Methods of exposure of plastics to direct weathering, to weathering using glass-filtered daylight, and to intensified weathering by daylight using Fresnel mirrors (ISO 877 : 1994)

English version of DIN EN ISO 877

DIN EN ISO 877

ICS 83.080.01

Supersedes DIN 53388, April 1984 edition.

Descriptors: Plastics, resistance to weathering, daylight tests, testing.

Kunststoffe – Verfahren zur natürlichen Bewitterung, zur Bestrahlung hinter Fensterglas und zur beschleunigten Bewitterung durch Sonnenstrahlung mit Hilfe von Fresnelspiegeln (ISO 877 : 1994)

European Standard EN ISO 877 : 1996 has the status of a DIN Standard.

A comma is used as the decimal marker.

National foreword

This standard has been published in accordance with a decision taken by CEN/TC 249 to adopt, without alteration, International Standard ISO 877 as a European Standard.

The responsible German body involved in its preparation was the *Normenausschuß Kunststoffe* (Plastics Standards Committee), Technical Committee *Verhalten gegen Umgebungseinflüsse.*

The DIN Standards corresponding to the International Standards referred to in clause 2 of the EN are as follows:

International Standard	DIN Standard
ISO 105-A01	DIN EN ISO 105-A01
ISO 105-A02	DIN EN 20105-A02
ISO 105-B01	DIN 54003
ISO 291	DIN EN ISO 291*)
ISO 294	DIN 16770-2
ISO 2557-1	DIN 16700
ISO 2818	DIN EN ISO 2818
ISO 3167	DIN EN ISO 3167
ISO 4892	DIN 53387

Amendments

DIN 53388, April 1984 edition, has been superseded by the specifications of EN ISO 877, which is identical to ISO 877.

Previous editions

DIN 53388-1: 1967-08; DIN 53388: 1956-07, 1959-07, 1974-04, 1984-04.

*) At present at the stage of draft.

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National Annex NA
Standards referred to

(and not included in **Normative references** and **Annex ZA**)

DIN 16700	Moulding techniques for plastic moulding materials – Production processes and equipment – Concepts
DIN 16770-2	Preparation of specimens of thermoplastic moulding materials by injection moulding
DIN 53387	Artificial weathering and ageing of plastics and elastomers by exposure to filtered xenon arc radiation
DIN 54003	Testing of colour fastness of textiles – Determination of colour fastness of dyed materials and prints to daylight
DIN EN 20105-A02	Tests for colour fastness of textiles – Grey scale for assessing change in colour (ISO 105-A02 : 1993)
DIN EN ISO 3167	Plastics – Multi-purpose test specimens (ISO 3167 : 1993)
DIN EN ISO 105-A01	Tests for colour fastness of textiles – General principles of testing (ISO 105-A01 : 1994)
DIN EN ISO 291	Plastics – Standard atmospheres for conditioning and testing (ISO/DIS 291 : 1996)*)
DIN EN ISO 2818	Plastics – Preparation of test specimens by machining (ISO 2818 : 1996)

*) At present at the stage of draft.

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN ISO 877

December 1996

ICS 83.080

Descriptors: Plastics, resistance to weathering, daylight tests, testing.

English version

Plastics

Methods of exposure to direct weathering, to weathering using glass-filtered daylight, and to intensified weathering by daylight using Fresnel mirrors
(ISO 877 : 1994)

Plastiques – Méthodes d'exposition directe aux intempéries, ou d'exposition indirecte sous verre, et à la lumière du jour intensifiée par des miroirs de Fresnel (ISO 877 : 1994)

Kunststoffe – Verfahren zur natürlichen Bewitterung, zur Bestrahlung hinter Fensterglas und zur beschleunigten Bewitterung durch Sonnenstrahlung mit Hilfe von Fresnelspiegeln (ISO 877 : 1994)

This European Standard was approved by CEN on 1996-11-22.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

The European Standards exist in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom.

CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

Ref. No. EN ISO 877 : 1996 E

Foreword

International Standard

ISO 877 : 1986 Plastics – Methods of exposure to direct weathering, to weathering using glass-filtered daylight, and to intensified weathering by daylight using Fresnel mirrors,

which was prepared by ISO/TC 61 'Plastics' of the International Organization for Standardization, has been adopted by Technical Committee CEN/TC 249 'Plastics', the Secretariat of which is held by IBN, as a European Standard.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, and conflicting national standards withdrawn, by June 1997 at the latest.

In accordance with the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard:

Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom.

Endorsement notice

The text of the International Standard ISO 877 : 1994 was approved by CEN as a European Standard without any modification.

NOTE: Normative references to international publications are listed in Annex ZA (normative).

Contents

Introduction

Outdoor-exposure tests of the type specified in this International Standard are needed to evaluate the performance of plastics when exposed to daylight. The results of such tests should be regarded only as an indication of the effect of exposure to direct weathering (Method A), or to indirect weathering using glass-filtered daylight (Method B) or to intensified daylight (Method C) by the methods described. Results obtained after exposure for a given time may not be comparable to those obtained after other exposures of equal time using the same method. When identical materials are exposed at different times for extended periods of several years, they generally show comparable behaviour after equal-exposure intervals. However, even in long-term tests, the results may be affected by the season in which the tests are started. This is particularly true when exposure tests are performed in accordance with Method C, using the Fresnel-reflecting concentrators described in this International Standard.

Fresnel-reflecting concentrators of the type described in Method C, which employ solar radiation as the source of ultraviolet light, are utilized to provide accelerated outdoor-exposure testing of many plastics materials.

However, some plastics materials, especially those that may tend to be comparatively moisture-sensitive, may not exhibit losses in certain properties at the same rate as in outdoor, natural exposures.

The results of short-term outdoor-exposure tests can give an indication of the relative outdoor performance, but should not be used to predict the absolute long-term performance of a material. Even results of tests carried out for longer than 24 months can show an effect of the season in which the exposure was started. Comparisons of non-full-year exposure will exhibit seasonal effects.

A system of classifying and characterizing climates in different parts of the world is given in annex B.

It is noted that the test method chosen is usually designed to expose the material to the most severe conditions associated with any particular climate. It should, therefore, be borne in mind that the severity of exposure in actual use is, in most cases, likely to be less than that specified in this International Standard, and allowance should be made accordingly when interpreting the results. For example, vertical exposure at 90° from the horizontal is considerably less severe in its effects on plastics than near-horizontal exposure, particularly in tropical regions, where the sun is most powerful at high zenith angles.

Polar-facing surfaces are much less likely to be degraded than equator-facing surfaces because they are less exposed to solar radiation. However, the fact that they may remain wet for longer periods may be of significance for materials affected by moisture.

1 Scope

This International Standard specifies methods of exposing plastics to solar radiation, either by direct exposure to natural weathering (Method A), to indirect solar radiation by modification of its spectral distribution with glass to simulate ageing of plastics behind building or automotive window glass (Method B), or to solar radiation intensified by the use of Fresnel mirrors to achieve acceleration of the weathering processes (Method C). The purpose is to assess changes produced after specified stages of such exposures.

This International Standard specifies the general requirements for the apparatus and operating procedures for using the test methods described. Although this International Standard does not include direct weathering using black-box test fixtures, attention is drawn to this method of exposure testing of materials under conditions simulating their end-use temperatures.[1)]

Methods B and C exclude the effects of weathering influences such as wind and rain, although the Method C apparatus used to produce intensified solar radiation is equipped to provide moisture in the form of water spray.

