TABLE 6.2.1

SURFACE CONDITION OF WELDS (see Notes 1, 2)

Surface condition (Note 3)	Surface treatment	Chemical treatment (see Clause 6.2.6)	Acceptance criteria
I (see Clause 6.2.2)	Mechanically polished, Electropolished, Chemically treated, As-welded (see Note 4)	Optional	See Table 6.3.3
II (see Clause 6.2.3)	Mechanically treated, Electropolished, Electrocleaned, Chemically treated, As-welded	Optional	
III (see Clause 6.2.4)	Slag removed or wire brushed or both As-welded	No	

NOTES:

1 Finishes may be mixed, e.g. Grade II or III finish one side and Grade I finish the other side. Also see Clause 6.2.3.

2 Cleaning, descaling and passivation procedures should generally follow ASTM A380.

3 Guidance to choice of surface finish is given in Appendix B.

4 For high quality automatically produced welds by welding processes PAW and TIG.

6.2.2 Surface Condition I—Polished

For Surface Condition I, the weld reinforcement shall be removed by grinding or linishing if the welded zone is to be polished to a specified finish (see Clause 6.2.5). Automatically produced welds by welding processes PAW and Gas Tungsten Arc Welding (TIG) shall not be subjected to grinding and polishing if they meet the R_a value specified (see Clause 6.2.5). As the final operation, chemical cleaning or electropolishing according to ASTM B912 and/or ISO 15730 may be used to improve corrosion resistance of the surface.

6.2.3 Surface condition II—Cleaned

For Surface Condition II, the weld and heat affected area shall be protected from oxidation during welding or cleaned by any of the following processes as specified by the principal:

(a) *Acid pickling and passivation (refer to ASTM A380)* Welds shall be cleaned of all slag and flux residues. The structure shall then be acid pickled (usually with nitric/hydrofluoric acid mixtures) by placing it in a bath, or by swabbing the area or by application of a pickling paste, until all traces of the heat tint and oxides are removed. This process may be assisted by mechanical agitation or brushing. Pickling acids should be chloride free (refer to WTIA Technical Note 16). Passivation, usually by nitric acid, shall be included in this treatment, with the aim of restoring the chromium oxide surface layer. Commercial pickling pastes and baths include nitric acid. A subsequent passivation by nitric acid alone will further increase the corrosion resistance against aggressive environments and should be specified in these circumstances. The surface shall then be washed clean of all residues using fresh clean water. Care should be taken to conform with health and safety instructions.

(b) *Electropolishing (refer to ASTM B912 and/or ISO 15730)* may be used as an alternative to pickling to remove imperfections from the surface of stainless steel. It may be used as a final operation after wire brushing (see item (d)) and buffing or linishing (see item (e)) in order to improve corrosion resistance of mechanically treated surfaces. The treatment should be carried out such as to ensure complete removal of both the dark oxide and underlying chromium-depleted layer, if full

corrosion resistance is to be achieved. Because electropolishing cannot penetrate insulating slag and scale, it is common to acid pickle weld zones prior to electropolishing the entire surface. This provides a luster and slightly reduces the surface roughness by removing sharp edges and peaks of polishing lines.

(c) *Electrocleaning* is performed using portable machines, locally applying the same process as electropolishing with either acidic or neutral solutions. This technique effectively removes weld oxidation and passivates the surfaces without the need for aggressive pickling acids. The surface may not be highly polished, but is effectively cleaned by this process. The chromium depleted layer may not be fully removed on thick weldments with high heat input, if low current density and short dwell times are employed.

(d) *Stainless steel wire brushing* The straw-coloured oxide (AWS D18.2 Class 3) of GTAW welds may be removed immediately after welding by brushing with a stainless steel wire brush.

(e) *Abrasive polishing of weld and adjacent areas* The weld and heat affected zone shall be buffed or linished to remove all oxides. The final finish is to be specified by the principal. Passivation may be required to restore corrosion resistance in aggressive environments.

(f) *Abrasive blasting* Abrasive grit blasting of the weldment may be used, provided that the grit is iron free. Typically alumina, garnet and silicon carbide are used. Steel grit shall not be used as the surface will be roughened and more difficult to clean. It will also require passivation if used in aggressive conditions as sulphide inclusions will be exposed.

