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Welding — Recommendations for welding of metallic materials —

Part 8: Welding of cast irons

The European Standard EN 1011-8:2004 has the status of a British Standard

ICS 25.160.10

BSI
British Standards

National foreword

This British Standard is the official English language version of EN 1011-8:2004. It partially supersedes BS 4570:1985.

The UK participation in its preparation was entrusted to Technical Committee ISE/35, Cast iron, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

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

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the *BSI Catalogue* under the section entitled "International Standards Correspondence Index", or by using the "Search" facility of the *BSI Electronic Catalogue* or of British Standards Online.

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Summary of pages

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EUROPEAN STANDARD

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Welding - Recommendations for welding of metallic materials - Part 8: Welding of cast irons

Soudage - Recommandations pour le soudage des matériaux métalliques - Partie 8: Soudage des fontes

Schweißen - Empfehlungen zum Schweißen metallischer Werkstoffe - Teil 8: Schweißen von Gusseisen

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

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Contents

Foreword

This document (EN 1011-8:2004) has been prepared by Technical Committee CEN/TC 190 “Foundry technology”, 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of an identical text or by endorsement, at the latest by May 2005, and conflicting national standards shall be withdrawn at the latest by May 2005.

Within its programme of work, Technical Committee CEN/TC 190 requested CEN/TC 190/WG 5 "Welding of cast iron" to prepare the following standard:

EN 1011-8, *Welding — Recommendations for welding of metallic materials — Part 8: Welding of cast irons.*

This is one of a series of European Standards for requirements for fusion welding of metallic materials.

This European Standard, with the general title *Welding - Recommendations for welding of metallic materials,* is composed of the following parts:

— 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, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

1 Scope

This document specifies the requirements for fusion welding of unalloyed and low-alloy cast iron castings produced in accordance with:

— EN 1561, *Founding — Grey cast irons*;

— EN 1562, *Founding — Malleable cast irons*;

— EN 1563, *Founding — Spheroidal graphite cast irons*.

This document does not apply to the joint welding of cast iron castings to other materials.

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 1011-1:1998, *Welding — Recommendations for welding of metallic materials — Part 1: General guidance for arc welding.*

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

EN ISO 15609-1, *Specification and qualification of welding procedures for metallic materials — Welding procedure specification — Part 1: Arc welding (ISO 15609-1:2004).*

NOTE Informative references to documents used in the preparation of this standard, and cited at the appropriate places in the text, are listed in the bibliography.

3 Terms and definitions

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

3.1
production welding
any welding carried out during manufacturing before final delivery to the end user

NOTE It includes joint welding and finishing welding (see 3.2 and 3.3).

3.2
joint welding
production welding used to assemble components together to obtain an integral unit

3.3
finishing welding
production welding carried out in order to ensure the agreed quality of the casting

3.4
repair welding
any welding carried out after final delivery of the casting to the end user

3.5
homogeneous filler metal
any filler metal which results in a deposited metal with the same type of microstructure as the parent metal

3.6
semi-homogeneous filler metal
any filler metal which results in a deposited metal with a steel-type microstructure

3.7
non-homogeneous filler metal
any filler metal which results in a deposited metal with a microstructure that differs from the parent metal

3.8
cast welding
welding by pouring liquid metal into a specially prepared groove in a casting

3.9
liquid metal welding
cast welding with additional use of a metal arc welding process

4 Abbreviations and symbols

For the purposes of this document, the abbreviations and symbols given in EN 1011-1:1998 shall apply.

5 Provision for quality assurance requirements

For the purposes of this document, the provisions for quality assurance requirements given in Annex A shall apply.

6 Storage, handling and identification of parent metal

Storage and handling shall be carried out in such a manner that the parent metal is not adversely affected. Provision shall be made for correct identification, e.g. grade and storage.

7 Fusion welding processes

Fusion welding processes shall be either one or a combination of the following welding processes with their reference number in accordance with EN ISO 4063:

111 manual metal arc welding (metal arc welding with covered electrode);

114 self-shielded tubular-cored arc welding;

12 submerged arc welding;

13 gas-shielded metal arc welding;

141 tungsten inert gas welding; TIG welding;

15 plasma arc welding;

185 magnetically impelled arc butt welding;

24 flash welding;

311 oxy-acetylene welding;

42 friction welding;

71 aluminothermic welding;

and additionally:

— cast welding;

— liquid metal welding.

