INTERNATIONAL STANDARD

ISO 25239-4

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Friction stir welding — Aluminium

Part 4: Specification and qualification of welding procedures

Soudage par friction-malaxage — Aluminium

Partie 4: Descriptif et qualification des modes opératoires de soudage

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

ISO 25239-4 was prepared by the International Institute of Welding, which has been approved as an international standardizing body in the field of welding by the ISO Council.

ISO 25239 consists of the following parts, under the general title *Friction stir welding — Aluminium*:

— *Part 1: Vocabulary*

— *Part 2: Design of weld joints*

— *Part 3: Qualification of welding operators*

— *Part 4: Specification and qualification of welding procedures*

— *Part 5: Quality and inspection requirements*

Requests for official interpretations of any aspect of this part of ISO 25239 should be directed to the ISO Central Secretariat, who will forward them to the IIW Secretariat for an official response.

Introduction

Welding processes are widely used in the fabrication of engineered structures. During the second half of the twentieth century, fusion welding processes, wherein fusion is obtained by the melting of parent material and usually a filler metal, dominated the welding of large structures. Then, in 1991, Wayne Thomas at TWI invented friction stir welding (FSW), which is carried out entirely in the solid phase (no melting).

The increasing use of FSW has created the need for this International Standard in order to ensure that welding is carried out in the most effective way and that appropriate control is exercised over all aspects of the operation. This International Standard focuses on the FSW of aluminium because, at the time of publication, the majority of commercial applications for FSW involved aluminium. Examples include railway carriages, consumer products, food processing equipment, aerospace structures, and marine vessels.

To parts of this International Standard are listed in the foreword.

Part 1 defines terms specific to FSW.

Part 2 specifies design requirements for FSW joints in aluminium.

Part 3 specifies requirements for the qualification of an operator for the FSW of aluminium.

Part 4 specifies requirements for the specification and qualification of welding procedures for the FSW of aluminium. A welding procedure specification (WPS) is needed to provide a basis for planning welding operations and for quality control during welding. Welding is considered a special process in the terminology of standards for quality systems. Standards for quality systems usually require that special processes be carried out in accordance with written procedure specifications. Metallurgical deviations constitute a special problem. Because non-destructive testing of the mechanical properties is impossible at the present level of technology, this has resulted in the establishment of a set of rules for qualification of the welding procedure prior to the release of the WPS to actual production. This part of ISO 25239 defines these rules.

Part 5 specifies a method for determining the capability of a manufacturer to use the FSW process for the production of aluminium products of the specified quality. It defines specific quality requirements, but does not assign those requirements to any specific product group. To be effective, welded structures should be free from serious problems in production and in service. To achieve that goal, it is necessary to provide controls from the design phase through material selection, fabrication, and inspection. For example, poor design can create serious and costly difficulties in the workshop, on site, or in service. Incorrect material selection can result in welding problems, such as cracking. Welding procedures have to be correctly formulated and qualified to avoid imperfections. To ensure the fabrication of a quality product, management should understand the sources of potential trouble and introduce appropriate quality and inspection procedures. Supervision should be implemented to ensure that the specified quality is achieved.

The International Organization for Standardization (ISO) draws attention to the fact that it is claimed that compliance with this document may involve the use of patents concerning friction stir welding given in Clauses 5 to 7.

ISO takes no position concerning the evidence, validity and scope of this patent right.

The following holder of this patent right has assured ISO that it is willing to negotiate licenses under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statement of the holder of this patent right is registered with ISO. Further information may be obtained from:

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Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights other than those identified above. ISO shall not be held responsible for identifying any or all such patent rights.

Friction stir welding — Aluminium

Part 4:
Specification and qualification of welding procedures

1 Scope

This part of ISO 25239 specifies the requirements for the specification and qualification of welding procedures for the friction stir welding (FSW) of aluminium. In this part of ISO 25239, the term “aluminium” refers to aluminium and its alloys.

This part of ISO 25239 does not apply to friction stir spot welding.

NOTE Service requirements, materials or manufacturing conditions can require more comprehensive testing than is specified in this part of ISO 25239.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 209, *Aluminium and aluminium alloys — Chemical composition*

ISO 857-1, *Welding and allied processes — Vocabulary — Part 1: Metal welding processes*

ISO 2107, *Aluminium and aluminium alloys — Wrought products — Temper designations*

ISO 3134 (all parts), *Light metals and their alloys — Terms and definitions*

ISO 4136, *Destructive tests on welds in metallic materials — Transverse tensile test*

ISO 5173, *Destructive tests on welds in metallic materials — Bend tests*

ISO 6520-1, *Welding and allied processes — Classification of geometric imperfections in metallic materials — Part 1: Fusion welding*

ISO 9017, *Destructive tests on welds in metallic materials — Fracture test*

ISO 10042, *Welding — Arc-welded joints in aluminium and its alloys — Quality levels for imperfections*

