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Paints and varnishes — Artificial weathering and exposure to artificial radiation — Exposure to filtered xenon-arc radiation

Peintures et vernis — Vieillissement artificiel et exposition au rayonnement artificiel — Exposition au rayonnement filtré d'une lampe à arc au xénon

Reference number
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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 11341 was prepared by Technical Committee ISO/TC 35, *Paints and varnishes*, Subcommittee SC 9, *General test methods for paints and varnishes.*

This second edition cancels and replaces the first edition (ISO 11341:1994), which has been revised both technically and editorially. It also replaces ISO 2809:1976.

The main technical changes compared to ISO 11341:1994 are:

a) Tables 1 and 2: The spectral irradiance distribution tables have been recalculated from the previous wavelength range of 300 nm to 800 nm to a wavelength range of 300 nm to 400 nm. New tolerances have been introduced based on spectral irradiance measurements made with typical xenon-arc instruments. In Table 2, the central values have been corrected using Table B.1 and B.2.

b) Subclause 6.2: The required irradiance values have been recalculated from the previous wavelength range of 300 nm to 800 nm to a wavelength range of 300 nm to 400 nm. Additionally, narrow-band spectral irradiance values at 320 nm and 420 nm have been included.

c) Subclause 6.2: An option for using high irradiance levels (up to about three times that of the sun) has been included.

d) Subclauses 6.6 and 9.2: Both black-standard and black-panel thermometers are now included.

e) Subclause 9.3: The test-chamber air temperature is now specified.

f) Table 3: The values of the relative humidity in cycles A and B have been harmonized with those in cycles C and D.

g) Clause 9.5: An additional wetting/drying cycle has been included for special applications.

Introduction

Coatings of paints, varnishes and similar materials (subsequently referred to simply as coatings) are exposed to artificial weathering, or to artificial radiation, in order to simulate in the laboratory the ageing processes which occur during natural weathering or during exposure tests under glass cover.

In contrast to natural weathering, artificial weathering involves a limited number of variables which can be controlled more readily and which can be intensified to produce accelerated ageing.

The ageing processes which occur during artificial and natural weathering cannot be expected to correlate with each other because of the large number of factors which influence these processes. Definite relationships can only be expected if the important parameters (distribution of the irradiance over the photochemically relevant part of the spectrum, temperature of the specimen, type of wetting and wetting cycle, and relative humidity) are the same in each case or if their effect on the coatings is known.

Paints and varnishes — Artificial weathering and exposure to artificial radiation — Exposure to filtered xenon-arc radiation

1 Scope

This International Standard specifies a procedure for exposing paint coatings to artificial weathering in xenon-arc lamp apparatus, including the action of liquid water and water vapour. The effects of this weathering are evaluated separately by comparative determination of selected parameters before, during and after weathering.

The standard describes the most important parameters and specifies the conditions to be used in the exposure apparatus.

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 1513, *Paints and varnishes — Examination and preparation of samples for testing*

ISO 1514, *Paints and varnishes — Standard panels for testing*

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

ISO 3270, *Paints and varnishes and their raw materials — Temperatures and humidities for conditioning and testing*

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

CIE Publication No. 85:1989, *Solar spectral irradiance*

3 Terms and definitions

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

3.1
ageing behaviour
change in the properties of a coating during weathering or exposure to radiation

NOTE One measure of ageing is the radiant exposure H in the wavelength range below 400 nm or at a specified wavelength, e.g. 340 nm. The ageing behaviour of coatings exposed to artificial weathering, or to artificial radiation, depends on the type of coating, the conditions of exposure of the coating, the property selected for monitoring the progress of the ageing process and the degree of change of this property.

3.2
radiant exposure
H
amount of radiant energy to which a test panel has been exposed, given by the equation

$$H = \int E \, \mathrm{d}t$$

where

E is the irradiance, in watts per square metre;

t is the exposure time, in seconds

NOTE 1 H is therefore expressed in joules per square metre.

NOTE 2 If the irradiance E is constant throughout the whole exposure time, the radiant exposure H is given simply by the product of E and t.

3.3
ageing criterion
given degree of change in a selected property of the coating under test

NOTE The ageing criterion is specified or agreed upon.

4 Principle

Artificial weathering of coatings or exposure of coatings to filtered xenon-arc radiation is carried out in order to obtain the degree of change in a selected property after a certain radiant exposure H, and/or the radiant exposure which is required to produce a certain degree of ageing. The properties selected for monitoring should preferably be those which are important for the practical use of the coatings. The properties of the coatings exposed are compared with those of unexposed coatings prepared from the same coating materials at the same time and in the same way (control specimens) or with those of coatings exposed at the same time whose behaviour during testing in exposure apparatus is already known (reference specimens).

