

# INTERNATIONAL STANDARD

# ISO 489

Second edition  
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## Plastics — Determination of refractive index

*Plastiques — Détermination de l'indice de réfraction*



Reference number  
ISO 489:1999(E)

<b>Contents</b>	<b>Page</b>
<b>1 Scope</b> .....	<b>1</b>
<b>2 Normative references</b> .....	<b>1</b>
<b>3 Apparatus and materials</b> .....	<b>2</b>
<b>3.1 Method A</b> .....	<b>2</b>
<b>3.2 Method B</b> .....	<b>3</b>
<b>4 Preparation of test specimens</b> .....	<b>3</b>
<b>4.1 Method A</b> .....	<b>3</b>
<b>4.2 Method B</b> .....	<b>4</b>
<b>4.3 Required number of specimens or measurements</b> .....	<b>4</b>
<b>5 Conditioning</b> .....	<b>4</b>
<b>6 Procedure</b> .....	<b>4</b>
<b>6.1 Method A</b> .....	<b>4</b>
<b>6.2 Method B</b> .....	<b>8</b>
<b>7 Precision</b> .....	<b>9</b>
<b>8 Test report</b> .....	<b>10</b>

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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

This second edition cancels and replaces the first edition (ISO 489:1983), of which it constitutes a technical revision.



# Plastics — Determination of refractive index

## 1 Scope

This International Standard specifies two test methods for determining the refractive index of plastics, namely:

- Method A: a refractometric method for measuring the refractive index of moulded parts, cast or extruded sheet or film, by means of a refractometer. It is applicable not only to isotropic transparent, translucent, coloured or opaque materials but also to anisotropic materials. The method is recommended when great accuracy is required. It is not applicable to powdered or granulated material.
- Method B: an immersion method (making use of the Becke line phenomenon) for determining the refractive index of powdered or granulated transparent materials by means of a microscope. Monochromatic light should, in general, be used to avoid dispersion effects. The accuracy of this method is about the same as that of method A. It is applicable to isotropic translucent, coloured materials but is not applicable to opaque materials nor to anisotropic materials.

NOTE 1 The refractive index is a fundamental property which can be used for checking purity and composition, for the identification of materials and for the design of optical parts. The change in refractive index with temperature may give an indication of transition points of materials.

NOTE 2 The accuracy of method B is approximately the same as that of method A when an experienced operator uses the method with extreme care (see clause 7).

## 2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 291:1997, *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*.

### 3 Apparatus and materials

#### 3.1 Method A

**3.1.1 Abbe refractometer**, or any other refractometer that can be shown to give the same results, accurate to 0,001 and capable of measuring the refractive index in the range from 1,300 to 1,700. A temperature-controlling device (3.1.4) shall be provided for the specimens and prisms.

**3.1.2 White or sodium lamp**, used as a source of light.

**3.1.3 Contacting liquid.**

**WARNING — The contacting liquid may present an environmental hazard during handling, storage and disposal. Verify its toxicity and follow national and regional regulations for safe handling and disposal.**

The contacting liquid shall have a refractive index higher than that of the material to be examined and shall not soften, attack or dissolve the plastic material. The liquids listed in Table 1 may be used for the respective plastic materials, but other liquids meeting these requirements may also be used.

**Table 1 — Contacting liquids**

Plastic material	Contacting liquid
Cellulose derivatives	Aniseed oil or 1-bromonaphthalene
Fluorine-containing polymers	1-Bromonaphthalene
Urea-formaldehyde	Aniseed oil or 1-bromonaphthalene
Phenol-formaldehyde	1-Bromonaphthalene
Polyethylenes	1-Bromonaphthalene
Polyamides	1-Bromonaphthalene
Unsaturated polyester	1-Bromonaphthalene
Polyisobutylene	Saturated aqueous solution of zinc chloride made slightly acid
Poly(methyl methacrylate)	Saturated aqueous solution of zinc chloride made slightly acid or 1-bromonaphthalene
Polystyrene	Saturated potassium mercury(II) iodide solution
Styrene-acrylonitrile copolymers	1-Bromonaphthalene
Vinyl resins (vinyl chloride copolymer or plasticized PVC)	1-Bromonaphthalene
Poly(vinyl chloride)	1-Bromonaphthalene
Poly(ethylene terephthalate)	Methylene iodide
Polycarbonate	Methylene iodide
Diethylene glycol bis(allyl carbonate) (CR 39)	Methyl salicylate, aniseed oil or 1-bromonaphthalene
Polyarylate	Saturated aqueous solution of zinc chloride made slightly acid, methylene iodide or 1-bromonaphthalene
Polyetheretherketone	Methylene iodide
Polypropylene	1-Bromonaphthalene