ISO 13916, *Welding — Guidance on the measurement of preheating temperature, interpass temperature and preheat maintenance temperature*

ISO 14175, *Welding consumables — Gases and gas mixtures for fusion welding and allied processes*

ISO 15607:2003, *Specification and qualification of welding procedures for metallic materials — General rules*

ISO 15613, *Specification and qualification of welding procedures for metallic materials — Qualification based on pre-production welding test*

ISO 15614-2, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 2: Arc welding of aluminium and its alloys*

ISO 17637, *Non-destructive testing of welds — Visual testing of fusion-welded joints*

ISO 17639, *Destructive tests on welds in metallic materials — Macroscopic and microscopic examination of welds*

ISO/TR 17671-1, *Welding — Recommendations for welding of metallic materials — Part 1: General guidance for arc welding*

ISO 25239-1, *Friction stir welding — Aluminium — Part 1: Vocabulary*

ISO 25239-5:2011, *Friction stir welding — Aluminium — Part 5: Quality and inspection requirements*

ISO 80000-1:2009, *Quantities and units — Part 1: General*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 209, ISO 857-1, ISO 3134, ISO 6520-1, ISO 10042, ISO 15607, ISO 15613, ISO 15614-2, ISO/TR 17671-1, and ISO 25239-1 apply.

4 Symbols and abbreviated terms

For the purposes of qualification of welding procedures, the abbreviations listed in ISO 15607:2003, Table 1, apply.

5 Development and qualification of welding procedures

5.1 General

Qualification of welding procedures shall be performed prior to production welding.

The manufacturer shall prepare a preliminary welding procedure specification (pWPS) and shall ensure that it is applicable for production using experience from previous production jobs and the general fund of knowledge of welding technology.

A pWPS shall be used as the basis for the establishment of a welding procedure qualification record (WPQR). The pWPS shall be tested in accordance with one of the methods listed in Clause 6 (welding procedure test) or Clause 7 (pre-production welding test). Clause 6 shall be used when the production part or joint geometry is accurately represented by a standardized test piece or pieces, as shown in 6.2. Clause 7 shall be used when the production part or joint geometry is not accurately represented by the standardized test pieces, as shown in 6.2. The information required in a pWPS is given in 5.2.

NOTE For some applications, it can be necessary to supplement or reduce the list.

A welding procedure specification (WPS) covers a certain range of parent material thicknesses as well as a range of aluminium alloys.

Ranges and tolerances in accordance with the relevant International Standard (see Clause 2) and the manufacturer's experience shall be specified when appropriate.

An example of a pWPS form is shown in Annex A.

5.2 Technical content of a pWPS

5.2.1 General

The following information, as a minimum, shall be included in a pWPS.

5.2.2 Manufacturer information

— identification of the manufacturer

— identification of the pWPS

5.2.3 Parent material type(s), temper(s), and reference standard(s)

5.2.4 Parent material dimensions

— thickness of the members comprising the welded joint

— outside diameter of tube

5.2.5 Equipment identification

— model

— serial number

— manufacturer

5.2.6 Tool identification

— material

— drawing or drawing number

5.2.7 Clamping arrangement

— method and type of jigging, fixtures, rollers, and backing (dimensions and material)

— tack welding process and conditions, when required — the pWPS shall indicate any required tack welding or prohibited tack welding

5.2.8 Joint design

— sketch of the welded joint design and dimensions

— weld run sequence and direction, if applicable

— run-on and run-off plates, material type, reference standard, and dimensions of run-on and run-off plates

— placement of exit hole

5.2.9 Joint preparation and cleaning methods

5.2.10 Welding details

— tool motion (e.g. rotation in either the clockwise or anticlockwise direction, rotation speed including downward and upward motion)

— tool position (e.g. heel plunge depth) or axial force, as applicable

— tool cooling (internal, external, cooling medium), if applicable

— tilt angle

— side tilt angle, lateral offset

— dwell time at start of weld

— dwell time at end of weld

— joint configuration

— weld overlap area (WOA) for a butt joint or lap joint in tube

— lap joint: advancing or retreating side near the upper sheet edge, direction of welding

5.2.11 Welding speed

— welding speed, including details of any changes during welding

— ramp-up/ramp-down or upslope/downslope speeds when applied

5.2.12 Welding position

— applicable welding positions

5.2.13 Pre-weld heat treatment

— when pre-weld heat treatment should be applied

5.2.14 Preheating temperature

— when preheating should be applied

— use of ISO 13916 for the application of this subclause, 5.2.15 and 5.2.16

— when preheating of the friction stir welding tool should be applied

5.2.15 Preheat maintenance temperature

— when preheat maintenance should be applied

5.2.16 Interpass temperature

— when an interpass temperature should be maintained

5.2.17 Shielding gas

— designation in accordance with ISO 14175 and, when applicable, the composition, manufacturer and name, and gas flow rate

5.2.18 postweld processing

— solution heat treatment, ageing, stress relieving (or the methods to correct distortion and straighten distorted parts), removal of toe flash or any other postweld processing of the weldment

— postweld heat treatment

— temperature range and minimum time for postweld heat treatment or ageing shall be specified or reference shall be made to other standards which specify this information

6 Qualification based on a welding procedure test

6.1 General

The preparation, welding, and testing of test pieces shall be in accordance with 6.2 and 6.3.

