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Plastics — Methods of test for the determination of the effects of immersion in liquid chemicals

Plastiques — Méthodes d'essai pour la détermination des effets de l'immersion dans des produits chimiques liquides

Reference number
ISO 175:2010(E)

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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 2.

The main task of technical committees is to prepare International Standards. 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 document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 175 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 6, *Ageing, chemical and environmental resistance*.

This third edition cancels and replaces the second edition (ISO 175:1999), of which it constitutes a minor revision.

Introduction

Because of their varied applications, plastics are frequently brought into contact with liquids such as chemical products, motor fuels, lubricants, etc., and, possibly, with their vapours.

Under the action of a liquid, a plastic material may be subjected to several phenomena which may occur simultaneously. On the one hand, absorption of liquid and extraction of constituents soluble in the liquid may occur. On the other hand, a chemical reaction, often resulting in a significant change in the properties of the plastic, may occur. The equilibrium swelling ratio for a crosslinked polymer in a liquid that is a solvent for the same but non-crosslinked polymer is a measure of the degree of crosslinking.

The behaviour of plastics in the presence of liquids can be determined only under arbitrarily fixed conditions aimed at making comparisons between different materials. The choice of test conditions (nature of the liquid, immersion temperature and immersion time), as well as the choice of the properties in which changes are to be measured, depends on the eventual application of the plastic under test.

It is not possible, however, to establish any direct correlation between the experimental results and the behaviour of the plastic in service. These tests do, nevertheless, permit a comparison to be made of the behaviour of different plastic materials under specified conditions, thus allowing an initial evaluation of their behaviour in relation to certain groups of liquids.

NOTE In view of its special importance, the particular case of the determination of the quantity of water absorbed is dealt with in ISO 62. ISO 175 is concerned with the effects of water only where changes in the dimensions and physical properties of the plastic occur as a result of the action of the water.

INTERNATIONAL STANDARD **ISO 175:2010(E)**

Plastics — Methods of test for the determination of the effects of immersion in liquid chemicals

1 Scope

1.1 This International Standard specifies a method of exposing test specimens of plastic materials, free from all external restraint, to liquid chemicals, and methods for determining the changes in properties resulting from such immersion. It does not cover environmental stress cracking (ESC) which is dealt with by the various parts of ISO 22088.

1.2 It only considers testing by immersion of the entire surface of the test specimen1).

NOTE This method may not be appropriate for simulating partial or infrequent wetting of plastics.

1.3 It is applicable to all solid plastics that are available in the form of moulding or extrusion materials, plates, tubes, rods or sheets having a thickness greater than 0,1 mm. It is not applicable to cellular materials.

2 Normative references

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

ISO 291:2008, *Plastics — Standard atmospheres for conditioning and testing*

ISO 294-3, *Plastics — Injection moulding of test specimens of thermoplastic materials — Part 3: Small plates*

ISO 2818, *Plastics — Preparation of test specimens by machining*

ISO 3126, *Plastics piping systems — Plastics components — Determination of dimensions*

ISO 4582, *Plastics — Determination of changes in colour and variations in properties after exposure to daylight under glass, natural weathering or laboratory light sources*

IEC 60296, *Fluids for electrotechnical applications — Unused mineral insulating oils for transformers and switchgear*

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1) Although it is not within the scope of this International Standard, it may also be of interest, when dealing with volatile liquids or those which give off vapours, to subject the specimen to only the gaseous phase above the liquid. In this event, it is advisable to proceed exactly as indicated, but to suspend the specimen above the liquid, seal the container and maintain it at the test temperature throughout.

3 Principle

Test specimens are completely immersed in a test liquid for a specified time and at a specified temperature.

Their properties are determined before immersion and after removal from the liquid, as well as after drying, if applicable. In the last-mentioned case, the determinations are made, if possible, one after the other on the same specimens.

NOTE The comparison of different plastics by means of this test is valid only if the specimens used are of the same shape, of the same dimensions (in particular of the same thickness) and in as nearly as possible the same state (of internal stress, surface, etc.).

Methods are specified for determining the following:

a) changes in mass, dimensions and appearance immediately after removal from the liquid and after removal and drying;

b) changes in physical properties (mechanical, thermal, optical, etc.) immediately after removal from the liquid and after removal and drying;

c) the amount of liquid absorbed.

Measurements are made immediately after removal when it is necessary to ascertain the state of the material while it is still being acted on by the liquid. Measurements are made after removal and drying when it is necessary to ascertain the state of the material after the liquid, provided it is volatile, has been eliminated. It also allows the influence of a soluble constituent to be determined.

4 General requirements and procedure

4.1 Test liquids

4.1.1 Choice of test liquid

If information is required about the behaviour of a plastic in contact with a specific liquid, that liquid shall be used. The test liquid shall be of analytical quality.

Industrial liquid chemicals are not generally of absolutely constant composition. The tests shall be carried out using defined chemical products, either on their own or as a mixture, which are as representative as possible of the products under consideration in their effect on the plastic material concerned. When technical-grade chemicals are used, they shall be of agreed origin and quality, and care shall be taken that only one manufacturing batch is used for all measurements in any one series.

