INTERNATIONAL STANDARD

**ISO
5085-1**

First edition
1989-11-15

Textiles — Determination of thermal resistance —

Part 1 :
Low thermal resistance

Textiles — Détermination de la résistance thermique —

Partie 1 : Faible résistance thermique

INTERNATIONAL ISO

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 approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 5085-1 was prepared by Technical Committee ISO/TC 38, *Textiles*.

ISO 5085 consists of the following parts, under the general title *Textiles — Determination of thermal resistance* :

— *Part 1: Low thermal resistance*

— *Part 2: High thermal resistance*

Annexes A to D form an integral part of this part of ISO 5085.

Introduction

The thermal insulation provided by woven and knitted fabrics and nonwoven fibre aggregates (fleeces, batts and wads) is of considerable practical significance in connection with the use of these materials as clothing (especially cold-weather clothing), bedding (blankets, quilts), carpets, roof insulation, etc.

The measurement of the thermal resistance of textiles allows the incorporation of the values for clothing and furnishing fabrics into calculations for thermal environments, heat losses from rooms, etc. Thermal resistances of layers of fabrics are additive, thus the values for whole clothing assemblies can be calculated.

The method of test can be easily adapted to allow for provision of air gaps between layers of fabric.

It has been suggested that a simple measurement of thickness provides an adequate measure of the thermal insulation of, say, blankets. This is only acceptable, however, if a common value can be assumed for the thermal insulation per unit thickness. However, the transmission of heat through a textile can occur not only by conduction through the fibres and the entrapped air but also by radiation through the air spaces within the fabric. Because of this, there is a considerable variation in the thermal insulation per unit thickness, and thickness is, therefore, an unreliable guide to the warmth provided by, say, blankets even when they are of one type (e.g. raised, cellular or terry).

ISO 5085 is published in two parts. This part is suitable for the determination of low thermal resistances, i.e. up to about 0,2 m^2·K/W, although it may be usable for values up to about 0,4 m^2·K/W. For values greater than about 0,2 m^2·K/W, the method specified in ISO 5085-2 is suitable.

This page intentionally left blank

Textiles — Determination of thermal resistance —

Part 1:
Low thermal resistance

1 Scope

1.1 This part of ISO 5085 specifies a method for the determination of the resistance of fabrics, fabric assemblies or fibre aggregates in sheet form to the transmission of heat through them in the "steady state" condition. It applies to materials whose thermal resistance is up to approximately $0,2$ m^2·K/W (see however "Introduction", last paragraph).

1.2 The method is suitable for materials up to 20 mm thick (above this thickness, edge losses become appreciable). Advice on suitable components for constructing the apparatus is given in annex A, means of determining the thermal conductivity are described in annex B and numerical values for some textile materials are given in annex C.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 5085. 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 5085 are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 139 : 1973, *Textiles — Standard atmospheres for conditioning and testing.*

ISO 8302 : —[1], *Thermal insulation — Determination of steady-state areal thermal resistance and related properties — Guarded hot plate apparatus.*

3 Definitions

For the purposes of this part of ISO 5085, the following definitions apply.

3.1 thermal resistance, R : The ratio of the temperature difference between the two faces of a test specimen to the rate of flow of heat per unit area normal to the faces. It is analogous to electrical resistance in the case of current flow through an electrical conductor.

3.2 thermal conductivity, k : The quantity of heat that passes in unit time through unit area of a slab of infinite extent and of unit thickness when unit difference of temperature exists between the faces of the slab. For a flat material having parallel faces,

$$R = \frac{d}{k}$$

where d is the thickness of the slab.

Thermal conductivity is the reciprocal of thermal resistance per unit thickness.

NOTE — Since a textile is a heterogenous system consisting of fibres and air, the term "thermal conductivity" does not have its usual precise meaning since, in addition to conduction, heat can be transferred through a textile by radiation and possibly by convection. The heat transfer rate incorporated in the definition is therefore the overall transfer by conduction and by radiation (and by convection where applicable).

4 Units

The SI unit of thermal resistance is the square-metre kelvin per watt (m^2·K/W).

NOTE — A practical unit of thermal resistance, widely used in the field of textiles and clothing, is the "tog" :

　　　1 tog = $0,1$ m^2·K/W

The SI unit of thermal conductivity is the watt per metre kelvin [W/(m·K)].

---

1) To be published.

5 Principle

The temperature drop across a material of known thermal resistance and across a specimen of the material under test in series with it are measured, and from the values obtained the thermal resistance of the specimen is determined.

6 Apparatus

6.1 Description

The principle of the apparatus is that, for conductors in series with respect to the direction of heat flow, the ratio of the temperature drop across the conductors is equal to the ratio of their thermal resistance. Thus, if the temperature drop across a material of known thermal resistance (the "standard resistance") and that across a test specimen in series with it are measured, the thermal resistance of the test specimen can be calculated. The specimen is tested in the horizontal plane.

