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Incorporating corrigendum December 2009

Railway applications — Welding of railway vehicles and components —

Part 3: Design requirements

ICS 25.160.10; 45.060.01

British Standards

National foreword

This British Standard is the UK implementation of EN 15085-3:2007, incorporating corrigendum December 2009.

The UK participation in its preparation was entrusted by Technical Committee RAE/1, Railway applications, to Subcommittee RAE/1/-/2, Structural requirements and welding.

A list of organizations represented on this Subcommittee can be obtained on request to its secretary.

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Bahnanwendungen - Schweißen von Schienenfahrzeugen und -fahrzeugteilen - Teil 3: Konstruktionsvorgaben

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Foreword

This document (EN 15085-3:2007) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2008, and conflicting national standards shall be withdrawn at the latest by April 2008.

This series of European Standards EN 15085 "Railway applications — Welding of railway vehicles and components" consists of the following parts:

— Part 1: General

— Part 2: Quality requirements and certification of welding manufacturer

— Part 3: Design requirements

— Part 4: Production requirements

— Part 5: Inspection, testing and documentation

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Introduction

Welding is a special process in the manufacture of railway vehicles and their parts. The required provisions for this process are laid down in the standards series EN ISO 3834. The basis of these provisions is the basic technical welding standards in respect of the special requirements for the construction of railway vehicles.

This European Standard is aimed at defining the terms of enforcement applicable to European Standards; it is not construed as a substitute to these standards.

This European Standard can also be used by internal and external parties, including certification bodies, to assess the organisation's ability to meet customer, regulatory and the organisation's own requirements.

1 Scope

This series of standards applies to welding of metallic materials in the manufacture and maintenance of railway vehicles and their parts.

This part of the series specifies design and classification rules applicable to the manufacture and maintenance of railway vehicles and their parts. Upon agreement with the customer, drawings issued prior to this European Standard may be subject to the provisions of this European Standard.

This European Standard does not define parameters for the dimensioning (refer to other standards e.g. on fatigue testing).

2 Normative references

The following referenced documents are indispensable for the application 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.

EN 1011-2, *Welding — Recommendations for welding of metallic materials — Part 2: Arc welding of ferritic steels*

EN 1708-2, *Welding — Basic weld joint details in steel — Part 2: Non internal pressurized components*

EN 10025-2, *Hot rolled products of structural steels — Part 2: Technical delivery conditions for non-alloy structural steels*

EN 12663, *Railway applications — Structural requirements of railway vehicle bodies*

EN 13749, *Railway applications — Wheelsets and bogies — Methods of specifying structural requirements of bogie frames*

EN 15085-1:2007, *Railway applications — Welding of railway vehicles and components — Part 1: General*

EN 15085-2:2007, *Railway applications — Welding of railway vehicles and components — Part 2: Quality requirements and certification of welding manufacturer*

EN 15085-4:2007, *Railway applications — Welding of railway vehicles and components — Part 4: Production requirements*

EN 15085-5:2007, *Railway applications — Welding of railway vehicles and components — Part 5: Inspection, testing and documentation*

EN 22553, *Welded, brazed and soldered joints — Symbolic representation on drawings (ISO 2553:1992)*

EN ISO 4063, *Welding and allied processes — Nomenclature of processes and reference numbers (ISO 4063:1998)*

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

EN ISO 6520-1, *Welding and allied processes — Classification of geometric imperfections in metallic materials — Part 1: Fusion welding (ISO 6520-1:2007)*

EN ISO 6520-2, *Welding and allied processes — Classification of geometric imperfections in metallic materials — Part 2: Welding with pressure (ISO 6520-2:2001)*

EN ISO 9692-1, *Welding and allied processes — Recommendation for joint preparation — Part 1: Manual metal-arc welding, gas-shielded metal-arc welding, gas welding, TIG welding and beam welding of steels (ISO 9692-1:2003)*

EN ISO 9692-2, *Welding and allied processes —Joint preparation — Part 2: Submerged arc welding of steels (ISO 9692-2:1998)*

EN ISO 9692-3, *Welding and allied processes — Recommendation for joint preparation — Part 3: Metal inert gas welding and tungsten inert gas welding of aluminium and its alloys (ISO 9692-3:2000)*

EN ISO 10042, *Welding — Arc-welded joints in aluminium and its alloys — Quality levels for imperfections (ISO 10042:2005)*

EN ISO 13919-1, *Welding — Electrons and laser beam welded joints — Guidance on quality levels for imperfections — Part 1: Steel (ISO 13919-1:1996)*

EN ISO 13919-2, *Welding — Electron and laser beam welded joints — Guidance on quality levels for imperfections — Part 2: Aluminium and its weldable alloys (ISO 13919-2:2001)*

EN ISO 14555, *Welding — Arc stud welding of metallic materials (ISO 14555:2006)*

EN ISO 15614-1, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys (ISO 15614-1:2004)*

EN ISO 15614-12, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 12: Spot, seam and projection welding (ISO 15614-12:2004)*

EN ISO 17653, *Destructive tests on welds in metallic materials — Torsion test of resistance spot welds (ISO 17653:2003)*

ISO 10447, *Resistance welding — Peel and chisel testing of resistance spot, projection and seam welds*

CEN ISO/TR 15608, *Welding — Guidelines for a metallic materials grouping system (ISO/TR 15608:2005)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 15085-1:2007 apply.

4 Design requirements

4.1 General

As regards welds forming an integral part of items of rolling stock, except for specific provisions laid down within the framework of the project or in the product specification, design and requirements shall be defined as follows.

4.2 Joint static dimensioning

Calculated stresses shall be less than or equal to the admissible strength of the assembly considered which are proposed in the specification or by the manufacturer and accepted by the acceptance authority.

Examples of welding bead static dimensioning: "effective cross-sections a_R" are given in Annex B and Annex C.

Calculation on local areas shall be performed to ensure that the cross section of the weld is both required and sufficient to withstand static stresses.

4.3 Joint fatigue dimensioning

Joints shall be designed according to stress and safety categories.

The admissible fatigue strength, which are defined by standards, codes, methods, guidelines or by stress/cycle diagrams, are proposed in the specification or by the manufacturer and shall be accepted by the acceptance authority or the responsible national safety authority.

The reference curve shall either be laid down in specifications or proposed by the manufacturer and approved by the customer. Usually, this curve applies to a given type of joint (butt weld, fillet weld etc.).

4.4 Stress categories and stress factors

The stress category is determined by the stress factor according to Table 1. The stress factor is the ratio of the calculated fatigue stress to the admissible fatigue stress of the joint type, adjusted by the appropriate safety factor. The standard or source of data for the admissible stress shall be agreed between the customer and the manufacturer and, if required with the national safety authority. In this context the European Standards on railway vehicle manufacturing shall be applied, e.g. EN 12663, EN 13749. In addition to this the application of national standards is also possible.

Alternatively, the admissible fatigue stress can be obtained from fatigue tests on representative joint samples. The statistical evaluation of the fatigue tests shall be done according to a standard or a guideline agreed with the national safety authority. European Standards for structural requirements of railway vehicles shall also be applied, e.g. EN 12663. Furthermore the application of national standards is also possible.

Table 1 — Stress categories

Stress category	Stress factor (S)		
	Fatigue strength values from calculation standard	Fatigue test values for representative joint sample	
		Option 1	Option 2 [a]
High	≥ 0,9	≥ 0,8	≥ 0,9
Medium	0,75 ≤ S < 0,9	0,5 ≤ S < 0,8	0,75 ≤ S < 0,9
Low	< 0,75	< 0,5	< 0,75

[a] The decisive limiting value shall be agreed with customer or acceptance authority.

4.5 Safety categories

The safety category defines the consequences of failure of the single welded joint in respect to the effects on persons, facilities and the environment.

The safety categories are differentiated as follows:

Low: Failure of the welded joint does not lead to any direct impairment of the overall function. Consequential events with personal injuries are unlikely.

Medium: Failure of the welded joint leads to an impairment of the overall function or can lead to consequential events with personal injuries.

High: Failure of the welded joint leads to consequential events with personal injuries and breakdown of the overall function.

If required in the contract, the acceptance of the safety categories defined by the designer for each weld shall be subjected to the approval of the customer and/or the national safety authority.

For the determination of the safety category, also Annex G should be considered.

4.6 Weld performance classes

Weld performance classes shall be defined in the design phase depending on the safety category and the stress category. The responsible welding coordinator should be consulted with respect to practicability and feasibility.

Welded joints of railway vehicles are divided into six weld performance classes (see Table 2).

Table 2 — Weld performance classes

Stress categories	Safety categories		
	High	Medium	Low
High	CP A [a]	CP B [c]	CP C2
Medium	CP B [b]	CP C2	CP C3
Low	CP C1 [d]	CP C3	CP D

[a] Weld performance class CP A is a special class which applies only for welds with full penetration and full accessibility for inspection in production and maintenance.

[b] Weld performance class CP B:
CP B for safety category „high“: is only valid for welds with full penetration and full accessibility for inspection in production and maintenance.

[c] CP B for safety category „medium“: is also valid for welds without the possibility for a volumetric test; in this case a special remark “medium safety category/increase of surface test is required” shall be indicated on the drawing and the tests according to Table 1 of EN15085-5:2007 shall be carried out.

[d] Weld performance class CP C1:
CP C 1 is also valid for welds without the possibility for volumetric testing. In this case a special remark “surface test necessary” shall be indicated on the drawing and the tests according to Table 1 of EN 15085-5:2007 shall be carried out.

Joints with weld performance class CP A, CP B and CP C1, which can be inspected during production but cannot be inspected and repaired in maintenance, shall be allocated to the next higher inspection class according to Table 3 or the stress level shall be reduced.

If it is not possible to fulfil the requirements of a weld performance class, the designer shall reduce the stress category or change the design, see Annex D and Annex E.

Finishing-up a weld is one of the possible ways of increasing the admissible fatigue stresses of an assembly and may consequently lead to a downscaling of the weld performance class.

Weld performance classes and inspection classes shall be shown on drawings or in other documents, e.g. parts lists.

4.7 Weld inspection classes

The inspection class applicable to each welded joint is defined depending on the weld performance class defined formerly, see Table 3.

These inspection classes are used to identify the various types and minimum levels of inspections on the welded joints.

Table 3 — Correspondence between weld performance classes and inspection classes

Weld performance class	Inspection class Minimum requirement
CP A	CT 1
CP B	CT 2
CP C1	CT 2
CP C2	CT 3
CP C3	CT 4
CP D	CT 4

The tests applicable to these inspection classes shall be at minimum the same as described in EN 15085-5.

4.8 Relationship between stress category, safety category, weld performance class, quality levels for imperfections, inspection class and testing

Table 4 shows a summary of the relationship between stress category, safety category, weld performance class, quality levels for imperfections, inspection class and testing according to Table 1, Table 2, Table 3, Table 5 and Table 6 as well as EN 15085-5:2007, Table 1.

Table 4 — Relationship between stress category, safety category, weld performance class, quality levels for imperfections, inspection class and testing

Stress category	Safety category	Weld performance class	Quality levels for imperfections EN ISO 5817 EN ISO 10042	Inspection class	Volumetric tests RT or UT	Surface tests MT or PT	Visual examination VT
High	High	CP A	see Table 5 or Table 6	CT 1	100%	100 %	100 %
High	Medium	CP B	B	CT 2	10%	10 %	100 %
High	Low	CP C2	C	CT 3	Not required	Not required	100 %
Medium	High	CP B	B	CT 2	10%	10 %	100 %
Medium	Medium	CP C2	C	CT 3	Not required	Not required	100 %
Medium	Low	CP C3	C	CT 4	Not required	Not required	100 %
Low	High	CP C1	C	CT 2	10 %	10 %	100 %
Low	Medium	CP C3	C	CT 4	Not required	Not required	100 %
Low	Low	CP D	D	CT 4	Not required	Not required	100 %

5 Quality levels for imperfections

5.1 General

Weld imperfections shall be as defined in accordance with EN ISO 6520-1 and EN ISO 6520-2.

