INTERNATIONAL STANDARD

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Plastics — Methods of exposure to laboratory light sources —

Part 2:
Xenon-arc sources

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

Partie 2: Sources à arc au xénon

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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.

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 4892-2 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*

Annex A of this part of ISO 4892 is for information only.

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Plastics — Methods of exposure to laboratory light sources —

Part 2:
Xenon-arc sources

1 Scope

This part of ISO 4892 specifies methods for exposing specimens to xenon-arc light sources. General guidance is given in ISO 4892-1.

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

ISO 4892-1:1994, *Plastics — Methods of exposure to laboratory light sources — Part 1: General guidance.*

CIE Publication No. 20:1972, *Recommendations for the integrated irradiance and the spectral distribution of simulated solar radiation for testing purposes.*

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

3 Principle

3.1 A xenon arc, when fitted with suitable filters and properly maintained, produces radiation with a spectral energy distribution similar to that of terrestrial sunlight in the ultraviolet and visible regions of the spectrum.

3.2 Specimens of the samples to be tested are exposed to the light source under controlled environmental conditions.

3.3 The procedure may include measurement of the irradiance and radiant exposure at the surface of the specimen.

3.4 It is recommended that a similar material of known behaviour be exposed simultaneously with the experimental material as a reference.

3.5 Intercomparison of results obtained from specimens exposed in different apparatus should not be made unless reproducibility has been established among devices for the material to be tested.

4 Apparatus

4.1 Laboratory light source

4.1.1 Quartz-jacketed xenon-arc lamps emit radiation in a range that extends from below 270 nm in the ultraviolet through the visible region of the spectrum and into the infrared.

To simulate direct natural exposure, the radiant energy must be filtered to provide a spectral power distribution that closely approximates to that of terrestrial daylight (method A), as described in CIE Publication No. 85.

Filters designed to reduce the irradiance below 320 nm are used to simulate daylight filtered through window glass (method B).

Additional filters to reduce the level of non-actinic infrared energy may be desirable when heating of the specimen adversely influences the photochemical-reaction rate or causes thermal degradation not experienced during real-time natural exposure.

The characteristics of xenon arcs and filters are subject to change during use due to ageing, and lamps and filters shall be replaced at suitable intervals. Furthermore, they are subject to change due to the accumulation of dirt and shall therefore be cleaned at suitable intervals. Follow the manufacturer's recommendations for replacement and cleaning of lamps and filters.

4.1.2 Recommendations for UV-radiation distributions of filtered xenon-arc sources, together with tolerance limits, are given in table 1 for artificial weathering (method A) and table 2 for simulated exposure to daylight behind window glass (method B).

4.1.3 For reference purposes, an irradiance of 550 W/m^2 in the 290 nm to 800 nm passband has been selected (see CIE Publication No. 20). It is not necessarily the preferred irradiance. When mutually agreed upon between interested parties, other irradiance levels may be selected. Report the irradiance and the passband selected.

Table 1 — Relative spectral irradiance for artificial weathering (method A)

Wavelength, λ nm	Relative spectral irradiance[1)] %
$290 < \lambda \leqslant 800$	100
$\lambda \leqslant 290$	0[2)]
$290 < \lambda \leqslant 320$	0,6 ± 0,2
$320 < \lambda \leqslant 360$	4,2 ± 0,5
$360 < \lambda \leqslant 400$	6,2 ± 1,0

1) The spectral irradiance between 290 nm and 800 nm is defined as 100 %.

2) Xenon arcs operating as specified in method A emit a small amount of radiation below 290 nm. In some cases, this can cause degradation reactions which do not occur in outdoor exposures.

Table 2 — Relative spectral irradiance for daylight behind window glass (method B)

Wavelength, λ nm	Relative spectral irradiance[1)] %
$300 < \lambda \leqslant 800$	100
$\lambda \leqslant 300$	0
$300 < \lambda \leqslant 320$	< 0,1
$320 < \lambda \leqslant 360$	3,0 ± 0,5
$360 < \lambda \leqslant 400$	6,0 ± 1,0

1) The spectral irradiance between 300 nm and 800 nm is defined as 100 %.

4.1.4 The irradiance at the test specimen surface shall not vary by more than ± 10 % comparing any two points in the sample holder plane parallel to the lamp axis. If this is not possible, specimens shall be periodically repositioned to provide equivalent exposure periods in each location.

NOTE 1 Depending on the exact design of test chamber (4.2) used, the spectral-irradiance values may be time-averaged values.

4.2 Test chamber

The test chamber contains a frame, carrying specimen holders if necessary, with provision for passing air over the specimens for temperature control.

The source(s) of radiant energy shall be located, with respect to the specimens, such that the irradiance at the specimen surface complies with 4.1.3 and 4.1.4.

