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**Plastics — Methods of exposure to  
laboratory light sources —**

**Part 1:  
General guidance**

*Plastiques — Méthodes d'exposition à des sources lumineuses de  
laboratoire —*

*Partie 1: Lignes directrices générales*



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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation 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 61, *Plastics*, Subcommittee SC 6, *Ageing, chemical and environmental resistance*.

This third edition cancels and replaces the second edition (ISO 4892-1:1999), which has been technically revised.

ISO 4892 consists of the following parts, under the general title *Plastics — 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

Plastics 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 plastics. Outdoor exposures to solar radiation and to solar radiation filtered by window glass are described in ISO 877 (all parts).<sup>[1]</sup> However, it is often necessary to determine more rapidly the effects of radiation, heat and moisture on the physical, chemical and optical properties of plastics 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 eventual 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 never reproduce exactly all the exposure stresses experienced by plastics exposed in actual-use conditions. 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 UV 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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# Plastics — Methods of exposure to laboratory light sources —

## Part 1: General guidance

### 1 Scope

This part of ISO 4892 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 plastics to laboratory light sources. Information regarding performance requirements is for producers of artificial accelerated weathering or artificial accelerated irradiation devices.

NOTE In this part of ISO 4892, the term “light source” refers to radiation sources that emit UV radiation, visible radiation, infrared radiation or any combination of these types of radiation.

This part of ISO 4892 also provides information on the interpretation of data from artificial accelerated weathering or artificial accelerated irradiation exposures. More specific information about methods for determining the change in the properties of plastics after exposure and reporting these results is given in ISO 4582.

### 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 291, *Plastics — Standard atmospheres for conditioning and testing*

ISO 293, *Plastics — Compression moulding of test specimens of thermoplastic materials*

ISO 294-1, *Plastics — Injection moulding of test specimens of thermoplastic materials — Part 1: General principles, and moulding of multipurpose and bar test specimens*

ISO 294-2, *Plastics — Injection moulding of test specimens of thermoplastic materials — Part 2: Small tensile bars*

ISO 294-3, *Plastics — Injection moulding of test specimens of thermoplastic materials — Part 3: Small plates*

ISO 295, *Plastics — Compression moulding of test specimens of thermosetting materials*

ISO 2818, *Plastics — Preparation of test specimens by machining*

ISO 3167, *Plastics — Multipurpose test specimens*

ISO 4582, *Plastics — Determination of changes in colour and variations in properties after exposure to daylight under glass, natural weathering or laboratory light sources*

ISO 4892-2, *Plastics — Methods of exposure to laboratory light sources — Part 2: Xenon-arc lamps*

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

ISO 4892-4, *Plastics — 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 following terms and definitions apply.

NOTE Definitions of other terms that are related to weathering tests are found in Reference [2].

#### 3.1 control

<weathering testing> 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 plastic made with the original formulation.

#### 3.2 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

#### 3.3 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 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.

#### 3.4 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 may be 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 lightfastness tests.

#### 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 plastic 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 UV 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 passbands are used) do not take into consideration the effects of temperature, moisture and differences in relative spectral irradiance 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 exterior 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 in Reference [3].

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

- a) the differences in the relative spectral irradiance of the laboratory light source and solar radiation;
- b) the irradiance levels higher than those experienced in actual-use conditions;
- c) the exposure cycles that use continuous exposure to radiation from a laboratory light source without any dark periods;
- d) the specimen temperatures higher than those in actual conditions;

- e) the exposure conditions that produce unrealistic temperature differences between light- and dark-coloured specimens;
- f) the exposure conditions that produce very frequent cycling between high and low specimen temperatures, or that produce unrealistic thermal shock;
- g) the unrealistic levels of moisture in the accelerated test compared with 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 may not be sensitive to exposure stresses that produce failure in the test material or it may be very sensitive to an exposure stress that has very little effect on the test material. The variability in results for the reference material may 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 Reference [4]. Reference [5] 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

### 5.1 Irradiance

**5.1.1** Laboratory light sources are used to provide irradiance for the test specimens. In ISO 4892-2, a xenon-arc lamp is used to provide the irradiance for the specimens, in ISO 4892-3 a fluorescent UV lamp and in ISO 4892-4 an open-flame sunshine 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 radiation source.

**NOTE** The spectral irradiance produced in an artificial accelerated weathering device is very important. Ideally, the relative spectral irradiance produced by the device is expected to be a very close match to that of solar radiation, especially in the short-wavelength UV region. [Annex C](#) provides information about important benchmark solar spectra 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** If the minimum 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. The repositioning procedure and schedule shall be agreed upon by all interested parties.

**NOTE** Reference [6] describes several possible procedures, including random positioning of replicate specimens, that can be used to reduce the variability in exposure stresses experienced by specimens during exposure.

**5.1.5** If the irradiance at any position in the area used for specimen exposure is at least 90 % of the maximum irradiance, it is not necessary to use periodic repositioning of the specimens during exposure to ensure uniform radiant exposure. While periodic repositioning of the specimens may not be necessary, it is nevertheless good practice in order to be sure that the variability in exposure stresses experienced during the exposure period is kept to the minimum.

**NOTE 1** Depending on the specific sensitivity of the material, periodic repositioning of the specimens is good practice to minimize variability in stresses experienced during the exposure.

**NOTE 2** Random placement of replicate specimens is also good practice to reduce the effect of any variability in the conditions within the exposure area.

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

**5.1.7** A radiometer that complies with the requirements outlined in ISO 9370 may be used to measure the irradiance,  $E$ , or spectral irradiance,  $E_\lambda$ , and the radiant exposure,  $H$ , or spectral radiant exposure,  $H_\lambda$ , in the plane of the specimen surface.

**5.1.7.1** 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. 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. A full calibration of the radiometer that is traceable to a recognized radiometric standards body shall be conducted at least once per year. More frequent calibrations are recommended.

For fluorescent UVB lamps, field radiometers shall 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 1 Reference [Z] provides specific guidance on the calibration of radiometers using spectroradiometers. This method can be used to calibrate the instrument radiometer(s).

NOTE 2 Refer to ISO 9370 for definitions of field and reference radiometers.

