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**Friction stir welding — Aluminium —  
Part 3:  
Qualification of welding operators**

*Soudage par friction-malaxage — Aluminium —  
Partie 3: Qualification des opérateurs soudeurs*

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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.

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

ISO 25239-3 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.

The 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. ISO 25239-4 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.

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# Friction stir welding — Aluminium —

## Part 3: Qualification of welding operators

### 1 Scope

This part of ISO 25239 specifies requirements for the qualification of welding operators 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.

### 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 17636 (all parts), *Non-destructive testing of welds — Radiographic testing*<sup>1)</sup>

ISO 17640, *Non-destructive testing of welds — Ultrasonic testing — Techniques, testing levels, and assessment*

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

ISO 25239-4:2011, *Friction stir welding — Aluminium — Part 4: Specification and qualification of welding procedures*

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

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 25239-1 apply.

### 4 Requirements

#### 4.1 Welding operator qualification

Welding operators shall be qualified by one of the following tests, as detailed in 4.3:

— standard welding test, see 4.3.1;

<sup>1)</sup> To be published. (Revision of ISO 17636:2003)

- welding procedure test, see 4.3.2;
- pre-production welding test or production welding test, see 4.3.3;
- production welding sample test, see 4.3.4.

In addition, the welding operator's knowledge of the welding unit to be used for the qualification test shall be tested. See Annex A.

Any of the welding operator qualification tests can be supplemented by a test of knowledge related to welding technology. Such a test is recommended, but it is not mandatory. Annex B includes an example of such an examination.

The essential variables and ranges of qualification are specified in 4.2 and the validity is specified in Clause 5. Provided that the welding operator works in accordance with a welding procedure specification (WPS), the range of qualification shall be limited only as specified in 4.2.

A suggested form for the welding operator's qualification certificate is shown in Annex C.

## 4.2 Essential variables and ranges of qualification

### 4.2.1 General

The qualification of welding operators is based on essential variables, as specified in 4.2.2 to 4.2.5. For each essential variable, a range of qualification is defined. If a welding operator is required to weld outside the range of qualification, then a new qualification test is required.

NOTE Friction stir welding is a mechanized process. However, because it is also a solid-state welding process, the essential variables are different from those applicable to fusion welding processes.

### 4.2.2 Friction stir welding methods

A successful welding operator qualification test made with any type of FSW method qualifies an operator only for that welding method. This subclause applies to FSW methods that include, but are not limited to, robotic, single spindle, multiple spindle, bobbin tool, retractable probe, or any other FSW method defined in the WPS used for that qualification test.

### 4.2.3 Welding equipment

The following changes require a new qualification:

- a change from welding with a joint sensor to welding without, although welding without a joint sensor also qualifies an operator to weld with a joint sensor;
- a change from one type of welding machine to another type of welding machine that requires additional training to operate — a test made with any type of machine qualifies only that type of machine, although the addition or removal of jigs and fixtures, feeding units and other ancillary equipment does not change the type of machine;
- addition, removal or change of control system.

### 4.2.4 Parent materials

A successful test weld made in any aluminium alloy qualifies an operator for all aluminium alloys.

A successful test weld of any parent material thickness qualifies an operator for all parent material thicknesses.

A successful test weld of any parent material form (including, but not limited to, sheet, tube, castings, forgings or extrusions) qualifies an operator for all parent material forms and for all tube diameters.

