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Welding — Laser-arc hybrid welding of steels, nickel and nickel alloys — Quality levels for imperfections

Soudage — Soudage hybride laser-arc des aciers, du nickel et des alliages de nickel — Niveaux de qualité par rapport aux défauts

Reference number
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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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.

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.

ISO 12932 was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 10, *Unification of requirements in the field of metal welding*.

Requests for official interpretation of any aspect of this International Standard 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.

Introduction

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

Some 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 International Standard 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 is defined by the application standard or the responsible designer in conjunction with the manufacturer, user and/or other parties concerned. The quality level is expected to be prescribed prior to the start of production, preferably at the enquiry or order stage. For special purposes, additional details can be prescribed.

The quality levels given in this International Standard 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 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 is expected to 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 are intended to include not only the cost of welding, but also of inspection, test and repair.

Although this International Standard includes types of imperfection relevant to the laser-arc hybrid 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 are dependent on the inspection methods and the extent of testing specified in the application standard or contract.

This International Standard 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 International Standard is directly applicable to visual examination 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 non-destructive testing methods, such as ultrasonic, radiographic and penetrant testing, and they can need to be supplemented by requirements for inspection, examination and testing.

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

Welding — Laser-arc hybrid welding of steels, nickel and nickel alloys — Quality levels for imperfections

1 Scope

This International Standard specifies quality levels of imperfections in laser-arc hybrid welded joints for all types of steel, nickel and its alloys. It applies to material thickness ≥0,5 mm.

Three quality levels are given in order to permit application for a wide range of welded fabrication. They are designated by 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 3.3) of the product manufactured.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable to its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2553, *Welding and allied processes — Symbolic representation on drawings — Welded, brazed and soldered joints*

ISO 5817:2003, *Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) — Quality levels for imperfections*

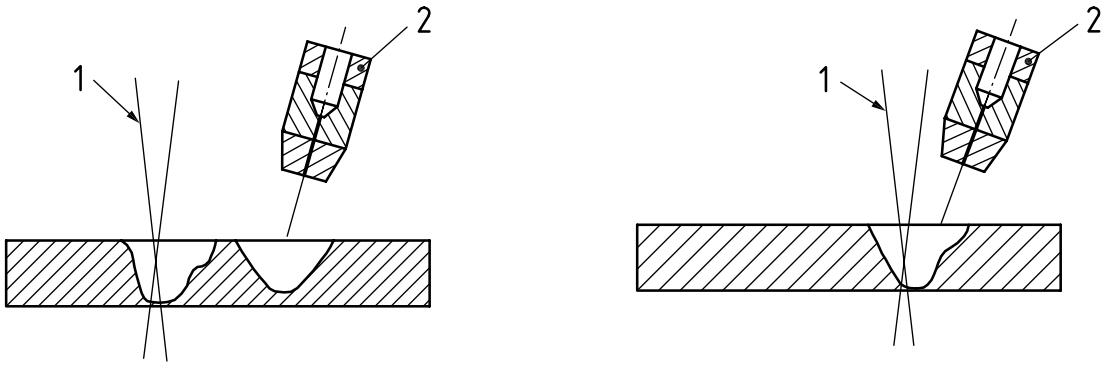
ISO 6520-1, *Welding and allied processes — Classification of geometric imperfections in metallic materials — Part 1: Fusion welding*

3 Terms and definitions

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

3.1
hybrid welding
welding in which two or more welding processes are used simultaneously in the same weld pool

Note 1 to entry: Hybrid welding differs from combinations of processes where at least two melt pools exist which are completely separated by a solid component in the solidification phases. Examples of a combined process (a) and a laser-arc hybrid welding process (b) are given in Figure 1 by using a laser beam and the additional energy source of an arc.



a) Combined process **b) Hybrid process**

Key
1 laser beam
2 torch

Figure 1 — Combination of welding processes

3.2
quality level
description of the quality of a weld on the basis of type, size and amount of selected imperfections

[SOURCE: ISO 5817:2003, 3.1]

3.3
fitness-for-purpose
ability of a product, process or service to serve a defined purpose under specific conditions

[SOURCE: ISO 5817:2003, 3.2]

3.4
short imperfection
<cases when the weld is 100 mm long or longer> imperfection for which, in the 100 mm which contains the greatest number of imperfections, the total length of the imperfections is not greater than 25 mm

[SOURCE: ISO 5817:2003, 3.3, modified.]

3.5
short imperfection
<cases when the weld is less than 100 mm long> imperfection in which the total length of the imperfections is not greater than 25 % of the length of the weld

[SOURCE: ISO 5817:2003, 3.3, modified.]

