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

*Soudage — Assemblages en aluminium et alliages d'aluminium
soudés à l'arc — Niveaux de qualité par rapport aux défauts*

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CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

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Contents

	Page
Foreword.....	iv
Introduction.....	vi
1 Scope.....	1
2 Normative references.....	1
3 Terms and definitions.....	1
4 Symbols.....	2
5 Assessment of imperfections.....	3
Annex A (informative) Examples of the determination of the percent porosity.....	16
Annex B (informative) Additional information and guidelines for users of this document.....	18
Bibliography.....	19

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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 10, *Quality management in the field of welding*.

This third edition cancels and replaces the second edition (ISO 10042:2005), of which it constitutes a minor revision. The changes compared to the previous edition are as follows:

- reference numbers from ISO 4063 have been deleted in the Scope;
- in [Table 1](#), 1.3, reference number ISO 6520-1 has been changed from “2012 - uniformly distributed porosity” to “2018 - surface porosity”;
- in [Table 1](#), 1.8, a new figure has been inserted and changes to quality levels B and C have been made;
- in [Table 1](#), 1.9, changes to quality level C have been made;
- in [Table 1](#), 1.14, a drawing has been added;
- in [Table 1](#), 1.15, changes to quality level D have been made;
- in [Table 1](#), 1.18, a drawing has been deleted and a new one inserted, and reference to 6520-1-5013 “shrinkage groove” has been deleted;
- in [Table 1](#), 1.19 to 1.21, imperfections have been added with values from ISO 5817: poor restart, stray arc, spatter;
- in [Table 1](#), 2.2, changes to quality levels B and C have been made;
- in [Table 1](#), 2.10, changes to quality levels C and D have been made;
- in [Table 1](#), 2.11, a drawing has been deleted and new ones introduced, requirements for “Butt joint (full penetration)” have been updated;
- in [Table 1](#), 2.12, a new drawing has been introduced with new requirements, and changes to quality levels C and D have been made;

— editorial changes have been made.

Requests for official interpretation of any aspect of this document should be directed to the secretariat of ISO/TC 44/SC 10 via your national standards body. A complete listing of these bodies can be found at www.iso.org.

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Introduction

This document is intended to be used as a reference in drafting application codes and/or other application standards. It contains a simplified selection of arc welding imperfections based on the designations given in ISO 6520-1.

Some imperfections described in ISO 6520-1 have been used directly while others have been grouped together. The basic numerical referencing system from ISO 6520-1 has been used.

The purpose of this document is to define the dimensions of typical imperfections which can be expected in normal fabrication. It can be used within a quality system for the production of welded joints. It provides three sets of dimensional values from which a selection can be made for a particular application. The quality level necessary in each case needs to be defined by the application standard or the responsible designer, in conjunction with the manufacturer, user and/or other parties concerned. The quality level are prescribed before the start of production, preferably at the enquiry or order stage. For special purposes, additional details can be necessary.

The quality levels given in this document provide basic reference data and are not specifically related to any particular application. They refer to the types of welded joint in fabrication and not to the complete product or component itself. It is possible, therefore, that different quality levels are applied to individual welded joints in the same product or component.

It is normally be expected that, for a particular welded joint, the dimensional limits for imperfections can all be covered by specifying one quality level. In some cases, it can be necessary to specify different quality levels for different imperfections in the same welded joint.

The choice of quality level for any application takes account of design considerations, subsequent processing (e.g. surfacing), mode of stressing (e.g. static, dynamic), service conditions (e.g. temperature, environment) and consequences of failure. Economic factors are also important and include not only the cost of welding but also of inspection, test and repair.

Although this document includes types of imperfection relevant to the arc welding processes given in [Clause 1](#), only those which are applicable to the process and application in question are considered.

Imperfections are quoted in terms of their actual dimensions, and their detection and evaluation can require the use of one or more methods of non-destructive testing. The detection and sizing of imperfections is dependent on the testing methods and the extent of testing specified in the application standard or contract.

This document does not address the methods used for the detection of imperfections. However, ISO 17635 contains a correlation between the quality level and acceptance level for different NDT (non-destructive testing) methods.

This document is directly applicable to visual testing of welds and does not include details of recommended methods of detection or sizing by other non-destructive means. There are difficulties in using these limits to establish appropriate criteria applicable to NDT methods such as ultrasonic (UT), radiographic (RT) and penetrant testing (PT), for which additional requirements for testing can be necessary.

