INTERNATIONAL STANDARD

ISO 15741

First edition
2001-12-15

Paints and varnishes — Friction-reduction coatings for the interior of on- and offshore steel pipelines for non-corrosive gases

Peintures et vernis — Revêtements réduisant le frottement pour l'intérieur de gazoducs en acier enterrés et immergés pour le transport de gaz non corrosifs

Reference number
ISO 15741:2001(E)

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

International Standard ISO 15741 was prepared by Technical Committee ISO/TC 35, *Paints and varnishes*, Subcommittee SC 14, *Protective paint systems for steel structures*.

Annexes A, B, C, D, E, F and G form a normative part of this International Standard.

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Introduction

Internal coating of pipelines is used to reduce friction and improve the flow conditions when conveying non-corrosive gases, and to offer sufficient corrosion protection during storage and transport of the pipes. The reduction in friction depends on various parameters like the pressure and temperature of the gas, and the diameter of the pipe. Therefore it is not possible to give a single figure for this reduction in friction.

In order to establish sufficient corrosion protection and to ensure optimum performance of the internal coating in the steel pipes, it is necessary for owners of pipelines, planners, consultants, companies carrying out the work, inspectors of protective coatings and manufacturers of coating materials to have at their disposal state-of-the-art information in concise form including requirements for the coating. Such information has to be as complete as possible, unambiguous and easily understandable to avoid difficulties and misunderstandings between the parties concerned.

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Paints and varnishes — Friction-reduction coatings for the interior of on- and offshore steel pipelines for non-corrosive gases

1 Scope

This International Standard specifies requirements and methods of test for liquid epoxy paints and internal coatings of such paints in steel pipes and fittings for the conveyance of non-corrosive gas. It also deals with the application of the paint. Other paints or paint systems are not excluded provided they comply with the requirements given in this International Standard. The coating consists of one layer, which is normally shop-applied on blast-cleaned steel by airless spray or other suitable spraying techniques. The applied and cured paint film must be smooth to give the desired reduction in friction. Brush application is only used for small repair jobs.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 2409:1992, *Paints and varnishes — Cross-cut test*

ISO 2431:1993, *Paints and varnishes — Determination of flow time by use of flow cups*

ISO 2808:1997, *Paints and varnishes — Determination of film thickness*

ISO 2811 (all parts), *Paints and varnishes — Determination of density*

ISO 2812-1:1993, *Paints and varnishes — Determination of resistance to liquids — Part 1: General methods*

ISO 2812-2:1993, *Paints and varnishes — Determination of resistance to liquids — Part 2: Water immersion method*

ISO 2815:—[1)], *Paints and varnishes — Buchholz indentation test*

ISO 3233:1998, *Paints and varnishes — Determination of percentage volume of non-volatile matter by measuring the density of a dried coating*

ISO 3251:—[2)], *Paints, varnishes and plastics — Determination of non-volatile-matter content*

ISO 6743-4:1999, *Lubricants, industrial oils and related products (class L) — Classification — Part 4: Family H (Hydraulic systems)*

ISO 6860:1984, *Paints and varnishes — Bend test (conical mandrel)*

ISO 7253:1996, *Paints and varnishes — Determination of resistance to neutral salt spray (fog)*

1) To be published. (Revision of ISO 2815:1973)

2) To be published. (Revision of ISO 3251:1993)

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ISO 8501-1:1988, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings*

ISO 8503-1:1988, *Preparation of steel substrates before application of paints and related products — Surface roughness characteristics of blast-cleaned steel substrates — Part 1: Specifications and definitions for ISO surface profile comparators for the assessment of abrasive blast-cleaned surfaces*

ISO 8503-2:1988, *Preparation of steel substrates before application of paints and related products — Surface roughness characteristics of blast-cleaned steel substrates — Part 2: Method for the grading of surface profile of abrasive blast-cleaned steel — Comparator procedure*

3 Terms and definitions

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

3.1
coat
a continuous layer of a coating material resulting from a single application

[ISO 4618-1]

3.2
coater
the company which is responsible for application of the coating material in accordance with the provisions of this International Standard

3.3
coating material manufacturer
the supplier of the coating material

3.4
corrosion
physico-chemical interaction between a metal and its environment which results in changes in the properties of the metal and which may often lead to impairment of the function of the metal, the environment or the technical system of which these form a part

[ISO 8044]

3.5
dry film thickness (DFT)
the thickness of a coating remaining on the surface when the coating has hardened

[ISO 12944-5]

3.6
natural gas
complex mixture of hydrocarbons, primarily methane, but generally also including ethane, propane and higher hydrocarbons in much smaller amounts and some non-combustible gases, such as nitrogen and carbon dioxide

[ISO 14532]

3.7
nominal dry film thickness
NDFT
the dry film thickness specified for each coat or for the whole paint system to achieve the required durability

[ISO 12944-5]

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3.8
paint
a pigmented coating material in liquid or in paste or powder form which, when applied to a substrate, forms an opaque film having protective, decorative or specific technical properties

[ISO 4618-1]

3.9
pinhole
film defect characterized by small pore-like flaws in a coating which extend entirely through the applied film and have the general appearance of pinpricks when viewed by reflected light

3.10
pot life
the maximum time during which a coating material supplied as separate components should be used after they have been mixed together

[ISO 4618-1]

3.11
purchaser
the organization or individual that buys the coated pipes and fittings

3.12
substrate
the surface to which the coating material is applied or is to be applied

[ISO 4618-1]

3.13
tack-free
the state of a coating when a finger touching the surface no longer leaves a pronounced mark

4 Coating material

4.1 General

The coating material shall typically be a two-pack epoxy paint. It shall not contain any substances which will be released from the paint film after it has cured and are proven to be detrimental to the operation of the pipeline and the quality of the gas.

