IS 14753 (1999): Polymethyl Methacrylate (PMMA) (Acrylic) Sheets [PCD 12: Plastics]

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पालिमैथिल मैथैक्रिलेट (पीएमएमए) (ऐक्रिलिक) चद्दरें

Indian Standard

POLYMETHYL METHACRYLATE (PMMA) (ACRYLIC) SHEETS

ICS 83.140 : 10

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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Plastics Sectional Committee, PCD 12

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Plastics Sectional Committee, had been approved by the Petroleum, Coal and Related Products Division Council.

Acrylic sheets now available as clear transparent sheets and in various colours in transparent, translucent and opaque shades are being widely used for numerous applications. The areas of its applications are luminaries both as light control and decorative-cum-protective covers, reflectors, advertising, building, furnishing and furnitures, sanitary articles, agriculture, automobile, marine, defence and aviation, safety, industrial applications, aquarium, murals, sundry and many other areas where a man can think of using acrylic sheets to suit his/her requirements. These considerations led the committee to formulate specification for polymethyl methacrylate (acrylic) sheets.

Considerable assistance has been derived from the following publications while preparing this standard:

ISO 7823-1 : 1991(E) Plastics — Polymethyl methacrylate sheets — types, dimensions and characteristics — Part 1 Cast sheets, issued by the International Organization for Standardization (ISO).

ISO 7823-2 : 1989(E) Plastics — Polymethyl methacrylate sheets — types, dimensions and characteristics — Part 2 Melt calendered extruded sheets, issued by the International Organization for Standardization (ISO).

ASTM D 702-81 Cast methacrylate plastic sheets, rods, tubes and shapes — Specification, issued by American Society for Testing and Materials (ASTM).

ASTM D 4802-88 Poly (Methyl Methacrylate) Acrylic plastic sheet — Specification, issued by American Society for Testing and Materials (ASTM).

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

POLYMETHYL METHACRYLATE (PMMA) (ACRYLIC) SHEETS

1 SCOPE

This standard covers the requirements and methods of sampling and test for polymethyl methacrylate (acrylic) sheets.

2 NORMATIVE REFERENCES

The following standards contain provision which through reference in the text, constitute provisions of this standard. At the time of publication the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
1070 : 1992	Reagent grade water
4905 : 1968	Methods for random sampling
13360 (Part 5/ Sec 1) : 1996/ ISO 527-1 : 1993	Plastics — Methods of testing: Part 5 Mechanical properties, Section 1 Determination of tensile properties — General principles
13360(Part 5/ Sec 4) : 1996/ ISO 180 : 1993	Plastics — Methods of testing: Part 5 Mechanical properties, Section 4 Determination of izod impact strength
13360 (Part 5/ Sec 13) : 1992	Plastics — Methods of testing: Part 5 Mechanical properties, Section 13 Determination of Rock well hardness
13360 (Part 6/ Sec 1) : 1999	Plastics — Methods of testing: Part 6 Thermal properties, Section 1 Determination of vicat softening temperature of thermo-plastic materials
13360 (Part 6/ Sec 3) : 1997	Plastics — Methods of testing: Part 6 Thermal properties, Section 3 Determination of temperature of deflection under load — General test method
13360 (Part 9/ Sec 5) : 1999	Plastics — Methods of testing: Part 9 Optical properties, Section 5 Determination of haze and luminous transmittance of transparent plastics

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 13360 (Part 5/Sec 1), IS 13360 (Part 5/Sec 4), IS 13360 (Part 5/Sec 13), IS 13360 (Part 6/Sec 1), IS 13360 (Part 6/Sec 3), IS 13360 (Part 9/Sec 5) and the following shall apply.

3.1 Cast Acrylic Sheets —Thermoplastic sheets manufactured by polymerization of methyl methacrylate monomer by cell-casting process.

3.2 Specific Gravity—The ratio of the mass in air of a given volume of the material at a specified temperature to that of an equal volume of water at the same temperature under prescribed conditions.

3.3 Haze —The haze of a specimen is that percentage of transmitted light, which while passing through the specimen deviates from the incident beam by forward scattering. For the purpose of this standard, only light flux deviating more than 2.5° on average is considered as haze.

3.4 Luminous Transmittance—The ratio of transmitted to incident light (sodium D-line).

3.5 Yellowness —Deviation in chroma from whiteness or a water whiteness in the dominant wave length range from 570 to 580 nm.

3.6 Yellowness Index *(YI)*—The magnitude of yellowness relative to magnesium oxide for CIE Source C. Yellowness index is expressed as follows:

$$YI = [100\,(1.28\,X_{CIE} - 1.06\,Z_{CIE})]/Y_{CIE}$$

where

X_{CIE}, Y_{CIE} and Z_{CIE} are tristimulus values (Note 1) of the specimen relative to Source C.

NOTE — By this test method, positive (+) yellowness index describes the presence and magnitude of yellowness; specimen with a negative (–) yellowness index will appear bluish.