Should any ozone be generated from operation of the lamp(s), the lamp(s) shall be isolated from the test specimens and operating personnel. If the ozone is in an air stream, it shall be vented directly to the outside of the building.

To reduce the effect of any eccentricity in the lamp, or when more than one lamp is used in a single chamber to increase irradiance, the uniformity of exposure may be improved by rotating the frame carrying the specimens around the light source(s) and, if necessary, by periodically changing the position of each specimen.

The specimen holders may also rotate about their own axis, thus exposing directly to the radiation from the light source the side of the specimen holder that was previously not directly exposed.

Programmes may be used which employ a dark cycle obtained by extinguishing the light source to provide controlled exposure conditions without the presence of simulated solar radiation.

When any of these operating modes or programmes are used, they shall be reported in full.

4.3 Radiometer

When a radiometer is used, it shall comply with the requirements outlined in ISO 4892-1:1994, subclause 5.2.

4.4 Black-standard/black-panel thermometer

The black-standard or black-panel thermometer used shall comply with the requirements outlined in ISO 4892-1:1994, subclause 5.1.5.

4.5 Relative-humidity control equipment

The relative humidity of the air passing over the test specimens shall be controlled at an agreed value, and measured by suitable instruments inserted into the test chamber and shielded from the lamp radiation.

4.6 Spray system

Specimens may be sprayed with distilled or demineralized water (having a conductivity below 5 µS/cm) intermittently under specified conditions. The spray system shall be made from inert materials that do not contaminate the water employed. The water shall leave no observable stains or deposits and should therefore preferably contain less than 1 ppm of solids. In addition to distillation, a combination of deionization and reverse osmosis can be used to produce water of the required quality. The pH of the water used shall be reported.

4.7 Specimen holders

Specimen holders may be in the form of an open frame, leaving the back of the specimen exposed, or they may provide the specimen with a solid backing. They shall be made from inert materials that will not affect the test results, for example non-oxidizing alloys of aluminium or stainless steel. Brass, steel or copper shall not be used in the vicinity of the test specimens. The backing used may affect the results, particularly with transparent specimens, and shall be agreed on between the interested parties.

4.8 Apparatus to assess changes in properties

The apparatus required by the International Standards relating to the determination of the properties chosen for monitoring (see also ISO 4582) shall be used.

5 Test specimens

Refer to ISO 4892-1.

6 Test conditions

6.1 Black-standard/black-panel temperature

Two black-standard temperatures have been selected for reference purposes:

65 °C ± 3 °C

100 °C ± 3 °C

NOTE 2 The higher temperature is intended for special tests, but will increase the tendency of the specimen to undergo thermal degradation and influence the test results.

These temperatures are not necessarily the preferred ones. When mutually agreed upon, another temperature may be selected, but shall be stated in the exposure report.

If water spray is used, the temperature requirements apply to the end of the dry period. If the thermometer does not attain equilibrium during a short cycle, the specified temperature shall be established without water spray and the maximum temperature attained during the dry cycle shall be reported.

Even if the exposure apparatus is operated in an alternating mode, measurement by black-standard thermometer shall be carried out in the continuous mode.

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

6.2 Relative humidity

The relative humidity used shall be as agreed between the interested parties, but should preferably be one of the following:

(50 ± 5) %

(65 ± 5) %

NOTE 3 The relative humidity of the air as measured in the test chamber is not necessarily equivalent to the relative humidity of the air very close to the specimen surface owing to the different temperatures of test specimens having different colours and thicknesses.

6.3 Spray cycle

The spray cycle used shall be as agreed between the interested parties, but should preferably be the following one:

duration of spraying: 18 min ± 0,5 min

dry interval between spraying: 102 min ± 0,5 min

6.4 Cycles with dark periods

The conditions in 6.1 and 6.3 are valid for continuous presence of radiant energy from the source. More complex cycles may be programmed, including dark periods that allow high relative humidities and the formation of condensate at elevated chamber temperatures.

Such programmes shall be given, with full details of the conditions, in the exposure report.

7 Procedure

7.1 Mounting the test specimens

Attach the specimens to the specimen holders in the equipment in such a manner that the specimens are not subject to any applied stress. Identify each test specimen by suitable indelible marking, avoiding areas to be used for subsequent testing. As a check, a plan of the test-specimen positions may be made.

If desired, in the case of specimens used to determine change in colour and appearance, a portion of each test specimen may be shielded by an opaque cover throughout the test. This gives an unexposed area adjacent to the exposed area for comparison. This is useful for checking the progress of the exposure, but the data reported shall always be based on a comparison with control specimens stored separately in the dark.

7.2 Exposure

Before placing the specimens in the test chamber, be sure that the apparatus is operating under the desired conditions (see clause 6). Maintain these conditions throughout the exposure.

