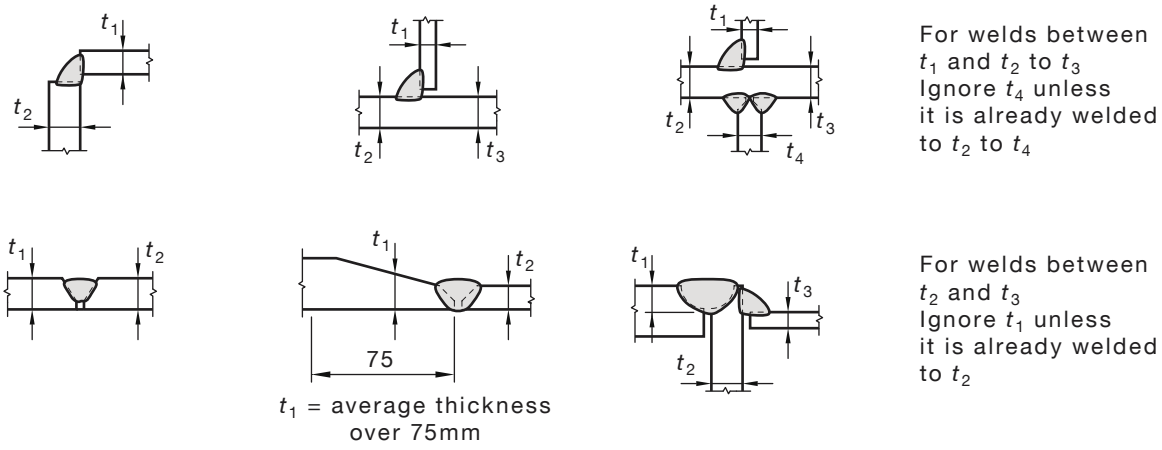
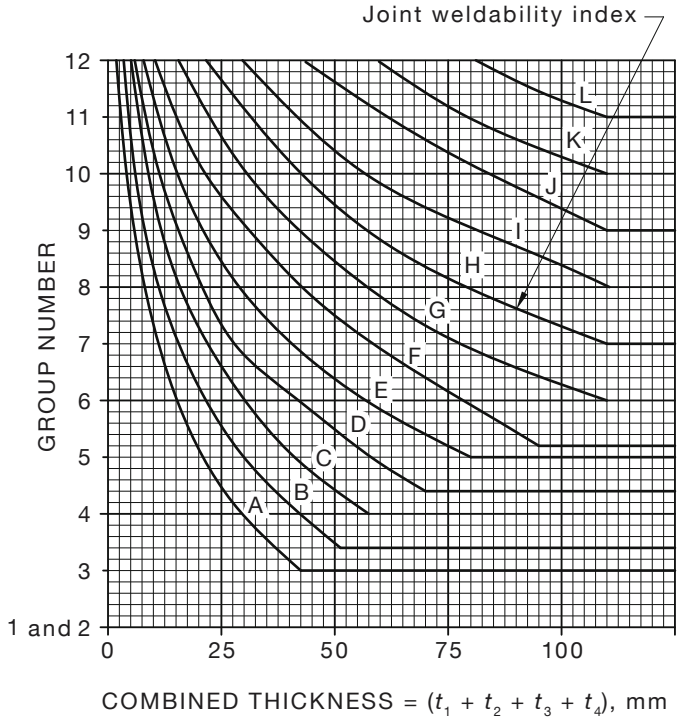




NOTE: Combined thickness is shown only up to 125 mm for convenience.

