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Standard Test Method for Measuring the Evaporative Resistance of Clothing Using a Sweating Manikin[1]

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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 evaporative 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. Evaporative 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 resistance values (Test Method F1291) to determine the comfort or stress of people in different environments.

1. Scope

1.1 This test method covers the determination of the evaporative resistance of clothing ensembles. It describes the measurement of the resistance to evaporative heat transfer from a heated sweating thermal manikin to a relatively calm environment. Information on measuring the local evaporative resistance values for individual garments and ensembles is provided in Annex A1.

1.1.1 This is a static test that provides a baseline clothing measurement on a standing manikin.

1.1.2 The effects of body position and movement are not addressed in this test method.

1.2 The evaporative resistance values obtained apply only to the particular ensembles evaluated and for the specified environmental conditions of each test, particularly with respect to air movement and sweating simulations.

1.3 Evaporative resistance values reported in SI units shall be regarded as standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

F1291 Test Method for Measuring the Thermal Insulation of Clothing Using a Heated Manikin

2.2 *ISO Standards:*[3]

ISO 9920:2007 Ergonomics of the Thermal Environment—Estimation of the Thermal Insulation and Evaporation Resistance of a Clothing Ensemble

3. Terminology

3.1 *Definitions:*

3.1.1 *clothing area factor (f_{cl}), n*—the ratio of the surface area of the clothed body to the surface area of the nude body.

3.1.2 *clothing ensemble, n*—a group of garments worn together on the body at the same time.

3.1.3 *evaporative resistance, n*—the resistance to evaporative heat transfer from the body to the environment.

3.1.3.1 *Discussion*—The following evaporative resistance values can be determined in this test method when measured under isothermal conditititions:

[1] This test method is under the jurisdiction of ASTM Committee F23 on Personal Protective Clothing and Equipment and is the direct responsibility of Subcommittee F23.60 on Human Factors.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

R_{ea} = evaporative resistance of the air layer on the surface of the sweating nude manikin.
R_{et} = total evaporative resistance of the clothing and surface air layer around the manikin.
R_{ecl} = intrinsic evaporative resistance of the clothing. When measurements are made under non-isothermal conditions, the following apparent evaporative resistance values can be determined.
AR_{ea} = apparent evaporative resistance of the air layer on the surface of the sweating nude manikin.
AR_{et} = apparent total evaporative resistance of the clothing and surface air layer around the manikin.
AR_{ecl} = apparent intrinsic evaporative resistance of the clothing.

Total evaporative resistance values are measured directly with a manikin. Intrinsic clothing evaporative resistance values are determined by subtracting the air layer resistance around the clothed manikin from the total evaporative resistance value for the ensemble.

3.1.4 *total thermal resistance (R_t)* —the total thermal resistance (insulation) of the clothing and surface air layer around the manikin.

4. Significance and Use

4.1 This test method can be used to quantify and compare the evaporative resistance provided by different clothing systems. The evaporative resistance values for ensembles measured under isothermal conditions can be used in models that predict the physiological responses of people in different environmental conditions. Garment evaporative resistance values can be compared as well (see Annex A1).

4.2 The measurement of the evaporative resistance provided by clothing is complex and dependent upon the apparatus and techniques used. It is not practical in a test method of this scope to establish details sufficient to cover all contingencies. Departures from the instructions in this test method have the potential to lead to significantly different test results. Technical knowledge concerning the theory of heat transfer, moisture transfer, temperature, humidity, and air motion measurement, and testing practices is needed to evaluate which departures from the instructions given in this test method are significant. Standardization of the method reduces, but does not eliminate, the need for such technical knowledge. Report any departures with the results.

5. Apparatus[4]

5.1 *Manikin*—A standing manikin shall be used that is formed in the shape and size of an adult male or female and heated to a constant average surface temperature.

5.1.1 *Size and Shape*—The manikin shall be constructed to simulate the body of a human being; that is, it shall consist of a head, chest/back, abdomen/buttocks, arms, hands (preferably with fingers extended to allow gloves to be worn), legs, and feet. Total surface area shall be 1.8 ± 0.3 m^2, and height shall be 170 ± 10 cm. The manikin's dimensions shall correspond to those required for standard sizes of garments because deviations in fit will affect the results.