Other fusion welding processes shall be agreed between the manufacturer and the purchaser by the time of acceptance of the order.

8 Welding consumables

8.1 General

An appropriate filler metal (see 3.5, 3.6 and 3.7) shall be selected in accordance with the requirements of the weld and the welding process.

Any special recommendations given by the manufacturer and/or supplier of the welding consumables shall be taken into account.

Welding consumables (e.g. filler metals, gases and fluxes) shall conform to the appropriate European and/or International Standards, as applicable, (see Annex B, Tables B.1 and B.2).

It can be necessary to manufacture appropriate filler metals, especially for oxy-acetylene and liquid metal welding. To avoid confusion, such products shall be identified.

8.2 Supply, storage and handling

For the purposes of this document, the supply, storage and handling requirements given in EN 1011-1 shall apply.

9 Equipment

9.1 General

For the purposes of this document, the equipment requirements given in EN 1011-1 shall apply.

9.2 Ancillary equipment

If applicable, the ancillary equipment shall include:

a) power source for welding equipment and additional machinery;

b) facilities for joint preparation;

c) facilities for preheating and post-weld heat treatment including temperature measurement equipment;

d) cranes and other handling equipment;

e) peening equipment;

f) electrode baking ovens, electrode bags etc. for handling filler metals;

g) cleaning equipment;

h) equipment for destructive and non-destructive testing;

i) fixtures and welding jigs;

j) personal protection equipment directly connected with welding.

10 Fabrication

10.1 General

When welding cast iron castings, consideration shall be given to the:

— need for trained and approved welders;

— need for a responsible welding co-ordinator;

— casting geometry;

— temperature control;

— stress conditions caused by welding;

— material behaviour;

— working conditions;

— inspection requirements.

NOTE Selection of the requirement category (see EN 729-1) is recommended and should be carried out with due consideration of any special operating conditions and joint strains together with any economic factors.

Prior to welding, there shall be an agreement made between the parties concerned which includes the requirements for finishing welding, joint welding and repair welding, as applicable.

If applicable, finishing and/or repair welding methods to correct casting non-conformities shall be carefully planned and prepared.

The casting surface to be welded shall be checked by a suitable non-destructive test method, in order to ensure sound material after complete removal of any casting non-conformity.

10.2 Butt welding

Butt welding shall be in accordance with EN 1011-1.

10.3 Fillet welding

Fillet welding shall be in accordance with EN 1011-1.

11 Weld preparation

11.1 Joint welds

Preparation shall be carried out in accordance with EN 1011-1.

NOTE In addition, joint welding should meet the recommendations given in Table B.1 and Table B.2.

11.2 Finishing welds and repair welds

Preparation shall remove any crack, pore, notch and contamination. The area to be welded shall be suitable for the welding process (see B.1 and B.2).

NOTE Recommendations on weld preparation are given in B.2.

If contamination cannot be removed (e.g. during repair welding), other measures shall be used, such as the selection of special filler metals.

12 Positioning of parts to be welded

Positioning of parts to be welded shall be carried out in accordance with EN 1011-1.

13 Pre-heat temperature and interpass temperature

The pre-heat temperature T_p and interpass temperature T_i shall be within the recommended values given in B.4 and Tables B.1 and B.2, depending on the influence of the following process parameters:

— filler metal;

— parent material grade;

— geometry of the casting;

— welding process;

— welding parameters.

14 Tack welds

Tack welds shall be in accordance with EN 1011-1.

15 Temporary attachments

Temporary attachments shall be in accordance with EN 1011-1.

16 Run-on plates and run-off plates

Run-on and run-off plates shall be in accordance with EN 1011-1.

17 Arcing

Arcing shall be in accordance with EN 1011-1.

18 Inter-run cleaning and inter-run treatment

Inter-run cleaning and inter-run treatment shall be in accordance with EN 1011-1.

19 Heat input

If applicable, heat input can be estimated in accordance with EN 1011-1.

20 Welding procedure specification (WPS)

If a welding procedure specification is required:

— for arc welding its content shall be in accordance with EN ISO 15609-1;

— for other welding methods, its content may be modified. In this case, its content shall be agreed in writing between the parties concerned.

