

Australian Standard™

Welding of ferrous castings

Part 1: Steel castings



This Australian Standard was prepared by Committee MT-001, Iron and Steel. It was approved on behalf of the Council of Standards Australia on 28 March 2006. This Standard was published on 24 April 2006.

The following are represented on Committee MT-001:

Australian Railway Associations
Australian Building Codes Board
Australian Foundry Institute
Australian Industry Group
Australian Steel Institute
Bureau of Steel Manufacturers of Australia
Institute of Material Engineering Australasia

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 Standards may also be withdrawn.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 Standards can be found by visiting the Standards Web Shop at www.standards.com.au and looking up the relevant Standard in the on-line catalogue.

Alternatively, the printed Catalogue provides information current at 1 January each year, and the monthly magazine, *The Global Standard*, has a full listing of revisions and amendments published each month.

Australian Standards™ and other products and services developed by Standards Australia are published and distributed under contract by SAI Global, which operates the Standards Web Shop.

We also welcome suggestions for improvement in our Standards, and especially encourage readers to notify us immediately of any apparent inaccuracies or ambiguities. Contact us via email at mail@standards.org.au, or write to the Chief Executive, Standards Australia, GPO Box 476, Sydney, NSW 2001.

This Standard was issued in draft form for comment as DR 05344.

Australian Standard™

Welding of ferrous castings

Part 1: Steel castings

Originated as AS 1988—1977.
Previous edition AS 1988—1989.
Revised and redesignated as AS 1988.1—2006.

COPYRIGHT

© Standards Australia

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.

Published by Standards Australia GPO Box 476, Sydney, NSW 2001, Australia

ISBN 0 7337 7387 7

PREFACE

This Standard was prepared by the Australian members of the Joint Standards Australia/Standards New Zealand Committee MT-001, Iron and Steel to supersede AS 1988—1989, *Welding of steel castings*.

After consultation with stakeholders in both countries, Standards Australia and Standards New Zealand decided to develop this Standard as an Australian, rather than an Australian/New Zealand Standard.

The objective of this edition is to revise the list of welding consumables and to introduce details on welded connections and the qualification of procedures and personnel.

Steel castings may require welding to make them satisfactory for their intended service, and this has long been accepted as part of the normal production process. The procedures in this Standard can be specified to ensure good welding practice during production, repair, rectification, and fabrication of steel castings. In fabrication, the use of welding has to be taken into account at the design and foundry stages.

During the preparation of this Standard, cognisance was taken of the following Standards.

AS/NZS

- 1554 Structural steel welding
- 1554.1 Part 1: Welding of steel structures

ISO

- 11970 Specification and approval of welding procedures for production welding of steel castings

This Standard is one of a series of Standard covering the range of cast irons and steels. The series comprises the following:

AS

- 1830 Grey cast iron
- 1831 Ductile cast iron
- 1832 Malleable cast iron
- 1833 Austenitic cast iron
- 1988 Welding of ferrous castings
- 1988.1 Part 1: Steel castings (this Standard)
- 1988.2 Part 2: Iron castings
- 2027 Wear-resistant white cast iron
- 2074 Cast steels
- 4314 Metal castings—Patterns, pattern equipment and coreboxes for the production of sand moulds and sand cores
- 4738 Metal castings
- 4738.1 Part 1: Ferrous sand moulded
- 5049 Cast iron—Designation of microstructure of graphite

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.

