INTERNATIONAL STANDARD

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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: Guide général

Reference number
ISO 4892-1:1994(E)

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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 4892-1 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 6, *Ageing, chemical and environmental resistance*.

Together with the other parts of ISO 4892, it cancels and replaces ISO 4892:1981, of which it constitutes a technical revision.

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 sources*

— *Part 3: Fluorescent UV lamps*

— *Part 4: Open-flame carbon-arc lamps*

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Introduction

The effects of weather on the colour and other properties of plastics are of considerable technical and commercial importance. Outdoor exposure tests are described in ISO 877:—, *Plastics — Methods of exposure to direct weathering, to weathering using glass-filtered daylight and to intensified weathering by daylight using Fresnel mirrors* (to be published — revision of ISO 877:1976). There is a need to gain information by accelerated procedures, and for this purpose artificial light sources are used. In contrast to natural weathering, accelerated exposure in artificial light devices is conducted under more controlled conditions that are designed to accelerate polymer degradation and product failures.

Generally valid correlations between the ageing processes which occur during artificial and natural weathering cannot be expected because of the large number of factors involved. Certain relationships can only be expected to hold if the more significant parameters are either the same or their effect on the plastic is known.

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Plastics — Methods of exposure to laboratory light sources —

Part 1:
General guidance

1 Scope

1.1 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.

1.2 It also describes and recommends methods for determining irradiance and radiant exposure, and a black-standard/black-panel thermometer.

1.3 Methods of evaluation of results from exposure are not within the scope of ISO 4892. Refer to ISO 4582.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 4892. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 4892 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 291:1977, *Plastics — Standard atmospheres for conditioning and testing.*

ISO 293:1986, *Plastics — Compression moulding test specimens of thermoplastic materials.*

ISO 294:—[1], *Plastics — Injection moulding of test specimens of thermoplastic materials.*

ISO 295:1991, *Plastics — Compression moulding of test specimens of thermosetting materials.*

ISO 2557-2:1986, *Plastics — Amorphous thermoplastics — Preparation of test specimens with a specified reversion — Part 2: Plates.*

ISO 2818:—[2], *Plastics — Preparation of test specimens by machining.*

ISO 3167:1993, *Plastics — Multipurpose test specimens.*

ISO 4582:1980, *Plastics — Determination of changes in colour and variations in properties after exposure to daylight under glass, natural weathering or artificial light.*

ISO 4892-2:1994, *Plastics — Methods of exposure to laboratory light sources — Part 2: Xenon-arc sources.*

1) To be published. (Revision of ISO 294:1975)

2) To be published. (Revision of ISO 2818:1980)

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

ISO 4892-4:1994, *Plastics — Methods of exposure to laboratory light sources — Part 4: Open-flame carbon-arc lamps*.

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

3 Principle

Specimens of the sample to be tested are exposed to light sources under controlled environmental conditions. The methods described include means which may be used to measure irradiance at the face of the specimen and radiant exposure.

4 General considerations

4.1 Variability of results

The quality and intensity of solar radiation at the earth's surface vary with climate, location and time. In the case of natural weathering, there are factors other than solar radiation that affect the ageing process, such as temperature, temperature cycling, humidity, etc. A minimum of two contiguous years of natural exposure at a particular location may be required to minimize the variability among results from repeated exposures.

Experience has shown that correlation between results of testing with laboratory light sources and in natural daylight at a particular locality is imprecise and can only be assumed for a specific type and formulation of material and for particular properties, where such correlation has been demonstrated from past experience.

With different types of plastics, the correlation factor for the same laboratory source may be different.

4.2 Purpose of tests

Testing with laboratory light sources usually has at least one of the following purposes:

4.2.1 To obtain results from accelerated tests that attempt to reproduce the effects of prolonged exposure to natural daylight, changes in test specimens are determined at each of a number of exposure stages to give a complete picture of performance throughout the exposure. This may be used, with interpolation if necessary, to estimate the amount of radiant exposure necessary to produce a specified change in the material.