(g) *Gas purging* Inert gas purging of the weld penetration and any heat affected areas is used where the welds cannot be accessed for mechanical cleaning or pickling (see Clause 6.2.6).

(h) *Gas shielding* The welded zone can be left as-welded where the weld and heat affected zone have a low degree of oxidation (see Clause 6.2.6).

NOTE: Care is needed when using mechanical methods of cleaning (Items (d), (e) and (f)). Overheating of material when using rotary buffing equipment and cross contamination should be avoided. Pickling and/or passivation, or electropolishing may be used as a final operation to improve corrosion resistance of the steel surface.

6.2.4 Surface condition III—As-welded

Surface Condition III does not impose heat tint limits and is only suitable if appearance and corrosion resistance are not important. (See Clause 5.19).

6.2.5 Surface roughness

The finish shall be specified by the principal (see Appendix G) by one of the following methods:

(a) Surface roughness (R_a) value as defined in AS 2382 or ASME B46.1.

(b) Sample comparison.

Maximum roughness R_{max} value may be specified by the principal in addition to R_a (see Appendix B).

The principal and the fabricator should agree upon the finishing procedure used. If surface roughness is defined according to Item (b), the principal and the fabricator shall retain corresponding samples or photographs of them.

6.2.6 Surface discoloration

The weld and heat-affected zone surface may be permitted to have light straw colour oxide (for example, AWS D18.2 Samples 1 through 3, as shown in Figure 6.2.6, can be used as a guide). For product contact surface, blue, brown or black oxide heats (Sample 4 and above) shall not be acceptable. Any discoloration shall be so tightly adhering to the surface that normal operations will not remove it. Post-weld conditioning may be specified by the principal to meet discoloration requirements.

The principal and the fabricator should agree upon the acceptable degree of weld discoloration either using the weld discoloration levels of AWS D18.2:2009 in Figure 6.2.6 or by sample comparison (see Table 6.3.3).

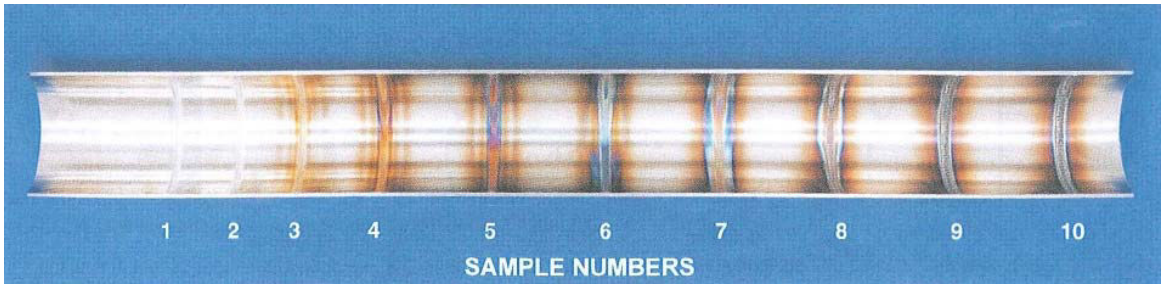

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FIGURE 6.2.6 WELD DISCOLORATION LEVELS ON INSIDE OF AUSTENITIC STAINLESS STEEL TUBE ACCORDING TO AWS D18.2:2009

6.3 METHODS OF INSPECTION AND PERMISSIBLE LEVELS OF IMPERFECTIONS

6.3.1 Methods of inspection of completed welds

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

In addition, 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 6.3.1(A) and (B) shall be carried out in accordance with Clause 6.4 or Clause 6.5, as applicable.

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

6.3.2 Permissible levels of imperfection

The size, number and spacing of imperfections permitted for the weld categories shall not exceed the relevant levels given in Tables 6.3.1(A) and (B) and Table 6.3.2.