3.7 Change in Yellowness Index *(ΔYI)*—The difference between an initial value, and determined after a prescribed treatment of the plastic.

$$\Delta YI = YI - YI_o$$

NOTE — By this calculation positive (+) ΔYI indicates increased yellowness and negative (–) ΔYI indicates decreased yellowness or increased blueness.

3.8 Diffusion Factor (of a Diffusing Surface by Reflection and/or by Transmission)—Ratio of the mean values of luminance measured at 20° and 70° to the luminance measured at 5° from the normal, when the surface considered is illuminated normally.

NOTES

1 The diffusion factor is intended to give an indication of the special distribution of the diffused flux. It is equal to 1 for every uniform diffuser, whatever the value of the diffuse reflectance.

2 This way of defining the diffusion factor can only be applied to materials for which the indicatrix of diffusion does not differ appreciably from that of ordinary depolished and opal glasses.

3.9 Translucent—Transmitting light diffusely, but not permitting a clear view of objects beyond the specimen and not in contact with it.

3.10 Transparency—The degree of regular transmission, that is the property of a material which enables objects to be seen clearly through a sheet.

4 REQUIREMENTS

4.1 Protection of Surface

Unless otherwise agreed between the supplier and the purchaser, the surface of the sheet, as delivered, shall be protected by suitable material, for example kraft paper pasted with a water soluble or pressure-sensitive adhesive or a polyethylene or any other suitable film; readily removable without surface contamination or damage.

4.2 Appearance

4.2.1 *Surface Defects*

The sheets shall have a smooth surface. There shall be no surface defects, scratches or marks larger than 5 mm^2 each anywhere in the sheet.

4.2.2 *Inclusion Defects*

There shall be no bubbles, large inclusions, cracks or other defects that could adversely affect the performance of the sheet in its intended application. There shall be no foreign matter inclusions larger than 4 mm^2 each anywhere in the sheet.

4.2.3 *Classification of Defects*

The area of defects found in the sheet shall be classified as specified in Table 1. Each defect shall be considered separately.

Table 1 Classification of Defects

Classification (1)	Surface Defects (2)	Inclusion Defects (3)
Negligible	Less than 2 mm^2	Less than 1 mm^2
Acceptable	2 to 5 mm^2	1 to 4 mm^2

4.2.4 *Distribution of Defects*

4.2.4.1 There shall not be a significant (for the application) amount of fine defects, each of which is defined as negligible in Table 1, within 1 m^2 anywhere in the sheet.

4.2.4.2 No defect defined as acceptable in Table 1 shall be within 500 mm of another acceptable defect anywhere in or on the sheet.

4.3 Colour

The colour distribution shall be homogenous, unless otherwise specified. Variations in colours shall be agreed between the purchaser and the supplier.

4.4 Visual Examination

The sheets shall be visually examined as given in **4.4.1** for scratch, air bubbles, foreign material or any other marks except such special marks which have been specified by the purchaser.

4.4.1 A colourless (transparent) acrylic sheet with alternate black and white lines, approximately 125 mm wide shall be mounted with its lines being vertical. The sheet shall be of such a size that it is able to form a complete background for the largest sample sheet to be inspected. The specimen shall be visually examined by keeping the sheets in front of a vertical illuminator which shall be constructed out of a wooden box as per the details given in Fig. 1. The tube lights are fitted vertically at equidistance in such a way that entire box is illuminated uniformally. Inside of the box shall be painted with black colour. The sheet to be inspected shall be held in a vertical plane at a convenient height by a support set at an angle of 60° to the black and white screen. One edge of the sheet shall be in contact with one edge of the screen. The screen shall be observed through the sheet and examined for distortion of the black and white screen. The sample shall then be rotated in a vertical plane through 180° and the specimen again examined for distortion.

4.5 Dimensions

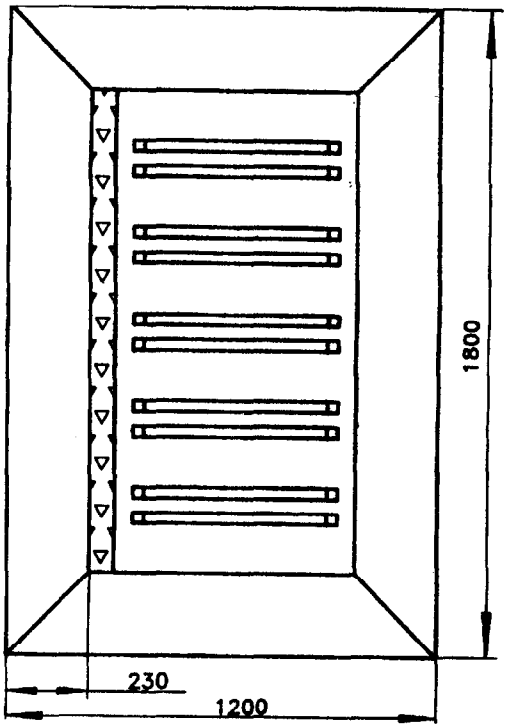
4.5.1 The preferred dimensions, after trimming, for the supply of cast acrylic sheets shall be as follows.

