BRITISH STANDARD

BS ISO 2531:2009

Incorporating corrigendum November 2010

Ductile iron pipes, fittings, accessories and their joints for water applications

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National foreword

This British Standard is the UK implementation of ISO 2531:2009, incorporating corrigendum November 2010.

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INTERNATIONAL STANDARD

ISO 2531

Sixth edition
2009-12-15

Ductile iron pipes, fittings, accessories and their joints for water applications

Tuyaux, raccords et accessoires en fonte ductile et leurs assemblages pour l'eau

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Foreword

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

ISO 2531 was prepared by Technical Committee ISO/TC 5, *Ferrous metal pipes and metallic fittings*, Subcommittee SC 2, *Cast iron pipes, fittings and their joints*.

This sixth edition cancels and replaces the fifth edition (ISO 2531:1998), of which it constitutes a technical revision. A new classification system for pipes and fittings based on pressure is introduced with minimum wall thickness determined by allowable operating pressure.

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Ductile iron pipes, fittings, accessories and their joints for water applications

1 Scope

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

— to convey water (e.g. for human consumption and raw water),

— operated with or without pressure, and

— installed below or above ground.

NOTE In this International Standard, all pressures are relative pressures expressed in bar [1].

This International Standard specifies materials, dimensions and tolerances, mechanical properties and standard coatings of pipes, fittings and accessories. It also gives performance requirements for all components including joints.

This International Standard applies to pipes, fittings and accessories cast by any type of foundry process or manufactured by fabrication of cast components, as well as corresponding joints in the size range DN 40 to DN 2600 inclusive.

It is applicable to pipes, fittings and accessories which are

— manufactured with socketed, flanged or spigot ends (joint design and gasket shapes are outside the scope of this International Standard),

— normally delivered internally and externally coated.

Pipes and fittings are classified according to allowable operating pressure.

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.

ISO 4016, *Hexagon head bolts — Product grade C*

ISO 4034, *Hexagon nuts — Product grade C*

ISO 4633, *Rubber seals — Joint rings for water supply, drainage and sewerage pipelines — Specification for materials*

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

ISO 7005-2, *Metallic flanges — Part 2: Cast iron flanges*

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1) 100 kPa = 1 bar

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ISO 7091, *Plain washers — Normal series — Product grade C*

ISO 10803, *Design method for ductile iron pipes*

ISO 10804, *Restrained joint systems for ductile iron pipelines — Design rules and type testing*

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

3 Terms and definitions

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

3.1
accessory
any casting other than a pipe or fitting, which is used in a pipeline

EXAMPLE 1 Glands and bolts for mechanical flexible joints (see 3.18).

EXAMPLE 2 Glands, bolts and locking rings or segments for restrained joints (see 3.24).

NOTE The term accessory is not relevant for valves or hydrants of any type.

3.2
allowable operating pressure
PFA
maximum internal pressure, excluding surge, which a component can safely withstand in permanent service

3.3
allowable site test pressure
PEA
maximum hydrostatic pressure that a newly installed component can withstand for a relatively short duration, when either fixed above ground level or laid and backfilled underground, in order to measure the integrity and tightness of the pipeline

NOTE This test pressure is different from the system test pressure, which is related to the design pressure of the pipeline.

3.4
batch
quantity of castings from which a sample may be taken for testing purposes during manufacture

3.5
component
any product defined as an element of a pipe, fitting or accessory

See 3.1, 3.9 and 3.22.

3.6
deviation
amount by which the design length may differ from the standardized length of a pipe or a fitting

NOTE Pipes and fittings are designed to a length selected in the range of standard length plus or minus the deviation (see Table 6); they are manufactured to this length plus or minus the tolerance given in Table 7.

3.7
diametral stiffness of a pipe
characteristic of a pipe allowing it to resist diametral deflection under loading

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3.8
ductile iron
type of cast iron used for pipes, fittings and accessories in which graphite is present primarily in spheroidal form

3.9
fitting
casting other than a pipe, which allows pipeline deviation, change of direction or bore

NOTE Flanged sockets, flanged spigots and collars are also classified as fittings.

