INTERNATIONAL STANDARD

ISO 13468-1

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Plastics — Determination of the total luminous transmittance of transparent materials —

Part 1:
Single-beam instrument

Plastiques — Détermination du facteur de transmission du flux lumineux total des matériaux transparents —

Partie 1: Instrument à faisceau unique

Reference number
ISO 13468-1:1996(E)

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.

International Standard ISO 13468-1 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 11, *Products*.

ISO 13468 consists of the following parts, under the general title *Plastics — Determination of the total luminous transmittance of transparent materials*:

— *Part 1: Single-beam instrument*

— *Part 2: Double-beam instrument*

Annex A of this part of ISO 13468 is for information only.

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Plastics — Determination of the total luminous transmittance of transparent materials —

Part 1:
Single-beam instrument

1 Scope

This part of ISO 13468 covers the determination of the total luminous transmittance, in the visible region of the spectrum, of planar transparent and substantially colourless plastics, using a single-beam photometer with a specified CIE standard light source and photodetector. This part of ISO 13468 cannot be used for plastics which contain fluorescent materials.

This part of ISO 13468 is applicable to transparent moulding materials, films and sheets not exceeding 10 mm in thickness.

NOTES

1 Total luminous transmittance can also be determined by a double-beam spectrophotometer as in part 2 of the standard. Part 1, however, provides a simple but precise, practical and quick determination. This method is suitable for use not only for analytical purposes but also for quality control.

2 Substantially colourless plastics include those which are faintly tinted.

3 Specimens more than 10 mm thick may be measured provided the instrument can accommodate them, but the results may not be comparable with those obtained using specimens less than 10 mm thick.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 13468. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 13468 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 291:1977, *Plastics — Standard atmospheres for conditioning and testing.*

ISO 5725-1:1994, *Accuracy (trueness and precision) of measurement methods and results — Part 1: General principles and definitions.*

ISO 5725-2:1994, *Accuracy (trueness and precision) of measurement methods and results — Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method.*

ISO 5725-3:1994, *Accuracy (trueness and precision) of measurement methods and results — Part 3: Intermediate measures of the precision of a standard measurement method.*

ISO 7724-2:1984, *Paints and varnishes — Colorimetry — Part 2: Colour measurement.*

ISO/CIE 10526:1991, *CIE standard colorimetric illuminants.*

ISO/CIE 10527:1991, *CIE standard colorimetric observers.*

CIE Publication No. 17.4:1987, *CIE International lighting vocabulary* [also published as IEC 50(845):1987, *International electrotechnical vocabulary — Chapter 845: Lighting*].

3 Definitions

For the purposes of this part of ISO 13468, the definitions given in CIE Publication No. 17.4 for *transparent medium*, *transmittance*, *regular transmittance* and *luminous flux* apply, together with the following:

3.1 transparent plastics: Plastics in which the transmission of light is essentially regular and which have a high transmittance in the visible region of the spectrum.

NOTE 4 Provided their geometrical shape is suitable, objects will be seen distinctly through plastic which is transparent in the visible region.

3.2 total luminous transmittance: The ratio of the transmitted luminous flux to the incident luminous flux when a parallel beam of light passes through a specimen.

4 Apparatus

4.1 The apparatus shall consist of a stabilized light source, an associated optical system, an integrating sphere fitted with ports, and a photometer. Ingress of external light into the integrating sphere shall be prevented. A schematic arrangement of the apparatus is shown in figure 1.

4.2 The light source and/or photodetector shall be fitted with filters so that the output of the combined system corresponds to the CIE standard colorimetric observer as specified in ISO/CIE 10527 and CIE standard illuminant D_{65} as specified in ISO/CIE 10526. The output of the photodectector shall be proportional, to within 1 %, to the incident flux over the flux range used. The spectrophotometric characteristics of the light source and the photodetector shall be kept constant during measurements on specimens. The measurement conditions shall be such that the specimen temperature does not increase while measurements are made.

4.3 The light source shall be combined with an optical system to produce a parallel beam of light; the angle which any ray of this beam makes with the axis of the beam shall not exceed 0,087 rad (5°). The beam shall not be vignetted at either port of the sphere.

The diameter of the beam shall be 0,5 to 0,8 times the diameter of the entrance port of the integrating sphere.

