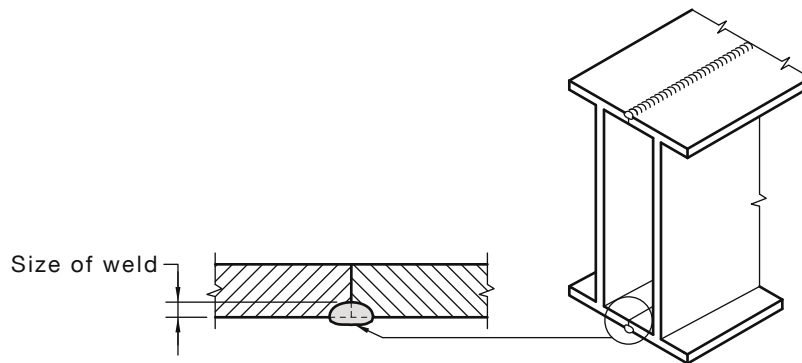
The effective area of a slot weld shall be as for a fillet weld of the same size and effective length. Where a slot weld is made by completely or partially filling the slot (i.e. not made with a fillet weld around the perimeter of the slot), the effective area shall be as for plug welds (see Clause 3.6).

3.8 COMBINING STEEL SECTIONS

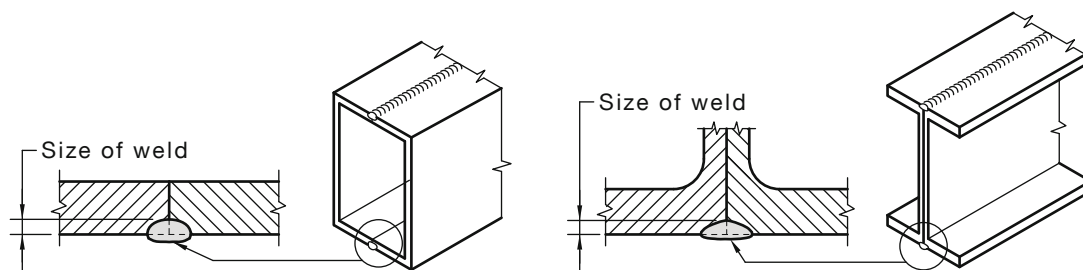
The size of welds made for the purpose of combining steel sections to form composite members (see Figure 3.8) shall be not less than 3 mm.



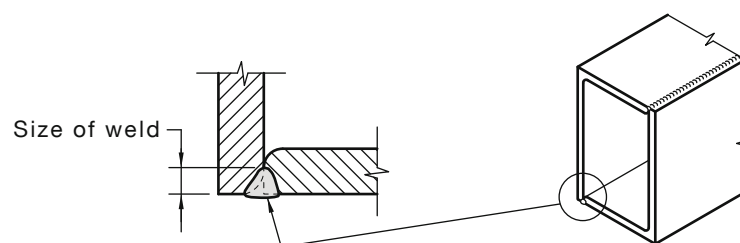
(a) Hollow sections



(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.

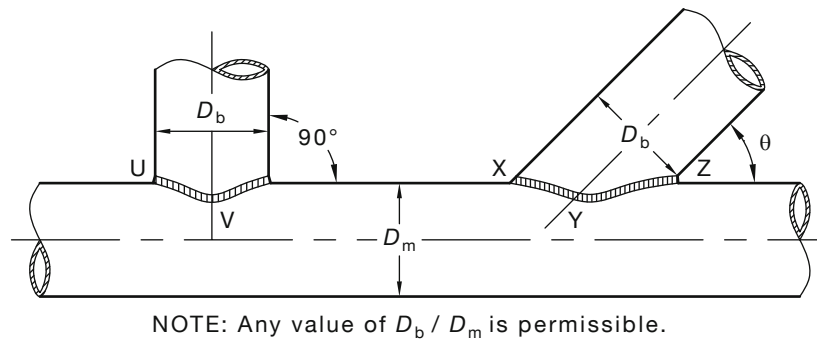
The flattening of the section shall be made over the minimum length practicable. The change of shape shall be gradual, with no evidence of splitting or cracking in the flattened portion. Typical flattened circular hollow section joints are shown in Figure 4.5.5.4.

