INTERNATIONAL STANDARD

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Textiles — Physiological effects — Measurement of thermal and water-vapour resistance under steady-state conditions (sweating guarded-hotplate test)

Textiles — Effets physiologiques — Mesurage de la résistance thermique et de la résistance à la vapeur d'eau en régime stationnaire (essai de la plaque chaude gardée transpirante)

Reference number
ISO 11092:1993(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 11092 was prepared by Technical Committee ISO/TC 38, *Textiles*.

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

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Introduction

ISO 11092 is the first of a number of standard test methods in the field of clothing comfort.

The physical properties of textile materials which contribute to physiological comfort involve a complex combination of heat and mass transfer. Each may occur separately or simultaneously. They are time-dependent, and may be considered in steady-state or transient conditions.

Thermal resistance is the net result of the combination of radiant, conductive and convective heat transfer, and its value depends on the contribution of each to the total heat transfer. Although it is an intrinsic property of the textile material, its measured value may change through the conditions of test due to the interaction of parameters such as radiant heat transfer with the surroundings.

Several methods exist which may be used to measure heat and moisture properties of textiles, each of which is specific to one or the other and relies on certain assumptions for its interpretation.

The sweating guarded-hotplate (often referred to as the "skin model") described in this International Standard is intended to simulate the heat and mass transfer processes which occur next to human skin. Measurements involving one or both processes may be carried out either separately or simultaneously using a variety of environmental conditions, involving combinations of temperature, relative humidity, air speed, and in the liquid or gaseous phase. Hence transport properties measured with this apparatus can be made to simulate different wear and environmental situations in both transient and steady states. In this standard only steady-state conditions are selected.

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Textiles — Physiological effects — Measurement of thermal and water-vapour resistance under steady-state conditions (sweating guarded-hotplate test)

1 Scope

This International Standard specifies methods for the measurement of the thermal resistance and water-vapour resistance, under steady-state conditions, of e.g. fabrics, films, coatings, foams and leather, including multilayer assemblies, for use in clothing, quilts, sleeping bags, upholstery and similar textile or textile-like products.

The application of this measurement technique is restricted to a maximum thermal resistance and water-vapour resistance which depend on the dimensions and construction of the apparatus used (e.g. 2 m^2·K/W and 700 m^2·Pa/W respectively, for the minimum specifications of the equipment referred to in this International Standard).

The test conditions used in this standard are not intended to represent specific comfort situations, and performance specifications in relation to physiological comfort are not stated.

2 Definitions

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

2.1 thermal resistance, R_{ct}: Temperature difference between the two faces of a material divided by the resultant heat flux per unit area in the direction of the gradient. The dry heat flux may consist of one or more conductive, convective and radiant components.

Thermal resistance R_{ct}, expressed in square metres kelvin per watt, is a quantity specific to textile materials or composites which determines the dry heat flux across a given area in response to a steady applied temperature gradient.

2.2 water-vapour resistance, R_{et}: Water-vapour pressure difference between the two faces of a material divided by the resultant evaporative heat flux per unit area in the direction of the gradient. The evaporative heat flux may consist of both diffusive and convective components.

Water-vapour resistance R_{et}, expressed in square metres pascal per watt, is a quantity specific to textile materials or composites which determines the "latent" evaporative heat flux across a given area in response to a steady applied water-vapour pressure gradient.

2.3 water-vapour permeability index, i_{mt}: Ratio of thermal and water-vapour resistances in accordance with equation (1):

$$i_{mt} = S \cdot \frac{R_{ct}}{R_{et}} \qquad \ldots (1)$$

where S equals 60 Pa/K

i_{mt} is dimensionless, and has values between 0 and 1. A value of 0 implies that the material is water-vapour impermeable, that is, it has infinite water-vapour resistance, and a material with a value of 1 has both the thermal resistance and water-vapour resistance of an air layer of the same thickness.

2.4 water-vapour permeability, W_d: Characteristic of a textile material or composite depending on water-vapour resistance and temperature in accordance with equation (2):

$$W_d = \frac{1}{R_{et} \cdot \phi_{T_m}} \quad \ldots (2)$$

where

ϕ_{T_m} is the latent heat of vaporization of water at the temperature T_m of the measuring unit

equals, for example, 0,672 W·h/g at T_m = 35 °C

Water-vapour permeability is expressed in grams per square metre hour pascal.

