INTERNATIONAL STANDARD

ISO 12944-6

Second edition
2018-01

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.

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 second edition cancels and replaces the first edition (ISO 12944-6:1998), which has been technically revised.

The main changes compared to the previous edition are as follows:

— the normative references have been updated;

— the terms and definitions have been revised;

— 4.2 “Additional performance tests” has been revised and the Note deleted;

— 5.1 “Test panels” has been revised;

— 5.4 “Paint systems” has been revised and requirements for maximum film thickness added;

— 5.6 “Test procedures and duration” has been revised and includes a revised Table 1;

— Table 1 “Test procedures for paint systems applied to carbon steel, hot dip galvanized steel or steel with thermal-sprayed metallic coating” has been divided into two separate tables, one containing categories C1 to C5 and one containing categories Im1 to Im3;

— the former Table 2 has been deleted;

— Clause 6 “Paint system assessment” has been revised;

— in 6.2 a new Table 3 “Assessment before artificial ageing” has been included;

— in 6.3 a new Table 4 “Assessment after artificial ageing for the specified time” has been included;

— in Clause 7 “Test report” the following items were added: “photographic documents […]”, “thickness of zinc layer […]”, and “thickness of the thermal-sprayed metallic coating […]”;

— Annex A has been revised and Figures A.1 and A.2 have been added;

— a new normative Annex B “Cyclic ageing test” has been added;

— the former Annex B has been deleted;

— a Bibliography has been added;

— the text has been editorially revised.

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

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 can 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.

This document provides a way of assessing paint systems by means of laboratory tests in order to be able to select the most suitable.

Cyclic ageing testing according to Annex B is introduced within this document. It is currently used in C5 VH/ H and C4 VH. In case of C5 H and C4 VH the test regime including salt spray and condensation test can still be used as alternative to cyclic ageing test. For the future, it is intended to remove salt spray and condensation tests as alternative tests for C5 H and C4 VH.

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

Part 6: Laboratory performance test methods

1 Scope

This document specifies laboratory test methods and test conditions for the assessment of paint systems for the corrosion protection of carbon steel structures.

The test results are intended to be considered as an aid in the selection of suitable paint systems and not as exact information for determining durability.

This document covers protective paint systems designed for application to uncoated steel, hot dip galvanized steel according to ISO 1461 and steel surfaces with thermal-sprayed metallic coating according to ISO 2063-1 and ISO 2063-2.

This document does not apply to protective paint systems for electroplated or painted steel.

The environments for corrosivity categories C2 to C5 and Im1 to Im3 defined in ISO 12944-2 are considered.

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 1513, *Paints and varnishes — Examination and preparation of test samples*

ISO 2063-1, *Thermal spraying — Zinc, aluminium and their alloys — Part 1: Design considerations and quality requirements for corrosion protection systems*

ISO 2063-2, *Thermal spraying — Zinc, aluminium and their alloys — Part 2: Execution of corrosion protection systems*

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

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

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

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 4628-8, *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*

ISO 6270-1, *Paints and varnishes — Determination of resistance to humidity — Part 1: Condensation (single-sided exposure)*

ISO 7384, *Corrosion tests in artificial atmosphere — General requirements*

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 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 15528, *Paints, varnishes and raw materials for paints and varnishes — Sampling*

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*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12944-1 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
artificial ageing
procedure designed to accelerate the ageing of a paint system, i.e. to reduce the corrosion-protective efficiency more rapidly than by natural weathering

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 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.

4.2 Additional performance tests

Additional tests are recommended if

a) more information is needed on corrosion protection behaviour;

b) chemical resistance is required;

c) mechanical resistance is required;

d) cathodic protection is applied.

Additional test methods may be agreed between the interested parties.

5 Tests

5.1 Test panels

5.1.1 Carbon steel

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 × 75 mm. The panel thickness will depend on the test, but shall be 3 mm at least. Unless otherwise agreed, the panel surface shall be prepared by blast-cleaning to minimum surface preparation grade Sa 2½ 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. The panels shall not be curved. In all other respects, test panels shall comply with ISO 7384.

5.1.2 Hot dip galvanized steel

The test panels shall be made of hot dip galvanized steel in accordance with ISO 1461, unless otherwise agreed. Size and thickness shall be as for carbon steel substrates. Surface preparation shall be as agreed between the interested parties. Suitable surface preparation methods are given in ISO 12944-4 and in

ISO 12944-5:2018, Annex B. The thickness of the zinc layer shall be determined and documented in the test report.

5.1.3 Thermal-sprayed metallic coatings

The test panels shall be made of steel with a thermal-sprayed metallic coating in accordance with ISO 2063-1 and ISO 2063-2, 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 and in ISO 12944-5:2018, Annex B. Usually no further surface preparation of the thermal sprayed metal coating is necessary. The thickness of the thermal-sprayed metallic coating shall be determined and documented in the test report.