5.1.2 *Sweat Generation*—The manikin must have the ability to evaporate water from its surface. The sweating system can be a water-fed capillary body suit worn over a thermal manikin. Sweating can also be simulated by supplying water to and maintaining it at the inner surface of a waterproof, but moisture-permeable fabric skin.

5.1.2.1 *Sweating Surface Area*—The entire surface of the manikin shall be heated and sweating including the head, chest, back, abdomen, buttocks, arms, hands, legs, and feet.

5.1.3 *Surface Temperature*—The manikin shall be constructed so as to maintain a uniform temperature distribution over the nude body surface, with no local hot or cold spots. The mean surface (skin) temperature of the manikin shall be 35°C. Local deviations from the mean surface temperature shall not exceed ±0.5°C. Temperature uniformity of the nude manikin shall be evaluated at least once annually using an infrared thermal imaging system or equivalent method. This procedure shall also be repeated after repairs or alterations are completed that could affect temperature uniformity, for example, replacement of a heating element.

5.2 *Power-Measuring Instruments*—Power to the manikin shall be measured so as to give an average over the period of a test. If time proportioning or phase proportioning is used for power control, then devices that are capable of averaging over the control cycle are required. Integrating devices (watt-hour meters) are preferred over instantaneous devices (watt meters). Overall accuracy of the power monitoring equipment must be within ±2 % of the reading for the average power for the test period. Since there are a variety of devices and techniques used for power measurement, no specified calibration procedures shall be given. However, an appropriate power calibration procedure is to be developed and documented.

5.3 *Equipment for Measuring the Manikin's Surface (Skin) Temperature*—The mean surface temperature shall be measured with point sensors or distributed temperature sensors.

5.3.1 *Point Sensors*—Point sensors shall be thermocouples, resistance temperature devices (RTD's), thermistors, or equivalent sensors. They shall be no more than 2 mm thick and shall be well-bonded, both mechanically and thermally, to the manikin's surface. Lead wires shall be bonded to the surface or pass through the interior of the manikin, or both. Each sensor temperature shall be area-weighted when calculating the mean surface temperature for the body. If point sensors are used, a minimum of 15 point sensors are required. At least one sensor shall be placed on the head, chest, back, abdomen, buttocks, and both the right and left upper arm, lower arm, hand, thigh, calf, and foot. These sensors must be placed in the same position for each test and the placement of the sensors shall be given in the report.

5.3.2 *Distributed Sensors*—If distributed sensors are used (for example, resistance wire), then the sensors must be distributed over the surface so that all areas are equally weighted. If several such sensors are used to measure the temperature of different parts of the body, then their respective

[4] Information on laboratories with sweating manikins can be obtained from the Textile Protection and Comfort Center, North Carolina State University, Raleigh, NC 27695 or from the Institute for Environmental Research, Kansas State University, Manhattan, KS 66506.

temperatures shall be area-weighted when calculating the mean surface (skin) temperature. Distributed sensors shall be less than 1 mm in diameter and firmly attached to the manikin surface at all points.

5.4 *Controlled Environmental Chamber*—The manikin shall be placed in a chamber at least 1.5 by 1.5 by 2.5 m in dimension that can provide uniform conditions, both spatially and temporally.

5.4.1 *Spatial Variations*—Spatial variations shall not exceed the following: air temperature ±1°C, relative humidity ±5 %, and air velocity ±50 % of the mean value. In addition, the mean radiant temperature shall not be more than 1.0°C different from the mean air temperature. The spatial uniformity shall be verified at least annually or after any significant modifications are made to the chamber. Spatial uniformity shall be verified by recording values for the conditions stated above at heights of 0.1, 0.6, 1.1, 1.4, and 1.7 m above the floor at the location occupied by the manikin. Sensing devices specified below shall be used when measuring the environmental conditions.

5.4.2 *Temporal Variations*—Temporal variations shall not exceed the following: air temperature ±0.5°C, mean radiant temperature ±0.5°C, relative humidity ±5 %, air velocity ±20 % of the mean value for data averaged over 5 min. (see 5.4.5).

