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Paints and varnishes — Exposure of coatings to artificial weathering — Exposure to fluorescent UV lamps and water

Peintures et vernis — Exposition des revêtements au vieillissement artificiel — Exposition au rayonnement de lampes à fluorescence UV et à l'eau

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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 11507 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 11507:1997), which has been technically revised. The main changes are:

— the data on the lamps (tables in 5.1.2) have been harmonized with the data given in ISO 4892-3;

— the purity of the water for wetting the test panels has been changed from grade 2 to grade 3;

— conditioning of the coated test panels prior to testing has been deleted.

Introduction

Coatings from paints, varnishes and similar materials are weathered in the laboratory, in order to simulate ageing processes occurring during natural weathering. Generally, valid correlations between ageing during artificial and natural weathering cannot be expected because of the large number of influencing factors. Certain relationships can only be expected if the effect of the important parameters (spectral distribution of the irradiance in their photochemically relevant range, temperature of the specimen, type of wetting, wetting cycle relative humidity) on the coating is known. However, unlike natural weathering, testing in the laboratory is carried out taking into consideration a limited number of variables which can be controlled and therefore the results are more reproducible.

Paints and varnishes — Exposure of coatings to artificial weathering — Exposure to fluorescent UV lamps and water

1 Scope

This International Standard specifies exposure conditions for paint coatings exposed to artificial weathering in apparatus including fluorescent UV lamps and condensation or water spray. The effects of weathering are evaluated separately by comparative testing of chosen parameters.

NOTE The ultraviolet light produced by fluorescent lamps simulates only part of the UV region of natural sunlight and, consequently, the test pieces are subjected to a small but destructive portion of the spectrum.

Due to the lack of visible and infra-red energy in the light from such UV lamps compared to sunlight, the test pieces are not heated above the temperature of the surrounding air in the way in which they would be in practical use.

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 3696:1987, *Water for analytical laboratory use — Specification and test methods*

ISO 4892-1:1999, *Plastics — Methods of exposure to laboratory light sources — Part 1: General guidance*

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

3 Terms and definitions

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

3.1
ageing criterion
given degree of change in a selected property of the coating under test

NOTE The ageing criterion is specified or agreed upon.

[ISO 11341:2004]

3.2
ageing behaviour
change in the properties of a coating during weathering or exposure to radiation

[ISO 11341:2004]

NOTE One measure of ageing is the radiant exposure below 400 nm or the radiant exposure at a specific wavelength that is necessary to cause a specific property change.

3.3
irradiance
E
radiant flux/area for a specified wavelength range, expressed in watts per square metre

3.4
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.

[ISO 11341:2004]

4 Principle

Artificial weathering of coatings using fluorescent UV lamps and condensation or water spray is carried out in order to produce a certain radiant exposure or mutually agreed total number of operation hours and a given degree of a change in a property or properties.

The properties of the exposed coatings are compared with those of unexposed coatings, prepared from the same coating materials under identical conditions, or with coatings whose degradation properties are known. These properties are evaluated in accordance with criteria agreed in advance between the interested parties.

Radiation, temperature and humidity all contribute to the ageing process. Therefore, apparatus specified in this International Standard simulates all three factors.

The results obtained by the use of this method do not necessarily relate directly to the results obtained under natural exposure conditions. The relationship between these results needs to be established before the method can be used to predict performance. Different chemical behaviour can result in a different correlation between accelerated weathering and natural weathering.

5 Apparatus

5.1 Test chamber

5.1.1 General

The test chamber consists essentially of a conditioned enclosure, made from corrosion-resistant material, in which are housed the lamps, a heated water-tray or spray nozzles and test panel racks.

5.1.2 Lamps

UV lamps emit UV light from a low-pressure mercury arc. The required spectral distribution is achieved by a careful selection of the type of phosphor coating on the inner surface of the lamp and the nature of the glass used in the construction of the tubes.

Unless otherwise specified, the lamp shall be one of the three types listed below:

Type I: This lamp emits a significant amount of radiation at wavelengths below 300 nm which is not present in the sun's radiation. Some lamps of this type have a measurable emittance at the 254 nm mercury line. Due to the higher quantum energy of this radiation, photochemical ageing processes can be initiated which do not take place in natural weathering. Therefore, this type of fluorescent lamp should be used only when specially agreed between the parties concerned.

