Domestic Commercial Vessel
INSTRUCTIONS TO SURVEYORS

Subject: Welding inspection for aluminum vessels in accordance with AS/NZS 1665.

General: AS/NZS 1665:2004 assumes that the welder is qualified; that the weld is made in accordance with an approved Welding Procedure Specification (WPS) and that the completed weld complies with the standard.

Weld categories: AS/NZS 1665:2004 has three categories **(A, B & C)** for butt welds and one category **(B)** for fillet welds characterized by permissible levels of imperfection.

Weld Category A

Weld Category A is the highest level. It is intended for the more sever fatigue conditions in structures and is specified only for full penetration butt welds. Category A welds must be dressed flush by machining and finished in the direction of the applied stresses.

Weld Category B

Weld Category B is intended for butt welds subject to a tensile stress approaching the maximum permissible stress, and for fillet welds. Weld Category B is typically specified for structural welds in aluminum fabrication.

Weld Category C

Weld Category C is intended for butt welds carrying only static compressive stresses or static tensile stress less than 80% of the maximum allowable, or discontinuous (intermittent) butt welds subject to fatigue.

Generally

The surveyor has a role in categorizing and indicating the weld categories for each weld and subsequent non-destructive examination. Commonly weld types can be categorized as follows:

- full penetration butt welds are Category A
- continuous and double continuous butt welding is category B
- fillet welds are category B
- weld Category B is likely to be widely specified

Note: The selection of a higher than necessary weld category for any joint is not considered desirable, because there will likely be little or no improvement in weld performance.

Qualification of procedures and personnel: Welding procedures i.e. the weld preparation, the welding consumables and the welding parameters must be qualified before the commencement of welding/fabrication. A record of this qualification must be created, known as a Welding Procedure Qualification Record (WPQR). A WPQR may be qualified by:

- documentary evidence of relevant prior experience by the fabricator;
- the preparation and testing of standard test plate;
- production and testing of a suitable length of test plate of the same geometry and material thickness as the component upon which the procedures are to be applied;
- prototype testing of a prototype or production component.

Note: A completed WPS together with records of any tests carried out as required by the application standard to which the procedure was qualified constitutes documentary evidence of prior experience.

WPS's must be developed based on the WPQR's and based on the limits of AS 1665 (clause 4.4) prior to the commencement of production welding. The approved WPS must be made available to the welder during fabrication.

Welders must be qualified for the process, weld position, weld type and weld category for which they are welding. Welders not qualified for the required position and process must demonstrate and ability to comply with the documented WPS by producing a test plate and having it assessed

by means of a nick-break test or a fillet break test (as appropriate) and a macro test.

Generally, welders wishing to carry out most production welding positions should qualify in the vertical up and overhead positions.

Welding preparation:

Joint preparation

Jigging or tacking may be used to hold parts in proper relation and orientation. Jigging is preferred wherever practical.

Cleaning

All surfaces to be welded must be smooth and free from oxide, paint, grease and moisture. No more than 6 hours shall be left between cleaning and welding.

Welding consumables:

AS 1665 specifies 5183 weld wire for the welding of 5083 to 5083; & 5183 or 5356 wire for 5083 to 6061.

The standard allows the use of 5556 wire for both applications above. However, in general it is advised that only 5183 wire is used for vessel construction, other filler wires should generally not be used.

Welding consumables should be third party/classification society certified.

Selection and extent of NDE:

The selection and extent of Non Destructive Examination (NDE) shall be carried out on the following basis

Consequence of failure

- **CF1**: failure of the nominated weld will result in total loss of structure function, danger to life or substantial financial consequences.
- **CF2**: failure of the nominated weld resulting in total loss of structure function, no danger to life and moderate financial consequences.
- **CF3:** failure of the nominated weld resulting in partial loss of function, total loss of function imminent.
- **CF4**: failure of the nominated weld resulting in partial loss of function of structure, total loss of function being unlikely.