During natural weathering, solar radiation is considered to be the essential cause for the ageing of coatings. The same is valid for exposure to radiation under glass. Therefore, in artificial weathering and exposure to artificial radiation, particular importance is attached to the simulation of this parameter. The xenon-arc radiation source used is therefore fitted with one of two different filter systems, designed to modify the spectral distribution of the radiation produced so that, with one of the filters, it matches the spectral distribution, in the ultraviolet and visible regions, of global solar radiation (method 1) and, with the other filter, it matches the spectral distribution, in the ultraviolet and visible regions, of global solar radiation filtered by 3-mm-thick window glass (method 2).

Two spectral energy distributions are used to describe the irradiance values and permitted deviations of the filtered test radiation in the ultraviolet range below 400 nm. In addition, CIE Publication No. 85 is used for the specification of the irradiance in the range up to 800 nm because only in that range can the xenon-arc radiation be adapted to match solar radiation sufficiently well.

During testing in exposure apparatus, the spectral irradiance E may change due to ageing of the xenon-arc lamp and the optical-filter system. This occurs particularly in the ultraviolet region which is photochemically important for polymeric materials. Therefore, measurements are made not only of the duration of the exposure, but also of the radiant exposure H in the wavelength range below 400 nm, or at a specific wavelength, e.g. 340 nm, and used as reference values for the ageing of coatings.

It is impossible to simulate accurately every aspect of the way in which the weather acts on coatings. Therefore, in this International Standard, the term artificial weathering is used as distinct from natural weathering. Testing using simulated solar radiation filtered by window glass is referred to in this International Standard as exposure to artificial radiation.

5 Required supplementary information

For any particular application, the test method specified in this International Standard shall be completed by supplementary information. The items of supplementary information are given in Annex A.

6 Apparatus

6.1 Test chamber

The test chamber shall consist of a conditioned enclosure made from corrosion-resistant material, capable of housing the radiation source, including its filter system, and the test-panel holders.

6.2 Radiation source and filter system

One or more xenon-arc lamps shall be used as the optical radiation source. The radiation emitted by them shall be filtered by a system of optical radiation filters so that the relative spectral distribution of the irradiance (relative spectral energy distribution) in the plane of the test-panel holders is sufficiently similar either to global solar ultraviolet and visible radiation (method 1) or to global solar ultraviolet and visible radiation filtered by 3-mm-thick window glass (method 2).

Tables 1 and 2 give the spectral irradiance distribution, as a percentage of the total irradiance between 290 nm and 400 nm, required when using xenon-arc lamps with daylight filters (Table 1) and when using xenon-arc lamps with window-glass filters (Table 2).

Table 1 — Required spectral irradiance distribution for xenon-arc lamps with daylight filters [method 1 (artificial weathering)]

Wavelength, λ nm	Minimum[a,b] %	CIE No. 85:1989, Table 4[c,d] %	Maximum[a,b] %
$\lambda \leqslant 290$			0,15
$290 < \lambda \leqslant 320$	2,6	5,4	7,9
$320 < \lambda \leqslant 360$	28,2	38,2	38,6
$360 < \lambda \leqslant 400$	55,8	56,4	67,5

[a] The minimum and maximum limits in this table are based on 113 spectral irradiance measurements with water- and air-cooled xenon-arc lamps with daylight filters from different production lots and of various ages, used in accordance with the recommendations of the manufacturer. The minimum and maximum limits are at least at three sigma from the mean of all the measurements.

[b] The minimum and maximum columns will not necessarily sum to 100 % because they represent the minima and maxima for the measurement data used. For any individual spectral irradiance, the percentages calculated for the passbands in this table will sum to 100 %. For any individual xenon lamp with daylight filters, the calculated percentage in each passband shall fall within the minimum and maximum limits given. Test results can be expected to differ if obtained using xenon-arc apparatus in which the spectral irradiances differed by as much as that allowed by the tolerances. Contact the manufacturer of the xenon-arc apparatus for specific spectral irradiance data for the xenon arc and filters used.

[c] The global solar radiation data from Table 4 of CIE Publication No. 85:1989 are given in Annex B. These data shall always serve as target values for xenon-arc lamps with daylight filters.