Unless otherwise agreed, the coating material shall be qualified in accordance with 4.2 and 4.3 and shall not be changed after qualification.

The manufacturer of the coating material shall provide on request infrared spectrograms of the base component and the curing agent component (see 4.2.8).

In addition, the manufacturer shall provide a product data sheet (see 4.6), a health and safety data sheet and a certificate stating the test results obtained in accordance with 4.2 and 4.3 respectively and, if applicable, deviating test conditions.

The manufacturer shall also provide with every batch of the coating material a batch test certificate stating the information as given in 4.8.

Unless otherwise agreed, the applied coating shall provide corrosion protection during storage and transport for a minimum period of one year without significant breakdown of the coating.

The typical operating-temperature range for this type of coating is between −20 °C and 110 °C.

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Where, subsequently, external coatings have to be applied, care shall be taken not to allow the internal coating to be damaged by the elevated temperatures which may occur.

4.2 Particular requirements for qualification of the coating material

4.2.1 General

The following subclauses describe the laboratory test methods which are required for qualification of the coating material.

4.2.2 Non-volatile matter (by mass)

When determined in accordance with ISO 3251, the non-volatile matter (by mass) of the coating material shall comply with the value specified by the coating material manufacturer in the qualification certificate (Table 2).

4.2.3 Non-volatile matter (by volume)

When determined in accordance with ISO 3233, the non-volatile matter (by volume) of the coating material shall comply with the value specified by the coating material manufacturer in the product data sheet (Table 1).

4.2.4 Viscosity

When determined by the method specified by the manufacturer, the viscosity of the ready-mixed coating material shall comply with the value specified by the coating material manufacturer in the qualification certificate (Table 2).

The viscosity should preferably be measured in accordance with ISO 2431.

4.2.5 Density

When determined in accordance with one of the parts of ISO 2811, the density of the coating material shall comply with the value specified by the coating material manufacturer in the product data sheet (Table 1).

4.2.6 Ash (residue on ignition)

When determined in accordance with the method described in annex A, the ash (residue on ignition) of the coating material shall comply with the value specified by the coating material manufacturer in the qualification certificate (Table 2).

4.2.7 Pot life

The pot life is considered to be the time taken by the ready-mixed coating material to reach a condition at which it can no longer be applied satisfactorily. The pot life shall be specified in the product data sheet (see 4.6).

4.2.8 Infrared spectrograms

Infrared spectrograms of the base component and the curing agent component shall be submitted on request.

4.2.9 Appearance

The appearance and continuity of the coating shall be inspected visually without any magnification.

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4.3 Particular requirements for qualification of the cured paint film

4.3.1 Preparation of test panels

Perform the tests specified in 4.3.3 to 4.3.12 on coatings applied to the required dry film thickness specified in 4.3.3 by spraying on to test panels (steel or glass). Prepare steel test panels as specified in 5.2 and glass panels as specified in annex E. Apply the paint in accordance with the instructions of the coating material manufacturer. Perform each test at least in duplicate.

4.3.2 Conditioning of test panels

If specified, condition the coated test panels using one of the following cycles, depending on the substrate and on the individual test. Cycle B and cycle C are optional and the choice of the conditioning cycle depends on the time available to perform the test procedure.

Cycle A

Substrate: steel or glass

— condition at 18 °C to 25 °C and $\leqslant$ 80 % relative humidity until the coating is at least tack-free (see 3.13);

— dry for 30 minutes in a circulating-air oven at (75 ± 2) °C;

— condition for a minimum of 30 minutes at 18 °C to 25 °C and $\leqslant$ 80 % relative humidity before testing.

Cycle B

Substrate: steel or glass

— condition at 18 °C to 25 °C and $\leqslant$ 80 % relative humidity until the coating is at least tack-free (see 3.13);

— dry for 30 minutes in a circulating-air oven at (150 ± 2) °C;

— condition for a minimum of 30 minutes at 18 °C to 25 °C and $\leqslant$ 80 % relative humidity before testing.

Cycle C

Substrate: steel or glass

— condition at 18 °C to 25 °C and $\leqslant$ 80 % relative humidity until the coating is at least tack-free (see 3.13);

— dry for 30 minutes in a circulating-air oven at (40 ± 2) °C;

— condition for a minimum of 30 minutes at 18 °C to 25 °C and $\leqslant$ 80 % relative humidity before testing.

4.3.3 Dry film thickness

Unless otherwise agreed, the dry film thickness of the coating, applied on a glass or steel panel, shall be between 60 μm and 100 μm except for the test described in 4.3.6 (resistance to neutral salt spray).

