

English Version

Welding - Recommendations for welding of metallic materials - Part 1: General guidance for arc welding

Soudage - Recommendations pour le soudage des
matériaux métalliques - Partie 1 : Lignes directrices
générales pour le soudage à l'arc

Schweißen - Empfehlungen zum Schweißen metallischer
Werkstoffe - Teil 1: Allgemeine Anleitungen für das
Lichtbogenschweißen

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: Avenue Marnix 17, B-1000 Brussels

Contents

Page

Foreword.....	3
Introduction	4
1 Scope	4
2 Normative references	4
3 Terms and definitions	5
4 Principles	6
4.1 General.....	6
4.2 Fundamental information for fabrication	6
4.3 Non-conformance and corrective actions.....	6
5 Requirements on welding production	6
5.1 Equipment and devices.....	6
5.2 Workplace.....	7
5.3 Personnel.....	7
5.4 Welding processes	7
5.5 Sub-contracting	7
6 Parent metals and welding consumables	8
6.1 Storage and handling.....	8
6.2 Material certificates	8
7 Planning.....	8
7.1 Information on drawings.....	8
7.2 Assembly for welding.....	8
7.3 Run-on and run-off plates.....	8
7.4 Temporary attachments.....	9
7.5 Fabrication and inspection feasibility	9
7.6 Welding procedure specification	9
7.7 Weld sequence.....	9
8 Welding fabrication.....	9
8.1 Welding instructions	9
8.2 Joint preparation and surface cleaning	9
8.3 Preheating	10
8.4 Arc strikes	10
8.5 Tack welds.....	10
8.6 Weld run sequence.....	10
8.7 Heat input	10
8.8 Protection against oxidation	12
8.9 Weld imperfections.....	12
8.10 Traceability.....	12
9 Elimination of distortion or inherent stresses.....	13
10 Post-weld heat treatment	13
11 Surface cleaning and treatment	13
12 Inspection and documentation.....	13
Bibliography	14

Foreword

This document (EN 1011-1:2009) has been prepared by Technical Committee CEN/TC 121 "Welding", 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of an identical text or by endorsement, at the latest by September 2009, and conflicting national standards shall be withdrawn at the latest by September 2009.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 1011-1:1998

EN 1011 consists of the following parts, under the general title *Welding — Recommendations for welding of metallic materials*:

Part 1: General guidance for arc welding

Part 2: Arc welding of ferritic steels

Part 3: Arc welding of stainless steels

Part 4: Arc welding of aluminium and aluminium alloys

Part 5: Welding of clad steel

Part 6: Laser beam welding

Part 7: Electron beam welding

Part 8: Welding of cast irons

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

EN 1011 is issued in several parts in order that it may cover the different types of weldable metallic materials and specific welding processes.

This part of EN 1011 deals with the production and control of arc welding of metallic materials and is appropriate for all types of fabrication.

Specific materials advice is covered by parts 2, 3, 4, 5 and 8. Parts 6 and 7 refer to laser and electron beam welding and each cover a range of materials.

Permissible design stresses in welds, methods of testing and acceptance levels are not included because they depend on the service conditions of the fabrication. These details may be obtained from the relevant application standard or design specification.

It has been assumed in the drafting of this standard that the execution of its provisions is entrusted to appropriately qualified, trained and experienced personnel.

1 Scope

This European Standard contains general guidance for the arc welding of metallic materials in all forms of product (e.g. cast, wrought, extruded, forged).

The processes and techniques referred to in this Part of EN 1011 may not all be relevant to all materials. Additional information relevant to specific materials is given in the relevant Parts of the Standard.

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 287-1, *Qualification test of welders — Fusion welding — Part 1: Steels*

EN 473, *Non destructive testing — Qualification and certification of NDT personnel — General principles*

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

EN 1011-3, *Welding — Recommendations for welding of metallic materials — Part 3: Arc welding of stainless steels*

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

EN 1011-5, *Welding — Recommendations for welding of metallic materials — Part 5: Welding of clad steel*

EN 1011-6, *Welding — Recommendations for welding of metallic materials — Part 6: Laser beam welding*

EN 1011-7, *Welding — Recommendations for welding of metallic materials — Part 7: Electron beam welding*

