INTERNATIONAL STANDARD

ISO 877-3

First edition
2009-06-01

Plastics — Methods of exposure to solar radiation —

Part 3: Intensified weathering using concentrated solar radiation

Plastiques — Méthodes d'exposition au rayonnement solaire —

Partie 3: Exposition intensifiée par rayonnement solaire concentré

Reference number
ISO 877-3:2009(E)

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Published in Switzerland

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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.

ISO 877-3 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 6, *Ageing, chemical and environmental resistance*.

Together with the other parts (see below), it cancels and replaces ISO 877:1994, which has been technically revised.

ISO 877 consists of the following parts, under the general title *Plastics — Methods of exposure to solar radiation*:

— *Part 1: General guidance*

— *Part 2: Direct weathering and exposure behind window glass*

— *Part 3: Intensified weathering using concentrated solar radiation*

Introduction

The International Organization for Standardization (ISO) draws attention to the fact that it is claimed that compliance with this document may involve the use of American patents US 6659638 B1, US 7318672 B2 and US 4807247 concerning the temperature control discussed in Subclause 6.3. ISO takes no position concerning the evidence, validity and scope of these patent rights.

The holder of these patent rights has assured ISO that he is willing to negotiate licences under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statement of the holder of these patent rights is registered with ISO. Information may be obtained from:

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Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights other than those identified above. ISO shall not be held responsible for identifying any or all such patent rights.

Plastics — Methods of exposure to solar radiation —

Part 3:
Intensified weathering using concentrated solar radiation

1 Scope

This part of ISO 877 specifies a method for exposing plastics to concentrated solar radiation using reflecting concentrators to accelerate the weathering processes. The purpose is to assess property changes produced after specified stages of such exposures. General guidance concerning the scope of ISO 877 is given in ISO 877-1:2009, Clause 1. The reflecting concentrators used in these exposures are sometimes referred to as "Fresnel reflectors" because in cross-section the array of mirrors used to concentrate the solar radiation resembles the cross-section of a Fresnel lens.

For additional information about solar concentrating exposures, including a partial list of standards in which they are specified, refer to the Bibliography.

2 Normative references

The following referenced documents are indispensable for the application 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.

ISO 877-1:2009, *Plastics — Methods of exposure to solar radiation — Part 1: General guidance*

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

ASTM G 90, *Standard Practice for Performing Accelerated Outdoor Weathering of Nonmetallic Materials Using Concentrated Natural Sunlight*

ASTM G 179, *Standard Specification for Metal Black Panel and White Panel Temperature Devices for Natural Weathering Tests*