This lamp, commonly called UVB-313, has a peak emission at 313 nm and the relative spectral irradiance given in Table 1.

Table 1 — Relative ultraviolet spectral irradiance for UVB-313 lamps [a,b]

Spectral passband (λ = wavelength in nm)	Minimum [c] %	CIE No. 85:1989, Table 4 [d,e] %	Maximum [c] %
$\lambda < 290$	1,3	0	5,4
$290 \leqslant \lambda \leqslant 320$	47,8	5,4	65,9
$320 < \lambda \leqslant 360$	26,9	38,2	43,9
$360 < \lambda \leqslant 400$	1,7	56,4	7,2

[a] This table gives the irradiance in the given passband, expressed as a percentage of the total irradiance between 250 nm and 400 nm. To determine whether a specific type I (UVB-313) lamp meets the requirements of this table, the spectral irradiance from 250 nm to 400 nm shall be measured. The total irradiance in each passband is then summed and divided by the total irradiance between 250 nm and 400 nm.

[b] The minimum and maximum limits given in this table are based on 44 spectral irradiance measurements with type I (UVB-313) lamps from different production lots and of various ages [18]. The spectral irradiance data are for lamps within the ageing recommendations of the apparatus manufacturer. As more spectral irradiance data become available, minor changes in the limits are possible. The minimum and maximum limits are at least three sigma from the mean for all the measurements.

[c] 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 distribution, the percentages calculated for the passbands in this table will sum to 100 %. For any individual type I (UVB-313) fluorescent lamp, the calculated percentage in each passband shall fall within the minimum and maximum limits given. Test results can be expected to differ between exposures using type I (UVB-313) lamps in which the spectral irradiance differs by as much as that allowed by the tolerances. Contact the manufacturer of the fluorescent UV apparatus for specific spectral irradiance data for the type I (UVB-313) lamp used.

[d] The data from Table 4 in CIE Publication No. 85:1989 is the global solar irradiance on a horizontal surface for an air mass of 1,0, an ozone column of 0,34 cm at STP, 1,42 cm of precipitable water vapour and a spectral optical depth of aerosol extinction of 0,1 at 500 nm. These data are provided for reference purposes only.

[e] For the solar spectrum represented by Table 4 in CIE No. 85:1989, 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. Because the primary emission of fluorescent UV lamps is concentrated in the 300 nm to 400 nm passband, there are limited data available for the visible light emission of fluorescent UV lamps. The percentages of UV irradiance and visible irradiance on specimens exposed in fluorescent UV apparatus can vary due to the number of specimens being exposed and their reflectance properties.

Type II: This lamp, commonly called UVA-340, with agreement with solar radiation in the photochemically important short-wavelength range, has a peak emission at 340 nm and the relative spectral irradiance given in Table 2.

Table 2 — Relative ultraviolet spectral irradiance for UVA-340 lamps [a,b]

Spectral passband (λ = wavelength in nm)	Minimum [c] %	CIE No. 85:1989, Table 4 [d,e] %	Maximum [c] %
$\lambda < 290$		0	0,01
$290 \leqslant \lambda \leqslant 320$	5,9	5,4	9,3
$320 < \lambda \leqslant 360$	60,9	38,2	65,5
$360 < \lambda \leqslant 400$	26,5	56,4	32,8

[a] This table gives the irradiance in the given passband, expressed as a percentage of the total irradiance between 290 nm and 400 nm. To determine whether a specific type II (UVA-340) lamp meets the requirements of this table, the spectral irradiance from 250 nm to 400 nm shall be measured. Typically, this is done in 2 nm increments. The total irradiance in each passband is then summed and divided by the total irradiance between 290 nm and 400 nm.

[b] The minimum and maximum limits for Type II (UVA-340) lamps in this table are based on more than 60 spectral irradiance measurements with type II (UVA-340) lamps from different production lots and of various ages [18]. The spectral irradiance data are for lamps within the ageing recommendations of the apparatus manufacturer. As more spectral irradiance data become available, minor changes in the limits are possible. The minimum and maximum limits are at least three sigma from the mean for all the measurements.

