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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

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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 on 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 the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 35, *Paints and varnishes*, Subcommittee SC 14, *Protective paint systems for steel structures*.

This second edition cancels and replaces the first edition (ISO 15741:2001), which has been technically revised.

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.

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

1 Scope

This document 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 document. 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 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 2409, *Paints and varnishes — Cross-cut test*

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

ISO 2812-1:2007, *Paints and varnishes — Determination of resistance to liquids — Part 1: Immersion in liquids other than water*

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

ISO 2815, *Paints and varnishes — Buchholz indentation test*

ISO 3233-1, *Paints and varnishes — Determination of the percentage volume of non-volatile matter — Part 1: Method using a coated test panel to determine non-volatile matter and to determine dry film density by the Archimedes principle*

ISO 3251, *Paints, varnishes and plastics — Determination of non-volatile-matter content*

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

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

ISO 8501-1, *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, *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, *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*

ISO 9227, *Corrosion tests in artificial atmospheres — Salt spray tests*

ISO 19840:2012, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Measurement of, and acceptance criteria for, the thickness of dry films on rough surfaces*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4618 and the following apply.

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

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
coater
company which is responsible for application of the coating material in accordance with the provisions of this document

3.2
coating material manufacturer
supplier of the coating material

3.3
dry film thickness
DFT
thickness of a coating remaining on the surface when the coating has hardened/cured

[SOURCE: ISO 12944-5:2007, 3.10]

3.4
natural gas
complex gaseous 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

[SOURCE: ISO 14532:2014, 2.1.1.1]

3.5
nominal dry film thickness
NDFT
dry film thickness specified for each coat or for the whole paint system

[SOURCE: ISO 12944-5:2007, 3.11]

3.6
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

3.7
purchaser
organization or individual that buys the coated pipes and fittings

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.

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 3233-1, 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).

4.2.5 Density

When determined in accordance with one of the parts of the ISO 2811 series, 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.

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 ≤80 % relative humidity until the coating is at least tack-free;

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

— condition for a minimum of 30 min at 18 °C to 25 °C and ≤80 % relative humidity before testing.

Cycle B

Substrate: steel or glass

— condition at 18 °C to 25 °C and ≤80 % relative humidity until the coating is at least tack-free;

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

— condition for a minimum of 30 min at 18 °C to 25 °C and ≤80 % relative humidity before testing.

Cycle C

Substrate: steel or glass

— condition at 18 °C to 25 °C and ≤ 80 % relative humidity until the coating is at least tack-free;

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

— condition for a minimum of 30 min at 18 °C to 25 °C and ≤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 19840.

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.

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 9227 for 480 h.

After the test, allow the test panels to dry for at least 30 min at 18 °C to 25 °C and ≤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 three steel panels. The dimensions of the panels shall be approximately 100 mm × 50 mm × 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 ≤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 diameter of 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 ≤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.

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 2812-1:2007, Method 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 ≤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 ≤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 ≤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 ≤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 document. 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.

4.6 Product data sheet

The coating material manufacturer's product data sheet, when applicable, 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)
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	
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).

4.7 Qualification certificate

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

Table 2 — Minimum information to be included in the 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 9227	See 4.3.6
Resistance to artificial ageing		See 4.3.7

[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.

Table 2 *(continued)*

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.

4.8 Batch test certificate

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

Table 3 — Minimum information to be included in the 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			
Expiry date for use			
Non-volatile matter by mass — base component	See 4.2.2		
Viscosity — base component	[a]		
Viscosity — curing agent component	[a]		
Density — base component	See 4.2.5		
Density — curing agent component	See 4.2.5		
Ash — base component[b]	See 4.2.6		
Ash — curing agent component[b, c]	See 4.2.6		
Infrared spectrogram[c, d, e]	See 4.2.8		

[a] As specified by the coating material manufacturer.

[b] If required.

[c] If pigmented.

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

[e] Only on request.

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)[b]			
Viscosity or mixing ratio:			
— single feed airless spraying equipment	As specified	At every chance of shift and for every new batch	As specified
— plural feed airless spraying equipment	As specified	At start of production and once per shift	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 2808:2007, Table A.2	Twice per shift[a]	As specified
Porosity (pinholes)	Wet-sponge test (Annex G)		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	Maximum of five pores

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

[b] Viscosity of mixed paint should only be measured, if coating is applied by single feed airless spraying equipment. If plural feed airless equipment (automatic dosage) is used, a dosage control shall be installed and mixing ratio shall be monitored at start and once per shift.

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 2 1/2 in accordance with ISO 8501-1.

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} (specified in 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 content 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. Viscosity of mixed paint should only be measured, if coating is applied by single feed airless spraying equipment. If plural feed airless equipment (automatic dosage) is used, a dosage control shall be installed and mixing ratio shall be monitored.

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 (30 ± 5) mm.

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.