The values given for imperfections are for welds produced using normal welding practice. Requirements for smaller (more stringent) values as stated in quality level B can include additional manufacturing processes, e.g. grinding, TIG dressing.

Welding — Arc-welded joints in aluminium and its alloys — Quality levels for imperfections

1 Scope

This document specifies quality levels for imperfections in arc-welded joints in aluminium and its alloys. It applies to material thicknesses above 0,5 mm.

Three quality levels are given in order to permit application to a wide range of welded constructions. They are designated by symbols B, C and D. Quality level B corresponds to the highest requirement on the finished weld. The quality levels refer to production quality and not to the fitness for purpose (see 3.2) of the product manufactured.

This document is applicable to all types of welds (e.g. butt welds, fillet welds and branch connections), to manual, mechanized and automated welding, and to all welding positions.

It is applicable to the following welding processes:

- metal inert gas welding (MIG welding); gas metal arc welding /USA;
- tungsten inert gas welding (TIG welding); gas tungsten arc welding /USA;
- plasma arc welding.

It is not applicable to metallurgical aspects (e.g. grain size, hardness).

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*

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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

quality level

description of the quality of a weld on the basis of type, size and amount of selected imperfections

3.2

fitness for purpose

ability of a product, process or service to serve a defined purpose under specific conditions

3.3 short imperfection

<welds of length ≥ 100 mm> imperfection whose total length is not greater than 25 mm in any 100 mm of their length

3.4 short imperfection

<welds less than 100 mm long> imperfection whose total length is not greater than 25 % of the length of the weld

3.5 systematic imperfection

imperfection that is repeatedly distributed in the weld over the weld length to be examined, the size of each individual imperfection being within the specified limits

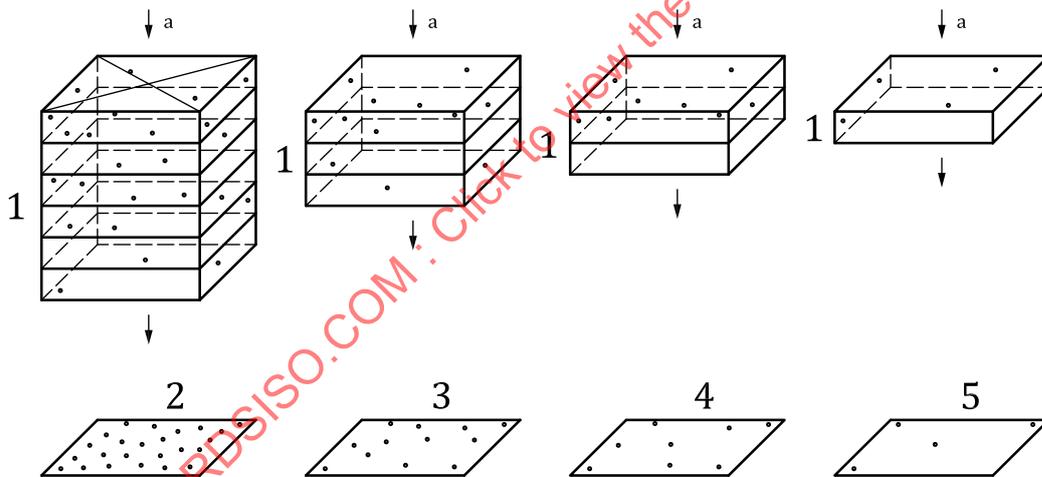
3.6 cross-sectional area

area to be considered after fracture or sectioning

3.7 projected area

area where imperfections distributed along the volume of the weld under consideration are imaged two-dimensionally

Note 1 to entry: In contrast to the *cross-sectional area* (3.6), the occurrence of imperfections is dependent on the weld thickness when exposed radiographically (see Figure 1).



- Key**
- | | | | |
|---|-------------------------|---|----------------------|
| 1 | 4 pores per volume unit | 4 | 2-fold thickness |
| 2 | 6-fold thickness | 5 | 1-fold thickness |
| 3 | 3-fold thickness | a | Direction of X-rays. |

Figure 1 — Radiographic films of specimens with identical occurrence of pores per volume unit

4 Symbols

The following symbols are used in [Table 1](#).

