
**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 soudeurs — Soudage par fusion des
composants métalliques*

STANDARDSISO.COM : Click to view the full PDF of ISO 24394:2023



STANDARDSISO.COM : Click to view the full PDF of ISO 24394:2023



COPYRIGHT PROTECTED DOCUMENT

© ISO 2023

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

	Page
Foreword	v
Introduction	vi
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
4 Qualification test requirements	3
4.1 General.....	3
4.1.1 Specific to the welder qualification test.....	3
4.1.2 Specific to the welding operator qualification test.....	3
4.2 Welding processes.....	4
4.3 Welding positions.....	5
4.4 Product types or semi-finished products applicable to welder qualification tests.....	5
4.5 Material groups.....	9
4.6 Material thickness.....	10
4.6.1 Butt weld material thickness.....	10
4.6.2 Fillet weld material thickness.....	10
4.6.3 Casting repair material thickness.....	10
4.7 Special qualification tests.....	10
4.7.1 General requirements.....	10
4.7.2 Special qualification tests for welders.....	10
4.7.3 Special qualification tests for welding operators.....	11
4.8 Designation for qualification test.....	11
4.8.1 Welder qualification test.....	11
4.8.2 Welding operator qualification test.....	12
5 Conditions required for welder and welding operator qualification tests	12
5.1 Physical requirements for welder and welding operator.....	12
5.2 Person responsible for welder and welding operator qualification tests.....	13
6 Performing the welder and welding operator qualification test	13
6.1 Practical qualification test.....	13
6.1.1 General requirements.....	13
6.1.2 Specific requirements for the welder qualification test.....	13
6.2 Theory test.....	14
7 Test pieces	14
8 Examination and testing	18
8.1 General.....	18
8.2 Visual inspection and dimensional examination.....	19
8.3 Surface imperfection detection.....	19
8.4 Radiographic examination.....	19
8.5 Metallographic examinations.....	19
8.6 Bend test.....	20
8.7 Fracture surface examination.....	20
9 Acceptance criteria	20
10 Qualification test certificate and documentation	20
11 Period of validity of the qualification	21
12 Requalification test	21
Annex A (normative) Test piece acceptance criteria	22
Annex B (normative) Welder or welding operator qualification test record	27
Annex C (informative) Welder qualification test certificate	28

Annex D (informative) Welding operator qualification test certificate	29
Annex E (informative) Guidelines for the theory test	31
Bibliography	34

STANDARDSISO.COM : Click to view the full PDF of ISO 24394:2023

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 document 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).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

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*.

This third edition cancels and replaces the second edition (ISO 24394:2018), which has been technically revised.

The main changes are as follows:

- [3.8](#): note to entry added;
- [Table 4](#) revised;
- editorial revisions.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html. Official interpretations of ISO/TC 44 documents, where they exist, are available from this page: <https://committee.iso.org/sites/tc44/home/interpretation.html>.

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 proven to possess the minimum degree of skill and knowledge required for the fusion welding of aerospace hardware.

STANDARDSISO.COM : Click to view the full PDF of ISO 24394:2023

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 fusion welding of metallic materials for aerospace applications.

NOTE Success in the test is an essential precondition for the qualification of welders and welding operators in new production and repair work in aerospace. However, welding equipment operators 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 6520-1, *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*

3 Terms and definitions

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

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

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

3.1

parent material form

type of the semi-finished product

Note 1 to entry: Semi-finished products are sheets or 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 — Definition revised and note 1 to entry 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 conformity to 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, modified — Definition revised.]

3.6

examining body

organization that has been appointed to verify conformity to 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, modified – Definition revised.]

3.7

rework

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

EXAMPLE Drawings, 3D models, specifications for manufacturing.

Note 1 to entry: In the case of a welded product, the engineering authority is usually the organization that has responsibility for the engineering definition of the product.

Note 2 to entry: In civil aviation, the design authority is normally the type certificate holder, a legal entity related to the airworthiness authorities.

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 is to be qualified

[SOURCE: ISO/TR 25901-1:2016, 2.5.6, modified — Definition revised.]