5.4.3 *Relative Humidity Measuring Equipment*—Any humidity sensing device with an accuracy of ±5 % relative humidity and a repeatability of ±3 % is acceptable (for example, wet bulb/dry bulb, dew point hygrometer). Only one location needs to be monitored during a test to ensure that the temporal uniformity requirements are met.

5.4.4 *Air Temperature Sensors*—Shielded air temperature sensors shall be used. Any sensor with an overall accuracy of ±0.15°C is acceptable (for example, RTD, thermocouple, thermistor). The sensor shall have a time constant not exceeding 1 min. The sensor(s) shall be 0.5 m in front of the manikin. If a single sensor is used, it shall be 1.0 m above the floor. If multiple sensors are used, they shall be spaced at equal height intervals and their readings averaged.

5.4.5 *Air Velocity Indicator*—An omni-directional anemometer with ±0.05 m/s accuracy shall be used. Measurements shall be averaged for at least 1 min at each location. If it is demonstrated that velocity does not vary temporally by more than ±0.05 m/s, then it is not necessary to monitor air velocity during a test. However, the value of the mean air velocity must be reported. If air velocity is monitored, then measurement location requirements are the same as for temperature.

6. Sampling and Test Specimens

6.1 *Sampling*—It is desirable to test three identical ensembles to reflect sample variability. However, if only one ensemble is available (that is often the case with prototype garments), replicate measurements shall be made on one ensemble.

6.1.1 If only one ensemble is available, the garments must be removed from the manikin after each test, dried, and conditioned as specified in 6.4 before retesting.

6.2 *Specimen Size and Fit*—Select the size of garments that will fit the manikin appropriately (that is, the way the manufacturer designed them to be worn on the human body during their intended end use). For example, some knitted garments are designed to fit the body relatively tightly. Others are designed to fit loosely to accommodate a wider range of body dimensions or to allow other garments to be worn underneath. In a stationary manikin test, large air layers in the clothing system will contribute to a higher evaporative resistance value than small air layers. Therefore, garments that do not have the appropriate fit on the manikin (that is, too tight or too loose), will cause errors in measurement.

6.2.1 When manikin measurements are used to compare materials used in certain garments, those garments must be made from the same pattern so that design and fit variables are held constant. In addition, they must be tested with the same companion garments in the ensemble (for example, underwear, footwear, and so forth).

6.2.2 When manikin measurements are used to compare a variety of garments, the same size garments of a given type shall be tested as indicated by the size label in the garments (for example, large). However, if it is determined that the fit of a garment is inappropriate, it is acceptable to use another size and state it in the report.

6.3 *Specimen Preparation*—Garments shall be tested in the as-received condition or after dry cleaning or laundering in accordance with the manufacturer's instructions. The cleaning procedures and number of processings shall be stated in the report.

6.4 *Conditioning*—Allow the clothing components to come to equilibrium with the atmosphere in the test chamber by conditioning them in the chamber for at least 12 hours.

7. Calibration of Sweating Manikin

7.1 *Calibration*—Calibrate the sweating manikin using the isothermal procedures in Section 8.

7.1.1 The intrinsic clothing evaporative resistance of the calibration ensemble (R_{ecl}) is 0.016 (kPa·m^2/W), assuming the f_{cl} value is 1.22.

7.2 *Calibration Clothing Ensemble*—The garments required for use in this calibration ensemble are:

7.2.1 *Protective Nomex III Shirt*—203 g/m^2 (6.0 oz/yd^2) plain weave Nomex IIIA button up long sleeve shirt (Bulwark #SND6NV), with two chest pockets.[5] The shirttail shall hang over the trousers, and the top button shall remain unbuttoned.

7.2.2 *Protective Nomex III Pants*—203 g/m^2 (6.0 oz/yd^2) plain weave Nomex IIIA pants (Bulwark #PNW3NV), with two side pockets and two back pockets.[5]

7.2.3 *Men's Underwear Briefs*—180 g/m^2 (5.3 oz/yd^2) ± 10 %, 100 % cotton jersey knit; jockey style that fits snugly at the waist and legs.

