International Standard 4892

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Plastics — Methods of exposure to laboratory light sources

Plastiques — Méthodes d'exposition à des sources lumineuses en laboratoire

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

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It has been approved by the member bodies of the following countries :

Australia	Greece	Romania
Austria	Hungary	South Africa, Rep. of
Belgium	Ireland	Spain
Brazil	Israel	Sweden
Bulgaria	Italy	Switzerland
Canada	Japan	Turkey
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Finland	Netherlands	USSR
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Plastics — Methods of exposure to laboratory light sources

MODIFICATION TO FOREWORD *(Inside front cover)*

The following sentence is to be added at the end of the Foreword :

> "This International Standard cancels and replaces ISO Recommendations R 878-1968 and R 879-1968, of which it constitutes a technical revision."

Plastics — Methods of exposure to laboratory light sources

0 Introduction

The effects of light on the colour and other properties of plastics are of considerable technical and commercial importance. Methods of exposing plastics to natural light are dealt with in ISO 877 and ISO 4607. There is, also, a need to gain information more rapidly by accelerated procedures and for this purpose specific artificial light sources are used. However, experience has shown that many problems arise when trying to correlate the results obtained from testing using artificial light sources with those obtained in natural daylight (see annex A).

For some specific applications it may be possible to use certain fluorescent lamps as light sources. However, there is at present insufficient information on the reliability and repeatability of the results from such exposures to warrant inclusion of this type of apparatus in this International Standard. Investigations into these matters are being undertaken and it is hoped that as a result, fluorescent lamp light sources may be incorporated in a future revision of this International Standard.

Information on fluorescent lamps and their possible use is given in annex D, which may assist interested parties in making their own investigations into the use of such devices.

1 Scope

This International Standard specifies methods for exposing specimens to laboratory light sources in order to assess changes produced by such exposure.

The following types of light source are included :

a) xenon arc lamp;

b) enclosed carbon arc lamp;

c) open-flame carbon arc lamp.

Of the different light sources, the xenon arc is advantageous in that it can, when correctly filtered and maintained, yield a spectrum most closely approximating to that of daylight. The carbon arc sources yield light which is considerably different from daylight and their use is decreasing. However, they have been found useful for some specific purposes and are still in considerable use in some countries; for this reason they have been included in this International Standard.

This International Standard also specifies means of determining radiation dosage.

For the method of determination of changes in properties after exposure, reference is made to ISO 4582.

2 Field of application

Testing with laboratory light sources usually has one of the following purposes :

a) to obtain results by accelerated testing under controlled, less variable conditions to indicate behaviour that would result from prolonged exposure to natural daylight;

b) for control tests on a material of known light resistance to establish that the level of quality of different batches does not vary from a known acceptable control.

NOTE — Guidance concerning the problems of correlation between the effects of exposure to artificial light sources and those obtained after exposure to natural light is given in annex A.

For a), changes in the specimens are determined at each of a number of light exposure stages, to give a sufficiently full picture of the performance throughout exposure. This method is also used, with interpolation if necessary, to find the amount of exposure needed to produce a specified change in the material.

For b), a suitable exposure stage is selected in advance from a knowledge of the expected light resistance of the material, and the change in the specimens is evaluated at this stage only. Alternatively, the exposure stage may be determined at which a defined change in the properties of the exposed test specimens occurs.

3 References

ISO 105, *Textiles — Tests for colour fastness.*

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

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

ISO 295, *Plastics — Compression moulding test specimens of thermosetting materials.*

ISO 877, *Plastics — Determination of resistance to change upon exposure under glass to daylight.*

ISO 2557, *Plastics — Amorphous thermoplastic moulding materials — Preparation of test specimens with a defined level of shrinkage.*

ISO 2579, *Plastics — Instrumental evaluation of colour difference.*[1)]

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

ISO 3167, *Plastics — Preparation and use of multipurpose test specimens.*

ISO 3557, *Plastics — Recommended practice for spectrophotometry and calculation of colour in CEI systems.*[1)]

ISO 3558, *Plastics — Assessment of the colour of near-white or near-colourless materials.*[1)]