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

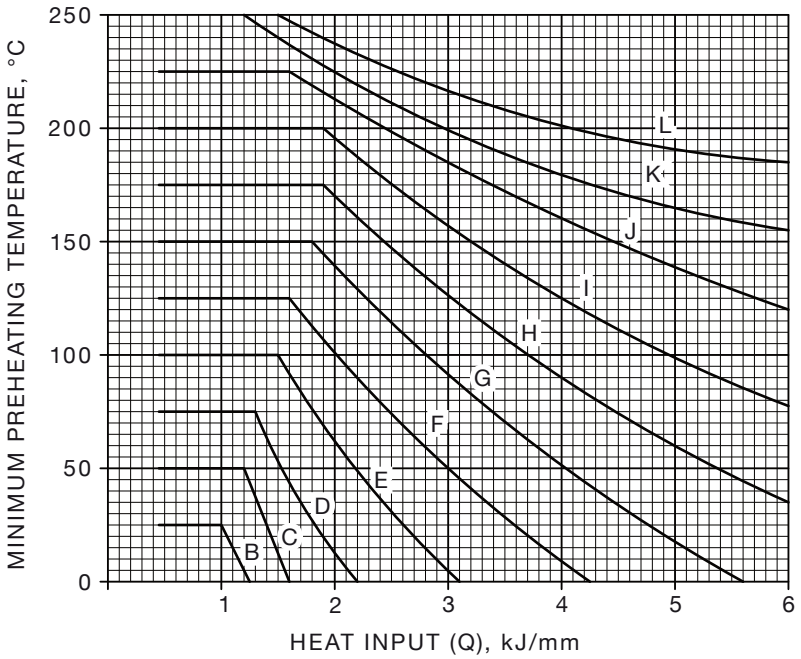


FIGURE 5.3.4(B) PREHEATING DETERMINATION FOR HYDROGEN-CONTROLLED MANUAL METAL-ARC ELECTRODES AND SEMI-AUTOMATIC OR AUTOMATIC PROCESSES

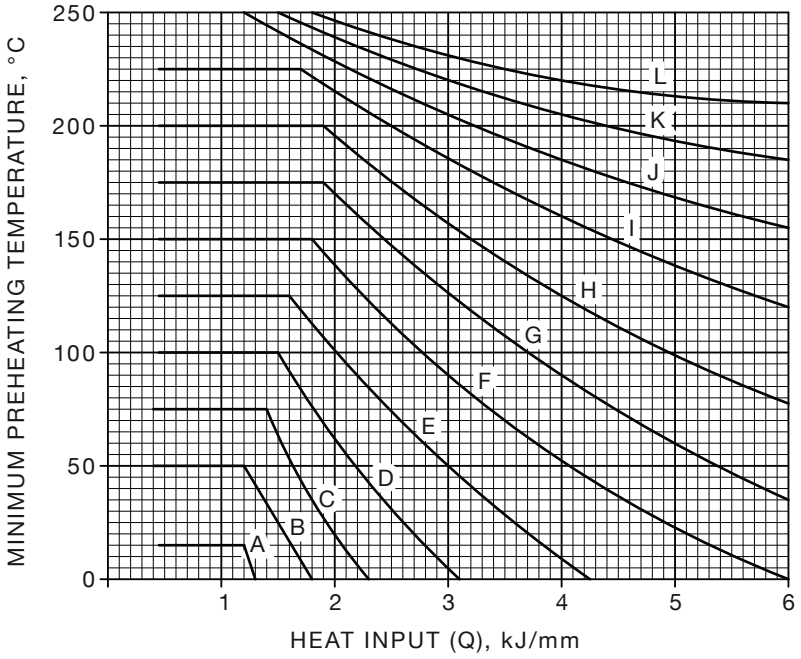


FIGURE 5.3.4(C) PREHEATING DETERMINATION FOR MANUAL METAL-ARC ELECTRODES OTHER THAN HYDROGEN CONTROLLED

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 40 mm and four times the thickness of the thicker part.

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 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.

(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.

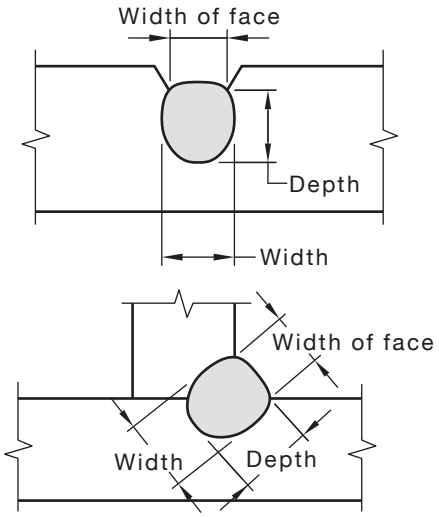


FIGURE 5.6 UNACCEPTABLE WELD RUN IN WHICH DEPTH AND WIDTH EXCEED THE WIDTH OF THE WELD FACE

5.7 CONTROL OF DISTORTION AND RESIDUAL STRESS

5.7.1 General

In the assembly and joining of parts of a structure or 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 or 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.

Welding under conditions of severe external shrinkage restraint shall be carried out 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 inter-run 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, before 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, by heating or by the controlled application of weld runs. Where flame-heating methods are applied, the following restrictions shall apply:

(a) Solid water jets may be used for cooling, only if arranged before use in accordance with Appendix D, Item (r).

(b) The temperature of steels shall not exceed 600°C.