Note: It may be necessary to take into account that the failure of a weld whilst in itself having a minor or low consequence of failure, could lead to a more serious consequence of failure should further welds fail as a direct result.

Modes of failure

- **fatigue:** Growth of a fatigue crack – normally only applies to welds of category A and B
- **lack of strength:** Result of excessive loads normally only applies to welds of category A & B
- **leakage of the structure:** Results in a leakage of contents; tanks, vessels, pipes normally only applies to welds of categories B & C

Note: Welds may fail as a result of a single failure mode or a combination

Mode of failure	**Quality assurance requirements**			
	Consequence of failure level			
	CF1	**CF2**	**CF3**	**CF4**
Fatigue	PWQ & VE, plus RE or UE	PWQ & VE		
Lack of strength	PWQ & VE, plus RE or UE	PWQ & VE plus PT	PWQ & VE	
Leakage	PWQ & VE plus LT			

PWQ *= Procedure and welder qualification* ***VE*** *= Visual Examination* ***RE*** *= Radiographic examination*

UE *= Ultrasonic examination* ***PT*** *= proof/load testing* ***LT*** *= Leak testing*

Radiographic & Ultrasonic examination

For Consequence of Failure – level 1 **(CF1)** welds the amount of RT or UT examination considered appropriate is

- 20% to 100% for weld category A
- 2% to 5% for weld category B

Allowable extent of imperfections

A summary for welds of category B as commonly used on a typical 10-20m DCV.

- no cracks;
- no craters;
- a single isolated exposed porosity is allowable so long as it is smaller than 1mm;
- welds should be relatively flat (little convexity or concavity);
- undercut should not exceed a depth of 0.05t- 0.1t or 1-1.5mm;
- internal porosity, slag and oxide inclusion must not reduce the effective throat thickness of a weld by more than 5%;
- intermittent lack of fusion must be no greater than 1.5mm; and
- aggregate of all imperfections shall not result in more than 5% effective loss of design throat thickness.

See Annex A full specification of allowable extent of imperfections

Defect repair

Where the extent of imperfection(s) exceeds a value show in Annex A, the imperfection is classed as a defect and the weld must be repaired.

Repair must be made in accordance with the standard and if appropriate a repair procedure may need to be qualified. In preparation for the repair, the defect shall be completely removed so as to leave a smooth transition at the ends of the cut-out.

Guidance on defects and repairs are given in Annex B and additional information can be found in Chapter 9 of WITIA Technical Note 2.

Repaired welds are subject to the same inspection and quality requirements as the original weld.

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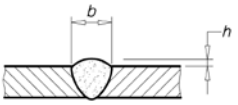
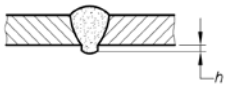
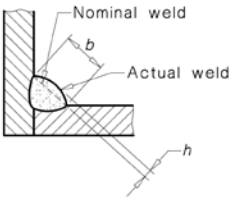
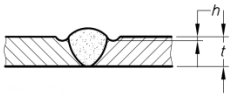
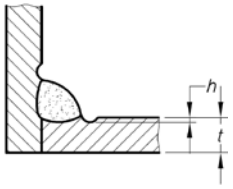
Annex A