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

ISO 4607, *Plastics — Determination of resistance to natural weathering.*

4 Principle

Specimens of the material to be tested are exposed to the light source together with means of assessing the light dosage. These may comprise one or more of the following :

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

4.2 Instrumental means of measuring irradiance and/or integrating this to give the light dosage over a period of time.

5 Apparatus

5.1 Laboratory light sources

5.1.1 General

To improve the correlation with natural sunlight it is necessary that the spectrum of the light source be as near as possible to that of natural sunlight, particularly in the ultra-violet region, because some plastics are very sensitive to the spectral distribution of the radiation. However, the intensity of the radiation will generally be higher than that of natural sunlight because of the need to accelerate the degradation processes in laboratory tests even though correlation with the simulated exposure condition may be weakened (see annex A).

Recommendations for the integrated irradiance and spectral distribution of simulated solar radiation for test purposes in the laboratory are given in CIE* publication No. 20 (TC 22) 1972. The recommendation for the integrated irradiance for testing the deterioration resistance of materials and equipment exposed to natural radiation is

$$1\ \text{kW/m}^2\ (=\ 100\ \text{mW/cm}^2)\ \pm\ 10\ \%$$

The spectral distribution is given in table 2.1 of CIE publication No. 20 (TC 22) 1972 (reproduced herein as annex C). Although this is the present standard, for various reasons it is not practicable to reproduce this radiation level exactly in either spectral distribution or intensity with presently available apparatus.

Three laboratory light sources in current use are included in this International Standard.

5.1.2 Xenon arc lamp

The xenon arc lamp emits radiation in a range which extends from below 270 nm in the ultra-violet through the visible spectrum and into the infra-red. For exposure tests, light from the lamp is filtered to reduce shorter wavelength emissions and also to remove as much of the infra-red as possible, so that radiation reaching specimens exposed to it has a spectral power distribution that closely matches sunlight. The facility may also be available to reduce shorter wavelength energy further so that an alternative spectrum, similar to that of solar

1) At present at the stage of draft.

*) International Commission on Illumination.

radiation as received behind window glass, may be obtained. These two modes of operation are often available on the same equipment, using different filter systems.

The characteristics of xenon arcs and filters are subject to changes in use due to ageing, and they shall be replaced at appropriate intervals. Further, they are subject to changes due to the accumulation of dirt, and they shall be cleaned at appropriate intervals as agreed between the interested parties.

The irradiance at the test specimen face in the wavelength range 300 to 890 nm shall normally be 1 000 ± 200 W/m². If, exceptionally, other intensities are used, this shall be stated in the test report. Irradiance below 300 nm shall not exceed 1 W/m². The irradiance shall not vary by more than ± 10 % over the whole test specimen area.

5.1.3 Enclosed carbon arc lamp

The lamp comprises an arc formed between pure carbon rod electrodes, solid at one pole and cored at the other, and has automatic carbon feed.

NOTE — The carbon rods in normal usage need changing about every 24 h, but rods of longer life which need changing after 48 h are now available and thus facilitate ease of running over week-ends and minimize the dark periods necessitated by the changing of carbons.

The arc is enclosed in a globe made of heat-resistant glass transmitting less than 1 % light at 275 nm and shorter wavelengths, and approximately 90 % from 370 nm throughout the visible spectrum.

The globe fits securely; it is clean and free from chips or cracks and it is so maintained at each change of electrodes. The characteristics of the glass filter are subject to changes in use due to ageing, and the globes shall be discarded at appropriate intervals as agreed between the interested parties and immediately when any noticeable discoloration or cloudiness (as compared with an unused globe) occurs.

It is useful to provide a means to minimize the formation of the deposits of ash from the burnt carbon on the globe. One such device uses a permanent magnet, suitably positioned at the top of the globe, which collects most of the ash.

The irradiance at the test specimen face in the wavelength range 300 to 750 nm shall normally not exceed 500 W/m². If, exceptionally, higher intensities are used, this shall be stated in the test report. Irradiance below 300 nm shall not exceed 1 W/m².

5.1.4 Open-flame carbon arc lamp

The lamp comprises an arc formed in free air between carbon rod electrodes, of the copper-coated impregnated core type. The lamp has automatic carbon feed.