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 weld joint (butt/groove or 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 [Figure 1](#) to [Figure 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 or 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 6](#).

4.2 Welding processes

This document covers qualification testing for the following welding processes with their reference numbers in accordance with ISO 4063:1998:¹⁾

- 111 manual metal arc welding (metal arc welding with covered electrode);²⁾
- 12 submerged arc welding;²⁾
- 13 gas-shielded metal arc welding;
- 141 TIG welding/gas tungsten arc welding;
- 15 plasma arc welding;
- 31 oxy-fuel gas welding;
- 51 electron beam welding;
- 52 laser beam welding.

NOTE 1 Other fusion welding processes not specified in ISO 4063:1998 can be covered.

NOTE 2 Attention is drawn to the fact that ISO 4063:1998 and ISO 4063:2023 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 4063:2023

Process number	Process designation in ISO 4063:1998	Process designation in ISO 4063:2023
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 or rod)

1) Cancelled and replaced by ISO 4063:2023.

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

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](#).

A test piece welded in the fixed position also qualifies for welding parts when not in the fixed position, for example 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 or 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 or plate (S), tube (T) and castings (C).

Test pieces with tube (TP3, TP4 and TP5) do not qualify for sheet or 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 or 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 given in ISO 6947.

Test piece TP5 (see [Figure 5](#)) 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.

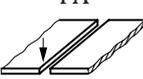
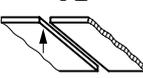
Excluding in-process welding in casting facilities, a welder who is qualified to weld sheet or plate or tube is also qualified to weld on castings within his or her range of qualification regarding the welding position and geometric shape of the work piece (planar or tubular).

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, for example Nickel Alloy 718, the welder qualification test pieces (TP1 to TP4) shall be of the same casting alloy.

As an alternative, qualifications according to 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								
		Butt weld on sheet or plate				Butt weld on tube				
Form or joint type	Test piece welding position (ISO 6947)	PA	PC	PE	PF	PA	PC	PE	PF	H-L 045
Sheet or plate butt weld		X				X ^{a,b}				
Sheet or plate butt weld		X	X			X ^{a,b}	X ^{a,b,c}			
		X		X		X ^{a,b}		X ^{a,b}		
		X			X	X ^{a,b}			X ^{a,b}	

NOTE 1 X indicates what the welder is qualified for.

NOTE 2 The arrows in PA, PC and PE show the welding position.

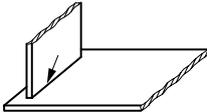
NOTE 3 The arrow in PF shows the weld progression or direction.

^a Applicable for longitudinal weld on a tube.

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

^c Applicable for circumferential weld on a tube in a 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

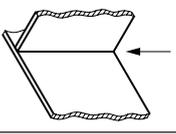
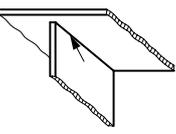
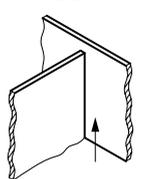
Test weld		Qualified welding position				
		Fillet weld on sheet or plate				
Form or joint type	Test piece welding position (ISO 6947)	PA	PB	PC	PD	PF
Sheet or plate fillet weld		X				
		X	X			

NOTE 1 X indicates for which the welder is qualified.

NOTE 2 The arrows in PA, PB, PC and PD show the welding position.

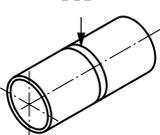
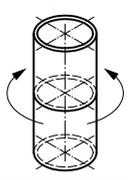
NOTE 3 The arrow in PF shows the weld progression or direction.

Table 3 (continued)

Test weld		Qualified welding position				
Form or joint type	Test piece welding position (ISO 6947)	Fillet weld on sheet or plate				
		PA	PB	PC	PD	PF
Sheet or plate fillet weld	PC 	X	X	X		
	PD 	X	X		X	
	PF 	X	X			X

NOTE 1 X indicates for which the welder is qualified.
 NOTE 2 The arrows in PA, PB, PC and PD show the welding position.
 NOTE 3 The arrow in PF shows the weld progression or direction.

