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AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Practice for Preparing Multipurpose Test Specimens and Bars of Thermoplastics by Injection Moulding[1]

This standard is issued under the fixed designation D 5939; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the general principles to be followed for injection moulding test specimens of thermoplastics and gives details of mould designs for preparing specimen types for reference data, that is, for multipurpose-test specimens according to ISO 3167 (Specification D 5936) and for bars 80 mm × 10 mm × 4 mm. This practice provides a basis for establishing reproducible moulding conditions. This practice promotes uniformity in describing the various essential parameters of the moulding operation and also establishes a uniform practice in reporting moulding conditions. The special conditions required to prepare test specimens in a comparable and reproducible state will vary for each material used. These conditions are given in the ISO standard for the relevant material or are to be agreed upon between interested parties.

NOTE 1—ISO round-robin tests with acrylonitrile/butadiene/styrene (ABS), styrene/butadiene (S/B) and polymethylmethacrylate (PMMA) showed that design of the mould is one of the important factors in preparation of test specimens.

1.2 This practice is identical to ISO 294-1. This standard is comparable to Practice D 3641 but neither standard should be substituted for the other.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 3641 Practice for Injection Molding Test Specimens of Thermoplastic Molding and Extrusion Materials[2]
D 5935 Practice for Plastics—Acquisition and Presentation of Comparable Single-Point Data[3]
D 5936 Specification for Multipurpose Test Specimens Used for Testing Plastics[3]
D 5940 Practice for Preparing Small Plate Test Specimens of Thermoplastics by Injection Moulding[3]
D 5942 Test Method for Determining Charpy Impact Strength of Plastics[3]

2.2 *ISO Standards:*[4]

ISO 179:1993 Plastics—Determination of Charpy Impact Strength
ISO 294-1 Injection Moulding of Test Specimens of Thermoplastic Materials—Part 1: General Principles, Multipurpose Test Specimens and Bars
ISO 294-2 Plastics—Injection Moulding of Test Specimens of Thermoplastics—Part 2: Small Tensile Bars (ISO Mould Type C)
ISO 294-3 Plastics—Injection Moulding of Test Specimens of Thermoplastics—Part 3: Small Plates (ISO Moulds Type D)
ISO 294-4 Plastics—Injection Moulding of Test Specimens of Thermoplastics—Part 4: Determination of Moulding Shrinkage
ISO 3167:1993 Plastics—Multipurpose Test Specimens
ISO 10350:1993 Plastics—The Acquisition and Presentation of Comparable Single-Point Data
ISO 11403-1:1994 Plastics—Acquisition and Presentation of Comparable Multipoint Data—Part 1: Mechanical Properties
ISO 11403-2 Plastics—Acquisition and Presentation of Comparable Multipoint Data—Part 2: Thermal and Processing Properties
ISO 11403-3 Plastics—Acquisition and Presentation of Comparable Multipoint Data—Part 3: Environmental Influences on Properties

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *cavity*, *n*—the part of hollow space of the mould that forms one specimen.

3.1.2 *clamping force* F_M, *n*—the force clamping the plates of the mould. It is expressed in kilonewton, kN. The minimum clamping force is calculated according to Eq 1.

$$F_M \geq A_P \times P_{max} \times 10^{-3} \qquad (1)$$

where:

[1] This practice is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D20.61 on U.S. Technical Advisory Group for ISO/TC 61 on Plastics.

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[2] *Annual Book of ASTM Standards*, Vol 08.02.

[3] *Annual Book of ASTM Standards*, Vol 08.03.

[4] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

F_M = the clamping force (see 3.1.2), in kN,
A_P = the projected area (see 3.1.18), in mm^2, and
P_{max} = the maximum value of the melt pressure (see 3.1.12), in MPa.

3.1.3 *cooling time* t_C, *n*—the time from the end of the injection period until the mould starts to open. It is expressed in seconds, s.

3.1.4 *critical cross-sectional area* A_C, *n*—cross-sectional area of a cavity of a single- or multi-cavity mould at the position that forms the critical portion of the test specimen. It is expressed in square millimetres, mm^2. The critical portion of the test specimen for tensile bars, for example, is their narrow section, which bears the most stress during testing.

