INTERNATIONAL STANDARD

ISO 1268-10

First edition
2005-02-01

Fibre-reinforced plastics — Methods of producing test plates —

Part 10: Injection moulding of BMC and other long-fibre moulding compounds — General principles and moulding of multipurpose test specimens

Plastiques renforcés de fibres — Méthodes de fabrication de plaques d'essai —

Partie 10: Moulage par injection de BMC et d'autres mélanges à mouler à longues fibres — Principes généraux et moulage d'éprouvettes à usages multiples

Reference number
ISO 1268-10:2005(E)

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Published in Switzerland

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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 1268-10 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 13, *Composites and reinforcement fibres*.

Together with the other parts (see below), this part of ISO 1268 cancels and replaces ISO 1268:1974, which has been technically revised.

ISO 1268 consists of the following parts, under the general title *Fibre-reinforced plastics — Methods of producing test plates*:

— *Part 1: General conditions*

— *Part 2: Contact and spray-up moulding*

— *Part 3: Wet compression moulding*

— *Part 4: Moulding of prepregs*

— *Part 5: Filament winding*

— *Part 6: Pultrusion moulding*

— *Part 7: Resin transfer moulding*

— *Part 8: Compression moulding of SMC and BMC*

— *Part 9: Moulding of GMT/STC*

— *Part 10: Injection moulding of BMC and other long-fibre moulding compounds — General principles and moulding of multipurpose test specimens*

— *Part 11: Injection moulding of BMC and other long-fibre moulding compounds — Small plates*

Introduction

Many factors in the injection-moulding process 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 long 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.

The principles described in this part of ISO 1268 are the same as those in ISO 10724-1. Only a few details of the moulds have changed, as has specimen thickness, because of the use of long-fibre reinforcements. It is therefore possible to compare the properties of long-fibre moulding compounds with those of thermosetting powder moulding compounds (PMCs) and thermoplastics.

Fibre-reinforced plastics — Methods of producing test plates —

Part 10: Injection moulding of BMC and other long-fibre moulding compounds — General principles and moulding of multipurpose test specimens

1 Scope

This part of ISO 1268 specifies the general principles to be followed while injection moulding test specimens of bulk moulding compound (BMC) and gives details of mould designs for preparing one type of specimen for use in establishing reproducible moulding conditions. Where appropriate, this part of ISO 1268 may be applied to sheet moulding compound (SMC) formulated for injection moulding. 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 Tests have shown that mould design in an important factor in the reproducible preparation of test specimens.

This part of ISO 1268 is intended to be read in conjunction with ISO 1268-1.

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 472, *Plastics — Vocabulary*

ISO 1268-1, *Fibre-reinforced plastics — Methods of producing test plates — Part 1: General conditions*

ISO 1268-11, *Fibre-reinforced plastics — Methods of producing test plates — Part 11: Injection moulding of BMC and other long-fibre moulding compounds — Small plates*

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

ISO 3167, *Plastics — Multipurpose test specimens*

ISO 10350-2, *Plastics — Acquisition and presentation of comparable single-point data — Part 2: Long-fibre-reinforced plastics*

ISO 10724-1, *Plastics — Injection moulding of test specimens of thermosetting powder moulding compounds (PMCs) — Part 1: General principles and moulding of multipurpose test specimens*

ISO 10724-2, *Plastics — Injection moulding of test specimens of thermosetting powder moulding compounds (PMCs) — Part 2: Small plates*

ISO 11403-1, *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 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 472 and the following apply.

3.1
mould temperature
T_C
average temperature of the mould cavity surfaces measured after the system has attained thermal equilibrium and immediately after opening the mould

NOTE It is expressed in degrees Celsius (°C).

3.2
temperature of material
T_M
temperature of the plasticized material in a free shot

NOTE 1 It is given by the temperature of the wall of the screw cylinder.

NOTE 2 It is expressed in degrees Celsius (°C).

3.3
pressure on material
p
pressure on the plasticized material in front of the screw at any time during the moulding process (see Figure 1)

NOTE 1 It is expressed in megapascals (MPa).