When comparing the results of exposure using Method C with results using Methods A and B, differences in specimen temperatures, ultraviolet radiant exposure levels and moisture deposition should be taken into account. Additionally, when comparing Method C exposures to Method B exposures, the glass or other transparent materials used as filters should be identical. Exposure results being compared should be for ultraviolet radiant exposure levels that agree closely with each other.

This International Standard also specifies methods for determining radiation dosage. The methods are applicable to plastics materials of all kinds and to products and portions of products.

NOTE 1 For the determination of changes in properties after exposure, see ISO 4582.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 105-A01:—[2)], *Textiles — Tests for colour fastness — Part A01: General principles of testing.*

ISO 105-A02:1993, *Textiles — Tests for colour fastness — Part A02: Grey scale for assessing change in colour.*

1) ASTM G 7-89, *Standard practice for atmospheric environmental exposure testing of nonmetallic materials* and ASTM D 4141-82 (reapproved 1987), *Standard practice for conducting accelerated outdoor exposure tests of coatings.*

2) To be published. (Revision of ISO 105-A01:1989)

ISO 105-B01:1989, *Textiles — Tests for colour fastness — Part B01: Colour fastness to light: Daylight.*

ISO 291:1977, *Plastics — Standard atmospheres for conditioning and testing.*

ISO 293:1986, *Plastics — Compression moulding test specimens of thermoplastic materials.*

ISO 294:1975, *Plastics — Injection moulding test specimens of thermoplastic materials.*

ISO 2557-1:1989, *Plastics — Amorphous thermoplastics — Preparation of test specimens with a specified maximum reversion — Part 1: Bars.*

ISO 2818:1994, *Plastics — Preparation of test specimens by machining.*

ISO 3167:1993, *Plastics — Multipurpose test specimens.*

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

ISO 4892:1981, *Plastics — Methods of exposure to laboratory light sources.*

WMO, *Guide to meteorological instruments and methods of observation,* WMO No. 8, Fifth Edition, World Meteorological Organization, Geneva, 1983.

3 Definitions

For the purposes of this International Standard, the following definitions apply.

3.1 direct (beam) solar radiation: Solar flux, coming from a small solid angle centred on the sun's disc, incident on a surface perpendicular to the axis of that solid angle.

Convention dictates that the plane angle of direct radiation is about 6°.

3.2 direct weathering; direct exposure: By convention, weathering (or exposure) due to radiation, incident on a surface, which is unmodified by either transmission through transparent materials or reflection by mirrors.

3.3 Fresnel-reflector system: Flat mirrors arranged in an array such that they reflect onto a target having an illuminated area which simulates the shape and size of the flat mirror.

3.4 natural weathering: Long-term exposure of materials to the elements, usually conducted on fixed-angle or seasonally adjusted racks (see ASTM G 7-89[1]).

These exposures are used to assess the effects of environmental factors on various functional and decorative parameters of interest.

3.5 pyrheliometer: Radiometer used to measure the direct (beam) solar irradiance incident on a surface normal to the sun's rays.

3.6 pyranometer: Radiometer used to measure the total solar radiant energy incident upon a surface per unit time per unit area.

The energy measured includes direct and diffuse radiant energy as well as radiant energy reflected from the background.

4 Principle

Specimens or, if required, sheets or other shapes from which specimens can be cut, are exposed to direct natural daylight, or to window glass-filtered daylight, or to intensified sunlight using a Fresnel-mirror concentrator, as specified. After the prescribed exposure interval, the specimen(s) are removed from exposure and tested for changes in optical, mechanical or other properties of interest. The exposure stage may be a given interval of time, or may be expressed in terms of a given total solar or solar-ultraviolet-radiation dosage. The latter is preferred whenever the main objective of the exposure is to determine resistance to light ageing, since it minimizes the effect of variations in the quality and intensity of solar radiation with climate, location and time.

Methods of assessing the radiation dosage may comprise one or more of the following:

- instrumental means of measuring irradiance, and means for integration to give the light dosage over a period of time;

- evaluation of physical standards which change in colour or in other well-defined properties upon exposure to light, the degree of change indicating the light dosage.

Unless otherwise specified, test pieces for the determination of change in colour and change in mechanical properties are exposed in an unstrained state.

Climatic conditions and variations thereof during the test are monitored and reported with other conditions of exposure.

5 Apparatus

5.1 General requirements

Exposure equipment consisting essentially of an appropriate test rack shall be used. The rack, holders and other fixtures shall be made from inert materials that will not affect the test results. Noncorrosive aluminium alloy, stainless steel or ceramics have been found suitable. Certain timbers that have been suitably impregnated with preservatives such as copper-chromium-arsenic mixtures or that have been shown not to interact with exposure tests may be used. Materials having thermal properties which differ from these materials may give different results. Copper or zinc or their alloys, iron or steels other than stainless steels, galvanized or plated metals or timbers other than those above should not be used in the vicinity of the test specimens.

When installed, the racks employed in test methods A and B shall be capable of providing the desired angle of inclination (see 7.1), and shall be such that no portion of the test pieces shall be closer than 0,5 m to the ground or to any other obstruction. Specimens may be mounted directly on the rack, or in suitable holders which are then affixed to the rack. Mounting fixtures shall be secure, but should apply as little stress as possible to the specimens, and should permit shrinkage, expansion or warping to occur without constraint, so far as possible.

If backing is necessary to support the test pieces or to simulate special end-use conditions, such backing shall be of inert material. Specimens that require support to prevent sagging of the test piece, but do not require backing to elevate the temperature, or require no "solid" backing, should be supported with fine-strand wire netting, or slit-expanded aluminium or stainless steel backing.

NOTE 2 For tests on finished products, it is recommended that, wherever possible, the fixtures should closely simulate those used in practice.

It is essential that the condition of the apparatus used in the two indirect-exposure methods (Methods B and C) be monitored to ensure that spectrum-modifying changes do not occur on ageing. For this reason the spectral transmittance of the glass for Method B test, and the specular spectral reflectance of the mirror system for Method C tests, must be periodically measured. Alternatively, the glass or the mirrors should be periodically replaced in their respective apparatus.

5.2 Fixture for exposure testing using Method A

The design of the rack shall be suited to the types of pieces being tested, but for many purposes a flat frame mounted on a support is suitable. This frame shall consist of rails of approved timber or other approved materials to which the test specimens themselves, or suitable specimen holders, may be secured. The test fixture may be adjustable with respect to both solar altitude (i.e. tilt) and azimuth.

5.3 Fixture for exposure testing using Method B

The test fixture consists of either a test rack, or open-bottomed box, with a framed lid of appropriate window, windscreen or automotive side-window glass. The enclosure shall be equipped with a rack that is positioned in a plane parallel to that of the glass cover, on which specimens may be mounted directly or in suitable holders. The test fixture may be adjustable with respect to both solar altitude (i.e. tilt) and azimuth. A schematic of an acceptable under-glass exposure case is shown in figure 1.

Sufficient space between the lid and the rack is necessary to ensure adequate ventilation; a minimum of 75 mm has been found suitable. To minimize shadows, the usable-exposure area under the glass shall be limited to the area of the glass cover with dimensions reduced by the distance from the cover to the specimens.

The glass used for the lid shall be flat, uniformly transparent and without defects. For exposure testing under building-window glass, single-strength glass of 2 mm to 3 mm thickness having a transmittance of approximately 90 % at wavelengths in the visible range of the spectrum from 370 nm and 830 nm and a transmittance of less than 1 % at wavelengths of 300 nm to 310 nm and shorter, is recommended. To maintain these characteristics, it is usually necessary to replace the glass at intervals of not more than two years.

Other types of glass or glazing materials may be used as agreed upon by the interested parties.