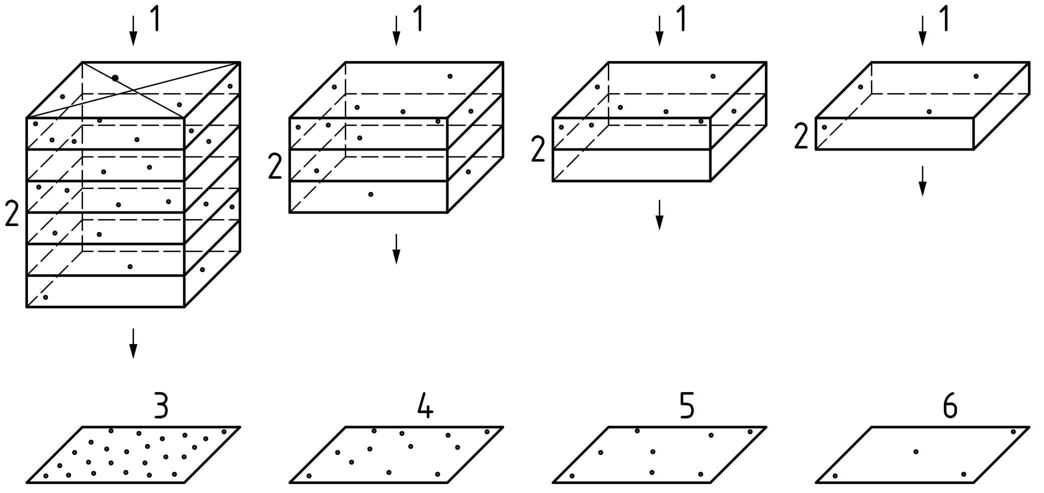
3.6
systematic imperfection
imperfection that is repeatedly distributed in the weld over the weld length to be examined, the size of the single imperfection being within the specified limits

[SOURCE: ISO 5817:2003, 3.4, modified.]

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, the occurrence of imperfections is dependent on the weld thickness when exposed radiographically (see Figure 2).

[SOURCE: ISO 5817:2003, 3.5, modified — “Figure 1” has been replaced by “Figure 2”.]



Key

1 direction of X-rays
2 four pores per volume unit
3 six-fold thickness
4 three-fold thickness
5 two-fold thickness
6 one-fold thickness

Figure 2 — Radiographic films of specimens with identical occurrence of pores per volume unit

3.8
cross-sectional area
area to be considered after fracture or sectioning

[SOURCE: ISO 5817:2003, 3.6.]

4 Symbols

For the purposes of this document, the following symbols apply.

a nominal throat thickness of the fillet weld (given in ISO 2553)

A area surrounded by pores

b width of weld reinforcement

d diameter of pore

d_A diameter of pore within area surrounded by pores

h height or width of imperfection

l length of imperfection in longitudinal direction of the weld

l_p length of projected or fracture surface area

s connected cross-section or nominal butt weld thickness (given in ISO 2553)

t wall or plate thickness (nominal size)

w_p width of the weld or width or height in case of fracture area

z leg length of a fillet weld (given in ISO 2553)

α angle of weld toe

β angle of angular misalignment

5 Assessment of imperfections

Limits to imperfections are given in Table 1. These limits apply to the finished weld and may also be applied to an intermediate stage of fabrication.

If a method other than macro examination is used for the detection of imperfections, only those imperfections which can be detected with a maximum magnification of tenfold, shall be considered. Microcracks (see Table 1, No 2.2) and micro lack of fusion (see Table 1, No 1.5)are excluded.

Systematic imperfections are only permitted in quality level D, provided other requirements of Table 1 are fulfilled.

A welded joint should normally be assessed separately for each individual type of imperfection.

Different types of imperfection occurring at any cross-section of the joint, which weaken the cross-section, may need special consideration (see Table 1, multiple imperfections).

The limits for multiple imperfections (see Table 1) are only applicable to cases where the requirements for a single imperfection are not exceeded.

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

Table 1 — Limits to imperfections

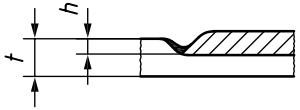
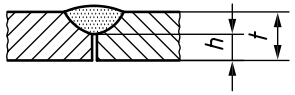
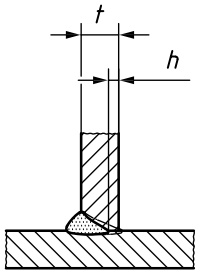
No.	ISO 6520-1 reference	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
1 Surface imperfections							
1.1	100	Crack	—		Not permitted	Not permitted	Not permitted
1.2	104	Crater crack	—		Permitted	Not permitted	Not permitted
1.3	2017	Surface pore	Maximum dimension of a single pore for — butt welds — fillet welds	≤ 3	$d \le 0{,}3\ s$ $d \le 0{,}5\ a$	Not permitted	Not permitted
			Maximum dimension of a single pore for — butt welds — fillet welds	> 3	$d \le 0{,}3\ s$, but max. 3 mm or width of weld, whichever is smaller $d \le 0{,}5\ a$, but max. 3 mm	$d \le 0{,}2\ s$, but max. 2 mm $d \le 0{,}4\ a$, but max. 2 mm	Not permitted
1.4	2025	End crater pipe		≤ 3	$h \le 0{,}2\ t$	Not permitted	Not permitted
				> 3	$h \le 0{,}2\ t$, but max. 2 mm	$h \le 0{,}1\ t$, but max. 1 mm	Not permitted
1.5	401	Lack of fusion (incomplete fusion)	—	≥ 0,5	Not permitted	Not permitted	Not permitted
		Micro lack of fusion	Usually only visible under the microscope (50 ×)		Permitted	Permitted	Not permitted
1.6	4021	Incomplete root penetration	For single-side butt welds  For single-side T-joint welds (butt welds) 		Short imperfections: $h \le 0{,}15\ t$, but max. 1 mm	Not permitted	Not permitted