[d] For the solar spectrum represented by Table 4 in CIE Publication No. 85:1989 (see Annex B), the UV irradiance (290 nm to 400 nm) is 11 % and the visible irradiance (400 nm to 800 nm) is 89 %, expressed as a percentage of the total irradiance from 290 nm to 800 nm. These percentages of UV irradiance and visible irradiance for actual specimens exposed in xenon-arc apparatus may vary, however, due to the number of specimens being exposed and their reflectance properties.

Table 2 — Required spectral irradiance distribution for xenon-arc lamps with window-glass filters (method 2)

Wavelength, λ nm	Minimum[a,b] %	CIE No. 85, Table 4, plus effect of window glass[c,d] %	Maximum[a,b] %
$\lambda \leqslant 300$			0,29
$300 < \lambda \leqslant 320$	0,1	$\leqslant 1$	2,8
$320 < \lambda \leqslant 360$	23,8	33,1	35,5
$360 < \lambda \leqslant 400$	62,4	66,0	76,2

[a] The minimum and maximum limits in this table are based on 35 spectral irradiance measurements with water- and air-cooled xenon-arc lamps with window glass filters from different production lots and of various ages, used in accordance with the recommendations of the manufacturer. The minimum and maximum limits are at least at three sigma from the mean of all the measurements.

[b] The minimum and maximum columns will not necessarily sum to 100 % because they represent the minima and maxima for the measurement data used. For any individual spectral irradiance, the percentages calculated for the passbands in this table will sum to 100 %. For any individual xenon-arc lamp with window glass filters, the calculated percentage in each passband shall fall within the minimum and maximum limits given. Test results can be expected to differ if obtained using xenon-arc apparatus in which the spectral irradiances differed by as much as that allowed by the tolerances. Contact the manufacturer of the xenon-arc apparatus for specific spectral irradiance data for the xenon arc and filters used.

[c] The data in this column was determined by multiplying the CIE No. 85:1989 Table 4 data by the spectral transmittance of 3-mm-thick window glass (see Annex B). These data shall always serve as target values for xenon-arc lamps with window-glass filters.

[d] For the CIE No. 85:1989 Table 4 plus window glass data, the UV irradiance (300 nm to 400 nm) is typically about 9 % and the visible irradiance (400 nm to 800 nm) typically about 91 %, expressed as a percentage of the total irradiance from 300 nm to 800 nm. The percentages of UV irradiance and visible irradiance for actual specimens exposed in xenon-arc apparatus may vary, however, due to the number of specimens being exposed and their reflectance properties.

Normally, the radiant flux shall be chosen so that the time-averaged irradiance E in the plane of the test-panel holders is

— 60 W/m^2 between 300 nm and 400 nm, or 0,51 W/(m^2·nm) at 340 nm (method 1);

— 50 W/m^2 between 300 nm and 400 nm, or 1,1 W/(m^2·nm) at 420 nm (method 2).

If agreed between the interested parties, high-irradiance testing may be used. In this case, the radiant flux shall be chosen so that the time-averaged irradiance E in the plane of the test-panel holders is

— 60 W/m^2 to 180 W/m^2 between 300 nm and 400 nm, or 0,51 W/(m^2·nm) to 1,5 W/(m^2·nm) at 340 nm (method 1);

— 50 W/m^2 to 162 W/m^2 between 300 nm and 400 nm, or 1,1 W/(m^2·nm) to 3,6 W/(m^2·nm) at 420 nm (method 2).

NOTE 1 High-irradiance testing has been shown to be useful for several materials, e.g. automotive interior materials. When using high-irradiance testing, the linearity of the property change with the irradiance has to be checked carefully. Results obtained at different irradiance levels can only be compared if the other test parameters (black-standard or black-panel temperature, chamber air temperature, relative humidity) are similar.

NOTE 2 It is recommended that the actual irradiance E between 300 nm and 800 nm is measured and reported. In the case of discontinuous operation (see 9.4), this value includes the radiation reflected from the inside walls of the test chamber which reaches the plane of the test-panel holders.

NOTE 3 The conversion factors used above to calculate the narrow-band (340 nm or 420 nm) irradiance from the broad-band (300 nm to 400 nm) irradiance are mean values for a variety of filter systems. Details of such conversion factors will normally be provided by the manufacturer.

The irradiance E at any point over the area used for the test panels shall not vary by more than ± 10 % of the arithmetic mean of the total irradiance for the whole area. Any ozone formed by the operation of the xenon-arc lamps shall not enter the test chamber but shall be vented separately. If this is not possible, specimens shall be periodically repositioned to provide equivalent exposure periods in each location.

