IEC 60068-2-5

Edition 3.0 2018-04

INTERNATIONAL STANDARD

Environmental testing –
Part 2-5: Tests – Test S: Simulated solar radiation at ground level and guidance for solar radiation testing and weathering

IEC 60068-2-5:2018-04(en)

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FOREWORD

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International Standard IEC 60068-2-5 has been prepared by IEC technical committee 104: Environmental conditions, classification and methods of test.

This third edition cancels and replaces the second edition of published in 2010. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) the title of this document has been modified;
b) the current thermal effect test method, specified as "Test method Sa" has been retained and the weathering test method specified as "Test method Sb" has been added.

The text of this International Standard is based on the following documents:

CDV	Report on voting
104/735/CDV	104/789/RVC

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60068 series, published under the general title *Environmental testing*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

This part of IEC 60068 describes methods of simulation designed to examine the effect of solar radiation on equipment and components at the surface of the earth. The main characteristics of the environment to be simulated are the spectral irradiance of solar radiation, as observed at the earth's surface, and the intensity of received energy, in combination with controlled temperature conditions. However, the combination of solar radiation with other environments, for example temperature, humidity, water spray (to simulate wetting) and air velocity, should be considered. Two different methods are described, one aiming at the thermal effects, a second aiming at the weathering effects.

ENVIRONMENTAL TESTING –

Part 2-5: Tests – Test S: Simulated solar radiation at ground level and guidance for solar radiation testing and weathering

1 Scope

This part of IEC 60068-2 specifies the methods for testing equipment or components under simulated solar radiation conditions.

This document is applicable to the equipment and components at the surface of the earth.

The purpose of testing is to investigate to what extent the equipment or components are affected by simulated solar radiation in the presence of moisture to reproduce the weathering effects (temperature, humidity and/or wetting) that occur when they are exposed in actual end-use environments to daylight or to daylight filtered through window glass. This document specifies two test methods, test method Sa: thermal effect test, and test method Sb: weathering test.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60068-1, *Environmental testing – Part 1: General and guidance*

IEC 60068-2-1, *Environmental testing – Part 2-1: Tests – Test A: Cold*

IEC 60068-2-2, *Environmental testing – Part 2-2: Tests – Test B: Dry heat*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60068-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
black standard temperature
insulated black panel temperature
characteristic value of the test specimen's(s') surface temperature measured by an insulated black panel thermometer, consisting of a black painted stainless steel panel and a resistance temperature sensor embedded in insulating material (white PVDF, polyvinylidene difluoride) attached

Note 1 to entry: More details are described in ISO 4892-1.

Note 2 to entry: It is designed to approximate the maximum surface temperature of any material with thermal insulating properties and for control in weathering test apparatus.

3.2
black panel temperature
uninsulated black panel temperature
characteristic value of the test specimen's(s') surface temperature measured by an uninsulated black panel thermometer, consisting of a black painted stainless steel panel and a resistance temperature sensor attached

Note 1 to entry: More details are described in ISO 4892-1.

Note 2 to entry: It is designed to approximate the maximum surface temperature of any material and for control in weathering test apparatus.

4 General remarks

4.1 Overview

The effect of solar radiation on the test specimen(s) will depend on the level of irradiance, the spectral irradiance, the location, the time of day and the sensitivity of the material of the test specimen(s).

4.2 Irradiance of solar radiation

The irradiance at sea level is influenced by the solar constant and the attenuation and scattering of solar radiation in the atmosphere. For test purposes, CIE 85:1989, Table 4 gives a value of 1 090 W/m^2 for the global solar radiation at the surface of the earth from the sun at zenith; this value is based on a solar constant E_0 = 1 367 W/m^2.

4.3 Spectral irradiance of solar radiation

The standard spectral irradiance of the global solar radiation specified for this test, in accordance with the recommendations of CIE 85:1989, Table 4 (see Annex A), is given in Figure 1 and in Table 1.

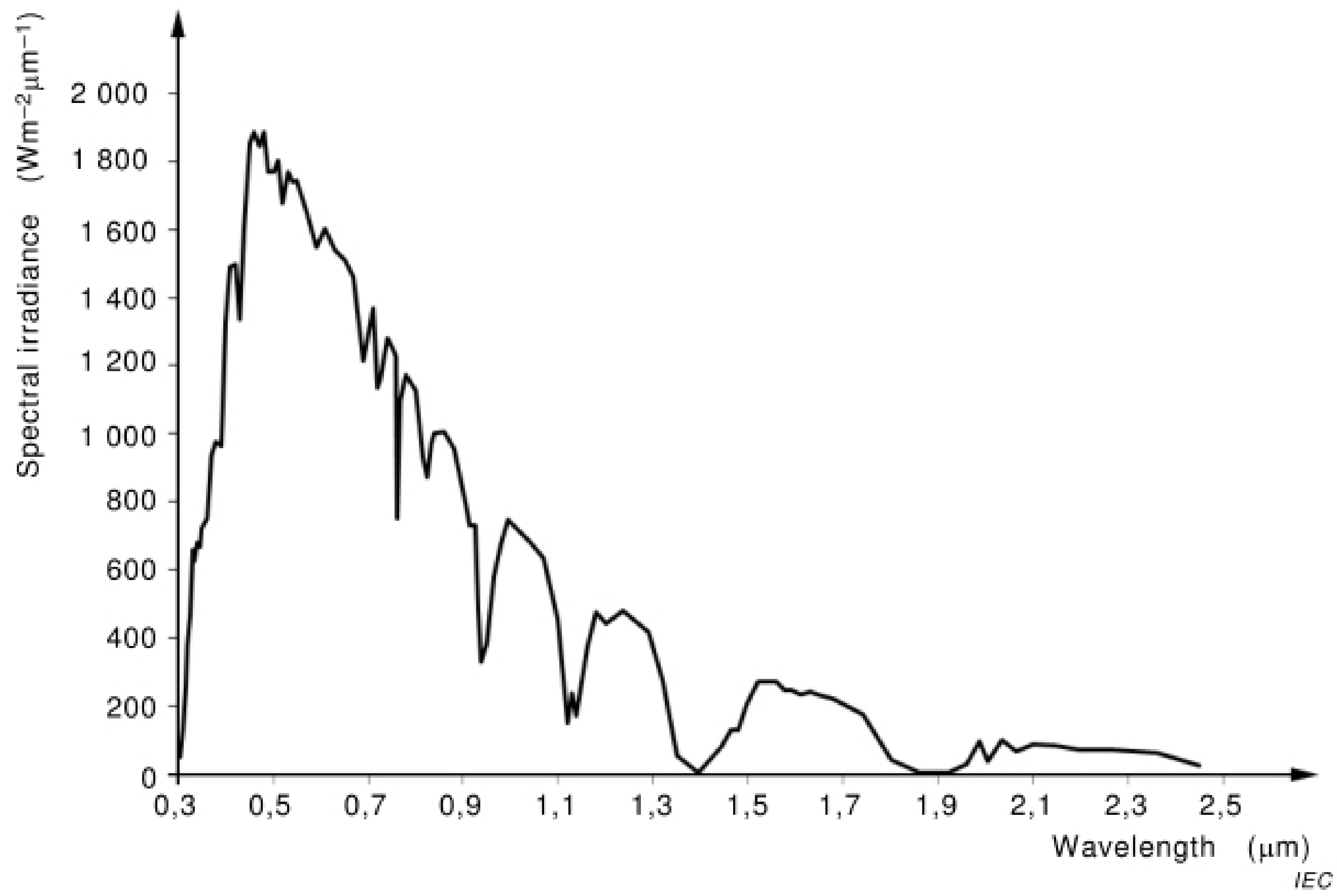


Figure 1 – Global solar spectral irradiance at sea level

Table 1 – Spectral irradiance

Spectral region	Ultra-violet B[a]	Ultra-violet A	Visible	Infra-red	Total radiation
Bandwidth	300 nm to 320 nm	320 nm to 400 nm	400 nm to 800 nm	800 nm to 2 450 nm	300 nm to 2 450 nm
Irradiance	4,06 W/m^2	70,5 W/m^2	604,2 W/m^2	411,2 W/m^2	1 090 W/m^2
Proportion of total radiation	0,4 %	6,4 %	55,4 %	37,8 %	100 %

NOTE This table is a condensed version of CIE 85:1989, Table 4.

