To calculate the total arc energy for multi-arc processes, the arc energy for each individual arc shall be calculated using the above equation. 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 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).

2 The permitted heat input range (see Clauses 4.11 and 5.3) should be shown on WPS documents and 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.

$$\text{from } Q_{\min} = \frac{60\,E_{\min} I_{\min}}{100\,V_{\max}} \qquad \text{to } Q_{\max} = \frac{60\,E_{\max} I_{\max}}{100\,V_{\max}}$$

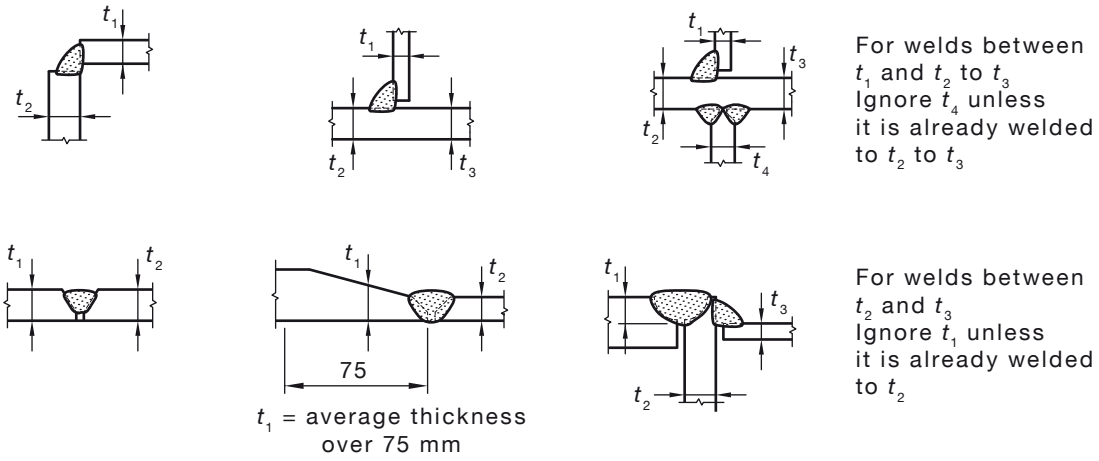


FIGURE 5.3.4 CALCULATION OF COMBINED THICKNESS

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 greater than 10 km/h, unless the welding area is suitably protected in order to reduce the wind 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 specified by Clause 5.3;

(b) have cascaded ends, multi-run;

(c) have a length of not less than the lesser of 40 mm and four times the thickness of the thicker part; and

(d) be continuous for the length specified.

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), with the following conditions:

(a) This requirement may be waived where testing of the welding procedure to be used has demonstrated that welds where the weld depth exceeds the width of the weld at the face are free from cracks.

(b) 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.

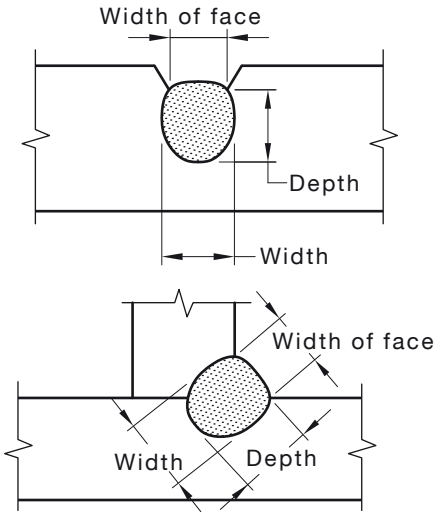


FIGURE 5.6 UNACCEPTABLE WELD RUN IN WHICH DEPTH AND WIDTH EXCEED THE WIDTH OF THE WELD FACE

5.7 CONTROL OF DISTORTION AND RESIDUAL STRESS

5.7.1 General

In the assembly and joining of parts of a structure or of built-up members and in the welding of reinforcing parts to members, the procedure and sequence shall be such as will maintain distortion and shrinkage within the required structural limits.

NOTES:

1 Guidance on distortion and shrinkage is given in AS 3990, AS 4100 and NZS 3404.1.

2 The order in which weld joints and/or weld runs are deposited can have an effect on the residual stress, mechanical properties, hardness, corrosion, distortion, ease of welding, likelihood of defects including lamellar tearing, fatigue and final appearance, and so influence the performance of the final joint. For critical joints, bead placement should be carefully considered by the fabricator when developing the welding procedure specification.

In the making of welds under conditions of severe external shrinkage restraint, the welding shall be carried continuously to completion, or to a point that will ensure freedom from cracking before the joint is allowed to cool below the minimum specified preheating and interrun temperatures.

