

BS EN 545:2010



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Ductile iron pipes, fittings, accessories and their joints for water pipelines — Requirements and test methods

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee PSE/10, Iron pipes and fittings.

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

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September 2010

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English Version

**Ductile iron pipes, fittings, accessories and their joints for water
pipelines - Requirements and test methods**

Tuyaux, raccords et accessoires en fonte ductile et leurs
assemblages pour canalisations d'eau - Prescriptions et
méthodes d'essai

Rohre, Formstücke, Zubehörteile aus duktilem Gusseisen
und ihre Verbindungen für Wasserleitungen -
Anforderungen und Prüfverfahren

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Foreword

This document (EN 545:2010) has been prepared by Technical Committee CEN/TC 203 “Cast iron pipes, fittings and their joints”, the secretariat of which is held by AFNOR.

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of an identical text or by endorsement, at the latest by March 2011, and conflicting national standards shall be withdrawn at the latest by March 2011.

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 545:2006.

In this standard Annex A is normative and Annexes B, C, D, E and F are informative.

This standard is in conformity with the general requirements already established by CEN/TC 164 in the field of water supply.

In respect of potential adverse effects on the quality of water intended for human consumption, caused by the products covered by this standard:

- this standard provides no information as to whether the products may be used without restriction in any of the member states of the EU or EFTA;
- it should be noted that, while awaiting the adoption of verifiable European criteria, existing national regulations concerning the use and/or the characteristics of these products remain in force.

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, Croatia, 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.

1 Scope

This European Standard specifies the requirements and associated test methods applicable to ductile iron pipes, fittings, accessories and their joints for the construction of pipelines outside buildings:

- to convey different types of water (e.g. raw water, treated water, re-used water) for all types of applications (e.g. water intended for human consumption, for fire protection, for snow making, for irrigation, for hydro-electricity etc.);
- with or without pressure;
- to be installed below or above ground.

This European Standard is applicable to pipes, fittings and accessories which are:

- manufactured with socketed, flanged or spigot ends;
- supplied externally and internally coated;
- suitable for fluid temperatures between 0 °C and 50 °C, excluding frost;
- not intended for use in areas subject to reaction to fire regulations.

This does not preclude special arrangements for the products to be used at higher temperatures.

This European Standard covers pipes and fittings cast by any type of foundry process or manufactured by fabrication of cast components, as well as corresponding joints and accessories, in a size range extending from DN 40 to DN 2 000, inclusive.

This European Standard specifies requirements for materials, dimensions and tolerances, mechanical properties and standard coatings of ductile iron pipes and fittings. It also gives performance requirements for all components including joints. Joint design and gasket shapes are outside the scope of this standard.

In addition, reference is made to the minimum performance requirements of couplings, flange adaptors and saddles manufactured for use with ductile iron pipes and fittings.

NOTE In this European Standard, all pressures are relative pressures, expressed in bars (100 kPa = 1 bar).

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 196-1, *Methods of testing cement — Part 1: Determination of strength*

EN 197-1, *Cement — Part 1: Composition, specifications and conformity criteria for common cements*

EN 681-1, *Elastomeric seals — Material requirements for pipe joint seals used in water and drainage applications — Part 1: Vulcanized rubber*

EN 805:2000, *Water supply — Requirements for systems and components outside buildings*

EN 1092-2, *Flanges and their joints — Circular flanges for pipes, valves, fittings and accessories, PN designated — Part 2: Cast iron flanges*

EN 1333:2006, *Flanges and their joints — Pipework components — Definition and selection of PN*

EN 14901, *Ductile iron pipes, fittings and accessories — Epoxy coating (heavy duty) of ductile iron fittings and accessories — Requirements and test methods*

EN ISO 4016, *Hexagon head bolts — Product grade C (ISO 4016:1999)*

EN ISO 4034, *Hexagon nuts — Product grade C (ISO 4034:1999)*

EN ISO 6506-1, *Metallic materials — Brinell hardness test — Part 1: Test method (ISO 6506-1:2005)*

EN ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature (ISO 6892-1:2009)*

EN ISO 7091, *Plain washers — Normal series — Product grade C (ISO 7091:2000)*

EN ISO 9001:2000, *Quality management systems — Requirements (ISO 9001:2000)*

3 Terms and definitions

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

3.1
ductile iron
cast iron used for pipes, fittings and accessories in which graphite is present substantially in spheroidal form

3.2
pipe
casting of uniform bore, straight in axis, having socket, spigot or flanged ends, except for flanged socket pieces, flanged spigot pieces and collars which are classified as fittings

3.3
fitting
casting other than a pipe which allows pipeline deviation, change of direction or bore

NOTE In addition flanged socket pieces, flanged spigot pieces and collars are also classified as fittings.

3.4
accessory
any casting/fabrication other than a pipe or fitting which is intended for use in a ductile iron pipeline including:

- Glands and bolts for mechanical flexible joints (see 3.14);
- Glands, bolts and locking rings for restrained flexible joints (see 3.15);
- Pipe saddles for service pipe connections;
- Adjustable flanges and flanges to be welded or screwed;
- Flange adaptors for use with ductile iron pipes and fittings (see 4.1.3.2);
- Couplings for use with ductile iron pipes and fittings (see 4.1.3.2)

NOTE 1 Valves of all types are not covered by the term accessory.

NOTE 2 Wide tolerance flange adaptors and couplings are covered by EN 14525.