[a] Radiation shorter than 300 nm reaching the earth's surface is insignificant

4.4 Radiation source

If the source of radiation used for the test does not meet the standard spectral distribution given in Table 1, the exact spectral absorption data of the material and the exact spectral irradiance of the alternative radiation source in the range from 300 nm to about 3 000 nm and for the solid angle of 2π sr above the specimen surface shall be known or measured.

Detail of a radiation source is described in Annex B.

5 Test method Sa: thermal effect test

5.1 Conditioning

5.1.1 General

During the entire test, the irradiation, the temperature within the chamber, the humidity and any other specified environmental conditions shall be maintained at the levels appropriate to the particular test procedure specified in the relevant specification. The relevant specification shall state which preconditioning requirements are to be applied.

Detail of instrumentation is described in Annex D.

5.1.2 Temperature

The temperature within the chamber during irradiation and darkness periods shall be controlled in accordance with the procedure (Sa 1, Sa 2 or Sa 3) specified.

NOTE Additionally, an insulated black panel thermometer or an uninsulated black panel thermometer can be used to measure the maximum surface temperature. This temperature can be influenced by ventilation.

5.1.3 Humidity

Different humidity conditions, particularly condensation, can markedly affect photochemical degradation of materials, paints, plastics, etc. If applicable, the values given in IEC 60068-2-78 should be used.

The relevant specification shall state the humidity and whether it is to be maintained during

a) the irradiation periods only;

b) the periods of darkness only;

c) the whole test duration.

5.1.4 Ozone and other contamination gases

Ozone, generated by short wavelength ultra-violet test sources, will normally be excluded from the test chamber by the radiation filter(s) used to correct the spectral energy distribution.

As ozone and other contaminating gases can significantly affect the degradation processes of certain materials, it is important to exclude these gases from the test chamber, unless otherwise required by the relevant specification.

5.1.5 Surface contamination

Dust and other surface contamination may significantly change the absorption characteristics of irradiated surfaces. Unless otherwise required, specimens should be tested in a clean condition. However, if effects of surface contamination are to be assessed, the relevant specification should include the necessary information on preparation of surfaces, etc.

5.1.6 Mounting of test specimen(s)

The specimen(s) to be tested shall be placed either on raised support, on a turntable or a specified substrate of known thermal conductivity and thermal capacity within the chamber as stated in the relevant specification, and so spaced from other specimen(s) as to avoid shielding from the source of radiation or re-radiated heat. Temperature sensors should be attached to specimen(s) as required.

5.1.7 Test facility

It shall be ensured that the optical parts of the test facility, lamps, reflectors and filters, etc. are clean.

The level of irradiation over the specified measurement plane shall be measured immediately prior to each test.

Any ancillary environmental conditions, for example ambient temperature, humidity and other parameters if specified, should be monitored continuously during the test.

5.1.8 Test apparatus

The chamber in which the tests are to be carried out shall be provided with means for obtaining, over the specified irradiation measurement plane, an irradiance of 1 090 (1 ± 10 %) W/m^2 with the spectral distribution given in Table 1. The value of 1 090 W/m^2 shall include any radiation reflected from the test chamber and received by the specimen(s) under test. It should not include long-wave infra-red radiation emitted by the test chamber. The minimum and maximum levels of the relative spectral irradiance are given in Table 2.

Table 2 – Minimum and maximum levels of the relative spectral irradiance

Spectral region	Ultra-violet B	Ultra-violet A	Visible	Infra-red	Total radiation
Bandwidth	300 nm to 320 nm	320 nm to 400 nm	400 nm to 800 nm	800 nm to 2 450 nm	300 nm to 2 450 nm
Proportion of total radiation (%)	0,4	6,4	55,4	37,8	100,0
Minimum level (%)	0,3	4,2	43,8	33,7	–
Maximum level (%)	0,7	7,4	57,0	50,5	–

Means shall also be provided whereby the specified conditions of temperature, air flow and humidity can be maintained within the chamber.

The temperature within the chamber shall be measured (with adequate shielding from radiated heat) at a point or points in a horizontal plane 0 mm to 50 mm below the specified irradiation measurement plane, at half the distance between the specimen under test and the wall of the chamber, or at 1 m from the specimen, whichever is the lesser.

5.2 Initial measurements

The specimen(s) shall be submitted to the visual, dimensional and functional checks specified by the relevant specification.

5.3 Testing

5.3.1 General

During exposure, the temperature within the chamber shall rise or fall by 1 K/min and be maintained at one of the preferred values given in IEC 60068-2-1 or IEC 60068-2-2 or the relevant specification.

In procedure Sa 1, the temperature within the chamber shall start to rise 2 h before the irradiation period starts.

During the darkness period in procedures Sa 1 and Sa 2, the temperature within the chamber shall fall with average rate of 1 K/min and be maintained at +25 °C, unless otherwise specified.

The requirements for irradiation, temperature and time relationships are given in Figure 2. Throughout the specified test duration, the temperature within the chamber shall be maintained within ±2 K of that shown for the appropriate procedure.

The level of irradiance shall be 1 090 (1 ± 10 %) W/m^2 or specified in the relevant specification. Acceleration of the test by increasing the irradiation above this level is not recommended. The total daily irradiation approximating the most severe natural conditions is simulated by procedure Sa 1 with a duration of exposure to the standard irradiation conditions of 8 h per day. Thus, exposure for periods in excess of 8 h will effect acceleration over natural conditions. However, continuous exposure of 24 h per day (procedure Sa 3) could mask any degradation effects of cyclic thermal stressing, and this procedure is therefore not generally recommended in this instance.

The specimen shall be exposed, for the duration called for in the relevant specification, to one of the test procedures outlined in 5.3.2, 5.3.3 and 5.3.4 (see Figure 2).