If conducting a series of tests in a liquid of doubtful composition, it is important to take all the samples of the liquid from the same container.

4.1.2 Types of test liquid

Types of test liquid are given in Annex A.

4.2 Test conditions

4.2.1 Test temperatures

The preferred test temperatures are:

a) (23± 2) °C;

b) (70± 2) °C.

If a different temperature has to be used in order to correspond to the temperature at which the plastic is to be used, it shall be selected from one of the following temperatures:

−269 °C; −196 °C; −161 °C; −70 °C; −55 °C; −40 °C; −25 °C; −10 °C; 0 °C; 5 °C; 25 °C; 40 °C; 55 °C; 70 °C; 85 °C; 100 °C; 105 °C; 125 °C; 150 °C; 175 °C; 200 °C; 225 °C; 250 °C; 275 °C; 300 °C; 350 °C; 400 °C; 450 °C; 500 °C; 600 °C; 700 °C; 800 °C; 900 °C; 1 000 °C

NOTE These temperatures originate from ISO 3205:1976.

The following temperatures are recommended:

0 °C; 20 °C; 27 °C; 40 °C; 55 °C; 85 °C; 95 °C; 100 °C; 125 °C; 150 °C

with a tolerance of ± 2 °C on temperatures up to and including 100 °C and ± 3 °C on temperatures greater than 105 °C up to and including 200 °C. In the special case of testing plastic pipes, the temperature of 60 °C given in the annex to ISO 3205:1976 may be used.

In the event that the test is to be carried out at a temperature above normal ambient conditions, it may be desirable to condition another series of specimens at this temperature for a period equal to that of the test, and to measure their properties after this conditioning in order to be able to distinguish the effect of temperature from that of the liquid.

In the case of long-duration tests, specimens stored in air at 23 °C may undergo a change in properties. Preparation of an additional series of test specimens is recommended for comparison purposes.

4.2.2 Measurement temperature

The temperature for the determination of changes in mass, dimensions or physical properties is 23 °C ± 2 °C. If the immersion temperature is different, bring the specimen to 23 °C by the procedure described in 4.6.3.

4.3 Immersion time

The preferred immersion times are:

a) 24 h for a short-duration test;

b) 1 week for a standard test (particularly at 23 °C);

c) 16 weeks for a long-duration test.

If other immersion times need to be used, for example if it is desired to perform tests as a function of time or to plot the curve until equilibrium is reached, it is recommended that the immersion times be chosen from the following standard scale:

d) 1 h — 2 h — 4 h — 8 h — 16 h — 24 h — 48 h — 96 h — 168 h;

e) 2 weeks — 4 weeks — 8 weeks — 16 weeks — 26 weeks — 52 weeks — 78 weeks;

f) 1,5 years — 2 years — 3 years — 4 years — 5 years.

4.4 Test specimens

Depending upon the measurements to be made after immersion (mass, dimensions, physical properties) and the nature and form of the plastic material (sheet, film, rod, etc.), the specimens will be of very diverse shapes and dimensions.

They may be obtained directly by moulding, or by machining. In the latter case, cut surfaces shall be machined to a fine finish and shall show no trace of carbonization that could be attributed to the method of preparation.

For the specimens specified in 5.3.1 and 5.3.2, the preferred specimen size is 60 mm × 60 mm with a thickness depending on the type of plastic material:

- for thermoplastics, the preferred thickness is 1,0 mm to 1,1 mm;
- for moulding compounds, the specimen is identical to that specified in ISO 294-3;
- for semi-finished materials, the specimen should preferably be prepared by machining in accordance with ISO 2818, leaving at least one original surface intact;
- for composites, the preferred thickness is at least 2 mm.

NOTE Tests using specimens thinner or thicker than the recommended 1 mm can be conducted to determine whether specimen thickness effects changes in mass, dimensions, appearance or amount of liquid absorbed.

The number of specimens to be used will be specified in the International Standards relevant to the tests to be carried out after treatment. In the absence of specific International Standards, at least three specimens shall be tested.

4.5 Conditioning

Condition the specimens in atmosphere 23/50, class 2, as defined in ISO 291:2008.

NOTE For certain plastics which are known to approach temperature equilibrium and, in particular, humidity equilibrium rapidly or very slowly, shorter or longer conditioning periods can be specified in the appropriate product specifications (see Annex B).

4.6 Procedure

4.6.1 Quantity of test liquid

The quantity of test liquid used shall be at least 8 ml per square centimetre of the total surface area of the specimen in order to avoid too high a concentration of any extracted products in the liquid during the course of the test. The test liquid shall cover the specimen completely.

NOTE A different quantity of liquid might, however, be specified in particular International Standards; for example, for rigid PVC and polyolefin pipes, where the amount of extractable substances is known to be very small, a smaller quantity of liquid is specified in the relevant International Standards.