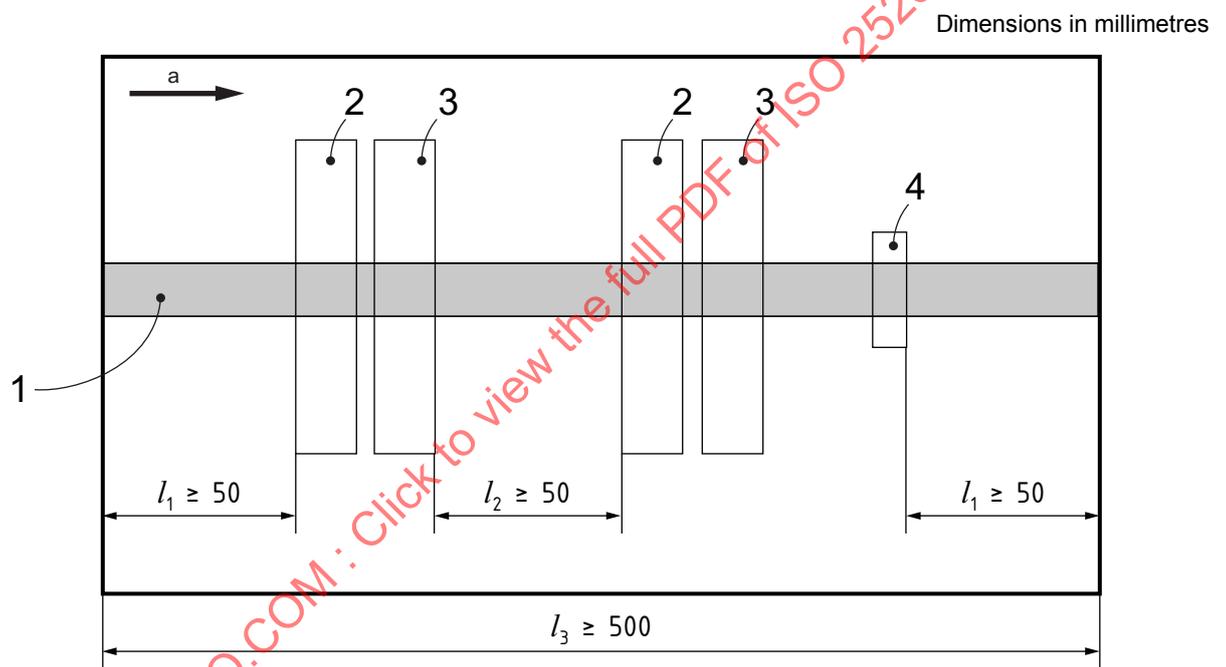
#### 4.2.5 Weld joint geometry

A successful test weld made in any weld joint geometry qualifies an operator for all weld joint geometries.

### 4.3 Qualification methods

#### 4.3.1 Qualification based on standard welding test

The test piece shown in Figure 1 shall be used for the standard welding test. A welding operator who has successfully completed the welding test in accordance with 4.4 shall be considered qualified for the method and type of welding machine used for the test.



#### Key

- 1 weld
- 2 root bend test piece
- 3 face bend test piece
- 4 macroscopic examination test specimen
- $l_1$  minimum length of weld from the edge of the test piece to a test specimen
- $l_2$  minimum length of weld between face bend and root bend test specimens
- $l_3$  minimum total length of weld

<sup>a</sup> Weld direction.

The width of the test piece shall be sufficient for extracting the bend test specimens.

**Figure 1 — Location of destructive test specimens**

#### 4.3.2 Qualification based on welding procedure test

A welding operator shall have successfully completed a welding procedure test in accordance with ISO 25239-4:2011, Clause 6, to be considered qualified for the method and type of welding machine used.

#### 4.3.3 Qualification based on pre-production welding test or production welding test

A welding operator shall have successfully completed a pre-production welding test in accordance with ISO 25239-4:2011, Clause 7 or a production welding test, to be considered qualified for the FSW method and type of welding machine used for the test.

#### 4.3.4 Qualification based on production welding sample test

A welding operator having successfully set up a production part shall be considered qualified if representative samples of the items that are produced are approved by the examiner or the examining body. This testing of production samples shall be in accordance with the requirements of 4.4 or the requirements of the contracting parties, whichever is more stringent.

### 4.4 Test welds

#### 4.4.1 General

Test welds shall be made in accordance with a WPS, except when 4.3.2 or 4.3.3 applies. The welding and testing of test pieces shall be witnessed by the examiner.

The test welds used for qualification of a welding operator shall have a length of at least 500 mm. If the qualification is based on pre-production tests, production tests or production sample tests and the product used has a shorter weld length than 500 mm, then the number of products tested shall be such that the required weld length is met. However, no more than three products shall be tested.

The test piece and test specimens shall be marked with the identification of the examiner or the examining body and the welding operator before welding starts.

The examiner may stop the test if the welding conditions are not correct or if it appears that the welding operator does not have the skill to fulfil the requirements of this part of ISO 25239.