5.3.2 Procedure Sa 1 – 24 h cycle, 8 h irradiation and 16 h darkness, repeated as required

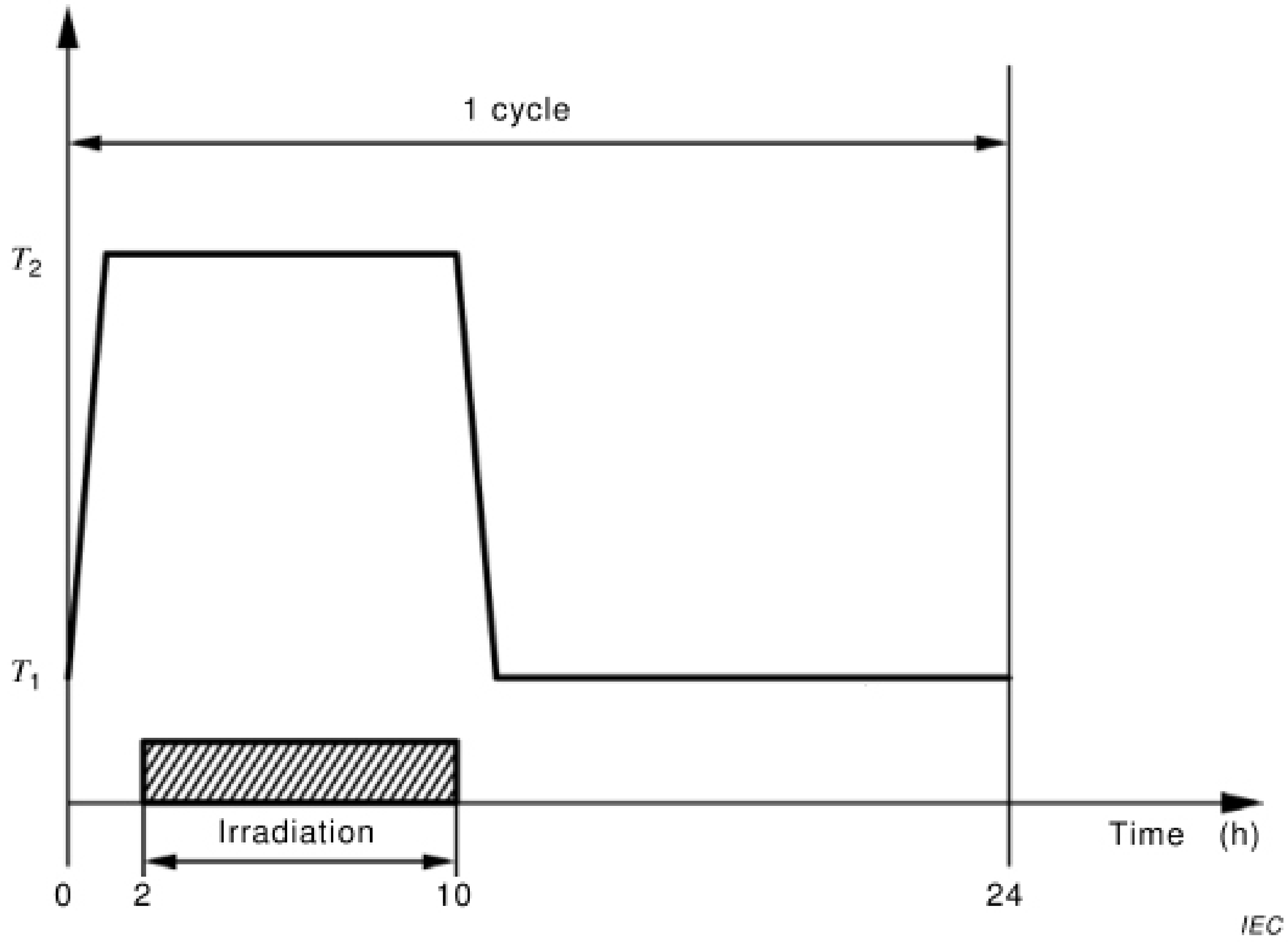
This gives a total irradiation of 8,72 kWh/m^2 per diurnal cycle, which approximates to the most severe natural conditions. Procedure Sa 1 is specified where the principal interest is in thermal effects.

5.3.3 Procedure Sa 2 – 24 h cycle, 20 h irradiation and 4 h darkness, repeated as required

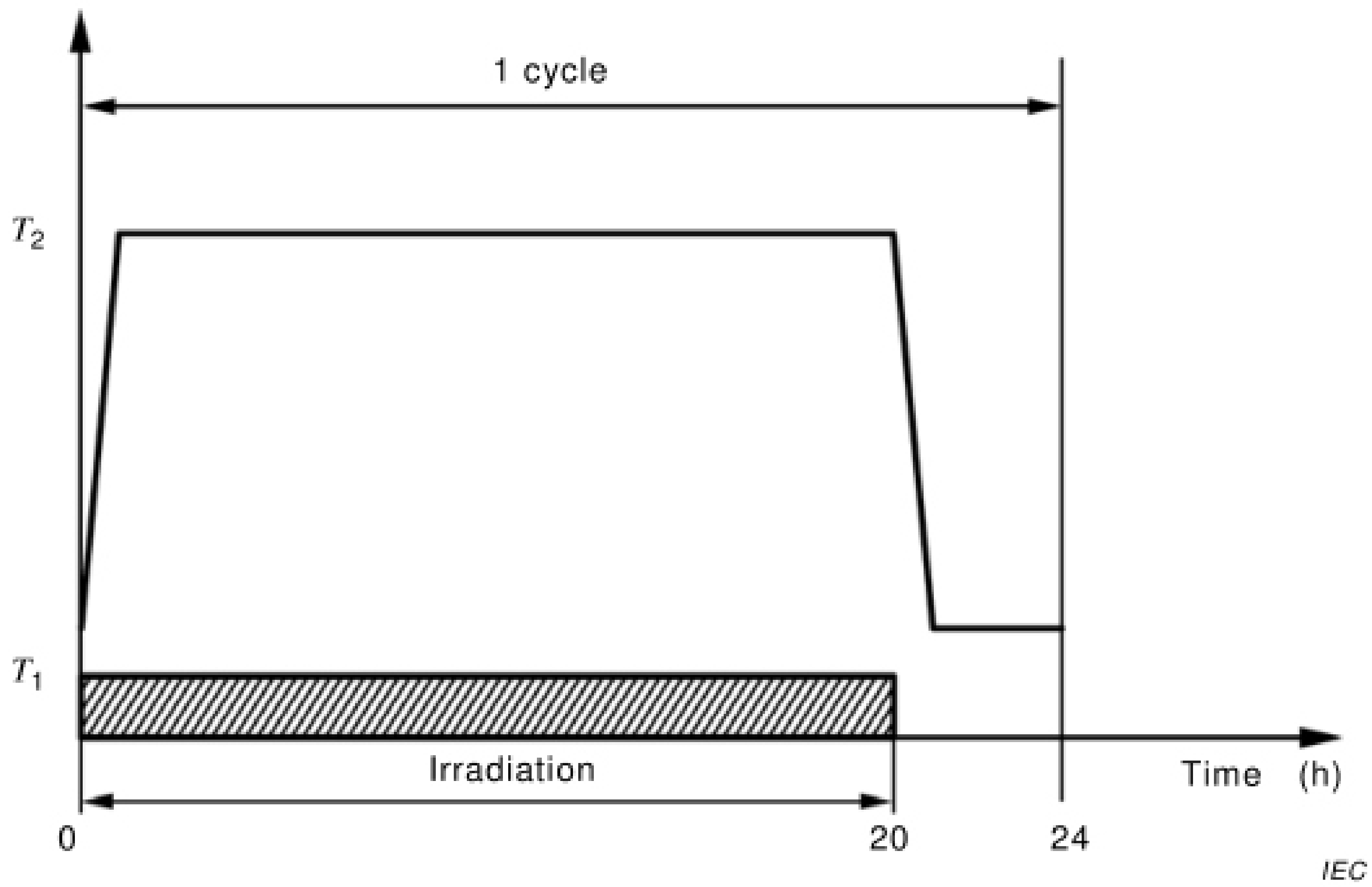
This gives a total irradiation of 21,8 kWh/m^2 per diurnal cycle and is applicable where the principal interest is in degradation effects.

