INTERNATIONAL STANDARD

ISO 294-4

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Plastics — Injection moulding of test specimens of thermoplastic materials —

Part 4:
Determination of moulding shrinkage

Plastiques — Moulage par injection des éprouvettes de matériaux thermoplastiques —

Partie 4: Détermination du retrait au moulage

ISO

Reference number
ISO 294-4:1997(E)

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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 294-4 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 9, *Thermoplastic materials*.

Together with the other parts, this part of ISO 294 cancels and replaces the second edition of ISO 294 (ISO 294:1995) which has been revised to improve the definition of the injection-moulding parameters and has been restructured to specify four types of ISO mould for the production of the basic specimen types required for the acquisition of comparable test data.

Care has been taken to ensure that the ISO moulds described can all be fitted in existing injection-moulding equipment and have interchangeable cavity plates.

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet central@iso.ch
X.400 c=ch; a=400net; p=iso; o=isocs; s=central

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ISO 294 consists of the following parts, under the general title *Plastics — Injection moulding of test specimens of thermoplastic materials*:

— *Part 1: General principles, and moulding of multipurpose and bar test specimens*

— *Part 2: Small tensile bars*

— *Part 3: Small plates*

— *Part 4: Determination of moulding shrinkage*

Annex A of this part of ISO 294 is for information only.

Introduction

See ISO 294-1.

In the injection moulding of thermoplastics, the difference between the dimensions of the mould cavity and those of the moulded articles produced from it may vary with the design and operation of the mould. Such differences may depend on the size of the injection-moulding machine, the shape and dimensions of mouldings, the degree and direction of flow or movement of the material in the mould, the sizes of the nozzle, sprue, runner and gate, the cycle on which the machine is operated, the temperature of the melt and the mould, and the magnitude and duration of the hold pressure. Moulding and post-moulding shrinkage are caused by crystallization, volume relaxation and orientation relaxation of the material and by thermal contraction of both the thermoplastic material and the mould. Post-moulding shrinkage may also be influenced by humidity uptake.

Plastics — Injection moulding of test specimens of thermoplastic materials —

Part 4:
Determination of moulding shrinkage

1 Scope

See ISO 294-1:1996, clause 1.

This part of ISO 294 specifies a method of determining the moulding shrinkage and post-moulding shrinkage of injection-moulded test specimens of thermoplastic material in the directions parallel to and normal to the direction of melt flow.

In contrast to ISO 2577, which describes the determination of shrinkage for thermosets, this part of ISO 294 excludes the effects of humidity uptake on moulding shrinkage. For cases when post-moulding shrinkage is caused by the uptake of humidity only, see ISO 175.

The measurement of moulding and post-moulding shrinkage is useful in making comparisons between thermoplastics and in checking uniformity of manufacture.

The method is not intended as a source of data for design calculations of components. Information on the typical behaviour of a material can be obtained, however, by carrying out measurements at different melt and mould temperatures, injection velocities and hold pressures, as well as at different values of other injection-moulding parameters. The information thus obtained is important in establishing the suitability of the moulding material for the production of moulded articles with accurate dimensions.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 294. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 294 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 175:1981, *Plastics — Determination of the effects of liquid chemicals, including water.*

ISO 294-1:1996, *Plastics — Injection moulding of test specimens of thermoplastic materials — Part 1: General principles, and moulding of multipurpose and bar test specimens.*

ISO 294-3:1996, *Plastics — Injection moulding of test specimens of thermoplastic materials — Part 3: Small plates.*

ISO 2577:1984, *Plastics — Thermosetting moulding materials — Determination of shrinkage.*

3 Definitions

For the purposes of this part of ISO 294, the definitions given in ISO 294-1 apply, plus the following:

3.1 moulding shrinkage, S_M: The difference in dimensions between a dry test specimen and the mould cavity in which it was moulded, both the mould and the test specimen being at room temperature when measured.

It is expressed as a percentage of the mould cavity dimension concerned.