CONTENTS

	<i>Page</i>
SECTION 1 SCOPE AND GENERAL	
1.1 SCOPE	5
1.2 EXCLUSIONS	5
1.3 REFERENCED DOCUMENTS	5
1.4 DEFINITIONS	8
1.5 BASIC WELDING REQUIREMENTS	8
1.6 SAFETY	8
SECTION 2 CASTINGS, BACKING PLATES AND WELDING CONSUMABLES	
2.1 CASTINGS.....	9
2.2 BACKING MATERIAL.....	9
2.3 WELDING CONSUMABLES.....	9
SECTION 3 DETAILS OF WELDED CONNECTIONS	
3.1 GENERAL	10
3.2 BUTT WELDS	10
3.3 FILLET WELDS	11
3.4 COMPOUND WELDS	16
3.5 SEAL WELDS	17
3.6 PLUG WELDS	17
3.7 SLOT WELDS	17
SECTION 4 QUALIFICATION OF PROCEDURES AND PERSONNEL	
4.1 QUALIFICATION OF WELDING PROCEDURE	18
4.2 METHODS FOR QUALIFYING A WELDING PROCEDURE.....	18
4.3 PORTABILITY OF QUALIFIED WELDING PROCEDURES	19
4.4 QUALIFICATION OF WELDING CONSUMABLES	20
4.5 QUALIFICATION OF WELDING PROCEDURE BY TESTING.....	28
4.6 RETESTS	32
4.7 RANGE OF APPROVAL.....	32
4.8 RECORDS OF TESTS	34
4.9 QUALIFICATION OF WELDING PERSONNEL—WELDERS.....	35
4.10 ACCEPTANCE LEVELS.....	38
SECTION 5 WORKMANSHIP	
5.1 PREPARATION OF EDGES FOR WELDING.....	39
5.2 ASSEMBLY.....	39
5.3 PREHEATING AND POSTWELD HEAT TREATMENT	41
5.4 WELDING UNDER ADVERSE WEATHER CONDITIONS	49
5.5 TACK WELDS.....	49
5.6 WELD DEPTH-TO-WIDTH RATIO	49
5.7 DISTORTION	50
5.8 BACKGOUGING AND REPAIR OF DEFECTS IN WELDS	50
5.9 ARC STRIKES.....	51
5.10 CLEANING OF FINISHED WELDS.....	51

SECTION 6 QUALITY OF WELDS

6.1	GENERAL	52
6.2	REPAIRS.....	52
6.3	FABRICATION	52

APPENDICES

A	PURCHASING REQUIREMENTS.....	53
B	TYPICAL FORMS FOR WELDING PROCEDURES	55

STANDARDS AUSTRALIA

Australian Standard

Welding of ferrous castings

Part 1: Steel castings

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard specifies the requirements for fusion welding of steel castings where it is used for the following:

- (a) To rectify and/or modify a casting as part of the normal production process.
- (b) To rectify a casting that has been in service.
- (c) For the joining together of steel castings by fusion welding, where the subsections of the final fabrication are designed for the foundry planning stage.

NOTE: For prequalification refer to AS/NZS 1554.1.

The provisions in this Standard are applicable to the following welding processes:

- (i) Manual metal-arc welding (MMAW).
- (ii) Submerged arc welding (SAW).
- (iii) Gas metal-arc welding (GMAW or MIG), including pulsed mode.
- (iv) Gas tungsten-arc welding (GTAW or TIG).
- (v) Flux-cored arc welding (FCAW).
- (vi) Electroslag (including consumable guide) welding (ESW).
- (vii) Electrogas welding (EGW).

1.2 EXCLUSIONS

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

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

The Standard does not apply to hard facing (see AS/NZS 2576) or the welding of steel castings complying with AS 1210. For the fusion welding and fusion weld repair of cast irons, reference should be made to AS 1988.2.

