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**Welding for aerospace applications —
Qualification test for welders and welding
operators — Fusion welding of metallic
components**

*Soudage pour applications aérospatiales — Épreuve de qualification
pour soudeurs et opérateurs — Soudage par fusion des composants
métalliques*



Reference number
ISO 24394:2008(E)

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
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Contents

Page

Foreword	iv
Introduction.....	v
1 Scope	1
2 Normative references	1
3 Terms and definitions	2
4 Qualification test requirements	3
4.1 General	3
4.2 Welding processes	4
4.3 Welding positions	4
4.4 Product types/semi-finished products applicable to welder qualification tests	4
4.5 Material groups	5
4.6 Butt weld material thickness	6
4.7 Fillet weld material thickness	6
4.8 Special qualification tests	6
4.9 Designation for qualification test	7
5 Conditions required for welder and welding operator qualification tests.....	8
5.1 Physical requirements for welder and welding operator	8
5.2 Person responsible for welder and welding operator qualification tests	8
6 Performing the welder and welding operator qualification test	8
6.1 Practical qualification test	8
6.2 Theory test	9
7 Test pieces	9
8 Examination and testing	13
8.1 General	13
8.2 Visual and dimensional examination	14
8.3 Surface imperfection detection.....	14
8.4 Radiographic examination.....	14
8.5 Metallographic examinations	14
8.6 Bend test	14
8.7 Fracture surface examination	14
9 Acceptance criteria	14
10 Qualification test certificate and documentation	15
11 Period of validity of the qualification	15
12 Requalification test	16
Annex A (normative) Test piece acceptance criteria	17
Annex B (normative) Welder/welding operator qualification test record according to ISO 24394	22
Annex C (informative) Welder qualification test certificate	23
Annex D (informative) Welding operator qualification test certificate	24
Annex E (informative) Guidelines for the theory test.....	26
Bibliography.....	30

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 24394 was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*.

Requests for official interpretations of any aspect of this International Standard should be directed to the Secretariat of ISO/TC 44 via your national standards body, a complete listing which can be found at www.iso.org.

This corrected version of ISO 24394:2008 incorporates the following corrections:

- *page 1, Clause 2* — “:2007” has been added to ISO/TR 25901 and the reference transferred to the bibliography, with consequent renumbering of the bibliography entries;
- *page 5, Table 1* — thicker section separation lines have been added;
- *page 6, 4.7* — the heading and wording have been updated;
- *page 6, 4.8.1, last paragraph* — “piece” has been deleted;
- *page 9, 6.2* — “theoretical” has been deleted and “theory” added in two places;
- *page 13, Table 3, TP 1, paragraph 4* — “(see (8.4))” has been deleted, and “(see 8.4)” added;
- *page 14, 8.7* — “fracture examination” has been deleted, and “fracture surface examination” added in three places;
- *page 15, Clause 9* — addition of a new 1st sentence to the 4th paragraph;
- *page 16, penultimate paragraph* — “re-qualification” has been deleted and “requalification” added;
- *page 21, Table A.4* — in the last row, “ $\geq 0,2$ mm” has been deleted and “ $\leq 0,2$ mm” added;
- *page 23, Annex C and page 24, Annex D* — under “Description of special test conditions...”, the phrases “1. Notes on material and test piece dimensions” and “2. Notes on reservations and particulars” have been deleted.

Introduction

A welder or welding operator qualification test properly passed in accordance with this International Standard demonstrates that the welder or welding operator concerned has been proved to possess the minimum degree of skill and knowledge required for the fusion welding of aerospace hardware.

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Welding for aerospace applications — Qualification test for welders and welding operators — Fusion welding of metallic components

1 Scope

This International Standard specifies requirements for the qualification of welders and welding operators for the fusion welding of metallic materials for aerospace applications.

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 4063, *Welding and allied processes — Nomenclature of processes and reference numbers*¹⁾

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

ISO 6520-1:2007, *Welding and allied processes — Classification of geometric imperfections in metallic materials — Part 1: Fusion welding*

ISO 6947, *Welds — Working positions — Definitions of angles of slope and rotation*²⁾

ISO 8596, *Ophthalmic optics — Visual acuity testing — Standard optotype and its presentation*

ISO 9606-2, *Qualification test of welders — Fusion welding — Part 2: Aluminium and aluminium alloys*

ISO 14731, *Welding coordination — Tasks and responsibilities*

ISO 17636, *Non-destructive testing of welds — Radiographic testing of fusion-welded joints*

ISO 23277, *Non-destructive testing of welds — Penetrant testing of welds — Acceptance levels*

ISO 23278, *Non-destructive testing of welds — Magnetic particle testing of welds — Acceptance levels*

ASTM E 1742, *Standard practice for radiographic examination*

EN 462-1, *Non-destructive testing — Image quality of radiographs — Part 1: Image quality indicators (wire type) — Determination of image quality value*

EN 462-2, *Non-destructive testing — Image quality of radiographs — Part 2: Image quality indicators (step/hole type) — Determination of image quality value*

EN 462-3, *Non-destructive testing — Image quality of radiographs — Part 3: Image quality classes for ferrous metals*

1) To be published. (Revision of ISO 4063:1998)

2) To be published. (Revision of ISO 6947:1990)

EN 462-4, *Non-destructive testing — Image quality of radiographs — Part 4: Experimental evaluation of image quality values and image quality tables*

EN 4179, *Aerospace series — Qualification and approval of personnel for non-destructive testing*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 6520-1, ISO 9606-2, ISO 14731 and the following apply.

3.1

parent material form

type of the semi-finished product

NOTE Semi-finished products are sheets/plates, tubes and castings.