NOTE 3 Exposure under glass may give rise to different results compared to exposure to the open atmosphere because of a difference in spectral distribution and a difference between under-glass and open-air temperature.

5.4 Apparatus for exposure testing using Method C

The test fixture is a Fresnel-reflecting concentrator device comprising 10 flat mirrors that focus direct solar radiation onto an air-cooled sample area. The mirrors shall be arranged to simulate tangents to a parabolic trough such that they reflect sunlight uniformly onto the specimens mounted in the target area. An essentially complete description of the apparatus is given in documentation cited in annex C. A schematic of the device is shown in figure 2.

The test machines are usually deployed with their axes oriented in a north-south direction such that the mirror system faces the equator. The opposite polar-facing end is altitude-adjustable to account for seasonal variations in solar altitude at zenith.

The plane of the mirror system shall be maintained at a near-normal orientation to the beam component of solar radiation by a sun-tracking mechanism. The tracking mechanism usually consists of two photoreceptor cells that are installed on top of the wind tunnel such that they face the sun. A "T" shadow maker is mounted above the cells so that one-half of each cell is equally illuminated when the machine is in focus. As one cell receives more solar radiation than the other, the balance is disturbed and a signal is furnished through a null-operated d.c. amplifier to a reversible motor which then adjusts the machine to maintain focus.

An alternative approach is to use a computer-controlled tracking system that adjusts the azimuth and altitude with respect to the sun throughout the year. Alternatively, a clock drive that maintains the device's azimuthal position with respect to the sun may also be used.

The test machine's effective target area is slightly less than the dimensions of the mirrors used, and is typically 130 mm × 1 400 mm. The mirrors shall possess a high specular spectral reflectance in the ultraviolet and visible wavelength regions from 295 nm to 700 nm. The mirrors shall be adjusted such that the nonuniformity of intensified solar radiation in the target plane is less than 5 %. The mirrors employed on Fresnel-reflector test machines shall be flat and shall have a specular spectral reflectance of 65 % or greater at 310 nm wavelength.[3)]

The apparatus shall be provided with a mounting area for affixing a removable optical-mirror sample having a minimum area of 25 mm^2. The essential requirement is that the optical-mirror specimen be manufactured from the same batch and lot as the mirror stock-material used to irradiate the target sample area. The optical-mirror sample is mounted simultaneously with the mirrors used to irradiate the sample area, and its specular spectral reflectance shall be periodically measured.

NOTE 4 The degree of weathering acceleration provided by the apparatus is greatest when operated in dry, desert or high altitude climates.

Water sprayed on the specimen shall be free of silica (less than 0,01 mg/litre) and contain less than 20 mg/litre total solids. Distillation or demineralization of the water may be required. All material which comes into contact with specimen spray water shall be of a nature that will not contaminate the water.[4)]

The test machines shall be equipped with a mechanism for delivery of water spray to the samples during irradiation. Use of specific spray cycles relates to the end-use application of the plastics material.

3) This can be measured using ASTM E 903-82 (1988). *Test method for solar absorptance, reflectance, and transmittance of materials using integrating spheres,* or an equivalent method.

4) A Hach Model SI-7 low-range silica test kit may be used. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