- EN 1011-8, *Welding — Recommendations for welding of metallic materials — Part 8: Welding of cast irons*
- EN 1418, *Welding personnel — Approval testing of welding operators for fusion welding and resistance weld setters for fully mechanized and automatic welding of metallic materials*
- 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 9606-2, *Qualification test of welders — Fusion welding — Part 2: Aluminium and aluminium alloys (ISO 9606-2:2004)*
- EN ISO 9606-3, *Approval testing of welders — Fusion welding — Part 3: Copper and copper alloys (ISO 9606-3:1999)*
- EN ISO 9606-4, *Approval testing of welders — Fusion welding — Part 4: Nickel and nickel alloys (ISO 9606-4:1999)*
- EN ISO 9606-5, *Approval testing of welders — Fusion welding — Part 5: Titanium and titanium alloys, zirconium and zirconium alloys (ISO 9606-5:2000)*
- EN ISO 9692 (all parts), *Welding and allied processes — Recommendations for joint preparation*
- EN ISO 14175, *Welding consumables — Gases and gas mixtures for fusion welding and allied processes (ISO 14175:2008)*
- EN ISO 15607, *Specification and qualification of welding procedures for metallic materials — General rules (ISO 15607:2003)*
- EN ISO 15609-1, *Specification and qualification of welding procedures for metallic materials — Welding procedure specification — Part 1: Arc welding (ISO 15609-1:2004)*
- EN ISO 15609-3, *Specification and qualification of welding procedures for metallic materials — Welding procedure specification — Part 3: Electron beam welding (ISO 15609-3:2004)*
- EN ISO 15609-4, *Specification and qualification of welding procedures for metallic materials — Welding procedure specification — Part 4: Laser beam welding (ISO 15609-4:2004)*
- EN ISO 17662, *Welding — Calibration, verification and validation of equipment used for welding, including ancillary activities (ISO 17662:2005)*
- CEN/TR 14599:2005, *Terms and definitions for welding purposes in relation with EN 1792*
- IEC/TS 62081, *Arc welding equipment — Installation and use*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in CEN/TR 14599:2005 and the following apply.

3.1

thermal efficiency

k

ratio of heat energy introduced into the weld to the electrical energy consumed by the arc

4 Principles

4.1 General

If the manufacturer is recommended to use a control system, the requirement should be in accordance with the appropriate part of EN ISO 3834.

4.2 Fundamental information for fabrication

Before the start of fabrication, the customer shall inform the manufacturer of all the information, which is important to the manufacturing process, the operational loading and the envisaged service life of the end product. If no quality requirements are defined, the limiting values for imperfections shall be as stated in the relevant specification. Such information should comprise, for example:

- 1) Application standard and any additional requirements such as technical rules, guidelines, and statutory requirements.
- 2) Any specific requirements for welding production, testing and heat treatment.
- 3) Production (detail) drawings with information relating to dimensions and weld forms, if documents from the manufacturer are not viewed as adequate by the customer or regulatory authority.
- 4) Qualification requirements for welding, welding related and NDE personnel
- 5) Methods of welding and testing.
- 6) Requirements relating to the selection, identification and traceability of material and personnel, if required.
- 7) Requirements on machining and surface finish.

4.3 Non-conformance and corrective actions

Where applicable, the method and extent of recording non-conformance has to be specified. Before the start of fabrication, the procedure and the methods for rectifying deficiencies, for compensating for distortion and for correcting weld defects are to be defined.

5 Requirements on welding production

5.1 Equipment and devices

The manufacturer shall have adequate equipment and resources for meeting the requirements of the contract. All the welding related equipment shall be matched to the respective welding process, the working task and the design of the final product.

All electrical equipment which is used in connection with the welding operation shall be installed and used in accordance with IEC/TS 62081 and local regulations. Devices for measuring the welding parameters, such as arc voltage, welding current, wire feed rate, travel speed and shielding/purging gas flow rates, and also for monitoring the preheat and interpass temperatures, shall be available either as part of the welding apparatus or by providing portable equipment. Such equipment shall be calibrated, verified or validated in accordance with EN ISO 17662 where relevant.

5.2 Workplace

The workplace shall be efficiently protected against the detrimental effects of weather, for example wind, rain, snow and draught, in order not to generate weld defects beyond the acceptance levels specified in the contract.

5.3 Personnel

The welding personnel comprises welders, operators and welding coordinators. They shall be employees of the company or shall be contractually bound and shall have the necessary prerequisites from a technical and personal point of view for the job area. Above all, they shall have sufficient knowledge and practical experience in the area of welding and the materials to be processed. They shall be authorized to ensure the quality requirements are met.