Fulfilment of the requirements of this part of ISO 15239 can also serve to qualify the welding operator (see ISO 25239-3).

6.2 Test pieces

6.2.1 Shape and dimensions of test pieces

6.2.1.1 General

The length or number of test pieces shall be sufficient to allow all required tests to be performed.

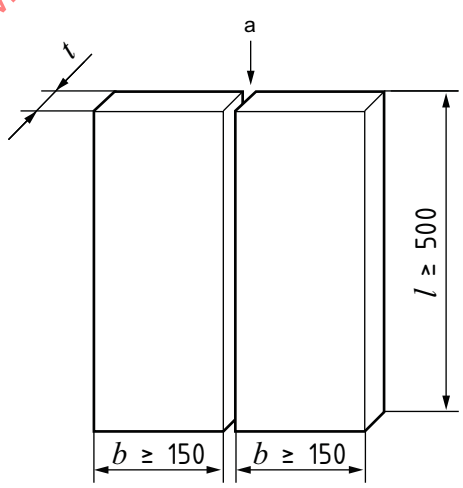
Test pieces longer than the minimum size may be used to allow for the provision of extra specimens, for re-testing specimens or both (see 6.3.4).

The rolling direction or extrusion direction shall be marked on the test piece.

6.2.1.2 Butt joint in sheet with full penetration

The test piece shall be prepared in accordance with Figure 1.

Dimensions in millimetres



Key

b width of components
l length of components
t material thickness

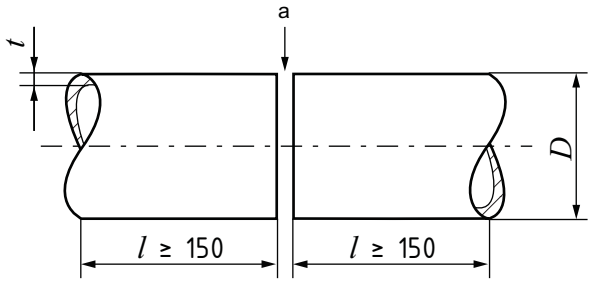
a Joint preparation and fit-up, as specified in the pWPS.

Figure 1 — Test piece for a butt joint in sheet with full penetration

6.2.1.3 Butt joint in tube with full penetration

The test piece shall be prepared in accordance with Figure 2.

Dimensions in millimetres



Key

D outside diameter of tube
l length of components
t material thickness
a Joint preparation and fit-up, as specified in the pWPS.

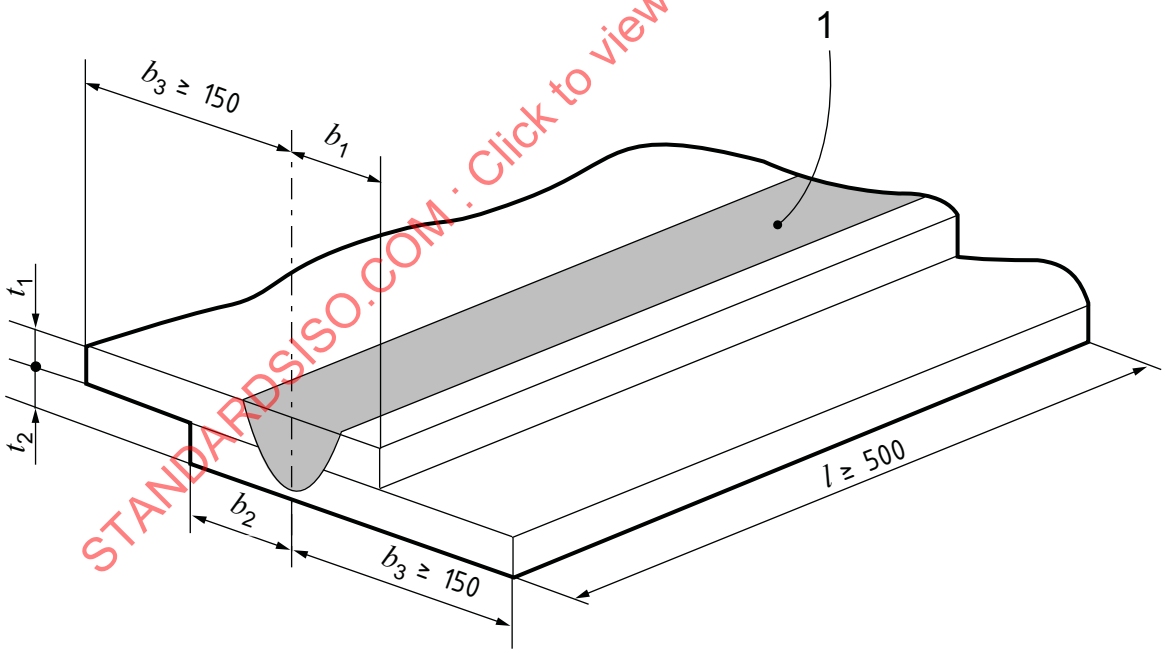
Figure 2 — Test piece for a butt joint in tube with full penetration