NOTE 2 The pressure on the material, which is generated hydraulically, can be calculated from the force F_s acting longitudinally on the screw using Equation (1):

$$p = \frac{4 \times 10^3 \times F_s}{\pi \times D^2} \tag{1}$$

where

p is the pressure on the material, in megapascals (MPa);

F_s is the longitudinal force, in kilonewtons (kN), acting on the screw;

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

3.4
maximum pressure on the material
p_{max}
maximum value of the pressure on the material

NOTE It is expressed in megapascals (MPa).

3.5
hold pressure
p_H
pressure on the material during the hold time (see Figure 1)

NOTE It is expressed in megapascals (MPa).

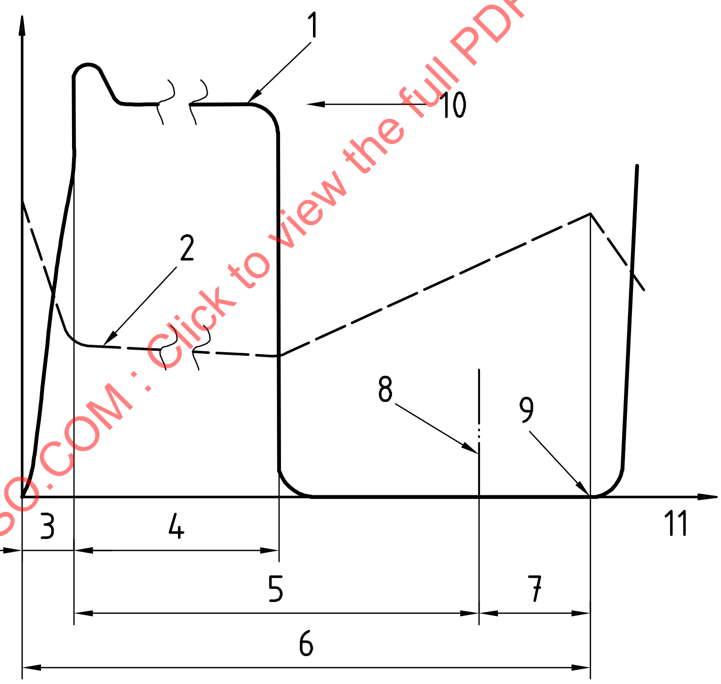
3.6
moulding cycle
complete sequence of operations in the moulding process required for the production of one set of test specimens (see Figure 1)

NOTE It is expressed in seconds (s).

3.7
cycle time
t_T
time required to carry out a complete moulding cycle

NOTE 1 It is expressed in seconds (s).

NOTE 2 The cycle time is the sum of the injection time t_I, the cure time t_{CR} and the mould open time t_O.



Key

1 pressure on material, p
2 longitudinal position of the screw
3 injection time, t_I
4 hold time, t_H
5 cure time, t_{CR}
6 cycle time, t_T
7 open time, t_O
8 mould opening
9 mould closing
10 hold pressure, p_H
11 time

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

3.8
injection time
t_I
time from the instant the screw starts to move forward until the switchover point between the injection period and the hold period

NOTE It is expressed in seconds (s).

3.9
cure time
t_{CR}
time from the end of the injection period until the mould starts to open

NOTE It is expressed in seconds (s).

3.10
hold time
t_H
time from the end of the injection period until the hold pressure p_H is released

NOTE It is expressed in seconds (s).

3.11
mould-open time
t_O
time from the instant the mould starts to open until the mould is closed and exerts the full locking force

