No.70 Guidelines on welding procedure qualification tests of aluminium alloys for hull construction and marine structures

(June 2000) (Rev.1 Nov 2006) (Rev.2 Sep 2021)

1. Scope of application

This document gives general guidance for the qualification tests of the welding procedures intended to be used for the aluminium alloys for hull construction and marine structures specified in the UR W25.
This document specifically excludes the welding procedure intended for LNG containment.

2. Welding procedure

2.1 Welding processes

The welding processes below indicated, together with their relevant numbering according to ISO 4063:2009, are in general used for welding aluminium alloys.

- 131 - metal-arc inert gas welding (MIG welding)
- 141 - tungsten inert gas arc welding (TIG welding)
- 15 - plasma arc welding

2.2 Welding consumable

The welding consumables should be approved in accordance with the requirements specified in UR W 26.
Where non approved welding consumables are used at the discretion of the Classification Society, the requirements for the qualification of the welding procedures should be established on a case by case basis. In general additional tests on deposited weld metal are required in accordance with UR W26.

2.3 Welding procedure specification

A welding procedure specification should be prepared by the shipyard or manufacturer and proposed for acceptance; this document is also referred to as preliminary welding procedure specification (pWPS) and can be modified and amended during the procedure tests as deemed necessary.

In its final version the welding procedure specification (WPS) should be used as a basis for the production welds and should include all the parameters characterizing the welding process, in particular:

- type of welding process and equipment as appropriate
- type of joint, preparation and backing material, if any
- parent metal and thickness range
- welding consumable
- welding position/s
- minimum pre-heat and maximum interpass temperature
- postweld heat treatment if applicable
- shielding gas
- welding parameters
- other information relevant to the welding procedure as applicable.

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2.4 Welding procedure qualification

Welding procedure tests, according to the proposed pWPS, should be carried out for the qualification of the welding procedure.

The test pieces should be chosen so as to cover all the production welds in accordance with the range of approval given in clause 5.

The actual parameters used for welding the qualification test pieces and the results of the inspection and tests carried out should be recorded in the WPAR (welding procedure approval record).

The qualification tests (welding and testing) should be witnessed by the Surveyor.

The WPAR should in general be issued by the shipyard or manufacturer and should be signed by the Surveyor.

2.5 Certificate of approval of the welding procedure

Upon the satisfactory completion of the qualification tests, a certificate of approval of the welding procedure should in general be issued by the Society to the shipyard or manufacturer stating the conditions of the approval of the WPS such as thickness range, positions, type of Al alloy/s, welding consumable, etc.

3. Qualification of welding procedures

3.1 Butt weld

3.1.1 Assembly and welding

The test pieces should be of sufficient size to ensure a reasonable heat distribution during welding and to provide for the required test specimens, after sufficient discard at the ends, see Fig. 1.

The edge preparation and fit up should be in accordance with the pWPS.

If tack welds are to be fused into the production joint they should be included in the test pieces.

The test assembly should have the following minimum size:

- manual and semiautomatic welding: length L = 350 mm; width W = 300 mm,
- automatic welding: length L = 1000 mm; width W = 400 mm.

The cleaning of the parts to be welded should be carried out in accordance with the welding procedure.

The welding should be carried out in accordance with the pWPS and under the general conditions of production welding which it represents.

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3.1.2 Examinations and tests

Non destructive examinations and destructive tests should be carried out in accordance with the requirements of Table 1.

Test specimens should be taken in accordance with Figure No. 2.

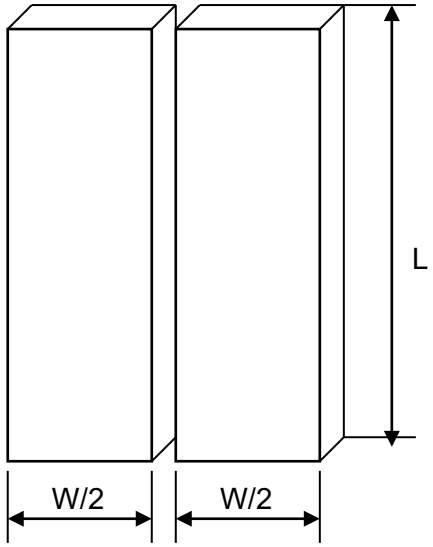

Fig. 1 Test assembly for butt weld

Table 1

Type of test	Extent of testing
Visual examination	100%
Radiographic or ultrasonic examination	100%
Penetrant test	100%
Transverse tensile test	2 specimens
Transverse bend test (1)	2 root and 2 face specimens
Macro examination	1 specimen
(1): 2 root and 2 face bends can be substituted by 4 sides bends for t ≥ 12 mm	