5.2 Quality levels for imperfections

Quality levels for imperfections related to the weld performance class shall be as listed in Table 5 and Table 6 in accordance with EN ISO 5817 and EN ISO 10042.

5.2.1 Quality levels for imperfections for fusion welded joints (beam welding excluded)

5.2.1.1 Steel

Quality levels for imperfections according to EN ISO 5817 are given in Table 5.

Table 5 — Quality levels for imperfections for steel related to weld performance class

Imperfections according to EN ISO 5817	Weld performance classes			
	CP A	CP B	CP C1 / CP C2 / CP C3	CP D
1.1 to 1.6, 1.13, 1.15, 1.18, 1.19, 1.22, 2.1, 2.7, 2.8, 2.11 to 2.13,	B	B	C	D
1,7, 1.8, 1.9, 1.11, 1.14, 1.17, 1.23, 2.2, 2.3 to 2.6, 2.9, 2.10, 3.1	Not permitted	B	C	D
1.10, 1.16, 1.20, 1.21, 3.2	Not applicable	B	C	D
1.12 [a], 4.1, 4.2	These imperfections are not assessed			

[a] For CPA, see also 7.3.15.

5.2.1.2 Aluminium and its alloys

Quality levels for imperfections according to EN ISO 10042 are given in Table 6.

Table 6 — Quality levels for imperfections for aluminium and its alloys related to weld performance class

Imperfections according to EN ISO 10042	Weld performance classes			
	CP A	**CP B**	**CP C1 / CP C2 / CP C3**	**CP D**
1.1, 1.2, 1.4, 1.5, 1.7 to 1.9, 1.15, 2.1, 2.3, 2.6, 2.10,	B	B	C	D
1.3	Not permitted	Not permitted	Not permitted	D
1.6, 1.10, 1.11, 1.14, 1.16, 1.18, 2.2, 2.4, 2.5, 2.7 to 2.9, 3.1	Not permitted	B	C	D
1.12, 1.13, 1.17, 2.11, 2.12, 3.2	Not applicable	B	C	D
4.1	These imperfections are not assessed			

For T-joint butt welds in CPA, the radius at the toe shall be ≥ 3 mm. See also Figure 17.

5.2.2 Quality levels for imperfections for laser and electron beam welding related to the weld performance class

Quality levels for imperfections shall be according to EN ISO 13919-1 and EN ISO 13919-2 and are given in Table 7 and Table 8.

Table 7 — Quality levels for imperfections for laser and electron beam welding for steel related to the weld performance class

Imperfections according to EN ISO 13919-1	Weld performance classes			
	CP A	**CP B**	**CP C1 / CP C2 / CP C3**	**CP D**
1 to 4, 6, 7, 18	B	B	C	D
5, 8, 10 to 16	Not permitted	B	C	D
9, 17	Not applicable	B	C	D

Table 8 — Quality levels for imperfections for laser and electron beam welding for aluminium and its alloys related to the weld performance class

Imperfections according to EN ISO 13919-2	Weld performance classes			
	CP A	CP B	CP C1 / CP C2 / CP C3	CP D
1 to 5, 7, 8, 20	B	B	C	D
6, 9, 11 to 18	Not permitted	B	C	D
10, 19	Not applicable	B	C	D

5.2.3 Quality levels for imperfections for stud welding related to the weld performance class

Stud welded joints are permitted for weld performance classes CP C3 and CP D only. The requirements according to EN ISO 14555 shall be fulfilled.

5.2.4 Quality requirements for resistance spot welding, projection welding and resistance seam welding related to the weld performance class

The quality requirements for resistance spot welding, projection welding and resistance seam welding are defined in Table F.2. For the surface quality, Table F.3 applies.

Resistance spot welding, projection welding and resistance seam welding is not permitted for weld performance classes CP A and CP B.

5.2.5 Defining quality requirements for other welding processes

The quality requirements for other welding processes may be agreed between the customer and the manufacturer. If required, this shall also be agreed with the national safety authority.

6 Choice of parent metals and welding consumables

6.1 Choice of parent metals

The parent metals shall meet the requirements of material groups according to CEN ISO/TR 15608 and shall have an established weldability. The weldability according to ISO/TR 581 is considered to be established if the materials correspond with the appropriate EN standards and are identified as weldable by them.

For a parent metal without an established weldability the manufacturer shall, by means of Welding Procedure Qualification Record (WPQR), demonstrate to the customer or operator that the characteristics of the joints achieved by using the parent metals comply with the requirements laid down by the design office or engineering department (see EN 15085-4:2007, 5.4).

For parts of railway vehicles with welded joints of safety category medium and high, only parent metals may be used for which fatigue strength values for dynamic load exist or are agreed.

6.2 Choice of welding consumables

When the properties of the chosen welding consumables are in doubt the manufacturer shall, by means of Welding Procedure Qualification Record (WPQR), demonstrate to the customer or operator that the characteristics of the joints achieved by using the chosen welding consumables comply with the requirements laid down by the design office or engineering department (see EN 15085-4:2007, 5.3.1).

7 Weld joint design

7.1 General

Welded joints with sharp edges and steep changes of cross-section should be avoided. The force path should be as undisturbed as possible.

If possible the centre lines of the welded parts should coincide in one point. Weld seams should be avoided in high stress areas. If this is not possible, higher requirements of inspection shall be planned.

If required, to make a decision in the process of development an evidence of the calculated thickness of the weld a can be proved by production weld test.

With respect to the weldability of the parent materials and the welding consumables the requirements and recommendations information of their manufacturers shall be observed.

For steel components with stress in thickness direction, suitable design measures according to EN 1011-2 shall be taken and material with the required reduction of material in thickness direction shall be selected.

The backings (permanent supports of the weld pool) shall be considered for the calculation. The backings of an aluminium construction have preferably a groove.

On T-joints of aluminium or steel constructions, it can be necessary to use backings with a bevel, for instance for single-bevel butt weld.

Corrosion protection should be ensured by suitable welding design, e.g. full penetration weld. Partial penetration welds or intermittent welds should have sufficient corrosion protection.

The place of the marking with a marking punch shall be shown in the drawing.

In order to curtail deformation, welded joints should be positioned along the centreline of the assembly or symmetrically to this centreline.

Assemblies shall be designed so as to offer the best access possible when welding or inspecting them.

The accumulation of joints should be avoided. If necessary, forged pieces or castings can be used.

Welding secondary parts onto tension flanges by transverse beads should be avoided.

In the heat-affected zone of cold deformed steel or aluminium and its alloys the decrease of strength shall be considered in calculation.

Designs with mixed assemblies combining welded joints with bolted or riveted joints should be avoided.

Requirements for resistance spot welding are given in Annex F.

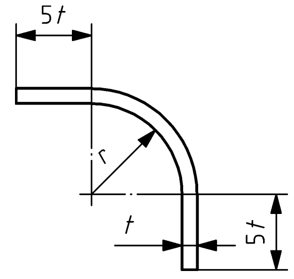
7.2 Welding in cold formed areas

In cold formed areas (including the related surface of $5 \times t$) of material of the material groups 1.1, 1.2 and 1.4 according to CEN ISO/TR 15608, welding shall only be permitted for certification level CL 3 structures. For certification level CL 1 and certification level CL 2 structures, it shall only be permitted if:

— after bending and before welding a heat treatment (normalizing) has been done, or

— conditions of Table 9 are observed (ratio of bending radius to thickness of the metal sheet).

Table 9 — Welding in cold formed areas (for steel)

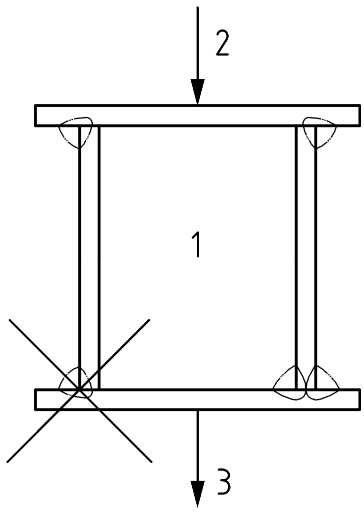
min. *r* / *t*	max. *t*	
10	50	
3	24	
2	12	
1,5	8	
1	4 [a]	

[a] Admissible up to 6 mm for material S235J2 according to EN 10025-2.

7.3 Manufacturing provisions

7.3.1 Box girders

In the case of box section welds with tension flange (flexion stressed), the web assemblies on lower flanges joined by single fillet welds are allowed only if calculations show the web stiffness is such that the stress level in the weld root is less than the value specified. Figure 1 shows an example of box girder with high stress level in the tension flange.



Key

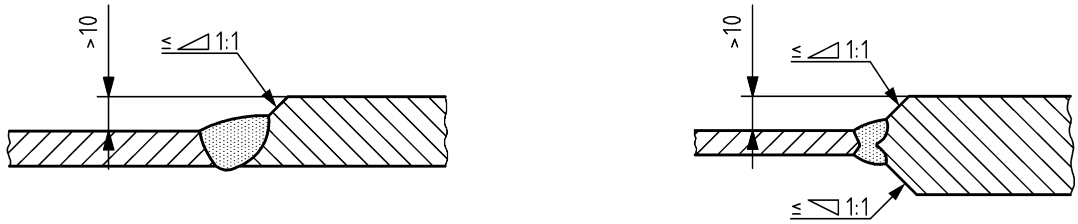
1 box section beam
2 compression flange
3 tension flange

Figure 1 — Example of box girder with high stress level in the tension flange

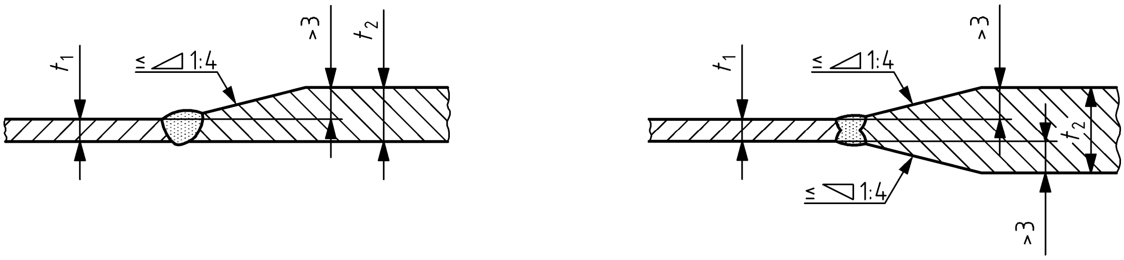
7.3.2 Butt welds on parts of dissimilar thickness

For parts of dissimilar thickness, the transition between the various sections shall be gradual, with a slope not exceeding the values given in Figure 2. If the weld is not thick enough to cover the transition, the part featuring the greater thickness shall be bevelled accordingly.