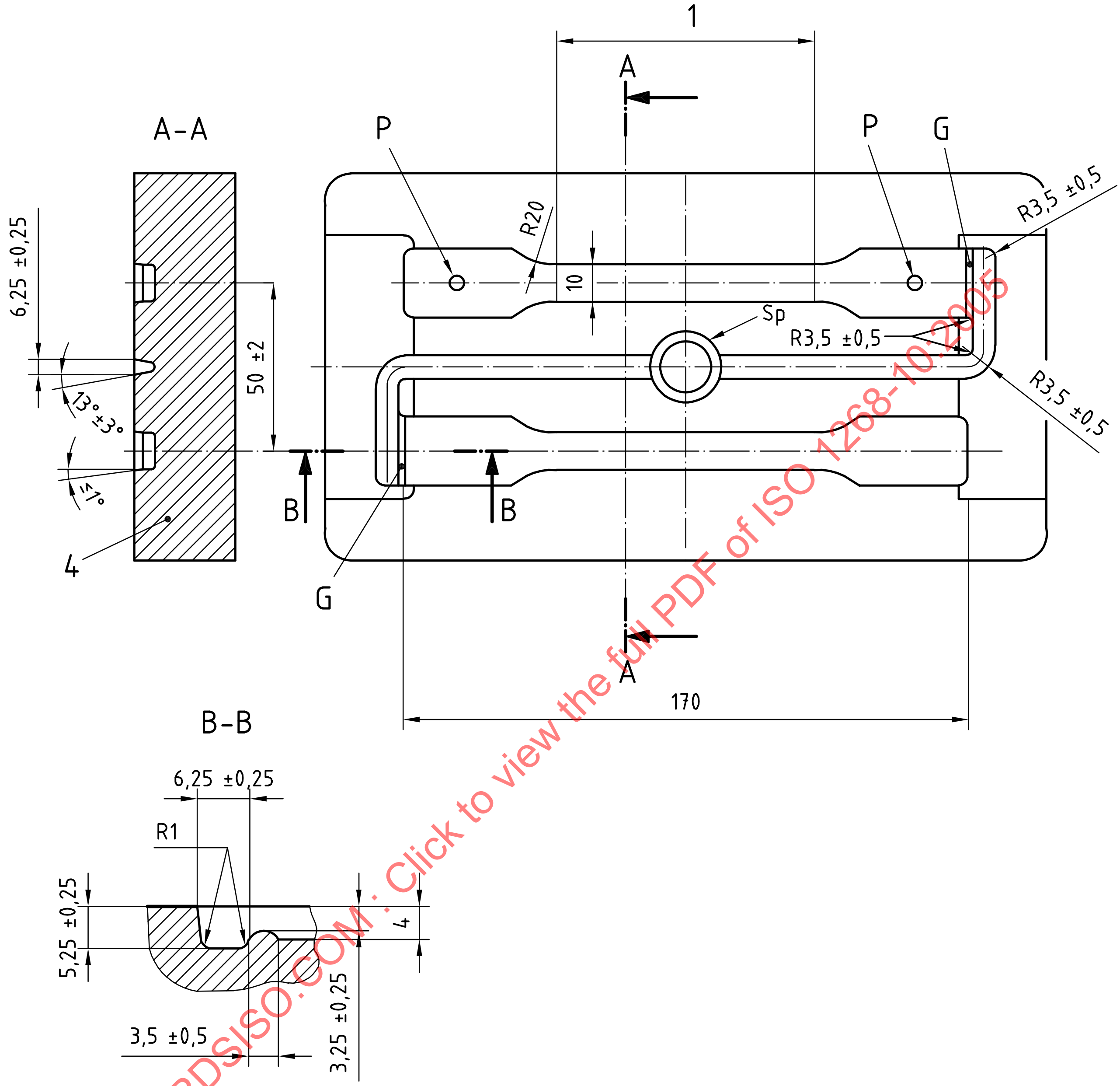
NOTE It is expressed in seconds (s) and includes the time required to remove the mouldings from the mould.

3.12
cavity
that part of the hollow space in a mould which produces one specimen

3.13
two-cavity mould
mould that contains two identical cavities in a parallel-flow arrangement (see Figure 2)

NOTE Identical flowpath 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



Key

1 preferably 82 mm

Sp sprue

G gate

P pressure sensor (optional)

shot capacity V_S = 30 000 mm^3

projected area A_p = 6 500 mm^2

Figure 2 — Two-cavity plate for a type A ISO mould

3.14
ISO mould
any one of the standard moulds (designated type A, D1 and D2) intended for the reproducible preparation of test specimens with comparable properties

NOTE 1 The moulds have a fixed plate with a central sprue, plus a two-cavity plate as described in 3.13. Additional details are given in 4.1.4.

NOTE 2 An example of a complete mould is shown in Annex C.

