INTERNATIONAL STANDARD

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

Part 6:
Laboratory performance test methods

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

Partie 6: Essais de performance en laboratoire

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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.

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

International Standard ISO 12944-6 was prepared by Technical Committee ISO/TC 35, *Paints and varnishes,* Subcommittee SC 14, *Protective paint systems for steel structures*.

ISO 12944 consists of the following parts, under the general title *Paints and varnishes — Protective paint systems for steel structures*:

— *Part 1: General introduction*

— *Part 2: Classification of environments*

— *Part 3: Design considerations*

— *Part 4: Types of surface and surface preparation*

— *Part 5: Protective paint systems*

— *Part 6: Laboratory performance test methods*

— *Part 7: Execution and supervision of paint work*

— *Part 8: Development of specifications for new work and maintenance*

Annex A of this part of ISO 12944 forms an integral part of this part of ISO 12944. Annex B is for information only.

Introduction

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

There are different ways of protecting steel structures from corrosion. ISO 12944 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, it is necessary for owners of such structures, planners, consultants, companies carrying out corrosion protection work, inspectors of protective coatings and manufacturers of coating materials to have at their disposal state-of-the-art information in concise form on corrosion protection by paint systems. Such information has to be as complete as possible, unambiguous and easily understandable to avoid difficulties and misunderstandings between the parties concerned with the practical implementation of protection work.

This International Standard — ISO 12944 — 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 is familiar with other relevant International Standards, in particular those dealing with surface preparation, as well as relevant national regulations.

Although ISO 12944 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 standard may result in serious financial consequences.

ISO 12944-1 defines the overall scope of all parts 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 for a given project.

ISO 12944-6 provides a way of assessing paint systems by means of laboratory tests in order to be able to select the most suitable.

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

Part 6:
Laboratory performance test methods

1 Scope

This part of ISO 12944 specifies laboratory test methods and test conditions for the assessment of paint systems for the corrosion protection of steel structures. The test results are to be considered as an aid in the selection of suitable paint systems and not as exact information for determining durability.

This part of ISO 12944 covers protective paint systems designed for application to uncoated steel, hot-dip-galvanized steel and steel surfaces with thermally sprayed zinc coatings.

This part of ISO 12944 does not apply to protective paint systems for electroplated or painted steel.

Certain tests in this part of ISO 12944 are not applicable to many water-borne paint systems (see 4.2). Nevertheless, some water-borne paint systems are amenable to testing and evaluation using the procedures described herein, and their results could be taken into account.

The environments defined in ISO 12944-2 are considered.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 12944. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 12944 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 554:1976, *Standard atmospheres for conditioning and/or testing — Specifications.*

ISO 1512:1991, *Paints and varnishes — Sampling of products in liquid or paste form.*

ISO 1513:1992, *Paints and varnishes — Examination and preparation of samples for testing.*

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

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

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

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

ISO 3231:1993, *Paints and varnishes — Determination of resistance to humid atmospheres containing sulfur dioxide.*

ISO 4624:1978, *Paints and varnishes — Pull-off test for adhesion.*

ISO 4628-1:1982, *Paints and varnishes — Evaluation of degradation of paint coatings — Designation of intensity, quantity and size of common types of defect — Part 1: General principles and rating schemes.*

ISO 4628-2:1982, *Paints and varnishes — Evaluation of degradation of paint coatings — Designation of intensity, quantity and size of common types of defect — Part 2: Designation of degree of blistering.*

ISO 4628-3:1982, *Paints and varnishes — Evaluation of degradation of paint coatings — Designation of intensity, quantity and size of common types of defect — Part 3: Designation of degree of rusting.*

ISO 4628-4:1982, *Paints and varnishes — Evaluation of degradation of paint coatings — Designation of intensity, quantity and size of common types of defect — Part 4: Designation of degree of cracking.*

ISO 4628-5:1982, *Paints and varnishes — Evaluation of degradation of paint coatings — Designation of intensity, quantity and size of common types of defect — Part 5: Designation of degree of flaking.*

ISO 6270:1980, *Paints and varnishes — Determination of resistance to humidity (continuous condensation).*

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

ISO 7384:1986, *Corrosion tests in artificial atmospheres — General requirements.*

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

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

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

ISO 12944-1:1998, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 1: General introduction.*

ISO 12944-2:1998, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 2: Classification of environments.*

ISO 12944-4:1998, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 4: Types of surface and surface preparation.*

ISO 12944-5:1998, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 5: Protective paint systems.*

3 Definitions

For the purposes of this part of ISO 12944, the following definitions apply in addition to those given in ISO 12944-1.