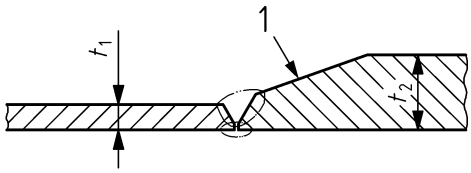
Dimensions in millimetres



1:1 for CP C3 and CP D



NOTE 1:4 for CP A, CP B, CP C1 and CP C2 welding beads. Joint preparations are shown on the drawings. Slope < 1:1 is an angle of < 45°, slope < 1:4 is an angle of < 14°.



Key

1 slope

Complementary accuracy of chamfer position. The external shape of the weld shall match the slope.

Figure 2 — Butt joint on parts of dissimilar thickness

7.3.3 Plug welds and slot welds

Plugs weld and slot welds are only permissible for welds of weld performance classes CP C2, CP C3 or CP D in so far as the weld has only shearing stress.

The dimensions of the cylindrical or oblong slot shall allow access of the electrode or the welding torch at an angle of 45° minimum. On thin sheet, these requirements are complied with if the diameter of the hole is greater than or equal to four times the thickness of the part and if the total length of the oblong holes is greater than or equal to three times the diameter of the hole.

For fillet welds in holes or slots, the following properties shall be respected:

— diameter of the hole shall be: $d > (3 to 4) \times t_2$ or

— width of the slot shall be: $c > 3 \times t_2$.

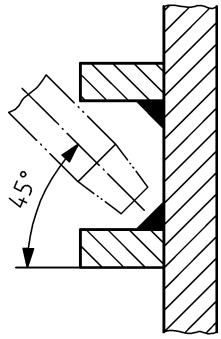
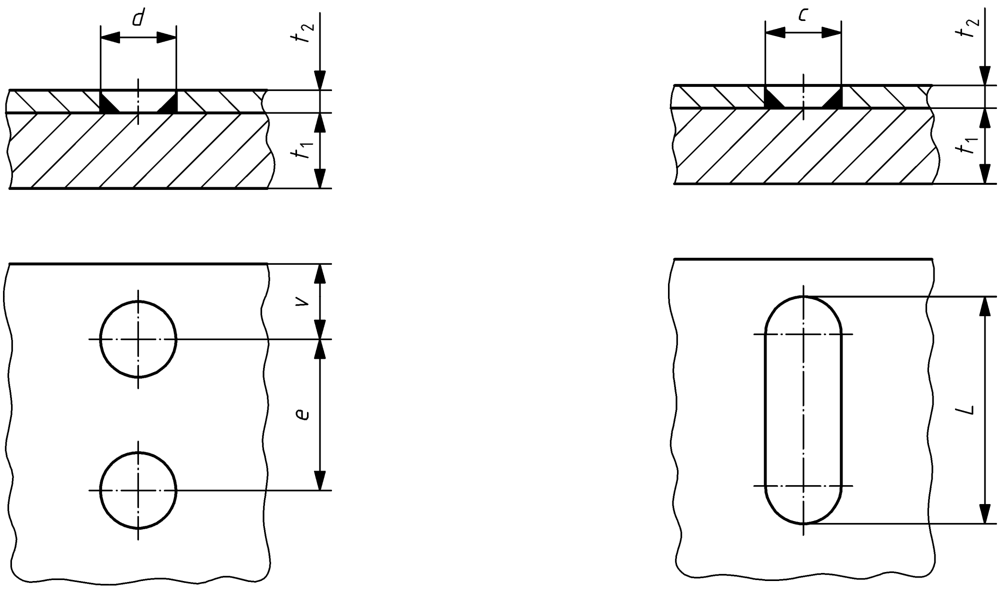


Figure 3 — Weldability access for plug and slot welds

Dimensions in millimetres



Fillet weld in a hole

Fillet weld in a slot

d minimum 12

c minimum 12

$v \geq d$

$3 \times d \leq e \leq 4 \times d$

$l \geq 2\ c$

Figure 4 — Dimensions for plug and slot welds

7.3.4 Proximity of two joints

Welds should be positioned in such a distance that the heat affected zones do not overlap. The overlapping of heat affected zones is acceptable as long as the effects on heat-treated or hardened areas are considered in design (e.g. residual stresses, drop in strength, hardness decrease).

In order to reduce angular deformation and stress build-up, the minimum distance between two joints is determined according to the thickness of the parts jointed and the clamping arrangement of the assembly.

For thicknesses less than 20 mm, and particularly for aluminium and high strength steels, it is recommended to maintain molten areas at least 50 mm apart, see Figure 5.

Dimensions in millimetres

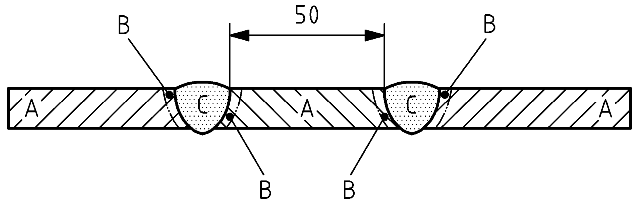


Figure 5 — Minimum distance between molten areas

7.3.5 Stiffeners welded to a longitudinal weld

Openings on components when crossing a butt weld by a fillet weld should be avoided. The excess weld material in this area should be ground to enable welding without interruption at crossing welds.

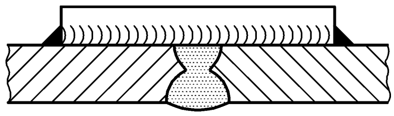
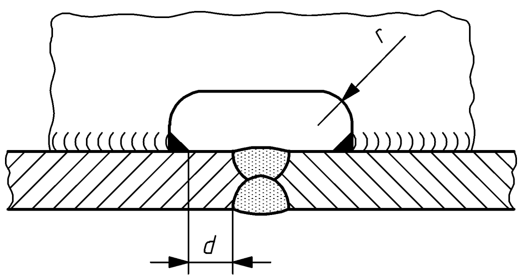


Figure 6 — Stiffeners fitted perpendicularly to a longitudinal weld

7.3.6 Filler and drain ports

Therefore, drainage cut-outs should be avoided. If they are necessary, these openings shall be large enough to be surrounded by a seal weld without inducing a stress build-up in the heat affected zone of the connecting weld.



r according to EN 1708-2, but minimum 30 mm

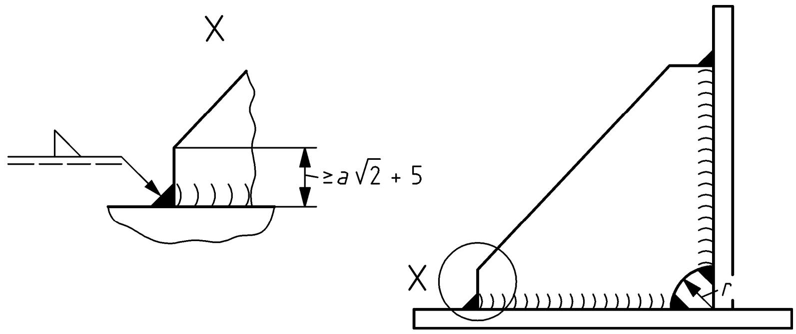
$d \geq 20$ mm

Figure 7 — Filler and drain ports

7.3.7 Gusset ends and stiffener ends

Figure 8 and Figure 9 show design examples for gusset ends and stiffeners ends. In order to make weld returns in proper conditions, gusset ends and stiffener ends should be designed as shown in Figure 8.

Dimensions in millimetres



r according to EN 1708-2, but minimum 30 mm

Figure 8 — Design of gusset and stiffener ends

On highly stressed assemblies, gussets shall be continuously welded.

7.3.8 Gusset shape

Most failures affecting fatigue stressed parts (dynamic loaded parts) are due to shape-related problems which poorly channel stresses and induce stress build-ups.

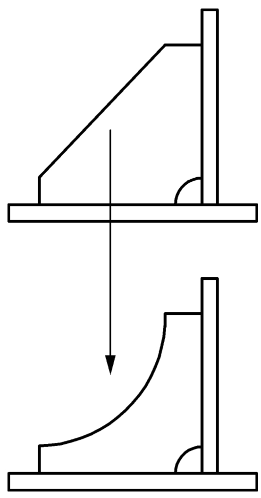


Figure 9 — Gusset shape

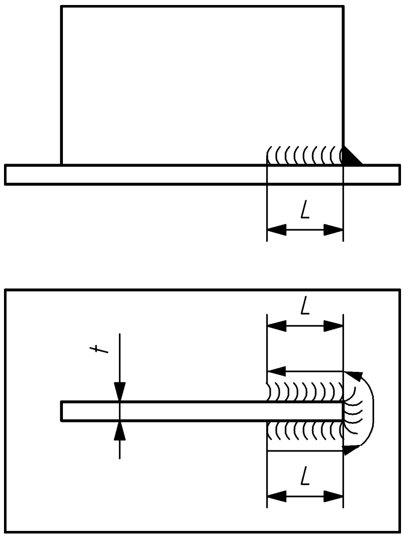
7.3.9 Weld return

The weld shall run around the ends of the gusset. If possible without interruption over a length *l* which is, at least equal to thickness 2 *t*,

a) generally to avoid corrosion problems at the end of the plate independent of the weld performance class;

b) at high stressed edges;

c) if welds are CP C3 or CP D, the weld return is not obligatory.



$l \geq 2\,t$ where l_{min} = 10 mm

Key

t plate thickness

l length of continuation

Weld return is to be performed if possible without interruption.

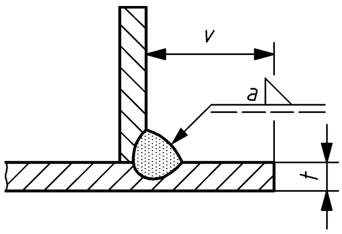
Figure 10 — Weld return

7.3.10 Fillet weld

When designing fillet welds the following requirement should be considered:

Fillet welds should normally be isosceles. If there are constructive reasons or if a better force flux is necessary, additionally to throat thickness a, the fillet weld leg length z shall also be applied to the drawing.

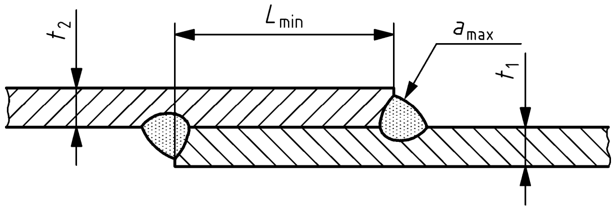
The throat thickness a of the fillet weld should not be greater than prescribed by the calculation. However, this may be increased for technological or welding engineering purposes.



The edge distance v should be $v \geq 1{,}5\,a + t$

Figure 11 — Edge distance for fillet welds

For thicknesses less than 20 mm, and particularly for aluminium and high strength steels, it is recommended to maintain molten areas at least 50 mm apart, see Figure 12.



$t_2 \leq t_1$

$l_{min} = 3 \times t_2$ (min 50 mm for 5 mm ≤ t_2 ≤ 20 mm)

$$a_{max} = \frac{t}{\sqrt{2}} - \frac{t}{10}$$

The section specified a shall be less than or equal to a_{max} calculated.

Figure 12 — Minimum overlapping distance for overlapping welds

7.3.11 Butt welds

For weld performance class CP A and CP B welds, run-on and run-off plates shall be used at the beginning and at the end of welds, see Figure 13 for an example. For other butt welds, run-on and run-off plates tabs may be used to prevent an insufficient penetration at the beginning and welding craters at the end of the welding beads (see EN 15085-4:2007, 5.2.1). They shall be indicated on the drawings.

The run-on and run-off plates shall be made so as to enable the welding to be started or stopped beyond its necessary length.