**5.1.7.2** 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 passband 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-panel sensor is used to measure and control the temperature within the exposure chamber. The black panel of the black surface temperature sensor shall be mounted within the specimen exposure area so that it is in the same plane and orientation and receives the same radiation and experiences the same cooling conditions as a flat test panel surface. For three-dimensional specimens, the black panel shall be in a plane and orientation that best represents the majority of the specimen surface of interest or at the plane of the primary surface of interest.

**5.2.2** Two types of black surface temperature sensors may be used: black-standard thermometer (BST) and 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 radiation 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) (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 radiation 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 can 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 1 As convection cooling acts from both sides, installation geometry influences the stability of black panel thermometers.

NOTE 2 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.

**5.2.4** At low irradiance levels, the difference between the temperature indicated by a black-panel or black-standard thermometer and the real specimen temperature may be small. When radiation sources that emit very little infrared radiation are used, there will generally be only very small differences in the temperatures indicated by the two types of black panel or between light- and dark-coloured specimens.

**5.2.5** In order to evaluate the range of surface temperatures of the exposed specimens and to better control the irradiance or the conditions in the exposure chamber, the use of a white-panel or white-standard thermometer, in addition to the black-panel or black-standard thermometer, is recommended. The white-panel or white-standard thermometer shall be constructed in the same way as the corresponding black-panel or black-standard thermometer, except for the use of a white coating with a good resistance to ageing. The reflectance of the white coating shall be at least 60 % between 450 nm and 800 nm and at least 30 % between 800 nm and 1 500 nm.

**5.2.6** Manufacturers of exposure devices shall ensure that devices designed to meet the requirements of this part of ISO 4892 are able to meet the following requirements for control of the temperature of the black or white temperature sensor at the position where it is intended to operate. These requirements apply to equilibrium conditions.

**Table 1 — Requirements for set-point temperature of the black or white temperature sensor at the position where it is intended to operate**

Set-point temperature	Allowable deviation of the sensor temperature at the position in which sensor operates
≤70 °C	±3 °C
>70 °C	±4 °C

**5.2.7** Manufacturers of exposure devices shall ensure that devices designed to meet the requirements of this part of ISO 4892 are able to meet the following requirements for control of the temperature of a

black or white temperature sensor at any position within the allowed exposure area. These requirements apply to equilibrium conditions.

**Table 2 — Requirements for set-point temperature of the black or white temperature sensor at any position within the allowed exposure area**

Set-point temperature	Allowable deviation of the sensor temperature when sensor placed anywhere in the exposure area
≤70 °C	±5 °C
>70 °C	±7 °C

NOTE For some materials, differences in degradation rate may occur between devices operating within the allowable temperature ranges. Periodic repositioning of specimens or random positioning of replicate specimens during exposure will reduce the variability caused by differences in temperature within the exposure area.

**5.2.8** The test report shall indicate whether a black-standard or black-panel thermometer and whether a white-standard or white panel thermometer was used.

NOTE Different temperatures may be indicated by a single type of black-standard or black-panel thermometer, depending on the specific design of the device supplied by different manufacturers.

**5.2.9** If the exposure chamber air temperature is measured, the temperature-sensing element shall be shielded from the radiation source and water spray. The chamber air temperature measured at this position may not be the same as the chamber air temperature near the surface of the exposed specimens. Manufacturers of devices that control chamber air temperature shall ensure that their equipment is able to maintain the measured chamber air temperature within ±3 °C of the set point at under equilibrium conditions for set points up to 70 °C and within ±4 °C of the set point for set points greater than 70 °C.

**5.2.10** Calibrate the temperature sensor used to measure the chamber air temperature in accordance with the sensor manufacturer’s instructions at least annually.

**5.3 Humidity and wetting**

**5.3.1** The presence of moisture on the exposed face of the specimen, particularly long wet periods and the cyclic change between wet and dry periods, may have a significant effect in accelerated laboratory exposure tests. Any device operated in accordance with any of the parts of this International Standard which attempts to simulate the effects of moisture shall have means for providing moisture to specimens using one or more of the following methods:

- a) humidification of the chamber air;
- b) formation of condensation;
- c) water spray;
- d) immersion.

**5.3.2 Water purity**

**5.3.2.1** For xenon-arc and carbon-arc instruments, the purity of the water used for spraying the specimens is very important. Without proper treatment to remove cations, anions, organics and, in particular, silica, exposed specimens will develop spots or stains that do not occur in exterior exposures. Unless otherwise specified, water used for specimen spray shall contain a maximum of 1 µg/g of solids and a maximum of 0,2 µg/g of silica. Distillation, or a combination of deionization and reverse osmosis, can effectively produce water of the desired purity. If the water used for specimen spray contains more than 1 µg/g of solids, the solids and silica levels shall be reported. Recirculation of water used

for specimen spray is not recommended and shall not be done unless the recirculated water meets the purity requirements listed above.

**5.3.2.2** The purity of water used for spraying in instruments using UV fluorescent lamps is not as critical as in xenon-arc and carbon-arc instruments. Therefore, the test panels shall be sprayed using water that has been purified so as to have less than 2,0 µg/g dissolved solids content and <0,5 µg/g suspended silica content.

**5.3.3** If specimens are found to have deposits or stains after exposure, the water purity shall be checked to determine whether it meets the purity requirements specified in 5.3.2. On some occasions, exposed specimens can be contaminated by deposits from bacteria that can grow in the purified water used for specimen spray. If bacterial contamination is detected, the entire system used for specimen water spray shall be flushed with a chlorinating solution such as sodium hypochlorite and thoroughly rinsed prior to resuming exposures.

**5.3.4** Although conductivity does not always correlate with silica content, it is recommended that the conductivity of the water used for specimen spray be continuously monitored and that exposures be stopped whenever the conductivity is above 5 µS/cm.

**5.3.5** All components of the specimen spray unit shall be fabricated from stainless steel or some other material that does not contaminate the water with materials that could absorb UV radiation or form unrealistic deposits on test specimens.

**5.3.6** If humidity control is required, sensors used to measure humidity shall be placed within the chamber air-flow and shielded from direct radiation and water spray. When humidity is controlled, the measured relative humidity shall be maintained within ±10 % of the set point humidity.