TABLE 6.3.1(A)

PERMISSIBLE LEVEL OF INTERNAL IMPERFECTIONS AS DETERMINED BY RADIOGRAPHIC OR ULTRASONIC EXAMINATION FOR WELDS OF CATEGORY 1A, 1B and 1C (see notes 1 and 2)

Type of imperfection	Thickness of thinner parent metal (t) mm	Weighting factor					Maximum permissible level (see Notes 4, 5 and 6)*
		Height of imperfection (h), mm (see Note 3)*					
		≤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 8*					

TABLE 6.3.1(B)

PERMISSIBLE LEVEL OF INTERNAL IMPERFECTIONS AS DETERMINED BY RADIOGRAPHIC OR ULTRASONIC EXAMINATION FOR WELDS OF CATEGORY FA (see note 2)

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

LEGEND

X = Not permitted

L = Weld length under consideration

* Notes appear on following page.

NOTES TO TABLES 6.3.1(A) and 6.3.1(B):

1 Welds in Categories 2A, 2B and 2C are not subject to radiographic or ultrasonic examination.

2 For adjacent imperfections, see Clause 6.3.3.

3 For the purpose of radiographic examination or routine ultrasonic examination, *h* is to be taken as 2 mm. If the ultrasonic or radiographic examination indicates that *h* may be greater than 2 mm, h is to be determined by sectioning or vertical ultrasonic sizing.

4 For any weld length under consideration, the imperfection level is 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.

5 No imperfection exceeding a height of *t*/20 or 2 mm (whichever is the greater) shall be permitted within a distance of *t* of the end of a weld.

6 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.

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

8 Internal porosity is not considered to be a particularly serious imperfection in terms of this Standard and is cause for rejection of a weld only where it is present in sufficient quantity to render inspection difficult for the other imperfections listed in Table 6.3.1(A) and 6.3.1(B). Where such a level of porosity is present, it shall be recorded and referred to the principal for consideration. For radiographic inspection, porosity levels representing a loss of projected area not exceeding 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.

6.3.3 Adjacent imperfections

6.3.3.1 *Aligned*

Where adjacent imperfections are aligned, they shall be assessed as shown in Item (a) of Figure 6.3.3.

6.3.3.2 *Overlapping*

Where there is a horizontal displacement between adjacent imperfections, the effective length (L) shall be as shown in Item (b) of Figure 6.3.3.

6.3.3.3 *Overlapping vertical displacement*

Where imperfections occur one above the other in the vertical plane of the weld, they shall be assessed as shown in Item (c) of Figure 6.3.3.

TABLE 6.3.2

PERMISSIBLE LEVELS OF SURFACE IMPERFECTIONS REVEALED BY VISUAL AND LIQUID PENETRANT EXAMINATION (see Notes and Figure 6.3.2)

Imperfection		Maximum allowable dimension or number of imperfections for butt welds		
Type	**Parameter**	**Class A (See Note 5)**	**Class B**	**Class C**
Cracks	Length (L) Cumulative length (Σ)	Nil	Nil	Crater cracks only 6 mm in 1000 mm of weld (crater cracks only)
Reinforcement	Height (h)	0.8 mm (see Note 4)	For t< 6 mm: 1.5 mm For 6<t≤12 mm: 3 mm For 12<t≤25 mm: 4.5 mm For t>25 mm: 6 mm	Not specified
Excess penetration	Height (h)	As for reinforcement		
Overlap	Length (L) Cumulative length (Σ)	Nil	Nil	t, but not greater than 10 mm 30 mm in 300 mm, but proportionately less for shorter lengths
Lack of fusion	Length (L)	Nil	Nil	Where located more than 3t from the end of a weld, 2t/3, but not greater than 20 mm. Where located within 3t from the end of a weld, 3 mm.
	Cumulative length (Σ)			t in 6t length, but proportionately less for shorter lengths
Undercut	Depth (h)	Nil	t/10 but not greater than 0.5 mm	t/10 but not greater than 0.5 mm
Surface porosity	Size of pore (d) Number of pores	Nil	Nil	t/3 but not greater than 2 mm 2 pores per 12t length
Shrinkage groove or root cavity		Nil	Nil	As for undercut
Linear misalignment	Depth (h)	5% but not greater than 1.5 mm	10% but not greater than 3 mm	10% but not greater than 3 mm
Crater, solid inclusion, poor restart, spatter, torn surface, grinding mark, chipping mark		Nil	Nil	Not specified
Weld bead width		Straight and uniform	Not specified	Not specified

(*continued*)

TABLE 6.3.2 (*continued*)