3.2

welder

person who holds and manipulates the electrode holder, welding torch or blowpipe by hand

[ISO/TR 25901:2007 ^[2]]

NOTE In this International Standard a blowpipe is considered to be a gas welding torch.

3.3

welding operator

(welding for aerospace applications) person who operates adaptive control, automatic, mechanized, or robotic welding equipment

3.4

examiner

person who has been appointed to verify compliance with the applicable standard

NOTE In certain cases, an external independent examiner can be required.

[ISO/TR 25901:2007 ^[2]]

3.5

examining body

organization appointed to verify compliance with the applicable standard

NOTE In certain cases, an external independent examining body can be required.

[ISO/TR 25901:2007 ^[2]]

3.6

rework

any corrective action made to a weldment in the as-welded condition

3.7

design/engineering authority

organization that has the responsibility for the structural integrity or maintenance of airworthiness of the hardware and compliance with all relevant documents

3.8

backing

material placed at the reverse side of a joint preparation for the purpose of supporting molten weld metal

[ISO/TR 25901:2007 ^[2]]

3.9**welding procedure specification****WPS**

document that has been qualified and provides the required variables of the welding procedure to ensure repeatability during production welding

[ISO/TR 25901:2007 ^[2]]

3.10**preliminary welding procedure specification****pWPS**

document containing the required variables of the welding procedure which has to be qualified

[ISO/TR 25901:2007 ^[2]]

4 Qualification test requirements**4.1 General****4.1.1 Specific to the welder qualification test**

The welder qualification tests are classified according to:

- a) parent material form;
- b) types of welds (butt/fillet);
- c) welding processes;
- d) material groups;
- e) thickness ranges;
- f) welding positions.

4.1.2 Specific to the welding operator qualification test

The welding operator qualification tests are classified according to:

- a) welding processes;
- b) material groups;
- c) thickness ranges.

In the practical part of the welding operator qualification test, a test weld of any product type/semi-finished product of any weld type shall qualify for all product types/semi-finished products and all weld types.

4.1.3 Common to the welder and welding operator qualification test

The welding coordinator of the plant or the fabricator selects from Table 2 the test piece as required for the production work on which the welder or welding operator will be employed. Two complementary specific test pieces (TP5 and TP6) may also be chosen as defined in 4.4 and 4.8.1.

4.2 Welding processes

This International Standard covers qualification testing for the following welding processes with their reference numbers in accordance with ISO 4063:1998:

- 111 Manual metal arc welding (metal arc welding with covered electrode)³⁾
- 12 Submerged arc welding³⁾
- 13 Gas-shielded metal arc welding
- 141 Tungsten inert gas welding (TIG welding)
- 15 Plasma arc welding
- 31 Oxy-fuel gas welding
- 51 Electron beam welding
- 52 Laser beam welding

NOTE Other fusion welding processes not yet specified in ISO 4063 may be covered.

4.3 Welding positions

Depending on welding positions in actual production, the welding position of the test piece shall be chosen in accordance with Table 1.

4.4 Product types/semi-finished products applicable to welder qualification tests

Depending on the types of products in actual production, a distinction is made between welder qualification tests for sheet/plate (S), tube (T), and castings (C).

A welder qualification test for sheet/plate (S) and tube (T) may be combined, see Table 1.

The range of qualification for each welding position is given in Table 1. The welding positions are specified in ISO 6947. The test pieces shall be welded in accordance with the nominal angles of the welding positions in accordance with ISO 6947.

Test piece TP5 (see Table 2) is mandatory for structural tube frameworks of outside diameter, $D < 26$ mm. It is optional for structural tube frameworks of $D \geq 26$ mm.

The welder qualification test for casting is intended for the repair of castings. Test piece TP6 (see Table 2) shall be used for qualification. Welds shall be made in welding positions PA or PB, which qualifies for all welding positions for casting repairs only.

Alternatively, a welder who is qualified to weld sheet/plate and tube is also authorized to repair castings, within his/her range of qualification.

3) This process may require a special qualification test as defined in 4.8.

Table 1 — Range of qualification for welding positions

Test piece (see Table 2)	Welding position of test piece according to ISO 6947:1990	Qualified welding position														
		Plate or tube $D > 26$ mm										Tube $D \leq 26$ mm				
		Butt weld				Fillet weld					Butt weld			Fillet weld		
		PA	PC	PE	PF	PA	PB	PC	PD	PF	PA	PC	PF	PB	PD	PF
	PA	X	—	—	—	—	—	—	—	—	X ^a	—	—	—	—	—
	PC	X	X	—	—	—	—	—	—	—	—	X ^a	—	—	—	—
	PE	X	X	X	—	—	—	—	—	—	—	—	—	—	—	—
	PF	X	—	—	X	—	—	—	—	—	—	—	—	—	—	—
	PA	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—
	PB	—	—	—	—	X	X	—	—	—	—	—	—	—	—	—
	PC	—	—	—	—	X	X	X	—	—	—	—	—	—	—	—
	PD	—	—	—	—	X	X	—	X	—	—	—	—	—	—	—
	PF	—	—	—	—	X	X	—	—	X	—	—	—	—	—	—
	PA	—	—	—	—	—	—	—	—	—	X ^b	—	—	—	—	—
	PC	X	X	—	—	—	—	—	—	—	—	X	—	—	—	—
	PF	X	—	X	X	—	—	—	—	—	X	—	X	—	—	—
	PB	—	—	—	—	(X)	(X)	—	—	—	—	—	—	X	—	—
	PD	—	—	—	—	(X)	(X)	—	(X)	—	—	—	—	X	X	—
	PF	—	—	—	—	(X)	(X)	—	—	(X)	—	—	—	X	—	X

X indicates those welding positions for which the welder is qualified.

