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Paints and varnishes — Determination of resistance to cyclic corrosion conditions —

Part 3:

Testing of coating systems on materials and components in automotive construction

Peintures et vernis — Détermination de la résistance aux conditions cycliques de corrosion —

Partie 3: Essais de systèmes de revêtements sur matériaux et composants en construction automobile

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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 of 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 www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 35, *Paints and varnishes*, Subcommittee SC 9, *General test methods for paints and varnishes*.

A list of all parts in the ISO 11997 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document was prepared on the basis of SEP 1850[9] and VDA 233-102[10].

Paints and varnishes — Determination of resistance to cyclic corrosion conditions —

Part 3:
Testing of coating systems on materials and components in automotive construction

1 Scope

This document specifies a method based on a cyclic corrosion test for testing the corrosion protection of automobiles using coating systems on aluminium, steel or galvanized steel.

The test method uses corrosive conditions (temperature and humidity ramps and salt spray) to create realistic corrosion patterns. These corrosion patterns are typical for automobiles, and they are comparable in the case of sufficiently similar protective coating systems. In particular, the accelerated test investigates the delamination/corrosion creep that results from defined artificial damage to a coating. Investigations of surface and edge corrosion or investigations of adhesive specimens or components are also covered. This cyclic corrosion test is also suitable for testing corrosion in flanged areas or near gaps.

This document was developed for the assessment of coated substrates (test specimens, bodywork and mounted parts) in the automotive industry. Other applications, such as components with unpainted metallic coatings, were not part of the scope of the standardization work. This document was originally developed for coating systems on aluminium, steel or galvanized steel but it can also be used for the assessment of the corrosion resistance of coating systems on other metals and their alloys.

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

ISO 3574, *Cold-reduced carbon steel sheet of commercial and drawing qualities*

ISO 4618, *Paints and varnishes — Terms and definitions*

ISO 4628-1, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 1: General introduction and designation system*

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 4628-10, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 10: Assessment of degree of filiform corrosion*

ISO 9227:2017, *Corrosion tests in artificial atmospheres — Salt spray tests*

ISO 17872, *Paints and varnishes — Guidelines for the introduction of scribe marks through coatings on metallic panels for corrosion testing*

ISO 20567-1, *Paints and varnishes — Determination of stone-chip resistance of coatings — Part 1: Multi-impact testing*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4618 apply.

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

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

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

4 Principle

WARNING — This document may involve hazardous materials, operations and equipment. This document does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this document to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

The test specimens are tested in a cyclic test that involves salt spray, humidity ramps and temperature ramps. In this way, realistic corrosion patterns are created for coated substrates of steel, galvanized steel and aluminium. The results of the tests are assessed based on subjective criteria that are agreed beforehand between the contractual partners.

5 Apparatus and test equipment

The typical laboratory and glass or plastics apparatus, together with the following.

5.1 Corrosion test chamber

All parts of the test chamber that come into contact with salt spray, condensate or test solutions shall be made of a material that is resistant to attack by the test solutions and does not itself affect the action of the test solutions or the salt spray/condensate on the test specimens.

The test may be carried out in separate chambers as long as the climatic conditions for the cycles are met. Chambers that can perform all conditions are available and recommended.

Test chambers shall consist of a cooling unit, heating, pressure equalization as well as the necessary measurement and control equipment to set and maintain the climate data described in Annex B (temperature ±2 °C, relative humidity ±5 %) as measured at a reference point in the closed chamber at defined temperature/relative humidity values. When passing through temperature ramps in phases with constant relative humidity, deviations in relative humidity of −8 % to +5 % are permitted.

The test chamber shall be designed in such a way that no drops fall from the ceiling or side walls onto the test specimens positioned below them. A test solution that has already been sprayed shall not be returned to the storage container.

The usable space for the test and/or the space for positioning the test specimens and test specimen holders is only that part of the test chamber that is outside of the direct spray jet. In this space, it is possible to demonstrate that there is a uniform distribution of the spray jet in accordance with 5.4.

The holders for the test specimens are to be produced from a durable, non-metallic non-conductive material. The holder should be designed as such that the gathering of test solution on the holder is prevented as much as possible. No conductive bridge is allowed between test specimens. If it is necessary to hang up test specimens, the material used shall be a durable, non-metallic and non-conductive material. The connection points on the test specimen should be at least 20 mm to the left or right from the scribe.