3.15
critical cross-sectional area
A_C
cross-sectional area of the cavity of an ISO 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

NOTE 1 It is expressed in square millimetres (mm^2).

NOTE 2 For tensile bar test specimens, the critical portion of the test specimen is the narrow section that is subjected to the greatest stress during testing.

3.16
moulding volume
V_M
ratio of the mass of the moulding to the density of the solid plastic

NOTE It is expressed in cubic millimetres (mm^3).

3.17
projected area
A_p
overall profile of the moulding projected onto the parting plane

NOTE It is expressed in square millimetres (mm^2).

3.18
locking force
F_M
force holding the cavity plates of the mould closed

NOTE 1 It is expressed in kilonewtons (kN).

NOTE 2 The minimum locking force necessary may be calculated from the inequality:

$$F_M \geqslant A_p \times p_{max} \times 10^{-3} \quad (2)$$

where

F_M is the locking force, in kilonewtons (kN);

A_p is the projected area, in square millimetres (mm^2);

p_{max} is the maximum value of the pressure on the material, in megapascals (MPa).

3.19
injection velocity
v_I
average velocity of the material as it passes through the critical cross-sectional area A_C

NOTE 1 It is expressed in millimetres per second (mm/s).

NOTE 2 It is applicable to multi-cavity moulds only (in this case a two-cavity mould), and is calculated from Equation (3):

$$v_I = \frac{V_M}{t_I \times A_C \times 2} \tag{3}$$

where

v_I is the injection velocity, in millimetres per second ($mm \cdot s^{-1}$);

2 is the number of cavities;

A_C is the critical cross-sectional area, in square millimetres (mm^2);

V_M is the moulding volume, in cubic millimetres (mm^3);

t_I is the injection time, in seconds (s).

3.20
mass of the moulding
m_M
total mass of the moulding, including the specimens, runners and sprue

NOTE It is expressed in grams (g).

3.21
shot capacity
V_S
product of the maximum metering stroke of the injection-moulding machine and the cross-sectional area of the screw

NOTE It is expressed in cubic millimetres (mm^3).

4 Apparatus

4.1 Type A ISO mould (two-cavity)

4.1.1 ISO moulds (see 3.14) are strongly recommended for producing test specimens for the acquisition of data that are intended to be comparable (see ISO 10350-2, ISO 11403-1, ISO 11403-2 and ISO 11403-3, and ISO 10724-1 and ISO 10724-2), as well as for use in the resolution of disputes involving International Standards.

4.1.2 Multipurpose test specimens as specified in ISO 3167 shall be moulded in the 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 ± 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 (4,5 ± 0,5) mm.

b) The width and height of the runner system shall be (6,25 ± 0,25) mm and (5,25 ± 0,25) mm, respectively, with a radius of 1 mm for the runner floor-to-wall angles at the gate.

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 have a length of (3,5 ± 0,5) mm, all radii having a minimum value of 1 mm.

f) The draft angle of the runners shall be (13 ± 3)°. 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;

— width of central section: 10,0 to 10,2;

— length of central parallel-sided section: 80,0 to 82,0.

h) Ejector pins shall be located outside the test area of the specimen, i.e. at the shoulders of dumbbell specimens produced from type A ISO moulds.

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 5 °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 suitable sensor position is shown in Figure 2.

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 1268-11:

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 by a mark outside the test area, 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.

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. Therefore, where appropriate, the surfaces of the mould cavities shall be highly polished. The direction of polishing shall correspond 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, see the Bibliography.

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 3.16) to the shot capacity V_S (see 3.21) shall be between 30 % and 70 % 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 ±0,2 s;
- hold pressure, p_H ±5 %;
- hold time, t_H ±5 %;
- material temperature, T_M ±5 °C (kept within these limits by adjusting the temperature of the screw cylinder wall);
- mould temperature, T_C ±3 °C;
- mass of moulding, m_M ±2 %.

4.2.3 Screw

The screw shall be of a type suitable for bulk moulding compounds.

It is recommended that a back flow valve be installed.

4.2.4 Locking force

The mould locking force F_M shall be high enough to prevent extensive flash formation under any operating conditions.

