
**Internal protection by polymeric
lining for ductile iron pipes —
Requirements and test methods —**

**Part 2:
Epoxy lining**

*Protection interne des tuyaux en fonte ductile par revêtement
polymérique — Exigences et méthodes d'essai —*

Partie 2: Revêtement époxy

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Published in Switzerland

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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

A list of all parts in the ISO 24131 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The ISO 24131 series specifies the requirements and test methods applicable to factory applied polymeric linings for ductile iron pipes according to ISO 2531, ISO 7186 and ISO 16631. The ISO 24131 series is intended to include several types of polymeric linings.

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Internal protection by polymeric lining for ductile iron pipes — Requirements and test methods —

Part 2: Epoxy lining

1 Scope

This document specifies the requirements and test methods applicable to factory applied internal epoxy lining for ductile iron pipes according to ISO 2531, ISO 7186 and ISO 16631.

It covers internal linings for use in the conveyance of raw water, potable water and sewage water for operating temperature up to 50 °C.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 2531, *Ductile iron pipes, fittings, accessories and their joints for water applications*

ISO 4624, *Paints and varnishes — Pull-off test for adhesion*

ISO 7186:2011, *Ductile iron products for sewerage applications*

ISO 11357-2, *Plastics — Differential scanning calorimetry (DSC) — Part 2: Determination of glass transition temperature and step height*

ISO 16631, *Ductile iron pipes, fittings, accessories and their joints compatible with plastic (PVC or PE) piping systems, for water applications and for plastic pipeline connections, repair and replacement*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2531 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1

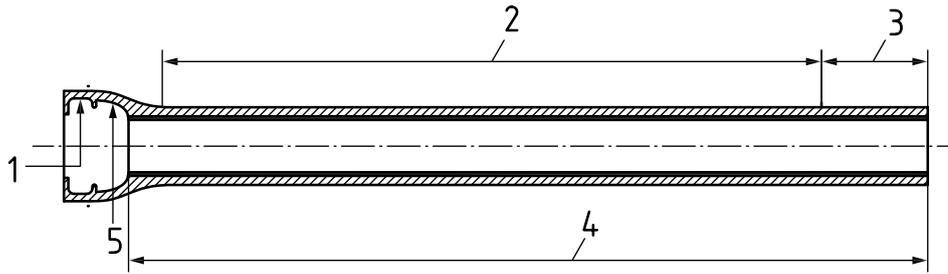
epoxy lining

factory applied lining

Note 1 to entry: It can be with either

- fusion bonded epoxy powder applied by spraying or dipping in a fluidised bed on preheated parts, with or without post curing, or
- two-pack liquid epoxy consisting of a base and a catalyst component which are mixed together in the proportion specified by the manufacturer before application.

Note 2 to entry: See [Figure 1](#).



Key

- 1 gasket seat
- 2 pipe barrel
- 3 spigot end
- 4 lining
- 5 internal socket profile

Figure 1 — Location of the defined pipe areas

3.2

epoxy

family of basic components or cured end products of epoxy resins, which are a class of reactive prepolymers and polymers which contain epoxide groups

Note 1 to entry: Epoxy is created by mixing two different compounds known as a resin and a hardener.

3.3

operating temperature

applicable temperatures under which the product maintains its properties

3.4

chalking

superficial reaction of *epoxy lining* (3.1) due to exposure to UV-radiation

Note 1 to entry: The process is confined to the surface only and results in a dulling of the surface.

3.5

minimum lining thickness

minimum value of the lining thickness measured at the lined item

3.6

local thickness

measured thickness at any one point of one lined product

3.7

adhesion

pull off test

force per unit area, applied perpendicular to the surface, which is necessary to separate the lining from its substrate

3.8

cross linkage

chemical reaction between epoxy resin and hardener to form the final cured lining

3.9

non-porosity

absence of electrical puncture in a high voltage test (holiday test) under defined test conditions

3.10**protection of pipe ends**

factory applied coating/lining on spigot end and internal socket profile of pipes

Note 1 to entry: See [Figure 1](#).