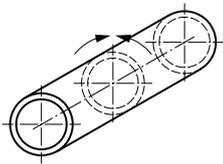
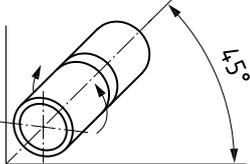
Table 4 — Range of qualification for welding positions, joint type and base metal form for TP3

Test weld		Qualified welding position					
Form or joint type	Test piece welding position (ISO 6947)	Butt weld on tube			Butt weld on sheet or plate ^b		
		PA	PC	PH	PA	PC	PF
Tube butt weld	PA ^a 	X					
	PC ^c 	X ^a	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 The arrows in PA and PC show the welding position.
 NOTE 3 The arrows in 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 or 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 4 (continued)

Test weld		Qualified welding position					
Form or joint type	Test piece welding position (ISO 6947)	Butt weld on tube			Butt weld on sheet or plate ^b		
		PA	PC	PH	PA	PC	PF
Tube butt weld	<p>PH</p> 	X ^a		X			
	<p>H-L045</p> 	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 The arrows in PA and PC show the welding position

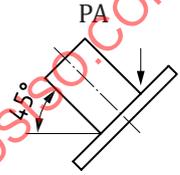
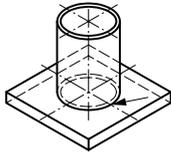
NOTE 3 The arrows in PH and H-L045 show the weld progression or direction.

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

^b Qualification is only valid for sheet or 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

Test weld		Qualified welding position				
Form or joint type	Test piece welding position (ISO 6947)	Tube to sheet or plate fillet weld				
		PA	PB	PD	PH	PJ
Tube to sheet or plate fillet weld	<p>PA</p> 	X ^a				
	<p>PB</p> 	X ^a	X			

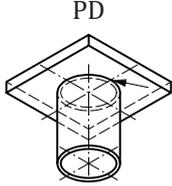
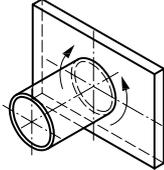
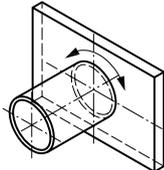
NOTE 1 The qualification is valid for any tube of outer diameter equal to or larger than the outer diameter of the test piece.

NOTE 2 The arrows in PA, PB and PD show the welding position

NOTE 3 The arrows in PH and PJ show the weld progression or direction.

^a Only applicable for a rotating tube to sheet or plate assembly with the torch in welding position PA.

Table 5 (continued)

Form or joint type	Test weld Test piece welding position (ISO 6947)	Qualified welding position				
		Tube to sheet or plate fillet weld				
		PA	PB	PD	PH	PJ
Tube to sheet or plate fillet weld	PD 	X ^a	X	X		
	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 The arrows in PA, PB and PD show the welding position NOTE 3 The arrows in PH and PJ show the weld progression or direction. ^a Only applicable for a rotating tube to sheet or 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 or engineering authority.

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

4.7.2 Special qualification tests for welders

Examples include:

- a) qualification for surfacing or 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;
- h) qualification for welding positions that are not covered by [Table 2](#) to [Table 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 include:

- a) qualification for surfacing or 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 in accordance with ISO 4063:1998;
- symbol of product type or semi-finished product (see 4.4);
- welding position and test piece number (see Table 2 to Table 5);
- material group (see 4.5);
- test piece material thickness(es) (see 4.6); in case of different thicknesses on fillet welds, the thinner value shall be indicated;
- test piece outside diameter(s), if applicable;
- possibly X for a special qualification test (see 4.7).

For test pieces TP5 and TP6, welding positions do not need to be indicated.

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

where

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 or plate);

PA1 is the welding position and number of the test piece (see Table 2 or Table 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

where

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 tube 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

where

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 an eye test) shall be documented on the welder or 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.

Eyesight 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 tests shall be administered by competent personnel.

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

- Jaeger No. 2 eye chart at approximately 400 mm;
- Visus 0,8 at approximately 400 mm;
- eyesight requirements of EN 4179 or ISO 18490.

NOTE The results of the three 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 tests, requalification tests 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 following provisions, 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 or her 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 or welding operator qualification test record.