5.7.2 Stressed parts

Parts that are stressed shall not be cut or welded, except where—

(a) the effect of such actions on the flexural, tensile and compressive capacity of the member is considered;

(b) the matter is the subject of agreement between the fabricator and the principal in accordance with Appendix D, Item (p); and

(c) appropriate safety precautions are taken to prevent damage to or failure of the structure.

NOTE: See the requirements for modification of existing structures in AS 4100 or NZS 3404.1, as appropriate.

5.7.3 Peening

Peening may be used on intermediate weld runs for control of shrinkage stresses in thick welds, to prevent cracking. No peening shall be done on the root or surface layer of the weld or in the base metal at the edges of the weld. Care should be taken to prevent overlapping or cracking of the weld or base metal.

The procedure to be adopted for peening shall be established by the fabricator and approved by the principal prior to use in accordance with Appendix D, Item (q).

5.7.4 Correction of distortion

Distortion resulting from welding and fabrication may be corrected by mechanical means, heating or the controlled application of weld runs. Where flame-heating methods are applied, the following restrictions shall apply:

(a) Where solid water jets are used for cooling, their use shall be agreed to in accordance with Appendix D, Item (r).

(b) The temperature of steels shall not exceed the tempering temperature less 20°C.

Improperly fitted parts may be cut apart and rewelded provided the procedure is established and approved in accordance with Appendix D, Item (r).

5.8 BACKGOUGING AND REPAIR OF DEFECTS IN WELDS

5.8.1 General

Where welds are found to have defects as classified by Clause 6.7, either the defects shall be repaired, or the entire weld shall be removed and replaced. Repairing or rewelding shall be carried out in accordance with this Standard, and the principal shall be advised of all such repairs.

5.8.2 Removal of weld metal

Removal of the weld metal or portions of the base metal shall be effected by machining, grinding, chipping, oxygen gouging, air-arc gouging or plasma gouging, in such a manner that the remaining weld metal or base metal is not nicked or undercut. Unacceptable portions of the weld shall be removed, without substantial removal of the base metal. The surfaces shall be cleaned thoroughly before welding. Oxygen-gouged and air-arc-gouged surfaces shall be at least cleaned by grinding or machining, to remove all carbon absorption or contamination.

Gouged areas requiring rewelding shall have a root radius of not less than 5 mm and sufficient width to allow the welder reasonable access to reinstate the weld.

Unacceptable undercutting (refer to Table 6.2) shall be made good by the deposition of additional weld metal in accordance with this Standard or by the removal of the undercut by grinding in accordance with Clause 5.8.3.

NOTE: The use of preheat prior to air-arc gouging should be considered. Guidance may be obtained from WTIA Technical Note 15.

5.8.3 Grinding

Grinding shall comply with the following requirements:

(a) The ground area shall blend smoothly into the surrounding surface, without abrupt changes in contour.

(b) The grinding shall not extend below the surface of the parent material by more than—

  (i) for material less than 10 mm thick, 0.5 mm; or

  (ii) for material not less than 10 mm thick, the lesser of 0.07 times the nominal thickness and 3 mm.

5.8.4 Stop/starts

Where stop/starts occur in the length of continuous automatic longitudinal fillet or butt weld, with stress ranges for detail Category 112 or 125 as specified in AS 4100 or NZS 3404.1, they shall be repaired by the following procedure:

(a) Grind the stopped end of the weld so that it tapers to the root of the joint with a slope of at least 4:1.

(b) Restart the weld from the top of the taper slope.

(c) Grind the repaired weld to a smooth surface.

The site of the repair shall be subjected to 100% magnetic particle examination in accordance with Section 6.

NOTE: In rectangular hollow section joints, welds should not be started or stopped at corners.

5.9 TEMPORARY ATTACHMENTS

Welds joining temporary attachments to the structure shall be made to the same standards as final welds. All temporary attachments shall be removed, unless otherwise specified on the drawings or other documents. Temporary welds and attachments shall not be allowed on the tension flanges of beams, girders and similar members. When temporary welds or attachments are removed, the surface shall be—

(a) reinstated to a reasonably smooth condition, by grinding or by a combination of welding and grinding;

(b) checked by magnetic particle examination or other suitable method, to ensure soundness; and

(c) finished to the requirements of Clause 5.8.3.

5.10 ARC STRIKES

Arc strikes outside the area of permanent welds should be avoided on any material. Cracks or blemishes resulting from arc strikes on members, other than those that are essentially statically loaded, shall be ground to a smooth contour in accordance with Clause 5.8.3 and checked by magnetic particle examination or other suitable method to ensure soundness.

5.11 CLEANING OF FINISHED WELDS

Slag shall be removed from completed welds. The weld and adjacent base metal shall be cleaned by brushing or other suitable means. Tightly adhering spatter remaining after the cleaning operation is acceptable, unless its removal is required for subsequent non-destructive testing or surface treatment.

