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Classification of thermoregulatory properties

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National foreword

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Classification of thermoregulatory properties

Classement des propriétés de thermorégulation

Klassifizierung von thermoregulierenden Eigenschaften

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Foreword

This document (CEN/TR 16422:2012) has been prepared by Technical Committee CEN/TC 248 “Textiles and textile products”, the secretariat of which is held by BSI.

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Introduction

This Technical Report has been developed to help retailers, manufacturers and consumers with the evaluation of thermoregulatory properties of textiles, and selection of the most appropriate methods to define their individual material performance requirements.

In order to encourage the use of the widest possible selection of materials and technologies, this report takes the form of advice and guidance on the tests or groups of tests which would verify the defined performance characteristics of a material or a product composite. It summarises the scope and application of the test described, and provides an indication of suggested range of results for the referred test method or methods to allow the user to grade performance of the material under evaluation. Where a choice of test methods are available for measuring the same parameter on a material, each is described to allow the user of the standard to select the most appropriate method for his requirements.

This report introduces also a system of three performance levels for the different thermoregulatory properties:

— thermal insulation;

— water vapour transmission (breathability);

— air permeability;

— water penetration resistance and repellence;

— liquid sweat management.

The large differences in the conditions of use necessitate a flexible use of the properties and performance levels. This allows a choice of the appropriate level for each property and so to compose a 'product profile', adapted to each specific type of use. There is for example, a significant difference between thermoregulatory properties required for outerwear clothing for cool, windy and rainy weather during low activity, and socks for warm indoor use during intense physical or sport activity. In addition, the work clothing for a shop assistant requires different properties of thermoregulation than the underwear intended for skiing, or home wear for the elderly. The ambient temperature, ambient moisture, wind and level of activity, the contact to skin or other layers of clothing influence the requirements.

At the point of issue, it is recognised that the industry is in a constant state of development with regard to new technology for innovative fibres and performance applications, and that methods required to evaluate these new technologies may in the future be different to those in this report. Subsequent revisions will consider the addition of any new test methods required to keep advice current to the industry and its changing needs.

This document includes annexes. In Annex A, there is consideration for product design and use situations, as material performance is not the sole contributory factor to the thermoregulatory performance of the final product or ensemble in use. This Annex also has examples of marking products. Annex B specifies two alternative methods for liquid sweat transport and liquid sweat buffering.

1 Scope

This Technical Report outlines test methods available for the measurement of thermoregulatory properties of textile materials for use in clothing, and provides guidance on the most suitable methods for selection where choices are available to the user.

The document also provides classification of the thermoregulatory properties in three performance levels.

This Technical Report excludes consideration for the thermoregulatory properties of Personal Protective Equipment (PPE) and clothing items or textile products for which a standard already specifies a particular requirement.

This Technical Report excludes also phase change materials (PCM) and similar smart materials for thermoregulation, for which CEN/TR 16298 may give better guidance.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 24920, *Textiles – Determination of resistance to surface wetting (spray test) of fabrics*

EN 29865, *Textiles – Determination of water repellency of fabrics by the Bundesmann rain-shower test*

EN 31092, *Textiles – Determination of physiological effects – Measurement of thermal and water-vapour resistance under steady-state conditions (sweating guarded-hotplate test)*

EN ISO 9237, *Textiles – Determination of permeability of fabrics to air (ISO 9237)*

EN 20811, *Textiles – Determination of resistance to water penetration – Hydrostatic pressure test.*

ISO 5085-1, *Textiles – Determination of thermal resistance – Part 1: Low thermal resistance*

AATCC TM 195, *Liquid moisture management properties of textile fabrics*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
thermoregulatory properties
properties of textiles which influence the thermoregulation of the human body to maintain the core body temperature at a stable and comfortable state

Note 1 to entry: The properties are thermal insulation, water vapour transmission (breathability), air permeability, water penetration resistance and repellence and liquid sweat management.

3.2
thermal insulation (resistance)
R_{ct}
a quantity specific to textile materials or composites which determines the dry heat flux between the two faces of a material related to area and temperature gradient, expressed in square metres Kelvin per watt ($m^2 \cdot K/W$).

Note 1 to entry: The dry heat flux may consist of one or more conductive, convective and radiant components.

3.3
water vapour transmission (breathability)
WVT
ability of the fabric to transport water vapour expressed either as an absolute value by the water vapour resistance R_{et}, by the water vapour permeability WVP, or by the relative value related to thermal insulation by the water vapour permeability index i_{mt}.

3.4
water vapour resistance
$\boldsymbol{R_{et}}$
quantity specific to textile materials and composites, which determines the 'latent' evaporative heat flux between the two faces of a material related to area and water vapour pressure gradient, expressed in square metres pascal per watt ($m^2 \cdot Pa/W$).

Note 1 to entry: The evaporative heat flux may consist of both diffusive and convective components.

3.5
water vapour permeability index
$\boldsymbol{i_{mt}}$
transport properties related to thermal insulation expressed by an index between 0 and 1

3.6
water vapour permeability
WVP
rate of water vapour transmission expressed in grams per square metre hour pascal (g/m^2 Pa h)

3.7
air permeability
AP
volume of air passing perpendicularly through a test specimen under specified conditions of test area, pressure difference and time

3.8
water penetration resistance
WP
resistance to the penetration of water through the material under a specific hydrostatic pressure

3.9
water repellence
ability of fabric to resist surface wetting by water

3.10
liquid sweat management
consists, on one hand, of the uptake or buffering of the sweat from the skin and, on the other hand, of the transport of the sweat from the skin to the ambience

3.11
skin contact products
fabrics or garments intended primarily to be worn next to the skin

Note 1 to entry: Typical examples are underwear, t-shirts, shirts, blouses, trousers, nightwear.

3.12
second layer or intermediate layer products
fabrics or garments intended to be worn above the skin contact products and beneath the outer layer products

Note 1 to entry: Typical examples are sweaters, shirts, vests, blouses.

3.13
outer layer products
fabrics or garments intended to be worn outermost of the layer of clothing, primarily outdoors

Note 1 to entry: Typical examples are overcoats, jackets, trousers, overalls, rainwear.

4 Test methods

4.1 Thermal insulation

4.1.1 General

For the purposes of this Technical Report, two EN or ISO test methods have been identified for the measurement of thermal insulation. Both test methods give the thermal insulation value in $m^2 \cdot K/W$, and the results from the two tests are comparable.