Dimensions in millimetres

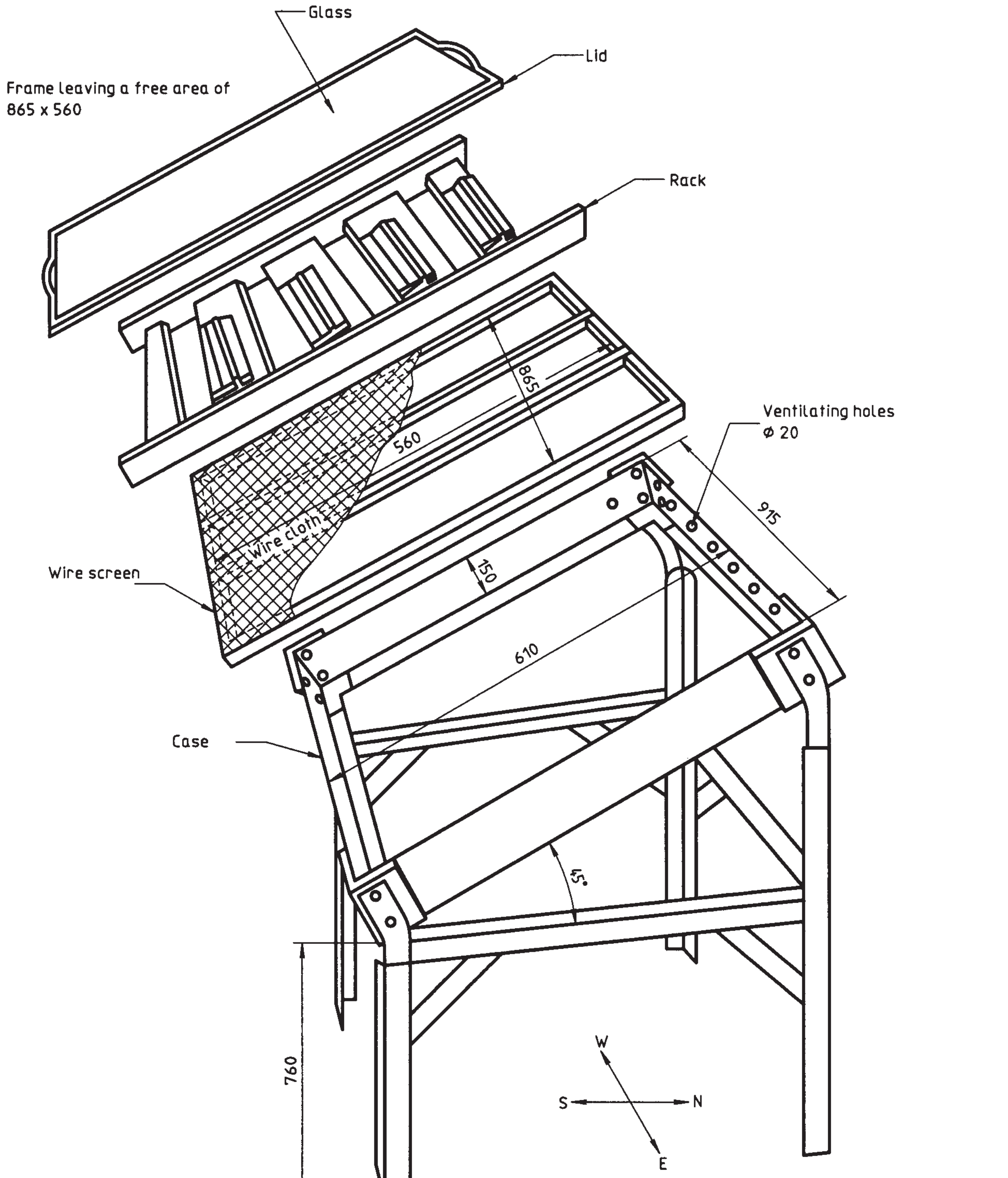
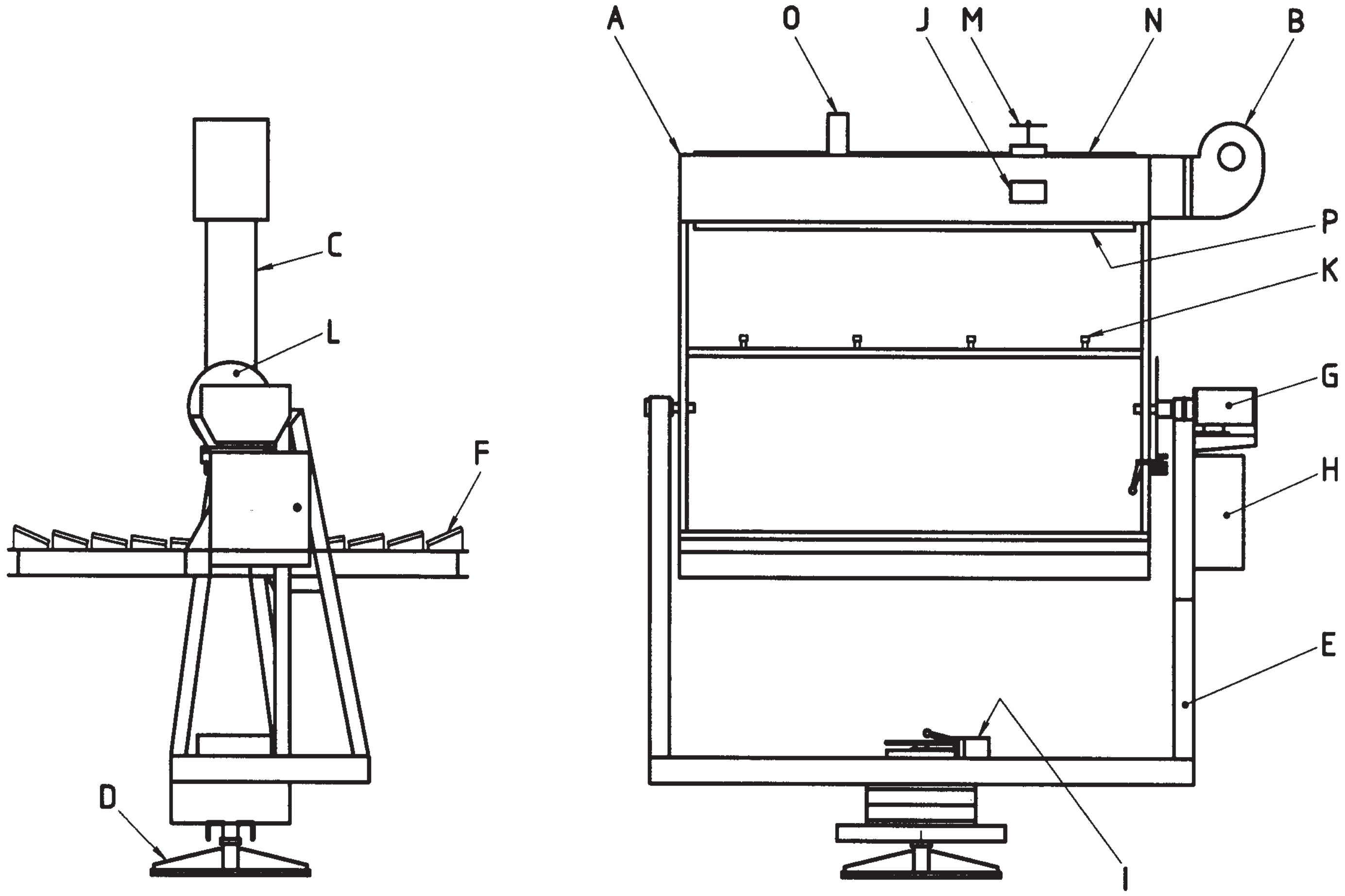
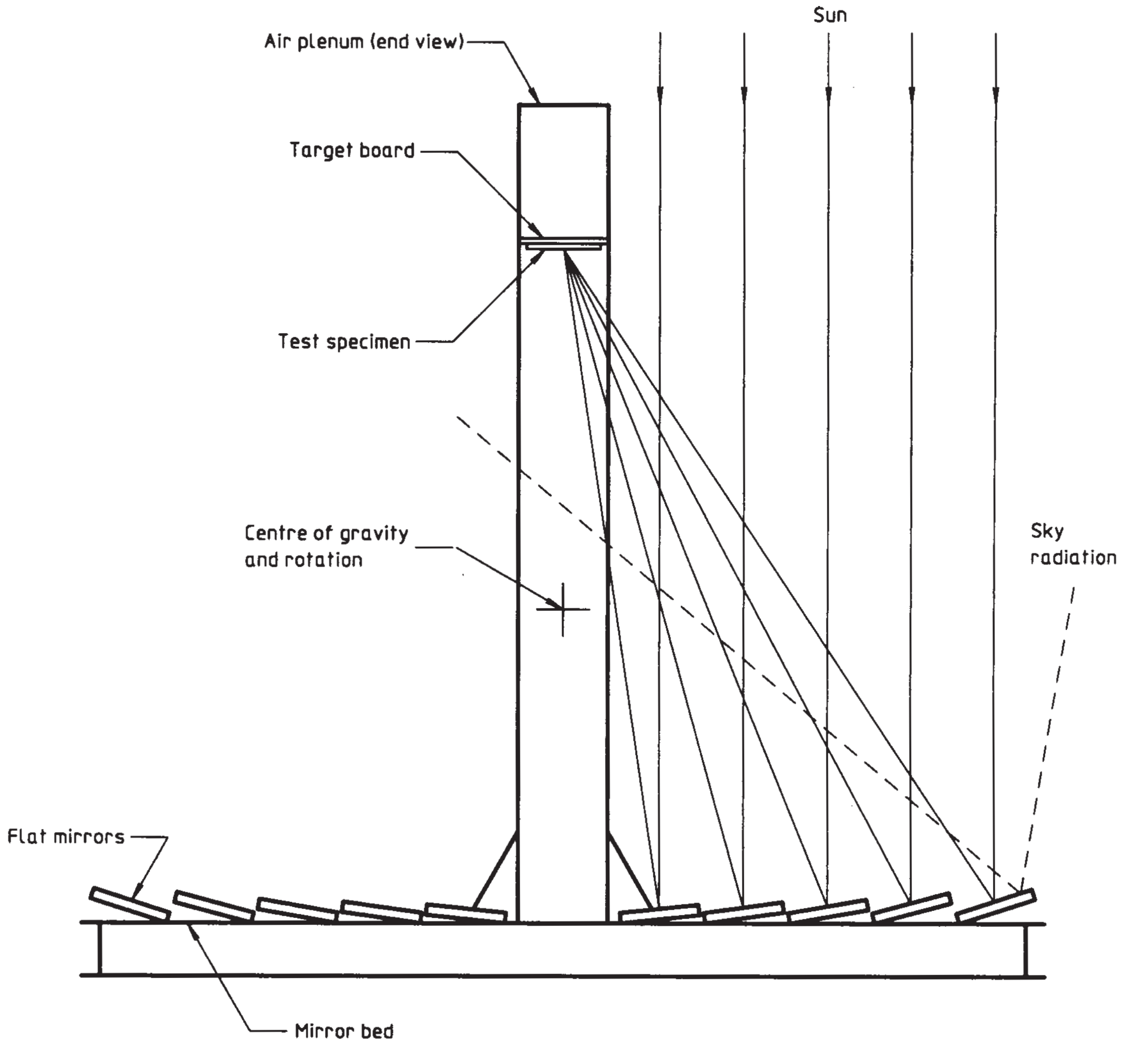


Figure 1 — Typical exposure case for weathering of plastics using glass-filtered daylight



A	Air plenum	I	Gear box, azimuth drive
B	Air blower	J	Air flow switch
C	Rotor assembly	K	Water spray nozzle
D	Turntable assembly	L	Clutch disc, elev drive
E	A-frame assembly	M	Solar cells/shadow hat
F	Mirror	N	Sample protection door
G	Gear box, elev drive	O	Door release mechanism
H	Control box	P	Air deflector

a) Schematic of machine



b) Schematic of optical system

Figure 2 — Fresnel reflecting concentrator accelerated weathering machine

5.5 Apparatus for measurement of climatic factors

5.5.1 Apparatus for measurement of solar radiation

5.5.1.1 Pyranometers

Pyranometers shall meet or exceed the requirements for a second class instrument as defined by the World Meteorological Organization (WMO). In addition, pyranometers shall be calibrated at least annually, and their calibration factor shall be traceable to the world radiometric reference (WRR) (see the WMO Guide, chapter 9).

