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

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

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

*Partie 4: Lampes à arc au carbone*

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# Foreword

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

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

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

— *Part 1: General guidance*

— *Part 2: Xenon-arc lamps*

— *Part 3: Fluorescent UV lamps*

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

# Introduction

Coatings of paints, varnishes and similar materials (subsequently referred to simply as coatings) are exposed to laboratory light sources, in order to simulate in the laboratory the ageing processes which occur during natural weathering or behind window glass.

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

## Part 4: Open-flame carbon-arc lamps

## 1 Scope

This part of ISO 16474 specifies methods for exposing specimens to open-flame carbon-arc lamps in the presence of moisture to reproduce the weathering effects that occur when materials are exposed in actual end-use environments to daylight or to daylight filtered through window glass.

The specimens are exposed to filtered open-flame carbon-arc light under controlled conditions (temperature, humidity and/or wetting). Different types of filters are used to simulate either direct exposure to the environment or exposure through window glass.

Specimen preparation and evaluation of the results are covered in other International Standards for specific materials.

General guidance is given in ISO 16474-1.

NOTE Open-flame carbon-arc exposures for plastics are described in ISO 4892-4.

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

ISO 4618, *Paints and varnishes — Terms and definitions*

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

ISO 16474-1, *Paints and varnishes — Methods of exposure to laboratory light sources — Part 1: General guidance*

## 3 Terms and definitions

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

**3.1**
**radiant exposure**
*H*
amount of radiant energy to which a test panel has been exposed

Note 1 to entry: Radiant exposure is given by the equation $H = \int E \cdot \mathrm{d}t$

where

$H$ is the radiant exposure, in joules per square metre;

$E$ is the irradiance, in watts per square metre;

$t$ is the exposure time, in seconds

Note 2 to entry: If the irradiance $E$ is constant throughout the whole exposure time, the radiant exposure $H$ is given simply by the product of $E$ and $t$.

# 4 Principle

**4.1** Specimens of the materials to be tested are exposed to glass-filtered open-flame carbon-arc light, to heat, to relative humidity and to water (see 4.3) under controlled environmental conditions.

**4.2** The exposure conditions may be varied by selection of

a) the light filter(s);

b) the temperature during light exposure;

c) the relative humidity of the chamber air during light and dark exposures, when test conditions requiring control of humidity are used;

d) the type of wetting (see 4.3);

e) the water temperature and wetting cycle;

f) the timing of the light/dark cycle.

**4.3** Wetting is usually produced by spraying the test specimens with demineralised/ deionized water or by condensation of water vapour onto the surfaces of the specimens.

**4.4** The procedure may include measurements of the irradiance and radiant exposure in the plane of the specimens.

**4.5** It is recommended that a similar material of known performance (a control) be exposed simultaneously with the test specimens to provide a standard for comparative purposes.

**4.6** Intercomparison of results obtained from the test specimens exposed in different types of apparatus should not be made unless an appropriate statistical relationship has been established between the apparatuses for the particular material to be tested.

# 5 Apparatus

## 5.1 Laboratory light source

### 5.1.1 General

Open-flame carbon-arc light sources typically use one, three or four pairs of carbon rods which contain a mixture of rare-earth metal salts and have a surface coating of a metal such as copper. An electric current is passed between the carbon rods which burn, giving off ultraviolet, visible and infrared radiation. The pairs of carbon rods are burned in sequence, with one pair burning at any one time. Use the carbon rods recommended by the manufacturer of the apparatus. The radiation reaching the specimens passes through glass filters. Three types of glass filter are used in practice. Tables 1 and 2 show the typical relative spectral power distribution for open-flame carbon-arc lamps with daylight and window-glass filters, respectively. When extended-UV filters are used, the relative spectral power distribution shall meet the requirements of Table 3.

NOTE Solar spectral irradiance for a number of different atmospheric conditions is described in CIE No. 85. The benchmark daylight used in this part of ISO 16474 is that defined in CIE No. 85:1989, Table 4.