Expose the test specimen and, if required, the irradiance-measuring device for the specified period of exposure. It is desirable to vary the position of the test specimens in the apparatus from time to time to reduce any local inequalities of exposure. When the specimens are so adjusted, they shall remain in the same orientation as when initially mounted.

If it is necessary to remove a test specimen for a periodic inspection, care shall be taken not to handle or disturb the test surface. After inspection, the test specimen shall be returned to its holder or to the test chamber with its test surface in the same orientation as before.

7.3 Measurement of radiant exposure

If used, mount the light-dosage measurement instrument so that the radiometer indicates the irradiance at the exposed surface of the test specimen.

The exposure interval shall be expressed in terms of incident spectral radiant energy per unit area of the exposure plane, in joules per square metre, for the passband selected.

7.4 Determination of changes in properties after exposure

These shall be determined as specified in ISO 4582.

8 Exposure report

Refer to ISO 4892-1.

Annex A
(informative)

Xenon-arc lamp apparatus

A.1 Apparatus with air-cooled xenon-arc lamps

A.1.1 Description and conditions of use

A.1.1.1 The test apparatus employed utilizes one or more air-cooled xenon-arc lamps as the source of radiation. Different-type and different-size lamps operating in different wattage ranges are employed in several of the different sizes and types of apparatus.

In some of the various models of exposure apparatus, the lamp wattage can be varied so that, when the specimens are exposed in the holders, the irradiance at the face of the specimens is at the specified level.

A.1.1.2 The radiation system consists of either one centrally positioned xenon-arc lamp or three lamps arranged in symmetrical fashion, depending on the type of apparatus. A heat-absorbing system consisting of any or all of the following may be used: an air- or water-cooled absorber (UV and visible-light mirrors may be attached to the absorber to reflect radiation), single or multiple quartz cylinders with forced air circulated through the inner cylinder and water between concentric quartz cylinders. All cooling air shall be discharged outside the laboratory building. Also, an infrared reflecting coating may be installed on the inner quartz surface to reduce further the heat emitted from the lamp and prevent a portion of the heat from entering the test chamber.

Artificial weathering (method A) requires filtration of the light source so that the specimens see a low end spectral cut-off value approximately equal to that of terrestrial daylight. Units with a single lamp use a special coating on quartz filters in combination with a UV-limiting outer cylinder. Units with three lamps add special UV glass outside the two concentric quartz cylinders. These special UV glass filters are in one-third-cylindrical sections and are arranged to form a complete cylinder installed between the central optical system and the specimen holders.

Daylight behind window glass (method B) requires filtration of the light from the light source so that the specimens see a low end spectral cut-off value approximately equal to that of light behind window glass. Units with a single lamp use the already mentioned infrared-absorbing filters or spectral coating on quartz filters with a UV cut-off value approximately equal to that of light behind window glass in combination with an outer cylinder. Units with three lamps add window glass outside the two concentric quartz cylinders. These window-glass filters are in one-third-cylindrical sections and are arranged to form a complete cylinder installed between the central optical system and the specimen holders.

The transmissivity of infrared-absorbing and window-glass filters changes with continual use and such filters are discarded after 4 000 h of use or in accordance with the manufacturer's specifications.

Combinations of the various filter elements used in test apparatus with one or more air-cooled xenon-arc lamps make it possible to produce various time-averaged spectral distributions that are not within the scope of this part of ISO 4892.

The irradiance selected for reference purposes as stated in 4.1.3 is achieved in this type of apparatus by various methods. Some apparatus requires the sample holders to rotate about their vertical axis to achieve a time-averaged value of 60 W/m^2 in the case of method A and 50 W/m^2 in the case of method B in the UV range between 290 nm and 400 nm as measured with a radiometer mounted in the specimen plane as described in ISO 4892-1. Units with internally adjustable irradiance control using either one or three lamps can operate at these levels both in the mode in which the specimens rotate about their vertical axis and in the mode in which they do not rotate. Xenon lamps are discarded when the desired irradiance values can no longer be achieved.

In apparatus in which the lamp wattage can be varied over a wide range, the specified values of UV irradiance are adjusted independently of the operating mode, with or without turning specimen holders. The xenon lamps are discarded when the preset spectral irradiance is no longer achievable by automatic control.

A.1.1.3 Apparatus for use in this method is equipped with a countdown timer for controlling the length of exposure. Some types of apparatus are also equipped with a radiometer designed to switch off the apparatus as soon as a preset radiant exposure has been reached.

A.1.2 Temperature and humidity control

A.1.2.1 Because of the sensitivity of some plastics to temperature, accurate, close control of the test temperature is extremely important in tests carried out using this method. The temperature is measured using a black-standard thermometer, which is mounted on the revolving specimen rack so that its surface is in the same relative position and subjected to the same influences as the test specimens.

