INTERNATIONAL STANDARD

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Protective clothing — Assessment of resistance of materials to molten metal splash

Vêtements de protection — Évaluation de la résistance des matériaux à la projection de métal fondu

Reference number
ISO 9185:1990(E)

Foreword

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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 9185 was prepared by Technical Committee ISO/TC 94, *Personal safety -- Protective clothing and equipment*.

Annexes A and B form an integral part of this International Standard.

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Introduction

There has been increasing interest in recent years in the flammability performance of textiles. In the metal industries the principal environmental hazards are heat and molten metal splash, and this International Standard is intended to provide a test method by which the protective ability of differing materials can be assessed.

The test takes into account the heat transfer properties of the material being tested and its dynamic resistance to penetration by the molten metal. The full test procedure is based on stepped increases in mass of metal but it is expected that performance specifications will simply require a specified mass of metal to be poured at which the material should not cause damage to the skin simulant.

It has been assumed in the drafting of this International Standard that its procedures are entrusted to appropriately qualified and experienced people. The principle of the test method is such that any metal can be used, but for particular molten metals (e.g. sodium), changes in the materials used for the apparatus will be necessary and additional safety measures needed.

If changes in sensitivity of the test are needed, for example to accommodate the assessment of materials as protection against a particular metal hazard, then two of the test conditions (pour height and specimen angle to the horizontal) can be varied. Recommended test conditions for a small range of metals are given in annex A.

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Protective clothing — Assessment of resistance of materials to molten metal splash

1 Scope

This International Standard describes a method for assessing the resistance of materials used in protective clothing to molten metal splash. It is important to note that good resistance of a material to a pure molten metal does not guarantee a good performance against slag.

2 Definitions

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

2.1 pour height: The vertical distance from the axis of rotation of the pouring ring to the centre of the pin frame.

2.2 molten metal splash index: A figure equal to the minimum mass of molten metal poured which just causes damage of the skin simulant.

2.3 damage: Any smoothing, modification of the embossing or pin-holing on the surface of the skin simulant extending in total for at least 5 mm across its width. Where the damage is in discrete spots, the widths of each spot are added across any horizontal section.

3 Principle

Materials are tested by pouring small quantities of molten metal on to the test specimen supported at an angle to the horizontal on a small pin frame. Damage is assessed by placing a PVC skin simulant directly behind the test specimen and noting damage to the skin simulant after pouring. Any adherence of the metal to the test specimen surface is also noted. Depending on the result, the test is repeated using a greater or smaller mass of metal, until the minimum quantity to cause damage to the skin simulant is observed.

4 Apparatus

4.1 Commercial grade metal, appropriate to the end use.

NOTE 1 It is recommended that coarse filings or small pieces cut from solid bar or sheet should be used, as fine filings have been found difficult to melt. A range of pouring temperatures appropriate to different metals is given in annex A.

4.2 PVC skin simulant, comprising an embossed PVC sheet, of mass per unit area 230 g/m^2 $\pm$ 10 g/m^2 which, when tested as described in annex B, shows no smoothing or modification of the embossing of the central area at a block temperature of 166 °C $\pm$ 2 °C, but shows smoothing or modification of the central area at a block temperature of 183 °C $\pm$ 2 °C.

4.3 Crucible[1], the approximate external dimensions being height 97 mm, top diameter 80 mm, bottom diameter 56 mm, and capacity (brim full) 190 ml.

4.4 Detachable crucible holder, to enable the crucible containing the molten metal to be quickly and safely removed from the furnace to the test apparatus.

4.5 Furnace, capable of operating at a temperature 100 °C above the pouring temperature specified in annex A. The furnace type may be either a muffle furnace or an induction type furnace.

NOTE 2 Muffle furnaces are capable of holding at least four crucibles, i.e. internal furnace size is approximately 135 mm × 190 mm × 780 mm, but take several hours to melt metals such as steel, iron and copper. Induction fur-

1) For most molten metals, a graphite impregnated material (if an induction furnace is used) or a ceramic material (if a muffle furnace is used) has been found suitable for the crucible.

naces melt a single crucible of these metals in less than 30 min.