NOTE — The carbon rods in normal usage need changing about every 24 h, but rods of longer life which need changing after 60 h are now available and thus facilitate ease of running tests over week-ends and minimize the dark periods necessitated by the changing of carbons.

Light reaching the specimens passes through a heat-resistant glass filter with transmission of less than 1 % at 255 nm and with approximately 90 % transmission from 360 nm throughout the visible spectrum. The characteristics of the glass filters are subject to changes in use due to ageing and formation of deposits, and they shall be replaced at appropriate intervals as agreed between the interested parties.

The irradiance at the test specimen face in the wavelength range 300 to 750 nm shall normally not exceed 600 W/m². If, exceptionally, higher intensities are used, this shall be stated in the test report. Irradiance below 300 nm shall not exceed 2 W/m².

5.2 Test enclosure

The enclosure contains a cylindrical frame carrying specimen holders, with provision for passing air over the specimens for control of temperature. If the lamps lead to the production of significant amounts of ozone, it is essential to ensure that this does not come into contact with the test specimens by venting the cooling air outside the building.

NOTE — Care should also be taken to protect laboratory staff from the effects of ozone.

The lamp is so placed that the amount of radiation received by the specimens does not vary more than ± 10 % over the entire area in which the specimens are exposed.

To reduce the effect of any eccentricity in the lamp, or when more than one lamp is used in a single enclosure to increase the amount of radiation, the radiation distribution shall be improved by rotating the frame carrying the specimens around the light source and, if necessary, by periodically changing the position of each specimen vertically.

The specimen holders may rotate on their own axes as well as rotating with the frame, thus exposing to the direct radiation of the light source the side of the specimen holder that was previously in the dark. This method helps to maintain a low black panel temperature on the specimens. Alternatively, dark cycles may be produced by cycling the source on and off. If either of these cycles is used, it shall be fully reported.

5.3 Black panel thermometer, to indicate the test temperature (see note 1).

It consists of a blackened absorbing metal plate that approximates the absorption characteristics of a "black body". The plate shall be at least 1 mm thick and of a size to fit the specimen holders. The temperature of the plate is indicated by a suitable thermometer or thermocouple making good thermal contact.

The black panel thermometer is mounted in a specimen holder with the blackened metal side facing the lamp, and readings are taken after sufficient time for the temperature to become steady.

The black panel temperature is controlled by adjustment of the cooling air circulation (see note 2).

The temperature used shall be as agreed by the interested parties according to the nature of the material and its proposed application, and should preferably be one of the following :

45 ± 3 °C
55 ± 3 °C
63 ± 3 °C

For special purposes, higher temperatures may be desirable, but this will increase the tendency for thermal degradation effect to influence the test results.

NOTES

1 The black panel temperature represents the highest specimen surface temperature likely to be achieved. Specimens of lighter colours, and thinner specimens where some cooling from the back occurs, will have lower temperature.

2 This can conveniently be achieved by means of a thermostat whose sensor is placed in the test enclosure. When it is necessary to minimize the variation of temperature to within ± 1 °C, care must be taken to place the sensor in the best position so that it responds to the temperature variations as fast as possible.

5.4 Relative humidity

The relative humidity of the air passing over the test specimens may be controlled at an agreed value if required, and measured by wet-and-dry bulb thermometers or other suitable instruments inserted into the test space and shielded from the lamp radiation. The relative humidity used shall be as agreed by the interested parties and should preferably be one of the following :

35 ± 5 %
50 ± 5 %
65 ± 5 %
90 ± 5 %

NOTE — Owing to the varying temperatures of test specimens having different colours and thicknesses, the moisture content of the air very close to the specimens cannot be taken to correspond to the relative humidity of the air as measured.

5.5 Spray

If agreed between the interested parties, specimens may be sprayed with distilled or deionized water intermittently under specified conditions. Preferably, the solids content and the pH of the water used should be reported. If spray is used, the maximum temperature requirements of 5.3 apply to the end of the dry period.

The spray cycle used shall be as agreed between the interested parties and shall preferably be one of the time cycles given in table 1, already in established use in some countries.

The spray system shall be made from inert materials which do not contaminate the water employed.

