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**Plastics — Injection moulding of test specimens of thermosetting powder moulding compounds (PMCs) —**

**Part 1:**

General principles and moulding of multipurpose test specimens

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*Plastiques — Moulage par injection d'éprouvettes en compositions de poudre à mouler (PMC) thermodurcissables —*

*Partie 1: Principes généraux et moulage d'éprouvettes à usages multiples*

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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.

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 10724-1 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 12, *Thermosetting materials*.

Together with part 2, this part of ISO 10724 cancels and replaces ISO 10724:1994, which has been revised to improve the definition of the injection-moulding parameters and has been restructured to specify two 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.

As far as possible, the wording of this part of ISO 10724 and its definitions corresponds to that in its counterpart for thermoplastic materials, ISO 294:1996, *Plastics — Injection moulding of test specimens of thermoplastics materials*. Unlike the latter, however, there is no need for the separate moulding of rectangular bars (80 mm × 10 mm × 4 mm, which should be taken from the central portion of the multipurpose test specimen) or for the moulding of small tensile bars ( $\geq 60$  mm × 10 mm × 3 mm). Therefore the type B and type C ISO moulds specified in ISO 294 have not been included in this part of ISO 10724. Regardless of this, and to avoid confusion, the designation of the different mould types in this part of ISO 10724 and in ISO 294 correspond to each other.

ISO 10724 consists of the following parts, under the general title *Plastics — Injection moulding of test specimens of thermosetting powder moulding compounds (PMCs)*:

- Part 1: *General principles and moulding of multipurpose test specimens*
- Part 2: *Small plates*

Annexes A to D of this part of ISO 10724 are for information only.

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## Introduction

Many factors in the injection-moulding process which can influence the properties of moulded test specimens and hence the measured values obtained when the specimens are used in a test method. The thermal and mechanical properties of such specimens are in fact strongly dependent on the conditions of the moulding process used to prepare the specimens. Exact definition of each of the main parameters of the moulding process is a basic requirement for reproducible and comparable operating conditions.

It is important in defining moulding conditions to consider any influence the conditions may have on the properties to be determined. Thermosets may show differences in orientation and length of anisotropic fillers such as short fibres and in curing. Residual ("frozen-in") stresses in the moulded test specimens may also influence properties. Due to the crosslinking of thermosets, molecular orientation is of less influence on mechanical properties than it is for thermoplastics. Each of these phenomena must be controlled to avoid fluctuation of the numerical values of the measured properties.

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# Plastics — Injection moulding of test specimens of thermosetting powder moulding compounds (PMCs) —

## Part 1:

### General principles and moulding of multipurpose test specimens

#### 1 Scope

This part of ISO 10724 specifies the general principles to be followed when injection moulding test specimens of thermosetting powder moulding compounds (PMCs) and gives details of mould designs for preparing one type of specimen for use in establishing reproducible moulding conditions. Its purpose is to promote uniformity in describing the main parameters of the moulding process and also to establish uniform practice in reporting moulding conditions. The particular conditions required for the reproducible preparation of test specimens which will give comparable results will vary for each material used. These conditions are given in the International Standard for the relevant material or are to be agreed upon between interested parties.

NOTE ISO round-robin tests with phenolic (PF), urea-formaldehyde (UF), melamine (MF), melamine phenolic (MP) and unsaturated-polyester (UP) injection-moulding materials have shown that mould design is an important factor in the reproducible preparation of test specimens.

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#### 2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 10724. 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 10724 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 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 294-2:1996, *Plastics — Injection moulding of test specimens of thermoplastic materials — Part 2: Small tensile bars.*

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

ISO 472:—<sup>1)</sup>, *Plastics — Vocabulary.*

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

ISO 3167:1993, *Plastics — Multipurpose test specimens.*

ISO 10350-1:1998, *Plastics — Acquisition and presentation of comparable single-point data — Part 1: Moulding materials.*

1) To be published. (Revision of ISO 472:1988)

ISO 10724-2:1998, *Plastics — Injection moulding of test specimens of thermosetting materials — Part 2: Small plates.*

ISO 11403-1:1994, *Plastics — Acquisition and presentation of comparable multipoint data — Part 1: Mechanical properties.*

ISO 11403-2:1995, *Plastics — Acquisition and presentation of comparable multipoint data — Part 2: Thermal and processing properties.*

ISO 11403-3:—<sup>2)</sup>, *Plastics — Acquisition and presentation of comparable multipoint data — Part 3: Environmental influences on properties.*

### 3 Definitions

For the purposes of this part of ISO 10724, the definitions given in ISO 472 as well as the following apply.