The parts to be assembled and the plates, which are "integrated" into the design or implanted as small plates on the parts to be welded, are homogenous.

The preparation of these plates shall be the same as that used on the joints to be made.

The plates shall be either fixed by mechanical or magnetic means and can be welded.

After having completed the joint, the plates can either be mechanically removed or cut using a blowpipe or plasma. A longitudinal grinding shall be made after the removal of the plates.

Any rupture caused by shock is prohibited.

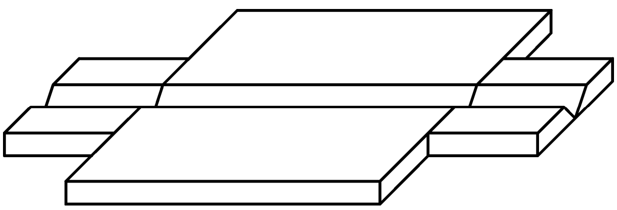


Figure 13 — Example of run-on and run-off plates for butt welds

7.3.12 Clamped joints

Cold cracking and hot cracking are the cause of many failures. Designers should be aware that clamping welds facilitates (residual stresses) the development of both types of cracking. Welded joints with increased residual stresses caused by clamping can lead to cold cracking and hot cracking.

Several particular assemblies should be avoided as their residual stresses may lead to such problems:

— during welding full round bars or thick-walled pipes on thick plates, the weld will not be in a position to shrink properly (*a*) in Figure 14);

— when welding small, thick plates (doubler) that will keep their shape (*b*) in Figure 14);

— when welding ribs into thick-walled pipes that will keep their shape (*c*) in Figure 14);

— when welding parts joined at the last moment between two rigid assemblies that will keep their shape.

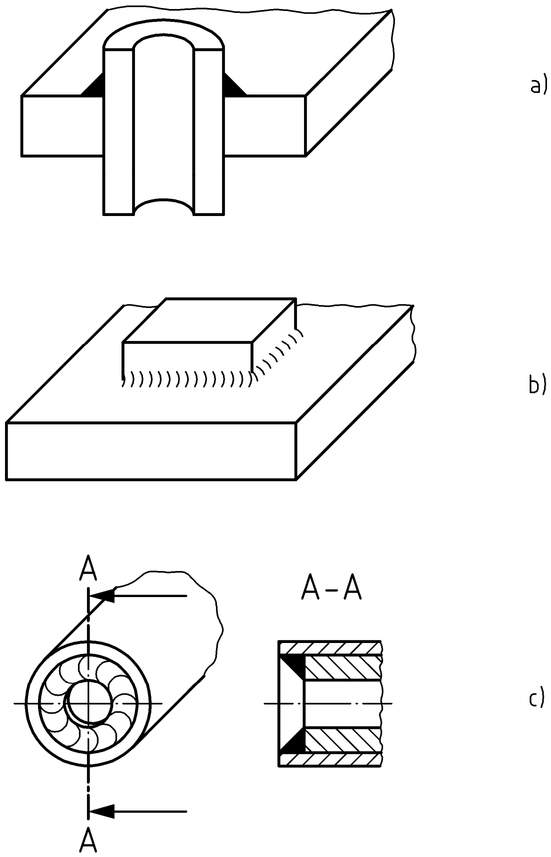


Figure 14 — Clamped joints

In order to avoid cracking hazard, fillet welds shall feature minimum welding bead cross-sections depending on the thickness of the plates to be jointed.

7.3.13 Mixed assemblies

This type of assembly should be avoided as only one of the components is stressed.

Welded and bolted assemblies are not complementary to transmit stress or reduce the stresses induced by weld shrinkage.

In this case, only the weld is stressed. Thus, the weld may be the cause of fatigue cracking on a mixed assembly subject to cyclic stresses. Hence, calculations apply to the weld alone.

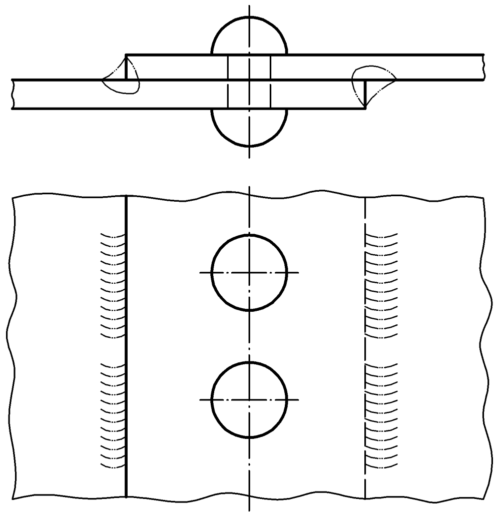


Figure 15 — Mixed assemblies

Only nuts with proven weldability may be welded against turning.

7.3.14 Prevention of corrosion problems

If necessary, in order to prevent corrosion related problems, the designer shall ensure closure at the back of the weld through weld return and/or back welding or the use of a sealing compound.

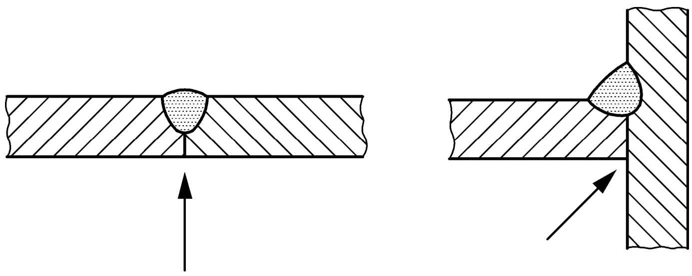


Figure 16 — Corrosion locations

7.3.15 Weld toe – Improvement of shape of welds

The work performed after welding of an assembly is aimed at improving the fatigue behaviour of the welds.

This improvement may consist of an increase in service life (for a given stress level) or an increase in fatigue limit (for a given service life).

The reduction of peak stresses is achieved by reducing the stress concentration (notch effect) on geometric features of welding beads, the most significant instance being that of the toe on a fillet weld.

The weld toe improvement work to be performed on a weld shall be laid down in a procedure and the gain in admissible stress shall be verified by the designer.

In the case of toe grinding, the depth shall be $k \leq 0,3$ mm and the radius shall be $r \geq 3$ mm, see Figure 17.

Direction of grinding marks shall be in line with the direction of the principal stress.

Butt joint

T-joint

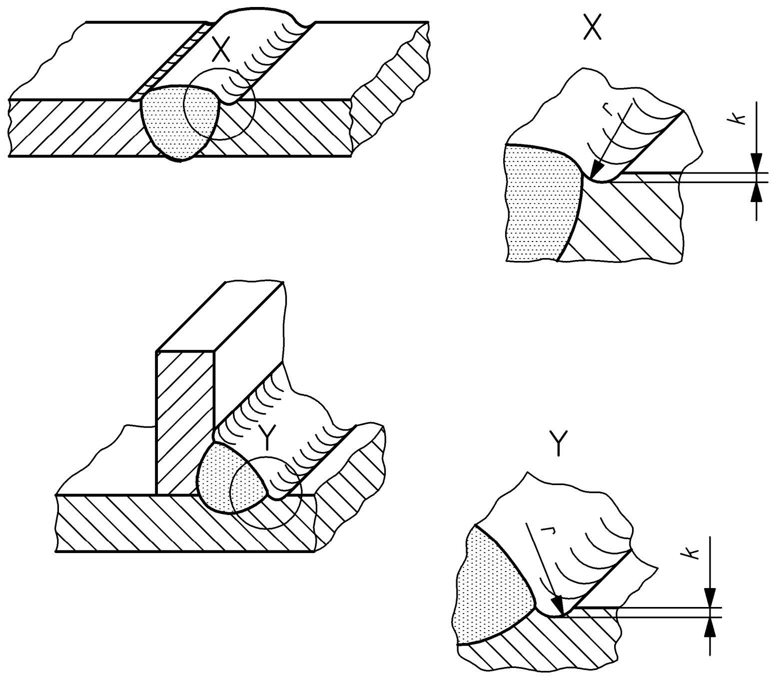


Figure 17 — Weld toe improvement

7.3.16 Work aimed at lessening residual tensile stresses

7.3.16.1 General

In order to lessen residual tensile stresses, pre-stressing operations may be performed, e.g. peening, or stress-relieving by heat treatment.

7.3.16.2 Parameters and characteristics of pre-stressing peening

The peening parameters and characteristics should be agreed in the order of the customer.

In case of using peening, the following shall be considered:

— steel shot material suitable for the job (type and size);

— coverage of weld and heat affected zone.

Recommended values of compressive residual stresses for steel are as follows:

— greater than 260 MPa at 0,1 mm underneath the surface;

— at a depth of 0,5 mm greater than or equal to 50 MPa.

7.3.16.3 Heat treatment to relieve residual tensile stresses

For post-welding heat treatments, normalising treatments or stress relieving treatments, all provisions should be made to curtail final deformations or prevent the need for cold straightening.

Specific heat treatment conditions shall be shown on the relevant drawings or mentioned in related documents.

This document shall list:

— maximum temperature of kiln at the time of loading;

— mean rate of temperature rise;

— time the part is maintained at treatment temperature;

— treatment temperature;

— maximum cooling rate;

— temperature at which parts are withdrawn from the kiln;

— cooling conditions of parts subsequent to withdrawal from the kiln.

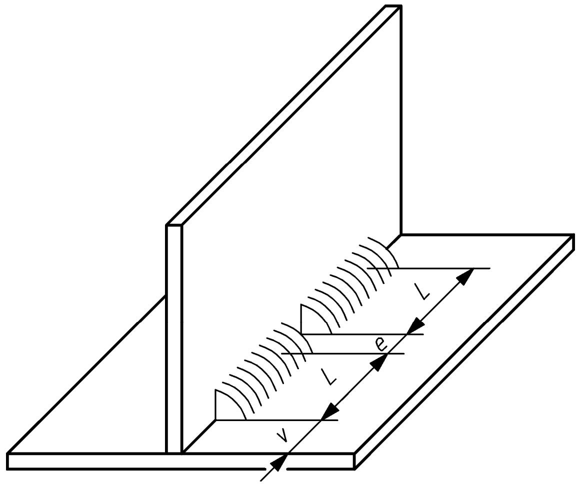
Temperatures shall be recorded e.g. using a calibrated recording pyrometer.

7.3.17 Intermittent welds

The minimum weld length of intermittent welds should be:

— for $t_{\max} < 10 mm$: $l_{\min} > 5 \times t_{\max}$, but at least 20 mm for steel and 30 mm for aluminium alloys,

— for $t_{\max} > 10 mm$: $l_{\min} > 3 \times t_{\max}$, but at least 50 mm, see Figure 18.



$e \leq 3 \times L$
$v \leq 0,5 \times L$

Figure 18 — Intermittent welds

7.4 Joint preparation

Joint preparation shall be defined by the manufacturer who may draw upon EN ISO 9692-1, EN ISO 9692-2, EN ISO 9692-3.

See for information Annex B and Annex C.

Indications given on the drawing shall be according to EN 22553. Additionally, the following information is necessary:

— weld performance class according to this European Standard, shall be given on the drawings. If one drawing contains different classes, they shall be indicated close to the weld. For welds produced by resistance spot welding, additionally the surface quality according to Table F.3 shall be indicated;

— certification level CL 1 to CL 3 according to EN 15085-2 for each component shall be indicated on the drawing or in parts lists. This level depends on the highest weld performance class of the component. EN 15085-2:2007, Annex A contains examples for a possible allocation of components to the certification level;

— weld form, weld thickness and weld length (see Annex B) shall be indicated on the drawing;

— welding consumables shall be given on drawings, parts lists or other documents.