[c] 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 distribution, the percentages calculated for the passbands in this table will sum to 100 %. For any individual type II (UVA-340) fluorescent lamp, the calculated percentage in each passband shall fall within the minimum and maximum limits given. Test results can be expected to differ between exposures using type II (UVA-340) lamps in which the spectral irradiance differs by as much as that allowed by the tolerances. Contact the manufacturer of the fluorescent UV apparatus for specific spectral irradiance data for the type II (UVA-340) lamp used.

[d] The data from Table 4 in CIE Publication No. 85:1989 is the global solar irradiance on a horizontal surface for an air mass of 1,0, an ozone column of 0,34 cm at STP, 1,42 cm of precipitable water vapour and a spectral optical depth of aerosol extinction of 0,1 at 500 nm. These data are provided for reference purposes only and are intended to serve as a target.

[e] For the solar spectrum represented by Table 4 in CIE No. 85:1989, 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. Because the primary emission of fluorescent UV lamps is concentrated in the 300 nm to 400 nm passband, there are limited data available for the visible light emission of fluorescent UV lamps. The percentages of UV irradiance and visible irradiance on specimens exposed in fluorescent UV apparatus can vary due to the number of specimens being exposed and their reflectance properties.

Type III: This lamp, commonly called UVA-351 and used to simulate the UV region of solar radiation behind window glass, has a peak emission at 351 nm and the relative spectral irradiance given in Table 3.

Table 3 — Spectral irradiance for UVA-351 lamps for daylight behind window glass [a,b]

Spectral passband (λ = wavelength in nm)	Minimum [c] %	CIE No. 85:1989, Table 4, plus effect of window glass [d,e] %	Maximum [c] %
$\lambda < 300$		0	0,2
$300 \leqslant \lambda \leqslant 320$	1,1	$\leqslant 1$	3,3
$320 < \lambda \leqslant 360$	60,5	33,1	66,8
$360 < \lambda \leqslant 400$	30,0	66,0	38,0

[a] This table gives the irradiance in the given passband, expressed as a percentage of the total irradiance between 290 nm and 400 nm. To determine whether a specific type III (UVA-351) lamp meets the requirements of this table, the spectral irradiance from 250 nm to 400 nm shall be measured. The total irradiance in each passband is then summed and divided by the total irradiance between 290 nm and 400 nm.

[b] The minimum and maximum limits given in this table are based on 21 spectral irradiance measurements with type III (UVA-351) lamps from different production lots and of various ages [18]. The spectral irradiance data are for lamps within the ageing recommendations of the apparatus manufacturer. As more spectral irradiance data become available, minor changes in the limits are possible. The minimum and maximum limits are at least three sigma from the mean for all the measurements.

[c] 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 distribution, the percentages calculated for the passbands in this table will sum to 100%. For any individual type III (UVA-351) fluorescent lamp, the calculated percentage in each passband shall fall within the minimum and maximum limits given. Test results can be expected to differ between exposures using type III (UVA-351) lamps in which the spectral irradiance differs by as much as that allowed by the tolerances. Contact the manufacturer of the fluorescent UV apparatus for specific spectral irradiance data for the type III (UVA-351) lamp used.

[d] The data from Table 4 in CIE Publication No. 85:1989 plus the effect of window glass was determined by multiplying the CIE No. 85:1989 Table 4 data by the spectral transmittance of typical 3-mm-thick window glass (see ISO 11341). These data are provided for reference purposes only and are intended to serve as a target.

[e] For the CIE No. 85:1989 Table 4 plus window glass data, the UV irradiance from 300 nm to 400 nm is typically about 9 % and the visible irradiance (400 nm to 800 nm) is typically about 91 %, expressed as a percentage of the total irradiance from 300 nm to 800 nm. Because the primary emission of fluorescent UV lamps is concentrated in the 300 nm to 400 nm passband, there are limited data available for the visible light emission of fluorescent UV lamps. The percentages of UV irradiance and visible irradiance on specimens exposed in fluorescent UV apparatus can vary due to the number of specimens being exposed and their reflectance properties.