4.6.2 Positioning of specimens

Place each set of test specimens in a suitable container (see 5.2) and completely immerse them in the test liquid (using a weight if necessary). When several materials of the same composition are to be tested, it is permissible to put several sets of specimens in the same container.

Ensure that, for every specimen, only an insignificant proportion of the surface of the specimen makes contact with the surfaces of other specimens, with the walls of the container or with any weight that is used.

During the test, stir the liquid, for example by swirling it in the container, at least once per day.

If the test lasts longer than seven days, replace the liquid with an equal amount of the original liquid every seventh day (see Note 2 to 4.6.3).

If the liquid is unstable (for example in the case of sodium hypochlorite), replace the liquid more frequently.

If light is likely to affect the action of the test liquid, it is recommended that the test be carried out either in darkness or under defined illumination conditions.

It may be necessary in certain cases to specify the height of the liquid level above the specimens (for example if there is a risk of oxidation) or to measure the volume of the liquid absorbed. The volume absorbed by the specimen is the difference between the initial volume of the liquid and the volume of the remaining liquid. Where it is necessary to calculate this, the apparatus shall allow the measurement of the volume of the liquid alone.

4.6.3 Rinsing and wiping

At the end of the period of immersion, bring the temperature of the specimens back to ambient temperature if necessary by transferring them quickly into a fresh quantity of test liquid at room temperature and leaving them for a period of 15 min to 30 min.

Use one of the following procedures for rinsing the specimens after they have been removed from the test liquid:

a) For specimens which have been immersed in acid, alkali or other aqueous solutions, rinse thoroughly with clean water. Hygroscopic reagents such as concentrated sulfuric acid may remain adsorbed on the surface of the specimens even after rinsing, requiring immediate special treatment to avoid moisture pickup before and during weighing.

b) For specimens removed from non-volatile, non-water-soluble organic liquids, rinse with a non-aggressive but volatile solvent such as light naphtha.

NOTE 1 In the case of specimens immersed in volatile liquids such as acetone or alcohol at ambient temperature, rinsing and wiping may not be necessary.

Wipe the specimens dry with filter paper or a lint-free cloth.

NOTE 2 It may be necessary to examine the test liquid at the end of the test. This examination could be a simple visual examination, a measurement of the volume or mass of the liquid not absorbed, or a more rigorous examination, including, for example, a titration.

This examination may not be meaningful if the liquid has been replaced during the test.

4.7 Expression of results

4.7.1 Numerical expression

In addition to giving the measurements made before and after immersion, the value of the property after immersion (X_2) may be expressed (except in special cases of changes in mass) as a percentage of the value before immersion (X_1), using the following formula:

$$\frac{X_2}{X_1} \times 100$$

4.7.2 Graphical expression

In every case where measurements are made as a function of time, it is recommended that graphs be plotted. Plot the values obtained (including the original value), or the differences in value, as the ordinates and the immersion times t as the abscissae. If it is necessary to shorten the immersion-time scale, either a $t^{0,5}$ scale or a $\log t$ scale may be used.

The double-logarithmic plot as recommended in ISO 62 of, for example, the mass or volume of liquid absorbed versus the immersion time allows the determination of the concentration at saturation and the diffusion coefficient over short immersion times if the absorption follows Fick's laws.

5 Determination of changes in mass, dimensions and appearance

5.1 General

These determinations may, if necessary, be carried out on the same specimens.

At least three specimens shall be used.

5.2 Apparatus

5.2.1 For all tests

5.2.1.1 **Beakers**, of suitable dimensions, fitted with lids (airtight, if necessary) and fitted with condensers in the case of volatile liquids or those which give off vapours. The apparatus shall be resistant to the corrosive effects of the liquids being used. Beakers that can be tightly sealed shall be used when conducting tests above room temperature, in order to minimize loss of the liquid by evaporation.

5.2.1.2 **Enclosure**, thermostatically maintained at the test temperature. Venting shall be provided when tests are conducted at elevated temperatures with volatile liquids.

5.2.1.3 **Thermometer**, of suitable range and accuracy.

5.2.1.4 **Ventilated oven**, if required, capable of being maintained at the chosen drying temperature.

In the absence of any special instructions, use an oven maintained at (50 ± 2) °C.

5.2.2 For determinations of changes in mass

5.2.2.1 **Weighing bottle.**

5.2.2.2 **Balance**, accurate to within 1 mg for specimens of mass equal to or greater than 1 g, or to within 0,1 mg for specimens of mass less than 1 g.

5.2.3 For determinations of dimensional changes and changes in volume

5.2.3.1 **Dial micrometer**, with flat anvils and/or ball anvil, accurate to 0,01 mm.

5.2.3.2 **Calliper gauge**, capable of measuring to an accuracy of 0,1 mm.

5.2.3.3 **Graduated glass tube**, to determine the initial volume of the specimen.

