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Plastics — Determination of total luminous transmittance and reflectance

Plastiques — Détermination de la transmission lumineuse totale et de la réflectance

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Foreword

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This document was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 5, *Physical-chemical properties*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document specifies not only the total luminous transmittance of colourless and transparent plastics that have been covered by ISO 13468-1, but also specifies the transmittance of translucent materials such as opal sheets and the reflectance of materials such as translucent and/or opaque sheets or films.

Plastics — Determination of total luminous transmittance and reflectance

1 Scope

This document specifies the determination of total luminous transmittance and total luminous reflectance on clear, translucent or opaque plastics. Specimen shapes include moulded plaque or discs, films and sheets.

Fluorescent plastics and chromatic colour plastics are not covered by this document.

NOTE The scope of ISO 13468-1 shows that ISO 13468-1 covers planar transparent and substantially colourless plastics. The method in this document provide the way to trap diffused light and covers to measure translucent and opaque plastics.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO/CIE 11664-1, *Colorimetry — Part 1: CIE standard colorimetric observers*

ISO 11664-2, *Colorimetry — Part 2: CIE standard illuminants*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
total luminous transmittance
τ_t
ratio of the transmitted luminous flux to the incident luminous flux when a collimated beam of light passes through a specimen

3.2
total luminous reflectance
ρ_t
ratio of the reflected luminous flux to the incident luminous flux when a collimated beam of light reflected on a specimen

4 Principle

When evaluating the total luminous transmittance of light diffusing material, the scattered light will go toward the edge of the specimen by its light diffusing property. This method intends to collect scattered light from the edge of the specimen toward inside of the integrating sphere. This method is suitable for not only light diffusing materials but also clear materials.

This method can also evaluate total luminous reflectance of clear, translucent or opaque materials.

NOTE When evaluating the specimen which has almost zero absorption of light such as PMMA milky white, sum of total luminous transmittance and total luminous reflectance will be 100 % or around.

5 Apparatus

5.1 The apparatus shall consist of a stabilized light source, an associated optical system, an integrating sphere with ports, and a photometer comprising a photo-detector, signal processor and display unit or recorder (see Figure 1).

5.2 The light source and the photometer shall be used in conjunction with a filter to provide an output corresponding to the photopic standard luminous efficiency $V(\lambda)$ (as defined in ISO/CIE 11664-1), which is identical to the colour-matching function $\bar{y}(\lambda)$ specified in ISO/CIE 11664-1 under CIE standard illuminant D65 as specified in ISO 11664-2. The output of the photodetector shall be proportional to the incident flux, to within 1 % of the incident flux, over the range used. The spectral and photometric characteristics of the light source and photometer shall be kept constant during measurements.

5.3 The total port area (sum of area of the port a, b, c and d) shall not exceed 4,0 % of the internal reflecting area of the sphere. It is desirable for the diameter of integrating sphere to be not less than 150 mm to be big enough for a specimen to pull together the scatter light to the thickness direction of the specimen enough.

5.4 Ports a, b and c shall be centred on the same great circle of the sphere. The angle between line ac and line bc shall be 14 °. Where the line ac means the line which links the centre of port c to the centre of port a, and the line bc means the line which links the centre of port b to the centre of port c. Port d shall not be in the great circle on the sphere with port a, b and c.

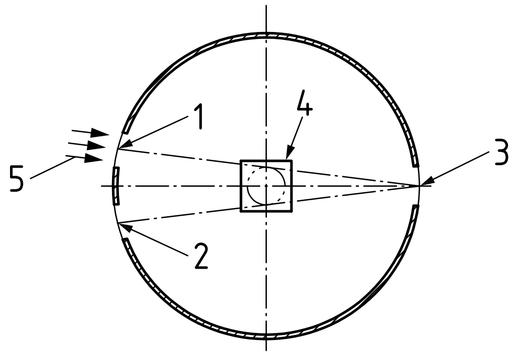
5.5 The light source and its associated optical system shall produce a collimated light beam, no ray of which makes an angle of more than 0,05 rad (3°) with the beam axis. The centre of light flux shall be matched up precisely with the centre of the port a. The cross-section of light flux shall be circular and have sharp image. The diameter of light flux at the port a shall be 0,5 to 0,6 times of specimen, excluding evaluation of reflectance for opaque specimen.