4.6 Temperature probe, either a small thermocouple or an optical non-contact temperature device, capable of measuring molten metal temperatures up to 1 650 °C.

4.7 Pouring apparatus, pin frame and tray, shown in figure 1, consisting of a pouring device supported on adjustable legs, a specimen holder and a sand tray.

The sand tray shall have minimum dimensions of approximately 250 mm wide × 350 mm long × 50 mm deep and shall be filled with dry sand to a depth of 30 mm to 40 mm.

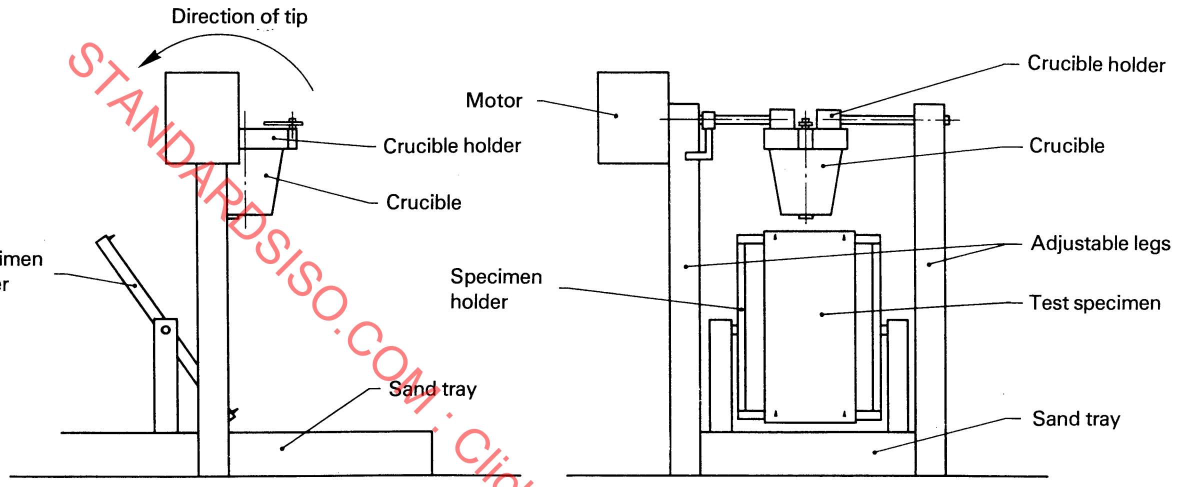


Figure 1 — Pouring apparatus

Dimensions in millimetres

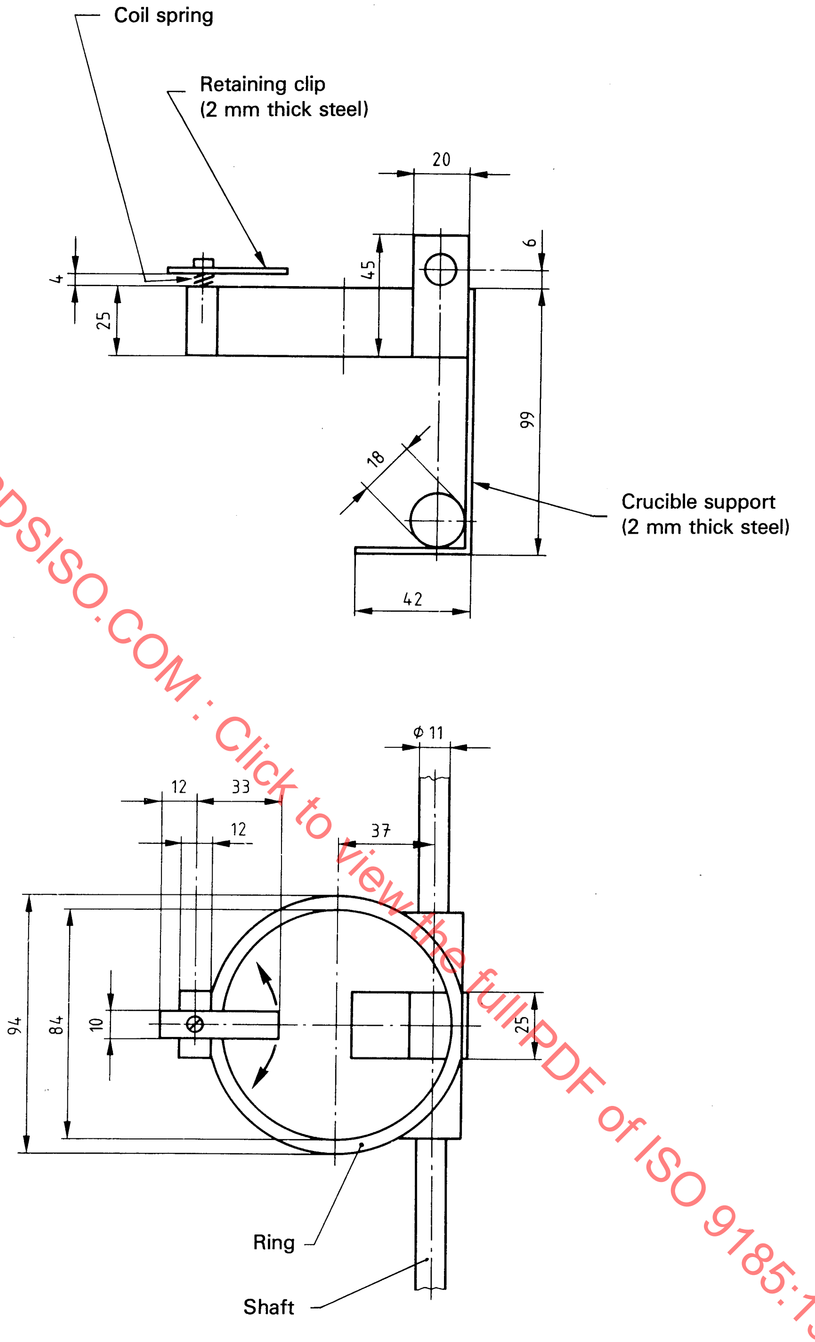


Figure 2 — Pouring device

The pouring device, consisting of crucible holder and drive shaft, shall be constructed in steel (see design in figure 2).

The pouring apparatus shown in figure 1 is fitted with an electric motor. An alternative version is shown in figure 3 with a circuit diagram for the motor drive shown in figure 4.

A metal bar is attached to the pouring device to serve as a stop to prevent the crucible rotating before the molten metal is poured.

The drive shaft shall be firmly supported and be adjustable in height so that the specified pour height (see annex A) can be achieved.

The specimen holder shall consist of a rectangular pin frame, 160 mm ± 5 mm wide × 248 mm ± 2 mm deep made from 8 mm square steel. It shall have four tenter pins, two on the top edge and two on the bottom edge, spaced 80 mm ± 2 mm apart and 40 mm ± 2 mm from the respective corners. The pin frame shall be supported on a suitable frame which enables the angle of the specimen to the horizontal to be varied (see annex A) and the position of the test specimen relative to the pouring device to be adjusted so that the main impact of the molten metal is near the centre of the test specimen.

