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Arc-welded joints in steel — Guidance on quality levels for imperfections

*Assemblages en acier soudés à l'arc — Guide des niveaux d'acceptation
des défauts*



Reference number
ISO 5817:1992(E)

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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 5817 was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, Sub-Committee SC 10, *Unification of requirements in the field of metal welding*.

Annex A of this International Standard is for information only.

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Introduction

This International Standard should be used as a reference in the drafting of application codes and/or other application standards. It may be used within a total quality system for the production of satisfactory 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 defined by the application standard or the responsible designer in conjunction with the manufacturer, user and/or other parties concerned. The level shall be prescribed before the start of production, preferably at the inquiry or order stage. For special purposes, additional details may need to be prescribed.

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

Quality levels are listed in table 0.1.

Table 0.1 — Quality levels for weld imperfections

Level symbol	Quality level
D	Moderate
C	Intermediate
B	Stringent

The three quality levels are arbitrarily identified as D, C and B and are intended to cover the majority of practical applications.

It would normally be hoped that for a particular welded joint the dimensional limits for imperfections could all be covered by specifying one quality level. In some cases, however, e.g. for certain type of steels and structures as well as for fatigue loading or leak tightness applications, it may be necessary to specify different quality levels for different imperfections in the same welded joint or to include additional requirements.

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 that of inspection, test and repair.

Although this International Standard includes types of imperfections relevant to the arc welding processes given 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 may require the use of one or more methods of non-destructive testing. The detection and sizing of imperfections is dependent on the inspection methods and the extent of testing specified in the application standard or contract.

This International Standard does not include details of recommended methods of detection and sizing and, therefore, it needs to be supplemented by requirements for examination, inspection and testing. It should be appreciated that methods of non-destructive examination may not be able to give the detection, characterization and sizing necessary for use within certain types of imperfections shown in table 1.

Although this International Standard covers a material thickness range of 3 mm to 63 mm, it may well be applicable to thicker or thinner joints provided consideration is given to those technical factors which may influence the situation.

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Arc-welded joints in steel — Guidance on quality levels for imperfections

1 Scope

This International Standard provides guidance on levels of imperfections in arc-welded joints in steel. Three levels are given in such a way as to permit application for a wide range of welded fabrications. The levels refer to production quality and not to the fitness-for-purpose (see 3.1) of the product manufactured.

This International Standard applies to

- unalloyed and alloyed steels;
- the following welding processes and their defined sub-processes in accordance with ISO 4063:
 - 11 metal-arc welding without gas protection;
 - 12 submerged-arc welding;
 - 13 gas-shielded metal-arc welding;
 - 14 gas-shielded welding with non-consumable electrode;
 - 15 plasma arc welding;
- manual, mechanized and automatic processes;
- all welding positions;
- butt welds, fillet welds and branch connections;
- materials in the thickness range 3 mm to 63 mm.

When significant deviations from the joint geometries and dimensions described in this International Standard are present in the welded product, it is necessary to evaluate to what extent the provisions of this standard can apply.

Metallurgical aspects, e.g. grain size, hardness, are not covered by this International Standard.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 2553:1992, *Welded, brazed and soldered joints — Symbolic representation on drawings*.

ISO 4063:1990, *Welding, brazing, soldering and braze welding of metals — Nomenclature of processes and reference numbers for symbolic representation on drawings*.

ISO 6520:1982, *Classification of imperfections in metallic fusion welds, with explanations*.

3 Definitions

For the purposes of this International Standard, the following definitions apply.

3.1 fitness-for-purpose: A product is fit for its intended purpose when it functions satisfactorily in service during its stipulated lifetime. The product may deteriorate in service, but not to such a degree that fracture and subsequent failure occurs. Products may, of course, be misused or overloaded; it is presumed that the actual conditions during service correspond to the intended conditions, including statistical variations, e.g. live loads.

3.2 Weld thickness

3.2.1 fillet weld thickness, a ; nominal throat thickness: Height of the largest isosceles triangle that can be inscribed in the weld section (see ISO 2553).