3.10
flange
end of a pipe or fitting, extending perpendicular to its axis, with bolt holes equally spaced in a circle

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

3.11
flanged joint
joint between two flanged ends

3.12
flexible joint
joint providing significant angular deflection and movement parallel and/or perpendicular to the pipe axis

3.13
gasket
sealing component of a joint

3.14
hoop stress
σ
stress in a pipe or fitting under pressure, acting tangentially to the perimeter of a transverse section

3.15
joint
connection between the ends of pipes and/or fittings in which a gasket is used to effect a seal

3.16
laying length
L_e
length by which a pipeline progresses when an additional pipe is installed

NOTE 1 For socket and spigot pipes, it is equal to the total length of the pipe, L_{tot}, minus the maximum spigot insertion depth, L_i, as given by the manufacturer and as shown in Figure 4. For flanged pipes, it is equal to the total length of the pipe.

NOTE 2 It is expressed in metres.

3.17
maximum allowable operating pressure
PMA
maximum internal pressure, including surge, which a component can safely withstand in service

3.18
mechanical flexible joint
flexible joint in which sealing is obtained by applying pressure to the gasket by mechanical means

EXAMPLE A gland.

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3.19
nominal pressure
PN
numerical designation, which is a convenient rounded number, used for reference purposes

NOTE 1 All components of the same nominal size, DN, designated by the same PN number have compatible mating dimensions.

NOTE 2 Adapted from ISO 7268.

3.20
nominal size
DN
alphanumeric designation of size for components of a pipework system, which is used for reference purposes

NOTE 1 It 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.

NOTE 2 Adapted from ISO 6708:1995, definition 2.1.

3.21
ovality
out-of-roundness of a pipe section, equal to Equation (1)

$$100\,\frac{(A_1 - A_2)}{(A_1 + A_2)} \tag{1}$$

where

A_1 is the maximum axis, in millimetres;

A_2 is the minimum axis, in millimetres.

3.22
pipe
casting of uniform bore, with straight axis, having either socket, spigot or flanged ends

NOTE This does not apply to flanged sockets, flanged spigots and collars, which are classified as fittings.

3.23
push-in flexible joint
flexible joint assembled by pushing the spigot through the gasket into the socket of the mating component

3.24
restrained joint
joint in which a means is provided to prevent separation of the assembled joint

3.25
socket
female end of a pipe or fitting to make the connection with the spigot of the next component

3.26
spigot
male end of a pipe or fitting

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3.27
spigot end
maximum insertion depth of the spigot, L_i, plus 50 mm

See L_i in Figure 4.

3.28
standardized length
length of pipe barrel and fitting body or branch as defined in this International Standard

NOTE 1 For socket and spigot pipes, and fittings, it is designated L_u (l_u for branches). For flanged pipes, and fittings, it is designated L (l for branches). See Figures 4 to 27.

NOTE 2 For flanged pipes and fittings, the standardized length L (l for branches) is equal to the total length. For socketed pipes and fittings, the standardized length L_u (l_u for branches) is equal to the total length minus the spigot insertion depth, as indicated in the manufacturer's catalogues.

3.29
type test
proof-of-design test, which is done once and is repeated only after change of design

4 Technical requirements

4.1 General

4.1.1 Pipes and fittings

Thicknesses, lengths and coatings are specified in this subclause, 4.2.3, 4.2.4 and 4.4 for pipes, and 4.5 for fittings. When, by agreement between the manufacturer and the purchaser, pipes and fittings with different lengths, thicknesses and/or coatings, and other types of fittings than those given in 8.3 and 8.4, are supplied in accordance with this International Standard, they shall comply with all the other requirements of this International Standard. This includes pipe and fittings manufactured to national standards and regulations.

The standard nominal sizes, DN, of pipes and fittings are the following:

40, 50, 60, 65, 80, 100, 125, 150, 200, 250, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1000, 1100, 1200, 1400, 1500, 1600, 1800, 2000, 2200, 2400 and 2600.

The stiffness and allowable diametral deflection of ductile iron pipes are as given in Annex D.

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

4.1.2 Surface condition and repairs

Pipes, fittings and accessories shall be free from defects and surface imperfections which could impair their compliance with the requirements of Clauses 4 and 5.

When necessary, pipes and fittings may be repaired, for example by welding, to remove surface imperfections and localized defects which do not affect the entire wall thickness, provided that the repaired pipes and fittings comply with all the requirements of Clauses 4 and 5.

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4.1.3 Types of joints and interconnection

4.1.3.1 General

Joint design and gasket shapes are beyond the scope of this International Standard.

Rubber gasket materials shall conform to the requirements of ISO 4633 for water applications. When materials other than rubber are necessary (e.g. high-temperature flanged joints), they shall conform to the appropriate International Standards.

