
**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*

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 14, *Welding and brazing in aerospace*.

Any feedback, question or request for official interpretation related to any aspect of this document should be directed to the Secretariat of ISO/TC 44/SC 14 via your national standards body. A complete listing of these bodies can be found at www.iso.org/members.html. Official interpretations, where they exist, are available from this page: <https://committee.iso.org/sites/tc44/home/interpretation.html>.

This second edition cancels and replaces the first edition (ISO 24394:2008). It also incorporates the Amendment ISO 24394:2008/Amd 1:2012. The main changes compared to the previous edition are:

- the terms welding equipment operator and automatic welding have been introduced as [3.4](#) and [3.12](#);
- old subclause 4.1.3 has been moved to [4.1](#);
- requirements in [4.4](#) have been refined;
- Tables 1 to 4 have been created to present the ranges of qualification for welding positions for every test piece;
- in [4.5](#), material group F has been introduced;
- the header of [4.6](#) has been changed and new subclause [4.6.3](#) has been created;
- in [4.6.1](#) and [4.6.2](#), the qualification of thickness ranges has been clarified;
- requirements in [5.1](#) have been changed;
- a bullet list has been added to [6.1.1](#);
- in [6.2](#), a new requirement has been introduced that the theory test shall be documented;
- references to EN 462 series for radiographic images have been deleted;

- [Clause 9](#) has been reworded to clearly state that only the features created by welding shall be assessed for TP6;
- [Clause 10](#) has been changed so that if a welder/welding operator needs vision correction, it shall be noted on the test certificate;
- in Tables A.1 to A.4, new material group F has been included;
- the document has been editorially revised.

This corrected version of ISO 24394:2018 corrects [Table 4](#) and the footnotes to [Tables A.2](#) and [A.3](#).

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Introduction

A welder or welding operator qualification test properly passed in accordance with this document 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 document specifies requirements for the qualification of welders and welding operators for the fusion welding of metallic materials for aerospace applications.

NOTE Success in the test is an essential precondition for the qualification of welders (3.2) and welding operators (3.3) in new production and repair work in aerospace. However, welding equipment operators (3.4) do not need to be qualified according to this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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*

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

ISO 6947, *Welding and allied processes — Welding positions*

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

ISO 14731, *Welding coordination — Tasks and responsibilities*

ISO 18490, *Non-destructive testing — Evaluation of vision acuity of NDT personnel*

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

SAE AMS 2694C, *In-Process Welding of Castings*

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.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1

parent material form

type of the semi-finished product

Note 1 to entry: 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

Note 1 to entry: In this document, a blowpipe is considered to be a gas welding torch.

[SOURCE: ISO/TR 25901-1:2016, 2.5.24, modified — In the definition, the word “welding” has been added before “torch” and “during welding” has been replaced with “by hand” at the end. Also, Note 1 to entry has been added.]

3.3

welding operator

<welding for aerospace applications> person who prepares the joint and sets up mechanized or automated welding equipment and thereby has direct influence on the welded joint quality

3.4

welding equipment operator

<welding for aerospace applications> person who only operates automatic welding equipment and has no direct influence on the welded joint quality

3.5

examiner

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

Note 1 to entry: In certain cases, an external independent examiner can be required.

[SOURCE: ISO/TR 25901-1:2016, 2.5.29]

3.6

examining body

organization that has been appointed to verify compliance with the applicable standard

Note 1 to entry: In certain cases, an external independent examining body can be required.

[SOURCE: ISO/TR 25901-1:2016, 2.5.30]

3.7

rework

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

3.8

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

3.9

backing

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

3.10

welding procedure specification

WPS

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

[SOURCE: ISO/TR 25901-1:2016, 2.5.4]

3.11**preliminary welding procedure specification****pWPS**

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

[SOURCE: ISO/TR 25901-1:2016, 2.5.6, modified — In the definition, “has to” has been changed to “needs to”.]

3.12**automatic welding**

welding in which all operations are performed without welding operator intervention during the process

Note 1 to entry: Manual adjustment of welding variables by the welding operator during welding is not possible.

[SOURCE: ISO 14732:2013, 3.1]

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.

The welding coordinator of the plant or the fabricator shall select from [Table 6](#) the test piece as required for the production work on which the welder is to be employed. Two complementary specific test pieces (TP5 and TP6) may also be chosen as defined in [4.4](#) and [4.7.1](#).

4.1.2 Specific to the welding operator qualification test

The welding operator qualification tests are classified according to welding process and welding machine type.

NOTE Machine type within the scope of this document stands for longitudinal, orbital, circumferential and robotic welding machines.

For multiple welding machine types, additional qualification shall be at the discretion of the responsible welding coordinator.

The welding operator has to show theoretical knowledge of the welding process.

In the practical part of the qualification test, the welding operator shall demonstrate competency in operating the welding machine according to an established WPS.

A test weld of any type of weld with a process on a given welding machine type shall qualify for all product types/semi-finished products and all types of welds with this process and this machine type.

The test weld can be performed on dedicated test pieces or production parts.

When substituting test pieces with actual production parts, testing shall be carried out according to [Table 7](#).

4.2 Welding processes

This document 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)¹⁾
- 12 Submerged arc welding¹⁾
- 13 Gas-shielded metal arc welding
- 141 TIG welding with solid filler material (wire/rod)
- 15 Plasma arc welding
- 31 Oxy-fuel gas welding
- 51 Electron beam welding
- 52 Laser beam welding

NOTE 1 Other fusion welding processes not yet specified in ISO 4063 can be covered.

NOTE 2 Attention is drawn to the fact that ISO 4063:1998 and ISO 4063:2009 sometimes have different processes for the same process number. The main differences are as follows (see [Table 1](#)):

- a) process designation was changed or modified for processes 121, 131, 135, 136 and 141;
- b) process 137 was split into processes 132 and 133;
- c) process 136 was split into processes 136 and 138.

Table 1 — Equivalent process numbers and designations between ISO 4063:1998 and ISO 4063:2009

Process number	Process designation in ISO 4063:1998	Process designation ISO 4063:2009
121	Submerged arc welding with one wire electrode	Submerged arc welding with solid wire electrode
131	Metal inert gas welding; MIG welding	MIG welding with solid wire electrode
132	—	MIG welding with flux cored electrode
133	—	MIG welding with metal cored electrode
135	Metal active gas welding; MAG welding	MAG welding with solid wire electrode
136	Tubular cored metal arc welding with active gas shield	MAG welding with flux cored electrode
137	Tubular cored metal arc welding with inert gas shield	—
138	—	MAG welding with metal cored electrode
141	Tungsten inert gas welding; TIG welding	TIG welding with solid filler material (wire/rod)

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 2](#), [Table 3](#), [Table 4](#) and/or [Table 5](#).