4.5.1.1 *Size I* — The sheets up to 2 m^2 surface area:

a) 765 × 610 mm
b) 1 220 × 915 mm
c) 1 220 × 1 525 mm
d) 1 375 × 915 mm
e) 1 750 × 1 140 mm
f) 1 830 × 915 mm

4.5.1.2 *Size II* — The sheets offering more than 2 m^2 surface area:

a) 1 220 × 1 830 mm
b) 1 780 × 1 180 mm
c) 1 800 × 1 200 mm
d) 2 170 × 1 050 mm



All dimensions in millimetres.

FIG. 1 FLUORESCENT BOX FOR VISUAL EXAMINATION

4.5.1.3 The tolerance for the dimensions shall be $^{+5}_{-0}$ mm.

NOTE—The dimensions of sheets above are after trimming. Sheets can also be supplied with gasket as per mutual agreement between the supplier and the purchaser. In case of sheets with gaskets the dimensions shall be approx. 25 mm plus both in length and width than the trimmed dimensions.

4.5.2 *Thickness*

The preferred thickness and permissible thickness variation for the acrylic sheets shall be as given in Table 2.

Table 2 Permitted Variations of Thickness

Thickness (mm)	**Tolerance** (mm)	
	Size I	Size II
(1)	(2)	(3)
2.0	±0.43	± 0.6
2.5	±0.43	± 0.6
3.0	± 0.5	± 0.6
4.0	± 0.5	± 0.7
5.0	± 0.6	± 0.8
6.0	± 0.8	± 0.9
8.0	± 0.9	± 1.0
10.0	± 1.0	± 1.1
12.0 – 13.0	± 1.1	± 1.3
15.0	± 1.4	± 1.4
18.0	± 1.4	± 1.4
20.0 – 25.0	± 1.4	± 1.4
30.0	± 1.8	± 1.8

NOTES

1 The tolerances given above are for the batch, that is in a batch the sheets can have a minimum and maximum thickness as specified above.

2 The sheets may also be supplied in sizes other than those mentioned in this clause as per the mutual agreement between the supplier and the purchaser.

4.5.3 *Measurements*

Measurements of dimensions shall be made at room temperature, except that in case of dispute measurements shall be made under standard conditions, 27 ± 2°C and 65 ± 5 percent relative humidity. For measurements made under ambient conditions, due allowance shall be made for dimensional changes due to the differences in temperature and relative humidity between test locations.

4.6 Specific Gravity

The specific gravity of a sample sheet shall be measured by the method given in Annex A and the values of the specific gravity shall not be less than 1.18 and more than 1.20. Test samples shall be conditioned for 48 h at 27 ± 2°C and 65 ± 5 percent RH prior to testing.

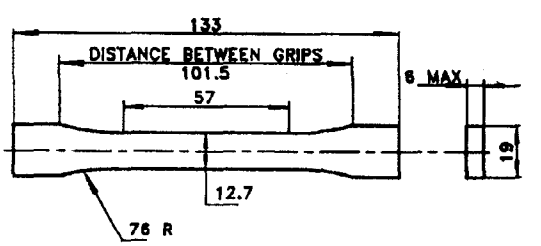
4.7 Water Absorption

A test sample, 75 mm long × 25 mm wide × thickness of material, shall be tested in accordance with Annex B. The water absorption shall not be more than 0.4 percent of the dry mass of the sample after 24 h immersion.

4.8 Tensile Strength and Elongation

Five test specimens shall be prepared by machining in accordance with **5.1** and shall conform to Fig. 2. Before carrying out the test, test specimens shall be annealed in accordance with **5.2** and conditioned for 48 h at 27 ± 2°C and 65 ± 5 percent RH. Test specimens when tested in accordance with IS 13360 (Part 5/Sec 1) shall show a tensile strength of 570 kg/cm^2, *Min* and elongation at rupture shall not be less than 4.0 percent.

The mean of the five determinations shall be taken as the representative value of tensile strength and elongation of the test sample sheets.



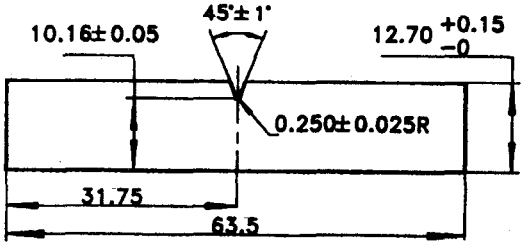
All dimensions in millimetres.

FIG. 2 SPECIMEN FOR TENSILE STRENGTH

4.9 Impact Strength

Five test specimens shall be prepared by machining in accordance with **5.1** and shall conform to Fig. 3. The thickness of the test specimen shall be within the range of 3.2 to 6.3 mm. Before carrying out the test, test specimens shall be annealed in accordance with **5.2** and conditioned for 48 h at 27 ± 2°C and 65 ± 5 percent. Test shall be carried out in accordance with IS 13360 (Part 5/Sec 4). The impact strength of the sheets shall not be less than 1.6 kg cm/cm of the notch.

The impact strength of the material, reported as the arithmetic mean value of the results for each specimen type.