Unless otherwise agreed, the dry film thickness shall be measured in accordance with ISO 2808:1997, Method No. 2 for glass and Method No. 10 for blast-cleaned steel, following the procedure given in annex B.

4.3.4 Adhesion

When determined in accordance with ISO 2409, the cross-cut classification of the coating applied on steel panels and conditioned using cycle B or C (see 4.3.2) shall be equal to or lower than 1.

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4.3.5 Buchholz hardness

When determined in accordance with ISO 2815, the Buchholz hardness of the coating, applied on glass or steel panels and conditioned using cycle B or C (see 4.3.2) shall have a value of 94 or more.

4.3.6 Resistance to neutral salt spray

The coating, applied on steel panels with a dry film thickness of 60 μm to 75 μm, conditioned using cycle B or C (see 4.3.2), and with an X-cut down to the substrate located at least 20 mm from any edge, shall be tested in accordance with ISO 7253 for 480 h.

After the test, allow the test panels to dry for at least 30 min at 18 °C to 25 °C and $\leqslant$ 80 % relative humidity.

The coating shall be free from any signs of deterioration, for example blistering (except in the area within 2,0 mm from the X-cut), cracking and staining. Any corrosion shall extend not more than 2,0 mm at the most from the X-cut. It shall not be possible to remove by means of clear plastic tape more than 3,0 mm of the coating in any direction from the area around the X-cut.

4.3.7 Resistance to artificial ageing

Prepare two different sets of coated test panels, each set consisting of 3 steel panels. The dimensions of the panels shall be approx. 100 mm $\times$ 50 mm $\times$ 0,8 mm.

Carry out the following procedure:

— condition set 1 using cycle C (see 4.3.2);

— condition set 2 using cycle C (see 4.3.2) and then age the panels at 80 °C in a circulating-air oven for 100 h, followed by conditioning for 24 h at 18 °C to 25 °C and $\leqslant$ 80 % relative humidity;

— after ageing, subject the test panels to a bend test in accordance with 4.3.8.

The result of the bend test shall comply with the requirement specified in 4.3.8.

4.3.8 Bend test (conical mandrel)

Prepare steel panels and condition them using cycle B or C (see 4.3.2). When the panels are tested in accordance with ISO 6860, the maximum extent of cracking along the panel from the small end of the mandrel shall be less than or equal to 13 mm, and there shall be no loss of adhesion.

4.3.9 Resistance to gas pressure variations

Prepare steel panels and condition them using cycle B or C (see 4.3.2). When the panels are tested in accordance with annex C, they shall have a generally good appearance when examined in accordance with 4.2.9 and shall not show any blistering. The adhesion value shall fulfil the requirements as given in 4.3.4 after conditioning for 24 h and 40 h at 18 °C to 25 °C and $\leqslant$ 80 % relative humidity.

4.3.10 Resistance to water immersion

Prepare steel panels and condition them using cycle B or C (see 4.3.2). When the panels are tested in accordance with ISO 2812-2 for 480 h, the coating shall not show any blistering or appreciable softening. The examination shall be carried out 3 min after the panels have been removed from the test liquid.

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4.3.11 Resistance to chemicals

Prepare steel panels and condition them using cycle B or C (see 4.3.2). When the panels are tested in accordance with ISO 2812-1:1993, Method No. 1, Procedure A, for 168 h, the coating shall not show any blistering or appreciable softening. Use the following test liquids: cyclohexane; 95 % by volume diethylene glycol solution in water; hexane; methanol; toluene and lubricating oil (e.g. compressor seal oil in accordance with ISO 6743-4). The test panels shall be completely immersed in the test liquid.

The examination shall be carried out at 18 °C to 25 °C and $\leqslant$ 80 % relative humidity 3 min after the panels have been removed from the test liquid. After conditioning for 24 h at 18 °C to 25 °C and $\leqslant$ 80 % relative humidity, the adhesion value shall fulfil the requirements given in 4.3.4. A change in the colour of the coating shall not be considered as an indication of inferior coating quality.

4.3.12 Resistance to hydraulic blistering

Prepare steel panels and condition them using cycle B or C (see 4.3.2). When the panels are tested in accordance with annex D, the coating shall not show any blistering. The examination shall be carried out at 18 °C to 25 °C and $\leqslant$ 80 % relative humidity 3 min after the panels have been removed from the test liquid. The adhesion value shall fulfil the requirements given in 4.3.4 after conditioning at 18 °C to 25 °C and $\leqslant$ 80 % relative humidity for 24 h.

4.4 Packaging, labelling and storing

All coating materials and solvents shall be stored in the original container bearing the manufacturer's label and instructions. At least the following information shall be shown on the label:

— the name of the coating material;

— the name of the manufacturer of the coating material;

— the colour of the coating material;

— the batch number;

— instructions and warnings regarding health, safety and environmental protection;

— a reference to the relevant product data sheet;

4.5 Quality assurance

It is necessary to ensure that the goods or services supplied comply in all respects with the requirements of this International Standard. The coater shall therefore set up and maintain a quality assurance system as, for example, detailed in ISO 9001.