5.6 The white reference which is attached on the port c shall have the even high reflectance for all wavelengths of the visible ray. Barium sulfate and Polytetrafluoroethylene (PTFE) are suitable. The inner wall of the integrating sphere shall have a coating applied that has the same reflectance as a white reference.

5.7 The light trap which is attached on the port b or port c shall absorb light completely when port b or port c doesn't have specimen nor white reference attached.

5.8 When the specimen has higher haze and higher thickness, specimen shape shall be circular and loaded with specimen holder specified on the Figure 3. The inner surface of specimen holder shall have metallic luster. Because the specimen holder can collect scattering light which go toward the edge of the specimen.

5.9 The photometer is attached on the port d. The photometer shall be fitted with baffles to prevent light falling on it directly from the specimen.



Key

1 port a

2 port b

3 port c

4 port d: photometer

5 incident light

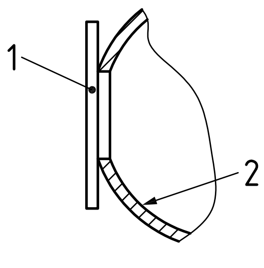
Figure 1 — Apparatus (integrating sphere and ports)

6 Specimen

6.1 Specimen shall be machined from film, sheet, injection moulded article or compression moulded article. Specimen shall be flat. The thickness of specimen shall be original thickness.

6.2 There are two types of the specimen.

6.2.1 For the test without specimen holder, see Figure 2.



Key

1 specimen

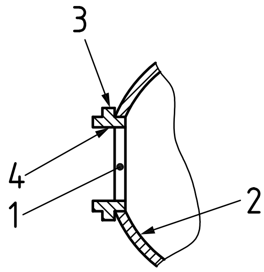
2 inner surface of integrating sphere

Figure 2 — Specimen without specimen holder

Diameter of the specimen shall be the range from 1,7 to 2,0 times of the diameter of the port.

This type covers the specimen which has thinner thickness than 10 % of the diameter of the port, or lower Haze than 30 %.

6.2.2 For the test with specimen holder, see Figure 3.



Key

1 specimen

2 inner surface of integrating sphere

3 specimen holder

4 metallic surface

Figure 3 — Specimen with specimen holder

If the thickness of specimen is thicker than 10 % of the diameter of the port and the haze of the specimen is more than 30 %, specimen shall be set in the specimen holder. Edge of the specimen shall be painted with white paint which does not affect the specimen. The specimen shall be attached tightly to the inner surface of the specimen holder. The scattering light which goes toward the edge will go toward the inside of integrating sphere by the specimen holder and white paint.

6.3 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.

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

7 Conditioning

7.1 Prior to the test, condition the specimens in accordance with ISO 291, at 23 °C ± 2 °C and (50 ± 10) % relative humidity, unless otherwise specified in the applicable material specification, for a length of time dependent on the specimen thickness and material such that the specimens reach thermal equilibrium.

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

7.2 Set up the apparatus in an atmosphere maintained at 23 °C ± 2 °C and (50 ± 10) % relative humidity.

8 Procedure

Total luminous transmittance and reflectance shall be evaluated by the following procedure.

a) Put the white reference on the port b and port c, and adjust the standard incident light (τ_1) as the instrument reading is 100.

b) At the status of a), put the specimen on port a and read the instrument reading as transmitting light flux (τ_2).

c) Then maintain the white reference on the port c, and put the light trap on the port b instead of white reference. Then, read the instrument reading as incident light flux in the light trap (τ_3).

d) Then put the white reference on port b instead of the specimen, and put the specimen on port c instead of white reference. Then, read the instrument reading as reflection light flux (τ_4). On this procedure, specimen shall be covered by light trap or black felt unless otherwise the specimen is opaque.

