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Rigid cellular plastics — Determination of water absorption

Plastiques alvéolaires rigides — Détermination de l'absorption d'eau

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Contents

Page

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.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 2896 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 10, *Cellular plastics*.

This third edition cancels and replaces the second edition (ISO 2896:1987), which has been technically revised.

Annex A forms a normative part of this International Standard.

Rigid cellular plastics — Determination of water absorption

1 Scope

This International Standard specifies a method for the determination of the water absorption of rigid cellular plastics by measuring the buoyant force on a test specimen after immersion under a 50 mm head of water for 4 days. Corrections are specified to take account of any change in volume of the specimen and also to correct for the volume of water in the cut surface cells of the specimen. The water absorption is expressed as the average, for several specimens, of the percentage increase in volume relative to the original volume.

The method described is intended for quality control and for use in product specifications.

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 1923:1981, *Cellular plastics and rubbers — Determination of linear dimensions*

3 Principle

The water absorption of a material is determined by measurement of the buoyant force on a specimen immersed in distilled water for a specified time.

4 Materials

4.1 Distilled water, de-aerated (by storage for at least 48 h after distillation), for use as the immersion liquid.

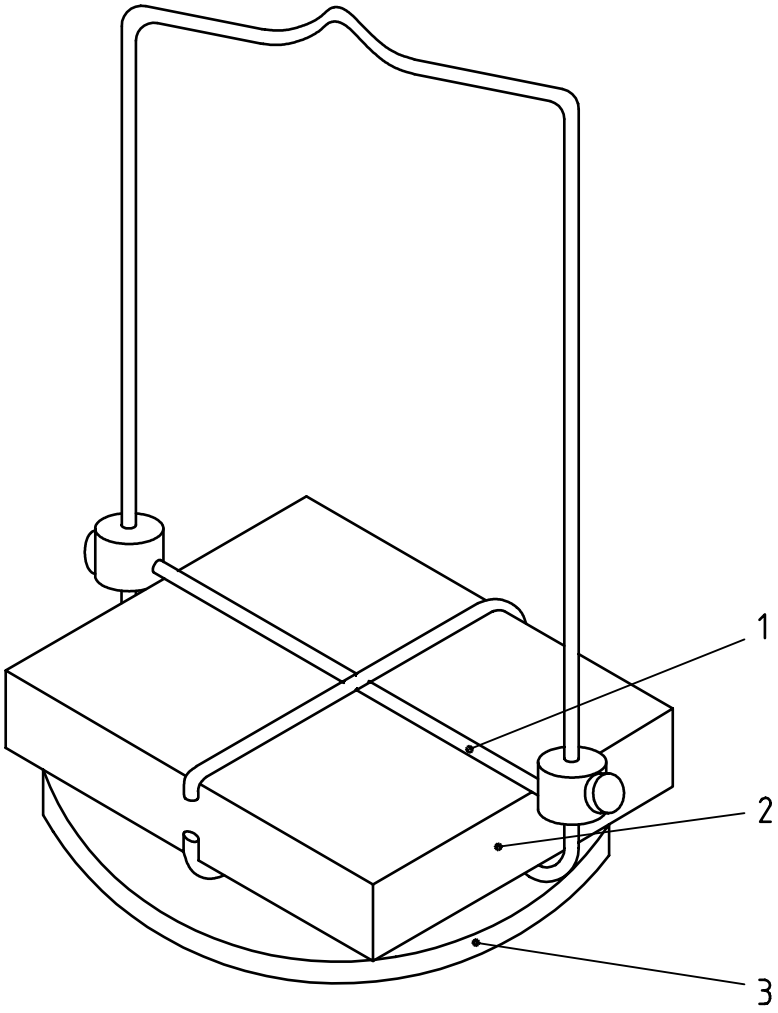
5 Apparatus

5.1 Balance, accurate to 0,1 g and capable of suspending the cage (5.2).

5.2 Underwater-weighing cage, made of a stainless material not attacked by distilled water and large enough to contain a test specimen. A sinker heavy enough to compensate for the upthrust produced by the test specimen shall be attached to the base of the cage. The cage shall be fitted with a means of suspending it from the balance. See Figure 1 for an example.