### 5.1.2 Spectral irradiance of open-flame carbon-arc lamps with daylight filters (Type 1)

The data in Table 1 are typical of an open-flame carbon-arc lamp with glass filters used to simulate daylight (see CIE No. 85:1989, Table 4).

### 5.1.3 Spectral irradiance of open-flame carbon-arc lamps with window glass filters (Type 2)

The data in Table 2 are typical of an open-flame carbon-arc lamp with window-glass filters.

### 5.1.4 Spectral irradiance of open-flame carbon-arc lamps with extended-UV filters (Type 3)

The data in Table 3 are typical of an open-flame carbon-arc lamp with extended-UV filters. A typical example of a suitable type 3 filter is that commonly known as Corex 7058[1)].

**Table 1 — Typical ultraviolet spectral power distribution for open-flame carbon-arc lamps with daylight filters (type 1)[a,b]**

| Spectral passband | Typical distribution for open-flame carbon-arc lamp with daylight filters[c] | CIE No. 85:1989, Table 4[d,e] |
|---|---|---|
| ($\lambda$ = wavelength in nm) | % | % |
| $\lambda < 290$ | 0,05 | |
| $290 \le \lambda \le 320$ | 2,9 | 5,4 |
| $320 < \lambda \le 360$ | 20,5 | 38,2 |
| $360 < \lambda \le 400$ | 76,6 | 56,4 |

[a] This table gives the irradiance in the given passband, expressed as a percentage of the total irradiance between 290 nm and 400 nm. To determine the relative spectral power distribution of an open-flame carbon-arc lamp through a specific daylight filter or set of filters, the spectral power distribution shall be measured from 250 nm to 400 nm. Typically, this is done in 2 nm increments. The total irradiance in each passband is then summed and divided by the total irradiance between 290 nm and 400 nm.

[b] The table gives typical data for an open-flame carbon-arc lamp with borosilicate-glass daylight filters. There is currently not enough data available to develop a specification for the open-flame carbon-arc lamp with a daylight filter.

[c] For any individual spectral power distribution, the calculated percentages for the passbands in this table will sum to 100 %.

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

[e] For the solar spectrum represented by CIE No. 85:1989, Table 4, the UV irradiance (290 nm to 400 nm) is 11 % and the visible irradiance (400 nm to 800 nm) is 89 %, expressed as a percentage of the total irradiance between 290 nm to 800 nm.

1) Corex 7058 is an example of a suitable product available commercially. This information is given for the convenience of users of this part of ISO 16474 and does not constitute an endorsement by ISO of this product.

**Table 2 — Typical ultraviolet spectral power distribution for open-flame carbon-arc lamps with window-glass filters (type 2)[a,b]**

| Spectral passband | Typical distribution for open-flame carbon-arc lamp with window-glass filters[c] | CIE No. 85:1989, Table 4, plus effect of window glass[d,e] |
|---|---|---|
| ($\lambda$ = wavelength in nm) | % | % |
| $\lambda < 300$ | 0,0 | |
| $300 \leq \lambda \leq 320$ | 0,3 | ≤ 1 |
| $320 < \lambda \leq 360$ | 18,7 | 33,1 |
| $360 < \lambda \leq 400$ | 81,0 | 66,0 |

[a] This table gives the typical irradiance in the given passband, expressed as a percentage of the total irradiance between 290 nm and 400 nm. To determine the irradiance in each passband for an open-flame carbon-arc lamp with a specific set of window-glass filters, the spectral power distribution shall be measured from 250 nm to 400 nm. Typically, this is done in 2 nm increments. The total irradiance in each passband is then summed and divided by the total irradiance between 290 nm and 400 nm.

[b] The table gives typical data for an open-flame carbon-arc lamp with window-glass filters. There is currently not enough data available to develop a specification for the spectral power distribution.

[c] For any individual spectral power distribution, the calculated percentages for the passbands in this table will sum to 100 %. Contact the manufacturer of the carbon-arc apparatus for the spectral power distribution data for the particular carbon arcs and window-glass filters used.