4.1.3.2 Flanged joints

Flanged joints shall be designed to facilitate attachment to flanges whose dimensions and tolerances comply with ISO 7005-2 or EN 1092-2. This ensures interconnection between all flanged components (pipes, fittings, valves, etc.) of the same DN and PN and adequate joint performance. Bolts and nuts shall comply, as a minimum, with the requirements of ISO 4016 and ISO 4034, property class 4.6. Where washers are required, they shall comply with ISO 7091.

In addition, each type of flange joint shall be designed to meet the performance requirements of 5.3.

Although it does not affect interconnection, the manufacturer shall indicate in his handbook whether his products are normally delivered with fixed flanges or loose flanges.

4.1.3.3 Flexible joints

Pipes and fittings with flexible joints shall be in accordance with 4.2.2.1 for their spigot external diameters, DE, and their tolerances. This provides the possibility of interconnection between components equipped with different types of flexible joints. In addition, each type of flexible joint shall be designed to meet the performance requirements of 5.2.

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

For interconnection with existing pipelines which can have external diameters not in accordance with 4.2.2.1, the manufacturer's guidance should be followed as to the appropriate means of interconnection (e.g. adaptors).

4.1.3.4 Restrained joints

Restrained joints for ductile iron pipelines shall be designed in accordance with ISO 10804. Their spigot external diameters, DE, and their tolerances shall comply with 4.2.2.1.

4.1.4 Materials in contact with water intended for human consumption

When used under the conditions for which they are designed, in permanent or in temporary contact with water intended for human consumption, ductile iron pipes, fittings and their joints shall not have detrimental effects on the properties of that water for its intended use.

Ductile iron pipeline systems, including pipes, fittings, accessories and joints, consist of various materials. When used for conveying water intended for human consumption, the materials in contact with the water shall meet the relevant requirements of the national standards or regulations in the country of use with respect to effect on water quality.

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4.2 Pressure classification and dimensional requirements

4.2.1 Pressure classifications

4.2.1.1 General

Components with flexible joints shall be classified by the allowable operating pressure (PFA) in bar, prefixed by the letter C.

Components with flanged joints shall be classified by the PN number of the flange.

Allowable component pressure relationships shall be the following:

a) Allowable operating pressure (PFA) = C, in bar

b) Allowable maximum operating pressure (PMA) = 1,20 × PFA, in bar

c) Allowable site test pressure (PEA) = (1,20 × PFA) + 5, in bar

The allowable pressures within a pipeline system shall be limited to the lowest pressure classification of all components within the system.

4.2.1.2 Preferred pressure classes

Preferred pressure classes of components with flexible joints are C25, C30, and C40. Other pressure classes are allowable, including C20, C50, C64 and C100.

Pressure classes for components with flanged joints are PN10, PN16, PN25 and PN40.

4.2.1.3 Allowable pressures

Allowable pressures of components are as given in Tables 1 and 2.

Table 1 — Allowable pressures of components with flexible joints for preferred classes

Pressure class C	Allowable operating pressure PFA bar	Maximum allowable operating pressure PMA bar	Allowable site test pressure PEA bar
25	25	30	35
30	30	36	41
40	40	48	53

Table 2 — Allowable pressures of components with flanged joints

Pressure class PN	Allowable operating pressure PFA bar	Maximum allowable operating pressure PMA bar	Allowable site test pressure PEA bar
10	10	12	17
16	16	20	25
25	25	30	35
40	40	48	53

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The allowable pressure for fittings as specified in Tables 15 to 33 are as follows:

— socketed fittings, except tees, are given in Table 3;

— socketed tees may be less than those given in Table 3 and shall be given in the manufacturer's handbook;

— all flanged fittings and fittings with one flange, such as double-socketed tees with flanged branch, flanged spigots and flanged sockets, are limited by the flange PN and are given in Table 2.

Table 3 — Allowable pressures for socketed fittings

Nominal size DN	Allowable operating pressure PFA bar	Maximum allowable operating pressure PMA bar	Allowable site test pressure PEA bar
40 to 200	64	77	82
250 to 350	50	60	65
400 to 600	40	48	53
700 to 1400	30	36	41
1500 to 2600	25	30	35

Appropriate limitations shall be taken into account, which can prevent the full range of these pressures being used in an installed pipeline. For example, operation at the PFA values can be limited by the lower pressure capability of other pipeline components, e.g. flanged pipework, certain types of tees and specific designs of flexible joints. When other limitations exist due to the joint type or to any specific design arrangement, they shall be given in the manufacturer's handbook.