Table 1 — Spray cycles

Time of spraying	Dry interval between spraying
min	min
3	17
5	25
12	48
18	102

5.6 Specimen holders

Specimen holders may be in the form of an open frame, leaving the back of the specimen exposed, or they may provide the specimen with a solid backing. They shall be made from inert materials that will not affect the test results, for example aluminium or stainless steel. Brass, steel or copper shall not be used in the vicinity of the test specimens.

The backing used may affect the results, particularly with transparent specimens, and shall be agreed between the interested parties.

5.7 Means of determining radiation dosage

One of the following is required, depending upon the method selected.

5.7.1 Blue dyed wool standards No. 1 to No. 7, as specified in ISO 105, section B01, and the grey scale for assessing change in colour, as specified in ISO 105, section A02 (see also annex B, clauses B.3 and B.4).

5.7.2 Other physical standards agreed between the interested parties.

NOTE — Work is currently in progress within ISO/TC 61 concerning standards based on poly(methyl methacrylate) and polyethylene.

5.7.3 Instrumental means of measuring light dosage, comprising a photo-receptor system mounted beside the test specimens and connected to an integrating device to indicate the total energy received over a period.

The photo-receptor system shall be sensitive to radiation received over a solid angle similar to that over which radiation is received by the test specimens, and the spectral response of the photo-receptor system shall be as agreed between the interested parties and shall correspond to the spectral regions that produce changes in the test specimens.

The instrument shall be calibrated in suitable radiometric units, such as joules per square metre, for the specific light source. The calibration shall not be affected by variations in light intensity or temperature.

NOTES

1 Research is proceeding in certain countries on the spectral response required to give the best estimate of light dosage in relation to its effect on plastics. It is known that for some materials the short-wave end of the ultra-violet range is particularly important, but it is not possible at present to recommend a particular spectral response.

2 Prolonged exposure of an instrumental measuring device to radiation will probably affect its reliability.

3 For the physical standards of light dosage (blue wool or coloured plastics standards), the spectral response is determined by the choice of the particular dyestuffs used.

5.8 Apparatus to assess changes in properties : the necessary apparatus required by the International Standards relating to the determination of the properties chosen for monitoring (see also ISO 4582).

6 Test specimens

6.1 Test specimens for determination of changes of colour

Use rectangular strips the surface dimensions of which are at least 15 mm and compatible with the particular apparatus used for the exposure (see clause 5).

At least two specimens shall be tested. It may be necessary to use more for products where the colour is not uniform or the sensitivity to exposure is irregular. A further test specimen shall be stored in the dark and shall constitute the reference standard for assessment of colour change.

NOTE — It is known that some materials will change colour during storage in the dark. When it is possible to evaluate this alteration for the period considered, for example by instrumental measurements, the change in colour of the reference test specimen shall be reported.

6.2 Test specimens for determination of changes in other properties

It is recommended that test specimens be prepared in advance, the number and dimensions of which are compatible with

a) the particular apparatus used for the exposure (see clause 5);

b) the requirements of the International Standards relating to the determination of the properties chosen for monitoring;

c) the required number of exposure stages;

d) the determination of the original values and further control tests at each exposure stage.

It may be necessary to determine behaviour after several exposure stages, or at only one stage (see clause 2).

If the material to be tested is an extrusion or moulding compound in granules or in chips or in another 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 this sheet. The method used shall be agreed between the interested parties and shall be closely related to the method by which the material is to be processed by the user.

NOTE — Attention is drawn to ISO 293, ISO 294, ISO 295, ISO 2557 and ISO 3167.

If the material to be tested is in the form of an extrusion, moulding, sheet, etc., test specimens may be prepared from these products 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 composites, which may delaminate at the edges, shall be exposed in sheet form and test specimens shall be cut after exposure. In no circumstances shall any of the material be removed from the front exposed face during the course of specimen preparation.

The results obtained from test specimens prepared before exposure may differ from those obtained from test specimens cut from an exposed sheet owing to the possible effects of the exposure on the cut edges.

NOTE — Attention is drawn to ISO 2818.

Test specimens shall always be conditioned after machining, but in some circumstances it may be necessary to precondition the sheets prior to machining to facilitate specimen preparation.

7 Procedure

7.1 Mounting of test specimens

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

Expose the blue dyed wool standards or other physical standards in a similar manner to the test specimens for determination of exposure stage.