[d] The data from CIE No. 85:1989, Table 4, plus the effect of window glass was determined by multiplying the CIE No. 85:1989, Table 4, data by the transmission typical for window glass used in the USA and Europe. These data are provided for comparison purposes only.

[e] For the CIE No. 85:1989, Table 4 plus window glass data, the UV irradiance between 300 nm and 400 nm ranges from 7,7 % to 10,6 % and the visible radiation ranges from 89,4 % to 92,3 %, expressed as a percentage of the total irradiance between 300 nm and 800 nm.

**Table 3 — Ultraviolet spectral power distribution for open-flame carbon-arc lamps with extended-UV filters (type 3)[a,b]**

| Spectral passband | Minimum[c] | Maximum[c] | CIE No. 85:1989, Table 4[d,e] |
|---|---|---|---|
| ($\lambda$ = wavelength in nm) | % | % | % |
| $\lambda$ < 290 | | 4,9 | |
| 290 ≤ $\lambda$ ≤ 320 | 2,3 | 6,7 | 5,4 |
| 320 < $\lambda$ ≤ 360 | 16,4 | 24,3 | 38,2 |
| 360 < $\lambda$ ≤ 400 | 68,1 | 80,1 | 56,4 |

[a] This table gives the irradiance in the given passband, expressed as a percentage of the total irradiance between 250 nm and 400 nm. To determine whether a specific filter or set of filters for an open-flame carbon-arc lamp meets the requirements of this table, the spectral power distribution shall be measured from 250 nm to 400 nm. Typically, this is done in 2 nm increments. The total irradiance in each wavelength passband is then summed and divided by the total irradiance from 250 nm to 400 nm.

[b] The minimum and maximum limits in this table are based on 24 spectral power distribution measurements with open-flame carbon-arc lamps with filters from different production lots and of various ages, used in accordance with the recommendations of the manufacturer. The minimum and maximum limits are at least three sigma from the mean for all the measurements. Open-flame carbon-arc lamps emit significant amounts of short-wavelength UV radiation between 250 nm and 280 nm. The intensity of this short-wavelength UV radiation varies with the age and initial transmission properties of the extended-UV filters used, as well as the composition of the carbon rods. The composition of the carbon rods can vary between production lots and between manufacturers.

[c] The minimum and maximum columns will not necessarily sum to 100 % because they represent the minima and maxima for the measurement data used. For any individual spectral power distribution, the percentages calculated for the passbands in this table will sum to 100 %. For any individual open-flame carbon-arc lamp with extended-UV filters, the calculated percentage in each passband shall fall within the minimum and maximum limits given. Test results can be expected to differ if obtained using open-flame carbon-arc apparatuses in which the spectral power distributions differed by as much as that allowed by the tolerances. Contact the manufacturer of the carbon-arc apparatus for specific spectral power distribution data for the carbon-arc lamp and filters used.

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

[e] For the solar spectrum represented by CIE No. 85:1989, Table 4, the UV irradiance (290 nm to 400 nm) is 11 % and the visible irradiance (400 nm to 800 nm) is 89 %, expressed as a percentage of the total irradiance between 290 nm and 800 nm.

### 5.1.5 Factors which can affect the spectral power distribution of open-flame carbon-arc lamps

The following factors can affect the spectral power distribution:

a) differences in the composition and thickness of the filters can have large effects on the amount of short-wavelength UV radiation transmitted;

b) accumulation of dirt or other residues on the filter can affect the filter transmission properties;

c) differences in the composition of the metallic salts used in the carbon rods can affect the spectral power distribution.

### 5.1.6 Irradiance uniformity

The irradiance at any position in the area used for specimen exposure shall be at least 80 % of the maximum irradiance. Requirements for periodic repositioning of specimens when this requirement is not met are described in ISO 16474-1.