Improperly fitted parts may be cut apart and rewelded, if arranged 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. A repair weld procedure may be required in such instances.

NOTE: The principal may require that a welding procedure for repairs be qualified and approved.

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 re-welding 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 6.2.2) shall be made good by either the deposition of additional weld metal in accordance with this Standard or the removal of the undercut by grinding in accordance with Clause 5.8.3.

NOTE: The use of preheat before air-arc or plasma gouging should be considered. Guidance may be obtained from WTIA Technical Note 5.

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 a length of continuous automatic longitudinal fillet or butt weld, with stress ranges for detail category 112 in accordance with AS 4100 or NZS 3404.1, they shall be repaired by the following procedures:

(a) Grind the stopped end of the weld so that it tapers to the root of the joint with a slope of not less than 4:1.

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

(c) Grind the repaired weld to a smooth surface, to blend into the profile of the existing weld.

The site of the repair shall be subjected to 100% magnetic particle examination in accordance with Clause 6.5.

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 5.8.2.

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 in accordance with Clause 6.5.

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

(a) not reduce the thickness of the thinner base metal or weld metal by more than 0.8 mm or 5% of the thickness, whichever is lesser; or

(b) not leave reinforcement that exceeds 0.8 mm.

Reinforcements shall be removed where welds form part of a faying or contact surface. Any dressing of reinforcements shall blend smoothly with the plate surfaces. See Appendix D, Item (s).

SECTION 6 QUALITY OF WELDS

6.1 CATEGORIES OF WELDS

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

The compliance of 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, Clause 7.4.

In addition, for Category SP 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 Table 6.2.1 shall be carried out in accordance with Clause 6.3 or 6.4, as appropriate.

NOTE: Table 7.4 includes guidance on the suggested extent of non-destructive examination (NDE), 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 Tables 6.2.1 and 6.2.2.

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 in the manner shown in Figure 6.2.3(a).

6.2.3.2 *Overlapping*

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

6.2.3.3 *Overlapping vertical displacement*

Where imperfections occur above each other in the vertical plane of the weld, they shall be assessed in the manner shown in Figure 6.2.3(c).

6.2.4 Interpretation of tests

Where qualification by both a macro test and side-bend tests are required (see Clause 4.7), the bend tests 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 6.2.1

PERMISSIBLE LEVELS OF IMPERFECTIONS AS DETERMINED BY RADIOGRAPHIC OR ULTRASONIC EXAMINATION FOR WELDS OF CATEGORY SP

Type of imperfection (see Notes 1 to 3)	Thickness of thinner parent metal (*t*) mm (see Note 4)	Weighting factor					Maximum permissible imperfection level (see Notes 5, 6, 7 and 8)
		Height of imperfection (*h*), mm					
		≤2	>2 ≤4	>4 ≤10	>10 ≤20	>20	
Cracks	All	Not permitted					
Inclusions, lack of penetration, or lack of fusion:	≤10	2	X	X	X	X	*L*/5
	>10 ≤20	2	4	X	X	X	*L*/4
	>20 ≤40	1	2	5	X	X	*L*/2
	>40	1	2	5	10	X	*L*
Porosity	All	See Note 9					

LEGEND:
X = not permitted
L = weld length under consideration

NOTES:

1 For adjacent imperfections, see Clause 6.2.3.

2 For the purpose of radiographic examinations and routine ultrasonic examinations, *h* shall to be taken as 2 mm. Where an ultrasonic or a radiographic examination indicates that *h* may be greater than 2 mm, *h* shall be determined by sectioning or vertical ultrasonic sizing in accordance with AS 2207.

3 Any imperfections that are suspected of being lamellar tears should be recorded on the NDE report and referred to the principal for consideration.

4 See also Clause 3.2.1.

5 For any weld length under consideration, the imperfection level shall be calculated by multiplying the length of each imperfection by its weighting factor and adding these weighted lengths to determine a total imperfection level. The total imperfection level shall be less than the maximum permissible imperfection level.

6 Any imperfections shall not exceed a height equal to the greater of 2 mm and *t*/20, within a distance of *t* of the end of a weld.

7 Where the length of a continuous weld exceeds 1 m, the maximum permissible imperfection level shall not be exceeded in any continuous weld length of 1 m.

8 Where continuous or adjacent imperfections cross the division between examination lengths, the examination lengths shall be relocated to include the most severe combination of imperfections.