Table 1 — Conditions of evaluations of luminous transmittance and reflectance

	Port a	Port b	Port c	Port d
Procedure a)	Vacant	White reference	White reference	photometer
Procedure b)	Specimen	White reference	White reference	photometer
Procedure c)	Vacant	Light trap	White reference	photometer
Procedure d)	Vacant	White reference	Specimen with light trap	photometer

9 Calculation procedure

Total luminous reflectance and total luminous transmittance are derived by Formulae (1) and (2).

$$\rho_t = \frac{\tau_4}{\tau_1 - (\tau_1 - \tau_3)\left(1 - \frac{\tau_4}{\tau_1}\right)} \times 100 \quad (1)$$

$$\tau_t = \frac{\tau_2}{2\tau_1 - \tau_3 - (\tau_1 - \tau_3)\left(1 - \frac{\rho_t}{100}\right)} \times 100 \quad (2)$$

where

τ_t is the total luminous transmittance (%);

ρ_t is the total luminous reflectance (%);

τ_1 is the standard incident light;

τ_2 is the transmitting light flux;

τ_3 is the incident light flux in the light trap;

τ_4 is the reflection light flux.

NOTE See Annex B for derivations of Formulae (1) and (2).

10 Precision

Interlaboratory trials based on ISO 5725-2 have not been achieved at the time of publication. Measurements example of total luminous transmittance and total luminous reflectance are shown in Table A.1, Annex A.

11 Expression of results

Total luminous transmittance and total luminous reflectance shall be calculated to a decimal one column, and shall be expressed in accordance with following example.

EXAMPLE τ_t = 60,2 (%), ρ_t = 39,5 (%)

12 Test report

The test report shall include at least the following:

a) a reference to this document, i.e. ISO 26723:2020;

b) name, type, thickness, size and shape of specimens;

c) evaluation type (transmittance, reflectance or both);

d) light incident surface if the surface property or appearance is different between two faces;

e) average evaluation results of three specimens;

f) model number and manufacturer of the equipment;

g) other noticed issue which is out of the scope of this document;

h) evaluation date.

Annex A
(informative)

Measurement examples of total luminous transmittance and total luminous reflectance

A.1 Characteristics of this method

If light diffusing materials, like translucent plastics used for the cover of lighting fixture, are evaluated with ISO 13468-1, evaluating results are often shown lower than actual performance because of efficiency of the integrating sphere or edge-loss (edge-loss: light flux which scatter away from the edge of the specimen.) This document aims to maximize efficiency of the integrating sphere and minimizing edge-loss.

The efficiency of the integrating sphere is better as the opening ratio of the integrating sphere (the ratio of the opening area to the area inside the integrating sphere) is smaller.

Practically, integrating spheres with diameters of 150 mm to 300 mm are available and used.

The magnitude of edge-loss depends on specimen size, specimen thickness, optical properties (transmittance and diffusing property) and the diameter of incident light flux. Edge-loss will be smaller when the specimen size is bigger or specimen thickness is thinner, if the diameter of incident light flux is fixed.

Edge-loss is the phenomenon that incident light scatter from the edge of the specimen through diffusing and transmitting in the inside of the specimen. So, edge-loss will be higher when the specimen has higher transmittance and/or higher diffusibility. Hence, edge-loss will be smaller when the diameter of the incident light flux is smaller, because the distance from incident light to the edge of the specimen will be longer, and the amount of light which reaches the edge of the specimen from incident light will decrease.