The purchaser shall have the right to undertake inspection and testing of the coated goods during any stage of coating at which the quality of the finished goods may be affected and to undertake inspection or testing of coating materials, or other materials used, to ensure compliance with the requirements given in 4.2 and 4.3.

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4.6 Product data sheet

The coating material manufacturer's product data sheet shall give information regarding at least the items listed in Table 1.

Table 1 — Minimum information to be included in product data sheet

Date of issue	
Name of coating material	
Name of coating material manufacturer	
Colour of coating material	
Type of curing agent	
Shelf life	
Non-volatile matter by volume [a]	Test method used (see 4.2.3)
Density [b]	Test method used (see 4.2.5)
Pot life [a]	(see 4.2.7)
Flash point [c]	
Time to complete curing	
Recommended thinner	
Maximum allowed quantity of thinner, in %	
Recommended surface preparation grade	
Recommended method of application	
Recommended maximum/minimum dry film thickness of the applied coating	
Recommended cleaning solvent (for the application equipment)	
Recommended application conditions (air and steel temperature and relative humidity)	
Recommended minimum curing conditions	
Recommended maximum/minimum service temperature	
Recommended storage conditions	
Reference to instructions and warnings regarding health, safety and environmental protection	
Theoretical spreading rate (l/m^2 or kg/m^2) for a given dry film thickness	

[a] Only for the mixed coating material.

[b] Give separately for base component and curing agent component (if pigmented).

[c] Give separately for base component, curing agent component and mixed coating material.

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4.7 Qualification certificate

The qualification certificate shall give, as a minimum, the values of the properties listed in Table 2.

Table 2 — Minimum information to be included in qualification certificate

Date of issue		
Name of coating material		
Name of coating material manufacturer		
Authority for issue		
Property	**Test method**	**Subclause**
Non-volatile matter by mass [a]	ISO 3251	See 4.2.2
Ash [b]	Annex A	See 4.2.6
Viscosity [c]		See 4.2.4
Adhesion	ISO 2409	See 4.3.4
Buchholz hardness	ISO 2815	See 4.3.5
Resistance to neutral salt spray	ISO 7253	See 4.3.6
Resistance to artificial ageing		See 4.3.7
Bend test (conical mandrel)	ISO 6860	See 4.3.8
Resistance to gas pressure variations	Annex C	See 4.3.9
Resistance to water immersion	ISO 2812-2	See 4.3.10
Resistance to chemicals — Resistance to cyclohexane — Resistance to 95 % by volume diethylene glycol solution in water — Resistance to hexane — Resistance to methanol — Resistance to toluene — Resistance to lubricating oil (e.g. compressor seal oil)	ISO 2812-1	See 4.3.11
Resistance to hydraulic blistering	Annex D	See 4.3.12

[a] Separately for base component, curing agent component and mixed coating material.

[b] Separately for base component and curing agent component (if pigmented).

[c] Only for the mixed coating material.

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4.8 Batch test certificate

The batch test certificate shall give, as a minimum, the information and test results for the items listed in Table 3.

Table 3 — Minimum information to be included in batch test certificate

Item	Test method	Information from the coating material manufacturer	Test result
Date of issue			
Batch number			
Name of coating material			
Name of coating material manufacturer			
Production date			
Expiry date for use			
Non-volatile matter by mass — base component	See 4.2.2		
Non-volatile matter by mass — curing agent component [a]	See 4.2.2		
Viscosity — base component	[b]		
Viscosity — curing agent component	[b]		
Density — base component	See 4.2.5		
Density — curing agent component	See 4.2.5		
Ash — base component [c]	See 4.2.6		
Ash — curing agent component [c, d]	See 4.2.6		
Infrared spectrogram [d, e]	See 4.2.8		

[a] The non-volatile matter by mass of the curing agent component shall not be used for any purposes other than batch consistency checks.

[b] As specified by the coating material manufacturer.

[c] If required.

[d] If pigmented.

[e] Separately for base component and curing agent component.

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5 Application of the coating material

5.1 General

During application of the coating material, all steps in the coating process shall be assessed and recorded. The parameters listed in Table 4 shall be included.

Table 4 — Minimum items to be checked and recorded during the coating process

Items	Method	Frequency	Acceptance criteria
Coating material			
Name of product	Visual examination	At every change of shift	As specified
Name of manufacturer		At every change of shift	As specified
Batch number		At every change of shift	As specified
Surface condition prior to surface preparation	Visual examination	Every pipe	As specified
Surface condition after surface preparation			
Surface cleanliness	ISO 8501-1	Twice per shift	As specified
Surface profile	ISO 8503-2	Twice per shift	As specified
Surface imperfections			
E.g. dents, laps	Visual examination	Every pipe	Subject to agreement
Wet paint (mixed)			
Viscosity and temperature	As specified	Every time paint is mixed and every time painting is interrupted	As specified
Environmental conditions in the painting area			
Ambient temperature	Instrumental	At every change of shift	As specified
Steel temperature	Instrumental	At every change of shift	As specified
Relative humidity	Instrumental	At every change of shift	As specified
Dew point	Instrumental	At every change of shift	As specified
Cured paint film on pipes			
Appearance and continuity	Visual examination	Spot test	No sagging
Dry film thickness	ISO 2808:1997, Method 10	Twice per shift	As specified
Porosity (pinholes)	Wet-sponge test (annex G)	[a]	As required
Cured paint film on steel test panels			
As described in Table 5	See Table 5	Twice per shift	As specified in Table 5
Paint film on glass test panels			
Porosity (pinholes)	Annex E	At every change of shift and for every new batch	Max. 5 pores

[a] The wet-sponge test shall be carried out only if the porosity test on glass panels constitutes a failure.