5.3 Cylindrical vessel, at least 250 mm in diameter and 250 mm in height.

5.4 Low-permeability plastic film, for example polyethylene.



Key

1 Mesh cage

2 Specimen

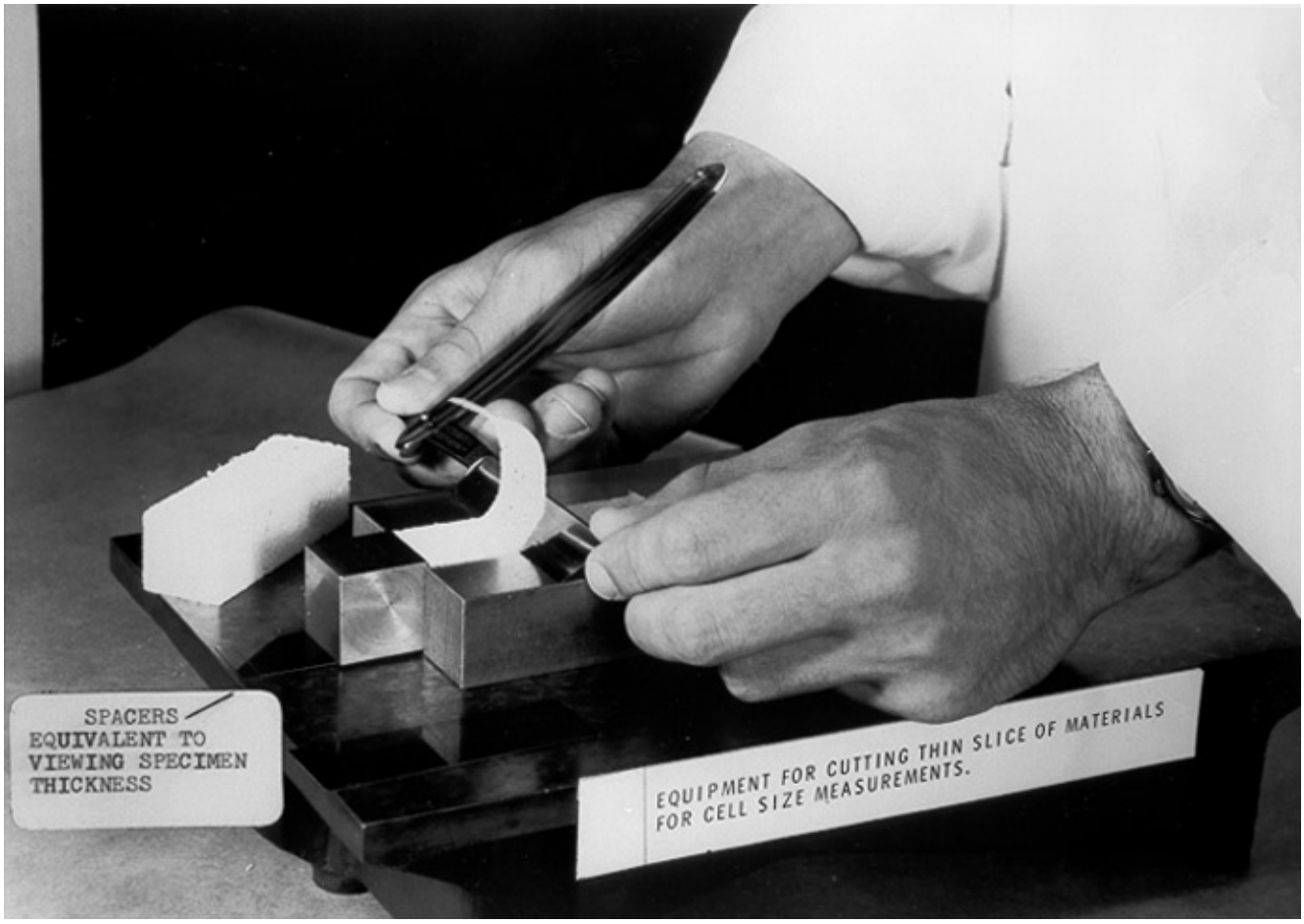
3 Sinker

Figure 1 — Test specimen in mesh underwater-weighing cage

5.5 Slicer: cutting-blade apparatus capable of preparing thin specimens (0,1 mm to 0,4 mm thick) for cell size viewing. Figure 2 shows an acceptable apparatus.

5.6 Slide assembly, consisting of two pieces of slide glass hinged by tape along one edge, between which is placed a calibrated scale (3 cm in length) printed on a thin plastic sheet (see Figure 3).

