International Standard 4542

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Metallic and other non-organic coatings — General rules for stationary outdoor exposure corrosion tests

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 4542 was developed by Technical Committee ISO/TC 107, *Metallic and other non-organic coatings*, and was circulated to the member bodies in October 1978.

It has been approved by the member bodies of the following countries :

Australia	India	South Africa, Rep. of
Bulgaria	Ireland	Spain
Czechoslovakia	Israel	Sweden
Egypt, Arab Rep. of	Italy	Switzerland
France	Japan	United Kingdom
Germany, F. R.	Netherlands	USA
Hungary	Poland	USSR

No member body expressed disapproval of the document.

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Metallic and other non-organic coatings — General rules for stationary outdoor exposure corrosion tests

0 Introduction

Corrosion testing under outdoor exposure conditions is carried out in order to :

a) obtain data on the behaviour of protective coatings in natural atmospheric environments;

b) assess the corrosion resistance of different protective coatings under particular types of atmospheric conditions;

c) compare the results of testing under given laboratory and outdoor exposure conditions;

d) investigate the mechanism of corrosion of particular protective coatings;

e) determine the duration of effective protection;

f) obtain information on the corrosivity of the atmosphere at various locations;

g) show the influence of the design of components on resistance to corrosion.

It involves exposure of coated test specimens to the action of atmospheric factors under field conditions and periodic observations of the test specimens over a period that may extend for several years.

The atmospheric conditions at a field station depend not only on geographical location and atmospheric composition, but also on additional local factors which may either be constant or may vary periodically or accidentally in a particular microclimate.

1 Scope and field of application

This International Standard gives guidance on methods of stationary testing, in natural outdoor atmospheric conditions, of protective metallic, conversion and other non-organic coatings. Mobile corrosion testing is not included in this International Standard, but it may be necessary, in some circumstances, to supplement stationary tests with mobile tests.

2 Reference

ISO 4540, *Metallic coatings — Coatings cathodic to the substrate — Rating of electroplated test specimens subjected to corrosion tests.*

3 Test specimens

3.1 Type

The following types of test specimens may be used :

— specially prepared specimens covered with the protective coating to be tested;

— coated production articles or parts thereof.

It should be noted, however, that the performance of specially prepared specimens may differ from that of production articles.

If production articles are used for testing, they should be selected to give the maximum possible information concerning the type of failure likely to affect the performance of the article in use.

3.2 Shape and dimensions

To minimize edge effects and to obtain representative corrosion, the surface area of the test specimens should be as large as possible and, in any case, not less than 50 cm^2 (5 cm × 10 cm).

If the coated articles used are smaller than 50 cm^2 in area, specimens of the same kind may be combined to total the required minimum surface area, but the results obtained will not necessarily be strictly comparable with those obtained on specially prepared test specimens of the specified minimum area.

3.3 Preparation

Clean the test specimens thoroughly before exposure to remove any contaminants that may affect the performance of the coating system being tested. The cleaning method to be employed depends upon the nature of the surface and the contaminants, but shall not include the use of any abrasives or solvents which may attack the surfaces of the test specimens.

NOTE — If the effect of controlled damage, such as scribing or bending, is to be studied, it should be carried out at this stage.

3.4 Marking

Mark the test specimens in such a way that no confusion during the exposure test is possible. Markings should be legible and durable over the whole period of exposure and should be

made on those areas of the test specimens that are not subjected to visual assessment and that have no functional purpose.

Test specimens may be marked by one of the following methods :

a) positional notch coding before the protective coating is applied (preferred method);

b) stamping appropriate numbers (with a numbering stamp);

c) hanging on the test specimen a number plate made of a corrosion-resistant material, hanging free of the specimen and attached by means of a loose-fitting, non-metallic thread, for example nylon thread;

d) painting with suitably durable paints on the reverse side of the test specimen.

Numbers should preferably be marked on the front (test) side of the test specimens, at their bottom edge. The holes on which number plates are hung should be situated near the bottom edge of the specimen so that the plate itself cannot come into direct contact with either the test specimen to which the plate is attached or with neighbouring test specimens after they have been positioned in the frame.

Mark test specimens with figures and letters so that the following information is indicated :

a) the type of coating;

b) a serial number;

c) the place and conditions of testing.

The markings should be minimized, preferably by using a simple code that enables them to be associated with the information required (see clause 6).