4.2.2 For tests intended to establish that the level of quality of different batches does not vary from a known, acceptable control, a suitable exposure time is selected from a knowledge of the expected light resistance of the material, and the change in the test specimens is evaluated at this time only. When exposures to a fixed time are used, the reproducibility of the exposure test must be established for the type of material being evaluated. Alternatively, the exposure time necessary to produce a defined change in the test specimens may be determined.

4.2.3 To test performance specifications, changes in properties are evaluated in accordance with prescribed procedures to determine the acceptability of the product.

4.3 Factors tending to decrease the degree of correlation

Use of ultraviolet radiation of wavelengths shorter than those occurring in natural exposure.

Use of a spectral distribution that differs widely from that of daylight.

Use of a very high irradiance.

Use of high specimen temperatures, particularly with materials which readily undergo changes from thermal effects alone.

Use of impure water.

4.4 Radiation

4.4.1 Most plastics are spectrally selective in their reaction to radiant exposure. In order that the light source in the exposure apparatus produces the same type of photochemical reaction in the plastics material as is produced by exposure to natural daylight, it is important that the spectral power distribution of daylight be reproduced as faithfully as possible by the artificial light source.

4.4.2 CIE Publication No. 85:1989 is the international criterion for comparison of artificial sources with natural daylight. Global solar irradiance in the wavelength range 300 nm to 2 450 nm is given as 1 090 $W \cdot m^{-2}$. The spectral irradiance for the UV, visible and infrared portions is given in table 1.

3) To be published.

Table 1 — Spectral global irradiance (condensed data from table 4 of CIE Publication No. 85:1989)

Wavelength nm	Distribution % of total	Irradiance $W \cdot m^{-2}$
300 to 320	0,4	4
320 to 400	6,4	70
400 to 800	55,4	604
800 to 2 450	37,8	412
300 to 2 450	100,0	1 090

4.4.3 Direct radiation from xenon burners, open-flame carbon arcs and some fluorescent lamps contains considerable amounts of short-wavelength ultraviolet radiation not present in natural daylight. With proper selection of filters for xenon and carbon arc devices, much of the short-wavelength light can be eliminated. Fluorescent lamps can be selected to have a spectral output corresponding to a particular ultraviolet region of sunlight. The xenon arc, when appropriately filtered, produces radiation with a spectral power distribution that is the best simulation of average sunlight in the UV and visible region.

4.4.4 Accelerated degradation may result from exposure to short-wavelength ultraviolet radiation not present in terrestrial sunlight, or by emphasizing spectral regions to which plastics may be particularly sensitive. Increasing the intensity of incident radiation without changing its spectral distribution can also produce acceleration. Any method of acceleration may lead to anomalous results.

Proper selection of the spectral power distribution of the light source as well as specimen temperature may provide acceleration without introducing anomalies that could result from exposure to abnormally high values of either irradiance or temperature.

4.4.5 It is recommended that periods of exposure be defined in terms of ultraviolet radiant energy. Therefore, this part of ISO 4892 describes means to measure irradiance — either by broadband or narrowband techniques — at the face of the specimen and radiant exposure.

4.5 Temperature

4.5.1 The maximum surface temperature of exposed materials depends primarily on the radiation absorption and emission by the specimen, the thermal conduction within the specimen and the heat transmission between the specimen and the air or specimen holder, and is therefore not exactly predictable. Since it is not practical to monitor the individual specimen temperatures, a specified black plate shall be the controlling temperature sensor.

4.5.2 There are different types of black-panel thermometer and a black-standard thermometer available for use in different types of apparatus. The essential difference between the black-standard thermometer and the black-panel thermometer is the heat-insulated mounting of the black-plate. The temperature indicated by the black-standard thermometer corresponds to that of the exposed surface of dark samples with poor thermal conductivity. The surface temperatures of light or well conducting samples will generally be below that of the black-standard thermometer.

At low irradiances, the difference between the temperature indicated by a black-panel or black-standard thermometer and a specimen may be small.

The temperature indicated by a black-standard or black-panel thermometer is also affected by the temperature and speed of the surrounding air.

