INTERNATIONAL STANDARD

ISO 12944-9

First edition
2018-01

Paints and varnishes — Corrosion protection of steel structures by protective paint systems —

Part 9: Protective paint systems and laboratory performance test methods for offshore and related structures

Peintures et vernis — Anticorrosion des structures en acier par systèmes de peinture —

Partie 9: Systèmes de peinture protectrice et méthodes d'essai de performance en laboratoire pour la protection des sctructures offshore et structures associées

Reference number
ISO 12944-9:2018(E)

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

Published in Switzerland

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Foreword

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

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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

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

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

This first edition of ISO 12944-9 cancels and replaces ISO 20340:2009, which has been technically revised.

A list of all parts in the ISO 12944 series can be found on the ISO website.

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Introduction

Unprotected steel in the atmosphere, in water and in soil is subject to corrosion that can lead to damage. Therefore, to avoid corrosion damage, steel structures are normally protected to withstand the corrosion stresses to which they will be subjected during the service life required of the structure.

There are different ways of protecting steel structures from corrosion. ISO 12944 (all parts) deals with protection by paint systems and covers, in the various parts, all features that are important in achieving adequate corrosion protection. Additional or other measures are possible but require particular agreement between the interested parties.

In order to ensure effective corrosion protection of steel structures, owners of such structures, planners, consultants, companies carrying out corrosion protection work, inspectors of protective coatings and manufacturers of coating materials need to have at their disposal state-of-the-art information in concise form on corrosion protection by paint systems. It is vital that such information is as complete as possible, unambiguous and easily understandable to avoid difficulties and misunderstandings between the parties concerned with the practical implementation of protection work.

ISO 12944 (all parts) is intended to give this information in the form of a series of instructions. It is written for those who have some technical knowledge. It is also assumed that the user of ISO 12944 (all parts) is familiar with other relevant International Standards, in particular those dealing with surface preparation.

Although ISO 12944 (all parts) does not deal with financial and contractual questions, attention is drawn to the fact that, because of the considerable implications of inadequate corrosion protection, non-compliance with requirements and recommendations given in this document may result in serious financial consequences.

ISO 12944-1 defines the overall scope of ISO 12944. It gives some basic terms and definitions and a general introduction to the other parts of ISO 12944. Furthermore, it includes a general statement on health, safety and environmental protection, and guidelines for using ISO 12944 (all parts) for a given project.

Offshore and related structures require specific attention in order to be able to withstand the severe corrosion stresses to which they are exposed during their service life and to minimize the risk of failures that would impact safety, operating costs or capital cost.

In order to establish sufficient corrosion protection and ensure optimum performance of the coating, it is necessary to specify the requirements for the protective paint system(s) along with the relevant laboratory performance tests to assess its (their) likely durability.

In order to achieve the same performance as indicated by testing, proper surface preparation and application of the paint is essential. Close attention needs to be given to the execution of the work.

This document places emphasis on high-durability paint systems, with the aim of minimizing maintenance and hence reducing safety considerations and environmental impact.

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Paints and varnishes — Corrosion protection of steel structures by protective paint systems —

Part 9:
Protective paint systems and laboratory performance test methods for offshore and related structures

1 Scope

This document specifies the performance requirements for protective paint systems for offshore and related structures (i.e. those exposed to the marine atmosphere, as well as those immersed in sea or brackish water). Such structures are exposed to environments of corrosivity category CX (offshore) and immersion category Im4 as defined in ISO 12944-2.

This part of ISO 12944 describes paint systems for high durability according to ISO 12944-1.

This document is applicable to structures made of carbon steel and does not cover Cd/Bi Cr and Zn/Bi Cr surfaces. It is not applicable to surfaces under insulation or concrete.

This document is applicable for paint systems intended for a service temperature range between –20 °C and +80 °C, and the performance testing is aimed at verifying suitability of the paint systems for this temperature range.

This document is applicable for paint systems for submerged service (Im4) which are intended for ambient operating temperatures up to a maximum of 50 °C.

This document specifies:

— the test methods to be used to determine the composition of the separate components of the protective paint system;

— the laboratory performance test methods for the assessment of the likely durability of the protective paint system;

— the criteria to be used to evaluate the results of performance tests.

This document covers the requirements for new work and any repairs necessary before start-up. It can also be used in relation to maintenance where complete refurbishment is carried out and the underlying metal substrate is completely exposed by abrasive blast-cleaning.

It does not address maintenance in general where methods of surface preparation other than abrasive blast-cleaning are typically used.

This document deals with structures, made of carbon steel of not less than 3 mm thickness, which are designed using an approved strength calculation.

The following are not covered by this document:

— structures built of stainless steel as well as those built of copper, titanium or aluminium or their alloys;

— steel cables;

— buried structures;

— pipelines;

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— the interiors of storage tanks.