In order to accelerate ageing further, deviations from the above specifications concerning relative spectral energy distribution and irradiance may be agreed between the interested parties provided that, for the property selected for the particular coating to be tested, the correlation with natural weathering is known. Such further accelerated ageing may be carried out either by increasing the irradiance or by shifting the short-wavelength end of the spectral energy distribution band in a defined manner to shorter wavelengths. Details of any such deviations from the methods specified shall be stated in the test report.

Ageing of the xenon-arc lamps and filters causes the relative spectral energy distribution to change during operation and the irradiance to decrease. Renewal of the lamps and filters will help keep the spectral energy distribution and the irradiance constant. The irradiance may also be kept constant by adjustment of the apparatus. Follow the manufacturer's instructions.

6.3 Test chamber conditioning system

To maintain the test chamber at the black-standard or black-panel temperature specified in 9.2, humidity- and temperature-controlled dust-free air shall be circulated through the test chamber. The temperature and relative humidity of the air in the test chamber shall be monitored using temperature and humidity sensors protected against direct radiation. Only distilled or demineralized water shall be used to maintain the relative humidity at the level specified in 9.5.

NOTE When the test chamber is fed continuously with fresh air, the operating conditions of the apparatus may differ, for example, in the summer from those in the winter, because the moisture content of the air in the summer is generally higher than in the winter. This may influence the test results. The reproducibility of the test may be improved by circulating the air in an essentially closed circuit.

6.4 Device for wetting the test panels (for use in method 1)

NOTE 1 Method 1 includes wetting of the test panels; this is intended to simulate the effects of rain and condensation in an outdoor environment.

The device for wetting the test panels shall be designed so that, during the whole of the wetting period specified in 9.5, the surface under test of all the test panels shall be wetted in one of the following ways:

a) the surface is sprayed with water;

b) the panels in the test chamber are immersed in water.

NOTE 2 Wetting the samples by spraying with water and by immersion in water does not necessarily lead to similar results.

If the test panels rotate around the radiation source, the water-spray nozzles shall be arranged so that the requirements of 9.5 are met for each test panel.

Distilled or demineralized water having a conductivity below 2 µS/cm and a residue on evaporation of less than 1 mg/kg shall be used for wetting.

Recycled water shall not be used unless filtered to give water of the required purity since there is a danger of deposits forming on the test panel surfaces. Such deposits can lead to false results.

The supply tanks, supply pipes and spray nozzles for the water shall be made of corrosion-resistant material.

6.5 Test-panel holders

The holders for the test panels shall be made of an inert material.

6.6 Black-standard/black-panel thermometer

Use either a black-standard or black-panel thermometer to measure the temperature in the plane of the test panels during the dry period.

If a black-standard thermometer is used, it shall consist of a plane (flat) stainless-steel plate with a thickness of about 0,5 mm. Typical length and width dimensions are about 70 mm by 40 mm. The surface of this plate facing the light source shall be coated with a black layer that has good resistance to ageing. The coated surface shall absorb at least 90 % to 95 % of all incident radiation up to 2 500 nm. A platinum resistance temperature sensor shall be attached to, and in good thermal contact with, the centre of the plate on the side remote from the radiation source. This side of the plate shall be attached to a 5-mm-thick backing plate made of unfilled poly(vinylidene fluoride) (PVDF). A small space sufficient to hold the platinum resistance temperature sensor shall be machined in the PVDF backing plate. The distance between the sensor and the edge of the recess in the PVDF plate shall be about 1 mm. The length and the width of the PVDF plate shall be sufficiently large to ensure that no metal-to-metal thermal contact exists between the black-coated metal plate and the holder on which it is mounted. The metal parts of this holder shall be at least 4 mm from the edges of the metal plate. Black-standard thermometers which differ in construction are permitted as long as the temperature indicated by the alternative construction is within ± 1,0 °C of that indicated by the specified construction at all steady-state temperature and irradiance settings the exposure device is capable of attaining. In addition, the time needed for the alternative black-standard thermometer to reach the steady state shall be within 10 % of the time needed for the specified black-standard thermometer to reach the steady state.