#### 4.4.2 Testing and acceptance levels of test welds

##### 4.4.2.1 Visual testing

Visual testing shall be carried out in accordance with ISO 25239-4:2011, 6.3.2, except in the case of 4.4.1 where, if the length of weld is less than 500 mm, the amount of material to be disregarded shall be specified in the WPS.

The weld shall have an as-welded surface and shall be free of cracks or cavities. The weld width shall not show any variations due to insufficient tool pressure. If a full penetration weld is specified, then there shall be no incomplete penetration.

##### 4.4.2.2 Non-destructive and destructive testing

###### 4.4.2.2.1 Extent of testing

Welds shall be bend tested in accordance with 4.4.2.2.2 or 100 % tested with an appropriate non-destructive, volumetric testing method (radiographic or ultrasonic testing). Testing shall be done in accordance with ISO 17636 (radiographic testing) or ISO 17640 (ultrasonic testing).

One test specimen for macroscopic examination shall be taken from the test weld(s).

The acceptance levels shall be as specified in ISO 25239-5:2011, Annex A.

#### 4.4.2.2.2 Bend test

Bend testing shall be performed in accordance with ISO 25239-4:2011, 6.3.3.4. The location of the test specimen blanks shall be in accordance with Figure 1. Two face and two root bend test specimens shall be taken from the test weld(s). For material over 12 mm thick, four side bend test specimens may be substituted for the face bend and root bend test specimens.

If a partial penetration weld is specified in the WPS, the specimen shall be machined from the root side to a thickness equal to the specified minimum weld penetration before testing.

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.

#### 4.4.2.2.3 Macroscopic examination

One macroscopic examination shall be carried out in accordance with ISO 25239-4:2011, 6.3.3.5. The location of the test specimen blank shall be in accordance with Figure 1.

The acceptance levels shall be as specified in ISO 25239-5:2011, Annex A.

#### 4.4.3 Re-testing

If the welded assembly fails to meet the requirements of 4.4.1 and 4.4.2, then the test shall be rejected. A duplicate assembly may be welded using the same procedure and subjected to examination. If the second assembly fails to meet the requirements, then the welding operator shall be required to have additional training before a new test is made.

If a bend test specimen fails to meet the requirements, then two additional test specimens shall be prepared from the same welded assembly and tested. If both retests are acceptable, the welding operator shall be qualified. If one or both retests are not acceptable, the welding operator is not qualified.

#### 4.5 Test record

The results of all testing shall be documented. The format of the documentation shall be decided by the manufacturer.

NOTE The documentation can be on paper or electronic media.

### 5 Certificate

#### 5.1 General

It shall be verified that the welding operator passed the qualification test. All essential variables shall be recorded on the certificate. If the test piece(s) fail(s) any of the required tests, no certificate shall be issued.

The certificate shall be issued under the sole responsibility of the examiner or examining body and shall contain all the information detailed in Annex C. It is recommended that the format of Annex C be used as the welding operator's qualification test certificate. If a different welding operator qualification test certificate is used, it shall contain the information required in Annex C.

NOTE In some countries, an examiner can be employed by the company performing welding.

## 5.2 Period of validity

### 5.2.1 Initial qualification

The welding operator's qualification is valid from the date of welding of the test pieces, provided the required tests have been carried out and acceptable test results are available.

The welding operator's qualification test certificate is valid for a period of 2 years, the period of validity ending on the last day of the month.

### 5.2.2 Confirmation of the validity

The welding coordinator or the person responsible from the employer shall confirm that the welding operator has been working within the initial range of qualification. This shall be confirmed every 6 months. If such a confirmation is not given and the qualification expires, the welding operator shall be required to pass a new qualification test before resuming welding.

### 5.2.3 Prolongation of qualification

The welding operator's qualification test certificates can be prolonged every 2 years by an examiner or examining body.

Before prolongation of the certification takes place, the specifications of 5.2.2 shall be satisfied and the following conditions shall be confirmed:

- all records and evidence used to support prolongation shall be traceable to the welding operator and shall identify the WPS(s) used in production;
- evidence used to support prolongation shall be of a volumetric nature (radiographic testing or ultrasonic examination) or, for destructive testing (fracture or bend), shall have been made on two welds during the previous 6 months — evidence relating to prolongation shall be retained for a minimum of 2 years;
- the welds satisfy the acceptance levels for imperfections specified in 4.4.

