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Plastics — Method for estimating heat build up of flat surfaces by simulated solar radiation

National foreword

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Plastiques - Méthode d'estimation de l'échauffement de surfaces planes par rayonnement solaire simulé

Kunststoffe - Verfahren mit simulierter Sonnenstrahlung zur Bewertung der Aufheizung auf ebenen Oberflächen

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European foreword

This document (EN 16795:2015) has been prepared by Technical Committee CEN/TC 249 “Plastics”, the secretariat of which is held by NBN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2016 and conflicting national standards shall be withdrawn at the latest by June 2016.

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Introduction

Solar radiation causes the temperature of irradiated surfaces to rise substantially above the temperature of the surrounding air. The resulting surface temperature depends on the climatic parameters at the location in question, the spectral absorption of the surface, the geometric dimensions and on the specific structure of the object. Generally, the darker the colour, the more the sun's energy is absorbed and the higher is the heat build-up.

The performance characteristics of most of the materials are also defined by the in service temperature. Such materials can be window profiles or other polymeric carrier materials. The micro climate at house walls is also essential defined by the absorbed solar radiation (depending on the material properties). The same applies for interior room and automobile temperatures.

The examples reveal the significance of the knowledge of the temperature of sun irradiated surfaces. If the temperature magnitude is estimated to be critical, provisions can be taken to optimize the in-service micro climate, e.g. reduction of the in-service temperature by improvement of the spectral reflection characteristics or appropriate change in design and improving the air conditioning.

1 Scope

This European Standard specifies a method for estimating the temperature increase of a flat polymer surface, due to its solar radiant energy absorption, compared to the ambient temperature.

For that purpose, a specimen and black and white reference plates are exposed to simulated solar radiation under specified conditions (simulated solar radiation, ambient air temperature, convective flow). For opaque specimens, a thermally sensitive electrical element at the backside or a pyrometer is used to measure the surface temperature. For translucent specimens, a pyrometer is used to measure surface temperature.

NOTE Some specific polymeric materials are translucent (transparent) and might have a transmittance window in a wavelength range where the used pyrometer is sensitive (e.g. polyethylene). The surface temperature of these materials cannot be measured with the contact and the contactless method.

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.

EN ISO 4892-1, *Plastics - Methods of exposure to laboratory light sources - Part 1: General guidance (ISO 4892-1)*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 9370 apply.

4 Abbreviations

BST black-standard thermometer

CHT chamber air temperature

RTD resistance temperature detector

WST white-standard thermometer

5 Principle

5.1 A xenon or metal halide arc lamp, fitted with filters, is used to simulate the spectral irradiance of global solar radiation.

5.2 Specimens are exposed to various levels of simulated global solar radiation, heat, and relative humidity and air flow under controlled environmental conditions, including:

a) the irradiance level;

b) the air flow directed over the test specimen;

c) the ambient air temperature during the exposure to simulated global solar radiation;

d) the relative humidity in the chamber during the exposure to simulated global solar radiation.

5.3 The procedure may include measurements of the global irradiance in the plane of the specimens.

5.4 The procedure includes measurements of the surface temperature in the plane of the specimens.

5.5 It is recommended to expose simultaneously with the test specimens a black standard (BST) and white standard (WST) thermometer as specified in EN ISO 4892-1 to provide a standard for comparative purposes.

5.6 Comparison of results obtained from specimens exposed in different apparatus should not be made unless an appropriate statistical relationship has been established between the apparatuses for the particular material exposed.

6 Apparatus

6.1 General

The equipment comprises a test chamber, an ozone-free radiation source which generates UV, visible, and infrared radiation similar to solar radiation. A contactless surface temperature device (pyrometer) or contact temperature measuring systems may be part of the device.

6.2 Test chamber

The design of the test chamber may vary, but it shall be constructed from inert material and shall be equipped with a blower which generates a defined airflow to be directed across the specimens. In addition to the controlled lamp wattage, the test chamber shall provide for control of ambient temperature. For exposures that require control of humidity, the test chamber shall include humidity-control facilities that meet the requirements of EN ISO 4892-1.

NOTE 1 If the lamp system (one or more lamps) is centrally positioned in the chamber, the effect of any eccentricity of the lamp(s) on the uniformity of exposure can be reduced by using a rotating frame carrying the specimens or by repositioning or rotating the lamps.

NOTE 2 The required irradiance level can be adjusted by means of the lamp wattage. In this case, the lamp wattage is controlled not the irradiance.

6.3 Laboratory radiation source

6.3.1 General

The radiation source shall comprise one or more xenon-arc or metal halide radiation sources which emit radiation from below 270 nm in the ultraviolet through the visible spectrum and into the infrared. In order to simulate global solar radiation, filters shall be used to remove short-wavelength UV radiation (<290 nm). In addition, filters to remove infrared radiation (>800 nm) may be used to prevent unrealistic heating of the test specimens.

6.3.2 Spectral irradiance of xenon and metal halide arc lamps with global solar radiation filters

Table 1 specifies the minimum and maximum levels of the relative spectral irradiance, in the visible and infrared wavelength range. Filters are a useful tool to achieve these values.