4.1.2 ISO 5085-1, Textiles – Determination of thermal resistance – Part 1: Low thermal resistance

Scope

The standard 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 $m^2 \cdot K/W$.

The method is only suitable for materials of up to 20 mm thickness (if the material is thicker, lateral edge losses are more substantial).

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.

Application

Two methods are specified in the standard (single and double plate methods). In the context of this Technical Report, the single plate method should be used.

4.1.3 EN 31092, (ISO 11092) Textiles – Determination of physiological effects – Measurement of thermal and water-vapour resistance under steady-state conditions (sweating guarded-hotplate test)

Scope

The standard specifies test methods for the measurement of the thermal resistance and water vapour-resistance of fabrics, under steady-state conditions.

The application of this measurement technique is restricted to a maximum thermal resistance (and water-vapour resistance) which depends on the dimensions and construction of the apparatus used, for the minimum specifications of the equipment referred to in this international standard. This value is 2 $m^2 \cdot K/W$.

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.

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 thermal resistance R_{ct} of a material is 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.

4.2 Water vapour transmission (breathability)

4.2.1 General

Several methods for testing of the water vapour transmission through textile materials are in use. In the context of this Technical Report EN 31092 should be used, which specifies the measurement of water vapour resistance and water vapour permeability index.

4.2.2 EN 31092 (ISO 11092) Textiles – Determination of physiological effects – Measurement of thermal and water-vapour resistance under steady-state conditions (sweating guarded-hotplate test)

Scope

The application of this measurement technique is restricted to a maximum (thermal resistance and) water-vapour resistance which depends on the dimensions and construction of the apparatus used, for the minimum specifications of the equipment referred to in this International standard. This value is 700 $m^2 \cdot Pa/W$.

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 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 water-vapour resistance R_{et} of a material is determined by subtracting the water-vapour resistance of the boundary air layer above the surface of the test apparatus from that of the test specimen plus boundary air layer, both measured under the same conditions.

Particularly for knitted fabrics and thick cold protective garments, which due to the thickness would get high water vapour resistance values, a more relevant value is the water vapour permeability index i_{mt} which expresses the relation between thermal insulation R_{ct} and water vapour resistance R_{et}.

NOTE For quality control purposes the standard EN ISO 15496, *Textiles - Measurement of water vapour permeability of textiles for the purpose of quality control* can be used to measure the WVP, provided that for a given article the WVR R_{et} value measured according to 4.2.2 is known.

4.3 Air permeability

Testing should be in accordance with EN ISO 9237 (ISO 9237), *Textiles – Determination of permeability of fabrics to air*.

Scope

The standard describes a method for measuring the permeability of fabrics to air and is applicable to most types of fabrics, including industrial fabrics for technical purposes, nonwovens and made-up textile articles that are permeable to air.

Principle

The rate of flow of air passing perpendicularly through a given area of fabric is measured at a given pressure difference across the fabric test area over a given time period.

In the context of this document, the measurement should be carried out at a pressure drop across the specimen test area of 100 Pa and the area of the specimen holder 20 cm^2.

4.4 Water penetration resistance and repellence

4.4.1 General

Protection against liquid water can be expressed with different fabric properties, e.g. resistance to hydrostatic head pressure or water repellence. Several EN or ISO standards are available for testing and for this Technical Report the following can be applied as appropriate, but the results of the different methods may not be compared.

4.4.2 EN 20811 (ISO 811), Textile fabrics – Determination of resistance to water penetration – Hydrostatic pressure test

Scope

The standard specifies a hydrostatic pressure method for determining the resistance of fabrics to penetration by water.

Principle

The hydrostatic head supported by a fabric is a measure of the resistance to the penetration of water through the fabric. A specimen is subjected to a steadily increasing pressure of water on one face, under standard conditions, until penetration occurs in three places. The pressure at which the water penetrates the fabric at the third place is noted. The water pressure may be applied from below or from above the test specimen. The chosen alternative should be stated in the test report. The result is immediately relevant to the behaviour of fabrics articles which are subjected to water pressure for short or moderate periods of time.

In the context of this report, a test speed of 60+/-3 cm H_2O/min should be used.

NOTE The hydrostatic pressure value cmH_2O can also be given in the SI unit Pa. 1 cmH_2O corresponds to approximately 100 Pa (1 cmH_2O = 98,066 Pa).

4.4.3 EN 29865 (ISO 9865), Textiles – Determination of water repellency of fabrics by the Bundesmann rain-shower test

Scope

The standard describes a method for the determination of the water repellency of textile fabrics by a rain-shower test known as the Bundesmann method.

The test may be used to assess the effectiveness of finishing procedures for rendering textile fabrics water-repellent.

Principle

Test specimens of textile fabrics are mounted on cups and then exposed to an artificial rain shower under defined conditions. The water repellency is assessed by visual comparison of the wet specimens with reference photographs. The water absorbed by specimens during the test is calculated by weighing. The water penetrating the specimens is collected in the cups and recorded.

4.4.4 EN 24920 (ISO 4920) Textiles – Determination of resistance to surface wetting (spray test) of fabrics

Scope

The standard specifies a spray test method for determining the resistance of any fabric, which may or may not have been given a water-resistant or water-repellent finish, to surface wetting by water.

It is not intended for use in predicting the rain penetration resistance of fabrics, since it does not measure penetration of water through the fabric.

Principle

A specified volume of distilled water is sprayed on a test specimen which has been mounted on a ring and placed at an angle of 45 ° so that the centre of the specimen is at a specified distance below the spray nozzle. The spray rating is determined by comparing the appearance of the specimen with descriptive standards and photographs.

4.5 Liquid sweat management

4.5.1 General

No EN or ISO standards are available for the testing of liquid sweat management through textile fabrics at the time of publication of this document. In the context of this document, the following two test methods as appropriate can be applied for this property.

4.5.2 AATCC Test Method 195-2009, Liquid moisture management properties of textile fabrics

Scope

This test method is for the measurement, evaluation and classification of liquid moisture management properties of textile fabrics. The test method produces objective measurements of liquid moisture management properties of knitted, woven and nonwoven textile fabrics.

The results obtained with this test method are based on water resistance, water repellency and water absorption characteristics of the fabric structure, including the fabric's geometric and internal structure and the wicking characteristics of its fibres and yarns.