If humidity control is required, the humidity sensors shall be calibrated at least annually in accordance with the exposure device manufacturer's instructions.

**5.3.7** Any device that introduces periods of wetting of the exposed specimens by any method shall have means to programme the periods with and without wetting.

## 5.4 Other requirements for the exposure device

**5.4.1** Although various designs of exposure device are used in practice, each device shall meet the following requirements.

**5.4.1.1** Any device intended to simulate the effects of light and dark cycles shall have an electronic controller or mechanical device to programme periods with or without radiation.

**5.4.1.2** Manufacturers shall ensure that devices that provide periods during which the exposure conditions are different have means to time each period. The length of each exposure period shall be controlled to within ±10 % of the shortest period used. It is desirable to use timers that are as accurate and have as high a repeatability as possible. Optionally, a means to record the length of each test period may also be provided.

**5.4.2** To fulfil the requirements of particular test procedures, the device may need to provide means to register or record the following operating parameters:

- a) the line voltage;
- b) the lamp wattage;
- c) the lamp current;

- d) the spectral irradiance (or the integrated spectral irradiance) within the passband used and the radiant exposure.

## 6 Test specimens

### 6.1 Form, shape and preparation

**6.1.1** The methods used for the preparation of test specimens can have a significant impact on their apparent durability. Therefore, the method used for specimen preparation shall be agreed upon by the interested parties. It should preferably be closely related to the method normally used to process the material in typical applications. A complete description of the method used for the preparation of test specimens shall be included in the test report.

**6.1.2** The dimensions of the test specimens are normally those specified in the appropriate test method for the property or properties to be measured after exposure. When the behaviour of a specific type of article is to be determined, the article itself should be exposed whenever possible.

**6.1.3** If the material to be tested is an extrusion- or moulding-grade polymer in the form of granules, chips, pellets or some other raw state, specimens to be exposed shall be cut from a sheet produced by the appropriate method. The exact shape and dimensions of the specimens will be determined by the specific test procedure used for measurement of the property of interest. The procedures used to machine or cut individual test specimens from a larger sheet or article may affect the results of the property measurement, and hence the apparent durability of the specimens. For preparation of test specimens, the procedures described in ISO 293, ISO 294-1, ISO 294-2 and ISO 294-3, ISO 295 and ISO 3167 have been found to be satisfactory.

**6.1.4** In some cases, individual specimens used for property measurement may need to be cut from a larger specimen which has been exposed. For example, materials that delaminate at the edges may be exposed in the form of larger sheets from which individual test specimens are cut after exposure. The effects of any cutting or machining operation on the properties of individual test specimens are usually much larger when the test specimens are cut from a large piece after exposure. This is especially true for materials that embrittle on exposure. Follow the procedures described in ISO 2818 for preparation of test specimens by machining. Only cut individual test specimens for property measurement from larger specimens that have been exposed when this preparation procedure is specifically specified.

When test specimens are cut from an exposed sheet or larger article, they should preferably be taken from an area that is at least 20 mm from the fixture holding the material or from the exposed specimen edges. In no circumstances shall any material from the exposed face be removed during test specimen preparation.

**6.1.5** When comparing materials in an exposure test, use test specimens that are similar in dimensions and exposed area.

**6.1.6** Label test and control specimens using markings that will not become illegible during the exposure and will not affect the measurement of the desired properties.

**NOTE** Guidance on this is given in Reference [11].

Do not touch the exposed surfaces of specimens or the optical components of the device with the bare skin because this is likely to transfer oils that may act as UV absorbers or contain contaminants that affect degradation.



## 6.2 Number of test specimens

**6.2.1** The number of test specimens for each set of test conditions or each exposure period shall be that specified in the appropriate test method for the property or properties to be measured after exposure.

For the determination of mechanical properties, it is recommended that the number of test specimens exposed be twice that required by the relevant International Standard (due to the large standard deviation known to occur in measuring the mechanical properties of "weathered" materials).

**6.2.2** If the test method used for property measurement does not specify the number of test specimens to be exposed, it is recommended that a minimum of three replicate specimens of each material be prepared for each exposure stage.

**6.2.3** When destructive tests are used to determine the properties being measured, the total number of test specimens required will be determined by the number of exposure periods used and whether unexposed file specimens are tested at the same time as exposed specimens.

**6.2.4** Control materials of known durability should preferably be included with each exposure test. It is recommended that control materials known to have relatively poor and relatively good durability be used. Before any laboratory to laboratory comparisons are made, it is necessary for all the interested parties to agree on the control materials to be used. The number of specimens of the control material should preferably be the same as that used for test materials.

## 6.3 Storage and conditioning

**6.3.1** Unless otherwise specified by contract or by the relevant materials standard, condition test specimens that have been cut or machined from large pieces in accordance with ISO 291. In some circumstances, it may be necessary to precondition the sheets prior to cutting or machining to facilitate specimen preparation.

**6.3.2** When using tests to characterize the mechanical properties of the materials being exposed, specimens shall be appropriately conditioned before all property measurements. Use the conditions described in ISO 291, where appropriate. The properties of some plastics are very sensitive to moisture content, and the duration of conditioning may need to be longer than that specified in ISO 291, particularly where specimens have been exposed to climatic extremes.

**6.3.3** File specimens shall be stored in the dark under normal laboratory conditions, preferably in one of the standard atmospheres given in ISO 291.

**6.3.4** Some materials will change colour during storage in the dark, particularly after exposure. It is essential that colour measurement or visual comparison be carried out as soon as possible after exposure once the exposed surface has dried.

NOTE In some cases, additional evaluation of colour change after a conditioning period such as 24 h will be very helpful in determining whether the colour is stable after the specimens have been removed from the exposure chamber.

## 7 Test conditions and procedure

### 7.1 Set points for exposure conditions

The conditions and procedures for the artificial accelerated weathering or artificial accelerated irradiation exposure depend upon the particular method selected. Refer directly to the appropriate part of ISO 4892 (ISO 4892-2, ISO 4892-3 or ISO 4892-4) or to any other relevant International Standard. For each exposure test, specific set points for important parameters such as irradiance, temperature and

humidity are used. Typically, these parameters are measured and controlled at a single position within the test chamber that is known as the control point. Table 3 lists the maximum allowable deviation from the set point when the exposure device is operating at equilibrium conditions.