The moulding shrinkage S_{Mp} parallel to the melt flow direction is determined at the mid-point of the width of the test specimen, and the moulding shrinkage S_{Mn} normal to the flow direction at the mid-point of the length.

NOTE — The value obtained for the moulding shrinkage is corrected to the room-temperature dimension of the mould. It is reduced, therefore, by an amount corresponding to the thermal expansion of the mould.

This correction ΔS_M to the moulding shrinkage is given by

$$\Delta S_M = -\alpha_M(T_M - 23)$$

where

α_M is the linear coefficient of expansion of the mould, in degrees Celsius to the minus one (°C^{-1});

T_M is the mould temperature, in degrees Celsius.

For example, for normal steel ($\alpha_M = 1{,}2 \cdot 10^{-5}$ °C^{-1}) and at a mould temperature T_M of 100 °C, the correction ΔS_M is –0,01 %.

3.2 post-moulding shrinkage, S_P: The difference in the dimensions of a moulded test specimen before and after a post-moulding treatment, measured at room temperature.

It is expressed in percent, %.

The post-moulding shrinkage S_{Pp} parallel to the melt flow direction and the post-moulding shrinkage S_{Pn} normal to the flow direction are defined in analogous fashion to S_{Mp} and S_{Mn} in 3.1.

3.3 total shrinkage, S_T: The difference in dimensions between a test specimen after a post-moulding treatment and the mould cavity in which it was moulded, measured at room temperature.

It is expressed in percent, %.

The total shrinkage S_{Tp} parallel to the melt flow direction and the total shrinkage S_{Tn} normal to the flow direction are defined in analogous fashion to S_{Mp} and S_{Mn} in 3.1.

3.4 cavity pressure, p_C: The pressure of the thermoplastic material in the cavity at any time during the moulding process, measured centrally near the gate.

It is expressed in megapascals, MPa.

3.5 cavity pressure at hold, p_{CH}: The cavity pressure (3.4) 1 s after the end of the injection time t_I (see figure 1).

It is expressed in megapascals, MPa.

4 Apparatus

4.1 Mould

Use a type D2 ISO mould, giving 60 mm × 60 mm × 2 mm plate specimens, as specified in ISO 294-3:1996, subclause 4.1.

Reference marks may be engraved in the mould cavity to facilitate the measurement of the dimensions of the test specimens produced from the mould using optical techniques. Such reference marks, if used, shall be located within 4 mm of the edges of the mould cavity.

Installation of a pressure sensor P, recommended for parts 1 to 3 of this International Standard [see ISO 294-1:1996, subclause 4.1.1.4, item k) and ISO 294-3:1996, figure 2], is mandatory for shrinkage measurements.

4.2 Injection-moulding machine

See ISO 294-1:1996 and ISO 294-3:1996, subclause 4.2 in each, but adding the following tolerance limits to the list of operating conditions given in subclause 4.2.2 of ISO 294-1:

Cavity pressure, p_C ±5 %

4.3 Equipment for measuring dimensions

The equipment shall be capable of measuring the length and width of each test specimen and of the mould cavity to within 0,01 mm, the measurements being made between the centres of opposite sides or between the opposite edges or between pairs of reference marks (see annex A). When measuring the length of a test specimen, take care to include the 0,5-mm-high step at the gate end of the specimen. If a mechanical instrument is used, ensure that the jaws of the instrument do not produce a significant indentation.

It is recommended that a calibration plate be used to periodically check the measuring equipment.

4.4 Oven

The oven is necessary only if post-moulding shrinkage is to be measured by agreement between the interested parties.

5 Procedure

5.1 Conditioning of material

See ISO 294-1:1996, subclause 5.1.

5.2 Injection moulding

5.2.1 For the basic injection-moulding conditions, see ISO 294-3:1996, subclause 5.2.

5.2.2 The moulding shrinkage is preferably determined for one or more values of the cavity pressure at hold p_{CH} (see 3.5) selected from 20 MPa, 40 MPa, 60 MPa, 80 MPa and 100 MPa. Intermediate values may also be used, however.