If the lamps are of the same type, they shall be fixed in banks of at least four. Combinations of lamps with different spectral emissions are not recommended but, if they are used, provision shall be made to ensure uniformity of the spectral irradiance at the surface of the specimens, e.g. by changing the positions of the specimens at intervals. Since the spectral output decreases with age, the lamps shall be renewed or rotated in accordance with the apparatus manufacturer's recommendations.

5.1.3 Device for wetting the test panels

The test panels shall be wetted by condensation from the heated water-tray or by spray. Condensation is ensured by room air cooling of the backs of the specimens. For spraying, water conforming to the requirements of grade 3 of ISO 3696:1987 shall be used. In cases where specimen thickness or low thermal conductivity does not allow condensation, use method B (see 8.2.2).

5.1.4 Test panel racks

When using condensation to wet the test panels, the design of the racks shall be such that, when the panels are mounted in place, there will be sufficient free access of air to cool the back of each panel and produce condensation on the front.

5.1.5 Black-panel thermometer

When the apparatus is operating at the specified parameters, the temperature shall be monitored by means of a remote sensor attached to a black panel. The black-panel thermometer shall be exposed to the same exposure conditions as the specimens.

NOTE Fluorescent UV lamps emit relatively little infra-red radiation compared to xenon-arc and carbon-arc sources. In fluorescent UV apparatus, heating of the test panel is primarily by convection of heated air across the panel. Therefore, there is only a small difference between the temperature of the black-panel thermometer, that of the test-panel surface and that of the air in the test chamber.

Indicate the type of black-panel thermometer used in the test report.

5.1.6 Radiometer

The use of a radiometer to monitor irradiance and radiant exposure is optional. If a radiometer is used, it shall conform to 5.1.7 of ISO 4892-1:1999.

5.2 Reference material

The use of reference material has been found to be advisable.

6 Sampling

Take a representative sample of the product to be tested (or of each product in the case of a multicoat system), as described in ISO 15528.

Examine and prepare each sample for testing, as described in ISO 1513.

7 Test panels

7.1 Substrate

The substrate used for the preparation of the test panels shall be that usually used in practice (e.g. plaster, wood, metal or plastics material).

Unless otherwise agreed or specified, standard test panels prepared in accordance with ISO 1514 shall be used. The test panels shall be flat and their dimensions shall match those of the test panel racks (see manufacturer's recommendations).

When using condensation to wet the test panels, the maximum test-panel thickness shall be such that condensation occurs on the front of the panel.

7.2 Preparation and coating

Unless otherwise specified, prepare each test panel in accordance with ISO 1514 and then coat it by the specified method with the product or system under test.

Unless otherwise agreed, coat only the front of each test panel with the coating material or coating system to be tested. If necessary, coat the backs and edges of the test panels with a protective paint.

7.3 Drying and conditioning

Dry (or stove) and age (if applicable) each coated test panel for the specified time and under the specified conditions.

Mark all the test panels indelibly.

7.4 Thickness of coating

Determine the thickness, in micrometres, of the dried coating by one of the non-destructive procedures specified in ISO 2808.

7.5 Number of test panels

Generally, for each coating material, an appropriate number of test panels is tested in one apparatus. In the case of graduated testing, the number of test panels for each coating material will have to be increased.

If required, at least one additional test panel for each coating material shall be prepared as a reference specimen. It shall be stored at room temperature, avoiding humidity and direct radiation.

NOTE The properties of some reference coatings can change during storage.

8 Procedure

8.1 Mounting the test panels

Secure the test panels in the racks and arrange in the apparatus in accordance with the manufacturer's instructions. All spaces shall be occupied by test panels or blanks.

To ensure uniform exposure of the test panels, follow the instructions of the manufacturer of the test apparatus, e.g. rotating the test panels at intervals of not more than 3 days (it is assumed that such minor interruptions will not adversely affect the end result).

8.2 Exposure

8.2.1 Method A — Exposure including condensation

Locate the apparatus in a draft-free but ventilated environment maintained at a temperature of (23 ± 5) °C.

Maintain the black-panel temperature during the irradiation (dry) phase at (60 ± 3) °C for a period of 4 h, unless otherwise agreed or specified.