Table 1 - Allowable extent of welding imperfections

Type of imperfection	Description of imperfection	Butt or grove welds			Fillet welds
		Weld Category			
		Category A	Category B	Category C	
Cracks	All types of cracks in or adjacent to the weld	Not permitted			
Crater defects	Shrinkage cavity or tears	Not permitted		Total size ≤20% of weld width	Not Permitted
Excess reinforcement (1)		h ≤ 1 mm (2)	h ≤ (1.5 + 0.15b) and ≤ 3 mm	h ≤ (1.5 + 0.2b) and ≤ 5 mm	
Excess penetration		h ≤ 1 mm (2)	h ≤ 2 mm	h ≤ 3 mm	
Excess convexity of reinforcement					h ≤ (1.5 + 0.15b) and ≤ 3 mm
Undercut (3)(4)		Not Permitted	Continuous h ≤ 0.05t and ≤ 1 mm	Continuous h ≤ 0.07t and ≤ 2 mm	Continuous h ≤ 0.05t and ≤ 1 mm
			Intermittent h ≤ 0.1t and ≤ 1.5 mm	Intermittent h ≤ 0.1t and ≤ 3 mm	Intermittent h ≤ 0.1t and ≤ 1.5 mm
Exposed porosity	Refers to a single, isolated exposed pore	Not permitted	≤ 1 mm	≤ 1 mm	≤ 1 mm
Internal porosity, tungsten, and oxide inclusions	Isolated	3% loss of cross section (5)	5% loss of cross Section (5)	7% loss of cross Section (5)	5% loss of design throat thickness (6)
	Clustered	3% loss of cross section (7)	5% loss of cross Section (7)	7% loss of cross Section (7)	5% loss of design throat thickness (6)
Lack of fusion and incomplete penetration	Fusion defects including lack of root, side-wall and inter-run fusion **Note:** Incomplete penetration is where the design depth of penetration is not achieved	Not permitted	Continuous defect not permitted		
			Intermittent h ≤ 0.1t and ≤ 1.5 mm (8)	Intermittent h ≤ 0.75t and ≤ 3 mm (8)	Intermittent h ≤ 0.05t and ≤ 1.5 mm (8)
Copper inclusions		Not permitted	Not permitted	Not permitted	Not permitted
Aggregate of all Imperfections (9)		3% loss of cross section	5% loss of cross section	7% loss of cross section	5% loss of cross section

***t** = minimum thickness of parent metal at the weld, in millimeters*

***h** = dimension (height or depth) of the imperfection, in millimeters*

***b** = width of weld reinforcement, in millimeters*

Notes for Table 1:

(1) For a double-sided weld, the allowable height of the reinforcement shall be considered independently for each side.

(2) Reinforcement and excess penetration shall blend smoothly into the parent metal surface at the weld toes. Where the weld needs to be mechanically dressed to achieve the specified limit, the direction of dressing shall be parallel to the direction of major stress. The dressed weld shall have a maximum height above the parent metal of 1 mm at its centre. Care shall be taken that the dressing of the weld does not reduce the thickness of the parent material. Guidance on the dressing of welds is given in Chapter 10 of WTIA Technical Note 2.

(3) The total length of undercut is the aggregate of both sides of the weld. A smooth transition to the adjacent material shall be provided.

(4) One or more imperfections of the same type of total length greater than 25 mm in any 100 mm length of the weld, or a maximum of 25% of the weld for a weld shorter than 100 mm, shall be considered as continuous. Where the total length of the imperfection is less than these values, the imperfection shall be considered as intermittent. The length of an isolated imperfection in a weld is determined in accordance with Figure 6.1(a). Where two or more local imperfections occur in a weld, the effective total length is determined in accordance with Figure 6.1(b) or 6.1(c) as appropriate.

(5) The cross-sectional area of the weld is calculated by multiplying the minimum parent material thickness by the average width of the weld reinforcement. Where there are adjacent vertical imperfections, the combined effect on the loss of cross-sectional area shall be determined in accordance with Figure 6.2.

(6) The use of radiography for fillet welds is not always reliable, because of difficulties in interpretation. Porosity and inclusions can be evaluated from the fillet break test (see Clause 4.2.9).

(7) Clustered porosity, as revealed by radiography, is considered to be a group of pores that fall within an inscribed circle of diameter equal to the width of the weld reinforcement. The total defect size is considered to be the sum of the areas of the individual pores in the cluster.

(8) Where a lack of fusion or penetration defect is identified by radiography, further examination is required to determine the depth (height) of the defect. Where this is not possible for multi-pass welds, it may be assumed that the depth of the defect extends over the height of one weld run.