The apparatus is shown diagrammatically in figure 1. The principal parts are as follows.

6.1.1 Mild-steel disc (A), 330 mm in diameter and approximately 6 mm thick, which has been annealed to relieve internal stresses.

6.1.2 Ring electric heaters (B$_1$ and B$_2$), of 75 W and 125 W respectively, clamped to the lower face of the disc A and connected in parallel.

6.1.3 Disc of insulating board (C), of thermal resistance within the range 0,075 m^2·K/W to 0,125 m^2·K/W and of thickness between 5 mm and 15 mm. The disc shall be 330 mm in diameter and in contact with the hot plate of the apparatus.

The surfaces of the disc shall be smooth, flat and parallel.

6.1.4 Cold plate (D), 330 mm in diameter, to give a pressure of 6,9 Pa over the whole area of 855 cm^2.

The surfaces of the plate shall be smooth, flat and parallel.

6.1.5 Insulation (E), to reduce heat wastage.

6.2 Temperature measurement

T$_1$, T$_2$ and T$_3$ are temperature sensors at each of the sites indicated in figure 1. These sensors shall be 0,20 mm to 0,315 mm diameter copper-constantan thermocouples, calibrated to 0,01 K, or equally accurate sensors of similar size. The temperature sensors are fixed permanently in good thermal contact with separate 25 mm diameter discs of approximately 0,1 mm thick copper foil, which are fixed, with an epoxy-resin or similar adhesive, in small grooves in the surfaces of the disc C and the cold plate D. Aluminium foil discs, 0,006 mm thick and 140 mm in diameter, are stuck centrally over sensors T$_2$ and T$_3$, the whole of the exposed faces of C and D then being painted with dull black lacquer to ensure an emissivity approaching unity.

NOTE — A suitable indicator device or recorder is recommended for recording temperatures.

6.3 Automatic temperature control

This is achieved by means of a temperature-sensitive element (M), incorporated in a control system.

6.4 Calibration of the standard thermal resistance

The standard thermal resistance shall be calibrated by one of the following procedures:

a) conduct tests with samples of known thermal resistance, treating the standard thermal resistance as the unknown quantity to be evaluated, as described in 9.1 and 10.2;

b) use the method described in annex A;

c) use a guarded hot plate apparatus complying with ISO 8302 to measure the heat flow, with the mean temperature of the standard thermal resistance being between 309 K and 313 K.

NOTE — The thermocouples should already be in place and the temperature drop measured with these rather than with the thermocouples in the plates of the disc of insulating board.

6.5 Contact thermal resistance

Because of the finite size of the temperature sensors, a small temperature difference exists between T$_2$ and T$_3$ when the hot and cold plates are placed in contact. This is indicative of a contact thermal resistance for which allowance shall be made in evaluating the thermal resistance of a test specimen. Calculation of the contact resistance is described in clause 10.

6.6 Cabinet

The apparatus is enclosed in the cabinet shown diagrammatically in figure 2. The purpose of the cabinet is to provide both a shield against neighbouring sources of radiant heat and controlled ventilation across the face of the apparatus.

The extractor fan draws air past the apparatus from the standard atmosphere in the room through an adjustable slot at the other end of the cabinet. The fan characteristics shall be such that the air speed past the test specimen is within the range 0,25 m/s to 1 m/s.
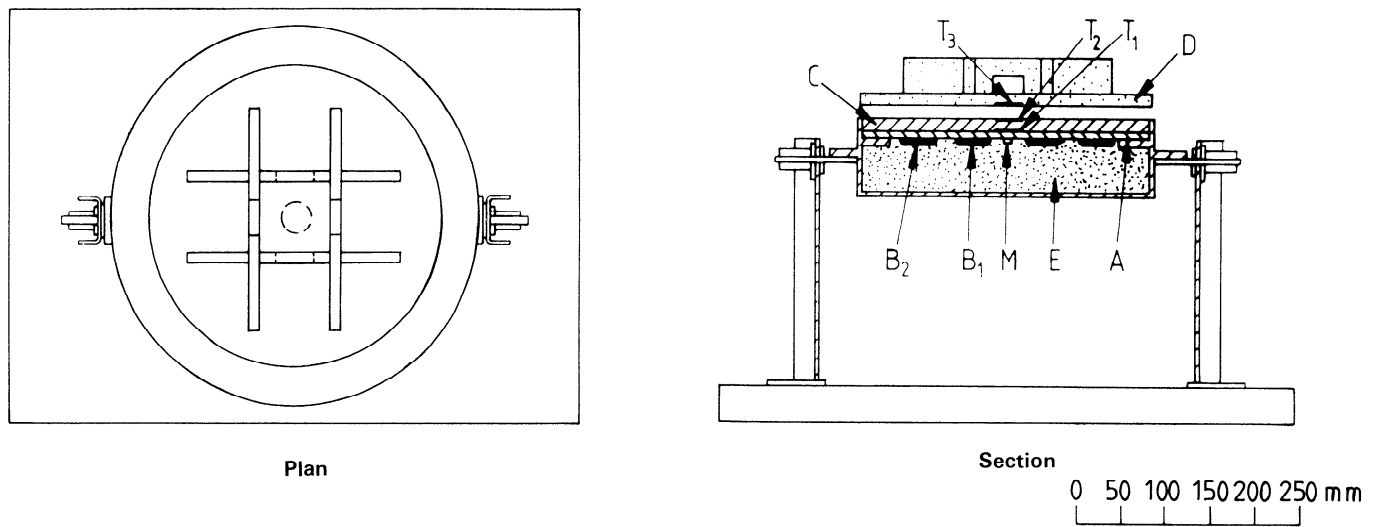
Plan