3.5

component

any product defined in 3.2 to 3.4

3.6

flange

end of a pipe, fitting or accessory extending perpendicular to its axis, with bolt holes equally spaced on a circle

NOTE A flange can be fixed (e.g. integrally cast, screwed or welded) or adjustable; an adjustable flange comprises a ring, in one or several parts assembled together, which bears on an end joint hub and can be freely rotated around the barrel axis before jointing.

3.7

spigot

male end of a pipe or fitting

3.8

spigot end

maximum insertion depth of the spigot plus 50 mm

3.9

socket

female end of a component to make the connection with the spigot of the next component

3.10

gasket

sealing component of a joint

3.11

joint

connection between the ends of two components in which a gasket is used to effect a seal

3.12

flexible joint

joint which permits significant angular deflection both during and after installation and which can accept a slight offset of the centreline

3.13

push-in flexible joint

flexible joint assembled by pushing the spigot through the gasket in the socket of the mating component

3.14

mechanical flexible joint

flexible joint in which sealing is obtained by applying pressure to the gasket by mechanical means, e.g. a gland

3.15

restrained flexible joint

flexible joint in which a means is provided to prevent separation of the assembled joint

3.16

flanged joint

joint between two flanged ends

3.17

nominal size

DN

alphanumeric designation of size for components of a pipework system, to be used for reference purposes, which comprises the letters DN followed by a dimensionless whole number which is indirectly related to the physical size, in millimetres, of the bore or outside diameter of the end connections

[EN ISO 6708:1995]

3.18

nominal pressure

PN

alphanumeric designation related to a combination of mechanical and dimensional characteristics of a component of a pipework system, to be used for reference purposes, which comprises the letters PN followed by a dimensionless number

[EN 1333:2006]

NOTE All components of the same nominal size DN and designated by the same PN number have compatible mating dimensions.

3.19

leak tightness test pressure

pressure applied to a component during manufacture in order to ensure its leak tightness

3.20

allowable operating pressure

PFA

maximum hydrostatic pressure that a component is capable of withstanding continuously in service

[EN 805:2000]

3.21

pressure class

C

alphanumeric designation of a family of components, including their joints, relating to their operating pressures as verified by all the performance tests described in this standard, which includes the letter C followed by a dimensionless number equal to the maximum PFA in bars of the family of components

3.22

allowable maximum operating pressure

PMA

maximum pressure occurring from time to time, including surge, that a component is capable of withstanding in service

[EN 805:2000]

3.23

allowable test pressure

PEA

maximum hydrostatic pressure that a newly installed component is capable of withstanding for a relatively short duration, in order to insure the integrity and tightness of the pipeline

[EN 805:2000]

NOTE This test pressure is different from the system test pressure (STP), which is related to the design pressure of the pipeline and is intended to ensure its integrity and leak tightness.

3.24

diametral stiffness of a pipe

characteristic of a pipe which allows it to resist ovalization under loading when installed

3.25

performance test

proof of design test which is done once and must be repeated after each change of design

3.26

laying length

length by which a pipeline progresses when an additional pipe or fitting is installed

NOTE For socketed pipes and fittings the laying length L_e is equal to the overall length (OL) minus the maximum spigot insertion depth (X) as given by the manufacturer. For flanged pipes and fittings, the laying length is equal to the overall length.

3.27

standardized length

length of pipe barrel and fitting body or branch, as specified in this standard (see 4.3.3)

NOTE For socketed pipes (see Figure 5) and socketed fittings, the standardized length, L_u (l_u for branches), is equal to the overall length (OL) minus the depth of the socket (DOS) as given by the manufacturer. For flanged pipes and fittings, the standardized length, L (l for branches), is equal to the overall length.

3.28

deviation

design length allowance with respect to the standardized length of a pipe or a fitting

3.29

ovality

out of roundness of a pipe section

NOTE It is equal to: $100 \left(\frac{A_1 - A_2}{A_1 + A_2} \right)$

where:

A_1 is the maximum axis, in millimetres;

A_2 is the minimum axis, in millimetres.

3.30

pipe minimum thickness

minimum thickness at any point of the pipe (see Tables 16 and 17) used in the calculation of its PFA and pressure class

3.31

thickness for pipe stiffness calculation

thickness based on the pipe minimum thickness and the DN used in the calculation of the pipe diametral stiffness

4 Technical requirements

4.1 General

4.1.1 Ductile iron pipes, fittings and accessories

Nominal sizes, pressure classes, thicknesses, lengths and coatings are specified in 4.1.1, 4.2, 4.3.1, 4.3.3, 4.5 and 4.6 respectively. When pipes, fittings and accessories with different pressure classes, lengths and/or coatings and other types of fittings than those given in 8.3 and 8.4, are supplied with reference to this standard, they shall comply with all the other requirements of this standard.

Non-centrifugally cast pipes shall be considered as fittings.

NOTE 1 Other types of fittings include angle branches, tees and tapers with other combinations DN x dn, draining tees, etc.

The standardized nominal sizes DN of pipes and fittings are as follows: 40, 50, 60, 65, 80, 100, 125, 150, 200, 250, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1 000, 1 100, 1 200, 1 400, 1 500, 1 600, 1 800, 2 000.

The allowable pressures of ductile iron pipes and fittings shall be as given in Annex A.

NOTE 2 Annexes B and C give respectively the longitudinal bending resistance and the diametral stiffness of ductile iron pipes.

NOTE 3 When installed and operated under the conditions for which they are designed (see Annexes D, E and F), ductile iron pipes, fittings, accessories and their joints maintain all their functional characteristics over their reasonable economic operating life, due to the constant material properties, to the stability of their cross section and to their design with high safety factors.