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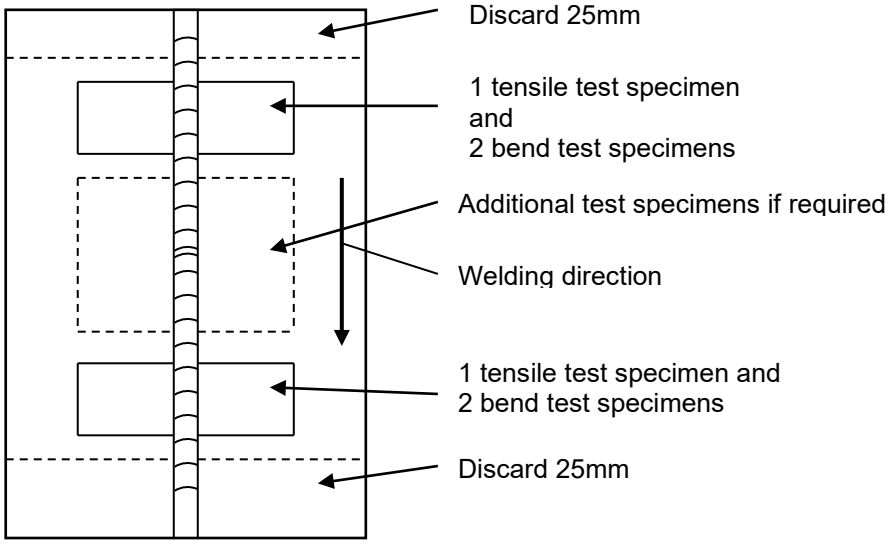

Fig.2 Location of test specimens for a butt joint in plate

3.1.3 Non destructive examination

Non destructive examinations should be carried out after any required post weld heat treatment, natural or artificial ageing, and prior to the cutting of the test specimens.

Welds should be free from cracks. Imperfections detected by visual or non-destructive testing should be assessed in accordance with ISO 10042:2018, level B, except for excess weld metal or convexity, excess throat thickness and excess of penetration for which the level C applies.

3.1.4 Transverse tensile test

The specimens for transverse tensile tests should be machined to the dimensions given in UR W2.
The tensile strength should meet the requirements stated in Table 2.

Table 2

Grade (Alloy designation)	Minimum tensile strength (N/mm^2)
5754	190
5086	240
5083	275
5383	290
5059	330
5456	290
6005A	170
6061	170
6082	170

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3.1.5 Bend test

The specimens for bend tests should be machined to the dimensions given in UR W2. For dissimilar or heterogeneous butt joints longitudinal bend tests may be required instead of transverse bend tests.

The bend test specimens should be bent on a mandrel with maximum diameter as given in the formula below. The bending angle shall be 180°.

$$d = \frac{(100 x t_s)}{A} - t_s$$

where
d is the maximum former diameter
t_s is the thickness of the bend test specimen (this includes side bends)
A is the minimum tensile elongation required by the alloy grade, temper condition and thickness (for combination between different alloys, the lowest individual value should be used).

After testing the test specimens should not reveal any open defect in any direction greater than 3 mm. Defects appearing at the corner of the specimens may be disregarded, unless there is evidence that they result from lack of fusion.

Note: Wrap around method bend tests are recommended for the above mandrel diameter for each alloy.

3.1.6 Macro examination

The test specimen should be prepared and etched on one side to clearly reveal the fusion line, the HAZ and the build up of the runs and the unaffected base metal. The examination should reveal a regular weld profile, thorough fusion between adjacent layers of weld and base metal and the absence of defects such as cracks and lack of fusion.
The acceptance levels specified in 3.1.3 apply.

3.2 T-fillet weld

3.2.1 Assembly and welding

The minimum size of the test assemblies should be as follows:

- manual and semiautomatic welding: length L = 350 mm; width W = 150 mm,
- automatic welding: length L = 1000 mm; width W = 150 mm.

The two plates should be positioned and tack welded edgewise so as to constitute a T assembly without clearance.

Welding on one or both sides and fit up should be as detailed in the pWPS.

In general for manual and semiautomatic welding a stop/restart position should be included in the test length and should be clearly marked for subsequent examination.

The cleaning of the parts to be welded should be carried out in accordance with the welding procedure.

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3.2.2 Examination and tests

Non destructive examination and destructive tests should be carried out in accordance with the requirements of Table 3

Table 3

Type of test	Extent of testing
Visual examination	100%
Penetrant test	100%
Macro examination (1)	2 specimens
Fracture test	1 specimen
(1): One of the macro sections should be taken at the position of the stop/restart (see 3.2.1)	

3.2.3 Visual examination and surface crack detection

The requirements specified in 3.1.3 should be complied with.