If a black-panel thermometer is used, it shall consist of a plane (flat) metal plate that is resistant to corrosion. Typical dimensions are about 150 mm long, 70 mm wide and 1 mm thick. The surface of the plate facing the light source shall be coated with a black layer that has good resistance to ageing. The coated surface shall absorb at least 90 % to 95 % of all incident radiation up to 2 500 nm. Firmly attached to the centre of the exposed surface shall be the thermally sensitive element of a stem-type black-coated bimetallic coil thermometer with a dial display or a resistance thermometer. The back of the metal panel shall be open to the atmosphere within the test chamber.

If any change in appearance of the black surface is observed, the manufacturer's instructions shall be followed.

NOTE 1 The black-standard thermometer described differs from the black-panel thermometer in that, in the former, the black plate is fixed on a thermally insulated mounting. The temperatures measured therefore correspond approximately to those measured on the exposed surface of test panels with a black or dark-coloured coating on a substrate of low thermal conductivity. The surface temperatures of light-coloured test panels will usually be lower.

NOTE 2 The surface temperature of a test panel depends on a number of factors, including the amount of radiation absorbed, the amount of radiation emitted, thermal-conduction effects within the test panel and heat transfer between the test panel and the air and between the test panel and the holder, and cannot therefore be predicted with accuracy.

NOTE 3 At conditions used in typical exposure tests (not high-irradiance tests), the temperature indicated by a black-standard thermometer will usually be about 5 °C higher than that indicated by a black-panel thermometer. The difference between the black-panel temperature and the black-standard temperature increases when high-irradiance testing is being carried out (see 6.2).

NOTE 4 The black-standard thermometer is also called an insulated black-panel thermometer. The black-panel thermometer is also called an uninsulated black-panel thermometer.

In order to be able to determine the range of surface temperatures of the test panels during exposure, and to control better the exposure conditions in the apparatus, the use of an analogously designed white-standard or white-panel thermometer is recommended in addition to the black-standard or black-panel thermometer. For this purpose, a white coating with good ageing resistance having a reflectance of at least 90 % in the wavelength range between 300 nm and 1 000 nm and at least 60 % between 1 000 nm and 2 000 nm shall be used.

6.7 Radiometer

The irradiance E and radiant exposure H of the surfaces of the test panels in the test chamber shall be measured using a radiometer with a photo-electric receiver cell with a field of view of 2π sr and a good cosine response. The radiometer shall be calibrated on the basis of the spectral distribution given in Table B.1. The calibration shall be checked in accordance with the manufacturer's instructions.

NOTE Direct comparison of the radiant exposure measured in the exposure apparatus with that measured during natural weathering is possible if the radiometer used is of the same type in each case.

6.8 Calibration of exposure apparatus

The apparatus shall be calibrated in accordance with the manufacturer's specifications.

7 Sampling

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.

8 Preparation of test panels

The substrate used for the preparation of the test panels shall be that usually used in practice (e.g. plasterboard, wood, metal, plastics materials) and the method of application and drying of the coating shall be that normally used in practice to give a coating of the usual thickness.

Unless otherwise agreed or specified, standard panels conforming to the requirements of ISO 1514 shall be used as substrate for the test coating.

NOTE 1 Preferably, flat test panels of dimensions appropriate to the holders in the test chamber should be used.

Unless otherwise agreed, only the front sides of the test panels shall be coated with the material or coating system to be tested. The rear sides and edges of the test panels shall be coated, if necessary, with a coating suitable to protect the substrate from deterioration during the period of the test.

Stoving paints shall be dried under the same conditions as laid down for their normal use. In the case of air-drying paints, the coated test panels shall be stored horizontally and allowed to dry at a temperature of (23 ± 2) °C and a relative humidity of (50 ± 5) %, in accordance with the requirements of ISO 3270. The duration of drying and subsequent storage shall be as specified.

All the test panels shall be permanently marked in a suitable way. The thickness of the test coating shall be determined in accordance with ISO 2808.

In the case of testing carried out over a series of different test periods, an adequate number of test panels shall be prepared for each coating material.

If required, at least one additional test panel for each coating shall be prepared and stored at a temperature of 18 °C to 28 °C in the dark for use as a control specimen.

NOTE 2 Such coated panels can change their properties during storage.

Coatings such as alkyd paints which are sensitive to storage in the dark shall be stored under conditions agreed between the interested parties.

9 Procedure

9.1 Mounting the test panels

Mount the test panels in the holders (6.5) so that the surrounding atmosphere has free access to the coatings to be tested.

NOTE It may be agreed that the arrangement of the test panels in the holders be changed at regular intervals, for example the upper row exchanged with the lower row.