3.11**abrasion resistance**

ability of materials and structures to withstand abrasion

3.12**impact resistance**

energy which a lining can withstand without damage under defined test conditions

3.13**indirect impact resistance**

impact energy applied from outside of the pipe with deformation to which a lining can withstand without damage under defined test conditions

3.14**ovalization**

100 times the measured vertical deflection, (caused by the applied load) divided by the measured pipe external diameter

3.15**routine test**

test carried out to control the manufacturing process

Note 1 to entry: The frequency of the test is defined by this document or the manufacturer.

3.16**performance test**

test which is done once and thereafter only when there is a change in the lining material or lining process

4 Technical requirements**4.1 General**

The following technical requirements shall be demonstrated by routine tests applied in production, on in-process and finished lined products with defined frequency. Routine tests shall be in accordance with the overview of requirements provided in [Table A.2](#).

Quality assurance for epoxy lining shall be in accordance with [Annex A](#).

4.2 Surface preparation

Prior to lining application, all surfaces to be lined shall be substantially clean and free from oil, grease and moisture.

In cold weather, or anytime when moisture tends to condense on the surface of the pipe, it shall be uniformly warmed for sufficient time to dry prior to cleaning. The surface temperature shall be maintained at least 3 °C above the dew point.

Surface preparation shall be designed in order to reach the required performances specified in this document. It is the responsibility of the manufacturer to demonstrate the fitness for purpose of surface

preparation technology and to put in place a quality control procedure to ensure the stability of those performances.

NOTE The requirements of Class Sa 2.5 of ISO 8501-1 and \leq Rating 3 dust quantity and Class 2 for dust size of ISO 8502-3 can be applied.

4.3 Lining appearance

The lining of the final product shall be of

- uniform colour, except for permitted marking;
- uniform appearance and smoothness, except for allowable repairs;
- free of visible defects (i.e. pinholes, bubbles, blisters, wrinkles, cracks or voids).

Slight superficial colour variations due to repairs or long exposure to sunlight (chalking) are permissible.

4.4 Minimum lining thickness

When measured in accordance with the method defined in 6.1.3, the minimum local thickness shall be greater than 200 μm and the minimum average thickness shall be greater than or equal to 250 μm .

4.5 Adhesion (pull off test/cross cut knife test)

Adhesion (pull off test) shall be tested in accordance with the test method defined in 6.1.4 on production samples.

The lining adhesion shall achieve an average value of at least 8,0 MPa and a minimum single value of 6,0 MPa. The manufacturer shall determine the test locations on the products.

Alternatively, the adhesion test can also be done by cross cut knife test method. Where the cross knife test is chosen for adhesion, it shall be carried out according to Annex B. The adhesion rating shall be no more than level 2.

4.6 Cross linkage (MIBK/ ΔT_g)

When tested in accordance with the test method defined in 6.1.5, after wiping with a methyl isobutyl ketone (MIBK) solution, the cloth and the lining surface shall be visually examined. Any discolouration, matting and/or smearing observed shall not exceed the limits specified by the lining manufacturer.

Alternatively, the cross linkage of lining can be determined by its change in glass transition temperature (ΔT_g) and ΔT_g shall be no more than 5 $^{\circ}\text{C}$.

4.7 Non-porosity

When tested in accordance with the test method described in 6.1.6, with a voltage of 1 500 V, the lined body of the product shall be free from porosity. This means that no electrical puncture should occur. This requirement does not apply to pipe ends.

The electrode shall not be damaged and shall be in constant touch with the lining.

4.8 Protection of pipe ends

Spigot end and internal socket profile (see Figure 1) shall be coated in accordance with ISO 2531, ISO 7186 and ISO 16631.

4.9 Marking

All pipes shall be marked legibly and durably according to the pipe standards, ISO 2531, ISO 7186 and ISO 16631. Reference to this document shall be legibly and durably applied by any method upon the external surface.

Marking shall be checked in accordance with the test method described in [6.1.7](#).

4.10 Repairs

Repairs shall be carried out when there is a fault. The fault can be

- localized damage,
- holding point,
- earthing surface for the non-porosity test, or
- other lining fault.

