TABLE 4.12.2(B)

RANGE OF QUALIFICATION FOR WELDING CONSUMABLES

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

LEGEND

X = welding consumables for which the welder is qualified

— = welding consumables for which the welder is not qualified

FCAWgs= flux cored arc welding—gas shielded

NOTES:

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

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

SECTION 5 WORKMANSHIP

5.1 PREPARATION OF EDGES FOR WELDING

5.1.1 General

Surfaces and edges to be welded shall be uniform and free from fins, tears, cracks and other defects that would adversely affect the quality or strength of the weld. Surfaces to be welded and surfaces adjacent to a weld shall also be free from loose or thick scale, slag, rust, grease, paint or other foreign matter that could prevent proper welding. Millscale that withstands vigorous wire brushing, rust-inhibiting coatings, antispatter compound, metallic coatings and weld-through primers that do not interfere with weld quality or the welding operation may remain.

5.1.2 Thermal cutting

Surfaces to be incorporated in a weld shall not have a surface roughness greater than Class 3 as defined in WTIA Technical Note 5.

Surfaces not incorporated in a weld shall have a surface roughness not exceeding CLA 25 µm (centre-line average method).

Cut surface roughness exceeding these values shall be repaired by grinding to give a value less than the specified roughness. Grinding marks shall be parallel to the direction of the cut.

Notches and gouges, not closer than $20t$ (where t is the component thickness) and not exceeding 1% of the total surface area on an otherwise satisfactory surface, are acceptable provided imperfections greater than $t/5$ but not exceeding 1 mm in depth are removed by machining or grinding. Imperfections outside the above limits shall be repaired by welding in accordance with this Standard.

A re-entrant corner shall be shaped notch free to a radius of at least 10 mm.

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

5.2 ASSEMBLY

5.2.1 General

The alignment of parts to be welded shall be made as carefully as possible having regard to the normal tolerances associated with the fabrication and erection procedures specified in the application Standard.

5.2.2 Alignment of butt-welded joints

Ends of parts to be joined by butt welds shall be carefully aligned, having regard to the procedure being employed.

Where the parts are effectively restrained against bending, because of eccentricity in alignment, the surfaces of plates of equal thickness shall not be out of alignment by more than 10% of the thickness of the plates, unless otherwise approved by the principal.

The dimensions of butt-welded joints that differ from those shown on the detailed drawings or other documents by more than the tolerances shown in Table 5.2.2 shall be referred to the principal for approval. [See Appendix D, Item (n).]

Root openings wider than those permitted in Table 5.2.2, but not wider than the lesser of 9 mm and twice the thickness of the thinner part, may be corrected by welding to acceptable dimensions, prior to joining of the parts by welding. Root openings wider than the lesser of 9 mm and twice the thickness of the thinner part shall be corrected by welding only with the approval of the principal.

Where the root is to be gouged back to sound metal, the root tolerances given in Table 5.2.2 may be disregarded.

TABLE 5.2.2

ALLOWABLE JOINT TOLERANCES

Dimension	Tolerance
Root face (root not gouged)	±1.5 mm
Root gap without backing (root not gouged)	±1.5 mm
Root radius (root not gouged)	+3, −0 mm
Root gap with backing	+6, −1.5 mm
Angle of preparation	+10, −5°

NOTE: For gouged preparations, see Clause 5.2.2.

5.2.3 Alignment of fillet welds and incomplete penetration butt welds

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

Where the separation is 1.5 mm or greater, the size of the fillet weld shall be increased by the amount of the separation or the fabricator shall demonstrate that the required design throat thickness has been obtained.

5.2.4 Backing material

5.2.4.1 *Backing thickness*

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

TABLE 5.2.4

RECOMMENDED MINIMUM BACKING THICKNESS

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

5.2.4.2 *Separation of backing material*

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

5.3 PREHEATING AND INTER-RUN CONTROL

5.3.1 General

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

A1 **'Text deleted'**

NOTE: Excessive preheating should be avoided.

5.3.2 Need for preheating

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

5.3.3 Extent of preheating and cooling after welding

Where preheating is required, it shall be applied in such a manner that the parts being welded are at the specified minimum temperature as specified in AS ISO 13916. The preheat shall be applied in such a manner as will ensure that the full thickness of the materials to be welded are heated to the required temperature.