5.2 Spray nozzle(s)

Nozzles that are suitable for the temperature range of the test and that fulfil the conditions in 5.4 are used to generate the spray. Nozzles that use compressed air (see 5.5) to atomize the droplets shall be used. It is necessary to set the flow rate to be constant so that it is within the limits specified in 5.4. It is to be noted that the spray jet shall not point directly at the test specimens to be tested. The number and arrangement of the spray nozzles are to be selected in such a way that the specifications in 5.4 for the usable space are fulfilled.

The spray nozzles shall be made from a durable material such as glass or plastic.

5.3 Test solution

The initial solution in the storage container is a preparation of NaCl in distilled, demineralized or deionized water with a maximum conductivity of 20 µS/cm at (25 ± 2) °C in accordance with ISO 9227 but having a NaCl concentration of 10 g/l. The purity of sodium chloride shall be as specified in ISO 9227.

This solution is to be used in such a way that the sodium chloride concentration of the sprayed and collected test solution is (10 ± 1) g/l, as this can deviate from the prepared solution depending on the chamber. The density of a corresponding solution is (1,005 ± 0,000 5) g/cm^3 at 25 °C. The pH value (6,5 to 7,2) is to be maintained. Use hydrochloric acid or sodium hydroxide to adjust the pH if necessary.

WARNING — Hydrochloric acid (CAS No. 7647-01-0) solution is toxic, corrosive, irritating and very toxic to aquatic life. Refer to Safety Data Sheet for details. Handling of hydrochloric acid solution shall be restricted to skilled personnel or conducted under their control. Care shall be taken in the disposal of this solution.

WARNING — Sodium hydroxide (CAS No. 1310-73-2) solution is toxic, corrosive and irritating. Refer to Safety Data Sheet for details. Handling of sodium hydroxide solution shall be restricted to skilled personnel or conducted under their control. Care shall be taken in the disposal of this solution.

5.4 Quantity and distribution of the spray

The quantity of test solution to be sprayed over a defined period of time in accordance with 5.3 is selected in such a way that (3,0 ± 1,0) ml/h of sprayed solution is collected on average in each of the collecting devices that are used. The collected quantity in the test chamber should be controlled when the chamber is loaded with specimens in a manner similar to the test procedure. A period of at least 16 h of constant salt spray operation is recommended before the test and during regular checks of the salt spray phase.

Glass or plastic funnels with a diameter of 100 mm which are fitted into a measuring cylinder made of glass or plastic using a plug are examples of suitable collecting devices.

NOTE Funnels made of glass or plastic that have their pipe sections inside measuring cylinders have proven themselves to be suitable collecting devices. Funnels with a diameter of 100 mm have a collection area of approximately 80 cm^2.

To demonstrate the uniform distribution of the spray, at least two of the collecting devices – depending on the size of the chamber – shall be placed in the zone where the test specimens are usually placed.

In the case of very large chambers (walk-in chambers), at least one collection device is to be used for every 4 m^2 of positioning area.

For calibration purposes and for the verification of the uniform distribution of the spray, follow the procedure specified in ISO 9227:2017, 6.5.

5.5 Compressed air

The compressed air used to generate the salt spray shall be free of oil and solid contaminants. It shall be at a suitable pressure depending upon the type of spray nozzle and adjusted so that the collection rate of sprayed solution in the chamber and the concentration of sprayed solution collected are kept within the specified limits.

NOTE Humidification of the spray air can be necessary to prevent evaporation of the spray during the test. Saturation towers as described in ISO 9227 represent one common method to humidify the air.

5.6 Mass-loss coupons to demonstrate constant test conditions.

To test the apparatus, use at least three mass-loss coupons with dimensions of 150 mm × 70 mm and a thickness of (0,9 ± 0,2) mm, made of CR4 steel in accordance with ISO 3574 with practically fault-free surfaces (roughness Ra = 0,9 µm to 1,4 µm).

At least five mass-loss coupons should be used when the test chamber is being commissioned.

5.7 Balance, accurate to at least 0,001 g.

6 Test specimen preparation

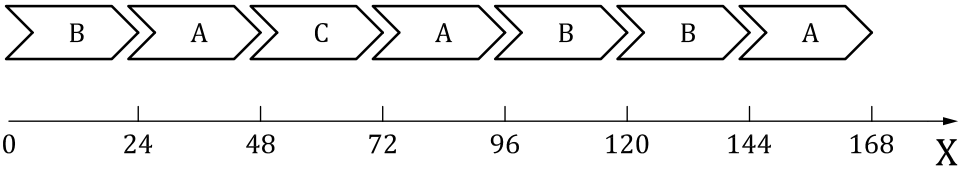
If not otherwise specified, apply an artificial defect (prior damage) to the coating, for example:

- scribe in accordance with ISO 17872;
- stone impact in accordance with ISO 20567-1;
- cross cut in accordance with ISO 2409.