5.2.3.4 **Specimen-immersion apparatus**, capable of determining the volume of the remaining liquid (see Reference [8] in the Bibliography), for example two glass bulbs connected by a graduated capillary and completely sealed [see Figure 1 a)]. To begin the immersion, the apparatus is turned through 180° so that the specimen in bulb 1 is immersed in the liquid [see Figure 1 b)]. To determine the volume of liquid remaining, the apparatus is turned back to its starting position. The liquid flows into bulb 2 and the change in volume of the liquid can be read from the scale on the capillary [see Figure 1 c)]. After reading the volume, the apparatus is turned back through 180° and the immersion continued.

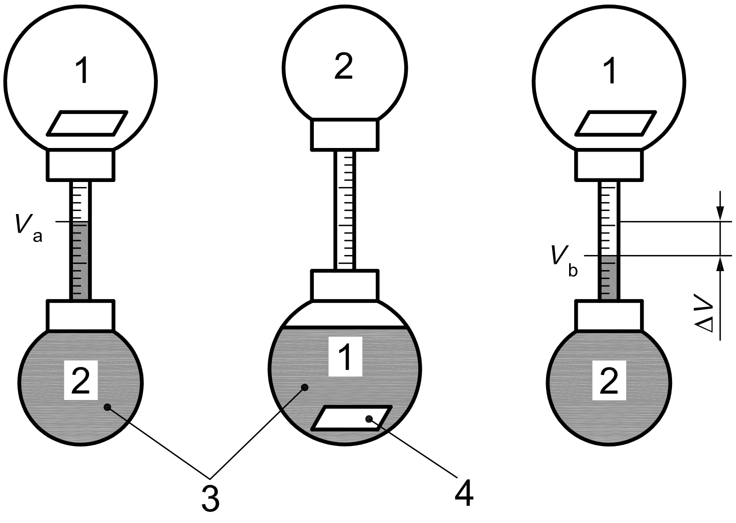
5.3 Test specimens (see also 4.4)

5.3.1 Moulding materials

Specimens shall be square with an edge (60 ± 1) mm long and a thickness between 1,0 mm and 1,1 mm. They shall be moulded to shape under the conditions specified in the appropriate product specification (or under the conditions prescribed by the supplier).

NOTE 1 The general principles for the preparation of moulded specimens are described in ISO 293, ISO 294-3 and ISO 295.

NOTE 2 A square specimen measuring 50 mm × 50 mm × 4 mm can be used by agreement between the interested parties. Using this 4-mm-thick specimen will increase the time necessary to reach equilibrium by a factor of 16 relative to 1-mm-thick specimens.



a) **b)** **c)**

Key

1	bulb 1	3	liquid	V_a	volume before immersion
2	bulb 2	4	specimen	V_b	volume after immersion

Figure 1 — Specimen-immersion apparatus

5.3.2 Extrusion compounds

Specimens shall be square with an edge (60 ± 1) mm long and a thickness between 1,0 mm and 1,1 mm. They shall be cut from a sheet of this thickness prepared under the conditions given in the appropriate product specification (or under the conditions given by the supplier of the material).

A square specimen measuring 60 mm × 60 mm × 2 mm may be used by agreement between the interested parties.

5.3.3 Sheets and plates

Specimens shall be square with an edge (60 ± 1) mm long and shall be machined in accordance with ISO 2818 from the sheet or plate submitted for test.

If the nominal thickness of the sheet or plate is less than or equal to 25 mm, the thickness of the specimens shall be the same as that of the sheet or plate.

If the nominal thickness is greater than 25 mm, and in the absence of special provisions in the relevant specification, the thickness of the specimen shall be reduced to between 1,0 mm and 1,1 mm or between 2,0 mm and 2,1 mm by machining one face only.

NOTE For Fickian diffusion, the time to reach equilibrium increases in proportion to the square of the specimen thickness. In particular, 25-mm-thick specimens will typically require more than 5 years to reach equilibrium.

5.3.4 Tubes and rods

5.3.4.1 Tubes

If possible, reference shall be made to the relevant International Standards for the material under test[2]. In the absence of specific International Standards, the specimen shall be a piece of tube of length (60 ± 1) mm, obtained by cutting it at right angles to its longitudinal axis.

For tubes of outside diameter greater than 60 mm, a length of (60 ± 1) mm shall be cut and the test specimen prepared from this length by making a cut along each of two planes containing the longitudinal axis of the tube, so as to give a developed width of (60 ± 1) mm when measured on the outer surface.

5.3.4.2 Rods

For rods of diameter less than or equal to 60 mm, the test specimen shall be a piece of the rod of length (60 ± 1) mm, obtained by cutting it at right angles to its longitudinal axis.

For rods of diameter greater than 60 mm, in the absence of any specification agreed between the interested parties, the test specimen shall be a (60 ± 1) mm length of the rod with its diameter reduced to (60 ± 1) mm by machining concentrically.

5.3.5 Profile sections

In the absence of specific International Standards, cut a (60 ± 1) mm long piece of the profile section and use this as the test specimen. Ensure the thickness of the piece approximates as closely as possible to 1,0 mm to 1,1 mm, if necessary by machining one face only. The exact thickness to be achieved and the machining conditions shall be subject to agreement between the interested parties.