21 Traceability

Traceability shall be in accordance with EN 1011-1.

22 Peening

Peening shall be in accordance with EN 1011-1.

NOTE To minimize residual stress, when using non-homogeneous filler metal, peening is recommended immediately after welding. For further information, see the instructions of the filler metal manufacturer.

23 Inspection and testing

Inspection and testing shall be carried out in accordance with the contract.

24 Quality requirements

Quality requirements shall be in accordance with EN 1011-1.

The requirement class and/or the quality level shall be agreed between the manufacturer and the purchaser prior to welding. Joint welds shall conform to the requirement class given in Table A.1, and/or the quality level given in Table A.2.

25 Correction of non-conformity

Correction of non-conformity shall be carried out in accordance with EN 1011-1.

26 Distortion

If necessary, the method of correction of castings unacceptably distorted by the welding process shall be agreed between the manufacturer and the purchaser.

NOTE Any method used to correct distortion should not be deleterious to the casting structure.

27 Post weld heat treatment

The details of any post weld heat treatment shall be agreed between the manufacturer and the purchaser prior to welding (see recommendations in Table B.1 and B.2).

NOTE Post weld heat treatment can be necessary because of the need to reduce residual stresses in welded castings and/or to adjust the mechanical properties of the material.

28 Post weld cleaning

Post weld cleaning shall be in accordance with EN 1011-1.

Annex A
(normative)

Quality requirements

A.1 General

This annex deals with quality requirements that need to be met. The requirement class, quality level and corresponding tests shall be chosen so that the welding quality meets the agreed mechanical and technological requirements of the casting.

Test frequencies and test methods are not given in this annex.

The test requirements shall be agreed between the manufacturer and the purchaser by the time of acceptance of the order.

A.2 Requirements for fusion welding

A.2.1 Agreement

In planning the welding procedure for the particular cast iron casting, the following shall be considered:

— stresses in the casting caused by the welding process;

— the weldability of the material;

— the operating conditions;

— the test procedures.

For each welded casting, only the requirements concerning the necessary conditions of use of the component shall be defined. These requirements and the quality levels shall be agreed between the manufacturer and the purchaser by the time of acceptance of the order (see Tables A.1 and A.2). This agreement shall be recorded.

A.2.2 Requirements

The three requirement classes and eleven criteria for fusion welding are given in Table A.1.

The requirement class for weld workmanship criterion shall be selected from Table A.1. The weld workmanship (No. 1 in Table A.1) requirement class limits for external and internal imperfections shall be chosen by reference to Table A.2.

1) excess weld metal
2) excessive convexity
3) incompletely filled groove
4) incomplete root penetration
5) fillet weld having a throat thickness smaller than the nominal value
6) excessively asymmetric fillet weld

} especially for joint welding

7) undercut and root concavity
8) end-crater pipe
9) surface pore
10) visible slag inclusions
11) spatter
12) stray arcing
13) visible cracks
14) crater cracks

Numbers and types of internal imperfections with reference to Table A.2:

15) gas cavities
16) solid inclusions
17) lack of fusion
18) incomplete fusion
19) internal cracks
20) crater pipe

The limits for the types of external and internal imperfections listed above are categorized by three quality levels (B, C, D). These quality levels can differ for each imperfection type.

A.2.3 Inspection and testing

The conformity of the weld with the requirement classes given in Table A.1 and the limits for external and internal imperfections given in Table A.2 shall be verified by visual examination and, if required, by destructive or non-destructive testing. Any other requirements shall be verified by suitable tests carried out on test specimens produced at the same time as the welding of the casting. The test type, the scope and range of testing and the time of testing shall be defined and recorded.

Table A.1 — Criteria and requirement classes for fusion welding of cast iron castings

No.	Criterion	Requirement class		
		1	2	3
1	Weld workmanship a) external imperfections b) internal imperfections	+ +	+ •	+ —
2	Hardening traverse (e.g. for wear)	+	•	—
3	Strength	+	•	—
4	Toughness	•	—	—
5	Reduction of internal stress	•	•	—
6	Machining	•	•	—
7	Corrosion	•	•	—
8	Weld tightness	•	•	—
9	Microstructure	•	—	—
10	Coating	•	•	—
11	Colour match	•	•	—