(X) indicates those welding positions for which the welder is qualified for welding on tube $D > 26$ mm, but not on plate.

— indicates those welding positions for which the welder is not qualified.

^a Only applicable for a longitudinal weld on a tube.

^b Only applicable for a rotating tube with the torch in welding position PA.

4.5 Material groups

Depending on the application, the welder and welding operator qualification tests are subdivided into the following material groups.

Material group A: Unalloyed steel, low-alloyed steels, high-alloyed ferritic steels.

Material group B.1: Non precipitation hardenable high-alloyed austenitic steels, nickel alloys, cobalt alloys.

Material group B.2: Precipitation hardenable high-alloyed austenitic steels, nickel alloys, and cobalt alloys.

Material group C: Titanium and titanium alloys, niobium, zirconium and other reactive metals.

Material group D: Aluminium and magnesium alloys.

Material group E: Materials that do not conform to material groups A to D (e.g. molybdenum, tungsten, copper alloys).

Qualification of material group B.2 also qualifies material group B.1, but not vice versa.

4.6 Butt weld material thickness

A test piece of thickness, t , shall qualify a welder or welding operator to weld a thickness range of $0,67t$ to $4t$, except that when $t \geq 25$ mm, the qualification range is $0,67t$ to unlimited. Two independent test welds, of different material thicknesses, shall qualify all material thicknesses from the minimum to the maximum parent material thicknesses tested.

4.7 Fillet weld material thickness

A test piece of thickness, t_1 , shall qualify a welder or welding operator to weld a thickness range of $0,67t_1$ to $4t_1$, of the thinner material, except that when $t_1 \geq 25$ mm, the qualification range is $0,67t_1$ to unlimited. Two independent test welds, of different material thicknesses, shall qualify all material thicknesses from the minimum to the maximum parent material thicknesses tested.

4.8 Special qualification tests

4.8.1 General requirements

Any changes to the requirements defined in this International Standard are classified as special qualification tests.

As required by actual production, the welding coordinator shall specify the geometry of the test pieces, welding process, material, and material thickness range. A special qualification test only qualifies for welding under the specific conditions represented by the special qualification test.

If test methods are not in accordance with this International Standard, they shall be defined by the welding coordinator. The welding coordinator shall define additional test methods and also increase the quality requirements as defined by the design/engineering authority.

A special qualification test shall be marked with an "X" in the designation.

4.8.2 Special qualification tests for welders

Examples are:

- a) qualification for surfacing/cladding welds;
- b) qualification for welds with special condition for welding position and/or accessibility;
- c) qualification for restriction to weld only tack welds;
- d) qualification for welding test where start and end of weld seam is on additional material, to be cut off;
- e) qualification for butt welds without filler material;
- f) qualification for welds on dissimilar material groups;
- g) qualification for welds with backing.

A welder qualified for welding with backing may only weld using backing in production.

A welder qualified without using backing may weld with or without using backing in production.

4.8.3 Special qualification tests for welding operators

Examples are:

- a) qualification for surfacing/cladding welds;
- b) qualification for welds on dissimilar material groups.

4.9 Designation for qualification test

4.9.1 Welder qualification test

The designation for a welder qualification test comprises the following:

- "welder qualification test";
- number of this International Standard;
- welding processes code number according to ISO 4063;
- symbol of product type/semi-finished product (see 4.4);
- welding position and test piece number (see Table 1);
- material group (see 4.5);
- test piece material thickness (see 4.6 or 4.7);
- possibly X for a special qualification test (see 4.8).

EXAMPLE 1 Welder qualification test ISO 24394-31-S-PA1-A-t1

Explanation:

ISO 24394	= number of this International Standard
31	= welding process (oxyfuel gas welding; oxy-fuel gas welding)
S	= product type (sheet/plate)
PA1	= welding position and number of test piece (see Table 1)
A	= material group (see 4.5)
t1	= test piece material thickness 1 mm (see 4.6)

EXAMPLE 2 Welder qualification test ISO 24394-141-T-PF3-D-t1-X

Explanation:

ISO 24394	= number of this International Standard
141	= welding process (tungsten inert gas welding; TIG welding)
T	= product type (tube)
PF3	= welding positions PF and test piece 3 (see Table 1)
D	= material group (aluminium and magnesium alloys)
t1	= test piece material thickness 1 mm
X	= special qualification test

4.9.2 Welding operator qualification test

The designation for a welding operator qualification test comprises the following:

- "welding operator qualification test";
- number of this International Standard;
- welding processes code number in accordance with ISO 4063;
- material group (see 4.5);

- test piece material thickness (see 4.6. and 4.7);
- possibly X for a special qualification test (see 4.8).

EXAMPLE Welding operator qualification test ISO 24394-15-A-t1

Explanation:

ISO 24394	= number of this International Standard
15	= welding process (plasma arc welding)
A	= material group (unalloyed and low-alloyed steels, high-alloyed ferritic steels)
t1	= test piece material thickness 1 mm

5 Conditions required for welder and welding operator qualification tests

5.1 Physical requirements for welder and welding operator

Examine visual acuity (eyesight) in accordance with ISO 8596. The minimum acuity grade for a maximum distance of 400 mm shall be 0,8 reciprocal arc minutes for each eye. Corrective vision may be used to fulfil eye test requirements. Colour perception shall be examined, e.g. according to the Ishihara test.

Vision shall be tested to these requirements at least every 2 years.