[5] The sole source of supply for the Nomex IIIA shirt and pants known to the committee at this time is Bulwark Protective Apparel, 545 Marriott Drive, Nashville, TN 37214; Phone: 800-667-0700. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

7.2.4 *Men's T-Shirt*—140 g/m^2 (4.1 oz/yd^2) ± 10 %, 100 % cotton jersey knit, short-sleeve, crew neck T-shirt.

7.2.5 *Men's Socks*—Basic knit sock that covers foot and extends up the calf no more than 25.4 cm (10 in.) from the bottom of the heel. Each individual sock must be composed of at least 75 % cotton and shall weigh 33 ± 5 g.

7.2.6 *Athletic Shoes*—Fabric/soft leather and soft sole.

7.2.7 The size of the calibration garments shall be selected based on the measurements of the manikin. The garments shall fit the manikin properly as described in 6.2.

7.3 The total evaporative resistance (R_{et}) provided by this ensemble shall be measured periodically, for example, at the beginning of each series of tests.

8. Test Procedure

8.1 *Environmental Test Conditions*

8.1.1 *Isothermal Conditions*—The air temperature is the same as the manikin's surface temperature, so no dry heat exchange is occurring between the manikin and the environment. This is the preferred condition for measuring evaporative resistance.

8.1.1.1 *Air Temperature*—The air temperature shall be 35 ± 0.5°C during a test.

8.1.1.2 *Air Velocity*—The air velocity shall be 0.4 ± 0.1 m/s during a test.

8.1.1.3 *Relative Humidity*—The relative humidity shall be 40 ± 5 % during a test.

8.1.2 *Non-Isothermal Conditions*—The clothing ensemble is tested under environmental conditions that simulate actual conditions of use. The same environmental conditions are used for the insulation test (Test Method F1291) and the non-isothermal sweating manikin test. The air temperature is lower than the manikin's surface temperature, so dry heat loss is occurring simultaneously with evaporative heat loss, and it is possible that condensation will develop in the clothing layers. The evaporative resistance determined under non-isothermal conditions shall be referred to as the apparent evaporative resistance value. The apparent evaporative resistance values for ensembles shall only be compared to those of other ensembles measured under the same environmental conditions

8.1.2.1 State the air temperature, air velocity, and relative humidity used in the non-isothermal tests.

8.2 *Mean Surface (Skin) Temperature of Manikin*—The manikin's surface temperature shall be maintained at 35 ± 0.5°C for all tests. The mean surface temperature shall not be allowed to drift more than ±0.2°C during a 30 min test.

8.3 *Sweating*—The entire manikin surface must have water available for evaporation throughout the test period. The water on the surface shall be supplied or added to the surface of the manikin in the same manner as was used to generate the evaporative resistance value during calibration.

8.4 Pre-wet (for example, spray) the manikin's surface until it is saturated. Then start delivering water to the manikin's surface so as to keep it saturated. This water must be heated to 35 ± 0.5°C before being delivered to the manikin.

NOTE 1—It is usually possible to detect saturation visually by a color change (that is, surfaces that are wet will be darker than those that are dry). An IR camera is also acceptable for use to ensure that the surface is completely saturated. It is possible that a gradual decrease in power over time will indicate that the manikin is drying out in places, and the manikin's surface is no longer saturated.

8.5 Dress the standing manikin in the garments to be tested. Record a description of the garments and the dressing procedures. For example: Is the shirt tail tucked in the pants or is it left hanging out? Are all fasteners closed? Position the manikin so that it is hanging with its arms at its sides and its feet above the floor. Take a photograph of the ensemble on the manikin for the report (optional).

8.5.1 Bring the dressed manikin to 35 ± 0.5°C and allow the system to reach steady-state (that is, the mean surface temperature of the manikin and the power input remain constant ±3 %).

8.5.2 After the manikin system reaches equilibrium conditions, record the manikin's surface temperatures, the air temperature, the relative humidity, and the power to the manikin's body segments every 1 min. The average of these measurements taken over a period of 30 min will be sufficient to determine the total evaporative resistance value.

8.6 *Dry Test*—Measure the total thermal insulation (R_t) provided by the clothing ensemble without the manikin wearing his sweating suit and sweating. This shall be conducted in accordance with Test Method F1291.