All welds shall be identified by an item number indicated on drawings, parts lists or other documents.

If no admissible tolerances are given on the drawing, according to EN ISO 13920:1996 the following shall apply:

a) tolerance class B for linear and angular dimensions;

b) tolerance class F for straightness, flatness and parallelism.

Annex A
(informative)

List of welded joints

Name of company, department:

LIST OF WELDED JOINTS

Project: Order number: Certification/qualification level for manufacturer: Date:

Part description	Drawing number	Revision	Item X	Item Y	Thickness t_1	Thickness t_2	Type of joint	Joint preparation type	Weld performance class	Imperfection acceptance level	Inspection class	WPQR WPS	Welding process	Welding consumables used	Shielding gas type	Comments

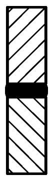
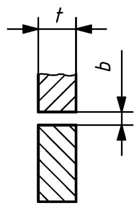
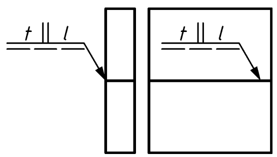
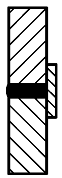
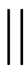
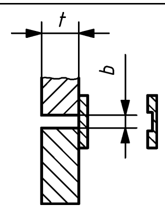
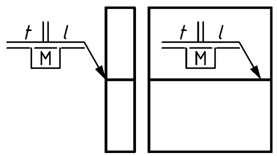
Annex B
(informative)

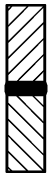
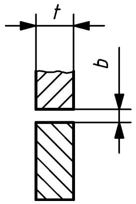
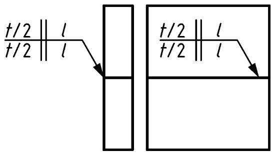
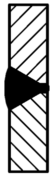
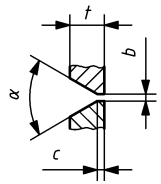
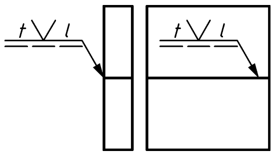
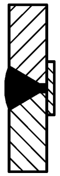
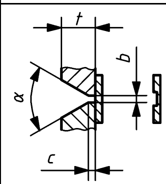
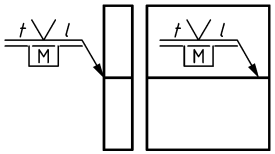
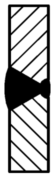
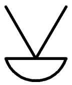
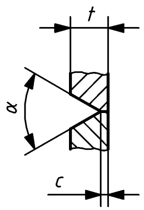
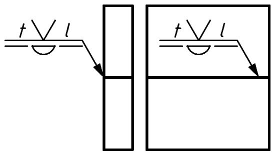
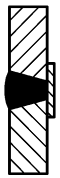
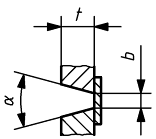
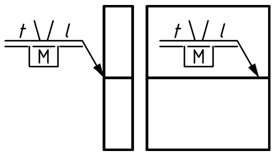
Joint preparation of welds

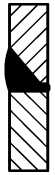
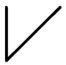
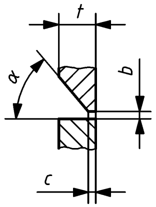
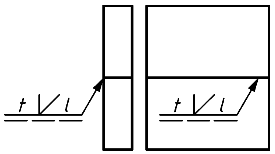
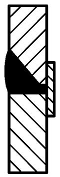
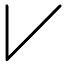
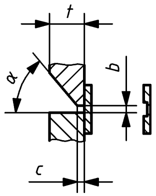
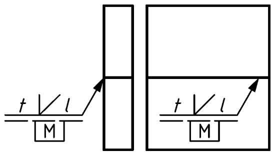
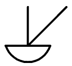
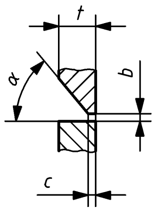
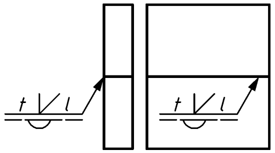
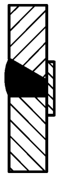
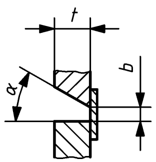
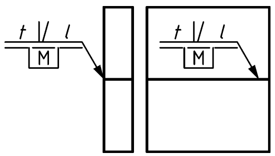
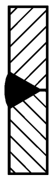
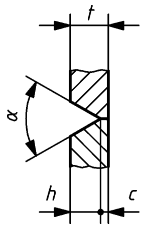
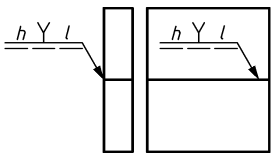
Table B.1 gives an overview of recommended joint preparations and throat thicknesses used for welds on railway vehicles produced by welding processes 111, 114, 131, 135, 136, 137, 141, 15 and 311 according to EN ISO 4063. Other joint preparations may be used if approved according to EN 15085-4:2007.

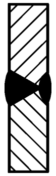
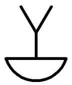
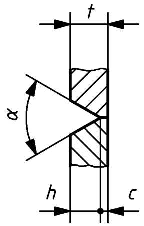
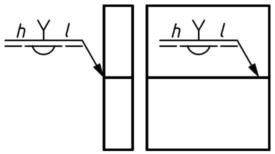
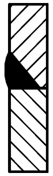
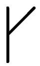
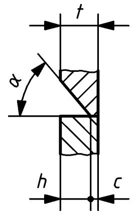
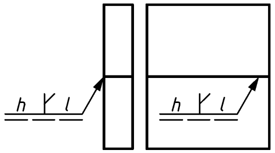
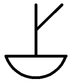
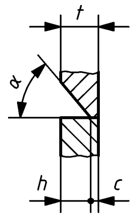
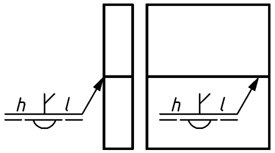
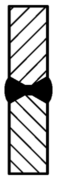
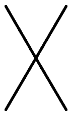
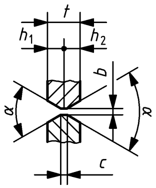
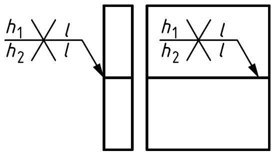
For welding symbols, see EN 22553, for joint preparation see EN ISO 9692.

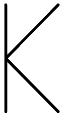
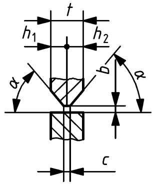
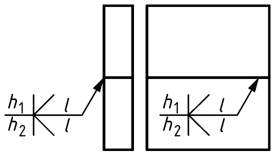
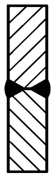
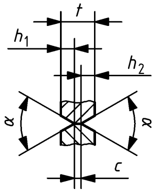
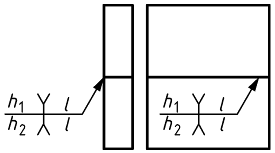
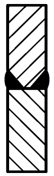
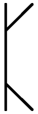
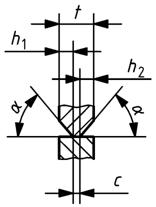
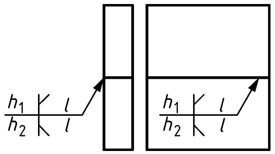
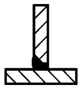
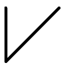
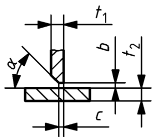
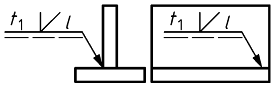
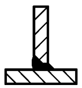
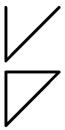
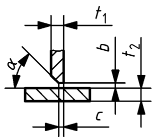
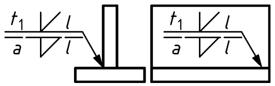
Table B.1 — Joint preparations and throat thicknesses of welds

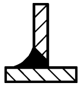
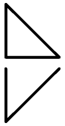
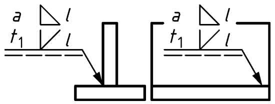
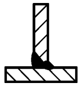
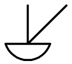
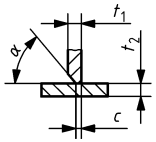
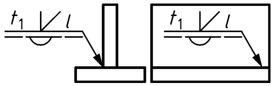
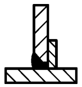
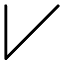
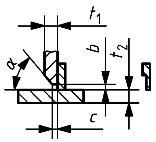
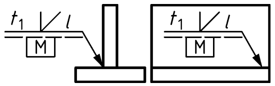
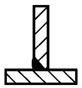
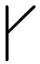
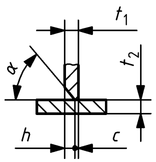
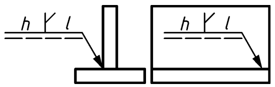
No.	Marking	Figure	Symbol	Joint preparation sectional view	Symbolic drawing	Material thickness t (mm)		Angle a		Gap b (mm)		Thickness of root face c (mm)		Depth of preparation h (mm)		Design throat thickness a_R (mm)
						Al [a]	Steel	Al [a]	Steel	Al [a]	Steel	Al [a]	Steel	Al [a]	Steel	
1a	Plain butt weld one-sided					≤ 4	≤ 4	–	–	0 – 2	0 – 3	–	–	–	–	$a_R = t$
1b	Plain butt weld with backing bar [a b]					≤ 6	≤ 6	–	–	0 – 3	0 – 3	–	–	–	–	$a_R = t$

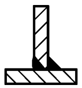
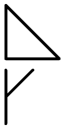
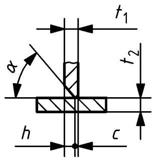
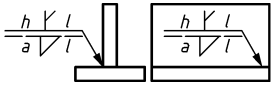
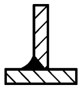
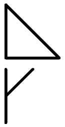
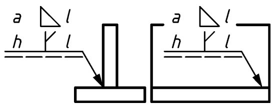
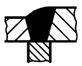
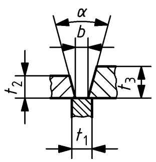
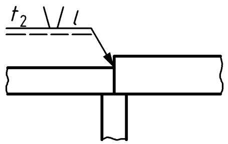
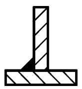
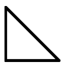
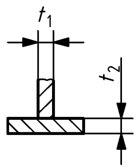
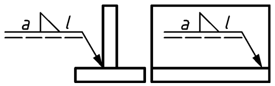
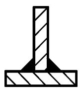
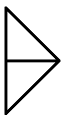
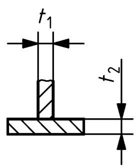
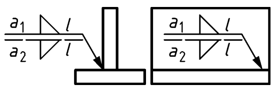
No.	Marking	Figure	Symbol	Joint preparation sectional view	Symbolic drawing	Material thickness t (mm)		Angle a		Gap b (mm)		Thickness of root face c (mm)		Depth of preparation h (mm)		Design throat thickness a_R (mm)
						Al [a]	Steel	Al [a]	Steel	Al [a]	Steel	Al [a]	Steel	Al [a]	Steel	
1c	Plain butt weld at both sides					3 – 6	3 – 6	–	–	0 – 2	0 – 3	–	–	–	–	$a_R = t$
2a	Butt weld in V joint					3 – 15	3 – 15	60 – 70	50 – 60	0 – 2	0 – 3	0 – 2	0 – 2	–	–	$a_R = t$
2b	Butt weld in V joint with backing bar [b]					3 – 15	3 – 15	60 – 70	50 – 60	0 – 4	2 – 4	0 – 2	0 – 2	–	–	$a_R = t$
2c	Butt weld in V joint with sealing run [c]					3 – 15	3 – 15	60 – 70	50 – 60	0 – 2	0 – 2	0 – 2	0 – 2	–	–	$a_R = t$
2d	Square edge weld with backing bar [b]					8 – 20	12 – 30	30 – 40	20 – 40	4 – 10	6 – 15	–	–	–	–	$a_R = t$