A.1.2.2 A ventilation system provides a constant stream of air through the test chamber and over the test specimens. The temperature of the air is automatically controlled by recirculating warm air from the test chamber mixed with cooler room air. In some types of apparatus the black-standard temperature is automatically controlled as an alternative.

In some types of apparatus, it is possible to adjust the fan speed to keep constant the difference between the black-standard temperature and the chamber temperature, even at different levels of UV irradiance.

A.1.2.3 The specimen holders may be vertical or inclined and are mounted on a revolving cylindrical rack which is rotated around the lamp system at between 2 rpm and 7 rpm, depending on the type of apparatus, and which is centred both horizontally and vertically with respect to the exposure area in the specimen holders.

A.1.2.4 Depending on the type of apparatus, the test chamber is air-conditioned by adding moisture to the air using an ultrasonic humidifier unit or by means of water atomized by an aerosol device and fed into the air stream. The relative humidity in the test chamber is measured and controlled using either a capacitative sensor or a contact hygrometer.

A.2 Apparatus with water-cooled xenon-arc lamps

A.2.1 Description and conditions of use

A.2.1.1 The test apparatus employed utilizes a water-cooled xenon-arc lamp as the source of radiation. While all of the xenon-arc lamps employed are of the same general type, different-size lamps operating in different wattage ranges are employed in several of the different sizes and types of apparatus. In each of the various models of exposure apparatus, the diameter of the specimen rack, lamp size and lamp wattage can be varied so that, when the specimens are exposed in the holders, the irradiance at the surface of the specimens is at the specified level.

A.2.1.2 The xenon-arc lamp used consists of a xenon burner tube, an inner glass filter and the necessary accessories. For artificial weathering (method A), borosilicate glass inner and outer filters are used so that the irradiation at the specimen has a lower spectral cut-off value approximately equal to that of terrestrial daylight. For daylight behind window glass (method B), a borosilicate glass inner filter and a soda-lime glass outer filter are used so that the irradiation at the specimen has a lower spectral cut-off value approximately equal to that of window glass. Other glass filters are available with different spectral cut-off values. Because of transmission changes (solarization), outer filters are discarded after 2 000 h of use and inner filters after 400 h of use.

The irradiance of 550 W/m^2 in the wavelength range 290 nm $\leqslant \lambda \leqslant$ 800 nm as stated in 4.1.3 is achieved, in the case of method A, when a spectral irradiance of 0,50 W/$(\text{m}^2\cdot\text{nm})$ at 340 nm is selected and, in the case of method B, when a spectral irradiance of 1,25 W/$(\text{m}^2\cdot\text{nm})$ at 420 nm is selected.

Because the light intensity drops with continued use, xenon burners are discarded when the preset spectral irradiance is no longer achievable by automatic control.

A.2.1.3 All types of xenon-arc exposure apparatus are equipped with suitable starters, reactance transformers and indicating and control equipment for either manually or automatically controlling the wattage of the lamp. In manually controlled units, the wattage of the lamp may require periodic adjustment to maintain the preset spectral irradiance.

A.2.1.4 To cool the lamp, distilled or deionized water is circulated through the lamp assembly at a minimum flow rate of 378,5 l/h. To prevent contamination and minimize the formation of deposits, the water is purified by the use of a mixed-bed deionizer just ahead of the lamp. The recirculated lamp water is cooled without contaminating it by the use of the heat-exchange unit employing either tap water or a refrigerant as the heat-transfer medium.

A.2.1.5 Apparatus for use in this method is equipped with a countdown timer for controlling the length of exposure. Some apparatus is also equipped with a light monitor designed to switch off the apparatus as soon as a given radiant exposure has been reached.

A.2.2 Temperature and humidity control

A.2.2.1 Because of the sensitivity to temperature of some plastics, accurate, close control of the test temperature is extremely important in tests made by this procedure. The temperature is measured and controlled using either a black-standard thermometer or a black-panel thermometer, which is mounted on the revolving specimen rack so that its surface is in the same relative position and subjected to the same influences as the test specimens.

A.2.2.2 The exposure apparatus is enclosed in an insulated cabinet to minimize the effects of any variation in room temperature. A ventilation system provides a constant stream of air through the test chamber and over the test specimens. The temperature of the air is automatically controlled by recirculating warm air from the test chamber mixed with cooler room air.

It may be necessary to adjust and control the fan speed both to meet the specified black-standard or black-panel temperature and to keep constant the specified dry-bulb temperature.

A.2.2.3 The specimen holders are mounted on a vertical or inclined cylindrical frame or rack which is rotated at 1 rpm around the lamp which is centred both horizontally and vertically with respect to the exposure area in the sample holders.