4.5.5.5 End-to-surface connections of rectangular hollow sections

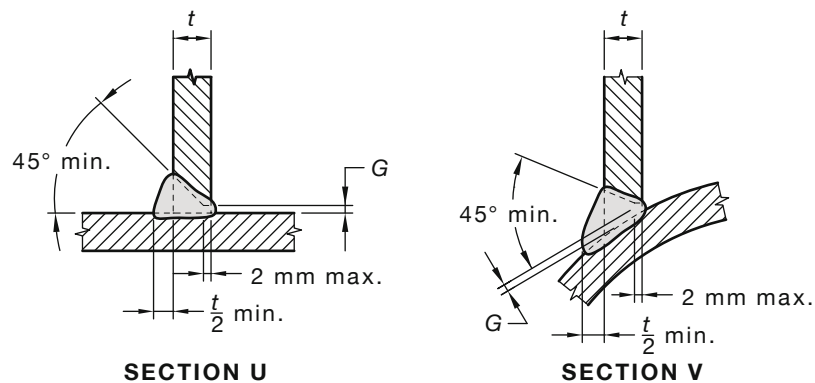
For end-to-surface connections of rectangular hollow sections, the following shall also apply, as appropriate:

- (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.

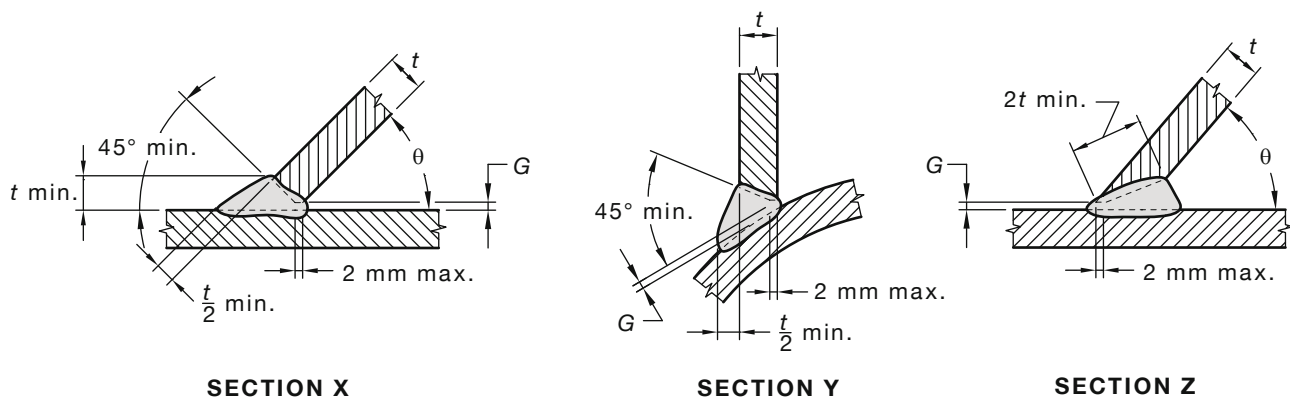
- (b) *Angle of intersection less than 30°* Where the end of a rectangular hollow section member is welded to the surface of another rectangular hollow section member of greater width, with the axes of the members intersecting at an angle of less than 30°, the welding procedure shall be qualified in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