1) This process can require a special qualification test as defined in [4.7](#).

A test piece welded in the fixed position also qualifies for welding parts when not in the fixed position, e.g. rotational turntable for tubes.

TP6 shall be welded in PA or PB, which qualifies for all welding positions for in-process welding of castings in casting facilities.

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).

Test pieces with tube (TP3, TP4 and TP5) do not qualify for sheet/plate.

NOTE 1 Tube welding has overlapping start and stop points. This is not the case for sheet or plate welding. Therefore, test pieces with tube (TP3, TP4 and TP5) do not qualify for sheet/plate.

The range of qualification for each welding position is given in [Table 2](#), [Table 3](#), [Table 4](#) and [Table 5](#). 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 6](#)) is mandatory for structural tube frameworks of outside diameter, $D < 26$ mm. It is optional for structural tube frameworks of $D \geq 26$ mm.

Test piece TP 6 is required for in-process welding of castings in casting facilities.

NOTE 2 Within the scope of this document, in-process welding is welding on castings to correct casting defects.

Excluding in-process welding in casting facilities, a welder who is qualified to weld sheet/plate or tube is also qualified to weld on castings within his/her range of qualification regarding the welding position and geometric shape of the work piece (planar or tubular).

NOTE 3 Casting facilities are excluded because casting methods and in-process welding of castings are subject to specific engineering requirements.

In instances of structural welding of castings requiring specific welding techniques, e.g. Nickel Alloy 718, the welder qualification test pieces (TP1 to TP4) shall be of the same casting alloy.

As an alternative, qualifications per SAE AMS 2694C are acceptable for in-process welding of castings, but the period of validity according to [Clause 11](#) applies.

Table 2 — Range of qualification for welding positions, joint type and base metal form for TP1

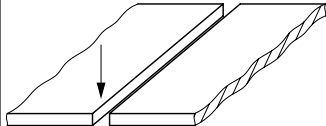
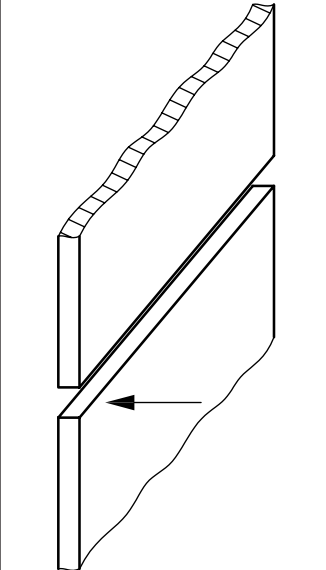
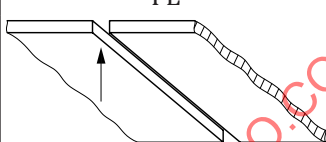
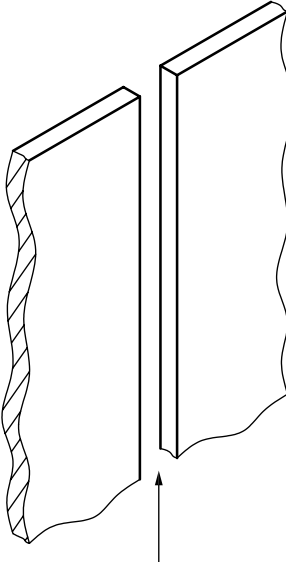
Test weld		Qualified welding position(s)								
Form/Joint type	Test piece welding position (ISO 6947)	Sheet/Plate				Tube				
		Butt weld								
		PA	PC	PE	PF	PA	PC	PE	PF	H-L 045
Sheet/ Plate/ Butt weld	PA 	X				X ^{a,b}				
	PC 	X	X			X ^{a,b}	X ^{a,b,c}			
	PE 	X		X		X ^{a,b}		X ^{a,b}		
NOTE 1 X indicates for which the welder is qualified.										
NOTE 2 Arrows of PA, PB and PC show the welding position.										
NOTE 3 Arrow to PF shows the weld progression or direction.										
^a Applicable for longitudinal weld on a tube.										
^b Applicable for circumferential weld on rotating tube, if tube diameter is $D > 26$ mm.										
^c Applicable for circumferential weld on tube in fixed position, if tube diameter is $D > 26$ mm.										

Table 2 (continued)

Test weld		Qualified welding position(s)								
		Sheet/Plate				Tube				
Form/Joint type	Test piece welding position (ISO 6947)	Butt weld								
		PA	PC	PE	PF	PA	PC	PE	PF	H-L 045
	PF 	X			X	X ^{a,b}			X ^{a,b}	

NOTE 1 X indicates for which the welder is qualified.

NOTE 2 Arrows of PA, PB and PC show the welding position.

NOTE 3 Arrow to PF shows the weld progression or direction.

^a Applicable for longitudinal weld on a tube.

^b Applicable for circumferential weld on rotating tube, if tube diameter is $D > 26$ mm.

^c Applicable for circumferential weld on tube in fixed position, if tube diameter is $D > 26$ mm.

Table 3 — Range of qualification for welding positions, joint type and base metal form for TP2

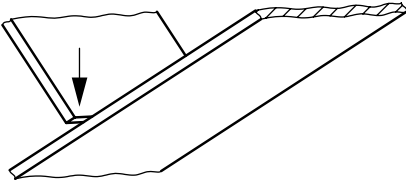
Test weld		Qualified welding position(s)				
		Sheet/Plate				
Form/Joint type	Test piece welding position (ISO 6947)	Fillet weld				
		PA	PB	PC	PD	PF
	PA 	X				
NOTE 1 X indicates for which the welder is qualified. NOTE 2 Arrows of PA, PB, PC and PD show the welding position NOTE 3 Arrow to PF shows the weld progression or direction.						