7 Procedure

7.1 Test conditions – Test procedure

The test duration is six test cycles (6 weeks), if not otherwise agreed. A test cycle lasts 7 days. It consists of daily cycles A, B and C, the sequence of which is specified as shown in Figure 1.



Key

X	test time, in hours
A, B, C	daily cycle

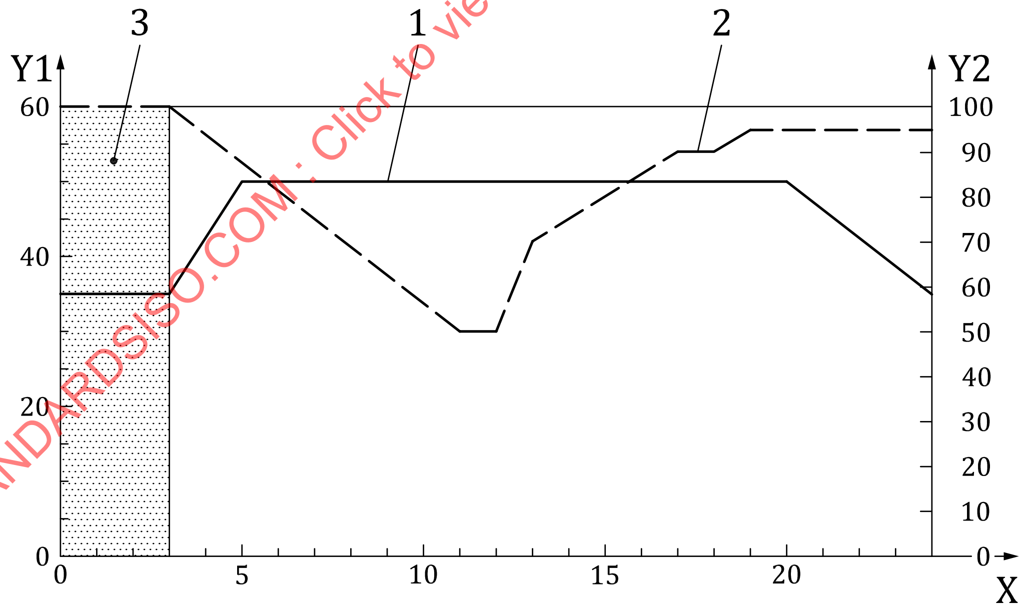
Figure 1 — Test cycle with sequence of daily cycles A, B and C

The daily cycles are characterized by the following features:

- daily cycle A, in accordance with Figure 2 and Table B.1, with a salt spray phase of 3 h (10 g/l NaCl solution);
- daily cycle B, in accordance with Figure 3 and Table B.2, with an assessment phase;
- daily cycle C, in accordance with Figure 4 and Table B.3, with a low-temperature phase.

NOTE The ramps specified in this document are based on the current status of the control technology for the chambers. They are intended to ensure that the temperature and relative humidity loadings necessary for the corrosion processes can be achieved. An example for the programming of the chambers is given in Table C.1.

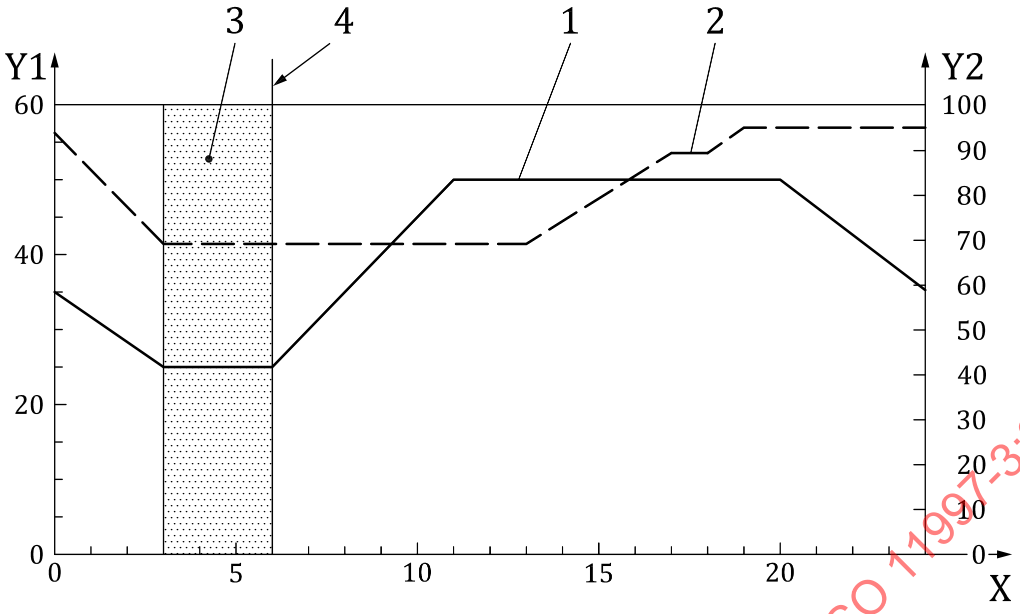
The positioning of test specimens in the test chamber (or the removal of test specimens) is carried out solely during the first daily cycle B of the assessment phase during the fourth, fifth and sixth hours after the start of daily cycle B – see Figure 3.