4.4 Using this instrument, the repeatability standard deviation shall be 0,2 % or less. The within-laboratory reproducibility over long time intervals shall not exceed the repeatability by a factor of more than 3.

4.5 The design of the instrument shall be such that it reads zero when the incident flux is zero.

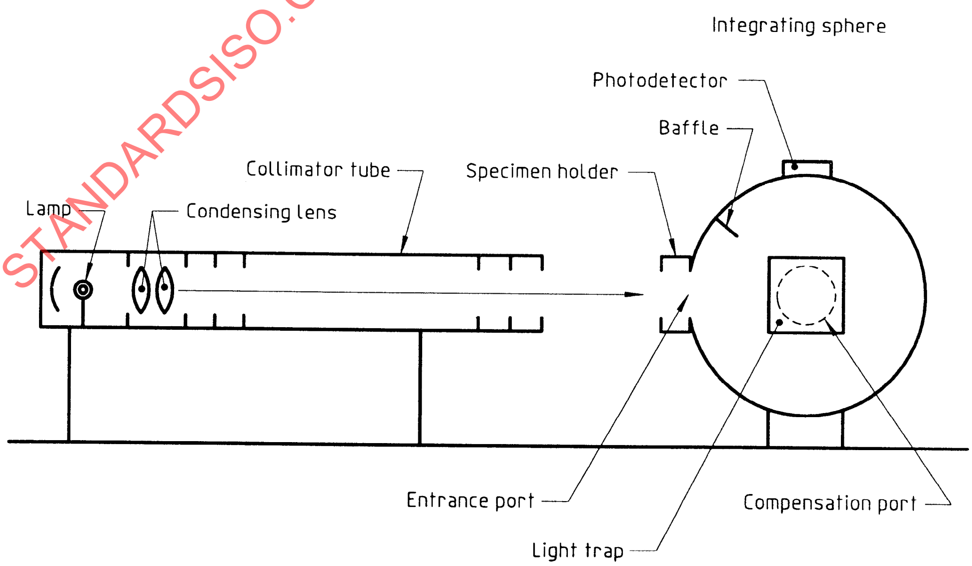

Figure 1 — Schematic arrangement of the apparatus

4.6 The integrating sphere used to collect the transmitted flux may be of any diameter as long as the total port area does not exceed 3,0 % of the internal area of the sphere.

NOTES

5 It is recommended that the diameter of the integrating sphere is not less than 150 mm so that specimens of a reasonable size can be used.

6 When the diameter of the integrating sphere is 150 mm and the diameters of the entrance, compensation and photodetector ports are 30 mm, the ratio of the total port area to the internal area of the sphere is 3,0 %.

4.7 The entrance and compensation ports of the integrating sphere shall be circular and of the same size. The entrance port, compensation port and photodetector port shall not lie on a great circle of the sphere.

4.8 The photodetector shall be fitted with baffles to prevent light falling on it directly from the specimen.

4.9 The surfaces of the interior of the integrating sphere and the baffles shall be of substantially equal luminous reflectance which, determined in accordance with ISO 7724-2, shall be 90 % or more and shall not vary by more than ± 3 %. When direct measurement of the reflectance of the internal surface of an integrating sphere is difficult, the measurement may be carried out instead on a surface prepared from the same material in the same way as the internal surface.

4.10 The light trap shall absorb 95 % or more of the light incident on it.

4.11 The specimen holder shall be such as to hold the specimen rigidly in a plane normal ± 2° to the light beam and as closely as possible to the integrating sphere to ensure that all the light which passes through the specimen, including scattered light, is collected.

The holder shall be designed so that it keeps flexible specimens, such as film, flat.

NOTE 7 It is recommended that thin, flexible film is clamped round the edge in a double-ring-type holder or double-sided adhesive tape is used to stick it to the edge of the holder. The latter method is used for thicker specimens, which cannot be mounted in the double-ring-type holder.

5 Test specimens

5.1 Specimens shall be cut from film, sheet or injection-moulded or compression-moulded mouldings.

5.2 Specimens shall be free of defects, dust, grease, adhesive from protecting materials, scratches and blemishes, and shall be free from visibly distinct internal voids and particles.

