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The University of Sydney
Welding Technology Institute of Australia

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Australian/New Zealand Standard

Structural steel welding

Part 1: Welding of steel structures

Originated in Australia as AS CA8—1933.
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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee WD-003, Welding of Structures, to supersede AS/NZS 1554.1:2004.

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 2004 edition:

(a) Amendments to the following Clauses

1.2, 1.7 (new title), 1.7.1 (new), 2.1(c), 2.3.1, 3.2.5 (new paragraph), 4.1.2(d)(f)(h)(j)(k) (new sub clauses), 4.1.2 (k), 4.2 (b), 4.6.1.1, 4.6.1.3 (new), 4.10 (new note), 4.12.2, 5.1.1 (new note), 5.1.2 (note added), 5.3.3 (second paragraph–new), 5.3.4 (note added), 5.3.5 (new), 5.7.1 (note added), 6.4.3 (note added), 7.2(a) (new), 7.3 (first paragraph–new), Appendix F (new), Appendix G (new).

(b) Amendments to the following Tables

4.6.1(A), 4.6.1(B), 4.6.1(C), 4.6.2, 4.7.1 (new notes, notes 1 and 3 amended), 4.11(D) (new), 4.11(A) (items b, e, o, u), 4.11(C) item (d), 4.12.2.3 (A), 4.12.2.3(B) (new), 5.3.4(A), B1 (new steel types added), E4 (items deleted).

(c) Amendments to the following Figure

3.2.5(c) (new).

The Standard requires that weld preparations, welding consumables and welding procedures be qualified before commencement of welding. Prequalified joint preparations, welding consumables and welding procedures are also given in the Standard.

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

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

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

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STANDARDS AUSTRALIA/STANDARDS NEW ZEALAND

Australian/New Zealand Standard
Structural steel welding

Part 1: Welding of steel structures

S E C T I O N 1 S C O P E A N D G E N E R A L

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).

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

The 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, the 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 are those that ~~t~~ are

(i) not subject to fatigue conditions; or

(ii) subject to fatigue conditions, where—

(A) the stress range in the welded joint complies with the permissible stress range of stress categg rl76(C11(,)-11( )1D11(,)-11(orE11(or)-11(N)11(NF11(of)-11(A)-11(S

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1.2 EXCLUSIONS

The 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).

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

This Standard does not apply to underwater welding.

The Standard does not cover the design of welded connections or permissible stresses in welds, nor 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.

NOTE: The Joint Standards Australia/Standards New Zealand Committee on welding of structures can act in an advisory capacity concerning equivalent suitability, but specific approval remains the prerogative of the inspecting authority.

1.4 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

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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.

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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 are met:

(i) Testing of the material to determine compliance with any of the grade types in the Standards nominated in Item (c) above has been carried out to the satisfaction of the principal.

(ii) A comparison of supplied test 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.

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 1858.1, AS/NZS 1167.2, AS/NZS 2717.1, AS/NZS ISO 17632, ISO 14341 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.

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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.

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SECTION 3 DETAILS OF WELDED CONNECTIONS

3.1 GENERAL

3.1.1 Permissible weld types

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

3.1.2 Design stresses

Where welded joints are to be welded in accordance with this Standard, the maximum stresses in the joints shall not exceed the maximum values given in AS 3990, AS 4100 or NZS 3404.1, 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.

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

(i) where < 60°, D 3 mm; or

(ii) where 60°, D;

where

D = depth of preparation

= 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 3.2.5.

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

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

3.3 FILLET WELDS

3.3.1 Size of weld

The size of a fillet weld shall be the leg length, as defined by AS 2812.

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

Where there is a root gap, the size shall be given by the lengths of the legs of the inscribed triangle, reduced by the amount shown in Table E3, Appendix E.

3.3.2 Design throat thickness

The design throat thickness (T) 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.

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

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3.3.3 Effective length

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

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

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

3.3.4 Effective area

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

3.3.5 Minimum size of fillet welds

The minimum size of a fillet weld, including the first run of a multi-run fillet weld, other than a fillet weld used to reinforce a butt weld, shall conform to Table 3.3.5 except that the size of the weld need not exceed the thickness of the thinner part joined (see also Clause 5.3).

TABLE 3.3.5

MINIMUM SIZE (LEG LENGTH) OF FILLET WELDS

millimetres

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

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

3.3.6 Maximum size of fillet welds along edges

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

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

(b) for material with thickness of not less than 6 mm (see Figure 3.3.6(b)), the thickness of the material minus 1 mm; or

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

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

NOTE: Where seal welding is required, such a procedure has to be specified clearly on the drawings or other documents (see Clause 3.1.2).

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 (t) mm	Depth of filling mm

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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.

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, NZS 3404.1 requires the welding procedures to have been approved by the principal, prior to the commencement of welding.

4.1.2 Butt welds

For complete penetration and incomplete penetration butt welds, the following 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)(used without further testing. A change in welding direction between vertically up and vertical down shall require separate qualification.

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

(d) A procedure qualification on a single 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.

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(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 multiple-run fillet welds may be qualified on op. 1 2(d o1(shal( )sha0o)-f12

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4.1.4 Qualification of multiple welding positions

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

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

4.2 METHODS FOR QUALIFYING A WELDING PROCEDURE

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

(a) A prequalified procedure in accordance with Clause 4.3.

(b) Production of documentary evidence of relevant prior experience by the fabricator.

NOTES:

1 A completed welding procedure sheet such as that shown in Appendix C, together with records of any tests carried out as required by the application Standard to which the procedure was qualified (e.g. AS/NZS 3992, AWS D1.1), constitutes documentary evidence of prior experience. All WPSs should meet the requirements of essential variables of AS/NZS 1554.1.

2 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 penetration, material type and direction of rolling, material thickness, edge preparation, welding conditions, including welder access and conditions of restraint to be used in production, and testing it in accordance with Clause 4.7.

(e) Destructive testing of a prototype joint, structure or component.

(f) A welding procedure qualified by another fabricator, see Clause 4.4.

4.3 PREQUALIFIED WELDING PROCEDURES

Welding procedures shall be deemed to be prequalified, where—

(a) the joint preparations are prequalified in accordance with Clause 4.5;

(b) the materials are prequalified in accordance with Clause 2.1;

(c) the consumables are prequalified in accordance with Clause 4.6;

(d) the workmanship and welding techniques, including the preheat and inter-run temperature requirements, comply with this Standard; and

(e) there is documentary evidence of a satisfactory macro test in accordance with Clause 4.7.4, including a satisfactory macro or a sketch or photograph of it, showing the position number, the sequence of runs, the minimum leg length, the throat thickness and the scale of the sketch.

NOTE: For the purpose of this requirement, a digital or scanned image is considered to be the equivalent of a photograph.

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TABLE 4.11(B)

CHANGES IN ESSENTIAL VARIABLES REQUIRING REQUALIFICATION FOR ELECTROGAS AND ELECTROSLAG WELDING

(a) A significant change in filler metal or consumable guide metal composition

(b) A change in consumable guide metal core cross-sectional area of more than 30%

(c) A change in fluxing system (e.g. cored electrode, external flux)

(d) A change in flux composition, including consumable guide coating

(e) A change in shielding gas composition of any one constituent of more than 5% of the total flow

(f) A change in welding current of more than 10%

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