5.2 Person responsible for welder and welding operator qualification tests

The welding coordinator (see ISO 14731) shall be designated, in writing, as responsible for welder and welding operator qualification test. This welding coordinator shall be an international welding engineer (IWE) or shall have similar knowledge, and be qualified by the responsible design authority or recognized examining body. The welding coordinator may authorize another person to conduct the welder or welding operator qualification test.

NOTE The person responsible for welder and welding operator qualification tests can differ from the person responsible for implementing 4.1.3.

6 Performing the welder and welding operator qualification test

6.1 Practical qualification test

6.1.1 General requirements

The requirements listed below, which are also applicable to any special qualification tests, shall be satisfied:

- a) all required parameter settings of the welding equipment shall be made by the welder or welding operator on his own in accordance with the welding procedure specification (WPS) or preliminary welding procedure specification (pWPS);
- b) welding may be performed with or without fixtures according to the WPS or pWPS;
- c) any rework performed on a test piece shall be performed using the WPS or pWPS valid for qualification testing — rework shall only be performed with the agreement of the person authorized to conduct the welder or welding operator qualification test;
- d) rework by welding on the root side of butt welds is not permitted;
- e) each test piece shall be clearly identified and traceable to the welder or welding operator;
- f) the welding wire, if required, shall be mentioned in the WPS or pWPS.

The welded test pieces shall be assessed by the person authorized to conduct the welder or welding operator qualification test and shall be clearly identified in the welder/welding operator qualification test record.

Annex B specifies minimum requirements for the content of the welder/welding operator qualification test record and recommends a format.

6.1.2 Specific requirements for the welder qualification test

The welding coordinator should choose the material that is most difficult to weld from the material group used by the welder in actual production. In the practical part of the welder qualification test, the welder shall weld the test pieces (see Table 2) of the related test, or according to special qualification tests defined by the welding coordinator, in line with specified conditions and under the surveillance of the person authorized to conduct the welder qualification test.

6.2 Theory test

A theory test is required. The content of the theory test and the grading shall be at the discretion of the welding coordinator. See Annex E for guidelines.

7 Test pieces

Test pieces (see Table 2) shall be applied according to the required welder qualification test, see 4.1.3.

Table 2 — Test pieces

Dimensions in millimetres

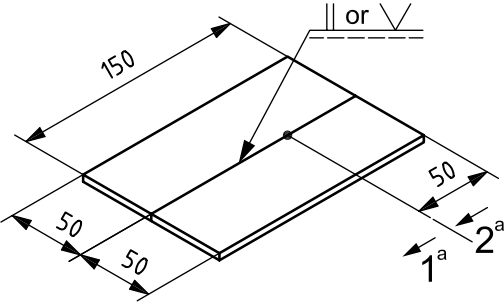
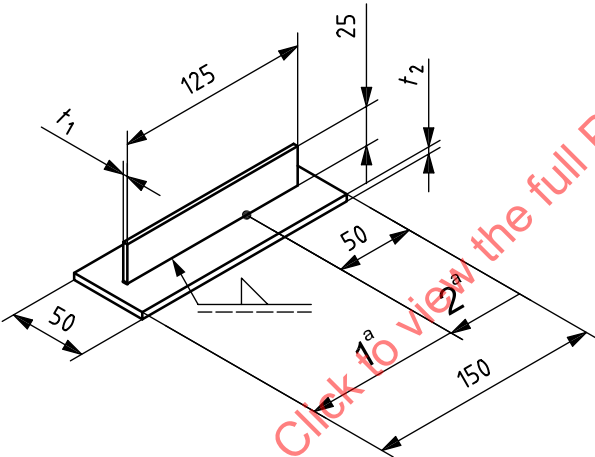
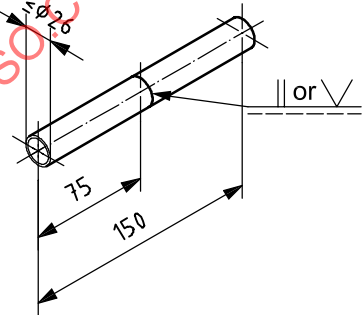
Test piece No.	Dimensions and welding conditions (Dimensions without tolerance indication are approximate values) Illustration	Remarks
TP1	 a welding sequence	
TP2	 a welding sequence	t_1: thinner plate/sheet, t_2: thicker plate/sheet $t_2 \geq 1,5 t_1$ NOTE Weld direction can be from right to left or left to right.
TP3		—

Table 2 (continued)

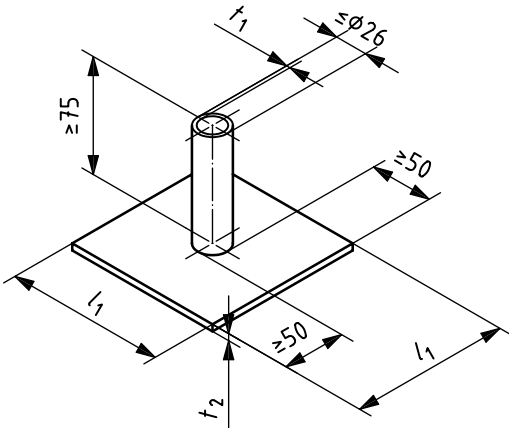
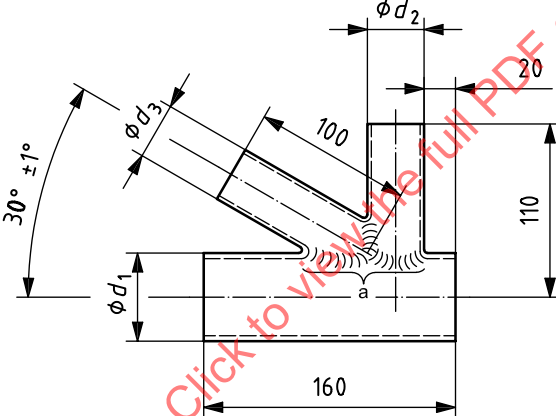
Test piece No.	Dimensions and welding conditions (Dimensions without tolerance indication are approximate values) Illustration	Remarks
TP4		$t_1 \leq t_2 \leq 1,5 t_1$
TP5	 a All welds indicated by rippling shall be performed.	Tube wall thickness and diameters occurring in production. Diameter ratios: $d_1 > 1,2 d_2$ $d_3 \leq d_2$ Tube axis: d_1: horizontal d_2: vertical