All dimensions in millimetres.

FIG. 3 TEST SPECIMEN FOR IMPACT STRENGTH

4.10 Rockwell Hardness

Test specimen shall be 25 mm square having a thickness of 6 mm or more shall be prepared in accordance with **5.1**. Before carrying out the test, test specimens shall be annealed in accordance with **5.2** and conditioned for 48 h at 27 ± 2°C and 65 ± 5 percent. Test shall be carried out in accordance with IS 13360 (Part 5/ Sec 13). The rockwell hardness shall be RHM 100 ± 5.

4.11 Effect of Heat on Rigidity, that is Temperature of Deflection Under Load

Test specimen shall be 127 × 12.7 × any width from 6.4 to 12.7 mm shall be prepared in accordance with **5.1**. In cases where sheet thickness is less than 6.4 mm, two or more specimens may be cemented to each other with a suitable solvent/adhesive such that the side faces remains parallel otherwise shall be grinded properly to have parallel surfaces. The specimens shall be annealed in accordance with **5.2** prior to testing. The specimens shall not show a deflection of 0.25 mm until it reaches a temperature in excess of 85°C when tested in accordance with IS 13360 (Part 6/Sec 3). Test shall be carried out separately for nominal stress of 1.80 MPa and 0.45 MPa.

Report the temperature deflection at 1.80 MPa and 0.45 MPa.

4.12 Vicat Softening Temperature

Test specimen shall be flat sections of plastics of not less than 2.3 mm and not more than 4.2 mm thickness, preferably cut/machined from sheet sample. Test shall be carried out in accordance with IS 13360 (Part 6/Sec 1). The vicat softening temperature shall not be less than 100°C.

4.13 Burning Rate

A test sample 125 ± 5 mm in length × 12.5 ± 0.2 mm width × the thickness of the sheet when tested in accordance with Annex C shall show a burning rate of not more than 40 mm per minute.

4.14 Refractive Index

A test sample made out of colourless transparent sheet when tested in accordance with Annex D at 27 ± 2°C with sodium D-line shall show a refractive index not more than 1.49. Test samples shall be conditioned for 48 h at 27 ± 2°C and 65 ± 5 percent RH prior to testing.

4.15 Haze and Luminous Transmittance

Test sample made out of colourless transparent sheets when tested in accordance with IS 13360 (Part 9/Sec 5) shall show minimum transmittance of 91 percent and haze percent shall not exceed 3. Test samples shall be conditioned for 48 h at 27 ± 2°C and 65 ± 5 percent RH prior to testing.

Report total luminous transmittance T_t, diffuse transmittance T_d and haze percent, H.

NOTE— For the transparent coloured and coloured translucent sheets, the value of luminous transmittance and haze shall be as agreed between the purchaser and the supplier.

4.16 Stability Towards Yellowing

This property shall be tested by the method given in **4.16.1**.

4.16.1 *Yellowness Index Method*

This method is intended primarily for determining the degree of yellowness (or change on degree of yellowness) under day light illumination of cast acrylic sheets. This method is based upon tristimulus values calculated from data obtained on the hard GE type spectrophotometer or any other suitable equivalent apparatus.

The magnitude and sign of the yellowness index is calculated from the following equation:

$$YI = [100\,(1.28\,X_{CIE} - 1.06\,Z_{CIE})]/Y_{CIE}$$

4.16.1.1 *Change in yellowness index*

The magnitude and direction of change in yellowness index is calculated from the following equation:

$$YI = YI - YI_o$$

where

X_{CIE}, Y_{CIE} and Z_{CIE} = tristimulus values of the specimen relative to source C.

4.16.1.2 Yellowness index values of PMMA sheets produced from virgin monomer shall be as given in Table 3.

Table 3 Yellowness Index (*YI*) of PMMA (Acrylic) Sheets (Produced from Virgin Monomer — MMA) Colour Code 001 — Clear Transparent

Thickness, t (mm)	*YI* for Sheet	*YI*/t of Sheet
(1)	(2)	(3)
2	3.6 to 4.2	1.80 to 2.10
2.5	3.7 to 4.3	1.8 to 1.72
3	3.8 to 4.4	1.27 to 1.47

4.16.1.3 The guidance regarding derivation of equations for calculation of yellowness index from photoelectric tristimulus colorimeter measurements is given in Annex E.

4.17 Diffusion Factor and Uniformity of Diffusion

4.17.1 *Diffusion Factor*

The specimen being measured is illuminated on one face by a beam of light normal to the surface. The luminance measurements shall be obtained by using a photometer at 70°, 20° and 5° to the normal to the specimen. Test specimens shall be conditioned for 48 h at 27 ± 2°C and 65 ± 5 percent RH prior to testing. The diffusion factor then shall be calculated as:

$$\text{Diffusion factor} = \frac{L_{20} + L_{70}}{2L_5}$$

where

L_5, L_{20} and L_{70} are the luminance values of the surface when viewed at 5°, 20° and 70° to the normal.