5.4 Determination of changes in mass[3]

5.4.1 Procedure

5.4.1.1 Conditioning

Condition the specimens in accordance with 4.5 and select the test conditions in accordance with 4.1 to 4.3.

5.4.1.2 Measurement of initial mass

Determine the mass m_1 of each specimen to the nearest 1 mg in the case of specimens of mass greater than or equal to 1 g, or to the nearest 0,1 mg in the case of specimens of mass less than 1 g.

Immerse the specimens in the test liquid as indicated in 4.6.2.

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[2] The preparation of methods of test for plastics pipes is the responsibility of ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids*. The general procedures described in this International Standard have been used as a basis for the appropriate methods of evaluating the effects of liquid chemicals on plastic pipes.

ISO 4433 (all parts), specifies the method of test for polyolefin, PVC and PVDF pipes.

[3] In the case of water, see ISO 62.

5.4.1.3 Measurement of mass immediately after removal from the liquid

After removal from the test liquid, rinse and wipe the specimens in accordance with 4.6.3 and place each specimen in a tared weighing bottle, stopper it and determine the mass of the specimen m_2 to the nearest 1 mg or 0,1 mg as appropriate (see 5.4.1.2).

If the liquid used for the test is volatile at ambient temperature, the time during which the specimen is exposed to the air shall not exceed 30 s. If it is necessary to continue the test after weighing (i.e. when testing as a function of time), immediately replace the specimens in the test liquid and put the beakers back in the thermostatically controlled enclosure.

5.4.1.4 Measurement of mass immediately after removal and after drying

After carrying out 5.4.1.3, remove the specimens from the weighing bottles and dry them in the oven at the specified temperature to constant mass. For 1-mm-thick specimens dried at (50 ± 2) °C, this usually takes 2 h. Allow the specimens to cool if necessary, recondition them in accordance with 4.5 and determine the mass m_3 of each specimen.

NOTE The reconditioning stage may be omitted by agreement between the interested parties.

5.4.1.5 Measurement of mass only after drying

Alternatively, immediately after removal from the test liquid, rinse and wipe the specimens in accordance with 4.6.3, then place them in the oven and proceed as in 5.4.1.4.

5.4.2 Calculation and expression of results

5.4.2.1 Report, as applicable, for each specimen, the mass, in milligrams,

a) before immersion, m_1;

b) immediately after removal from the liquid, m_2;

c) after removal, drying and reconditioning, m_3.

Calculate, as applicable, the values of

$$m_2 - m_1$$

and/or

$$m_3 - m_1$$

and report these values together with their signs.

5.4.2.2 In addition, calculate the following.

5.4.2.2.1 Change in mass per unit area

For each specimen, calculate the increase or decrease in mass per unit area, expressed in milligrams per square centimetre, using the following formulae:

- immediately after removal from the liquid (if applicable):

$$\frac{m_2 - m_1}{A}$$

— after removal, drying and reconditioning:

$$\frac{m_3 - m_1}{A}$$

where A is the total initial surface area, in square centimetres, of the specimen.

5.4.2.2.2 Percentage change in mass

For each specimen, calculate the percentage increase or decrease in mass using the following formulae:

— immediately after removal from the liquid (if applicable):

$$\frac{m_2 - m_1}{m_1} \times 100$$

— after removal, drying and reconditioning:

$$\frac{m_3 - m_1}{m_1} \times 100$$

5.4.2.3 In every case, calculate the arithmetic mean of the results for specimens taken from the same sample.

5.5 Determination of changes in dimensions

5.5.1 Procedure

5.5.1.1 Conditioning

Condition the specimens in accordance with 4.5 and select the test conditions in accordance with 4.1 to 4.3.

5.5.1.2 Measurement of initial dimensions

5.5.1.2.1 Square specimens

Mark the four sides of the specimen and measure the length of each side to the nearest 0,1 mm, using the calliper gauge. Record the mean, l_1.

Measure, to the nearest 0,01 mm, the thickness of the specimen at four marked points situated at least 10 mm from the edges of the specimen, using the dial micrometer. Record the mean, h_1.

5.5.1.2.2 Rods and profile sections

Measure and record the length l_1 of the specimen to the nearest 0,1 mm, using the calliper gauge.

Measure the thickness of the specimen at four marked points to the nearest 0,01 mm, using the dial micrometer. Record the mean, h_1.

If the thickness of a profile section is not constant, measure it in two regions of different thickness.

5.5.1.2.3 Tubes

Measure the mean outside diameter d_1, the length l_1 and the wall thickness h_1 as specified in ISO 3126.

5.5.1.3 Measurement of initial volume

Measure the volume V_1 of the test specimen at 23 °C, using the graduated glass tube (5.2.3.3).

5.5.1.4 Immersion

Immerse the specimens as indicated in 4.6.2, using a beaker or the apparatus described in 5.2.3.4.