Dimensions in millimetres

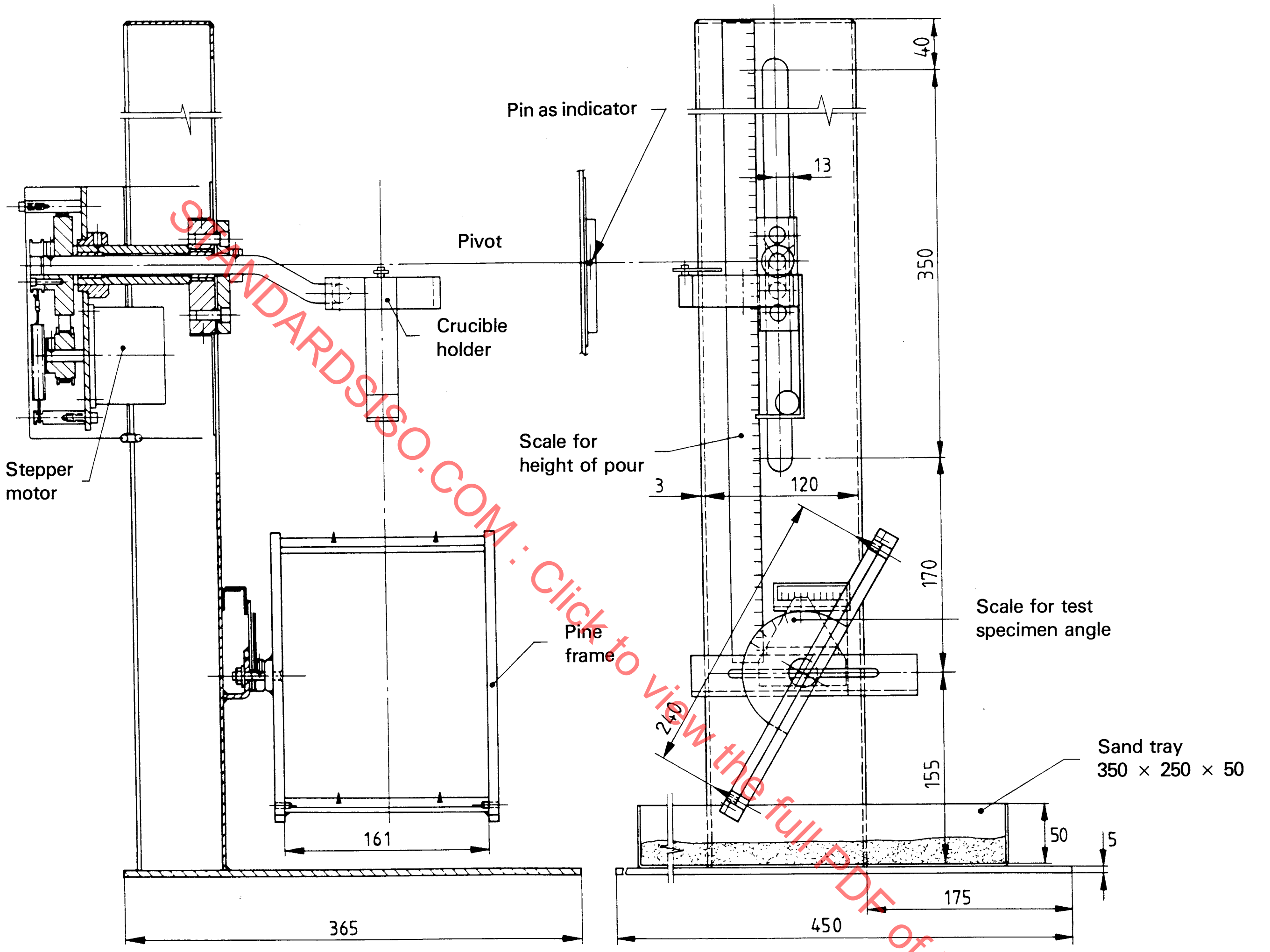