5.3 Specimens shall be large enough to cover the entrance port and the compensation port of the integrating sphere.

NOTE 8 For a 150 mm diameter sphere, a disc of 50 mm or 60 mm in diameter or a square with a side of the same length is recommended.

5.4 Three specimens shall be taken from each sample of a given material unless otherwise specified.

6 Conditioning

6.1 Prior to the test, condition the specimens in accordance with ISO 291, at 23 °C ± 2 °C and (50 ± 5) % relative humidity, for a length of time dependent on the specimen thickness and material such that the specimens reach thermal equilibrium.

NOTE 9 16 h is usually sufficient for specimens less than 0,025 mm thick. For thicker material, more than 40 h is recommended.

6.2 Set up the test apparatus in an atmosphere maintained at 23 °C ± 2 °C and (50 ± 5) % relative humidity.

7 Procedure

7.1 Allow the apparatus sufficient time to reach thermal equilibrium before making any measurements.

7.2 Make the two readings described in table 1. The specimen shall be mounted directly on the integrating sphere. The compensation port shall be covered with a light trap.

Adjust the photometer so that the reading τ_1 is 100.

7.3 Repeat the readings τ_1 and τ_2, making additional readings with the specimen in positions selected to determine uniformity.

7.4 Measure the thickness of the specimen in three places to an accuracy of 0,02 mm for sheet and 1 µm for film.

7.5 Carry out the procedure on each of the three specimens in turn.

8 Expression of results

Calculate the total luminous transmittance τ_t, in percent, using the following equation:

$$\tau_t = \frac{\tau_2}{\tau_1} \times 100$$

NOTE 10 Annex A discusses in mathematical terms the effect of the compensation port on the efficiency of the integration sphere.

9 Precision

The precision data were determined from an interlaboratory trial organized and analysed in accordance with ISO 5725-1, 2 and 3 in 1993 involving 8 laboratories and 10 samples (see table 2). No outliers were detected by Grubb's test.

Reproducibility: Precision under conditions in which test results are obtained with the same method on identical test material in different laboratories with different operators using different equipment, and expressed in terms of a reproducibility standard deviation or a reproducibility deviation.

Reproducibility within laboratory: Precision under conditions in which test results are obtained with the same method on identical material in the same laboratory, and with any operator, equipment and/or time of measurement.

NOTE 11 Of the transparent plastics measured in the laboratory trial, the total luminous transmittance obtained for PMMA was the same as the theoretical value and the reproducibility standard deviation was satisfactory.

These results demonstrated that clear-cast PMMA sheet may be used as a reference material for calibration of the apparatus (see note 12 in annex A).

10 Test report

The test report shall include the following information:

a) all details necessary for identification of the test specimens and the source of the specimens;

b) the type of light source used;

c) the thickness of the specimens (the average of the three measurements);

d) the total luminous transmittance τ_t (the average of the three calculated results to the nearest 0,1 %);

Table 1 — Measurements

Reading	Specimen over entrance port	Specimen over compensation port	Light trap over compensation port	Quantity measured
τ_1	No	Yes	Yes	Incident light
τ_2	Yes	No	Yes	Total light transmitted by specimen

Table 2 — Interlaboratory trials data

Transparent plastics			Reproducibility-within-laboratory standard deviation, s_{RW}	Reproducibility standard deviation, s_R
	Nominal thickness	τ_t %	%	%
PMMA	2 mm	92,6	0,05	0,11
PMMA-I	2 mm	92,3	0,06	0,13
PVC	2 mm	87,0	0,04	0,17
PS	2 mm	89,6	0,06	0,15
MABS	2 mm	89,8	0,05	0,10
PC	3 mm	88,3	0,04	0,23
PP	50 µm	92,4	0,06	0,23
PP(SiO_2)	50 µm	92,1	0,04	0,24
PE-HD	30 µm	90,7	0,04	0,23
PVDC	10 µm	90,3	0,08	0,22

Annex A
(informative)

Use of a compensation port to increase the efficiency of an integrating sphere

The efficiency of an integrating sphere depends on the area of the internal surface, the number of ports and the way they are covered.

An error, due to the inefficiency of an integrating sphere when transmittance is measured by a single-beam instrument with an entrance port and an exit port, is inevitable.

A compensation port can be introduced, however, to avoid this error, making it unnecessary to calibrate the instrument with a reference standard.

