
**Welding — Fusion-welded joints in
steel, nickel, titanium and their alloys
(beam welding excluded) — Quality
levels for imperfections**

*Soudage — Assemblages en acier, nickel, titane et leurs alliages
soudés par fusion (soudage par faisceau exclu) — Niveaux de qualité
par rapport aux défauts*

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Foreword

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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*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 121, *Welding and allied processes*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This fourth edition cancels and replaces the third edition (ISO 5817:2014), which has been technically revised.

The main changes are as follows:

- editorial updates;
- actual throat thickness a_A , used in [Table 1](#), nos 1.3, 1.4, 1.16 and 3.2;
- figures for [Table 1](#), nos 1.4, 1.5, 1.6, 1.11, 1.14, 1.16, 1.19, 2.12, 2.13 and 4.1 changed or added;
- [Table 1](#), no. 4.1: exclusion of several imperfections and change of acceptance criteria;
- Former Annex B deleted.

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

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

Some of the imperfections described in ISO 6520-1 have been used directly and some have been grouped together. The basic numerical referencing system from ISO 6520-1 has been used.

The purpose of this document is to specify dimensions of typical imperfections which might be expected in normal fabrication. It may 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 should be specified by the application standard or the responsible designer in conjunction with the manufacturer, user and/or other parties concerned. The quality level shall be prescribed before the start of production, preferably at the enquiry or order stage. For special purposes, additional details may be prescribed. If the welds will be subsequently coated with a protective coating, lining or paint, the welds might require more thorough post weld treatment or surface finishing to achieve the requirements in ISO 8501-3.

The quality levels given in this document provide basic reference data and are not specifically related to any particular application. They refer to 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.

The main part of the document takes no account for fitness or design for purpose. [Annex B](#) gives a possibility to address design for purpose for fatigue applications.

It would 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 should take 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 should include not only the cost of welding but also of inspection, testing and repair.

Although this document includes types of imperfection relevant to the fusion welding processes listed in [Clause 1](#), only those which are applicable to the process and application in question need to be 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 methods.

This document is directly applicable to visual testing of welds and does not include details of recommended methods of detection or sizing by non-destructive means. It should be considered that there are difficulties in using these limits to establish appropriate criteria applicable to non-destructive testing methods, such as ultrasonic testing (UT), radiographic testing (RT), eddy current testing (ET), penetrant testing (PT) and magnetic particle testing (MT) and that these will possibly need to be supplemented by requirements for inspection, examining and testing.

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 may include additional manufacturing processes, e.g. grinding, TIG dressing.

[Annex B](#) gives additional requirements for welds subject to fatigue.

Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) — Quality levels for imperfections

1 Scope

This document specifies quality levels of imperfections in fusion-welded joints (except for beam welding) in all types of steel, nickel, titanium and their alloys. It applies to material thickness $\geq 0,5$ mm. It covers fully penetrated butt welds and all fillet welds. Its principles can also be applied to partial-penetration butt welds.

Quality levels for beam-welded joints in steel are presented in ISO 13919-1.

Three quality levels are given in order to permit application to a wide range of welded fabrication. They are designated by symbols B, C and D. Quality level B corresponds to the highest requirement on the finished weld.

Several types of loads are considered, e.g. static load, thermal load, corrosion load, pressure load. Additional guidance on fatigue loads is given in [Annex B](#).

The quality levels refer to production and good workmanship.

This document is applicable to:

- a) non-alloy and alloy steels;
- b) nickel and nickel alloys;
- c) titanium and titanium alloys;
- d) manual, mechanized and automatic welding;
- e) all welding positions;
- f) all types of welds, e.g. butt welds, fillet welds and branch connections;
- g) the following welding processes and their sub-processes, as defined in ISO 4063:
 - 11 metal arc welding without gas protection;
 - 12 submerged arc welding;
 - 13 gas-shielded metal arc welding;
 - 14 gas-shielded arc welding with non-consumable tungsten electrode;
 - 15 plasma arc welding;
 - 31 oxyfuel gas welding (for steel only).