Table 2 (continued)

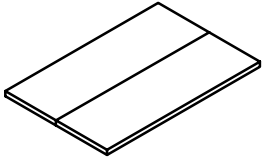
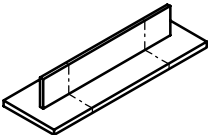
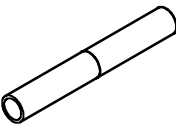
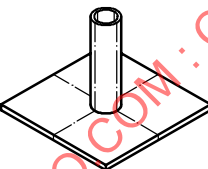
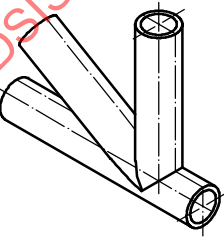
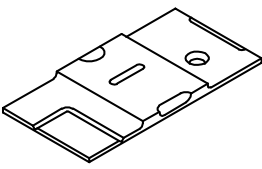
Test piece No.	Dimensions and welding conditions (Dimensions without tolerance indication are approximate values) Illustration	Remarks
TP6	Isometric view of the test piece showing various welds and dimensions. Dimensions and delivery conditions Side view dimensions: 3,5 ± 0,5, 1,3 ± 0,3, 60, 75°, 90°, R3, A, A, Ø10. Section A-A dimensions: 3, 5 x 45°, 8 ± 0,5, R3. Top view dimensions: 80, 3,5, R10, 30, 30, 30, 160, 30, 50, R3. All welds indicated by rippling shall be performed.	

8 Examination and testing

8.1 General

The test piece(s) shall be tested and examined in accordance with Table 3. The test results shall be documented in the welder/welding operator qualification test record in accordance with Annex B.

Table 3 — Test pieces and appropriate test methods

Test piece no. and designation	Illustration	Test method
TP1 Butt weld on plate/sheet		Visual inspection (see 8.2) Dimensional examination (see 8.2 and Table A.1) Surface imperfection detection (see 8.3) Radiographic examination (see 8.4), or, as an alternative, fracture test (see 8.7) or bend test (see 8.6) for test pieces in unalloyed steel
TP2 Fillet weld on plate/sheet		Visual inspection (see 8.2) Dimensional examination (see 8.2 and Table A.1) Surface imperfection detection (see 8.3) Examination of two macro-sections of fillet weld — one section shall be taken through the stop/start point
TP3 Butt weld on tube		Visual inspection (see 8.2) Dimensional examination (see 8.2 and Table A.1) Surface imperfection detection (see 8.3) Radiographic examination (see 8.4), or, as an alternative, fracture test (see 8.7) or bend test (see 8.6) for test pieces in unalloyed steel
TP4 Tube on plate		Visual inspection (see 8.2) Dimensional examination (see 8.2 and Table A.1) Surface imperfection detection (see 8.3) Examination of two macro-sections — one section shall be taken through the stop point
TP5 Structural tube framework		Visual inspection (see 8.2) Dimensional examination (see 8.2 and Table A.1) Surface imperfection detection (see 8.3) Examination of macro-sections of fillet welds in the parting faces of the symmetrically cut tube junction
TP6 Fill weld on casting		Visual inspection (see 8.2) Surface imperfection detection (see 8.3) Radiographic examination (see 8.4) — The unwelded casting blanks shall be radiographically examined in accordance with the applicable standards for castings in aerospace (e.g. ISO 17636) — the radiographic images shall be supplied with the casting

8.2 Visual and dimensional examination

Visual inspection shall be carried out with the test piece in the as-welded condition. Visual examination for external weld imperfections/features shall be performed at up to 10 times magnification, and with an angled mirror, if required.

Compliance with the specified test piece dimensions shall be checked. The angles of test piece TP5 shall be checked.

The weld geometries shall be measured with callipers, fillet weld gauges, or other suitable means. The actual dimensions shall be recorded in the welder/welding operator qualification test record form, see Annex B, and compared with criteria from Table A.1.

8.3 Surface imperfection detection

The test pieces shall be examined for surface imperfections. Suitable test methods are fluorescent penetrant testing (see ISO 23277) or magnetic particle testing (see ISO 23278) for material group A.

8.4 Radiographic examination

Radiographic examinations shall be defined by an approved level 3 in accordance with EN 4179 or equivalent, carried out in accordance with a suitable qualified standard (e.g. ISO 17636).

In the case of tube welds, at least two elliptical radiographic images offset by 90° shall be made per weld in accordance with ISO 17636. The radiographic images shall comply with EN 462-1, EN 462-2, EN 462-3, EN 462-4 or ASTM E 1742. Depending on the material thickness, the highest image quality value has to be achieved.