NOTE 1 In countries in which the leg length, z , is used as the dimension of a fillet weld, the limits for imperfections may be reformulated so that they refer to the leg length.

3.2.2 butt weld thickness, s : Minimum distance from the surface of the part to the bottom of the penetration, which cannot be greater than the thickness of the thinner of the parts (see ISO 2553).

3.3 short imperfections: One or more imperfections of total length not greater than 25 mm in any 100 mm length of the weld or a maximum of 25 % of the weld length for a weld shorter than 100 mm.

3.4 long imperfection: One or more imperfections of total length greater than 25 mm in any 100 mm length of the weld or a minimum of 25 % of the weld length for a weld shorter than 100 mm.

3.5 projected area: Area given by length of weld examined multiplied by the maximum width of weld.

3.6 surface crack area: Area to be considered after fracture.

4 Symbols

The following symbols are used in table 1.

- a nominal fillet weld throat thickness (fillet thickness)
- b width of weld reinforcement
- d diameter of pore
- h size (height or width) of imperfection
- l length of imperfection
- s nominal butt weld thickness or, in the case of partial penetration, the prescribed depth of penetration
- t wall or plate thickness
- z leg length of fillet welds (in case of isosceles right angle triangular section $z = a\sqrt{2}$)

5 Evaluation of welds

Limits for imperfections are given in table 1.

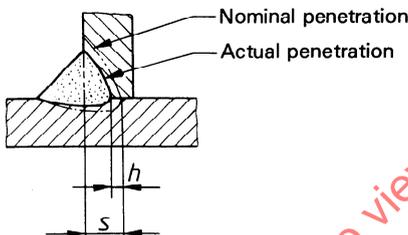
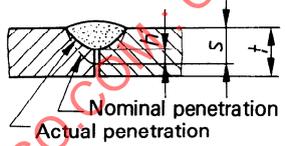
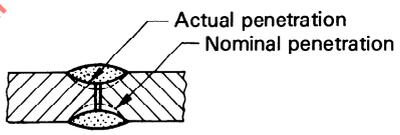
A welded joint should normally be evaluated separately for each individual type of imperfection (Nos. 1 to 25).

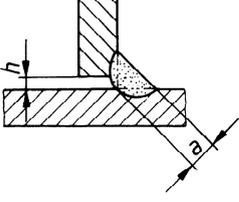
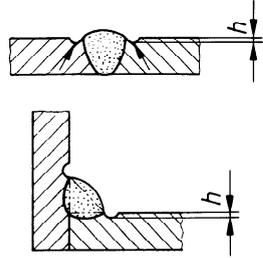
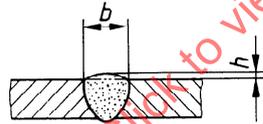
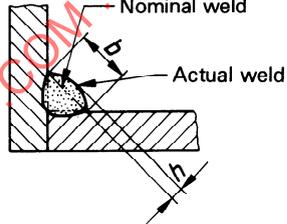
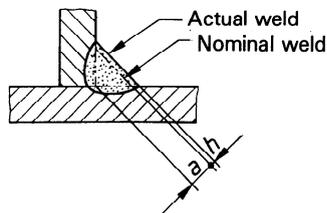
Different types of imperfection occurring at any cross-section of the joint may need special consideration (see No. 26).