The lining manufacturer should establish the repair procedure. The material to be used shall satisfy two conditions:

- be suitable for protecting pipes under the required service conditions;
- be compatible in all aspects with the previously applied lining.

The repairs shall conform to the requirements specified in [4.4](#), [4.6](#) and [4.7](#).

The information about handling, transportation and storage of epoxy lined pipes is given in [Annex C](#).

5 Performance requirements

5.1 General

The following technical requirements shall be demonstrated by performance tests in order to verify the lining material and process prior to production lining. Performance tests shall be in accordance with the overview of requirements provided in [Table A.1](#). Where there is a change of lining material or process, the performance tests shall be undertaken on the new lining material or process.

5.2 Materials in contact with water intended for human consumption

When used under the conditions for which it is designed, in permanent or in temporary contact with water intended for human consumption, the lining shall not have any detrimental effects on the properties of that water for its intended use.

When used for conveying water intended for human consumption, the lining materials in contact with the water shall meet the relevant requirements of ISO 2531, or the national standards or regulations in the country of use with respect to effect on water quality.

5.3 Abrasion resistance only for sewage applications

The linings shall conform to the requirements of abrasion resistance in accordance with ISO 7186:2011, 7.7.

5.4 Chemical resistance only for sewage applications

The linings shall conform to the requirements of chemical resistance in accordance with ISO 7186:2011, 7.6. If needed, the chemical resistance test can be performed at pH 1 by agreement between manufacturer and purchaser.

5.5 Impact resistance

When tested in accordance with the test method described in [6.2.3](#), no holidays shall be permitted.

5.6 Indirect impact resistance

Due to handling activities and pipe laying, the epoxy lined pipes can be impacted from the outside causing minor deformations and damages to the lining.

The minimum impact resistance shall be determined in accordance with the test defined in [6.2.4](#) with an impact energy of at least 50 J.

The lining shall subsequently show no damage when tested in accordance with [6.1.6](#).

5.7 Resistance to hot water

When tested in accordance with the test method defined in [6.2.5](#) the lining adhesion shall meet a minimum requirement of 6,0 MPa. In addition, on visual examination there shall be no cracks, wrinkles, disbondment or blisters.

5.8 Resistance to ovalization

There shall be no detrimental damage to the lining when the lined pipe is tested according to [6.2.6](#) and subjected to an ovalization not less than given in [Table 1](#). This shall be checked by visual inspection and non-porosity test (see [6.1.6](#)) while the pipe is under load.

Table 1 — Pipe ovalization

Nominal size DN	Pipe ovalization %
80 to 250	2
300 to 600	3
≥700	4

After the above test, the lining shall withstand without failure an ovalization equal to not less than twice the value given in [Table 1](#). This shall be checked by visual inspection.

6 Test methods

6.1 Routine tests

6.1.1 Surface preparation

The blasted or ground surface of the product shall be visually checked for its conformity. It is the responsibility of the manufacturer to demonstrate the fitness for purpose of surface preparation technology and to put in place a quality control procedure to ensure the stability of those performances.

6.1.2 Lining appearance

The appearance of the finished lining shall be checked visually.

6.1.3 Lining thickness

The thickness of the lining shall be measured with non-destructive instruments (e.g. based on magnetic or electro-magnetic principles) with a measuring accuracy of $\pm 2\%$.

A minimum of 10 measurements evenly distributed over the circumference at each end of the pipe (between 100 mm and 300 mm after the spigot end and socket end) shall be carried out prior to the determination of the minimum value.

6.1.4 Adhesion

Adhesion (pull off/cross cut knife) shall be defined on surfaces of a lined product, or coated test plates (if more convenient). The test plates should be manufactured of identical material and coated by the identical process. In order to properly test the adhesion of the lining to the surface, the test areas shall be selected in such a way that the lining thickness is no less than 250 μm .

Pull off test shall be conducted as specified in ISO 4624.

If fracture is only associated with the adhesive and the result is less than 8,0 MPa, the test may be deemed as a no-test, and another test should be performed with a suitable adhesive for the lining.