\+ mandatory requirement
— no requirement
• requirement to be agreed
Class 1 for castings for safety components only, e.g. required monitoring plant
Class 2 for castings with special requirements
Class 3 for castings without special requirements

Table A.2 — Limits for external and internal imperfections

No.	Type of imperfection	Requirements/ remarks	Limits for imperfections for quality level		
			B	C	D
External imperfections [a]					
1	Excess weld metal, see Figure A.1	Smooth transition is required; only for non-homogeneous welding without subsequent machining	$h \leq 1$ mm + 0,1 b, max. 5 mm	$h \leq 1$ mm + 0,15 b, max. 7 mm	$h \leq 1$ mm + 0,25 b, max. 10 mm
2	Excessive convexity, see Figure A.2	Smooth transition is required; only for non-homogeneous welding without subsequent machining	$h \leq 1$ mm + 0,15 b, max. 4 mm	$h \leq 1$ mm + 0,25 b, max. 5 mm	No special requirements
3	Incompletely filled groove, see Figure A.3	The filled groove thickness shall not be below the minimum tolerance of the wall thickness. Smooth transition is required; only for non-homogeneous welding without subsequent machining	$h \leq 0{,}05\ t$, max. 3 mm	$h \leq 0{,}1\ t$, max. 3 mm	$h \leq 0{,}2\ t$, max. 4 mm
4	Incomplete root penetration, see Figure A.4	Only for single-side butt welds.	Not permitted	Short imperfections $h \leq 0{,}2\ t$	No special requirement
5	Fillet weld having a throat thickness smaller than the nominal value, see Figure A.5	Only for non-homogeneous welding without subsequent machining	Not permitted	$h \leq 0{,}5$ mm + 0,1 a max. 1 mm	$h \leq 0{,}5$ mm + 0,1 a max. 2 mm
6	Excessively asymmetric fillet weld, see Figure A.6	Only for non-homogeneous welding without subsequent machining	$h \leq 1{,}5$ mm + 0,5 a	$h \leq 2$ mm + 0,15 a Occasional local excess permitted	$h \leq 2$ mm + 0,2 a Occasional local excess permitted
7	Undercut and root concavity, see Figure A.7	Smooth transition is required; undercut at the top pass at butt joints and root imperfections at the transition between weld seam and parent metal. Smooth edge rounding is not an undercut	$h \leq 0{,}5$ mm	$h \leq 1$ mm	$h \leq 1{,}5$ mm
8	End-crater pipe	Open crater reducing the cross-section of the weld	Not permitted	Short imperfections up to 2 mm depth without sharp transitions permitted	Short imperfections up to 4 mm depth without sharp transitions permitted

Table A.2 (*continued*)

No.	Type of imperfection	Requirements/ remarks	Limits for imperfections for quality level		
			B	C	D
9	Surface pore	In top pass and root pass	Discrete pores up to 5 % of weld area with maximum pore diameter of 3 mm	Discrete pores up to 10 % of weld area with maximum pore diameter of 5 mm	Discrete pores up to 20 % of weld area with maximum pore diameter of 5 mm
10	Visible slag inclusions	In top pass and root pass	Not permitted	Visible imperfections up to 10 % of weld area with a maximum diameter of 4 mm are allowed, provided these are dispersed.	Visible imperfections up to 25 % of weld area with a maximum diameter of 4 mm are allowed
11	Spatter	Fused metal spatter on weld or casting surfaces	Acceptance dependent upon the application		
12	Stray arcing	Local and superficial alteration of the parent metal as a result of stray arcing close to the welding	Not permitted	Not permitted	No requirements
13	Visible cracks	All types of cracks except micro cracks ($h \times l$ < 1 mm) [b]	Not permitted	Not permitted	Not permitted
14	Crater crack	All types [b]	Not permitted	Allowed	Allowed
Internal imperfections					
15	Gas cavities	Gas cavities are single voids or pores, clusters of pores, pore lines, elongated cavities	Small randomly dispersed cavities with a diameter of up to 1 mm are allowed, but no continuous or wormhole porosity	Locally permitted with a diameter up to 3 mm, but no connected porosities, no clusters of pores and non continuous wormhole porosity.	No special requirements
16	Solid inclusions	Solid inclusions are non-homogeneous metal inclusions, single slags, slag lines and clusters of slags	Up to 3 imperfections per 50 mm × 50 mm of weld surface with a diameter of up to 2 mm	Up to 3 imperfections per 50 mm × 50 mm of weld surface with a diameter of up to 5 mm	No special requirements
17	Lack of fusion	Incomplete fusion of the joint flanks, between the welding bead and the welding pass [b]	Not permitted	Acceptance in low stress areas only	
18	Incomplete fusion, see Figure A.8	Incomplete weld in root at corners and fillets	Not permitted	Acceptance in low stress areas only	
19	Internal cracks	Internal cracks within the filler metal and within the heat-affected zone [b]	Not permitted	Less than 1 mm long	No special requirements