Metallurgical aspects, such as grain size and hardness, are not covered by 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 25901 (all parts), *Welding and allied processes — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in the ISO 25901 series 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 quality level

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

3.2 short imperfection

<welds 100 mm long or longer> imperfection whose total length is not greater than 25 mm in the 100 mm of the weld which contains the greatest number of imperfections

3.3 short imperfection

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

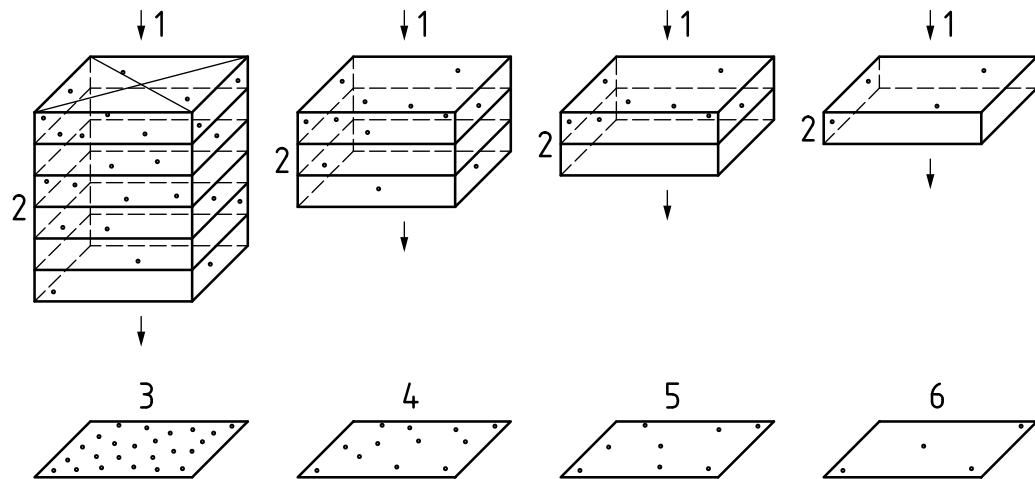
3.4 systematic imperfection

imperfection that is repeatedly distributed in the weld over the weld length to be tested, the size of a single imperfection being within the specified limits

3.5 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, the occurrence of imperfections is dependent on the weld thickness when exposed radiographically (see [Figure 1](#)).

**Key**

1	direction of rays	3	sixfold thickness	5	twofold thickness
2	four pores per volume unit	4	threefold thickness	6	onefold thickness

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

3.6**cross-sectional area**

area to be considered after fracture or sectioning

3.7**smooth transition**

even surface with no irregularities or sharpness at the transition between the weld bead and the parent material and/or the adjacent welding bead(s)

3.8**fatigue class****FAT_x**

classification reference to S-N curve

Note 1 to entry: x is the stress range in MPa at $2 \cdot 10^6$ cycles.

Note 2 to entry: Fatigue properties are described by S-N curves (stress-number of cycle-curves).

Note 3 to entry: See [Annex B](#).

4 Symbols

<i>a</i>	nominal throat thickness of the fillet weld (see also ISO 2553)
<i>a_A</i>	actual throat thickness (throat thickness of the finalized weld) (see ISO/TR 25901-1)
<i>A</i>	area surrounding the gas pores
<i>b</i>	width of weld reinforcement
<i>d</i>	diameter of gas pore
<i>d_A</i>	diameter of area surrounding the gas pores
<i>h</i>	height or width of imperfection

i	penetration in fillet welds
l	length of imperfection in longitudinal direction of the weld
l_p	length of projected or cross-sectional area
r	radius of weld toe
s	nominal butt weld thickness
t	wall or plate thickness (nominal size)
w_p	width of the weld or width or height of the cross-sectional area
z	leg length of a fillet weld (see also ISO 2553)
α	angle of weld toe
β	angle of angular misalignment

5 Assessment of imperfections

Limits for imperfections in accordance with ISO 6520-1 are given in [Table 1](#).

If, for the detection of imperfections, macro-examination is used, only those imperfections shall be considered which can be detected with a maximum of tenfold magnification. Excluded from this are micro lack of fusion (see [Table 1](#), 1.5) and microcracks (see [Table 1](#), 2.2).