Principle

The liquid moisture management properties of a textile are evaluated by placing a fabric specimen between two horizontal (upper and lower) electrical sensors each with seven concentric rings of pins. A predetermined amount of test solution that aids the measurement of electrical conductivity changes is dropped onto the centre of the upward-facing test specimen surface. The test solution is free to move in three directions: radial spreading on the top surface, movement through the specimen from top surface to the bottom surface, and radial spreading on the bottom surface of the specimen. During the test, changes in electrical resistance of specimens are measured and recorded.

The electrical resistance readings are used to calculate fabric liquid moisture content changes that quantify dynamic liquid moisture transport behaviours in multiple directions of the specimen. The summary of the measured results are used to grade the liquid moisture management properties of a fabric by using predetermined indices.

4.5.3 Liquid sweat transport and liquid sweat buffering[1)]

Scope

This test method is intended for measuring moisture management properties of knitted, woven and nonwoven textile fabrics, namely buffering index, sweat transport and sweat uptake.

Principle

The buffering capacity and transport of liquid sweat of a textile material is measured with the sweating guarded hotplate, specified in EN 31092 (ISO 11092). Measuring unit and air in the climatic cabinet are set isothermally to 35 °C and the relative humidity is set to 30 %. To perform the test, the sweating guarded-hotplate's measuring unit is covered with a thin foil which is water and water vapour impermeable. On the top of the foil a polyester-woven fabric is placed. This fabric simulates the sweating human skin and the foil prevents water being wicked into the measuring unit during the test. 15 cm³ of water with a temperature of 35 °C are evenly distributed onto the polyester-woven fabric. Then a specimen item is placed wrinkle free on the polyester-woven fabric. After exactly 15 min the specimen is removed. During the test, on the one hand, water vapour diffusion is taking place through the specimen. On the other hand, the specimen is absorbing water out of the underlying polyester-woven fabric which is also partly evaporated.

Measurement can be performed according to Method A or Method B. In Method A, a gas meter and two temperature sensors are inserted in a circuit with a pump and a drying column maintaining relative humidity at 30 %. The total amount of water vapour being transported through the specimen is derived from the air volume circulating through the gas meter during the test period. Method B provides an alternative if it is not possible to modify the sweating guarded hotplate by adding a gas meter. In Method B a thin plastic sheet is stuck on the bottom face of a frame which allows the carrying of the specimen and the polyester-woven fabric to a scale without loss of liquid water. The total amount of water vapour being transported through the specimen is then determined by a weighing procedure of the specimen and the polyester-woven fabric before and immediately after the test period. In both methods A and B the sweat uptake is also determined with a similar weighing procedure. It has been shown that both methods provide similar results.

The test specifications for Method A and Method B are shown in Annex B.

5 Performance levels of material properties

5.1 General

The textile material properties are classified into three performance levels A, B and C. A is very good, B is good and C is acceptable, in relation to the intended climates and activities. Tables 1, 2 and 3 are for warm climates and Tables 4, 5 and 6 refer to cold climates and Table 7 refers to very cold climates for multilayer materials (see Annex A for examples of application).

[1)] The test method is known as BPI 1.2.1 (Bekleidungsphysiologisches Institut, Hohenstein).

5.2 Performance levels for warm climate clothing materials

Table 1 — Performance levels for skin contact materials, warm climate

Property	Unit	A	B	C
Thermal insulation ISO 5085-1 or EN 31092	m² K/W	$R_{ct} \leq 0,015$	$0,015 < R_{ct} \leq 0,03$	$0,03 < R_{ct} \leq 0,04$
Water vapour transmission				
Knitted fabrics Water vapour permeability index EN 31092	index 0 -1	$i_{mt} \geq 0,35$	$0,35 > i_{mt} \geq 0,25$	$0,25 > i_{mt} \geq 0,15$
Woven fabrics Water vapour resistance EN 31092	m² Pa/W	$R_{et} \leq 3$	$3 < R_{et} \leq 4$	$4 < R_{et} \leq 5$
Air permeability EN ISO 9237	mm/s	-	-	-
Water penetration resistance and repellence				
Water penetration resistance EN 20811	cm H_2O	-	-	-
Water repellence EN 29865 EN 24920	grade 1-5 spray rate	-	-	-
Liquid sweat management				
Liquid moisture management AATCC TM 195	index	OMMC≥ 4	4 > OMMC ≥ 3	OMMC <3
Liquid sweat transport Annex B (25 °C; 50 % r.h.)	g/m² h	$F \geq 810$	$810 > F \geq 765$	$765 > F \geq 695$
Liquid sweat buffering Annex B	index 0-1	$K_f \geq 0,95$	$0,95 > K_f \geq 0,85$	$0,85 > K_f \geq 0,78$

Table 2 — Performance levels for second (intermediate) layer materials, warm climate

Property	Unit	A	B	C
Thermal insulation ISO 5085-1 or EN 31092	m² K/W	$R_{ct} \leq 0,02$	$0,02 < R_{ct} \leq 0,035$	$0,035 \leq R_{ct} \leq 0,045$
Water vapour transmission				
Knitted fabrics Water vapour permeability index EN 31092	index 0 -1	$i_{mt} \geq 0,35$	$0,35 > i_{mt} \geq 0,25$	$0,25 > i_{mt} \geq 0,15$
Woven fabrics Water vapour resistance EN 31092	m² Pa/W	$R_{et} \leq 4$	$4 < R_{et} \leq 5$	$5 < R_{et} \leq 6$
Air permeability EN ISO 9237	mm/s	$100 < AP$	$5 < AP \leq 100$	$AP \leq 5$
Water penetration resistance and repellence				
Water penetration resistance EN 20811	cm H_2O	-	-	-
Water repellence EN 29865 EN 24920	grade 1-5 spray rate	-	-	-
Liquid sweat management				
Liquid moisture management AATCC TM 195	index	OMMC≥ 3	3 > OMMC > 2	OMMC ≤ 2
Liquid sweat transport Annex B (25 °C; 50 % r.h.)	g/m² h	-	-	-
Liquid sweat buffering Annex B	index 0-1	-	-	-