**3.1 mould temperature,  $T_C$ :** The average temperature of the mould cavity surfaces measured after the system has attained thermal equilibrium and immediately after opening the mould.

It is expressed in degrees Celsius (°C).

**3.2 melt temperature,  $T_M$ :** The temperature of the plasticized material in a free shot.

It is expressed in degrees Celsius (°C).

**3.3 melt pressure,  $p$ :** The pressure of the plastic material in front of the screw at any time during the moulding process (see Figure 1).

It is expressed in megapascals (MPa).

The melt pressure, which is generated hydraulically for instance, can be calculated from the force  $F_S$  acting longitudinally on the screw using equation (1):

$$p = \frac{4 \times 10^3 \times F_S}{\pi \times D^2} \quad (1)$$

where

$p$  is the melt pressure, in megapascals (MPa);

$F_S$  is the longitudinal force, in kilonewtons (kN), acting upon the screw;

$D$  is the screw diameter, in millimetres (mm).

**3.4 hold pressure,  $p_H$ :** The melt pressure during the hold time (see Figure 1).

It is expressed in megapascals (MPa).

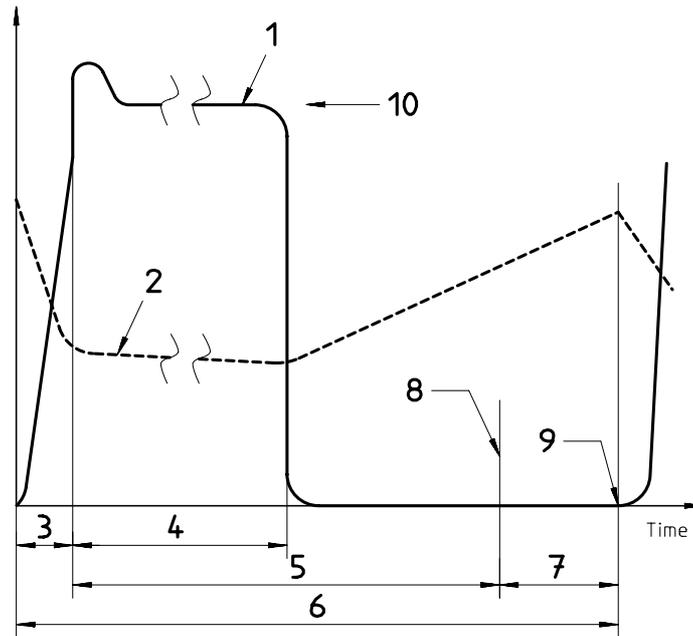
**3.5 moulding cycle:** The complete sequence of operations in the moulding process required for the production of one set of test specimens (see Figure 1).

**3.6 cycle time,  $t_T$ :** The time required to carry out a complete moulding cycle.

It is expressed in seconds (s).

The cycle time is the sum of the injection time  $t_I$ , the cure time  $t_{CR}$  and the mould-open time  $t_O$ .

2) To be published.

**Key**

- |                                      |                         |
|--------------------------------------|-------------------------|
| 1 Melt pressure, $p$                 | 6 Cycle time, $T$       |
| 2 Longitudinal position of the screw | 7 Open time, $t_O$      |
| 3 Injection time, $t_1$              | 8 Mould opening         |
| 4 Hold time, $t_H$                   | 9 Mould closing         |
| 5 Cooling time, $t_{CR}$             | 10 Hold pressure, $p_H$ |

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**Figure 1 — Schematic diagram of an injection-moulding cycle, showing the melt pressure (full line) and the longitudinal position of the screw (dashed line) as a function of time**

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**3.7 injection time,  $t_1$ :** The time from the instant the screw starts to move forward until the switchover point between the injection period and the hold period.

It is expressed in seconds (s).

**3.8 cure time,  $t_{CR}$ :** The time from the end of the injection period until the mould starts to open.

It is expressed in seconds (s).

**3.9 hold time,  $t_H$ :** The time from the end of the injection period until the hold pressure  $p_H$  is released.

It is expressed in seconds (s).

**3.10 mould-open time,  $t_O$ :** The time from the instant the mould starts to open until the mould is closed and exerts the full locking force.