8.5 Metallographic examinations

Metallographic test specimens shall be prepared from test pieces TP2, TP4 and TP5 in accordance with the indications in Table 3. The weld cross-sections at 90° to the longitudinal direction of the weld shall be ground, polished and etched until the fusion line is visible. The sections shall be examined at a minimum of 10 times magnification for internal imperfections.

8.6 Bend test

A bend test, in accordance with a suitable qualified standard (e.g. ISO 5173), may be used as a substitute for, or in addition to, radiographic examination of butt welds and metallographic examination of fillet welds.

Any substitutions or additions shall be approved by the relevant design/engineering authority except for unalloyed steels, where this substitution can be used without special approval.

8.7 Fracture surface examination

The fracture surface examination is only applicable for material group A on oxyfuel welding.

If test pieces TP1 and TP3 are subjected to a fracture surface examination in accordance with Table 3, the test specimens shall be prepared to the tester's instructions in a manner that a fracture will occur in the weld when being bent over the face side. The weld fracture shall be checked at approximately 10 times magnification for internal imperfections in accordance with Table A.3.

9 Acceptance criteria

The test piece acceptance criteria shall be in accordance with the requirements of Tables A.1 to A.4.

For test piece TP6, the results shall be compared with the radiographic images that were taken before welding. The acceptance criteria given in the casting specification shall be used for the radiographs.

If a test piece fails to meet the acceptance criteria, an additional test piece may be welded. If this test piece also fails to meet the acceptance criteria, the test has been failed.

If the welder or welding operator fails the test, the candidate shall be given additional training or allowed to practice. The person authorized to conduct the welder's qualification test shall decide if and when a new test can be taken.

10 Qualification test certificate and documentation

A welder qualification test certificate (for an example of a form, see Annex C) or a welding operator qualification test certificate (for an example of a form, see Annex D) shall be used to document that the welder or welding operator has passed the qualification test. The qualification test designation (see 4.9) shall be stated. Special conditions (see 4.8) shall be stated under "Notes".

The welder or welding operator qualification test certificate is only valid when supplied with a comprehensive welder/welding operator qualification test record (for an example, see Annex B). The welder/welding operator qualification test record shall identify the materials used, test piece thicknesses, special test data (if applicable), and test results.

If actual production parts have been used for the requalification, the parts shall be clearly defined and all test records including, but not limited to, radiographic images shall be retained and traceable until expiration of the welder or welding operator qualification.

Test documents and test pieces/test specimens shall be retained until expiration of the period of validity of the welder or welding operator qualification test certificate.

The welder or welding operator qualification test certificate shall be signed and dated by the welding coordinator or the examining body. The qualification test record shall be signed and dated by either the examiner or the examining body.

Only welders or welding operators possessing a valid qualification test certificate (see Annexes B and C) are authorized to perform welding operations for aerospace applications.

11 Period of validity of the qualification

The welder or welding operator qualification test certificate is valid for a period of 2 years. By way of a requalification test, the qualification for welding with the corresponding processes, material groups, and product/semi-finished product types can be extended for another period of 2 years.

At any time during the period of validity, the welding coordinator shall request a requalification test if any of the following circumstances apply:

- a) there is a reason to question the ability of the welder or welding operator to meet the requirements for qualification;
- b) the welder or welding operator has not been working for more than 6 months with the welding process for which the welder or welding operator is qualified;
- c) unacceptable results of representative components.

12 Requalification test

For the requalification test, the same requirements as for the initial qualification tests apply.

For welders or welding operators performing specific repetitive tasks (such as surfacing or tack welding), the test pieces for requalification may be adapted to the geometry of components to be welded. These modifications are at the discretion of the welding coordinator (see 4.1).

For requalification tests on butt welds, actual production parts may be used to replace test pieces, if they are consistent with the requirements of the welding process, the material group and testing as identified in the respective initial qualification test.

When the requalification tests are conducted on production parts, a short description of the test conditions shall be added to the qualification test certificate.

Successful requalification tests shall be entered into the welder or welding operator qualification test certificate on the basis of the welder/welding operator qualification test record.

For the theory part of the test, see Annex E.

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Annex A (normative)