9.2 Black-standard/black-panel temperature

For normal testing, set the black-standard temperature (BST) to (65 ± 2) °C or the black-panel temperature (BPT) to (63 ± 2) °C. If the test panels are periodically wetted during exposure, measure the BST/BPT at the end of each dry phase. Even when the apparatus is being operated in the discontinuous mode (see 9.4), always use the black-standard or black-panel thermometer (6.6) continuously.

When testing for colour changes, use a BST of (55 ± 2) °C or a BPT of (50 ± 2) °C. At higher temperatures, large-scale degradation of the binder can occur, leading to chalking and loss of gloss, making the accurate assessment of colour changes difficult.

NOTE 1 The BST of 65 °C and the BPT of 63 °C have no relationship to each other. A BPT of 63 °C or 50 °C usually means higher surface temperatures than a BST of 65 °C or 55 °C, respectively. All four temperatures represent different test conditions, and different test results are to be expected in each case.

If a black-panel thermometer is used, then the type of thermometer and the way in which it is mounted on the test-panel holder shall be stated in the test report.

Other temperatures may be selected when agreed between the interested parties, but shall be stated in the test report.

NOTE 2 The BST or BPT is not identical to the real test-panel temperature (see Note 2 to 6.6).

9.3 Test-chamber air temperature

For normal testing, use a test-chamber air temperature of (38 ± 3) °C.

9.4 Exposure of test panels

Expose the test panels and the radiometer (6.7) either continuously (continuous run) or with periodically changing irradiance (discontinuous run), using method 1 or method 2 (see Clause 4) and operating the black-standard or black-panel thermometer continuously in either case.

If operating in the discontinuous mode, the periodic changes in irradiance are produced by rotating the test-panel holders through an angle of 180° to turn the test panels out of and bring them back into the direct radiation from the radiation source.

NOTE Discontinuous operation may be necessary in order to ensure that the mean irradiance is that specified in 6.2.

9.5 Wetting the test panels and relative humidity in the test chamber

Unless otherwise agreed, wet the test panels repeatedly as specified for cycles A and B or keep the relative humidity in the test chamber constant as specified for cycles C and D (see Table 3).

Table 3 — Test panel wetting cycles

Cycle	A	B	C	D
Operating mode	Continuous run	Discontinuous run	Continuous run	Discontinuous run
Wetting time, min	18	18	—	—
Dry period, min	102	102	Permanently dry	Permanently dry
Relative humidity during dry period, %	40 to 60	40 to 60	40 to 60	40 to 60

NOTE The relative humidity of the air as measured in the test chamber is not necessarily equivalent to the relative humidity of the air very close to the specimen surface since test specimens will have different colours and hence different temperatures.

Cycles A and B shall be used for artificial weathering (method 1). Cycles C and D are intended to simulate exposure behind window glass (method 2).

During wetting, the exposure to radiation shall not be interrupted.

For specific applications, e.g. paints for masonry or automotive coatings, different wetting/drying cycles, e.g. 3 min wetting/17 min drying or 12 min wetting/48 min drying have been found satisfactory. If one of these cycles is used, this shall be reported in the test report.

9.6 Exposure of test panels together with reference specimens

Simply considering ageing to be a function of the radiant exposure makes no allowance for differences between different types of apparatus, nor for possible changes in the spectral distribution of the irradiance within the relative spectral energy distributions given in Tables 1 and 2, nor for different test-panel temperatures. These parameters all have a significant effect on the way in which a coating ages and the speed at which it ages.

One way of taking into account the effect of all the relevant parameters during the test period is to expose reference specimens in the same apparatus and under the same conditions as for the test panels being examined. The reference specimen shall be as similar as possible to the test coating with regard to its chemical structure and ageing behaviour.

9.7 Duration of test

Test until

a) either the surfaces of the test panels have been subjected to an agreed radiant exposure;

b) or an agreed or specified ageing criterion (see 3.3) is satisfied.

In the latter case, remove and examine the test panels at various stages during the test period and determine the end point by plotting an ageing curve.

No single test duration or test programme can be specified which would be suitable for all types of coating. The total number of tests and the number of stages in each test shall be chosen as a function of the requirements of the individual tests and shall be agreed between the interested parties for each particular case. If not otherwise agreed, take two test panels for each assessment.

Testing of the test panels shall be carried out without interruption except for cleaning or exchanging the xenon-arc lamps or the filter system or, when testing in stages, removal of the test panels.

If panels are evaluated for changes in gloss or colour, the panels shall be removed from the weathering instrument at the end of the dry period.

