
**Paints and varnishes — Methods of
exposure to laboratory light sources —
Part 1:
General guidance**

*Peintures et vernis — Méthodes d'exposition à des sources lumineuses
de laboratoire —*

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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. www.iso.org/directives

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 35, *Paints and varnishes*, Subcommittee SC 9, *General test methods for paints and varnishes*.

This first edition of ISO 16474-1, together with ISO 16474-2, cancels and replaces ISO 11341:2004, which has been technically revised. This first edition of ISO 16474-1, together with ISO 16474-3, cancels and replaces ISO 11507:2007, which has been technically revised.

ISO 16474 consists of the following parts, under the general title *Paints and varnishes — Methods of exposure to laboratory light sources*:

- *Part 1: General guidance*
- *Part 2: Xenon-arc lamps*
- *Part 3: Fluorescent UV lamps*
- *Part 4: Open-flame carbon-arc lamps*

Introduction

Coatings from paints, varnishes and similar materials are often used outdoors or in indoor locations where they are exposed to solar radiation or to solar radiation behind glass for long periods. It is therefore very important to determine the effects of solar radiation, heat, moisture and other climatic stresses on the colour and other properties of polymers. Outdoor exposures to solar radiation and to solar radiation filtered by window glass are described in ISO 2810[9]. However, it is often necessary to determine more rapidly the effects of light, heat and moisture on the physical, chemical and optical properties of coatings with artificial accelerated weathering or artificial accelerated irradiation exposures that use specific laboratory light sources. Exposures in these laboratory devices are conducted under more controlled conditions than found in natural environments and are intended to accelerate polymer degradation and product failures. Relating results from accelerated weathering or artificial accelerated irradiation exposures to those obtained in actual-use conditions is difficult because of variability in both types of exposure and because laboratory tests often do not reproduce all the exposure stresses experienced by coatings exposed in actual-use conditions. In addition, the increase in rate of degradation by the accelerated test compared with natural exposure conditions varies with the type of material and its formulation. No single laboratory exposure test can be specified as a total simulation of actual-use exposures. The relative durability of materials in actual-use exposures can be very different depending on the location of the exposure because of differences in solar radiation, time of wetness, temperature, pollutants and other factors. Therefore, even if results from specific accelerated weathering or artificial accelerated irradiation exposures are found to be useful for comparing the relative durability of materials exposed in a particular outdoor location or in particular actual-use conditions, it cannot be assumed that they will be useful for determining the relative durability of materials exposed in a different outdoor location or in different actual-use conditions.

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Paints and varnishes — Methods of exposure to laboratory light sources —

Part 1: General guidance

1 Scope

1.1 This part of ISO 16474 provides information and general guidance relevant to the selection and operation of the methods of exposure described in detail in subsequent parts. It also describes general performance requirements for devices used for exposing paints and varnishes to laboratory light sources. Information about such performance requirements is provided for producers of artificial accelerated weathering or artificial accelerated irradiation devices.

1.2 This part of ISO 16474 also provides information on the interpretation of data from artificial accelerated weathering or artificial accelerated irradiation exposures.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 test samples*

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 4618, *Paints and varnishes — Terms and definitions*

ISO 9370, *Plastics — Instrumental determination of radiant exposure in weathering tests — General guidance and basic test method*

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

ISO 16474-2, *Paints and varnishes — Methods of exposure to laboratory light sources — Part 2: Xenon-arc lamps*

ISO 16474-3, *Paints and varnishes — Methods of exposure to laboratory light sources — Part 3: Fluorescent UV lamps*

ISO 16474-4, *Paints and varnishes — Methods of exposure to laboratory light sources — Part 4: Open-flame carbon-arc lamps*

3 Terms and definitions

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

**3.1
artificial accelerated irradiation**

exposure of a material to a laboratory radiation source intended to simulate window-glass-filtered solar radiation or radiation from interior lighting sources and where specimens are subjected to relatively small changes in temperature and relative humidity in an attempt to produce more rapidly the same changes that occur when the material is used in an indoor environment

Note 1 to entry: These exposures are commonly referred to as fading or light fastness tests.

**3.2
artificial accelerated weathering**

exposure of a material in a laboratory weathering device to conditions which may be cyclic and intensified compared with those encountered in outdoor or in-service exposure

Note 1 to entry: This involves a laboratory radiation source, heat and moisture (in the form of relative humidity and/or water spray, condensation or immersion) in an attempt to produce more rapidly the same changes that occur in long-term outdoor exposure.

Note 2 to entry: The device may include means for control and/or monitoring of the light source and other weathering parameters. It may also include exposure to special conditions, such as acid spray to simulate the effect of industrial gases.