5.5.1.2 Pyrheliometers

Pyrheliometers shall meet or exceed the requirements for a first class instrument as defined by the World Meteorological Organization (WMO). In addition, pyrheliometers shall be calibrated at least annually, and their calibration factors shall likewise be traceable to the world radiometric reference (WRR).

5.5.1.3 Total ultraviolet radiometers (TUVRs)

When used to define exposure stages, TUVRs shall have a bandpass that maximizes the acceptance of radiation in the 300 nm and 400 nm wavelength region, and they shall be cosine-corrected to include ultraviolet sky radiation. Commercially available TUVRs require semi-annual calibration checks if they are deployed between 40° north and 40° south latitudes (annual calibrations are satisfactory if deployed outside this band).

5.5.1.4 Narrow-band ultraviolet radiometers (NBUVRs)

When used to define exposure stages, NBUVRs shall be cosine-corrected if used in conjunction with either natural fixed angles or glass-filtered exposures; they shall possess an acceptance angle that exceeds the mirror system's effective field-of-view if used in conjunction with intensified solar-radiation exposure testing using a Fresnel-reflecting concentrator. In either case, they shall be calibrated at least every six months, or more often if required to ensure stability of their instrument constants.

5.5.2 Dyed blue wool references

When used to define exposure stages, blue wool references shall be used in conformance with ISO 105-B01 (see annex A).

5.5.3 Other climate-measuring instruments

Instrumentation required for the measurement of air temperature, sample temperature, relative humidity, rainfall, wet time and sunshine hours shall be appropriate to the exposure method used, and shall be agreed upon between the parties involves.

NOTE 5 Time-of-wetness measurements are usually determined by methods that employ galvanic cells, or similar "electrical" means.[5)]

6 Test specimen

6.1 Form and preparation

The dimensions of the test specimen(s) shall be those specified in the applicable test method or specification for the property or properties to be measured after exposure, unless a sample is required to be exposed in the form of a sheet or other shape from which the test specimen(s) can later be cut for specific tests.

If the material to be tested is an extrusion or moulding compound in the form of granules, chips or other raw state, specimens shall be produced directly from it by an appropriate method, or a sheet shall be made from it by an appropriate method and the specimens cut from the sheet. The method used shall be agreed by the interested parties and should be closely related to the method by which the material is to be processed by the user. For preparation of test specimens, use ISO 293, ISO 294, ISO 2557-1 and ISO 3167, as appropriate.

If the material to be tested is in the form of an extrusion, moulding, sheet, etc., test specimens may be prepared from the materials either before or after exposure, depending on the specific requirements of the tests and the nature of the material. For example, materials which embrittle markedly on weathering shall be exposed in the form in which they are to be tested, since subsequent machining is difficult; on the other hand, materials such as laminates, which may delaminate at the edges, should be exposed in sheet form and the specimens should be cut after exposure.

NOTE 6 For the preparation of test specimens by machining, see ISO 2818.

When the behaviour of a specific type of article is to be established, the article itself should be exposed wherever possible. Such articles or portions large enough for test purposes shall be exposed as they are. In cases where pieces of material are exposed and test specimens cut from them afterwards, the exposed weathered surface shall not be removed.

Test specimens cut from exposed sheet shall be taken from sheet at least 20 mm from the edge, and from fixtures holding the material, or from supports that are not intended to simulate the conditions of exposure of the materials in service. Under no circumstances shall any of the material be removed from the front exposed face during the test specimen preparation.

Only test pieces of similar dimensions and having approximately the same exposed areas shall be compared.

6.2 Number of test specimens

The number of test pieces for each test condition or exposure stage shall be at least that specified in the appropriate test method for the property or properties to be measured after exposure.

NOTE 7 For the determination of mechanical properties, it is recommended that the number of test specimens to be exposed be twice that required by the relevant International Standard (due to the large standard deviation known to occur in measuring the mechanical properties of "weathered" plastics).

The total number of test specimens required will be determined by the necessity for measurement of ini-

5) The method described in ASTM G 84 is used in the United States and Canada to measure time-of-wetness.

tial values and the values after each of a number of exposure stages.

6.3 Conditioning and storage

If test specimens are to be obtained by machining and if it is necessary to precondition the sample to facilitate specimen preparation, the details of such preconditioning shall be recorded.

Before testing, the test pieces shall be conditioned as applicable in accordance with the requirements of the material specification and the test procedure to be used; the conditioning procedure used shall be recorded in accordance with the applicable descriptions given in ISO 291. If the conditioning period used exceeds the minimum period specified in ISO 291 because the results of subsequent tests would otherwise be significantly affected (for example, in the case of test pieces of materials where the property to be measured is very sensitive to moisture content and/or the test pieces have been exposed to climatic extremes), the minimum conditioning period used shall be recorded.

The control samples shall be stored in the dark under normal laboratory conditions, preferably in one of the standard atmospheres given in ISO 291.

NOTE 8 Some materials will change colour during storage in the dark, particularly after weathering.

7 Test conditions

7.1 Exposure aspect for test Methods A and B

The exposure aspect shall be fixed, facing the equator, and at an angle of tilt from the horizontal chosen in accordance with one of the following conditions, depending upon the purpose of the exposure test.

a) For maximum annual exposure to total solar radiation at most mid-latitude regions of the world, and in the absence of an overriding specification, the tilt angle from horizontal shall be the site latitude angle minus 10°.

b) For maximum annual exposure to solar ultraviolet radiation in the band bounded by latitude 40° north and 40° south, the tilt angle from horizontal shall be 5° to 10°.[6)]

NOTE 9 At equatorial to mid-latitude desert sites, the maximum annual exposure to solar ultraviolet radiation is more closely approximated by exposing at a tilt of the latitude angle divided by 2.

c) Any other specific angle between 10° and 90° from the horizontal.

NOTE 10 Option c) may be used to obtain results relevant to special purposes; for example, vertical exposure may be required to simulate conditions on the face of a building, or 45° may be used for comparison with established data bases.

7.2 Exposure site

7.2.1 Test sites for Methods A and B

Exposure test sites shall be on open ground well away from trees and buildings. For exposure at tilt angles of 45° facing the equator, no obstruction, including adjacent racks, in an easterly, westerly or equatorial direction, shall subtend a vertical angle greater than 20°, or in a polar direction greater than 45°. For exposures at tilt angles of less than 30°, obstructions shall not subtend an included angle greather than 20° in the polar direction. Unless service conditions dictate otherwise, natural soil covering is recommended, for example, grass in temperate regions, or stabilized sand in desert regions. Vegetation shall be kept cut low.

Additionally, for some applications, it may be desirable to include exposure in uncleared areas in jungle or forest regions in order to assess the effects of biological growth, termites and rotting vegetation. In choosing such sites, care shall be taken to ensure that:

a) the uncleared site is truly representative of the general environment;

b) the exposure facilities and access paths do not grossly interfere with or modify the environment.