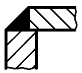
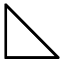
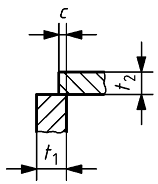
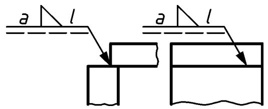
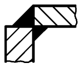
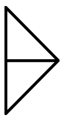
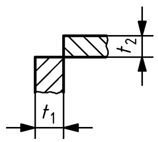
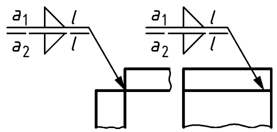
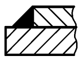
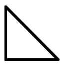
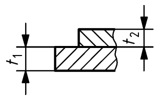
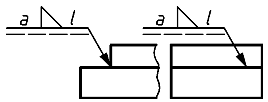
No.	Marking	Figure	Symbol	Joint preparation sectional view	Symbolic drawing	Material thickness t (mm)		Angle a		Gap b (mm)		Thickness of root face c (mm)		Depth of preparation h (mm)		Design throat thickness a_R (mm)
						Al [a]	Steel	Al [a]	Steel	Al [a]	Steel	Al [a]	Steel	Al [a]	Steel	
3a	HV weld [d]					3 – 15	3 – 15	50 – 60	40 – 60	0 – 2	1 – 3	1 – 2	1 – 2	–	–	$a_R = t$
3b	HV weld with backing bar [b]					3 – 15	3 – 15	50 – 60	40 – 60	0 – 4	2 – 4	1 – 2	1 – 2	–	–	$a_R = t$
3c	HV weld with sealing run [c]					3 – 15	3 – 15	50 – 60	40 – 60	0 – 2	0 – 2	1 – 2	1 – 2	–	–	$a_R = t$
3d	Square edge weld one-sided with backing bar [b]					8 – 20	12 – 30	30 – 40	20 – 40	4 – 10	6 – 15	–	–	–	–	$a_R = t$
4a	Y weld					3 – 15	3 – 15	60 – 70	50 – 60	–	–	≤ 0,2 t	≤ 0,2 t	≥ 0,8 t	≥ 0,8 t	$a_R \leq t - c$

No.	Marking	Figure	Symbol	Joint preparation sectional view	Symbolic drawing	Material thickness t (mm)		Angle a		Gap b (mm)		Thickness of root face c (mm)		Depth of preparation h (mm)		Design throat thickness a_R (mm)
						Al [a]	Steel	Al [a]	Steel	Al [a]	Steel	Al [a]	Steel	Al [a]	Steel	
4b	Y weld with sealing run [e]					3 – 15	3 – 15	60 – 70	50 – 60	–	–	≤ 0,2 t	≤ 0,2 t	≥ 0,8 t	≥ 0,8 t	$a_R \leq t - c$
5a	HY weld					3 – 15	3 – 15	50 – 60	40 – 60	–	–	≤ 0,2 t	≤ 0,2 t	≥ 0,8 t	≥ 0,8 t	$a_R \leq t - c$
5b	HY weld with sealing run					3 – 15	3 – 15	50 – 60	40 – 60	–	–	≤ 0,2 t	≤ 0,2 t	≥ 0,8 t	≥ 0,8 t	$a_R \leq t - c$
6	DV weld (X weld) [c]					≥ 12	≥ 12	60 – 70	50 – 60	0 – 3	0 – 3	1 – 2	1 – 2	$h_{1/2}$ 1/3 t – 1/2 t		$a_R = t$

No.	Marking	Figure	Symbol	Joint preparation sectional view	Symbolic drawing	Material thickness t (mm)		Angle a		Gap b (mm)		Thickness of root face c (mm)		Depth of preparation h (mm)		Design throat thickness a_R (mm)
						Al [a]	Steel	Al [a]	Steel	Al [a]	Steel	Al [a]	Steel	Al [a]	Steel	
7	DHV weld (double HV weld) [c]					≥ 12	≥ 12	50 – 60	40 – 60	0 – 2	1 – 3	1 – 2	1 – 2	$h_{1/2}$ 1/3 t – 1/2 t		$a_R = t$
8	DY weld (double Y weld)					≥ 12	≥ 12	60 – 70	50 – 60	–	–	≤ 0,2 t	≤ 0,2 t	≥ 0,4 t	≥ 0,4 t	$a_R \leq t - c$
9	DHY weld (double HY weld)					≥ 12	≥ 12	50 – 60	40 – 60	–	–	≤ 0,2 t	≤ 0,2 t	≥ 0,4 t	≥ 0,4 t	$a_R \leq t - c$
10a	HV weld [d]					3 – 15	3 – 15	50 – 60	50 – 60	1 – 3	1 – 3	0 – 2	0 – 2	–	–	$a_R = t_1$
10b	HV weld with fillet weld as sealing run [c]					3 – 15	3 – 15	50 – 60	50 – 60	0 – 3	0 – 3	0 – 2	0 – 2	–	–	$a_R = t_1$

No.	Marking	Figure	Symbol	Joint preparation sectional view	Symbolic drawing	Material thickness t (mm)		Angle a		Gap b (mm)		Thickness of root face c (mm)		Depth of preparation h (mm)		Design throat thickness a_R (mm)
						Al [a]	Steel	Al [a]	Steel	Al [a]	Steel	Al [a]	Steel	Al [a]	Steel	
10c	HV weld with additional fillet weld [d]					3 – 15	3 – 15	50 – 60	50 – 60	0 – 3	0 – 3	0 – 2	0 – 2	–	–	$a_R = t_1$
10d	HV weld with sealing run [c]					3 – 15	3 – 15	50 – 60	50 – 60	0 – 3	0 – 3	0 – 2	0 – 2	–	–	$a_R = t_1$
10e	HV weld with backing bar [b d]					3 – 20	3 – 20	50 – 60	50 – 60	0 – 5	0 – 5	0 – 2	0 – 2	–	–	$a_R = t_1$
11a	HY weld					3 – 15	3 – 15	50 – 60	50 – 60	–	–	≤ 0,2 t	≤ 0,2 t	–	–	$a_R \leq t_1 - c$

No.	Marking	Figure	Symbol	Joint preparation sectional view	Symbolic drawing	Material thickness t (mm)		Angle α		Gap b (mm)		Thickness of root face c (mm)		Depth of preparation h (mm)		Design throat thickness a_R (mm)
						Al [a]	Steel	Al [a]	Steel	Al [a]	Steel	Al [a]	Steel	Al [a]	Steel	
11b	HY weld with fillet weld as sealing run [e]					3 – 15	3 – 15	50 – 60	50 – 60	–	–	≤ 0,2 t	≤ 0,2 t	–	–	$a_R \leq h+a \leq t_1$
11c	HY weld with additional fillet weld					3 – 15	3 – 15	50 – 60	50 – 60	–	–	≤ 0,2 t	≤ 0,2 t	–	–	$a_R \leq h \leq t_1$ in special cases: $a_R \leq h+a \leq t_1$
12	Joint between three members					t_2 4 – 20	t_2 4 – 20	30 – 40	20 – 40	4 – 10	4 – 10	–	–	–	–	$a_R = b$ [f] $a_R = t_2$ [g]
13a	Fillet weld					Al: a_{min} 3 mm, a_{max} 12 mm Steel: a_{min} 2 mm, a_{max} 12 mm										$a_R = a \leq 0{,}7 \times t_{min}$
13b	Double fillet weld					Al: a_{min} 3 mm, a_{max} 12 mm Steel: a_{min} 2 mm, a_{max} 12 mm										$a_R = a_1 + a_2 \leq t_{min}$ $a_{max} \leq 0{,}7 \times t_{min}$

No.	Marking	Figure	Symbol	Joint preparation sectional view	Symbolic drawing	Material thickness t (mm)		Angle α		Gap b (mm)		Thickness of root face c (mm)		Depth of preparation h (mm)		Design throat thickness a_R (mm)
						Al [a]	Steel	Al [a]	Steel	Al [a]	Steel	Al [a]	Steel	Al [a]	Steel	
13c	Corner seam weld					t_1 ≥ 1	t_1 ≥ 1	–	–	–	–	–	–	–	–	$a_R = a \le 0{,}7 \times t_2$ $t_2 \le t_1$
13d	Corner seam weld					t_2 ≥ 3	t_2 ≥ 3	–	–	–	–	–	–	–	–	$a_R = a_1 + a_2 \le t_2$ $a_1 \le 0{,}7 \times t_2$ $t_2 \le t_1$
13e	Lap seam weld					t_2 ≥ 1,5 t_1 ≥ 3	t_2 ≥ 1,5 t_1 ≥ 2	–	–	–	–	–	–	–	–	$a_R = a \le 0{,}7 \times t_2$ $t_2 \le t_1$

It is possible to depart from this weld preparation, if special welding processes (for example mechanized welding processes) are used and the required throat thickness is proved by a work specimen.

[a] Aluminium and aluminium alloys.

[b] M or MR (see EN 22553).

[c] Before welding the sealing run the root shall be grooved out.

[d] For HV weld without a sealing run there shall be steps by design, production and testing for a safe root fusion (test specimens).

[e] The sealing run serves to prevent gap corrosion.

[f] Force transmission from t_1 to t_2 and t_3; the thicknesses t_2 and t_3 and the joint root opening b shall be additionally considered at the calculation.

[g] Force transmission from t_2 to t_3.

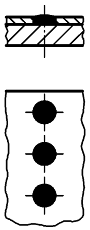
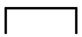
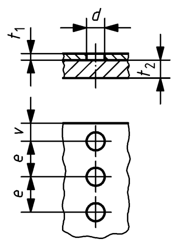
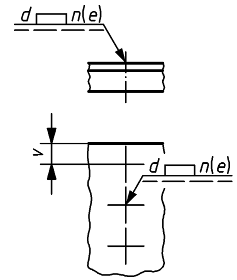
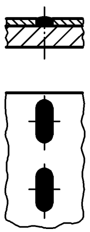
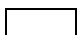
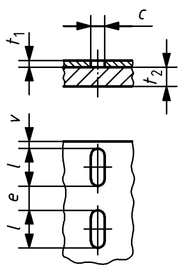
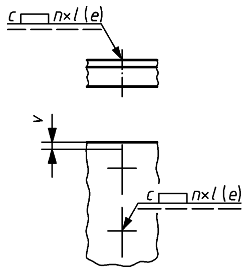
Annex C
(informative)

Joint preparation for plug welds

Table C.1 gives an overview of recommended joint preparations and throat thicknesses used for plug welds on railway vehicles.