(a) Butt-welded connections



(b) Butt-welded right-angled connections

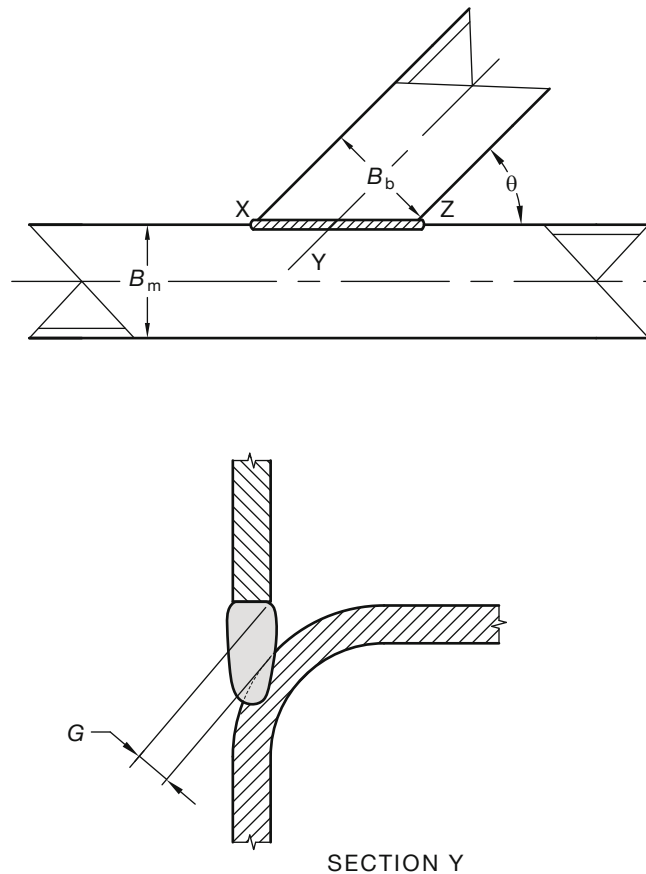


(c) Butt-welded acute-angled connections

NOTES:

- 1 $\theta \geq 30^\circ$.
- 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.

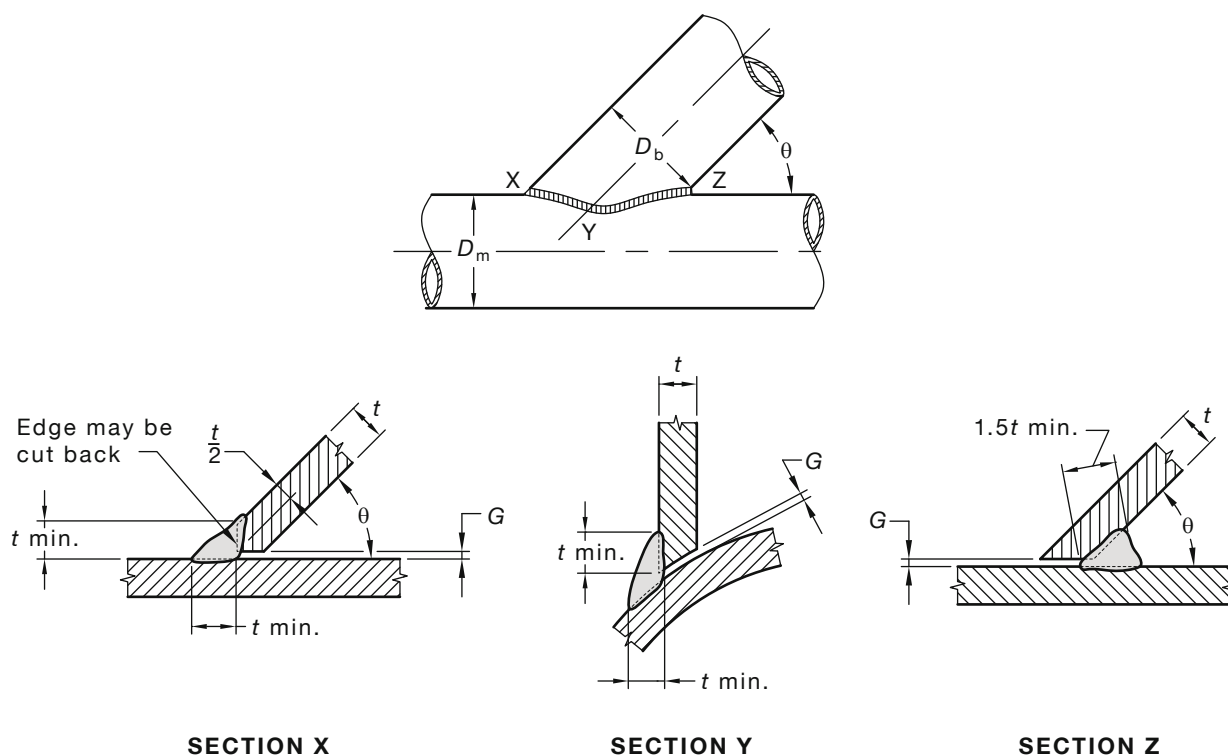
FIGURE 4.5.5.1(A) TYPICAL BUTT WELDS FOR CIRCULAR AND UNEQUAL-WIDTH RECTANGULAR HOLLOW SECTIONS



