



SLOVENSKI STANDARD
SIST EN 17528:2022

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Oblačila - Fiziološki učinki - Merjenje odpornosti proti vodni pari s pomočjo lutke za potenje

Clothing - Physiological effects - Measurement of water vapour resistance by means of a sweating manikin

Bekleidung - Physiologische Wirkungen - Messung des Wasserdampfdurchgangswiderstandes mittels einer schwitzenden Prüfpuppe

Vêtements - Effets physiologiques - Mesurage de la résistance à la vapeur d'eau à l'aide du mannequin transpirant

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Clothing - Physiological effects - Measurement of water vapour resistance by means of a sweating manikin

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
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European foreword

This document (EN 17528:2022) has been prepared by Technical Committee CEN/TC 248 "Textiles and Textile Products", the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2023 and conflicting national standards shall be withdrawn at the latest by April 2023.

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EN 17528:2022 (E)

Introduction

The type of clothing worn by people directly affects the heat exchange between the human body and the environment. The heat transfer is both sensible (conduction, convection, and radiation) and latent (evaporation). The water vapour resistance of a clothing ensemble is dependent upon the designs and materials used in the component garments, the amount of body surface area covered by the clothing, the distribution of the layers over the body, looseness or tightness of fit, and the increased surface area for heat loss. Water vapour resistance measurements made on fabrics alone do not take these factors into account. Measurements of the resistance to evaporative heat loss provided by clothing can be used with thermal insulation values (EN ISO 15831) to determine the comfort or stress of people in different environments.

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1 Scope

This document specifies the requirements of the sweating manikin and the test procedure used to measure the water vapour resistance of a clothing ensemble, as it becomes effective for the wearer in practical use in a defined environment, with the wearer either standing or moving. This water vapour resistance, among other parameters, can be used to determine the effect of clothing on the physiology of the wearer in specific climate/activity scenarios.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN ISO 11092, *Textiles - Physiological effects - Measurement of thermal and water-vapour resistance under steady-state conditions (sweating guarded-hotplate test) (ISO 11092)*

EN ISO 15831, *Clothing - Physiological effects - Measurement of thermal insulation by means of a thermal manikin (ISO 15831)*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1

clothing ensemble

group of garments worn together on the body at the same time

3.2

water vapour resistance of clothing

water-vapour pressure difference between the manikin's skin surface and ambient atmosphere divided by the resulting evaporative heat flux per unit area in the direction of the gradient of water-vapour pressure

3.3

total water vapour resistance of clothing

$R_{et,M}$

total water-vapour resistance from manikin's surface to ambient atmosphere, including clothing and boundary air layer, under defined conditions measured with a stationary manikin

Note 1 to entry: $R_{et,M}$ is expressed in square metres pascal per watt ($m^2 \cdot Pa/W$).

3.4

resultant total water vapour resistance of clothing

$R_{etr,M}$

total water-vapour resistance from manikin's surface to ambient atmosphere, including clothing and boundary air layer, under defined conditions measured with a manikin moving its legs and arms

Note 1 to entry: $R_{etr,M}$ is expressed in square metres pascal per watt ($m^2 \cdot Pa/W$).

EN 17528:2022 (E)**3.5****air water vapour resistance** $R_{ea,M}$

water-vapour resistance of the boundary (surface) air layer around the sweating nude manikin, under defined conditions measured with a stationary manikin

Note 1 to entry: $R_{ea,M}$ is expressed in square metres pascal per watt ($m^2 \cdot Pa/W$).

3.6**resultant air water vapour resistance** $R_{ear,M}$

water-vapour resistance of the boundary (surface) air layer around the sweating nude manikin, under defined conditions measured with a manikin moving its legs and arms

Note 1 to entry: $R_{ear,M}$ is expressed in square metres pascal per watt ($m^2 \cdot Pa/W$).

3.7**basic water vapour resistance of clothing** $R_{ecl,M}$

water-vapour resistance from manikin's surface to the outer clothing surface (including enclosed air layers), under defined conditions measured with a stationary manikin

Note 1 to entry: $R_{ecl,M}$ is expressed in square metres pascal per watt ($m^2 \cdot Pa/W$).

3.8**resultant basic water vapour resistance of clothing** $R_{eclr,M}$

water-vapour resistance from manikin's surface to the outer clothing surface (including enclosed air layers), under defined conditions measured with a manikin moving its legs and arms

Note 1 to entry: $R_{eclr,M}$ is expressed in square metres pascal per watt ($m^2 \cdot Pa/W$).