Alternatively, suitably mount instrumental means of measuring light dosage so that the photo-receptor measures the irradiation level at the test specimen location (but see note 2 to 5.7.3).

If water spray is used (see 5.5), protect blue dyed wool standards from the water by a suitable transparent cover, for example silica or poly(methyl methacrylate) sheet containing no ultra-violet absorber. It is advisable to first check that the covers are transparent to the incident light by running a comparison test on covered and uncovered standards under dry conditions.

If desired, in the case of specimens used to determine change in colour and appearance, a portion of each test specimen may be shielded by an opaque cover throughout the test. This gives an unexposed area adjacent to the exposed area for comparison. This is useful for checking the progress of exposure, but the data reported shall always be based on the contrast with the unexposed comparison specimens.

It is desirable to vary the position of the specimens in the apparatus from time to time to reduce any local inequalities of exposure.

7.2 Measurement of radiation dosage

Historically, the blue dyed wool standards developed for textile testing have been used in the testing of plastics. It is well recognized that this method has severe limitations, particularly when consecutive exposures of standard No. 7 are used. Consecutive exposure of standard No. 7 should only be employed when no better alternative is available.

NOTE — Measurements of radiation dosage may only be compared for like light sources. Misleading conclusions may result if measurements of unlike sources, for example artificial light and natural light or different types of artificial light, are compared.

7.2.1 Using blue dyed wool standards (ISO 105)

Details are given in annex B.

7.2.2 Using other physical standards

As appropriate to the standard and as agreed between the interested parties.

7.2.3 Using instrumental means

When using instrumental determination of radiation dosage, the exposure stage is given in terms of the amount of energy received by the instrument and test specimens.

7.3 Determination of changes after exposure

These shall be determined as specified in ISO 4582.

8 Test report

The test report shall include the following particulars :

a) reference to this International Standard;

b) complete identification of the materials tested and the method of preparation of the test specimens;

c) type and details of the lamp used and, if possible, the irradiance at the surface of the test specimens;

d) mode of operation of lamp and filter system used;

e) mean value and variation in black panel temperature and, if recorded, mean value and variation of relative humidity of the air passing over the specimens;

f) conditions of water spray, if used;

g) nature of backing, if used;

h) the exposure stages used and the method for determining light dosage (if instrumental methods are used, the exposure stage should be defined in terms of joules per square metre);

j) presentation of results as required by ISO 4582.

Annex A

Correlation of the effects of exposure to artificial light sources and exposure to natural daylight

(This annex forms part of the Standard.)

A.1 General

The quality and intensity of solar radiation at the earth's surface vary with climate, location and time, but the average effect of a whole year's weathering, at a particular location, normally differs little from one year to another.

In the case of natural weathering there are factors other than solar radiation that affect the ageing process, such as temperature, temperature cycling, humidity, etc.

Experience has shown that correlation between results of testing with laboratory light sources, and in natural daylight at a particular locality, is imprecise and can only be assumed for a specific type and formulation of a material and for particular properties, where such correlation has been demonstrated from past experience.

With different types of plastics, the correlation factor for the same laboratory source may be different.

A.2 Factors tending to decrease the degree of correlation

A.2.1 Use of ultra-violet radiation of wavelengths shorter than those occurring in natural exposure.

Such radiation, being of high quantum energy, may produce effects that happen only slowly or not at all in natural exposure.

The xenon arc, when appropriately filtered, produces radiation with a spectral energy distribution similar to that of average sunlight. The enclosed carbon arc permits controlled evaluation of the resistance of plastics to radiation rich in ultra-violet energy in the wavelength region occurring in sunlight. The radiation from the open-flame carbon arc contains considerable amounts of ultra-violet light of wavelength shorter than that found in natural daylight. Fluorescent tubes can be selected to have a spectral output corresponding to that of the ultra-violet region in sunlight.

A.2.2 Use of high specimen temperatures, particularly with materials which can readily undergo changes from thermal effects alone.

In such cases the results may indicate the effects of heating rather than those of light exposure.