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 15528. 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 method and procedure for checking the thicknesses of dry films on rough surfaces (blast cleaned steel and thermal-sprayed metallic coating) shall be in accordance with ISO 19840, and hot dip galvanized surfaces in accordance with ISO 2808, unless otherwise agreed between the interested parties. Acceptance criteria, as stated in ISO 19840 shall apply unless otherwise agreed.

The maximum thickness of each coat on each panel shall be

— less than 1,5 × the nominal dry film thickness (NDFT) if the NDFT is ≤60 µm;

— less than 1,25 × the nominal dry film thickness (NDFT) if the NDFT is >60 µm.

Unless otherwise agreed, condition the coated test panels for two weeks in standard climate variant according to ISO 3270 of (23 ± 2) °C and (50 ± 5) % before testing.

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

Annex A defines the procedure that shall be followed to produce the scribe line for the ISO 9227 test and for the cyclic ageing test according to ISO 12944-9. Annex B defines the procedure that shall be followed for the cyclic ageing test.

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 and duration

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

Tests according to Table 1 shall be performed with separate sets of test panels.

In cases when both test regimes' durations are defined either regime may be used.

Table 1 — Test procedures for paint systems applied to carbon steel, hot dip galvanized steel or steel with thermal-sprayed metallic coating for atmospheric corrosivity categories

		Test regime 1			Test regime 2
Corrosivity category as defined in ISO 12944-2	Durability ranges according to ISO 12944-1	ISO 2812-2 (water immersion) h	ISO 6270-1 (water condensation) h	ISO 9227 (neutral salt spray) h	Annex B (cyclic ageing test) h
C2	low	—	48	—	—
	medium	—	48	—	—
	high	—	120	—	—
	very high	—	240	480	—
C3	low	—	48	120	—
	medium	—	120	240	—
	high	—	240	480	—
	very high	—	480	720	—
C4	low	—	120	240	—
	medium	—	240	480	—
	high	—	480	720	—
	very high	—	720	1 440	1 680
C5	low	—	240	480	—
	medium	—	480	720	—
	high	—	720	1 440	1 680
	very high	—	—	—	2 688

Table 2 — Test procedures for paint systems applied to carbon steel, hot dip galvanized steel or steel with thermal-sprayed metallic coating for immersion categories

Immersion category as defined in ISO 12944-2	Durability ranges according to ISO 12944-1	ISO 2812-2 (water immersion) h	ISO 6270-1[a] (water condensation) h	ISO 9227[a] (neutral salt spray) h
Im1	high	3 000	1 440	—
	very high	4 000	2 160	—
Im2	high	3 000	—	1 440
	very high	4 000	—	2 160
Im3	high	3 000	—	1 440
	very high	4 000	—	2 160

[a] Only relevant if systems are partially or temporarily immersed/buried.

An interruption of greater than 72 h is not permitted, and the total duration of interruptions shall not exceed 10 % of the total test time. The total duration of test interruptions shall not be considered part of the elapsed test time.

Systems tested according to C5 vh are also suitable for lower corrosivity categories and durabilities.

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 12944-2:2017, Table 2, use the following materials:

For Im1: water as defined in ISO 2812-2. The panels without scribe line shall be partially immersed in the aerated test medium.

For Im2 and Im3: sodium chloride, 5 % (mass fraction) aqueous solution (instead of water). The panels without scribe line shall be partially immersed in the test medium.

If an Im3 structure is under cathodic protection it is recommended to perform an additional appropriate cathodic disbondment test.

6 Paint system assessment

6.1 General

The assessments to be carried out are given in Table 3 and Table 4.

The assessment of partially immersed panels shall be carried out on the immersed area and the area exposed to the gaseous zone.

Two of the three test panels shall comply with the requirements specified in 6.2 and 6.3.

6.2 Assessment before artificial ageing

Table 3 — Assessment before artificial ageing

Assessment method	Requirements	Conditions
ISO 2409, Cross-cut	Classification 0 to 2	Only if the dry-film thickness of the paint system is less than or equal to 250 µm (measured value without correction, calibrated on smooth surface).
ISO 4624, Method A or B, Pull-off	Minimum pull-off value of 2,5 MPa for each measurement 0 % adhesive failure between steel/metalized steel respectively and the first coat (unless pull-off values are at least 5 MPa)	It is required that the force built up is controlled and linear as described in ISO 4624, e.g. by using automatic hydraulic test equipment. Push-off adhesion testing is not permitted. Ensure to cut around circumference of the dolly through to the carbon steel. A minimum of three dollies per panel shall be pulled off.

Repeat pull-off tests in case of high amount of failure in glue, or in thermal-sprayed metallic coating, if the requirements defined are not fulfilled.

6.3 Assessment after artificial ageing for the specified time

The assessment after artificial ageing for the specified time is given in Table 4.