3 Symbols and units

R_{ct} is the thermal resistance, in square metres kelvin per watt

R_{et} is the water-vapour resistance, in square metres pascal per watt

i_{mt} is the water-vapour permeability index, dimensionless

R_{ct0} is the apparatus constant, in square metres kelvin per watt, for the measurement of thermal resistance R_{ct}

R_{et0} is the apparatus constant, in square metres pascal per watt, for the measurement of water-vapour resistance R_{et}

W_d is the water-vapour permeability, in grams per square meter hour pascal

ϕ_{T_m} is the latent heat of vaporization of water at the temperature T_m, in watt hours per gram

A is the area of the measuring unit, in square metres

T_a is the air temperature in the test enclosure, in degrees Celsius

T_m is the temperature of the measuring unit, in degrees Celsius

T_s is the temperature of the thermal guard, in degrees Celsius

p_a is the water-vapour partial pressure, in pascals, of the air in the test enclosure at temperature T_a

p_m is the saturation water-vapour partial pressure, in pascals, at the surface of the measuring unit at temperature T_m

v_a is the speed of air above the surface of the test specimen, in metres per second

s_v is the standard deviation of air speed v_a, in metres per second

R.H. is the relative humidity, in percent

H is the heating power supplied to the measuring unit, in watts

ΔH_c is the correction term for heating power for the measurement of thermal resistance R_{ct}

ΔH_e is the correction term for heating power for the measurement of water-vapour resistance R_{et}

α is the slope of the correction line for the calculation of ΔH_c

β is the slope of the correction line for the calculation of ΔH_e

4 Principle

The specimen to be tested is placed on an electrically heated plate with conditioned air ducted to flow across and parallel to its upper surface as specified in this International Standard.

For the determination of thermal resistance, the heat flux through the test specimen is measured after steady-state conditions have been reached.

The technique described in this International Standard enables the thermal resistance R_{ct} of a material to be determined by subtracting the thermal resistance of the boundary air layer above the surface of the test apparatus from that of a test specimen plus boundary air layer, both measured under the same conditions.

For the determination of water-vapour resistance, an electrically heated porous plate is covered by a water-vapour permeable but liquid-water impermeable membrane. Water fed to the heated plate evaporates and passes through the membrane as vapour, so that no liquid water contacts the test specimen. With the test specimen placed on the membrane, the heat flux required to maintain a constant temperature at the plate is a measure of the rate of water evaporation, and from this the water-vapour resistance of the test specimen is determined.

The technique described in this International Standard enables the water-vapour resistance R_{et} of a material to be determined by subtracting the water-vapour resistance of the boundary air layer above the surface of the test apparatus from that of a test specimen plus boundary air layer, both measured under the same conditions.

5 Apparatus

5.1 Measuring unit, with temperature and water supply control, consisting of a metal plate approximately 3 mm thick with a minimum area of 0,04 m^2 (e.g. a square with each side 200 mm in length) fixed to a conductive metal block containing an electrical heating element [see figure 1, items (1) and (6)]. For the measurement of water-vapour resistance, the metal plate (1) must be porous. It is surrounded by a thermal guard [item (8) of figure 2] which is in turn located within an opening in a measuring table (11).

The coefficient of radiant emissivity of the plate surface (1) shall be greater than 0,35, measured at 20 °C between the wavelengths 8 µm to 14 µm, with the primary beam perpendicular to the plate surface and the reflection hemispherical.

Channels are machined into the face of the heating element block (6) where it contacts the porous plate to enable water to be fed from a dosing device (5).

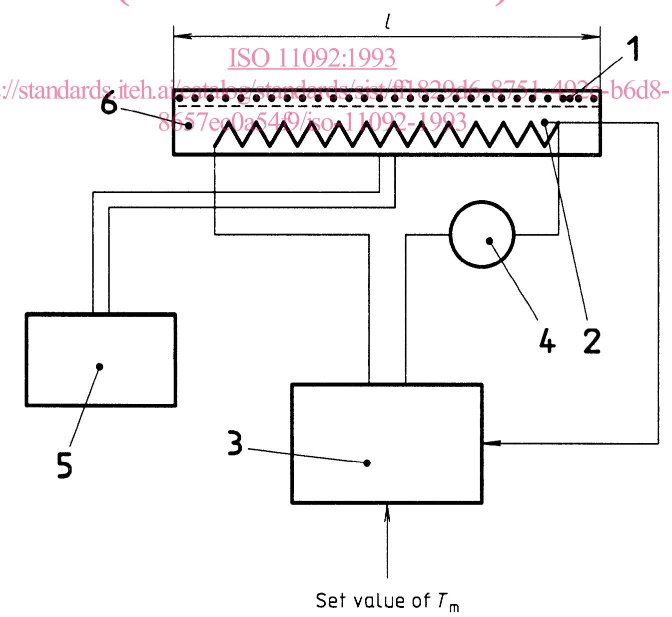
The position of the measuring unit with respect to the measuring table shall be adjustable, so that the upper surface of test specimens placed on it can be made coplanar with the measuring table.

Heat losses from the wiring to the measuring unit or to its temperature-measuring device should be minimized, e.g. by leading as much wiring as possible along the inner face of the thermal guard (8).