Table 3 (continued)

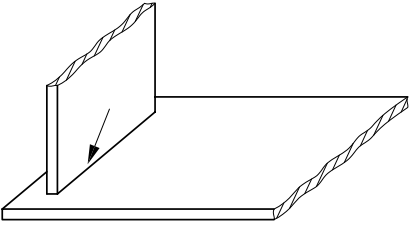
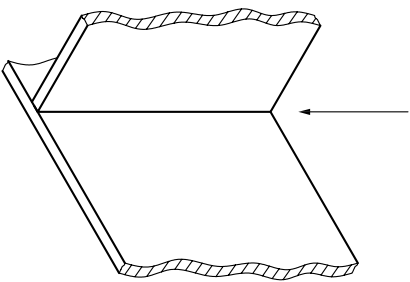
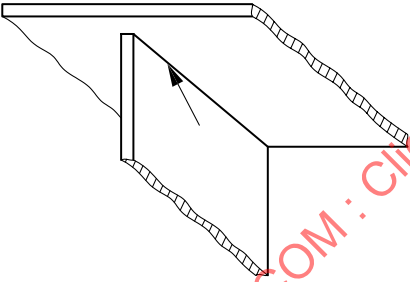
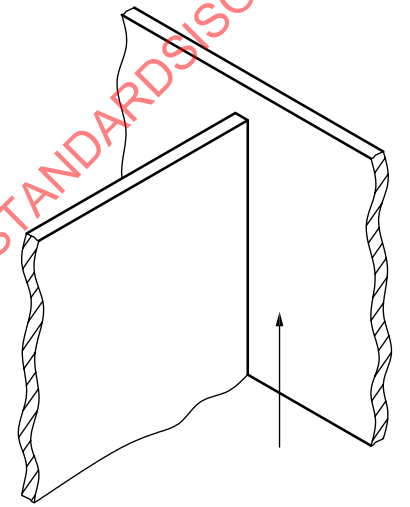
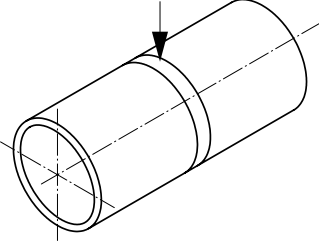
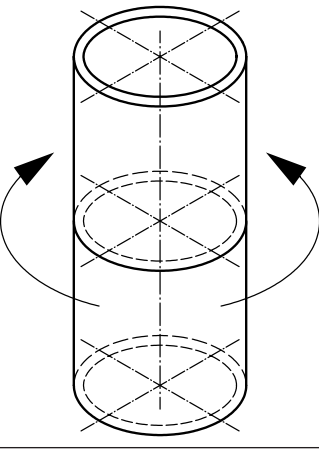
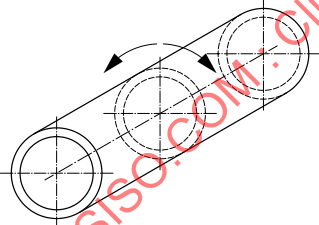
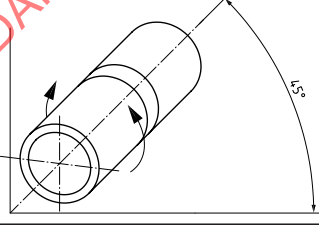
Test weld		Qualified welding position(s)				
Form/Joint type	Test piece welding position (ISO 6947)	Sheet/Plate				
		Fillet weld				
		PA	PB	PC	PD	PF
Sheet/ Plate/ Fillet weld	PB 	X	X			
	PC 	X	X	X		
	PD 	X	X		X	
	PF 	X	X			X
NOTE 1 X indicates for which the welder is qualified. NOTE 2 Arrows of PA, PB, PC and PD show the welding position NOTE 3 Arrow to PF shows the weld progression or direction.						

Table 4 — Range of qualification for welding positions, joint type and base metal form for TP3

Form/Joint type	Test weld	Qualified welding position(s)					
		Butt weld on tube			Butt weld on sheet/plate ^b		
		PA	PC	PH	PA	PC	PF
Tube/ Butt weld	PA ^a 	X					
	PC ^c 	X ^a	X				
	PH 	X ^a		X			
	H-L045 	X ^a	X	X			

NOTE 1 The qualification is valid for any tube of outer diameter equal to or larger than the outer diameter of the test piece.

NOTE 2 Arrows of PA and PC show the welding position

NOTE 3 Arrow to PH and H-L045 show the weld progression or direction.

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

^b Qualification is only valid for sheet/plate, if run-on and run-off tabs are used in production.

^c Pipe is not rotating during welding. Only one welding direction is required.

Table 5 — Range of qualification for welding positions, joint type and base metal form for TP4

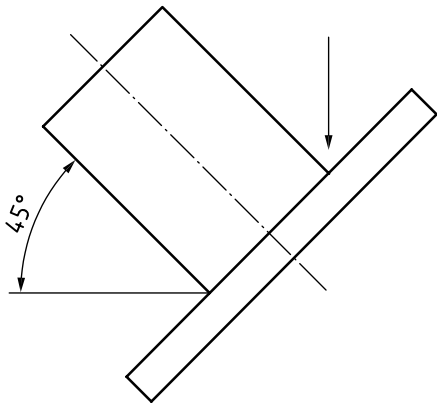
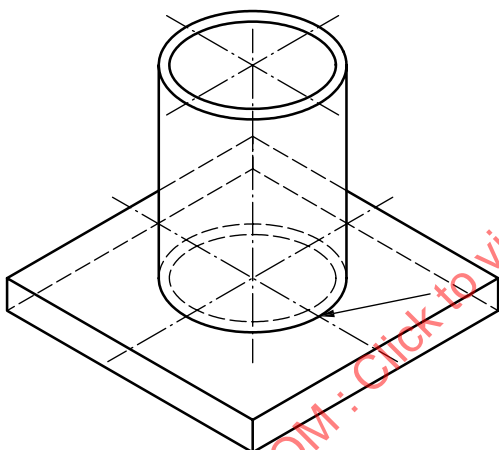
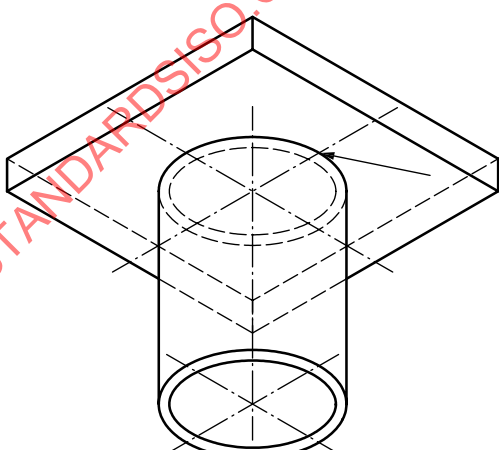
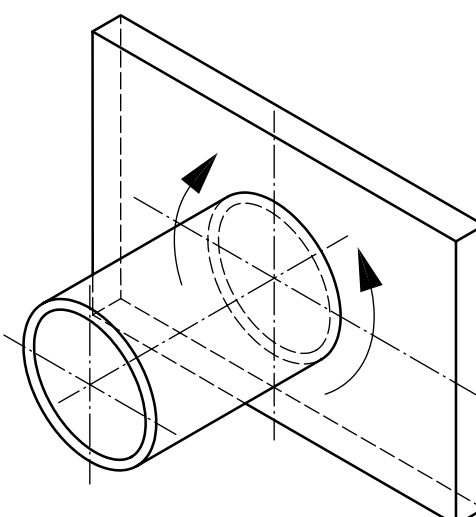
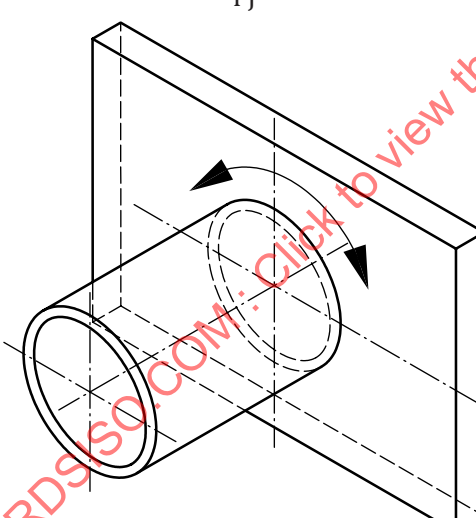
Form/Joint type	Test weld Test piece welding position (ISO 6947)	Qualified welding position(s)				
		Tube to sheet/plate fillet weld				
		PA	PB	PD	PH	PJ
Tube to sheet/ plate/fillet weld	PA 	X ^a				
	PB 	X ^a	X			
	PD 	X ^a	X	X		
NOTE 1 The qualification is valid for any tube of outer diameter equal to or larger than the outer diameter of the test piece. NOTE 2 Arrows of PA, PB and PD show the welding position NOTE 3 Arrow to PH and PJ show the weld progression or direction. ^a Only applicable for a rotating tube to sheet/plate assembly with the torch in welding position PA.						