3.5 Number

Select the number of test specimens in any one series of tests according to the type of specimen, the number required to evaluate a particular physical property and the number expected to be removed for examination during the period of exposure. The number of test specimens of each type used for a given evaluation should not be less than three for test specimens having a surface area of at least 50 cm^2. If the specimens have smaller surface areas, take a correspondingly greater number of test specimens.

3.6 Standard specimens

It is desirable that standard test specimens of solid metals, for example zinc, copper or low alloy steel, should be included alongside the test specimens of the coating system being examined in order to be able to assess the prevailing corrosive conditions. Therefore, such metals should be chosen from those for which data concerning performance in a variety of locations have been established. The standard test specimens should be stored under the conditions specified in 3.7.

3.7 Storage

Store the test specimens before exposure in a clean, dry atmosphere in an air-conditioned, temperature-controlled room with a relative humidity of 50 % or less, or sealed in a desiccator, or by sealing the specimens into evacuated plastics bags containing a desiccant.

4 Operating conditions

4.1 Corrosion environment

Select the test conditions bearing in mind that the data obtained for a given set of test specimens should correspond with, or be similar to, the actual conditions of use of metals, coatings or articles. Before exposure, assess the corrosion factors indigenous to the place where testing is to be carried out.

The factors affecting corrosion vary with the nature of the material being tested and may include any or all of the following :

a) atmospheric humidity and its fluctuations;

b) air temperature and its fluctuations;

c) atmospheric precipitation;

d) solar radiation;

e) hours of sunshine;

f) period(s) of wetting of the surface;

g) direction and speed of winds;

h) atmospheric pollution, both chemical (such as the presence of gases and vapours) and physical (such as dust, smoke and foreign matter);

j) dust composition.

The recommended methods and frequency of monitoring these factors are given in annex A.

4.2 Atmospheric field stations and types of exposure

4.2.1 Location of field stations

An outdoor field station comprises an area of ground (testing ground) or a building (i.e. a roof) where suitable equipment for fixing the test specimens is placed. A fence round the exposure site is recommended in order to prevent the possibility of interference with the specimens.

The location of the field station should be such as to permit periodic observations of the test specimens and daily recording or evaluation of the atmospheric factors specified in 4.1. It is advantageous to locate the field stations near to or at a meteorological station.

The location of the field station should be selected mainly from the point of view of the ease of examination.

Two kinds of field station for atmospheric corrosion testing are distinguished :

a) permanent field stations, established in places of definite environmental atmospheric conditions that are characteristic of a given macroclimatic area or, within this area, of a given microclimatic area;

b) special testing field stations, established periodically for a predetermined period of time only, in places of specific climatic and corrosive conditions.

4.2.2 Types of exposure

Depending upon the purpose of testing, the following modes of exposure of the test specimens may be used :

a) open space exposure, i.e. direct exposure to all atmospheric contaminants;

b) exposure either under a cover that protects the test specimens completely from solar radiation and atmospheric precipitation, or in a partly enclosed space, such as shutter sheds, where the test specimens are protected also by shuttered side-walls;

c) closed space exposure, where the external circumstances may have only limited influence on the test specimens.

4.2.2.1 Racks or frames for full exposure

For open-space exposure, the test specimens should be placed directly on racks or frames which enable large numbers of test specimens to be exposed.

The racks or frames, in addition to meeting the exposure requirements (see 4.4), should :

a) either be made of materials sufficiently corrosion-resistant under the specified conditions or be protected by coatings resistant to the conditions;

b) be secured so as to prevent undesirable displacement and movement of the test specimens;

c) be designed so that the lowest edge of the test specimens is not less than 0,5 m from the ground, thus preventing spray reaching the test specimens when it rains.

The height of the vegetation in the neighbourhood of the racks should not be greater than 0,2 m.

Objects which may screen the test specimens from solar radiation should not be near the racks.

4.2.2.2 Sheds for covered exposure

For testing specimens under covered exposure, such as shielding under umbrella roofs, the test specimens should also be placed on racks or frames. Normal roofing materials may be used for constructing umbrella roofs.

The roof should be inclined so as to enable water to flow down and should normally ensure protection against rain water, water dripping from the roof and water rebounding from the ground. It should also ensure complete or partial shielding of the test specimens from solar radiation.

The maximum height of the roof should be not more than 3 m and it should overlap the racks by not more than 3 m.

4.2.2.3 Sheds for enclosed exposure

The design of the shutter shed should ensure protection against atmospheric precipitation, solar radiation and wind, but should allow the air flow from the outside to be maintained. The exterior surfaces of the shed walls and doors should be painted white.