**3.3
control material**

material which is of similar composition and construction to the test material and which is exposed at the same time for comparison with the test material

Note 1 to entry: An example of the use of a control material would be when a formulation different from one currently being used is being evaluated. In that case, the control would be the coating made with the original formulation.

**3.4
file specimen**

portion of the material to be tested which is stored under conditions in which it is stable and which is used for comparison between the exposed and unexposed states

**3.5
reference material**

material of known performance

**3.6
reference specimen**

portion of the reference material that is to be exposed

4 Principle

4.1 General

Specimens of the samples to be tested are exposed to laboratory light sources under controlled environmental conditions. The methods described include the requirements which have to be met for the measurement of the irradiance and radiant exposure in the plane of the specimen, the temperature of specified white and black sensors, the chamber air temperature and the relative humidity.

4.2 Significance

4.2.1 When conducting exposures in devices that use laboratory light sources, it is important to consider how well the accelerated-test conditions simulate the actual-use environment for the paint or varnish being tested. In addition, it is essential to consider the effects of variability in both the accelerated test and actual exposures when setting up exposure experiments and when interpreting the results from artificial accelerated weathering or artificial accelerated irradiation exposures.

4.2.2 No laboratory exposure test can be specified as a total simulation of actual-use conditions. Results obtained from artificial accelerated weathering or artificial accelerated irradiation exposures can be considered as representative of actual-use exposures only when the degree of rank correlation has been established for the specific materials being tested and when the type and mechanism of degradation are the same. The relative durability of materials in actual-use conditions can be very different in different locations because of differences in solar radiation, time of wetness, relative humidity, temperature, pollutants and other factors. Therefore, even if results from a specific exposure test conducted in accordance with any of the parts of this International Standard are found to be useful for comparing the relative durability of materials exposed in a particular environment, it cannot be assumed that they will be useful for determining the relative durability of the same materials in a different environment.

4.2.3 Even though it is very tempting, it is invalid to assign to all materials a “general acceleration factor” relating “x” hours or megajoules of radiant exposure in an artificial accelerated weathering or artificial accelerated irradiation exposure to “y” months or years of actual exposure. Such acceleration factors are invalid for the following reasons:

- a) acceleration factors are material-dependent and can be significantly different for each material and for different formulations of the same material;
- b) variability in the rate of degradation in both actual-use and artificial accelerated weathering or artificial accelerated irradiation exposures can have a significant effect on the calculated acceleration factor;
- c) acceleration factors calculated based on the ratio of irradiance between a laboratory light source and solar radiation (even when identical pass-bands are used) do not take into consideration the effects of temperature, moisture and differences in spectral power distribution between the laboratory light source and solar radiation.

NOTE Acceleration factors determined for a specific formulation of a material are valid, but only if they are based on data from a sufficient number of separate outdoor or indoor environmental tests and artificial accelerated weathering or artificial accelerated irradiation exposures so that results used to relate times to failure in each exposure can be analysed using statistical methods. An example of a statistical analysis using multiple laboratory and actual exposures to calculate an acceleration factor is described by J.A. Simms^[1].

4.2.4 There are a number of factors that might decrease the degree of correlation between accelerated tests using laboratory light sources and exterior exposures (more specific information on how each factor can alter the stability ranking of materials is given in [Annex B](#)):

- a) differences in the spectral irradiance of the laboratory light source and solar radiation;
- b) irradiance levels higher than those experienced in actual-use conditions;
- c) exposure cycles that use continuous exposure to light from a laboratory light source without any dark periods;
- d) specimen temperatures higher than those in actual conditions;
- e) exposure conditions that produce unrealistic temperature differences between light- and dark-coloured specimens;
- f) exposure conditions that produce very frequent cycling between high and low specimen temperatures, or that produce unrealistic thermal shock;
- g) unrealistic levels of moisture in the accelerated test compared to actual-use conditions;
- h) the absence of biological agents, pollutants or acidic precipitation or condensation.

4.3 Use of accelerated tests with laboratory light sources

4.3.1 Results from artificial accelerated weathering or artificial accelerated irradiation exposures conducted in accordance with any of the parts of this International Standard are best used to compare the relative performance of materials. Comparisons between materials can only be made when the materials are tested at the same time in the same exposure device. Results can be expressed by comparing the exposure time or radiant exposure necessary to reduce the level of a characteristic property to some specified level. A common application of this is a test conducted to establish that the level of quality of different batches does not vary from that of a control of known performance.