Table 1 *(continued)*

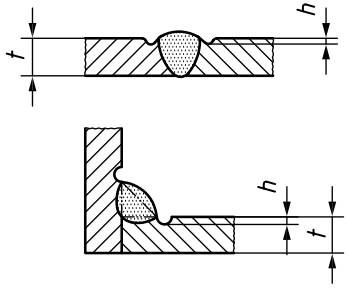
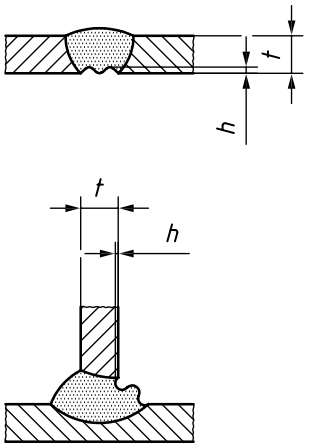
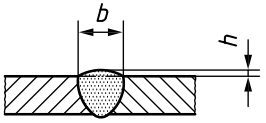
No.	ISO 6520-1 reference	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
1.7	5011 5012	Continuous undercut Intermittent undercut	Smooth transition is required. This is not regarded as a systematic imperfection. 		$h \leq 0{,}2\ t$, but max. 1 mm	$h \leq 0{,}1\ t$, but max. 0,5 mm	$h \leq 0{,}05\ t$, but max. 0,5 mm
1.8	5013	Shrinkage groove (butt weld) Shrinkage groove (T-joint, full penetration)	Smooth transition is required. 		$h \leq 0{,}2\ t$, but max. 1 mm	$h \leq 0{,}1\ t$, but max. 0,5 mm	$h \leq 0{,}05\ t$, but max. 0,5 mm
1.9	502	Excess weld metal (butt weld, parallel joint, overlap joint)	Smooth transition is required. 		$h \leq 1$ mm + 0,25 b, but max. 10 mm	$h \leq 1$ mm + 0,15 b, but max. 7 mm	$h \leq 1$ mm + 0,1 b, but max. 5 mm

Table 1 *(continued)*

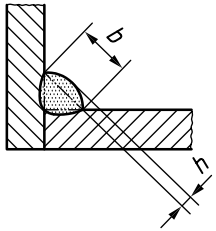
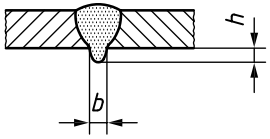
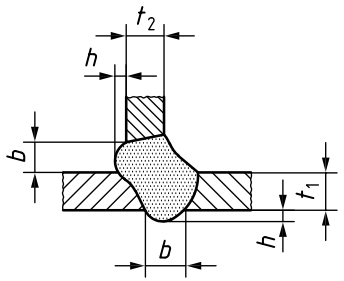
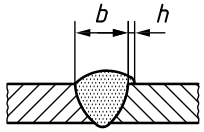
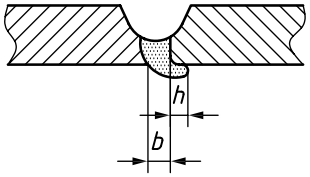
No.	ISO 6520-1 reference	Imperfection designation	Remarks	*t* mm	Limits for imperfections for quality levels		
					D	C	B
1.10	503	Excessive convexity (fillet weld	Smooth transition is required. 		$h \leq 1\ mm + 0{,}25\ b$, but max. 5 mm	$h \leq 1\ mm + 0{,}15\ b$, but max. max. 4 mm	$h \leq 1\ mm + 0{,}1\ b$, but max. 3 mm
1.11	504	Excess penetration		≤ 3	$h \leq 1\ mm + 0{,}6\ b$	$h \leq 1\ mm + 0{,}3\ b$	$h \leq 1\ mm + 0{,}1\ b$
				> 3	$h \leq 1\ mm + 1{,}0\ b$ or 5 mm, whichever is smaller	$h \leq 1\ mm + 0{,}6\ b$ or 4 mm, whichever is smaller	$h \leq 1\ mm + 0{,}3\ b$ or 3 mm, whichever is smaller
1.12	5061	Overlap			$h \leq 0{,}2\ b$	Not permitted	Not permitted
	5062				$h \leq 0{,}2\ b$	Not permitted	Not permitted