NOTE — For values higher than 80 MPa, a correspondingly high locking force will be necessary, and this may not be possible with normal commercial equipment.

5.2.3 Determine the hold pressure p_H which corresponds to each value of p_{CH} selected and mould test specimens at each of these pressures, taking account of the following additional instructions:

— Select the change-over point between injection and hold carefully to avoid a depression (C) in the time vs pressure curve (see figure 1) and to give a peak which does not extend more than 20 % beyond the peak in the correct curve (curve A).

NOTE — Large peaks in the cavity pressure lead to overloading of the cavity followed by backflow of the melt. The orientation of the material near the gate will thus be perturbed.

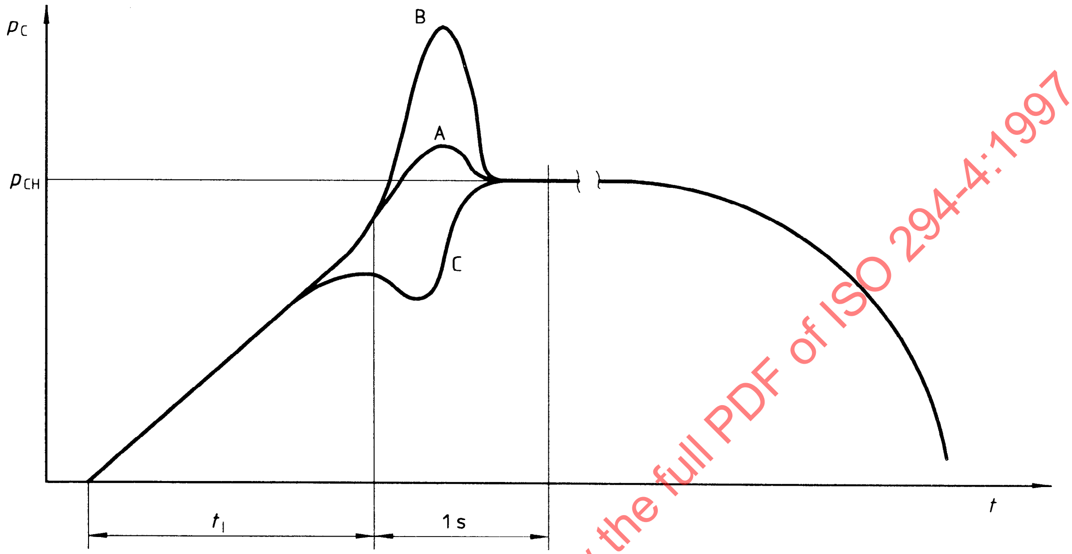

Figure 1 — Schematic plot of cavity pressure versus time, showing injection times t_I which are correct (A), too long (B) and too short (C)

— Keep the hold pressure constant during the hold period.

— Select the cooling time to be the minimum value at which the mouldings can be removed from the mould without distortion.

— For the hold time, see ISO 294-1:1996, subclause 5.2.4, and for the maintenance of steady-state conditions, see ISO 294-1:1996, subclause 5.2.5.

5.3 Measurement of mould temperature

See ISO 294-1:1996, subclause 5.3.

5.4 Measurement of melt temperature

See ISO 294-1:1996, subclause 5.4.

5.5 Treatment of test specimens after demoulding

5.5.1 In order to minimize warpage, cut each test specimen from the runner immediately after demoulding. Take care that the sides which will be used for the measurement of the dimensions are not damaged during the cutting operation.

5.5.2 Allow the test specimens to cool to room temperature by placing them on a material of low thermal conductivity and, if necessary, weighted under a suitable load that will prevent warping but will not significantly affect shrinkage. Store them at a temperature of 23 °C ± 2 °C for between 16 h and 24 h. If a material shows a marked difference in moulding shrinkage when stored in humid and dry atmospheres, store specimens made of such material in a dry atmosphere (e.g. in an airtight box together with desiccant).