4.2.2 Diameter

4.2.2.1 External diameter

Table 14 gives the values of the external diameter, DE, of the spigot end of pipes and fittings, when measured circumferentially using a circumferential tape as specified in 6.1.1. The positive tolerance is + 1 mm and applies to all pressure classes of pipes and also to flanged spigot fittings.

The negative tolerance depends on the design of each type of joint and shall be as specified in national standards, or, when not so specified, in manufacturers' handbooks, for the type of joint and the nominal size considered.

In addition, the ovality (see 3.21) of the spigot end of pipes and fittings shall

— remain within the tolerances of DE for DN 40 to 200, and

— not exceed 1 % of DE for DN 250 to DN 600 or 2 % for DN > DN 600.

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

4.2.2.2 Internal diameter

The nominal values of the internal diameters of centrifugally cast pipes, expressed in millimetres, are approximately equal to the numbers indicating their nominal sizes, DN.

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4.2.3 Wall thickness

4.2.3.1 Pipes with flexible joints

The minimum wall thickness for pipes, e_{min}, shall be not less than 3,0 mm and shall be determined using Equation (2):

$$e_{min} = \frac{PFA \times SF \times DE}{20R_m + (PFA \times SF)} \quad (2)$$

where

e_{min} is the minimum pipe wall thickness, in millimetres;

PFA is the allowable operating pressure, in bar;

SF is the safety factor for PFA (= 3);

DE is the nominal pipe external diameter (see Table 14), in millimetres;

R_m is the minimum tensile strength of ductile iron, in megapascals (R_m = 420 MPa; see Table 8).

NOTE Equation (2) is derived from Barlow's equation, i.e. hoop stress, σ = PD/2t (see 3.14)

For pipes centrifugally cast, the minimum wall thickness, e_{min}, shall not be less than 3,0 mm. The nominal wall thickness, e_{nom}, is equal to the minimum wall thickness, e_{min}, plus (1,3 + 0,001 DN).

For pipes not centrifugally cast, the minimum wall thickness, e_{min}, shall not be less than 4,7 mm. The nominal wall thickness, e_{nom}, is equal to the minimum wall thickness, e_{min}, plus (2,3 + 0,001 DN).

For centrifugally cast pipes, nominal pipe wall thicknesses for preferred ductile iron pressure classes are given in Table 14. For other pressure classes, as given in Annex C, the user should confirm the availability with the manufacturer.

4.2.3.2 Flanged pipes

Flanged pipe shall be classified by PN number. The pressure class of the barrel of the flanged pipes shall be equal to or greater than a value in bar equal to the PN of the flanges. The pressure class of the flanged pipe barrel to be used for fabricated flanged pipe shall be as indicated in 8.2 for welded-on flanges, screwed-on flanges and integrally cast flanges.

NOTE Pipe threads are regarded as loss of wall thickness.

4.2.3.3 Fittings

Nominal wall thicknesses, e_{nom}, are given for fittings in Tables 15 to 29, with allowable pressures given in 4.2.1.3. The minimum wall thickness, e_{min}, for fittings is: $e_{min} = e_{nom} - (2,3 + 0,001\ DN)$.

Fittings with other pressure classifications are allowed. The manufacturer shall be responsible for the design of the fittings including the determination of wall thickness. The minimum wall thickness, e_{min}, shall be not less than 3,0 mm.

The design shall be carried out by a calculation method, e.g. finite element analysis, or an experimental method, e.g. hydrostatic testing, using a safety factor of 3 against failure with respect to PFA.

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4.2.4 Length

4.2.4.1 Socket and spigot pipes

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

Table 4 — Standardized lengths of socket and spigot pipe

Dimensions in metres

DN	Standardized lengths, L_u [a]
40 and 50	3
60 to 600	4 or 5 or 5,5 or 6 or 9
700 and 800	4 or 5,5 or 6 or 7 or 9
900 to 2600	4 or 5 or 5,5 or 6 or 7 or 8,15 or 9
NOTE Not all the standardized lengths are available in all countries.	
[a] See 3.28.	

The manufacturers' design lengths, L_u (see 3.28), shall be within a deviation (see 3.6) of ± 250 mm with respect to the lengths given in Table 4 and shall be given in their handbooks. The actual length, L_u, shall be measured according to 6.1.3 and shall not differ from the manufacturer's design length by more than the tolerance 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 %.