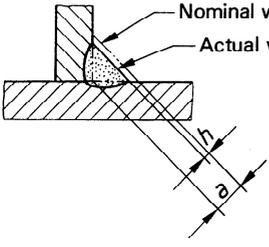
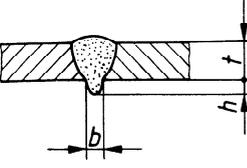
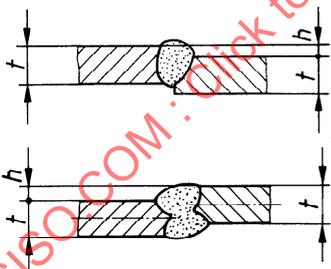
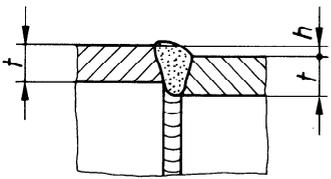
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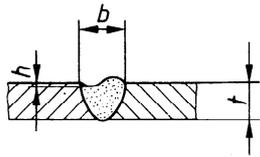
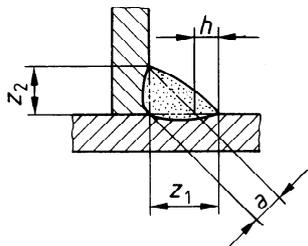
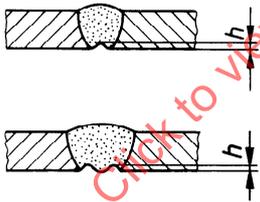
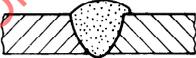
Table 1 — Limits for imperfections

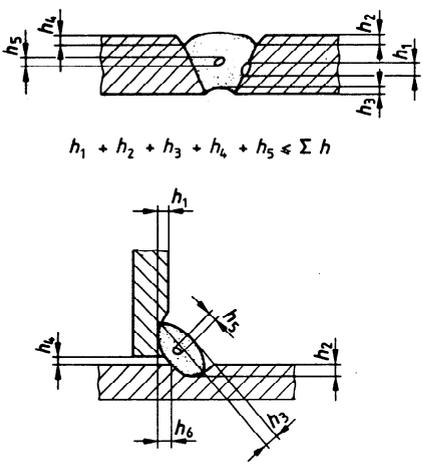
No.	Imperfection designation	ISO 6520 reference	Remarks	Limits for imperfections for quality levels		
				Moderate D	Intermediate C	Stringent B
1	Cracks	100	All types of cracks except micro cracks ($h \cdot l < 1 \text{ mm}^2$), crater cracks, see No. 2	Not permitted		
2	Crater crack	104		Permitted	Not permitted	
3	Porosity and gas pores	2011 2012 2014 2017	The following conditions and limits for imperfections shall be fulfilled: a) Maximum dimension of the summation of the projected or surface crack area of the imperfection b) Maximum dimension of a single pore for — butt welds — fillet welds c) Maximum dimension for a single pore	4 % $d \leq 0,5 s$ $d \leq 0,5 a$ 5 mm	2 % $d \leq 0,4 s$ $d \leq 0,4 a$ 4 mm	1 % $d \leq 0,3 s$ $d \leq 0,3 a$ 3 mm
4	Localized (clustered) porosity	2013	The total pore area within the cluster should be summed and calculated as a percentage of the greater of the two areas: an envelope surrounding all the pores or a circle with a diameter corresponding to the weld width. The permitted porous area should be local. The possibility of masking other imperfections should be taken into consideration. The following conditions and limits for imperfections shall be fulfilled: a) Maximum dimension of the summation of the projected or surface crack area of the imperfection b) Maximum dimension of a single pore for — butt welds — fillet welds c) Maximum dimension for localized clustered porosity	16 % $d \leq 0,5 s$ $d \leq 0,5 a$ 4 mm	8 % $d \leq 0,4 s$ $d \leq 0,4 a$ 3 mm	4 % $d \leq 0,3 s$ $d \leq 0,3 a$ 2 mm
5	Elongated cavities, wormholes	2015 2016	Long imperfections for — butt welds — fillet welds In any case, maximum dimension for elongated cavities, wormholes	$h \leq 0,5 s$ $h \leq 0,5 a$ 2 mm	Not permitted	Not permitted
			Short imperfections for — butt welds — fillet welds In any case, maximum dimension for elongated cavities, wormholes	$h \leq 0,5 s$ $h \leq 0,5 a$ 4 mm or Not Larger Than Thickness (NLTT)	$h \leq 0,4 s$ $h \leq 0,4 a$ 3 mm or NLTT	$h \leq 0,3 s$ $h \leq 0,3 a$ 2 mm or NLTT