The rate of cooling from the preheating or inter-run temperatures should be uniform and as slow as practicable. Delayed cooling by means of insulation or heat may be desirable in extreme cases or complex joints.

The measurement of preheat and inter-run temperature shall comply with AS ISO 13916.

5.3.4 Determination of preheating temperature

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

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

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

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

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

where

CE = carbon equivalent

C = carbon content, as a percentage

Mn = manganese content, as a percentage

Cr = chromium content, as a percentage

Mo = molybdenum content, as a percentage

V = vanadium content, as a percentage

Ni = nickel content, as a percentage

Cu = copper content, as a percentage

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

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

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

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

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

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

where

Q = arc energy, in kilojoules per millimetre

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

I = welding current, in amperes

V = travel speed, in millimetres per minute

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

To calculate the total arc energy for multi-arc processes, the arc energy for each individual arc shall be calculated using Equation 5.3.4(2). The total arc energy for the process is the sum of all arc energies for each individual arc.

Where it is desired to apply preheating temperatures not determined by this method, the welding procedure shall be qualified in accordance with Section 4.

NOTES:

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

2 Hydrogen-controlled consumables are those with a hydrogen classification of H5, H10, or H15. GMAW consumables complying with AS/NZS 2717.1 do not have a hydrogen rating but typically comply with H5 unless contamination is present.

3 The preheat prediction methods given herein are designed to minimize the risk of heat-affected zone cold cracking under most fabrication circumstances. The Standard does not address the issue of weld-metal cold cracking. If encountered, weld procedure modifications may be required, including the application of additional preheat beyond that predicted and the use of lower hydrogen consumables. There is evidence that weld-metal cold cracking is more likely to occur with multi-pass welds in restrained plates over 20 mm thick and where high heat input runs are used (i.e. larger weld bead sizes).

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

from $Q_{\min} = \dfrac{60\,E_{\min}\,I_{\min}}{1000\,V_{\max}}$ to $Q_{\max} = \dfrac{60\,E_{\max}\,I_{\max}}{1000\,V_{\min}}$

TABLE 5.3.4(A)
PREHEAT DETERMINATION

Parent metal		Weldability group number
Standard	**Grade (see Note 1)**	
AS/NZS 1163	C250 C350, C450	1
AS 1397	G250 G300, G350 G450, G500, G550	1 5 4
AS 1450	C200, H200 C250, H250 C350, H350 C450	1 4 5 4
AS 1548	PT430, PT460 PT490, PT540	4 5
AS/NZS 1594 (see Note 2)	HA1, HA3, HA4, HA200, HA250/1 HA250, HU250 HA300, HA300/1, HU300, XF300 HA350 HW350 (see Note 2) HA400 XF400 XF500 HA1006, HA1010 HA1016, HXA1016	1 3 3 4 5 4 3 4 1 3
AS/NZS 1595	CA1010, CA60T, CA70T, CA85T, CA1 CA2, CA3, CA4, CA5SN, CA220, CA260 CA350 CA400, CA450 CW300	1 1 3 4 5
AS 2074	C1 C2 C3 C4-1 C4-2 C7A-1 C7A-2	5 2 6 5 6 4 5
AS/NZS 3678 and AS/NZS 3679.2	200 250, 300 350, WR350 (see Note 2), 400, 450 A1006 XK1016	1 4 5 1 4
AS/NZS 3679.1	300 350	4 5

NOTES:

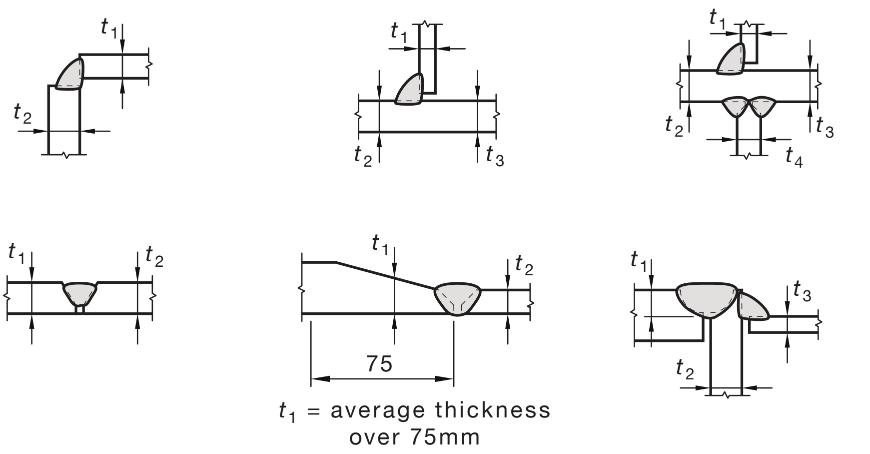
1 The weldability of each impact tested steel variant is the same as its base steel.