Welded joints shall not be painted until after the welding has been completed, inspected and accepted. See Appendix D, Item (s).

5.12 DRESSING OF BUTT WELDS

The surface of butt welds that have been dressed flush shall be finished so as to—

(a) reduce the thickness of the thinner base metal or weld metal by more than 0.8 mm or 5% of the thickness, whichever is the lesser; or

(b) leaving reinforcement that exceeds 0.8 mm.

Reinforcements shall be removed where the weld forms part of a faying or contact surface. Any dressing of reinforcement shall blend smoothly into the plate surfaces. See Appendix D, Item (s).

In addition, Category FP welds shall be dressed in accordance with the fatigue requirements of AS 3990, AS 4100 or NZS 3404.1, as appropriate.

SECTION 6 QUALITY OF WELDS

6.1 CATEGORIES OF WELDS

According to the intended application, welds shall be Category GP, Category SP or Category FP (see Clause 1.6).

The compliance of the completed welds with these categories shall be determined in accordance with the different inspection requirements and different acceptance levels of imperfections for the categories, as given in Clause 6.2.

6.2 METHODS OF INSPECTION AND PERMISSIBLE LEVELS OF IMPERFECTIONS

6.2.1 Methods of inspection of completed welds

Welds shall be inspected in accordance with Clause 7.3 and, where appropriate, with Clause 7.4.

In addition, for Category SP and Category FP butt welds, where radiographic or ultrasonic examination is required by the principal and is specified on the drawings or other documents, examination for the relevant types of imperfections shown in Tables 6.3(A) and 6.3(B) shall be carried out in accordance with Clause 6.3 or Clause 6.4, as appropriate.

NOTE: Table 7.4 includes guidance on the suggested extent of non-destructive examination, which is consistent with the principles on which this Standard is based.

6.2.2 Permissible levels of imperfection

The size, number and spacing of imperfections within the weld zone that are permitted for the weld categories shall not exceed the relevant levels given in Table 6.2 and Tables 6.3(A) and 6.3(B).

Imperfections of parent metal origin are not considered a cause for rejection of the weld.

6.2.3 Adjacent imperfections

6.2.3.1 *Aligned*

Where adjacent imperfections are aligned, they shall be assessed as shown in Figure 6.2.3(a).

6.2.3.2 *Overlapping*

Where there is a horizontal displacement between adjacent imperfections within the weld zone, the effective length (L) shall be as shown in Figure 6.2.3(b).

6.2.3.3 *Overlapping vertical displacement*

Any imperfections occurring one above the other in the vertical plane of the weld shall be assessed as shown in Figure 6.2.3(c).

6.2.4 Interpretation of tests

Where qualification by macro test and side-bend test is required (see Clause 4.7), the bend test shall be used solely to reveal imperfections not observed in the macro-section. Tearing at the ends of imperfections shall not be considered for the purposes of assessing the depth or height of imperfections. Any imperfections observed may be assumed to extend the total length of the weld, unless additional sections are taken to show the extent of the imperfections.

TABLE 6.2

PERMISSIBLE LEVELS OF IMPERFECTIONS IN BUTT AND FILLET WELDS AS DETERMINED BY VISUAL, MAGNETIC PARTICLE AND LIQUID PENETRANT EXAMINATION OF THE WELD ZONE

Imperfection		Symbol	Maximum allowable dimension or number of imperfections (see Figure 6.2)			
Type	Parameter		GP	SP		FP
Butt welds						
Cracks	Length	l	Crater cracks only	No cracks allowed		
	Cumulative length	Σl	6 mm in 1000 mm weld (crater cracks only)			
Lack of fusion or incomplete penetration	Depth for GP Length for SP	As for undercut depth		l	Where located more than $3t$ from end of weld, $2t/3$, but not greater than 20 mm Where located within $3t$ from end of weld, 3 mm	Not allowed (if exposed at weld surface)
				Σl	t in $6t$ length, but proportionally less for shorter length	
Undercut (continuous)	Depth	h	$t/10$, but not greater than 1.5 mm (see Note 3)	$t/20$, but not greater than 1 mm (see Note 3)		Not allowed
Undercut (intermittent)	Depth	h	$t/5$, but not greater than 2 mm (see Note 3)	$t/10$, but not greater than 1.5 mm (see Note 3)		Not allowed
Shrinkage grooves Root concavity	—	—	As for undercut			Not allowed
A1 Reinforcement (each side)	Height	h	Not limited	For $t \le 12$ mm .....3 mm For $12 < t \le 25$ mm .....5 mm For $t > 25$ mm .....6 mm		$h \le 0.2$ mm + $0.1W$, 2 mm (max.) Smoothly blended at weld toes
A1 Excess penetration	Height (depth)	—	As for reinforcement			$h \le 0.2$ mm + $0.05W$, 1 mm (max.) Smoothly blended at weld toes
Misalignment	—	—	See Clauses 5.2.2 and 5.2.3			