**3.1.4 Temperature-controlled water bath**, capable of maintaining the temperature at  $(23 \pm 0,5)$  °C for the main prism, sub-prism and the specimen.

NOTE The circulating water should be distilled water.

## 3.2 Method B

**3.2.1 Microscope**, having a magnifying power of at least  $\times 200$ , an objective giving approximately  $\times 20$  of primary magnification and a substage condenser fitted with a centering illuminating-aperture diaphragm capable of being stopped down to give a very narrow axial beam.

**3.2.2 Monochromatic light**, usually the sodium D line, having a wavelength of 589 nm, is used as the light source for the microscope.

**3.2.3 Immersion liquids**, with different refractive indices.

**WARNING — The contacting liquid may present an environmental hazard during handling, storage and disposal. Verify its toxicity and follow national and regional regulations for safe handling and disposal.**

The immersion liquids listed in Table 2 with known refractive indices can be used separately and also as mixtures when different increments of accuracy are needed (for example, a difference of 0,002 to within  $\pm 0,001$ ). The immersion liquids shall not soften, attack, dissolve or swell the surface of the particles.

**Table 2 — Immersion liquids**

Immersion liquid	Refractive index at 23 °C $n_D^{23}$
<i>n</i> -Butyl carbonate	1,410
Tri- <i>n</i> -butyl citrate	1,444
<i>n</i> -Butyl phthalate	1,491
1-Bromonaphthalene	1,657
Diiodomethane (methylene iodide)	1,747
Aqueous solution of potassium mercury(II) iodide	1,419 to 1,733 <sup>a</sup>
Silicone oils	1,37 to 1,56 <sup>a</sup>
<sup>a</sup> Useful range for the purpose of the test.	

## 4 Preparation of test specimens

### 4.1 Method A

Cut, from the sample, specimens of such a size as to fit on the face of the fixed half of the refractometer prisms.

The following dimensions are recommended for sheet specimens:

width: 8 mm

length: 20 mm

thickness: 3 mm to 5 mm

For maximum accuracy, the surface of the test specimen in contact with the prism (the measurement face) shall be optically flat and well-polished. Eliminate any burs formed by cutting or any contamination attached to the specimen.

Satisfactory contact between the specimen and the prism is indicated when the dividing line between the light and dark halves of the eyepiece field appears sharp and straight.

Ensure that the edge of the specimen (perpendicular to the first) is also optically flat and fairly well-polished. The two polished surfaces shall intersect along a sharp line without a bevelled or rounded edge.

The following dimensions are recommended for film specimens:

- width: 8 mm
- length: 20 mm
- thickness: the actual film thickness, but not less than 2  $\mu\text{m}$

For anisotropic material, see 6.1.3.

## 4.2 Method B

The test sample consists of particles of the material to be examined, for example powder, granules or chips. The particles shall have dimensions sufficiently small and be so distributed as to permit simultaneous observation of approximately equal areas of the sample and the surrounding area in the field of view.

Ensure that the thickness of the test sample is significantly lower than the working distance of the microscope objective.

## 4.3 Required number of specimens or measurements

For sheets or films, five specimens are required. In the case of powders, pellets and granules, a quantity of sample sufficient to make five measurements is required.

## 5 Conditioning

**5.1** Condition the specimens in accordance with ISO 291 at  $(23 \pm 2)$  °C and at  $(50 \pm 5)$  % relative humidity for not less than 88 h prior to the test if no other period of conditioning is stated in the relevant material specification.

**5.2** Set up the test apparatus in an atmosphere maintained at  $(23 \pm 2)$  °C and  $(50 \pm 5)$  % relative humidity.