3 Principle

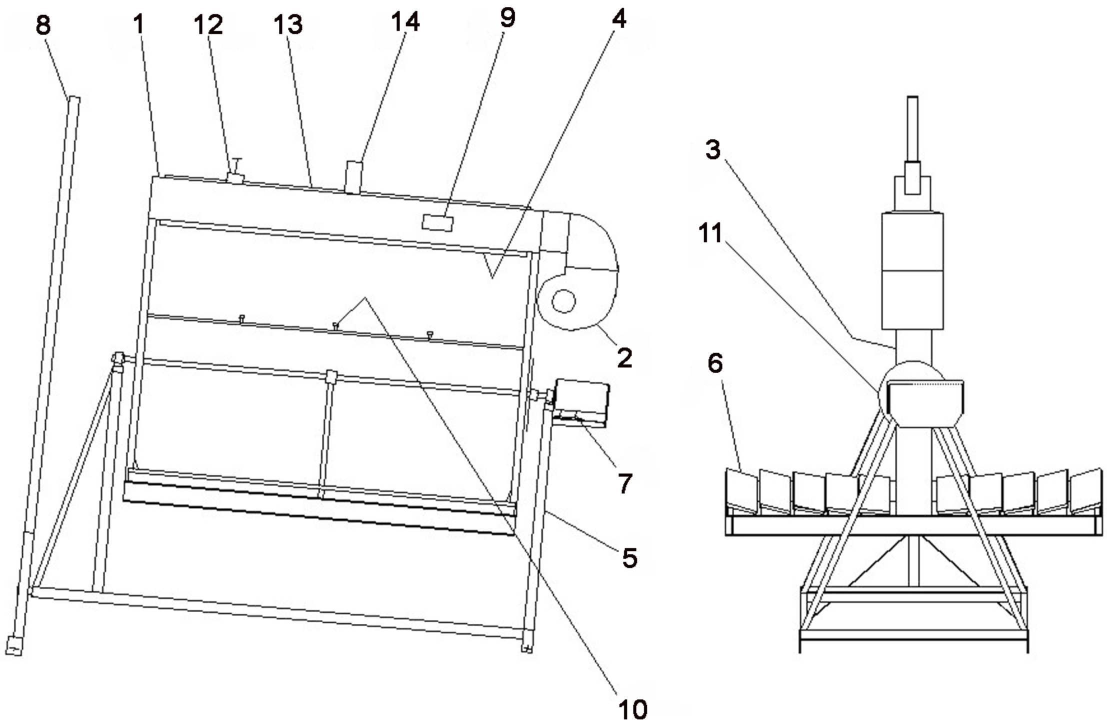
This part of ISO 877 describes a method for performing accelerated weathering on plastics using intensified solar radiation. General guidance is given in ISO 877-1:2009, Clause 4.

4 Apparatus

4.1 General requirements

Refer to ISO 877-1:2009, Subclause 5.1, for general requirements.

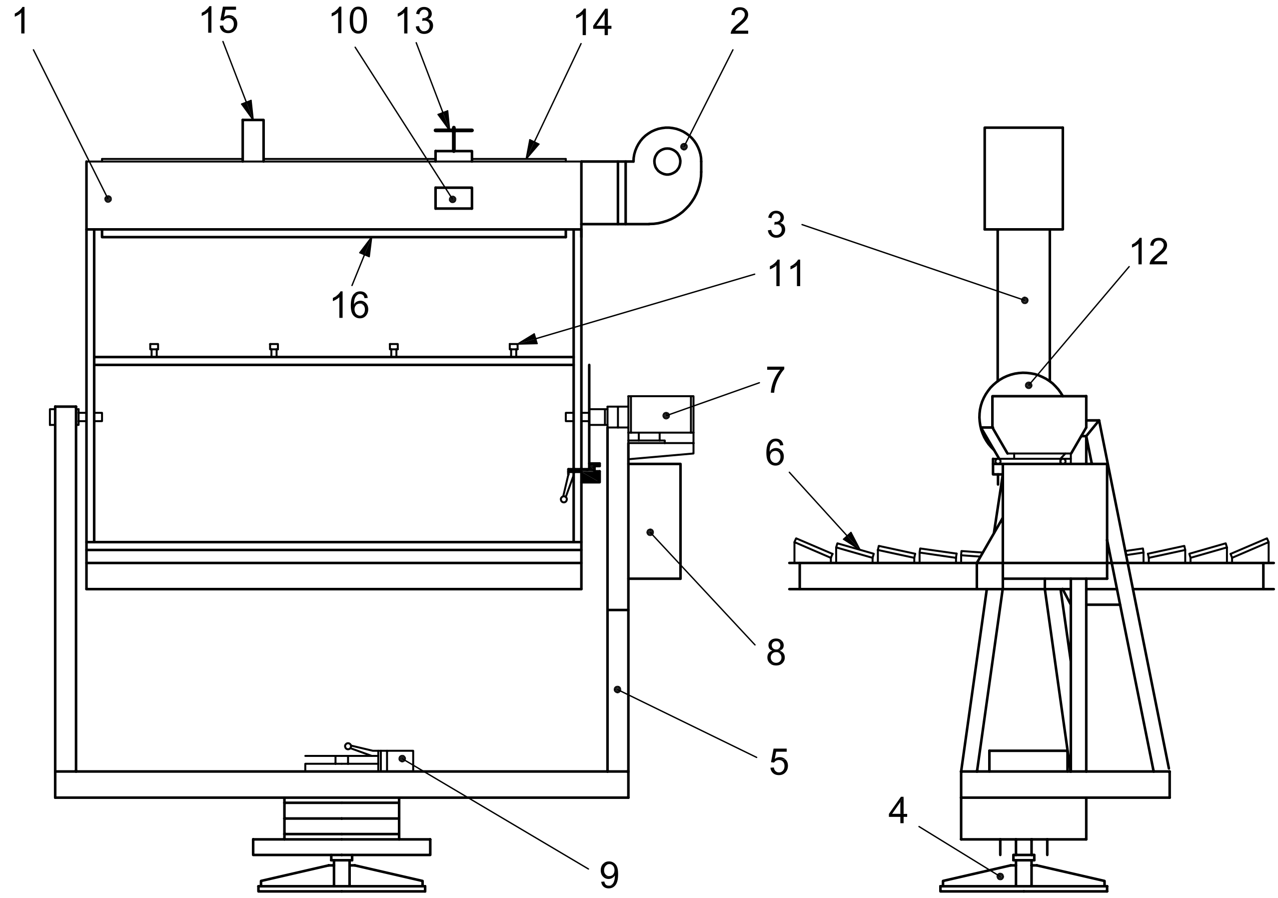
All requirements for the solar concentrating device, operation of the device and measurement of the solar radiation within the specimen exposure area shall be in accordance with ASTM G 90. See Figures 1 and 2 for schematic diagrams of the two types of test apparatus.