4.17.2 *Uniformity of Diffusion*

This test is applicable only for sheets having diffusion factors between 0.85 and 0.9, when measured as in **4.17.1**. For this test, a rectangular box containing one 20 W tubular fluorescent lamp shall be used. The inside of the box shall be painted matt black. One long side of the box shall be opened and it shall contain a slot, so that acrylic sheet of 610 × 100 × 3 mm may be placed there to cover the lamp completely and the sheet remains 70 mm away from the lamp surface. One test sheet shall be placed in this box and viewed from outside while the lamp is burning. The test sheet shall appear to be uniformly bright.

NOTES

1 The testing facilities for carrying out these tests are not readily available in the country. Till such time the testing facilities are created in the country, these tests should be done only after mutual agreement between the supplier and the purchaser.

2 The test procedure for sheets having different values of diffusion factor is under consideration.

4.18 Residual Monomer Test

The residual methyl methacrylate content in polymethyl methacrylate when tested in accordance with Annex F shall not exceed by more than 2 percent by mass.

5 PREPARATION OF TEST SPECIMENS

5.1 Preparation of Test Specimen by Cutting/Machining

Test specimens for various tests and of various shapes of cast acrylic sheets shall be prepared by cutting, machining, shaping and any other suitable operations, using appropriate tool (the best recommended system is cutting/shaping on pentograph machine). Such operations shall be done keeping the masking paper intact such as to protect original gloss/surface of sheet. The specimen thus prepared shall have dimensional uniformity as required by individual test specimens and shall also be smooth edged, without any cracks, nicks and burr at edges. The specimens shall not have any inclusion, foreign particles, fish eye, air void, scratches and/or any visual defect that may impart variation or affect test values.

When it is necessary to machine the sheet to reduce it to the required dimension for a particular test method, one original surface shall be left intact.

5.2 Annealing

Prior to conditioning, the specimens prepared by cutting and machining shall be annealed, to remove mechanical stresses developed during process, at 80 ± 2°C for 16 h and shall be cooled down to room temperature in a desiccator.

6 STANDARD TEST CONDITIONS

The requirements given in **4.6** to **4.18** shall be conducted at an ambient temperature of 27 ± 2°C and 65 ± 5 percent relative humidity, unless otherwise specified in the particular testing method.

7 PACKING AND MARKING

7.1 Packing

The sheets shall be supplied in suitable form as agreed between the purchaser and the supplier.

7.2 Marking

Every sheet shall be marked suitably with the following information:

a) Indication of the source of manufacture and recognized trade-mark, if any;

b) Dimensions indicating length, width and thickness of the sheet;

c) Colour code and/or name of colour of sheets;

d) Month and year of manufacture; and

e) Batch number and code number.

7.3 BIS Certification Marking

7.3.1 The sheets may also be marked with the Standard Mark.

7.3.2 The use of the Standard Mark is governed by the provisions of *Bureau of Indian Standards Act,* 1986 and the Rules and Regulations made thereunder. The details of conditions under which the licence for the use of Standard Mark may be granted to manufacturer or producers may be obtained from the Bureau of Indian Standards.

8 SAMPLING AND CRITERIA FOR CONFORMITY

8.1 Lot

All the packages of polymethyl methacrylate (acrylic) sheets of the same group and type, produced under uniform conditions of manufacture shall constitute a lot.

8.1.1 *Number of Samples*

For ascertaining the conformity of the material in a lot to the requirements of the specification, tests shall be carried out on each lot separately. The number of packages to be selected from the lot shall depend upon the size of the lot and shall be in accordance with Table 4.

Table 4 Scale of Sampling

(*Clause* 8.1.1)

Lot Size (No. of Packages)	No. of Packages to be Selected in a Sample
(1)	(2)
Up to 150	3
151 to 500	4
501 and above	5

8.1.2 Each package in the sample shall be selected at random from each lot. For this purpose reference may be made to IS 4905.

8.2 Number of Tests

8.2.1 From each package selected in the sample, the sheets shall be tested for protection of surface (**4.1**), appearance (**4.2**), colour (**4.3**), visual examination (**4.4**) and dimensions (**4.5**).

8.2.2 The sheets having been found satisfactory as per **8.2.1**, shall then be further tested for the various requirements as per **4.6** to **4.18**. For this purpose the requisite number of sheets shall be selected at random, approximately equal in number, from each package selected as per col 2 of Table 3. The number of test specimens shall be cut from different portions of the sheets, which shall be sufficient for carrying out all the above tests.

8.3 Criteria for Conformity

8.3.1 Any sample sheet failing in one or more requirements of the specification shall be termed as defective.

8.3.2 No defective sheet shall be found in the sample for the lot to be considered as conforming to the specification.

ANNEX A

(*Clause* 4.6)

METHOD OF MEASUREMENT OF SPECIFIC GRAVITY

A-1 APPARATUS

A-1.1 Analytical Balance

A balance with a precision within 0.1 mg, accuracy within 0.05 percent relative that is 0.05 percent of the mass of the specimen in air, and equipped with a stationary support for the immersion vessel above the balance pan (pan straddle).