5.2 Surface preparation

First check that the surfaces are free from any foreign matter such as welding flux, welding spatter, salts, oil or grease. If necessary, wash the surfaces with a high-pressure jet of fresh water. Remove organic contaminants using detergents or suitable organic solvents.

Then blast-clean the surfaces to surface preparation grade Sa 2½ in accordance with ISO 8501-1.

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Remove, using suitable methods, any surface irregularities or imperfections which may have become visible.

Check the surface profile. Unless otherwise agreed, it shall be such that R_{y5} (see ISO 8503-1) is between 25 μm and 60 μm.

During and after blast-cleaning and prior to application of the coating material, the temperature of the steel surface shall be at least 3 °C above the dew point or the minimum curing temperature given by the coating material manufacturer, whichever is the higher.

5.3 Paint preparation

Before removing each component from its container, stir or agitate it until it is homogeneous, using equipment which is capable of homogenizing the entire contents of the container without excessively entraining air into the material. Mix the two components (base component and curing agent component) thoroughly and, if necessary, dilute in accordance with the coating material manufacturer's instructions. After the material has been homogenized, it shall be continuously mixed at a slow speed. The mixed paint shall be free of any lumps and pieces of skin. Measure the viscosity in accordance with the method recommended by the manufacturer and record it. Check whether it complies with the value specified by the manufacturer and keep it constant during the application procedure.

5.4 Paint application

Check the surface to be coated to see whether it still complies with the specified surface preparation grade and profile (see 5.2).

Apply the paint in a covered or enclosed space, shielded from wind, blowing dust and inclement weather, using the application parameters recommended by the coating material manufacturer and approved by the coater.

The ambient temperature and relative humidity and the temperature of the steel surface during application and subsequent drying/curing shall be in accordance with the recommendations of the manufacturer of the coating material. The temperature of the steel shall be at least 3 °C above the dew point. In the case of accelerated curing, the temperature shall be as agreed between the coating material manufacturer and the coater.

Spray the paint continuously and uniformly on to the whole surface to be coated. The coating shall be uniform, and particular attention shall be given to achieving the specified dry film thickness. Unless otherwise specified or agreed, maintain a cutback length of (20 ± 5) mm.

5.5 Health and safety and protection of the environment

It is the duty of clients, specifiers, contractors, coating material manufacturers, inspectors and all other personnel involved in the undertaking to carry out the work for which they are responsible in such a manner that they do not endanger the health and safety of themselves or others.

In pursuance of this duty, each person shall ensure that all the statutory requirements of the country in which their work, or any part of the work, is carried out are complied with.

6 Production control

6.1 Assessment of the coating on the pipes

6.1.1 Appearance

Inspect the coating visually for uniformity of colour, smoothness and freedom from runs, holidays and other defects that could be detrimental to its quality.

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6.1.2 Dry film thickness

Unless otherwise specified or agreed, the minimum dry film thickness of the coating shall be 60 μm above the peaks in the profile of the substrate and shall be determined in accordance with annex B.

6.2 Assessment of the coating on steel panels

6.2.1 Preparation of test panels

Perform the tests specified in 6.2.2 to 6.2.5 on coatings applied by spraying on to steel test panels, to give the dry film thickness specified in 4.3.3. Prepare the test panels as specified in 5.2 and apply the paint in accordance with the instructions of the coating material manufacturer. Use conditioning cycle B or C (see 4.3.2). Perform each test at least in duplicate.

Table 5 shows the required frequency of the tests specified in 6.2.2 to 6.2.5.

6.2.2 Adhesion

When determined in accordance with ISO 2409, the cross-cut classification of the coating shall be equal to or lower than 1.

6.2.3 Buchholz hardness

When determined in accordance with ISO 2815, the Buchholz hardness of the coating shall be at least 94.

6.2.4 Bend test

When determined in accordance with ISO 6860, the maximum extent of cracking along the panel from the small end of the mandrel shall be less than or equal to 13 mm, and there shall be no loss of adhesion.

6.2.5 Curing test

When tested in accordance with annex F, the coating shall not show any softening, wrinkling or blistering.

6.2.6 Porosity test

The porosity of both the wet and the dry film shall be checked on glass panels by the method given in annex E. Porosity is considered to be any coating defect (pinhole) through which light can pass directly. More than 5 pinholes shall constitute a failure.