## 6 Procedure

### 6.1 Method A

If an Abbe refractometer (3.1.1) is used, carry out the following procedure. For other refractometers, modify the procedure in accordance with the manufacturer's recommendations, if necessary.

Carry out the determination at  $(23 \pm 0,5)$  °C.

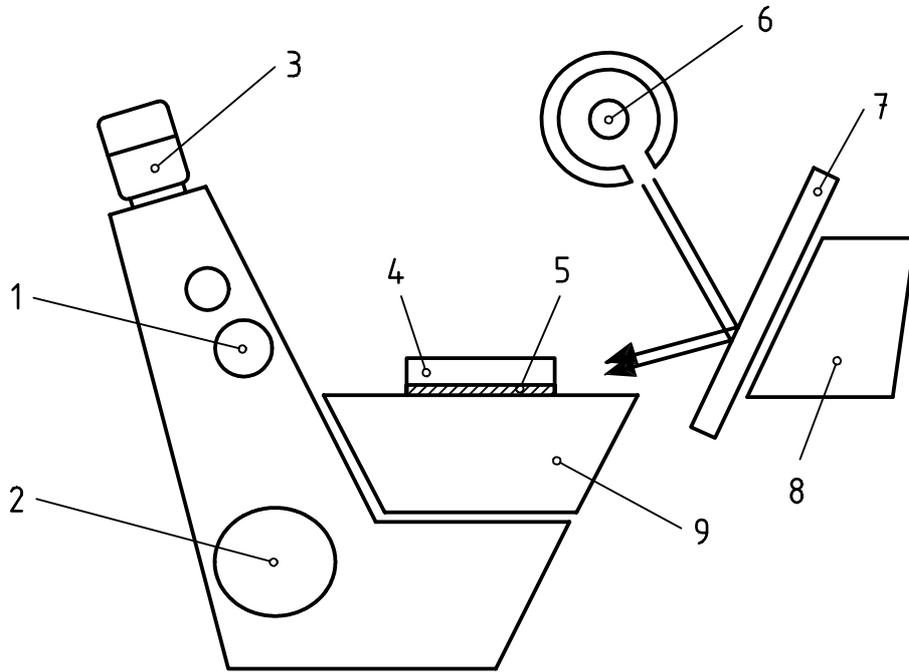
#### 6.1.1 Transparent sheet

Place a small drop of the contacting liquid (3.1.3) on the well-polished surface of the transparent sheet specimen (the measurement face) and place it in firm contact with the surface of the prism with the polished edge of the specimen towards the light source as shown in Figure 1. Adjust the index arm of the refractometer until half of the eyepiece field is dark.

Adjust the compensator (Amici prisms) drum until all colours have been removed from the field. Then adjust the index arm by means of the vernier until the dividing line between the light and dark portions of the field coincides exactly with the point of intersection of the eyepiece cross-hairs as shown in Figure 2.

Read the refractive index of the material from the instrument scale.

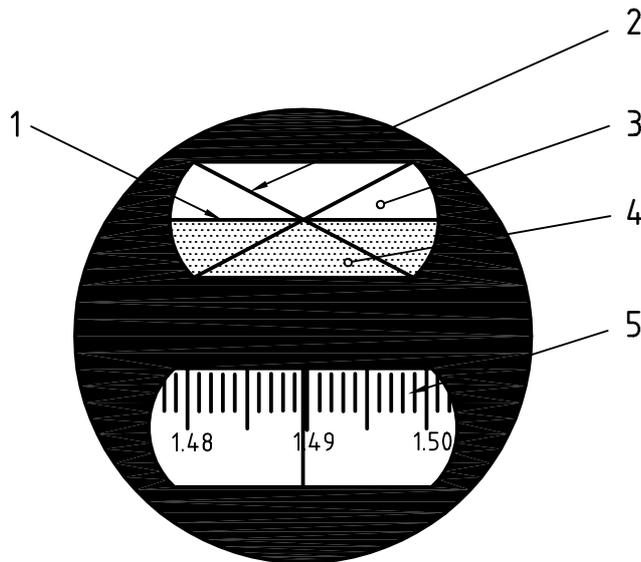
The dispersion, if required, can be found by noting the compensator drum reading and using this, together with the value of the refractive index, to read the dispersion from a chart supplied with the instrument.