2 Weldability Group Number 5 for CW 300, HW350 and WR350 steels is based on the typical maximum carbon equivalent encountered in Australia and New Zealand, rather than the maximum specification limits normally applied.

TABLE 5.3.4(B)

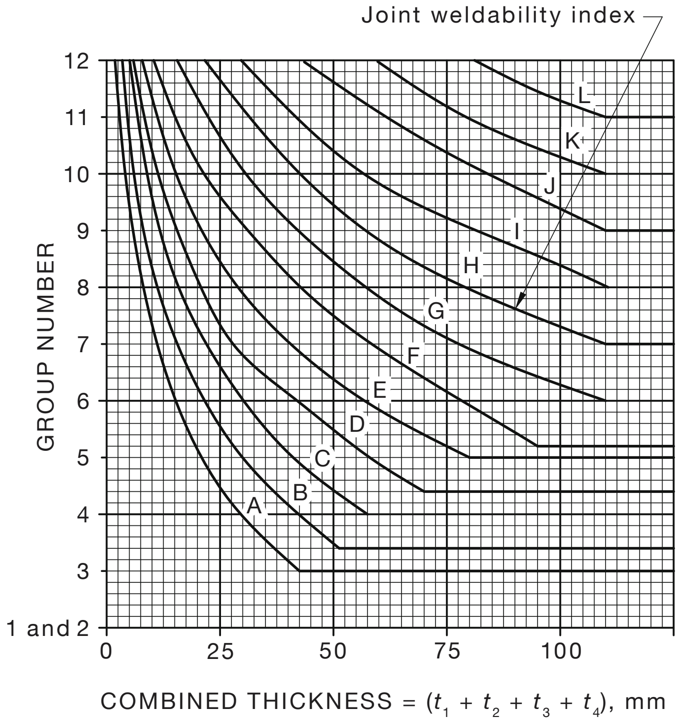
RELATIONSHIP BETWEEN CARBON EQUIVALENT AND WELDABILITY GROUP NUMBER

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



For welds between t_1 and t_2 to t_3
Ignore t_4 unless it is already welded to t_2 to t_4

For welds between t_2 and t_3
Ignore t_1 unless it is already welded to t_2



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

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

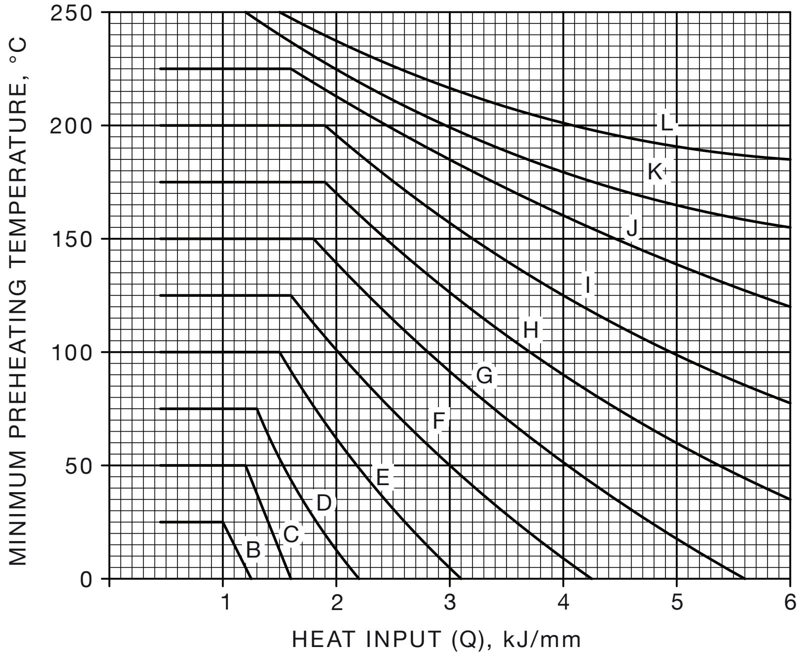


FIGURE 5.3.4(B) PREHEATING DETERMINATION FOR HYDROGEN-CONTROLLED CONSUMABLES AND PROCESSES (see Note 3 of Clause 5.3.4)