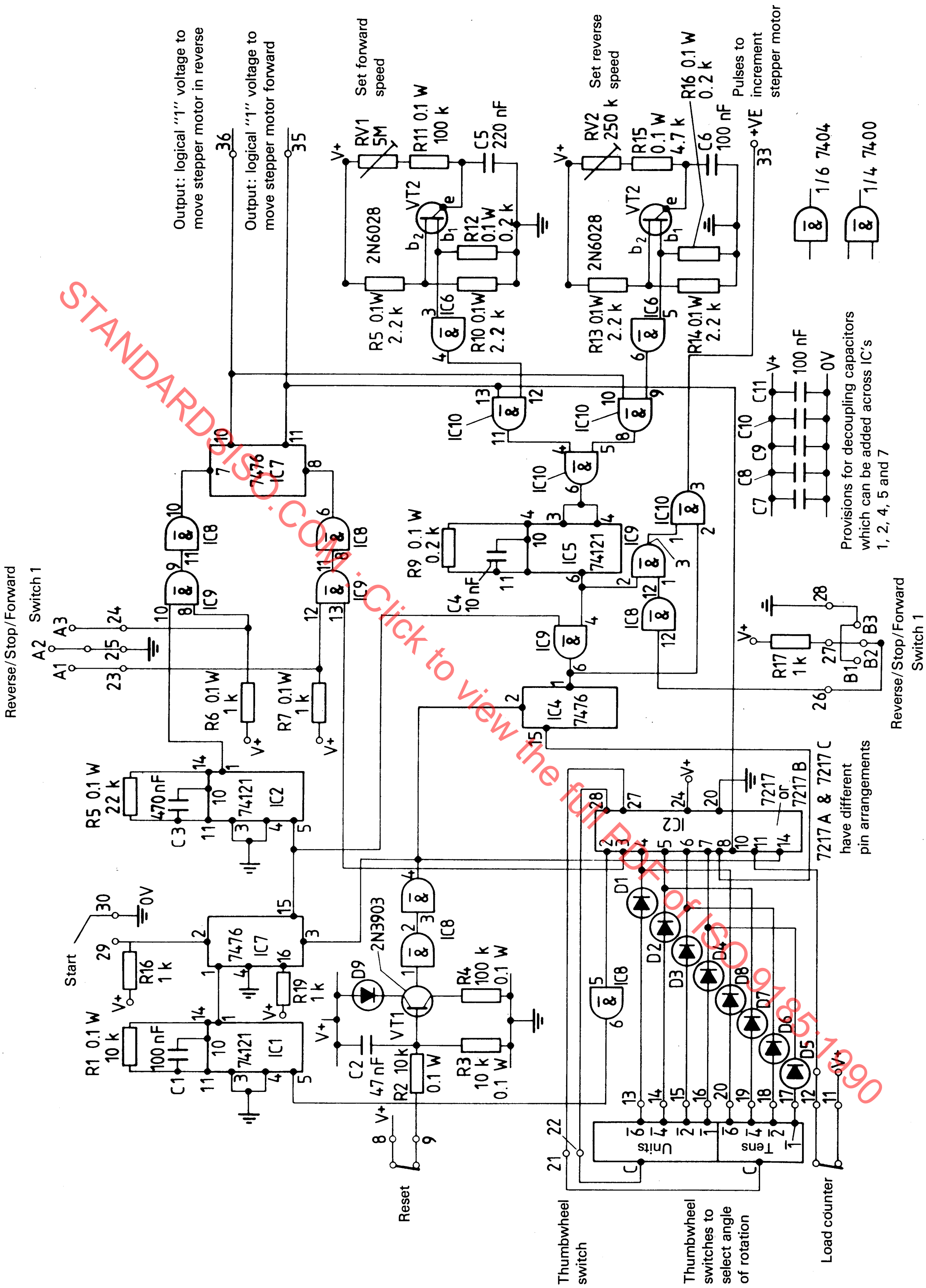