5.6 Measurement of moulding shrinkage

5.6.1 If not already known, measure, at a temperature of 23 °C ± 2 °C, to the nearest 0,02 mm, the length l_C and width b_C of the cavity between appropriate reference points on opposite sides. These may be the centres of the sides and of the step at the gate end, the centres of the edges, or reference marks engraved in the mould cavity (see annex A).

Record these measurements for use in the calculation of the shrinkage.

NOTE — From time to time, it is advisable to check the reference marks engraved in the mould cavity for wear.

5.6.2 Before measuring the dimensions of a specimen, place it on a flat surface or against a straight edge in order to determine any warpage. Discard any specimen for which the warpage exceeds 2 mm in height (i.e. out-of-plane deformation).

5.6.3 Measure, at a temperature of 23 °C ± 2 °C, to the nearest 0,02 mm, the length l_1 and width b_1 of the specimen between reference points corresponding to those used for the mould cavity (see 5.6.1).

Minor warpage (less than 2 mm) may be reduced by compressing to give a flat surface. During measurement of the dimensions, any warpage shall be less than 1 mm.

NOTE — Warpage decreases a dimension in accordance with the following approximate equation:

$$-\Delta X \approx 4H^2/3X$$

where

X is the magnitude, in millimetres, of the dimension (length l or width b);

H is the warpage height (out-of-plane deformation), in millimetres.

For a magnitude X of 60 mm and a warpage height H of 1 mm for instance, the decrease in X is 0,02 mm, which corresponds to the tolerance limit given in 5.6.1 and 5.6.3.

5.6.4 Carry out the measurements using at least five test specimens for each set of moulding conditions.

5.7 Treatment following measurement of moulding shrinkage

The conditions of treatment (temperature, humidity or other environments) for the time period between the measurement of moulding shrinkage and the measurement of post-moulding shrinkage shall be as specified in the relevant material standard or as agreed between the interested parties.

NOTE — The conditions of post-moulding treatment may reflect those of storage or those of use.

5.8 Measurement of post-moulding shrinkage

After the post-moulding treatment, measure the test specimens again, at a temperature of 23 °C ± 2 °C, to the nearest 0,02 mm (see 5.6.2 to 5.6.4) and record the new length l_2 and width b_2.

6 Expression of results

6.1 Moulding shrinkage

The moulding shrinkage S_{Mp} parallel to the melt flow direction and the moulding shrinkage S_{Mn} normal to the flow direction are given, as percentages, by the following equations:

$$S_{Mp} = 100\,(l_C - l_1)/l_C \qquad \ldots (1)$$

$$S_{Mn} = 100\,(b_C - b_1)/b_C \qquad \ldots (2)$$

where

l_C and b_C are the length and width, in millimetres, across the centre of the cavity (see 5.6.1);

l_1 and b_1 are the corresponding length and width, in millimetres, of the test specimen (see 5.6.3).

6.2 Post-moulding shrinkage

The post-moulding shrinkage S_{Pp} parallel to the melt flow direction and the post-moulding shrinkage S_{Pn} normal to the flow direction are given, as percentages, by the following equations:

$$S_{Pp} = 100\,(l_1 - l_2)/l_1 \qquad \ldots (3)$$

$$S_{Pn} = 100\,(b_1 - b_2)/b_1 \qquad \ldots (4)$$

where l_2 and b_2 are the length and width, in millimetres, of the test specimen after the post-moulding treatment (see 5.8).

6.3 Total shrinkage

The total shrinkage S_{Tp} parallel to the melt flow direction and the total shrinkage S_{Tn} normal to the flow direction are given, as percentages, by the following equations:

$$S_{Tp} = 100\,(l_C - l_2)/l_C \qquad \ldots (5)$$

$$S_{Tn} = 100\,(b_C - b_2)/b_C \qquad \ldots (6)$$

where the symbols are as defined above.