3.2.4 Macro examination and fracture test

The fracture test as well as the macro examination should, in general, satisfy the acceptance level specified in 3.1.3.

Dimension of leg size, throat and penetration should in general be reported.

4. Re-testing

If the test assembly fails to comply with any of the requirements for visual examination or NDE, one further test assembly should be welded and subjected to the same examination.

If any test specimen fails to comply with the relevant requirements, two additional test specimens should be obtained for each one that failed. These specimens can be taken from the same assembly, if there is sufficient material, or from a new test assembly. For the acceptance both tests should give satisfactory results.

Where failed in the above re-testing, the pWPS should be modified before further consideration by the Surveyor is given to a new test assembly for re-qualification.

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5. Range of approval

5.1 General

The approval of the WPS obtained by a shipyard or a manufacturer is valid for welding in all its workshops under the same technical and quality control.

All the conditions of validity stated below should be met independently of each other. Changes outside of the ranges specified may require a new welding procedure test.

5.2 Parent metal

The aluminium alloys are grouped into three groups:

- Group A: aluminium-magnesium alloys with Mg content ≤ 3.5% (alloy 5754)
- Group B: aluminium-magnesium alloys with 4% ≤ Mg ≤ 5.6% (alloys 5059, 5083, 5086, 5383 and 5456)
- Group C: aluminium-magnesium-silicon alloys (alloys 6005A, 6061 and 6082)

For each Group, the qualification made on one alloy qualifies the procedure also for the other alloys of the same Group with equal or lower specified tensile strength after welding.

The qualification made on Group B alloy qualifies the procedure also for Group A alloys.

5.3 Thickness

The qualification of a WPS carried out on a test assembly of thickness t is valid for the thickness range given in Table 4.

In case of butt-joints between dissimilar thickness, t is the thickness of the thinner material.

In case of fillet joints between dissimilar thickness, t is the thickness of the thicker material.

Table 4 Range of qualification for parent material thickness

Thickness of the test piece, t (mm)	Range of qualifications
$t \leq 3$	0.5 to 2 t
$3 < t \leq 20$	3 to 2 t
$t > 20$	≥ 0.8 t

In addition to the requirements of Table 4, the range of qualification of the throat thickness *a* is given in Table 5.

Table 5 Range of qualifications for the throat thickness of fillet welds

Throat thickness of the test piece, *a* (mm)	Range of qualifications
$a < 10$	0.75 a to 1.5 a
$a \geq 10$	≥ 7.5

Where a fillet weld is qualified by means of a butt weld test, the throat thickness range qualified should be based on the thickness of the deposited weld metal.

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Where the majority of production work is fillet welding, an additional fillet weld test may be required.

5.4 Welding position

Provided that comparable welding parameters are used for the included welding positions a test in any one position qualifies for welding in all positions except for vertical downwards (PG) position where in any case separate welding procedure test is required.

5.5 Type of joint

The range of approval for the types of joint in relation to the type of joint used in the procedure qualification test is as follows:

- butt-joint welded from one side with backing qualifies also for welding from both sides with gouging;
- butt-joint welded from one side without backing qualifies also for welding from one side with backing, from both sides with gouging and from both sides without gouging;
- butt-joint welded from both sides with gouging only qualifies that condition,
- butt-joint welded from both sides without gouging qualifies also for welding from both sides with gouging and from one side with backing.

5.6 Welding process

The approval is valid only for the welding process used in the welding procedure test. It is not permitted to change a multi run deposit into a single run (or single run on each side) or viceversa for a given process. In the case of a multi-process procedure, the approval is only valid for applying the processes in the order used during the procedure qualification tests.

Note: For multi-process procedures each welding process may be approved separately or in combination with other processes. Similarly one or more processes may be deleted from an approved WPS provided the joint thickness is within the approved thickness range of the relevant welding process to be applied.

5.7 Welding consumables

The welding consumable used in the qualification tests qualifies:

1) Approved welding consumables of the same strength as the consumable used in the procedure qualification tests.
2) Approved welding consumables of higher strength than the consumable used in the procedure qualification tests.

The qualification given to shielding gas and backing gas is restricted to the gas/gas mixture used in the welding procedure test, see ISO 14175:2008 or other recognised standards for gas designations.

5.8 Type of current

Changes in the type of current (AC, DC, pulsed) and polarity require a new welding procedure qualification.

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5.9 Preheat and interpass temperature

The lower limit of approval is the preheat temperature applied at the start of the welding procedure test.

The upper limit of approval is the interpass temperature reached in the welding procedure test.

5.10 Post-weld heat treatment or ageing

Addition or deletion of post weld heat treatment or ageing is not permitted except that artificial ageing for 6000 series alloys gives approval for prolonged natural ageing.

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