4.1.2 Surface condition and repair

Pipes, fittings and accessories shall be free from defects and surface imperfections which can lead to non-compliance with Clauses 4 and 5.

When necessary, pipes and fittings may be repaired, for example by welding, in order to remove surface imperfections and localized defects which do not extend through the entire wall thickness, provided that:

- the repairs are carried out according to the manufacturer's written procedure;
- the repaired pipes and fittings comply with all the requirements of Clauses 4 and 5.

4.1.3 Types of joints and interconnection

4.1.3.1 General

Elastometric gasket materials shall comply with the requirements of EN 681-1, type WA. When materials other than rubber are necessary (e.g. for high temperature flanged joints), they shall comply with the appropriate European Technical Specification or where no European Technical Specification exists, the appropriate International Standard.

4.1.3.2 Flexible joints

Components with flexible joints shall comply with 4.3.2.1 for their spigot external diameter DE and their limit deviations. This offers the possibility of interconnection between components equipped with different types of flexible joints.

The design of the sockets and the gaskets for use with the above spigots shall throughout all possible tolerance combinations:

- ensure leak tightness at minimum compression under shear and/or angular deflection;
- ensure both leak tightness and satisfactory anchorage (restrained joint) under shear and/or angular deflection.

In addition, each type of flexible joint shall be designed to fulfil the performance requirements of Clauses 5 and 7, and in particular in case of interconnexion of components from different suppliers such joints shall meet these performance requirements.

Couplings and flange adaptors manufactured for use with ductile iron pipes and fittings shall meet the performance requirements of flexible joints as detailed in Clauses 5 and 7.

NOTE 1 For interconnection with certain types of joints operating within a different tolerance range on DE, the manufacturer's guidance should be followed as to the means of ensuring adequate joint performance at high pressures (e.g. measurement and selection of external diameter).

NOTE 2 For interconnection with existing pipelines which can have external diameters not in compliance with 4.3.2.1, the manufacturer's guidance should be followed as to the appropriate means of interconnection (e.g. adaptors).

4.1.3.3 Flanged joints

Flanges shall be designed such that they can be attached to flanges whose dimensions and tolerances comply with EN 1092-2. This ensures interconnection between all flanged components (pipes, fittings, valves, etc.) of the same PN and DN and adequate joint performance.

Bolts and nuts shall comply as a minimum with the requirements of EN ISO 4016 and EN ISO 4034, grade 4.6. Where washers are required they shall comply with EN ISO 7091.

Although it does not affect interconnection, the manufacturer shall state whether his products are normally delivered with fixed flanges or adjustable flanges.

Flange gaskets may be one of any type given in EN 1514 (all parts).

4.1.3.4 Pipe saddles

Pipe saddles for service connections manufactured for use with ductile iron pipes shall meet the performance requirements as detailed in Clauses 5 and 7.

4.1.4 Materials in contact with water intended for human consumption

Components of a pipe system include several materials given in this standard. When used under the conditions for which they are designed, in permanent or in temporary contact with water intended for human consumption, the components shall not change the quality of that water to such an extent that it fails to comply with the requirements of national regulations.

For this purpose, reference shall be made to the relevant national regulations and standards, transposing EN standards when available, dealing with the influence of materials on water quality and to the requirements for external systems and components as given in EN 805.

4.2 Pressure class

In accordance with 3.21, the pressure class of a component is defined by a combination of its structural performance and the performance of its non-restrained flexible joint.

Restrained joints may reduce the PFA; in this case the PFA shall be declared by the manufacturer.

Annex A gives the PFA, PMA and PEA of the components and their pressure classes.

4.3 Dimensional requirements

4.3.1 Pipes and fittings thickness

The minimum iron wall thickness of pipes DN 40 to DN 2 000 is given as a function of the nominal size (DN) and pressure class (C) in Tables 16 and 17.

For fittings, the nominal thickness e given in tables and on Figures of Subclauses 8.3 and 8.4 is the nominal thickness corresponding to the main part of the body. The actual thickness at any particular point may be increased to meet localized high stresses depending on the shape of the casting (e.g. at internal radius of bends, at the branch-body junction of tees etc.).

The measurement of the wall thickness shall be in accordance with 6.1.1.

Annex A gives the maximum values of PFA, PMA and PEA.

The limit deviations on the nominal wall thickness of fittings shall be as given in Table 1.

Table 1 — Limit deviations on thickness of fittings

Nominal iron wall thickness e mm	Limit deviations on the nominal wall thickness ^a mm
$\leq 7,0$	- 2,3
$> 7,0$	- (2,3 + 0,001 DN)
^a The lower limit only is given so as to ensure sufficient resistance to internal pressure.	

4.3.2 Diameter

4.3.2.1 External diameter

Subclause 8.1 specifies the values of the external diameter DE of the coated spigot ends of pipes and fittings and their maximum allowable limit deviations, when measured using a circumferential tape in accordance with 6.1.2. These limit deviations apply to the spigot ends of all pressure classes of pipes and fittings.

NOTE 1 Certain types of flexible joints operate within a different range of tolerance (see 4.1.3.2).

For $DN \leq 300$, the external diameter of the pipe barrel measured with a circumferential tape shall be such as to allow the assembly of the joint over at least two thirds of the pipe length from the spigot when the pipe needs to be cut on site.

For $DN > 300$, if requested by the customer, the manufacturer shall be able to supply pipes suitable for cutting, allowing the assembly of the joint over at least two thirds of the pipe length from the spigot. Such pipes shall be marked.