Key

X	time, in hours
Y1	temperature, in degrees Celsius (°C)
Y2	relative humidity, in percent (%)
1	temperature
2	relative humidity
3	salt spray phase (10 g/l NaCl solution)

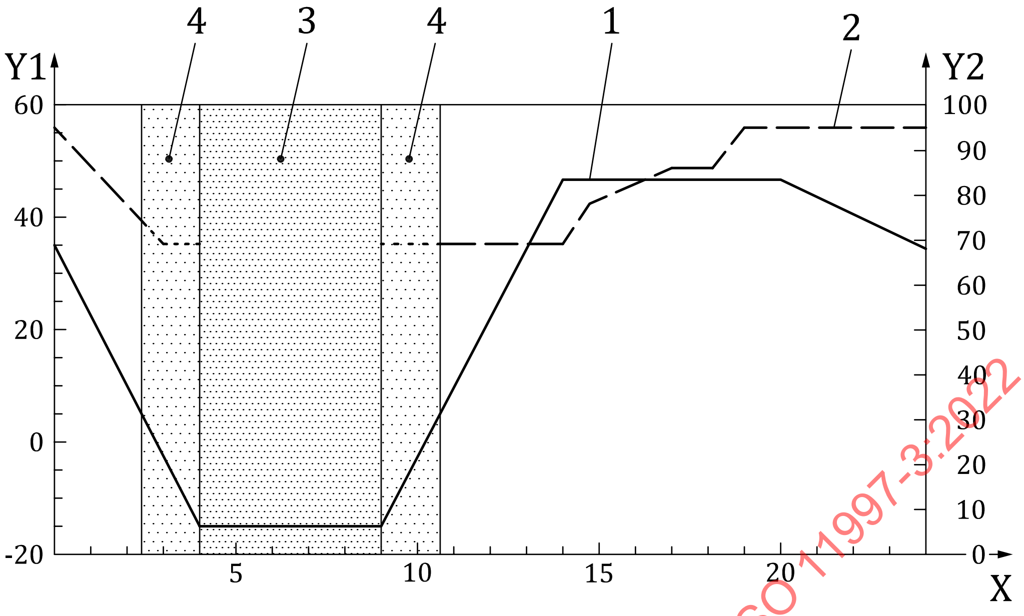
Figure 2 — Daily cycle A with a salt spray phase of 3 h (10 g/l NaCl solution)



Key

X	time, in hours
Y1	temperature, in degrees Celsius (°C)
Y2	relative humidity, in percent (%)
1	temperature
2	relative humidity
3	assessment phase
4	start of test after first placing test specimens in the chamber

Figure 3 — Daily cycle B with assessment phase



Key

X	time, in hours
Y1	temperature, in degrees Celsius (°C)
Y2	relative humidity, in percent (%)
1	temperature
2	relative humidity
3	low-temperature phase (−15 °C),
4	temperature range <5 °C with undefined relative humidity

Figure 4 — Daily cycle C with low-temperature phase (−15 °C)

7.2 Interruption of the test

It is permitted to open the test chamber during the test cycle only in the assessment phases (fourth, fifth and sixth hours) in daily cycle B. The test chamber shall not be switched off during this time.

7.3 Positioning of test specimens in the chamber

If not otherwise agreed, the surface to be assessed of the test specimen is positioned in the test chamber at an angle of (20 ± 5)° to the vertical with the side to be tested facing upwards. The test specimens shall not touch one another and shall not shield one another from the spray. The test specimens may be arranged at different levels in the chamber if the solution does not drop from test specimens or test specimen holders onto test specimens below them.