Tasks and responsibilities of the welding coordinators shall be specified, see for example EN ISO 14731.

Welders shall be tested in accordance with the requirements of EN 287-1 or the appropriate part of EN ISO 9606, unless otherwise specified, and shall hold valid test certificates.

Welding operators shall be tested in accordance with the requirements of EN 1418, unless otherwise specified, and shall hold valid test certificates.

If inspection is required, the inspection personnel shall be qualified in accordance with EN 473, unless otherwise specified.

5.4 Welding processes

This standard covers welds made by one of the following welding processes to EN ISO 4063 or by a combination of these processes:

- 111 Manual metal-arc welding with covered electrode;
- 114 Self-shielded tubular cored arc welding;
- 12 Submerged arc welding;
- 131 Metal inert gas welding; MIG welding;
- 135 Metal active gas welding; MAG welding;
- 136 Tubular -cored metal-arc welding with active gas shield;
- 137 Tubular -cored metal-arc welding with inert gas shield;
- 141 Tungsten inert gas welding; TIG welding;
- 15 Plasma arc welding.

5.5 Sub-contracting

The manufacturer can contract other companies to carry out the fabrication or partial jobs, such as the heat treatment or testing. These companies shall be adequately qualified and be able to demonstrate this with the necessary transparency, if required in the contract or the application standard. The sub-contractors shall be provided in good time with all the customer information necessary for fabrication, together with the description of the job and the definition of the quality requirements and documentation. Nevertheless, the manufacturer is responsible to the customer for the required manufacture of the final product to a suitable quality.

6 Parent metals and welding consumables

6.1 Storage and handling

The parent metals shall be suitable for welding. Parent metals and welding consumables shall be stored and processed in accordance with best practice e. g. to retain identification and avoid damage and deterioration.

Welding consumables shall be matched to the parent metals and the selected welding process. They are to be stored and handled in accordance with the recommendations of the suppliers.

If the consumables or their packaging show signs of damage or deterioration, they shall not be used. Examples are cracked or flaked coatings on covered electrodes, rusty or dirty wire electrodes and wires with flaked or damaged protective coatings.

Welding consumables returned to the stores shall be treated in accordance with the manufacturer's/supplier's recommendations before re-issue.

6.2 Material certificates

The parent metals and welding consumables should be designated in accordance with the relevant European Standard. If required by the application standard or the contract, certificates relating to chemical composition, to mechanical/technological properties and other assured quality characteristics shall be presented.

7 Planning

7.1 Information on drawings

Designations and symbols of the welded joints shall be in accordance with EN 22553.

7.2 Assembly for welding

The parts to be welded shall be assembled in such a way that the joints are easily accessible and visible to the welders/operators involved. The accessibility for inspection shall also be considered.

Accumulations of welds and cross-joints should be avoided. If this is not possible, consideration should be given in advance as to whether measures for the relief of stresses or additional inspection, are/is needed in these areas.

Unless otherwise specified, the edges and surfaces to be joined by fillet welds shall be in as close contact as possible. Fillet welds are to be clearly indicated as throat thickness or the leg length. The application of deep penetration processes or special weld designs may be taken into account.

The use of rings or strips as permanent material backing, and use of socket or lap joints is only permissible providing they are not rejected for any operational reasons (for example alternating load, corrosion, low-temperature use). The backing material shall be compatible with the parent metal and/or weld metal.

7.3 Run-on and run-off plates

The ends of butt welds shall be welded to provide the full weld thickness. This may be achieved by the use of run-on and/or run-off plates. These shall be produced from a material which is compatible with that of the parts to be joined. The thickness, the weld preparation and the length of the run-on and run-off plates depend on the welding task and the welding process.

7.4 Temporary attachments

Welded attachments for the introduction and transmission of external forces from handling or assembly are to be dimensioned in such a way that they are able to transmit these forces without damaging the structure. If necessary, the plate edges shall be rounded. Vent holes may be needed (for example on saddle plates) to prevent build-up of pressure by thermal expansion of a trapped gas.

Where the assembly or erection method requires the use of temporary welded attachments, these shall be configured in such a way that they can be easily removed without damaging the structure. The location of these attachments shall also be taken into consideration. The material of attachments, welding consumables, and the welding procedures used shall be compatible with the parent metal. It should be ensured that welds of this type are executed only when they are contractually permissible, and that unintended detrimental effects, for example stress raisers and/or shrinkage stresses, are avoided.