The minimum locking force F_M for a type A ISO mould is given by $F_M \geqslant 6\,500 \times p_{max} \times 10^{-3}$ (see 3.18), i.e. 520 kN for a maximum pressure on the material of 80 MPa.

An injection-moulding system with interchangeable cavity plates will need to take into account the type D1 and D2 ISO moulds for which A_p is 11 000 mm^2, thus requiring a significantly higher mould-locking force.

4.2.5 Thermometers

A needle-probe thermometer accurate to ±1 °C shall be used to measure the material temperature T_M (see 3.2). A surface thermometer accurate to ±1 °C shall be used to measure the temperature of the surface of the mould cavity, which gives the mould temperature T_C (see 3.1).

5 Procedure

5.1 Conditioning of material

Prior to moulding, condition the bulk moulding compound as required in the relevant material standard or, in the absence of such information, as recommended by the manufacturer.

Avoid exposing materials to an atmosphere at a temperature significantly below the temperature of the workshop to avoid condensation of moisture onto the material.

5.2 Injection moulding

5.2.1 Set the machine to the conditions specified in the relevant material standard or, in the absence of such information, agreed between the interested parties.

5.2.2 For many moulding compounds, a suitable range for the injection velocity v_I is (150 ± 50) mm/s when using a type A ISO mould.

For a given value of the injection velocity v_I, the injection time t_I is inversely proportional to the number of cavities n in the mould [see Equation (3) in 3.19]. Any changes in the injection velocity during the injection period should therefore be kept as small as possible.

5.2.3 A convenient way of determining the hold pressure p_H, a parameter which is frequently not specified, is by the following procedure:

Starting from zero, gradually increase the pressure on the material until the mouldings are free from sink marks, voids and other visible faults and have minimum flash. Use this pressure as the hold pressure.

This procedure can be used for most injection-moulding presses.

5.2.4 Ensure that the hold pressure is maintained constant until the material in the gate region has cured, i.e. until the mass of the moulding has reached an upper limiting value under these conditions.

5.2.5 Discard the mouldings until the machine has reached steady-state operation. Then record the operating conditions and begin test specimen collection.

During the moulding process, maintain the steady-state conditions by suitable means, e.g. by checking the mass of the moulding m_M.

5.2.6 In the event of any change in material, empty the machine and clean it thoroughly. Discard at least 10 mouldings made using the new material before beginning test specimen collection again.

5.3 Measurement of mould temperature

Determine the mould temperature T_C after the system has attained thermal equilibrium and immediately after opening the mould. Measure the temperature of the mould-cavity surface at several points on each side of the mould cavity using a surface thermometer. Between each pair of readings, cycle the mould for a minimum of 10 cycles before continuing with the next measurement. Record each measurement and calculate the mould temperature as the average of all the measurements.

5.4 Measurement of the material temperature

5.4.1 Measure the material temperature T_M by one of the following methods:

5.4.2 After thermal equilibrium has been attained, inject a free shot of at least 30 cm^3 into a non-metallic container of a suitable size and immediately insert the probe of a preheated rapid-response needle thermometer into the centre of the plasticized material, moving it about gently until the reading of the thermometer has reached a maximum.

Ensure that the preheating temperature is close to the material temperature. Confirm this by using the same injection conditions for free shots as those to be used to mould the specimens, allowing the appropriate cycle time to elapse between each free shot.

5.4.3 Alternatively, the material temperature may be measured by means of a suitable temperature sensor, provided the result obtained can be shown to be the same as that obtained using the free-shot method. The sensor shall cause only low heat losses and shall respond rapidly to material temperature changes. Mount the sensor in a suitable place, such as in the nozzle of the injection-moulding machine. In case of doubt, use the method described in 5.4.2.

5.5 Post-moulding treatment of test specimens

Once removed from the mould, allow the test specimens to cool gradually and at the same rate to room temperature in order to avoid any differences in the history of individual test specimens.

NOTE Experience has shown that at least a part of this cooling time can have a significant influence on the degree of curing of bulk moulding compounds.