Key

1 air plenum
2 air blower
3 rotor assembly
4 air deflector
5 A-frame assembly
6 mirror
7 gear box
8 mast for manual elevation adjustment
9 air flow switch
10 water spray nozzles
11 clutch disc for elevation drive
12 solar cells with shadow hat
13 specimen protection door
14 door release mechanism

Figure 1 — Schematic diagram of test apparatus with single-axis tracking and manual elevation adjustment



Key

1 air plenum
2 air blower
3 rotor assembly
4 turntable assembly
5 A-frame assembly
6 mirror
7 gear box for elevation drive
8 control box
9 gear box for azimuth drive
10 air flow switch
11 water spray nozzles
12 clutch disc for elevation drive
13 solar cells with shadow hat
14 specimen protection door
15 door release mechanism
16 air deflector

Figure 2 — Schematic diagram of test apparatus with dual-axis tracking

4.2 Apparatus for measurement of climatic factors

Refer to ISO 877-1:2009, Subclause 5.2.

5 Test specimens

Refer to ISO 877-1:2009, Clause 6.

NOTE When irregularly shaped specimens are used, air flow and specimen cooling may be adversely affected. In addition, irradiance will not be uniform on all surfaces of a shaped specimen.

6 Exposure conditions

6.1 Orientation of mirrors

For specific information on the orientation of the mirrors, refer to ASTM G 90.

6.2 Exposure site

Fresnel-reflecting solar concentrating devices operate most effectively at locations that receive at least 3 500 h of sunshine per year and where the average daytime relative humidity is less than 30 %. ASTM G 90 provides requirements for the exposure site's average ratio of direct solar radiation to global normal solar radiation.

NOTE In regions that receive 3 500 h of solar radiation and where the average daytime relative humidity is less than 30 %, the average ratio of direct solar radiation to global normal solar radiation is at least 0,75. Areas that meet these criteria have a minimum diffuse component of solar radiation (sky radiation). The use of reflecting solar concentrator devices in regions of moderate to high diffuse solar irradiance will substantially reduce the amount of UV radiation at the specimen target board. Moderate to high levels of humidity and urban aerosols result in scattering of the direct component of solar radiation so that ultraviolet radiation is scattered into the hemispherical sky dome and is not available to be focused by the mirrors on to the specimen target board. This is shown in Figure 3. In addition, the use of reflecting solar concentrator devices in regions of moderate to high diffuse solar irradiance may give different stability rankings for materials compared to exposures conducted in accordance with ISO 877-2 because of the differences in UV radiation.