The temperature controller (3), including the temperature sensor of the measuring unit (2), shall maintain the temperature T_m of the measuring unit (7) constant to within $\pm$ 0,1 K. The heating power H shall be measurable by means of a suitable device (4) to within $\pm$ 2 % over the whole of its usable range.

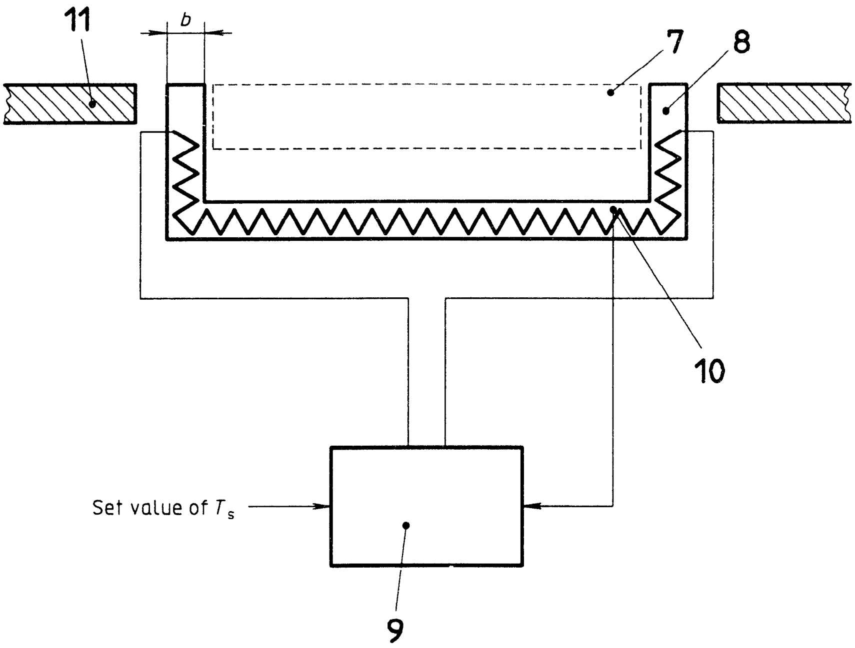
Water is supplied to the surface of the porous metal plate (1) by a dosing device (5) such as a motor-driven burette. The dosing device is activated by a switch which senses when the level of water in the plate falls more than approximately 1,0 mm below the plate surface, in order to maintain a constant rate of evaporation. The level switch is mechanically connected to the measuring unit.

Before entering the measuring unit, the water shall be preheated to the temperature of the measuring unit. This can be achieved by passing it through tubes in the thermal guard before it enters the measuring unit.



1 Metal plate
2 Temperature sensor
3 Temperature controller
4 Heating-power measuring device
5 Water-dosing device
6 Metal block with heating element

Figure 1 — Measuring unit with temperature and water supply control



7 Measuring unit according to 5.1

8 Thermal guard

9 Temperature controller

10 Temperature-measuring device

11 Measuring table

Figure 2 — Thermal guard with temperature control

5.2 Thermal guard with temperature control [item (8) of figure 2], consisting of a material with high thermal conductivity, typically metal, and containing electrical heating elements.

Its purpose is to prevent heat leakage from the sides and bottom of the measuring unit (7).

The width b of the thermal guard (figure 2) should be a minimum of 15 mm. The gap between the upper surface of the thermal guard and the metal plate of the measuring unit shall not exceed 1,5 mm.

The thermal guard may be fitted with a porous plate and water-dosing system similar to that of the measuring unit to form a moisture guard.

The thermal guard temperature T_s measured by the temperature sensor (10) shall, by means of the controller (9), be maintained at the same temperature as the measuring unit T_m to within ± 0,1 K.

5.3 Test enclosure, into which is built the measuring unit and thermal guard, and in which the ambient air temperature and humidity are controlled.

The conditioned air shall be ducted so that it flows across and parallel to the upper surface of the measuring unit and thermal guard. The height of the duct above the measuring table shall not be less than 50 mm.

The drift of the temperature T_a of this air flow shall not exceed ± 0,1 K for the duration of a test. For the measurement of thermal resistance and water-vapour resistance values below 100 $m^2 \cdot Pa/W$, an accuracy of ± 0,5 K is sufficient.

The drift of the relative humidity R.H. of this air flow shall not exceed ± 3 % R.H. for the duration of a test.

This air flow is measured at a point 15 mm above the measuring table over the centre of the uncovered measuring unit and at an air temperature T_a of 20 °C. The air speed v_a measured at this point shall have a mean value of 1 m/s, with the drift not exceeding ± 0,05 m/s for the duration of a test.