Table 1 *(continued)*

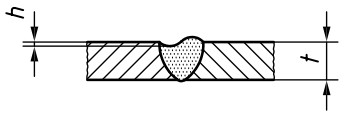
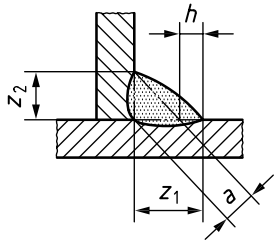
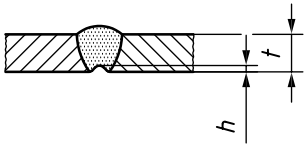
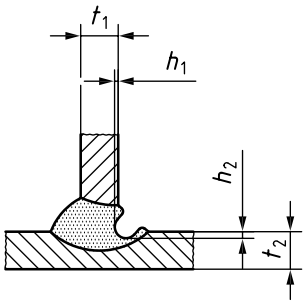
No.	ISO 6520-1 reference	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
1.13	509 511	Sagging Incompletely filled groove	Smooth transition is required 	≤ 3	Short imperfections: $h \leq 0{,}25\ t$	Short imperfections: $h \leq 0{,}1\ t$	Not permitted
				> 3	Short imperfections: $h \leq 0{,}25\ t$, but max. 2 mm	Short imperfections: $h \leq 0{,}1\ t$ but max. 1 mm	Short imperfections: $h \leq 0{,}05\ t$, but max. 0,5 mm
1.14	510	Burn through	—		Not permitted	Not permitted	Not permitted
1.15	512	Excessive asymmetry of fillet weld (excessive unequal leg length)	In cases where an asymmetric fillet weld has not been prescribed.  Partial penetration single-side hybrid welding.		$h \leq 2$ mm + 0,2 a	$h \leq 2$ mm + 0,15 a	$h \leq 1{,}5$ mm + 0,15 a
1.16	515	Root concavity	Smooth transition is required.  	≤ 3	$h \leq 0{,}2$ mm + 0,1 t The limit depends on the thicker plate.	Short imperfections: $h \leq 0{,}1\ t$ The limit depends on the thicker plate.	Not permitted
				> 3	Short imperfections: $h_{(x)} \leq 0{,}3\ t_{(x)}$, but max. 2 mm	Short imperfections: $h_{(x)} \leq 0{,}2\ t_{(x)}$, but max. 1 mm	Short imperfections: $h_{(x)} \leq 0{,}1\ t_{(x)}$, but max. 0,5 mm

Table 1 *(continued)*

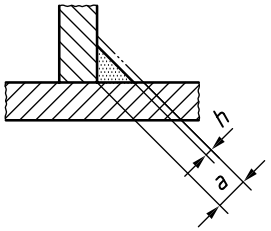
No.	ISO 6520-1 reference	Imperfection designation	Remarks	*t* mm	Limits for imperfections for quality levels		
					D	C	B
1.17	516	Root porosity	Spongy formation at the root of a weld due to bubbling of the weld metal at the moment of solidification (e.g. lack of gas backing)		Locally permitted	Not permitted	Not permitted
1.18	5213	Insufficient throat thickness	 Only applicable if *a* is specified. Not fully connected web and single-side hybrid welding.	≤ 3	Short imperfections: $h \leq 0{,}2$ mm + 0,1 *a*	Short imperfections: $h \leq 0{,}2$ mm	Not permitted
				> 3	Short imperfections: $h \leq 0{,}3$ mm + 0,1 *a*, but max. 2 mm	Short imperfections: $h \leq 0{,}3$ mm + 0,1 *a*, but max. 1 mm	Not permitted
1.19	602	Spatter	—	≥ 0,5	Acceptance depends on application, e.g. material, corrosion protection		
2 Internal imperfections							
2.1	100	Crack	All types of cracks except micro-cracks and crater cracks		Not permitted	Not permitted	Not permitted
2.2	1001	Microcrack	A crack usually only visible under the microscope (50x)		Permitted	Acceptance depends on type of parent metal with particular reference to crack sensitivity	
2.3	2011 2012	Gas pore Uniformly distributed porosity	The following conditions and limits for imperfections shall be fulfilled (see Annex A for information): a1) Maximum dimension of the area of the imperfections (inclusive systematic imperfection) related to the projected area NOTE The porosity in the project area depends on the numbers of layers (volume of the weld).		for single layer: ≤ 2,5 % for multilayer: ≤ 5 %	for single layer: ≤ 1,5 % for multilayer: ≤ 3 %	for single layer: ≤ 1 % for multilayer: ≤ 2 %
			a2) Maximum dimension of the cross-sectional area of the imperfections (inclusive systematic imperfection) related to the fracture area (only applicable to production, welder or procedure tests)		≤ 2,5 %	≤ 1,5 %	≤ 1 %
			b) Maximum dimension for a single pore for — butt welds — fillet welds		$d \leq 0{,}5\ s$, but max. 5 mm $d \leq 0{,}5\ a$, but max. 5 mm	$d \leq 0{,}4\ s$, but max. 4 mm $d \leq 0{,}4\ a$, but max. 4 mm	$d \leq 0{,}3\ s$, but max. 3 mm $d \leq 0{,}3\ a$, but max. 3 mm

Table 1 *(continued)*

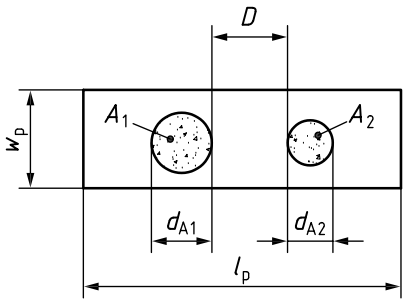
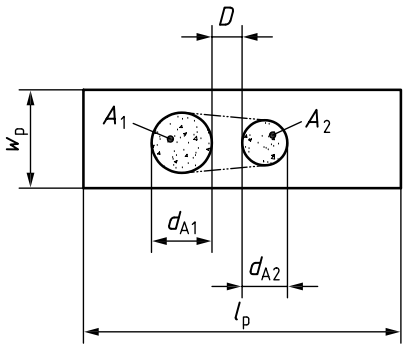
No.	ISO 6520-1 reference	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
2.4	2013	Clustered (localized) porosity	case 1 ($D > d_{A2}$)  case 2 ($D < d_{A2}$)  The sum of the different pore areas ($A_1 + A_2 + ...$) related to the evaluation area $l_p \times w_p$ (case 1). Reference length for l_p is 100 mm If D is less than d_{A1} or d_{A2}, whichever is smaller, an envelope surrounding the porosity areas $A_1 + A_2$ shall be considered as one area of imperfection (case 2).				