6.2.1.4 Lap joint

The test piece shall be prepared in accordance with Figure 3.

The weld may be either partial or full penetration through all the sheets.

Dimensions in millimetres



Key

1 weld
b_1 edge to weld centreline distance of upper sheet, as specified in the pWPS
b_2 edge to weld centreline distance of lower sheet, as specified in the pWPS
b_3 distance between weld centre and edge of test piece
l test piece length
t_1 parent material thickness of upper sheet
t_2 parent material thickness of lower sheet

Figure 3 — Test piece for a lap joint

6.2.2 Welding of test pieces

The test pieces shall be welded in accordance with the pWPS. If tack welds are to be consumed during friction stir welding of the production joint, then they shall be included in the test piece. The location of tack welds shall be clearly marked on the test piece.

Welding of the test pieces shall be witnessed by an examiner.

6.3 Examination and testing of test pieces

6.3.1 Extent of testing

Testing includes both non-destructive testing (NDT) and destructive testing. Testing shall be performed in accordance with the requirements of Table 1 and Table 2. Annex B provides additional information on NDT.

Testing of the test pieces shall be witnessed by an examiner.

Table 1 — Examination and testing of the test pieces for butt joints (Figure 1, Figure 2)

Type of examination and testing	Extent of examination and testing
Visual testing[a]	100 %
Transverse tensile test[b]	Two test specimens
Transverse bend test for wrought materials (in accordance with ISO 5173)[c]	Two root test specimens
Fracture test for cast materials or wrought/cast combinations (in accordance with ISO 9017)	Two face test specimens
Macroscopic examination	One test specimen
Additional tests (e.g. non-destructive)[d]	If required

[a] Testing shall be carried out to avoid discarded areas, as shown in Figure 4.

[b] For a butt joint in tube, at least one transverse tensile test specimen should be taken from the WOA, if possible.

[c] For material over 12 mm in thickness, four transverse side-bend test specimens may be substituted for the two root and two face-bend test specimens. One longitudinal face-bend test specimen and one longitudinal root-bend test specimen may be substituted for the four transverse-bend test specimens.

[d] Additional tests shall be carried out in accordance with the relevant requirements of the design specification.

Table 2 — Examination and testing of the test pieces for lap joints (Figure 3)

Type of examination and testing	Extent of examination and testing
Visual testing[a]	100 %
Macroscopic examination	Two test specimens
Additional tests (e.g. peel test, shear test, hammer S-bend test, non-destructive test)[b]	If required

[a] Testing shall be carried out to avoid discarded areas, as shown in Figure 6.

[b] Additional tests shall be carried out in accordance with the relevant requirements of the design specification. Information on the hammer S-bend test is given in Annex C.

Examination and testing of test pieces including tack welds or start/end areas of a butt joint in tube shall be in accordance with the design specification.

Specific service, material or manufacturing conditions may require more comprehensive testing in order to obtain additional test data.

6.3.2 Visual testing and acceptance levels

The test pieces shall be visually tested in accordance with ISO 17637 prior to extracting the test specimens. The extent of testing shall be as specified in 6.3.1, Table 1 or Table 2.

Apply the acceptance levels of ISO 25239-5:2011, Annex A.

6.3.3 Destructive tests

6.3.3.1 General

The extent of testing shall be as required in Table 1 and Table 2.