6 Report on test-specimen preparation

The report shall include the following information:

a) a reference to this part of ISO 1268;

b) the date, time and place the specimens were moulded;

c) a full description of the material used (type, designation, manufacturer, lot number);

d) details of any conditioning of the material carried out prior to moulding;

e) the type of specimen produced, the relevant standard and the gate size and location;

f) details of the injection-moulding machine used (manufacturer, shot capacity, mould-locking force, control systems);

g) the moulding conditions:

— material temperature T_{M} (see 3.2), in degrees Celsius,

— mould temperature T_{C} (see 3.1), in degrees Celsius,

— injection velocity v_{I} (see 3.19), in millimetres per second,

— injection time t_{I} (see 3.8), in seconds,

— hold pressure p_{H} (see 3.5), in megapascals,

— maximum pressure on the material $p_{\max}$ (see 3.4), if a pressure sensor is installed, in megapascals,

— hold time t_{H} (see 3.10), in seconds,

— cure time t_{CR} (see 3.9), in seconds,

— cycle time t_{T} (see 3.7), in seconds,

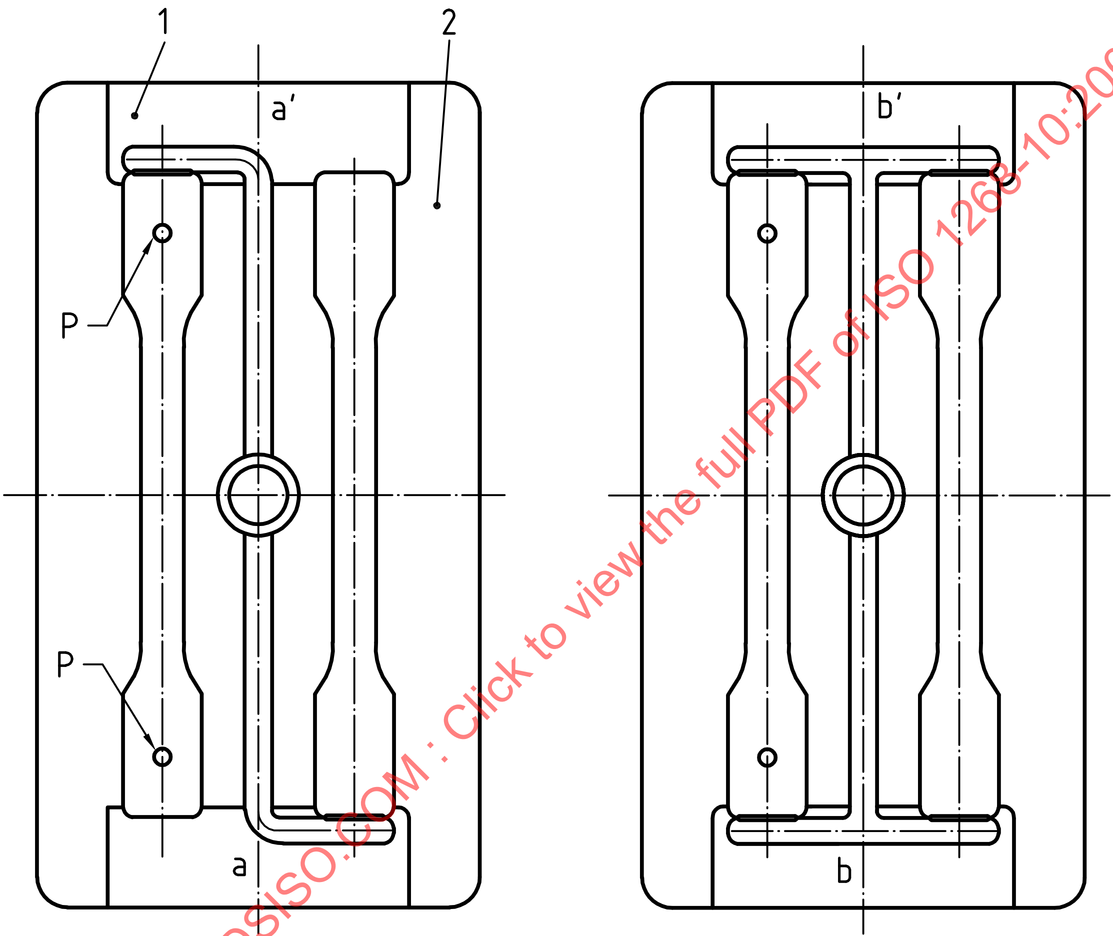
— mass of the moulding m_{M} (see 3.20), in grams;

h) any other relevant details (e.g. the number of mouldings initially discarded per cavity, the number retained, any post-moulding treatment).