Maintain the black-panel temperature during the condensation phase at (50 ± 3) °C for a period of 4 h, unless otherwise agreed or specified.

Weekly examination of the test panels is recommended. This examination shall be carried out towards the end of the dry phase of the test cycle.

NOTE The absorption of water into the coating can affect the appearance.

When the apparatus is started for the first time, or after a period of shut-down, allow it to equilibrate at the specified conditions.

It is recommended that the apparatus be checked frequently to ensure that condensation has occurred on the test panels.

8.2.2 Method B — Exposure including water spray

Instead of, or in addition to, water condensation phases, periods of water spray can be used.

For example, the following cycle can be used: 5 h dry at a continuous irradiance of 45 W/m^2 (290 nm to 400 nm), a black-panel temperature of (50 ± 3) °C and a relative humidity < 15 %; then 1 h water spray at the same irradiance and a black-panel temperature of (25 ± 3) °C, but with no control of the relative humidity; then start the dry period again.

8.3 Duration of exposure

Continue the exposure until the agreed or specified ageing criterion or the specified radiant exposure (see 3.1 and 3.4) is reached.

It is not possible to specify a duration of exposure which would be valid for all the different types of surface coating. The duration of the exposure will also depend on the type of lamp used.

The exposure of the test panels is normally carried out without interruption except for servicing, maintenance of the apparatus and examination of the panels.

9 Calibration

Black-panel thermometers shall be calibrated in accordance with the manufacturer's recommendations.

Apparatus equipped with an irradiance control system shall be calibrated in accordance with the manufacturer's recommendations.

10 Examination of test panels (ageing criteria)

It shall be agreed between the interested parties which properties of the coating shall be measured prior to, during and after ageing, as well as which methods shall be used to do this.

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

Unless otherwise agreed, the test panels shall not be washed or polished during examinations.

11 Precision

Precision data for this International Standard are not yet available.

12 Supplementary test conditions

For any particular application of the method specified in this International Standard, more details, in addition to those in the preceding clauses, might need to be given, such as the following:

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 exposure;

d) duration and conditions of conditioning of the test panels before starting the exposure (in the event of other tests having been performed beforehand on the same test specimen);

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

f) full details of the duration of exposure and conditions of exposure;

g) any particular test requirements, e.g. agreed limit of colour change for the assessment of colour fastness.

13 Test report

The test report shall contain at least the following information:

a) all information necessary for complete identification of the product tested (manufacturer, trade name, batch number, etc.);

b) a reference to this International Standard (ISO 11507:2006);

c) all details of the procedure including:

   1) the type of lamp used (type I, II or III or, if another type was used, details of that type and the radiant exposure H),

   2) the cycle used,

   3) the starting phase (wet or dry);

d) the items of supplementary information referred to in Clause 12;

e) a reference to the international or national standard, product specification or other document supplying the information referred to in Clause 12);

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

g) any deviations from the procedure specified;

h) any unusual features (anomalies) observed during testing;

i) the date of testing.

Bibliography

[1] ISO 2813, *Paints and varnishes — Determination of specular gloss of non-metallic paint films at 20°, 60° and 85°*

[2] ISO 3668, *Paints and varnishes — Visual comparison of the colour of paints*

[3] 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*

[4] 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*

[5] 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*

[6] 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*

[7] 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*

[8] ISO 4628-6, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 6: Assessment of degree of chalking by tape method*

[9] ISO 4628-7, *Paints and varnishes — Evaluation of degradation of coatings; Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 7: Assessment of degree of chalking by velvet method*

[10] 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*

[11] 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*

[12] ISO 4892-3:2006, *Plastics — Methods of exposure to laboratory light sources — Part 3: Fluorescent UV lamps*

[13] ISO 7724-1, *Paints and varnishes — Colorimetry — Part 1: Principles*

[14] ISO 7724-2, *Paints and varnishes — Colorimetry — Part 2: Colour measurement*

[15] ISO 7724-3, *Paints and varnishes — Colorimetry — Part 3: Calculation of colour differences*

[16] ISO 11341:2004, *Paints and varnishes — Artificial weathering and exposure to artificial radiation — Exposure to filtered xenon-arc radiation*

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

[18] ASTM G 154, *Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials*

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