NOTES:

- 1 $\theta \geq 30^\circ$.
- 2 The values for width of root gap (G) are given in Table E4, Appendix E.
- 3 Placing pieces of metal in the root gap for bridging the gap is not permitted.
- 4 Sections X and Z are the same as Sections X and Z of Figures 4.5.5.1(A) and 4.5.5.2.
- 5 For unequal-width rectangular hollow sections, see Figure 4.5.5.1(A).

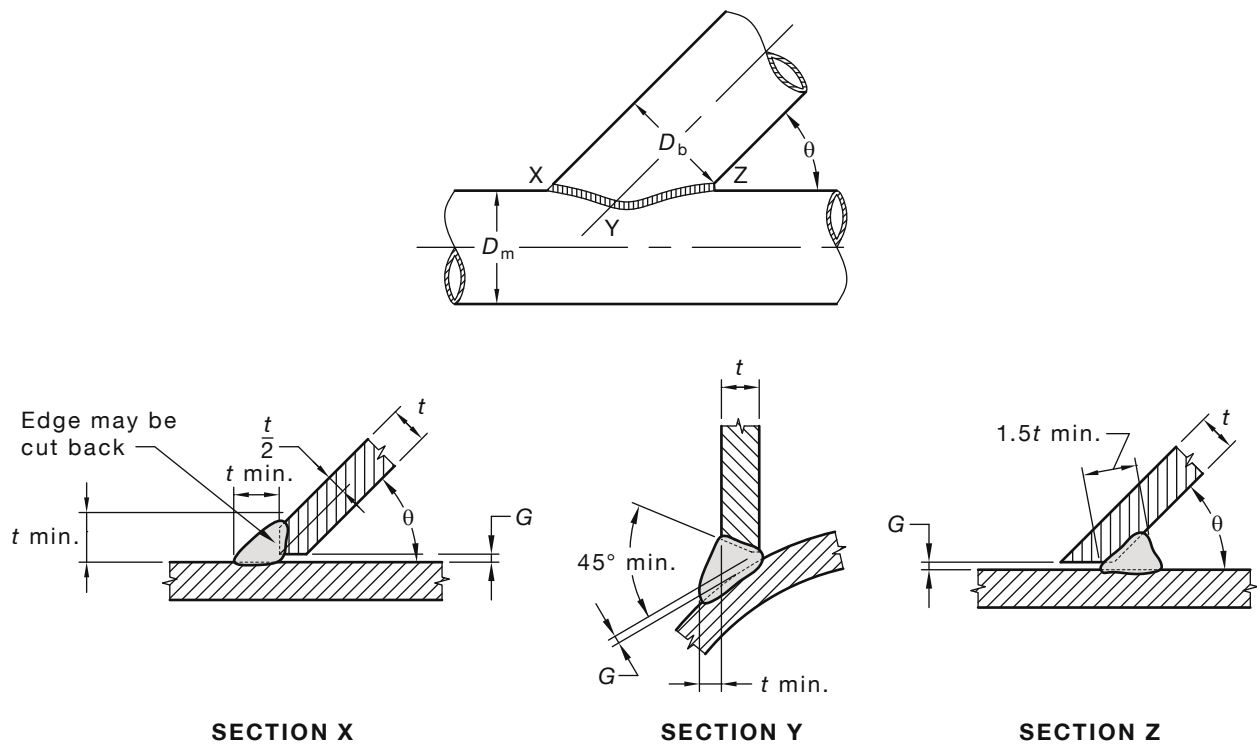
FIGURE 4.5.5.1(B) PREQUALIFIED BUTT WELDS FOR EQUAL-WIDTH RECTANGULAR HOLLOW SECTIONS