Table A.2 (*concluded*)

No.	Type of imperfection	Requirements/ remarks	Limits for imperfections for quality level		
			B	C	D
20	Crater pipe	A shrinkage cavity at the end of a weld run and not eliminated before or during subsequent weld runs	Not permitted	Not permitted	No special requirements

[a] Dimensional variations are allowed within the relevant casting tolerances

[b] Proof of conformity is often difficult. Indications resulting from non-destructive examination tests with values up to 1 mm + 0,05 × wall thickness in millimetres are not classified as lack of fusion and cracks

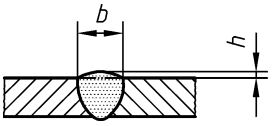

Figure A.1 Excess weld metal

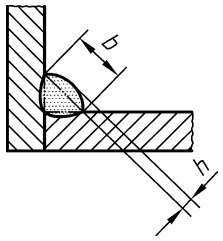

Figure A.2 — Excessive convexity

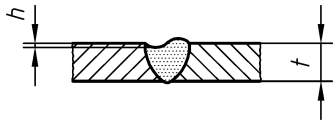

Figure A.3 — Incompletely filled groove

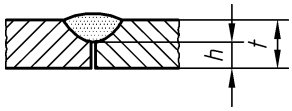

Figure A.4 — Incomplete root penetration

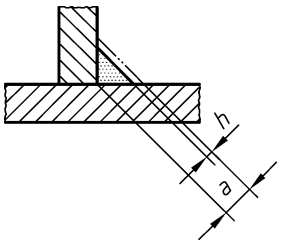

Figure A.5 — Fillet weld

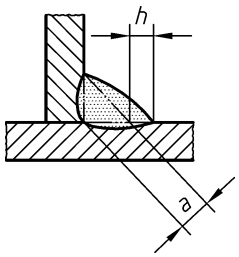

Figure A.6 — Excessively asymmetric fillet weld

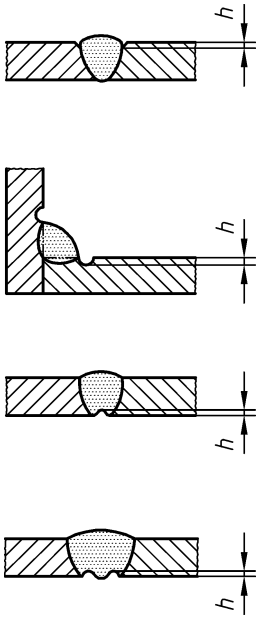

Figure A.7 — Undercut and root concavity

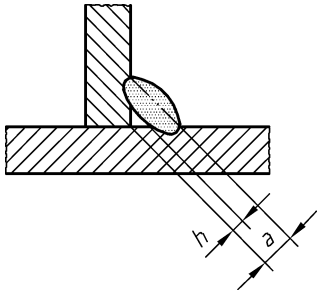

Figure A.8 — Incomplete fusion

Key (Figures A.1 to A.8)
a Nominal throat thickness of fillet welds
b Weld width
h Weld thickness deviation
t Component wall thickness

Annex B
(informative)

Welding technology for cast iron castings

B.1 General

For welding cast iron castings, one of the three following procedures is generally used:

— welding with either homogeneous or semi-homogeneous filler metal (see Table B.1);

— welding with non-homogeneous filler metal (see Table B.2);

— welding without filler metal.

In the absence of a pre-set qualification scheme, a preliminary test should be carried to make sure that the chosen procedure is suitable. Subsequently, if required, a welding procedure specification (WPS) can be prepared.