Test piece acceptance criteria

Table A.1 — Required dimensions and permissible deviations of form

Dimensions in millimetres

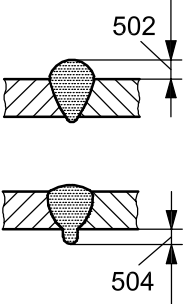
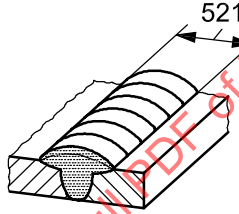
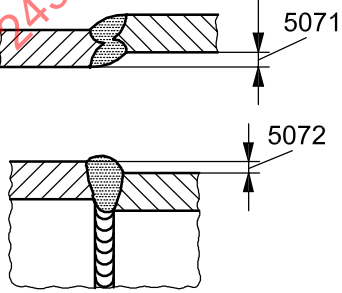
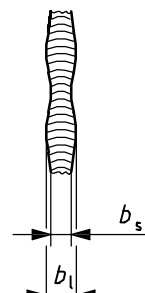
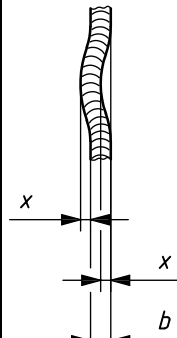
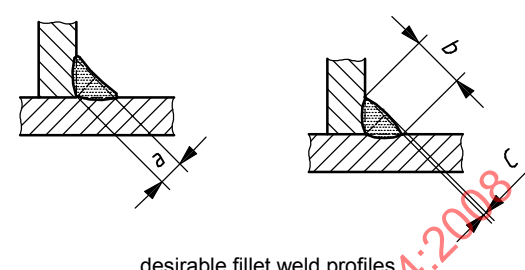
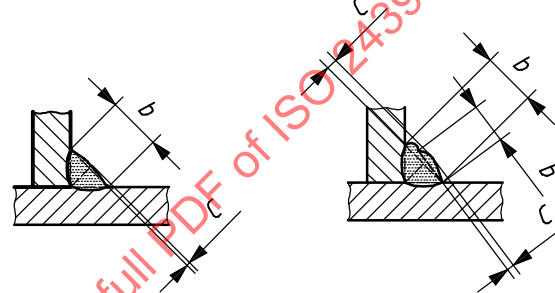
Imperfection ^a	Excess weld metal/excess penetration		Weld width of face side		Linear misalignment
	502/504		5212		5071/5072
Illustration ^a					
Material group	A B C E	D	A B C E	D	A B C D E
Determination	$x = 0,6t + 0,6 \text{ mm}^b$		$x = 0,2t + 1,8 \text{ mm}^b$ $b = 1,8t + 5 \text{ mm}$		$b = 2t + 6 \text{ mm}$
Test piece thickness, t^c , mm	max.	max.	max.	max.	max.
0,4	0,9	1,9	5,7	6,8	0,5t
0,5	0,9	1,9	5,9	7,0	
0,6	1,0	2,0	6,1	7,2	
0,8	1,1	2,0	6,4	7,6	
1,0	1,2	2,0	6,8	8,0	
1,2	1,4	2,1	7,2	8,4	
1,5	1,5	2,1	7,7	9,0	
1,6	1,6	2,2	7,9	9,2	
1,8	1,7	2,2	8,2	9,6	
2,0	1,8	2,2	8,6	10,0	
2,5	2,1	2,3	9,5	11,0	1,0
3,0	2,4	2,4	10,4	12,0	

Table A.1 (continued)

Dimensions in millimetres

Imperfection ^a	Weld width deviation ^d	Weld track deviation		Throat thickness ^e		
Illustration ^a		 Deviations from the intended weld track shall be smooth and uniform on the face side of the weld. Reject the weld otherwise.		 desirable fillet weld profiles		
				 acceptable fillet weld profiles		
Material group	A B C D E	A B C E	D	A B C D E	A B C E	D
Determination	$x = \frac{b_l - b_s}{b_l + b_s}$	$x = 0,25b_{\max}^f$ mm		$a = 0,4t + 0,8$ mm	$a = 0,4t + 2$ mm	$a = 0,4t + 3,1$ mm
Test piece thickness, t^c , mm	max.	max.	max.	min.	max.	max.
0,4	0,25	1,4	1,7	1,0	2,1	3,2
0,5		1,5	1,8	1,0	2,1	3,2
0,6		1,5	1,8	1,1	2,2	3,4
0,8		1,6	1,9	1,2	2,4	3,5
1,0		1,7	2,0	1,2	2,4	3,5
1,2		1,8	2,1	1,3	2,5	3,6
1,5		1,9	2,2	1,4	2,6	3,7
1,6		2,0	2,3	1,5	2,7	3,8
1,8		2,1	2,4	1,6	2,8	3,9
2,0		2,2	2,5	1,6	2,8	3,9
2,5		2,4	2,8	1,8	3,0	4,1
3,0		2,6	3,0	2,0	3,2	4,3

^a Reference number according to ISO 6520-1:2007 given, where available.

^b In case of misalignment, determination is to be made from the outermost surface.

^c For mating parts that have been fillet welded, the thickness of the thinner member shall be used.

^d b_l is the largest measured weld width and b_s is smallest measured weld width.

^e Convexity, C , of a weld or individual surface bead shall not exceed the following values:

Weld width of face side or individual surface bead, b , mm	Convexity, C , mm
$b \leq 8$	$\leq 1,6$
$8 \text{ mm} < b < 25 \text{ mm}$	≤ 3
$b \geq 25$	≤ 5

^f See column "Weld width of face side" for values of $b_{\max}$.

Table A.2 — Unacceptable surface imperfections

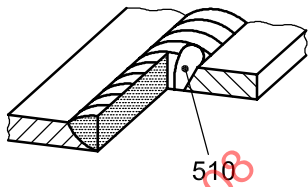
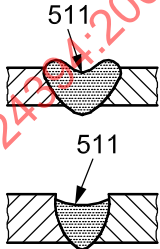
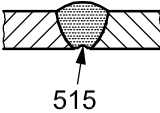
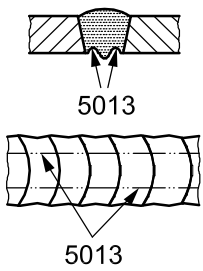
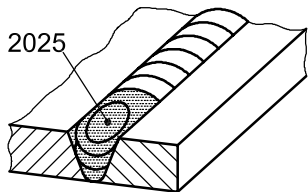
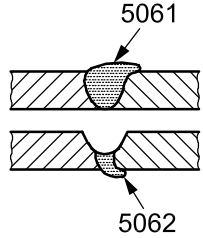
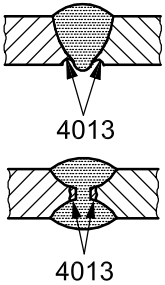
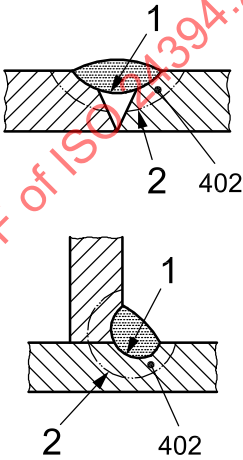
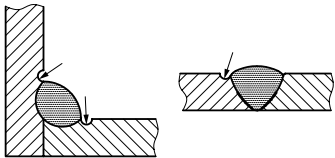
Reference number in accordance with ISO 6520-1:2007	Unacceptable imperfections	Illustration
100	Cracks	—
2018	Surface porosity	—
510	Burn-through	
(511)	Underfill ^a	
515	Root concavity	
601	Stray arc	—
5013	Shrinkage groove	
602	Spatter	—
—	Drop-through ^b	—
2025	End crater pipe	
506	Overlap	