NOTE 11 To obtain the most reliable results, weathering-exposure tests should be conducted at sites in a number of different environments, in particular those that resemble as closely as possible the intended conditions of use. For guidance on climatic conditions, see 10.2 .

7.2.2 Test sites for Method C

The Fresnel-concentrator test devices required for Method C operate best in dry, sunny climates receiving 3 500 or more hours of sunshine per year, and at

6) Exposure at 5° to 10° from the horizontal is approximately equivalent to horizontal exposure yet enables drainage of excess rainwater.

test sites having an average daytime annual relative humidity of less than 30 %. For optimum levels of weathering acceleration, the minimum requirement for performing intensified solar radiation testing using Method C is a ratio of direct irradiance to global normal solar irradiance of 0,8.

NOTE 12 Use of Method C apparatus in regions of moderate to high diffuse solar irradiance will substantially reduce the test machine's effectiveness in providing concentrated ultraviolet radiation at the specimen target board. Such a loss in effectiveness may greatly reduce the degree of exposure acceleration achieved, although acceptable results may be obtained with respect to correlation. As discussed in ISO/TR 9673, moderate to high levels of humidity and urban aerosols result in the scattering of the direct solar radiation (beam component) to an extent that the ultraviolet component is scattered into the hemispherical sky dome and is not available in the direct beam for concentrated focusing by the Method C machine's mirror system (see figure 2).

7.3 Presentation of the test specimens

For the determination of changes in colour and mechanical properties, test specimens shall be exposed in the unstrained state, unless otherwise specified.

Unless use of backing is required, either to support the test specimen (see 5.1) or to simulate conditions of use (see 5.2), test specimens shall be exposed without backing or support (other than that necessary to maintain their position), and their rear surfaces shall otherwise be open to the air.

If backing or general support of the rear surface of the test specimen is used, the sample exposed shall be considered to consist of the test piece plus backing, or support.

NOTE 13 The backing or general support may significantly affect the temperature of the exposed sample since the backing influences the thermal insulation provided to the unexposed side of the specimen.

In cases where the intended use of the material renders it necessary to consider exposure in direct contact with specific backing materials, the test may be modified to take account of this requirement.

8 Exposure stages

The same exposure stage (by whichever method it is defined) will not necessarily give the same change in a test specimen, irrespective of the exposure test site. The exposure stages specified shall be regarded as giving only a general indication of the degree of change in the material's properties as a result of the given exposure, and results should always be considered in terms of the characteristics of the exposure site.

The exposure stages at which changes in properties of the test specimen are determined are specified by one of the following procedures.

8.1 Elapsed time

8.1.1 Duration of exposure

The exposure stages shall be specified in terms of the duration of exposure selected from the following, unless otherwise specified:

a) weeks: 2; 3; 4 (Method C);
b) months: 1; 3; 6; 9 (Methods A, B and C);
c) years: 1; 1,5; 2; 3; 4; 6 (Methods A and B).

The results for exposure stages of less than one year when testing in accordance with Methods A and B will depend on the season of the year in which the exposure was made. For longer exposure stages, seasonal effects are averaged, but results may still depend upon the particular season in which exposure was begun (for example, whether started in spring or autumn).

8.1.2 Method C

The degree of acceleration factors that can be experienced with Method C testing is dependent on both the material and the time of the year. The ultraviolet content of natural solar radiation is time-of-year dependent. Thus, wintertime testing requires longer exposure periods on the Fresnel-reflector test machines to achieve equal accumulation of ultraviolet radiant energy and equal levels of degradation compared to summertime testing.

Testing to specific levels (quantities) of solar radiant exposure is preferable to simple elapsed-time exposure-level determination. The only way to reduce time-of-year disparities in exposure results using Method C is to test for a standard reference radiant exposure in terms of joules per square metre solar ultraviolet radiation. For guidance in selecting exposure stages based on total solar ultraviolet radiant exposure, the average annual solar ultraviolet radiant exposure on an at-latitude rack in a typical subtropical climate may be used as an "equivalent standard reference year". Typical values are given in table 1 for subtropical Florida exposures. Values based on annual solar ultraviolet radiant exposure for other climatic regions can also be used for determining an "equivalent standard reference year".

Table 1 — Typical subtropical Florida values of average annual radiant exposure

Radiant exposure $MJ \cdot m^{-2}$ Solar	UV	Time
6 280	308 (at 300 nm – 385 nm)	1 year

8.2 Solar radiation dosage

Since the amount of solar radiation is one of the most important factors in the deterioration of plastics during weathering exposure, stages may be defined in terms of the amount of solar radiation received by the specimens. Although the use of total solar radiant energy to define exposure stages is optional, total solar radiant energy shall be measured and reported for each exposure stage in all exposure tests covered by this International Standard.

8.2.1 Instrumental measurement of solar radiant exposure

Instruments used to measure radiant exposure shall be mounted on fixtures that are closely adjacent to the sample exposure rack area.

8.2.1.1 Total solar radiant exposure

For exposure tests performed in accordance with Method A, solar irradiance shall be measured with a pyranometer (see 5.5.1.1), with the plane of its receiver mounted parallel to the plane of the exposure test rack. The solar irradiance shall be recorded and integrated to give the total solar radiant exposure in joules per square metre for each exposure stage. If mounted at a tilt from the horizontal of greater than 10°, care shall be exercised to ensure that no objects are permitted to reflect disproportionate amounts of sunlight onto the receiver, and to ensure that the pyranometer's foreground matches that of the exposure test samples as closely as possible. The pyranometer glass dome shall be cleaned daily with distilled or deionized water and dried with a soft lens-type tissue.

For exposure tests performed in accordance with Method B, a pyranometer such as required for Method A shall be mounted under a framed piece of glass in such a manner that the plane of its receiver is the same distance from the plane of the glass as are the samples being exposed to glass-filtered daylight. The glass either shall be selected from the same lot as is used in sample testing to Method B, or its spectral characteristics shall be demonstrated to be essentially identical to that lot.

When testing in accordance with method C, a pyrheliometer, as defined in 5.5.1.2, shall be affixed to an equatorial sun-tracking mount, and shall be operated continuously during all periods that the Method C test machines are in operation. The amount shall be adjusted daily to account for the changing declination of the sun; the pyrheliometer glass window shall be cleaned daily, using distilled or deionized water, and a soft lens-type tissue.

8.2.1.2 Energy in specified wavelength intervals

Pyranometers and pyrheliometers used to determine total solar irradiance measure all of the infrared portion of solar radiation in addition to radiation of ultraviolet and visible wavelengths. Since the infrared energy has no direct photochemical effect on the weathering of plastics, although it does affect the temperature of exposed specimens, it may be preferred to confine the solar measurements to the wavelength ranges that are photochemically active, which are principally in the ultraviolet portion of the spectrum.

As an example, solar ultraviolet radiation may be measured in the broadband wavelength range of 300 nm to 400 nm, using a commercially available total ultraviolet radiometer that meets the specifications in 5.5.1.3[7)].

Alternately, exposure stages may be followed using narrow-band ultraviolet radiometers (NBUVRs) that meet the specifications in 5.5.1.4[8)]. In either case, ultraviolet radiometers, when used to determine or monitor exposure stages, shall be mounted and maintained in accordance with the procedures speficied for pyranometers in this International Standard. Ultraviolet radiant exposure shall be measured and reported in joules per square metre.

8.2.2 Dyed blue wool references

The use of blue wool references for the assessment of colour fastness to light is specified in ISO 105-B01.

NOTE 14 It is advisable to check that the covers are transparent to the incident light by performing a comparison test on covered and uncovered references under dry conditions.