Table 5 (continued)

Form/Joint type	Test weld Test piece welding position (ISO 6947)	Qualified welding position(s)				
		Tube to sheet/plate fillet weld				
		PA	PB	PD	PH	PJ
	PH 	X ^a	X		X	
	PJ 	X ^a	X			X
NOTE 1 The qualification is valid for any tube of outer diameter equal to or larger than the outer diameter of the test piece. NOTE 2 Arrows of PA, PB and PD show the welding position NOTE 3 Arrow to PH and PJ show the weld progression or direction. ^a Only applicable for a rotating tube to sheet/plate assembly with the torch in welding position PA.						

4.5 Material groups

The welder qualification tests are subdivided into the following material groups.

- Material group A: Unalloyed steel, low-alloyed steels, high-alloyed ferritic steels.
- Material group B: Austenitic, martensitic and precipitation hardening steels.
- 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 other material groups (e.g. molybdenum, tungsten, copper alloys).
- Material group F: Nickel alloys, cobalt alloys.

A test piece made in material groups A, B, C, D and E only qualifies for welding in the same material group.

A test piece made in material group F qualifies for welding in material group F, and also for welding in austenitic materials of group B but not vice versa.

4.6 Material thickness

4.6.1 Butt weld material thickness

A test piece of thickness, t , shall qualify a welder 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 pieces, of different material thicknesses t , shall qualify butt welding of all intermediate thicknesses.

4.6.2 Fillet weld material thickness

A test piece of thickness, t_1 , shall qualify a welder 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 pieces, of different material thicknesses t_1 , shall qualify fillet welding of all intermediate thicknesses of the thinner members.

4.6.3 Casting repair material thickness

Welding of test piece TP 6 qualifies for all material thicknesses for in-process welding of castings in casting facilities.

4.7 Special qualification tests

4.7.1 General requirements

Any changes to the requirements defined in this document 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 document, 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.

4.7.2 Special qualification tests for welders

Examples are:

- qualification for surfacing/cladding welds;
- qualification for welds with special condition for welding position and/or accessibility;
- qualification for restriction to weld only tack welds;
- 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;
- h) qualification for welding positions that are not covered by [Tables 2](#) to [5](#).

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.

4.7.3 Special qualification tests for welding operators

Examples are:

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

4.8 Designation for qualification test

4.8.1 Welder qualification test

The designation for a welder qualification test comprises the following:

- "welder qualification test";
- reference to this document (i.e. ISO 24394);
- welding processes code number according to ISO 4063:1998;
- symbol of product type/semi-finished product (see [4.4](#));
- welding position and test piece number (see [Tables 2](#) to [5](#));
- material group (see [4.5](#));
- test piece material thickness (see [4.6](#));
- possibly X for a special qualification test (see [4.7](#)).

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

Explanation:

ISO 24394 is the number of this document;

31 is the welding process (oxyfuel gas welding; oxy-fuel gas welding);

S is the product type (sheet/plate);

PA1 is the welding position and number of test piece (see [Table 2](#) or [3](#));

A is the material group (see [4.5](#));

t1 is the test piece material thickness 1 mm (see [4.6](#)).

EXAMPLE 2 Welder qualification test ISO 24394-141-T-PF3-D-t1-d10-X.

Explanation:

ISO 24394 is the number of this document;

141 is the welding process (tungsten inert gas welding; TIG welding);

T is the product type (tube);

PF3 is the welding position PF and test piece 3 (see [Table 4](#));

D is the material group (aluminium and magnesium alloys);

t1 is the test piece material thickness 1 mm;

d10 is the outside pipe diameter 10 mm;

X is the special qualification test (e.g. with backing).

4.8.2 Welding operator qualification test

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

- "welding operator qualification test";
- reference to this document (i.e. ISO 24394);
- welding processes code number in accordance with ISO 4063:1998;
- possibly X for a special qualification test (see [4.7](#)).

EXAMPLE Welding operator qualification test ISO 24394-15-robotic.

Explanation:

ISO 24394 is the number of this document

15 is the welding process (plasma arc welding)

robotic is the robotic welding machine

5 Conditions required for welder and welding operator qualification tests

5.1 Physical requirements for welder and welding operator

The candidate shall provide documented evidence of satisfactory vision in accordance with the following requirements. Any limitations (e.g. visual aids when required to pass the eye sight test), shall be documented on the welder/welding operator test certificate. Any limitations in colour perception shall be evaluated by the welding coordinator prior to certification and shall be approved in writing.