[Annex B](#) specifies minimum requirements for the content of the welder or welding operator qualification test record and recommends a format.

6.1.2 Specific requirements for the welder qualification test

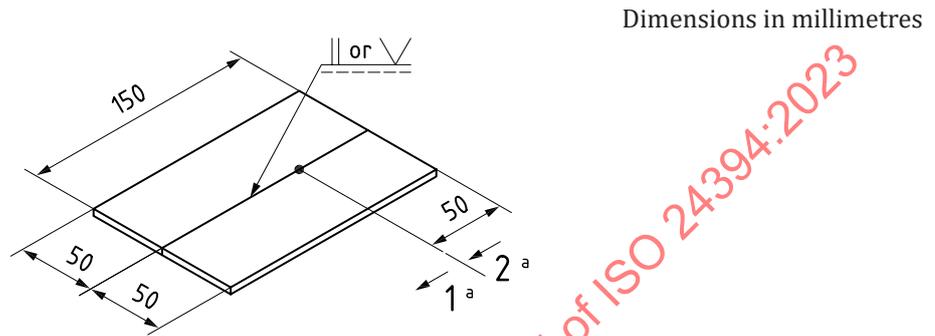
The welding coordinator should choose the material that is most difficult to weld from the material group used by the welder in actual production. In the practical part of the welder qualification test, the welder shall weld the test pieces (see [Figure 1](#) to [Figure 6](#)) of the related test, or according to special qualification tests defined by the welding coordinator, see [4.7.1](#), 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.

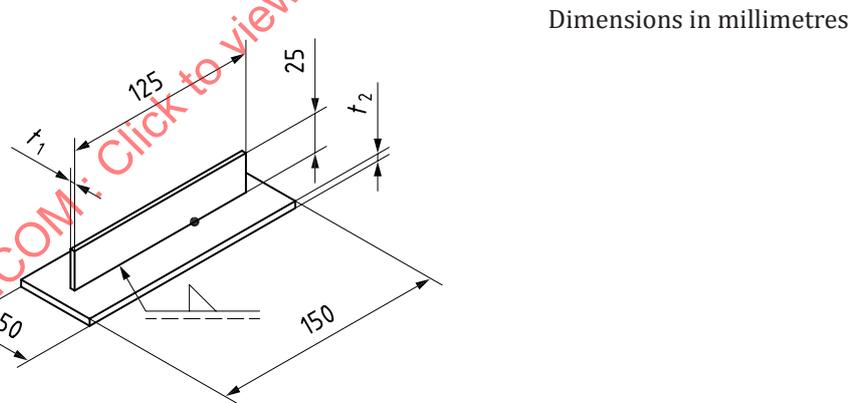
7 Test pieces

Test pieces (see Figure 1 to Figure 6) shall be applied according to the required welder qualification test, see 4.1.1.



^a Welding sequence. For materials susceptible to cracking, the welding sequence may be altered.

Figure 1 — Test piece no. TP1



Key

t_1 thinner sheet or plate

t_2 thicker sheet or plate

$t_2 \geq 1,5 t_1$

The weld direction is optional but shall be maintained in one direction only. Stop and restart after approximately 50 mm weld length.

NOTE This weld stop and restart is intended to simulate a weld wire change.

Figure 2 — Test piece no. TP2

Dimensions in millimetres

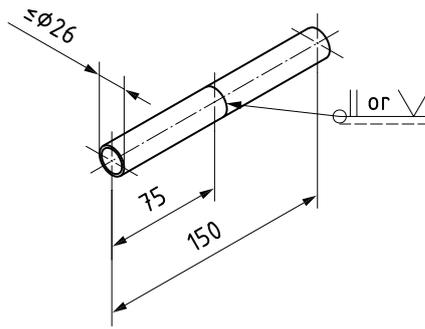
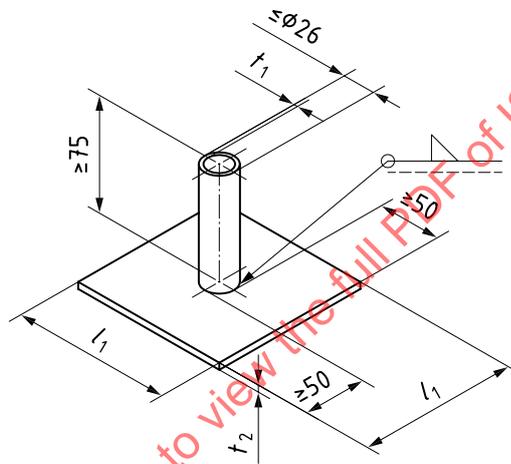