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 1461, *Hot dip galvanized coatings on fabricated iron and steel articles — Specifications and test methods*

ISO 1514, *Paints and varnishes — Standard panels for testing*

ISO 2063 (all parts), *Thermal spraying — Zinc, aluminium and their alloys*

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

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

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 3270, *Paints and varnishes and their raw materials — Temperatures and humidities for conditioning and testing*

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

ISO 4628-2, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 2: Assessment of degree of blistering*

ISO 4628-3, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 3: Assessment of degree of rusting*

ISO 4628-4, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 4: Assessment of degree of cracking*

ISO 4628-5, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 5: Assessment of degree of flaking*

ISO 4628-6, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 6: Assessment of degree of chalking by tape method*

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 9117-3, *Paints and varnishes — Drying tests — Part 3: Surface-drying test using ballotini*

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

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ISO 12944-1, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 1: General introduction*

ISO 12944-2, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 2: Classification of environments*

ISO 12944-4, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 4: Types of surface and surface preparation*

ISO 12944-5, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 5: Protective paint systems*

ISO 15711:2003, *Paints and varnishes — Determination of resistance to cathodic disbonding of coatings exposed to sea water*

ISO 16474-3:2013, *Paints and varnishes — Methods of exposure to laboratory light sources — Part 3: Fluorescent UV lamps*

ISO 19840, *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*

ISO 29601, *Paints and varnishes — Corrosion protection by protective paint systems — Assessment of porosity in a dry film*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12944-1, ISO 12944-5, ISO 1461, ISO 2063 (all parts) and the following apply.

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

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

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

3.1
offshore and related structures
permanently installed or moored structures with high requirements for long-term integrity

Note 1 to entry: Typical examples are oil and gas production facilities.

3.2
product technical-data sheet
product TDS
document designed to provide information on a specific paint product

Note 1 to entry: The type of information typically includes product uses, features, service properties, application properties, application instructions, packaging information and information on storage and handling.

Note 2 to entry: See 6.4 for specifically required minimum information.

3.3
safety data sheet
SDS
document designed to provide information regarding the health and safety aspects of a paint product or thinner

Note 1 to entry: The SDS typically includes information concerning generic material identification, hazardous ingredients, physical data, fire and explosion data, health hazards, reactivity data, spill or leak procedures, special protection requirements and other special precautions.

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3.4
qualification
process for the evaluation of protective paint systems using test criteria which allow the selection of suitable paint systems for distinct environmental exposure conditions

Note 1 to entry: The process comprises:

— description of the paint system (for an example, see Table 2);

— application testing (see Clause 8);

— laboratory performance testing and assessment of the results (see Clause 9);

— full identification of the paints (see 6.5.2 and Annex C).

3.5
volatile organic compound
VOC
any organic liquid and/or solid that evaporates spontaneously at the prevailing temperature and pressure of the atmosphere with which it is in contact

Note 1 to entry: Under US Government legislation, the term VOC is restricted solely to those compounds that are photochemically active in the atmosphere (see ASTM D3960). Any other compound is then defined as being an exempt compound.

3.6
splash and tidal zones
areas that are alternately wet and dry because of the influence of tides, winds and/or waves or ballasting/loading

3.7
holding primer
fast-drying primer that is applied to blast-cleaned carbon steel to protect it during fabrication of a structure, but does not allow the carbon steel to be welded

Note 1 to entry: Primers which do allow the carbon steel to be welded are called “pre-fabrication primers”.

4 Field of application

4.1 Type of environment

This document deals with the atmospheric corrosivity category CX (offshore) for operating temperature and the immersion category Im4 as defined in ISO 12944-2.

The structure may be divided into different zones based on the type of environment each zone is exposed to:

— one zone corresponds to the area exposed to atmospheric category CX (offshore);

— another zone corresponds to the area that is permanently immersed in sea water, i.e. category Im4;

— two further zones correspond to the tidal and splash zones which are a combination of category CX (offshore) and Im4:

  — the tidal zone is the area in which the water level changes because of natural or artificial effects, thus giving rise to increased corrosion due to the combined effect of cyclic exposure to water and the atmosphere;

  — the splash zone is the area wetted by wave and spray action which can give rise to exceptionally high corrosion stresses, especially with sea water.

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In this document, the splash and tidal zones are combined for qualification purposes into one set of tests (see Table 3).

4.2 Type of surface and surface preparation

This document deals with the following types of surface (more information is given in ISO 12944-4):

— uncoated carbon steel surfaces;

— metal-coated surfaces (thermal-sprayed metallic coating or hot-dip galvanized steel);

— surfaces painted with pre-fabrication primer;

— previously painted surfaces from which the existing paint system has been completely removed.

Except for metal-coated surfaces, surface preparation shall be by blast cleaning to preparation grade Sa 2½ (minimum) as defined in ISO 8501-1 and to surface profile "medium (G)" as defined in ISO 8503-1.