A-1.2 Wire

A corrosion-resistant wire preferably stainless steel or copper for suspending the specimen.

A-1.3 Sinker

A sinker for use with specimens of plastics having specific gravity less than 1.

A-1.4 Immersion Vessel

A beaker or other wide-mouthed vessel for holding the water and immersed specimen.

A-1.5 Thermometer

A thermometer with an accuracy of ± 1°C.

A-2 PROCEDURE

A-2.1 The test specimen shall be a single piece of the material under test of any size and shape that can conveniently be prepared and tested, provided that its volume shall not be less than 1 cm^3 and its surface and edges shall be made smooth. The thickness of the specimen shall be at least 1 mm for each 1 g of weight. A specimen weighing 1 g to 5 g usually will be found convenient, but specimens up to approximately 50 g may be used. Care shall be taken in cutting specimens to avoid changes in density resulting from compressive stresses or frictional heating.

A-2.2 Weigh the specimen in air to the nearest 0.1 mg or 0.05 percent relative, whichever is greater and record it as *a*.

A-2.3 Attach to the balance a piece of fine wire sufficiently long to reach from the hook above the pan to the support for the immersion vessel. Attach the specimen to the wire, such that it is suspended about 25 mm above the vessel support.

A-2.4 Mount the immersion vessel on the support and completely immerse the suspended specimen (and sinkers, if used) in water at a temperature of 27 ± 2°C. The vessel shall not touch the wire or specimen. Remove any bubbles adhering to the specimen, wire or sinker. Weigh the suspended specimen (and of sinter, if used) completely immersed and of the wire partially immersed in water to the required precision. Record this mass as *b*. Unless otherwise specified, weigh rapidly in order to minimize absorption of water by the specimen.

A-2.5 Weigh the wire (and sinker, if used) in water with immersion to the same depth as used in the previous step. Record this mass as *w* at **A-2.4**.

A-3 CALCULATIONS

A-3.1 Calculate the specific gravity of the sheet as follows:

$$\text{Specific gravity} = \frac{a}{a + w - b}$$

where

a = apparent mass of specimen, without wire or sinker, in air;

b = apparent mass of specimen (and of sinker, if used) completely immersed and of the wire partially immersed in water; and

w = apparent mass of totally immersed wire (and of sinker, if used) and of partially immersed wire in water.

ANNEX B

(*Clause* 4.7)

TEST FOR WATER ABSORPTION

B-1 PROCEDURE

B-1.1 Condition the specimens in a desiccator over anhydrous calcium chloride for at least 16 h. Measure the thickness to the nearest 0.02 mm, weigh to the nearest mg and immerse for a period of 24 ± 1 h in distilled water (*see* IS.1070) at 27 ± 2°C on removal from water, wipe dry the exposed surface with blotting paper or clean cloth. Reweigh the specimen to the nearest mg and complete the weighing within 2 minutes of the removal of the specimen from water. Record the increase in mass in mg.

B-2 CALCULATION AND REPORT

B-2.1 When the test has been carried out at an immersion temperature higher than 20°C, calculate the equivalent water absorption at 20°C by applying the correction factor given in Fig. 4. Report this as the water absorption for the mean thickness of the specimen under test at 20°C.

NOTE — Report the temperature of the water at which test was carried out.

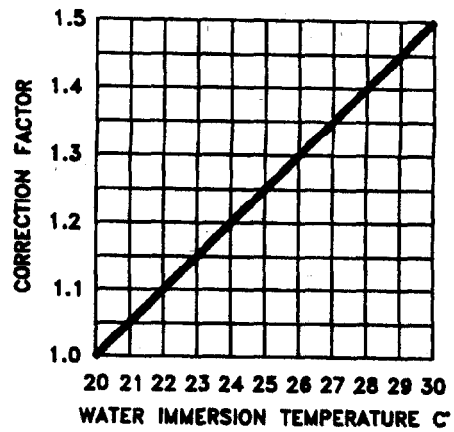


FIG. 4 CORRECTION FACTOR FOR INTERPRETATION OF VALUES OF WATER ABSORPTION

ANNEX C

(*Clause* 4.13)

TEST FOR BURNING RATE

C-1 APPARATUS

C-1.1 Test Chamber

A laboratory hood, totally enclosed with a heat-resistant glass window for observing the test. The exhaust fan is turned off during the test and turned on immediately following the test in order to remove products of combustion which may be toxic when testing some materials.

C-2 PROCEDURE

C-2.1 Clamp one end of the specimen to a support with its longitudinal axis horizontal and its transverse axis inclined at 45° to the horizontal. Under the test specimen clamp a piece of 20 mesh Bunsen burner gauze, about 10 cm^2, in a horizontal position 10 mm below the edge of the specimen, and with about 13 mm of the specimen extending beyond the edge of the gauze. Any material remaining on the screen from the previous test must be burned off or a new screen used for each test. A pan of water shall be placed on the floor of the hood in position to catch any burning particles which may drop during the test.