(continued)

TABLE 6.2 *(continued)*

Imperfection		Symbol	Maximum allowable dimension or number of imperfections (see Figure 6.2)		
Type	**Parameter**		**GP**	**SP**	**FP**
Fillet welds					
Overlap	Length	l	$2t$, but not greater than 20 mm	t, but not greater than 10 mm	Not allowed
	Cumulative length	Σl	60 mm in 300 mm, but proportionately less for shorter lengths	30 mm in 300 mm, but proportionately less for shorter lengths	
Toe shape (other than above)	—	—	No restriction	Suitable to permit required in NDE report	Smoothly blended
Surface pores	Size of pore	d	Not limited	$t/3$, but not greater than 5 mm	Not allowed
	Number of pores	—	Six per $12t$ length	Two per $12t$ length	
Loss of cross-sectional area (see Note 4)	L of A		≤ 10%	≤5%	≤3%
A1 Reinforcement	Height	h	Not limited	For $S \leq 12$ mm ..... 2 mm For $12 \leq S < 25$ mm ..... 3 mm For $S > 25$ mm ..... 4 mm	$h \leq 0.2$ mm + $0.1W$, 2 mm (max.) Smoothly blended at weld toes (see Note 5)
Undersize—intermittent (see Note 5)	Leg length	—	$S/5$, but not greater than 4 mm	$S/10$, but not greater than 3 mm	$S/10 \leq 2$ mm
Other surface imperfections	—	—	As for butt welds		Not allowed
Loss of cross-sectional area (see Note 4)	L of A	—	As for butt welds		≤3%

NOTES TO TABLE 6.2:

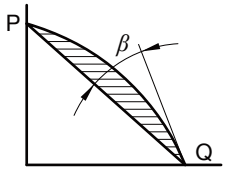
1 For adjacent imperfections, see Clause 6.2.3.

2 For a welding procedure qualification, the assessment of the test piece for compliance with the permissible levels of imperfections should be done with the aid of the macro test specimen. For calculation of the loss of cross sectional area, internal imperfections are estimated from the macro test specimen.

3 Undercut less than 0.5 mm in depth should be disregarded for Category GP and Category SP welds.

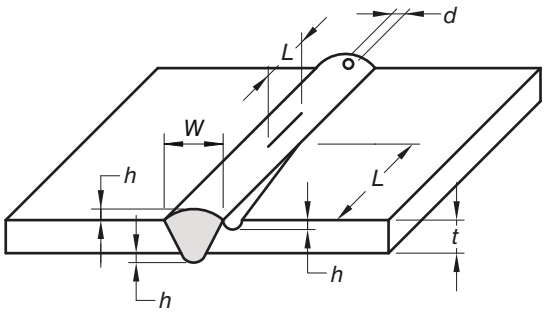
4 For the calculation of the loss of cross sectional area, all relevant surface imperfections shall be included. Where lack of root fusion is evident, the inspector shall assess the approximate depth of the imperfection. The macro test specimen from the welding procedure qualification may need examination for this purpose.

5 The angle β between the plane tangential to the weld bead surface at the toe and the plane through the line PQ shall be ≤15°. Slightly concave welds shall be acceptable, provided the design throat thickness requirements are fulfilled. This requirement also applies for the angle between the tangential planes between multi-run welds.

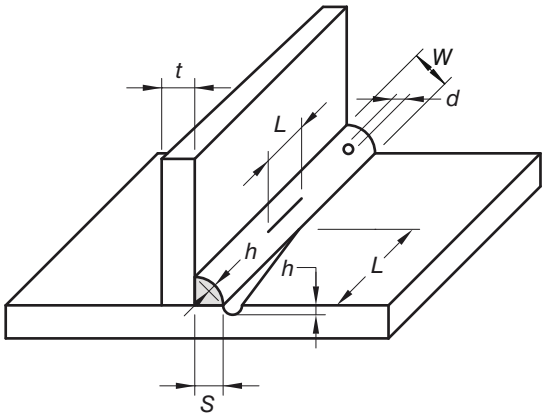


6 The cumulative length of intermittent undersize fillet welds shall not exceed 10% of the length of the weld.

A1



(a) Butt weld



(b) Fillet weld

LEGEND:
L = length or maximum dimensions of individual imperfections measured parallel to axis of weld
ΣL = sum of lengths of imperfections in stated weld length
h = height (depth) of imperfection
t = thickness of parent metal (thinner)
d = size of pore
S = size of fillet weld (see Clause 3.3.1)
W = width of weld face

FIGURE 6.2 DIMENSIONS REFERRED TO IN TABLE 6.2