For surface preparation before and after application of the thermal-sprayed metallic coating, see ISO 2063 (all parts).

Hot-dip galvanized steel shall be sweep blasted in accordance with ISO 12944-4.

4.3 Type of paint

The generic types of paint widely used in paint systems for the protection of carbon steel structures against corrosion are described in ISO 12944-5, but are not limited to those in ISO 12944-5.

5 Relationship between artificial ageing and natural exposure

The selection of a paint system for a specific situation should preferably be based on experience from the use of the system in similar cases. The reason is that the durability of a paint system depends on many external factors such as the environment, the design of the structure, the surface preparation, and the application and drying procedures.

The durability is of course also linked to the chemical and physical characteristics of the system, e.g. the type of binder and the dry-film thickness. The influence of these characteristics on the durability can be evaluated by artificial-ageing tests. Of primary interest is resistance to water or moisture, and to salt fog, as an indication of wet adhesion and the barrier properties. The ageing tests and durations specified hereafter have been selected to ensure, with a high probability, that paint systems really do have the characteristics needed for the durability required in the intended application.

However, results from artificial-ageing tests shall be used with caution. It shall be clearly understood that artificial ageing will not necessarily have the same effect as natural exposure. Many factors have an influence on the progress of degradation and, in the laboratory, it is not possible to accelerate all of them in the proper way. It is therefore difficult to make a reliable ranking of paint systems of very different compositions from artificial-ageing tests in the laboratory. This can sometimes lead to efficient protective paint systems being rejected because they cannot pass these tests. It is recommended that natural-exposure trials always be undertaken so that, in the long term, such anomalies can be resolved.

6 Paints

6.1 General

The performance of protective paint systems shall be tested in accordance with Clause 9 and the separate components of the system (the paints) shall be identified in accordance with 6.5

For each paint in the paint system, the manufacturer shall provide a product technical-data sheet (product TDS) (see 6.4) and a safety data sheet (SDS).

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Neither the chemical composition of the individual paints in the paint system (see 6.5.2 and 6.5.3) nor the description of the paint system (see 7.1) shall be changed after qualification.

6.2 Quality assurance

The paint manufacturer shall set up and maintain a quality assurance system such as is necessary to ensure that the goods or services supplied comply in all respects with the requirements of this document.

6.3 Packaging and labelling

All coating materials, solvents and thinners shall be stored in their 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 curing component;

— the name of the paint manufacturer;

— the colour of the coating material;

— the batch number;

— the date of manufacture;

— instructions and warnings regarding health, safety and environmental protection in accordance with applicable regulations;

— a reference to the relevant product TDS.

6.4 Required product information

At least the following information, in addition to that in the SDS, shall be provided in the product TDS with each product submitted to qualification testing:

— the date of issue;

— the name of the product;

— the name of the manufacturer;

— the generic name for the paint;

— the generic name for the curing agent;

— the generic name for each additional component;

— the colour of the coating material;

— the mixing ratio;

— the mixing instructions (including any induction time);

— the shelf life under the recommended storage conditions;

— the non-volatile matter by volume of the mixed product (determined in accordance with ISO 3233-1)[1)];

— the density of the mixed product (determined in accordance with the appropriate part of ISO 2811)[1)];

— the pot life of the mixed product[1)];

1) These values shall be obtained at (23 ± 2) °C and (50 ± 5) % RH or as otherwise agreed.

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— the time taken for the surface of the coating to dry (determined in accordance with ISO 9117-3)[1)];

— the time to full cure[1)];

— the recommended thinner(s) (name and/or No.);

— the maximum quantity of each thinner allowed for application;

— the recommended surface preparation grade (see ISO 8501-1) and profile (see ISO 8503-1);

— the recommended method of application;

— the minimum and maximum over-coating time;

— the recommended minimum and maximum dry film thickness;

— the solvent recommended for cleaning the equipment;

— the recommended application conditions (temperature and relative humidity);

— the maximum VOC content and the method to be used to check that it is not exceeded[2)];

— a reference to the SDS;

— the theoretical spreading rate (in m^2/l or m^2/kg for a dry film thickness of x µm).

6.5 Paint identification

6.5.1 General

Each paint in a paint system shall be subjected to two types of identification check:

a) A fingerprint check (see 6.5.2) shall be carried out on all the paints of the paint system submitted to qualification testing.

b) A routine batch check (see 6.5.3) shall be carried out initially and on every subsequent batch of the paints in a qualified paint system.

6.5.2 Fingerprint check

The aim of a fingerprint check is to confirm the consistency of the paints supplied with reference to qualified paints. After qualification of a paint system, this fingerprint may be used, if necessary, to verify that the paints supplied are identical to those subjected to qualification testing.

The fingerprint shall include at least the parameters given in Annex C.

6.5.3 Routine batch check

The results of a routine batch check, using simple laboratory techniques, can show differences in the composition of a paint by comparison with the sample(s) subjected to qualification testing.