1.3 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS	
1171	Non-destructive testing—Magnetic particle testing of ferromagnetic products, components and structures
1210	Pressure vessels
1391	Metallic materials—Tensile testing of ambient temperature
1470	Health and safety at work—Principles and practices
1544	Methods for impact tests on metals
1544.2	Part 2: Charpy V-notch
1674	Safety in welding and allied processes
1674.1	Part 1: Fire precautions
1674.2	Part 2: Electrical
1796	Certification of welders and welding supervisors
1815	Metallic materials—Rockwell hardness test
1815.1	Part 1: Test method scales (A, B, C, D, E, F, G, H, K, N, T)
1816	Metallic materials—Brinell hardness test
1816.1	Part 1: Test method (ISO 6506-1:1999, MOD)
1817	Metallic materials—Vickers hardness test
1817.1	Part 1: Test methods (ISO 6507-1:1997, MOD)
1858	Electrodes and fluxes for submerged-arc welding
1858.1	Part 1: Carbon steels and carbon-manganese steels
1988	Welding of ferrous castings
1988.2	Part 2: Iron castings
2062	Non-destructive testing—Penetrant testing of products and components
2074	Cast steels
2177	Non-destructive testing—Radiography of welded butt joints in metal (series)
2203	Cored electrodes for arc-welding
2203.1	Part 1: Ferritic steel electrodes
2205	Methods for destructive testing of welds in metal
2205.2.1	Part 2.1: Transverse butt tensile tests
2205.3.1	Part 3.1: Transverse guided bend test
2205.5.1	Part 5.1: Macro metallographic test for cross-section examination
2205.6.1	Part 6.1: Weld joint hardness test
2205.7.1	Part 7.1: Charpy V-notch impact fracture toughness test
2207	Non-destructive testing—Ultrasonic testing of fusion welded joints in carbon and low alloy steel
2799	Resistance welding equipment—Single-phase a.c. transformer type
2812	Welding, brazing and cutting of metals—Glossary of terms
2980	Qualification of welders for fusion welding of steels
3978	Non-destructive testing—Visual inspection of metal products and components
3990	Mechanical equipment—Steelwork
4100	Steel structures
4458	Pressure equipment—Manufacture

AS	
4738	Metal castings
4738.1	Part 1: Ferrous sand moulded
4882	Shielding gases for welding
AS/NZS	
1167	Welding and brazing—Filler metals
1167.2	Part 2: Filler metal for welding
1336	Recommended practices for occupational eye protection
1337	Eye protectors for industrial applications
1338	Filters for eye protectors
1338.1	Part 1: Filters for protection against radiation generated in welding and allied operations
1553	Covered electrodes for welding
1553.1	Part 1: Low carbon steel electrodes for manual metal-arc welding of carbon steels and carbon-manganese steels
1553.2	Part 2: Low and intermediate alloy steel electrodes for manual metal-arc welding of carbon steels and low and intermediate alloy steels
1554	Structural steel welding
1554.1	Part 1: Welding of steel structures
1995	Welding cables
2576	Welding consumables for build-up and wear resistance
2717	Welding—Electrodes—Gas metal arc
2717.1	Part 1: Ferritic steel electrodes
2865	Safe working in a confined space
3992	Pressure equipment—Welding and brazing qualification
4360	Risk management
4854	Welding consumables—Covered electrodes for manual metal arc welding of stainless and heat-resisting steels—Classification
AS/NZS ISO	
14343	Welding consumables—Wire electrodes, wires and rods for arc welding of stainless and heat resisting steels—Classification
ISO	
3581	Welding consumables—Covered electrodes for manual metal arc welding of stainless and heat-resisting steels—Classification
4969	Steel—Macroscopic examination by etching with strong mineral acids
9606	Approval testing of welders—Fusion welding
9606-1	Part 1: Steels
9692	Welding and allied processes—Recommendations for joint preparation
9692-1	Part 1: Manual metal-arc welding, gas-shielded metal-arc welding, gas welding, TIG welding and beam welding of steels
11970	Specification and approval of welding procedures for production welding of steel castings

17633	Welding consumables—Tubular cored electrodes and rods for gas shielded and non-gas shielded metal arc welding of stainless and heat-resisting steels— Classification
IEC	
60974	Arc welding equipment
60974-1	Part 1: Welding power sources
WTIA	Technical notes 3, 5, 7, 22, 18

1.4 DEFINITIONS

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

1.4.1 Inspecting authority

The authority having statutory powers over the control of the casting.

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

1.4.2 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 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 qualified to carry out such a procedure;
- (c) 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.

1.6 SAFETY

1.6.1 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/NZS 2865, AS/NZS 1336, AS/NZS 1337 and AS/NZS 1338.1.

1.6.2 Welding equipment

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

AS/NZS 1995, AS 2799, AS/NZS 1995 and IEC 60974-1.