**Table 3 — Maximum allowable deviation from exposure condition set points**

Set-point parameter	Maximum allowable deviation of the measurement from the set point at equilibrium
Irradiance measured at a single wavelength	$\pm 0,02 \text{ W}/(\text{m}^2 \cdot \text{nm})$
Irradiance measured over a broad passband (e.g. 300 nm to 400 nm)	$\pm 5 \text{ W}/\text{m}^2$
Irradiance measured over a wide passband (e.g. 300 nm to 800 nm)	$\pm 75 \text{ W}/\text{m}^2$
Temperature of black-standard thermometer	$\pm 3 \text{ }^\circ\text{C}$ for set points up to $70 \text{ }^\circ\text{C}$ $\pm 4 \text{ }^\circ\text{C}$ for set points greater than $70 \text{ }^\circ\text{C}$
Temperature of black-panel thermometer	$\pm 3 \text{ }^\circ\text{C}$ for set points up to $70 \text{ }^\circ\text{C}$ $\pm 4 \text{ }^\circ\text{C}$ for set points greater than $70 \text{ }^\circ\text{C}$
Temperature of chamber air (when controlled)	$\pm 3 \text{ }^\circ\text{C}$ for set points up to $70 \text{ }^\circ\text{C}$ $\pm 4 \text{ }^\circ\text{C}$ for set points greater than $70 \text{ }^\circ\text{C}$
Relative humidity (when controlled)	$\pm 10 \%$
NOTE The definition of passbands is found in ISO 9370.	

NOTE A single-point measurement does not mean conditions throughout the exposure chamber are the same. It does not mean two tests run in similar exposure devices will produce the same results. Exposure devices that control temperature only by means of a black-standard thermometer or black-panel thermometer will not produce the same results as exposure devices that simultaneously or alternatively control the air temperature.

**7.2 Property measurements on test specimens**

**7.2.1** Follow the procedures described in ISO 4582 for measuring properties of test specimens before and after exposure and for expressing the change in properties after exposure. Refer to the relevant International Standard for the specific procedures to follow for measuring specimen properties.

**7.2.2** If non-destructive tests are used to measure the properties of the materials being tested, the properties of the specimens shall be measured before beginning the exposure. The same property is then measured after each exposure period. Care shall be taken to make the property measurement after each exposure period in the same position on the specimen.

NOTE To monitor the response of the instrument used to measure the desired property, one can carry out a measurement on a reference or calibration specimen each time the test instrument is used.

**7.2.3** If destructive tests are used to measure the properties of the materials being tested, separate sets of specimens will be needed for each exposure period. The property is measured on each set of exposed specimens. It is recommended that the value of the property after exposure be compared with the property measured on a set of file specimens of the same material that is measured at the same time as the exposed specimens. Alternatively, the value of the property after exposure may be compared with that obtained prior to exposure.

## 8 Periods of exposure and evaluation of test results

### 8.1 General

The repeatability and reproducibility of results obtained in exposures conducted in accordance with any of the parts of this International Standard will vary with the materials being tested, the material property being measured and the specific test conditions and cycles that are used.

**NOTE** In round-robin studies<sup>[12]</sup> conducted by ASTM subcommittee G3.03, the 60° gloss values of replicate PVC tape specimens exposed in different laboratories using identical exposure devices and exposure cycles showed significant variability. The variability shown in these round-robin studies restricts the use of “absolute specifications” such as requiring a specific property level after a specific exposure period.

### 8.2 Use of control materials

**8.2.1** In most cases, periodic evaluation of test and control specimens is necessary to evaluate the direction of property change as a function of exposure. The time or radiant exposure necessary to produce a defined change in a material property can be used to evaluate or rank the durability of materials. This method is preferred over evaluating materials after an arbitrary time or radiant exposure.

**8.2.2** Exposure to an arbitrary time or radiant exposure may be used for the purpose of a specific test if agreed upon by all parties or if required for conformance to a specification. Two criteria are critical when selecting the single time or radiant exposure used.

- a) When control materials of minimum acceptable performance are used, statistical analysis of the results after exposure shall show that the test material is equivalent to or better than the control material.
- b) A substantial change in the property of interest shall be produced in the least stable material being evaluated.

**NOTE** An exposure time that produces a significant change in one type of material cannot be assumed to be applicable to other materials.

**8.2.3** Use appropriate statistical analysis when comparing the results given by test and control materials. Test and control materials can be considered different when the results of the statistical analysis are significant to at least the 90 % confidence level.

**NOTE** Reference [13] provides information on the use of statistical methods for analysing results from artificial accelerated weathering or artificial accelerated irradiation exposures.

### 8.3 Use of results in specifications

**8.3.1** If an International Standard or specification for general use requires a definite property level after a specific time or radiant exposure in an exposure test conducted in accordance with any of the parts of this International Standard, the specified property level shall be based on results obtained in a round-robin that takes into consideration the variability due to the exposure and the test method used to measure the property of interest. The round-robin shall be carried out in accordance with the relevant International Standard for conducting round-robin exposures and shall include a statistically representative sample of all laboratories or organizations which would normally conduct the exposure and property measurement.

**8.3.2** If an International Standard or specification for use between two or three parties requires a definite property level after a specific time or radiant exposure in an exposure test conducted in accordance with any of the parts of this International Standard, the specified property level shall be based on statistical analysis of results from at least two separate, independent exposures in each laboratory. The

design of the experiment used to determine the specification shall take into consideration the variability due to the exposure and the test method used to measure the property of interest.

**8.3.3** The round-robin studies cited in 8.1.1 demonstrated that the gloss values for a series of materials could be ranked with a high level of reproducibility between laboratories. When reproducibility in results from an exposure test conducted in accordance with any of the parts of this International Standard have not been established through round-robin testing, performance requirements for materials shall be specified in terms of comparison (i.e. rank) with a control material. Specimens of the control material shall be exposed simultaneously with the test specimen(s) in the same device. The specific control material used shall be agreed upon by the interested parties.