Annex A
(informative)

Examples of runner configurations

The layout of a mould may be changed by means of gate inserts (a-a' or b-b') as shown in Figure A.1.



a) Injection mould as specified in this part of ISO 1268 (Z-runner)

b) Variant with double-T runner (e.g. for studying weld-line strength)

Key

1 interchangeable gate insert

2 interchangeable two-cavity plate

P pressure sensor

Figure A.1 — Different types of runner configuration

Annex B
(informative)

Marking of test specimens

The purpose of marking test specimens is to permit the determination of the original position of the two specimens in the mould, even if the tabs at the ends of the specimen are cut off (e.g. to obtain a bar specimen with the dimensions of 80 mm × 10 mm × 4 mm). This kind of marking should preferably be done in addition to the marking by the heads of the ejector pins [see 4.1.4, item m) and item h)].

The numbers used, and their positions in the mould cavities, should preferably be as follows:

— the mirror images of the numbers "1" and "2" should be used;

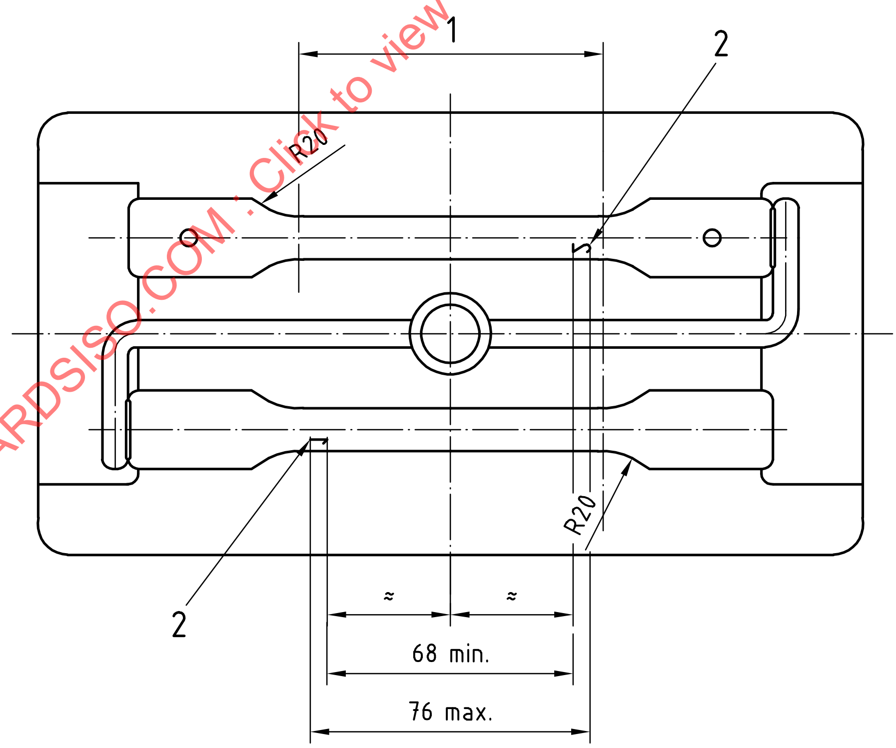
— the numbers should be legible, upright and aligned with the direction of flow of the material;

— the numbers should be outside the usual test-specimen support spans for flexural-loading tests, but within the length of an 80-mm-long bar specimen;

— the numbers should be just visible (i.e. not very deeply "engraved"), to avoid stress concentrations, etc.;

— the numbers should be located at the gate end of the cavity.

Dimensions in millimetres



Key

1 preferably 82 mm

2 cavity number

Figure B.1 — Positions of the cavity numbers