Table 3 — Performance levels for outer layer materials, warm climate

Property	Unit	A	B	C
Thermal insulation ISO 5085-1 or EN 31092	m² K/W	$R_{ct} \leq 0,02$	$0,02 < R_{ct} \leq 0,035$	$0,035 \leq R_{ct} \leq 0,045$
Water vapour transmission				
Knitted fabrics Water vapour permeability index EN 31092	index 0 -1	$i_{mt} \geq 0,35$	$0,35 > i_{mt} \geq 0,25$	$0,25 > i_{mt} \geq 0,15$
Woven fabrics Water vapour resistance EN 31092	m² Pa/W	$R_{et} \leq 4$	$4 < R_{et} \leq 5$	$5 < R_{et} \leq 6$
Woven fabrics, waterproof Water vapour resistance EN 31092	m² Pa/W	$R_{et} \leq 6$	$6 < R_{et} \leq 13$	$13 < R_{et} \leq 20$
Air permeability, windproof fabrics[2] EN ISO 9237	mm/s	$AP \leq 5$	$5 < AP \leq 100$	$100 < AP$
Water penetration resistance and repellence				
Water penetration resistance EN 20811	cm H_2O	$WR \geq 400$	$400 > WR \geq 130$	$WR > 130$
Water repellence EN 29865 EN 24920	grade 1-5 spray rate	5 5	4 4	3 3
Liquid sweat management				
Liquid moisture management AATCC TM 195	index	-	-	-
Liquid sweat transport Annex B (25 °C; 50 % r.h.)	g/m²[2] h	-	-	-
Liquid sweat buffering Annex B	index 0-1	-	-	-

[2] Classification of air permeability is recommended for garments which are intended for use in strong windy conditions. In warm climates an outer layer garment with higher air permeability (B or C) might be preferred e.g. at high air humidity.

5.3 Performance levels for cold climate clothing materials

Table 4 — Performance levels for skin contact materials, cold climate

Property	Unit	A	B	C
Thermal insulation ISO 5085-1 or EN 31092	m² K/W	$R_{ct} \geq 0,08$	$0,08 > R_{ct} \geq 0,05$	$R_{ct} < 0,05$
Water vapour transmission				
Knitted fabrics or thick cold protective fabrics Water vapour permeability index EN 31092	index 0 -1	$i_{mt} \geq 0,45$	$0,45 > i_{mt} \geq 0,35$	$0,35 > i_{mt} \geq 0,25$
Woven fabrics Water vapour resistance EN 31092	m² Pa/W	$R_{et} \leq 4$	$4 < R_{et} \leq 5$	$5 < R_{et} \leq 6$
Air permeability EN ISO 9237	mm/s	-	-	-
Water penetration resistance and repellence				
Water penetration resistance EN 20811	cm H_2O	-	-	-
Water repellence EN 29865 EN 24920	grade 1-5 spray rate	-	-	-
Liquid sweat management				
Liquid moisture management AATCC TM 195	index	OMMC≥ 4	4 > OMMC ≥ 3	OMMC <3
Liquid sweat transport Annex B (25 °C; 50 % r.h.)	g/m² h	$F \geq 810$	$810 > F \geq 765$	$765 > F \geq 695$
Liquid sweat buffering Annex B	index 0-1	$K_f \geq 0,95$	$0,95 > K_f \geq 0,85$	$0,85 > K_f \geq 0,78$

Table 5 — Performance levels for second (intermediate) layer materials, cold climate

Property	Unit	A	B	C
Thermal insulation ISO 5085-1 or EN 31092	m² K/W	$R_{ct} \geq 0{,}09$	$0{,}09 > R_{ct} \geq 0{,}06$	$0{,}06 > R_{ct} \geq 0{,}04$
Water vapour transmission				
Knitted fabrics or thick cold protective fabrics Water vapour permeability index EN 31092	index 0 -1	$i_{mt} \geq 0{,}55$	$0{,}55 > i_{mt} \geq 0{,}45$	$0{,}45 > i_{mt} \geq 0{,}35$
Woven fabrics Water vapour resistance EN 31092	m² Pa/W	$R_{et} \leq 5$	$5 < R_{et} \leq 6$	$6 < R_{et} \leq 7$
Air permeability EN ISO 9237	mm/s	$100 < AP$	$5 < AP \leq 100$	$AP \leq 5$
Water penetration resistance and repellence				
Water penetration resistance EN 20811	cm H_2O	-	-	-
Water repellence EN 29865 EN 24920	grade 1-5 spray rate	-	-	-
Liquid sweat management				
Liquid moisture management AATCC TM 195	index	OMMC≥ 3	3 > OMMC > 2	OMMC ≤ 2
Liquid sweat transport Annex B (25 °C; 50 % r.h.)	g/m² h	-	-	-
Liquid sweat buffering Annex B	index 0-1	-	-	-

Table 6 — Performance levels for outer layer products, cold climate

Property	Unit	A	B	C
Thermal insulation ISO 5085-1 or EN 31092	m² K/W	$R_{ct} \geq 0,09$	$0,09 > R_{ct} \geq 0,06$	$0,06 > R_{ct} \geq 0,04$
Water vapour transmission				
Knitted fabrics or thick cold protective fabrics Water vapour permeability index EN 31092	index 0 -1	$i_{mt} \geq 0,55$	$0,55 > i_{mt} \geq 0,45$	$0,45 > i_{mt} \geq 0,35$
Woven fabrics Water vapour resistance EN 31092	m² Pa/W	$R_{et} \leq 5$	$5 < R_{et} \leq 6$	$6 < R_{et} \leq 7$
• **Waterproof fabrics** Water vapour resistance EN 31092	m² Pa/W	$R_{et} \leq 8$	$8 < R_{et} \leq 15$	$15 < R_{et} \leq 22$
Air permeability EN ISO 9237	mm/s	$AP \leq 5$	$5 < AP \leq 100$	$100 < AP$
Water penetration resistance and repellence				
Water penetration resistance EN 20811	cm H_2O	$WR \geq 400$	$400 > WR \geq 130$	$WR > 130$
Water repellence EN 29865 EN 24920	grade 1-5 spray rate	5 5	4 4	3 3
Liquid sweat management				
Liquid moisture management AATCC TM 195	index	-	-	-
Liquid sweat transport Annex B (25 °C; 50 % r.h.)	g/m² h	-	-	-
Liquid sweat buffering Annex B	index 0-1	-	-	-

Table 7 — Performance levels for outer, multilayer materials for very cold climate