In addition, the ovality (see 3.29) of the spigot end of pipes and fittings shall:

- remain within the tolerance on DE (see Tables 16 and 17) for DN 40 to DN 200;
- not exceed 1 % for DN 250 to DN 600 or 2 % for $DN > 600$.

NOTE 2 The manufacturer's guidance should be followed as to the necessity and means of ovality correction; certain types of flexible joints can accept the maximum ovality without a need for spigot re-rounding prior to jointing.

4.3.2.2 Internal diameter

The nominal values of the internal diameter of centrifugally cast pipes, expressed in millimetres, are equal to the numbers indicating their nominal size, DN, and the limit deviations shall be as given in Table 2 which applies to lined pipes.

These limit deviations only apply to pipes with cement mortar lining thicknesses as given in Table 9 and up to the maximum DN given in Table 3 for each pressure class. For greater iron and/or cement mortar lining thicknesses these tolerances do not apply.

NOTE Due to the manufacturing process of ductile iron pipes and their internal linings, internal diameters with the lower limit deviation will only appear locally along the pipe length.

Compliance shall be demonstrated according to 6.1.3 or by calculation from the measurements taken for pipe external diameter, iron wall thickness and lining thickness.

Table 2 — Limit deviation on internal diameter

DN	Limit deviation ^a mm
40 to 1 000	- 10
1 100 to 2 000	- 0,01 DN
^a The lower limit only is given.	

Table 3 — Maximum DN for limit deviations on internal diameter for pressure classes

	Classes < 40	Class 40	Classes > 40
Maximum DN	2 000	600	250

4.3.3 Length

4.3.3.1 Standardized lengths of socket and spigot pipes

Pipes shall be supplied to the standardized lengths given in Table 4.

Table 4 — Standardized lengths of socket and spigot pipes

DN	Standardized lengths, L_u ^a m
40 and 50	3
60 to 600	5 or 5,5 or 6
700 and 800	5,5 or 6 or 7
900 to 1 400	5,5 or 6 or 7 or 8,15
1 500 to 2 000	8,15
^a See 3.27.	

The permissible deviations (see 3.28) on the standardized length L_u of pipes shall be as follows:

- for standardized length 8,15 m $\pm$ 150 mm;
- for all other standardized lengths $\pm$ 100 mm.

Pipes shall be designed to a length taken in the range: standardized length plus or minus the permissible deviation; they shall be manufactured to this design length plus or minus the limit deviations given in Table 7.

The manufacturer shall make the information available as to his design lengths.

The standardized length shall be measured according to 6.1.4 and shall be within the limit deviations given in Table 7.

Of the total number of socket and spigot pipes to be supplied in each diameter, the percentage of shorter pipes shall not exceed 10 %, in which case the length reduction shall be:

- up to 0,15 m for the pipes in which samples have been cut for testing (see 4.4);
- up to 2 m by increments of 0,5 m for DN < 700;
- up to 3 m by increments of 0,1 m for DN ≥ 700.

4.3.3.2 Standardized lengths of flanged pipes

Standardized lengths are given in Table 5. Other lengths are permissible and can be supplied within the manufacturing constraints related to each type of flange pipe.

Table 5 — Standardized lengths of flange pipes

Type of pipe	DN	Standardized lengths L^a m
With cast flanges	40 to 2 000	0,5 or 1 or 2 or 3
With screwed or welded flanges	40 to 600	2 or 3 or 4 or 5
	700 to 1 000	2 or 3 or 4 or 5 or 6
	1 100 to 2 000	4 or 5 or 6 or 7

^a See 3.27.

4.3.3.3 Standardized lengths of fittings

Fittings shall be supplied to the standardized lengths as given in 8.3 and 8.4.

NOTE Two series of dimensions are shown, the series A corresponding to ISO 2531 and the series B, generally limited up to DN 450.

The permissible deviations (see 3.28) on the standardized length of series A fittings shall be as given in Table 6. No deviation is permitted for the fittings of series B. Fittings shall be designed to a length taken in the range: standardized length plus or minus the permissible deviation; they shall be manufactured to this design length plus or minus the limit deviations given in Table 7.

Table 6 — Permissible deviation on lengths of fittings

Type of fitting	DN	Deviation mm
Flanged sockets	40 to 1 200	± 25
Flanged spigots	1 400 to 2 000	± 35
Collars, tapers		
Tees	40 to 1 200	+ 50/- 25
	1 400 to 2 000	+ 75/- 35

Bends 90° (1/4)	40 to 2 000	$\pm (15 + 0,03 \text{ DN})$
Bends 45° (1/8)	40 to 2 000	$\pm (10 + 0,025 \text{ DN})$
Bends 22°30' and 11°15' (1/16 and 1/32)	40 to 1 200	$\pm (10 + 0,02 \text{ DN})$
	1 400 to 2 000	$\pm (10 + 0,025 \text{ DN})$

4.3.3.4 Limit deviations on lengths

The limit deviations on lengths shall be as given in Table 7.

Table 7 — Limit deviations on length

Type of castings	Limit deviations mm
Socket and spigot pipes (full length or shortened)	- 30/+ 70
Fittings for socketed joints	± 20
Pipes and fittings for flanged joints	± 10 ^a
^a Smaller limit deviations are possible, but not less than ± 3 mm for DN ≤ 600 and ± 4 mm for DN > 600.	

4.3.4 Straightness of pipes

Pipes shall be straight, with a maximum deviation of 0,125 % of their length.

The verification of this requirement is usually carried out by visual inspection, but in case of doubt or in dispute the deviation shall be measured in accordance with 6.2.