4.5.3 For the sake of uniformity, the black-standard thermometer is strongly recommended, but black-panel thermometers may also be used by prior agreement. In this case, a description of the black-panel thermometer used and the type of mounting on the specimen holder shall be included in the test report.

4.6 Humidity and wetting

The presence of moisture, particularly in the form of condensation on the exposed face of the specimen, may have a significant effect in accelerated simulated exposure tests. All apparatus described in this part of ISO 4892 has means of providing humidification and of wetting the exposed face of the specimen.

5 Apparatus

5.1 Although various designs are used in practice, each apparatus shall include the elements specified in 5.1.1 to 5.1.6:

5.1.1 A source of radiant energy, located with respect to the specimens such that the irradiance at the specimen face complies with the requirements specified in ISO 4892-2, ISO 4892-3 or ISO 4892-4. Follow the apparatus manufacturer's instructions and recommended times for replacing lamps and filters.

5.1.2 Specimen holders, to support the specimens at the specified distance from the light source such that the spectral irradiance is distributed uniformly, within accepted tolerances, across the exposed surface. Designated sensing devices may be employed to monitor the radiant power and to adjust the emittance to minimize irradiance fluctuation.

5.1.3 Means of providing uniform wetting of the exposed face of the specimen. This may be with water spray nozzles or by condensing water vapour.

5.1.4 Means of providing humidification, controlled by suitable sensors placed in the test chamber air flow, but shielded from direct radiation and water spray.

5.1.5 Temperature sensors, to sense and control the air temperature within the test chamber and, when appropriate, to sense and/or control the temperature indicated by the specified black-plate sensor. Different types of apparatus use either a black-standard thermometer (see 5.1.5.1) or one of several types of black-panel thermometer (see 5.1.5.2). The thermometer is preferably mounted on a specimen holder in such a way that it receives the same radiation and cooling as a specimen mounted on the support would. It may also be located at a fixed distance from the light source, different from the specimen distance, and calibrated to give the temperature at the specimen.

5.1.5.1 Black-standard thermometer: The black-standard thermometer approximates the temperature of dark specimens, which have a low thermal conductivity, when they are irradiated at the specimen distance. This thermometer consists of a plane stainless-steel plate with a thickness of about 1 mm, a length of about 70 mm, and a width of about 40 mm. The surface of this plate facing the light source is coated with a flat, black layer which has good resistance to ageing. The coated black plate absorbs at least 95 % of all incident radiation up to 2 500 nm. The temperature of the plate is measured with a platinum resistance sensor. The sensor is fitted in good thermal contact with the plate at the centre of the plate on the side opposite the radiation source. This side of the metal plate is fixed to a 5-mm-thick baseplate made of unfilled poly(vinylidene fluoride) (PVDF) in such a way that a space is left in the area of the sensor. The distance between the sensor and the recess in the PVDF plate is about 1 mm. The length and width of the PVDF plate shall be sufficiently large to ensure that, when fitting the black-standard thermometer to the specimen holder, no metal-to-metal thermal contact exists between the metal plate and the specimen holder. The metal mounts of the specimen holder shall be located at least 4 mm from the edges of the metal plate.

In order to be able to measure the range of surface temperatures of the exposed specimens and to control better the irradiation level and the other conditions in the apparatus, the use of a white-standard thermometer in addition to the black-standard thermometer is recommended. The white-standard thermometer is of the same design as the black-standard thermometer. Instead of the flat, black coating, however, a white coating with good resistance to ageing is used. The reflectance of the white coating between 300 nm and 1 000 nm shall be at least 90 %, and at least 60 % between 1 000 nm and 2 500 nm.