Table C.1 — Joint preparations and throat thicknesses of plug welds

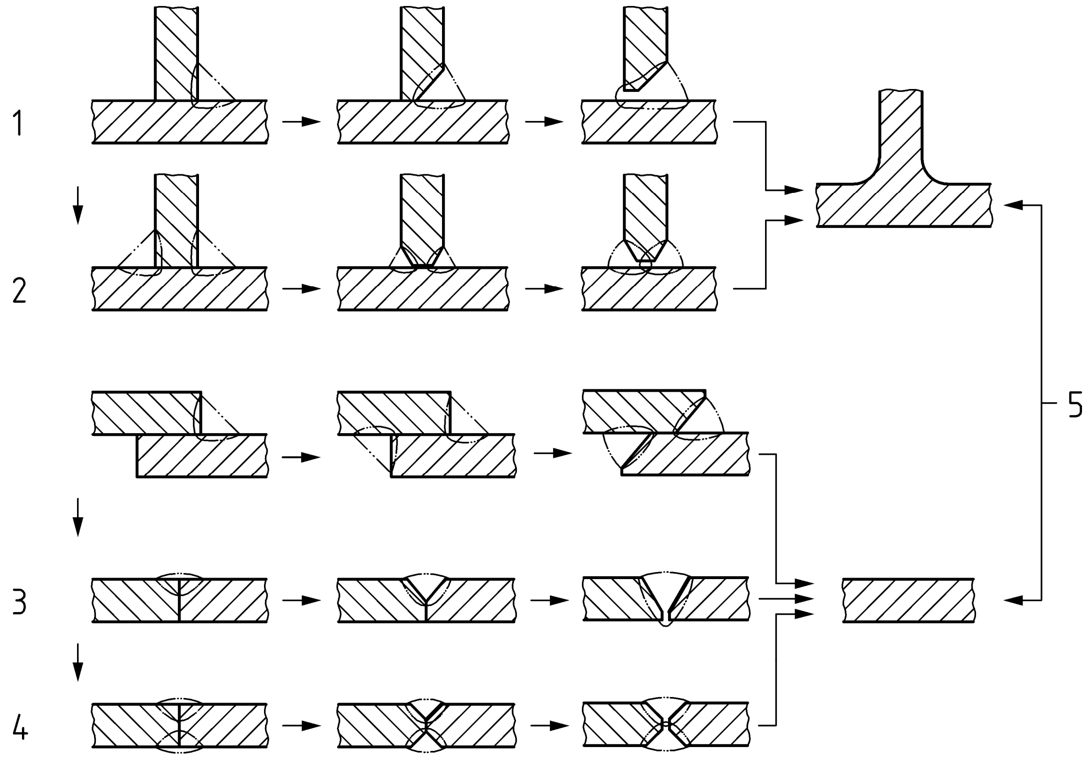
Dimensions in millimetres

No.	Marking	Figure	Symbol	Joint preparation sectional view	Symbolic drawing	Material thickness t_1		Material thickness t_2		Plug width c or d		Plug distance e		Design throat area a_R
						Al	Steel	Al	Steel	Al	Steel	Al	Steel	
1	Plug weld					≥ 3	≥ 2	≤ 4	≤ 4	$3 \times t_2 \leq d \leq 4 \times t_2$	$3 \times t_2 \leq d \leq 4 \times t_2$	$3 \times d \leq e \leq 4 \times d$	$3 \times d \leq e \leq 4 \times d$	$A = \frac{\Pi d^2}{4}$
2	Elongated plug weld					≥ 3	≥ 2	≤ 6	≤ 6	$3 \times t_2 \leq d \leq 4 \times t_2$	$c \geq 3 \times t_2$	$3 \times c \leq e \leq 4 \times c$	$3 \times c \leq e \leq 4 \times c$	$A_R = c(l - c)$
Conditions for edge distance v: $v \geq d$ or $v \geq c$														

Annex D
(informative)

Types of joints in relation to stresses and inspection classes

Figure D.1 shows possibilities for selecting a type of joint to lower stresses and inspection classes. The arrows show the type of joint appropriate to reduce the weld performance and the inspection class. In all cases, the magnitude and direction of loading has to be taken into account.



Key

1 welding with access from one side only

2 welding with access from both sides

3 welding with access from one side only

4 welding with access from both sides

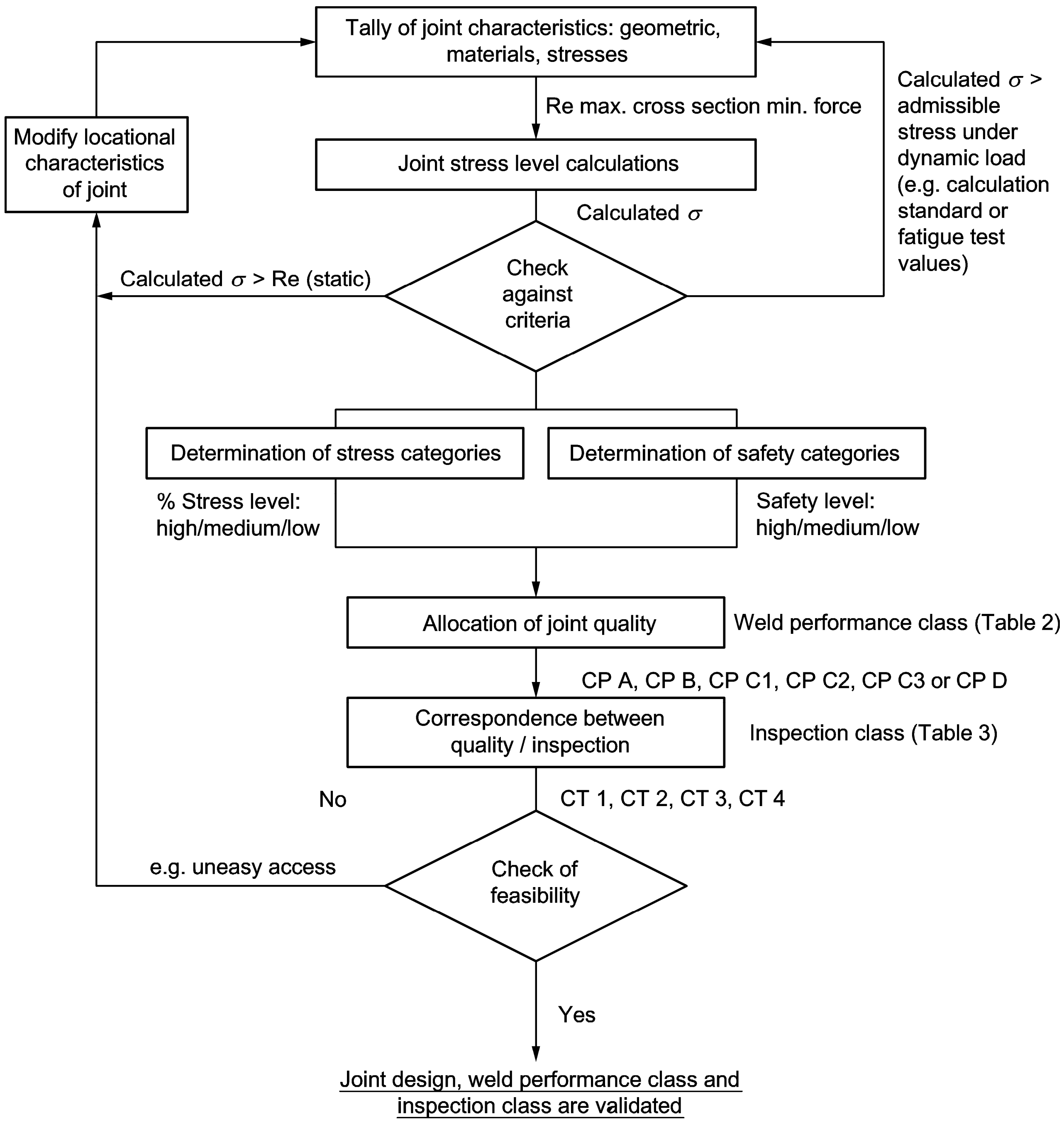
5 moulded or cast part

At each stage, the weld toe of fillet welds may be ground whereas butt welds may be ground flush.

Figure D.1 — Types of joints in relation to stresses and inspection classes

Annex E
(informative)

Welded joint validation chart



Annex F
(normative)

Resistance spot welding

F.1 General

Table F.1 provides minimum parameters for the design of the spot spacing and distance from the edge in dependency on the thickness of the workpiece for resistance spot welding.

Table F.1 — Spot spacing, distance from edge

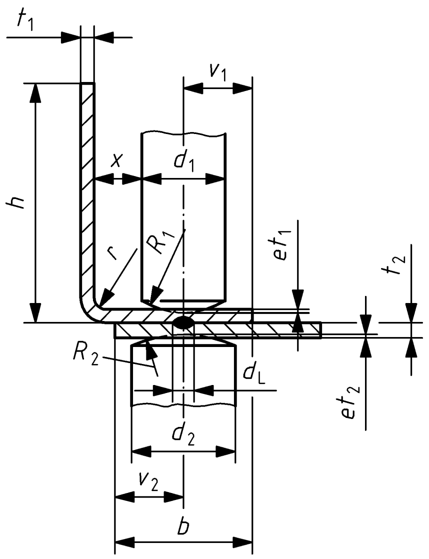
Dimensions in millimetres

Workpiece thickness t_1	1	1,25	1,5	1,75	2	2,5	3
Spot spacing e_1	25	35	35	35	40	50	50
Distance from edge v	≥ 10	≥ 10	≥ 10	≥ 10	≥ 15	≥ 15	≥ 15

Minimum shear pull forces and spot diameters are given in Tables F.4 and F.5.

If these values are deviated from for reasons of the design, a production weld test shall be taken to verify the design.

Dimensions in millimetres



Key

x side distance

d_L spot diameter

$d_{1,2}$ electrode diameter

r bending radius

t_1 smaller plate thickness

t_2 larger plate thickness

et_1 upper impression depth

et_2 lower impression depth

R bunching radius of the electrode

b overlap

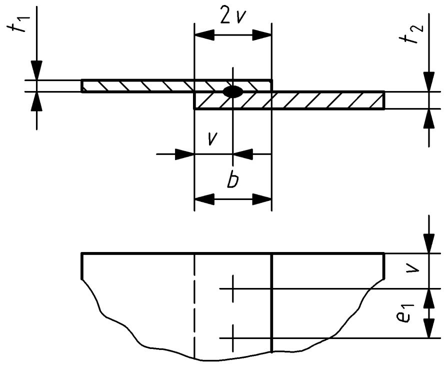
h shank height

v_1 distance from edge 1

v_2 distance from edge 2

$x > 5$ and $x > r$

Figure F.1 — Resistance spot welding of angled profiles and plates



Key

e_1 spot spacing

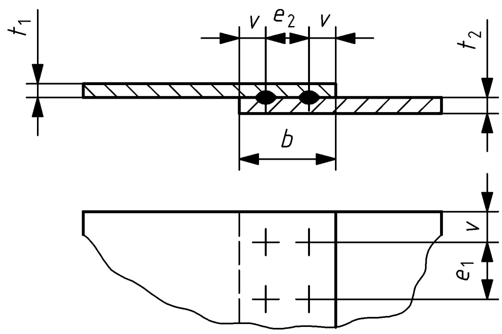
v distance from edge

t_1 smaller plate thickness

t_2 larger plate thickness

b overlap

Figure F.2 — Resistance spot welding of plates, single row



Key

e_1 spot spacing

e_2 spot row spacing

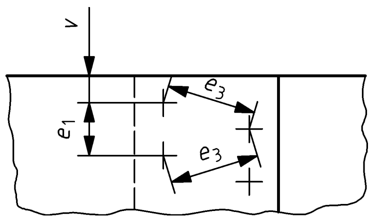
v distance from edge

t_1 smaller plate thickness

t_2 larger plate thickness

b overlap

Figure F.3 — Resistance spot welding of plates, double row



Key

e_1 spot spacing

e_3 spot spacing (double row, offset)

v distance from edge

Figure F.4 — Resistance spot welding of plates, double row, offset

Table F.2 defines the quality requirements for resistance spot welded joints, projection welded joints and resistance seam welded joints for production welds.