1.6.3 Other hazards

The welder shall identify and manage any other hazards from welding that are not covered by Clauses 1.6.1 and 1.6.2. In particular, due consideration shall be given to the control of emitted fumes, especially when welding through paints, primers and other surface coatings.

NOTES:

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

SECTION 2 CASTINGS, BACKING PLATES AND WELDING CONSUMABLES

2.1 CASTINGS

The steel castings to be welded shall have been made from any of the types of steel specified in AS 2074, or equivalent Standards, see AS 4738.1.

2.2 BACKING MATERIAL

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

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

2.3 WELDING CONSUMABLES

2.3.1 Electrodes and filler wires

Electrodes for manual metal-arc welding shall comply with AS/NZS 1553.1, AS/NZS 1553.2, AS/NZS 4854 or ISO 3581 as applicable (see Clause 4.4.1).

Electrodes or filler wires for processes other than manual metal-arc welding shall comply with AS 1858.1, AS 2203.1 AS/NZS 1167.2, AS/NZS 2717.1, AS/NZS ISO 14343 or ISO 17633, as applicable (see Clause 4.4.1).

Electrodes that do not comply with the above Standards may be used, provided that they are qualified in accordance with the requirements of Clause 4.4.2.

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 1858.1. Where the manufacturer makes specific recommendations covering conditioning and pretreatment of flux prior to use, such recommendations shall be followed.

Where flux is 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

Where 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 or AS 4100, as applicable.

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 AS/NZS 1554.1:2004, 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, in millimetres

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.

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 3.1.

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

3.3 FILLET WELDS

3.3.1 Size of weld

The size of 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 AS/NZS 1554.1:2004, Table E3, Appendix E.

3.3.2 Design throat thickness

The design throat thickness (DTT) of a fillet weld shall be as shown in AS/NZS 1554.1:2004, 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 3.2. Where such penetration is achieved, the size of the weld may be correspondingly reduced.

3.3.3 Effective length

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

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

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

3.3.4 Effective area

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

3.3.5 Minimum size of fillet welds

The minimum size of a fillet weld, including the first run of a multi-run fillet weld, other than a fillet weld used to reinforce a butt weld, shall conform to Table 3.1 except that the size of the weld need not exceed the thickness of the thinner part joined (see also AS/NZS 1554.1:2004, Clause 5.3).

TABLE 3.1
MINIMUM SIZE (LEG LENGTH)
OF FILLET WELDS

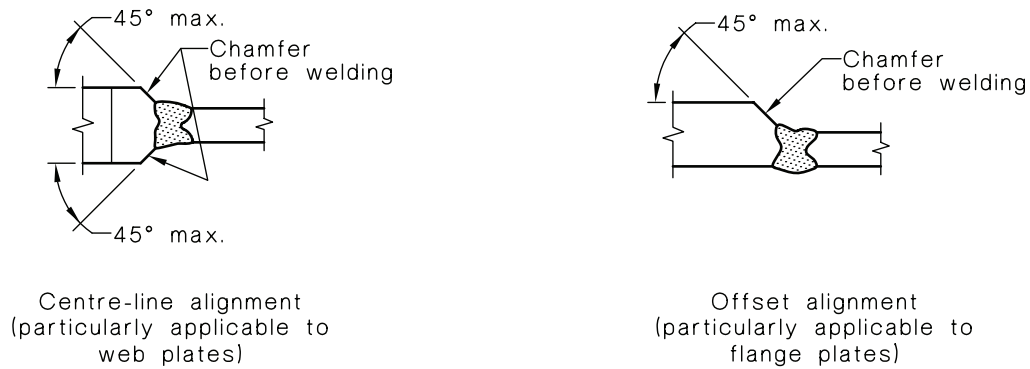
millimetres	
Thickness of thickest part (<i>t</i>)	Minimum size of fillet weld
≤3	$2t/3$ *
>3 ≤7	3 *
>7 ≤10	4 *
>10 ≤15	5
>15	6

