TC 61

INTERNATIONAL STANDARD

ISO 294

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Plastics — Injection moulding of test specimens of thermoplastic materials

Plastiques — Moulage par injection des éprouvettes en matériaux thermoplastiques

Reference number
ISO 294:1995(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 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 9, *Thermoplastic materials*.

This second edition cancels and replaces the first edition (ISO 294:1975), of which it constitutes a technical revision.

Annex A of this International Standard is for information only.

International Organization for Standardization
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Introduction

Many factors in the injection-moulding process can influence the properties of moulded test specimens and hence the results of tests using such specimens. The mechanical properties, in particular, of test specimens are strongly dependent on the conditions of the moulding process used to prepare the specimens.

An exact definition of each parameter of the moulding process is essential to ensure reproducible and comparable operating conditions.

It is important in defining the moulding conditions for a thermoplastic material to consider any dependence of the properties to be determined and the conditions used in the moulding process. Thermoplastics may exhibit molecular orientation (important mainly with heterogeneous polymers) or differences in crystallinity (for crystalline or semi-crystalline polymers). Residual ("frozen-in") stresses in the moulded specimens and thermal degradation of the polymer during moulding may also influence the properties of the specimens.

Each of these phenomena must be controlled to avoid fluctuation in the numerical values of test results.

General correlations between the properties of test specimens and basic injection-moulding parameters are given, for information only, in annex A.

Plastics — Injection moulding of test specimens of thermoplastic materials

1 Scope

This International Standard specifies the general principles to be followed when injection moulding test specimens of thermoplastic materials. It describes two preferred mould designs and gives examples of other acceptable mould designs. It provides a basis for establishing reproducible moulding conditions. Its purpose is to promote uniformity in describing the essential moulding parameters and also to establish uniform practice in reporting moulding conditions. The exact conditions required to prepare specimens in a defined, reproducible state will vary for each material, mould and machine used. These conditions shall be agreed upon between interested parties unless they are part of an International Standard for the relevant material.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard 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 179:1993, *Plastics — Determination of Charpy impact strength.*

ISO 180:1993, *Plastics — Determination of Izod impact strength.*

ISO 527-1:1993, *Plastics — Determination of tensile properties — Part 1: General principles.*

ISO 527-2:1993, *Plastics — Determination of tensile properties — Part 2: Test conditions for moulding and extrusion plastics.*

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

ISO 5725-1:1994, *Accuracy (trueness and precision) of measurement methods and results — Part 1: General principles and definitions.*

3 Definitions

For the purposes of this International Standard, the following definitions apply.

3.1 mould temperature: The average temperature of the mould cavity surface measured after the system has attained thermal equilibrium and immediately after opening the mould (see also 5.3).

It is expressed in degrees Celsius, °C.

3.2 melt temperature: The temperature of the molten plastic in a free shot (see also 5.4).

It is expressed in degrees Celsius, °C.

3.3 injection pressure: The maximum pressure applied to the plastic material in front of the screw during injection (see figure 1).

It is expressed in megapascals, MPa.

3.4 hold pressure: The pressure applied to the plastic material in front of the screw during the hold time (see figure 1).

It is expressed in megapascals, MPa.

3.5 moulding cycle: The complete sequence of moulding operations required for the production of a test specimen or a set of test specimens (see figure 1). The time required for a complete moulding cycle is a function of the injection time, the hold time, the cooling time and the mould open time as indicated in figure 1.

3.5.1 cycle time: The total time required to carry out the complete sequence of operations making up the moulding cycle. The sum of the cooling time and mould open time is the total time required to perform one moulding cycle.

It is expressed in seconds, s.

3.5.2 injection time: The time from the beginning of screw forward movement until the mould cavity is filled.

It is expressed in seconds, s.

3.5.3 hold time: The time interval between the point in time when the mould cavity is filled and the point in time when the hold timers have timed out.

It is expressed in seconds, s.

3.5.4 cooling time: The time from the beginning of screw forward movement until the mould starts to open.

It is expressed in seconds, s.

3.5.5 mould open time: The time interval from the instant the mould starts to open until the mould is closed again. This includes the time during which the moulded test specimens are removed from the mould.

It is expressed in seconds, s.

3.6 average melt velocity: The velocity of the front of the melt as it passes through the section of the mould which forms the critical portion of the test specimen. This portion is often the narrow, parallel-sided section which bears the most stress during testing.