Cross cut knife test shall be carried out according to [Annex B](#).

6.1.5 Cross linkage (MIBK/ ΔT_g)

The test shall be conducted using MIBK.

On a dust-free lined product, a clean white cloth dipped in MIBK shall be rubbed repeatedly on the surface over an area of at least 16 cm^2 for a period of (30 ± 5) s. The colour and the nature of both the cloth and the lined surface shall be noted.

The limits of discolouration, matting and/or smearing can be compared by testing the reference lined fresh sample supplied by the lining manufacturer.

The change in glass transition temperature ΔT_g of the lining reference sample shall be determined by differential scanning calorimetry (DSC) in accordance with ISO 11357-2.

6.1.6 Non-porosity

A holiday detector set at a voltage of 1 500 V and conductive rubber test electrodes are required as test instruments. A pulsed holiday detector shall be used unless there is an earthing electrode connected directly to the metal surface. The use of the detector shall follow the manufacturer's instructions. The holiday detector's suitability shall also be checked by demonstrating that it can detect a 1 mm diameter holiday drilled through the lining (in a lined surface) when set at the required 1 500 V.

During the measurement, the test electrode shall traverse all the lined surface with intimate contact, because any significant air gap results in a lower voltage being applied to the lining. The test electrode should be moved slowly with a maximum movement rate of 0,2 m/s. Holidays shall be indicated by an acoustic and/or optical signal from the test device.

6.1.7 Marking

The marking of the finished lining shall be checked visually.

6.1.8 Repairs

Repairs shall be carried out according to the manufacturer's written instructions and then subjected to visual inspection. All repairs shall subsequently meet the non-porosity test requirements.

6.2 Performance test

6.2.1 Abrasion resistance only for sewage applications

Abrasion test shall be conducted in accordance with ISO 7186:2011, 7.7.

6.2.2 Chemical resistance only for sewage applications

Chemical resistance test shall be conducted in accordance with ISO 7186:2011, 7.6.

6.2.3 Impact resistance

The impact resistance strength shall be tested by dropping a weight on the lining with a given energy and checking for the absence of lining holidays. The sample to be tested shall be supported by a rigid construction so that the impact energy caused by the impact of the falling weight is absorbed by the sample. The test specimen shall have a wall thickness no less than 6 mm. The lining thickness at the position of impact shall be no greater than 350 μm . The front surface of the falling weight shall be a section of a sphere of hardened steel with a diameter of 25 mm.

The test shall be carried out at a temperature of 18 °C to 25 °C. The impact energy shall not be less than 2,5 J \pm 5 %. Care shall be taken to ensure that as little as possible friction occurs when the falling weight is dropped.

Ten impacts, separated by at least 30 mm, shall be carried out. The occurrence (or not) of holidays shall be tested at each impact using the non-porosity test defined in [6.1.6](#). There should be no holiday resulting from any of the 10 impacts.

6.2.4 Indirect impact resistance

In order to test the impact resistance strength, the specimen (pipe or pipe shell with lining) shall be supported in such a way that the spring action of the specimen caused by the impact of falling weight is absorbed. The front surface of the weight used in the test (5 000 g) shall be part of a spheroidal surface (diameter of sphere 25 mm). The height of fall of the falling weight shall be 100 cm; the impact energy shall be adjusted to within 5 %. Care shall be taken to ensure that the impact energy is maintained at a constant level by ensuring that little or no friction is encountered when the falling weight is dropped. The test with 10 impacts at a minimum distance of 30 mm each shall be carried out at an ambient temperature of (23 \pm 2) °C.

Any damage to the lining shall be detected immediately after impact according to the non-porosity test defined in [6.1.6](#).

The pressure class, nominal diameter of the pipe and the impact energy shall be indicated in the test report.

6.2.5 Resistance to hot water

The test shall be carried out with six pieces of lined products. The test samples shall be immersed for 7 d in deionized water at (70 \pm 2) °C, or 14 d at (60 \pm 2) °C.

After this test period, the samples shall be taken from the water bath, cooled and dried. The samples shall be immediately prepared for testing and shall be tested in accordance with [6.1.4](#) within 24 h after removal from the hot water.