The xenon arc lamp produces a large proportion of infra-red radiation that should be reduced by filters. Efficient cooling of the specimens is necessary to guard against overheating. The enclosed carbon arc lamp source produces a certain amount of infra-red radiation, and care should be taken that this does not cause problems in overheating of specimens. The open-flame carbon arc lamp produces a relatively large amount of infra-red radiation, and air should be passed through the exposure chamber to prevent an excessive rise in temperature. Fluorescent tube sources produce little infra-red radiation, and there is generally no problem with overheating of specimens.

A.2.3 Use of a spectral distribution of radiation that differs widely from that of daylight.

In this respect the correctly filtered xenon arc is a reasonably satisfactory source for laboratory testing. The enclosed carbon arc and the open-flame carbon arc both give excess radiation in the region between 350 and 420 nm, relative to sunlight. Fluorescent tube sources normally are deficient in visible radiation relative to ultra-violet radiation as compared with sunlight.

A.2.4 Use of a very high light flux.

A.2.5 Factors that accelerate the rate of change in the specimens.

In general, factors that accelerate the rate of change in the specimens also tend to reduce the degree of correlation with natural daylight.

It may be possible to establish a correlation between the laboratory light dosage and the natural dosage to give similar effects with particular restricted types of materials, but with other types the correlation for the same laboratory source may be different.

A.3 Control testing

In control testing, the above factors also apply, but the situation is often more favourable than when attempting to forecast the behaviour of a material in natural light, for the following reasons :

a) The behaviour of the material will already be well known.

b) The object of the test is restricted to showing whether or not the light resistance of the test specimen is less than that of the standard product.

c) A sample of the product having reduced light resistance in daylight, due to some error of formulation or manufacture, is likely also to give poorer results under laboratory sources and this may be sufficient for a control test without needing close correlation.

d) Reproducibility should be improved when testing is carried out with the same apparatus, using the same cycle and the same duration of exposure.

Nevertheless, variation in ultra-violet spectral distribution, and high specimen temperatures in particular, may give completely misleading results even in control testing, and should not be used except in cases where a satisfactory correlation has been established for the particular product concerned.

It is recommended that for control testing the method should be closely specified and results reported as required by this International Standard (see clause 8).

Annex B

Use of blue dyed wool standards to measure light dosage

(This annex forms part of the Standard.)

B.1 General

The blue dyed wool standards were developed for textile testing and historically have been used with plastics because of their availability. Because, in general, there is a need to expose plastics for longer periods than those normally used for testing the light-fastness of textiles, the consecutive use of the No. 7 standard has been introduced.

Because of the known differences between the spectral sensitivity of the different blue dyes and the significant differences between the spectral energy distribution of the various artificial light sources, there is considerable doubt about the use of the blue dyed wool standards for this purpose. However, their ready availability and the fund of data based on their use ensure that there is still a demand for their application in exposure tests on plastics.

B.2 Procedure

Expose a set of blue dyed wool standards (ISO 105) comprising one strip each from No. 1 to No. 7 simultaneously.

Use the standards to determine the stages of radiation dosage (exposure stages) in accordance with table 2 by comparing the difference in colour between the exposed and unexposed blue standards with the contrast No. 4 on the grey scale as specified in ISO 105, clause A02. Thus, stage 1/1 is reached when standard 1 gives a contrast equal to No. 4 on the grey scale; 2/1 when standard 2 shows similar contrast, and in the same manner to stage 7/1 showing a contrast of 4 on the grey scale.

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

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

At stage 7/1, discard the blue standards, mount a second fresh standard 7 and continue exposure until this second standard 7 shows a contrast with the unexposed standard 7 equal to No. 4 on the grey scale. This stage is designated 7/2.

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

Repeat this procedure as often as required, giving stages 7/4 to 7/*n* (but see sub-clause 7.2).

Table 2 — Exposure stages

Stage	Description
1/1	Blue standard 1 to grey scale contrast 4
2/1	Blue standard 2 to grey scale contrast 4
3/1	Blue standard 3 to grey scale contrast 4
4/1	Blue standard 4 to grey scale contrast 4
5/1	Blue standard 5 to grey scale contrast 4
6/1	Blue standard 6 to grey scale contrast 4
7/1	First blue standard 7 to grey scale contrast 4
7/2	Second blue standard 7 to grey scale contrast 4
7/*n*	n^{th} blue standard 7 to grey scale contrast 4

B.3 Supply of blue dyed wool standards

Sets of the blue dyed wool standards can be obtained from the following organizations :

British Standards Institution
10 Blackfriars Street
MANCHESTER M3 5DT
England

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

American Society for Testing and Materials
1916 Race Street
PHILADELPHIA
Pennsylvania 19103
U.S.A.