Figure 3 — Test piece no. TP3

Dimensions in millimetres

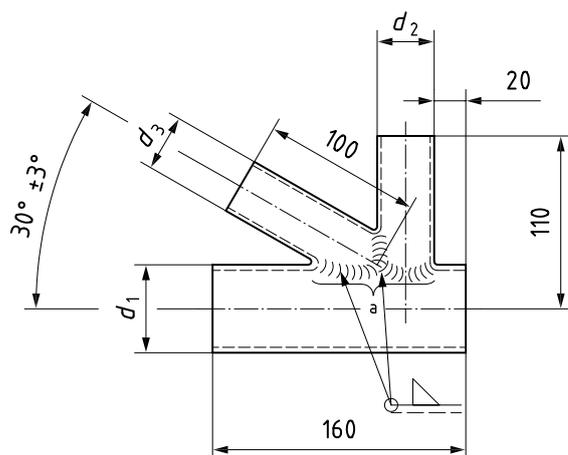


Key

$t_2 \geq 1,5 t_1$

Figure 4 — Test piece no. TP4

STANDARDSISO.COM : Click to view the full PDF of ISO 24394:2023



Key

diameter ratios: $d_1 > 1,2d_2$; $d_3 \leq d_2$

tube axis: d_1 : horizontal; d_2 : vertical

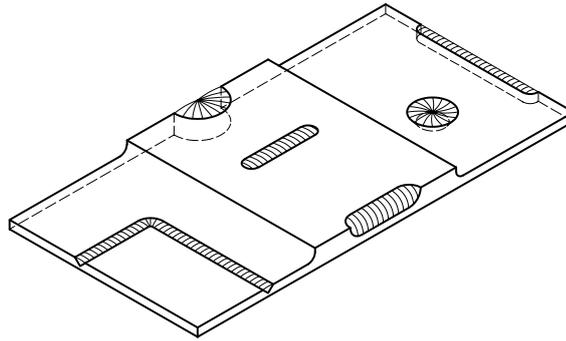
Tube wall thickness and diameters occurring in production.

^a All welds indicated by rippling shall be performed.

Figure 5 — Test piece no. TP5

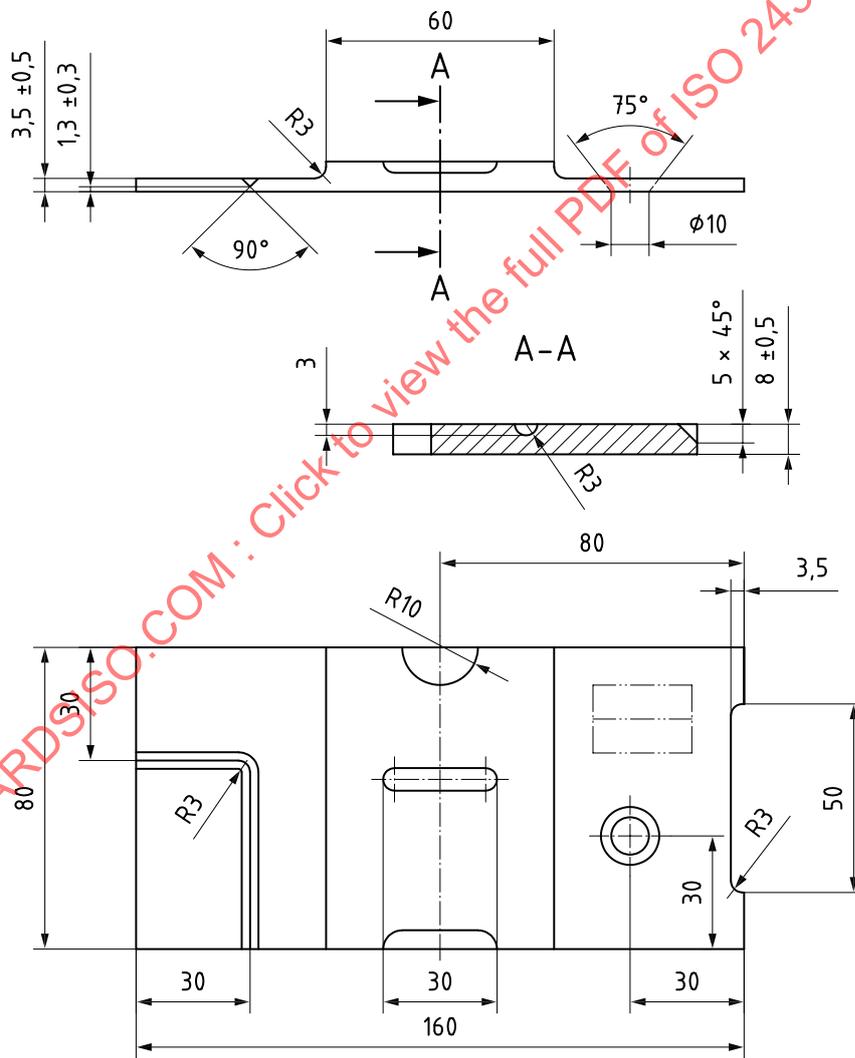
STANDARDSISO.COM : Click to view the full PDF of ISO 24394:2023