## 9 Test report

The test report shall contain the following information:

### 9.1 Specimen description.

- a) a full description of the specimens and their origin;
- b) the compound details, cure time and temperature, where appropriate;
- c) a complete description of the method used for preparation of the test specimens.

**NOTE** If exposure tests are conducted by a contracting agency, specimens are usually identified by code-number. In such cases, it is the responsibility of the originating laboratory to provide the complete specimen description when reporting the results of the exposure test.

### 9.2 Description of exposure test conducted in accordance with ISO 4892-2, ISO 4892-3 or ISO 4892-4, including the following:

- a) a description of the exposure device and radiation (light) source, including
  - 1) the type of device and radiation (light) source,
  - 2) a description of the filters used,
  - 3) if required, the irradiance at the specimen surface (including the passband in which the radiation was measured),
  - 4) the number of hours that the filters and the radiation (light) source had been used prior to beginning the exposure;
- b) the type of black and/or white temperature sensor used and the exact position of the sensor if it was not located in the test specimen exposure area;
- c) if required, the type of instrument used to measure the humidity;
- d) a complete description of the exposure cycle used, including the following information for each light and dark period:
  - 1) the set point for the black- and/or white-panel temperature sensor used and the maximum allowable deviation from the set point if different from that in [Table 1](#),
  - 2) the set point for the relative humidity and the maximum allowable deviation from the set point if different from that in [Table 1](#),
  - 3) for tests which include a water spray period, report the duration of the water spray and whether the water was sprayed on the exposed face, the back or both surfaces of the specimens (if the total solids of the water used for the spray was greater than 1 µg/g, report the total solids and the silica content),

- 4) for tests where water is condensed on the specimens, report the set point for the length of the condensation period,
  - 5) the length of each light and dark period;
- e) a description of the method used to mount the specimens in the exposure frame, including a description of any material used as backing for the test specimens;
  - f) the procedure for test specimen repositioning, if used;
  - g) a description of the radiometer used for measuring the radiant exposure, if used.

### 9.3 Test results.

- a) A complete description of the test procedure used for measurement of any properties reported.
- b) The results, presented in accordance with ISO 4582, and including the following:
  - 1) the results from property measurements on the test specimens;
  - 2) the results from property measurements on control specimens;
  - 3) the results from property measurements on unexposed film specimens, if determined;
  - 4) the exposure period (either the time, in hours, or the radiant exposure, in  $\text{J}\cdot\text{m}^{-2}$ , and the passband in which it was measured).

### 9.4 The date(s) of the exposure test.

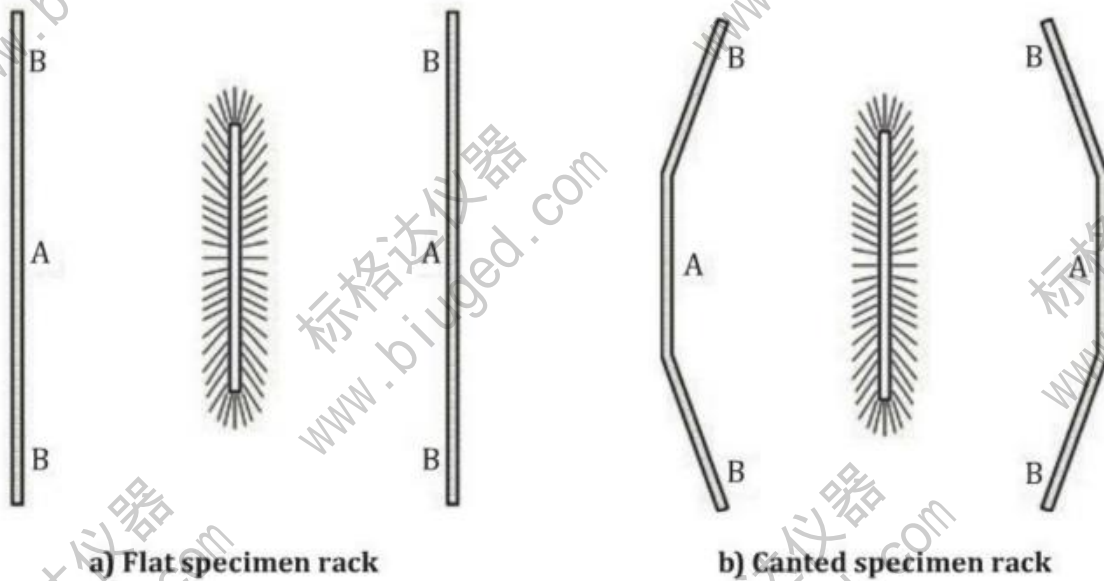
**Annex A**  
(normative)

**Procedures for measuring the irradiance uniformity in the specimen exposure area**

**A.1** This annex is normative for manufacturers of devices that expose materials to laboratory light sources.

**A.2** In devices that use a rack to hold the specimens and rotate them around a radiation source [shown at the centre of [Figures A.1 a\)](#) and [b\)](#)], measure the irradiance at a position in the specimen rack that is closest to the radiation source (position A in [Figure A.1](#)) and at two positions within the specimen rack that are farthest from the radiation source (position B in [Figure A.1](#)). Measurements made with a radiometer that is placed on the rack as it rotates around the radiation source will give the most realistic indication of irradiance uniformity. The relationship between the irradiance at position B relative to the irradiance at position A shall be as follows:

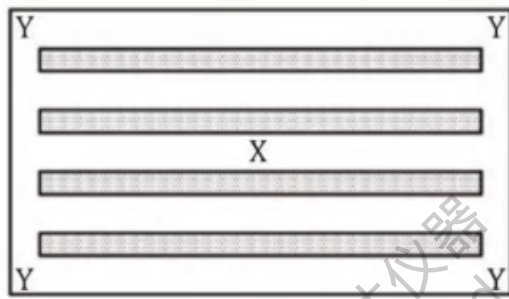
$$E_B \geq 0,7E_A \tag{A.1}$$



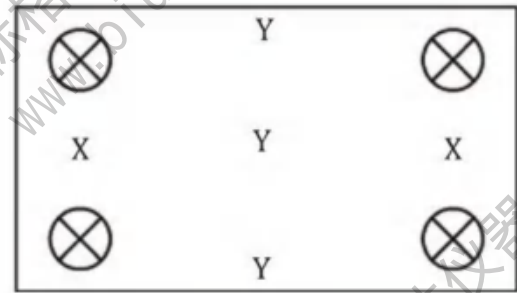
**Figure A.1** — Determining irradiance uniformity in devices using a rotating specimen rack