NOTE 1 Pipes cut for test purposes can be excluded from the 10 % limitation and treated as full-length pipes.

NOTE 2 When pipes are ordered on a meterage basis, the manufacturer can determine the required quantity of pipes to be supplied by the summation of the measured individual pipe laying lengths.

4.2.4.2 Flanged pipes

The lengths of flanged pipes shall be as given in Table 5. Other lengths are available by agreement between the manufacturer and the purchaser.

Table 5 — Standardized lengths of flanged pipe

Dimensions in metres

Type of pipe	DN	Standardized lengths, L [a]
With cast-on flanges	40 to 2600	0,5 or 1 or 2 or 3 or 4
With screwed-on or welded-on flanges	40 to 500	2 or 3 or 4 or 5
	600 to 1000	2 or 3 or 4 or 5 or 6
	1100 to 2600	4 or 5 or 6 or 7
[a] See 3.28.		

4.2.4.3 Fittings

Fittings shall be supplied in the lengths given in 8.3 and 8.4 except that, alternatively, socket fittings may be supplied in the lengths of the national standard of the country of manufacture.

NOTE Two series of dimensions are shown, series A and series B, which is generally limited to DN 450 maximum.

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The permissible deviations (see 3.6) on the lengths of series A fittings shall be as given in Table 6.

AC1 Table 6 — Permissible deviations on length of fittings

Dimensions in millimetres

Type of fitting	DN	Deviation
Flanged sockets Flanged spigots Collars, tapers	40 to 1200	±25
	1400 to 2600	±35
Tees	40 to 1200	+50 −25
	1400 to 2600	+75 −35
Bends 90° (1/4)	40 to 2600	±(15 + 0,03 DN)
Bends 45° (1/8)	40 to 2600	±(10 + 0,025 DN)
Bends 22° 30' (1/16) and 11°15' (1/32)	40 to 1200 1400 to 2600	±(10 + 0,02 DN) ±(10 + 0,025 DN)

AC1

4.2.4.4 Tolerances on lengths

The tolerances on lengths shall be as given in Table 7.

Table 7 — Tolerances on length

Dimensions in millimetres

Type of casting	Tolerance
Socket and spigot pipes (full length or shortened)	−30 +70
Fittings for socketed joints	± 20
Pipes and fittings for flanged joints	± 10 [a]

[a] By agreement between manufacturer and purchaser, smaller tolerances are possible, but not less than ± 3 mm for DN ⩽ 600 and ± 4 mm for DN > 600.

4.2.5 Straightness of pipes

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

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

4.3 Material characteristics

4.3.1 Tensile properties

Pipes, fittings and accessories made of ductile iron shall have the tensile properties given in Table 8.

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During the manufacturing process the manufacturer shall carry out suitable tests to verify these tensile properties; these tests may be either

a) a batch sampling system whereby samples are obtained from the pipe spigot or, for fittings, from samples cast separately or integrally with the casting concerned (test bars shall be machined from these samples and tensile tested according to 6.3), or

b) a system of process control testing (e.g. non-destructive), by which a positive correlation can be demonstrated with the tensile properties specified in Table 8; testing verification procedures shall be based on the use of comparitor samples having known and verifiable properties; this system of testing shall be supported by tensile testing in accordance with 6.3.

Table 8 — Tensile properties

Type of casting	Minimum tensile strength, R_m MPa	Minimum percent elongation after fracture, A %	
	DN 40 to DN 2600	DN 40 to DN 1000	DN 1100 to DN 2600
Pipes centrifugally cast	420	10	7
Pipes not centrifugally cast, fittings and accessories	420	5	5
By agreement between the manufacturer and the purchaser, the 0,2 % proof stress, R_{p02}, may be measured. It shall be not less than: 270 MPa when $A \geqslant 12$ % for DN 40 to DN 1000 or when $A \geqslant 10$ % for DN > 1000; 300 MPa in other cases. For centrifugally cast pipes of DN 40 to DN 1000 having a design minimum wall thickness of 10 mm or greater, the minimum elongation after fracture shall be 7 %.			

4.3.2 Brinell hardness

The hardness of the various components shall be such that they can be cut, tapped, drilled and/or machined with standard tools. In case of dispute, the hardness shall be measured according to 6.4.

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

4.4 Coating and linings for pipes

Pipes shall normally be delivered internally and externally coated.