3.1.5 *cycle time* t_T, *n*—the time used to carry out the moulding cycle, see 3.1.16. It is expressed in seconds, s. The sum of injection time t_I, cooling time t_C and mould open time $t_O$is the cycle time (see 3.1.9, 3.1.3 and 3.1.14).

3.1.6 *family mould, n*—mould that contains more than one cavity, which shows different geometries (see Fig. 1).

3.1.7 *hold pressure* p_H, *n*—the melt pressure (see 3.1.12), during the hold time interval (see Fig. 2). It is expressed in megapascals, MPa.

3.1.8 *hold time* t_H, *n*—the time interval of hold pressure (see 3.1.7). It is expressed in seconds, s.

3.1.9 *injection time* t_I, *n*—the time from the beginning of screw forward movement until switching over from the injection period to the hold period. It is expressed in seconds, s.

3.1.10 *injection velocity* v_I, *n*—the average velocity of the melt as it passes through the critical cross-sectional area A_C(see 3.1.4). It is expressed in millimetres per second, mm/s. It can be used for single- and multi-cavity moulds only and is calculated according to Eq 2.

$$v_I = \frac{V_M}{t_I \times A_C \times n} \tag{2}$$

where:
v_I = the injection velocity, in mm/s,
n = the number of cavities, see 3.1.18,
A_C = the critical cross-sectional area, see 3.1.4, in mm^2,
V_M = the moulding volume, see 3.1.17, in mm^3, and
t_I = the injection time, see 3.1.9, in s.

3.1.11 *ISO mould, n*—fixed plate with central sprue, combined with a cavity plate forming the central part of a preferred multicavity mould, see (3.1.18). For interchangeable cavity plates, ejector pins, and pressure sensors, see 5.1.3. For a complete mould see Appendix X1.

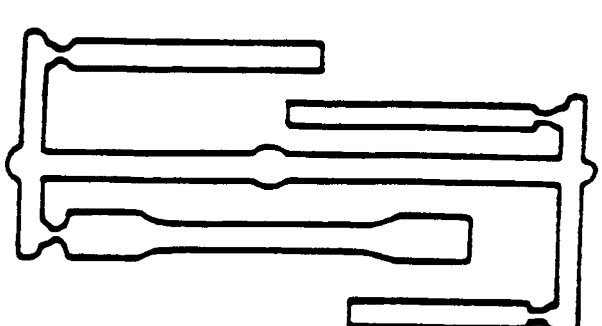


FIG. 1 Example of a Family Moulding

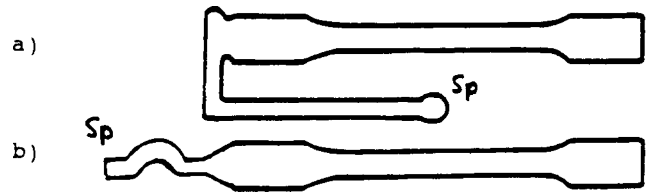


FIG. 2 Examples of Single Cavity Mouldings, with Sprue Sp (*a*) Normal to the Moulding Plate, and (*b*) Parallel, at the Parting Surface. (The Deflecting Runner Prevents from Jetting.)

3.1.12 *melt pressure p, n*—the pressure of the plastic material in front of the screw at any time of the moulding process (see Fig. 3). It is expressed in megapascals, MPa.

3.1.12.1 The melt pressure is calculated based upon the force $F_s$acting axially upon the screw, generated, for example, hydraulically (see Eq 3).

$$p = \frac{4 \times 10^3 \times F_s}{\pi \times D^2} \tag{3}$$

where:
p = the melt pressure, in MPa,
F_s = the axial force acting upon the screw, in kN, and
D = the screw diameter, in mm.

3.1.13 *melt temperature* T_M, *n*—the temperature of the molten plastic in a free shot (see 5.4.5 and 6.4). It is expressed in degrees Celsius, °C.

3.1.14 *mould open time* t_O, *n*—the time interval from the instant the mould starts to open until the mould is closed and attains full clamping force. It is expressed in seconds, s. This includes the time for removing the mouldings from the mould.