Dimensions in millimetres



a)

Dimensions and delivery conditions



b)

a All welds indicated by rippling shall be performed.

Figure 6 — Test piece No. TP6

8 Examination and testing

8.1 General

The test piece(s) shall be tested and examined in accordance with [Table 6](#). Additional testing may be applied at the discretion of the welding coordinator. The test results shall be documented in the welder or welding operator qualification test record in accordance with [Annex B](#).

Table 6 — Test pieces and appropriate test methods

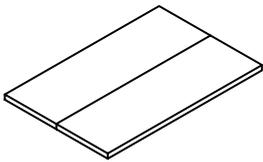
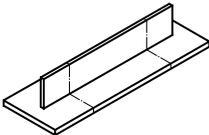
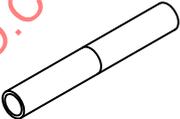
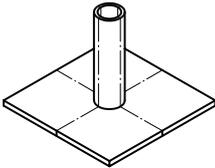
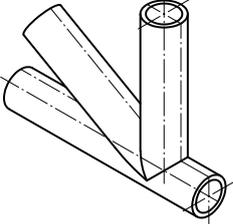
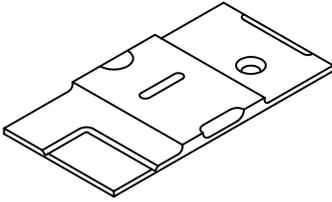
Test piece no. and designation	Illustration	Test method
<p>TP1 Butt weld on sheet or plate</p>		<p>Visual inspection (see 8.2) Dimensional examination (see 8.2 and Annex A) Surface imperfection detection (see 8.3) Radiographic examination (see 8.4) or, as an alternative, fracture test (see 8.7) or bend test (see 8.6) for test pieces in unalloyed steel</p>
<p>TP2 Fillet weld on sheet or plate</p>		<p>Visual inspection (see 8.2) Dimensional examination (see 8.2 and Annex A) Surface imperfection detection (see 8.3) Examination of two macro-sections of fillet weld – one section shall be taken through the stop/start point</p>
<p>TP3 Butt weld on tube</p>		<p>Visual inspection (see 8.2) Dimensional examination (see 8.2 and Annex A) 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</p>
<p>TP4 Tube to sheet or plate</p>		<p>Visual inspection (see 8.2) Dimensional examination (see 8.2 and Annex A) 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)</p>

Table 6 (continued)