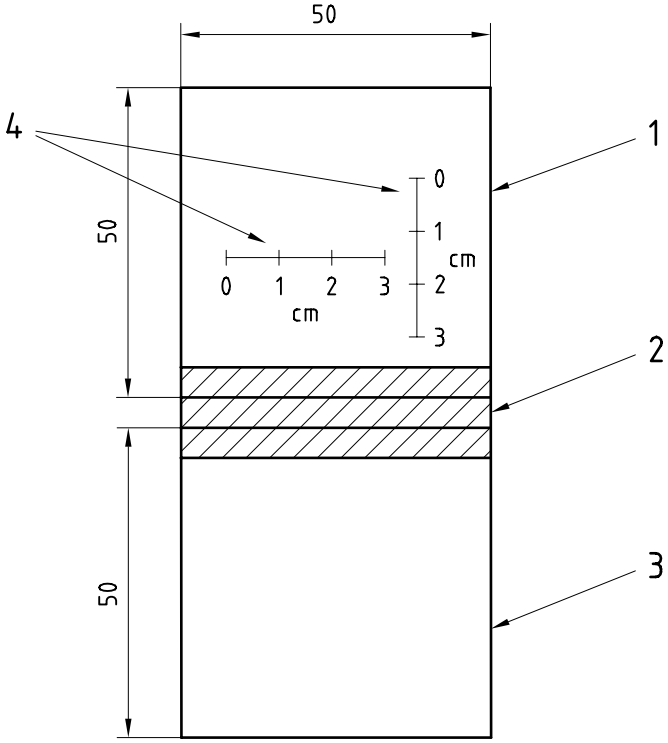
5.7 Projector: conventional 35 mm slide projector that accepts standard 50 mm × 50 mm slides, or a projection microscope with a calibrated scale.



NOTE The spacer thickness is chosen to give the required viewing-specimen thickness.

Figure 2 — Razor-blade equipment for slicing cellular plastics for determination of average cell diameter

Dimensions in millimetres



Key

1 Calibrated glass slide
2 Flexible tape hinge
3 Blank cover glass
4 Cell-count scales

Figure 3 — Slide assembly

6 Specimens

6.1 Number of specimens

At least three specimens shall be tested.

6.2 Dimensions

Specimens shall be at least 500 cm^3 in volume, with a nominal length of 150 mm and a nominal width of 150 mm. For materials produced and sold with natural or laminated skin surfaces, the thickness shall be as produced. For materials produced with a thickness greater than 75 mm and without skin surfaces, the material shall be trimmed to 75 mm in thickness for testing. The distance between two faces shall not vary by more than 1 % (tolerance of parallelism).

6.3 Preparation and conditioning

Surfaces of specimens shall be smooth and free from dust. Dry the specimens in a desiccator at ambient temperature until the results of two successive weighings, at intervals of at least 12 h, do not differ by more than 1 % of their mean.

7 Procedure

7.1 Operate in a room where the temperature is maintained in accordance with ISO 291. Unless otherwise specified[1)], conditions shall be (23 ± 2) °C and (50 ± 5) % relative humidity.

7.2 Weigh a specimen to the nearest 0,1 g (mass m_1).

7.3 Measure the dimensions of the specimen in accordance with ISO 1923 for the calculation of V_0.

7.4 Fill the cylindrical vessel (5.3) with de-aerated distilled water (4.1) at ambient temperature.

7.5 Immerse the assembled cage (5.2), remove any bubbles, attach it to the balance and determine the apparent mass (m_2) to the nearest 0,1 g.

7.6 Place the specimen in the cage. Re-immerse the cage so that the distance between the surface of the water and the top surface of the specimen is approximately 50 mm. Remove obvious air bubbles from the specimen with a brush or by agitation.

7.7 Cover the cylindrical vessel with low-permeability plastic film (5.4).

7.8 After (96 ± 1) h, or another agreed immersion period, remove the plastic film and determine the apparent mass (m_3), to the nearest 0,1 g, of the submerged cage containing the specimen.

7.9 Visually examine the specimen for evidence of swelling. To determine corrections for swelling and cut surfaces, follow procedure A (8.1) for uniform swelling and procedure B (8.2) for non-uniform swelling.

7.10 Carry out the above procedure for each specimen individually.

8 Corrections for swelling and cut surfaces

8.1 Procedure A (uniform swelling)

8.1.1 Applicability

Use procedure A when there is no evidence of non-uniform deformation of the specimen.

8.1.2 Correction for uniform swelling

Remove the specimen from the water and re-measure its dimensions within 4 h of removal. The correction for uniform swelling of the specimen S_0 is

$$S_0 = \frac{V_1 - V_0}{V_0}$$

where

V_0 is the original volume, in cubic centimetres, of the specimen (see 9.1);

1) For tropical countries, test conditions will normally be (27 ± 2) °C and (65 ± 5) % relative humidity.

$$V_1 = \frac{d_1 \times l_1 \times b_1}{1000}$$

d_1 being the specimen thickness, in millimetres, after immersion;

l_1 being the specimen length, in millimetres, after immersion;

b_1 being the specimen width, in millimetres, after immersion.