7) One of the most widely used commercial TUVRs possesses a 50 % bandpass from wavelengths 298 nm to 385 nm.

8) In 1991, there were several experimental NBUVR radiometers available commercially. The user is cautioned to thoroughly determine the suitability of a radiometer before using it to define exposure stages in long-term field testing.

There is no ideal response for an instrumental detector or for a reference material to monitor the exposure of all materials. Although it is known that most materials are particularly responsive to the short wavelength end of the ultraviolet region of the solar spectrum, the detailed responses of materials differ and depend on their chemical composition and the nature of any additives present.

9 Procedure

9.1 Mounting of test specimens

9.1.1 General procedure (Methods A, B and C)

Attach the test specimens to the test rack, or in suitable holders, using a clamping device of inert material. Ensure that sufficient space exists between the attachments and between battens to leave an unmasked area of sufficient dimensions to carry out the required optical and mechanical tests. Ensure that specimens required for mechanical tests are mounted properly with respect, for example, to notches, fillets, etc. Ensure that the method of mounting does not impose significant stress on the test specimen.

Identify each test specimen on the rear face by suitable indelible marking. Ensure that any scribe marks used for identification are not in an area that can affect the results of mechanical tests. As a check, a plan of the mounting positions may be retained.

If required, a portion of each test specimen may be covered by an opaque, weather-resistant mask during the test to provide an unexposed, masked area adjacent to the exposed area for comparison. This procedure is useful for checking the progress of exposure tests, but the data reported shall always be based on the comparison with the unexposed control specimens in storage.

NOTE 15 It is often useful to expose at the same time samples of one or more materials of known performance in order to monitor the exposure severity.

9.1.2 Method B

Mount the samples to be exposed to glass-filtered daylight according to the general procedures given in 8.1.1, but ensure that they are mounted within the area required by 5.3, and that the distance between the sample face and the glass lid is at least 75 mm.

9.1.3 Method C

Mount the test specimens in a suitable test frame such that a minimum of the 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 samples 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 6 mm to 13 mm between the exposed surface of the test specimen and the air deflector lip.

For insulated, backed exposures, mount samples into sample holders with samples backed with an insulating, water-resistant material (such as 12-mm-thick exterior plywood).

9.2 Mounting of radiometers and material references

If applicable, mount the radiometer or material references in accordance with 8.2. Mount the dyed blue wool references in accordance with the procedure for test specimens given in 9.1, and adjacent to them. Ensure that the requirements of annex A are met.

NOTE 16 Historically, the dyed blue wool references developed for the testing of textile colour fastness have been used in the testing of plastics. It is well recognized that this method has severe limitations when used to define exposure stages for plastics.

9.3 Climatic observations

Maintain a record of all climatic conditions and changes that may affect the exposure test results (see 10.2).

9.4 Exposure of test pieces

Unless otherwise specified, do not wash test specimens during exposure. If washing is required, use distilled water or water of equivalent purity and take care not to damage the weathered surface by abrasion, or otherwise.

Perform regular periodic inspections and maintenance of the site for the purpose of refixing loose test specimens, recording the general condition of test specimens, and repairing damage or deterioration to equipment, particularly after storms.

9.4.1 Method B

Perform regular periodic cleaning of the glass lid used in glass-filtered daylight-exposure tests. Clean the glass lids immediately after storms that deposit dirt, sand or debris. The underside of glass lids should be cleaned periodically to remove dust and sample exudates. Clean with water and wipe dry.

9.4.2 Method C

Perform regular periodic cleaning of the Fresnel-reflecting concentrator mirrors used in the intensified natural-weathering tests.

Measure the specular reflectance of the mirrors in the ultraviolet region from 295 nm to 400 nm every six months. This may be accomplished either by removing the removable mirror-monitoring samples (and replacing them after measurement), or with a demonstrably suitable portable reflectometer. Replace the mirrors for a given machine when the specular reflectance of the sample, or the mirror, at 310 nm decreases to less than 65 %.

Adjust the water-spray apparatus to provide conditions in accordance with one of the cycles given in table 2.

9.5 Determination of changes in properties

Expose the test piece for the appropriate exposure stage or stages, then remove it from the test fixture and determine the changes in appearance, colour, gloss and mechanical properties, in accordance with ISO 4582 and the appropriate test methods.

Perform the test(s) as soon as possible after exposure, consistent with the period required for conditioning, and record the interval between the end of the exposure and the commencement of testing.

Consider whether the value of an exposure-test program would be increased by adjusting subsequent withdrawal periods in the light of earlier results.

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

Cycle No.	Description
1	8 min spray, 52 min dry (during irradiation) plus 3 night-time sprays of 8 min duration (at 18:00 h, 24:00 h and 06:00 h)
2	3 min spray, 12 min dry (18:00 h to 06:00 h, night spraying only)
3	No spray
4	18 min spray, 102 min dry
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 inner plastic covers of solar hot-water collectors.
— Cycle No. 4: used in certain artificial-exposure devices described in ISO 4892.

10 Expression of results

10.1 Determination of changes in properties

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

10.2 Climatic conditions

10.2.1 Classes of climate

Climates are divided into five classes, each subdivided into several types. Annex B gives details of one such classification in use throughout the world. The classification of climates given is such that significant differences are to be expected between each of the climatic conditions with respect to their effects on the weathering behaviour of plastics.

As an overriding influence upon this regional classification, marine and industrial conditions are likely to produce significantly different effects with respect to the basic climatic conditions of the region. These particular conditions comprise the microclimate of the test site. In coastal regions, where the atmosphere may contain traces of salt and is generally otherwise clean, exposed samples receive a comparatively higher amount of solar radiation and are likely to degrade more rapidly than in non-desert[9] inland regions. In industrial areas, atmospheric pollution and dirt retained on the samples reduce the effect of solar radiation, although the pollution and dirt may at the same time make the effects of moisture more pronounced.

10.2.2 Climatic observations

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

10.2.2.1 Temperature

a) monthly mean of daily maxima;

b) monthly mean of daily minima;

c) monthly maximum and minimum.

10.2.2.2 Relative humidity

a) monthly mean of daily maxima;

b) monthly mean of daily minima;

c) monthly range.

10.2.2.3 Levels (values) of exposure stages

a) elapsed time (weeks, months, years);

b) total solar radiant exposure, expressed in joules per square metre.

For determining exposure levels using Method C, compute the solar radiant exposure H_s of the test specimens using the following equation:

$$H_s = M\rho_s\sum_{1}^{N} H_d$$

where

- H_s is the total solar radiant exposure, in joules per square metre;
- M is the number of mirrors;
- ρ_s is the average specular solar reflectance *at the average incident angle of 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 direct normal total daily solar radiant exposure measured in a 6° field of view using a pyrheliometer.

10.2.2.4 Precipitation

a) monthly total amount of rainfall, in millimetres;

b) monthly total time-of-wetness due to condensation, in hours;

c) monthly total time-of-wetness due to precipitation, in hours.

10.2.2.5 Time-of-wetness

a) monthly mean of the daily percent time-of-wetness;

b) monthly range of the daily percent time-of-wetness.

10.2.2.6 Other observations

Other observations, such as wind speed and direction, incidence and nature of any atmospheric pollution, total ultraviolet radiant exposure (if measured) and any special local features, may also be recorded.

11 Test report

The test report shall contain the following information:

a) sample details:

   1) a full description of the sample and its origin,

   2) compounding details, including cure time and temperature where appropriate,

   3) method of preparation of test piece;

b) test method used (Method A, B or C);

c) test details:

   1) exposure aspect (e.g. tilt and azimuth orientation),

9) Certain plastics are known to degrade more rapidly in specific desert exposure sites than in most coastal test sites.