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

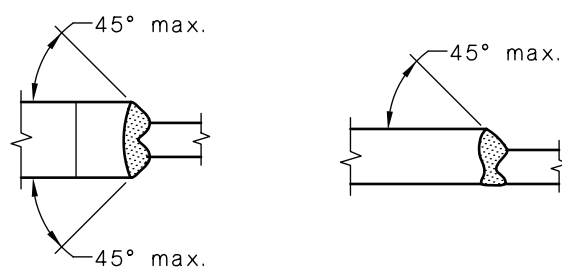
3.3.6 Maximum size of fillet welds along edges

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

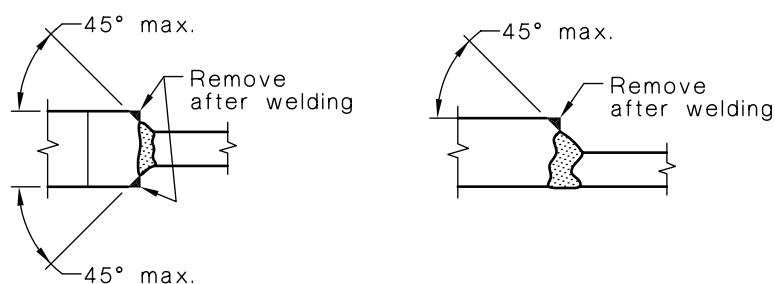
- for material with a thickness of less than 6 mm (see Figure 3.3(a)), the thickness of the material;
- for material with thickness of not less than 6 mm (see Figure 3.3(b)), the thickness of the material minus 1 mm;
- for material with a thickness of not less than 6 mm, where the weld is designated on the drawing to be built out to obtain the design throat thickness (see Figure 3.3(c)), the thickness of the material; or
- for a deep penetration fillet weld see Figure 3.2.



(i) Transition by chamfering thicker part

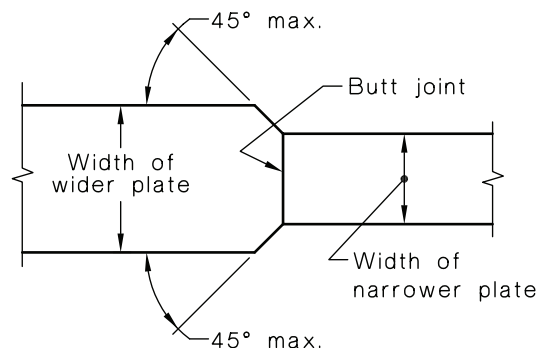


(ii) Transition by sloping weld surface



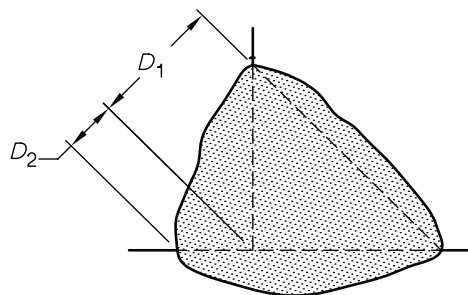
(iii) Transition by sloping weld surface and chamfering

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



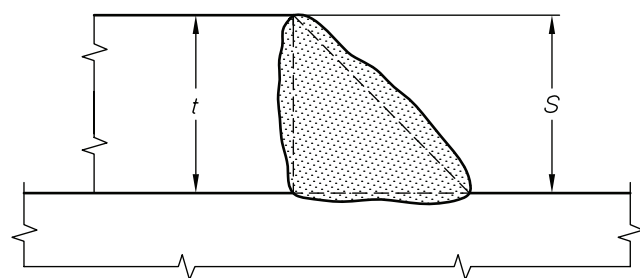
(b) Transition of butt joints in parts of unequal width, transition by chamfering wider part

FIGURE 3.1 TRANSITION OF THICKNESSES OR WIDTHS FOR BUTT
WELDS SUBJECT TO TENSION
(Reproduced from AS/NZS 1554.1)