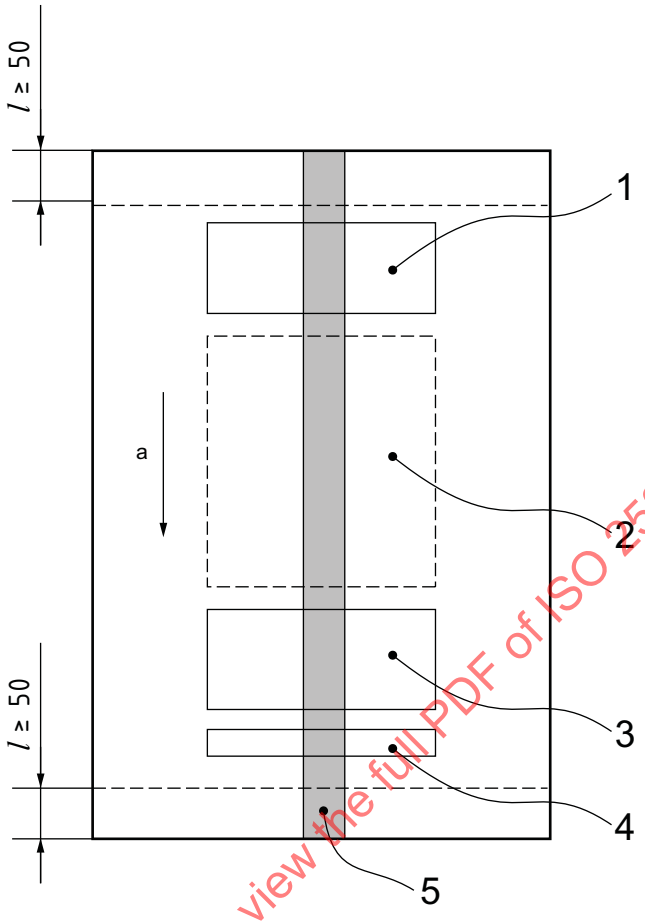
6.3.3.2 Location and extraction of test specimens

After the test piece has passed visual testing, test specimens shall be extracted.

The test specimens shall be located in accordance with Figure 4, Figure 5 or Figure 6.

It is acceptable to take, avoiding areas that have imperfections, the test specimens from locations within the acceptance limits of the visual testing method that was used to examine the test pieces.

Dimensions in millimetres



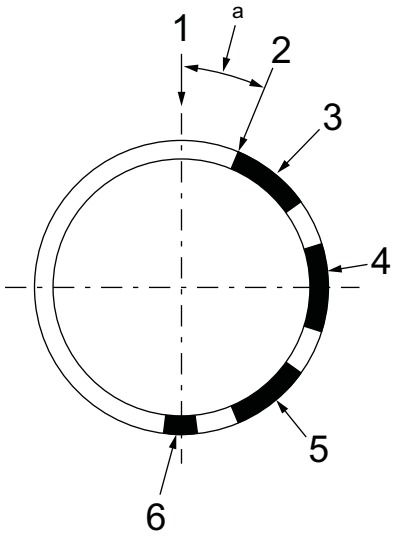
Key

1 area for: one tensile test specimen; bend test specimens or fracture test specimens
2 area for additional test specimens, if required
3 area for: one tensile test specimen; bend test specimens or fracture test specimens
4 area for one test specimen for macroscopic examination
5 weld
l length discarded from each end of the test weld

NOTE Not to scale.

[a] Direction of welding.

Figure 4 — Location of test specimens for a butt joint in sheet



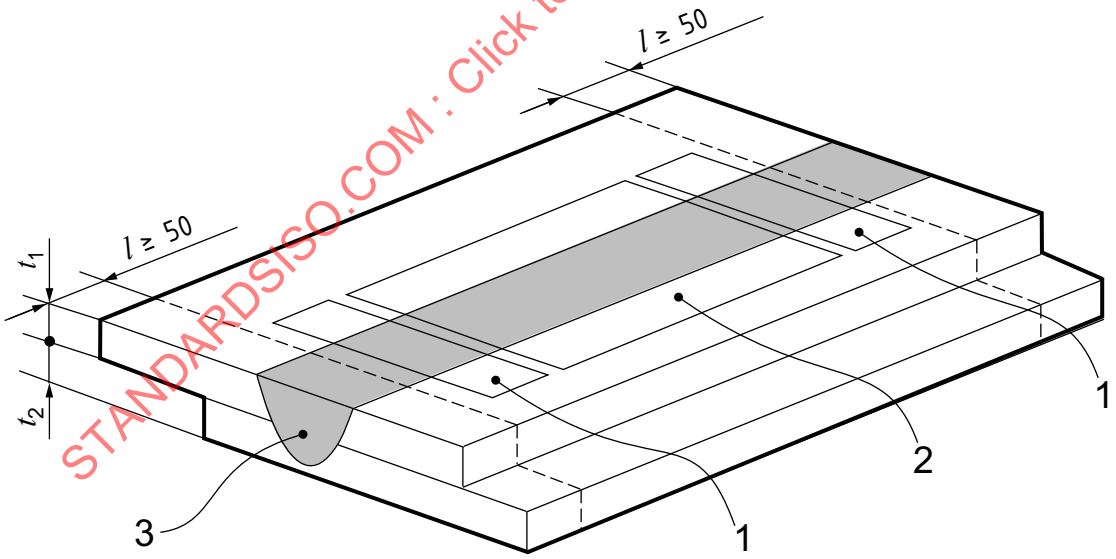
Key
1 start of weld
2 end of weld
3 area for: one tensile test specimen; bend test specimens or fracture test specimens
4 area for additional test specimens, if required
5 area for: one tensile test specimen; bend test specimens or fracture test specimens
6 area for one test specimen for macroscopic examination

NOTE Not to scale.