10 Evaluation of ageing behaviour

It shall be agreed between the interested parties which properties of the coating shall be determined prior to, during and after the exposure, using the appropriate standards.

NOTE Suitable methods include those given in ISO 2813, ISO 7724 parts 1 to 3, ISO 3668 and ISO 4628 parts 1 to 8 and part 10.

For intermediate examinations, the test panels shall not be washed or polished, unless agreed between the interested parties. For the final examination of the coating, it shall be agreed between the interested parties whether the surface on which the determination is made shall be unwashed, washed or polished.

The individual values of the properties determined shall be presented in such a way that the intermediate results and progressive changes in properties can be clearly seen. If required, the results shall also be presented in the form of a comparison with the values of the properties of unexposed control specimens or reference specimens exposed at the same time. For multi-stage tests, the results of intermediate examinations and those of the final examination shall be presented in the form of tables, or graphically, as a function of the radiant exposure.

11 Test report

The test report shall contain at least the following information:

a) all information necessary for identification of the product tested;

b) a reference to this International Standard, ISO 11341, including its date of publication;

c) the items of supplementary information referred to in Annex A;

d) a reference to the international or national standard, product specification or other document supplying the information referred to in c);

e) the method used (method 1 or method 2), i.e. the spectral distribution selected;

f) the results of the test, as specified in Clause 10;

g) the type of exposure apparatus used;

h) whether the apparatus was operated in the continuous or discontinuous mode (state the frequency in the case of discontinuous operation);

i) the type of radiometer used;

j) the mean value of and variation in the black-standard or black-panel temperature;

k) the mean value of and variation in the relative humidity of the air in the test chamber;

l) the mean value of and variation in the temperature of the air in the test chamber;

m) the wetting cycle used (see 9.5);

n) the exposure time and/or ageing criterion;

o) the irradiance E at the test panels between 300 nm and 400 nm, or at a specified wavelength, e.g. 340 nm, and the radiant exposure H of the test panels;

p) the irradiance E between 300 nm and 800 nm, if measured;

q) details of any reference specimens exposed;

r) whether the exposure was carried out in stages or not;

s) any deviation from the test methods specified;

t) any unusual features (anomalies) observed during the test;

u) the date of the test.

Annex A
(normative)

Required supplementary information

The items of supplementary information listed in this annex shall be supplied as appropriate to enable the method to be carried out.

The information required should preferably be agreed between the interested parties and may be derived, in part or totally, from an international or national standard or other document related to the product under test.

a) Substrate material, substrate thickness and surface preparation of the substrate.

b) Method of application of the test coating to the substrate.

c) Duration and conditions of drying (or stoving) and ageing (if applicable) of the coating before testing.

d) Duration of conditioning of the test panels before starting the test (in the event of other tests having been performed beforehand on the same test panels).

e) Thickness, in micrometres, of the dry coating and method of measurement in accordance with ISO 2808, and whether it is a single coating or a multi-coat system.

f) Any agreed deviation from the test method.

g) Any particular test requirements and the agreed limit of colour change for the assessment of colour fastness to light.

Annex B
(informative)

Global solar spectral irradiance and spectral transmittance of window glass

Table B.1 — Global solar spectral irradiance at sea level (see next page)
(Taken from CIE Publication No. 85:1989, Table 4)

Parameters:

Relative air mass = 1

Water vapour content = 1,42 cm precipitable water (PW)

Ozone content = 0,34 cm at STP (standard temperature and pressure)

Spectral optical depth of aerosol extinction (at λ = 500 nm) = 0,1

Ground reflectance = 0,2

λ = wavelength in nm

$E_{G\ (0\ to\ \lambda)}$: irradiance integrated from 0 to λ, in watts per square metre

$E_{G\ (0\ to\ \infty)}$: irradiance integrated from 0 to ∞, in watts per square metre