5.3.4 Procedure Sa 3 – Continuous irradiation as required

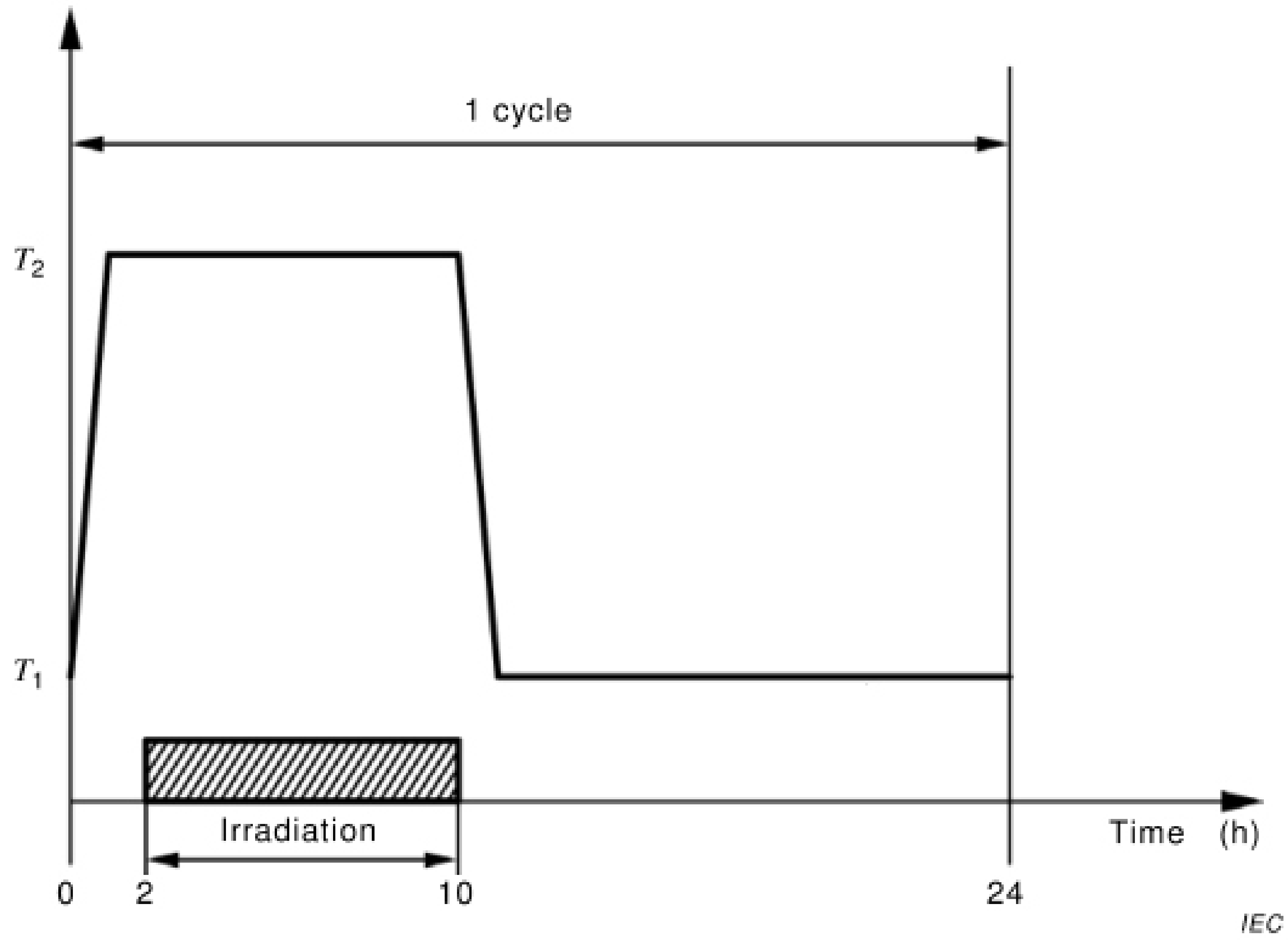
Procedure Sa3 is a simplified test, applicable where cyclic thermal stressing is unimportant and photochemical effects only are to be assessed. This procedure is also applicable for the assessment of heating effects on specimens with low thermal capacity.