If the porosity test on a glass panel is deemed a failure, the wet-sponge test given in annex G shall be carried out on the surfaces painted with the coating material which failed the glass-panel test, testing at least ten areas, excluding welds. The coating on these surfaces shall not have more than 1 pinhole per 100 cm^2

Table 5 — Required frequency of, and acceptance criteria for, the production-control tests specified in 6.2.2 to 6.2.5

Test	Method	Frequency	Acceptance criteria
Adhesion	ISO 2409	Twice per shift	Classification $\leqslant$ 1
Bend test	ISO 6860	Twice per shift	No loss of adhesion
Buchholz hardness	ISO 2815	Twice per shift	Hardness $\geqslant$ 94
Curing test	Annex F	Twice per shift	No softening, wrinkling or blistering

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7 Repairs

Defective coatings, or areas with insufficient dry film thickness, shall be repaired in accordance with the coating material manufacturer's recommendations.

8 Handling, transportation and storage

8.1 Handling

Coated pipes shall be handled in such a way that no damage is caused to the coating.

8.2 Transportation to the storage area

During transportation to the storage area at the coater's workshop, the coater shall take all relevant precautions to avoid damage to the coating.

8.3 Storage

Coated pipes shall be stored in such a way that the quality of the coating will not be affected.

8.4 Loading coated pipes for transportation

When loading pipes at the workshop or in the field, all relevant precautions shall be taken to avoid the possibility of damage to the pipes or to the coating during transportation.

The coater is responsible for ensuring that all pipes delivered to the purchaser are correctly coated and the coating is properly cured.

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Annex A
(normative)

Determination of ash (refer to subclause 4.2.5)

A.1 General

This annex describes a method for determining the ash residue from a coating.

A.2 Apparatus

Ordinary laboratory apparatus, together with the following:

A.2.1 Porcelain crucible.

A.2.2 Muffle furnace.

A.2.3 Desiccator, containing an active desiccant.

A.2.4 Analytical balance, capable of weighing to 1 mg.

A.3 Procedure

Weigh, to the nearest 1 mg, between 3 g and 5 g of the product into a porcelain crucible (A.2.1).

Place the crucible in a hood and heat with a low flame until the contents of the crucible are a dry, charred mass. Transfer to the muffle furnace (A.2.2) and ignite the residue at red heat (not exceeding 600 °C) until the ash is free of carbon.

Cool in the desiccator (A.2.3) and weigh.

Repeat the igniting, cooling and weighing until the difference between successive weighings does not exceed 1 mg.

A.4 Expression of results

Calculate the ash W_A, as a percentage by mass, using the following equation:

$$W_A = \frac{m_1}{m_0} \times 100 \qquad \text{(A.1)}$$

where

m_1 is the mass, in grams, of the residue after ignition;

m_0 is the mass, in grams, of the test portion.

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Annex B
(normative)

Dry film thickness (refer to subclause 4.3.3 and 6.1.2)

B.1 General

This annex describes the measurement of the dry film thickness of a coating on a blast-cleaned steel surface using an instrument based on the permanent-magnet principle or the inductive-magnet principle.

If a coating has been applied to a blast-cleaned steel substrate, the measurement of the dry film thickness is more complicated than for smooth, flat surfaces. The effect of surface roughness on the result increases with profile depth but is also related to the design of the measurement probe and the thickness of the coating.

B.2 Apparatus

Unless otherwise specified or agreed, the minimum dry film thickness of the coating shall be determined in accordance with ISO 2808:1997, Method No. 10, using a single-pole instrument of the permanent-magnet or inductive-magnet type.

B.3 Procedure

Before use, ascertain that the instrument is in good working order (see manufacturer's instructions).

Calibrate the instrument on a smooth, flat, level steel plate, using ISO 2808:1997, Method No. 10. It will then be necessary to determine a “correction factor” by taking a series of readings on the unpainted blast-cleaned surface and calculating the average. All readings subsequently taken on the painted surface are then reduced by the “correction factor” to give the true value of the thickness above the peaks.

Check the calibration at frequent intervals.

For each pipe or fitting tested, at least 8 values shall be recorded. Each value shall be constituted by the arithmetic mean of 5 different measurements taken very close to the point at which the thickness is to be measured. When during a series of measurements an individual dry film thickness value does not meet the specified criterion, a repeat measurement not more than 10 mm from the point of the first measurement shall be carried out. The first value shall then be rejected and replaced by the result of the repeat measurement. The maximum number of repeat measurements permitted is 2.

If any measurements are less than 80 % of the nominal dry film thickness (NDFT), then the specimen fails this test.

B.4 Results

Calculate the arithmetic mean of the measured values. Unless otherwise specified or agreed, the minimum dry film thickness of the coating shall be 60 μm above the peaks.

In cases of dispute of the result at one point, recalibrate the instrument and carry out five measurements, again very close to the point. Recalculate the arithmetic mean of the 5 measurements.

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Annex C
(normative)

Resistance to gas pressure variations (refer to subclause 4.3.9)

C.1 General

The test consists of verifying, by evaluation of visual appearance and determination of the adhesion, the behaviour of the applied coating after it has been subjected to pressure variations in a gaseous environment (N_2).

C.2 Apparatus and materials

C.2.1 **Sealed chamber**, capable of resisting the test pressures during the whole of the test.

C.2.2 **Nitrogen**, as pressurizing gas.

C.2.3 **Pressurizing system**, capable of increasing the pressure by 1 bar per minute.