C-2.2 Adjust a standard 10 mm diameter Bunsen burner with airports open to produce a blue flame approximately 25 mm high. For each attempt to ignite the specimen, place the burner so that the tip of the flame contacts the end of the test specimen. At the end of 30 s, remove the flame and place it at least 450 mm away from the specimen to reduce the effects of drift in the hood while the specimen is allowed to burn. In case the plastic does not continue to burn after the first ignition, place the burner in contact with the free end for a second period of 30s immediately after the specimen ceases to burn. Extinguish the burner flame after the second application and close the hood door for the remainder of the test.

C-2.3 Measure the extent of burning along the lower edge of the test specimen. If the specimen does not ignite on two attempts, the result is judged to be 'non-burning by this test'. If the specimen continues to burn after the first or second ignition, start the stopwatch when the flame along the lower edge reaches the mark 25 mm from the free end, and measure the time *t* (in seconds) until the flame reaches the mark 100 mm from the free end. A specimen that

burns to the 100 mm mark is judged to be 'burning by this test', and its burning rate is equal to 450/t cm/min. If a specimen does not burn to the 100 mm mark after the first or second ignition, it is judged to be 'self-extinguishing by this test', and 100 mm minus the unburned length (in cm) from the clamped end, measured along the lower edge, is its 'extent of burning'.

ANNEX D

(*Clause* 4.14)

TEST FOR REFRACTIVE INDEX

D-1 APPARATUS

D-1.1 The apparatus for the test shall consist of an Abbe refractometer, a suitable source of white light, and a small quantity of a suitable contacting liquid.

NOTE — Other suitable refractometers can be used with appropriate modification of procedure as described in **D-3.1**.

D-2 TEST SPECIMEN

D-2.1 The test specimen shall be of a size such as will conveniently fit on the face of the fixed half of the refractometer prisms. A specimen measuring 12.5 × 6 mm on one face is usually satisfactory.

D-2.2 The surface to be used in contact with the prism shall be flat and shall have a good polish. A second edge surface, perpendicular to the first and on one end, of the specimen, shall be prepared with a fair polish. The polished surfaces shall intersect without a bevelled or rounded edge.

D-3 PROCEDURE

D-3.1 Remove the hinged illuminating prism from the refractometer, if necessary. Place a source of diffuse light, so that good illumination is obtained along the plane of the surface of contact between the specimen and the refractometer prism. Place a small drop of a suitable contacting liquid on the polished surface of the specimen and then place the specimen in firm contact with the surface of the prism and with the polished edge of the specimen towards the source of light. Determine the index of refraction in the same manner as for liquids.

This shall be done by moving the index arm of the refractometer until the field seen through the eyepiece is one-half dark. Adjust the compensator (Amici Prisms) drum to remove all colour from the field. Adjust the index arm by means of the vernier until the dividing line between the light and dark portions of the field exactly coincides with the intersection of the cross-hairs as seen in the eyepiece. Read the value of the index of refraction for the sodium D-line directly from the instrument. Determine the dispersion by reading the compensator drum and applying this figure, along with the index of refraction, to a chart or table supplied with the instrument.

NOTE — Sodium light from some type of a sodium burner is of use in increasing the accuracy and ease of setting of the refractometer.

ANNEX E

(*Clause* 4.16.1.3)

DERIVATION OF EQUATIONS FOR CALCULATION OF YELLOWNESS INDEX FROM PHOTOELECTRIC TRISTIMULUS COLORIMETER MEASUREMENTS

E-1 By the definition given in **3.6**, yellowness index has been defined as:

$$YI = [100\,(1.28 \times X_{CIE} - 1.06\,Z_{CIE})]/Y_{CIE}$$

where

X_{CIE}, Y_{CIE} and Z_{CIE} = Tristimulus values (CIE Source C) obtained by integration from spectrophotometric data as described in **4.16.1**.

E-2 The equations giving calculated tristimulus values from the filter photometer readings are as follows:

$$X_{CIE} = 0.783\,2\,A_o f_x + 0.197\,Z_o f_z$$

$$Y_{CIE} = 1.000\,0\,Y_o f_y$$

$$Z_{CIE} = 1.181\,03\,Z_o f_z$$

where

A_o, Y_o and Z_o = instrumental filter (amber, green and blue reflectance) values relative to an instrument reference standard, and

t_x, f_y and f_z = ratios of the reflectances of the instrument reference standard to magnesium oxide for each filter.

E-3 Substituting these expressions for X_{CIE}, Y_{CIE} and Z_{CIE} in the equation for yellowness index (**E-1**).

$$YI = \frac{100\,[1.28\,(0.783\,2\,A_o f_x + 0.197\,Z_o f_z)] - 1.06\,(1.181\,03\,Z_o f_z)]}{1.000\,0\,Y_o f_y}$$

$$= \frac{100\,(1.002\,A_o f_x + 0.252\,4\,Z_o f_z - 1.252\,4\,Z_o f_z)}{Y_o f_y}$$

$$= 100\,(1.002\,A_o f_x - 0.999\,Zof_z)/Y_o f_y$$

E-4 Thus within the precision of the test method, for *reflectance* measurements,

$$YI = 100\,(A_o f_x - Z_o f_z)/Y_o f_y$$

For transmittance measurements ($f_x = f_y = f_z = 1$), this equation reduces to:

$$YI = 100\,(A_o - Z_o)/Y_o$$

These equations permit calculation of the yellowness index from tristimulus filter colorimeter readings without the labour of calculating approximate tristimulus values.