4.4.1 External coatings

Ductile iron pipeline systems can be installed in a wide range of external operating environments. These environments can be characterized according to their aggressivity. For relevant factors, see A.1.

Coatings specified by relevant International Standards are available as specified in A.2. Other coatings are available.

4.4.2 Internal linings

Ductile iron pipeline systems can be used to convey a wide range of raw waters and potable waters. These internal environments can be characterized by their aggressivity. Relevant factors to be considered for cement mortar linings without seal coats are given in B.1.

Linings specified by relevant International Standards are available as specified in B.2. Other linings are also available.

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4.5 Coatings and linings for fittings and accessories

Fittings and accessories shall normally be delivered internally and externally coated.

4.5.1 External coatings

Ductile iron pipeline systems can be installed in a wide range of external operating environments. These environments can be characterized by their aggressivity. For relevant factors, see A.1.

Coatings specified by relevant International Standards are available as specified in A.3. Other coatings are also available.

4.5.2 Internal linings

Ductile iron pipeline systems can be used to convey a wide range of raw waters and potable waters. These internal environments can be characterized according to their aggressivity. Relevant factors to be considered for cement mortar linings without seal coats are given in B.1.

Linings specified by relevant International Standards are available as specified in B.3. Other linings are also available.

4.6 Marking

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

a) a reference to this International Standard, i.e. ISO 2531;

b) the manufacturer's name or mark;

c) identification of the year of manufacture;

d) identification as ductile iron;

e) the DN;

f) the PN rating of flanges, if applicable;

g) the C pressure class of socket and spigot pipe.

Items b) to f) shall be cast-on or cold stamped. Items a) and g) can be applied by any method, e.g. painted on the castings.

5 Leaktightness requirements

5.1 Pipes and fittings

Pipes and fittings shall be designed to be leaktight at their allowable site test pressure (PEA). They shall be tested according to 6.5 and shall exhibit no visible leakage, sweating or any other sign of failure.

5.2 Flexible joints

5.2.1 General

All flexible joints for ductile iron pipes and components shall be designed in compliance with the requirements of 5.2. If the design has been tested and documented by the manufacturer and successfully used for a minimum of 10 years, the performance of a type test as specified in 5.2.2 for internal pressure, as specified

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in 5.2.3 for external pressure and as specified in 5.2.4 for negative internal pressure, is only required for significant changes in design which could adversely affect the performance of the joint.

Joint designs shall be type tested to demonstrate leaktightness to both internal and external pressure under the most unfavourable conditions of castings tolerances and joint movements.

There shall be a type test for at least one DN for each of the groupings given in Table 9. One DN is representative of a grouping when the performances are based on the same design parameters throughout the size range.

Table 9 — DN groupings for type tests

DN groupings	40 to 250	300 to 600	700 to 1000	1100 to 2000	2200 to 2600
Preferred DN in each grouping	200	400	800	1600	2400

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 PN may be considered as part of the adjacent grouping provided that it is of identical design and manufactured by the same process.

The type tests shall be carried out in the configuration of maximum design radial gap between the components to be jointed (smallest spigot together with largest socket).

In the type test, the maximum gap shall be equal to the maximum design radial gap with a tolerance of $^{0}_{-5}$ %. The internal socket diameter may be machined to achieve this, even if the resulting diameter is slightly outside the normal manufacturing tolerance.

All joints shall be performance tested with a spigot having an average iron wall thickness (over a distance of 2 DN, in millimetres, from the spigot face) equal to the specified minimum value for the pipe for which the joint is designed, $^{+10}_{0}$ %. It is permissible to machine the spigot of the pipe bore to achieve the required thickness.

Restrained flexible joints shall be designed and tested in accordance with ISO 10804.

5.2.2 Internal pressure

The leaktightness of joints to internal pressure shall be type tested as specified in 7.1 at a test pressure of 1,5PFA + 5 bar; the joints shall exhibit no visible leakage in the two following positions:

a) joint aligned and subjected to shear; the shear force across the joint, expressed in N, shall not be less than 30 times DN;

b) joint deflected; the test angular deflection shall be the maximum allowable deflection indicated in the manufacturer's handbook, but 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 2600. These minimum deflections do not apply to restrained joint pipe.

5.2.3 External pressure

The leaktightness of joints to external pressure shall be type tested as specified in 7.2; the joints shall exhibit no visible leakage when subjected to a shear load, expressed in newtons, not less than 30 times DN.