3.1 artificial ageing: A procedure designed to accelerate the ageing of a paint system, i.e. to reduce the corrosion-protective efficiency more rapidly than by natural weathering.

3.2 visual assessment method: A method for visually assessing a paint system in accordance with one of the parts of ISO 4628.

3.3 complementary assessment method: A method used in addition to the visual assessment methods.

3.4 requirements: Test results that must be achieved for a paint system in order for the system to be considered suitable for use in corrosion protection.

4 General

4.1 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, the dry-film thickness. These characteristics 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.

4.2 Additional performance tests

Additional tests are recommended if

a) it is considered necessary to assess the ability of a paint system to provide corrosion protection, by tests after cyclic ageing using ultraviolet (UV) radiation;

b) more information is needed on corrosion protection behaviour.

Additional test methods may also be used by agreement between the interested parties.

NOTE — If water-borne systems are being investigated, corrosion tests agreed between the interested parties should preferably be used. For example, ageing methods employing cyclic conditions (e.g. hot/cold temperatures, salt spray on/salt spray off) may be utilized, and the duration times given in table 1 may act as a guide.

5 Tests

5.1 Test panels

5.1.1 Steel substrates

The test panels shall be made of the same type of steel as used in practice, unless otherwise agreed. The minimum panel size shall be 150 mm × 70 mm. The panel thickness will depend on the test, but shall be 2 mm at least. Unless otherwise agreed, the panel surface shall be prepared by blast-cleaning to surface preparation grade Sa 2½ or Sa 3 as defined in ISO 8501-1. The surface roughness (profile) shall correspond to “medium (G)” as defined in ISO 8503-1. It can be checked by using a comparator as defined in ISO 8503-2. In all other respects, test panels shall comply with ISO 7384.

5.1.2 Zinc-coated steel substrates

The test panels shall be made of the zinc-coated steel used in practice, unless otherwise agreed. Size and thickness shall be as for steel substrates. Surface preparation shall be as agreed between the interested parties. Suitable surface preparation methods are given in ISO 12944-4.

5.2 Sampling of paints

Take a representative sample of the product to be tested (or of each product in the case of a multi-coat system), as described in ISO 1512. Examine and prepare each sample for testing, as described in ISO 1513.

5.3 Number of test panels

Unless otherwise agreed, prepare three panels for each test.

5.4 Paint systems

Preferably apply the paint to the panel by spraying. The paint shall be applied in accordance with the paint manufacturer's specifications. Each coat shall be homogeneous in thickness and appearance and free from runs, sags, misses, pinholes, wrinkling, gloss variations, cissing, particle inclusions, dry overspray and blisters. The dry-film thickness, as measured in accordance with ISO 2808, shall not exceed 20 % of the specified value.

Unless otherwise agreed, condition the coated test panels for three weeks in standard atmosphere (23 ± 2) °C/(50 ± 5) % relative humidity or (20 ± 2) °C/(65 ± 5) % relative humidity, as defined in ISO 554, before testing.

If the salt spray test is to be carried out (see table 1), the scratch line shall cut through the paint coating down to the substrate (see annex A).

Appropriate protection shall be applied to the edges and the backs of the panels.

5.5 Reference system

It is recommended that a paint system which has been in successful use for years on site, and whose performance as indicated by laboratory testing is well known, is used as a reference system. This system shall be as similar as possible in composition and/or generic type and thickness to the paint system being tested. Examples of suitable paint systems are given in ISO 12944-5.

5.6 Test procedures

The test procedures shall be as specified in tables 1 and 2.

When testing in accordance with ISO 2812-1, the following chemicals of recognized analytical quality shall be used:

a) NaOH, 10 % (m/m) aqueous solution;

b) H_2SO_4, 10 % (m/m), aqueous;

c) Mineral spirit, 18 % aromatics.