[a] WOA yielding one tensile test specimen, if possible.

Figure 5 — Location of test specimens for a butt joint in tube

Dimensions in millimetres



Key
1 area for two test specimens for macroscopic examination
2 area for peel test, shear test, hammer S-bend test specimens (see Annex C), if required
3 weld
l length discarded from each end of the test weld

NOTE Not to scale.

Figure 6 — Location of test specimens in a lap joint

6.3.3.3 Transverse tensile test and acceptance levels

For butt joints, transverse tensile testing of test specimens shall be performed in accordance with ISO 4136, except that the surface of the test specimens shall be in the as-welded condition.

The ultimate tensile strength of the test specimen shall not be less than the corresponding specified minimum value of the parent material required in the relevant International Standard (see Table 3).

For heat-treatable alloys, the specified tensile strength, $\sigma_{min,w}$, of the welded test specimen in the postweld condition shall satisfy the minimum requirement:

$$\sigma_{min,w} = \sigma_{min,pm} f_e \quad (1)$$

where

$\sigma_{min,pm}$ is the specified minimum tensile strength of the parent material required in the relevant International Standard;

f_e is the joint efficiency factor (see Table 3).

For combinations of different aluminium alloys, the lower $\sigma_{min,w}$ value of the two alloys shall be required.

In order to determine conformity to the f_e values in Table 3, f_e values calculated from Equation (1) shall be rounded in accordance with the rules specified in ISO 80000-1:2009, Annex B.

Table 3 — Efficiency for tensile strength of butt joints

Material type	Temper condition of parent material before welding[a,b]	Postweld condition	Joint efficiency factor f_e
Pure aluminium	All temper conditions	As welded	1,0[d]
Non-heat-treatable alloys	All temper conditions	As welded	1,0[d]
Heat-treatable alloys	T4	Natural ageing[c]	0,7
	T4	Artificial ageing[c]	0,7[e]
	T5 and T6	Natural ageing[c]	0,6
	T5 and T6	Artificial ageing[c]	0,7[e]

[a] Refer to ISO 2107.

[b] For parent material in tempers not shown, $\sigma_{min,w}$ shall be in accordance with the design specification.

[c] Ageing conditions shall be in accordance with the design specification.

[d] Irrespective of the actual parent material temper used for the test, $\sigma_{min,pm}$ is based on the specified minimum tensile strength of the "O" condition.

[e] Higher properties can be achieved if a full postweld heat treatment is applied; $\sigma_{min,w}$ shall be in accordance with the design specification.

6.3.3.4 Bend test and acceptance levels

For butt joints, the test specimens and bend testing shall be in accordance with ISO 5173. The advancing and retreating sides of the test specimens shall be marked prior to testing.

For all parent materials, the minimum bend angle shall be 150°, using the calculated former diameter based upon the parent material elongation as follows.

For elongation >5 %

$$d = \frac{100 \times t_s}{\Delta l} - t_s \qquad (2)$$

where

d is the maximum former diameter, in millimetres;

t_s is the thickness, in millimetres, of the bend test specimen (this includes side bends);

Δl is the minimum tensile elongation, expressed as a percentage, required by the material specification (for combinations of different alloys, the lowest individual value shall be used).

For an elongation ≤ 5 %, annealing shall be carried out before testing. The former diameter shall be calculated with the elongation given by the specified "O" temper conditions.

If the bend tests fail due to grain growth that occurred during the annealing process, additional bend tests shall be performed in accordance with Table 1, except that new test parameters shall be in accordance with the design specification.

Values of d shall be rounded down to the nearest whole number.

A smaller former diameter may be used.

During testing, the test specimens shall not reveal any single crack >3 mm in any direction. Cracking appearing at any edge of a test specimen during testing shall be ignored in the evaluation unless there is evidence that it is due to incomplete penetration or a cavity.

6.3.3.5 Macroscopic examination and acceptance levels

The test specimen shall be prepared and examined in accordance with ISO 17639 on one side to clearly reveal the weld region.

The macroscopic examination shall include unaffected parent material. Macroscopic examination before etching shall reveal no cracks.

Care should be taken when etching certain alloys to avoid producing false indications.

The acceptance levels of ISO 25239-5:2011, Annex A, shall apply. Other imperfections shall be within the specified limits of the relevant requirements or the design specification.

6.3.4 Re-testing

If the test piece fails to comply with any of the requirements for visual testing specified in 6.3.2, an additional test piece shall be welded and subjected to the same examination. If this additional test piece does not comply with the requirements, the welding procedure test has failed.