5.5.1.5 Measurement of dimensions immediately after removal from the liquid

After removal from the test liquid, rinse and wipe the specimens in accordance with 4.6.3 and make the same measurements on each specimen as in 5.5.1.2. Record the mean values, d_2, l_2 and h_2 or V_2, as appropriate.

It is important not to wait before commencing the determination of the dimensions.

5.5.1.6 Measurement of dimensions immediately after removal and after drying

After carrying out 5.5.1.5, dry the specimens in the oven at the specified temperature and for the specified time, usually for 2 h at (50 ± 2) °C. Allow the specimens to cool if necessary, recondition them in accordance with 4.5 and make the same measurements on each specimen as in 5.5.1.2. Record the mean values, d_3, l_3 and h_3 or V_3, as appropriate.

NOTE The reconditioning stage can be omitted by agreement between the interested parties.

5.5.1.7 Measurement of dimensions only after drying

Alternatively, immediately after removal from the test liquid, rinse and wipe the specimens in accordance with 4.6.3, then place them in the oven and proceed as in 5.5.1.6.

5.5.1.8 Measurement of volume of liquid absorbed

Determine the amount of absorbed liquid as described in 5.2.3.4, i.e. as the difference between the initial volume and the volume remaining after removal of the specimens.

5.5.2 Calculation and expression of results

5.5.2.1 In addition to reporting the initial and final dimensions or volumes, or both, express the swelling ratio as a ratio or as a percentage of the initial value:

$$Q = \frac{V_2 - V_1}{V_1} = \frac{\Delta V}{V_1} = \frac{V_b - V_a}{V_1}$$

or, expressed as a percentage:

$$Q' = \frac{\Delta V}{V_1} \times 100$$

A swelling ratio of zero signifies that the liquid has had no effect.

5.5.2.2 Calculate the arithmetic mean of the results relating to specimens taken from the same sample.

5.5.2.3 If applicable, plot graphs of the results as a function of the immersion time (see 4.7.2).

5.6 Determination of changes in colour or other appearance attributes

5.6.1 General

Examination of changes in colour or other appearance attributes may be conducted together with the other tests described in this International Standard, or they may be carried out separately. In every case, prepare supplementary specimens for comparison.

5.6.2 Procedure

5.6.2.1 If the changes in colour or other appearance attributes are determined as a complement to one of the tests specified in this International Standard, use the procedure specified for that test.

5.6.2.2 If the changes in colour or other appearance attributes are determined separately, use the general procedure (see Clause 4), subject to agreement between the interested parties.

5.6.2.3 Examine each specimen, in comparison with an untreated specimen, in accordance with ISO 4582 and record any changes in the following properties:

a) colour:

- by instrumental methods;
- by visual assessment using a grey scale;

b) other appearance properties:

- by instrumental measurements (gloss, transparency);
- by visual assessment of the changes in the following appearance properties:
  - development of crazing and cracking;
  - development of blisters, pitting and other similar effects;
  - presence of material which can be easily rubbed off;
  - tacky appearance;
  - delamination, warping or other deformation;
  - partial dissolution;

  using the notation scale given in Table 1.

Table 1

Qualitatively estimated changes
none
barely perceptible
slight
moderate
substantial

5.6.3 Expression of results

Express the results in accordance with ISO 4582 and, in the case of visual assessment of appearance properties, by the notation scale given in Table 1.

Report separately the results relating to specimens that have been simply immersed and wiped dry and those relating to specimens that have also been oven-dried and reconditioned.

6 Determination of changes in other physical properties

6.1 General

The properties investigated may include mechanical, electrical, thermal or optical properties.

6.2 Apparatus

6.2.1 Apparatus specified in 5.2, excluding the balances unless required for special cases.

6.2.2 Additional apparatus, as specified in the appropriate International Standards for the determination of the properties under investigation.

6.3 Test specimens

6.3.1 Shape and dimensions

The specimens shall have the shape and dimensions specified in the relevant International Standards for the determination of the properties under investigation.

If several sizes of test specimen are allowed, it is recommended that the size having a thickness nearest to 4 mm be chosen (see Note to Clause 3).

6.3.2 Preparation

Follow the instructions in the relevant International Standard.

Certain properties are very sensitive to internal stresses in the test specimens. Consequently, in order to evaluate end products, it is recommended that specimens taken from these products be used rather than specially moulded or extruded specimens.

6.3.3 Number

Prepare the number of specimens specified in the relevant International Standard. In the case of tests that alter the test specimen (in particular, tests to destruction), prepare additional specimens to serve as controls.

6.4 Procedure

6.4.1 Conditioning and measurement of initial values

Condition the specimens in accordance with 4.5 and select the test conditions in accordance with 4.1 to 4.3.

Determine the initial values of the selected physical properties in accordance with the relevant International Standards.

Immerse the specimens in the test liquid as indicated in 4.6.2.