Property	Unit	A	B	C
Thermal insulation ISO 5085-1 or EN 31092	m² K/W	$R_{ct} \geq 0,18$	$0,18 > R_{ct} \geq 0,12$	$0,12 > R_{ct} \geq 0,06$
Water vapour transmission				
Knitted fabrics or thick cold protective fabrics Water vapour permeability index EN 31092	index 0 -1	$i_{mt} \geq 0,55$	$0,55 > i_{mt} \geq 0,45$	$0,45 > i_{mt} \geq 0,35$
Woven fabrics Water vapour resistance EN 31092	m² Pa/W	$R_{et} \leq 13$	$13 < R_{et} \leq 20$	$20 < R_{et} \leq 40$
Waterproof fabrics Water vapour resistance EN 31092	m² Pa/W	$R_{et} \leq 22$	$22 < R_{et} \leq 35$	$35 < R_{et} \leq 55$
Air permeability EN ISO 9237	mm/s	$AP \leq 5$	$5 < AP \leq 100$	$100 < AP$
Water penetration resistance and repellence				
Water penetration resistance EN 20811	cm H_2O	$WR \geq 400$	$400 > WR \geq 130$	WR > 130
Water repellence EN 29865 EN 24920	grade 1-5 spray rate	5 5	4 4	3 3
Liquid sweat management				
Liquid Moisture Management AATCC TM 195	index	-	-	-
Liquid sweat transport Annex B (25 °C; 50 % r.h.)	g/m² h	-	-	-
Liquid sweat buffering Annex B	index 0-1	-	-	-

6 Marking

The classification can be used for informing about the thermoregulatory properties appropriate to a particular material or product.

The performance levels A, B and C according to Tables 1, 2, 3, 4, 5, 6 and 7 should be used for marking a product, see Clause 5.

If a property listed in the tables has not been tested or it does not fulfil the performance levels of the table, that property is not classified in the marking.

If a product is to be labelled, the labelling should be done according to the classification.

Examples of marking are shown in Annex A.

Annex A
(informative)

Examples of application

A.1 General

This Technical Report provides a system for classifying the thermoregulatory properties of materials used to produce functional clothing for different applications. The appropriate levels of performance depend on the intended use conditions (environment and physical activity). If more than one layer of clothing is used, each layer contributes to the thermoregulation and comfort of the wearer. The layers should interact to provide comfort for the user in an optimal ensemble. Besides the material properties, the design of the garments can strongly influence the comfort.

It has to be noted that the thermoregulatory properties of garments and clothing ensembles depend not only on the materials used but also on the design and fit of the garments and on the combinations used. Possible ventilation in air layers between skin and garments can contribute substantially to the heat and moisture transfer between the body and the environment. In that sense, for assessment of the real performance of products, thermal mannequins should be used.

A.2 Examples

Examples of marking are given in Tables A.1 to A.13.

a) *High activity indoors (e.g. aerobics)*

In most indoor sports and gymnastics, a high physical activity in combination with a relatively high temperature lead to high levels of perspiration. The clothing should be as thin as possible (low thermal insulation) with very good moisture management properties, i.e. low resistance to water vapour transmission and high liquid sweat management capacity.

Table A.1 — Marking example, skin contact, warm climates (see Table 1)

Thermal insulation	A
Water vapour transmission	A
Liquid sweat management	A

b) *High activity in low temperatures (e.g. cross country skiing, snow shovelling)*

The choice of clothing with an adequate thermal insulation at high activities in low temperatures is of primary importance. Too low insulation leads to cooling of the body. Too high insulation leads to perspiration, which however due to the low environment temperature would condensate within the clothing. Perspiration should be avoided, but if it occurs, it is important that the skin contact garments have good liquid sweat management properties. Outerwear garments should be wind- and rainproof, the intermediate layer(s) provide thermal insulation according to temperature and activity, and underwear be wicking.

Table A.2 — Marking example, skin contact, cold climates (see Table 4)

Thermal insulation	C
Water vapour transmission	A
Liquid sweat management	A

Table A.3 — Marking example, intermediate layer products, cold climates (see Table 5)

Thermal insulation	B
Water vapour transmission	A

Table A.4 — Marking example, outerwear, cold climates (see Table 6)

Thermal insulation	C
Water vapour transmission	B
Air permeability	A
Water repellence	B

c) *Low activity in low temperatures (e.g. slow walking)*

The lower the temperature is, the more thermal insulation is needed for low activities. The appropriate thermal insulation is generally achieved with a combination of insulating outerwear and intermediate layer. The outerwear should also have low air permeability, and in temperatures above or near 0 °C also water repellency.

Table A.5 — Marking example, skin contact, cold climates (see Table 4)

Thermal insulation	C
Water vapour transmission	A
Liquid sweat management	B

Table A.6 — Marking example, intermediate layer products, cold climates (see Table 5)

Thermal insulation	B
Water vapour transmission	A

Table A.7 — Marking example, outerwear, cold climates (see Table 6)

Thermal insulation	B
Water vapour transmission	B
Air permeability	A
Water repellence	A

d) *High activity in wet conditions (e.g. hiking)*

The water repellency properties in combination with good water vapour transmission of the outerwear are most crucial. Underwear with good wicking properties and intermediate layer with thermal insulation according to temperature and activity level are also essential for good comfort.

Table A.8 — Marking example, skin contact, warm climates (see Table 1)

Thermal insulation	B
Water vapour transmission	A
Liquid sweat management	A

Table A.9 — Marking example, intermediate layer products, warm climates (see Table 2)

Thermal insulation	B
Water vapour transmission	A
Liquid sweat management	B

Table A.10 — Marking example, outerwear, warm climates (see Table 3)

Thermal insulation	A
Water vapour transmission	A
Air permeability	B
Water repellence	A

e) *Low activity in wet conditions (e.g. boating)*

The water penetration resistance of the outerwear is extremely important.

Table A.11 — Marking example, skin contact, warm climates (see Table 1)

Thermal insulation	B
Water vapour transmission	A
Liquid sweat management	A

Table A.12 — Marking example, intermediate layer products, warm climates (see Table 2)

Thermal insulation	B
Water vapour transmission	A
Liquid sweat management	B

Table A.13 — Marking example, outerwear, warm climates (see Table 3)

Thermal insulation	A
Water vapour transmission	A
Air permeability	A
Water penetration resistance	A

Annex B
(informative)

Liquid sweat transport and liquid sweat buffering

B.1 Method A: Testing of textiles - Measurement of the buffering capacity and transport of liquid sweat of textiles with the sweating guarded-hotplate (Skin Model)[3)]

B.1.1 Aim of test

For the assessment of the physiological properties of textiles worn next to the skin not only their stationary thermophysiological properties (thermal and water vapour resistance) are important, measured according to EN 31092 (ISO 11092) with the sweating guarded-hotplate (Skin Model), but also their capacity to buffer in stationary sweat pulses and to transport liquid sweat, occurring in the practical use of textiles and clothing.