ANNEX F

(*Clause* 4.18)

TEST FOR RESIDUAL MONOMER IN SHEET

F-1 DETERMINATION OF RESIDUAL METHYL METHACRYLATE

F-1.1 Outlines of the Method

Methyl Methacrylate (MMA) content in polymethyl methacrylate (PMMA) is found out by gas-liquid chromatographic method. A solution of polymer in a suitable solvent is introduced into a gas liquid partition column and the components are separated as they pass through the column, with the carrier gas by different rates of adsorption on the column packing. The components are recorded on a chromatogram and calculated by comparing peak heights or areas with those obtained from a prepared standard analyzed under identical operating conditions, dilution and volume of sample injected.

F-1.2 Apparatus

F-1.2.1 *Chromatograph*

a) *Detector*—A hydrogen flame detector of sufficient sensitivity.
b) *Attenuator*—The instrument should be equipped with a multistep, attenuator to ensure maximum peaks from the detector output signal and keep within the recorder chart range.
c) *Oven*—When operating isothermally oven shall capable of maintaining test temperature to an accuracy of ±0.3°C during the time in which the test sample and corresponding reference standards are analyzed.
d) *Gas flow regulators*—The metering mechanisms shall be capable of maintaining flow rates that are constant to ±0.5 percent during the time in which the test sample and the corresponding reference standards are analyzed.
e) *Recorder*—0.1 millivolt with a full scale response time of one second.

F-1.2.2 *Column*

Any type or size of stainless steel column packed with suitable adsorbent which can ensure effectiveness separation may be used. The recorder pen shall turn to the base line after tracing each peak.

F-1.2.3 *Microsyringe*

10 microlitre capacity.

F-1.2.4 *Chemical Balance*

Sensitivity 0.1 mg.

F-1.3 Reagents

F-1.3.1 *Solvent*

The solvent shall be capable of completely dissolving the polymer, allowing column separation and of sufficient purity so as not to interfere in the analysis of the desired components. Acetone has been found satisfactory.

F-1.3.2 *Internal Standard Solvent*

To establish the calibration curve for methylmethacrylate monomer select suitable internal standard solvent. Methyl *iso*-butyl ketone (MTBK) has been found satisfactory.

F-1.3.3 *Carrier Gas*

Nitrogen or argon having sufficient purity.

F-1.3.4 *Hydrogen*

F-1.4 Calibration

Select the conditions of column temperature and carrier gas flow which shall produce adequate separation in the minimum amount of time and allow the instrument to come to equilibrium.

F-1.5 Procedure

F-1.5.1 *Method A*

Accurately prepare reference standards and represent the high and low ends of the expected analytical range. The standards shall be dissolved in the solvent used for the analysis, and shall be prepared as follows:

To establish calibration curve for methyl methacrylate monomer in the expected range

accurately weigh to the nearest 0.1 mg in the 100 ml volumetric flask approximately 2 mg of MMA for low reference standard and approximately 10 mg of MMA for high reference standard. Immediately after weighing dilute each flask with selected solvent to make equal volume and add equal known quantity of internal standard solvent into the respective flask. Place a seram stopper on each flask and mix thoroughly by shaking it for five minutes.

Introduce the desired quantity of standard into the instrument and allow the test sample to be completely eluted. Follow the same procedure for each prepared standard, being careful to introduce exactly the same volume, at room temperature each time. From standard chromatograms measure the peak heights of methyl methacrylate monomer and internal standard solvent used.

Calculate peak height of MMA/peak height of internal standard solvent up to three decimal places(*B*). Prepare a calibration curve by plotting the above ratio on ordinate and the mass of methyl methacrylate (mg) on the abscissa. The calibration shall pass through zero and be the best fit to the other standard points.

F-1.5.2 *Method B*

Weigh accurately 0.15 g of polymers test sample to the nearest 0.1 mg into 100 ml volumetric flask, dilute it with selected solvent, allow it to remain for 2 days for complete dissolution, add known quantity of internal standard solvent and with instrument set at the condition of reference standard, inject a test sample equal to volume at room temperature. After complete elution measure the peak heights of methylmethacrylate and internal standard solvent from the chromatogram obtained.

F-1.6 Calculation

Calculate the percent of residual methyl methacrylate in the polymer sample as follows:

a) Calculate peak height of MMA/internal standard peak height up to three decimal places (*B*).

b) Determine the mass of MMA (*A*) in mg corresponding to (*B*) using a calibration curve prepared separately.

Residual methyl methacrylate percentage =

$$\frac{A\ (\text{mg})}{1\ 000} \times \frac{100}{\text{Sample (g)}} = \frac{A \times 0.1}{\text{Sample (g)}}$$

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