Eye sight requirements shall be achieved by using one eye or both eyes. The candidate shall successfully achieve the near vision acuity and colour perception specified herein.

Eye sight tests shall be administered by competent personnel.

The method for testing near vision acuity shall be chosen from one of the following:

- a) Jaeger No. 2 eye chart at approximately 400 mm;

- b) Visus 0,8 at approximately 400 mm;
- c) Eye sight requirements of EN 4179/NAS 410 or ISO 18490.

NOTE The results of the 3 near vision testing methods are not fully comparable.

Colour perception shall be examined by a suitable method, e.g. the Ishihara test.

Near vision shall be tested to these requirements at least every 2 years. Colour perception shall be tested to these requirements at least every 5 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, requalification test and disqualification (see [Clause 11](#)). The welding coordinator shall have knowledge and experience relevant to the welding process, and be acceptable to the responsible design authority or recognized examining body. The welding coordinator may authorize another person to administer 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 [4.1.1](#).

6 Performing the welder and welding operator qualification test

6.1 Practical qualification test

6.1.1 General requirements

The provisions 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;
- g) when welding the test pieces, these shall be in a fixed position.

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 6](#)) 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 and shall be documented. See [Annex E](#) for guidelines.

7 Test pieces

Test pieces (see [Table 6](#)) shall be applied according to the required welder qualification test, see [4.1.1](#).

Table 6 — Test pieces

Dimensions in millimetres

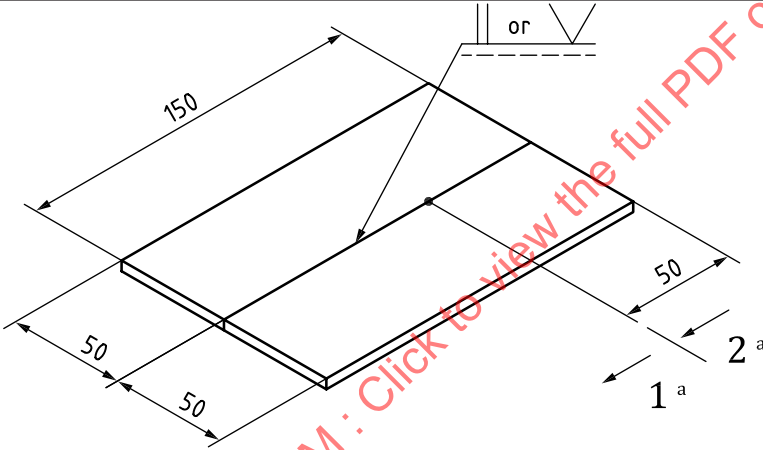
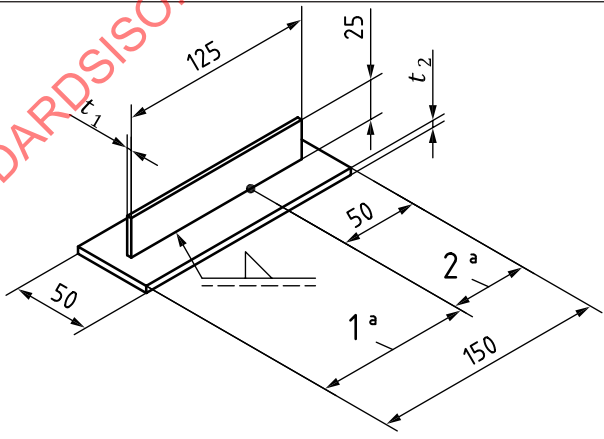
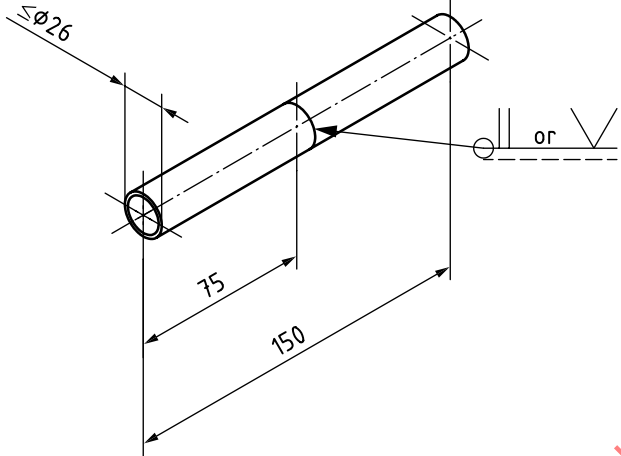
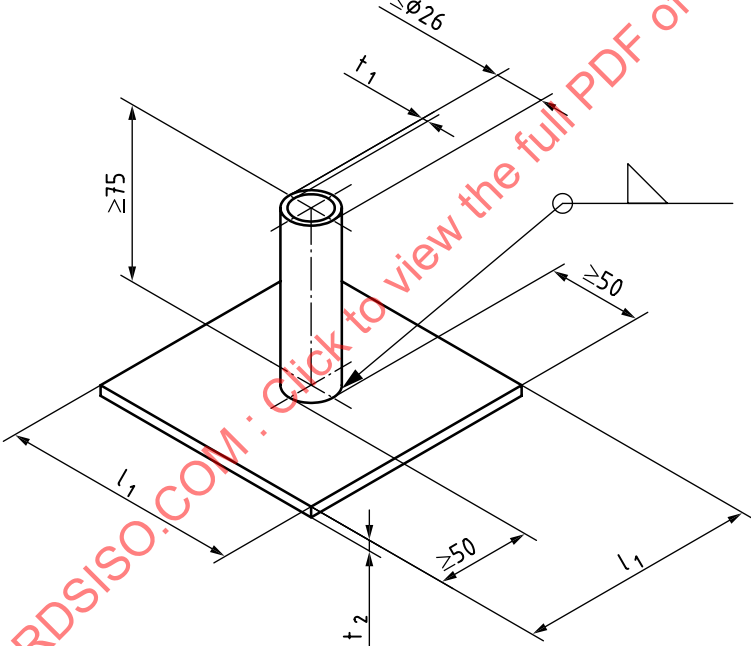
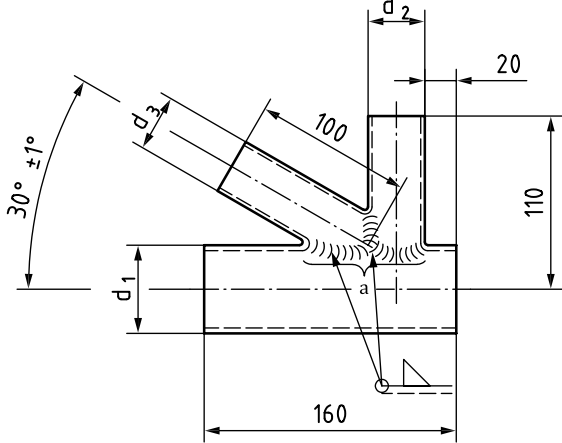
Test piece No.	Dimensions and welding conditions (Dimensions without tolerance indication are approximate values) Illustration	Remarks
TP1	 ^a Welding sequence — for materials susceptible to cracking, the welding sequence may be altered.	—
TP2	 ^a Welding sequence.	t_1: thinner sheet/plate t_2: thicker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

Table 6 (continued)

Test piece No.	Dimensions and welding conditions (Dimensions without tolerance indication are approximate values) Illustration	Remarks
TP3		—
TP4		$t_1 \leq t_2 \leq 1,5 t_1$
TP5		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

^a All welds indicated by rippling shall be performed.