C.3 Test specimens

Substrates can be of two types:

— approx. 100 mm × 50 mm × 1 mm steel panels;

— lengths of steel pipe approx. 100 mm long with a minimum diameter of 80 mm or, if the diameter is too large for the pipe to fit into the chamber, specimens obtained from the pipe or fitting.

The surfaces of the test panels or lengths of pipe shall be prepared and coated at the same time and in the same way as the corresponding production surfaces.

C.4 Procedure

C.4.1 General

Unless otherwise specified by the coating material manufacturer, wait a month after the coating has been applied to the test panels or lengths of pipe before carrying out any tests.

C.4.2 Cyclic pressure test

This test is carried out only as a qualification test on the inside coating.

Put the specimen in the chamber and subject it to the set of 10 test cycles shown schematically in Figure C.1, as follows:

— progressively increase the pressure in the chamber to 100 bar;

— keep the specimen under pressure for a fixed period of time to allow the pressurizing gas to penetrate into the coating:

  • 20 h for the 1st to 4th cycles and the 6th to 9th cycles,

  • 68 h for the 5th and 10th cycles;

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— release the pressure rapidly over a few minutes (not more than 5 minutes);

— leave the coating at atmospheric pressure for 4 h to permit the development of any blisters on the coating, so that a cycle lasts either 24 h or 72 h (this latter period corresponds to the weekend, i.e. from Friday to Monday).

Immediately at the end of the 10th test cycle, open the chamber and examine the appearance of the coating, noting all modifications (corrosion, spots or blisters). In addition, carry out an adhesion test in accordance with ISO 2409. Repeat the appearance examination after 24 h and after 48 h, again noting all modifications.

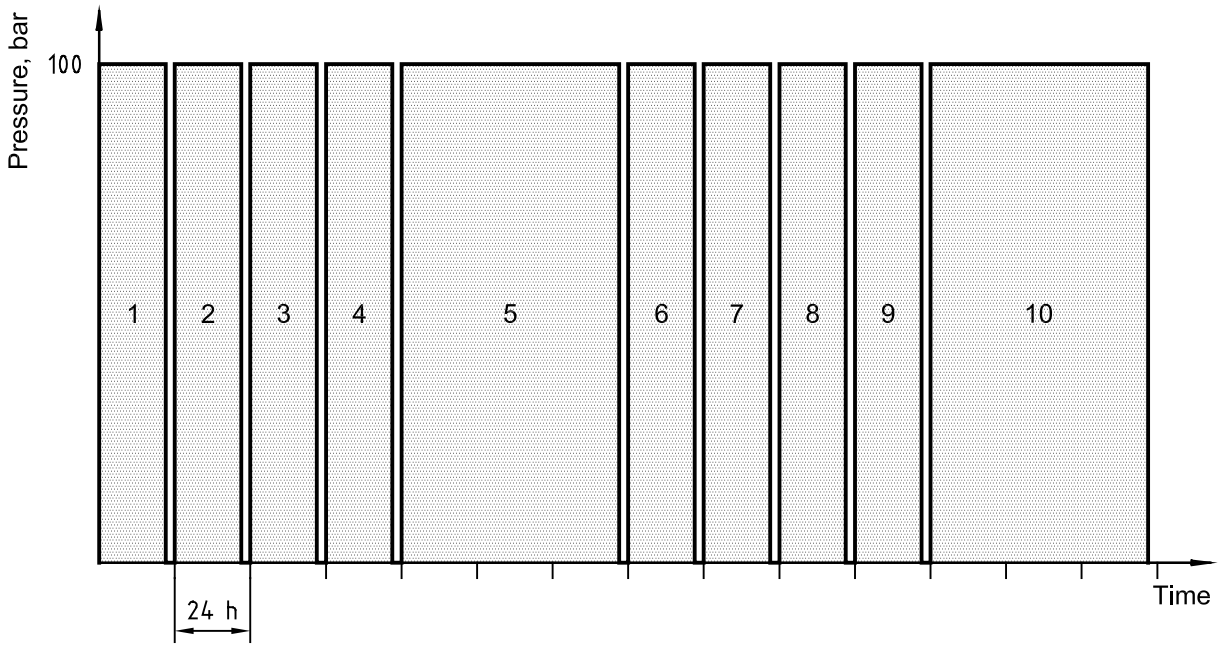


Figure C.1 — Complete set of pressure cycles

C.4.3 Decompression blistering test

This test is carried out only when the coated pipes are utilized at operating pressures higher than 100 bar. The test pressure shall be at least the pressure specified for that pipeline.

Put the specimen in the chamber and then subject it to the specified pressure for 24 h so that the pressurizing gas can penetrate into the coating.

Release the pressure rapidly over a few minutes (not more than 5 minutes).

Immediately at the end of the test cycle, open the chamber and examine the appearance of the coating, noting all modifications (corrosion, spots or blisters). In addition, carry out an adhesion test in accordance with ISO 2409. Repeat the appearance examination after 24 h and after 48 h, again noting all modifications.

C.5 Results

Record any degradation observed immediately on removing the specimen from the chamber and indicate any further changes after 24 h and 48 h.

Record the adhesion of the coating measured in the adhesion test.