The paint manufacturer shall carry out a routine batch check on each batch of paint. Such checks are subject to documentation forming part of the paint manufacturer‘s quality assurance system and are used to provide the certificate of conformity, if required by the purchaser.

The minimum data required for a simple identification check (if relevant to the product in question) are given in Table 1.

2) For details, see the SDS.

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Table 1 — Routine batch check (batch by batch, final product inspection)

Date of issue		Production date	
Name of paint		Product TDS No.	
Batch number		SDS No.	

	Test method	Test result	Specification with tolerance
Density	Appropriate part of ISO 2811	.....	..... g/cm^3 ±0,05 g/cm^3 [a]
Non-volatile matter by mass	ISO 3251	.....	..... % ±2 %

[a] For densities greater than 2 g/cm^3, the relevant tolerance is ±0,1 g/cm^3.

Each of the interested parties shall be entitled to carry out additional checks on any batch to verify the fingerprint.

6.6 Confidential information

This document describes an assessment process for protective paint systems for which confidential information has to be supplied by the paint manufacturer. Such information, and the detailed results of the assessment process, shall be the property of the purchaser but shall not be disseminated by the purchaser without prior agreement from the paint manufacturer.

7 Protective paint systems

7.1 Description

A protective paint system subject to qualification shall be described by:

a) the name and address of the manufacturer;

b) the type of environment (see 4.3) and the type of surface (see 4.2) that the paint system is designed for;

c) the surface preparation recommended for the surface (method and resultant grade);

d) the product designation for each coat in the paint system in the order of application. The following information is required for each product:

   — the trade name;

   — the generic name of the paint;

   — the colour range;

   — the nominal dry film thickness (NDFT).

The NDFT of the protective paint system is the sum of the NDFTs of each individual coat.

An example of a paint system description is given in Table 2.

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Table 2 — Example of a paint system description

Manufacturer		Type of substrate		Type of environment
Name: Address:				
Surface preparation				
	Trade name	**Colour shade**	**Generic type**	**NDFT** (µm)
1st coat				
2nd coat				
3rd coat				
4th coat				
etc.				
			Total NDFT (µm):	

7.2 Minimum requirements for protective paint systems

Paint systems that pass all the tests in this document are likely to provide offshore coatings with high durability. However, there are many factors that can influence the actual performance and durability of a coating.

Experience has shown that one of the parameters which is essential for the achievement of high durability in practice is the coating system make-up, primarily the number of coats and the total dry film thickness.

For this reason, this document establishes a set of minimum requirements for the coating systems for the various environmental zones.

It should be emphasized, however, that the paint systems given in Table 3 are made up of different generic coating types: primer, intermediate coat and topcoat. They should therefore only be considered as minimum requirements. In addition, the list is not intended to be comprehensive.

In special cases, coating systems based on fewer coats can be relevant. However, in such cases, this shall be accompanied by a significant increase in total dry film thickness compared to the minimum requirements in Table 3, and it is advisable to take special quality control measures during application to ensure that the NDFT is met.

If a holding primer is used, thus becoming part of the coating system (as an extra layer), this shall be agreed between the interested parties and the holding primer qualified in accordance with this document.

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Table 3 — Minimum requirements for protective paint systems and their initial performance

	Blast-cleaned carbon steel: Sa 2½; Surface profile: medium (G)							**Hot-dip-galvanized steel or steel with thermal-sprayed zinc coating**[a]
Type of environment according to 4.1	**CX (offshore)**		**Splash and tidal zones CX (offshore) and Im4**			**Im4**		**CX (offshore)**
Type of primer	Zn (R)[b]	Other primers	Zn (R)[b, c]	Other primers		Other primers		
NDFT (µm)	≥40	≥60	≥40	≥60	≥200	—	≥150	
Minimum number of coats[d]	3	3	3	3	2	1	2	2
NDFT of paint system (µm)	≥280	≥350	≥450	≥450	≥600	≥800	≥350	≥200
Minimum pull-off test value (before ageing) determined in accordance with ISO 4624, Method A or B[e] (MPa)[f]	5	5	5	5	5	8	5	5

[a] The thickness of the metallic coating shall be in accordance with ISO 1461 (hot-dip galvanized) or ISO 2063 (all parts) (thermal sprayed metal) and the metallic coating shall be prepared as specified in ISO 12944-4. Overcoating of thermal sprayed aluminium (TSA) is not recommended due to the risk of the overcoat flaking and corrosion of the TSA occurring. For TSA, a sealer coat only is recommended.

[b] Zn (R) = Zinc-rich primer as defined in ISO 12944-5.

[c] This coating system with an organic Zn (R) primer can also be used for Im4 service if a Zn (R) primer is desired. In this case, the NDFT of the complete system can be reduced to ≥ 350 µm.

[d] The number of coats does not include a tie coat, which might be needed when a Zn (R) silicate primer is used, for instance.