It is expressed in seconds (s).

It includes the time required to remove the mouldings from the mould.

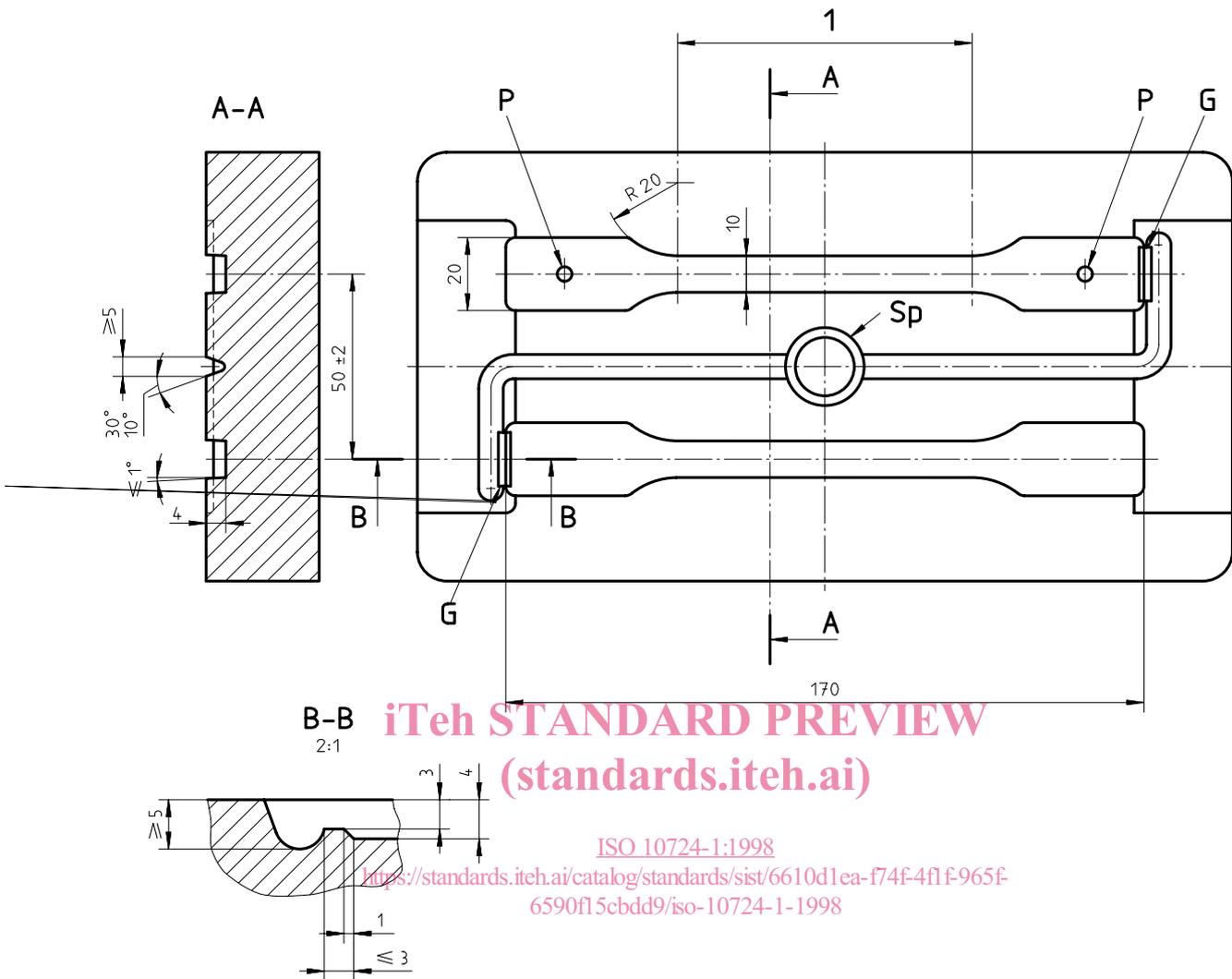
**3.11 cavity:** The part of the hollow space in a mould that produces one specimen.

**3.12 multi-cavity mould:** A mould that contains two or more identical cavities in a parallel-flow arrangement (see Figure 2).

The number of cavities in one multi-cavity mould is given by  $n$ .

Identical flow-path geometries and symmetrical positioning of the cavities in the cavity plate ensure that all test specimens from one shot are equivalent in their properties.