**Key**

- |                    |                     |                                  |
|--------------------|---------------------|----------------------------------|
| 1 Compensator drum | 4 Specimen          | 7 Opal-coloured reflective plate |
| 2 Index arm        | 5 Contacting liquid | 8 Sub-prism                      |
| 3 Eyepiece         | 6 Source of light   | 9 Main prism                     |

**Figure 1 — Method for measuring refractive index of transparent sheet**



**Key**

- |                                |                               |
|--------------------------------|-------------------------------|
| 1 Boundary line                | 4 Dark half of eyepiece field |
| 2 Cross-hair lines             | 5 Scale for refractive index  |
| 3 Light half of eyepiece field |                               |

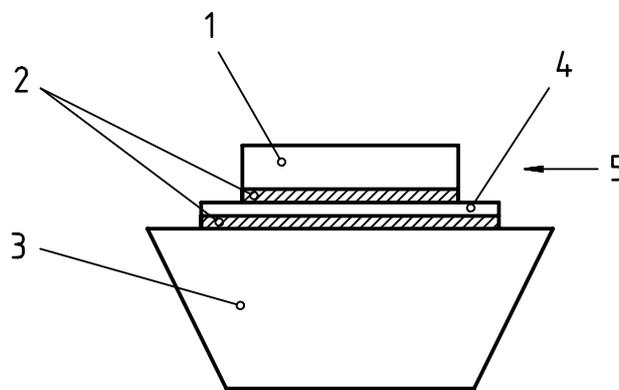
**Figure 2 — Refractometer field of vision**

**6.1.2 Film**

Place a drop of the contacting liquid (3.1.3) on the main prism followed by a film specimen. Place another drop of contacting liquid on the top of the film and then place the glass plate on the specimen as shown in Figure 3. The refractive index of the glass plate shall be greater than that of the film specimen.

Use the sodium lamp illuminator for the measurements of anisotropic film such as oriented ones so as to obtain a beam of steady incident light and to avoid any dispersion effects. As shown in Figure 1, open the sub-prism and place the opal-coloured reflective plate against it to reflect the light of the sodium lamp onto the edge of the glass plate.

NOTE It is difficult to measure the refractive index of film specimens because films are very thin and this results in a limited amount of incident light passing through the edge of the specimen. To compensate for this, place a glass plate on top of the specimen.



**Key**

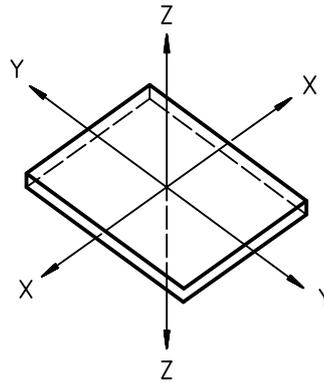
- 1 Glass plate
- 2 Contacting liquid
- 3 Main prism
- 4 Film specimen
- 5 Light

**Figure 3 — Method for measuring refractive index of film**

**6.1.3 Anisotropic material**

In the case of anisotropic material such as injection or extrusion mouldings, different values of the refractive index may be found when measurements are made in different parts of the specimen (Figure 4). In such cases, different specimens are prepared with their polished edges parallel or perpendicular to the machine direction.

By attaching a polarizing filter to the eyepiece of the Abbe refractometer, the measurement of specimens with multiple refractive indices can be made. By using different combinations of the specimen-positioning direction (illuminated surface facing the machine direction or at 90° from the machine direction) and of the polarizing-filter direction (rotating the filter 90° between two positions) as shown in Figure 5, the refractive index can be measured in any particular direction.