[e] It is required that the force built up is controlled and linear as described in ISO 4624, e.g. by using an automatic hydraulic test equipment

[f] Push-off adhesion testing is not permitted.

8 Application testing of paints

8.1 Paints sampled for application testing shall not exhibit any hard skin, grains or sediment in their original packaging. They shall be easy to stir. The products shall be tested within their shelf life and pot life.

8.2 Each paint used in the paint system shall show no sign of running or sagging when applied at a dry film thickness equal to at least 1,5 times the specified NDFT to a smooth, degreased vertical plate with an area of 1 m^2.

For primers and self-priming products, it is recommended that a blasted carbon steel plate with a "medium (G)" profile be used instead of a smooth plate.

9 Performance testing of the paint system

9.1 Preparation and conditioning of test panels

9.1.1 Type and size of panel and number of panels

Test panels shall be made from carbon steel complying with ISO 1514. Unless agreed otherwise, the minimum size of the panels shall be 150 mm × 75 mm × 3 mm. If the thickness of the panels is less than

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5 mm, the “sandwich” method of pull-off testing specified in ISO 4624 is recommended. Three panels shall be prepared for each test.

9.1.2 Surface preparation

Degrease the test panels using a suitable method and grit-blast them to at least Sa 2½ as defined in ISO 8501-1. Unless agreed otherwise, the surface profile of the test side of each panel shall correspond to “medium (G)” as defined in ISO 8503-1 and shall be checked with a comparator using the method specified in ISO 8503-2.

Other methods of surface preparation may be used to represent actual field conditions, as agreed between the interested parties.

The test panels shall be dry and free of dust and any other foreign matter.

All parameters related to surface preparation (cleanliness, roughness, dust level, etc.) shall be recorded as part of the test report.

For hot-dip galvanized steel and thermal-sprayed metallic coating the thickness of the metallic layer shall be measured and recorded before applying the paint system.

9.1.3 Application and curing

Coat the panels by spraying in strict accordance with the manufacturer's written instructions. Cure in accordance with the paint manufacturer's written instructions.

Protect the backs and edges of the test panels using an appropriate method agreed on between the interested parties.

9.1.4 Dry film thickness

For each coat, prior to over-coating, measure the DFT on the test face of the panel in accordance with ISO 19840 at five locations (centre and each corner, 15 mm to 20 mm from the panel edge) and record these measurements as the minimum, mean and maximum (see D.1).

The maximum thickness of each coat on each panel shall be

— less than 1,5 × the NDFT if the NDFT is ≤60 µm;

— less than 1,25 × the NDFT if the NDFT is >60 µm.

9.1.5 Over-coating time

For each coat, carry out over-coating in accordance with the paint manufacturer's most recent instructions.

Deviations from the over-coating time specified by the paint manufacturer shall be agreed between the interested parties and recorded in the test report.

9.1.6 Conditioning/curing

Condition the panels at controlled temperature and humidity in accordance with ISO 3270. If curing and conditioning are conducted under different conditions, they shall be clearly stated in the test report.

The coating system shall be fully cured in accordance with the manufacturer's most recent instructions before testing starts.

The conditioning shall be agreed on between the interested parties or be in accordance with the paint manufacturer’s instructions.

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9.1.7 Porosity detection

In order to avoid premature failure, carry out a suitable test to detect the presence of any pinholes in the coating.

Potential pin holing shall be checked in accordance with ISO 29601. No pinholes are permitted.

9.1.8 Scribe line

The scribe line shall be made in accordance with Annex A.

9.1.9 Assessment of corrosion

The corrosion from the scribe shall be assessed in accordance with Annex A.

9.2 Qualification tests

Carry out the qualification tests given in Table 4.

Optional tests may also be carried out, such as chemical resistance, impact resistance, abrasion resistance and thick film cracking resistance. The actual optional tests to be carried out shall be agreed between the interested parties.

Table 4 — Qualification tests

Test	Scribe line	Environment of corrosivity category CX (offshore)	Environment of combined corrosivity category CX (offshore) and immersion category Im4 (splash and tidal zones)	Environment of immersion category Im4
Cyclic ageing test (Annex B)	Yes (see 9.1.8)	4 200 h	4 200 h	—
Cathodic disbonding (ISO 15711, Method A, unless otherwise agreed)	No (artificial holiday used instead; see Table 5)	—	4 200 h	4 200 h
Sea water[a] immersion (ISO 2812-2)	Yes (see 9.1.8)	—	4 200 h	4 200 h

[a] Artificial sea water as defined in ISO 15711:2003, Table 1.

9.3 Assessment — Methods and requirements

9.3.1 General

Methods and requirements are given in Table 5.

Two out of three panels shall comply with the requirements in Table 5.

Any coating defect which develops within 10 mm of the edges of the test panel shall not be taken into account.