For the assessment of paint systems for suitability for use in the various categories for immersion in water and burial in soil as defined in ISO 12944-2, table 2, use the following materials:

For Im1: water as defined in ISO 2812-2;

For Im2 and Im3: sodium chloride, 5 % (m/m) aqueous solution (instead of water).

6 Paint system assessment

6.1 General

The tests to be carried out and the test durations for the paint systems in each corrosivity category (see ISO 12944-2, table 1) are given in 6.2.

Only one of the three test panels shall be allowed not to completely comply with the requirements specified in 6.3 and 6.4.

For example, a system with a total dry-film thickness below 250 μm will be qualified as “high” for corrosivity category C3 on steel if, for at least two of the three panels:

a) before testing, the classification obtained in accordance with ISO 2409 is 0 or 1

and

b) after 480 h of salt spray (ISO 7253), it has no defect when assessed in accordance with ISO 4628-2 to ISO 4628-5 and the classification obtained in accordance with ISO 2409 is 0 or 1

and

c) after 240 h of continuous condensation (ISO 6270), it has no defect when assessed in accordance with ISO 4628-2 to ISO 4628-5 and the classification obtained in accordance with ISO 2409 is 0 or 1.

NOTE — For paint systems intended for water and soil (categories Im1, Im2, Im3), “medium” durability is the minimum required level.

6.2 Tests and test durations

6.2.1 Paint systems on steel substrates

The tests and test durations given in table 1 are intended for paint systems applied on steel substrates.

For paint systems intended for corrosivity category C5-I (and after agreement between the interested parties), the ISO 2812-1 procedure can be replaced or supplemented by the ISO 3231 test using the test duration figures for ISO 6270, i.e. 240 h (10 cycles) for “low” durability, 480 h (20 cycles) for “medium” durability and 720 h (30 cycles) for “high” durability. This generally applies to paint systems with a zinc-rich primer.

6.2.2 Paint systems on zinc-coated steel substrates

The tests and test durations given in table 2 are intended for paint systems applied on zinc-coated steel (both hot-dip-galvanized and thermally sprayed).

6.3 Assessment before artificial ageing

Assessment methods	Requirements	
ISO 2409	Classification 0 or 1	

If the dry-film thickness of the paint system is greater than 250 μm, the following adhesion test shall be used instead of ISO 2409:

ISO 4624	Requirement:	no adhesion break to the substrate (A/B) allowed (unless pull-off values are 5 MPa or more)

6.4 Assessment after artificial ageing for the specified time

Assessment methods	Requirements		
ISO 4628-2	Blistering	0 (S0)	(assessment immediately)
ISO 4628-3	Rusting	Ri 0	(assessment immediately)
ISO 4628-4	Cracking	0 (S0)	(assessment immediately)
ISO 4628-5	Flaking	0 (S0)	(assessment immediately)
	After artificial ageing in accordance with ISO 7253 any corrosion of the substrate from the scratch shall not exceed 1 mm when calculated using the equation in annex A.		

Any defect occurring within 1 cm of the edges of panels shall not be taken into account.

Complementary assessment methods	Requirements	
ISO 2409	Classification 0 or 1	(assessment after 24 h reconditioning in accordance with 5.4)

If the dry-film thickness of the paint system is greater than 250 μm, the following adhesion test shall be used instead of ISO 2409:

ISO 4624	Requirement:	no adhesion break to the substrate (A/B) allowed (unless pull-off values are 5 MPa or more) (assessment after 24 h reconditioning in accordance with 5.4)

Table 1 — Test procedures for paint systems applied to steel

Corrosivity category as defined in ISO 12944-2	Durability ranges	ISO 2812-1[1] (chemical resistance) h	ISO 2812-2 (water immersion) h	ISO 6270 (water condensation) h	ISO 7253 (neutral salt spray) h
C2	Low	—	—	48	—
	Medium	—	—	48	—
	High	—	—	120	—
C3	Low	—	—	48	120
	Medium	—	—	120	240
	High	—	—	240	480
C4	Low	—	—	120	240
	Medium	—	—	240	480
	High	—	—	480	720
C5-I	Low	168	—	240	480
	Medium	168	—	480	720
	High	168	—	720	1 440
C5-M	Low	—	—	240	480
	Medium	—	—	480	720
	High	—	—	720	1 440
Im1	Low	—	—	—	—
	Medium	—	2 000	720	—
	High	—	3 000	1 440	—
Im2	Low	—	—	—	—
	Medium	—	2 000	—	720
	High	—	3 000	—	1 440
Im3	Low	—	—	—	—
	Medium	—	2 000	—	720
	High	—	3 000	—	1 440

1) Use method 1 (see 5.6 for the chemicals used). The purpose of the chemical-resistance test is not the assessment of corrosion protection properties but to assess the ability of a system to withstand highly industrial environments. Thus, the test duration remains the same whatever the durability range is.