Table 1 *(continued)*

No.	ISO 6520-1 reference	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
			The following dimension conditions and limits for imperfections shall be fulfilled (see Annex A for information): a) Maximum dimension of the summation of the projected area of the imperfection (inclusive systematically imperfection) b) Maximum dimension for a single pore for — butt welds — fillet welds		≤ 16 % $d \leq 0{,}5\ s$, but max. 4 mm $d \leq 0{,}5\ a$, but max. 4 mm	≤ 8 % $d \leq 0{,}4\ s$, but max. 3 mm $d \leq 0{,}4\ a$, but max. 3 mm	≤ 4 % $d \leq 0{,}3\ s$, but max. 2 mm $d \leq 0{,}3\ a$, but max. 2 mm

Table 1 *(continued)*

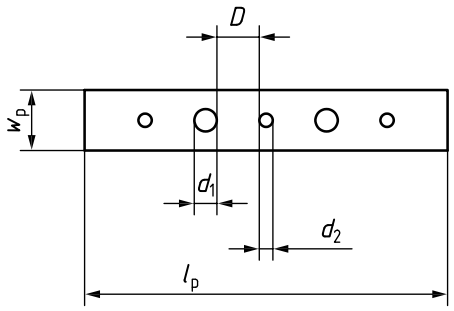
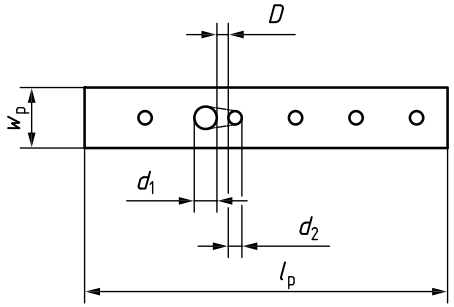
No.	ISO 6520-1 reference	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
2.5	2014	Linear porosity	case 1 ($D > d_2$)  case 2 ($D < d_2$)  The sum of the different pore areas $\left(\frac{{d_1}^2 \cdot \pi}{4} + \frac{{d_2}^2 \cdot \pi}{4} + \ldots\right)$ related to the evaluation area $l_p \cdot w_p$ (case 1). If D is smaller than the lesser diameter of one of the neighbouring pores, the full connected area of the two pores is to be taken into the sum of imperfections (case 2).				

Table 1 *(continued)*

No.	ISO 6520-1 reference	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
			The following conditions and limits for imperfections shall be fulfilled, and see Annex A for information: a1) Maximum dimension of the area of the imperfections (inclusive systematic imperfection) related to the projected area NOTE The porosity in the project area depends on the numbers of layers (volume of the weld).		for single layer: ≤ 8 % for multilayer: ≤ 16 %	for single layer: ≤ 4 % for multilayer: ≤ 8 %	for single layer: ≤ 2 % for multilayer: ≤ 4 %
			a2) Maximum dimension of the cross-sectional area of the imperfections (inclusive systematic imperfection) related to the fracture area (only applicable to production, welder or procedure tests)		≤ 8 %	≤ 4 %	≤ 2 %
			b) Maximum dimension for a single pore for — butt welds — fillet welds		$d \leq 0{,}5\ s$, but max. 4 mm $d \leq 0{,}5\ a$, but max. 4 mm	$d \leq 0{,}4\ s$, but max. 3 mm $d \leq 0{,}4\ a$, but max. 3 mm	$d \leq 0{,}3\ s$, but max. 2 mm $d \leq 0{,}3\ a$, but max. 2 mm
2.6	2015 2016	Elongated cavity Wormholes	— butt welds		$h \leq 0{,}5\ s$, but max. 4 mm $l \leq s$, but max. 75 mm	$h \leq 0{,}4\ s$, but max. 3 mm $l \leq s$, but max. 50 mm	$h \leq 0{,}3\ s$, but max. 2 mm $l \leq s$, but max. 25 mm
			— fillet welds		$h \leq 0{,}5\ a$, but max. 4 mm $l \leq a$, but max. 75 mm	$h \leq 0{,}4\ a$, but max. 3 mm $l \leq a$, but max. 50 mm	$h \leq 0{,}3\ a$, but max. 2 mm $l \leq a$, but max. 25 mm
2.7	202	Shrinkage cavity	—	≥ 0,5	Short imperfections permitted, but not breaking of the surfaces — butt welds: $h < 0{,}4\ s$, but max. 4 mm — fillet welds: $h < 0{,}4\ a$, but max. 4 mm	Not permitted	Not permitted