Eidgenössische 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

B.4 Supply of grey scale

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

British Standards Institution
10 Blackfriars Street
MANCHESTER M3 5DT
England

The Society of Dyers and Colourists
19 Piccadilly
BRADFORD 1
Yorkshire
England

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

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

Eidgenössische Materialprüfungs- und
Versuchsanstalt
Unterstrasse 11
ST GALLEN
Suisse

Japanese Standards Association
1-24 Akasaka 4
Minatoku
TOKYO
Japan

American Association of Textile Chemists and
Colorists
Research Triangle Park
NORTH CAROLINA 27709
USA

Annex C

Spectral distribution of simulated solar radiation

Reproduced from C.I.E. Publication No. 20 (TC 22) 1972, (table 2.1)

(This annex forms part of the Standard.)

Irradiance of the total radiation in spectral bands in W/m² and in percentages of E_T = 1,12 kW/m² (perpendicular incidence)

Range	Wavelength	Irradiance		Percentages of total radiation	
	µm	W/m²		%	
0	< 0,28	0		0	
	0,28 to 0,32*	5		0,5	
1	0,32 to 0,36	27	68	2,4	6,1
	0,36 to 0,40	36		3,2	
	0,40 to 0,44	56		5,0	
	0,44 to 0,48	73		6,5	
	0,48 to 0,52	71		6,3	
	0,52 to 0,56	65		5,8	
	0,56 to 0,60	60		5,4	
2	0,60 to 0,64	61	580	5,5	51,8
	0,64 to 0,68	55		4,9	
	0,68 to 0,72	52		4,6	
	0,72 to 0,76	46		4,1	
	0,76 to 0,80	41		3,7	
	0,80 to 1,0	156		13,9	
3	1,0 to 1,2	108	329	9,7	29,4
	1,2 to 1,4	65		5,8	
	1,4 to 1,6	44		3,9	
	1,6 to 1,8	29		2,6	
4	1,8 to 2,0	20	143	1,8	12,7
	2,0 to 2,5	35		3,1	
	2,5 to 3,0	15		1,3	
5	> 3,0**	—		—	
0 to 5	Σ	1 120	1 120	100	100

* Radiation below 0,3 µm does not reach the surface of the earth.

** Radiation above 3,0 µm is negligible.

Annex D

Information concerning exposure to the light from fluorescent tube lamps

(This annex forms part of the Standard.)

D.1 General

The use of fluorescent tube lamps as a light source for ageing plastics artificially may be attractive for the following reasons :

a) Cheapness.

b) They can be selected to yield a spectral output in the ultra-violet region corresponding to that of sunlight.

c) Spectral distribution changes very little with use and in operation it is easy to maintain substantially constant irradiance.

d) They produce little infra-red radiation and there is generally no problem with overheating of test specimens.

e) They afford a means of exposing test specimens of large surface area, for example when studying changes in mechanical properties involving a large number of test specimens.

f) When exposing articles rather than test specimens, the array of lamps can be arranged around the article.

This type of exposure is particularly attractive for investigating purely photo-chemical processes requiring a precise knowledge of the experimental parameters (for example kinetics of photodegradation, comparison of stabilizing systems' efficiency).

The nature and arrangement of the light source is given in D.2. The other experimental details such as the nature of the test enclosure, determination of radiation dosage and handling of test specimens should be as specified in this International Standard.

D.2 Light source

Generally, the light source should consist of a geometric array, often in cylindrical form, comprising a number of fluorescent lamps of suitable length and intensity depending on the exposed area of the test specimens. There are lamps about 600 mm long having a unit power of 20 W, and others about 1 200 mm long, having a unit power of 40 W. For particular applications, the array could be in the form of a wall panel.

Several types of fluorescent lamp may be used, each type giving light of a different spectral distribution. A list, not necessarily exhaustive, is given in table 3.