With liquid sweat appearing on the wearer's skin the textiles should take it up and transport it into the next textile layers or into the environmental air. This so-called buffering capacity and transport of liquid water (sweat) of a textile is measured quantitatively with the sweating guarded-hotplate, slightly modified from the design and procedures described in the above standards. A textile may be judged to perform the better, the more complete the transport of sweat from the skin is effected, and the less liquid sweat remains on the skin.

B.1.2 Definitions

B.1.2.1 Moisture permeability, F_1

Amount of liquid water in grams taken up by 1 m² of the textile material and within 1 h transported into ambient air with a water vapour pressure gradient of 1 hPa between the two sides of the textile material.

B.1.2.2 Sweat transport, F

Amount of liquid water (sweat) in grams taken up by 1 m² of the textile material and within 1 h transported into ambient air with specific temperature and relative humidity.

B.1.2.3 Buffering index, K_f

Portion of the sum of liquid water transported through the textile material (G_1) and remaining in the textile material (G_2) in grams during and after 15 min of getting into contact with the water related to the total amount of water offered to the textile material (G_0) in grams.

B.1.3 Principle of test

The buffering capacity and transport of liquid sweat of a textile material is measured with the sweating guarded-hotplate, specified in EN 31092 (ISO 11092) with the following additional components (Figure B.1):

— gas meter

— 2 temperature sensors at the inlet and outlet of the gas meter

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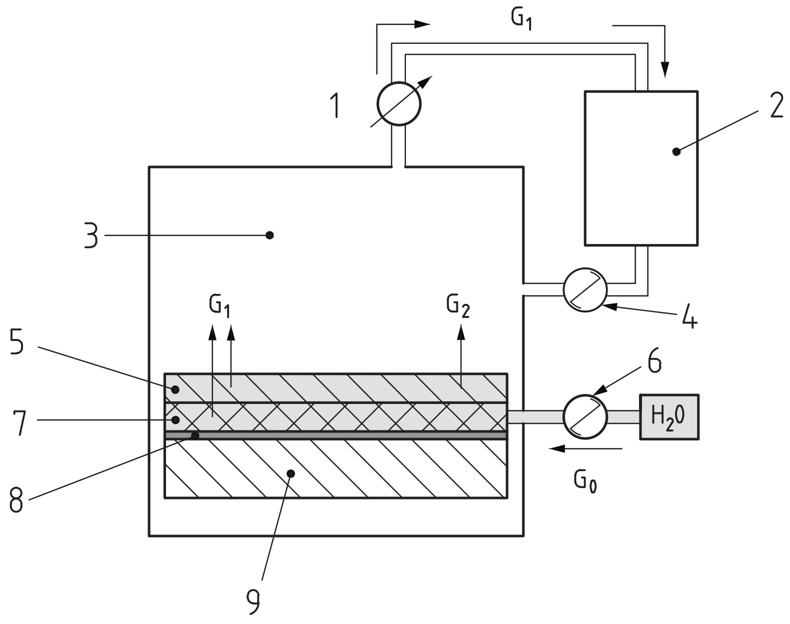

Key

1 gas meter

2 drying column

3 climatic cabinet (35 °C, 30 % r.h.)

4 air pump

5 specimen

6 syringe

7 hydrophobic polyester fabric

8 water and water vapour impermeable foil

9 measuring unit

Figure B.1 — Principle of apparatus

To perform the test the sweating guarded-hotplate's measuring unit kept at 35 °C is covered with a thin foil sized 25 cm x 25 cm which is water and water vapour impermeable. On top of the foil a polyester woven fabric with hydrophobic surface characteristics, a basis weight of 100 ± 3 g/m² and a size of 20 cm x 20 cm is placed[4]. This fabric simulates the sweating human skin, and the foil prevents the water from being wicked into the measuring unit for the duration of the test.

During the test, the air stream in the climatic cabinet (velocity 1 m/s) of the sweating guarded-hotplate is maintained at a constant temperature of 35 °C with a relative humidity of 30 %. This is affected by the climatic cabinet's air pump set to a pumping power of 3 000 l/h. With this pump the air of the climatic cabinet is circulated through a drying column filled with silica gel as drying agent. The total volume of the air circulated during the test period of 15 min is determined by a gas meter.

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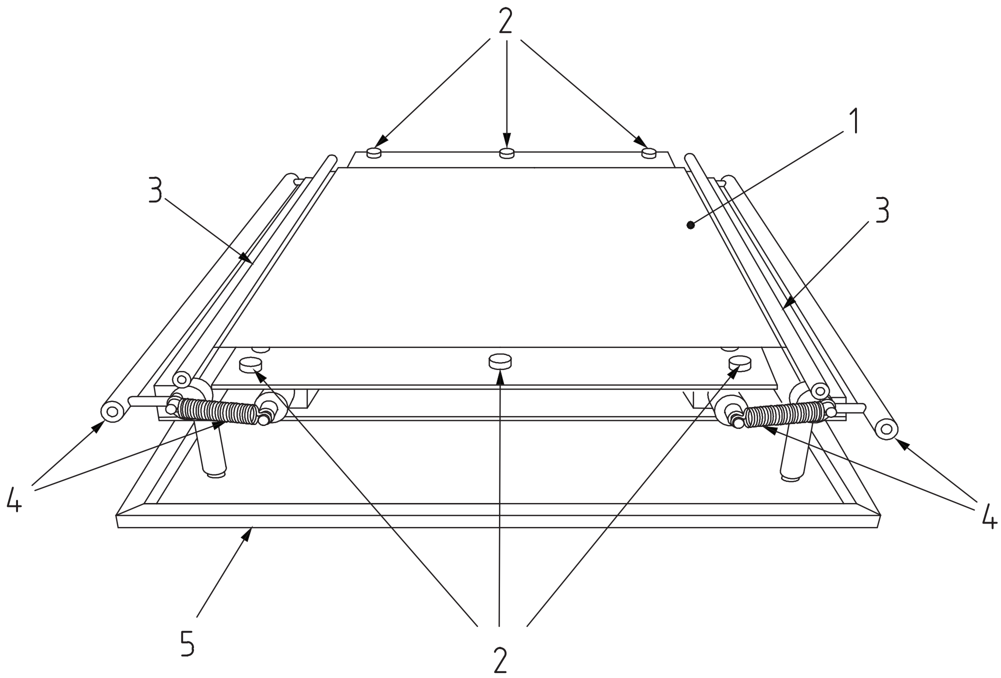
[4] A suitable reference for the PES-woven fabric is 'Vektron 4003' produced by Klopman International, Berliner Strasse 101, D-40880 Ratingen, Germany. This information is given for the convenience of users of this document and does not constitute an endorsement by CEN/TC248 of the product named. Equivalent products may be used if they can be shown to lead to the same results.