A	area of clustered porosity
a	nominal throat thickness of a fillet weld (see also ISO 2553)
b	width of the weld
d	diameter of a gas pore
d_A	diameter of area surrounding a area of clustered porosity
d_{Ac}	diameter of circle surrounding total gas pore area
h	height or width of an imperfection
l	length of imperfection in longitudinal direction of weld
l_p	length of projected or cross-sectional area
s	nominal butt weld thickness (see also ISO 2553)
t	wall or plate thickness (nominal size)
w_p	width or height of cross-sectional area
z	leg length of a fillet weld (see also ISO 2553)

5 Assessment of imperfections

Limits on imperfections are given in [Table 1](#).

Systematic imperfections are only permitted in quality level D, provided other requirements of [Table 1](#) are fulfilled.

A welded joint should usually be assessed for each individual type of imperfection separately (see [Table 1](#), 1.1 to 3.2).

Different types of imperfection occurring at any cross-section of the joint need special consideration (see multiple imperfections in [Table 1](#), 4.1).

The limits on multiple imperfections (see [Table 1](#)) are only applicable in cases where the requirements for a single imperfection are not exceeded.

Any two adjacent imperfections separated by a distance smaller than the major dimension of the smaller imperfection shall be considered as a single imperfection.

Table 1 — Limits on imperfections

No.	Reference No. in ISO 6520-1	Designation of imperfection	Remarks	t mm	Limits on imperfections for quality levels		
					D	C	B
1 Surface imperfections							
1.1	100	Crack	—	≥0,5	Not permitted	Not permitted	Not permitted
1.2	104	Crater crack	—	≥0,5	Not permitted $h \leq 0,4s$ or $0,4a$ $l \leq 0,4s$ or $0,4a$	Not permitted	Not permitted
1.3	2018	Surface porosity	For the assessment of the porosity, see examples given in Annex A .	≥0,5	≤2 %	≤1 %	≤0,5 %
1.4	2013	Clustered (localized) porosity					

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Table 1 (continued)

No.	Reference No. in ISO 6520-1	Designation of imperfection	Remarks	t mm	Limits on imperfections for quality levels	B
			<p>Reference length for l_p is 100 mm.</p> <p>The total gas pore area within the cluster is represented by a circle of diameter, d_A, surrounding all the gas pores.</p> <p>The requirements for a single gas pore shall be met by all the gas pores within this circle.</p> <p>A permitted porous area shall be local. The possibility of the pore cluster masking other imperfections shall be taken into consideration.</p> <p>If D is less than d_{A1} or d_{A2}, whichever is smaller, then the total gas pore area is represented by a circle of diameter, d_{Ac}, where $d_{Ac} = d_{A1} + d_{A2} + D$.</p> <p>Systematic clustered porosity is not permitted.</p>	<p>$d_A \leq 25$ mm</p> <p>or</p> <p>$d_{A,max} \leq w_p$</p> <p>d_A corresponds to d_{A1}, d_{A2} or d_{Ac} whichever is applicable</p>	Not permitted	Not permitted
1.5	2014	Linear porosity	—	$\geq 0,5$	Not permitted	Not permitted
1.6	2017	Surface pore	Maximum dimension of a single gas pore:	<p>0,5 to 3</p> <p>> 3</p>	<p>Not permitted</p> <p>$d \leq 0,3s$ or $0,3a$</p> <p>$d \leq 0,4s$ or $0,4a$</p> <p>max. 3 mm</p>	<p>$d \leq 0,1s$ or $0,1a$</p> <p>$d \leq 0,2s$ or $0,2a$</p> <p>max. 1,5 mm</p>
1.7	2025	End crater pipe	—	$\geq 0,5$	<p>$h \leq 0,4t$</p> <p>max. 3 mm</p>	<p>Not permitted</p> <p>$h \leq 0,2t$</p> <p>max. 1,5 mm</p>
1.8	401	Lack of fusion (incomplete fusion)	—	$\geq 0,5$	Short imperfections	Not permitted
						<p>$h \leq 0,1s$ or $0,1a$</p> <p>max. 3 mm</p>

Table 1 (continued)