The test pressure shall be not less than 2 bar.

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5.2.4 Negative internal pressure

The leaktightness of joints to negative internal pressure shall be type tested as specified in 7.3 at a test pressure of 0,9 bar below atmospheric pressure (approximately 0,1 bar absolute pressure). The maximum pressure change during the test period shall not be more than 0,09 bar after 2 h, when tested in the following two positions:

a) joint aligned and subjected to shear; the shear force across the joint, expressed in N, shall not be less than 30 times DN;

b) joint deflected; the test angular deflection shall be the maximum allowable deflection indicated in the manufacturer's handbook, but 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 2600. These minimum deflections do not apply to restrained joint pipe.

5.3 Flanged joints as cast, screwed, welded and adjustable

5.3.1 General

All flanged joints for ductile iron pipes and components shall be designed in compliance with the requirements of 5.3. If the design has been tested and documented by the manufacturer and successfully used for a minimum of 10 years, the performance of a type test as specified in 5.3.2 is only required for significant changes in design which could adversely affect the performance of the joint.

When flanges are involved, there shall be a type test for at least one DN for each of the groupings given in Table 9. 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 PN may be considered as part of the adjacent grouping provided that it is of identical design and manufactured by the same process.

5.3.2 Internal pressure and bending moment

In order to demonstrate their strength and leaktightness in service conditions, flanged joints shall be subjected to a type test. When tested as specified in 7.4, they shall show no visible leakage under the combined effects of a hydrostatic internal pressure and a bending moment as given in Table 10, where

— the pressure is (1,5PN + 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 those due to a possible external load calculated as a function of the length of the unsupported span of the testing arrangement (see 7.4).

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

The bending moments given in Table 10 are approximately equal to those resulting from the weight of the preferred classes of pipes (utilizing the nominal thicknesses), of the cement mortar lining, and of the water over an unsupported pipe length, L, between simple supports, with, for welded, integrally cast and adjustable flanged joints,

— L = 8 m for DN $\leqslant$ 250,

— L = 12 m for DN $\geqslant$ 300;

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and for screwed flanged joints,

— L = 6,8 m for DN $\leqslant$ 800,

— L = 10 m for DN $\geqslant$ 900.

Table 10 — Bending moments for flange joint type tests of preferred classes of pipes

DN	Integrally cast, welded and adjustable	Screwed
	kN·m	kN·m
40	0,6	0,4
50	0,7	0,6
60	0,9	0,7
65	1,0	0,8
80	1,3	1,0
100	1,7	1,4
125	2,4	2,0
150	3,1	2,7
200	4,8	4,5
250	7,1	6,7
300	22,1	9,3
350	29,1	12,6
400	36	16
450	45	20
500	54	25
600	77	35
700	100	47
800	129	52
900	161	140
1000	197	159
1100	237	192
1200	281	214
1400	383	274
1500	437	314
1600	495	355
1800	623	447
2000	766	549
2200	928	644
2400	1 100	764
2600	1 287	894

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6 Test methods

6.1 Dimensions

6.1.1 External diameter

Pipes with sockets and spigot ends shall be measured at their spigot by means of a circumferential tape for compliance with the outer diameter tolerance. They can also be verified by means of pass-fail gauges.

In addition, the pipes shall be visually inspected at their spigot for compliance with the ovality tolerance and, in case of doubt, checked by measurement of the maximum and minimum axes. This control may also be carried out by pass-fail gauges.

The frequency of testing is related to the system of production and the quality control used by the manufacturer.

6.1.2 Wall thickness

Pipe wall thickness compliance shall be demonstrated by the manufacturer; a combination of various means may be used, such as:

— pipe weight control;

— direct wall thickness measuring or gauging by suitable equipment, such as mechanical or ultrasonic equipment. The frequency of testing is related to the system of production and quality control used by the manufacturer.

6.1.3 Length

The length of centrifugally cast pipes with sockets and spigot ends shall be measured by means of suitable equipment

— on the first pipe cast from a new mold, for full length pipes, and

— on the first cut pipe, for pipes which are systematically cut to a predetermined length.

6.2 Straightness of pipes

The pipe shall be rolled on two supports or rotated along its axis on rollers, which in each case are separated by at least two thirds of the standard pipe length.

The point of maximum deviation from the true axis shall be determined, and the deviation measured at that point shall not exceed the limit fixed in 4.2.5.