Section

0   50 100 150 200 250 mm

Figure 1 — **Diagram of the apparatus**

All dimensions in millimetres and approximate

Observation window

450

Air flow

750

Extractor fan (air speed
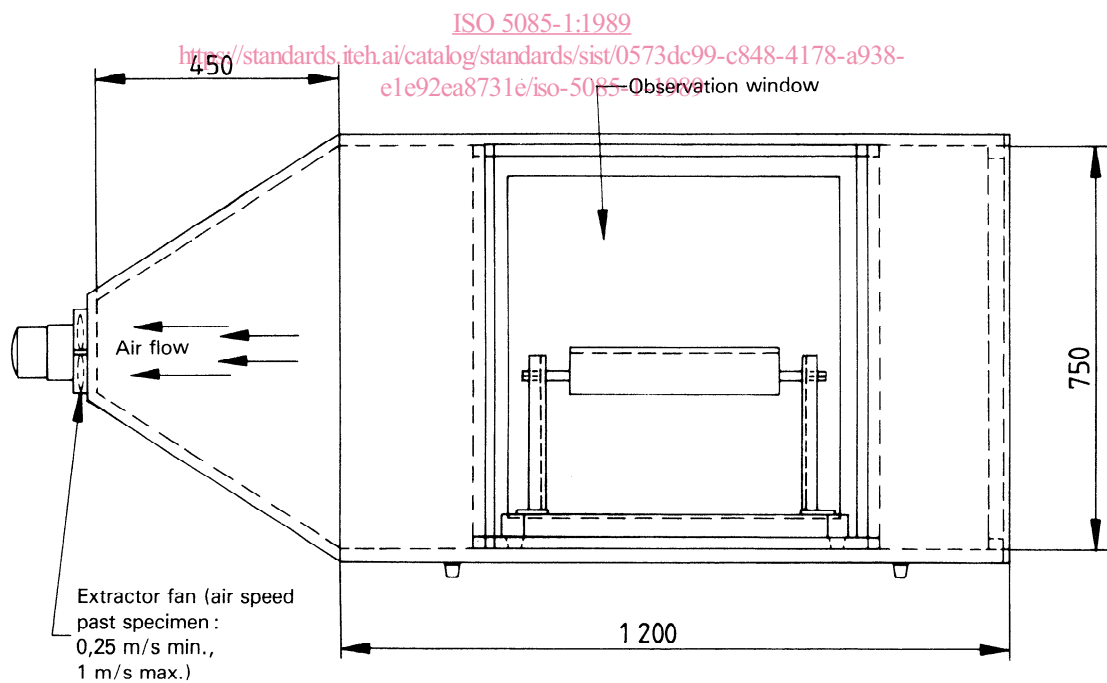past specimen :
0,25 m/s min.,
1 m/s max.)

1 200

Figure 2 — **Diagram of the cabinet** (side elevation)

7 Atmosphere for conditioning and testing

The conditioning and testing atmosphere shall be one of the standard atmospheres for testing textiles defined in ISO 139, i.e. a relative humidity of 65 % ± 2 % R.H. and a temperature of either 20 °C ± 2 °C or 27 °C ± 2 °C.

8 Test specimens

Cut circular test specimens of diameter 330 mm, avoiding creases and folds. Precondition them by laying them flat in the standard atmosphere for testing textiles (see clause 7) for 24 h. Where possible, test three specimens of each sample.

9 Procedure

Two methods are specified below. The first of these, the two-plate method, is normally used for materials which, when in use, are shielded from the ambient air, e.g. a blanket when covered by a bedspread. The second, the single-plate method, is normally used for materials which, when in use, have their outer faces exposed to the ambient air (e.g. bedspreads and outer-wear garments). The two-plate method is the preferred one on accuracy and reproducibility grounds, however, and it is recommended that this method be used for all materials.