For corrosivity category C5-I, the ISO 2812-1 procedure can be replaced or supplemented by the ISO 3231 test (10 cycles, 240 h for “low” durability; 20 cycles, 480 h for “medium” durability; and 30 cycles, 720 h for “high” durability).

Table 2 — Test procedure for testing adhesion of paint systems applied to zinc-coated steel

Corrosivity category as defined in ISO 12944-2	Durability ranges	ISO 6270 (water condensation h
C2	Low Medium High	240 240 240
C3	Low Medium High	240 240 240
C4	Low Medium High	240 240 480
C5-I	Low Medium High	240 480 720
C5-M	Low Medium High	240 480 720

7 Test report

The test report shall contain at least the following information:

a) the test laboratory (name and address);

b) the date of each test;

c) a description of the substrate and substrate surface preparation;

d) all details necessary to identify the protective paint system (manufacturer, names or reference numbers of the products, batch numbers, numbers of coats, dry-film thickness for each coat);

e) all details necessary to identify the reference system;

f) the duration and conditions of drying/curing and conditioning;

g) the classification of the paint system according to the test results obtained (corrosivity category and durability range, for example C5-I medium)

h) the tests carried out and the duration of each test;

i) the results for each test panel;

j) any deviation from the test methods specified.

The test report shall explicitly state that the test equipment and procedure was in accordance with the relevant ISO standard.

The test report shall be signed by the person performing the tests and by the laboratory manager or by another authorized representative of the laboratory.

An example of a test report form is given in annex B.

Annex A
(normative)

Scratch line for ISO 7253 test

A.1 Producing the scratch

The use of a scribing machine is recommended to ensure reproducible results. If this is not possible, the scratch tool shall be as described in ISO 2409:1992, subclause 4.1.1 (single-blade cutting tool).

The scratch line can be horizontal, vertical or diagonal. It shall be at least 50 mm long. In addition, it shall be at least 20 mm from any edge and penetrate down to the metal along its whole length.

A.2 Assessment of corrosion along the scratch

After the salt spray test, measure the maximum width C, in millimetres, of corrosion across the scratch. Calculate the corrosion of the substrate from the scratch, M, using the following equation:

$$M = \frac{C - W}{2}$$

where W is the original width, in millimetres, of the scratch.

Annex B
(informative)

Example of report form

Test laboratory: Address:

Dates of tests:

Substrate: Surface preparation:

Manufacturer: Address:

Paint system:

	Generic type	Trade name	Batch number	NDFT [1)]
1st coat				
2nd coat				
3rd coat				
4th coat				
5th coat				
6th coat				

1) NDFT = nominal (specified) dry-film thickness

Reference system:

	Generic type	Trade name	Batch number	NDFT
1st coat				
2nd coat				
3rd coat				
4th coat				
5th coat				
6th coat				

Drying/curing conditions: Test duration:

Atmospheric or water/soil corrosivity category as defined in ISO 12944-2:

Required durability range:

Tests	Results in accordance with 6.3 and 6.4		
	Panel 1	Panel 2	Panel 3
Measured dry-film thickness			
Assessment before test: (ISO 2409 or ISO 4624)			
Test 1: ISO ..... Test duration: .... h Assessment after test: ISO 4628-2 ISO 4628-3 ISO 4628-4 ISO 4628-5 ISO 2409 or ISO 4624			
Test 2: ISO ..... Test duration: .... h Assessment after test: ISO 4628-2 ISO 4628-3 ISO 4628-4 ISO 4628-5 ISO 2409 or ISO 4624			

Comments:

Signatures:

ICS 87.020

Descriptors: paints, varnishes, steel construction, corrosion, corrosion prevention, protective coatings, tests, laboratory tests, accelerated tests, artificial ageing tests, performance tests, comparative tests.

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