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**Corrosion protection of steel structures  
by protective paint systems —  
Assessment of, and acceptance criteria  
for, the adhesion/cohesion (fracture  
strength) of a coating —**

**Part 2:  
Cross-cut testing and X-cut testing**

*Anticorrosion des structures en acier par systèmes de peintures —  
Évaluation et critères d'acceptation de l'adhésion/cohésion (résistance à  
la rupture) d'un revêtement —*

*Partie 2: Essai de quadrillage et essai à la croix de Saint André*



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Case postale 56 • CH-1211 Geneva 20  
Tel. + 41 22 749 01 11  
Fax + 41 22 749 09 47  
E-mail [copyright@iso.org](mailto:copyright@iso.org)  
Web [www.iso.org](http://www.iso.org)

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## Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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

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

ISO 16276-2 was prepared by the European Committee for Standardization (CEN) Technical Committee CEN/TC 139, *Paints and varnishes*, in collaboration with Technical Committee ISO/TC 35, *Paints and varnishes*, Subcommittee SC 14, *Protective paint systems for steel structures*.

ISO 16276 consists of the following parts, under the general title *Corrosion protection of steel structures by protective paint systems — Assessment of, and acceptance criteria for, the adhesion/cohesion (fracture strength) of a coating*:

- Part 1: *Pull-off testing*
- Part 2: *Cross-cut testing and X-cut testing*

## Introduction

The main purpose of this part of ISO 16276 is to supplement the ISO 12944 series with regard to the field assessment of, and acceptance criteria for, the adhesion/cohesion of a coating.

**NOTE** This part of ISO 16276 is intended for assessment of cross-cut testing and X-cut testing of paint coatings on steel structures on site. ISO 2409 specifies a cross-cut test and ASTM D 3359 an X-cut test for general purposes, without instructions for interpretation of the results and without acceptance or rejection criteria.

Fracture strength testing is normally destructive and therefore requires repair work, the extent of which will depend on the specification and on the durability required of the protective paint coating.

An objective of this part of ISO 16276 is to minimize variability and achieve uniformity of practice in the assessment of the fracture strength of a protective paint coating and to establish acceptance/rejection criteria for such coatings. The method uses test equipment based on the cross-cut and X-cut principles.

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# Corrosion protection of steel structures by protective paint systems — Assessment of, and acceptance criteria for, the adhesion/cohesion (fracture strength) of a coating —

## Part 2: Cross-cut testing and X-cut testing

### 1 Scope

This part of ISO 16276 specifies procedures for rating the resistance of coating systems when a cut in the form of a right-angle lattice pattern (cross-cut) or in the form of an X (X-cut) is made into the coating, penetrating through to the substrate.

This part of ISO 16276 is only applicable if the cross-cut or X-cut test method is specified, together with the rating from the appropriate rating scale.

**NOTE** The characteristics of the coating can make the assessment of the result of a cross-cut or X-cut test difficult.

This part of ISO 16276 also specifies suitable equipment and defines inspection areas, sampling plans and acceptance/rejection criteria.

It does not specify ratings for particular coating systems.

### 2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2409:2006, *Paints and varnishes — Cross-cut test*

ISO 12944-7, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 7: Execution and supervision of paint work*

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*

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*

ASTM D 3359-02, *Standard Test Methods for Measuring Adhesion by Tape Test*

### 3 Terms and definitions

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

#### 3.1

##### **fracture strength**

force required to exceed the attachment forces

- between coats or between coat and substrate (adhesion) and/or
- within a coat (cohesion)

NOTE This part of ISO 16276 does not define a method for determining fracture strength (see ISO 16276-1).

#### 3.2

##### **adhesion**

phenomenon of attachment at the interface between a solid surface and another material caused by molecular forces

NOTE Adhesion should not be confused with cohesion.

[ISO 4618:2006]

#### 3.3

##### **cohesion**

forces that bind a film into an integral entity

NOTE Cohesion should not be confused with adhesion.

[ISO 4618:2006]

#### 3.4

##### **coat**

continuous layer of a coating material resulting from a single application

[ISO 4618:2006]

#### 3.5

##### **coating**

continuous layer formed from a single or multiple application of a coating material to a substrate

[ISO 4618:2006]

#### 3.6

##### **inspection area**

designated area to which a sampling plan has been applied, which can be the whole structure or a selected section of the structure

### 4 Principle

#### 4.1 General

The resistance of coating systems to adhesive and cohesive failures due to cutting is assessed using either the cross-cut test or the X-cut test, whereby it is assessed qualitatively using a scale from 0 to 5, minimum to maximum damage, for each method (see ISO 2409 and Annex A).

The cross-cut test is suitable for film thicknesses up to 250 µm. The X-cut test is not limited by thickness.



For hard coatings, it might not be possible to use the cross-cut test, in which case the X-cut test should be used.

For coatings containing pigments that have a flake format, the assessment of either the cross-cut or the X-cut might be misleading. The coating manufacturer should be consulted for recommendations.