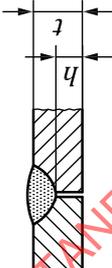
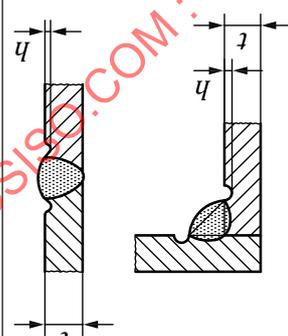
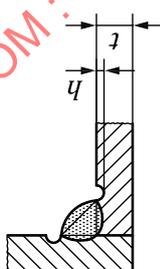
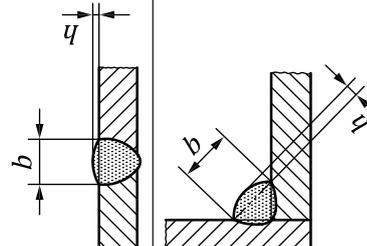
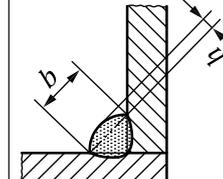
No.	Reference No. in ISO 6520-1	Designation of imperfection	Remarks	t mm	Limits on imperfections for quality levels		
					D	C	B
1.9	4021	Incomplete root penetration		≥0,5	Short imperfections but no systematic imperfections. $h \leq 0,2t$ max. 2 mm	Not permitted	Not permitted
1.10	5011	Continuous undercut		0,5 to 3 >3	$h \leq 0,2t$ $h \leq 0,2t$ but max. 1 mm	$h \leq 0,1t$ $h \leq 0,1t$ but max. 0,5 mm	Not permitted Not permitted
1.11	5012 502	Intermittent undercut (short imperfection) Excess weld metal	<p>Smooth transition required. 5012 is not regarded as a systematic imperfection.</p> 	0,5 to 3 >3	$h \leq 0,2t$ $h \leq 0,2t$ but max. 1,5 mm	$h \leq 0,1t$ $h \leq 0,1t$ but max. 1 mm	$h \leq 0,1t$ $h \leq 0,1t$ but max. 0,5 mm
1.12	503	Excessive convexity	<p>Smooth transition required.</p> 	≥0,5	$h \leq 1,5 \text{ mm } 0,2b$ max. 10 mm	$h \leq 1,5 \text{ mm } + 0,15b$ max. 8 mm	$h \leq 1,5 \text{ mm } + 0,1b$ max. 6 mm
1.12	503	Excessive convexity		≥0,5	$h \leq 1,5 \text{ mm } + 0,3b$ max. 5 mm	$h \leq 1,5 \text{ mm } + 0,15b$ max. 4 mm	$h \leq 1,5 \text{ mm } + 0,1b$ max. 3 mm

Table 1 (continued)

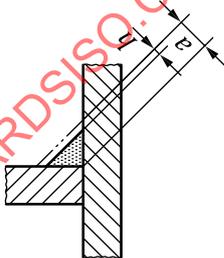
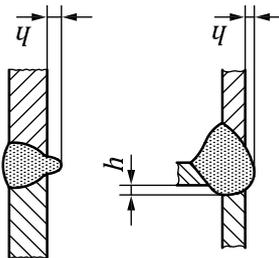
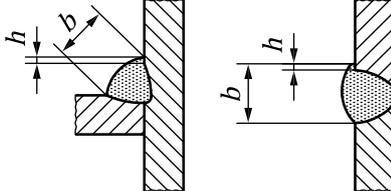
No.	Reference No. in ISO 6520-1	Designation of imperfection	Remarks	t mm	Limits on imperfections for quality levels		
					D	C	B
1.13	5213	Insufficient throat thickness	Not applicable to processes proven to give greater depth of penetration. 	≥0,5	h ≤ 0,3a max. 2 mm	h ≤ 0,2a max. 1,5 mm	h ≤ 0,1a max. 1 mm
1.14	504	Excess penetration		≥0,5	h ≤ 6 mm	h ≤ 4 mm	h ≤ 3 mm
1.15	506	Overlap		≥0,5	Short imperfections permitted, but h ≤ 0,2b	Not permitted	Not permitted

Table 1 (continued)