It is expressed in millimetres per second, mm/s.

The average melt velocity v_{av}, expressed in millimetres per second, is given by the equation

$$v_{av} = \frac{\pi D^2 v_s}{4 n A_c}$$

where

D is the screw diameter, in millimetres;

v_s is the screw advance speed, in millimetres per second;

n is the number of mould cavities;

A_c is the cross-sectional area, in square millimetres, of the critical portion (the test region) of the test specimen.

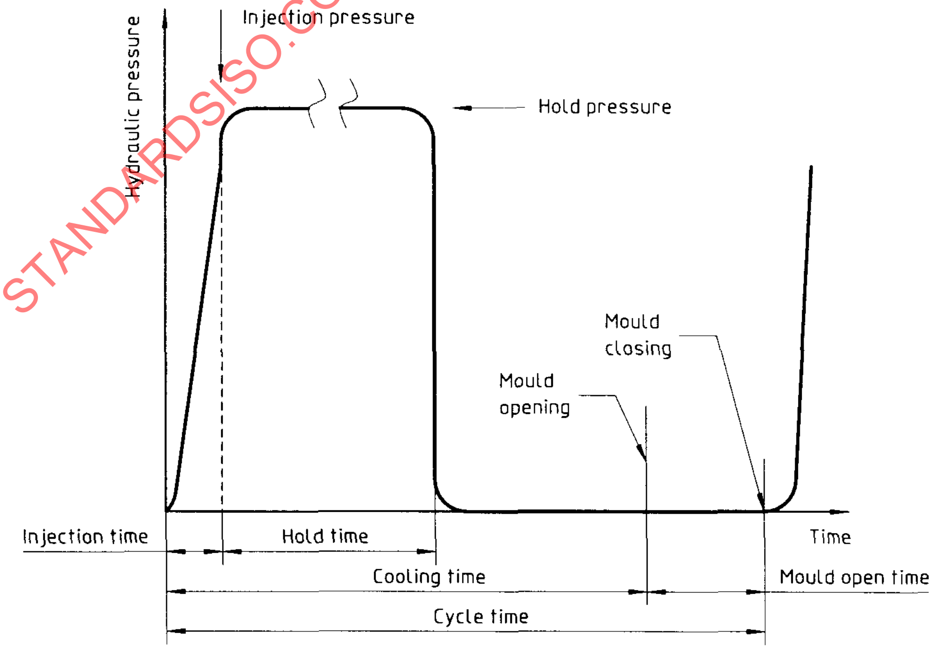

Figure 1 — Schematic diagram of an injection-moulding cycle (pressure as a function of time)

In the case of injection-moulding machines without microprocessor control, the average melt velocity v_{av}', expressed in millimetres per second, is given by the equation

$$v_{av}' = \frac{m}{\rho t A_c n}$$

where

m is the total mass, in grams, of the shot;

ρ is the density, in grams per cubic millimetre, of the melt;

t is the injection time, in seconds;

A_c is the cross-sectional area, in square millimetres, of the critical portion (the test region) of the test specimen.

NOTE 1 The values of v_{av} and v_{av}' are not necessarily comparable.

4 Apparatus

4.1 Injection mould

4.1.1 Mould types

Three basic types of mould are generally used for injection moulding test specimens. These are the single-cavity mould, the multi-cavity mould and the family mould. Care in choosing a suitable mould design is essential if requirements for reproducibility of test specimens are to be met.

NOTE 2 ISO round-robin tests with ABS, SB and PMMA have shown that the design of the mould is an important factor in the preparation of test specimens.

a) The single-cavity mould (see figure 2) consists of a mould with one cavity. The shape of the cavity may correspond to that of a dumbbell bar, a disc or another shape.

NOTE 3 A single-cavity mould occasionally gives unusual values for some properties. This may occur because the ratio of the specimen volume to the total volume of the single-cavity mould is less than for other types of mould. Also, the smaller total volume of this type of mould makes conformance with the volume-ratio requirements of 4.2.1 more difficult, and failure to meet these requirements may contribute to the occurrence of non-comparable values.

b) The multi-cavity mould (see figure 3) contains two or more identical cavities. The flow-path geometry is identical for each cavity and the cavities are positioned symmetrically in the mould, thus ensuring that all test specimens from one shot are equivalent in their properties. The series arrangement of cavities is not permitted.

c) The family mould (see figure 4) is a mould containing more than one cavity, not all of which are identical. There may be, for example, flat bars mixed with dumbbell bars and discs. A family mould may be used when the properties of test specimens obtained correspond to those obtained when using an ISO injection mould (see 4.1.2).