4.3.1.1 It is strongly recommended that at least one control be exposed with each test for the purpose of comparing the performance of the test materials to that of the control. The control material should be of similar composition and construction and be chosen so that its failure modes are the same as that of the material being tested. It is preferable to use two controls, one with relatively good durability and one with relatively poor durability.

4.3.1.2 Sufficient replicates of each control and each test material being evaluated are necessary in order to allow statistical evaluation of the results. Unless otherwise specified, use a minimum of three replicates for all test and control materials. When material properties are measured using destructive tests, a separate set of specimens is needed for each exposure period.

4.3.2 In some specification tests, test materials are exposed at the same time as a weathering reference material (e.g. blue wool test fabric). The property or properties of the test material are measured after a defined property of the reference material reaches a specified level. If the reference material differs in composition from the test material, it might not be sensitive to exposure stresses that produce failure in the test material or it might be very sensitive to an exposure stress that has very little effect on the test material. The variability in results for the reference material might be very different from that for the test material. All these differences between the reference material and the test material can produce misleading results when the reference material is used as a control or to determine the length of the exposure period.

NOTE 1 Definitions of control and reference materials that are appropriate to weathering tests are given in [Clause 3](#).

NOTE 2 Weathering reference materials can also be used to monitor the consistency of the operating conditions in an exposure test. Information about the selection and characterization of reference materials used for this purpose can be found in ASTM G 156[2]. ISO/TR 19032[3] describes a procedure which uses the change in the carbonyl index of a specific polyethylene weathering reference material to monitor conditions in both natural weathering and artificial accelerated weathering exposures.

4.3.3 In some specification tests, properties of test specimens are evaluated after a specific exposure time or radiant exposure using a test cycle with a prescribed set of conditions. Results from any accelerated exposure test conducted in accordance with any of the parts of this International Standard should not be used to make a “pass/fail” decision for materials, based on the level of a specific property after a specific exposure time or radiant exposure, unless the combined reproducibility of the effects of a particular exposure cycle and property measurement method has been established.

5 Requirements for laboratory exposure devices

Laboratory exposure devices shall be equipped with facilities to provide specimens with irradiance ([5.1](#)), temperature ([5.2](#)), humidity and wetting ([5.3](#)).

5.1 Irradiance

5.1.1 Laboratory light sources are used to provide irradiance for the test specimens. In ISO 16474-2 a xenon-arc lamp is used to provide the irradiance for the specimens, in ISO 16474-3 a fluorescent UV lamp, and in ISO 16474-4 an open-flame carbon-arc lamp.

5.1.2 The exposure device shall provide for placement of specimens and any designated sensing devices in positions that allow uniform irradiance from the light source.

NOTE The spectral irradiance produced in an artificial accelerated weathering device is very important. Ideally, the relative spectral irradiance produced by the device should be a very close match to that of solar radiation, especially in the short-wavelength UV region. [Annex C](#) provides information about a benchmark solar spectrum that can be used for comparing the spectral irradiance produced in the artificial accelerated exposure to that for solar radiation. Subsequent parts of this International Standard contain specific requirements for the relative spectral irradiance produced in the devices described in those parts.

5.1.3 Exposure devices shall be designed such that the irradiance at any location in the area used for specimen exposures is at least 70 % of the maximum irradiance measured in this area. Procedures for measuring irradiance uniformity by the device manufacturers are given in [Annex A](#).

NOTE The irradiance uniformity in exposure devices depends on several factors, such as deposits that can develop on the optical system and chamber walls. In addition, irradiance uniformity can be affected by the type of specimen and the number of specimens being exposed. The irradiance uniformity as guaranteed by the manufacturer is valid for new equipment and well-defined measuring conditions.

5.1.4 Depending on the specific sensitivity of the material periodic repositioning of the specimens is good practice in order to be sure that the variability in exposure stresses experienced during the exposure period is kept to the minimum. If the irradiance at any position in the area used for specimen exposure is between 70 % and 90 % of the maximum irradiance, specimens shall be periodically repositioned to reduce the variability in radiant exposure.

NOTE Random placement of replicate specimens is also good practice to reduce the effect of any variability in the conditions within the exposure area.

5.1.5 Follow the device manufacturer's instructions for lamp and filter replacement and for pre-ageing of lamps and/or filters.

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5.1.6 A radiometer that complies with the requirements outlined in ISO 9370 may be used to measure the irradiance E or spectral irradiance E_λ and the radiant exposure H or spectral radiant exposure H_λ in the plane of the specimen surface.

5.1.6.1 If used, the radiometer shall be mounted so that it receives the same radiation as the specimen surface. If it is not positioned in the specimen plane, it shall have a sufficiently wide field of view and be calibrated for irradiance at the specimen distance.