**A.3** In devices where specimens are positioned in a flat plane in front of a radiation source, measure the irradiance at a position in the specimen plane that is closest to the radiation source (position X in [Figure A.2](#)) and in two opposite corners of the plane where test specimens are placed (position Y in [Figure A.2](#)). The relationship between the irradiance at position Y relative to the irradiance at position X shall be as follows:

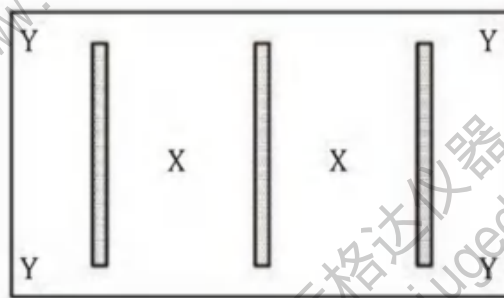
$$E_Y \geq 0,7E_X \tag{A.2}$$



a) Flat specimen plane with fluorescent lamps



b) Flat specimen plane with multiple point sources



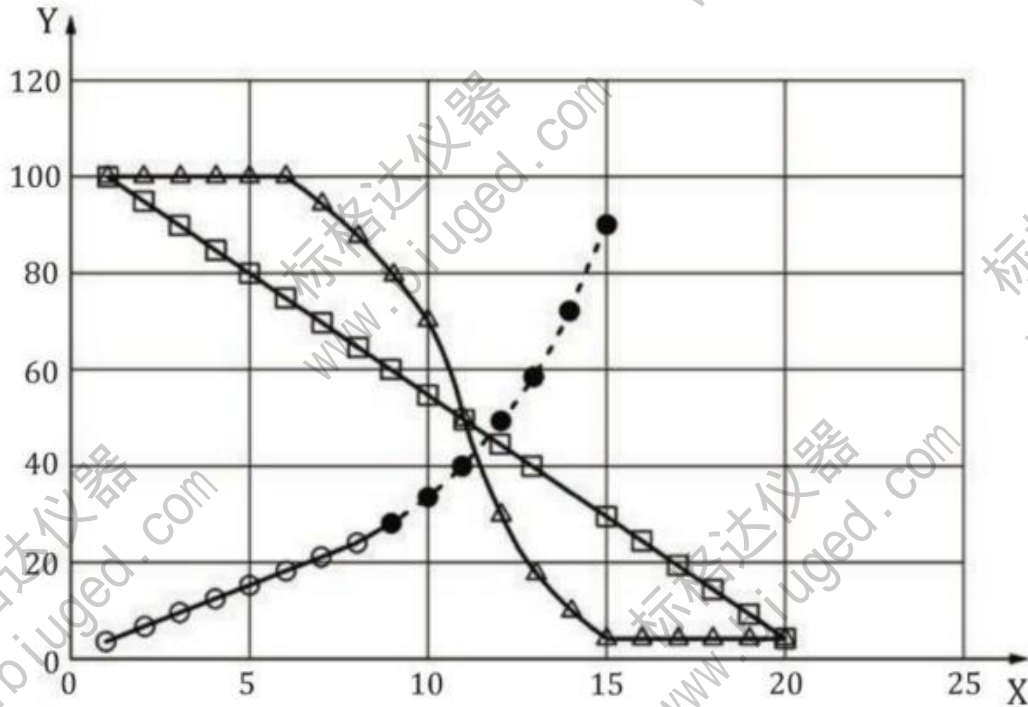
c) Flat specimen plane with multiple line sources

Figure A.2 — Determining irradiance uniformity in devices using a flat specimen plane

**A.4** If the design of the device is such that the maximum irradiance may not be at the centre of the exposure area or such that the minimum irradiance may not be at the position farthest from the centre, the actual maximum irradiance shall be used for  $E_A$  or  $E_X$  and the actual minimum irradiance shall be used for  $E_B$  or  $E_Y$  in [Formulae \(A.1\)](#) and [\(A.2\)](#). Additional measurements of the irradiance at other positions within the exposure area may also be made. In all cases, however, the irradiance measured at these positions shall be at least 70 % of the maximum irradiance. Unless otherwise specified, at least four measurements shall be made at the periphery of the proposed exposure area (e.g. near the corners of flat specimen planes where fluorescent lamps or line sources are used as the radiation sources). For more precise definition of the allowed exposure area, where  $E_X \geq E_Y$  or  $E_B \geq E_A$ , many more than four measurements near the periphery of the exposure area will be necessary.

**A.5** As an alternative to irradiance measurements, the uniformity of the irradiance may be determined by use of reference materials if the ageing of these materials is independent of the effects of heat or moisture or if the effects of heat and moisture are known. The change in the characteristic property of the reference material shall be a known function of the radiant exposure (preferably linear) and should preferably not show an induction time with little change in the property as a function of radiant exposure. [Figure A.3](#) is a typical plot showing the characteristic property of reference materials as a function of radiant exposure or exposure time. The preferred reference material is that which shows a completely linear response throughout the exposure period. Materials that show an induction period followed by a period of rapid change are not recommended for use as reference materials. Materials that show a linear response followed by a period where response is not linear shall only be used for exposure periods during which they exhibit a linear response. Expose reference material specimens at the centre of the exposure area and at positions farthest from the centre. All specimens shall be exposed at the same time. Expose the reference specimens until there is a measurable change in the characteristic property being monitored. The change in the measured property of the reference material at positions farthest from the centre shall be at least 70 % of the change measured for the specimen exposed at the centre.