NOTE 4 In many cases, simultaneous filling of the different types of cavity is not possible under different moulding conditions with a family mould. This is why this type of mould is not suitable for the preparation of reference test specimens.

4.1.2 ISO injection moulds

Type A and type B ISO injection moulds are strongly recommended for the preparation of specimens to be used in the generation of common data for International Standards for materials. These moulds shall be used in case of dispute.

4.1.2.1 Type A ISO injection mould

Dumbbell bars conforming to ISO 3167 for multipurpose test specimens shall be moulded in a two-cavity mould as shown in figure 5 and conforming to the requirements of 4.1.2.3.

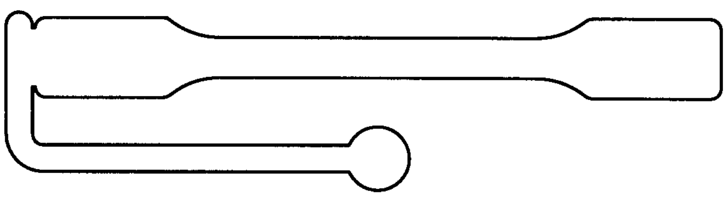

Figure 2 — Example of a single-cavity mould

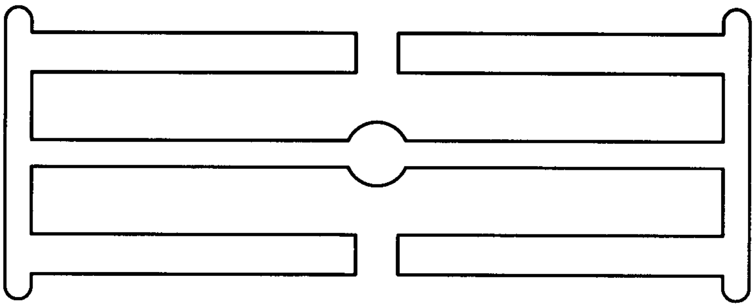

Figure 3 — Example of a multi-cavity mould

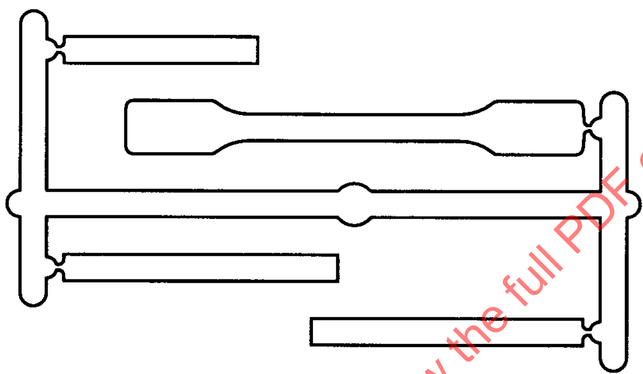

Figure 4 — Example of a family mould

Dimensions in millimetres

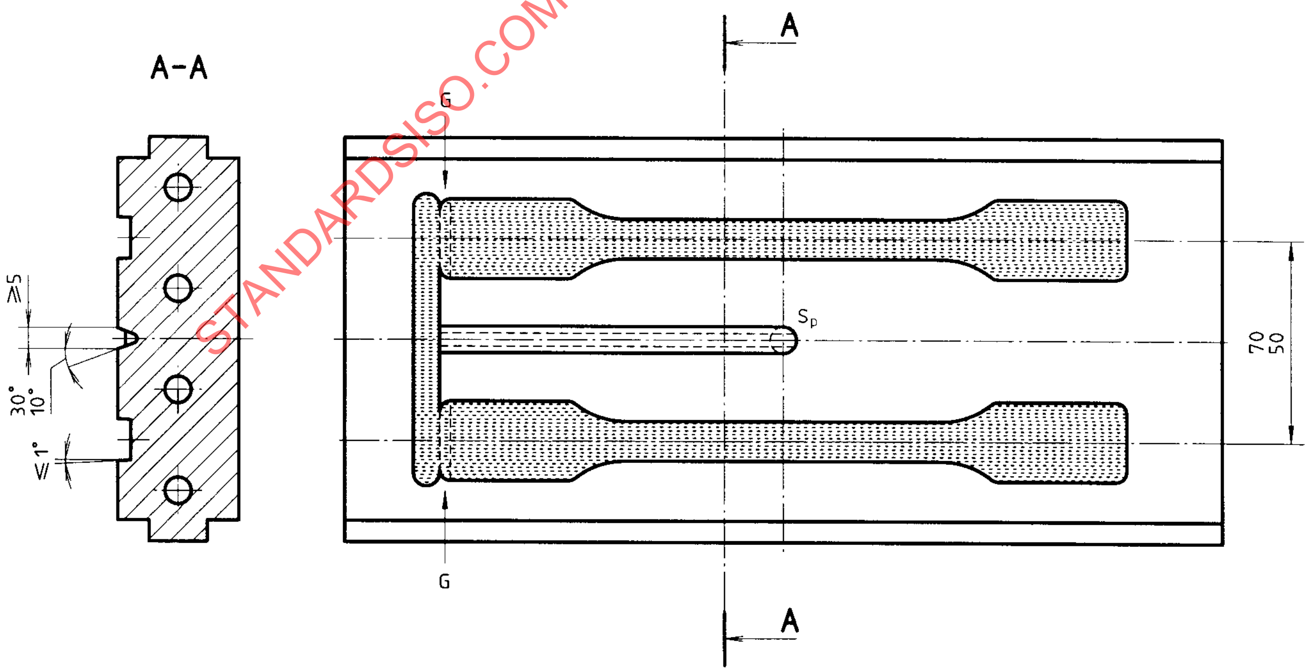

Figure 5 — Type A ISO injection mould

4.1.2.2 Type B ISO injection mould

Rectangular-section bars (80 mm × 10 mm × 4 mm) shall normally be moulded in a four-cavity mould with a "double-tee" runner as shown in figure 6 and conforming to the requirements of 4.1.2.3.

NOTE 5 Rectangular-section bar specimens can also be taken from the central, parallel-sided part of multipurpose test specimens produced using a type A ISO injection mould.

4.1.2.3 Design requirements