Figure 3 — Motorized pouring apparatus



NOTE — This circuit used in conjunction with a stepper motor and associated drive board will rotate the crucible through a preset angle before returning to the test position. A motor with a holding torque of 0,125 kg·m and a rotation of 1,8° per step is recommended. In this case the angle of rotation is the number selected on the thumbwheel switches × 1,8°.

Figure 4 — Circuit diagram for motor drive

4.8 Balance, capable of weighing to an accuracy of 1,0 g.

4.9 Template, in the form of a rigid rectangle 260 mm ± 2 mm × 100 mm ± 2 mm with adjacent edges, their centres forming the corners of a rectangle 240 mm ± 2 mm × 80 mm ± 2 mm.

5 Conditioning and testing atmospheres

An atmosphere having a temperature of 15 °C to 25 °C and relative humidity 55 % to 65 % shall be used for the conditioning of specimens. For testing, an atmosphere substantially free from draughts and having a temperature of 15 °C to 30 °C and a relative humidity of 20 % to 65 % shall be used.

6 Preparation and conditioning of test specimens

Lay out the laboratory sample without tension but free from wrinkles and creases on a flat, smooth surface. Initially, mark and cut seven test specimens using the template with the longer length in the machine direction (except where this does not apply, e.g. leather, when the direction of cutting is unimportant). Using the template, mark the position for the pins (of the pin frame) on the material by spots 2 mm in diameter at the centres of the holes for the pins. Cut a similar number of pieces of skin simulant and mark the position of the pins in an identical manner.

Subject the test specimen to the atmosphere for conditioning for 24 h. If the test is not carried out immediately after conditioning, place the test specimen in a sealed container until the start of the test. Begin testing each test specimen within 3 min of removing it from either the conditioning atmosphere or the container.

NOTE 3 The assessment uses an iterative procedure and therefore the exact number of test specimens needed cannot be stated. Seven test specimens are usually sufficient to give a result. If there is previous experience of the material or if a material is being assessed for compliance with a specification, fewer test specimens will be needed.

7 Operator safety

Suitable protective clothing and equipment shall be worn by the operator when using the high temperature furnace and the test apparatus, in order to protect against the hazard of accidental splashes from molten metal.

WARNING — In addition to the hazard of molten metal splashes, certain metals (e.g. sodium) ignite spontaneously when heated in air and produce toxic fumes when so heated. Additional safety measures will therefore be necessary when testing the resistance of materials to these metals.

8 Procedure

8.1 Setting up the apparatus

Adjust the position of the crucible holder (4.4) to give the specified pour height, and the angle of the pin frame (4.7) to give the required specimen angle to the horizontal (see annex A).

8.2 Preparation of molten metal

Place approximately 50 g (weighed to the nearest gram) of metal (or multiple of 50 g if it is known that the material under test will withstand a higher amount), either coarse ground or cut from bar or sheet, into the dry crucible (4.3) and melt it to a temperature slightly above that at which it will remain molten throughout the test (see annex A).

8.3 Attachment of test material to pin frame

Attach a piece of PVC skin simulant (4.2) to the pin frame by pushing the pins through the marked positions with the embossed side uppermost. Position the test specimen over the PVC skin simulant and attach it to the pin frame in an identical manner. Ensure that the test specimen is in intimate contact with the PVC skin simulant, free from creases and with the face of the material designed to be on the outside of a garment exposed to the molten metal.

8.4 Pouring of molten metal

Carefully transfer the crucible, using the detachable crucible holder, to the pouring ring (4.7). Allow the molten metal to cool to the pouring temperature (see annex A) and then operate the pouring device so that the crucible turns through at least 130 ° from the horizontal at a constant rate of 37° ± 2,5° per second. This rate is equivalent to a rotation of 90° in 2,5 s ± 0,2 s.

Pour the metal over the edge of the crucible and not via the pouring lip and ensure that an undamaged edge surface is used.

8.5 Examination

8.5.1 30 s after the completion of pouring, remove the test specimen and examine the skin simulant for any sign of damage as defined in 2.3. Note any such damage.

8.5.2 Note and record whether any molten metal has solidified and adhered to the surface of the test specimen.

8.6 Determination of mass of metal poured

Allow any metal remaining in the crucible to solidify sufficiently for it to be scraped out. Weigh this residue to the nearest gram and subtract it from the initial mass of metal melted. Record this as "metal poured".