Imperfection		**Maximum allowable dimension or number of imperfections for butt welds**		
Type	**Parameter**	**Class A (See Note 5)**	**Class B**	**Class C**
Imperfection	Imperfections for fillet welds			
Reinforcement	Height (*h*)	Flat or concave, smoothly blended at toes (See Note 6)	For *S*<12 mm:1 mm For *S*≥12 mm: 2 mm	Not Specified
Undersize—Intermittent (See Note 3)		*S*/10 but not greater than 2 mm	*S*/10 but not greater than 3 mm	*S*/5 but not greater than 4 mm
Other Imperfections	As for butt welds			

NOTES:

1 For adjacent imperfections, see Clause 6.3.3.

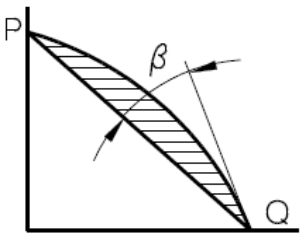
2 For a welding procedure qualification, the assessment of the test piece for compliance with the permissible levels of imperfections should be done with the aid of the macro test specimen. For calculation of the loss of cross-sectional area, internal imperfections are estimated from the macro test specimen.

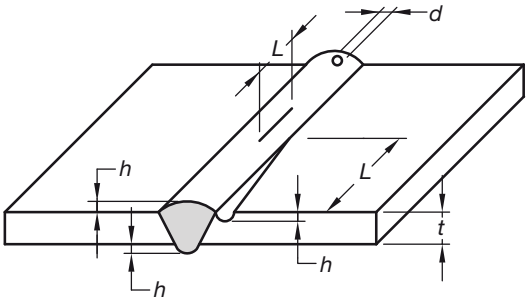
3 The cumulative length of intermittent undersize fillet welds shall not exceed 10% of the length of the weld.

4 All reinforcement is to be removed according to Clause 5.20, and the surface to be finished as specified. High quality automatically produced welds by welding processes PAW and TIG need not be dressed provided they meet requirements of this standard.

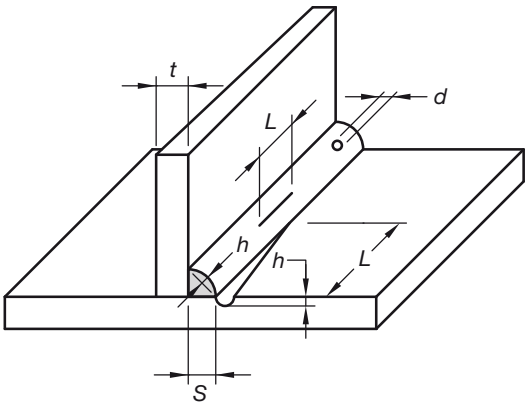
5 For hygienic applications, where the process-contact surface of the weld is to be used as is, welding process shall be limited to the automatic PAW and TIG. Autogenous welds and welds with filler wire are acceptable provided they meet requirements of this standard.

6 For FA fillet welds, the angle β between the plane tangential to the weld bead surface at the toe and the plane through the line PQ shall be less than or equal to 15°. Slightly concave welds shall be acceptable provided the design throat thickness requirement is fulfilled. This requirement also applies for the angle between the tangential planes between multi-runs.





(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)

FIGURE 6.3.2 DIMENSION OF SURFACE IMPERFECTIONS SPECIFIED IN TABLE 6.3.2

TABLE 6.3.3

ACCEPTANCE CRITERIA FOR SURFACE CONDITION I, II AND III REVEALED BY VISUAL EXAMINATION

Imperfection		Acceptance criteria		
Type	**Parameter**	**Condition I**	**Condition II**	**Condition III**
Discoloration (see Clause 6.2.6)	Colour of oxide on the weld and HAZ surface	Nil (AWS D18.2 samples 1)	AWS D18.2 samples 1 through 3 or as specified by the principal	Not specified
Roughness (see Note 3) (See Clause 6.2.5)	(a) R_a (see Note 1) (b) Sample comparison	As specified by the principal (see Note 2)	As specified by the principal	Not specified
Maximum Roughness R_{max} (see Note 4)	R_{max}	As specified by the principal	As specified by the principal	Not specified

NOTES:

1 R_a values for surface roughness shall be determined according to the AS 2382 or ASME B46.1 and Clause 6.2.5.

2 R_a value shall be specified by the principal for welds left in an as welded condition.

3 R_a of an abraded finish in corrosive service should have a transverse R_a <0.5 µm with a clean cut surface finish.

4 R_{max} may be specified for cleanability in hygienic service.

6.3.4 Qualifications of welding procedure by macro test and side-bend test (also see Clause 4.7)

Where qualification by macro test and side-bend test is required (see Table 4.7.1), 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.