The surface of the parent metal shall be carefully ground after the removal of these welded-on parts. If necessary, a surface inspection may be carried out to demonstrate that the material is free from unacceptable imperfections.

7.5 Fabrication and inspection feasibility

Jigs, fixtures and manipulators should be used, in order that the welding can be carried out in the most suitable welding position. The sequence of assembly and welding shall be carried out in such a way that all the welds can be examined in accordance with the relevant requirements. Welds which become hidden in the course of the fabrication process shall previously be subjected to at least one visual inspection, and to additional tests as required by the application standard or contract requirements.

7.6 Welding procedure specification

If required, welding procedure specifications, including for attachment welds, shall be prepared in accordance with the EN ISO 15609 series of standards before the start of fabrication. Welding procedure specifications shall be qualified by an appropriate method according to EN ISO 15607.

7.7 Weld sequence

The weld sequence shall be defined in the welding plan. In order to avoid distortion and/or excessively high inherent stresses, the weld buildup and the welding sequence shall be optimized.

8 Welding fabrication

8.1 Welding instructions

Appropriate instructions for all relevant welding activities shall be available for the welder/operator.

8.2 Joint preparation and surface cleaning

The joint preparation shall be carried out by thermal, mechanical, or other suitable methods, taking into account the selected welding process and the workpiece thickness, in accordance with the requirements of EN ISO 9692 series or a relevant application standard. The faying surfaces shall be free of cracks and notches.

Directly before welding, the material surface in the joint area shall be free of rust or other oxides, paint, grease, scale, remains from sandblasting, moisture and other contaminants which would have a detrimental effect on the quality of the weld. It is permissible to weld parent material covered with primer paint (see EN ISO 17652), provided it does not generate weld imperfections beyond the acceptance levels specified. If necessary, shaping tools, tensioning and clamping means for the welding, as well as jigs, fixtures and manipulators, should be cleaned before use. For some materials, e.g. stainless steel or aluminium, mechanically transferred

ferritic steel can be detrimental to service performance, and thus it may be necessary to cover steel clamping faces to prevent contamination. Contamination of all surfaces by contact with non-compatible materials, e.g. copper on aluminium or steel, or by grinding dust, shall be avoided.

8.3 Preheating

In the case of steels susceptible to cracking, preheating may be necessary. Details of preheating depend on material, welding process and welding conditions and are specified in EN 1011-2 for most applications. Reference should be made to EN ISO 13916 for measurement of preheat temperature.

Preheating shall be undertaken according to the applicable welding procedure specification and applied during welding, including tack welding and welding of temporary attachments, including run-on and run-off plates.

8.4 Arc strikes

Arc strikes on the material surface caused by welding, damaged welding cables or by improper execution of the magnetic particle testing are to be avoided at all costs. All initial striking of the arc should be within the fusion faces or on the run-on plate. Precautions shall be taken to avoid unintentional arc strikes.

If accidental arcing occurs, the metal surface shall be lightly dressed and, if necessary, subjected to visual inspection and/or crack detection.

8.5 Tack welds

If necessary, tack welds shall be applied to retain the components in their alignment during welding. The lengths of the individual tack welds and their frequency should be specified in the relevant welding procedure specification (WPS) or in other documents, if required. The tack welds shall be carried out in a balanced sequence in order to reduce the risk of distortion and to maintain good fit-up.

If a tack weld is to be included in a welded joint, the form of the tack weld shall be suitable for incorporation into the final weld and shall be carried out by qualified welders. These tack welds shall be free of cracks and other imperfection, such as lack of fusion and end crater cracks. Before welding over the tack weld, it shall be cleaned. Cracks or visible unacceptable imperfections shall be removed. All tack welds which are not included in the final weld should also fulfil the quality requirements.

8.6 Weld run sequence

The weld run sequence shall be specified in the welding procedure specification. The welding process, material properties and operating requirements have to be taken into account. In the case of multi-layer welding it is usually necessary to dress the surfaces of the preceding run in such a way that satisfactory quality in the subsequent run is possible (for example by removing edge notches in the faying surfaces and/or slag on the surface). Welding over cracks, surface pores, slag inclusions and lack of fusion without previous correction is not permitted.

8.7 Heat input

For many steels, abrupt cooling from the heat of welding is to be avoided, because of the risk of hardening or cracking. For this reason, depending on the type of material, thickness of material and heat input, preheating and the maintenance of an upper or lower interpass temperature may be required, as listed in the relevant parts of EN 1011. The heat input shall be chosen so as to be matched to the welding process (see table 1).