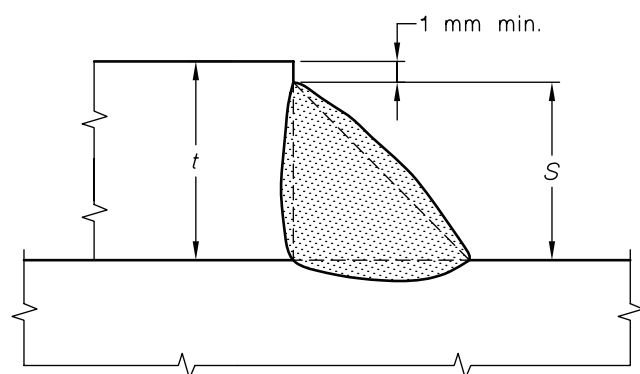


NOTE: $DTT = D_1 + 0.85 D_2$, where DTT is the design throat thickness for deep penetration fillet welds made by a fully automatic process.

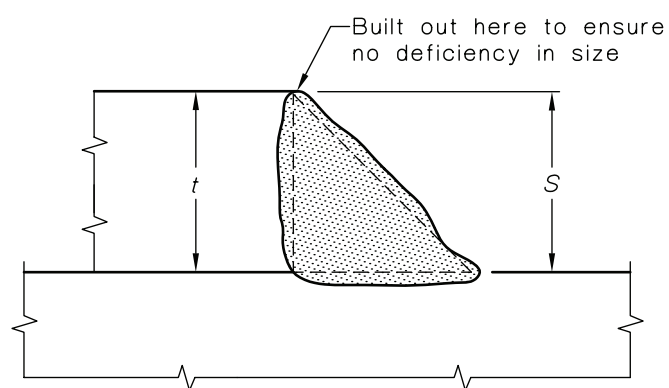
FIGURE 3.2 DEEP PENETRATION FILLET WELD
(Reproduced from AS/NZS 1554.1)



(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 MAXIMUM SIZE OF FILLET WELDS ALONG EDGES
(Reproduced from AS/NZS 1554.1)

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.

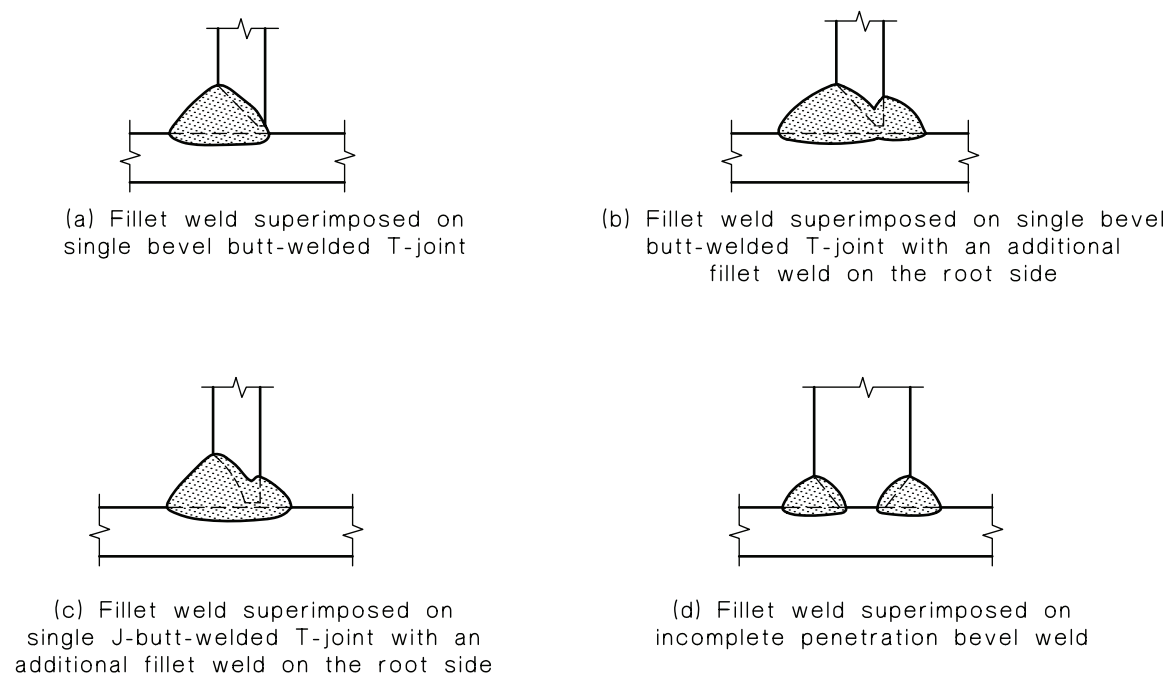


FIGURE 3.4 COMPOUND WELDS (Reproduced from AS/NZS 1554.1)