A.2 Measurement examples of total luminous transmittance and total luminous reflectance

Table A.1 — Measurement examples of total luminous transmittance and total luminous reflectance

Material	Colour	Thickness mm	Total luminous transmittance τ_t %	Total luminous reflectance ρ_t %	$(\tau_t+\rho_t)$ %
PMMA	Clear	3	92,6	7,4	100,0
PMMA	White	2	9,8	89,4	99,2
PMMA	Milky white (High transmittance A)	5	71,6	26,8	98,4
PMMA	Milky white (High transmittance B)	2	75,2	27,7	102,9
PMMA	Milky white (Middle transmittance A)	5	56,0	42,6	98,6
PMMA	Milky white (Middle transmittance B)	5	41,7	57,7	99,4
PMMA	Milky white (Low transmittance A)	5	22,9	78,1	101,0
PMMA	Milky white (Low transmittance B)	3	30,4	70,9	101,3
PC	Milky white (Low transmittance)	2	34,8	59,5	94,3
PC	Milky white (Low transmittance)	5	30,3	61,0	91,3
PVC	Milky white (Middle transmittance)	2	54,4	44,4	98,8
PVC	Milky white (Middle transmittance)	3	47,9	47,4	95,3
PVC	Milky white (Middle transmittance)	5	41,5	47,1	88,6
Film 1	Translucent	23 [a]	89,8	8,4	98,2
Film 2	Translucent	35 [a]	73,8	24,6	98,4

[a] Expressed in µm.

A.3 Measurement examples of the difference between ISO 13468-1 and this document

Measurement examples of the difference between ISO 13468-1 and this document are shown below Table A.2.

For clear specimen and relatively thinner milky white PMMA (2 mm thickness or around), measurement results are similar between these two methods. But for thicker milky white specimen (6mm thickness or around), difference of measurement results between these two methods tend to increase. Especially, for high transmittance milky white specimen is easy affected from edge-loss, because incident light is easy to reach the edge of the specimen.

Table A.2 — Measurement examples of the difference between ISO 13468-1 and this document

Method	**Material**	**Colour**	**Thickness** mm	**Total luminous transmittance τ_t** %
This document	PMMA	Clear	3	92,6
ISO 13468-1				92,6
This document	PMMA	White	2	9,8
ISO 13468-1				9,8
This document	PMMA	Milky white (High transmittance B)	2	75,2
ISO 13468-1				73,4
This document	PMMA	Milky white (Low transmittance B)	3	30,4
ISO 13468-1				30,1
This document	PMMA	Milky white (High transmittance B)	6	74,7
ISO 13468-1				68,1
This document	PMMA	Milky white (Low transmittance B)	6	18,2
ISO 13468-1				16,5

Annex B
(informative)

Derivation of formulae

Derivations of Formulae (1) and (2) from the results of Table 1 are as follows.

Procedure a): $\tau_1 = \tau_T - \tau_a$

Procedure b): $\tau_2 = \tau_t\,[\,\tau_T - \tau_a\,(1 - R)]$

Procedure c): $\tau_3 = \tau_T - \tau_a - \tau_b$

Procedure d): $\tau_4 = R\,[\,\tau_t - \tau_a - \tau_c\,(1 - R)]$

where

R	ρ_t / 100;
τ_T	is the total incident light flux;
τ_a	is the amount of light escaping from the port a;
τ_b	is the amount of light escaping from the port b;
τ_c	is the amount of light escaping from the port c.

For example, from procedure b):

$\tau_t = \tau_2\,/\,[\tau_T - \tau_a\,(1 - R)]$

where $\tau_T = \tau_1 + \tau_a$

$\tau_t = \tau_2\,/\,[\tau_1 + \tau_a - \tau_a\,(1 - \rho_t/100)]$

where $\tau_{a\,=}\ \tau_{b\,=}\ \tau_1 - \tau_3$

$\tau_t = \tau_2\,/\,[\tau_1 + \tau_1 - \tau_3 - (\tau_1 - \tau_3)\,(1 - \rho_t/100)]$

$=\tau_2\,/\,[2\tau_1 - \tau_3 - (\tau_1 - \tau_3)\,(1 - \rho_t/100)]$

Bibliography

[1] ISO 5725-2, *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*

[2] ISO 13468-1, *Plastics — Determination of the total luminous transmittance of transparent materials — Part 1: Single-beam instrument*

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