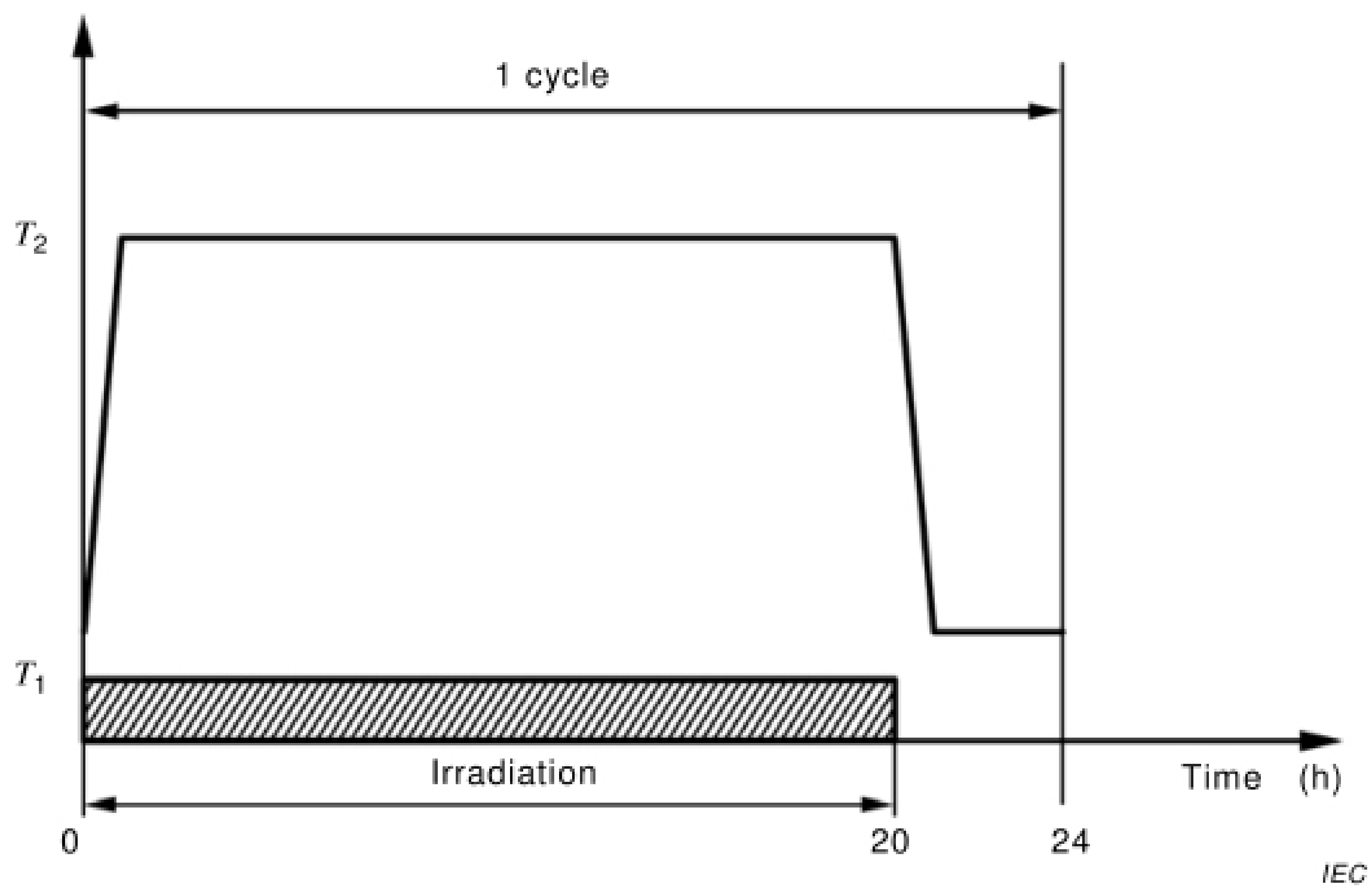
a) **Procedure Sa 1**



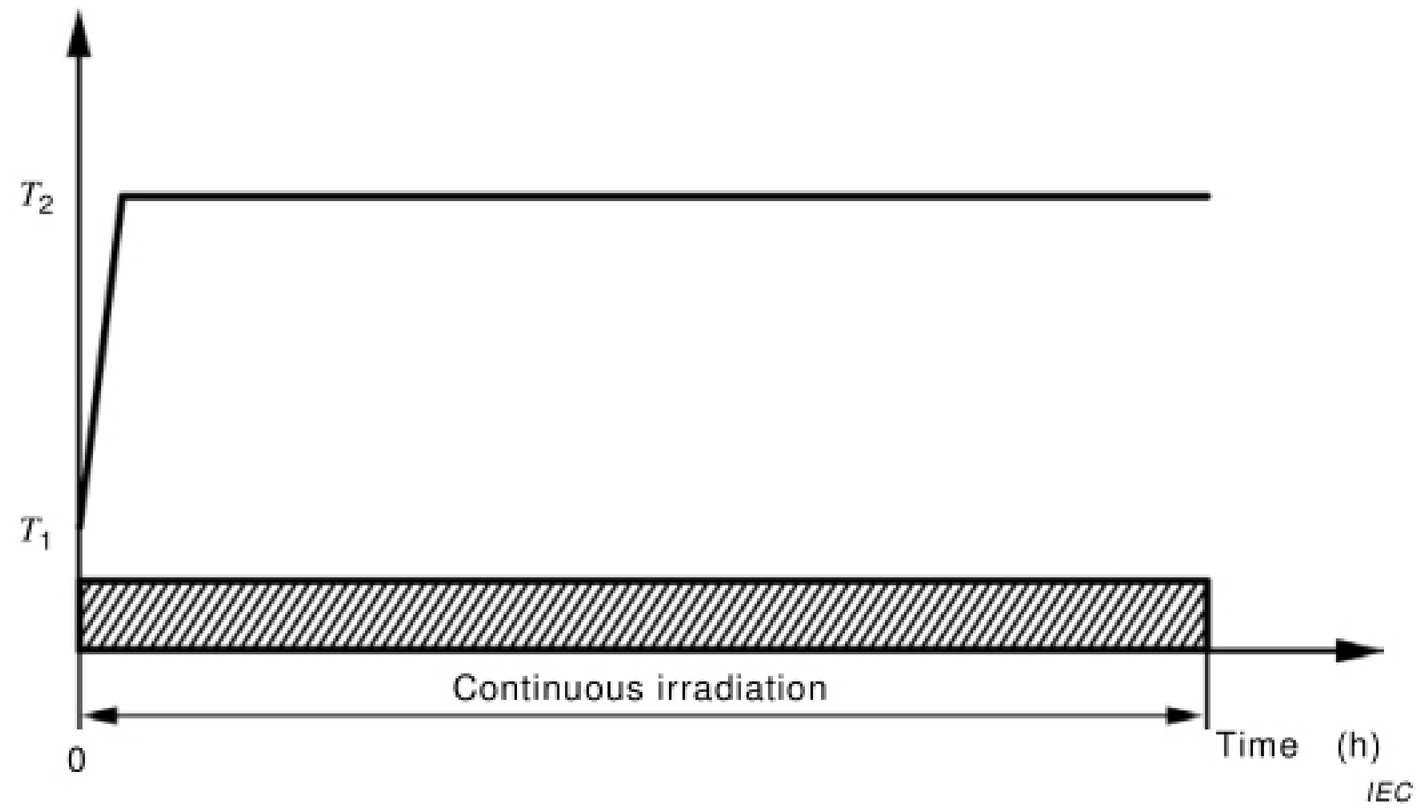
b) **Procedure Sa 2**



a) Procedure Sa 1



b) Procedure Sa 2



c) **Procedure Sa 3**

Key

T_1 lower temperature (25 °C if not otherwise specified)

T_2 upper temperature (40 °C if not otherwise specified)

Figure 2 – Test procedures Sa 1, Sa 2 and Sa 3

5.4 Final measurements

The specimen shall be submitted to the visual, dimensional and functional checks specified by the relevant specification.

6 Test method Sb: Weathering test with or without wetting

6.1 Test apparatus

6.1.1 Laboratory radiation source

6.1.1.1 Xenon arc lamp

The radiation source shall comprise one or more quartz-jacketed xenon-arc lamps that emit radiation from below 270 nm in the ultraviolet through the visible spectrum and into the infrared. In order to simulate solar radiation, filters shall be used to remove short-wavelength UV radiation (Table 3). For tests intended to simulate solar radiation through window glass, filters to minimize irradiance at wavelengths shorter than 310 nm shall be used (Table 4). In addition, filters to remove infrared radiation may be used to prevent unrealistic heating of the test specimen(s), which can cause thermal degradation not experienced during outdoor exposures.

6.1.1.2 Spectral irradiance of xenon-arc lamp(s) with daylight filters

Filters are used to filter xenon-arc emissions in order to simulate solar radiation (CIE 85:1989, Table 4). The minimum and maximum levels of the relative spectral irradiance in the UV wavelength range are given in Table 3.

Table 3 – Relative spectral irradiance of xenon-arc lamp(s) with daylight filters

Spectral passband (λ = wavelength in nm)	Minimum %	CIE 85:1989, Table 4 %	Maximum %
λ < 290	–	–	0,15
290 ≤ λ ≤ 320	2,6	5,4	7,9
320 < λ ≤ 360	28,2	38,2	39,8
360 < λ ≤ 400	54,2	56,4	67,5
NOTE More details regarding this table are given in ISO 4892-2.			

6.1.1.3 Spectral irradiance of xenon-arc lamp(s) with window glass filters

Filters are used to filter the xenon-arc lamp emissions in order to simulate solar radiation which has passed through a window glass. The minimum and maximum levels of the relative spectral irradiance in the UV region are given in Table 4.

Table 4 – Relative spectral irradiance for xenon-arc lamp(s) with window glass filters

Spectral passband (λ = wavelength in nm)	Minimum %	CIE 85:1989, Table 4, plus effect of window glass %	Maximum %
λ < 300	–	–	0,29
300 ≤ λ ≤ 320	0,1	≤ 1	2,8
320 < λ ≤ 360	23,8	33,1	35,5
360 < λ ≤ 400	62,4	66,0	76,2
NOTE More details regarding this table are given in ISO 4892-2.			

6.1.1.4 Uniformity of irradiance

The exposure area shall be designed such that the irradiance at any location used for test specimen(s) exposure is at least 70 % of the maximum irradiance measured in this area. If the minimum irradiance at any position in the area used for test specimen(s) exposure is between 70 % and 90 % of the maximum irradiance, the test specimen(s) shall be periodically repositioned to reduce the variability in radiant exposure. The repositioning procedure and schedule shall be agreed upon by all interested parties.