NOTE Actual measurements of irradiance are preferred over the use of reference materials because differences in property change between reference material specimens exposed at the extremes of the exposure area and those exposed at the centre may be significantly affected by differences in temperature and/or moisture conditions as well as differences in irradiance.



**Key**  
 X radiant exposure or exposure time (arbitrary units)  
 Y characteristic property (arbitrary units)

**Figure A.3 — Typical behaviour of the characteristic property as a function of exposure for a reference material showing linear change (square symbols), for a reference material showing an induction time before the property starts to change (triangular symbols) and for a reference material showing a period of linear change (empty circles) followed by a region of non-linear change (black-filled circles)**



## Annex B (informative)

### Factors that decrease the degree of correlation between artificial accelerated weathering or artificial accelerated irradiation exposures and actual-use exposures

#### B.1 Differences between the spectral distribution of the laboratory light source and that of solar radiation

Shorter-than-normal wavelengths are sometimes used to obtain faster failure rates in artificial accelerated weathering or artificial accelerated irradiation exposures. For outdoor exposures, the cut-on for short-wavelength UV radiation is generally considered to be about 300 nm. Exposures to UV radiation of wavelengths less than 300 nm may produce degradation reactions that do not occur when the material is used outdoors. If a laboratory light source used in an artificial accelerated weathering or irradiation exposure produces UV radiation of wavelengths shorter than that found in the actual-use conditions, the mechanism of degradation and the stability ranking of the materials tested can be dramatically different in the accelerated test.

If radiation in a specific region of the spectrum is known to produce the type of degradation of interest in the materials being tested, it may not be necessary to simulate solar radiation over the entire spectrum. However, laboratory light sources that have a very strong emission in a narrow band relative to the rest of the UV or visible spectrum may cause a particular reaction to be favoured relative to others that may be very important. This type of radiation source may also not produce changes caused in exposures to solar radiation. Exposures to radiation sources which only produce UV radiation may not produce the colour fade caused by visible radiation and may cause polymer yellowing that is more pronounced than that produced in exposures to solar radiation.

#### B.2 Irradiance levels higher than those experienced in actual-use conditions

Irradiance levels higher than those experienced in mean actual-use conditions are typically used in exposures to laboratory light sources in order to accelerate degradation. There are two main reasons why the use of abnormally high irradiance can change the mechanism of material degradation relative to the conditions found in an actual-use environment (polymers show a broad range of responses to irradiance<sup>[14]</sup> and these differences can alter the stability ranking of materials when results from artificially accelerated tests are compared with those from in-service exposures).

- a) In exterior exposures, polymers in an excited state caused by absorption of a high-energy photon will typically decay to the ground state before absorbing another high-energy photon. However, in exposures to laboratory light sources producing an abnormally high radiation flux, the rate of photon absorption is so high that the material will often absorb a high-energy photon when it is still in an excited state.<sup>[15]</sup>
- b) Free radicals are often formed in materials exposed to UV radiation. Reactions leading to degradation occur when the free radicals interact with the material. Free radicals can also recombine with other free radicals in reactions that do not lead to degradation. The high concentration of free radicals formed under high-irradiance conditions results in a greater percentage of recombination due to the close proximity of the free radicals. In this case, degradation is not a linear function of irradiance.<sup>[16]</sup>

Furthermore, oxygen diffusion can sometimes become rate-limiting in polymer oxidation processes where abnormally high irradiance (or abnormally high specimen temperatures) is used for test acceleration.<sup>[17]</sup> This can produce differences in the mechanism of degradation reactions and may

cause an abnormal ratio of surface to bulk oxidation, which could result in unnatural colour shifts or physical-property changes.

### **B.3 Continuous exposure to light with no dark periods**

Continuous exposure to radiation from laboratory light sources is often used in order to achieve accelerated degradation relative to actual-use conditions. However, continuous exposure to radiation may eliminate critical dark reactions that occur in outdoor exposures or indoor-use conditions where there are regular periods without radiation.

### **B.4 Specimen temperatures that are abnormally high relative to actual-use conditions**

Temperatures higher than those experienced in actual-use conditions are often used to obtain faster degradation in artificial accelerated weathering or artificial accelerated irradiation exposures. Some plastics are much more susceptible to degradation due to thermal effects than others. For materials that are subject to the same rate and type of photodegradation, exposures at abnormally high temperatures may make a temperature-sensitive material appear to be less durable than a less temperature-sensitive material. In addition, exposures of polymers at temperatures above their glass-transition temperature can dramatically alter the mechanism of degradation and the stability ranking compared with exposures conducted at a temperature below the glass-transition temperature. The black-panel temperature used in an artificial accelerated weathering or artificial accelerated irradiation exposure should be maintained in a reasonable range, which is usually no higher than the maximum observed for the surface temperature of black specimens in actual-use conditions.

### **B.5 Exposure conditions that produce unrealistically large temperature differences between light- and dark-coloured specimens**

Some laboratory light sources produce large amounts of infrared radiation. In order to prevent overheating of the specimens, the infrared radiation can be reduced by using infrared-absorbing or -reflecting filters, or by passing large amounts of air through the exposure chamber to cool the specimens. If measures to control the amount of infrared radiation reaching the specimens being exposed are not sufficient, the temperature differences between light- and dark-coloured specimens of the same material can be much larger than would be seen in natural exposures.

Some laboratory light sources produce very little visible and infrared radiation. When these types of laboratory light source are used, the temperature difference between dark- and light-coloured specimens may be much less than that found in outdoor exposures.

### **B.6 Temperature-cycling conditions that are different from those found in actual-use conditions**

Abnormally high temperature-cycling frequencies can produce mechanically induced cracking or other types of degradation not seen in exposures under actual-use conditions. Exposure devices which spray specimens with water when the radiation source is on can produce an abnormally rapid change in temperature that may also produce cracking not produced in the actual-use environment.

### **B.7 Unrealistic levels of moisture in the accelerated test compared with those found in actual-use conditions**

Moisture is very important in producing degradation of many polymers. If the amount of moisture, or the way in which specimens are exposed to the effects of moisture in an artificial accelerated weathering or artificial accelerated irradiation exposure, differs from that in the actual-use environment, the mechanism and rate of degradation may be very different. This can have a significant effect on the stability ranking of the materials.