The shed roof should be impervious and properly inclined with eaves and drain gutters.

The shutters should be of the venetian blind type, fixed and stable, so that air exchange is possible between the inside of the shed and the outside atmosphere and so that no rain or snow can penetrate to the interior of the shed. The wooden floor of the shed should be at least 0,5 m above ground level.

The internal dimensions of the shutter shed should be chosen according to the number of test specimens which are to be placed on racks or shelves inside the shed. The design of the racks and shelves and the positioning of specimens should be such as to ensure free air circulation between the test specimens and to prevent the formation of specific microclimatic conditions at particular remote spaces in the shed.

The shutter shed should be placed on an open space in the testing station. If more than one shed is placed on the same station, the distance between them should be such that the presence of one shed will not affect the climatic conditions inside another. It is recommended that the minimum distance between sheds be equal to twice their height.

4.3 Measuring instruments

The following measuring instruments may be used to record the exposure conditions :

a) hygrothermograph, to record the temperature and the absolute and relative humidities. To monitor the data obtained from this instrument, maximum-minimum thermometers and psychrometers are used;

b) rain-gauge, to measure the amount of atmospheric precipitation;

c) instrument to measure the amount of solar radiation;

d) sunshine recorder;

e) wind gauge with instruments to record the wind direction and speed;

f) instruments to determine the degree of atmospheric pollution depending on the type of naturally occurring pollution;

g) device for determination of the periods of wetting of the metal surface.

Instruments should be positioned and operated in accordance with their service and maintenance instructions. If testing specimens under umbrella roofs or in shutter sheds, it is recommended that the measuring instruments be placed with the test specimens.

4.4 Exposure of test specimens

Place the test specimens in such a way that :

a) contact does not occur either between individual test specimens or between the test specimens and any material that would affect their corrosion under the test conditions; this may be achieved by fixing the test specimens to the rack(s) or the frame(s) by means of suitable holders, hooks or clamps, made of non-metallic materials, resistant to atmospheric corrosion and that do not corrode the test specimens (porcelain insulators, etc.), and so that the area of contact between the test specimens and their holders is as small as possible;

b) corrosion products and rain water containing corrosion products do not drip from the surface of one test specimen onto another;

c) there is easy access to the surfaces of the test specimens;

d) they are easy to remove;

e) they are protected from falling out (for example by the action of wind), accidental contamination or damage;

f) they are all exposed to the same conditions with uniform access of air from all directions;

g) rain droplets rebounding from the ground cannot reach the surface of the test specimens;

h) for open-air exposure, the surface of the test specimens faces south in the northern hemisphere and north in the southern hemisphere (except that the direction of sources of corrosion, such as marine waters, can be taken into consideration) and the inclination of the test specimens is normally 45° unless otherwise specified;

j) they are not screened by vegetation or other articles;

k) for exposure under umbrella roofs or in shutter sheds, they are inclined at 45° unless otherwise specified;

m) they are randomly distributed over the entire range of racks available for exposure.

5 Test procedure

5.1 Positioning of test specimens

Draw up a scheme for the positioning of the test specimens on the racks, indicating the positions of particular specimens.

If testing simultaneously at various stations, maintain the exposure conditions as similar as possible in order to obtain, as far as possible, comparable results. This is particularly important for the positioning of test specimens on frames and racks, and for the design and dimensions of equipment used on exposure sites such as frames, racks, umbrella roofs and shutter sheds.

If testing metals, coatings and articles, the results of which are to be compared with the results of testing carried out at other times, place comparative standard specimens similarly to the test specimens so as to enable the corrosion resistance of the test specimens and standard specimens to be compared.

5.2 Duration of tests

Whenever possible, it is preferable to commence outdoor exposure tests in either April to May, or September to October.

If test specimens of the same type are to be removed periodically, place the test specimens on racks and frames in a sequence compatible with the scheme for their removal. Arrange all the test specimens, of one complete test programme, that are to be evaluated by visual examination at regular periodical intervals in such a way that the whole set of test specimens of the same kind is placed together.

The total period of test depends upon the type of the test specimen and the purpose of the examination. Since the atmospheric corrosion process proceeds at a relatively slow rate, it is recommended that the duration of testing be from 1 to 20 years, the results being recorded at regular intervals, usually once every 6 or 12 months, or on a schedule such as 1, 2, 5, 10 and 20 years, depending on the corrosion resistance of the coating being tested.