3.1.15 *mould temperature* T_c, *n*—the average temperature of the mould cavity surfaces measured after the system has attained stationary equilibrium under operating conditions and immediately after opening the mould (see 5.4.5 and 6.3). It is expressed in degrees Celsius, °C.

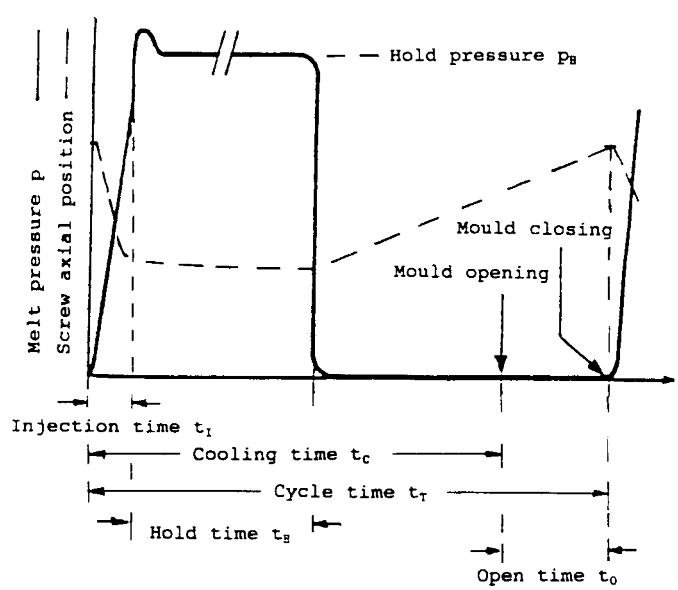


FIG. 3 Schematic Diagram of an Injection Moulding Cycle, Melt Pressure (Full Line), and Screw Axial Position (Dotted Line) as Function of Time

3.1.16 *moulding cycle*, *n*—the complete sequence of operations in the moulding process required for the production of one set of test specimens (see Fig. 3). The time required for a moulding cycle is related to the following times as indicated on Fig. 3.

3.1.17 *moulding volume* V_M, *n*—the ratio between the mass of the moulding and the density of the solid plastic. It is expressed in cubic millimetres, mm^3.

3.1.18 *multi-cavity mould*, *n*—mould that contains two or more identical cavities in a parallel flow arrangement (see Fig. 4 and Fig. 5). The number of cavities of a multi-cavity mould is *n*.

3.1.19 *projected area* A_P, *n*—the area of the moulding (see 3.1.18) projected to the parting surface. It is expressed in square millimetres, mm^2.

3.1.19.1 Identical geometries of flow paths and symmetrical positioning of cavities in the mould ensure that all test specimens from one shot are equivalent in their properties. No series arrangement of cavities is permitted.

3.1.20 *screw stroke volume* V_S, *n*—the product of the maximum metering stroke of the injection moulding machine and the cross-sectional area of its screw. It is expressed in cubic millimetres, mm^3.

3.1.21 *single-cavity mould*, *n*—mould with one cavity only (see Fig. 2).

4.

5. Apparatus

5.1 *Multi-Cavity Moulds*—ISO moulds, see 3.1.18, are strongly recommended for the use of test specimens that are used for the acquisition of comparable data. See ISO 10350 (Practice D 5935) and 11403, Parts 1 to 3, and are suitable for use in disputes involving international standards.

5.1.1 Mould multipurpose-test specimens, conforming to ISO 3167 (Specification D 5936), in the two-cavity ISO mould Type A using a Z or a T runner (see Appendix X2) as shown in Fig. 2 and conforming to 5.1.3. From these two types of runners, the Z runner is preferred with respect to its better symmetry for the clamping force. The bars moulded shall have the dimensions of the specimen Type A, ISO 3167 (Specification D 5936).

5.1.2 Mould rectangular bars (80 mm × 10 mm × 4 mm) in the four-cavity ISO mould Type B with double-T runner as shown in Fig. 4 and conforming to 4.1.1.3. The bars moulded shall have the same cross-section dimensions as the multipurpose-test specimens at their central part, see ISO 3167, and the length 80 mm± 2 mm.