Table 6 (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 a rectangular plate with a central rectangular cutout and four circular holes. The plate has a thickness of 3 mm and a central cutout of 60 mm by 60 mm. The holes have a diameter of 10 mm. The plate is welded to a base plate with a thickness of 8 mm. The welds are indicated by rippling. Dimensions and delivery conditions Top view: Overall dimensions 160 mm by 80 mm. Central cutout 60 mm by 60 mm. Four circular holes with diameter 10 mm. Distances between holes and cutout edges are 30 mm. Corner radius R3. Edge thickness 3.5 ± 0.5 mm. Internal thickness 1.3 ± 0.3 mm. 90° angle. Section A-A: Thickness 3 mm. Corner radius R3. 75° angle. 5 x 45° chamfer. 8 ± 0.5 mm dimension. Bottom view: Overall dimensions 160 mm by 80 mm. Central cutout 60 mm by 60 mm. Four circular holes with diameter 10 mm. Distances between holes and cutout edges are 30 mm. Corner radius R3. Edge thickness 3.5 mm. Internal thickness 8 mm. 50 mm dimension. 30 mm dimension. 30 mm dimension. 160 mm dimension. 80 mm dimension. 3.5 mm dimension. R10 radius. R3 radius. ^a 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 7](#). Additional testing may be applied at the discretion of the welding coordinator. The test results shall be documented in the welder/welding operator qualification test record in accordance with [Annex B](#).

Table 7 — Test pieces and appropriate test methods

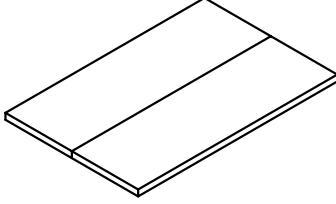
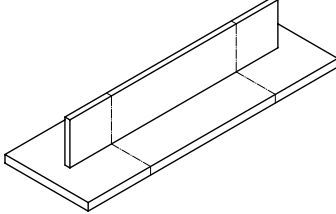
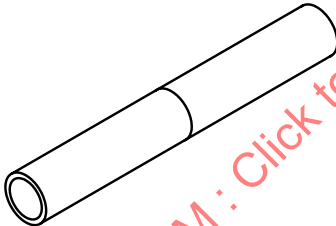
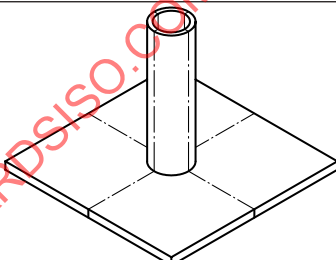
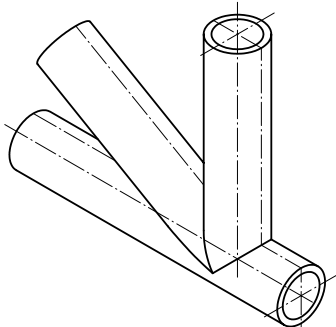
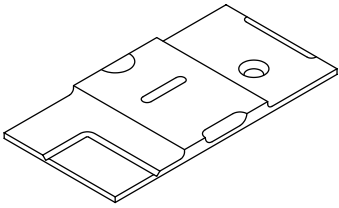
Test piece No. and designation	Illustration	Test method
TP1 Butt weld on sheet/plate		Visual inspection (see 8.2) Dimensional examination (see 8.2 and Table A.1) Surface imperfection detection (see 8.3) Radiographic examination (see 8.4), or, as an alternative, fracture test (see 8.7) or bend test (see 8.6) for test pieces in unalloyed steel
TP2 Fillet weld on sheet/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 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 to sheet/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 One section shall be taken at a location that represents the welding position to be tested (e.g. PH or PJ position)
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

Table 7 (continued)

Test piece No. and designation	Illustration	Test method
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 (all parts)] — 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 17636-1/ISO 17636-2 or ASTM E 1742).

Depending on the material thickness, the highest image quality value shall 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 7](#). 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 7](#), 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. Only the features created by welding shall be assessed. Any indications that have existed in the casting before welding shall be disregarded. 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.

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

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 [4.8](#)) shall be stated. Special conditions (see [4.7](#)) shall be stated under "Notes". It shall also be noted if a welder/welding operator needs corrected vision to pass the eyesight test.

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 at least 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 C](#) and [D](#)) are authorized to perform welding operations for aerospace applications.

11 Period of validity of the qualification

All new qualifications and any requalification shall be in accordance with this document from the date of issue.

The initial welder or welding operator qualification test certificate is valid for a period of 2 years. Certification is considered to expire at the end of the corresponding month in which the test pieces had been welded.

The welder or welding operator test certificate shall be renewed every two years, according to [Clause 12](#).

At any time during the period of validity, the welding coordinator shall disqualify the welder or welding operator and request a qualification 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.

Qualifications to previous revisions of this document remain valid within the limits given in the preceding.

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 of welders, actual production parts may be used to replace test pieces, if they are consistent with the requirements of the welding process, the material group, the welding position and testing as identified in the respective initial qualification test, e.g. requirements given in [Tables 2](#) to [5](#) and [Table 7](#).

For requalification tests of welding operators, the same requirements as given in [4.1.2](#) apply.

When the requalification tests of welders/welding operators 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](#).

