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Second edition
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Plastics — Methods of exposure to direct weathering, to weathering using glass-filtered daylight, and to intensified weathering by daylight using Fresnel mirrors

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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

Reference number
ISO 877:1994(E)

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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.

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.

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

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This second edition cancels and replaces the first edition (ISO 877:1976), which has been technically revised.

Annex A forms an integral part of this International Standard. Annexes B and C are for information only.

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.

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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.

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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.

Plastics — Methods of exposure to direct weathering, to weathering using glass-filtered daylight, and to intensified weathering by daylight using Fresnel mirrors

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.

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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.

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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.

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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.

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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.

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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

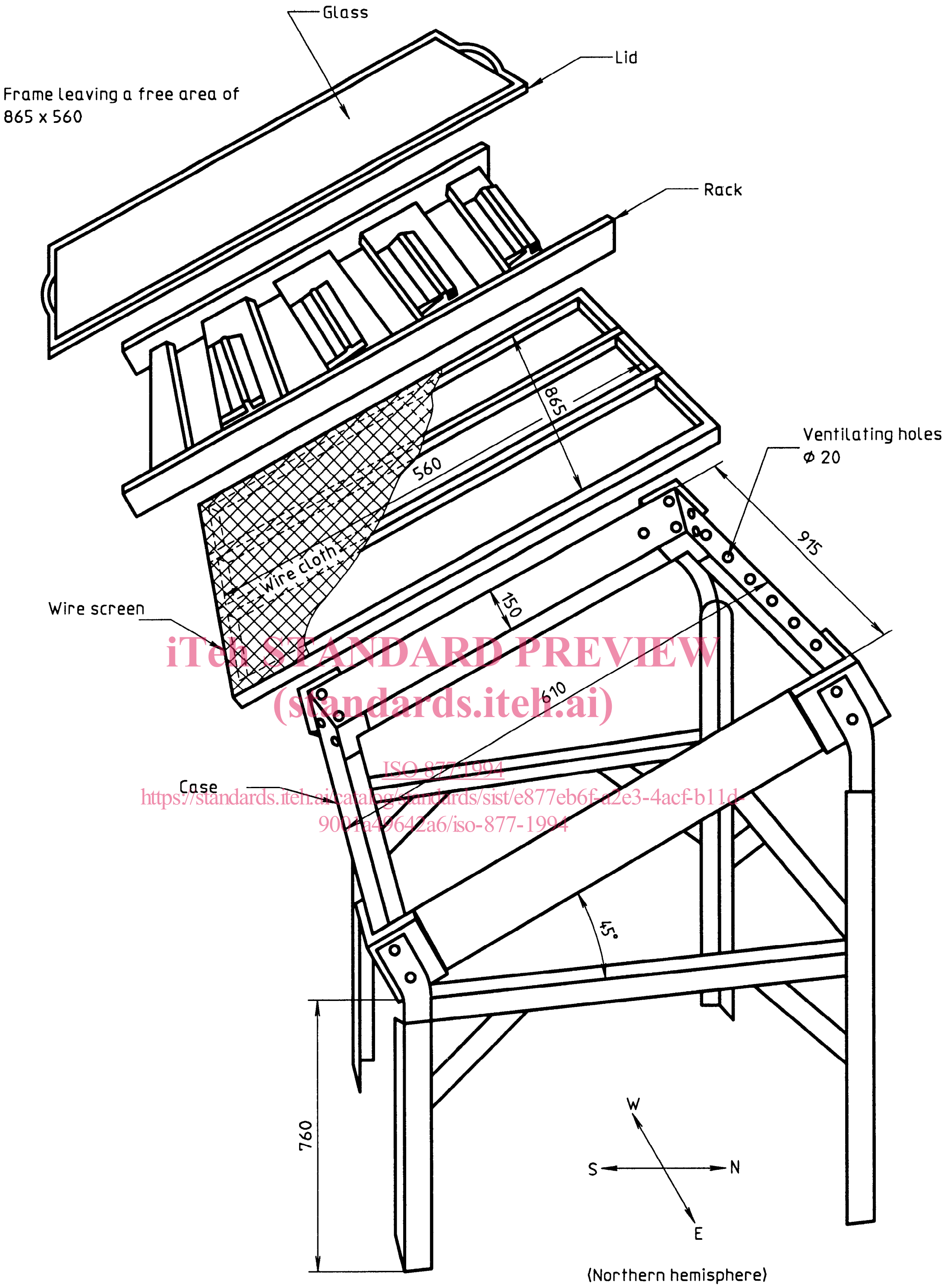

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Figure 1 — Typical exposure case for weathering of plastics using glass-filtered daylight