5.1.3 Ensure that the main construction details of the ISO moulds Types A and B conform to Fig. 2 and Fig. 4 and to the following common requirements:

5.1.3.1 Ensure that the sprue diameter on the nozzle side is at least 4 mm,

5.1.3.2 Ensure that both width and height (or diameter) of the runner system is at least 5 mm,

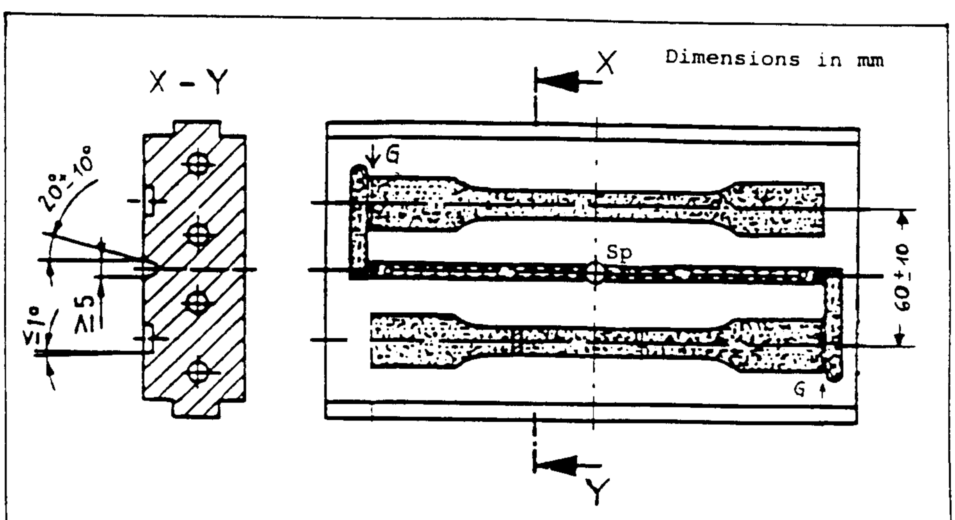
5.1.3.3 Ensure that the cavities are one-end gated, as shown in the relevant Fig. 2 and Fig. 4,

5.1.3.4 Ensure that the height of the gate is at least two-thirds of the height of the cavity, and the width of the gate equals that of the cavity at the point where the gate enters the cavity,

5.1.3.5 Ensure that the gate is as short as possible, not exceeding 3 mm,

5.1.3.6 Ensure that the draft angle of runners is at least 10°, but not more than 30°. The cavity shall have a draft angle not greater than 1°, except in the area of tensile-specimen shoulders where the draft angle shall be not greater than 2°.

5.1.3.7 Ensure that the dimensions of the cavities result in test specimens, whose dimensions conform to the requirements given in the relevant testing standard. To allow for different levels of moulding shrinkage select the dimensions of the



Sp	Sprue	Shot volume $V_s \approx$ 30 000 mm^3
G	Gates	Projected area $A_P \approx$ 6 300 mm^2