The heat input during welding can be viewed as a main influencing factor on the properties of ferritic and ferritic-austenitic stainless steel welds in particular. This influences the time/temperature cycle occurring during welding.

Where appropriate, the heat input value may be calculated as follows:

$$Q = k \frac{U \cdot I}{v} \cdot 10^{-3} \text{ in kJ/mm} \quad (1)$$

where

Q is the heat input;

k is the thermal efficiency;

U is the arc voltage, measured as near as possible to the arc, in V;

I is the welding current, in A

v is the travel speed in mm/s.

For further information see EN 1011-2.

Table 1 — Thermal efficiency factor k of welding processes

Process No	Welding process	k
12	Submerged arc welding	1,0
111	Manual metal-arc welding	0,8
131	MIG welding	0,8
135	MAG welding	0,8
114	Self-shielded tubular -cored arc welding	0,8
136	Tubular-cored wire metal-arc welding with active gas shield	0,8
137	Tubular-cored wire metal-arc welding with inert gas shield	0,8
141	TIG welding	0,6
15	Plasma arc welding	0,6

8.8 Protection against oxidation

In the case of high chromium ferritic or martensitic steels, austenitic and ferritic-austenitic stainless steels, during the welding of the root run, and also during subsequent runs, oxidation of the root of the weld shall be effectively prevented by the use of backing gas according to EN ISO 14175, in order not to impair the properties e. g. the corrosion resistance.

NOTE In the case of other materials, better surface quality may be achieved during single-sided welding of the root run by using a gas backing system.

8.9 Weld imperfections

Unacceptable imperfections outside the quality levels defined in the contract or in the application standard shall be repaired in accordance with a specified method.

If undercut or other imperfections are removed by grinding or other mechanical methods, care shall be taken to ensure that the thickness of the parent material or weld is not reduced below the specified minimum thickness.

Correction of unacceptable undercuts or incorrect root gaps in fillet welds by deposition of additional weld metal shall be in accordance with the corresponding parts of EN 1011.

Weld repairs performed after any post weld heat treatment require a separately qualified welding procedure specification.

8.10 Traceability

If specified, adequate identification measures shall be provided either by means of a marking or by other methods. Traceability may be required e.g. for parent metal, welding consumables, welders/operators, documentation and repairs.

NOTE Hard stamping should be avoided. If it is carried out, its use is forbidden in areas which are highly stressed, where dynamic loads are anticipated or in areas which are at risk of corrosion.

9 Elimination of distortion or inherent stresses

Parts which have been distorted beyond the specified tolerances by welding may be corrected only by a specified method. The method for correcting the distortion should not be deleterious to the component.

NOTE Depending on the material and application, mechanical straightening with subsequent heat treatment to reduce stresses may be better than flame straightening.

Peening of welds may be used only if specified.

10 Post-weld heat treatment

Post-weld heat treatment shall be carried out in accordance with specified procedures. The post-weld heat treatment parameters shall be documented, if required.

11 Surface cleaning and treatment

The surface of components shall be cleaned as required.

The use of grinding, abrasive blasting or jet blasting, and additional surface treatments, such as pickling (if necessary with subsequent rinsing and drying) or coating shall be specified.

12 Inspection and documentation

The extent of inspection, the test methods used and the need for parameter monitoring are to be specified when required. Inspections and test results shall be documented.

Any hold points during fabrication shall be considered.

Bibliography

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- [4] EN ISO 3834-3, *Quality requirements for fusion welding of metallic materials — Part 3: Standard quality requirements (ISO 3834-3:2005)*
- [5] EN ISO 3834-4, *Quality requirements for fusion welding of metallic materials — Part 4: Elementary quality requirements (ISO 3834-4:2005)*
- [6] EN ISO 3834-5, *Quality requirements for fusion welding of metallic materials — Part 5: Documents with which it is necessary to conform to claim conformity to the quality requirements of ISO 3834-2, ISO 3834-3 or ISO 3834-4 (ISO 3834-5:2005)*
- [7] EN ISO 13916, *Welding — Guidance on the measurement of preheating temperature, interpass temperature and preheat maintenance temperature (ISO 13916:1996)*
- [8] EN ISO 14731, *Welding coordination — Task and responsibilities (ISO 14731:2006)*
- [9] EN ISO 17652 (all parts), *Welding — Test for shop primers in relation to welding and allied processes*