6.3 Temperature control

Solar concentrating devices are equipped with a blower to cool the specimens. Specimen temperatures for most materials are typically 10 °C higher than the maximum temperature which would be reached if an identical specimen was exposed directly to solar radiation (without concentration) at normal incidence at the same time.

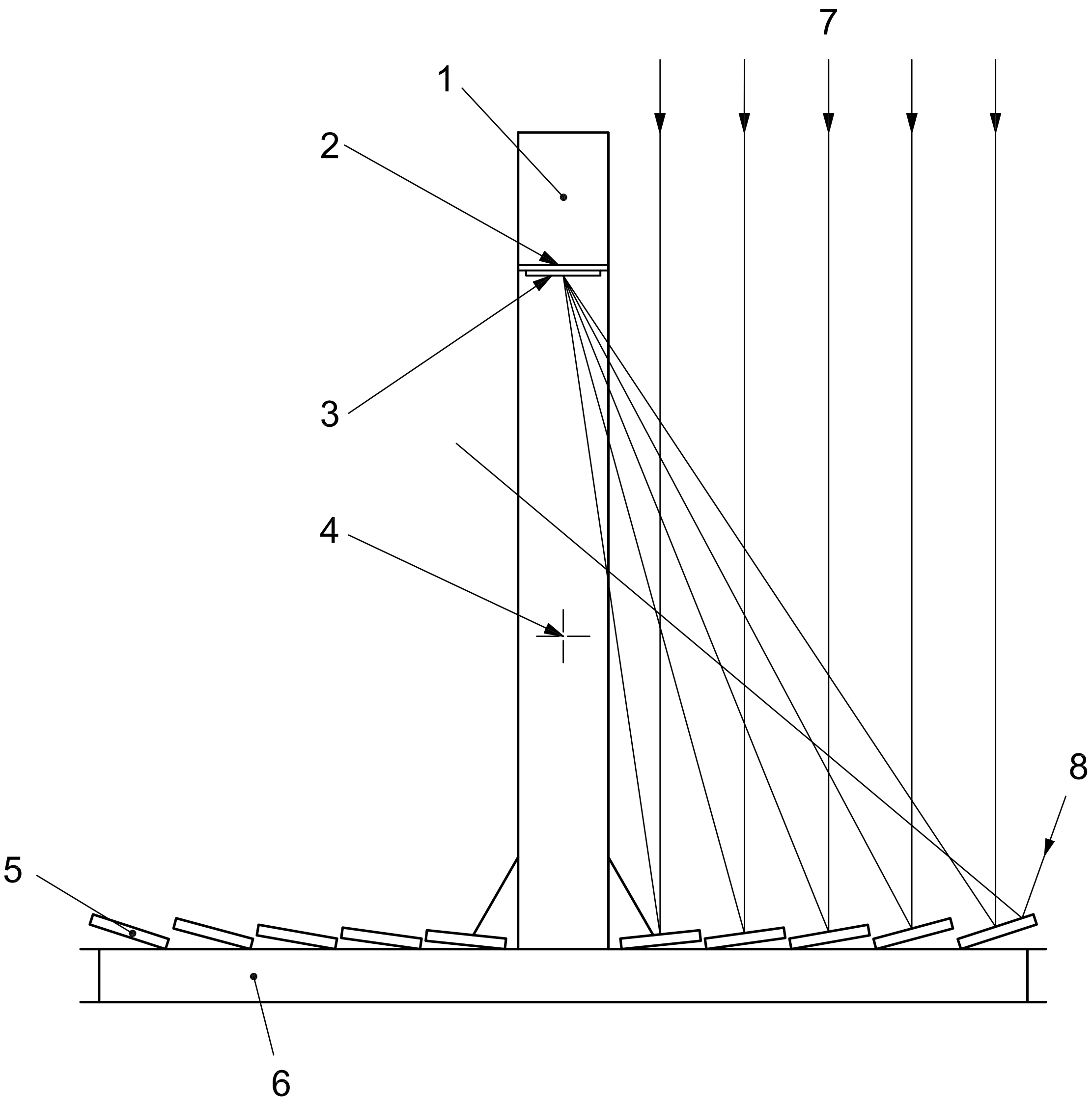
If more precise control of specimen temperature is required, the temperature of a black or white panel, the temperature of a black or white standard thermometer, the temperature of a particular specimen, the air temperature or the temperature indicated by a remote sensor may be monitored and used as an input to control the specimen temperature. If used, report the controlled temperature and any observed deviations in the test report.