5.3 Evaluation of results

Evaluate the corrosion changes of the test specimens using methods in accordance with the aim and programme of testing, for example by the scheme described in ISO 4540.

Evaluate the corrosion changes at the time intervals established in the programme of testing as described in 5.2. During the first 6 months of testing, assessment after every 2 months of exposure is recommended.

After completion of the exposure period, evaluate the results within 3 months. During this time, store the test specimens as specified in 3.7.

5.4 Recording of corrosion factors

During testing, record the external corrosion factors. Examples of these factors and of the frequency of recording are given in annex A.

Examples of monthly and yearly standard charts for recording the outdoor corrosion factors are given in annex B and annex C, respectively.

5.5 Expression of results

Report the detailed results of observations and evaluations of corrosion changes of each test specimen on suitable cards.

The cards should include the following information :

a) the number or reference of the test specimen;

b) the date of exposure;

c) a description of the appearance of the surface of the test specimen before testing;

d) the dates of assessment;

e) a detailed description of changes in surface appearance, loss or gain of mass or of other physical properties, separately for each evaluation, possibly with photographs of the test specimens before, during and after testing;

f) the quantitative results of assessment of corrosion changes by visual or other methods of evaluation, using standards, photographs and patterns.

6 Test report

The test report should contain the following information :

a) data concerning specially prepared test specimen(s) :

1) specification of the basis material (substrate);

2) specification of the coating and coating materials (type of coating), especially the actual coating thickness;

3) method of preparing and cleaning the surface before coating;

4) method of application of the coating;

5) method of preparing the surface after coating;

6) basic properties of the coating, including the test methods by which its properties, for example porosity, hardness and ductility, were evaluated;

b) data concerning production articles or parts thereof :

1) basic technical documentation, for example drawings, with specifications of materials and coatings (including type of coating), especially the actual coating thickness;

2) technical data on the properties to be tested, with the test methods by which they are to be evaluated, and including the initial values before exposure;

3) the method by which the surface was prepared and cleaned before the protective coating was applied;

c) data on the testing conditions :

1) place of exposure — reference of the field station;

2) method of placing or fixing the test specimens during testing;

3) duration of test, for example date of starting and completion;

d) the dates and results of evaluation of the corrosion changes for particular test specimens in accordance with 5.5, including both descriptive data and numerical assessment, possibly with additional remarks on the conduct of the test and photographs of the test specimens.

Additionally, it is recommended that the test report should contain results of any measurements of external corrosion factors. Annexes A, B and C give guidance on the measurement and recording of these factors.

Annex A

Outdoor corrosion factors characterizing exposure conditions

Measured value	Unit	Type and number of measurements	Expression of results
Air temperature	°C	Continuous measurements or at least 3 times per day	Average per day, month and year, minimum and maximum values
Relative humidity	%		
Absolute humidity	g/m^3		
Solar radiation	$J/cm^2 \cdot min.$ or $kJ/m^2 \cdot day$	Continuous	Total per month and year
Hours of sunshine	hours/day		
Precipitation – type	–	Continuous	–
– amount	mm/day		Average per month and year
– *duration*	h/day		
– pH	–	At least once per week	
– SO_4^{2-}	mg/m^3		
– Cl^-	mg/m^3		
Wind – direction	degrees	Continuous	Prevailing
– velocity	m/s		Average
Air contamination : – concentration : of SO_2	$mg\ SO_2/m^3$	At least once per week	Average per month and year
of Cl^-	$mg\ Cl^-/m^3$		
of NO_x	$mg\ NO_x/m^3$		
of NH_3	$mg\ NH_3/m^3$		
of H_2S	$mg\ H_2S/m^3$		
– cumulative per day : of SO_2	$mg\ SO_2/m^2$	Continuous	Total per month and year
of Cl^-	$mg\ Cl^-/m^2$		
Insoluble dust contamination (as solid particles) per day	g/m^2	Continuous measurement	Average per month and year and composition
Sudden weather changes and their character : – duration – intensity	–		–

Annex B

Example of monthly tabulation of the results of recording outside corrosion factors

Exposure station :

Month-year :

Day	Climatic conditions in a given month																									
	Air temperature							Relative humidity, %							Sun		Rain		Snow		Dew, h	Fog, h	Wetting, h	Wind	
	Local time					average	maximum	minimum	Local time				average	maximum	minimum	time, h	radiation, kJ/m² · day	time, h	amount, mm	thickness, cm	precipitation, cm				direction	velocity, m/s
	0	6	12	18					0	6	12	18														
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