3.9**effective water vapour resistance of clothing** $R_{ecl,e,M}$

difference between water-vapour resistance provided to a sweating manikin by a clothing ensemble and the water-vapour resistance of the sweating nude manikin, under defined conditions measured with a stationary manikin

Note 1 to entry: $R_{ecl,e,M}$ is expressed in square metres pascal per watt ($m^2 \cdot Pa/W$).

Note 2 to entry: $R_{ecl,e,M}$ is calculated with Formula (9).

3.10**resultant effective water vapour resistance of clothing** $R_{ecler,M}$

difference between water-vapour resistance provided to a sweating manikin by a clothing ensemble and the water-vapour resistance of the sweating nude manikin, under defined conditions measured with a manikin moving its legs and arms

Note 1 to entry: $R_{ecler,M}$ is expressed in square metres pascal per watt ($m^2 \cdot Pa/W$).

Note 2 to entry: $R_{ecler,M}$ is calculated with Formula (10).

3.11**clothing area factor** f_{cl}

ratio of the outer surface of the clothed manikin to the surface area of the nude manikin

Note 1 to entry: f_{cl} is dimensionless and is always higher or equal to 1.**4 Symbols and abbreviated terms**

A_w	total wet body surface area of the manikin	m ²
a_i	surface area of the body segment i of the manikin	m ²
f_i	fraction of the total manikin surface area represented by the surface area of segment i	
H_e	total heating power supplied to the manikin	W
H_{ei}	heating power supplied to the body segment i of the manikin	W
RH	relative humidity of the air within the climatic chamber	%
T_a	air temperature within the climatic chamber	°C
T_s	mean surface temperature of the manikin	°C
T_{si}	surface temperature of the body segment i of the manikin	°C
p_a	water vapour pressure of the air within the climatic chamber	Pa
p_s	water vapour pressure at the manikin's sweating surface	Pa
p_{si}	water vapour pressure at the body segment i of the manikin's sweating surface	Pa
v_a	air speed in the climatic chamber	m/s

5 Measurement and test methods**5.1 Principle**

The components of the clothing ensemble to be tested are placed on the manikin in the same arrangement as in practical use.

The manikin in the shape and size of an adult human body and, for the measurement of $R_{etr,M}$, with movable legs and arms, is internally heated to a constant surface temperature, uniform over its body. The manikin is placed in a climatic chamber where specified air temperature and air speed can be set, and air humidity controlled.

There will be an evaporative heat flow from the manikin's skin surface area through the clothing into the ambient air, which is measured after steady-state conditions have been reached. From this heat flow, related to the sweating nude manikin's body surface area, the clothing ensemble's water vapour resistance can be calculated, considering the difference of water-vapour partial pressure between the manikin's skin surface and the ambient air.

The measurement is performed with the manikin stationary and/or moving its legs and arms, with a specified number of movements per minute and a defined stride length. The water-vapour resistance values obtained include the water-vapour resistance provided by the clothing and the adhering air layer around the body. They apply only to the particular clothing ensemble, as tested, and to the specific conditions of the test, particularly with respect to the air movement around the manikin.

NOTE The principles described in this document can also be applied for other kinds of manikins (e.g. child manikin, female manikin, partial manikin, for example hand, torso, foot).

EN 17528:2022 (E)**5.2 Apparatus****5.2.1 Standard manikin****5.2.1.1 Size and shape**

The manikin, made from metal or plastic, shall be constructed to simulate the body of an adult human. It shall consist of anatomical segments covering head, chest, abdomen, back, buttocks, arms, hands (preferably with individual fingers extended to allow gloves to be worn), legs and feet, with at least one segment in each body part.

NOTE Experience shows that at least 15 body segments provide reasonable homogenous surface temperature, allow monitor heat flux and provide information about local differences.

The body height of the standard manikin shall be $(1,70 \pm 0,15)$ m, with a body surface area of $(1,7 \pm 0,3)$ m².

The manikin's body proportions should correspond to those required for standard sizes of garments, because deviations in fit will affect the results.

For the measurement of $R_{\text{etr,M}}$ the manikin's arms and legs shall be movable, with joints at least at the shoulder and hip. For the measurement of the clothing ensemble's resultant total water-vapour resistance, $R_{\text{etr,M}}$, the manikin, mechanically driven, shall perform (45 ± 2) double steps per min, and (45 ± 2) double arm movements per min cross walking. The stride length, measured from toe to toe, shall be (63 ± 10) cm, and the length of the arm movements, measured between the wrists at the base of the thumbs, (53 ± 10) cm.