(9) Total loss of cross-section is the sum of the contribution to the loss of cross-section of any defect listed in the table plus any other defects that may be observed, such as incompletely filled welds, root concavities, worm holes and misalignment of parent material.

Annex B

Guidance on Types of Defects & Repair

Dimensions

Main cause:	Improper welding technique.
Repair:	Remove and re-weld.
Preventive measures:	Workmanship – use appropriate WPS i.e. appropriate welding amperages & electrode manipulation speeds with appropriate travel angle.

Misalignment – High/Low

Main cause:	Carelessness. May be due to the joining of different thickness plates.
Repair:	Grinding (remove hard points). Care to be taken regarding surface finish and direction of grind marks.
Preventive measures:	Workmanship. Transition angles not to exceed 2.5:1

Craters

Main cause:	Improper weld termination. The center of the weld pool has become solid before the outside of the weld pool pulling the center apart during cooling. Molten pool too large.
Repair:	Start weld repair on parent metal and terminate on top of the first bead.
Preventive measures:	Remove arc slowly from the deposited weld metal ensuring the required amount of weld consumable is added to the weld pool. Use current tapering (crater fill) control on amperage.

Porosity

Main cause:	Improper material cleaning leading to Hydrogen entrapment. Too little shielding gas. Too much wind.
Repair:	Remove isolated or single pores with a rotary tool for weld repair. Follow up with NDE to ensure porosity has been completely removed.
Preventive measures:	Clean the joint fusion faces, use higher gas flow rate or better quality shielding gas, use a wind screen, use appropriate welding amperages, arc lengths and arc voltages.

Undercut

Main cause:	Electrode angle to inclined to face, excessive weaving of electrode, excessive amperage, incorrect travel speed.
Repair:	Clean undercut area of dirt, slag etc. by grinding or routing being careful not to remove base metal adjacent to the undercut. Fill the undercut with weld material being careful to use lower current and sufficient wire speed. A smaller electrode may be appropriate.
Preventive measures:	Workmanship – use the appropriate WPS i.e. appropriate welding amperages and electrode manipulation speeds with appropriate travel angle

Arc Strike

Main cause:	Carelessness
Repair:	Grind smooth and test for cracks. If cracks repair as any other crack.
Preventive measures:	In areas with difficult access protect adjacent areas with fire blankets.

Concavity

Main cause:	Electrode manipulation too fast, welding amperage too high, stick out too short.
Repair:	Remove weld material and re-weld. Discuss with welder whose workman ship it is, if repeat offender ask them to re qualify.
Preventive measures:	Use appropriate weld amperages and electrode manipulation speeds with appropriate travel angle

Convexity

Main cause:	Electrode manipulation too fast, welding amperage too high, stick out too long.
Repair:	Remove weld material and re-weld. Discuss with welder whose workmanship it is, if repeat offender ask them to re qualify.
Preventive measures:	Use appropriate weld amperages and electrode manipulation speeds with appropriate travel angle.

Cracks

Types Include:	Longitudinal, transverse, crater, throat, toe, root, underbead and heat-affected zone, hot & cold or delayed.
Main cause:	Incorrect filler metal, incorrect weld preparation, weld is too deep or too narrow, excessive dilution from parent metal, weld too cold, poor fit up, weld pool too long, weld pool too small, cooling rate too fast.
Repair:	Refer internal defect.

Inclusions (slag)

Main cause:	Low amperage, improper technique, welding in area with poor access, travel speed too slow in the vertical down. Surface inclusions can be indicative of subsurface inclusions that could be detected with UT or RT.
Repair:	Repairs of inclusions require removal by grinding or gouging and re-welding (if required).

Internal Defect

Main cause:	Varies
Repair:	Grind and remove material, testing with dye penetrant until defect is found. If defect is not found after removing the metal halfway through the part, re-weld the ground part then work from the opposite surface. Never grind a slot thought the part.
Preventive measures:	Workmanship – Use appropriate welding amperages and electrode manipulation speeds with appropriate travel angle. Care in pre-weld cleaning. Adequate joint design.