Table 1 *(continued)*

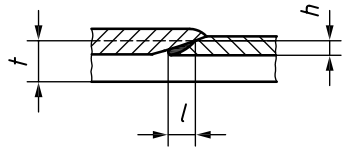
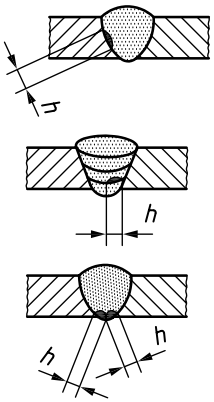
No.	ISO 6520-1 reference	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
2.8	2024	Crater pipe	 The larger value of h or l will be measured	0,5 to 3	h or $l < 0{,}2\ t$	Not permitted	Not permitted
				> 3	h or $l < 0{,}2\ t$, but max. 2 mm		
2.9	300 301 302 303	Solid inclusion Slag inclusion Flux inclusion Oxide inclusion	— butt welds		$h \le 0{,}4\ s$, but max. 4 mm $l \le s$, but max. 75 mm	$h \le 0{,}3\ s$, but max. 3 mm $l \le s$, but max. 50 mm	$h \le 0{,}2\ s$, but max. 2 mm $l \le s$, but max. 25 mm
			— fillet welds		$h \le 0{,}4\ a$, but max. 4 mm $l \le a$, but max. 75 mm	$h \le 0{,}3\ a$, but max. 3 mm $l \le a$, but max. 50 mm	$h \le 0{,}2\ a$, but max. 2 mm $l \le a$, but max. 25 mm
2.10	304	Metallic inclusion other than copper	— butt welds		$h \le 0{,}4\ s$, but max. 4 mm	$h \le 0{,}3\ s$, but max. 3 mm	$h \le 0{,}2\ s$, but max. 2 mm
			— fillet welds		$h \le 0{,}4\ a$, but max. 4 mm	$h \le 0{,}3\ a$, but max. 3 mm	$h \le 0{,}2\ a$, but max. 2 mm
2.11	3042	Copper inclusion	—		Not permitted	Not permitted	Not permitted
2.12	401 4011 4012 4013	Lack of fusion (incomplete fusion) Lack of side wall fusion Lack of inter-run fusion Lack of root fusion			Short imperfections permitted, but not breaking the surfaces — butt welds: $h \le 0{,}4\ s$, but max. 4 mm — fillet welds: $h \le 0{,}4\ a$, but max. 4 mm	Not permitted	Not permitted

Table 1 *(continued)*

No.	ISO 6520-1 reference	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
2.13	402	Lack of penetration	 T-joint (fillet weld with low laser power) Partial penetration weld – single-side and double-side welding.		Short imperfection: $h \leq 0{,}2\ a$, but max. 2 mm	Not permitted	Not permitted
			 T-joint (full penetration)		Short imperfections: $h \leq 0{,}2\ t$, but max. 2 mm	Not permitted	

Table 1 *(continued)*

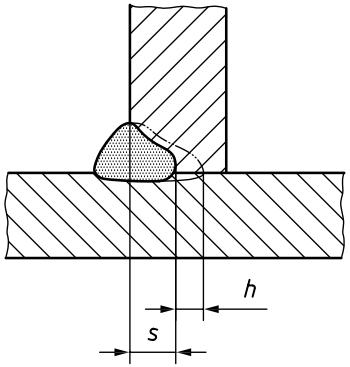
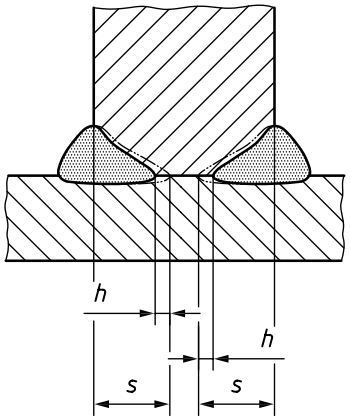
No.	ISO 6520-1 reference	Imperfection designation	Remarks	*t* mm	Limits for imperfections for quality levels		
					D	C	B
			 T-joint (partial penetration – one-side welding)		Short imperfections: $h \leq 0{,}2\ s$, but max. 2 mm	Not permitted	Not permitted
			 T-joint (partial penetration – double-side welding)		$h \leq 0{,}2\ s$, but max. 2 mm	$h \leq 0{,}1\ s$, but max. 1 mm	Not permitted

Table 1 *(continued)*

No.	ISO 6520-1 reference	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels			
					D	C	B	
			T-joint (full penetration – double-side welding)		$h \leq 0,2\ t$, but max. 2 mm	Not permitted	Not permitted	
			Butt joint (partial penetration)		$h \leq 0,2\ s$, but max. 2 mm	$h \leq 0,1\ s$, but max. 1,5 mm	Not permitted	
			Butt joint (full penetration)		Short imperfection: $h \leq 0,2\ t$, but max. 2 mm	Not permitted	Not permitted	