B.2 Preparation for welding

The casting area to be welded and the adjacent area should be properly cleaned prior to welding. The casting skin in these areas should be removed. Weld preparation should be carried out in accordance with EN ISO 9692-2 and, additionally, the shape and size of any joints should be taken into account.

Groove preparation should preferably be carried out mechanically, e.g. by grinding. If groove preparation is carried out thermally, e.g. by plasma arc cutting or powder flame cutting, the molten rim zone should be ground after solidification to remove any hardened zones and/or cracks. Flame-cutting, oxy-acetylene and arc-air-gouging are not suitable for cast irons.

B.3 Backing bar

The need for a backing bar depends on the welding process, the preheating temperature, the cast iron grade and the weld geometry.

When a high level of dilution is expected between the molten material and any backing bar, the effect of this dilution should be considered. To avoid any alteration to the chemical composition of the molten material, either a backing bar of the same chemical composition or a refractory material should be chosen.

B.4 Heat and temperature distribution

Equal temperature distribution through the section of the casting should be ensured during pre-heating and cooling.

The pre-heating temperature and the heating rate depend on the casting material type, the casting material grade, the complexity of the casting and the welding process. When a casting of complex design is heated (locally or completely), in order to avoid cracks and distortion, the heating rate should be ≤ 50 K/h until the temperature of the casting reaches 450 °C.

NOTE Examples of common heating processes are furnace heating, heating by means of a gas torch, heating elements and inductive heating.

Table B.1 — Welding of cast iron castings with homogeneous or semi-homogeneous filler metals

Procedure	Method	Grey cast iron GJL	Spheroidal graphite cast iron GJS	Malleable cast iron, blackheart GJMB	Malleable cast iron, whiteheart GJMW	Malleable cast iron, weldable grade EN-GJMW-360-12 (EN-JM1020)
Weld preparation	Preparation	Removing the casting skin in the casting welding area and its adjacent area and cleaning them.				
	— thermal	Plasma arc cutting; powder flame cutting (arc-air cutting conditional, flame cutting not suitable).			all methods	all methods
	— mechanical	Machining, grinding, back-chipping				
Use of backing bar		Graphitic material, loam, ceramics, spheroidal graphite cast iron, unalloyed steel				
Thermal treatment recommendations (local casting welding area or complete casting)	1) Preheating	Homogeneous filler metal: T_p = 550 °C to 700 °C (depending on the material and/or the procedure); Semi-homogeneous filler metal: T_p = 250 °C to 550 °C Maximum heating rate (dependent on the casting or component)				not necessary for wall thicknesses ≤ 8 mm; > 8 mm (see left)
	2) Casting temperature during welding	Homogeneous filler metal: outside welding area ≥ 450 °C Semi-homogeneous filler metal: outside welding area ≥ 250 °C (Semi-homogeneous filler metal: not recommended for grey cast irons GJL)				
	3) Cooling rate	Dependent on the complexity of the casting or component. From 450 °C to 150 °C ≤ 50 K/h for castings sensitive to stress				
Post weld heat treatment	Separate heat treatment or use of the residual welding heat	Any heat treatment method can be used, dependent on the parent metal, size and shape of the casting and other requirements.				

Table B.1 (*concluded*)