6.4.2 Measurement immediately after removal from the liquid

After removal from the test liquid, rinse and wipe the specimens in accordance with 4.6.3 and remeasure the properties as in 6.4.1.

If the liquid used in the test is volatile at ambient temperature, start determining the properties within 2 min to 3 min after removal of the specimens from the liquid.

6.4.3 Measurement after removal and after drying

After carrying out 6.4.2, dry the specimens in the oven, maintained at the specified temperature, for the specified time or, in the absence of any specification, at (50 ± 2) °C for 2 h ± 15 min. Allow the specimens to cool if necessary, recondition them in accordance with 4.5 and remeasure the properties in accordance with the relevant International Standards.

NOTE The reconditioning stage can be omitted by agreement between the interested parties.

6.4.4 Measurement only after drying

Alternatively, immediately after removal from the test liquid, rinse and wipe the specimens in accordance with 4.6.3, then place them in the oven and proceed as in 6.4.3.

6.5 Calculation and expression of results

6.5.1 Calculate the values of the properties as specified in the relevant International Standards.

Calculate, as applicable, the average values of:

Y_1 the value of the property for each specimen before immersion (or of the control specimen);

Y_2 the value of the property for each specimen immediately after removal from the liquid;

Y_3 the value of the property for each specimen after removal, drying and reconditioning.

6.5.2 For predictable properties (i.e. those which vary in accordance with a well defined law), calculate the final percentage value of each property with respect to the initial value[4] using the following formulae:

$\frac{Y_2}{Y_1} \times 100$ for the percentage change after removal from the liquid;

$\frac{Y_3}{Y_1} \times 100$ for the percentage change after removal, drying and reconditioning.

These percentages may be greater than, equal to or less than 100 %. A value of exactly 100 % signifies that the liquid has had no effect.

6.5.3 If applicable, plot graphs of the results as a function of the immersion time.

7 Precision

No relevant precision data are currently available. When interlaboratory data are obtained, a precision statement will be added.

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[4] This calculation has no significance for properties which vary arbitrarily.

8 Test report

The test report shall include the following information:

a) a reference to this International Standard;

b) all details necessary for complete identification of the material or product tested;

c) the type of specimen used, its method of preparation, its dimensions, surface condition, etc.;

d) the conditioning procedure used;

e) the test liquid used, the immersion temperature and the immersion time(s), and any other applicable conditions (illumination or darkness, exposure to vapour, etc.);

f) the temperature and length of any drying procedure used;

g) the methods of visual examination used;

h) the properties investigated and the methods of test used;

i) the results obtained, determined in accordance with 4.7, 5.4.2, 5.5.2, 5.6.3 and/or 6.5, as applicable, plus, if prepared, graphs of the results as a function of time;

j) if requested, the result of the examination of the test liquid after the test;

k) any occurrence likely to have had an effect on the results.

Annex A
(normative)

Types of test liquid

A.1 Tables A.1 and A.2 provide details of laboratory chemicals and miscellaneous products which may be used as test liquids by agreement between the interested parties.

All laboratory chemicals used shall be of laboratory reagent quality.

The quality, reference and/or composition of any of the miscellaneous products used shall, if necessary, be subject to agreement between the interested parties.

WARNING — The preparation of certain of these liquids by dilution of concentrated products can be dangerous and should be undertaken only under the supervision of an experienced chemist.

A.2 The hazards associated with the handling of these products, together with the precautions to be taken, are indicated in the tables by the following key:

A Products that are corrosive to various degrees and which should never come into contact with the skin or clothing. Use safety pipettes only.

B Flammable products, not to be handled near a source of ignition.

C Products that give off irritant or toxic fumes and which should be handled only under an efficiently ventilated hood.