8.1.3 Correction for the volume of water in the cut surface cells

8.1.3.1 Using the method described in annex A, determine the average cell diameter D of a specimen obtained from the same sample of material as that from which the water absorption specimens were taken. Use this average cell diameter D, expressed in millimetres, to calculate the volume V_c of the surface cells cut during specimen preparation as follows:

8.1.3.1.1 For samples with natural or laminated skin surfaces:

$$V_c = \frac{0{,}54D\,(l \times d + b \times d)}{500}$$

8.1.3.1.2 For samples having cut cells on all surfaces:

$$V_c = \frac{0{,}54D\,(l \times d + l \times d + b \times d)}{500}$$

8.1.3.2 For samples with an average cell diameter of less than 0,50 mm and a specimen volume of at least 500 cm^3, the correction for cut surface cells is relatively small (less than 3,0 %) and may be omitted.

8.2 Procedure B (non-uniform swelling)

8.2.1 Applicability

Use procedure B when there is evidence of non-uniform deformation of the specimen.

8.2.2 Combined correction for swelling and the volume of water in the cut surface cells

Obtain a cylindrical vessel similar to the one described in 5.3 but fitted with an overflow. Fill this vessel with water until it runs from the overflow. When the water level has stabilized, place a graduated receptacle of capacity at least 600 cm^3 under the overflow. This receptacle shall be capable of allowing the volume of water deposited in it to be measured to $\pm 0{,}5$ cm^3 (this may be done by weighing). Remove the specimen and cage from the original vessel. Allow them to drain until the surface water has run off (approximately 2 min). Carefully immerse the specimen and cage in the water-filled vessel and determine the volume of water displaced V_2. Repeat this procedure with the empty cage to determine its volume V_3.

The combined swelling and cut surface correction factor S_1 is given by

$$S_1 = \frac{V_2 - V_3 - V_0}{V_0}$$

where V_0 is the original volume of the specimen (see 9.1).

9 Expression of results

9.1 Calculate the original volume of the specimen using the equation

$$V = \frac{d \times l \times b}{1000}$$

where

V_0 is the original volume, in cubic centimetres, of the specimen;

d is the original thickness, in millimetres, of the specimen;

l is the original length, in millimetres, of the specimen;

b is the original width, in millimetres, of the specimen.

9.2 Calculate the water absorption WA_V, expressed as a percentage by volume, as follows:

9.2.1 If procedure A (8.1) was used:

$$WA_V = \frac{m_3 + V_1 \times \rho - (m_1 + m_2 + V_c \times \rho)}{V_0 \times \rho} \times 100$$

where ρ is the density of water (= 1 g/cm^3).

9.2.2 If procedure B (8.2) was used:

$$WA_V = \frac{m_3 + (V_2 - V_3)\rho - (m_1 + m_2)}{V_0 \times \rho} \times 100$$

where ρ is the density of water (= 1 g/cm^3).

9.3 Calculate the average water absorption for all specimens tested.

10 Precision and accuracy

10.1 Precision

Table 1 — Precision data

All values in volume % except where otherwise stated

Material	Thickness mm	Average water absorption	s_r	s_R	r	R
Polyisocyanurate	75	2,06	0,138	0,049	0,039	1,36
Extruded polystyrene	75	0,17	0,042	0,08	0,12	0,23

where

s_r is the within-laboratory standard deviation for the indicated material (obtained by pooling the within-laboratory standard deviations of the test results from all the participating laboratories):

$$s_r = [(s_1)^2 + (s_2)^2 + \ldots (s_n)^2]/n^{1/2}$$

s_R is the between-laboratory reproducibility, expressed as a standard deviation;

r is the within-laboratory critical interval between two test results (= 2,8 × s_r);

R is the between-laboratory critical interval between two test results (= 2,8 × s_R).

NOTE This table is based on a round robin conducted in 1996 in accordance with ASTM E 691, *Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method*, and involving two materials tested by seven laboratories. For each material, all the samples were prepared at one source, but the individual specimens were prepared at the laboratories which tested them. Each test result was the average of three individual determinations. Each laboratory obtained one test result for each material.

10.2 Concept of r and R in Table 1

If s_r and s_R have been calculated from a large enough body of data, and for test results that are averages from testing three specimens, then the following statements apply:

Repeatability: Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the r-value for that material, r being the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

Reproducibility: Two test results obtained by different laboratories shall be judged not equivalent if they differ by more than the R-value for that material, R being the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

10.3 Accuracy

The accuracy of this method cannot be determined because standard reference materials are not available.