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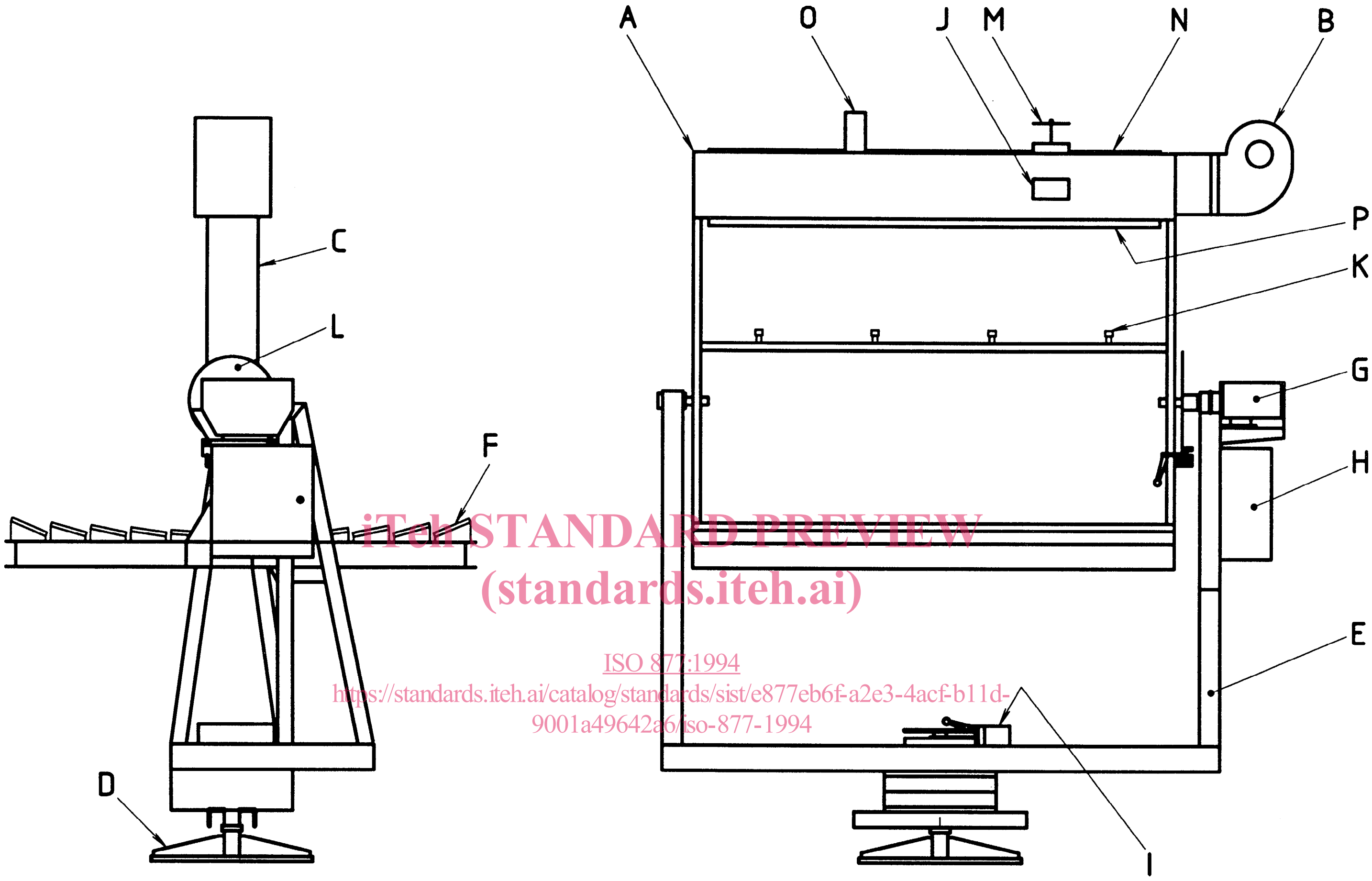