The array may be composed solely of one type of lamp, or a combination of types may be used such that the resulting total spectral energy distribution, particularly in the ultra-violet range, largely corresponds to that of sunlight.

D.2.1 Combination of lamps

Combinations of lamps, based for example on lamps of type A, B and C (see figures 1, 2 and 3), may be used. These combinations are suitable only when used in a cylindrical array and in conjunction with test enclosures which rotate the frame carrying the test specimens around the light source in order to ensure more even distribution of the radiation (see 5.2).

Alternatively, the lamp array itself may rotate while the frame remains stationary. This arrangement may be found more convenient if one side of a bulky specimen is irradiated or if specimens are to be exposed at several different distances from the lamps.

D.2.1.1 Combination I : lamp A alternating with lamp B in equal numbers around the array. This combination of lamps produces more radiation of shorter wavelength than in sunlight and is likely to be more rapid and severe in its effect than combination II.

D.2.1.2 Combination II : one lamp A for every three of lamp C, set symmetrically around the array. This combination is likely to be slower in its effects than combination I, but provides better correlation with the ultra-violet radiation in sunlight.

D.2.2 Single-type source

When only one type of lamp is used, any of the types of fluorescent tube A, B, C, D or E can be employed, but lamps of type D (see figure 4), the so-called actinic or superactinic lamps, may be preferred in connection with various mounting possibilities. The use of such lamps makes it possible to adapt the geometry of the system to the number, the size and the overall dimensions of the test specimens, provided, however, that the lamp-specimen distance, which determines the radiation energy level, is suitable.

NOTE — ANSI/ASTM G 53-77 Standard, *Recommended practice for operating light- and water-exposure apparatus (fluorescent-U.V. condensation type) for exposure of nonmetallic materials*, is a widely used national standard utilizing type E lamps.

It is better to use one type of fluorescent lamp when the aim is to expose an object or a large sheet, since this lessens the need for relative movements or changes in position between the lamps and the surface to be exposed, in order to achieve uniform irradiance across the surface.

D.3 Characteristics of fluorescent lamps

See table 3.

Table 3 — Characteristics of fluorescent lamps

Lamp type	Power W	Output peak nm	Spectral distribution
A	20	317	as figure 1
B	20	355	as figure 2
C	20	374	as figure 3
D	20 or 40	365	as figure 4
E	40	313	as figure 5

NOTE — Radiation from these lamps is produced by re-emission at longer wavelengths of the light from a low-pressure mercury vapour discharge source, by a fluorescent coating on the inner surface to the lamps. The broad spectral distribution illustrated in figures 1 to 5 corresponds to the output from the fluorescent coating which either converts or filters most of the original mercury light. Certain lines from the mercury spectrum show through the fluorescent coating, and although their contribution to the total output energy is negligible, they may affect the observed colour of the light. The lines having the most significant effect occur at 313, 365, 405, 435 and 550 nm. Their intensity depends largely on the effectiveness of the fluorescent coating as a filter.

The data in figures 1 to 5 give the light energy intensity at each wavelength relative to the peak intensity. The data cannot be used to compare absolute emission intensities of different lamps.

D.3.1 In principle, the distribution of spectral energies changes only little in use. However, due to ageing of the lamp, the intensity declines slowly. For example, for lamp D, after a pre-ageing period of about 100 h, the change in the energy flux is less than 5 % per 1 000 h, the service life of tubes being about 4 000 to 5 000 h. Therefore, lamps should be replaced sequentially in groups at regular intervals during operation, with no more than 2 000 h run for each lamp (this time may be varied in accordance with the original characteristics of the type of fluorescent lamp). Thus, the ultra-violet source always comprises a range from new to aged lamp so that problems of decline in lamp output are minimized, and a fairly constant total output is obtained.

D.3.2 The intensity of radiation emitted does not vary more than 5 % over 2/3 of the length taken at the centre of the tubes. It is recommended that the zones close to the electrodes, where the flux may be twice the value measured in the central part, should not be used.

D.3.3 The irradiance at the test specimen face in the wavelength range 280 to 400 nm should normally not exceed 50 W/m^2.

The intensities used should be reported. There should be no irradiance below 270 nm.