In order to simulate global solar radiation, filters shall be used to remove short-wavelength UV radiation (<290 nm). In addition, if values in Table 1 are not met, filters to remove infrared radiation (>800 nm) may be used to prevent unrealistic heating of the test specimens.

NOTE Solar spectral irradiance for a number of different atmospheric conditions is described in CIE Publication No. 85 [1]. The benchmark global solar irradiance used in this standard is that defined in Table 4 in CIE No. 85:1989.

Table 1 — Relative spectral irradiance of laboratory radiation sources simulating global solar radiation

Spectral passband (λ = wavelength in nm)	**Relative spectral portion**[a] %
290 ≤ λ ≤ 800	60 ± 9
800 ≤ λ ≤ 3 000	40 ± 9

[a] The minimum and maximum tolerance will not necessarily sum to 100 % because they represent tolerance of the measurement data used. For any individual spectral irradiance, the percentages calculated for the passbands in this table will sum to 100 %. For any individual simulated global solar radiation, the calculated percentage in each passband shall fall within the minimum and maximum limits given. Contact the manufacturer of the simulated global solar radiation apparatus for specific spectral irradiance data.

6.3.3 Irradiance uniformity

The irradiance at any position in the area used for specimen exposure shall be at least 80 % of the maximum irradiance.

NOTE The surface temperature might vary with the irradiance uniformity on sample level.

6.4 Radiometer

The radiometer used shall comply with the requirements given in ISO 9370.

6.5 Test chamber temperature and relative humidity

The chamber temperature sensor shall be located, radiation-shielded, possibly combined with a sensor which measures the relative humidity close to the exhaust air duct.

For exact calibration of the chamber temperature and relative humidity sensor it is necessary to move a calibrated working reference standard and the instrument sensor to about the same position so that a balanced temperature and humidity can be set for the measuring sensors and the ambient air. Calibration takes place as soon as the whole system is in thermal balance.

NOTE Typically, the thermal equilibrium is achieved after 30 min up to 1 h.

6.6 Surface temperature measurement device

6.6.1 Pyrometer

6.6.1.1 Minimum requirements for the pyrometer

A pyrometer may be used to measure the surface temperature of the test specimen on sample level.

The minimum requirements for the pyrometer are the following:

a) temperature range: 20 °C to 150 °C (traceably calibrated by a black body radiator);

b) spectral response: 8 µm to 14 µm;

c) IR detector: e.g. silicon based thermopile;

d) uncertainty: ± 0,6 % (in the considered temperature range);

e) spot size (diameter): maximum 30 mm.

6.6.1.2 Calibration of the pyrometer

The pyrometer shall be calibrated to a traceable national or international standard. Re-calibration by a qualified national or international calibration laboratory should be done at appropriate intervals (e.g. annually).

6.6.1.3 Emissivity of material

The temperature of a given object can only be measured correctly if its exact emissivity (ε) in the wavelength range between 8 µm and 14 µm is known and the pyrometer is set up accordingly. The emissivity (ε) is the ratio between the radiation emitted by a particular surface and that by a radiated black body at the same temperature.

The emissivity (ε) of a coated surface can be measured by an appropriate laboratory. In principle the emissivity (ε) depends on wavelength, temperature and angle [2].

NOTE 1 The emissivity of a material depends on the recording angle of the pyrometer.

The observation angle of the pyrometer shall be perpendicular with respect to the specimen to be evaluated. If the specimen to be evaluated is not perpendicular to the observation angle of the pyrometer, a cosine-correction shall be applied.

The emissivity of each sample can be different.

NOTE 2 In the temperature range of 20 °C to 100 °C, many coatings have an emissivity of around 0,95, polymers of 0,89 to 0,94, textile fabrics around 0,95.

6.6.2 Thermally sensitive electrical element

A thermally sensitive element such as a platinum resistance sensor (RTD) or a thermocouple may be attached to the centre of the specimen, in good thermal contact with the plate, on the side opposite the radiation source. This thermally sensitive element shall be thermally insulated from the surrounding ambient air, the radiation and forced air flow. Construction principles described for a BST sensor in accordance to EN ISO 4892-1 shall be used.

NOTE 1 There is a difference between the temperature measured by the thermally sensitive element at the back of the specimen and the actual temperature at the surface of the specimen. This temperature difference can be considered by an appropriate calibration procedure.

EN 16465 [3] describes two calibration procedures.

The surface temperature of a transparent material shall be measured with a pyrometer (see 6.6.1) because a thermally sensitive element such as a platinum resistance sensor can be heated up by the transmitted radiation.

NOTE 2 Experience is required to measure the surface temperature of light opaque, translucent and transparent specimens. A radiation pyrometer does not work. In these cases, the maximum temperature is below the surface.

6.7 Black and white standard thermometer

The BST and WST sensor used shall comply with the requirements for these devices given in EN ISO 4892-1.

Uninsulated black panel or white panel temperature sensors, as described in EN ISO 4892-1, are not allowed for this method.