9 Iterative testing

9.1 If there is no damage to the skin simulant, repeat the test procedure using new test specimens of material and skin simulant and using a quantity of metal in the crucible 50 g more than used in the previous test. If the capacity of the crucible is reached the test is not sufficiently severe to obtain skin damage. When damage is observed proceed to 9.2.

9.2 Repeat the test procedure using a quantity of metal in the crucible 10 g less than used in the previous test. If damage to the skin simulant is observed repeat from 9.2. When no damage to the skin simulant is observed proceed to 9.3.

9.3 Repeat the test procedure using the same quantity of metal in the crucible used in the previous test. If damage to the skin simulant is observed repeat from 9.2. If no damage to the skin simulant is observed repeat from 9.3 until four successive tests show no damage to the skin simulant.

9.4 Note the highest value of the mass of metal poured in these four tests and the lowest mass of metal poured that caused damage.

9.5 Record the mean of these two values to the nearest gram as the molten metal splash index.

10 Void tests

Declare any test void and repeat the test using that mass of metal if any of the following occurs:

a) the rotation of the crucible is noticeably discontinuous and is not carried out in the prescribed time;

b) the impact of the pour wanders horizontally across the test specimen;

c) the metal runs off the side of the test specimen or strikes within 25 mm of the top edge;

d) any of the molten metal does not first hit the test specimen;

e) the metal is not completely molten when poured;

f) the PVC skin simulant ignites.

11 Test report

The test report shall include the following:

a) a reference to this International Standard;

b) for each individual test specimen, the approximate mass of metal used (see 8.2), whether any molten metal adhered to the material, the result of the assessment of the skin simulant and the mass of metal poured;

c) the molten metal splash index calculated as specified in clause 9;

d) the metal used, pouring temperature, specimen angle to the horizontal and pouring height;

e) any deviations from the test procedure likely to have had an influence on the test result.

Annex A
(normative)

Pouring temperatures which have been found appropriate for certain metals

As this International Standard is solely a method of test it does not specify performance levels for materials but it does enable comparisons to be made between materials in terms of the protection provided against specific molten metals. The conditions recommended in table A.1 have been found appropriate for the metals given. The specimen angle shown for aluminium reflects the need to increase the sensitivity of the test for this metal in order to be able to compare materials more readily and demonstrates the flexibility of the basic method in that it enables a wide range of metals to be assessed.

Temperatures to which metals are heated before pouring are slightly higher than pouring temperatures to allow for cooling during transfer from furnace to pouring apparatus. For metals poured at higher temperatures the rate of cooling is greater than when poured at lower temperatures, and therefore the metal has to be heated to a higher temperature to accommodate transference from furnace to crucible holder. The critical temperature is the pouring temperature which can be estimated by use of predrawn temperature/time curves (cooling curves). The following "temperature above pouring temperature" were found to be practical for the following metals using an induction furnace and enable the pouring temperatures specified in table A.1 to be achieved:

Aluminium	820 °C
Copper	1 350 °C
Iron	1 500 °C
Mild steel	1 650 °C

Table A.1 — Pouring temperature, pouring height and specimen angle to the horizontal

Metal		Pouring temperature °C	Pouring height mm	Specimen angle to the horizontal degrees
Aluminium	Complying with designation Al 99.5 as specified in ISO/R 209:1971 (E) 99,5 %	780 ± 20	300 ± 5	45 ± 1
Copper	99 %	1 280 ± 20	225 ± 5	75 ± 1
Iron	Complying with ISO/R 185:1961 (E) containing the following: C 2,8 % to 3,2 %, Si 1,2 % to 2,0 %, P 0,3 % to 0,6 %	1 400 ± 20	225 ± 5	75 ± 1
Mild steel	Complying with designation C25 as specified in ISO/R 683-1:1968 (E)	1 550 ± 20	225 ± 5	75 ± 1