4.4 Material characteristics

4.4.1 Tensile properties

Components of ductile iron shall have the tensile properties given in Table 8.

The tensile strength shall be tested in accordance with 6.3.

Table 8 — Tensile properties

Type of casting	Minimum tensile strength, R_m MPa	Minimum elongation after fracture, A %	
	DN 40 to DN 2 000	DN 40 to DN 1 000	DN 1 100 to DN 2 000
Pipes centrifugally cast	420	10	7
Pipes not centrifugally cast, fittings and accessories	420	5	5
The 0,2 % proof stress ($R_{p0,2}$) may be measured. It shall be not less than: - 270 MPa when $A \geq 12$ % for DN 40 to DN 1 000 or $A \geq 10$ % for DN > 1 000; - 300 MPa in other cases. For centrifugally cast pipes of DN 40 to DN 1 000 and having a design minimum wall thickness of 10 mm or greater, the minimum elongation after fracture shall be 7 %.			

4.4.2 Hardness

The hardness of the various ductile iron components shall be such that they can be cut, drilled, tapped and/or machined with normal tools. The reference test for hardness shall be the Brinell hardness test in accordance with 6.4.

The Brinell hardness shall not exceed 230 HBW for pipes and 250 HBW for fittings and accessories. For components manufactured by welding, a higher Brinell hardness is allowed in the heat affected zone of the weld.

4.5 Coatings and linings for pipes

4.5.1 General

All pipes shall be delivered with an external coating and an internal lining.

The basic coating specification of pipes shall be with an external metallic zinc coating with finishing layer in accordance with 4.5.2, and an internal lining of cement mortar in accordance with 4.5.3.

The joint areas are generally coated as follows:

- external surface of spigot ends: same as external pipe coating;
- flanges and sockets (face and internal surface): bituminous paint or synthetic resin paint, alone or as a supplement to a primer or zinc coating.

This does not preclude the possibility that for special design reasons the upper limit deviation on the external diameter DE of the coated spigot can be greater than that specified in 8.1, provided that the interconnection of the products is ensured by the joint design.

All finished internal coatings (linings) shall comply with 4.1.4.

Pipes with cast flanges may be coated as fittings (see 4.6).

The maximum fluid temperature may be limited to 35°C for some polymeric coatings. If such coatings are to be used at higher temperatures, additional performance testing should be carried out.

Depending on the external and internal conditions of use, alternative coatings detailed in Annex D may be used.

NOTE Annexes D and E give advice on the field of use for pipes with coatings and linings according to this document.

4.5.2 External coating of zinc with finishing layer

4.5.2.1 General

The external coating of centrifugally cast ductile iron pipes shall comprise a layer of metallic zinc, covered by a finishing layer of a bituminous product or synthetic resin compatible with zinc. Both layers shall be works applied.

The zinc is normally applied on oxide-surfaced pipes after heat treatment; at the manufacturer's option, it may also be applied on blast-cleaned pipes. Prior to application of the zinc, the pipe surface shall be dry and free from rust or non-adhering particles or foreign matter such as oil or grease.

4.5.2.2 Coatings characteristics

The metallic zinc coating shall cover the external surface of the pipe and provide a dense, continuous, uniform layer. It shall be free from such defects as bare patches or lack of adhesion. The uniformity of the coating shall be checked by visual inspection. When measured in accordance with 6.6, the mean mass of zinc per unit area shall be not less than 200g/m². The purity of the zinc used shall be at least 99,99 %.

The finishing layer shall uniformly cover the whole surface of the metallic zinc layer and be free from such defects as bare patches or lack of adhesion. The uniformity of the finishing layer shall be checked by visual inspection. When measured in accordance with 6.7, the mean thickness of the finishing layer shall be not less than 70 µm and the local minimum thickness not less than 50 µm.

4.5.2.3 Repairs

Damage to coatings where the area of total removal of zinc and finishing layer has a width exceeding 5 mm and areas left uncoated (e.g. under test token, see 6.6) shall be repaired.

Repairs shall be carried out by:

- metallic zinc spray complying with 4.5.2.2, or application of zinc-rich paint containing at least 90 % zinc by mass of dry film and with a mean mass of applied paint not less than 220 g/m² and
- application of a finishing layer complying with 4.5.2.2.

4.5.3 Internal lining of cement mortar

4.5.3.1 General

Unless specified in the corresponding European Standard, the internal cement mortar lining of ductile iron pipes shall comply with the following requirements.

The cement mortar lining of ductile iron pipes shall constitute a dense, homogeneous layer covering the total internal surface of the pipe barrel.

Prior to application of the lining, the metal surface shall be free from loose material and oil or grease.

The cement mortar mix shall comprise cement, sand and water. If admixtures are used, they shall comply with 4.1.4, and they shall be declared. The ratio by mass of sand to cement shall not exceed 3,5. At the mixing stage, the ratio by mass of total water to cement depends on the manufacturing process and shall be determined such that the lining is in accordance with 4.5.3.2 and 4.5.3.3.

The cement shall be one of those listed in accordance with EN 197-1. The water used in the mortar mix shall be deemed to comply with *Drinking Water Directive* 98/83/EC. High alumina cement may be used to carry raw water, subject to national regulations, or for specific applications.

After application of the fresh lining, controlled curing shall be carried out so as to provide sufficient hydration to the cement.

The cured lining shall comply with 4.1.4, 4.5.3.2 and 4.5.3.3.

4.5.3.2 Strength of the lining

When measured in accordance with 7.1, the compressive strength of the cement mortar after 28 days of curing shall be not less than 50 MPa.