2) location and details of exposure site (e.g. longitude, latitude, altitude, annual climate characteristics, etc.),

3) class and type of climate (quote from annex B, giving reference authority),

4) nature of masking, backing, support and attachments, if used,

5) procedure for determining exposure stages,

6) total solar radiant exposure, including method used for determination,

7) details of washing, if any;

d) test results:

1) exposure stages used, and corresponding intervals between property measurements and sample removal from exposure,

2) climatological data,

3) presentation of results as required by ISO 4582;

e) the date of test.

Annex A
(normative)

Use of dyed blue wool references to measure light dosage

A.1 General

Dyed blue wool references were developed for textile testing and historically have been used with plastics because of their availability. Because, in general, plastics require longer exposure periods than those normally used for testing the lightfastness of textiles, the consecutive use of the number 7 standard has been introduced.

Owing to the differences between the spectral sensitivity of the blue wool references and the plastics materials, there is considerable doubt about the use of blue wool references for this application. However, their ready availability and the fund of data based on their use ensures that there is still a demand for their application in exposure tests on plastics.

A.2 Procedure

Simultaneously expose a set of dyed blue wool references (ISO 105-B01) comprising one strip each from numbers 1 to 7.

Use the references to determine the stages of radiation dosage (exposure stages) in accordance with table A.1 by comparing the difference in colour between the exposed and unexposed blue references with the contrast 4 on the grey scale; thus, stage 1/1 is reached when reference 1 gives a contrast equal to 4 on the grey scale; 2/1 when reference 2 shows similar contrast, and in the same manner to stage 7/1 showing a contrast of 4 on the grey scale.

NOTE 17 The duration of stage 7/1 is about one year in natural daylight in temperate climates.

Inspect the blue references as frequently as necessary to determine when each exposure stage is reached.

At stage 7/1, discard the blue references, mount a second fresh reference 7 and continue exposure until this second reference 7 shows a contrast with the unexposed reference 7 equal to 4 on the grey scale. The storage is designated 7/2.

Then discard the second reference 7 and mount a third fresh reference 7. Stage 7/3 is reached when this reference in turn gives a contrast of 4.

Repeat this procedure as often as required, giving stages, 7/4, ..., 7/*N*.

NOTE 18 Consecutive exposure of No. 7 reference should only by employed when no better alternative is available.

Table A.1 — Exposure stages

Stage	Description
1/1	Blue reference 1 to grey scale contrast 4
2/1	Blue reference 2 to grey scale contrast 4
3/1	Blue reference 3 to grey scale contrast 4
4/1	Blue reference 4 to grey scale contrast 4
5/1	Blue reference 5 to grey scale contrast 4
6/1	Blue reference 6 to grey scale contrast 4
7/1	First blue reference 7 to grey scale contrast 4
7/2	Second blue reference 7 to grey scale contrast 4
7/*N*	*N*th blue reference 7 to grey scale contrast 4

A.3 Supply of dyed blue wool references

Sets of the dyed blue wool light-fastness references can be obtained from the following organizations:

British Standards Institution
3 York Street
Manchester M2 2AT
United Kingdom

Beuth-Vertrieb GmbH
Burggrafenstrasse 4 - 7
D-1000 Berlin 30
Germany

American Society for Testing and Materials
1916 Race Street
Philadelphia
Pennsylvania 19103
USA

Eidg. Materialprüfungs- und Versuchsanstalt
Unterstrasse 11
St. Gallen
Switzerland

Association pour la détermination de la solidité des teintures et impressions sur textiles
12 rue d'Anjou
F 75008 Paris
France

Japanese Standards Association
1-24 Akasaka 4
Minatoku
Tokyo
Japan

and other countries.

A.4 Supply of grey scale

The grey scale for assessing change in colour can be obtained from the following organizations:

British Standards Institution
3 York Street
Manchester M2 2AT
United Kingdom

The Society of Dyers and Colourists
P.O. Box 244, Perkin House
82 Gratton Road
Bradford BD1 2JB
West Yorks
United Kingdom

Association pour la détermination de la solidité des teintures et impressions sur textiles
12 rue d'Anjou
F 75008 Paris
France

Eidg. Materialprüfungs- und Versuchsanstalt
Unterstrasse 11
St. Gallen
Switzerland

Japanese Standards Association
1-24 Akasaka 4
Minatoku
Tokyo
Japan

American Association of Textile Chemists and Colorists
P.O. Box 12215
Research Triangle Park
North Carolina 27709
USA

Beuth-Vertrieb GmbH
Burggrafenstrasse 4 - 7
D-1000 Berlin 30
Germany

Annex B
(informative)

Classification of climates

A well-known system of climate classification[10] is presented below, giving general classification (B.1 to B.6), subdivided into detailed types of climate with their letter designations.

B.1 Tropical rainy climates

a) Tropical rainforest — Af, Am

b) Tropical savanna — Aw

B.2 Dry climates

a) Steppe — BS

1) Tropical and subtropical steppe — Bsh

2) Middle latitude steppe — Bsk

b) Desert —BW

1) Tropical and subtropical desert — Bwh

2) Middle latitude desert — Bwk

B.3 Humid meso-thermal climates

a) Mediterranean subtropical/dry summer — Cs

b) Humid subtropical/warm summer — Ca

1) Dry winter — Caw

2) No dry season — Caf

c) Marine/cool summer — Cb, Cc

B.4 Humid micro-thermal climates

a) Humid continental/warm summer — Da

b) Humid continental/cool summer — Db

c) Subarctic — Dc, Dcl

B.5 Undifferentiated highland climates — H

B.6 Polar climates

a) Tundra — ET

b) Ice cap — EF

10) Trewartha, T.T. *An Introduction to Weather and Climate*. McGraw-Hill, New York, 1947, Plate 1.

Annex C
(informative)

Bibliography pertaining to Method C (accelerated weathering using Fresnel mirrors)

C.1 National standards and specifications

C.1.1 Japan

[1] JIS D 0205-1987, *Test method of weatherability for automotive parts.*

C.1.2 United States

[2] ASTM D 4364-84, *Standard practice for conducting accelerated outdoor weathering of plastics materials using concentrated natural sunlight* (currently under revision).

[3] ASTM G 90-85, *Standard practice for performing accelerated outdoor weathering of nonmetallic materials using concentrated natural sunlight.*

[4] ASTM D 4141-82 (Reapproved 1987), *Standard practice for conducting accelerated outdoor exposure tests of coatings.*

[5] SAE J 576, *Plastics materials for use in optical parts such as lenses and reflectors of motor vehicle lighting devices.*

[6] SAE J 1961, *Accelerated exposure of automotive exterior materials using a solar Fresnel-reflective apparatus.*

C.1.3 Australia

[7] AS 1575.1, under revision to include the ALTRAC Fresnel reflector-concentrator.

C.2 Other references

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

[9] ROBBINS JR., J.S., ZERLAUT, G.A., ROBBINS III, J.S. 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, Feb. 25 to Mar. 1, 1985.

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[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.

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[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.

Annex ZA (normative)
Normative references to international publications with their relevant European publications

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

Publication	Year	Title	EN	Year
ISO 105-A01	1994	Textiles - Tests for colour fastness - Part A01: General principles of testing	EN ISO 105-A01	1995
ISO 105-A02	1993	Textiles - Tests for colour fastness - Part A02: Grey scale for assessing change in colour	EN 20105-A02	1994