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

A welded joint should usually be assessed separately for each individual type of imperfection (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 for multiple imperfections (see [Table 1](#)) are only applicable for 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 for imperfections

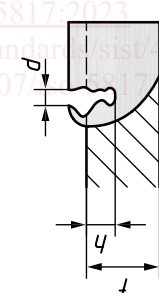
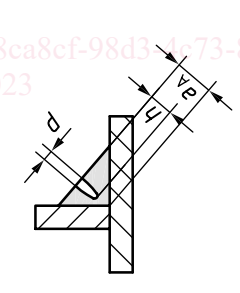
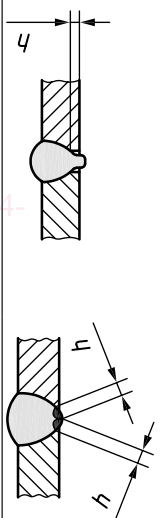
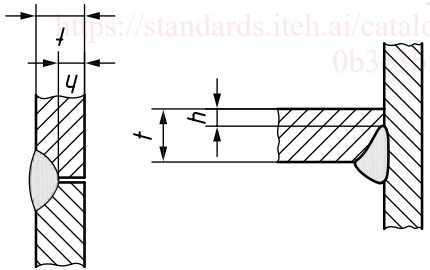
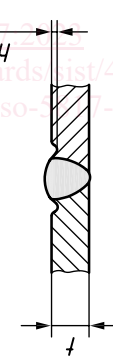
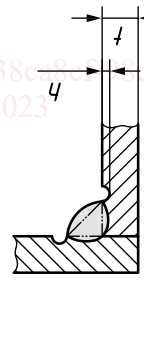
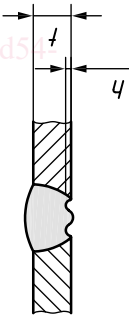
No.	Reference to ISO 6520-1	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
1 Surface imperfections							
1.1	100	Crack		≥ 0,5	Not permitted	Not permitted	Not permitted
1.2	104	Crater crack		≥ 0,5	Not permitted	Not permitted	Not permitted
1.3	2017	Surface pore	On the weld face or the weld root Maximum dimension of a single pore	0,5 to 3	Butt welds $d \leq 0,3 s$ fillet welds $d \leq 0,3 a_A$	Not permitted	Not permitted
				> 3	Butt welds $d \leq 0,3 s$, but max. 3 mm fillet welds $d \leq 0,3 a_A$, but max. 3 mm	butt welds $d \leq 0,2 s$, but max. 2 mm fillet welds $d \leq 0,2 a_A$, but max. 2 mm	Not permitted
1.4	2025	End crater pipe	— butt welds 	0,5 to 3	Butt welds $h \leq 0,2 s$ $d \leq 0,3 s$ fillet welds $h \leq 0,2 a_A$, $d \leq 0,3 a_A$	Not permitted	Not permitted
			— fillet welds 	> 3	Butt welds $h \leq 0,2 s$, but max. 2 mm $d \leq 0,3 s$, but max. 3 mm fillet welds $h \leq 0,2 a_A$, but max. 2 mm $d \leq 0,3 a_A$, but max. 3 mm	Butt welds $h \leq 0,1 s$, but max. 1 mm $d \leq 0,2 s$, but max. 2 mm fillet welds $h \leq 0,1 a_A$, but max. 1 mm $d \leq 0,2 a_A$, but max. 2 mm	Not permitted
1.5	401	Lack of fusion (incomplete fusion)		≥ 0,5	Not permitted	Not permitted	Not permitted
4014		Micro lack of fusion	Only detectable by micro examination ($\geq 50 \times$)	≥ 0,5	Permitted	Permitted	Not permitted

Table 1 (continued)

No.	Reference to ISO 6520-1	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
1.6	4021	Incomplete root penetration	<p>Only for single side butt welds (full penetration)</p> 	<p>Short imperfections: $h \leq 0,2 t$ but max. 2 mm</p>	Not permitted	Not permitted	
1.7	5011	Continuous undercut	<p>Smooth transition is required. This is not regarded as a systematic imperfection.</p> 	0,5 to 3	Short imperfections: $h \leq 0,1 t$	Not permitted	
	5012	Intermittent undercut (short imperfection)		> 3	<p>Short imperfections: $h \leq 0,2 t$ but max. 1 mm</p>	<p>Short imperfections: $h \leq 0,1 t$ but max. 0,5 mm</p>	
1.8	5013	Shrinkage grooves	<p>Smooth transition is required.</p> 	0,5 to 3	Short imperfections: $h \leq 0,1 t + 0,2$ mm	Not permitted	
				> 3	Short imperfections: $h \leq 0,2 t$ but max. 2 mm	Short imperfections: $h \leq 0,1 t$ but max. 0,5 mm	