For some materials of high reflectivity, or/and high sensitivity to irradiance and temperature, periodic repositioning of specimens is recommended to ensure uniformity of exposures, even when the irradiance uniformity in the exposure area is within the limits so that repositioning is not required.

## 5.2 Test chamber

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

The frame rotates about the central axis of the carbon-arc holder. A typical frame diameter is 96 cm. Other frame diameters may be used if mutually agreed upon by all interested parties. The test specimens shall be mounted directly on the frame or mounted in holders attached to the frame. The frame may be vertical or inclined.

The upper and lower carbon rods, as well as the filters, shall be installed in accordance with the instructions of the manufacturer of the apparatus.

The apparatus shall be fitted with equipment for programming exposure cycles within the operational limits of the apparatus.

## 5.3 Radiometer

The radiometer used shall comply with the requirements outlined in ISO 16474-1 and ISO 9370.

## 5.4 Black-standard/black-panel thermometer

The black-standard or black-panel thermometer used shall comply with the requirements for these devices given in ISO 16474-1.

NOTE Typically, this device is controlled by black-panel temperature only.

## 5.5 Wetting and humidity-control equipment

### 5.5.1 General

Specimens may be exposed to moisture in the form of water spray or condensation. If condensation or other methods are used to expose the test specimens to moisture, details of the procedures and exposure conditions used shall be included in the exposure report.

NOTE The relative humidity of the air can have a significant influence on the photodegradation of coatings.

### 5.5.2 Relative-humidity control equipment

For exposures where relative-humidity control is required, the location of the sensors used to measure the humidity shall be as specified in ISO 16474-1.

### 5.5.3 Spray system

The test chamber shall be equipped with a means of directing an intermittent water spray onto the fronts or backs of the test specimens under specified conditions. The spray shall be uniformly distributed over the test specimens. The spray system shall be made from corrosion-resistant materials that do not contaminate the water employed.

The water sprayed onto the test specimen surfaces shall have a conductivity below 5 µS/cm, contain less than 1 µg/g dissolved solids content and leave no observable stains or deposits on the test specimens. Care shall be taken to keep silica levels below 0,2 µg/g. A combination of deionization and reverse osmosis may be used to produce water of the desired quality.

A spray system designed to cool the test specimen by spraying the back surface of the test specimen or the test specimen backing might be required when the exposure programme specifies periods of condensation.

### 5.6 Specimen holders

Specimen holders may be in the form of an open frame, leaving the backs of the test specimens exposed, or they may provide the test specimens with a solid backing. They shall be made from inert materials that will not affect the results of the exposure, 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 might affect the results, as might any space between the backing and the test specimen, particularly with transparent test specimens, and shall be agreed on between the interested parties.

### 5.7 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.

## 6 Test specimens

Refer to ISO 16474-1.

## 7 Exposure conditions

### 7.1 Temperature

#### 7.1.1 Black-standard/black-panel temperature

For referee purposes, it is recommended that black-standard temperatures be used. However, for normal work, black-panel thermometers are widely used for open-flame carbon-arc lamp apparatus. In the case of the black-panel temperature, (63 ± 3) °C is typically used.

NOTE 1 Allowance will have to be made for the fact that the two types of thermometer indicate different temperatures, due to their different thermal conductivities (see ISO 16474-1). If a black-panel thermometer is used, the temperature indicated will be 3 °C to 12 °C lower than that indicated by a black-standard thermometer under typical exposure conditions.

If a black-panel thermometer is used, then the panel material, the type of temperature sensor and the way in which the sensor is mounted on the panel shall be included in the exposure report.

Other temperatures may be used when agreed on by the interested parties, but shall be stated in the exposure report.

NOTE 2 If higher temperatures are used for special exposures, the tendency for specimens to undergo thermal degradation will increase and this might affect the results of such exposures.

If water spray is used, the temperature requirements apply to the end of the dry period. If the thermometer does not reach a steady-state during the dry period after the short water-spray part of the cycle, check and report if the specified temperature is reached during a longer dry period without water spray.