Moulding, post-moulding and total shrinkage are related to each other by the following equation:

$$S_T = S_M + S_P - S_P S_M/100 \qquad \ldots (7)$$

NOTE — Moulding and post-moulding shrinkage are not expressed as a percentage of the same starting dimension [see equations (1) to (4)]. The total shrinkage, therefore, is not exactly the sum of the moulding and post-moulding shrinkage. The last term in equation (7) can be ignored in most cases, however.

7 Precision

The precision of this test method is not known because interlaboratory data are not available. When interlaboratory data are obtained, a precision statement will be added at the following revision.

8 Test report

The test report shall include the following information:

a) a reference to this part of ISO 294;

b) to h): see ISO 294-1:1996, clause 6, items b) to h), but replacing, in item g), the hold pressure p_H by the cavity pressure at hold p_{CH};

i) the moulding, post-moulding and total shrinkage, parallel and normal to the melt flow direction, in percent to the nearest 0,05 %.

Annex A
(informative)

Reference points for length and width measurement

Figure A.1 shows a perspective view of a test specimen with, in the foreground, the step at the gate end and the section (hatched) through which it has been cut from the runner.

For measurements made using a mechanical instrument of the lengths l_1 and l_2 and the widths b_1 and b_2, the centres S of the three moulded sides of the specimen and the centre G of the step are suitable reference points.

For optical measurements, the centres E of the moulded edges may be used, or marks M produced by the mould cavity plate within 4 mm of the edges (see 4.1) (figure A.1 shows one such mark only).

Any difference in height between a pair of reference points has no significant influence on the determination of the shrinkage provided the same reference points are used to measure the cavity as are used to measure the specimen. This correspondence avoids any effect due to the draft angle and allows different types of reference point to be used to measure a dimension, e.g. a "mechanical" reference point S on one side combined with an "optical" reference point E or M on the opposite side.

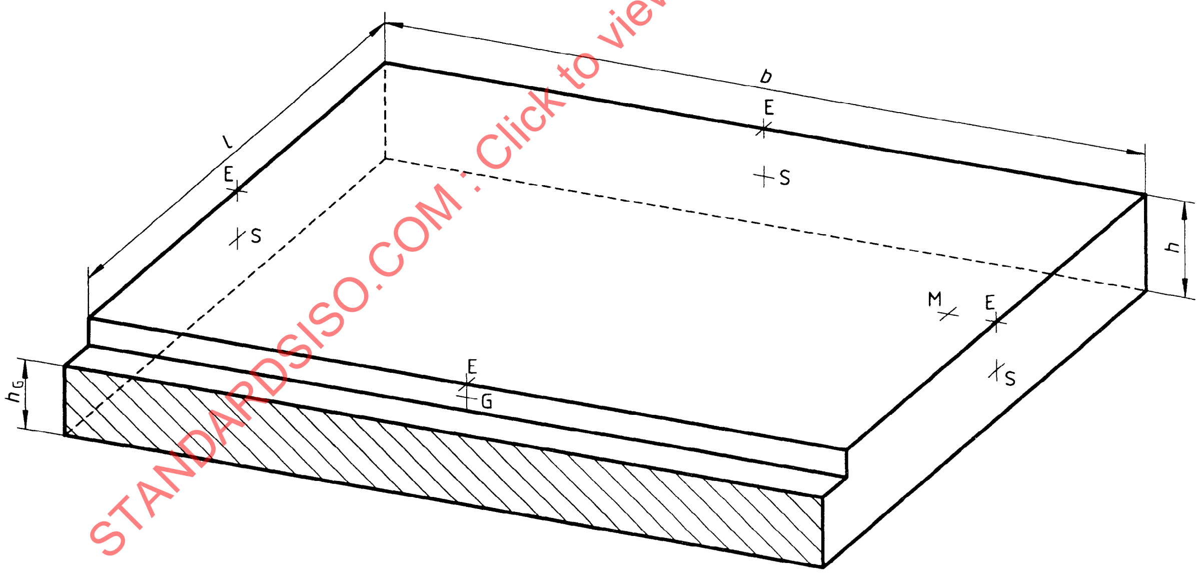

Figure A.1 — Perspective view of an injection-moulded plate specimen