The main design details of the ISO injection moulds shall be as shown in figures 5 and 6. In addition, the moulds shall meet the following requirements:

a) The sprue diameter on the nozzle side shall be at least 5 mm.

b) Both the width and height (or diameter) of the runner system shall be at least 5 mm.

c) The mould cavities shall be end-gated as shown in figures 5 and 6.

d) The height of the gate shall be two-thirds of the height of the cavity at the point where the gate enters the cavity. The transition in cross-section from the runner to the gate may be streamlined to avoid turbulent melt flow and shear heating at high injection speeds.

e) The gate shall be as short as possible, not exceeding 3 mm.

f) The draft angle of the runners shall be at least 10°, but not more than 30°. The specimen cavity shall have a draft angle no greater than 1°, except in the area of the shoulder (type A ISO injection mould), where the draft angle shall be not greater than 2°.

g) Machining tolerances on the cavity itself depend upon the material being moulded. Test specimens shall, in all cases, conform to the requirements for test specimen tolerances given in ISO standards for test methods (e.g. ISO 179, ISO 180, ISO 527-1, ISO 527-2).

h) Ejector pins, if used, shall be located outside the test area of the test specimen.

i) The mould-plate heat-transfer system shall be designed so that differences in temperature between any two points on the surface and between each half of the mould are less than 5 °C.

NOTE 6 A schematic drawing of a cooling system is given in figure 7 as a guideline.