Test piece no. and designation	Illustration	Test method
<p style="text-align: center;">TP5 Structural tube frame-work</p>		<p>Visual inspection (see 8.2)</p> <p>Dimensional examination (see 8.2 and Annex A)</p> <p>Surface imperfection detection (see 8.3)</p> <p>Examination of macro-sections of fillet welds in the parting faces of the symmetrically cut tube junction</p>
<p style="text-align: center;">TP6 Fill weld on casting</p>		<p>Visual inspection (see 8.2)</p> <p>Surface imperfection detection (see 8.3)</p> <p>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. the ISO 17636 series); the radiographic images shall be supplied with the casting</p>

8.2 Visual inspection and dimensional examination

Visual inspection shall be carried out with the test piece in the as-welded condition. Visual examination for external weld imperfections or features shall be performed at up to 10 times magnification and with an angled mirror, if required. For visual examination, it is recommended that the principles outlined in ISO 19828 are applied.

Conformity to 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 or welding operator qualification test record form, see Annex B, and compared with criteria from Annex A.

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 6. 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 or 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 6](#), 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.4](#).

9 Acceptance criteria

The test piece acceptance criteria shall be in accordance with the requirements of [Annex A](#), see [Table A.1](#) to [Table A.5](#).

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 or 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 or welding operator qualification test record (for an example, see [Annex B](#)). The welder or 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 or 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 [Annex C](#) and [Annex 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 were welded.

The welder or welding operator test certificate shall be renewed every two years in accordance with [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 document.

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, for example requirements given in [Table 2](#) to [Table 5](#) and [Table 6](#).

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

When the requalification tests of welders or 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 or 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

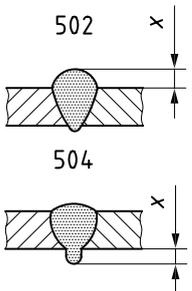
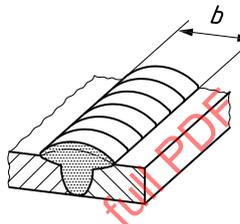
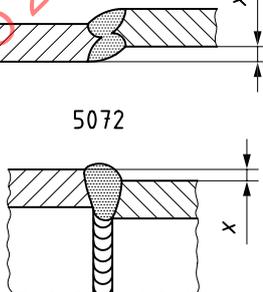
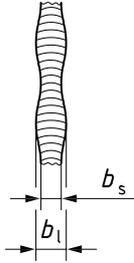
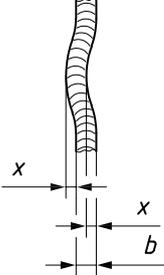
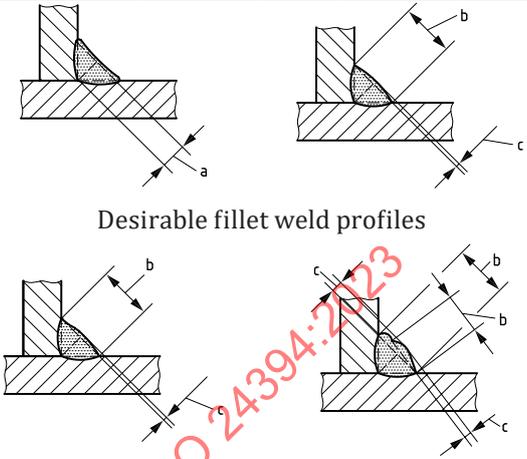
Weld feature ^a	Excess weld metal/excess penetration 502/504		Weld width of face side 5212		Linear misalignment 5071/5072
Illustration ^a					
Material group	A B C E F	D	A B C E F	D	A B C D E F
Determination	$x = 0,6t + 0,6 \text{ mm}^b$	$x = 0,2t + 1,8 \text{ mm}^b$	$b = 1,8t + 5 \text{ mm}$	$b = 2t + 6 \text{ mm}$	$x = 0,1t + 0,3 \text{ mm}$ 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
^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.					

Table A.2 — Imperfections

Imperfection ^a	Weld width deviation ^b	Weld track deviation	Throat thickness ^c			
Illustration ^a			 <p>Desirable fillet weld profiles</p> <p>Acceptable fillet weld profiles</p>			
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	$x = \frac{[2(b_l - b_s)]}{(b_l + b_s)}$	$x = 0,25b_{\max.}^d$		$a = 0,7t$	$a = 0,4t + 2 \text{ mm}$	$a = 0,4t + 3,1 \text{ mm}$
Test piece thickness, t^e	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 b_l is the largest measured weld width and b_s is the smallest measured weld width.