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 3.5, 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.

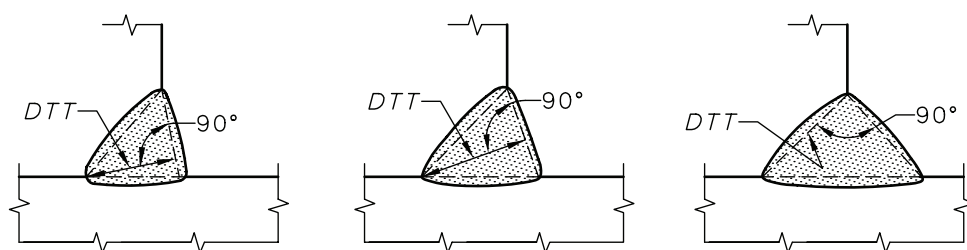


FIGURE 3.5 DESIGN THROAT THICKNESS OF COMPOUND WELDS WITH INCOMPLETE PENETRATION WELDS (Reproduced from AS/NZS 1554.1)

3.5 SEAL WELDS

Seal welds shall be single-run fillet welds or incomplete penetration butt welds, as applicable. The size of seal welds shall comply with Clauses 3.3.5 and 3.7, unless a larger weld is specifically required.

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

NOTE: Where seal welding is required, such a procedure should be specified clearly on the drawings or other documents (see Clause 3.1.3).

3.6 PLUG WELDS

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

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

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

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

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

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

3.7 SLOT WELDS

The length of the slot for slot welds shall be not 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).

SECTION 4 QUALIFICATION OF PROCEDURES AND PERSONNEL

4.1 QUALIFICATION OF WELDING PROCEDURE

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

The fabricator shall establish a welding procedure and list the applicable parameters in 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 (WPS) shall be developed from the PQR, based on the limits of the essential variables of Clause 4.7, and made available to the welder during fabrication.

The welding procedure may be approved on the welding procedure sheets by a principal's representative, who shall have, as a minimum, the qualification in accordance with Clause 4.9.

For the purpose of procedure test, the steels listed in Tables 4.1 and 4.2 shall be grouped as given in Table 4.5. The approval of a welding procedure for a particular type of steel shall include approval for all other steels in the group and between steels in the same group as permitted in Clause 4.7. Each group of steels shall be approved independently of other groups.

NOTES:

- 1 Forms suitable as PQR and WPS welding procedure sheets are shown in Appendix B.
- 2 Where no application Standard exists, the qualification of welding procedure should be agreed upon between the contracting parties (see Appendix A).
- 3 Where it is necessary, in fabrication welding, to join steel castings of widely different chemical composition, the preheating temperature, welding consumables, and postweld heat treatment should be agreed between the contracting parties, (see Appendix A).

4.2 METHODS FOR QUALIFYING A WELDING PROCEDURE

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

- (a) 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 4.5 where the type of joint allows such testing.

NOTE: The test piece may be made as a production test piece.

- (b) Preparation of a special test piece, such as shown in Figure 4.3, which simulates as closely as practicable the weld penetration, material type and thickness, edge preparation, welding conditions, including welder access and conditions of restraint to be used in production, and testing it in accordance with Clause 4.5.
- (c) Destructive testing of a prototype joint, structure or component acceptance criterion, which is subject to agreement between the purchaser and the supplier.
- (d) A welding procedure qualified by another fabricator, see Clause 4.4.

NOTE: For prequalification refer to AS/NZS 1554.1.