If two or more test chambers are used to carry out the different phases (salt spray, low-temperature and climate phases), drying-out of the test specimens shall be avoided when the test specimens are being transferred from one chamber to the other. If more than one chamber is used, this shall be stated in the test report.

Vehicle components or special corrosion test plates may also be used as specimens for the test. In the case of components, special care shall be taken to ensure that salt solution does not pool on the specimen, as this will affect the test conditions (climate). If this cannot be avoided, such pooling shall be removed at least once a week.

8 Method for evaluating chamber corrosivity

To check the repeatability of the test results of one set of apparatus and/or the reproducibility of the test results of different sets of apparatus, appropriate regular checks are to be carried out using mass-loss coupons (see 5.6).

Position the mass-loss coupons at an angle of (20 ± 5)° to the vertical. A suitable procedure for preparing and post-treating the mass-loss coupons is described in Annex A. Other methods described in ISO 8407 for removing of corrosion products were not approved during the interlaboratory tests. They may be suitable but need to be correlated with the pickling method.

Evaluate the mass-loss specimens gravimetrically by determining the mass change after the corrosion test. Weigh the mass-loss coupons to an accuracy of 1 mg. Divide the calculated mass loss by the area of the exposed surface of the mass-loss coupons to obtain the mass loss of metal per square metre of mass-loss plate.

If the average mass loss of at least three mass-loss coupons is outside the range specified in Table 1, the mass-loss procedure is not working in conformance with this document. In case the mass loss of the mass-loss coupons is not within the range specified in Table 1, check the test procedure and the preparation of the mass-loss coupons.

If an individual mass-loss coupon shows larger differences to the average than stated in Table 1, the reason shall be clarified.

Table 1 — Average mass loss of at least three mass-loss coupons

Test duration	Mass loss per unit area[a] g/m^2
1 test cycle	240 ± 75
2 test cycles	570 ± 160
3 test cycles	900 ± 220

[a] Calculation without cut edges.

9 Evaluation

At the end of the specified test duration, remove the test specimens from the chamber and rinse them with water to remove residues of salt solution from the surface.

If not otherwise agreed, immediately check the test surfaces for damage in accordance with ISO 4628-1, ISO 4628-2, ISO 4628-3, ISO 4628-4, ISO 4628-5, ISO 4628-8 and ISO 4628-10 or, if demanded, carry out further load tests such as a stone-impact test or cross-cut test.

10 Precision

Interlaboratory testing was carried out with selected materials (see Annex D for further information). It is not possible to make a normative statement on precision on the basis of this interlaboratory testing.

Precision depends on a range of parameters, including the evaluation procedure, the preparation of the test specimens, the film thickness of the coating, drying and conditioning of the test specimens, the application of scribes to the test specimens, and other prior damage.

11 Test report

The test report shall contain at least the following information:

a) all details necessary for the identification of the tested specimen;

b) a reference to this document, i.e. ISO 11997-3:2022;

c) additional information on the test specimen (see Annex E), if necessary;

d) the type of prior damage (see Clause 6);

e) the result of the test in comparison with the specified requirements (see Clause 9);

f) every deviation from the specified test method;

g) every unusual observation (deviation) during the test;

h) the date of the test.

Annex A

(informative)

Preparation and post-treatment of the mass-loss coupons

A.1 Preparation

Degrease the plates with n-heptane, white spirits or ligroin (not isopropanol or acetone).

Protect the rear side of the plates with a suitable removable adhesive tape. Leave the cut edges free.

A.2 Post-treatment

The corrosion effect leads to the formation of thick, strongly attached corrosion product layers that shall be removed mechanically, by bending and/or hammering for example, before pickling is carried out. Remove adhesive tape and, if necessary, adhesive residues from the rear side.

Then pickle the plates with freshly prepared, chemically pure hydrochloric acid solution, c (HCl) = 18 %, with hexamethylenetetramine c = 3,5 g/l as an inhibitor, for 20 min at a maximum of 40 °C. All visible corrosion products shall be removed. Subsequently, rinse twice with hot water and dry.

WARNING — Hexamethylenetetramine (CAS No. 100-97-0) is flammable, toxic, and may cause allergic skin reaction. Refer to Safety Data Sheet for details. Handling of hexamethylenetetramine shall be restricted to skilled personnel or conducted under their control. Care shall be taken in the disposal of this solution.

Alternative methods, such as those specified in ISO 8407, are permitted if the repeatability and reproducibility are approved.