**Key**

- X At right angle to the machine direction
- Y Machine direction
- Z Thickness

**Figure 4 — Film with multiple refractive indices**

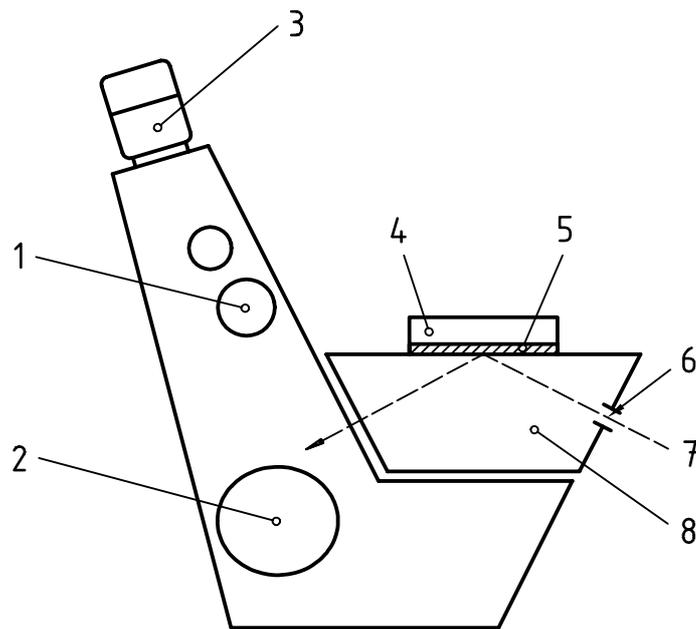
Measurement direction	Thickness (Z axis)	At right angle to machine direction (X axis)	Thickness (Z axis)	Machine direction (Y axis)
Positioning of specimen with multiple refractive indices (machine direction indicated by arrows)	<p>Light</p>	<p>Light</p>	<p>Light</p>	<p>Light</p>
Polarizing direction (indicated by arrows)				

**Figure 5 — Combination of specimen-positioning direction and polarizing-filter direction**

**6.1.4 Translucent, coloured and opaque material**

For translucent, coloured and opaque materials, the reflection mode of the Abbe refractometer shall be used. In this mode, the light enters the prism through an upper window and reflects at the interface between the prism and the specimen as shown in Figure 6.

NOTE In cases of translucent, coloured or opaque material, it is difficult to measure the refractive index by the transmission method because of a lack of reflected light. In such cases, it is possible to measure refractive indices by the reflection mode. When the reflection mode is used, the bright field and the dark field are inverted, and their contrast becomes poor.



### Key

1 Compensator drum	5 Contacting liquid
2 Index arm	6 Window for lighting
3 Eyepiece	7 Light
4 Specimen	8 Main prism

**Figure 6 — Method for measuring refractive index of translucent, coloured and opaque materials**

## 6.2 Method B

Carry out the following determination at  $(23 \pm 0,5) ^\circ\text{C}$ .

Place a small amount of an immersion liquid (3.2.3) on a slide. The immersion liquid shall be of a known refractive index (see Table 2) which is close to that of the material under test.

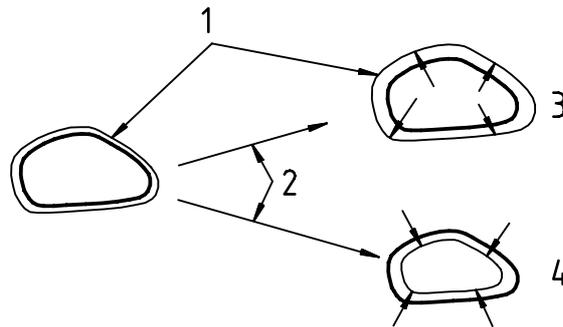
If the refractive index of the material to be examined is unknown, it is recommended that an immersion liquid with a refractive index of about 1,56 be used.

Place some particles of the material to be examined into the liquid on the slide and add a cover slip. Align the condenser and stop it down to give a narrow beam of axial illumination.

Place the sample preparation on the microscope stage and focus on the particles. Slightly defocus by increasing the separation between the microscope objective and the sample preparation. The Becke line, seen as a bright halo around or within the particle, will move towards the medium having the higher refractive index as shown in Figure 7.

Repeat the test with preparations in other immersion liquids with a known refractive index and particles of the material to be examined until a match is found, or until the index of the test sample is found to be between two known indices in the series of liquid standards. The Becke line phenomenon does not appear when the microscope objective is raised or lowered if the refractive index of the material to be examined is equal to the refractive index of the immersion liquid used for the determination test.

Any bubbles which appear during the preparation are useful for checking the focus when the match of the sample and the immersion liquid is close.