No.	Imperfection designation	ISO 6520 reference	Remarks	Limits for imperfections for quality levels		
				Moderate D	Intermediate C	Stringent B
6	Solid inclusions (other than copper)	300	Long imperfections for — butt welds — fillet welds In any case, maximum dimension for solid inclusions	$h \leq 0,5 s$ $h \leq 0,5 a$ 2 mm	Not permitted	Not permitted
			Short imperfections for — butt welds — fillet welds In any case, maximum dimension for solid inclusions	$h \leq 0,5 s$ $h \leq 0,5 a$ 4 mm or Not Larger Than Thickness (NLTT)	$h \leq 0,4 s$ $h \leq 0,4 a$ 3 mm or NLTT	$h \leq 0,3 s$ $h \leq 0,3 a$ 2 mm or NLTT
7	Copper inclusions	3042		Not permitted		
8	Lack of fusion (incomplete fusion)	401		Permitted, but only intermittently and not breaking the surfaces	Not permitted	
9	Lack of penetration (incomplete penetration)	402	 <p>Nominal penetration Actual penetration</p> <p>Figure A</p>  <p>Nominal penetration Actual penetration</p> <p>Figure B</p>  <p>Actual penetration Nominal penetration</p> <p>Figure C</p>	Long Imperfections: Not permitted	Short Imperfections: $h \leq 0,2 s$, max. 2 mm	
						$h \leq 0,1 s$, max. 1,5 mm

No.	Imperfection designation	ISO 6520 reference	Remarks	Limits for Imperfections for quality levels		
				Moderate D	Intermediate C	Stringent B
10	Bad fit-up, fillet welds		<p>An excessive or insufficient gap between the parts to be joined</p>  <p>Gaps exceeding the appropriate limit may in certain cases be compensated for by a corresponding increase in the throat</p>	$h \leq 1 \text{ mm} + 0,3 a$, max. 4 mm	$h \leq 0,5 \text{ mm} + 0,2 a$, max. 3 mm	$h \leq 0,5 \text{ mm} + 0,1 a$, max. 2 mm
11	Undercut	5011 5012	<p>Smooth transition is required</p> 	$h \leq 1,5 \text{ mm}$	$h \leq 1,0 \text{ mm}$	$h \leq 0,5 \text{ mm}$
12	Excess weld metal	502	<p>Smooth transition is required</p> 	$h \leq 1 \text{ mm} + 0,25 b$, max. 10 mm	$h \leq 1 \text{ mm} + 0,15 b$, max. 7 mm	$h \leq 1 \text{ mm} + 0,1 b$, max. 5 mm
13	Excessive convexity	503	<p>Nominal weld Actual weld</p> 	$h \leq 1 \text{ mm} + 0,25 b$, max. 5 mm	$h \leq 1 \text{ mm} + 0,15 b$, max. 4 mm	$h \leq 1 \text{ mm} + 0,1 b$, max. 3 mm
14	Fillet weld having a throat thickness greater than the nominal value		<p>For many applications a throat thickness greater than the nominal one may not be a reason for rejection</p> 	$h \leq 1 \text{ mm} + 0,3 a$, max. 5 mm	$h \leq 1 \text{ mm} + 0,2 a$, max. 4 mm	$h \leq 1 \text{ mm} + 0,15 a$, max. 3 mm