Annex B
(normative)

Climate data settings of the daily cycles

Table B.1 — Daily cycle A (salt spray cycle; total duration 24 h)

Test time h:min	Temperature °C	Relative humidity %	Note
0:00	35 constant	100 constant	salt spray
1:00			
2:00			
3:00			
4:00	ramp 35 → 50	ramp 100 → 50	
5:00			
6:00	50 constant		
7:00			
8:00			
9:00			
10:00			
11:00			
12:00		50 constant	
13:00		ramp 50 → 70	
14:00		ramp 70 → 90	
15:00			
16:00			
17:00			
18:00		90 constant	
19:00		ramp 90 → 95	
20:00		95 constant	
21:00	ramp 50 → 35		
22:00			
23:00			
24:00			

NOTE During ramp phases, transitions occur at an approximately constant rate over the entire duration.

Table B.2 — Daily cycle B (with assessment phase; total duration 24 h)

Test time h:min	Temperature °C	Relative humidity %	Note
0:00	ramp 35 → 25	ramp 95 → 70	
1:00			
2:00			
3:00			
4:00	25 constant	70 constant	assessment phase
5:00			
6:00			
7:00	ramp 25 → 50		
8:00			
9:00			
10:00			
11:00			
12:00	50 constant		
13:00			
14:00		ramp 70 → 90	
15:00			
16:00			
17:00			
18:00		90 constant	
19:00		ramp 90 → 95	
20:00		95 constant	
21:00	ramp 50 → 35		
22:00			
23:00			
24:00			

NOTE During ramp phases, transitions occur at an approximately constant rate over the entire duration.

Table B.3 — Daily cycle C (low-temperature cycle; total duration 24 h)

Test time h:min	Temperature °C	Relative humidity %	Note
0:00	ramp 35 → −15	ramp 95 → 70, undefined when the temperature is less than 5 °C	
1:00			
2:00			
3:00			
4:00			
5:00	−15 constant	70 constant, relative humidity is undefined when the temperature is less than 5 °C	low-temperature phase The automatic regulation of humidity should be switched off between <5 °C to −15 °C. 70 % is the target value which should be reached when the temperature rises >5 °C.
6:00			
7:00			
8:00			
9:00			
10:00	ramp −15 → 50		
11:00			
12:00			
13:00			
14:00			
15:00	50 constant	ramp 70 → 80	
16:00		ramp 80 → 90	
17:00			
18:00		90 constant	
19:00		ramp 90 → 95	
20:00		95 constant	
21:00	ramp 50 → 35		
22:00			
23:00			
24:00			

NOTE During ramp phases, transitions occur at an approximately constant rate over the entire duration.

Annex C
(informative)

Sample of specified data for the programming of climate data

Table C.1 — Climate data

Time	**Daily cycle A**		**Daily cycle B**		**Daily cycle C**	
	Temperature	Relative humidity	Temperature	Relative humidity	Temperature	Relative humidity
h:min	°C	%	°C	%	°C	%
0:00	35	100	35	95	35	95
1:00	35	100	32	87	23	89
2:00	35	100	28	78	10	83
3:00	35	100	25	70	−3	X
4:00	43	94	25	70	−15	X
5:00	50	88	25	70	−15	X
6:00	50	81	25	70	−15	X
7:00	50	75	30	70	−15	X
8:00	50	69	35	70	−15	X
9:00	50	63	40	70	−15	X
10:00	50	56	45	70	−2	X
11:00	50	50	50	70	11	70
12:00	50	50	50	70	24	70
13:00	50	70	50	70	37	70
14:00	50	75	50	75	50	70
15:00	50	80	50	80	50	80
16:00	50	85	50	85	50	85
17:00	50	90	50	90	50	90
18:00	50	90	50	90	50	90
19:00	50	95	50	95	50	95
20:00	50	95	50	95	50	95
21:00	46	95	46	95	46	95
22:00	43	95	43	95	43	95
23:00	39	95	39	95	39	95
24:00	35	95	35	95	35	95
Key	salt spray phase with 10 g/l NaCl solution					
	assessment phase					
	Low-temperature phase and no controlling of the relative humidity. It is recommended to switch off the humidity control for temperatures below 5 °C.					

NOTE If there are any doubts, the table-form presentation applies as given in Annex B.

Annex D
(informative)

Details of interlaboratory testing

D.1 Interlaboratory testing

Interlaboratory testing was conducted to try to determine the precision of the corrosion test procedure. The delamination *d* in accordance with ISO 4628-8 was used as a criterion. *d* is the average width of delamination minus the scribe width, all divided by 2.