<table>
<tr><th>Procedure</th><th>Method</th><th>Grey cast iron
GJL</th><th>Spheroidal graphite cast iron
GJS</th><th>Malleable cast iron, blackheart
GJMB</th><th>Malleable cast iron, whiteheart
GJMW</th><th>Malleable cast iron, weldable grade
EN-GJMW-360-12 (EN-JM1020)</th></tr>
<tr><td rowspan="10">Use of filler metals</td><td>Oxy-acetylene welding (311)</td><td>GJL rod
GJS rod</td><td colspan="3">GJS rod</td><td>Welding rods GII EN 12536</td></tr>
<tr><td rowspan="3">Manual metal arc welding (111)</td><td>GJL or GJS electrode covered or not covered</td><td colspan="3">GJS electrode, covered or not covered</td><td rowspan="3">Coated welding electrode, e.g. B-type EN 499</td></tr>
<tr><td>Alloy coated steel electrode</td><td colspan="3">Coated steel electrode. Coating with or without alloy</td></tr>
<tr><td colspan="4">Coated welding rod</td></tr>
<tr><td>Gas shielded metal arc welding (13)</td><td colspan="4">Wire electrodes with or without alloy for interpass temperature ≤ 300 °C only (in order to keep the shield gas property)</td><td>Wire electrode, unalloyed EN 440</td></tr>
<tr><td>TIG welding (141)</td><td colspan="4">Filler rods, cored wires for interpass temperatures ≤ 300 °C only (in order to keep the shield gas property)</td><td>Unalloyed rods EN 1668</td></tr>
<tr><td>Self-shielded tubular-cored arc welding (114)</td><td colspan="4">Cored wire; deposited metal (GJS)</td><td>Wire electrode, unalloyed EN 758</td></tr>
<tr><td>Cast welding</td><td>GJL or GJS melt material</td><td>GJS melt material</td><td colspan="3" rowspan="2">Not normally used</td></tr>
<tr><td>Liquid metal welding</td><td colspan="2">Same as cast welding, but with additional use of electrodes</td></tr>
<tr><td>Plasma arc welding (15)</td><td colspan="5">With or without small amounts of filler metal</td></tr>
<tr><td>Use of flux</td><td></td><td colspan="5">With or without alloy, can be used to improve the welding conditions.</td></tr>
<tr><td colspan="7">NOTE The numbers in brackets show the fusion welding process reference number, see Clause 7.</td></tr>
<tr><td colspan="7">T_p = preheating temperature</td></tr>
</table>

Table B.2 — Welding of cast iron castings with non-homogeneous filler metal

Procedure	Method	Grey cast iron	Spheroidal graphite cast iron	Malleable cast iron, blackheart	Malleable cast iron, whiteheart
		GJL	GJS	GJMB	GJMW [a]
Weld preparation	Preparation	Removing the casting skin in the casting welding area and its adjacent area and cleaning them.			
	— thermal	Plasma arc cutting; powder flame cutting (arc air cutting conditional, flame cutting not appropriate)			all methods
	— mechanical	machining, grinding, back-chipping			
Thermal setting recommendations (local welding area or complete casting)	1) Preheating	T_p max. 300 °C			Dependent on the decarburisation, not necessesary for wall thicknesses up to 4 mm.
	2) Interpass temperature T_i	Interpass temperature $T_i = T_p + 50$ K			
	3) Cooling	In still air			
Post-weld heat treatment	Separate heat treatment or use of the residual welding heat	Any heat treatment method can be used, dependent on the parent material, complexity of the casting and other requirements.			
Filler metals and powder	Manual metal arc welding (111)	Covered welding rod, according to EN ISO 1071			
	Gas shielded metal arc welding (13)	Solid wire electrodes, covered wire electrodes, according to EN ISO 1071			
	TIG welding (141)	Solid rods, filler rods, solid wire, filler wire, according to EN ISO 1071			
	Self shielded tubular-cored arc welding (114)	Cored wire electrode, according to EN ISO 1071			

NOTE The numbers in brackets show the fusion welding process reference number, see Clause 7.

[a] Weldable malleable cast iron EN-GJMW-360-12 (EN-JM 1020) (wall thickness ≤ 8 mm) can be welded with commercial unalloyed filler metals.

Bibliography

[1] EN 440, *Welding consumables — Wire electrodes and deposits for gas-shielded metal arc welding of non alloy and fine grain steels — Classification.*

[2] EN 499, *Welding consumables — Covered electrodes for manual metal arc welding of non alloy and fine grain steels — Classification.*

[3] EN 758, *Welding consumables — Tubular cored electrodes for metal arc welding with and without a gas shield of non alloy and fine grain steels — Classification.*

[4] EN 729-1, *Quality requirements for welding — Fusion welding of metallic materials — Part 1: Guidelines for selection and use.*

[5] EN 1561, *Founding — Grey cast irons.*

[5] EN 1562, *Founding — Malleable cast irons.*

[6] EN 1563, *Founding — Spheroidal graphite cast irons.*

[7] EN 1668, *Welding consumables — Rods, wires and deposits for tungsten inert gas welding of non-alloy and fine grain steels — Classification.*

[8] EN 12536, *Welding consumables — Rods for gas welding of non alloy and creep-resisting steels — Classification.*

[9] EN ISO 1071, *Welding consumables — Covered electrodes, wires, rods and tubular cored electrodes for fusion welding of cast iron — Classification (ISO 1071:2003).*

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

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