No.	Imperfection designation	ISO 6520 reference	Remarks	Limits for imperfections for quality levels								
				Moderate D	Intermediate C	Stringent B						
15	Fillet weld having a throat thickness smaller than the nominal value	—	<p>A fillet weld with an apparent throat thickness smaller than that prescribed should not be regarded as being imperfect if the actual throat thickness with a compensating greater depth of penetration complies with the nominal value</p> 	Long imperfections: Not permitted		Not permitted						
				Short imperfections: $h \leq 0,3 \text{ mm} + 0,1 a$ max. 2 mm	max. 1 mm							
16	Excessive penetration	504		$h \leq 1 \text{ mm} + 1,2 b$ max. 5 mm	$h \leq 1 \text{ mm} + 0,6 b$ max. 4 mm	$h \leq 1 \text{ mm} + 0,3 b$ max. 3 mm						
17	Local protrusion	5041		Permitted	Occasional local excess permitted							
18	Linear misalignment	507	<p>The limits relate to deviations from the correct position. Unless otherwise specified, the correct position is that when the centrelines coincide (see also clause 1). t refers to the smaller thickness</p>  <p>Figure A</p>  <p>Figure B</p>	<p>Figure A — Plates and longitudinal welds</p> <table border="1"> <tr> <td>$h \leq 0,25 t$ max. 5 mm</td> <td>$h \leq 0,15 t$ max. 4 mm</td> <td>$h \leq 0,1 t$ max. 3 mm</td> </tr> </table> <p>Figure B — Circumferential welds</p> <table border="1"> <tr> <td>max. 4 mm</td> <td>$h \leq 0,5 t$ max. 3 mm</td> <td>max. 2 mm</td> </tr> </table>			$h \leq 0,25 t$ max. 5 mm	$h \leq 0,15 t$ max. 4 mm	$h \leq 0,1 t$ max. 3 mm	max. 4 mm	$h \leq 0,5 t$ max. 3 mm	max. 2 mm
				$h \leq 0,25 t$ max. 5 mm	$h \leq 0,15 t$ max. 4 mm	$h \leq 0,1 t$ max. 3 mm						
max. 4 mm	$h \leq 0,5 t$ max. 3 mm	max. 2 mm										

No.	Imperfection designation	ISO 6520 reference	Remarks	Limits for imperfections for quality levels		
				Moderate D	Intermediate C	Stringent B
19	Incompletely filled groove	511	Smooth transition is required. 	Long imperfections: Not permitted		
	Sagging	509		$h \leq 0,2 t$, max. 2 mm	$h \leq 0,1 t$, max. 1 mm	$h \leq 0,05 t$, max. 0,5 mm
20	Excessive asymmetry fillet weld	512	It is assumed that an asymmetric fillet weld has not been expressly prescribed. 	$h \leq 2 \text{ mm} + 0,2 a$	$h \leq 2 \text{ mm} + 0,15 a$	$h \leq 1,5 \text{ mm} + 0,15 a$
21	Root concavity Shrinkage groove	515 5013	Smooth transition is required. 	$h \leq 1,5 \text{ mm}$	$h \leq 1 \text{ mm}$	$h \leq 0,5 \text{ mm}$
22	Overlap	506		Short imperfections are permitted	Not permitted	
23	Poor restart	517		Permitted	Not permitted	
24	Stray flash or arc strike	601		Acceptance may be influenced by post treatment. Acceptance depends on type of parent metal, with particular reference to crack sensitivity.		
25	Spatter	602		Acceptance depends on applications.		

No.	Imperfection designation	ISO 6520 reference	Remarks	Limits for imperfections for quality levels		
				Moderate D	Intermediate C	Stringent B
26	Multiple Imperfections in any cross-section ¹⁾	—	<p>For thicknesses $s \leq 10$ mm or $a \leq 10$ mm or less, special consideration may be necessary.</p>  <p>$h_1 + h_2 + h_3 + h_4 + h_5 \leq \Sigma h$</p> <p>$h_1 + h_2 + h_3 + h_4 + h_5 + h_6 = \Sigma h$</p>	<p>Maximum total height of short imperfections Σh</p> <p>0,25 s or 0,25 a, max. 10 mm</p>	<p>0,2 s or 0,2 a, max. 10 mm</p>	<p>0,15 s or 0,15 a, max. 10 mm</p>
<p>1) See annex A.</p>						

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