Dimensions in millimetres



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- Key**
- 1 Preferably 82
  - Sp sprue
  - G gate
  - P pressure sensor (optional)

Shot capacity  $V_S \approx 30\,000\text{ mm}^3$   
 Projected area  $A_P \approx 6\,300\text{ mm}^2$

**Figure 2 — Cavity plate for a type A ISO mould**

**3.13 ISO mould:** Any one of several standard moulds (designated type A, D1 and D2) intended for the reproducible preparation of test specimens with comparable properties. The moulds have a fixed plate with a central sprue, plus a multi-cavity cavity plate as described in 3.12. Additional details are given in 4.1.4.

An example of a complete mould is shown in annex C.

**3.14 critical cross-sectional area,  $A_C$ :** The cross-sectional area of the cavity in a multi-cavity mould at the position where the critical portion of the test specimen, i.e. that part on which the measurement will be made, is moulded.

It is expressed in square millimetres ( $\text{mm}^2$ ).

For tensile bar test specimens, for instance, the critical portion of the test specimen is the narrow section which is subjected to the greatest stress during testing.

**3.15 moulding volume,  $V_M$ :** The ratio of the mass of the moulding to the density of the solid plastic.

It is expressed in cubic millimetres ( $\text{mm}^3$ ).

**3.16 projected area,  $A_P$ :** The overall profile of the moulding projected on to the parting plane.

It is expressed in square millimetres ( $\text{mm}^2$ ).

**3.17 locking force,  $F$  :** The force holding the cavity plates of the mould closed.

It is expressed in kilonewtons (kN).

The minimum locking force necessary may be calculated from the inequality:

$$F_M \geq A_P \cdot p_{\max} \times 10^{-3} \quad (2)$$

where

$F_M$  is the locking force, in kilonewtons;

$A_P$  is the projected area, in square millimetres;

$p_{\max}$  is the maximum value of the melt pressure, in megapascals.

**3.18 injection velocity,  $v_I$ :** The average velocity of the melt as it passes through the critical cross-sectional area  $A_C$ .

It is expressed in millimetres per second (mm/s).

It is applicable to multi-cavity moulds only, and is calculated from equation (3):

$$v_I = \frac{V_M}{t_I \times A_C \times n} \quad (3)$$

where

$v_I$  is the injection velocity, in millimetres per second;

$n$  is the number of cavities;

$A_C$  is the critical cross-sectional area, in square millimetres;

$V_M$  is the moulding volume, in cubic millimetres;

$t_I$  is the injection time, in seconds.

**3.19 mass of the moulding,  $m_M$ :** The total mass of the moulding, including the specimens, runners and sprue.

It is expressed in grams (g).

**3.20 shot capacity,  $V_S$ :** The product of the maximum metering stroke of the injection moulding machine and the cross-sectional area of the screw.

It is expressed in cubic millimetres ( $\text{mm}^3$ ).

## 4 Apparatus

### 4.1 ISO (multi-cavity) moulds

**4.1.1** ISO moulds (see 3.13), are strongly recommended for producing test specimens for the acquisition of data which is intended to be comparable (see ISO 10350-1, ISO 11403-1, ISO 11403-2, and ISO 11403-3), as well as for use in the case of disputes involving International Standards.

4.1.2 Multipurpose test specimens as specified in ISO 3167 shall be moulded in a two-cavity type A ISO mould using a Z-runner (see annex A). The mould shall be as shown in Figure 2 and shall meet the requirements specified in 4.1.4.

4.1.3 Rectangular 80 mm (nominal) × 10 mm × 4 mm bars shall be cut symmetrically from the central parallel-sided section of the type A multipurpose test specimen (see ISO 3167) and the length shall be 80 mm ± 2 mm.