NOTES:

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

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

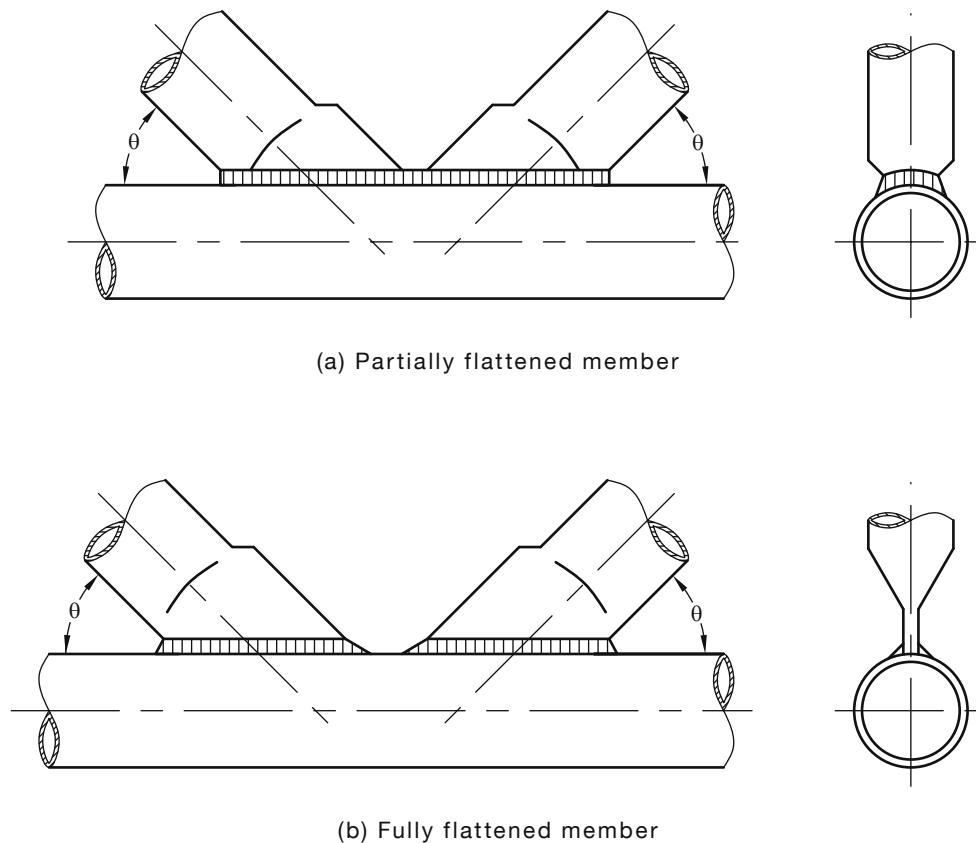


FIGURE 4.5.5.4 FLATTENED CIRCULAR HOLLOW SECTION JOINTS

4.6 QUALIFICATION OF WELDING CONSUMABLES

4.6.1 Prequalified welding consumables

4.6.1.1 General

Welding consumables shall be 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:

- Electrodes for manual metal-arc welding conform to Column 2 of Table 4.6.1(A).
- 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.
- Consumables for gas metal-arc welding conform to Column 5 of Table 4.6.1(A).
- 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)