NOTE Procedures for measuring irradiance uniformity by the device manufacturers are given in ISO 4892-1.

6.1.2 Test chamber

A laboratory radiation source(s) is used to provide irradiance for the test specimen(s). The test chamber shall be water-resistant and means shall also be provided whereby the specified conditions of temperature, air flow and humidity can be maintained within it.

Typical apparatus are shown in Annex C.

6.1.3 Temperature

The temperature-sensing element shall be shielded from the radiation source and water spray. The chamber air temperature measured at this position may not be the same as the chamber air temperature near the surface of the exposed test specimen(s).

The temperature within the chamber during irradiation and darkness periods shall be controlled in accordance with Table 5. The black standard temperature or black panel temperature shall be controlled (see Table 5). If the test is conducted under other temperature conditions with mutual agreement between interested parties, they shall be reported.

6.1.4 Humidity

The humidity within the chamber during irradiation and darkness periods shall be controlled in accordance with Table 5. If the test is conducted under other humidity conditions with mutual agreement between interested parties, they shall be reported.

6.1.5 Spray cycle

The test chamber may be equipped with a means of directing an intermittent water spray onto the exposed surface of the test specimen(s) under specified conditions. The spray shall be uniformly distributed over the specimen(s). If the test specimen(s) is not flat, the way in which products are sprayed should be determined by agreements between interested parties. The spray system shall be made from corrosion-resistant materials that do not contaminate the water used.

The water sprayed onto the test specimen(s) surfaces shall have a conductivity below 5 µS/cm, contain less than 1 µg/g dissolved solids and leave no observable stains or deposits on the test specimen(s). Silica levels shall be kept below 0,2 µg/g. A combination of deionization and reverse osmosis can be used to produce water of the desired quality.

6.1.6 Mounting of test specimen(s)

The test specimen(s) to be tested shall be placed on a specimen holder or a specified substrate as stated in the relevant specification, and so spaced from other specimens in order to avoid shielding from the source of radiation. Temperature sensors should be attached to the test specimen(s) as required.

6.1.7 Ozone and other contaminating gases

Ozone, generated by short wavelength ultra-violet test sources, will normally be excluded from the test chamber by the radiation filter(s) used to correct the spectral irradiance. As ozone and other contaminating gases can significantly affect the degradation processes of certain materials, it is important to exclude these gases from the test chamber, unless otherwise required by the relevant specification. To exclude ozone, an ozone treatment device should be used.

6.1.8 Surface contamination

Dust and other surface contamination may significantly change the absorption characteristics of irradiated surfaces. Unless otherwise required, the test specimen(s) should be tested in a clean condition. However, if effects of surface contamination are to be assessed, the relevant specification should include the necessary information on preparation of surfaces, etc.

6.2 Initial measurements

The test specimen(s) shall be submitted to the visual, dimensional and functional checks specified by the relevant specification.

6.3 Testing

6.3.1 General

Procedure Sb 1 specifies the test method with wetting exposure for actual end-use environments to daylight. Procedure Sb 2 specifies the test method for actual end-use environments to daylight filtered through window glass without wetting.

6.3.2 Test duration

The test duration for procedures Sb 1 and Sb 2 should be determined by agreement between the interested parties and test cycles should be repeated for the test duration.

6.3.3 Test procedure

Various conditions for each procedure are given in Table 5. All test conditions should be controlled. Otherwise, they should be measured and this shall be reported.

Detail of instrumentation is described in Annex D.

Table 5 – Exposure cycles

Procedure Sb 1 – Exposure cycle using daylight filters with wetting						
Exposure period	**Irradiance** [a b]		**Temperature** [c]		**Chamber temperature** °C	**Relative humidity** % [d]
	Broadband (300 nm to 400 nm) W/m²	**Narrowband** (340 nm) W/(m² × nm)	**Black standard temperature** °C	**Black panel temperature** °C		
102 min dry	60 ± 2	0,51 ± 0,02	65 ± 3	63 ± 3	38 ± 3	50 ± 10
18 min water spray	60 ± 2	0,51 ± 0,02	–	–	–	–
Procedure Sb 2 – Exposures using window glass filters without wetting						
Exposure period	**Irradiance** [a b]		**Temperature** [c]		**Chamber temperature** °C	**Relative humidity** % [d]
	Broadband (300 nm to 400 nm) W/m²	**Narrowband** (420 nm) W/(m² × nm)	**Black standard temperature** °C	**Black panel temperature** °C		
Continuous Irradiation	50 ± 2	1,10 ± 0,02	65 ± 3	63 ± 3	38 ± 3	50 ± 10

If the test is conducted under other conditions with mutual agreement between interested parties, they shall be reported.

NOTE 1 The ± tolerances given for irradiance, temperature and relative humidity are the allowable fluctuations which are defined as the positive and negative deviation from the setting of the sensor at the operational control set point during equilibrium conditions. This does not mean that the set value can vary by plus/minus the amount indicated from the given value.

NOTE 2 The black panel temperatures, 63 °C, and the black standard temperatures, 65 °C, are the ones most commonly used, but have no relationship to each other. The exposure results might therefore not be comparable.

[a] The irradiance values given are those that have historically been used. In apparatus capable of producing higher irradiances, the actual irradiance can be significantly higher than the stated values, e.g. up to 180 W/m² (300 nm to 400 nm) for xenon-arc lamps with daylight filters or 162 W/m² (300 nm to 400 nm) for xenon-arc lamps with window glass filters.

[b] For exposures, either broadband or narrowband for irradiance level shall be controlled.

[c] For exposures, either black standard temperature or black panel temperature shall be controlled.

[d] For materials sensitive to humidity, the use of (65 ± 10) % is recommended.

6.3.4 Ancillary environmental conditions

Any ancillary environmental conditions, for example ambient temperature, humidity, and other parameters if specified, should be monitored continuously during the test.

6.4 Final measurements

The test specimen(s) shall be submitted to the visual, dimensional and functional checks specified by the relevant specification.

7 Information to be given in the relevant specification

When this test is included in a relevant specification, the following details shall be given, in so far as they are applicable.

		Clause
a)	radiation source	4
b)	description of test specimen(s) support used for testing	5, 6
c)	type and scope of initial measurement	5, 6
d)	preconditioning	-
e)	number of test specimens	-
f)	test procedure	5, 6
g)	duration of the test	5, 6
h)	temperature during the test	5, 6
i)	humidity during the test	5, 6
j)	black standard temperature or black panel temperature	6
k)	type and scope of final measurement	5,6
l)	recovery	-
m)	criteria for evaluation	-

8 Information to be given in the test report

Information to be given in the test report is as follows:

- test standard (IEC 60068-2-5:20XX);
- test laboratory (name and address and details of accreditation – if any);
- test dates (dates when test was run);
- customer (name and address);
- type of test (procedure Sa 1, Sa 2, Sa 3, Sb 1 or Sb 2);
- required values (temperature, humidity, radiation, etc.);
- test period;
- purpose of test (development, qualification, etc.);
- test specimen(s) description (drawing, photo, quantity build status, etc.);
- test apparatus (manufacturer, model number, unique id, radiation source and its spectral irradiance, etc.);
- calibration data (last and next due date);
- initial and final measurements;
- observations during testing and actions taken (any pertinent observations);
- any unusual features observed;
- summary of test;
- any deviation from the specified test procedure.