λ	$E_{G(0\ to\ \lambda)}$	$\frac{E_{G(0\ to\ \lambda)}}{E_{G(0\ to\ \infty)}}$	λ	$E_{G(0\ to\ \lambda)}$	$\frac{E_{G(0\ to\ \lambda)}}{E_{G(0\ to\ \infty)}}$
305	0,24	0,000 2	880	760,35	0,697 3
310	0,90	0,000 8	905	774,29	0,710 1
315	2,19	0,002 0	915	781,63	0,716 8
320	4,06	0,003 7	925	787,23	0,722 0
325	6,39	0,005,9	930	790,11	0,724 6
330	9,69	0,008 9	937	793,00	0,727 3
335	12,83	0,011 8	948	798,36	0,732 2
340	16,23	0,014 9	965	807,64	0,740 7
345	19,57	0,017 9	980	817,18	0,749 4
350	24,99	0,022 9	993,5	839,65	0,770 0
360	32,51	0,029 8	1 040	865,89	0,794 1
370	41,86	0,038 4	1 070	884,94	0,811 6
380	51,62	0,047 3	1 100	896,19	0,821 9
390	61,27	0,056 2	1 120	898,43	0,823 9
400	74,56	0,068 4	1 130	900,46	0,825 8
410	89,48	0,082 1	1 137	903,07	0,828 2
420	104,47	0,095 8	1 161	911,15	0,835 6
430	117,85	0,108 1	1 180	920,41	0,844 1
440	133,89	0,122 8	1 200	932,64	0,855 3
450	152,45	1,139 8	1 235	954,24	0,875 1
460	171,34	0,157 1	1 290	971,98	0,891 4
470	189,82	0,174 1	1 320	980,26	0,899 0
480	208,69	0,191 4	1 350	982,20	0,900 8
490	226,39	0,207 6	1 395	982,40	0,901 0
500	244,08	0,223 8	1 442,5	985,07	0,903 4
510	262,10	0,240 4	1 462,5	987,28	0,905 4
520	278,88	0,255 8	1 477	989,47	0,907 4
530	296,60	0,272 0	1 497	993,77	0,911 4
540	314,00	0,288 0	1 520	999,49	0,916 6
550	340,21	0,312 0	1 539	1 004,62	0,921 3
570	373,30	0,342 3	1 558	1 009,88	0,926 2
590	404,20	0,370 7	1 578	1 014,16	0,930 1
610	436,17	0,400 0	1 592	1 018,06	0,933 7
630	467,07	0,428 3	1 610	1 022,41	0,937 6
650	497,39	0,456 2	1 630	1 026,75	0,941 6
670	526,68	0,483 0	1 646	1 032,32	0,946 7
690	550,98	0,505 3	1 678	1 042,63	0,956 2
710	570,17	0,522 9	1 740	1 053,24	0,965 9
718	578,35	0,530 4	1 800	1 055,74	0,968 2
724,4	591,01	0,542 0	1 860	1 055,99	0,968 4
740	608,92	0,558 4	1 920	1 056,14	0,968 6
752,5	619,96	0,568 6	1 960	1 057,11	0,969 5
757,5	626,16	0,574 2	1 985	1 059,27	0,971 4
762,5	629,87	0,577 7	2 005	1 060,11	0,972 2
767,5	639,46	0,586 4	2 035	1 063,13	0,975 0
780	658,53	0,603 9	2 065	1 065,29	0,977 0
800	678,78	0,622 5	2 100	1 068,90	0,980 3
816	689,81	0,632 6	2 148	1 072,80	0,983 9
823,7	696,60	0,638 9	2 198	1 077,11	0,987 8
831,5	704,52	0,646 1	2 270	1 082,67	0,992 9
840	718,81	0,659 2	2 360	1 088,21	0,998 0
860	738,91	0,677 3	2 450	1 090,40	1,000 0

Table B.2 — Transmittance through 3-mm-thick window glass [a]

Range	Wavelength, λ nm	Transmittance
UV-C	$\lambda < 280$	0
UV-B	$280 \leqslant \lambda \leqslant 320$[b]	0,10
UV-A	$320 < \lambda \leqslant 360$	0,65
UV-A	$360 < \lambda \leqslant 400$	0,88
VIS[b]	$400 < \lambda \leqslant 440$	0,88
	$440 < \lambda \leqslant 480$	0,90
	$480 < \lambda \leqslant 520$	0,90
	$520 < \lambda \leqslant 560$	0,90
	$560 < \lambda \leqslant 600$	0,90
	$600 < \lambda \leqslant 640$	0,88
	$640 < \lambda \leqslant 680$	0,86
	$680 < \lambda \leqslant 720$	0,84
	$720 < \lambda \leqslant 760$	0,82
	$760 < \lambda \leqslant 800$	0,80
Sum	280 to 3 000	0,85

[a] Source: Zentralabteilung Forschung der VEGLA — Vereinigte Glaswerke GmbH, Aachen, Germany, 1983.

[b] Radiation below 300 nm does not reach the surface of the Earth; at wavelengths above 3 000 nm, radiation levels are negligible.

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