NOTE The compressive strength of the lining is directly related to other functional properties such as high density, good bond and low porosity.

4.5.3.3 Thickness and surface condition

The nominal thickness of the cement mortar lining and its tolerance shall be as given in Table 9. When measured in accordance with 6.8, the lining thickness shall be within the specified tolerance.

The surface of the cement mortar lining shall be uniform and smooth. Trowel marks, protrusion of sand grains and surface texture inherent to the method of manufacture are acceptable. However, there shall be no recesses or local defects which reduce the thickness to below the minimum value given in Table 9.

Fine crazing and hairline cracks associated with cement rich surfaces may appear in dry linings. Shrinkage cracks inherent to cement-bound materials may also develop in the dry linings. After curing of the lining and under normal storage conditions, the crack width and the radial displacement (disbondment) shall not exceed the values given in Table 9.

Table 9 — Thickness of cement mortar lining

DN	Thickness		Maximum crack width and radial displacement
	Nominal value	Limit deviation ^a	
	mm		mm
40 to 300	4	- 1,5	0,4
350 to 600	5	- 2,0	0,5
700 to 1 200	6	- 2,5	0,6
1 400 to 2 000	9	- 3,0	0,8
^a The lower limit only is given.			

Cement mortar linings at pipe ends may have a chamfer of maximum length 20 mm and a maximum height of the lining thickness.

NOTE Storage of pipes and fittings in a hot, dry environment can cause metal expansion and mortar shrinkage which can result in the dry lining developing areas of disbondment and shrinkage cracks exceeding the width given in Table 9. When the lining is re-exposed to water, it will swell by absorption of moisture and the cracks will close to conform to Table 9 and will eventually heal by an autogenous process.

4.5.3.4 Repairs

Repairs to areas of damaged linings shall be carried out by the use of either cement mortar (see 4.5.3.1) or a compatible polymer mortar; application may be by hand held implement.

Prior to the application of the repair mortar, the damaged area shall be cut back to the sound lining or to the metal surface and all loose material shall be removed. After completion of the repair, the cement lining shall comply with 4.5.3.1, 4.5.3.2, 4.5.3.3, and 4.1.4.

4.6 Coatings for fittings and accessories

4.6.1 General

All fittings, accessories and pipes not centrifugally cast shall be delivered externally and internally coated either by a paint coating in conformity with 4.6.2 or by an epoxy coating in conformity with EN 14901; fittings may also receive an internal lining of cement mortar conforming with 4.5.3, machine or hand applied, as a supplement to or as a replacement of the above paint coating.

All finished internal linings shall comply with 4.1.4.

Depending on the external and internal conditions of use, alternative coatings detailed in Annex D may be used.

NOTE Annexes D and E give advice on the field of use for fittings with coatings and linings according to this document.

Parts of accessories made from metal other than ductile iron shall have an appropriate corrosion resistance. The corrosion resistance may be attained from the material itself or a suitable coating protection system.

4.6.2 Paint coating

4.6.2.1 General

For components the coating material shall be a bitumen or synthetic resin base. Appropriate additives (such as solvents, inorganic fillers, etc.) to allow easy application and drying are permitted. Prior to application of the coating, the casting surface shall be dry, free from rust or non-adhering particles or foreign matter such as oil or grease. The coating shall be works-applied.

4.6.2.2 Coating characteristics

The coating shall uniformly cover the whole surface of the casting and have a smooth regular appearance. Drying shall be sufficient to ensure that it will not stick to adjacent coated pieces.

When measured in accordance with 6.7, the mean thickness of the coating shall be not less than 70 µm and the local minimum thickness shall be not less than 50 µm.

4.7 Marking of pipes, fittings and accessories

4.7.1 Pipes and fittings

All pipes and fittings shall be legibly and durably marked and shall bear at least the following information:

- the manufacturer's name or mark;
- the identification of the year of manufacture;
- the identification as ductile iron;
- the DN;
- the PN rating of flanges for flange components;
- the reference to this European Standard, i.e. EN 545;
- the pressure class designation of centrifugally cast pipes.

The first five markings given above shall be cast-on or cold stamped; the other markings can be applied by any method, e.g. painted on the casting.

4.7.2 Accessories

All accessories shall be legibly and durably marked and shall bear at least the following information:

- the manufacturer's name or mark;
- the identification of the year of manufacture;
- the DN;
- the PN rating of flanges for flange components;
- the reference to this European Standard, i.e. EN 545;
- the PFA for couplings and saddles.

These markings should be cast on or cold stamped but where impracticable can be applied by painting or labelling or attached to the packaging.

4.8 Leak tightness

Components and their joints shall be designed to be leak tight at their allowable test pressure (PEA):

- components shall be tested in accordance with 6.5 and shall exhibit no visible leakage, sweating or any other sign of failure;
- joints shall comply with the performance requirements of Clause 5.

5 Performance requirements for joints and pipe saddles

5.1 General

In order to ensure their fitness for purpose in the field of water supply, all the joints and pipe saddles shall fulfil the relevant performance requirements of Clause 5.

One end of a coupling is classified as the joint as long as both ends are to the same design. Where the joint design for a coupling is the same as a flange adaptor, testing need only be carried out on either coupling or flange adaptor.

There shall be a performance test for at least one DN for each of the groupings given in Table 10. One DN is representative of a grouping when the performances are based on the same design parameters throughout the size range. If a grouping covers products of different designs and/or manufactured by different processes, the grouping shall be sub-divided.