NOTE 2—The dry thermal resistance tests are usually run before the sweating evaporative resistance tests because some manikin systems require the dry test data to be loaded into the computer program in order to correct for any dry heat loss that might be occurring from the manikin's surface to the environment during the subsequent sweating test (see Eq 1).

8.7 *Replication of Tests*—Three independent replications of the clothing test shall be conducted. If only one set of garments is being tested, they shall be removed, dried, and put back on the manikin for another test. In this way, normal variations in dressing and instrumentation will be taken into account.

8.8 *Nude Test*—Measure the evaporative resistance (R_{ea}) provided by the air layer around the nude manikin by conducting a test in the same environmental conditions used for the clothing tests. The nude manikin shall be tested at the beginning of each series of clothing tests.

9. Calculations

9.1 The parallel method of calculating the total evaporative resistance of the clothing ensemble shall be used, where the area-weighted temperatures of all body segments are summed and averaged, the power levels to all body segments are summed, and the areas are summed before the total resistance is calculated. Calculate the total evaporative resistance of the ensemble measured under isothermal conditions using Eq 1.

$$R_{et} = [(P_s - P_a)A]/[H_e - (T_s - T_a)A/R_t] \quad (1)$$

where:

R_{et} = total evaporative resistance of the clothing and surface air layer around the manikin (kPa·m^2/W),
P_s = water vapor pressure at the manikin's sweating surface (kPa),
P_a = water vapor pressure of the air (kPa),
A = manikin's surface area (m^2),

H_e = power required to heat the manikin (W),
T_s = manikin's surface temperature (°C),
T_a = air temperature (°C), and
R_t = total thermal resistance (insulation) of the clothing and surface air layer around the manikin (°C·m²/W).

9.2 Determine the average total evaporative resistance (R_{et}) of the sample by averaging the values from the three replications of the test. If the results for any of the three replications vary more than 10 % from the average of all three, then repeat the test on the specimen(s) lying outside the ±10 % limit. If the retest produces a value(s) within the ±10 % limit, then use the new value(s) instead. If the retest remains outside the ±10 % limit, then test an additional three specimens.

9.3 Determine the average intrinsic evaporative resistance of the clothing measured under isothermal conditions (R_{ecl}) using the mean R_{et} value and Eq 2.

$$R_{ecl} = R_{et} - \frac{R_{ea}}{f_{cl}} \tag{2}$$

where:

R_{ecl} = intrinsic evaporative resistance of the clothing (kPa·m²/W),
R_{et} = total evaporative resistance of the clothing and surface air layer around the manikin (kPa·m²/W),
R_{ea} = evaporative resistance of the air layer on the surface of the sweating nude manikin (kPa·m²/W), and
f_{cl} = clothing area factor (dimensionless).

9.3.1 Estimate the f_{cl} by using values in Table 1, or ISO 9920:2007, or measure them using a photographic method.[6]

9.4 Eq 1 and Eq 2 can also be used to calculate the apparent evaporative resistances, AR_{et} and AR_{ecl}, measured under non-isothermal conditions.

10. Report

10.1 State that the clothing ensembles were tested as directed in Test Method F2370.

10.2 Report the following information:

10.2.1 Report the number and location of temperature sensors on the manikin.

10.2.2 Report if the ensemble was tested under isothermal or non-isothermal conditions.

10.2.3 Describe the garments used in the ensembles (for example, fiber content, design features, fabric structure) and provide dressing details (for example, shirttail hanging out).

NOTE 3—It is recommended to include a photograph of the manikin dressed in each clothing ensemble in the report.

10.2.4 Report the average total evaporative resistance (R_{et} or AR_{et}) of the clothing and surface air layer around the manikin.

10.2.5 Report the average intrinsic evaporative resistance (R_{ecl} or AR_{ecl}) of the clothing and the clothing area factor (f_{cl}) used to calculate it.

10.2.6 Report the evaporative resistance of the air layer on the surface of the nude manikin (R_{ea} or AR_{ea}).

10.2.7 Specify the environmental test conditions listed in 8.1.

10.2.8 Explain any departures from the specified apparatus or procedure.

10.2.9 Specify any cleaning procedures used on the garments prior to testing and the number of processings, if applicable.