NOTE 3 During the water spray part of the cycle the black-standard or black-panel temperature is close to the water temperature.

NOTE 4 The additional measurement of a white-standard/white-panel temperature with a white-standard/white-panel thermometer according to ISO 16474-1 gives important information on the range of surface temperatures of differently coloured test specimens.

#### 7.1.2 Chamber air temperature

If required, the chamber air temperature may also be controlled. If so, use (40 ± 3) °C unless otherwise specified.

### 7.2 Relative humidity of chamber air

Unless otherwise specified, the relative humidity shall be set at 50 % and maintained at ± 10 %.

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

### 7.3 Spray cycle

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

| | |
|---|---|
| **Spray cycle 1** | duration of spraying period (front of the test specimens): (18,0 ± 0,5) min |
| | dry interval between spraying periods: (102,0 ± 0,5) min |
| **Spray cycle 2** | duration of spraying period (front of the test specimens): (12,0 ± 0,5) min |
| | dry interval between spraying periods: (48,0 ± 0,5) min |

## 8 Procedure

### 8.1 General

It is recommended that at least three test specimens of each material evaluated be exposed in each run to allow statistical evaluation of the results.

### 8.2 Mounting the test specimens

Attach the test specimens to the specimen holders in the equipment in such a manner that the test 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 exposure. 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 file specimens stored in the dark.

### 8.3 Exposure

Before placing the test specimens in the test chamber, be sure that the apparatus is operating under the desired conditions (see Clause 7). Programme the apparatus with the selected conditions to operate continuously for the required number of cycles at the selected exposure conditions. Maintain these conditions throughout the exposure, keeping any interruptions to service the apparatus and to inspect the test specimens to a minimum.

Expose the test specimens and, if used, the irradiance-measuring instrument for the specified period. Repositioning of the test specimens during exposure is desirable and might be necessary. Follow the guidance in ISO 16474-1.

Replace filters after 2 000 h of use, or when pronounced discoloration or milkiness develops, whichever occurs first. Clean the filters, at intervals recommended by the manufacturer, with a clean, dry, non-abrasive cloth or towel, or with a solution of detergent in water followed by rinsing with clean water. It is recommended that filters be replaced on a rotating schedule in order to provide more uniformity over long periods of exposure. In such cases, replace the filters sequentially, in pairs, every 500 h. Monitor the age and position of the filter panes so that the oldest pair is removed each time.

If it is necessary to remove a test specimen for periodic inspection, take care not to touch the exposed surface or alter it in any way. After inspection, return the test specimen to its holder or to its place in the test chamber with its exposed surface oriented in the same direction as before.

### 8.4 Duration of test

**8.4.1** Test until

a) either the surfaces of the test panels have been subjected to an agreed radiant exposure;

b) or an agreed or specified ageing criterion is satisfied.

In the latter case, remove and examine the test panels at various stages during the test period and determine the end point by plotting an ageing curve.

**8.4.2** No single test duration or test programme can be specified which would be suitable for all types of coating. The total number of tests and the number of stages in each test shall be chosen as a function of the requirements of the individual tests and shall be agreed between the interested parties for each particular case. If not otherwise agreed, take two test panels for each assessment.

**8.4.3** Testing of the test panels shall be carried out without interruption except for cleaning or exchanging the carbon rods or the filter system or, when testing in stages, removal of the test panels.

**8.4.4** If panels are evaluated for changes in gloss or colour, the panels shall be removed from the weathering instrument at the end of the dry period.

### 8.5 Measurement of radiant exposure

If used, mount the radiometer so that it measures the irradiance at the exposed surface of the test specimen. When radiant exposures are used, express the exposure interval in terms of incident radiant energy per unit area of the exposure plane, in joules per square metre ($J/m^2$) in the wavelength band selected.

### 8.6 Determination of changes in properties after exposure

These shall be determined as specified in ISO 4582.

## 9 Test report

Refer to ISO 16474-1.

# Bibliography

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

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

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