NOTE 1 Use of this method of temperature control may produce results that are not equivalent to typical solar concentrating exposures and may require longer radiant exposures to produce the same amount of degradation.

Unless otherwise specified, if measurement of black- or white-panel temperature is required, the panels shall be constructed, calibrated and maintained in accordance with ASTM G 179. Unless otherwise specified, if measurement of black- or white-standard temperature is required, the panels shall be constructed and maintained in accordance with ISO 4892-1.

NOTE 2 If a black-standard temperature is used, the temperature indicated will be higher than that indicated by a black-panel thermometer under typical exposure conditions.

Temperatures during the night-time are typically not controlled. If agreed upon by the interested parties, heat sources placed behind the specimens may be used to control night-time temperatures. If so, the method used to control night-time temperatures shall be included in the test report.



Key

1 air plenum (end view)
2 specimen target board
3 test specimen
4 centre of gravity and rotation
5 flat mirror
6 mirror bed
7 direct component of solar radiation
8 diffuse component of solar radiation (sky radiation)

Figure 3 — Reflecting mechanism in a solar concentrating device

6.4 Irradiance level

Measurement of total solar radiation and solar ultraviolet radiation for the determination of radiant exposure using solar concentrating exposures is described in ASTM G 90. The irradiance may be varied by changing the number of mirrors used in the device. This will also change the specimen temperature. Any modifications to the exposure conditions to modify the irradiance in the exposure area, as well as the method used to calculate or measure the modified irradiance level, shall be completely described in the test report.

NOTE These modifications will change the time necessary to produce the same radiant exposure in devices using all mirrors, and may not produce an equivalent result for the same radiant exposure.

7 Exposure stages

7.1 General

Since the amount of solar radiation is one of the most important factors in the deterioration of plastics during weathering exposure, exposure stages shall, unless otherwise specified, be defined in terms of total solar radiant exposure, solar UV radiant exposure or solar UV radiant exposure in a narrow passband.

7.2 Solar radiant exposure

7.2.1 Guidance for selection of the exposure stage

For guidance in selecting the exposure stage, Table 1 shows the average annual total solar radiation and solar ultraviolet radiation for sites in southern Florida and in the central Arizona desert. This data may be used as an “equivalent standard year” for setting desired exposure stages (e.g. an exposure stage of 305 MJ/m^2 total solar UV from 295 nm to 385 nm could be used to simulate a one-year latitude-angle exposure in southern Florida conducted in accordance with ISO 877-2:2009, method A).