It is important that at this point the air flow shall have a certain degree of turbulence, expressed by the related variation in air speed s_v/v_a, of between 0,05 and 0,1, measured at approximately 6 s intervals over a time period of at least 10 min with an instrument which has a time constant of less than 1 s.

6 Test specimens

6.1 Materials ⩽ 5 mm thick

Test specimens shall completely cover the surfaces of the measuring unit and thermal guard.

From each material to be tested, a minimum of three test specimens shall be cut and tested.

Before testing, specimens shall be conditioned for a minimum of 12 h at the temperature and humidity specified in either 7.3 or 7.4 as appropriate.

6.2 Materials > 5 mm thick

6.2.1 Specimens falling into this category require a special test procedure to avoid loss of heat or water vapour from their edges.

In the measurement of thermal resistance, corrections for thermal edge losses are necessary if the specimen thickness is greater than approximately twice the width b of the thermal guard (see figure 2). The deviation from the linear relationship between thermal resistance and specimen thickness can be determined and corrected by the factor $[1 + (\Delta R_{ct}/R_{ct\ measured})]$ using the measurement of the R_{ct} values for several thicknesses of a homogeneous material such as foam, up to a total thickness d of at least that of the specimen to be tested (see figure 3).

6.2.2 If the thermal guard is not fitted with a porous plate and water-dosing system similar to that of the measuring unit, for the measurement of water-vapour resistance the vertical sides of the cut specimens shall be surrounded by a water-vapour impermeable frame of approximately the same height as that of the free-standing specimen. The inner dimensions of the frame shall be the same on all sides as those of the porous plate of the measuring unit.

6.2.3 Before testing, specimens shall be conditioned for a minimum of 24 h at the temperature and humidity specified in either 7.3 or 7.4 as appropriate.

6.2.4 Specimens containing loose filling materials or having uneven thickness, such as quilts and sleeping bags, require a special mounting procedure as described in annex A.

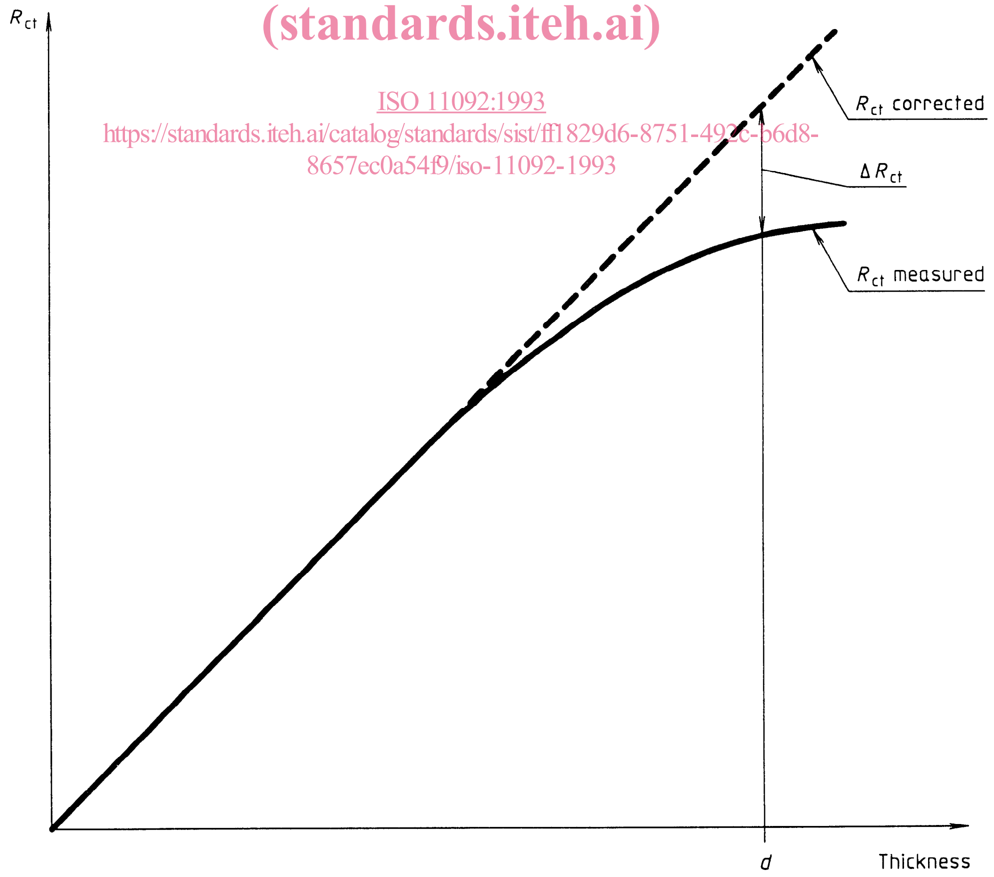


Figure 3 — Corrections for thermal edge losses during the measurement of thermal resistance