14 companies with 16 different sets of apparatus participated in this interlaboratory testing. Results that could be statistically evaluated were determined in the case of 14 sets of apparatus.

Seven different variants of substrate and coating were investigated, as presented in Table D.1.

Table D.1 — Variants in interlaboratory testing

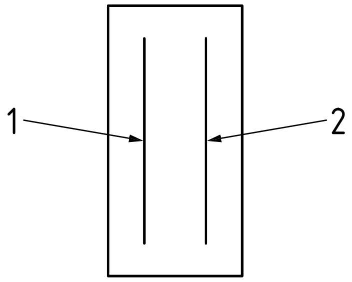
Variant[a]	Substrate	Pre-treatment	Cathodic e-coat	Filler	Basic coating material	Clear coating material	Single-layer coating material
1	steel, non-galvanized DC05	X	X	X	X	X	—
2	steel, galvanized DX56D+Z100MB	X	X	X	X	X	—
3	steel, galvanized DX56D+Z100MB	X	X	X	—	—	X
4	steel, non-galvanized DC05	X	X	X	—	—	X
5	steel, galvanized HX220BD+ZF100RB	X	X	X	X	X	—
6	aluminium, ground EN AW-6014	X	X	X	X	X	—
7	aluminium, ground EN AW-6016	X	X	X	X	X	—

[a] Variants 1 and 4 are in accordance with EN 10130; variants 2, 3 and 5 are in accordance with EN 10346; variants 6 and 7 are in accordance with EN 573-3.

D.2 Test specimens

Coated plates with dimensions of 100 mm × 200 mm were used. Each test specimen was subjected to prior damage by applying two scribes (see Figure D.1). A scribe with a width of 1 mm was applied centrally to all test specimens with a milling machine.

A second scribe was applied by each participant in interlaboratory testing using a scribe needle with a width of 1 mm using the method of Sikkens directly before the test was carried out. These scribes were applied through the coating right into the steel substrate in the case of variants 1 and 4. In the case of the galvanized variants 2, 3 and 5, the scribes were applied through the coating and metallic covering and into the steel substrate.



Key

1 centrally applied scribe (milled, 1 mm, scribe depth: coating +30 µm)

2 individually applied scribe (scribe needle using the method of Sikkens 1 mm)

Figure D.1 — Test plates used in interlaboratory testing

D.3 Corrosion test devices

Interlaboratory testing was carried out in calibrated corrosion test devices of different manufacturers and designs. The size of the test chamber was between 1 m^3 and 90 m^3.

D.4 Multiple determination

Five repeat test specimens for every variant were made available for each test chamber.

D.5 Evaluation

After a test duration of six weeks, the test specimens were evaluated at each particular test location after they were washed, dried and allowed 24 h of idle time. Depending on the capabilities at each test location, this was carried out either manually using a ruler or by means of image analysis.

After individual evaluation, the two scribes were again evaluated centrally using image analysis. Statistical evaluation was carried out in accordance with ISO 5725-2.

Repeatability limit, *r*

The repeatability limit, *r*, is the value below which the absolute difference between two test results – each the average of two valid determinations – can be expected to lie with a probability of 95 % when using this test procedure under repeatability conditions. The test results are determined here using the same test material by the same tester in the same laboratory within a short period of time in accordance with the standardized test procedure.

Reproducibility limit, *R*

The reproducibility limit, *R*, is the value below which the absolute difference between two test results – each the average of two valid determinations – can be expected to lie with a probability of 95 % when using this test procedure under reproducibility conditions. The test results are determined here using the same test material by the different testers in different laboratories in accordance with the standardized test procedure.

As the corrosion test is a destructive test, a separate test plate with the identical substrate and identical coating structure from the same batch had to be used to determine the repeatability limit for each determination.

Table D.2 shows the repeatability limit, *r*, and the reproducibility limit, *R*, as a function of scribe type and evaluation type.