Table 1 — Average annual total solar and total solar ultraviolet radiation for exposures conducted at a tilt angle equal to the latitude angle in southern Florida and the central Arizona desert

Location	Average annual radiant exposure at tilt angle equal to site latitude	
	Total solar radiation MJ/m^2	**Solar UV radiation** (295 nm to 385 nm) MJ/m^2
Southern Florida	6 310	305
Central Arizona	8 240	340

NOTE Traditionally, UV radiometers measuring from 295 nm to 385 nm have been used. The use of radiometers with a different measurement response (for example, radiometers that measure to 400 nm) can result in recorded UV radiant exposures that are up to 25 % to 30 % higher than the UV radiant exposure determined with radiometers that only measure up to 385 nm. See Annex A of ISO 9370:— for more information about the differences in measured total solar UV radiation between total ultraviolet radiometers that have differences in long-wavelength UV measurement cut-off.

The degree of acceleration for exposures conducted in accordance with this part of ISO 877 is dependent on both the material formulation and the time of year. The ultraviolet content of terrestrial solar radiation is time-of-year dependent. Therefore, exposures started in the fall or winter months will take longer to accumulate the specified radiant exposure than exposures started in the spring or summer.

7.2.2 Instrumental measurement of solar radiant exposure

Refer to ISO 877-1:2009, Subclause 8.3, for general guidance.

7.2.2.1 Total solar radiant exposure

Refer to ASTM G 90.

7.2.2.2 Radiant exposure in specified wavelength intervals

Refer to ASTM G 90.

8 Procedure

8.1 Mounting of test specimens

For general information regarding the mounting of the test specimens, refer to ISO 877-1:2009, Subclause 9.1. Orient specimens so that the surfaces to be exposed face the mirrors of the solar concentrating device.

Mount the test specimens in a suitable test frame such that a minimum of any test specimen is covered by the clamping fixture used.

For unbacked exposures, mount the framed specimens approximately 5 mm off the target board, with the test surfaces facing the mirrors. Position the specimens such that clearance is maintained between the air-delivery slot and the frame. Adjust the machine's air deflector to provide a clearance of from 10 mm to 14 mm between the exposed surfaces of the specimens and the air deflector lip.

For insulated, backed exposures, mount specimens in specimen holders with the specimens backed with an insulating, water-resistant material (such as 12-mm-thick exterior plywood).

For solar concentrating exposures, the total specimen thickness (including any backing material) must be limited to ensure adequate cooling. The maximum thickness of the specimen or specimen plus backing material shall therefore be 13 mm.

8.2 Mounting of reference materials (if used)

Refer to ISO 877-1:2009, Subclause 9.2. The same requirements described in Subclause 8.1 apply to the mounting of specimens of reference materials.

8.3 Climatic observations

Refer to ISO 877-1:2009, Subclause 9.3.

8.4 Exposure of test specimens

8.4.1 General

Conduct all exposures and maintain the solar concentrating device in accordance with ASTM G 90.

8.4.2 Exposure cycles

Select the exposure cycle according to the amount of water spray desired from the cycles described in Table 2.

8.4.3 Testing under glass

When cycle 3 is used for testing specimens behind glass, the characteristics of the glass used shall be as given in ISO 877-2. In addition, when under-glass exposures are used, the air flow across the specimen exposure area shall be set as high as possible in order to prevent unrealistic temperatures of the specimens exposed behind the glass. Finally, the transmission of the glass used shall be included in the test report.

Table 2 — Water spray cycles used with Fresnel-reflecting concentrators

Cycle No.	Description
1	8 min spray, 52 min dry (during irradiation) plus three night-time sprays of 8 min duration (at 21:00 h, 24:00 h and 03:00 h)
2	3 min spray, 12 min dry (from 19:00 h to 05:00 h only, i.e. no daytime spray)
3	No spray
Other	Other spray cycles may be used as agreed upon between the interested parties

NOTE Typical uses of the cycles are as follows:

— cycle No. 1: testing most plastics specimens;

— cycle No. 2: testing plastics specimens having an initially high gloss, such as automotive lens materials, transparent sheet, etc.;

— cycle No. 3: testing under glass, testing plastics-laminated glass, fade-only tests and testing inner covers of solar hot-water collectors.