### Key

- 1 Becke line
- 2 Lift the lens-barrel of the microscope to defocus slightly
- 3 Where the immersion liquid has a higher refractive index than that of the sample, the Becke line is seen moving towards the immersion liquid
- 4 In the opposite case, the Becke line is seen moving towards the particle

Figure 7 — Becke line and its movement

## 7 Precision

An international trial involving eight laboratories was conducted in 1996 to determine the precision of the two methods. Measurements were made on eleven samples for method A and six samples for method B, among which three samples were of the same materials. The data were analysed in accordance with ISO 5725-1, ISO 5725-2 and ISO 5725-3. The results are shown in Table 3. No outliers were detected by Grubb's test.

The anisotropic specimens were carefully selected and their orientation direction was identified for the series of measurements performed using method A.

Reproducibility means precision under conditions where 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 reproducibility standard deviation.

Reproducibility-within-laboratory means precision under conditions where test results are obtained with the same method on identical material in the same laboratory, and the operator, the equipment and the time of measurement are either partly or totally different.

NOTE 1 In method A, PMMA cast sheet and fully shrunk and annealed PMMA cast sheet, which would be expected to have little orientation and optical stress, give a reproducibility standard deviation of less than 0,000 4. Others range from 0,000 7 to 0,008 depending on the scattering of the data due to local differences within the samples. In the case of the fully shrunk and annealed PMMA cast sheet, the reproducibility standard deviation is slightly smaller than that calculated from the data from the within-laboratory tests. A possible interpretation is that the values of reproducibility were inverted for this particular material because  $s_R$  can only be greater than or equal to  $s_{RW}$ . Nonetheless, the precision of this method is very high for this material and the difference between  $s_R$  and  $s_{RW}$  is only 0,000 1 which corresponds to the detection limit of the method.

NOTE 2 In general, method B for granules gives worse reproducibility than method A. This is clearly shown by the data generated for sheet and granulated samples from the same material: for PMMA (2, 15) and PS (6,17).

Table 3 — Interlaboratory trial data

No.	Method	Plastic material	Average refractive index	Within-laboratory reproducibility standard deviation	Reproducibility standard deviation
			$n_D^{23}$	$s_{RW}$	$s_R$
1	A	PMMA cast sheet	1,491 1	0,000 36	0,000 41
2	A	PMMA shrunk and annealed cast sheet	1,491 4	0,000 58	0,000 46
3	A	PC extruded sheet (machine direction)	1,583 9	0,000 40	0,000 82
4	A	PC extruded sheet (transversal direction)	1,583 7	0,000 65	0,000 67
5	A	High-RI resin castings for spectacle lenses	1,657 9	0,000 20	0,001 02
6	A	PS pressed sheet	1,590 8	0,000 54	0,000 71
7	A	Cyclic-olefin copolymer	1,542 8	0,006 58	0,007 31
8	A	PP film (machine direction)	1,504 6	0,000 54	0,008 32
9	A	PP film (transversal direction)	1,504 1	0,000 37	0,000 46
10	A	FEP film (machine direction)	1,344 7	0,001 13	0,001 52
11	A	FEP film (transversal direction)	1,343 4	0,000 39	0,001 13
12	B	PMMA beads as polymerized	1,490 6	0,000 37	0,000 51
13	B	PC powder as polymerized	1,584 7	0,000 31	0,005 45
14	B	Cyclic-olefin copolymer (granulated)	1,541 7	0,000 33	0,002 53
15	B	PMMA shrunk and annealed (granulated)	1,490 9	0,000 34	0,000 92
16	B	PC (granulated)	1,582 5	0,000 42	0,003 04
17	B	PS (granulated)	1,591 9	0,000 52	0,004 69

## 8 Test report

The test report shall include the following information:

- a reference to this International Standard;
- all details necessary for the complete identification of the material under test;
- the method used (A or B);
- the type of light source and the wavelength used;

- e) the position in the original sample from which the specimen was cut (for method A only);
- f) the dispersion, if measured (for method A only);
- g) the refractive index to the nearest significant figure warranted by the precision of the measurements (to more than three significant figures if the refractive index is expressed using method A);
- h) any deviation, by agreement or otherwise, from the method specified;
- i) the date of measurement.

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