Table 4 — Assessment after artificial ageing for the specified time

Assessment methods	Requirements	Time of assessment	Conditions/Remarks
ISO 4628-2, Blistering	0 (S0)	Immediately	
ISO 4628-3, Rusting	Ri 0	Immediately	
ISO 4628-4, Cracking	0 (S0)	Immediately	
ISO 4628-5, Flaking	0 (S0)	Immediately	

Table 4 *(continued)*

Assessment methods	Requirements	Time of assessment	Conditions/Remarks
A.2, Corrosion at scribe after salt spray test	Max. 1,5 mm corrosion at scribe as average value	As soon as possible but within 8 h after end of test	Regardless of the type of the corrosion protection system used to protect the steel substrate, the measurement of corrosion at scribe is only for the corrosion of steel. The hot dip galvanized or thermal-sprayed metallic coating is considered as part of the corrosion protection system and not a part of the substrate. Assessment of corrosion at scribe shall be carried out according to Annex A (A.2) using a measuring device with an accuracy of 0,1 mm. The average corrosion value shall be reported with a precision of 0,1 mm.
A.2, Corrosion at scribe after cyclic ageing test	Max. 3,0 mm corrosion at scribe as average value	As soon as possible but within 8 h after end of test	Regardless of the type of the corrosion protection system used to protect the steel substrate, the measurement of corrosion at scribe is only for the corrosion of steel. The hot dip galvanized or thermal-sprayed metallic coating is considered as part of the corrosion protection system and not a part of the substrate. Assessment of corrosion at scribe shall be carried out according to Annex A (A.2) using a measuring device with an accuracy of 0,1 mm. The average corrosion value shall be reported with a precision of 0,1 mm.
ISO 2409, Cross-cut	Classification 0 to 2	assessment after 7 d in standard atmosphere as defined in ISO 3270	Only if the dry-film thickness of the paint system is less than or equal to 250 µm (measured value without correction, calibrated on smooth surface).
ISO 4624, Method A or B, Pull-off	Minimum pull-off value of 2,5 MPa for each measurement 0 % adhesive failure between steel/metalized steel respectively and the first coat (unless pull-off values are at least 5 MPa)	after 7 d reconditioning in a standard atmosphere as defined in ISO 3270	It is required that the force built up is controlled and linear as described in ISO 4624, e.g. by using automatic hydraulic test equipment. Push-off adhesion testing is not permitted. Ensure to cut around circumference of the dolly through to the carbon steel. A minimum of three dollies per panel shall be pulled off.

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

Repeat pull-off tests in case of high amount of failure in glue, if the requirements defined are not fulfilled.

7 Test report

The test report shall contain at least the following information:

a) reference to this document, i.e. ISO 12944-6;

b) the test laboratory (name and address);

c) the date of each test;

d) a description of the substrate and surface preparation;

e) 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);

f) all details necessary to identify the reference system;

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

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

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

j) the results for each test panel;

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

l) thickness of the zinc layer, if applicable;

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

n) 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 International 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 ISO 12944-9:2018, Annex D.

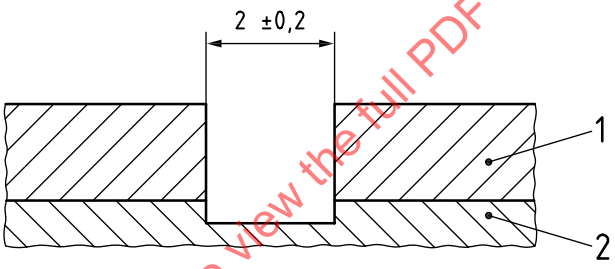
Annex A
(normative)

Scribe line for ISO 9227 test and ISO 12944-9 cyclic ageing test

A.1 Producing the scribe

A scribe line (see Figure 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 into 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 steel should be as low as possible.

Dimensions in millimetres



Key

1 coating
2 carbon steel

Figure A.1 — Cross section of scribe line

Dimensions in millimetres

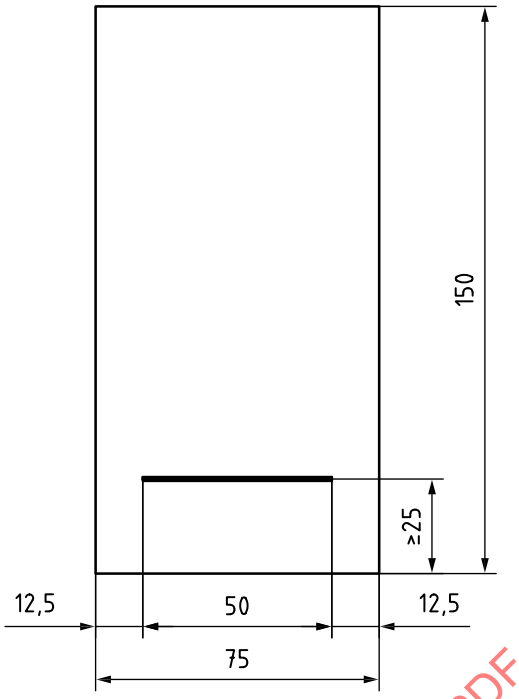


Figure A.2 — Example of test panel showing position of scribe line

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 with a precision of 0,1 mm.