For the cross-cut test, a matrix of cuts through the film is prepared and then inspected to assess the damage caused. The cross-cut test is performed as described in ISO 2409. The cuts can be made either individually using a cutting tool and a guide or template to achieve the correct spacing or by using a multiple-blade cutter with the correct number and spacing of blades.

For the X-cut test, two cuts are made at an angle to form an X. Adhesive tape is applied with a firm force (e.g. pressure from the thumb) over the cut and then removed at a prescribed angle. The X-cut test is performed as described in ASTM D 3359-02, method A, using Annex A of this document for the rating.

NOTE 1 The order of the ratings in Annex A is the reverse of that published in ASTM D 3359-02.

NOTE 2 The X-cut is also known as the St. Andrew's cross.

## 4.2 Principle of cross-cut method

The cross-cut method requires that a matrix of cuts be made through the coating to the substrate to produce even squares. The spacing of the cuts and hence the size of the squares is determined according to the thickness of the coating to be assessed. Adhesive tape is applied with a firm force to remove coating squares that are poorly attached after the cuts have been made. The result of the test is expressed as a rating according to the damage observed. For complete details, see ISO 2409.

## 4.3 Principle of X-cut method

The X-cut method requires that an X-cut be made through the coating using a sharp blade. Adhesive tape is applied with a firm force to remove coating that is poorly attached. The result of the test is expressed as a rating according to the damage observed. For the rating scale, see Annex A.

## 5 Apparatus and materials

### 5.1 Cross-cut test

Details of the required apparatus and materials are given in ISO 2409.

### 5.2 X-cut test

5.2.1 **Template**, to produce a straight edge.

5.2.2 **Single-blade cutter**, in accordance with ISO 2409.

5.2.3 **Transparent pressure-sensitive adhesive tape**, in accordance with ISO 2409.

## 6 Procedure

### 6.1 General

As cross-cut and X-cut tests are destructive test methods, repair work will be necessary when they are used on coated structures.

NOTE 1 To avoid damage to the coated structure, test panels can be used (see 6.3).

The results of cross-cut and X-cut tests are influenced by different aspects of the test conditions.

The conditions on site shall be in accordance with the paint system manufacturer's recommendations.

If the required atmospheric conditions are not fulfilled at the site over the specified time period, seek the advice of the paint system manufacturer.

NOTE 2 The age of the coating can affect the result of the test. Freshly applied coatings can have a different rating from those tested two or three months after application. The temperature, humidity and ventilation during drying/curing of the coating will also affect the rating obtained.

If the coated structure is fabricated using high-strength steel, care shall be taken not to damage the steel surface. Damage to the steel surface could result in failure of the structure due to the effects of corrosion.

### 6.2 Field tests on coated structures

Prior to testing, a recently applied protective paint coating shall be dried/cured in accordance with the manufacturer's recommendations.

In the absence of manufacturer's recommendations, the coating shall be dried/cured for at least 10 days in well-ventilated conditions and at a substrate temperature in excess of 15 °C and a relative humidity of less than 80 % prior to testing.

The following conditions shall be monitored and reported over a period of 24 h before testing (an indication of the estimated conditions is sufficient):

- the weather conditions, e.g. air temperature and relative humidity;
- the surface temperature of the coated structure;
- the condition of the surface (wet/dry).

The following conditions shall be measured and reported at the time of testing:

- the air temperature;
- the relative humidity;
- the surface temperature of the coated structure;

If the surface is wet, it shall be dried and the fact that it was dried shall be recorded in the test report.

NOTE If a coating is exposed to high humidity or water, it will absorb water, which can reduce its rating. Upon drying, the rating can increase again to a certain extent, unless the coating has started to degrade or corrosion of the substrate has occurred.

### 6.3 Test panels for use on site

Test panels shall be prepared, coated and cured/dried under the same conditions and in the same way as for the structure and shall be traceable to a location on the structure. Two alternative methods for conditioning the test panels are described in a) and b) below. Any variation in the conditions shall be agreed with the paint system manufacturer. The choice of method shall be agreed between the interested parties.

- a) The coated panels remain on site for one day and are then removed for storage under standard conditions [(23 ± 2) °C, (50 ± 5) % relative humidity] for a further period of at least 10 days prior to testing.
- b) The coated panels remain on site for at least 10 days. The atmospheric conditions at the site shall be in accordance with the recommendations of the paint system manufacturer. At the end of this period, the panels are then removed for storage under standard conditions [(23 ± 2) °C, (50 ± 5) % relative humidity] for a further period of at least 16 h prior to testing.

If the required atmospheric conditions are not fulfilled at the site over the specified time period, seek the advice of the paint system manufacturer. If no advice is offered by the paint system manufacturer, a possible solution would be to remove the panels from the site and store them as described in a). In that case, the atmospheric conditions are not taken into consideration.

**NOTE** The difference between these two options lies in the atmospheric conditions for the drying/curing process of the coating. Method a) enables the quality of the surface preparation, the coating and its application to be assessed. Method b) also includes the effects of the atmospheric conditions on the drying/curing process.

### 6.4 Cross-cut test

Carry out the test as described in ISO 2409.