## Annex A (normative)

### Functional knowledge of the welding unit

#### A.1 General

This annex specifies the knowledge of the welding unit required by a welding operator to ensure that procedures are followed and common practices are complied with.

#### A.2 Welding sequences and procedures

The welding operator shall understand welding procedure requirements and the influence of welding parameters on the weld, in particular:

- a) joint preparation and weld representation:
  - 1) conformity to the WPS for joint preparation,
  - 2) cleanliness of the edges to be welded;
- b) weld imperfections:
  - 1) identification of weld imperfections,
  - 2) identification of causes of weld imperfections,
  - 3) prevention of weld imperfections and remedial action necessary;
- c) welding operator qualification, including its range;
- d) process operation:
  - 1) knowledge of programming the welding unit (if relevant),
  - 2) knowledge of operation of the control system and understanding of the signals given by the control system,
  - 3) adjustment of tool motion,
  - 4) operation of auxiliary equipment,
  - 5) adjustment of jigs, fixtures, and set-up,
  - 6) setting and adjustment of parameters within the WPS,
  - 7) application of safety regulations and precautions,
  - 8) initiation of start and stop procedures.

## Annex B (informative)

### Knowledge of welding technology

#### B.1 General

This annex describes the job knowledge that a welding operator requires to ensure that the WPS is followed and that common practices are complied with. The job knowledge discussed in this annex is presented at the most basic level.

A test of job knowledge is recommended, but it is not mandatory. However, some countries require the welding operator to undergo a test of job knowledge. If the job knowledge test is carried out, this fact should be recorded on the welding operator's certificate.

Because of the differences in training programmes in various countries, it is proposed that only general objectives or categories of job knowledge be standardized. The actual questions that are used should be drawn up by the individual country, employer or engineering authority, and should include questions on areas covered in B.2 relevant to the welding operator's qualification test.

Testing of a welding operator's job knowledge can be accomplished by any of the following methods or combinations of these methods:

- written objective tests (multiple choice), given on paper or on a computer;
- oral questioning following a set of written questions.

The test of job knowledge is limited to the matters related to the welding method used in the test.

#### B.2 Requirements

The operator should have knowledge of:

- a) welding equipment:
  - 1) identification and assembly of essential components,
  - 2) selection of correct welding tools,
  - 3) the cooling system (if any),
  - 4) maintenance of the equipment;
- b) welding process:
  - 1) the control system,
  - 2) setting and controlling of welding parameters,
  - 3) correct alignment and travel of welding head,
  - 4) influence of parameters on the welding process,

- 5) inspection of welding tools,
- 6) causes and appearance of weld imperfections;
- c) parent materials, including their identification;
- d) safety and accident prevention:
  - 1) electrical risk,
  - 2) mechanical risk,
  - 3) noise risk;
- e) knowledge of visual testing of welds.

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**Annex C**  
(informative)

**Qualification test certificate for FSW operators**

Manufacturer's WPS No.: \_\_\_\_\_ Examiner or examining body: \_\_\_\_\_

WPS reference No. (if applicable): \_\_\_\_\_ Examiner/examining body reference No.: \_\_\_\_\_

Name of welding operator: \_\_\_\_\_

Method of identification: \_\_\_\_\_ Photograph (if required)

Date and place of birth: \_\_\_\_\_

Employer: \_\_\_\_\_

Code/testing standard: \_\_\_\_\_

Job knowledge: acceptable/not tested (delete as appropriate)

Weld details: \_\_\_\_\_ Welding method: \_\_\_\_\_

Welding unit/machine: \_\_\_\_\_

Joint sensor: \_\_\_\_\_

Single run/multi-run technique: \_\_\_\_\_

Single/multiple spindle: \_\_\_\_\_

Further information available in WPS No.: \_\_\_\_\_

Indicate on which of the following the qualification is based:

- standard welding test in accordance with 4.3.1;
- welding procedure test in accordance with 4.3.2;
- pre-production welding test or production welding test in accordance with 4.3.3;
- production welding sample test in accordance with 4.3.4.

For results of the qualification tests, see test report No.: \_\_\_\_\_

Location of test: \_\_\_\_\_ Date: \_\_\_\_\_ Examiner or examining body: \_\_\_\_\_

The qualification is valid until: \_\_\_\_\_