Table A.1 — Laboratory chemicals

Test liquid	**Concentration**[a]		**Precautions to be taken** (see clauses A.1 and A.2)	**Comments**	**Density at 20 °C**[b]
	% by mass	kg/m^3			kg/m^3
Acetic acid	99,5		A + C	Concentrated	1 050
Acetic acid	5	50		Add 50 ml of concentrated acetic acid to 950 ml of water	
Acetone	100		B		785
Ammonium hydroxide solution	25	230	A + C	Expressed as ammonia (NH_3)	907
Ammonium hydroxide solution	10	96	A + C	Expressed as ammonia (NH_3)	958
Aniline	100		A + C		1 021
Chromic acid solution	40 (as CrO_3)	550	A + C	Add 3 ml of concentrated sulfuric acid per litre of solution	
Citric acid solution	10	100			
Diethyl ether	100		B + C		719
Distilled water	100				
Ethanol		770	B	96 % by volume (71° O.P.)	802
Ethanol	50	460		1 000 ml of 96 % by volume ethanol and 740 ml of water	
Ethyl acetate	100		B + C		901
n-Heptane	100		B		683
Hydrochloric acid	36		A + C	Concentrated	1 180
Hydrochloric acid	10	105	A + C	Add 250 ml of concentrated hydrochloric acid to 750 ml of water	
Hydrofluoric acid [c]	40	450	A + C		1 160
Hydrogen peroxide	30	330	A	Not diluted	
Hydrogen peroxide	3	31	A	10 volumes of 30 % by volume H_2O_2 and 90 volumes of water	
Lactic acid	10	100			
Methanol	100		B + C		790
Nitric acid	70		A + C	Concentrated	1 420
Nitric acid	40	500	A	Add 500 ml of concentrated nitric acid to 540 ml of water	1 250
Nitric acid	10	105	A	Add 105 ml of concentrated nitric acid to 900 ml of water	1 050
Oleic acid	100				890
Phenol solution	5	50	A		
Sodium carbonate solution	20	216	A	Expressed as $Na_2CO_3 \cdot 10H_2O$	1 080
Sodium carbonate solution	2	20			1 010
Sodium chloride solution	10	108			1 070
Sodium hydroxide solution	40	575	A		1 430
Sodium hydroxide solution	1	10	A		1 010
Sodium hypochlorite solution	10		A + C	9,5 % active chlorine	
Sulfuric acid	98		A	Concentrated	1 840
Sulfuric acid	75	1 250	A	Add 695 ml of concentrated sulfuric acid to 420 ml of water	1 670
Sulfuric acid	10		A	$c(H_2SO_4) = 1$ mol/l	
Sulfuric acid	5		A	$c(H_2SO_4) = 0{,}5$ mol/l	
Toluene	100		B		871
2,2,4-Trimethylpentane (*iso*-octane)	100		B		698

[a] The numerical values of concentrations in grams per litre and in kilograms per cubic metre are the same.

[b] The mass per unit volume in grams per millilitre is obtained by dividing the mass per unit volume in kilograms per cubic metre by 1 000.

[c] If, during use, hydrofluoric acid solution is splashed onto the skin, treat the skin immediately with a solution or gel of calcium gluconate.

Table A.2 — Miscellaneous products

Test liquid	**Remarks**	**Precautions to be taken** (see A.1 and A.2)
Mineral oil	For example, reference oil No. 1, 2 or 3 as specified in ISO 1817:2005[a]	
Insulating oil	In accordance with IEC 60296	
Olive oil	Quality to be specified	
Cotton seed oil	Quality to be specified	
Solvent mixtures	For example, reference liquid A, B, C or D as specified in ISO 1817:2005[a]	B
Soap solution	1 % soap solution prepared from soap flakes	
Detergent	Quality and concentration to be specified	
Essence of turpentine	Quality to be specified	B
Kerosene	Quality to be specified	B
Petrol (gasoline)	Quality to be specified [b]	B

[a] ISO 1817 deals with the effect of liquids on vulcanized elastomers.

[b] The petrol shall not contain benzene.

Annex B
(informative)

Notes on the absorption of moisture by plastic specimens in equilibrium with a conditioning atmosphere

B.1 The amount and rate of absorption of moisture by a specimen conditioned in a humid atmosphere varies considerably depending on the nature of the plastic.

B.2 The conditioning procedures established in this International Standard (see 4.5) are generally satisfactory with the exception of:

a) materials that are known to reach equilibrium with their conditioning atmosphere only after a very long time (for example, certain polyamides);

b) new materials or those of unknown structure, for which no *a priori* forecast can be made either of their ability to absorb moisture or of the time required to reach equilibrium.

B.3 For the materials mentioned in B.2, one of the following procedures may be used:

a) Drying the material at elevated temperature. This procedure has the disadvantage that certain properties, in particular mechanical ones, differ in the dried state from those obtained after conditioning in an atmosphere at (23 ± 2) °C and (50 ± 10) % relative humidity.

b) Conditioning the specimens in an atmosphere 23/50, class 2, as defined in ISO 291:2008 until equilibrium is reached. In this case, a convenient criterion may be for the mass to be constant within 0,1 % for two determinations separated by an interval of h^2 weeks (h being the thickness, in millimetres, of the specimen). For certain polymers, it is sufficient to plot the mass/time graph, with time intervals very much less than h^2 weeks; for practical purposes, equilibrium is considered to be reached when the gradient of the graph, expressed as a percentage, is equivalent to 0,1 % over h^2 weeks.

Bibliography

[1] ISO 62, *Plastics — Determination of water absorption*

[2] ISO 293, *Plastics — Compression moulding test specimens of thermoplastic materials*

[3] ISO 295, *Plastics — Compression moulding of test specimens of thermosetting materials*

[4] ISO 1817:2005, *Rubber, vulcanized — Determination of the effect of liquids*

[5] ISO 3205:1976, *Preferred test temperatures*

[6] ISO 4433 (all parts):1997, *Thermoplastics pipes — Resistance to liquid chemicals — Classification*

[7] ISO 22088 (all parts), *Plastics — Determination of resistance to environmental stress cracking (ESC)*

[8] MENCER, H.J. and GOMZI, Z. Swelling Kinetics of Polymer-Solvent Systems. Eur. Polymer J., **30**(1), 1994, pp. 33-36

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