Annex A
(informative)

Standard solar spectral irradiance

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

Direct radiation from a xenon lamp contains considerable amounts of short-wavelength UV radiation not present in solar radiation. With proper selection of filters for these radiation sources, much of the short-wavelength radiation can be eliminated. However, some filters allow a small, but significant, amount of this short-wavelength (less than 300 nm) radiation through. Fluorescent lamps can be selected to have a spectral output corresponding to a particular UV region of solar radiation. The xenon arc, when appropriately filtered, produces radiation with a spectral power distribution that is a good simulation of average solar radiation throughout the UV and visible region.

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

Recently, an alternate standard solar spectrum based on atmospheric conditions at an altitude of 2 000 m has been developed. This solar spectrum is defined in ASTM G 177. The solar spectrum defined in ASTM G 177 is calculated using the SMARTS2 solar-radiation model. ASTM G173 provides the program and documentation for calculating solar spectral irradiance.

The SMARTS spectral model can be used to reliably reproduce the tables in CIE 85 with close agreement. Table A.1 compares the basic atmospheric conditions used for the standard solar spectrum defined in ASTM G 177 and the CIE 85:1989, Table 4, solar spectrum.

Table A.1 – Comparison of basic atmospheric conditions used for the solar spectrum defined in ASTM G 177 and that defined in CIE 85:1989, Table 4

Atmospheric and other conditions	ASTM G 177 solar spectrum	CIE 85:1989, Table 4, solar spectrum
Ozone (atm-cm)	0,30	0,34
Precipitable water vapour (cm)	0,57	1,42
Altitude (m)	2 000	0
Tilt angle	37° facing the equator	0° (horizontal)
Relative air mass	1,05	1,00
Albedo (ground reflectance)	Light, soil and wavelength-dependent	Constant at 0,2
Aerosol extinction	Shettle and Fenn rural (humidity-dependent)	Equivalent to Linke turbidity factor of about 2,8
Aerosol optical thickness at 500 nm	0,05	0,10

Table A.2 compares irradiance (calculated using rectangular integration) for the ASTM G 177 solar spectrum and the CIE 85:1989, Table 4, solar spectrum.

NOTE ASTM G 177 tabulates solar radiation out to 400 nm. However, the atmospheric, site latitude and other conditions used to develop the ASTM G 177 UV spectrum were input into the SMARTS2 solar radiation model to generate a full solar spectrum. This full-spectrum data was used to prepare the comparison above 400 nm given in Table A.2.

Table A.2 – Irradiance comparison for the ASTM G 177 solar spectrum and the CIE 85:1989, Table 4, solar spectrum

Passband nm	ASTM G 177 solar spectrum	CIE 85:1989, Table 4, solar spectrum
	Irradiance (W/m^2) in stated passband	
300 to 320	3,9	4,1
320 to 360	26,1	28,5
360 to 400	35,6	42,0
300 to 400	65,6	74,6
400 to 800	588,7	604,2
300 to 800	654,3	678,8
800 to 2 450	446,2	411,6
300 to 2 450	1 100,5	1 090,4

Annex B
(informative)

Radiation source

B.1 General

The radiation source may comprise one or more lamps and their associated optical components for example reflectors, filters, to provide the required spectral distribution and irradiance.

Typically, as the radiation source for simulating solar radiation in the laboratory, a xenon-arc lamp, metal-halide lamp, fluorescent lamp or LEDs are appropriate for the test method Sa and a xenon-arc lamp or UV fluorescent lamp are appropriate for the test method Sb.

B.2 Filters

The choice of filters depends on the radiation source and spectral irradiance. The present preference is therefore for glass filters to be used, although fundamentally a glass is not as accurately reproducible as a chemical solution. Some trial and error may be necessary to compensate for different optical densities by using different plate thicknesses. Glass filters are proprietary articles and manufacturers should be consulted concerning the choice of filters suitable for particular purposes. The choice will depend on the source and its method of use.

Some glass infra-red filters may be prone to rapid changes in spectral characteristics when exposed to excessive ultra-violet radiation. This deterioration may be largely prevented by interposing the ultra-violet filter between the source and the infra-red filter. Interference type filters, which function by reflecting instead of absorbing the unwanted radiation, thus resulting in reduced heating of the glass, are generally more stable than absorption filters.

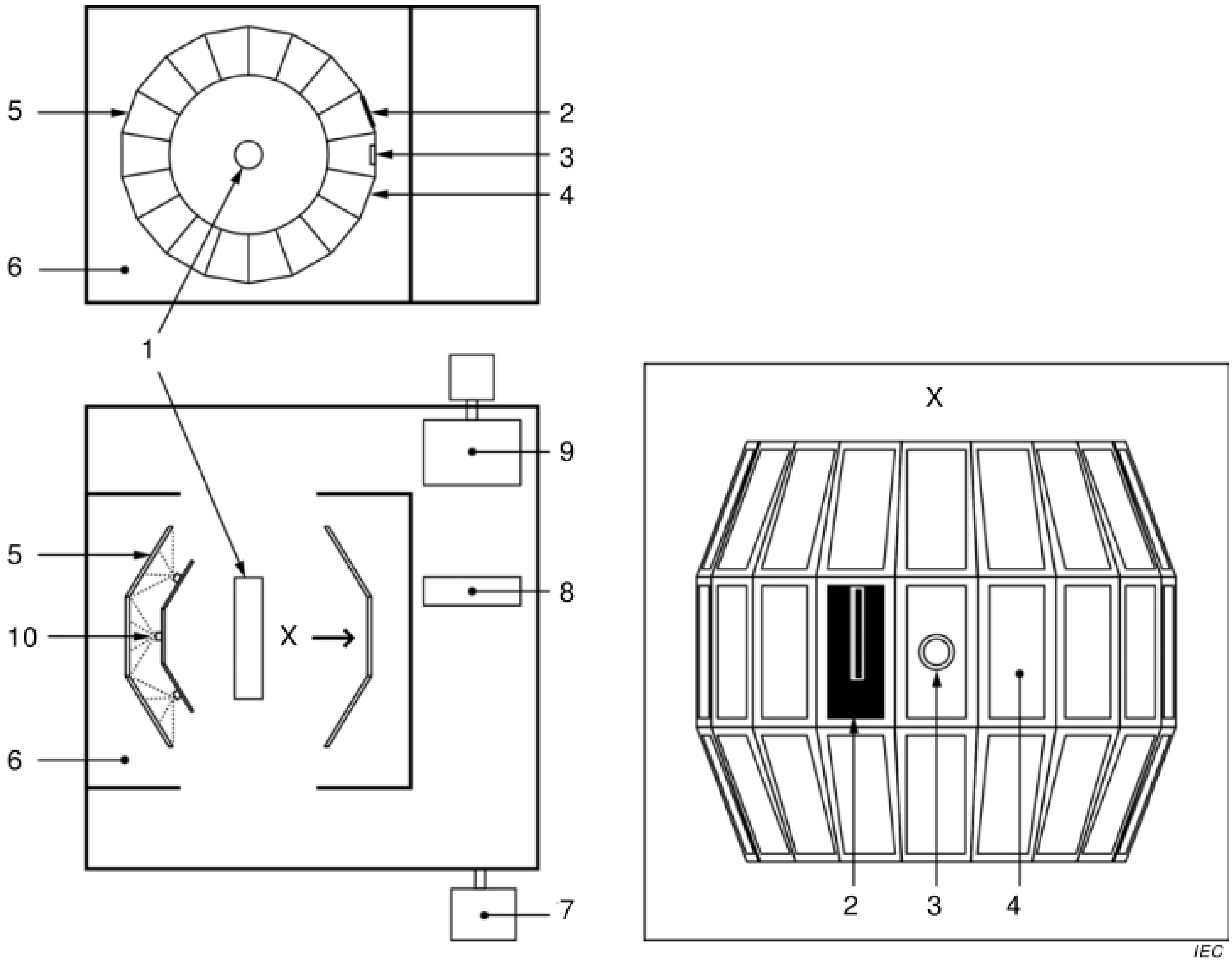
B.3 Uniformity of irradiance

Owing to the distance of the sun from the earth, solar radiation appears at the earth's surface as an essentially parallel beam. Artificial sources are relatively close to the working surface and means of directing and focusing the beam shall be provided with the aim of providing a uniform irradiance at the measurement plane within specification limits. Uniform irradiation is more readily achieved with a long-arc lamp mounted in a parabolic “trough” type reflector. By employing very elaborate mounting techniques, it is possible to irradiate, with some degree of uniformity, a large surface by a number of lamps. It is also possible using a rotating rack for the specimen holder.