FIG. 4 Cavity Plate of ISO Mould Type A

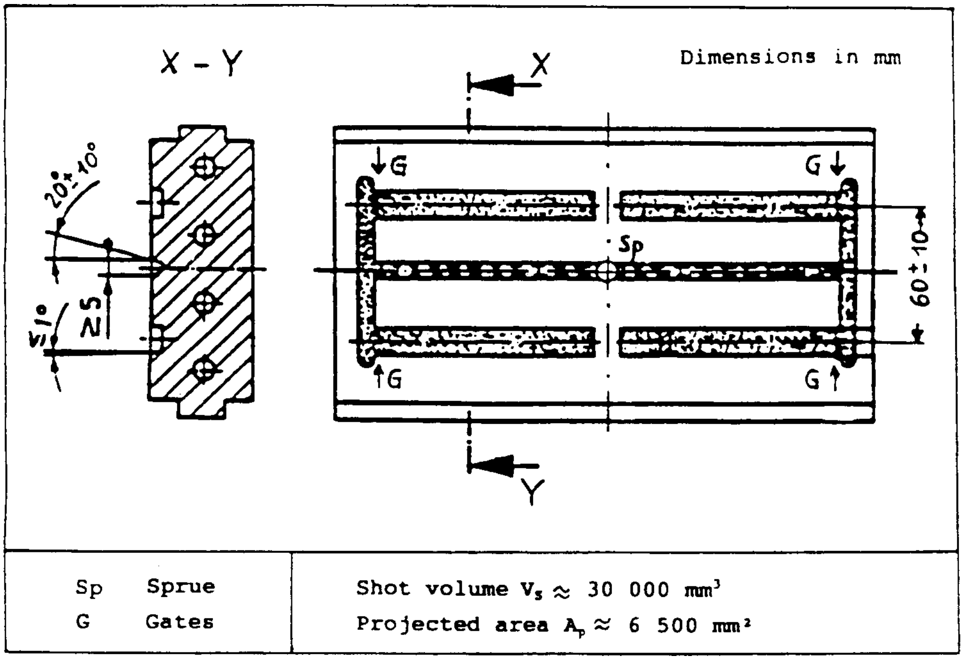


FIG. 5 Cavity Plate of ISO Mould Type B

cavities between the nominal and the upper values of the relevant fixed dimensions for the specimen type. In case of the ISO moulds A and B the essential dimensions of the cavities in mm are as follows (see ISO 3167 (Specification D 5936)):

Thickness	4.0 to 4.2
(Central) Width	10.0 to 10.2
Length (mould B)	80 to 82

5.1.3.8 Ensure that the ejector pins, if used, are located outside the test area of the test specimen, that is, at the shoulders of tensile bars of the ISO mould Type A and of Type C, see ISO 294-2, outside the central 20 mm length of the bars of the ISO mould Type B and outside the central area of 50 mm diameter of the small plates of the ISO moulds Type D, see ISO 294-3 (Practice D 5940),

5.1.3.9 Ensure that the heating-cooling system of the mould plates is designed so that differences in temperature at any point on a cavity surface and between both plates of the mould, under operating conditions are less than 5°C,

5.1.3.10 Ensure that the interchangeable cavity plates and gate inserts are permitted rapid changes from production of one type of test specimen to production of another type. This is made easy by taking values of the shot volume V_S as similar as possible. A perspective drawing of an example is given in Appendix X2,

5.1.3.11 Ensure that a pressure sensor is installed within the central runner, which gives proper controlling of the injection period and is mandatory for Part 4 of this practice. For a position suitable for common use with different ISO moulds, see ISO 294-3 (Practice D 5940), 5.1, and Fig. 2,

5.1.3.12 Ensure that for a common layout of interchangeable cavity plates suitable for the different ISO moulds, notice is taken of the Fig. 2 and Fig. 4, the Parts 2 and 3 of this practice and additional details as follows:

(*a*) It is recommended to use the cavity length of 170 mm for the multipurpose-test specimens to be moulded in the ISO mould Type A. This results in the maximum length of 180 mm that commonly can be used for hollow volume within the cavity plates.

(*b*) The value for a common width of the mould plates may be given by the minimum distance of couplings of the heating-cooling channels. Additionally, the optional installation of inserts may be respected for the ISO mould Type B, suitable for the injection moulding of notched bars, see ISO 179 (Test Method D 5942).

(*c*) Common cutting lines, for example, 170 mm apart, may be provided in order to separate the test specimens from the runners for the ISO moulds Types A, B, and C (see Part 2). A second pair of cutting lines 80 mm apart may be suitable for taking bars from multipurpose-test specimens (mould Type A) and may be used as well for separating injection moulded small plates, see Part 3.

5.1.3.13 For critical checking of the symmetry of multi-cavity moulds, mark the individual cavities outside the test area of the test specimen (see 5.1.3.8). For example, this may be provided by suitably engraving symbols on the heads of the ejector pins, thus avoiding any damage of the surface of the cavity plate.

5.1.3.14 Surface imperfections can influence the results especially of mechanical tests. Where appropriate, ensure that the surfaces of the mould cavities, therefore, are highly polished with machining in the direction in which the test specimen will be loaded during the test.

5.1.3.15 Ensure that the mould consists of many parts described in other international standards, a survey of which is given in Appendix X3.

5.2 *Single Cavity Moulds*—The cavity of a single cavity mould (see Fig. 1 and 3.1.20) may be that of a dumbbell bar, a disc, or other desired shape. A single cavity mould generally results in values for some specific properties different from