9 Expression of results

9.1 Determination of changes in properties

Changes in the properties of interest should preferably be determined in accordance with ISO procedures and test methods (see ISO 4582).

9.2 Climatic conditions

9.2.1 Climatic observations

9.2.1.1 General

The general description of the climate at the exposure site by class, type and special conditions shall be supplemented by the following detailed observations:

9.2.1.2 Temperature

Refer to ISO 877-1:2009, Subclause 10.3.

9.2.1.3 Relative humidity

Refer to ISO 877-1:2009, Subclause 10.3.

9.2.1.4 Levels (values) of exposure stages

For determining exposure levels, compute the solar radiant exposure H_s (total solar UV radiant exposure, or UV radiant exposure in a narrow passband), in joules per square metre, of the test specimens using the following equation:

$$H_\mathrm{s} = M \rho_\mathrm{s} \sum_{1}^{N} H_\mathrm{d}$$

where

M is the number of mirrors;

ρ_s is the average specular solar reflectance at the average angle of incidence at the mirrors (the optical system) for the known average solar spectral energy distribution at the equinox;

N is the number of days of exposure;

H_d is the total daily solar radiant exposure measured within a 6° field of view using radiometers that track the sun in the same configuration as the exposure device. For total solar radiation, a pyrheliometer is used. For solar UV radiation, a broad-band UV radiometer is used to measure global solar UV and a shaded-disc broad-band UV radiometer is used to measure diffuse solar UV. Direct solar UV radiation is determined by subtracting the diffuse from the global solar UV radiation. Detailed guidance is provided in ASTM G 90.

9.2.1.5 Precipitation

Refer to ISO 877-1:2009, Subclause 10.3.

9.2.1.6 Time of wetness

Refer to ISO 877-1:2009, Subclause 10.3.

9.2.1.7 Other observations

Refer to ISO 877-1:2009, Subclause 10.3.

10 Test report

Refer to ISO 877-1:2009, Clause 11. In addition to the information required by ISO 877-1:2009, Clause 11, report the following under item d) (details of the exposure):

9) the water spray cycle used,

10) the transmission of the glass used for under-glass exposures between 300 nm and 700 nm,

11) if temperature control was used, the type of thermometer used for the temperature control:

- black-standard thermometer (give description of thermometer and kind of mounting),
- black-panel thermometer (give description of thermometer and kind of mounting),
- specimen temperature thermometer (give description of thermometer and kind of mounting),
- air temperature thermometer (give description of thermometer and kind of mounting),

12) if temperature control was used, the mean value and variation of the controlled temperature for each part of the cycle (daytime and night-time),

13) if irradiance control was used, the percentage of the maximum irradiance employed (this can be reported as the number of exposed mirrors out of the total number of mirrors in the device).

Bibliography

Standards and specifications

[1] ISO 877-2:2009, *Plastics — Methods of exposure to solar radiation — Part 2: Direct weathering and exposure behind window glass*

[2] ISO 9370:—1), *Plastics — Instrumental determination of radiant exposure in weathering tests — General guidance and basic test method*

[3] ASTM D 4364, *Standard Practice for Performing Outdoor Accelerated Weathering Tests of Plastics Using Concentrated Sunlight*

[4] ASTM D 4141, *Standard Practice for Conducting Black Box and Solar Concentrating Exposures of Coatings*

[5] JIS D 0205, *Test method of weatherability for automotive parts*

[6] SAE J 576, *Plastic Material or Materials for Use in Optical Parts Such as Lenses and Reflex Reflectors of Motor Vehicle Lighting Devices*

[7] SAE J 1961, *Accelerated Exposure of Automotive Exterior Materials Using a Solar Fresnel Reflector Apparatus*

Other references

[8] BAUER, D.R., PAPUTA PECK, M.C., and CARTER, R.O., III, Evaluation of accelerated weathering tests for a polyester-urethane coating using photo-acoustic infrared spectroscopy, *J. Coatings Technol.*, **59** (755), pp. 103-109, 1987