4.1.4 The main constructional details of the type A ISO mould shall be as shown in Figure 2 and shall meet the following requirements:

- a) The sprue diameter on the nozzle side shall be at least 4 mm.
- b) Both the width and height (or the diameter) of the runner system shall be at least 5 mm.
- c) The cavities shall be one-end gated as shown in Figure 2.
- d) The height of the gate shall be at least two-thirds the height of the cavity, and the width of the gate shall be equal to that of the cavity at the point where the gate enters the cavity.
- e) The gate shall be as short as possible, in any case not exceeding 3 mm.
- f) The draft angle of the runners shall be 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 not be greater than 2°.
- g) The dimensions of the cavities shall be such that the dimensions of the test specimens produced conform to the requirements given in the relevant test standard. To allow for different degrees of moulding shrinkage, the dimensions of the cavities shall be chosen so that they are between the nominal value and the upper limit of the dimensions specified for the specimen concerned. In the case of the type A ISO mould, the main cavity dimensions, in millimetres, shall be as follows (see ISO 3167):
  - depth: 4,0 to 4,2; <https://standards.iteh.ai/catalog/standards/sist/6610d1ea-f74f-4ff1-f965f6590f15cbdd9/iso-10724-1-1998>
  - width of central section: 10,0 to 10,2;
  - length of central parallel-sided section: 80,0 to 82,0.
- h) Ejector pins, if used, shall be located outside the test area of the specimen, i.e. at the shoulders of dumbbell specimens produced from type A ISO moulds and outside the central 50-mm-diameter area of plate specimens from type D ISO moulds (see ISO 10724-2).
- i) The heating system for the mould plates shall be designed so that, under operating conditions, the difference in temperature between any point on the surface of a cavity and either plate is less than 3 °C.
- j) Interchangeable cavity plates and gate inserts are recommended to permit rapid changes in production from one type of test specimen to another. Such changes are facilitated by using shot capacities  $V_S$  which are as similar as possible. Examples of different runner configurations and the use of gate inserts is shown in annex A.
- k) It is recommended that a pressure sensor be fitted in the central runner, to give proper control of the injection period (the sensor is mandatory for ISO 2577). A sensor position suitable for the various types of ISO mould is given in subclause 4.1, item k), and in Figure 1 of ISO 10724-2:1998.
- l) To ensure that cavity plates are interchangeable between different ISO moulds, it is important to note the following constructional details in addition to those shown in Figure 2 and those given in ISO 10724-2:
  - 1) It is recommended that a cavity length of 170 mm be used for multipurpose test specimens moulded in the type A ISO mould. This gives a maximum length of 180 mm for the hollow space in cavity plates.

- 2) The width of the mould plates may be affected by the minimum distance required between the connection points for the heating channels.
  - 3) Lines along which the test specimens can be cut from the runners may be defined e.g. 170 mm apart for a type A ISO mould. A second pair of lines 80 mm apart may be defined for cutting bars from multipurpose test specimens from a type A ISO mould and may be used as well for cutting off small-plate mouldings (see ISO 10724-2).
- m) To make it easier to check that all the specimens from a mould are identical, it is recommended that the individual cavities be marked, but outside the test area of the specimen [see item h) above]. This can be done very simply by engraving suitable symbols on the heads of the ejector pins, thus avoiding any damage to the surface of the cavity plate. Another option is shown in annex B.
- n) Surface imperfections can influence the results, especially those of mechanical tests. Where appropriate, the surfaces of the mould cavities shall be highly polished therefore, the direction of polishing corresponding to the direction in which the test specimen will be placed under load when it is tested.

**4.1.5** For more information on those mould components described in other International Standards, the reader is referred to annex D.

## 4.2 Injection-moulding machine

For the reproducible preparation of test specimens capable of giving comparable results, only reciprocating-screw injection-moulding machines equipped with all the necessary devices for the control of the moulding conditions shall be used.

### 4.2.1 Moulding volume

The ratio of the moulding volume  $V_M$  (see 3.15) to the shot capacity  $V_S$  (see 3.20) shall be between 20 % and 80 % unless a higher ratio is required by the relevant material standard or is recommended by the manufacturer.

### 4.2.2 Control system

The control system of the injection-moulding machine shall be capable of maintaining the operating conditions within the following tolerance limits:

Injection time, $t_I$	$\pm 0,1$ s
Hold pressure, $p_H$	$\pm 5$ %
Hold time, $t_H$	$\pm 5$ %
Melt temperature, $T_M$	$\pm 3$ °C
Mould temperature, $T_C$	$\pm 3$ °C
Mass of moulding, $m_M$	$\pm 2$ %

### 4.2.3 Screw

The screw shall be of a type suitable for the moulding material (e.g. length, diameter, thread height, compression ratio).

It is recommended that a screw with a diameter in the range between 18 mm and 40 mm is used.

### 4.2.4 Locking force

The mould-locking force  $F_M$  shall be high enough to prevent flash forming under any operating conditions.