Dimensions in millimetres

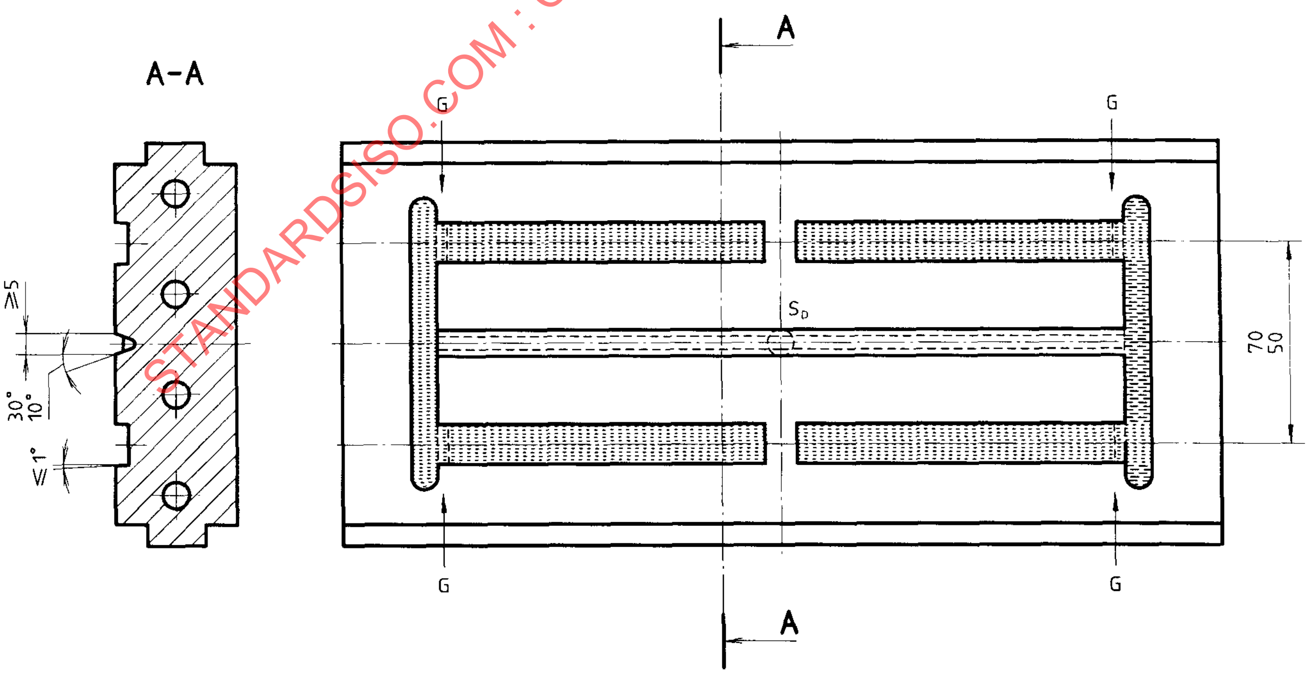

Figure 6 — Type B ISO injection mould

Dimensions in millimetres

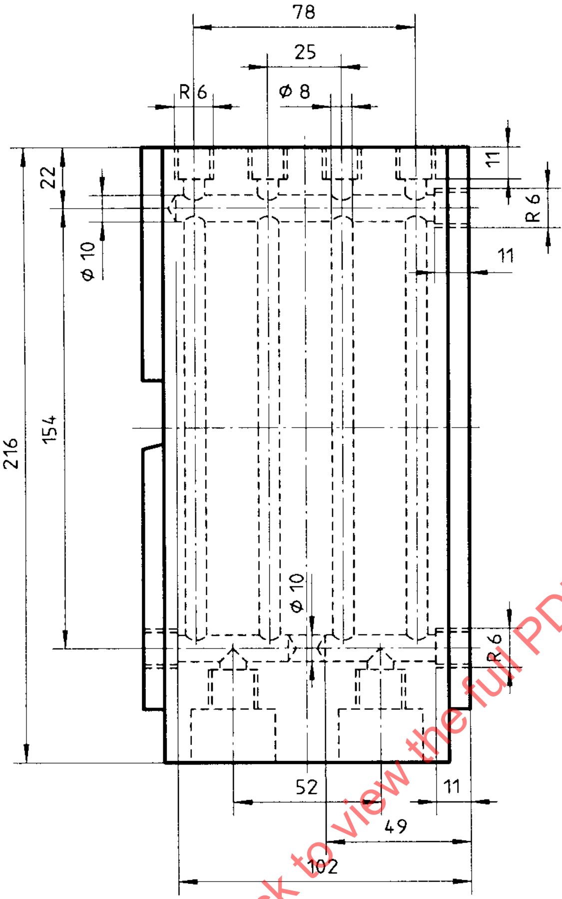

Figure 7 — Cooling system suitable for the ISO multi-cavity mould

j) Interchangeable mould plates and gate inserts are recommended to permit rapid changes from production of one type of test specimen to production of another type.

NOTE 7 A perspective drawing of a typical interchangeable mould plate is given in figure 8.