11 Test report

The test report shall include the following particulars:

a) a reference to this International Standard;

b) a description of the material tested, the type of material and the lot number;

c) details of the method used to prepare the test specimens, including whether the material was with or without skin;

d) the number of specimens tested and their dimensions;

e) the time of immersion;

f) the correction procedure used (A or B) and the corrections, expressed as a percentage by volume, i.e.:

$S_0 \times 100$

$S_1 \times 100$

$\frac{V_c}{V_0} \times 100$

g) the individual corrected results for water absorption and their average, expressed as a percentage by volume;

h) the average cell diameter for each specimen and the average for all the specimens tested, expressed in millimetres;

i) any observed anisotropic characteristics of the sample;

j) any observations relevant to the behaviour of the material;

k) the date of testing;

l) identification of the test facility.

Annex A
(normative)

Determination of average cell diameter (see 8.1.3.1)

A.1 Principle

A specimen of less than monocellular thickness is cut from the material on a slicer and its shadowgraph projected onto a screen by means of a scale slide assembly and projector. The average cell chord length is determined by counting the cells or cell-wall intersections within a specified distance, and this length is then converted to the average cell diameter by a mathematical formula.

A.2 Number of specimens

For cellular plastics having symmetrical cells of relatively uniform size, one specimen will normally provide a representative average cell diameter. For cellular plastics known to be significantly anisotropic, a specimen cut in each of the three principal directions will normally permit a representative average cell diameter to be determined.

A.3 Procedure

A.3.1 For each direction in which it is intended to determine the average cell diameter, cut a piece measuring 50 mm $\times$ 50 mm, and of the thickness of the sample, from the sample in the area to be tested. Prepare the cell-viewing specimen(s) by cutting a thin slice (less than monocellular) from one of the cut surfaces of each such piece of material. The slice shall be as thin as practicable so that the shadowgraph will not be occluded by overlapping cell walls. The optimum slice thickness will vary with the average cell size of the material, with smaller cell diameters requiring thinner slices.

A.3.2 Insert the slice into the slide assembly (5.6). Position the scale zero on the grid line at the top of the area to be measured. Reassemble the slide.

A.3.3 Insert the slide assembly into the projector (5.7). Focus the projector on a wall or screen so that a sharp-image shadowgraph results.

A.3.4 Determine the average cell chord length t from the projected shadowgraph as follows:

First count the number of cells (or cell walls) that intersect the 3 cm straight line projected with the specimen. Then divide the length of the line by the number of cells counted to obtain the average chord length t. If the specimen is less than 3 cm long, count the cells on the maximum grid length usable.

A.3.5 When the cell structure is anisotropic, determine the average cell diameter in each of the three principal directions and use the average of the three results.

A.4 Calculation

Calculate the average cell diameter using the equation

$$D = \frac{t}{0,616}$$

where

D is the average diameter, in centimetres, of the cells;

t is the average length, in centimetres, of the cell chord.

Multiply by 10 to convert to millimetres and report to two significant figures.

NOTE Assumptions made in the derivation of the equation for average cell diameter are that the cell shape is spherical and that the cells are relatively uniform with respect to size. Subclause A.3.4 describes the procedure for determining t, the average measured chord length of the randomly truncated cells. The relationship between t and the average cell diameter $\overline{d}$ appearing at the plane of the cut surface may be calculated as follows:

For any circle $x^2 + y^2 = r^2$, the mean value of the ordinates in the first quadrant is given by

$$\overline{y} = \frac{1}{r}\int_0^r \sqrt{r^2 - x^2}\,\mathrm{d}x = \frac{\pi r}{4} \tag{1}$$

where r is the radius of the cell in the surface plane.

$$\overline{y} = \frac{t}{2}$$

Therefore

$$\frac{t}{2} = \frac{\pi r}{4} \tag{2}$$

Since $r = \frac{\overline{d}}{2}$

$$t = \frac{\pi \overline{d}}{4} \tag{3}$$

Rearrangement of equation (3) yields

$$\overline{d} = \frac{t}{0,785} \tag{4}$$

The average diameter of the circular segments $\overline{d}$ is related to the diameter of the sphere D in the same manner. The average sphere diameter is larger than the average circular-segment diameter $\overline{d}$ because the cells are randomly truncated with respect to depth at the plane of the specimen surface. Equation (3) again applies, and the mean value of the sphere diameter with respect to the chord length is given by

$$D = \frac{\overline{d}}{0,785} \tag{5}$$

Combining equations (4) and (5) yields

$$D = \frac{t}{0,785^2} = \frac{t}{0,616} \tag{6}$$

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