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9.3.2 Assessment

Table 5 — Assessment of test panels — Methods and requirements

Assessment method	Requirement before qualification testing	Requirement after qualification testing	
ISO 4624 (pull-off test)	See Table 3. 0 % adhesive failure between carbon steel/metalized steel respectively and the first coat (unless pull-off values are at least 5 MPa)	Assessment after 2 weeks reconditioning. Minimum pull-off = 50 % of original value measured on the test panel. 0 % adhesive failure between carbon steel/metalized steel respectively and the first coat (unless pull-off values are at least 5 MPa)	
ISO 4628-2 (blistering)		0 (S0)	Carry out assessment immediately after the qualification test.
ISO 4628-3 (rusting)		Ri 0	Carry out assessment immediately after the qualification test.
ISO 4628-4 (cracking)		0 (S0)	Carry out assessment immediately after the qualification test.
ISO 4628-5 (flaking)		0 (S0)	Carry out assessment immediately after the qualification test.
ISO 4628-6 (chalking)		If agreed between the interested parties.	
Corrosion at scribe after cyclic ageing test (Annex A)		$M \leq 8{,}0$ mm for coating systems for high impact areas, these include: — floors, lay-down area; — helideck, escape routes; — splash zone – tidal zone; — other areas which are to be agreed between the interested parties. $M \leq 3{,}0$ mm for coating systems for all other CX applications. Assessment of degree of corrosion around the scribe shall be carried out according to Annex A (A.2), using a measuring device with an accuracy of 0,1 mm.	
Corrosion at scribe after sea water immersion (Annex A)		$M \leq 6{,}0$ mm	
Cathodic disbonding in accordance with ISO 15711:2003, method A	Immediately before the qualification test, form an artificial holiday (carbon steel totally exposed) of diameter 6 mm, using the procedure specified in method A of ISO 15711:2003.	After the qualification test, use a sharp, thin bladed knife to make two radial cuts at 45° to each other through the coating, intersecting at the centre of the holiday. Cut the coating down to the carbon steel. Attempt to lift the coating with the point of the knife. Record the total area now exposed (including the area of the holiday). Calculate the disbonded area as the difference between the total area exposed and the area of the holiday. From the disbonded area, calculate the corresponding equivalent diameter. The equivalent diameter of the disbonded area shall be not more than 20 mm.	

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Different scribe criteria for corrosion at scribe after cyclic testing are needed for areas exposed to mechanical wear, as listed in this document, because of the combination of two factors:

a) adhesion, barrier effect and high cohesive strength resulting in impact or abrasion resistance are more critical factors for performance than corrosion at scribe; and

b) zinc rich primers are often used and typically the only way to reach the 3 mm scribe criteria while potentially contributing to poor results in some or all of the desirable features as listed in a).

10 Test report

The test report shall contain at least the following information:

a) the test laboratory (name and address);

b) the date(s) of the tests;

c) all details necessary for complete identification of the protective paint system (see 7.1) including fingerprint data;

d) the type of environment in which the protective paint system is to be used (see 4.1) and the qualification tests carried out (see 9.2);

e) a description of the preparation and conditioning of the test panels (see 9.1);

f) the results of the assessment of the test panels before ageing (see Table 5);

g) the results of the assessment of all test panels after ageing for each qualification test (see Tables 4 and 5);

h) photographic documents focusing notably on scribe (before and after ageing test) and pull off tests failure (on test panel and on dollies);

i) thickness of the zinc layer, if applicable;

j) thickness of the thermal-sprayed metallic coating, if applicable;

k) any deviation from the specified test methods.

An example of a test report form is given in Annex D.

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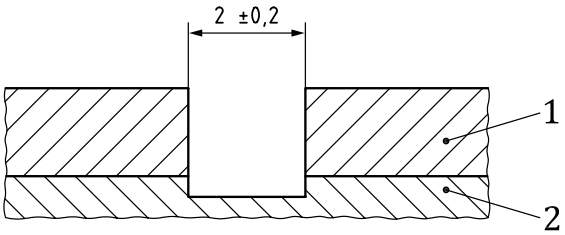
Annex A
(normative)

Scribe line for cyclic ageing test and sea water immersion

A.1 Producing the scribe

A scribe line (see Figures A.1 and Figure A.2) shall be made on each test panel to ensure full exposure to all the elements of the test. The scribe line shall be made mechanically (with a machine such as a drill press with cobalt slot drills). It shall be 50 mm long, 2 mm wide, minimum 12,5 mm from each long edge of the panel and minimum 25 mm from one of the short edges of the panel. It shall cut completely through the paint coating and into the carbon steel. The scribe has to be put in the cabinet horizontally. On hot-dip galvanized and thermal-sprayed metallic coating the scribe shall cut completely through the paint coating and the metal layer and into the carbon steel. The cut depth into the carbon steel should be as low as possible.