5.2.1.2 Sweat generation

The manikin shall have the ability to evaporate water from its surface. Sweating can be simulated by a tight-fitting water saturated skin body suit, for example high absorptive textile or a tight-fitting water-fed capillary body suit (cotton or other appropriate textile or material) worn over the thermal manikin. The entire surface of the manikin shall be heated and the skin body suit shall be saturated with water before the start of the test.

It shall be guaranteed that all parts of the manikin skin do not dry out during the test. This can be checked by monitoring the stability of the heating power supply for individual zones.

If a water-fed capillary system is used for sweat generation, each manikin's segment should be controlled individually regarding the sweating rate.

5.2.1.3 Surface temperature

The manikin shall be constructed so as to maintain the same average constant temperature T_s of $(34,0 \pm 0,2)$ °C measured at all segment surfaces.

The surface temperatures of the manikin shall be measured by at least one appropriate temperature sensor (e.g. thermocouples, thermistors, resistance temperature devices) per body segment. The sensors shall not protrude more than 0,5 mm from the manikin's surface and shall be well bonded, both mechanically and thermally, to the manikin's surface. Lead wires shall be bonded to the surface, or preferably pass through the interior of the manikin.

When calculating the mean skin surface temperature of the manikin's body, each sensor temperature shall be area-weighted, considering the portion of the body surface area covered by the sensor.

5.2.1.4 Heating equipment and power measurement

Each body segment of the manikin shall be equipped with an independently controlled heating system, whose capacity is sufficiently high to guarantee a constant surface temperature of $(34,0 \pm 0,2)$ °C in the nude manikin at each body segment.

The evaporative heat flow from the manikin's body through the clothing can be determined by measuring the heating power necessary to maintain a constant surface temperature, supplied to each of the manikin's body segments during the test period.

The power measuring equipment shall be capable of giving an accurate average over the test period. Its accuracy shall be within ± 2 % of the value for the average power supplied to each body segment of the manikin during the test period.

5.2.2 Controlled climatic chamber

5.2.2.1 General

The manikin shall be placed in a controlled climatic chamber, at least $2\text{ m} \times 2\text{ m} \times 2\text{ m}$ (length \times width \times height). The air flow in the chamber may be horizontal or vertical.

In the chamber, spatial uniformity shall be verified by recording values for the test conditions (see 5.4) at heights of 0,1 m, 1,1 m, and 1,7 m above the manikin sole height at the location occupied by the manikin. The temperature of the walls, floor and ceiling shall not differ more than 1 °C from the mean air temperature.

5.2.2.2 Air temperature sensor(s)

To monitor the air temperature in the chamber during the test, a single sensor with an overall accuracy of $\pm 0,15$ °C and a time constant not exceeding 1 min may be used. However, multiple sensors are preferable.

The temperature sensor(s) shall be placed at a distance of $(0,5 \pm 0,1)$ m from the manikin. If a single sensor is used, it shall be at least 1,0 m above the floor of the chamber. If multiple sensors are used, they shall be spaced at equal height intervals, and their readings averaged.

5.2.2.3 Relative humidity sensor

Any humidity sensing device with an accuracy of at least ± 2 % relative humidity and a repeatability of ± 3 % is acceptable. Only one location in the chamber needs to be monitored during the test to ensure that the temporal uniformity requirements mentioned in 5.2.2.1 are met.

5.2.2.4 Air speed sensor

For measuring the air speed in the climatic chamber an omni-directional anemometer with $\pm 0,05$ m/s accuracy shall be used. Measurements shall be averaged for at least 3 min at locations spaced at equal height intervals, $(0,5 \pm 0,1)$ m in front of the manikin. If it is demonstrated that the air speed does not vary temporally by more than $\pm 0,1$ m/s, then it is not necessary to monitor air speed during a test.

5.3 Selection and preparation of test garments

It is desirable to independently test three different specimens of the clothing ensemble. However, if only one specimen is available, it shall be removed from the manikin after each test, dried and conditioned as specified below before retesting.

The garments tested shall be an appropriate fit to the manikin.

Prior to testing, the garments shall be conditioned either at (34 ± 5) °C and (40 ± 20) % RH or at the test climate set in the climatic chamber for at least 12 h.