4.2 Injection-moulding machine

4.2.1 Screw-stroke volume

For the reproducible preparation of comparable test specimens, only reciprocating-screw injection-moulding machines equipped with the necessary devices for control of the moulding conditions shall be used. The ratio of the screw-stroke volume to the shot volume shall not be less than 2:1 or more than 10:1 unless, for thermally sensitive thermoplastics, a lower ratio is specified in the relevant International Standard or the manufacturer's recommendations.

4.2.2 Control system

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

Injection pressure	±3 %
Injection time	±0,1 s
Hold pressure	±5 %
Hold time	±5 %
Melt temperature	±3 °C
Mould temperature	±3 °C up to 80 °C
	±5 °C above 80 °C
Shot mass	±1 %

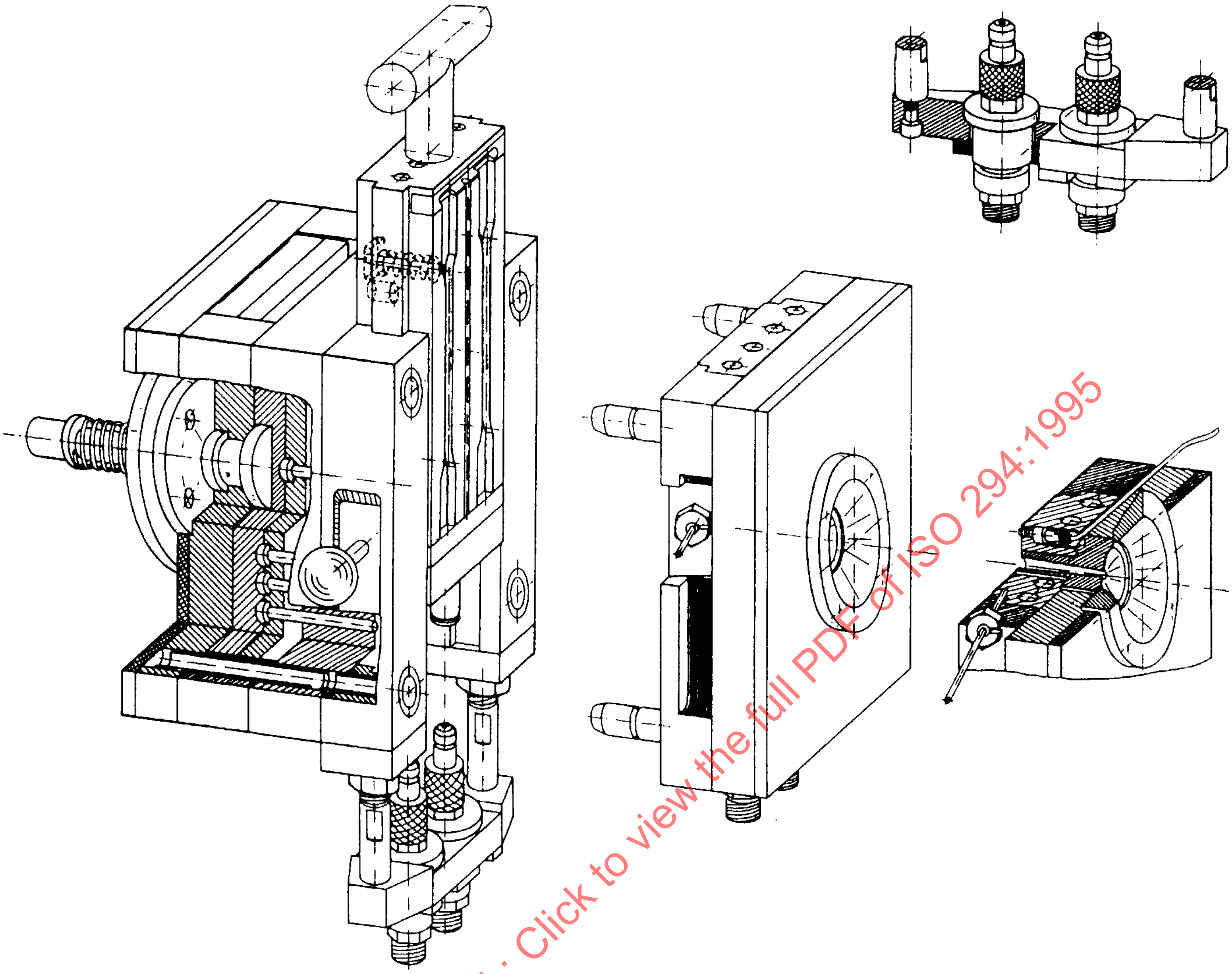

Figure 8 — Perspective view of a mould with an interchangeable multi-cavity plate

4.2.3 Screw

The screw shall be of a type suitable for the moulding material being used. This includes screw diameter, screw length, depth of thread, compression ratio, etc.