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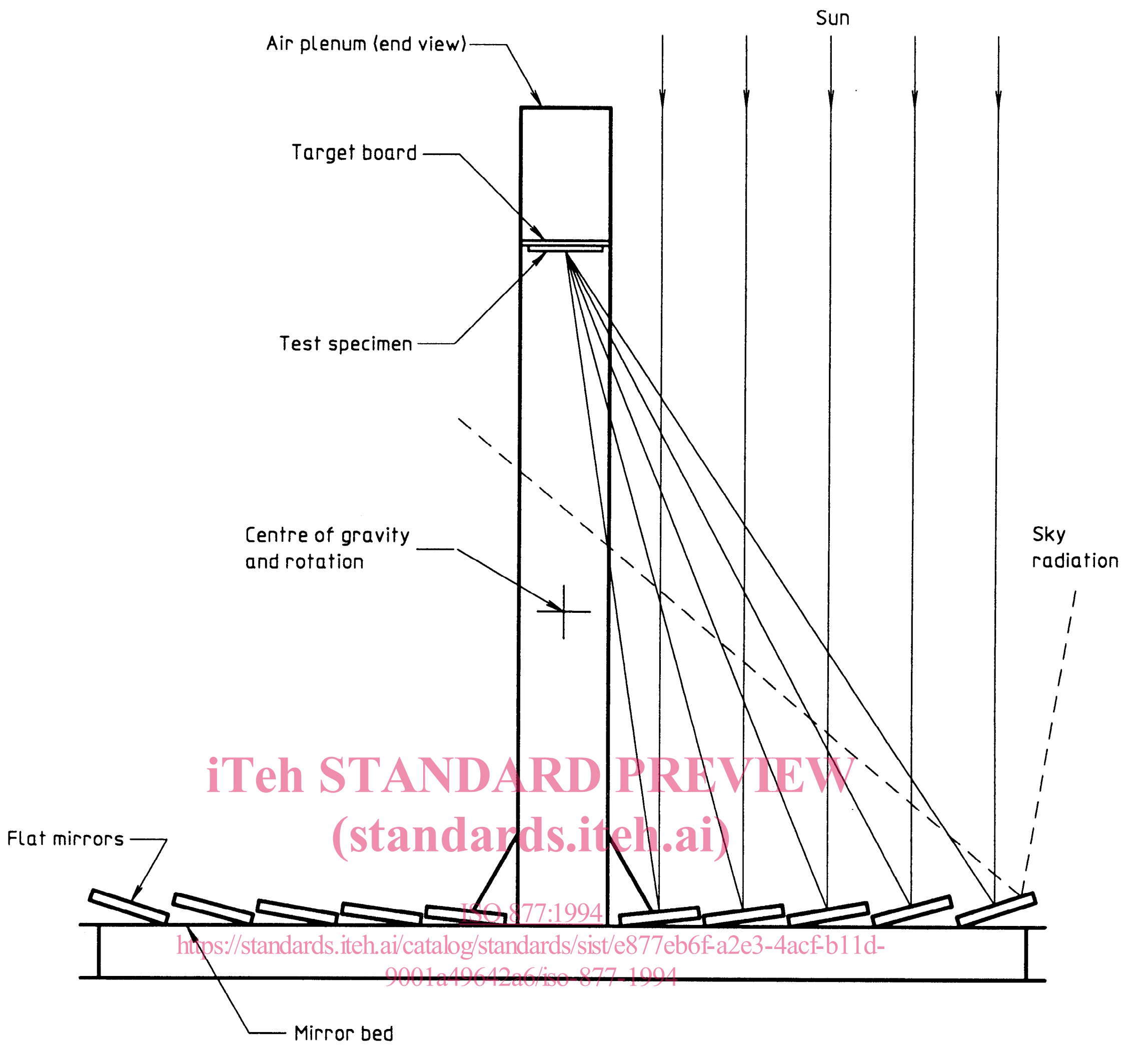
A	Air plenum
B	Air blower
C	Rotor assembly
D	Turntable assembly
E	A-frame assembly
F	Mirror
G	Gear box, elev drive
H	Control box
I	Gear box, azimuth drive
J	Air flow switch
K	Water spray nozzle
L	Clutch disc, elev drive
M	Solar cells/shadow hat
N	Sample protection door
O	Door release mechanism
P	Air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

a) Schematic of machine



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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 de-