6.2.6 Resistance to ovalization

The test shall be carried out on a pipe section (500 \pm 20) mm long, cut from the pipe barrel. The pipe section shall be placed on a support approximately 200 mm wide and 600 mm long, having a V shape with an angle between 170 °C and 180 °C. The load shall be applied at the pipe crown through a loading beam approximately 50 mm wide and 600 mm long. Both the V shape support and the loading beam

shall be covered with a sheet of elastomer with a thickness of (10 ± 5) mm and a hardness greater than or equal to 50 IRHD.

The load shall be increased steadily until the pipe ovalization reaches the relevant value given in [Table 1](#). The integrity of the lining shall be checked by visual inspection and by the non-porosity test defined in [6.1.6](#).

The load shall then be increased steadily until the vertical deflection reaches twice the value previously measured. The absence of lining failure shall be checked by visual inspection.

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Annex A (normative)

Quality assurance

A.1 General

The manufacturer should demonstrate the conformity of the product with this document by carrying out performance tests in accordance with [Table A.1](#) and routine tests in accordance with [Table A.2](#).

Table A.1 — Performance tests

No.	Test	Requirement	Subclause	Test method	Subclause
1	Materials in contact with potable water	National standards	5.2	National standards	-
2	Abrasion resistance only for sewage applications	ISO 7186	5.3	ISO 7186	6.2.1
3	Chemical resistance only for sewage applications	ISO 7186	5.4	ISO 7186	6.2.2
4	Impact resistance	No holiday after impact	5.5	Impact energy 2,5 J	6.2.3
5	Indirect impact resistance	No holiday after impact from outside	5.6	Impact energy 50 J	6.2.4
7	Resistance to hot water	Minimum adhesion $\geq 6,0$ MPa, after immersion in hot water	5.7	Immersion for 7 d at 70 °C or 14 d at 60 °C	6.2.5
8	Ovalization resistance	No damage	5.8	Static deformation test, holiday test, visual inspection	6.2.6

Table A.2 — Routine tests

No.	Test	Requirement	Subclause	Test method, minimum frequency	Subclause
1	Surface preparation	Defined by each manufacturer	4.2	Visual, 100 % of surface	6.1.1
2	Lining appearance	Uniform, free of visual defects	4.3	Visual, 100 % of surface	6.1.2
3	Lining thickness	Average thickness ≥ 250 μm (lining area)	4.4	Non-destructive method, once per shift	6.1.3
4	Adhesion (pull off test or cross cut knife test)	Average adhesion $\geq 8,0$ MPa, with the minimum $\geq 6,0$ MPa/ or No more than rating 2	4.5	Pull off method, 1/1 000 and at least once per week or Cross cut knife test, once per day	6.1.4 - Annex B
5	Cross linkage (MIBK or DSC)	No deviation against reference test sample/ $\Delta T_g \leq 5$ °C	4.6	MIBK test, once per shift/ DSC test once per week	6.1.5

Table A.2 (continued)

No.	Test	Requirement	Subclause	Test method, minimum frequency	Subclause
6	Non-porosity	No electrical puncture at 1,5 kV	4.7	High voltage test, once per shift	6.1.6

A.2 Performance tests, pipe size grouping

In order to ensure the fitness of the lining material, process and the products to be lined, all the pipes shall fulfil the technical requirements of [Clause 4](#) and performance requirements of [Clause 5](#).

In order to demonstrate this, the performance tests of [Clause 6](#) shall be performed on at least one DN for each of the groupings given in [Table A.3](#). One DN is representative of a grouping when the performances are based on the same design parameters and lining process 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, this DN may be considered as part of the adjacent grouping provided that it is of identical design and manufactured by the same process.

Table A.3 — DN grouping

DN grouping	80 to 250	300 to 600	700 to 1 000	1 100 to 2 000	2 200 to 2 600
Preferred DN in each grouping	200	400	800	1 600	2 400

A.3 Quality assurance system

The manufacturer controls the quality of the products during their manufacture by a system of process control in order to conform to the technical requirements of this document.