Table 10 — DN groupings for performance tests

DN groupings	40 to 250	300 to 600	700 to 1 000	1 100 to 2 000
Preferred DN in each grouping	200	400	800	1 600

For restrained joints, the PFA is generally less than the pressure class of the pipe and therefore DN groupings of table 10 may include more than one pipe pressure class; as such, one performance test shall be carried out for each DN sub-group with the same pipe pressure class.

When flanges are involved, there shall be a performance test for at least one PN for each of the groupings given in Table 10. The PN to be tested is the highest PN existing for each flange design. One PN is representative of a grouping when the performances are based on the same design parameters throughout the size range. If a grouping covers products of different designs and/or manufactured by different processes, the grouping shall be sub-divided.

If for a manufacturer a grouping contains only one DN or PN, this DN or this PN may be considered as part of the adjacent grouping provided that it is of identical design and manufactured by the same process.

5.2 Flexible joints

5.2.1 General

All joints shall be designed to be fully flexible; consequently, the allowable angular deflection declared by the manufacturer shall be not less than:

- 3°30' for DN 40 to DN 300;

- 2°30' for DN 350 to DN 600;
- 1°30' for DN 700 to DN 2 000.

All joints shall be designed to provide axial movement; the allowable withdrawal shall be declared by the manufacturer.

NOTE This permits the installed pipeline to accommodate ground movements and/or thermal effects without incurring additional stresses.

5.2.2 Test conditions

All joint designs shall be performance tested under the most unfavourable applicable conditions of tolerance and joint movement as given below:

- a) joint of maximum annulus (see 5.2.3.1) aligned, withdrawn to the allowable value to be declared by the manufacturer, and subject to shear (see 5.2.3.3);
- b) joint of maximum annulus (see 5.2.3.1) deflected to the allowable value to be declared by the manufacturer (see 5.2.1).

The joints shall exhibit no visible leakage, and the pipes or the fittings being tested with the joints shall not exhibit any detrimental damage, when subjected to the tests given in Table 11.

Table 11 — Performance tests for joints

Test	Test requirements	Test conditions	Test method
1) Positive internal hydrostatic pressure	Test pressure: (1,5 PFA + 5) bar Test duration: 2 h No visible leakage	Joint of maximum annulus, aligned and withdrawn, with shear load	In accordance with 7.2.2
		Joint of maximum annulus, deflected	
2) Negative internal pressure	Test pressure: - 0,9 bar ^a Test duration: 2 h Maximum pressure change during test period: 0,09 bar	Joint of maximum annulus, aligned and withdrawn, with shear load	In accordance with 7.2.3
		Joint of maximum annulus, deflected	
3) Positive external hydrostatic pressure	Test pressure: 2 bar Test duration: 2 h No visible leakage	Joint of maximum annulus, aligned, with shear load	In accordance with 7.2.4
4) Cyclic internal hydraulic pressure	24 000 cycles Test pressure: between PMA and (PMA - 5) bar No visible leakage	Joint of maximum annulus, aligned and withdrawn, with shear load	In accordance with 7.2.5
^a 0,9 bar below atmospheric pressure (approximately 0,1 bar absolute pressure).			

Test 3) (positive external pressure) may be omitted for mechanical joints, provided they have been performance tested according to Tests 1) and 2).

5.2.3 Test parameters

5.2.3.1 Annulus

All joints shall be performance tested at the extremes of manufacturing tolerance such that the annular gap between the sealing surfaces of the socket and of the spigot is equal to the maximum design value plus 0 %, minus 5 %. It is permissible to machine socket internal surfaces to achieve the required annulus for the performance test even though the resultant diameter can be slightly outside the normal manufacturing tolerance.

5.2.3.2 Pipe thickness

All joints shall be performance tested with a spigot having an average iron wall thickness equal to the specified minimum value for the pipe for which the joint is designed plus 10 %, minus 0 %. The average iron wall thickness shall be the mean of a total of at least 12 measurements taken on 6 lines (at approximately 60° around the circumference) over a distance of 2 x DN, in millimetres, from the spigot face (with a maximum of 1 m). It is permissible to machine the spigot of the test pipe in the bore to achieve the required thickness.

5.2.3.3 Shear

All joints shall be performance tested with a resultant shear force across the joints of not less than 50 x DN, in newtons, taking into account the weight of the pipe and of its contents and the geometry of the test assembly (see 7.2.2).

5.3 Restrained flexible joints

All restrained joints shall be designed to be at least semi-flexible; the allowable angular deflection declared by the manufacturer shall be not less than half of the value shown in 5.2.1.

All restrained joint designs shall be performance tested in accordance with 7.2 following the requirements of 5.2.2 and 5.2.3, except that:

- the withdrawal condition of 5.2.2 a) shall not apply;
- there shall be no external axial restraint in positive internal pressure tests so that the joint is subjected to the full end thrust.

During the positive internal pressure tests, the axial movement shall reach a stable value and cease.

When the restraining mechanism and the sealing component of a restrained joint are independent, such a joint does not need to be subjected to Test 2 and Test 3 of 5.2.2 if the unrestrained version of the joint has passed these tests.

5.4 Flanged joints as cast, screwed, welded and adjustable

In order to demonstrate their strength and leak tightness in service conditions, flanged joints shall be subjected to a performance test. When tested in accordance with 7.3, they shall show no visible leakage under the combined effects of a hydrostatic internal pressure and of a bending moment given in Table 12, where:

- the pressure is $(1,5 PN + 5)$ bar;
- the relevant bending moment is obtained by addition of the bending moments due to the weight of the components and of the water in the test assembly and to a possible external load calculated as a function of the length of the unsupported span of the testing arrangement (see 7.3).