Annex C
(informative)

Typical apparatus for weathering

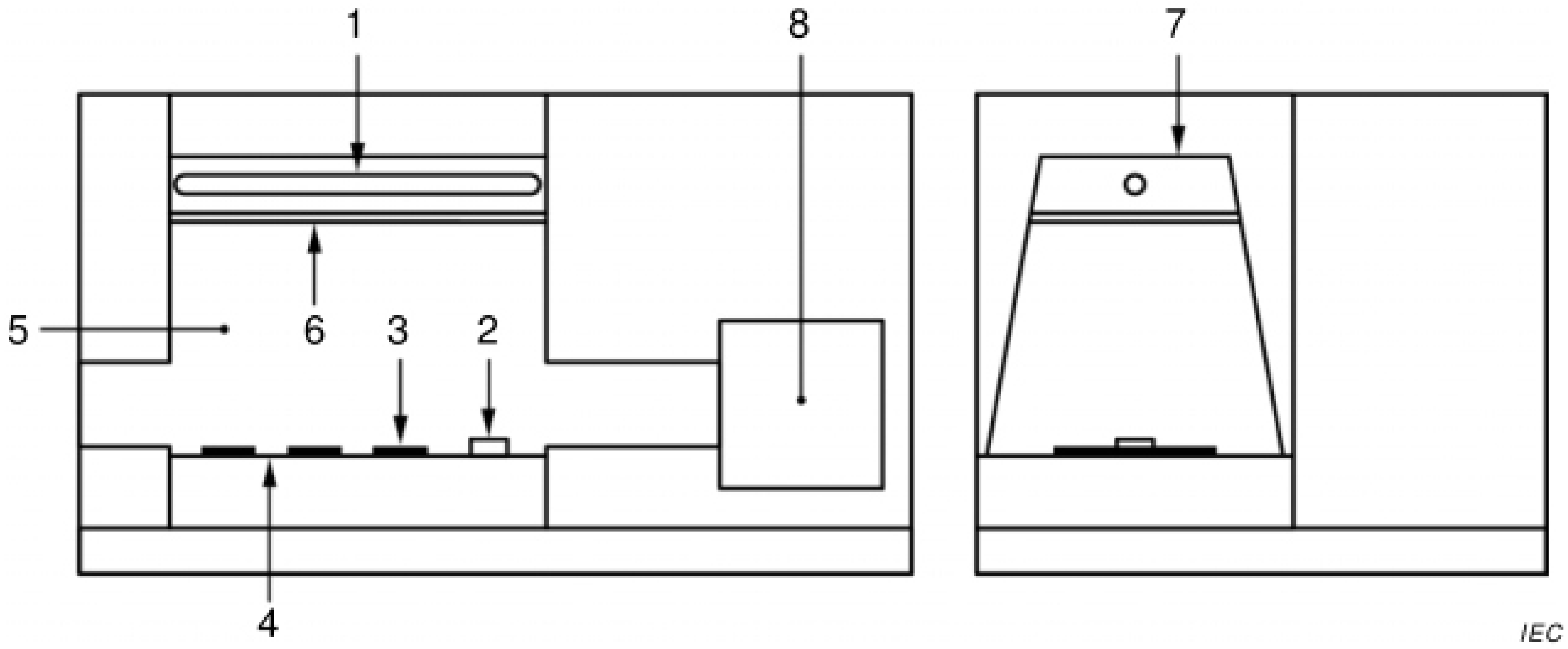
Examples of test apparatus are shown in Figure C.1 and Figure C.2.



Key

1 Radiation source
2 Insulated or uninsulated black panel thermometer
3 Light receptor
4 Test specimen
5 Rotating specimen holder
6 Test chamber
7 Humidifier
8 Temperature controlling unit
9 Fan
10 Spray nozzle

Figure C.1 – Example of test apparatus



Key

1	Radiation source	5	Test chamber
2	Light receptor	6	Filter
3	Test specimen	7	Reflecting mirror
4	Flat array	8	Fan

Figure C.2 – Example of test apparatus with flat array

Annex D
(informative)

Instrumentation

D.1 General

Test apparatus as described in ISO 4892 (all parts) should be used for the tests specified in this document.

D.2 Measurement of irradiance

The measurement instruments described in ISO 9370 are recommended for the purpose of monitoring the irradiance from laboratory radiation sources.

D.3 Measurement of spectral irradiance

Changes in the spectral characteristics of lamps, reflectors and filters may occur over a period of time, which could result in the spectral irradiance being significantly outside the permitted tolerances. Manufacturing tolerances can mean that lamp replacement could result in unacceptable changes in the level of irradiation compared with that initially set up. Regular monitoring is therefore essential, but monitoring of the detailed spectral irradiance within the test facility may not be practical while a test specimen is being tested.

D.4 Measurement of temperature

The surface temperature of exposed materials depends primarily on the amount of radiation absorbed, the emissivity of the specimen(s), the amount of thermal conduction within the specimen(s) and the amount of heat transmission between the specimen(s) and the air or between the specimen(s) and the specimen holder. Since it is not practical to monitor the surface temperature of individual test specimen(s), a specified black panel sensor is used to measure and control the temperature within the exposure chamber. The black surface temperature sensor fixed to a black panel shall be mounted within the specimen(s) exposure area so that it is in the same plane and orientation and receives the same radiation and experiences the same cooling conditions as a flat test panel surface. For a three-dimensional specimen(s), the black panel shall be in a plane and orientation that best represents the majority of the specimen surface of interest or at the plane of the primary surface of interest.

D.5 Difference between insulated black panel and uninsulated black panel thermometer

The maximum temperature on the surface of the test specimen(s) is determined by an insulated black panel or uninsulated black panel thermometer.

While the insulated black panel thermometer has an insulated back side, the uninsulated black panel thermometer is non insulated. At conditions used in typical exposure tests, the temperature indicated by an insulated black panel thermometer will be 3 K to 12 K higher than that indicated by an uninsulated black panel thermometer. Because insulated black panels with their thermometers are insulated, the response time of the thermometers for temperature changes is slightly slower than for an uninsulated black panel thermometer (see ISO 4892-1).

Bibliography

IEC 60068-2-78, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

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

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

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

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

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

CIE 85:1989, *Solar spectral irradiance*

ASTM G177, *Standard Tables for Reference Solar Ultraviolet Spectral Distributions: Hemispherical on 37° Tilted Surface*

ASTM G173, *Standard Tables for Reference Solar Spectral Irradiances: Direct Normal and Hemispherical on 37° Tilted Surface*

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