Table 1 *(continued)*

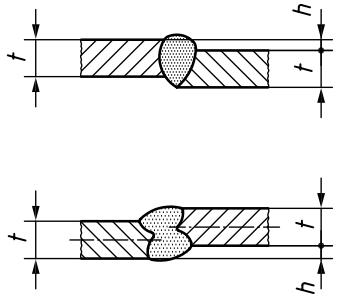
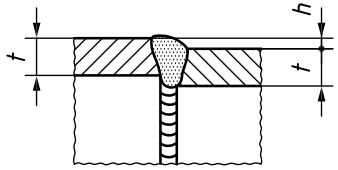
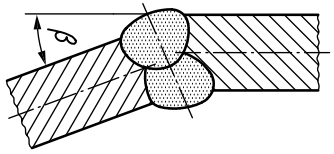
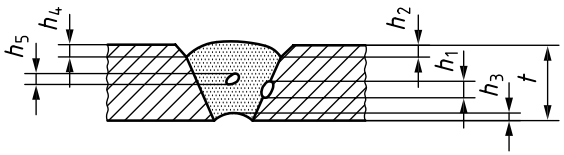
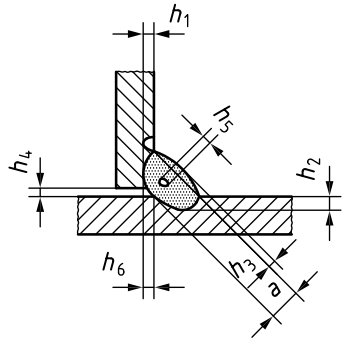
No.	ISO 6520-1 reference	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
3 Imperfections in joint geometry							
3.1	507	Linear misalignment	The limits relate to deviations from the correct position. Unless otherwise specified, the correct position is that when the centrelines coincide. It is also possible to define the upper or the lower surface as a reference line, e.g. in the case of combination of different thicknesses.	≤ 3	$h \leq 0{,}2$ mm + $0{,}25\ t$	$h \leq 0{,}2$ mm + $0{,}15\ t$	$h \leq 0{,}2$ mm + $0{,}1\ t$
			The smaller/lesser thickness is designated t. Linear misalignment within the given limits are not regarded as systematic imperfection (applicable to Figures A and B).  A — Plates and longitudinal welds	> 3	$h \leq 0{,}25\ t$, but max. 5 mm	$h \leq 0{,}15\ t$, but max. 4 mm	$h \leq 0{,}1\ t$, but max. 3 mm
			 B — Circumferential welds		$h \leq 0{,}5\ t$, but max.4 mm	$h \leq 0{,}3\ t$, but max. 3 mm	$h \leq 0{,}2\ t$, but max. 2 mm
3.2	508	Angular misalignment			$\beta \leq 4°$	$\beta \leq 2°$	$\beta \leq 1°$

Table 1 *(continued)*

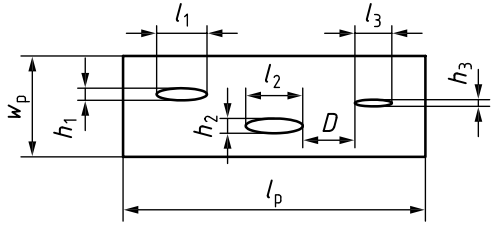
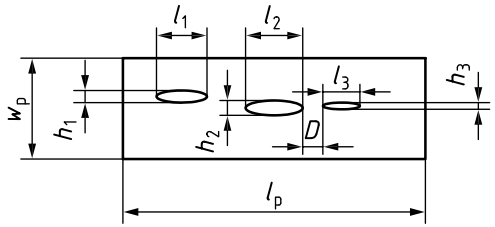
No.	ISO 6520-1 reference	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
3.3	617	Incorrect root	The limitation of Clause 5 as regards systematic imperfection does not apply. T-joint (one-side welding)	0,5 to 3	$h \leq 0{,}5$ mm + 0,1 a	$h \leq 0{,}3$ mm + 0,1 a	$h \leq 0{,}2$ mm + 0,1 a
				> 3	$h \leq 1$ mm + 0,3 a, but max. 4 mm	$h \leq 0{,}5$ mm + 0,2 a, but max. 3 mm	$h \leq 0{,}5$ mm + 0,1 a, but max. 2 mm
			  T-joint (double-side welding)	0,5 to 3	$h \leq 0{,}5$ mm	$h \leq 0{,}3$ mm	$h \leq 0{,}2$ mm
				> 3	$h \leq 1$ mm	$h \leq 0{,}5$ mm	$h \leq 0{,}5$ mm

Table 1 *(continued)*

No.	ISO 6520-1 reference	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
4 Multiple imperfections							
4.1	none	Multiple imperfections in any cross-section[a] Cross-section (macrograph) in the most unfavourable joint range	 $h_1 + h_2 + h_3 + h_4 + h_5 = \Sigma h$  $h_1 + h_2 + h_3 + h_4 + h_5 + h_6 = \Sigma h$	≤ 3	Not permitted	Not permitted	Not permitted
				> 3	Maximum total height of imperfections $\Sigma h \leq 0{,}4\,t$	Maximum total height of imperfections $\Sigma h \leq 0{,}3\,t$	Maximum total height of imperfections $\Sigma h \leq 0{,}2\,t$
					$\Sigma h \leq 0{,}25a$	$\Sigma h \leq 0{,}2a$	$\Sigma h \leq 0{,}15a$

[a] see Annex A.

Table 1 *(continued)*

No.	ISO 6520-1 reference	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
4.2	none	Projected or fracture surface area in longitudinal direction	case 1 ($D > l_3$)  $h_1 \cdot l_1 + h_2 \cdot l_2 + h_3 \cdot l_3 = \Sigma\, h \cdot l$ case 2 ($D < l_3$)  $h_1 \cdot l_1 + h_2 \cdot l_2 + \left(\frac{h_2 + h_3}{2}\right) \cdot D + h_3 \cdot l_3 = \Sigma\, h \cdot l$ The sum of the areas $\Sigma\, h \cdot l$ shall be calculated as a percentage to the evaluation area $l_p \cdot w_p$ (case 1). If D is smaller than the shorter length of one of the neighbouring imperfections, the full connection of the two imperfections is to be taken into the sum of imperfections (case 2). NOTE See Annex A for information.		$\Sigma\, h \cdot l \leq 16\ \%$	$\Sigma\, h \cdot l \leq 8\ \%$	$\Sigma\, h \cdot l \leq 4\ \%$

Annex A
(informative)

Examples of determination of percentage (%) porosity

Figures A.1 to A.9 give a presentation of different percentage porosities. This should assist the assessment of porosity on projected areas (radiographs) or cross-sectional areas.