[9] ROBBINS, J.S., JR., ZERLAUT, G.A., ROBBINS, J.S., III, and ANDERSON, T.E., The development of standards covering the Emmaqua® Test Method, Preprint, *Annual Paint Conference*, 1989, Australia

[10] ZERLAUT, G.A., RUPP, M.W., and ANDERSON, T.E., Ultraviolet radiation as a timing technique for outdoor weathering of materials, SAE Technical Paper 850348, *SAE International Congress*, Detroit, MI, USA, Feb. 25 to Mar. 1, 1985

[11] ZERLAUT, G.A., and ROBBINS, J.S., JR., Accelerated outdoor exposure testing of coil coatings by the Emmaqua® Test Method, Preprint, *Winter Meeting of the European Coil Coaters Assoc.*, Brussels, Nov. 1984

[12] ZERLAUT, G.A., and ELLINGER, M.L., Precision spectral ultraviolet measurements and accelerated weathering, *J. Oil Col. Chem. Assoc.*, **64**, pp. 387-397, 1981

[13] OAKLEY, E., Accelerated testing of durable coatings, lecture presented at Trent Valley Branch, *Oil and Color Chemists Assoc.*, Nov. 9, 1972

[14] PATILLO, P.J., Accelerated outdoor weatherability testing of pigments in paint, *J. Paint Technol.*, **40** (524), pp. 359-366, 1968

[15] OAKLEY, E., Test methods for high-durability coatings, *J. Paint Technol.*, **43** (555), pp. 43-64, 1971

1) To be published. (Revision of ISO 9370:1997)

[16] GARNER, B.L., and PATILLO, P.J., Accelerated outdoor exposure testing in evaluation of ultraviolet light stabilizers for plastics, *Ind. Eng. Chem. Prod. Res. Dev.*, **1**, pp. 249-253, 1962

[17] JOHNSTON-FELLER, R., and OSMER, D., Exposure evaluation: Quantification of changes in appearance of pigmented materials, *J. Coatings Technol.*, **49** (625), pp. 25-36, 1977

[18] SCOTT, J.L., and ANDERSON, T.E., The effect of wet time on accelerated outdoor exposures, *J. Oil Col. Chem. Assoc.*, **59**, pp. 404-413, 1976

[19] OAKLEY, E., and MARRON, J.J., Accelerated testing of durable coatings, *J. Oil Col. Chem. Assoc.*, **57**, pp. 22-29, 1974

[20] ROBBINS, J.S., III, "A Review of Recent Developments in the Use of ASTM Standard Practice G 90 for the Testing of Nonmetallic Materials", in ASTM STP 1202, *Accelerated and Outdoor Durability Testing of Organic Materials*, Warren D. Ketola and Douglass Grossman (Eds), ASTM International, 1994

[21] PUTMAN, W.J., "Parametric Control of a Fresnel Reflecting Concentrator Outdoor Accelerated Weathering Device", in ASTM STP 1294, *Durability Testing of Nonmetallic Materials*, Robert J. Herling (Ed.), ASTM International, 1996

[22] HARDCASTLE, H.K., Chapter 15: "A New Approach to Characterizing Reciprocity", in *Service Life Prediction: Challenging the Status Quo*, Jonathan W. Martin, Rose A. Ryntz, and Ray A. Dickie (Eds), Federation of Societies for Coatings Technology, Blue Bell, PA, USA, 2005

[23] HARDCASTLE, H.K., "A Characterization of the Relationship Between Light Intensity and Degradation Rate for Weathering Durability", in *Natural and Artificial Aging of Polymers — 2nd European Weathering Symposium*, Thomas Reichert (Ed.), Gesellschaft für Umweltsimulation, Pfinztal, Germany, 2005

ICS 83.080.01

Price based on 11 pages