During the test, water vapour diffusion is taking place through the specimen due to the difference in water vapour pressure between the surface of the PES-woven fabric placed on the measuring unit and the air within the climatic cabinet. In addition the specimen is absorbing water out of the underlying PES-woven fabric, which is simulating the sweating human skin. This water absorbed by the specimen is also at least partly evaporated into the air of the climatic cabinet. The total amount of moisture in the form of water vapour being transported into the ambient air is determined by the moisture content of the air volume which has to be circulated from the climatic cabinet through the drying column in order to maintain the water vapour pressure within the climatic cabinet at its set value of 30 % r.h. (= 16,9 hPa).

Optionally a device can be used to enhance the reproducibility of the measurements, see Figure B.2. This device has two functions: (1) in normal position it acts as a sample carrier and (2) when it is reversed it acts as a lid. When the device acts as a sample carrier, a system of clips allows to carry the specimen in closed position and to lay it on the PES fabric in opened position. By this way the specimen can be laid on the PES fabric in one operation with the maximum of planarity. The specimen is laid from a distance of 3 mm determined by spacers. When the device acts as a lid, it is possible to cover the wetted polyester fabric to allow the liquid water to spread completely and evenly while avoiding evaporation.



Key

1 specimen

2 spacers

3 clips (closed position)

4 mechanism to open and close the clips

5 lid

Figure B.2 — Sample carrier in reverse position

B.1.4 Test specimens

The test specimens are sized 21 cm x 21 cm. From each material to be tested, a minimum of three test specimens should be taken and tested. Prior to testing, the specimens should be conditioned at the test climate (35 °C, 30 % r.h.) for a minimum of 24 h.

B.1.5 Test procedure

The water and water vapour impermeable foil as well as the hydrophobic PES-woven fabric are placed on the measuring unit of the sweating guarded-hotplate. A bowl with about 0,2 l water with a temperature of 35 °C is placed within the climatic cabinet. Measuring unit and air in the climatic cabinet are set isothermally to 35 °C. The relative humidity within the climatic cabinet is set to 30 % r.h. The air stream in the climatic cabinet is set to 1 m/s.

After the air within the climatic cabinet has reached a steady-state temperature and humidity of 35 °C and 30 % r.h., respectively, the conditioned specimen is weighed (m_1).

The air pump of the climatic cabinet is switched off and the gas meter is reset to 0. Then the climatic cabinet is opened and the water bowl removed. After that with a syringe 15 cm³ of water with a temperature of 35 °C are evenly distributed onto the PES-woven fabric. Then the specimen item is placed wrinkle free on the PES-woven fabric and at the edge facing the air stream in the climatic cabinet fixed with adhesive tape to the measuring table of the sweating guarded-hotplate. The climatic cabinet is closed, and with switching on the air pump the test is started.

If the sample carrier is used then immediately after the water is distributed onto the PES-woven fabric, it is placed on the measuring unit acting as a lid with the specimen on its upper face. The climatic cabinet is closed. An elapsed period of 5 min allows the water to spread evenly in the PES fabric. The climatic cabinet is opened. The sample carrier is reversed and the specimen is laid on the PES fabric by releasing the clips. Immediately after that the climatic cabinet is closed and the air pump is switched on to start the test.

After about 13 min into the test period the air temperatures at the inlet and outlet of the gas meter T_i and T_o, respectively, are registered. After exactly 15 min (to be determined with a stop watch) the test is ended by switching off the air pump, and the air volume VA shown by the gas meter is registered. The specimen is then removed and weighed (m_2).

B.1.6 Evaluation of test results

B.1.6.1 Moisture permeability F_1

The moisture permeability F_1 of the specimen is determined as follows:

$$F_1 = \frac{G_1}{\Delta p \cdot \Delta t \cdot a} \text{ g/m}^2\text{·h hPa} \quad [1]$$

where

$$G_1 = \frac{V_A \cdot c_A}{1000} \text{ g} \quad [2]$$

$$c_A = \frac{216.6\rho_a}{273+T_a} \cdot \left(1+\frac{T_a-(T_i+T_o)/2}{273}\right) \text{ g/m}^3 \quad [3]$$

where

G_1 amount of water transported through the specimen during the test period in g;

Δp water vapour pressure difference between the two sides of the specimen in hPa (= 39,3 hPa);

Δt test period in h (= 0,25 h);

a area of the PES-woven fabric in m² (= 0,04 m²);

V_A air volume shown at the gas meter after the test period in l;

c_A correction factor for the air volume registered at the gas meter in g / m³;

p_a water vapour pressure in the climatic cabinet in hPa (= 16,9 hPa);

T_a air temperature in the climatic cabinet in °C (= 35 °C);

T_i air temperature at the inlet of the gas meter in °C;

T_o air temperature at the outlet of the gas meter in °C.

B.1.6.2 Sweat transport F

Under the assumption of a specific climate condition (e.g. 25 °C, 50 % r.h.) from the F_1 value, the amount of liquid sweat *F* in g can be deduced which during 1 h can be transported away from the wearer's skin by 1m² of the textile material tested:

$$F = F_1\,\Delta P \qquad \text{g / m}^2\text{ h} \quad [4]$$

with $\Delta P = p_s - p_A$ hPa [5]

where

p_s water vapour pressure at the wearer's skin in hPa (= 56,2 hPa);

p_A water vapour pressure in the ambience in hPa.

B.1.6.3 Sweat uptake G_2

The sweat uptake G_2 is the amount of water in g taken up by the specimen during the test period:

$$G_2 = m_2 - m_1 \quad \text{g} \qquad [6]$$

where

m_1 mass of the conditioned specimen before the test in g

m_2 mass of the specimen after the test period in g

B.1.6.4 Buffering index K_f

The buffering capacity of a textile material is quantified by the buffering index K_f , expressing the ratio of water (sweat) which after the simulated sweat pulse on the sweating guarded hotplate is either taken up and/or transported by the specimen during the test period related to the amount of water (sweat) offered to the specimen:

$$K_f = \frac{G_1 + G_2}{G_0} \qquad [7]$$

where

G_0 amount of water injected into the PES-woven fabric in g (= 15 g).

rdt K_f can lie between 0 and 1. The buffering capacity of a textile material is the better, the nearer K_f is to 1, the ideal case whe120re the total amount of sweat occurring during the sweat pulse is absorbed and transported away by the textile material.