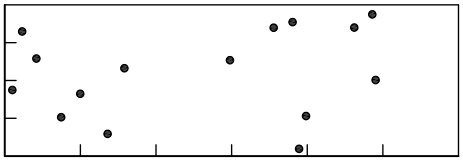


Figure A.1 — Surface percentage: 1 %**, 15 pores,** *d* **=** 1 mm

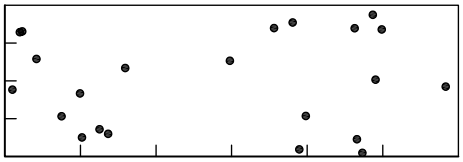


Figure A.2 — Surface percentage: 1,5 %**, 23 pores,** *d* **=** 1 mm

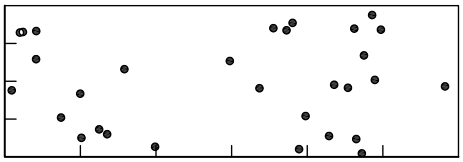


Figure A.3 — Surface percentage: 2 %**, 30 pores,** *d* **=** 1 mm

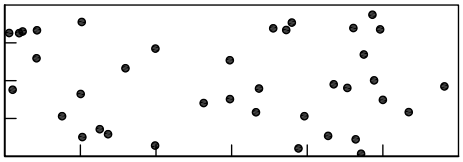


Figure A.4 — Surface percentage: 2,5 %**, 38 pores,** *d* **=** 1 mm

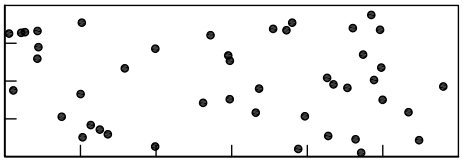


Figure A.5 — Surface percentage: 3 %**, 45 pores,** *d* **=** 1 mm

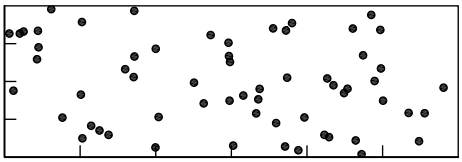


Figure A.6 — Surface percentage: 4 %**, 61 pores,** d **=** 1 mm

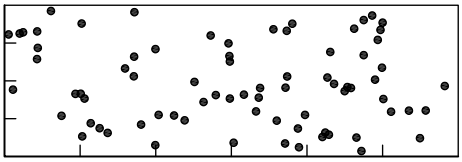


Figure A.7 — Surface percentage: 5 %**, 76 pores,** d **=** 1 mm

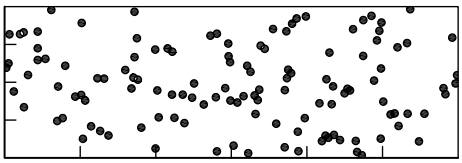


Figure A.8 — Surface percentage: 8 %**, 122 pores,** d **=** 1 mm

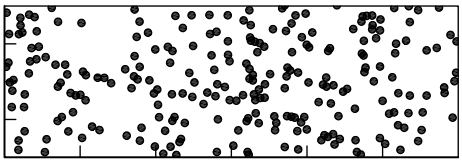


Figure A.9 — Surface percentage: 16 %**, 244 pores,** ***d*** **=** 1 mm

Annex B
(informative)

Additional information and guidelines for use of this International Standard

This International Standard specifies requirements for three quality levels for imperfections in welded joints of steel, nickel and its alloys for laser-arc hybrid welding according to the scope and for weld thickness ≥0,5 mm. It may be used (where applicable) for other fusion welding processes or weld thickness.

Different components are very often produced for different applications, but to similar requirements. The same requirements should, however, apply to identical components produced in different workshops to ensure that work is carried out using the same criteria. The consistent application of this International Standard is one of the fundamental cornerstones of a quality management system for use in the production of welded structures.

The summary of multiple imperfections shows a theoretical possibility of superimposed individual imperfections. In such a case, the total summation of all permitted deviations shall be restricted by the stipulated values for the different imperfections, that means, the limit value of a single imperfection ≤*h*, e.g. for a single pore, shall not be exceeded.

This International Standard may be used in conjunction with a catalogue of realistic illustrations showing the size of the permissible imperfections for the various quality levels by means of photographs showing the face and root side and/or reproductions of radiographs and of photomacrographs showing the cross-section of the weld. An example of such a catalogue is Reference [4]. This catalogue may be used with reference cards to assess the various imperfections and may be employed when opinions differ as to the permissible size of imperfections.

Bibliography

[1] ISO 4063, *Welding and allied processes — Nomenclature of processes and reference numbers*

[2] ISO 13919-1, *Welding — Electron and laser-beam welded joints — Guidance on quality levels for imperfections — Part 1: Steel*

[3] ISO 17635, *Non-destructive testing of welds — General rules for metallic materials*

[4] *Reference radiographs for the assessment of weld imperfections according to ISO 5817*. Villepinte: International Institute of Welding (IIW); Düsseldorf: Deutscher Verlag für Schweißen und verwandte Verfahren (DVS), 2005

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