## B.8 Absence of biological agents and pollutants

Plastic materials exposed in warm, wet locations are often subject to significant growth of biological agents such as fungi, bacteria and algae. Pollutants and acidic precipitation present in some exterior environments may have a significant effect on the mechanism and rate of degradation of some plastics. If these effects are not included in an artificial accelerated weathering or artificial accelerated irradiation exposure, the mechanism and stability ranking of the materials may be significantly different from that found in exterior exposures.

## Annex C (informative)

### Solar spectral irradiance standards

**C.1** The solar spectrum defined in CIE 85:1989, Table 4, [18] is often used as a benchmark for comparing solar radiation to the radiation produced in artificial accelerated weathering or artificial accelerated irradiation exposures, and is considered the benchmark for ISO 4892 standards. In CIE 85:1989, Table 4, global solar irradiance in the 300 nm to 2 450 nm band is given as 1 090 W/m<sup>2</sup> for a relative air mass of 1, with 1,42 cm of precipitable water and 0,34 cm of ozone (measured at a pressure of 1 atmosphere and a temperature of 0 °C). Table C.1 shows a broadband condensed spectral irradiance for global solar radiation at these atmospheric conditions in the UV, visible and infrared regions of the spectrum. This represents the maximum global solar irradiance that would be experienced by materials exposed on a horizontal surface at the equator near noon on a clear day at the spring or autumn equinox.

**Table C.1 — Spectral global irradiance (condensed from CIE 85:1989, Table 4)**

Wavelength nm	Irradiance W·m <sup>-2</sup>	Percent of total 300 nm to 2 450 nm	Percent of UV and visible 300 nm to 800 nm
300 to 320	4,1	0,4	0,6
320 to 360	28,5	2,6	4,2
360 to 400	42,0	3,9	6,2
300 to 400	74,6	6,8	11,0
400 to 800	604,2	55,4	89,0
300 to 800	678,8	62,2	100,0
800 to 2 450	411,6	37,8	
300 to 2 450	1 090,4	100,0	

**C.2** Direct radiation from xenon burners, open-flame carbon arcs, some fluorescent lamps and some other radiation sources used for artificial accelerated weathering or artificial accelerated irradiation exposures, such as mercury lamps or metal halide lamps, contains considerable amounts of short-wavelength UV radiation not present in solar radiation. With proper selection of filters for these radiation sources, much of the short-wavelength radiation can be eliminated. However, some filters allow a small, but significant, amount of this short-wavelength (less than 300 nm) radiation through. Fluorescent lamps can be selected to have a spectral output corresponding to a particular UV region of solar radiation. The xenon arc, when appropriately filtered, produces radiation with a spectral power distribution that is a good simulation of average solar radiation throughout the UV and visible region.

**C.3** CIE 85:1989 provides data on spectral solar irradiance for typical atmospheric conditions and this data can be used as a basis for comparing laboratory light sources with daylight. The data used for filtered xenon-arc radiation are given in CIE 85:1989, Table 4. However, CIE 85, which was published in 1989, has several disadvantages: Global solar spectral energy distribution starts at 305 nm, the increments are rather rough and the calculation code is no longer available. Therefore, efforts have been underway for several years to revise CIE 85. The reference spectra defined in CIE 85:1989, Table 4, can also be recalculated using the SMARTS2 model [19]. The basis for the revision is newer measurements and improved calculation models (SMARTS2 model [20]).

Recently, an alternate standard solar spectrum based on atmospheric conditions at 2000 m altitude has been developed. This solar spectrum is defined in Reference [21]. The solar spectrum defined in Reference [21] is calculated using the SMARTS2 solar-radiation model [22][23][24]. Reference [25] provides the programme and documentation for calculating solar spectral irradiance.

The SMARTS spectral model can be used to reliably reproduce the tables in CIE 85 with close agreement. [Table C.2](#) compares the basic atmospheric conditions used for the standard solar spectrum defined in ASTM G177 and the CIE 85, Table 4, solar spectrum.

**Table C.2 — Comparison of basic atmospheric conditions used for the solar spectrum defined in ASTM G177 and that defined in CIE 85:1989, Table 4**

Atmospheric and other conditions	ASTM G177 solar spectrum	CIE 85:1989, Table 4, solar spectrum
Ozone (atm-cm)	0,30	0,34
Precipitable water vapour (cm)	0,57	1,42
Altitude (m)	2 000	0
Tilt angle	37° facing the equator	0° (horizontal)
Relative air mass	1,05	1,00
Albedo (ground reflectance)	Radiation-, soil- and wavelength-dependent	Constant at 0,2
Aerosol extinction	Shettle and Fenn rural (humidity-dependent)	Equivalent to Linke turbidity factor of about 2,8
Aerosol optical thickness at 500 nm	0,05	0,10

**C.4** [Table C.3](#) compares irradiance (calculated using rectangular integration) for the ASTM G177 solar spectrum and the CIE 85:1989, Table 4, solar spectrum.

NOTE ASTM G177 tabulates solar radiation out to 400 nm. However, the atmospheric, site latitude and other conditions used to develop the ASTM G177 UV spectrum were input into the SMARTS2 solar radiation model to generate a full solar spectrum. The full-spectrum data were used to prepare the comparison above 400 nm given in [Table C.3](#).

**Table C.3 — Irradiance comparison for the ASTM G177 solar spectrum and the CIE 85:1989, Table 4, solar spectrum**

Passband	ASTM G177 solar spectrum	CIE 85:1989, Table 4, solar spectrum
Irradiance (W/m <sup>2</sup> ) in stated passband		
$300 \leq \lambda \leq 320$	3,9	4,1
$320 < \lambda \leq 360$	26,1	28,5
$360 < \lambda \leq 400$	35,6	42,0
$300 \leq \lambda \leq 400$	65,6	74,6
$400 < \lambda \leq 800$	588,7	604,2
$300 \leq \lambda \leq 800$	654,3	678,8
$800 < \lambda \leq 2\ 450$	446,2	411,6
$300 \leq \lambda \leq 2\ 450$	1 100,5	1 090,4

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