If any test specimen fails to comply with the requirements for destructive tests performed in accordance with 6.3.3, but only due to weld imperfections, then two further test specimens shall be tested for each one that failed. The additional test specimens shall be taken from the same test piece if there is sufficient material or from a new test piece. Each additional test specimen shall be subjected to the same tests as the initial test specimen that failed. If either of the additional test specimens fails to comply with the requirements, then the welding procedure test has failed.

6.4 Range of qualification

6.4.1 General

Each of the conditions given in 6.4.2 to 6.4.5 shall be met.

Additions, deletions or changes outside the ranges specified shall require a new welding procedure test to be performed.

6.4.2 Related to the manufacturer

A qualification test carried out by a manufacturer is valid for welding in workshops or sites under that manufacturer's technical and quality control.

Welding is considered to be carried out under the same technical and quality control conditions as long as the manufacturer who performed the welding procedure test retains complete responsibility for all corresponding welding.

6.4.3 Preheating temperature

The upper limit of qualification is the preheating temperature that was measured at the start of the welding procedure test. The lower limit is 30 °C below the measured preheating temperature, as specified in the WPS.

6.4.4 Interpass temperature

The upper limit of qualification is the highest interpass temperature reached during the welding procedure test. The lower limit of qualification is 30 °C below the interpass temperature, as specified in the WPS.

6.4.5 Other variables

The range of qualification for other variables shall be specified in the WPS.

6.5 Welding procedure qualification record

The WPQR is a statement of the results of assessing each test piece, including re-tests. The relevant items listed in the WPS shall be included, together with details of any features that would be rejectable, in accordance with the requirements of 6.3. If the test results are acceptable, then the WPQR is qualified and shall be signed and dated by the examiner or representative of the examining body. In addition, the pWPS is also qualified. A WPS shall be issued.

A standard format for the WPQR shall be used. An example of a WPQR form is shown in Annex D.

7 Qualification based on pre-production welding test

7.1 General

The pre-production welding test shall be carried out in accordance with the relevant subclauses of Clause 6, unless modified by 7.2 to 7.5.

Fulfilling the requirements of this part of ISO 25239 can also serve to qualify the welding operator (see ISO 25239-3).

7.2 Test pieces

Preparation and welding of test pieces shall be performed under the general conditions of production welding. The test pieces shall be designed so that their shapes and dimensions simulate the actual welding conditions of the structure. This includes welding positions and other essential items (e.g. stress conditions, heating effects, limited access and edge condition).

When actual components are used, jigs and fixtures shall be those that are used in production.

7.3 Examination and testing of test pieces

The test pieces shall be tested in accordance with the relevant subclauses of Clause 6.

The following tests, as a minimum, shall be performed:

— visual testing (100 %);

— macroscopic examination (the number depends on the geometry of the structure).

7.4 Range of qualification

Any WPS issued in accordance with this part of ISO 25239 is limited to the type of joint used in the pre-production welding test.

The range of qualification is generally in accordance with the relevant subclauses of 6.4 for welding.

7.5 Welding procedure qualification record

A standard format for the WPQR shall be used. An example of a WPQR form is shown in Annex D.

Annex A
(informative)

Preliminary welding procedure specification

Manufacturer's pWPS No.: _____
Manufacturer's WPQR No.: _____
Friction stir welding operator's name: _____
Parent material type, temper, and reference standard(s): _____
Parent material thickness (mm): _____
Outside diameter of tube (mm): _____
Equipment identification (model, serial number, and manufacturer): _____
Tool identification (sketch)[1)]:
Clamping arrangement (sketch)[1)]:
Tack welding: _____
Joint preparation and cleaning methods: _____

Joint design

Joint design and joint configuration	Welding sequences
(Sketch)[1)]	

Welding details

Run	Tool motion, rotation speed r/min	Heel plunge depth mm or axial force kN	Tilt angle °	Side tilt angle °	Dwell time s	Welding speed mm/min others

Welding position: _____
Pre-weld heat treatment: _____
Preheating temperature (°C): _____ Preheat maintenance temperature (°C): _____
Interpass temperature (°C): _____
Shielding gas: _____ Designation: _____ Gas flow rate (l/min): _____
Postweld processing: _____
Postweld heat treatment: _____
Time, temperature, method: _____
Heating and cooling rates: _____
Other information[1)] _____

.....

Manufacturer
Name, date and signature

_____

1) If required.

Annex B
(informative)

Non-destructive testing

When NDT is required, it should be performed on the test pieces before the test specimens are cut from them.

Depending on the joint geometry, parent materials, and work requirements, NDT, if required, should be performed in accordance with ISO 3452[1] (penetrant inspection), ISO 17636[2] (radiographic testing), and ISO 17640[3] (ultrasonic examination). If there are stringent requirements for weld integrity, then specific methods may have to be developed (e.g. phased-array ultrasonic testing or eddy-current testing).