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 diameter of 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 five 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 10 areas, excluding welds. The coating on these surfaces shall not have more than one 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 ≤ 1
Bend test	ISO 6860	Twice per shift	No loss of adhesion
Buchholz hardness	ISO 2815	Twice per shift	Hardness ≥ 94
Curing test	Annex F	Twice per shift	No softening, wrinkling or blistering

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.

Annex A
(normative)

Determination of ash (refer to 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 Formula (A.1):

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

where

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

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

Annex B
(normative)

Dry film thickness (refer to 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 dry film thickness of the coating shall be determined in accordance with ISO 2808.

B.3 Procedure

Before use, it shall be ascertained that the instrument is in good working condition and correctly adjusted (see manufacturer's instructions).

Adjustment and verification of instrument accuracy shall be carried out depending on the instrument type in accordance with ISO 19840 (see 6.2).

The instrument adjustment shall be checked at frequent intervals.

The measurement instrument shall then be used in accordance with the manufacturer's instructions and using a correction value according to ISO 19840:2012, Clause 7. The instrument might also be adjusted and verified according to ISO 19840:2012, Annex A (without using a correction value).

For each pipe or fitting tested, at least eight values shall be recorded. Each value shall be constituted by the arithmetic mean of five different measurements taken very close to the point at which the thickness is to be measured. When an individual dry film thickness value does not meet the specified criterion during a series of measurements, 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, very close to the point again. Recalculate the arithmetic mean of the five measurements.

Annex C
(normative)

Resistance to gas pressure variations (refer to 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:

— approximately 100 mm × 50 mm × 1 mm steel panels;

— lengths of steel pipe approximately 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:

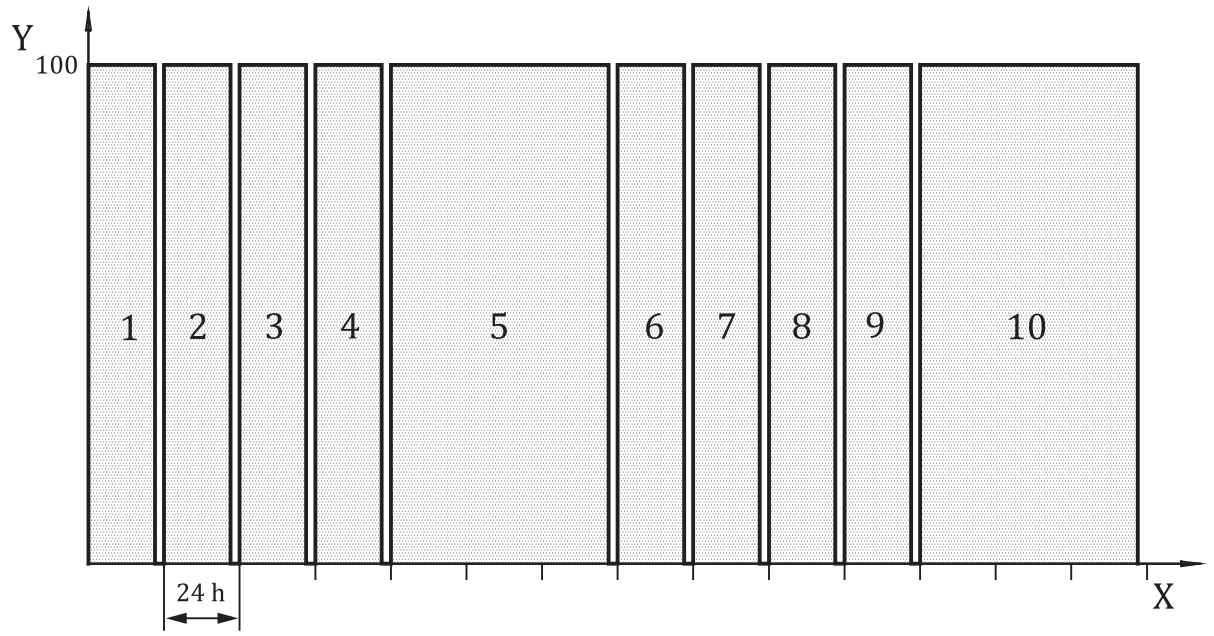
  — 20 h for the 1st to 4th cycles and the 6th to 9th cycles,

— 68 h for the 5th and 10th cycles;

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

— 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, noting again all modifications.



Key

X time

Y pressure, bar

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 min).

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, noting again 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.

Annex D
(normative)

Hydraulic-pressure blistering (refer to 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:

— approximately 100 mm × 50 mm × 1 mm steel panels;

— lengths of steel pipe approximately 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 min).

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, noting again 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.

Annex E
(normative)

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

Use a glass panel measuring approximately 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 (maximum 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 approximately 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 1 300 lm bulb, with the shield facing the bulb. Check for pinholes. More than five 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 ≤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 five pinholes shall constitute a failure.

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

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.

Annex F
(normative)

Curing test (refer to 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 ≤80 % relative humidity, following removal of the panels from the test liquid. The coating shall not show any softening, wrinkling or blistering.

Annex G
(normative)

Wet-sponge test (refer to 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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