Annex A (normative)

Test piece acceptance criteria

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

Dimensions in millimetres

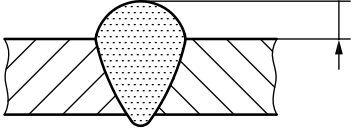
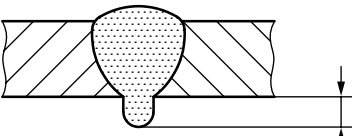
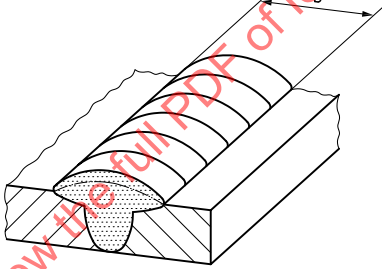
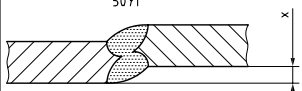
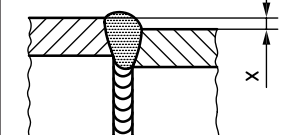
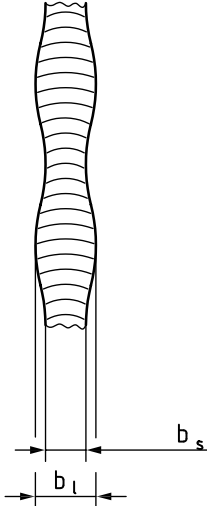
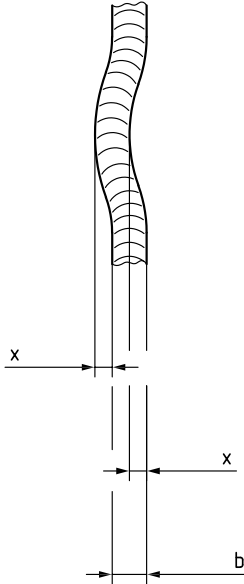
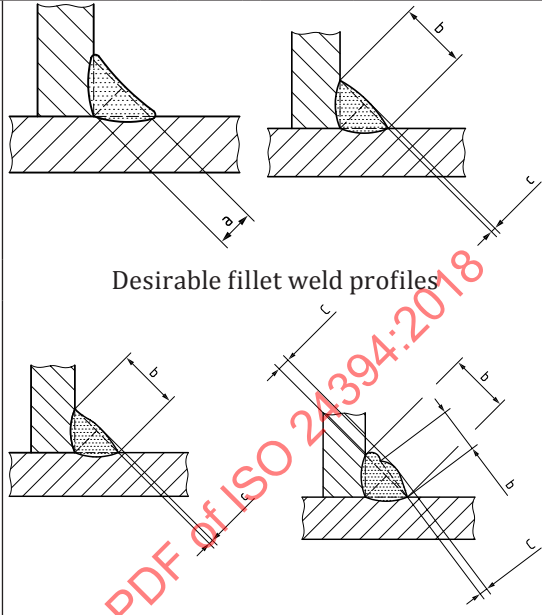
Imperfection ^a	Excess weld metal/ excess penetration 502/504		Weld width of face side 5212		Linear misalignment 5071/5072
Illustration ^a	502  504 				5071  5072 
Material group	A B C E F	D	A B C E F	D	A B C D E F
Determination	$x = 0,6t + 0,6 \text{ mm}^b$	$x = 0,2t + 1,8 \text{ mm}^b$	$b = 1,8t +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

Table A.1 (continued)

Imperfection ^a	Weld width deviation ^d	Weld track deviation	Throat thickness ^e			
Illustration ^a						
Material group	A B C D E F	A B C E F D	A B C D E F A B C E F D			
Determination	$x = \frac{[2(b_l - b_s)]}{(b_l + b_s)}$	$x = 0,25b_{\max.}^f$	$a = 0,7t$ $a = 0,4t + 2 \text{ mm}$ $a = 0,4t + 3,1 \text{ mm}$			
Test piece thickness, t^c	max.	max. max.	min. max. max.			
0,4	25 %	1,4	1,7	0,3	2,1	3,2
0,5		1,5	1,8	0,4	2,1	3,2
0,6		1,5	1,8	0,4	2,2	3,4
0,8		1,6	1,9	0,6	2,4	3,5
1,0		1,7	2,0	0,7	2,4	3,5
1,2		1,8	2,1	0,8	2,5	3,6
1,5		1,9	2,2	1,1	2,6	3,7
1,6		2,0	2,3	1,1	2,7	3,8
1,8		2,1	2,4	1,3	2,8	3,9
2,0		2,2	2,5	1,4	2,8	3,9
2,5		2,4	2,8	1,8	3,0	4,1
3,0		2,6	3,0	2,1	3,2	4,3

^a Ordinal number according to ISO 6520-1 given, where available.

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

^c For fillet mating parts of non-uniform thicknesses, the smaller thickness shall be taken as reference.

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

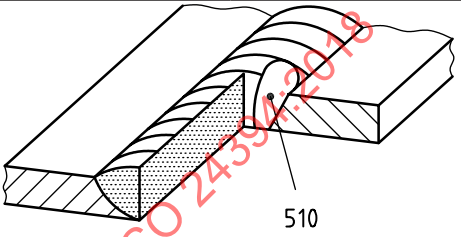
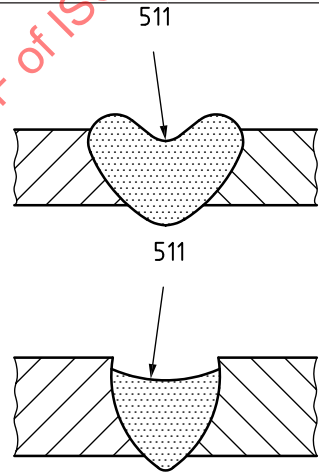
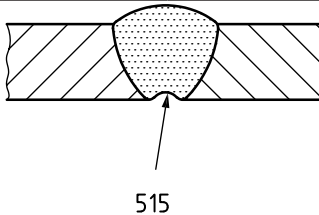
^e Convexity, C , of a weld or individual surface bead b shall not exceed the following values:

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

Table A.1 (continued)

^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	—

^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).