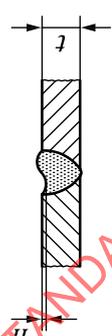
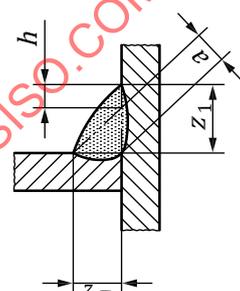
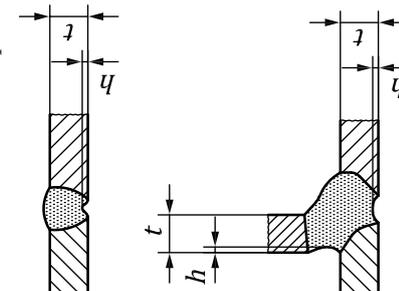
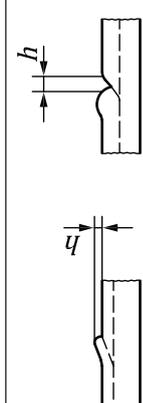
No.	Reference No. in ISO 6520-1	Designation of imperfection	Remarks	t mm	Limits on imperfections for quality levels		
					D	C	B
1.16	509 511	Sagging Incompletely filled groove	Smooth transition required. 	≥0,5	Short imperfections		
1.17	512	Excessive asymmetry of fillet weld (excessive unequal leg length)	Only for cases where a symmetric fillet weld has been specified. 	≥0,5	$h \leq 0,2t$ max. 1,5 mm	$h \leq 0,1t$ max. 1 mm	$h \leq 0,05t$ max. 0,5 mm
1.18	515	Root concavity	Smooth transition required. 	≥0,5	Short imperfections		
1.19	517	Poor restart		≥0,5	$h \leq 0,2t$ max. 1,5 mm	$h \leq 0,1t$ max. 1 mm	$h \leq 0,05t$ max. 0,5 mm
					Permitted The limit depends on the type of imperfection occurred due to restart.	Not permitted	Not permitted

Table 1 (continued)

No.	Reference No. in ISO 6520-1	Designation of imperfection	Remarks	t mm	Limits on imperfections for quality levels		
					D	C	B
1.20	601	Stray arc	—	≥0,5	Permitted for short imperfections	Not permitted	Not permitted
1.21	602	Spatter	—	≥0,5	Acceptance depends on application, e.g. material, corrosion protection	Acceptance depends on application, e.g. material, corrosion protection	Acceptance depends on application, e.g. material, corrosion protection
2 Internal imperfections							
2.1	100	Crack	All types of crack except microcracks and crater cracks.	≥0,5	Not permitted	Not permitted	Not permitted
2.2	1001	Microcrack	A crack usually only visible under the microscope (×50)	≥0,5	Permitted	Max. 0,6 mm × 0,02 mm but max. 4 imperfections per 2 mm × 2 mm	Max. 0,4 mm × 0,01 mm but max. 3 imperfections per 2 mm × 2 mm
2.3	2011	Gas pore	Maximum dimension of a single gas pore.	≥0,5	$d \leq 0,4s$ or $0,4a$ but max. 6 mm	$d \leq 0,3s$ or $0,3a$ but max. 5 mm	$d \leq 0,2s$ or $0,2a$ but max. 4 mm
2.4	2012	Uniformly distributed porosity	The assessment of porosity is done with respect to the cross-sectional area. See examples given in Annex A . The assessment of imperfections is done with respect to the projected area. See examples given in Annex A .	≥0,5	≤6 %	≤2 %	≤1 %
				0,5 to 3	≤6 %	≤2 %	≤1 %
				>3 to 12	≤10 %	≤4 %	≤2 %
				>12 to 30	≤15 %	≤6 %	≤3 %
				>30	≤20 %	≤8 %	≤4 %

Table 1 (continued)

No.	Reference No. in ISO 6520-1	Designation of imperfection	Remarks	t mm	Limits on imperfections for quality levels		
					D	C	B
2.5	2013	Clustered (localized) porosity		≥0,5	$d_A \leq 25 \text{ mm}$ or $d_{A,\text{max}} \leq W_p$	$d_A \leq 20 \text{ mm}$ or $d_{A,\text{max}} \leq W_p$	$d_A \leq 15 \text{ mm}$ or $d_{A,\text{max}} \leq W_p/2$

Table 1 (continued)