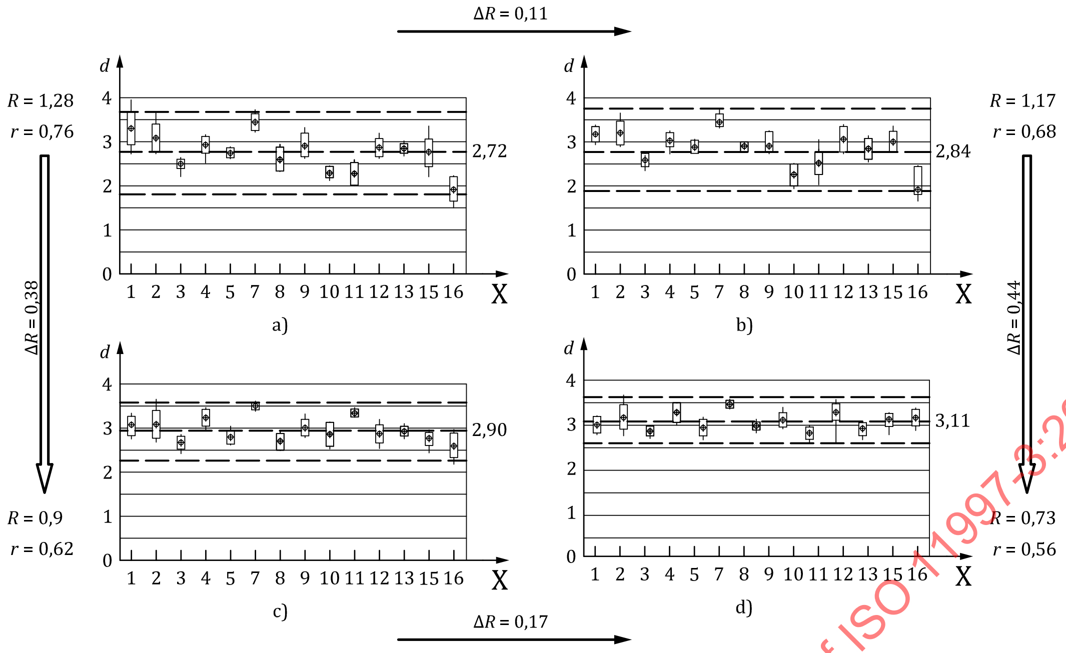
Table D.2 — Repeatability limit, *r*, and reproducibility limit, *R*, as a function of scribes and evaluation

			Individual scribe application **Individual evaluation**		**Central scribe application (with milling machine)** **Individual evaluation**		**Individual scribe application** **Central evaluation**		**Central scribe application (with milling machine)** **Central evaluation**	
Variant	**Substrate**	**Coating (incl. cathodic e-coat and filler)**	*r*	*R*	*r*	*R*	*r*	*R*	*r*	*R*
			mm	mm	mm	mm	mm	mm	mm	mm
1	steel, non-galvanized DC05	multi-layer	0,76	1,28	0,68	1,17	0.62	0,90	0,56	0,73
2	steel, galvanized DX56D+Z100MB	multi-layer	0,50	1,04	0,42	0,87	0,45	1,00	0,41	0,55
3	steel, galvanized DX56D+Z100MB	single-layer	0,50	0,77	0,56	0,68	0,47	0,76	0,35	0,46
4	steel, non-galvanized DC05	single-layer	0,83	1,53	0,63	1,39	0,52	0,94	0,57	0,79
5	steel, galvanized HX220BD+ZF100RB	multi-layer	0,61	1,09	0,49	1,04	0,57	1,02	0,36	0,62
6	aluminium, ground EN AW-6014	multi-layer	0,37	0,62	0,14[a]	0,25[a]	0,33	0,47	0,14[a]	0,20[a]
7	aluminium, ground EN AW-6016	multi-layer	0,67	0,87	0,30[a]	0,39[a]	0,48	0,77	0,22[a]	0,31[a]

[a] Almost no corrosion for scribes with a milling machine for variants 6 and 7.

It is possible to detect characteristic interrelationships when comparing *r* and *R* for different scribe and evaluation variants.

Figure D.2 shows the interrelationships for a typical, coated, non-galvanized steel substrate.



Key

a)	individual scribe application, individual evaluation
b)	central scribe application (with milling machine), individual evaluation
c)	individual scribe application, central evaluation
d)	central scribe application (with milling machine), central evaluation
X	test location
d	delamination in accordance with ISO 4628-8, in millimetres
r	repeatability limit, in millimetres
R	reproducibility limit, in millimetres
Δ*R*	difference between reproducibility limits, *R*, in millimetres, (for different scribe and evaluation methods)
⇨	high Δ*R*
→	low Δ*R*

Figure D.2 — Box-plot diagrams with repeatability and reproducibility limits for a coated steel substrate without galvanization as a function of scribes and evaluation (variant 1)

It is evident that a reduction in the reproducibility limit is achieved by central evaluation when the image analysis method is used. Central application of scribes using a milling process led only to a small reduction in the repeatability and reproducibility limits.

Figure D.3 shows an example of the repeatability and reproducibility limits for a galvanized, coated steel substrate.