Table F.2 — Quality requirements

Serial No.	Ref. No. to EN ISO 6520-2	Requirements	Weld performance class CP C1 and CP C2	Weld performance class CP C3	Weld performance class CP D
Quality requirements, general					
1		Classification of welding processes according to EN ISO 4063	21, 22	21, 22, 23	
2		Type of machine	Welding machines with programme cycle control and process inspection	Welding machine with programme cycle	The requirements CP C1, CP C2 and CP C3 are valid. For 21 the use of manual, foot table machines is permissible.
3		Field of application	Supporting part of rail vehicles (side walls, front walls, floors and outside parts as instrument cases, flaps, aprons, doors)		Subordinate parts (panels, cable ducts, ventilation grids)
4		Permissible sheet metal thickness ratio	$t_2 : t_1 \leq 3 : 1$ Other sheet metal ratios and welding of more than two sheets shall be agreed with the customer.		No requirements
5		Minimum shear pulling force	For 21 Table F.4 and Table F.5 For 22 and 23 these tables are valid in the sense corresponding to the connecting sector.		75 % of CP C1, CP C2 and CP C3
6		Surface appearance of the various parts	The surface of the joined parts shall be free of scale, rust, paint, dust, grease or other soiling at the place of the weld. Additionally surface coatings, lamination, corrosion protective, sealing, pastes and glue can be used if their welding suitability has been proved.		
7		Maximum hardness values for steel	The general requirements of EN ISO 15614-12 shall be applied. For the hardness values, EN ISO 15614-1 shall apply.		No requirements
Quality requirements, outer findings, external					
9	P 100	Crack	Not permissible		
10	P 2011 P 2012 P 2013	Gas pore Uniformly distributed porosity Localized porosity	Not permissible		Permissible if agreed between the contracting parties
11	P 602 P 612	Spatter Material extrusion	Permissible if agreed between the contracting parties		Permissible if agreed between the contracting parties
12	P 526	Surface imperfection	Surface quality 2 and 3 to table F.3 permissible		Surface quality 2, 3 and 4 according to Table F.3 permissible
13	P 522	Burn through from one side	Not permissible		Permissible

Serial No.	Ref. No. to EN ISO 6520-2	Requirements	Weld performance class CP C1 and CP C2	Weld performance class CP C3	Weld performance class CP D
14	P 5263	Adhering electrode material	Not permissible		Permissible if agreed between the contracting parties
Quality requirements, inner findings, internal					
15	P 5216	Insufficient depth of penetration of nugget	Minimum 30 % max. 90 % of the particular sheet metal thickness		No requirements
16	P 100	Crack	Permissible for 21 and 22 in the centre area of the welding lens (maximum half diameter) Not permissible for 22		
17	P 2011 P 300	Gas pore Solid material inclusion	Permissible for 21 and 23 in the middle half of the welding lens diameter		
18	P 2012 P 2013	Uniformly distributed porosity Localized porosity	For 22: $A \leq 2\%$ $d \leq 0{,}4t_1$ [a]		For 22: $A \leq 4\%$ $d \leq 0{,}5t_1$
19	P 400 P 401	Lack of fusion No weld	Not permissible		
20	P 525	Excessive sheet separation	Immediate next to the welding point: $h \leq 0{,}1(t_1 + t_2)$		Permissible
Testing and documentation					
21		Visual test [b]	100 %		
22		Simplified weld production test (SWPT) [c]	– daily before start of work – at change of the WPS – at tool modification		
23		Normal weld production test (NWPT) [d]	– for the prove of the WPS – to prove the quality in the production at regular intervals , depending on weld volume, weld equipment and welding performance class		Not required
24		Documentation	– NWPT 100 % Process inspection 100 %	– NWPT necessary	Not required

[a] A = area of imperfection, d = size of single imperfection (for instance length, width, diameter).

[b] Testing the completeness of welding and external assessment without use of optical instruments.

[c] SWPT: Rolling test, chipping test according to ISO 10447 or simplified torsion test (weld production test) according to EN ISO 17653.

[d] NWPT: for 21 and 23: button test according to EN ISO 15614-12 with a macrograph and for 22: NDT, button test according to EN ISO 15641-12 with a macrograph.

Table F.3 defines the surface quality for resistance spot welded joints, projection welded joints and resistance seam welded joints.

Table F.3 — Surface quality

Surface quality	Requirements	Application
1	Shall be agreed between manufacturer and customer.	Shall be agreed between manufacturer and customer.
2	Surfaces where welding marks (electrode impressions, ring shaped reinforcement-formation, imperfections, through heat distortion etc.) do not amount to more than 10 % of the particular single sheet metal thickness. Note: If required the indentation can be filled in.	For surfaces with aesthetic requirements (for instance side walls, front walls and roofs of passenger trains).
3	Surfaces where welding marks do not amount to more than 25 % of the particular metal thickness. In this area are also firmly adhering welding spatter permitted as long as the drawing does not demand that it shall be free of burrs and splatters.	Surfaces for non-aesthetic requirement (for instance freight wagons, transport containers, sheeting of floors).
4	Without quality requirements.	For simple parts of subordinate importance without aesthetic requirements.

F.2 Minimum shear pull forces

Table F.4 and Table F.5 contain the minimum shear pull forces for resistance spot welding joints dependent on metal thickness for weld performance classes CP C1, CP C2 and CP C3. These shall be proven by in the tensile shear test.

- steel: Table F.4;
- aluminium and alloys: Table F.5.

The given values are the minimum average values for one set of five individual spot welds.

Higher shear pull forces may be agreed between the contracting parties and shall be approved by production weld tests.

Table F.4 — Minimum shear pull forces for resistance spot welding joints of steel for weld performance classes CP C1, CP C2 and CP C3

t_1 (mm)	d_L (mm)	Tensile strength R_m of the parent metal [MPa]		
		≤ 360	> 360 to < 510	510 to < 620
		Minimum shear pull force per spot (kN)		
0,8	4,5	3,5	4,5	6,0
1,0	5,0	4,7	6,0	8,0
1,25	5,5	5,9	7,5	10,0
1,5	6,0	7,1	9,0	12,0
1,75	6,5	8,5	10,9	14,5
2,0	7,0	10,0	12,8	17,0
2,5	8,0	12,9	16,5	22,0
3,0	8,5	16,5	21,0	28,0

These values are valid for unalloyed and alloyed steel, also for the combination of them. For the combination of parent metals with different tensile strength, the material with the lower value shall be chosen.

Table F.5 — Minimum shear pull force for resistance spot welding joints of aluminium and alloys for the weld performance classes CP C1, CP C2 and CP C3

t_1 (mm)	d_L (mm)	Tensile strength R_m of the parent metal [MPa]		
		≤ 240	> 240 to 300	> 300 to 350
		Minimum shear pull force per spot (kN)		
0,8	4,5	1,1	1,3	1,5
1,0	5,0	1,5	1,8	2,1
1,25	5,5	2,0	2,3	2,8
1,5	6,0	2,5	2,9	3,5
2,0	7,0	3,5	4,1	4,8
2,5	8,0	4,5	5,3	6,2
3,0	8,5	5,5	6,4	7,6

For parent metals with different tensile strength, the material with the lower value shall be chosen.

Annex G
(informative)

Determination of safety category for welded joints

The basis for the determination of the relevant safety category for the welded joint is the definition of high, medium and low safety level as defined in 4.5.

Additionally, in the determination of safety category, the safety assumptions and requirements of the fatigue strength assessment versus the failure of welded joints, as contained in the applied calculation standard or guideline, should be also considered. Furthermore the practical experiences in fields of application, which the designer has collected in the fatigue design of welded components of railway vehicles, should be used.

To assist in defining high and medium safety categories, the designer should assess if the following apply:

1) a warning is given before fatigue failure;

2) there is a possibility to detect a crack at regular inspection;

3) the design of the component provides an alternative load path (non-statically determined system or redundant components);

4) the design of the welded components contains a feature to arrest a propagating crack.

The following should be used to support the selection of high and medium safety category:

— **High,** if none of the above criteria apply;

— **Medium,** if any one of the above criteria applies.

Examples of welded components for destination determination of safety category:

— High: welded connection between car body and bogie frame;

— Medium: welded joints of box girder of bogie frame, car body structure frame;

— Low: welded joints for damper connection, support for brake pipes and electric panels.

Annex H
(informative)

Welding of 6000 series aluminium alloy extrusions – Recommendations from the Aljoin project for improved crashworthiness

Heat treatable aluminium alloys, such as the 6000 series alloys used for the extrusions of car bodies, suffer from post weld weakening of the heat affected zone. Also the welding consumables are under-matched, in strength, to the parent material properties.

These effects should be considered, particularly when designing for crashworthy performance, to avoid problems of unstable fracture localised to the heat affected zone and weld metal. The consequences, under extreme loading conditions, can be unstable fractures running the full length of the car body.

It is thus recommended that:

- in the main structural welds along the car body length, the geometry of the extrusion should ensure that weld and strength of the heat affected zone is matched to the parent material strength. This will generally require the weld and heat affected zone to be thicker than the parent material, see ALJOIN research project report;
- where this is not possible, in the case of window pillars where the direction of extrusion is perpendicular to the main body side extrusions, the welded joint should be designed to be at least as strong as the connected parent part;
- this could be achieved e.g. by large corner gussets to lengthen the weld or by welded reinforcements attached across the weld.

6000 series aluminium alloys may be welded with either magnesium aluminium alloy type 5 welding consumables (see EN 1011-4) or silicon aluminium alloy type 4 welding consumables.

However, in the case of welds in the longitudinal direction, the Aljoin project report[1)] concluded that magnesium aluminium alloy welding consumables have significantly better fracture toughness. This was found to be particularly important where geometric effects, such as in partial penetration welds, constrain a fracture to the weld metal. This conclusion was supported by further research within the Aljoin Plus project report.[2)]

As such, the Aljoin research project report recommends the use of type 5 welding consumables for the longitudinal welds of carbody structures which use 6000 series extruded aluminium alloys.

NOTE prEN 1090-3:2007 also contains information about the choice of filler metals for plates.

In this special case, the type of welding consumables should be clearly indicated on the drawing or the parts list.

1) See [5] in Bibliography.

2) See [6] in Bibliography.

Bibliography

[1] EN 1011-4, *Welding — Recommendations for welding of metallic materials — Part 4: Arc welding of aluminium and aluminium alloys*

[2] prEN 1090-3, *Execution of steel structures — Part 3: Supplementary rules for high yield strength steels*

[3] EN ISO 3834 (all parts), *Quality requirements for fusion welding of metallic materials*

[4] ISO/TR 581, *Weldability — Metallic materials — General principles*

[5] *Aljoin research project report – Final Technical Report for the partly EU funded 'Aljoin' project – Contract No. G3RD-CT-2002-00829, Project No. GRD2-2001-50065 – Section 2 – Executive publishable summary*[3)]

[6] *Aljoin Plus project – A subsequent project to Aljoin funded by the UK Railway Safety and Standards Board and reported by Newrail (University of Newcastle upon Tyne). Newrail Report No. MS-20051108*

[7] EN ISO 13920:1996, *Welding — General tolerances for welded constructions — Dimensions for lengths and angles — Shape and position (ISO 13920:1996)*

3) Available free of charge from the RSSB websites.

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