No.	Reference No. in ISO 6520-1	Designation of imperfection	Remarks	t mm	Limits on imperfections for quality levels		
					D	C	B
			<p>Reference length for l_p is 100 mm.</p> <p>The total gas pore area within the cluster is represented by a circle of diameter d_A surrounding all the gas pores.</p> <p>The requirements for a single gas pore shall be met by all the gas pores within this circle.</p> <p>A permitted porous area shall be local. The possibility of the pore cluster masking other imperfections shall be taken into consideration.</p> <p>If D is less than d_{A1} or d_{A2}, whichever is smaller, then the total gas pore area is represented by a circle of diameter d_{Ac}, where $d_{Ac} = d_{A1} + d_{A2} + D$.</p> <p>Systematic clustered porosity is not permitted.</p>				<p>d_A corresponds to d_{A1}, d_{A2} or d_{Ac} whichever is applicable</p>
2.6	2014	Linear porosity	—	$\geq 0,5$	Short imperfections permitted	Not permitted	
2.7	2015 2016	Elongated cavity Wormhole	—	$\geq 0,5$	$l \leq 0,4s$ or $0,4a$ but max. 6 mm	$l \leq 0,3s$ or $0,3a$ but max. 4 mm	$l \leq 0,2s$ or $0,2a$ but max. 3 mm
2.8	303	Oxide inclusion	If several oxide inclusions $l_1, l_2, l_3, \dots, l_n$ exist in one cross-section, they are summed: $l = l_1 + l_2 + l_3 + \dots + l_n$.	$\geq 0,5$	Short imperfections		
					$l \leq s$ or a max. 10 mm	$l \leq 0,5s$ or $0,5a$ max. 5 mm	$l \leq 0,2s$ or $0,2a$ max. 3 mm
2.9	304	Metallic inclusion	—	$\geq 0,5$	$l \leq 0,4s$ or $0,4a$ but max. 6 mm	$l \leq 0,3s$ or $0,3a$ but max. 4 mm	$l \leq 0,2s$ or $0,2a$ but max. 3 mm

Table 1 (continued)

No.	Reference No. in ISO 6520-1	Designation of imperfection	Remarks	t mm	Limits on imperfections for quality levels		
					D	C	B
2.10	401	Lack of fusion (incomplete fusion)		≥0,5	Short imperfections permitted $h \leq 0,4t$ or $0,4a$ but max. 3 mm	Short imperfections permitted $h \leq 0,2t$ or $0,2a$ but max. 2 mm	Not permitted

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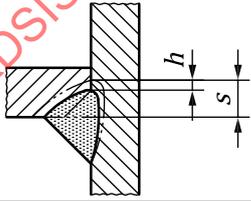
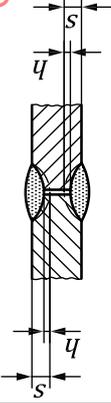
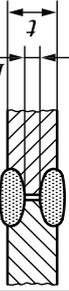
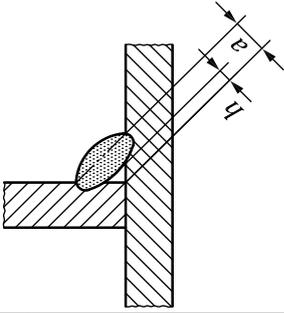
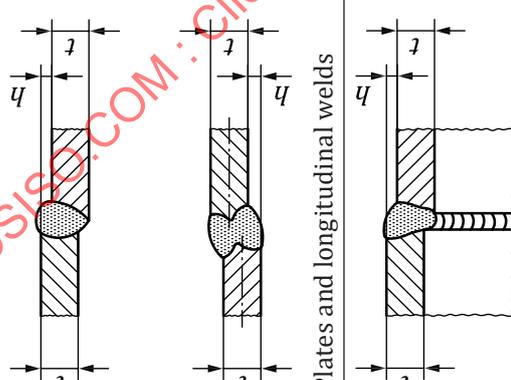
No.	Reference No. in ISO 6520-1	Designation of imperfection	Remarks	t mm	Limits on imperfections for quality levels		
					D	C	B
2.11	402	Lack of penetration (incomplete penetration)	Partial penetration:  	≥0,5	Short imperfections, but not systematic imperfections		
					$h \leq 0,4s$ max. 4 mm	$h \leq 0,2s$ max. 2 mm	Not permitted
2.12	4021	Incomplete root penetration for fillet welds	Full penetration:  	≥0,5	Short imperfection: $h \leq 0,2t$, but max. 2 mm	Not permitted	Not permitted
					Short imperfections	$h \leq 0,4a$ max. 4 mm	$h \leq 0,2a$ max. 2 mm

Table 1 (continued)

No.	Reference No. in ISO 6520-1	Designation of imperfection	Remarks	t mm	Limits on imperfections for quality levels		
					D	C	B
3 Imperfections in joint geometry							
3.1	507	Linear misalignment	<p>The limits relate to deviations from the correct position. Unless otherwise specified, the correct position is that when the centres coincide.</p> <p>t refers to the smaller thickness.</p>  <p>Plates and longitudinal welds</p> <p>Circumferential welds</p>	≥0,5	$h \leq 0,4t$ max. 8 mm	$h \leq 0,3t$ max. 4 mm	$h \leq 0,2t$ max. 2 mm
				≥0,5	$h \leq 0,4t$ max. 10 mm	$h \leq 0,3t$ max. 6 mm	$h \leq 0,2t$ max. 4 mm

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