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Annex D
(normative)

Hydraulic-pressure blistering (refer to subclause 4.3.12)

D.1 General

The test consists of verifying, by evaluation of the visual appearance and determination of the adhesion, the behaviour of the applied coating when subjected to pressure variations in a liquid environment (water/$CaCO_3$).

D.2 Apparatus and materials

D.2.1 Sealed chamber, capable of resisting the test pressures during the whole of the test.

D.2.2 Water saturated with $CaCO_3$, as pressurizing liquid.

D.2.3 Pressurizing system, capable of increasing the pressure by 1 bar per minute.

D.3 Test specimens

Substrates can be of two types:

— approx. 100 mm × 50 mm × 1 mm steel panels;

— lengths of steel pipe approx. 100 mm long with a minimum diameter of 80 mm or, if the diameter is too large for the pipe to fit into the chamber, specimens obtained from the pipe or fitting.

The surfaces of the test panels or lengths of pipe shall be prepared and coated at the same time and in the same way as the corresponding production surfaces.

D.4 Procedure

Unless otherwise specified by the coating material manufacturer, wait a month after the coating has been applied to the test panels or lengths of pipe before carrying out any tests.

This test is carried out at at least 100 bar if the maximum operating pressure is 100 bar or less. If the operating pressure is higher than 100 bar, the test pressure shall be at least the pressure specified for that pipeline.

Put the specimen in the chamber and then subject it to the specified pressure for 24 h so that the pressurizing liquid can penetrate into the coating.

Release the pressure rapidly over a few minutes (not more than 5 minutes).

Immediately at the end of the test cycle, open the chamber and examine the appearance of the coating, noting all modifications (corrosion, spots or blisters). In addition, carry out an adhesion test in accordance with ISO 2409. Repeat the appearance examination after 24 h and after 48 h, again noting all modifications.

D.5 Results

Record any degradation observed immediately on removing the specimen from the chamber and indicate any further changes after 24 h and 48 h.

Record the adhesion of the coating measured in the adhesion test.

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Annex E
(normative)

Porosity of a film of the coating material on a glass panel (refer to subclause 6.2.6)

Use a glass panel measuring approx. 75 mm × 25 mm × 2 mm and frosted on one side. Clean the panel by immersion in a suitable solvent and then in acetone. Allow the panel to dry in air for a few seconds.

Place a panel inside the pipe to be coated with the non-frosted side facing the wall of the pipe; keep it in position at each end by means of adhesive tape (max. overlap on glass 10 mm). Just before coating, check that the panel is free from dust or pollutants. Apply the coating material to the glass panel during the pipe-coating process.

Then examine the panel as follows:

a) **Wet film** — Five minutes after application of the coating material, place the glass panel over an opaque (dark) shield measuring approx. 300 mm × 300 mm with a 50 mm × 20 mm slot in the middle. Hold the panel, together with the shield, 130 mm from an illuminated 100 W bulb, with the shield facing the bulb. Check for pinholes. More than 5 pinholes shall constitute a failure.

b) **Cured film** — If the coating is acceptable in the wet state, allow it to cure for an additional 30 min in air at 18 °C to 25 °C and a relative humidity of $\leqslant$ 80 %, and then place in a circulating-air oven at (75 ± 2) °C for a minimum of 30 min. Repeat the examination described above. More than 5 pinholes shall constitute a failure.

Another curing schedule may be agreed between the coater and the coating material manufacturer.

NOTE If justified by the prevailing application and drying conditions or by the type of paint used, the test conditions may be modified by agreement between the interested parties.

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Annex F
(normative)

Curing test (refer to subclause 6.2.5)

Apply the coating material to steel panels and condition the coated panels as specified in 6.2.1. Test for resistance to the thinner which is recommended for thinning the coating material, in accordance with ISO 2812-1, for 4 h.

Examine the panels after a recovery period of 30 min at 18 °C to 25 °C and $\leqslant$ 80 % relative humidity following removal of the panels from the test liquid. The coating shall not show any softening, wrinkling or blistering.

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Annex G
(normative)

Wet-sponge test (refer to subclause 6.2.6)

G.1 General

The test consists of examining the coating for any porosity or other damage using a wet sponge, to which a low voltage is applied, as a scanning electrode.

Defects are indicated by an acoustic signal caused by the short circuit which occurs between the electrode (sponge) and the earth (steel substrate) at such defects.

G.2 Apparatus and materials

G.2.1 Adjustable low-voltage wet-sponge tester, equipped with an alarm, an electrode in the form of a sponge and conductors for connecting the coated pipe or fitting under test to earth.

G.2.2 Tap water.

G.3 Procedure

Set the test voltage to 9 V.

Connect up the instrument, connecting the earth lead, by means of a crocodile clip, to an uncoated section of the metal of the surface under test.

Moisten the sponge with tap water. Note that too much water will affect the performance.

Switch on the electrode and move it continuously in contact with the surface of the coating to be inspected; the rate of travel of the electrode is not limited, but it shall not be higher than the speed at which it can be demonstrated that a porosity defect can be detected.

The presence of a porosity defect is indicated by the emission of a high-pitched note from the alarm.

G.4 Results

Record the number of porosity defects per 100 cm^2.

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