Table A.2 (continued)

Reference number in accordance with ISO 6520-1:2007	Unacceptable imperfections	Illustration
4013	Lack of root fusion (incomplete root fusion)	
402	Incomplete penetration (lack of penetration)	 1 actual penetration 2 nominal penetration
501	Undercut ^a	
6101	Discoloration ^d	—
6021	Tungsten spatter	—

^a A butt weld condition in which the weld face or root surface is below the adjacent surface of the parent material (illustration given as "incompletely filled groove" in ISO 6520-1).

^b An undesirable sagging or surface irregularity, usually encountered when brazing or welding near the solidus of the parent material, caused by overheating with rapid diffusion or alloying between the filler material and the parent material.

^c Acceptable for welding without filler material (autogenous welding) with the following criteria: 0,05r or 0,5 mm, whichever is smaller.

^d Black discoloration on material groups B.1 and B.2; violet, green, blue, grey, white discoloration on material group C.

Table A.3 — Internal imperfections/features

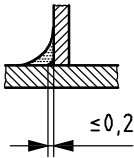
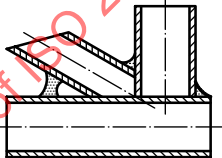
Reference number in accordance with ISO 6520-1:2007	Imperfections/features	Acceptance criteria
100	Cracks	not acceptable
200	Cavity (e.g. porosity)	see Table A.4
300	Solid inclusion	not acceptable
401	Lack of fusion (incomplete fusion)	not acceptable
402	Incomplete penetration (lack of penetration)	not acceptable
4021	Incomplete root penetration (on fillet weld)	not acceptable for material groups A, B, E ^a
^a See exceptions below.		
Dimensions in millimetres  For material group C and material thickness $t \leq 1,5$ mm, an imperfection $\leq 0,2$ mm is acceptable. For material group D, an imperfection $\leq 0,2$ mm is acceptable.  On test piece TP5 at the 30° angle, an incomplete root penetration of any size is acceptable.		

Table A.4 — Maximum size of cavities for butt welds

Dimensions in millimetres

Criteria	Material group	Test piece thickness, t							
		0,8	1,0	1,2	1,5	1,8	2,0	2,5	3,0
		Maximum size of cavities							
Individual size of cavity $0,3t$ (aluminium, $0,5t$) or 1,3 mm (aluminium, 1,6 mm), whichever is less.	A B C E	0,2	0,3	0,4	0,5	0,5	0,6	0,8	0,9
Distance between cavities shall be equal to or greater than twice the diameter of the larger adjacent cavity.	D	0,4	0,5	0,6	0,8	0,9	1,0	1,3	1,5
Accumulated length in any 76 mm of weld: maximum $1,33t$ or 6 mm, whichever is less.	A B C D E	1,1	1,3	1,6	2,0	2,4	2,7	3,3	4,0
Cavities $\leq 0,2$ mm are acceptable.									

Annex B (normative)

Welder/welding operator qualification test record according to ISO 24394

Company/department: _____

Address of test house/department: _____

Name of welder/welding operator: _____ Date of birth: _____

Identity number of welder/welding operator: _____

Welding process	pWPS or WPS-number	Product type or semi-finished product	Welding position	Test piece No.	Used for the test pieces		Results	Assessment p: pass f: fail
					Material and material condition	Thickness mm		
							obtained by (V) Visual examination (D) Dimensional examination (S) Surface imperfection detection (R) Radiographic examination (M) Metallographic examination (B) Bend test (F) Fracture surface examination Values/imperfections	

Examiner/examining body _____ Date: _____

Page: _____

Annex C
(informative)

Welder qualification test certificate

photograph

(if required)

Examiner/examining body or company

Certification of welder qualification test in accordance with ISO 24394

Qualification test certificate No.: _____ Welder's identity number: _____

Surname, first name: _____

Date of birth: _____

Address: _____

Manufacturer and location: _____

has on yyyy-mm-dd successfully passed the qualification test for welding on aerospace construction according to the welder qualification designation:

Description of special test conditions, if applicable:

This certificate will become invalid on yyyy-mm-dd (end of month of its date of issue +2 years), unless renewed by notation on the reverse side after passing a repeat test.

Place and date of issue: _____

Welding coordinator or examining body

Annex D
(informative)

Welding operator qualification test certificate

photograph

(if required)

Examiner/examining body or company

Certification of welding operator qualification test in accordance with ISO 24394

Qualification test certificate No.: _____ Welding operator identity number: _____

Surname, first name: _____

Date of birth: _____

Address: _____

Manufacturer and location: _____

has on yyyy-mm-dd successfully passed the qualification test for welding on aerospace construction according to the welding operator qualification designation:

Description of special test conditions, if applicable:

This certificate will become invalid on yyyy-mm-dd (end of month of its date of issue + 2 years), unless renewed by notation on the reverse side after passing a repeat test.

Place and date of issue: _____

Welding coordinator/examiner/examining body