B.1.7 Physiological assessment of the textile material

From a physiological point of view a textile material may be judged to be better, the higher its buffering index K_f. If for two fabric materials the same or similar K_f -values are found, the one with the higher sweat transport F would be considered to be better, because it is more capable not only to absorb the amount of moisture connected with a sweat pulse but also to transport the moisture away from the wearer's skin.

B.1.8 Calibration of test apparatus

Prior to each test series, the apparatus is calibrated with a 'standard' textile material[5)] of known buffering index K_f and known sweat transport F. Additionally, in regular intervals a 'bare-plate test' has to be performed without a textile material on the PES-woven fabric onto which 15 cm³ of water are distributed as described in B.1.5. The test is performed until the PES-woven fabric is completely dried. Then the amount of water G_1 determined according to B.1.6.1 should be 15 g ± 5 %.

B.1.9 Precision of results

With 3 single tests per textile material the precision (standard deviation) of the buffering index K_f is 0,02, of the moisture permeability F_1 0,48 g / m² h hPa, and of the sweat uptake G_2 0,3 g.

B.1.10 Test report

The test report should include at least the following information:

a) reference to this test specification;

---

5) For practical purposes, each laboratory can select an 'in-house calibration standard fabric', preferably with a fairly high liquid sweat transport value.

For information the hydrophobic polyester reference fabric (A.2.1. Clause 3, footnote 3) has obtained the following values:

Kf :	(A) 0.69, (B) 0.69, (C) 0.71, mean 0.70
F [g/m²h]:	(A) 835, (B) 794, (C) 849, mean 826
G2 [g]:	(A) 2.3, (B) 2.6, (C) 2.4, mean 2.4

b) complete description of the textile material tested;

c) number of test specimens per textile material tested and number of individual measurements on each test specimen;

d) arithmetic mean value of buffering index K_f, sweat transport F and sweat uptake G_2;

e) date of test.

B.2 Method B (Modification of Method A)

B.2.1 Purpose of this procedure

If it is not possible to modify the sweating guarded hotplate by adding a gas meter, the following alternative procedure can be used to implement Method A on any sweating guarded hotplate compliant with EN 31092 (ISO 11092).

B.2.2 Principle of test

The gas meter used to measure the transported liquid water is replaced by a weighing procedure of the specimen and the polyester (PES) fabric before and after the measuring period. A scale with a precision of 0,01 g is required.

If not explicitly mentioned in this procedure, other definitions, conditions and testing parameters are the same as in Method A.

Liquid water transported through the specimen (G_1) and remaining in the specimen (G_2) after 15 min can be calculated with the following formulae:

$$G_2 = m_{s,2} - m_{s,1}$$

$$G_1 = G_0 - (m_{p,2} - m_{p,1}) - G_2$$

where

$m_{s,1}$ mass of specimen before measurement in g;

$m_{s,2}$ mass of specimen after the test period (= 15 min) in g;

$m_{p,1}$ mass of PES fabric before measurement in g;

$m_{p,2}$ mass of PES fabric after the test period (= 15 min) in g;

G_0 amount of water injected into the PES-woven fabric in g (= 15 g);

G_1 amount of water transported through the specimen during the test period (= 15 min) in g;

G_2 the sweat uptake in g.

In order to perform weight checks reliably the impermeable foil used in the Method A procedure is replaced by a frame with a plastic sheet stuck on its bottom face. The frame with plastic sheet allows the specimen and the PES fabric to be carried directly from the machine to a scale without loss of water.

Dimensions of the frame are:

— outer size: 300 x 300 mm²:

— inner size: 230 x 230 mm²:

— thickness: 2 mm ± 0,1 mm.

The frame material should have a low thermal conductance. The plastic sheet must present a good stability with temperature and a good planarity to enable close contact with the plate of the skin-model. A suggested material for the plastic sheet is PET (Polyethylene terephthalate) with a thickness of 0,1 mm.

The frame is placed on the measuring unit with the plastic sheet in contact with the plate. A polyester woven fabric sized 200 mm x 200 mm is placed on the top of the plastic sheet.

B.2.3 Test procedure

After the air within the climatic cabinet has reached a steady-state temperature and humidity of 35 °C and 30 % r.h. respectively, the conditioned frame is placed on the scale. The scale with the frame is zeroed.

The conditioned PES fabric is placed on the frame and weighed (m_1).

The conditioned specimen is added on the top of the PES fabric and weighed (m_2).

The sample carrier described in Method A should be used in Method B. The conditioned specimen is removed from the scale and placed on the sample carrier.

The frame with the PES fabric is placed on the plate of the skin-model with the plastic sheet in contact with the plate.

15 cm³ of water at a temperature of 35 °C are evenly distributed on the PES fabric as much as possible.

Immediately after that, the sample carrier acting as a lid with the specimen on its upper face is placed on the frame. The climatic cabinet is closed.

An elapsed period of 5 min allows the water to spread evenly in the PES fabric. The climatic cabinet is opened. The sample carrier is reversed and the specimen is laid on the PES fabric by releasing the clips. Immediately after that, a stop watch is started and the climatic cabinet is closed.

About 20 seconds before an elapsed period of 15 min, the climatic cabinet is opened and after the exact completion of this period (to be determined with the stop watch) the frame with the PES fabric and the specimen is removed from the plate and placed on the scale. The ensemble is weighed (m_3).

The specimen is removed from the frame and the remaining PES fabric is weighed (m_4).

B.2.4 Evaluation of test results

Amount of water transported through the specimen during the test period (G_1) and the sweat uptake (G_2) are determined as follows:

$$G_0 = 15 \text{ g}$$

$$G_1 = G_0 + m_2 - m_3$$

$$G_2 = m_1 - m_2 + m_3 - m_4$$

where

m_1 mass of PES fabric before the measurement in g

m_2 mass of PES fabric and specimen before the measurement in g

m_3 mass of PES fabric and specimen after the test period in g

m_4 mass of PES fabric after the test period in g

Moisture permeability F_1, sweat transport F and buffering index K_f are determined as in Method A.

Bibliography

[1] EN ISO 15496, *Textiles — Measurement of water vapour permeability of textiles for the purpose of quality control (ISO 15496)*

[2] CEN/TR 16298, *Textiles and textile products — Smart textiles — Definitions, categorisation, applications and standardization needs*

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