9 Porosity is not considered to be a particularly serious imperfection and is cause for rejection of a weld only where it is present in sufficient quantity to render difficult an inspection for the other imperfections listed in Table 6.2.1. Any such level of porosity shall be recorded and referred to the principal for consideration. For radiographic inspections, porosity levels representing a loss of projected area of not more than 2% are permitted. If required, reference may be made to porosity charts in AS 4037, to assist in assessing the appearance of this level of porosity on a radiograph.

TABLE 6.2.2

PERMISSIBLE LEVELS OF IMPERFECTIONS IN BUTT AND FILLET WELDS AS DETERMINED BY VISUAL, MAGNETIC PARTICLE AND LIQUID PENETRANT EXAMINATION OF THE WELD ZONE (see also Figure 6.2.2)

Imperfection (see Note 1)		Symbol	Maximum allowable dimension or number of imperfections	
Type	Parameter		GP	SP
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	Length for SP Depth for GP	As for undercut depth		L: Where located more than $3t$ from end of weld, $2t/3$, but not more than 20 mm Where located within $3t$ of end of weld, 3 mm
				ΣL: t in $6t$ length, but proportionally less for shorter length
Undercut-continuous (see Note 2)	Depth	h	$t/10$, but not more than 1.5 mm	$t/20$, but not more than 1 mm
Undercut-intermittent (see Note 2)	Depth	h	$t/5$, but not more than 2 mm	$t/10$, but not more than 1.5 mm
Shrinkage grooves Root concavity	—	—	As for undercut	
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
Excess penetration	Height (depth)	—	As for reinforcement	
Linear misalignment	—	—	See Clauses 5.2.2 and 5.2.3	
Overlap (see Note 3)	Length	L	$2t$, but not more than 20 mm	t, but not more than 10 mm
	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
Surface pores (see Note 3)	Size of pore	d	Not limited	$t/3$, but not more than 5 mm
	Number of pores	—	Six per $12t$ length	Two per $12t$ length
Loss of cross-sectional area (see Notes 4 and 5)	Loss of area	—	≤10%	≤5%
FILLET WELDS				
Reinforcement	Height	h	Not limited	For $S \le 12$ mm, 2 mm For $12 < S \le 25$ mm, 3 mm For $S > 25$ mm, 4 mm
Undersize-intermittent (see Note 6)	Leg length	—	$S/5$, but not more than 4 mm	$S/10$, but not more than 3 mm
Other surface imperfections	—	—	As for butt welds	
Loss of cross-sectional area (see Note 5)	Loss of area	—	As for butt welds	

NOTES TO TABLE 6.2.2:

1 For adjacent imperfections, see Clause 6.2.3.

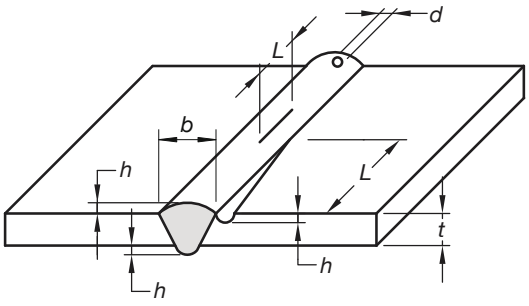
2 Undercut less than 0.5 mm in depth should be disregarded.

3 Where these allowances for overlap and surface pores are detrimental to any surface treatment, they may not be acceptable.

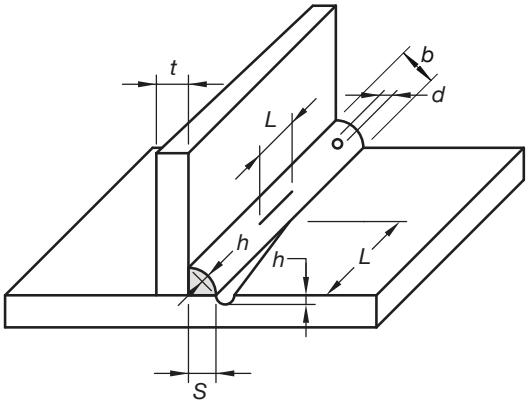
4 For a welding procedure qualification, the assessment of the test piece for compliance with the permissible levels of imperfections should be done with the aid of the macro test specimen. For calculation of the loss of cross-sectional area, internal imperfections are estimated from the macro test specimen.

5 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 is required to assess the approximate depth of the imperfection. The macro test specimen from the welding procedure qualification may need examination for this purpose.

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



(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)
b = width of weld face
d = size of pore
S = size of fillet weld (see Clause 3.3.1)

FIGURE 6.2.2 DIMENSIONS REFERRED TO IN TABLE 6.2.2