4.2.4 Mould-closing force

The mould-closing force shall be great enough to prevent excessive flashing under all operating conditions.

4.2.5 Thermometers

A calibrated, needle-type thermometer accurate to ±1 °C shall be used to measure the temperature of the melt. A calibrated surface thermometer accurate to ±1 °C shall be used to measure the temperature of the surface of the mould.

5 Procedure

5.1 Conditioning

Condition the pellets or granules of thermoplastic material prior to moulding, as required in the relevant International Standard for the material, or in accordance with the manufacturer's recommendations, if no such International Standard exists.

Protect plastics that take up water on exposure to the atmosphere by using impermeable containers. Before moulding, dry materials which may have absorbed moisture, using conditions suitable for the material and the drying equipment. Avoid exposing to the atmosphere materials which are at temperatures significantly below that of the workshop, in order to prevent condensation of moisture on the surface of the material.

5.2 Injection moulding

Set the machine to the conditions specified in the relevant International Standard for the material or by agreement between the interested parties if no such International Standard exists.

Modify the moulding conditions by adjustment of those moulding-process parameters whose values have not been specified until the mouldings are free of sink marks, voids and other visible defects and have minimal flash.

NOTE 8 For many thermoplastics, an average melt velocity of 200 mm/s ± 100 mm/s is suitable.

Maintain the hold pressure until the plastic material in the gate section has solidified, i.e. until the mass of the moulding has reached its maximum value under these conditions.

Discard the mouldings until the machine has reached steady-state conditions. At this time, the operating conditions shall be recorded and specimen collection may begin.

During moulding, maintain steady-state conditions by suitable means, e.g. by control of the mass of the shot.

Clean the machine carefully and thoroughly after any change in material.

5.3 Measurement of the mould temperature

Measure the mould temperature after the system has reached thermal equilibrium and immediately after opening the mould. Measure the temperature of the mould-cavity surface at several points in each half of the mould, using a calibrated surface thermometer (see 4.2.5).

Record each measurement individually, and take the average of these measurements as the mould temperature.

5.4 Measurement of the melt temperature

The melt temperature is measured when thermal equilibrium (i.e. the steady-state temperature) has been reached. Inject a free shot into a non-metallic container of suitable size, and immediately insert the needle of a preheated rapid-response needle thermometer into the centre of the molten plastic cake and move it gently until the reading of the thermometer has reached a maximum. The temperature to which the thermometer is preheated shall be close to the melt temperature to be measured. The injection conditions (except pressures) for the free shot shall be the same as those to be used to mould the specimens, including the provision of the same time between free shots.

The melt temperature may alternatively be measured by means of a suitable temperature sensor, provided the value obtained is the same as that obtained by the free-shot method. The sensor shall cause only low heat losses and shall respond rapidly to temperature changes in the melt. The sensor shall be mounted in a suitable place such as the nozzle of the injection-moulding machine.

5.5 Post-moulding treatment of test specimens

Allow test specimens removed from the mould to cool gradually and uniformly to room temperature in order to avoid any differences in the thermal history of the specimens. Keep specimens made of thermoplastics sensitive to exposure to the atmosphere in impermeable containers.

6 Precision

An ISO interlaboratory test conducted in 1986 to 1988 with a variety of thermoplastics demonstrated reasonable interlaboratory repeatability of test specimen preparation. However, it is strongly recommended that individuals responsible for each International Standard for materials develop and publish their own data and precision statement concerning test specimen preparation.

7 Test specimen preparation report

The test specimen preparation report shall include the following information:

a) the date, time and place of moulding;

b) the material used (type, designation, manufacturer, lot number);

c) details of conditioning of the material prior to moulding, if applicable;

d) details of the test specimens produced (type, relevant International Standard);

e) details of the mould used (type, number of cavities, gate size and gate location);

f) details of the injection-moulding machine used (manufacturer, maximum shot volume, mould-closing force, control system);