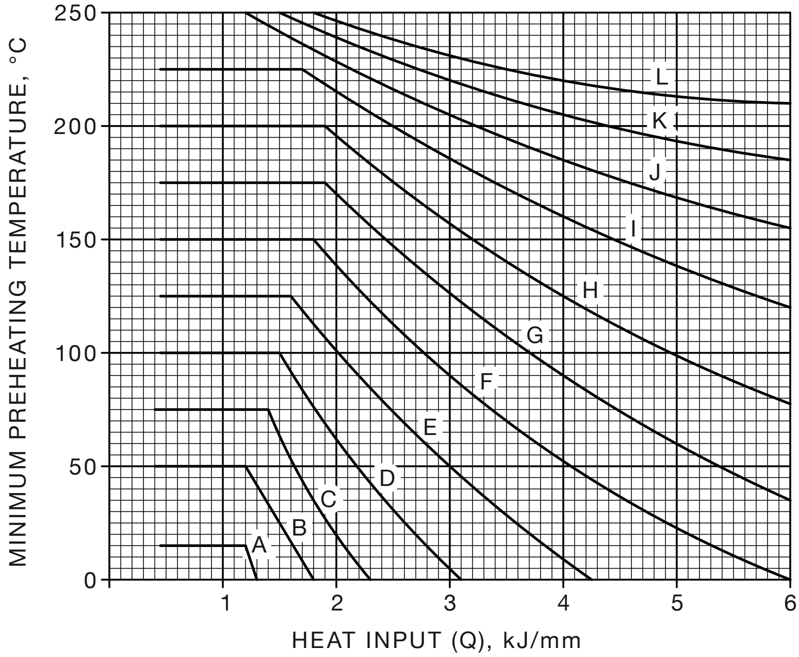


FIGURE 5.3.4(C) PREHEATING DETERMINATION FOR OTHER THAN HYDROGEN-CONTROLLED CONSUMABLES AND PROCESSES

5.4 WELDING UNDER ADVERSE WEATHER CONDITIONS

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

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

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

5.5 TACK WELDS

Tack welds shall—

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

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

(c) have a length of not less than the lesser of 20 mm and four times the thickness of the thicker part.

Tack welds applied to structural members thicker than 5 mm shall have a length of not less than 40 mm in lieu of the minimum specified in Item (c).

5.6 WELD DEPTH TO WIDTH RATIO

The depth and the maximum width of the deposited weld metal shall not exceed its width at the surface of the weld (see Figure 5.6); except that this requirement may be waived where the weld depth exceeds the width of the weld at the face, and the testing of the welding procedure to be used has demonstrated that such welds are free from cracks. This requirement shall not be waived where the maximum width in the cross-section of the weld material deposited exceeds the width of the weld at the surface.

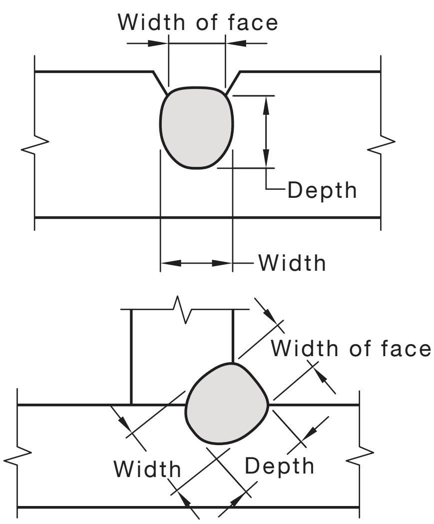


FIGURE 5.6 UNACCEPTABLE WELD RUN (DEPTH AND WIDTH EXCEED THE WIDTH OF THE WELD FACE)