Dimensions in millimetres



Key

1 coating
2 carbon steel

Figure A.1 — Cross section of scribe line

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Dimensions in millimetres

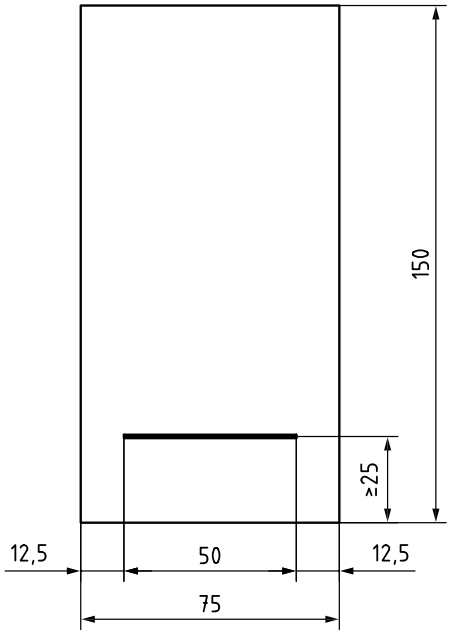


Figure A.2 — Example of test panel showing position of scribe line

A.2 Assessment of corrosion at scribe

After removing the non-adherent coating by a suitable method, measure the width of the steel corrosion at nine points (the midpoint of the scribe line and four other points, 5 mm apart, on each side of the midpoint). Calculate the corrosion at scribe M from the equation $M = (C - W)/2$, where C is the average of the nine width measurements and W is the measured and recorded width of the scribe. The result of the calculation of the average corrosion at scribe should be given in a precision of 0,1 mm.

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Annex B
(normative)

Cyclic ageing test

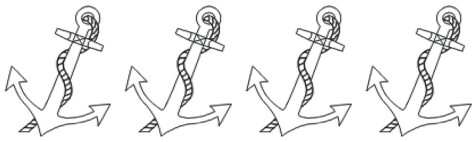
The exposure cycle used in this procedure lasts a full week (168 h) and includes:

a) 72 h of exposure to UV and condensation in accordance with ISO 16474-3 under the following conditions:

   — method A, cycle 1 of ISO 16474-3 alternating periods of 4 h exposure to UVA-340 lamps at (60 ± 3) °C and 4 h exposure to condensation at (50 ± 3) °C,

b) 72 h of exposure to neutral salt spray in accordance with ISO 9227;

c) 24 h of exposure to low temperature at (–20 ± 2) °C.

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
UV/condensation — ISO 16474-3			Neutral salt spray — ISO 9227			Low-temp. exposure at (–20 ± 2) °C
						

Start the UV/condensation period with UV exposure and finish with condensation.

Between the salt spray and low-temperature periods, rinse the panels with de-ionized water but do not dry them.

At the beginning of the low-temperature period, the panel shall reach the temperature of (–20 ± 2) °C within 30 min.

Expose the test panels for 25 cycles or 4 200 h.

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Annex C
(normative)

Fingerprint

Date of issue:			Base material		Curing agent	
Name of paint						
Name of manufacturer						
Batch number						
Production date						
	Test method	**Test result**	**Acceptance range**	**Test result**	**Acceptance range**	
Main parameters[a]						
Infrared spectra	See Bibliography					
Non-volatile matter (by mass)	ISO 3251		±2 %		±2 %	
Density	Appropriate part of ISO 2811		±0,05 g/cm^3		±0,05 g/cm^3	
Ash	See Bibliography		±3 %		±3 %	
Optional parameters						
Pigment content (by mass)	Zn metal	ASTM D6580		±1 %		±1 %
Content of functional groups	Epoxy OH Acidic Amine Isocyanate	See Bibliography				

[a] The results obtained will vary depending on colour shade.

NOTE Due to the potentially high margin of error in ASTM D6580 laboratory determination of zinc content in metallic zinc primers; it is acceptable for paint manufacturers to declare the theoretical metallic zinc content based on formulation. This can be confirmed between partners by declaration of formulation (in confidence) or by audit.

The binder properties (infrared spectra and content of functional groups) shall be determined after separation of the resin from the pigment and the solvent.

Many other additional tests could be useful in characterizing more precisely the components of paint.