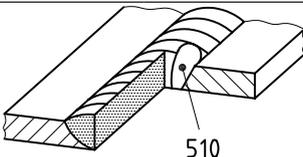
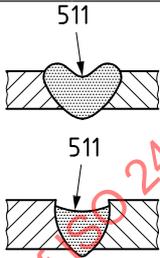
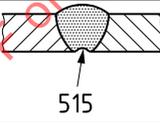
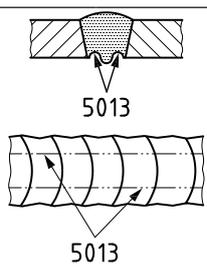
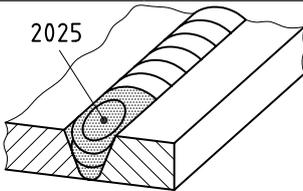
^c Convexity, C , of a weld or individual surface bead b shall not exceed the following values:

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

^d See column “Weld width of face side” for values of $b_{\max.}$

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

Table A.3 — Unacceptable surface imperfections

Reference number in accordance with ISO 6520-1	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 ^d	—
2025	End crater pipe	

^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 can 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 (continued)

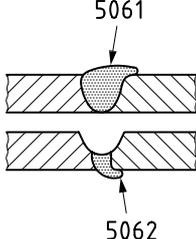
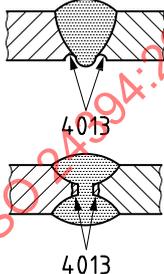
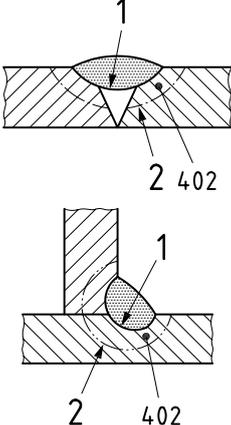
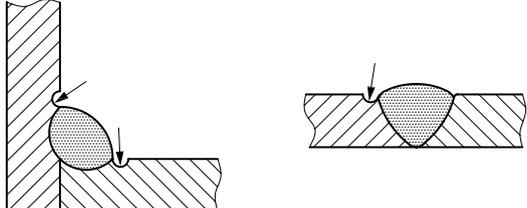
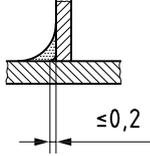
Reference number in accordance with ISO 6520-1	Unacceptable imperfections	Illustration
506	Overlap	 <p>5061</p> <p>5062</p>
4013	Lack of root fusion (incomplete root fusion)	 <p>4013</p> <p>4013</p>
402	Incomplete penetration ^e (lack of penetration)	 <p>1</p> <p>2 402</p> <p>1</p> <p>2 402</p> <p>1 actual penetration</p> <p>2 nominal penetration</p>
501	Undercut ^b	
6101	Discolouration ^c	—
6021	Tungsten spatter	—
<p>^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).</p> <p>^b Acceptable for welding without filler material (autogenous welding) with the following criteria: 0,05t or 0,5 mm, whichever is smaller.</p> <p>^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.</p> <p>^d Spatter can 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.</p> <p>^e Nominal penetration is required.</p>		

Table A.4 — Internal imperfections or features

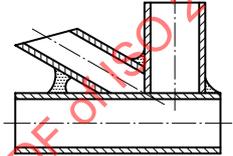
Dimensions in millimetres

Reference number in accordance with ISO 6520-1	Imperfections or features	Acceptance criteria
100	Cracks	Not acceptable
200	Cavity (e.g. porosity)	See Table A.5
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 the following exceptions:



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.5 — 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	A B C E F	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 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 or welding operator qualification test record

Company or department _____

Address of test house or department: _____

Name of welder or welding operator: _____

Date of birth: _____

Identity number of welder or 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 or imperfections	p: pass f: fail

Examiner or examining body _____

Date: _____

Page: _____