5.1.5.2 Black-panel thermometer: These thermometers are still used, but significantly different designs have been developed for use in different types of apparatus. Black-panel thermometers use a non-heat-insulated mounting for the black metal plate. This is the essential difference between the black-panel thermometer and the black-standard thermometer. Under given operating conditions, black-panel thermometers therefore tend to indicate lower temperatures than the standard design described in 5.1.5.1. One type of black-panel thermometer used consists of a plane stainless-steel plate with a thickness of about 1 mm, a length of about 150 mm and a width of about 70 mm. The surface of this plate facing the light source is coated with a flat, black layer. The coated black plate absorbs at least 90 % of all incident radiation up to 2 500 nm. The temperature of the plate is measured with either a black-coated stem-type bimetallic dial sensor or a resistance bulb sensor centrally positioned and firmly attached to the exposed surface of the black plate. Black-panel thermometers which differ in their dimensions, type of sensor element and sensor-element fixture shall be described in the test report. The type of mounting used to fit the black-panel thermometer on the specimen holder shall also be described in the test report.

5.1.6 Automatic programmer, to switch the specimen-wetting facilities and, optionally, the light source on and off at pre-programmed intervals.

5.2 The apparatus may also, optionally, include a radiometer to measure the irradiance E at the face of the specimen as well as the radiant exposure H of the specimen.

The irradiance and the radiant exposure at the specimen surface is measured with a photoelectronic sensor mounted so that it receives the same amount of radiation as the specimen surface. If the sensor is not positioned in the plane of the specimen, it shall have an adequate field of view and be calibrated to give the irradiance at the specimen.

The radiometer shall be calibrated in the emission range of the light source used. This calibration shall be checked in accordance with the instrument manufacturer's recommendations. Full calibration is required at least once per year.

When a radiation meter is used, the irradiance shall be measured in a wavelength range agreed on by all interested parties and stated in the test report. The 300 nm to 400 nm or 300 nm to 800 nm range is often used. In some types of apparatus, the irradiance can be measured at a specific wavelength (e.g. 340 nm).

NOTE 1 Direct comparison between the radiant exposure measured in an accelerated-ageing apparatus and natural weathering is best made when the same radiometer is used in each.

5.3 To meet the requirements of particular test procedures, the apparatus may need to include means of registering or recording the following operational parameters:

- Line voltage
- Lamp voltage
- Lamp current
- Black-standard thermometer or black-panel thermometer temperature
- Test-chamber air temperature
- Test-chamber relative humidity
- Water-spray cycles
- Water quality
- Spectral irradiance and radiant exposure
- Duration of exposure (radiation time and total, if different)

The accuracy of measurement of the test-chamber temperature and humidity shall be stated in the test report.

6 Test specimens

6.1 Form and preparation

6.1.1 The dimensions of the test specimens shall normally be those specified in the appropriate test method for the property or properties to be measured after exposure. For some tests, the test specimen may also be in the form of a sheet or other shape from which test specimens can later be cut for specific tests.

6.1.2 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 shall be cut from a sheet produced by the appropriate method. Test specimens of the material may also be formed by extrusion, injection-moulding or some other appropriate method.

For the preparation of test specimens, attention is drawn to ISO 293, ISO 294, ISO 295, ISO 2557-2 and ISO 3167.

The method used shall be agreed on by the interested parties and should be closely related to the method by which the material is to be processed by the user.

6.1.3 If the material to be tested is in the form of an extrusion, a moulding, a sheet, etc., test specimens may be prepared from the materials either before or after exposure, depending on the specific requirements of the tests and the nature of the material. For example, materials that embrittle markedly on weathering shall be exposed in the form in which they are to be tested, since subsequent machining is difficult; in particular, the notch for testing impact strength shall be cut before exposure and shall face the lamp during exposure. Materials such as laminate that may delaminate at the edges shall be exposed in sheet form and the specimens cut after exposure.

For the preparation of test specimens by machining, attention is drawn to ISO 2818.

6.1.4 When the behaviour of a specific type of article is to be determined, the article itself shall be exposed whenever possible. Articles, or parts thereof, which are large enough for test purposes shall be exposed as they are. When pieces of material are exposed and test specimens cut from them afterwards, the exposed surface shall not be removed. Whenever possible, test specimens cut from an exposed sheet shall not be taken less than 20 mm from fixtures holding the material or from supports that are not intended to simulate the conditions of exposure of the material in service. In no circumstances shall any ma-