A performance test shall be carried out on each type of flange joint available from the manufacturer in accordance with Table 10.

NOTE The bending moments given in Table 12 are equal to those resulting from the weight of the pipes and of the water over an unsupported pipe length L between simple supports, with:

- $L = 8$ m for $DN \leq 250$;
- $L = 12$ m for $DN \geq 300$.

Table 12 — Bending moments for flange joint performance tests

DN	Bending moment kN·m	DN	Bending moment kN·m
40	0,7	500	63
50	0,9	600	87
60	1,3	700	116
65	1,4	800	146
80	1,8	900	181
100	2,3	1 000	222
125	2,9	1 100	265
150	4,0	1 200	313
200	6,0	1 400	423
250	8,6	1 500	475
300	26,0	1 600	548
350	33,8	1 800	625
400	42	2 000	770
450	51		

5.5 Pipe saddles

5.5.1 Test conditions

All pipe saddle designs shall be performance tested under the most unfavourable conditions of tolerance as given below:

- a) with the outlet vertical and fitted with a service valve, saddle assembled on the pipe in accordance with the supplier's instructions, saddle joint of maximum annulus (see 5.5.2), apply a torque, in Nm, to the service valve equal to three times the DN of the largest service valve for the saddle, with a minimum of 100 Nm;
- b) with the outlet horizontal and fitted with a service valve, saddle assembled on the pipe in accordance with the supplier's instructions, saddle joint of maximum annulus (see 5.5.2), apply a minimum vertical force of 500 N to the square cap of the horizontal valve.

When subjected to the tests given in Table 13, the saddle joint shall exhibit no visible leakage, the saddles shall not exhibit any detrimental damage and their movement relative to the pipe shall not exceed 3 mm.

5.5.2 Annulus

All saddles shall be performance tested at the extremes of manufacturing tolerance such that the annular gap between the sealing surfaces of saddle and of the barrel of the pipe is equal to the maximum design value plus 0 %, minus 5 %. It is permissible to machine saddle internal surfaces to achieve the required annulus for the performance test even though the resulting dimension of the saddle may be slightly outside the normal manufacturing tolerance.

Table 13 — Performance tests for pipe saddles

Test	Test requirements	Test conditions	Test method
1) Positive internal hydrostatic pressure	Test pressure: (1,5 PFA + 5) bar Test duration: 2 h No visible leakage	Joint maximum annulus	In accordance with 7.4.1
2) Negative internal pressure	Test pressure: - 0,9 bar ^a Test duration: 2 h Maximum pressure change during test period: 0,09 bar	Joint maximum annulus	In accordance with 7.4.2
^a 0,9 bar below atmospheric pressure (approximately 0,1 bar absolute pressure).			

6 Test methods

6.1 Pipe dimensions

6.1.1 Wall thickness

Pipe wall thickness compliance shall be demonstrated by the manufacturer. He may use a combination of various means, e.g. direct wall thickness measurement, mechanical or ultrasonic measurement.

The iron wall thickness shall be measured by suitable equipment having an error limit $\pm 0,1$ mm.

6.1.2 External diameter

Socket and spigot pipes shall be measured at their spigot end by means of a circumferential tape or controlled by pass/fail gauges. In addition, they shall be visually inspected for compliance with the spigot allowable ovality and, in case of doubt; the maximum and minimum spigot axes shall be measured by suitable equipment or controlled by pass/fail gauges.

6.1.3 Internal diameter

The internal diameter of the lined pipes shall be measured by means of suitable equipment:

either

- a) two measurements shall be taken at right angles, at a cross section 200 mm or more from the end face; the mean value of these two measurements may then be calculated;

or

- b) a system of pass/fail gauges shall be passed along the bore of the pipe.

6.1.4 Length

The length of socket and spigot pipes shall be measured by suitable equipment:

- on one pipe from the first batch of pipes cast from a new mould, for as-cast pipes;
- on the first pipe, for pipes which are systematically cut to a pre-set length.

6.2 Straightness of pipes

The pipe shall be rolled on two gantries or rotated around its axis on rollers, which in each case are separated by not less than two thirds of the standardized pipe length.

The point of maximum deviation from the straight axis shall be determined and the deviation measured at that point.

6.3 Tensile testing of ductile iron components

6.3.1 Samples

The thickness of the sample and the diameter of the test bar shall be as given in Table 14.

6.3.1.1 Centrifugally cast pipes

A sample shall be cut from the spigot of the pipe. This sample may be cut parallel with or perpendicular to the pipe axis, but in case of dispute the parallel with axis sample shall be used.

6.3.1.2 Pipes not centrifugally cast, fittings and accessories

At the manufacturer's option, samples shall be either cast integrally with the castings or cast separately. In the latter case they shall be cast from the same metal as that used for the castings. If the castings are subjected to heat treatment, the samples shall be subjected to the same heat treatment cycle.

6.3.2 Preparation of test bar

A test bar shall be machined from each sample to be representative of the metal at the mid thickness of the sample, with a cylindrical part having the diameter given in Table 14.

The test bar shall have a gauge length equal to at least five times the nominal test bar diameter. The ends of the test bar shall be such that they will fit the testing machine.

The surface roughness profile of the cylindrical part of the test bar shall be such that $R_z \leq 6,3$.

If the specified diameter of the test bar is greater than 60 % of the measured minimum thickness of the sample, it is allowed to machine a test bar with a smaller diameter, or to cut another sample in a thicker part of the pipe.