9.1 Two-plate method

Lay the conditioned test specimen on the hot plate of the apparatus and place the cold plate gently on top of it, taking care not to compress the surface of the test specimen. Shield the edges from the air-flow, e.g. by wrapping a strip of woven blanket or masking tape round the apparatus.

Switch on the electric heaters and adjust the temperature controller so that T_2 registers a temperature within the range 304 K to 308 K. Maintain a steady state of temperature at each of the thermocouple sites T_1, T_2 and T_3 for a period of not less than 30 min before considering a test to be completed, and ensure that the fluctuations in the various temperature levels do not exceed ± 0,1 K throughout this period.

For materials of low bulk density (e.g. blankets), the duration of a test from the switching on of the heaters, and including the steady-state period, is approximately 2 h, but for denser materials it will be longer (approximately 3 h).

Note, to the nearest 0,01 K, the temperatures registered by T_1, T_2 and T_3.

9.2 Single-plate method

As in the method described in 9.1, lay the conditioned test specimen on the hot plate (with the edges shielded) but leave its outer face uncovered and place the cold plate underneath the apparatus. Support the cold plate, e.g. by three corks, to allow air circulation and cover with a circular piece of hardboard or metal sheet to the upper face of which a sheet of

aluminium foil has been stuck in order to shield the cold plate from the radiant heat emitted by the apparatus. T_3 is now used to measure the air temperature.

Note, to the nearest 0,01 K, the temperatures registered by T_1, T_2 and T_3. Repeat the test without a test specimen (i.e. conduct a "bare-plate" test).

10 Calculation and expression of results

10.1 Contact resistance

When the hot and cold plates of the apparatus are in contact and a steady state has been established, the contact resistance R_c is given by the equation

$$\frac{R_c}{R_s} = \frac{\theta_2 - \theta_3}{\theta_1 - \theta_2}$$

where

R_s is the thermal resistance of the "standard";

θ_1 is the temperature registered by T_1;

θ_2 is the temperature registered by T_2;

θ_3 is the temperature registered by T_3.

10.2 Thermal resistance of test specimen by the two-plate method

When a steady state has been established, the thermal resistance R_f of the test specimen (see appendix D) is given by the equation

$$\frac{R_f + R_c}{R_s} = \frac{\theta'_2 - \theta'_3}{\theta'_1 - \theta'_2}$$

where

R_c and R_s are as defined in 10.1;

θ'_1 is the temperature registered by T_1;

θ'_2 is the temperature registered by T_2;

θ'_3 is the temperature registered by T_3.

Now

$$\frac{R_f}{R_s} = \frac{R_f + R_c}{R_s} - \frac{R_c}{R_s}$$

Thus

$$\frac{R_f}{R_s} = \frac{\theta'_2 - \theta'_3}{\theta'_1 - \theta'_2} - \frac{\theta_2 - \theta_3}{\theta_1 - \theta_2}$$

Since R_s is known, R_f can be calculated.

10.3 Thermal resistance of test specimen by the single-plate method

In this case, the sum of two thermal resistances in series is calculated, i.e. that of the test specimen itself and that of the ambient air, the latter being sometimes referred to as the "surface resistance" at the exposed face of the test specimen.

When a steady state has been established,

$$\frac{R_f + R_c + R_a}{R_s} = \frac{\theta_2'' - \theta_a}{\theta_1'' - \theta_2''}$$

where

R_a is the thermal resistance of the ambient air;

R_c, R_s and R_f are as defined in 10.1 and 10.2;

θ_1'' is the temperature registered by T_1;

θ_2'' is the temperature registered by T_2;

θ_a is the temperature registered by T_3 (i.e. the ambient air temperature).

When the test is repeated without the test specimen (i.e. a "bare-plate" test) and a steady state has been established

$$\frac{R_c + R_a}{R_s} = \frac{\theta_2''' - \theta_a}{\theta_1''' - \theta_2'''}$$

where

θ_1''' is the temperature registered by T_1;

θ_2''' is the temperature registered by T_2;

θ_a is the temperature registered by T_3.

Hence

$$\frac{R_f}{R_s} = \frac{\theta_2'' - \theta_a}{\theta_1'' - \theta_2''} - \frac{\theta_2''' - \theta_a}{\theta_1''' - \theta_2'''}$$

Since R_s is known, R_f can be calculated.

11 Test report

The test report shall state:

a) that the procedure was conducted in accordance with this part of ISO 5085;

b) whether the two-plate or single-plate procedure was followed;

c) the thermal resistance of each specimen tested and the mean thermal resistance (see clause 10).

d) the conditioning atmosphere used (see clause 7).