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Annex D
(informative)

Examples of test reports

D.1 Example of test report for preparation of test panels

Laboratory: ISO 12944-9:20YY

Laboratory	Dates of tests
Name: Address:	End of panel preparation: Beginning of testing:

Description of paint system

Manufacturer	Type of environment	Type of substrate
Name: Address:		

Surface preparation:	

	Trade name	**Colour range**	**Generic type**	**NDFT** µm
1st coat				
2nd coat				
3rd coat				
4th coat				
etc.				
			Total	

Preparation of test panels

Substrate:	Surface preparation:	
Length, width and thickness:	Cleanliness:	Roughness:

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Application of paint system					
	Trade name	**Batch number**	**Temp.** °C	**RH** %	**Ease of application and method of application used (comments)**
1st coat					
2nd coat					
3rd coat					
4th coat					

Thickness measurements and allocation of panels to tests					
	1st coat	**2nd coat**	**3rd coat**	**4th coat**	
NDFT					

Panel No.	**Coating thickness measurements (min./mean/max.) (μm)**												**Test allocation**

Drying/curing conditions:

Comments:

Date of report and signatures:

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D.2 Example of test report for assessment of test panels after immersion in sea water in accordance with ISO 2812-2

Assessment before qualification tests												
	Panel No.				**Panel No. ....**				**Panel No. ....**			
	Individual	Mean	% adhesion failure to steel/ metalized steel	Pass/ Fail	Individual	Mean	% adhesion failure to steel/ metalized steel	Pass/ Fail	Individual	Mean	% adhesion failure to steel/ metalized steel	Pass/ Fail
ISO 4624 (MPa)												
Comments:												
Assessment after water immersion (4 200 h)												
	Panel No.				**Panel No. ....**				**Panel No. ....**			
	Individual	Mean	% adhesion failure to steel/ metalized steel	Pass/ Fail	Individual	Mean	% adhesion failure to steel/ metalized steel	Pass/ Fail	Individual	Mean	% adhesion failure to steel/ metalized steel	Pass/ Fail
ISO 4624 (MPa)												
ISO 4628-2												
ISO 4628-3												
ISO 4628-4												
ISO 4628-5												

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Assessment after water immersion (4 200 h)												
	Panel No.				**Panel No. ....**				**Panel No. ....**			
	Individual	Mean	% adhesion failure to steel/ metalized steel	Pass/ Fail	Individual	Mean	% adhesion failure to steel/ metalized steel	Pass/ Fail	Individual	Mean	% adhesion failure to steel/ metalized steel	Pass/ Fail
ISO 4628-6												
Corrosion at scribe (*M*, in mm)												
Comments:												

Date of report and signatures:

D.3 Example of test report for assessment of test panels after exposure testing

Exposure cycle (as specified in Annex B):

Assessment before qualification testing									
	Panel No.			**Panel No. ....**			**Panel No. ....**		
	Individual	Mean	Pass/ Fail	Individual	Mean	Pass/ Fail	Individual	Mean	Pass/ Fail
ISO 4624 (MPa)									
Comments:									
Assessment after exposure testing (4 200 h)									
	Panel No.			Panel No.			Panel No.		
	Individual	Mean	Pass/ Fail	Individual	Mean	Pass/ Fail	Individual	Mean	Pass/ Fail
ISO 4624 (MPa)									
ISO 4628-2									
ISO 4628-3									
ISO 4628-4									
ISO 4628-5									
ISO 4628-6									
Corrosion at scribe (*M*, in mm)									
Comments:									

Date of report and signatures:

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Bibliography

Terminology

[1] ISO 8044, *Corrosion of metals and alloys — Basic terms and definitions*

[2] ISO 4618, *Paints and varnishes — Terms and definitions*

Determination of ash (by mass)

[3] NF T30-012, *Paints — Determination of ash content in varnishes, paints and similar products*

Determination of content of functional groups

[4] ISO 11909, *Binders for paints and varnishes — Polyisocyanate resins — General methods of test*

[5] ISO 4629, *Binders for paints and varnishes — Determination of hydroxyl value — Titrimetric method*

[6] ISO 7142, *Binders for paints and varnishes — Epoxy resins — General methods of test*

[7] ISO 11908, *Binders for paints and varnishes — Amino resins — General methods of test*

Pigment content

[8] ISO 1247, *Aluminium pigments for paints*

[9] ISO 1248, *Iron oxide pigments — Specifications and methods of test*

[10] ISO 10601, *Micaceous iron oxide pigments for paints — Specifications and test methods*

[11] ISO 3549, *Zinc dust pigments for paints — Specifications and test methods*

[12] ISO 6745, *Zinc phosphate pigments for paints — Specifications and methods of test*

IR spectra

[13] ASTM D 2372, *Standard Practice for Separation of Vehicle from Solvent-Reducible Paints*

[14] ASTM D 2621, *Standard Test Method for Infrared Identification of Vehicle Solids from Solvent-Reducible Paints*

Others

[15] ISO 4628-8, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 8: Assessment of degree of delamination and corrosion around a scribe or other artificial defect*

[16] ISO 12944-8, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 8: Development of specifications for new work and maintenance*

[17] ISO 2114, *Plastics (polyester resins) and paints and varnishes (binders) — Determination of partial acid value and total acid value*

[18] ASTM D 3960, *Standard Practice for Determining Volatile Organic Compound (VOC) Content of Paints and Related Coatings*

[19] ASTM D6580, *Standard Test Method for the Determination of Metallic Zinc Content in Both Zinc Dust Pigment and in Cured Films of Zinc-Rich Coatings*

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