The total luminous transmittance is calculated as follows (see also figure A.1):

When a specimen is positioned over the compensation port to modify the incident-flux reading, the luminous flux in the integrating sphere Φ_1, which includes the flux reflected back into the sphere by the specimen $\Phi_c \times \rho'$, is given by the equation

$$\Phi_1 = \Phi - (\Phi_e + \Phi_c \times \alpha' + \Phi_c \times \tau') \qquad \ldots (A.1)$$

where

Φ is the total incident luminous flux;

Φ_e is the flux emerging from the entrance port;

Φ_c is the flux emerging from the compensation port;

τ' is the transmittance of the specimen (% transmittance $\tau = \tau' \times 100$);

ρ' is the reflectance of the specimen;

α' is the absorptance of the specimen.

Since $\tau' + \rho' + \alpha' = 1$ and assuming $\Phi_e \approx \Phi_c$

$$\Phi_1 = \Phi - 2\Phi_e + \Phi_e \times \rho' \qquad \ldots (A.2)$$

When a specimen is placed over the entrance port, the luminous flux in the sphere Φ_2 is given by the equation

$$\Phi_2 = \Phi - [(\Phi \times \rho' + \Phi \times \alpha') + (\Phi_e \times \tau' \times \alpha' + \Phi_e \times \tau'^2) + \Phi_c \times \tau']$$
$$= \tau' \times (\Phi - 2\Phi_e + \Phi_e \times \rho') \qquad \ldots (A.3)$$

From equations (A.2) and (A.3)

$$\tau' = \frac{\Phi_2}{\Phi_1} = \frac{\tau}{100}$$

Since the terms common to equations (A.2) and (A.3) cancel out, the efficiency of the integrating sphere has no influence on the luminous transmittance.

NOTE 12 τ_1 can be determined using an integration sphere with no compensation port or using an integration sphere with a compensation port over which a reflectance standard is placed. Since, however, spuriously high readings may be obtained due to the inefficiency of the integrating sphere used, it is necessary to use a standard calibrated using a double-beam spectrophotometer or using the procedure specified in this part of ISO 13468 unless it is proved that the efficiency of the sphere has little effect.

A well prepared clear-cast PMMA sheet 3 mm thick usually gives a theoretical maximum value of 92,6 % of total luminous transmittance.

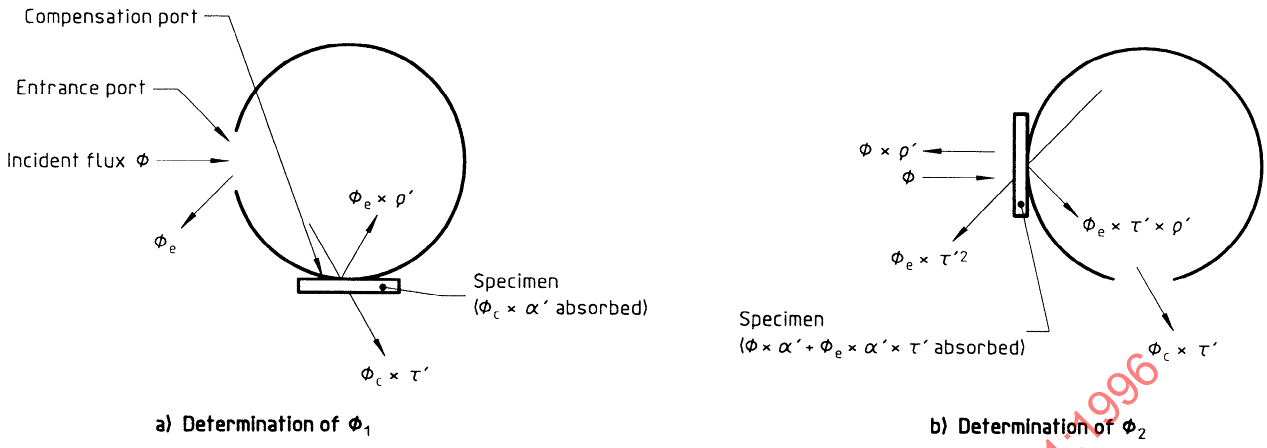

Figure A.1 — Determination of Φ_1 and Φ_2 for the integrating sphere