6.3 Tensile test

6.3.1 Sampling

The thickness of the sample and the diameter of the test bar shall be as indicated in Table 11.

6.3.1.1 Centrifugally cast pipes

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

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6.3.1.2 Pipes not cast centrifugally, fittings and accessories

Samples shall be taken, at the manufacturer's discretion, either from an integrally cast sample, from a sample attached to the casting, or from a sample cast separately. In the latter case, it shall be cast from the same metal as that used for the casting. If the casting is subjected to heat treatment, the sample shall be subjected to the same heat treatment.

6.3.2 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 diameters given in Table 11. 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. Other test bar shapes, complying with International Standards or national standards are permitted.

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

The surface roughness of the machined gauge length of the test bar shall be such that $Rz \leqslant 6{,}3$ µm.

Two methods of measuring the tensile strength may be used at the manufacturer's discretion:

Method A:

Produce the test bar to a nominal diameter ± 10 %, measure the actual diameter before the test with an accuracy of ± 0,01 mm and use this measured diameter to calculate the cross-sectional area and the tensile strength; or

Method B:

Produce the test bar to a nominal area, S_o, within a specified tolerance on the diameter (see Table 11) and use the nominal area to calculate the tensile strength.

AC1 **Table 11 — Dimensions of test bar**

Type of casting	Test bar method A	Test bar method B		
	Nominal diameter mm	Nominal area S_o mm²	Nominal diameter mm	Tolerance on diameter mm
Centrifugally cast pipes with wall thickness:				
— less than 6 mm	2,5	5	2,52	±0,01
— 6 mm up to but not including 8 mm	3,5	10	3,57	±0,02
— 8 mm up to but not including 12 mm	5	20	5,05	±0,02
— 12 mm and over	6	30	6,18	±0,03
Pipes, fittings and accessories not centrifugally cast:				
— integrally cast samples	5	20	5,05	±0,02
— separately cast sample:				
— thickness 12,5 mm for casting thickness less than 12 mm	6	30	6,18	±0,03
— thickness 25 mm for casting thickness 12 mm and over	12 or 14	—	—	—

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6.3.3 Equipment and test method

The tensile testing machine shall have suitable holders or grips to attach to the test bar ends so as to positively apply the test load axially. The testing machine shall have a force range suitable for testing the bars to failure whilst indicating the load applied.

The rate of stressing shall be as constant as possible within the limits of 6 N/mm^2 per second to 30 N/mm^2 per second.

The tensile strength shall be calculated by dividing the maximum force sustained by the test bar by the cross-sectional area of the test bar before testing. The elongation shall be measured by piecing together the broken parts of the test bar and taking the ratio of the extended gauge length to the original gauge length. Alternatively, the elongation may be measured directly by means of an extensometer.

6.3.4 Test results

Test results shall comply with Table 8. If they do not comply, the manufacturer shall:

a) in the case where the metal does not achieve the required mechanical properties, investigate the reason and ensure that all castings in the batch are either re-heat-treated or rejected; castings which have been re-heat-treated are then re-tested as specified in 6.3;

b) in the case of a defect in the test bar, carry out a further test. If it passes, the batch is accepted; if not, the manufacturer has the option to proceed in accordance with a) above.

NOTE The manufacturer can limit the amount of rejection by making additional tests, in order of manufacture, until the rejected batch of castings is bracketed by a successful test at each end of the interval in question.

6.3.5 Test frequency

The frequency of testing is related to the system of production and quality control used by the manufacturer (see 4.3.1). The maximum batch sizes shall be as given in Table 12.

Table 12 — Maximum batch sizes for tensile testing

Type of casting	DN	Maximum batch size	
		Batch sampling system	Process control testing system
Centrifugally cast pipes	40 to 300	200 pipes	1 200 pipes
	350 to 600	100 pipes	600 pipes
	700 to 1000	50 pipes	300 pipes
	1100 to 2600	25 pipes	150 pipes
Pipes not cast centrifugally, fittings and accessories	All sizes	4 t [a]	48 t [a]

[a] Mass of crude castings, excluding risers.

6.4 Brinell hardness

When Brinell hardness tests are carried out (see 4.3.2), they shall be performed either on the casting in dispute or on a sample cut from the casting. The surface to be tested shall be suitably prepared by slight local grinding, and the test shall be carried out in accordance with ISO 6506-1, using a ball of 2,5 mm or 5 mm or 10 mm diameter.

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