The cross-cut test is suitable for coating thicknesses up to 250 µm.

### 6.5 X-cut test

Make an X-cut through the coating using a single-blade cutter (5.2.2). Each cut shall be 40 mm long. The angle between the cuts at the intersection shall be between 30° and 45°. Using pressure-sensitive adhesive tape (5.2.3), apply with a firm force a piece 75 mm in length to the cut and pull off within 5 min. Determine the rating by inspection, using the information given in Annex A.

The X-cut test is not limited to any thickness.

## 6.6 Testing

### 6.6.1 General

Cross-cut and X-cut tests can be carried out in two ways:

testing the coating on the structure;

using test panels prepared at the same time and in the same way as the coating on the structure.

The method using test panels is intended to be used only if specified or if agreed between the interested parties.

### 6.6.2 Sampling plan

The sampling plan defines the number of measurements to be taken in an inspection area.

**6.6.3 Inspection areas**

Inspection areas will normally be defined in the project specification (see also ISO 12944-7 and ISO 12944-8). Unless the structure has been divided into individual inspection areas, the whole structure is considered as the inspection area for measurement purposes.

**NOTE** It is recommended that areas where the specified rating is difficult to achieve (e.g. areas where access for painting is difficult) be treated as individual inspection areas.

**6.6.4 Minimum number of measurements**

The minimum number of measurements to be made at random over an inspection area in order to assess the integrity of the coating system, is given in Table 1. For the purposes of this part of ISO 16276, the number of measurements given is considered as being representative of the inspection areas. The measurements shall also cover those areas where the specified rating is difficult to achieve, e.g. areas where access for painting is difficult (see the Note to 6.6.3).

**Table 1 — Minimum number of valid measurements within an inspection area**

Inspection area m <sup>2</sup>	Number of valid measurements
≤ 1 000	1 for each 200 m <sup>2</sup> area or part thereof
> 1 000	5, plus 1 for each additional 1 000 m <sup>2</sup> area or part thereof <sup>a</sup>
<sup>a</sup> Subdivision into smaller inspection areas is recommended.	

When test panels are used, the number of panels shall be equal to the number of measurements related to inspection areas.

**6.7 Interpretation of results**

Test results are rated by comparison with the rating tables given for the cross-cut test in Clause 8 of ISO 2409:2007 and for the X-cut test in Annex A.

**7 Expression of results**

The results of the test shall be reported as individual ratings.

In the event of a re-test (see Clause 8), the original rating and the re-test result shall be reported.

**8 Acceptance criteria**

For the acceptance of an inspection area, the appropriate criterion of the following two shall be fulfilled:

- For less than five tests, each test rating shall be equal to or better than the rating required by the specification.
- For five or more tests, 80 % of the test ratings shall be equal to or better than the rating required by the specification. For each of the remaining 20 %, only test ratings equal to the specified rating plus one rating level are acceptable.

For each 1 000 m<sup>2</sup> or part thereof, only one test which has given a failure result shall be re-done, and it shall be re-done only once.

## 9 Test report






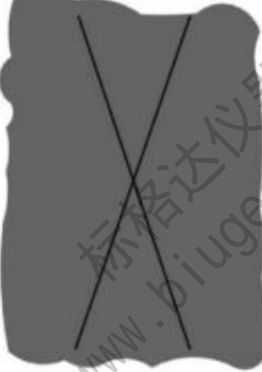
The test report shall contain at least the following information:

- a) all details necessary to identify the protective paint coating tested, including, but not limited to, the batch number of the paint system, the coating thickness (measured e.g. in accordance with ISO 19840) and the time and conditions of drying/curing, including the conditions during the 24 h before the test (see 6.2);
- b) a reference to this part of ISO 16276 (ISO 16276-2:2007);
- c) all details necessary to identify the substrate;
- d) all details necessary to describe the surface preparation of the substrate;
- e) the test method used (cross-cut or X-cut);
- f) all details necessary to identify the inspection areas;
- g) a statement that the acceptance criteria for each inspection area were or were not met;
- h) the results of the test, expressed as indicated in Clause 7 (including, where available, photographic documentation showing the area tested);
- i) the ambient temperature, the relative humidity and the surface temperature of the coated structure during the tests (see 6.2);
- j) the date and time of each test;
- k) the name of the inspector.

**Annex A**  
(normative)

**Classification of results of X-cut test**

NOTE The order of the ratings in this annex is the reverse of that published in ASTM D 3359-02.

 <p><b>Level 0</b> No peeling or removal of coating.</p>	 <p><b>Level 1</b> Trace peeling or removal along cuts or at their intersection.</p>
 <p><b>Level 2</b> Jagged removal along cuts, extending up to 1,5 mm out on either side.</p>	 <p><b>Level 3</b> Jagged removal along most of the length of the cuts, extending up to 3,0 mm out on either side.</p>
 <p><b>Level 4</b> Removal from most of the area of the X-cut under the tape.</p>	 <p><b>Level 5</b> Removal of coating beyond the area of the X-cut.</p>

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