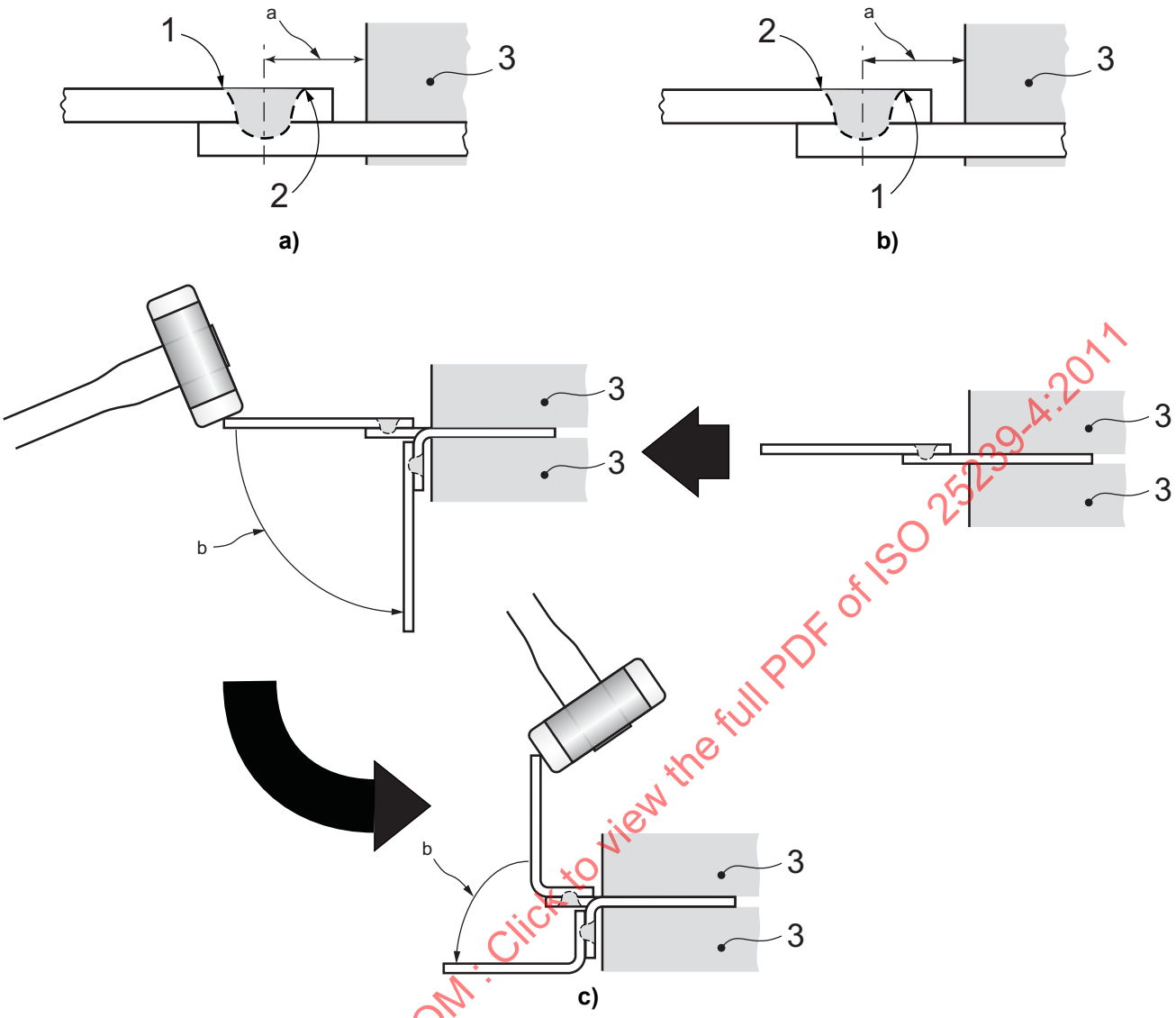
Annex C
(informative)

Hammer S-bend test of lap welds

The hammer S-bend test of lap welds has proven to be a sensitive method for qualitatively determining whether a weld contains imperfections, e.g. sheet thinning or hooks. Since this is a qualitative test, the appropriate distance from the centre of the weld to the vice (or holding clamp) should be adjusted to compensate for the ductility or lack of ductility and the thickness of the material being tested. For more ductile materials, the distance from the weld centre to the vice should be less than the distance for less ductile materials.

It is recommended that the hammer S-bend test be performed on two test specimens. The first test specimen should have the advancing side of the weld nearer to the hammer [Figure C.1 a)]. The second test specimen should have the retreating side nearer to the hammer [Figure C.1 b)].

This test does not replace other quantitative tests.



Key

1 advancing side of weld
2 retreating side of weld
3 vice

NOTE The large arrows indicate the sequence of testing.

a Clamp edge to weld centreline distance.

b Direction of swinging hammer.

Figure C.1 — Unrestrained hammer S-bend test method