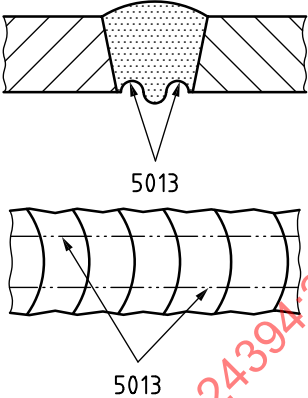
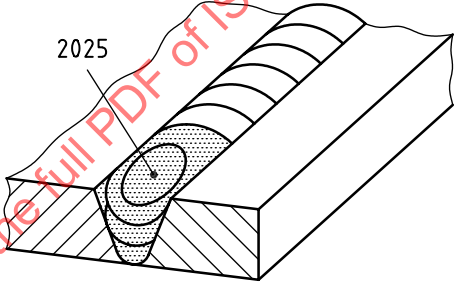
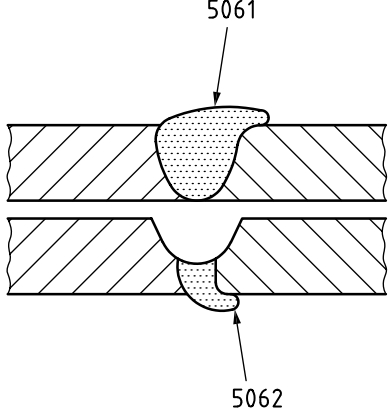
^b Acceptable for welding without filler material (autogenous welding) with the following criteria: 0,05t or 0,5 mm, whichever is smaller.

^c Black discolouration on material groups B and F; violet, green, blue, grey, white discolouration on material group C. For material group E the discolouration criteria shall be defined by the engineering authority.

^d Spatter may be acceptable on welding processes or materials where it cannot be avoided. In such cases, the acceptability is at the discretion of the welding coordinator.

^e Nominal penetration is required.

Table A.2 (continued)

Reference number in accordance with ISO 6520-1:2007	Unacceptable imperfections	Illustration
5013	Shrinkage groove	
602	Spatter ^d	
2025	End crater pipe	
506	Overlap	

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

^c Black discolouration on material groups B and F; violet, green, blue, grey, white discolouration on material group C. For material group E the discolouration criteria shall be defined by the engineering authority.

^d Spatter may be acceptable on welding processes or materials where it cannot be avoided. In such cases, the acceptability is at the discretion of the welding coordinator.

^e Nominal penetration is required.

Table A.2 (continued)

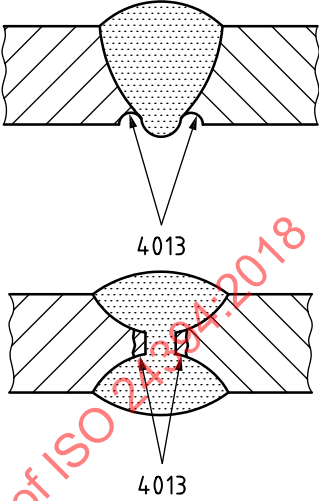
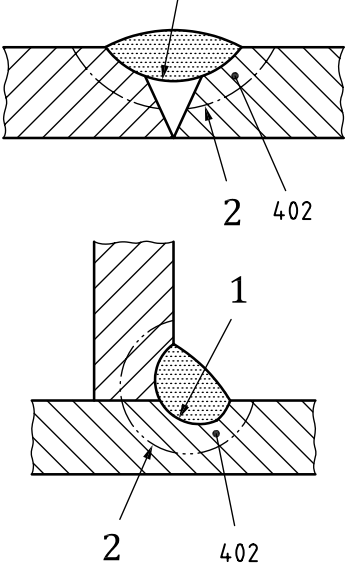
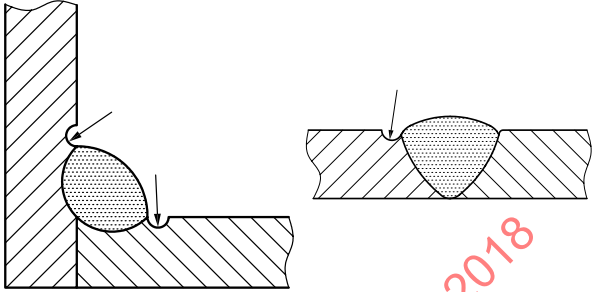
Reference number in accordance with ISO 6520-1:2007	Unacceptable imperfections	Illustration
4013	Lack of root fusion (incomplete root fusion)	
402	Incomplete penetration ^e (lack of penetration)	 1 actual penetration 2 nominal penetration
^a A butt weld condition in which the weld face or root surface is below the adjacent surface of the parent material (illustration given as "incompletely filled groove" in ISO 6520-1). ^b Acceptable for welding without filler material (autogenous welding) with the following criteria: 0,05t or 0,5 mm, whichever is smaller. ^c Black discolouration on material groups B and F; violet, green, blue, grey, white discolouration on material group C. For material group E the discolouration criteria shall be defined by the engineering authority. ^d Spatter may be acceptable on welding processes or materials where it cannot be avoided. In such cases, the acceptability is at the discretion of the welding coordinator. ^e Nominal penetration is required.		

Table A.2 (continued)

Reference number in accordance with ISO 6520-1:2007	Unacceptable imperfections	Illustration
501	Undercut ^b	
6101	Discolouration ^c	—
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 Acceptable for welding without filler material (autogenous welding) with the following criteria: 0,05t or 0,5 mm, whichever is smaller.

^c Black discolouration on material groups B and F; violet, green, blue, grey, white discolouration on material group C. For material group E the discolouration criteria shall be defined by the engineering authority.

^d Spatter may be acceptable on welding processes or materials where it cannot be avoided. In such cases, the acceptability is at the discretion of the welding coordinator.

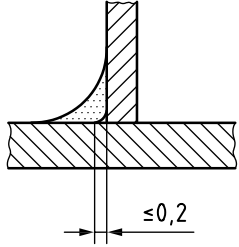
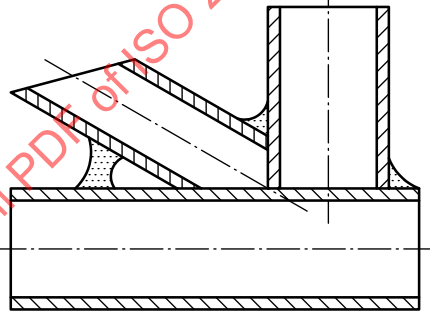
^e Nominal penetration is required.

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) ^a	Not acceptable for material groups A, B, E and F

^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	Maximum size of cavities for test piece thickness, t							
		0,8	1,0	1,2	1,5	1,8	2,0	2,5	3,0
Individual size of cavity $0,3t$ (aluminium, $0,5t$) or 1,3 mm (aluminium, 1,6 mm), whichever is less. Distance between cavities shall be equal to or greater than twice the diameter of the larger adjacent cavity.	A B C E F	0,2	0,3	0,4	0,5	0,5	0,6	0,8	0,9
	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 F	1,1	1,3	1,6	2,0	2,4	2,7	3,3	4,0

NOTE 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
					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	p: pass f: fail

Date: _____

Examiner/examining body _____

Page: _____