6.8 Defined airflow directed across the sample

At a constant chamber temperature, irradiance and relative humidity, the surface temperature range of the test specimen is defined by the airflow directed across the specimen. This range is enabled by the climate fan, which controls the speed of the air flow in the chamber and if available by the horizontal rotation of the test specimen around the laboratory radiation source.

NOTE The speed of the air flow determines the heat exchange between the air and in this way allows modifying the surface temperature of the specimen.

6.9 Specimen holders

Specimen holders may be in the form of an open frame, leaving the backs of the specimens exposed, or they may provide the 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 may affect the results, as may any space between the backing and the test specimen, particularly with transparent specimens, and shall be agreed on between the interested parties.

7 Test specimens

7.1 Form, shape and preparation

7.1.1 As geometry dependent convection strongly influences surface temperature, only flat specimens are to be investigated, in contrast to complex components.

7.1.2 When comparing materials in an exposure test, use test specimens that are similar in dimensions and irradiated area.

7.1.3 Label specimens using markings that will not affect the measurement of the surface temperature.

7.1.4 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 influence absorption and emission properties.

7.2 Number of test specimens

The number of test specimens shall be defined in the referring standard or by agreement between the interested parties.

8 Exposure conditions

8.1 Radiation

Control the irradiance at the levels indicated in Table 2.

The irradiance between 300 nm and 3 000 nm is a function of the lamp wattage. If the irradiances are not measured in the indicated pass bands the instrument manufacturer shall provide the relation between irradiance between 300 nm and 3 000 nm and the lamp wattage.

8.2 Black and white standard thermometer

Mount a BST and a WST sensor within the specimen exposure area so that it receives the same radiation and cooling conditions as a flat specimen surface.

8.3 Chamber air temperature

Exposures can be run either with the chamber air temperature (CHT) controlled at a specified level (see Table 2) or allowing the CHT to find its own level. The CHT shall be reported.

NOTE The possible specimen surface temperature is limited by the temperature of the air surrounding the sample (CHT) as the lower limit, and the BST temperature as the upper limit temperature (massive opaque dark polymers can have higher temperatures than the temperature indicated by a BST). It is then assumed that the actual specimen temperature lies somewhere between the two cited limits.

8.4 Relative humidity of chamber air

Exposures can be conducted either with the relative humidity controlled at a specified level, preferably (30 ± 10) % HR or allowing the relative humidity to find its own level.

NOTE The relative humidity can have an effect on the measured surface temperature.

8.5 Wind speed

Adjust the wind speed directed across the specimen enabled by the climate fan as required in Table 2.

8.6 Sets of exposure conditions

Table 2 lists various sets of conditions for exposures conducted with global solar radiation filters.

If no other exposure conditions are specified, use condition No. 3 (CHT control).

Table 2 — Exposure conditions for typical times of day (summer, cloudless, horizontal)

Condition No.	**Time of day**	**Irradiance** (300 nm to 3 000 nm) W/m^2	**Chamber temperature** °C	**Wind speed** m/s
1	ante and post meridiem	600	38	0,5 to 2
2	ante and post meridiem	600	uncontrolled	> 1
3	at noon	1 100	38	0,5 to 2
4	at noon	1 100	uncontrolled	> 1

9 Procedure

9.1 General

Specimens are exposed to irradiation. When the thermal equilibrium is achieved, the surface temperature is measured by either a thermally sensitive electrical element or a pyrometer.

9.2 Mounting the test specimens

Mounting of test specimens as well as BST and WST: avoid any shadows and reflexions at their surfaces.

Attach the specimens to the specimen holders in the equipment in such a manner that the specimens are not subject to any applied stress.

9.3 Exposure

Before exposing the specimens in the test chamber, be sure that the apparatus is operating under the desired conditions listed in Table 2.

9.4 Measurement of the surface temperature

If used, the pyrometer shall measure the surface temperature of the specimens and the BST and WST temperatures during the exposure.

If used, the thermally sensitive element (e.g. RTD) embedded within or on the back of the specimens shall measure a temperature which is related to the surface temperature of the specimen.

10 Test report

The test report shall contain the following information:

a) a reference to this European Standard (i.e. EN 16795);

b) description of the specimen including its geometry, e.g. edge lengths;

c) description of the exposure device and laboratory radiation source, including:

    1) type of device and laboratory radiation source;

    2) description of the filters used;

    3) irradiance and wavelength range at the specimen surface;

    4) type of BST and WST sensor used.

d) complete description of the exposure condition used;

e) 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) description of the radiometer for measuring the irradiance, if used;

g) description of the method used for measuring the surface temperature of the test specimen;

h) test results, including:

    1) surface temperature of the test specimen;

    2) surface temperature of the BST and WST sensor.

i) date(s) of the exposure test.

Bibliography

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

[2] ASTM E 408-13, *Standard Test Method for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques*

[3] EN 16465, *Plastics - Methods for the calibration of black-standard and white-standard thermometers and black-panel and white-panel thermometers for use in natural and artificial weathering*

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