5.1.6.2 The field radiometer shall be calibrated in the emission region of the light source used with a reference radiometer. The radiometer shall be calibrated using a light source filter combination of the same type that will be used for testing or an appropriate spectral mismatch factor has been taken into account. The calibration shall be checked in accordance with the radiation measuring instrument manufacturer's instructions.

For fluorescent UV lamps, it has been shown that the field radiometers have to be calibrated with lamps that have a spectral power distribution which is identical to that of the lamps that will be used for testing.

NOTE Refer to ISO 9370 for definitions of field and reference radiometers.

5.1.6.3 When measured, the irradiance in the wavelength range agreed upon by all interested parties shall be reported. Some types of device provide for measuring irradiance in a specific wavelength range (e.g. 300 nm to 400 nm or 300 nm to 800 nm) or in a narrow pass-band that is centred around a single wavelength (e.g. 340 nm).

5.2 Temperature

5.2.1 The surface temperature of exposed materials depends primarily on the amount of radiation absorbed, the emissivity of the specimen, the amount of thermal conduction within the specimen and the amount of heat transmission between the specimen and the air or between the specimen and the specimen holder. Since it is not practical to monitor the surface temperature of individual test specimens, a specified black surface sensor is used to measure and control the temperature within the exposure chamber. The black surface temperature sensor shall be mounted within the specimen exposure area so that it receives the same radiation and experiences the same cooling conditions as a flat test panel surface.

5.2.2 Two types of black surface temperature sensor may be used: a black-standard thermometer (BST) and a black-panel thermometer (BPT).

5.2.2.1 *Black-standard thermometers*, consisting of a plane (flat) stainless-steel plate with a thickness of 0,5 mm to 1,2 mm. A typical length and width is about 70 mm by 40 mm. The surface of this plate facing the light source shall be coated with a black layer which has good resistance to ageing. The coated black plate shall reflect no more than 10 % of all incident flux up to 2 500 nm. A thermally sensitive element such as a platinum resistance sensor shall be attached to the centre of the plate, in good thermal contact with the plate, on the side opposite the radiation source. This side of the metal plate shall be attached to a 5 mm thick baseplate made of unfilled poly(vinylidene fluoride) fluoride (PVDF). A small space sufficient to hold the platinum resistance sensor shall be machined in the PVDF baseplate. The distance between the sensor and this recess in the PVDF plate shall be about 1 mm. The length and width of the PVDF plate shall be sufficient so that no metal-to-metal thermal contact exists between the black-coated metal plate and the mounting holder into which it is fitted. The metal mounts of the holder of the insulated black panel shall be at least 4 mm from the edges of the metal plate. Black-standard thermometers which differ in construction from that specified above are permitted as long as the temperature indicated by the alternative construction is within $\pm 1,0$ °C of that of the specified construction at all steady-state temperature and irradiance settings the exposure device is capable of attaining. In addition, the time needed for an 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.

NOTE Black-standard thermometers are sometimes referred to as insulated black-panel thermometers.

5.2.2.2 *Black-panel thermometers*, consisting 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 this plate that faces the light source shall be coated with a black layer which has good resistance to ageing. The coated black plate shall reflect no more than 10 % of all incident flux up to 2 500 nm. A thermally sensitive element shall be firmly attached to the centre of the exposed surface. This thermally sensitive element may be a black-coated stem-type bimetallic dial sensor, a resistance-based sensor, a thermistor or a thermocouple. The back side of the metal panel shall be open to the atmosphere.

NOTE Black-panel thermometers are sometimes referred to as uninsulated black-panel thermometers.

5.2.2.3 Unless otherwise specified, temperatures shall be measured using either of the thermometer designs described above. If other means are used to measure the temperature of black or white panels, the exact construction of the black or white panel shall be included in the test report.

5.2.3 The temperature indicated by the black-panel or black-standard thermometer depends on the irradiance produced by the laboratory light source and the temperature and speed of the air moving in the exposure chamber. Black-panel temperatures generally correspond to those for dark coatings on metal panels without thermal insulation on the rear side. Black-standard thermometer temperatures generally correspond to those for the exposed surface of dark samples with poor thermal conductivity. At conditions used in typical exposures, the temperature indicated by a black-standard thermometer will be 3 °C to 12 °C higher than that indicated by a black-panel thermometer. The actual difference between a black-panel temperature and a temperature measured with a black-standard thermometer should, however, preferably be determined for each exposure condition. Because black-standard thermometers are insulated, their response time for temperature changes is slightly slower than for a black-panel thermometer.