6.4 RADIOGRAPHY

6.4.1 Method

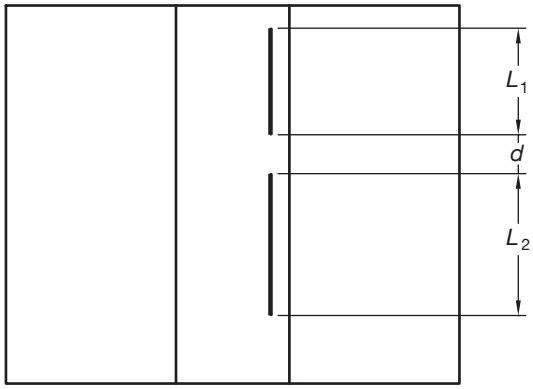
When required, radiography shall be carried out in accordance with AS 2177.1, using method XR2/-, GR1/- or GR2/- as follows:

(a) For thicknesses ≤12 mm: XR2/-, GR1/- or GR2/-.

(b) For thicknesses >12 mm: XR2/- or GR2/-.

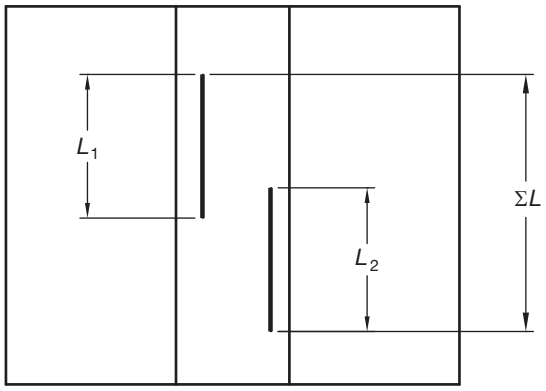
Where materials of different thicknesses are examined, the technique shall be selected according to the thicker plate.

NOTE: For thickness <6 mm, method XR1/- may be used by agreement between the principal and the fabricator, and the use of gamma radiography should be avoided.

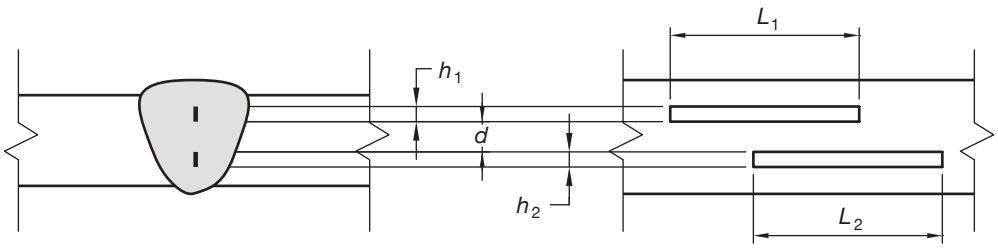


Where d is less than L_1 the smaller imperfection, $\Sigma L = L_1 + L_2 + d$
Where d is not less than L_1 the smaller imperfection, $\Sigma L = L_1 + L_2$

(a) Aligned imperfections



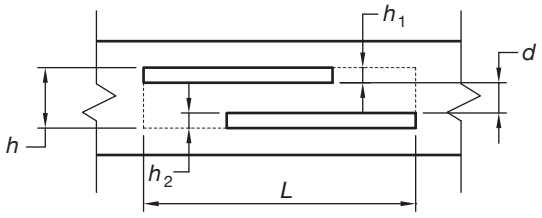
(b) Overlapping imperfections



(i) Cross-section

NOTE: Treat as separate defects.

(ii) Longitudinal section, where d > 5mm



NOTE: Treat as a single defect with dimensions *h* and *L* as shown.

(iii) Longitudinal section, where d < 5mm

(c) Overlapping vertical displacement

FIGURE 6.3.3 ASSESSMENT OF ADJACENT IMPERFECTIONS