11. Precision and Bias

11.1 *Precision*—An interlaboratory study was conducted in accordance with Practice E691 to determine the average evaporative resistance for the calibration ensemble. Five labs had a sample of the calibration garments that fit their manikin. Three replications of the test were conducted. Only one lab used the weighing method, and its values were omitted from the statistical analysis because they were greater than 10 % from the mean. The intrinsic evaporative resistance of the calibration ensemble (R_{ecl}) was 0.016 (kPa·m²/W). The 95 % repeatability limit (r) for data taken at a single lab was 0.0025 (kPa·m²/W), and the 95 % reproducibility limit (R) for data taken at different labs was 0.008 (kPa·m²/W). The variability from lab to lab is probably due to the complex nature of the apparatus and the fact that most manikins are one-of-a-kind

[6] McCullough, E. A., Jones, B. W., and Huck, J., ASHRAE Transactions, Vol. 91, Part 2, 1985, pp. 29-47.

TABLE 1 Clothing Area Factors (f_{cl}) for Typical Protective Clothing

Ensemble	Description	f_{cl}
1. Warm Weather Indoor Clothing (Base ensemble)	Short-sleeve shirt, Men's underwear briefs, Khaki pants, Belt, Socks, Athletic shoes	1.17
2. Cold Weather (Outdoor) Clothing	Base ensemble, Knit hat, Fiberfill jacket, Knit mittens	1.34
3. Chemical Protective Level B Ensemble	Base ensemble, Chemical protective hood, Chemical protective jacket, Chemical protective gloves, Belt, Chemical protective pants	1.60
4. Surgical Ensemble	Men's underwear briefs, Bouffant cap, Surgical mask, Scrub shirt, Scrub pants, Surgical gown, Surgical gloves, Socks, Athletic shoes, Shoe Covers	1.36
5. Cold Weather Expedition Ensemble	Thermal underwear (top and bottom), Cold Weather Expedition Suit, Fiberfill mittens, Men's underwear briefs, Socks, Work boots	1.48
6. Flame Resistant Protective Clothing (calibration ensemble)	Flame resistant long sleeve shirt, Men's underwear briefs, Flame resistant pants, Socks, Athletic shoes	1.22
7. Tyvek Coverall Ensemble	T-shirt, Men's underwear briefs, Socks, Athletic shoes, Tyvek coverall (no hood)	1.21
8. Fire Fighter Turnout Gear	Fire fighter helmet, T-shirt, Fire fighter turnout jacket, Green leather gloves, Men's underwear briefs, Fire fighter turnout pants, Socks, Work boots	1.48
9. Chemical Protective Level A Ensemble	Level A one-piece suit, Respirator, Men's underwear briefs, Socks, Athletic shoes	1.65

instruments. It is recommended that the evaporative resistance of ensembles be measured on the same manikin for comparison unless prior agreement has been established between manikins at different labs.

11.2 *Bias*—The procedure in this test method for determining total evaporative resistance has no bias because the value can be defined only in terms of a test method.

12. Keywords

12.1 evaporative resistance; protective clothing; sweating manikin

ANNEX

(Mandatory Information)

A1. LOCAL EVAPORATIVE RESISTANCE DATA

A1.1 Most sweating manikins are comprised of independently heated body zones or segments that are instrumented with sensors for measuring surface temperature and have a known surface area. See Fig. A1.1 for an example.

A1.2 It is acceptable to report the local total evaporative resistance value for each body zone in addition to the whole body total evaporative resistance value for the clothing ensemble. Each local total evaporative resistance value is calculated using Eq 1.

A1.2.1 It is difficult to determine the increase in surface area for a clothed individual body zone (that is, the clothing area factor). Therefore, local intrinsic evaporative resistance values shall not be reported.

A1.2.2 This test method uses the parallel method of calculating ensemble evaporative resistance. Therefore, the local total evaporative resistance values shall not be summed to determine the whole body total evaporative resistance value (serial method).

A1.2.3 Use caution in the interpretation of local total evaporative resistance data. Heat and moisture move from body zone to body zone within the clothing so they are not truly independent thermal measurements. The local values are also affected by the fit, layering, and coverage of the garments on the manikin's zones and on air flow patterns in the chamber.

A1.3 It is acceptable to report the local area-weighted total evaporative resistance value for a group of zones covered by a

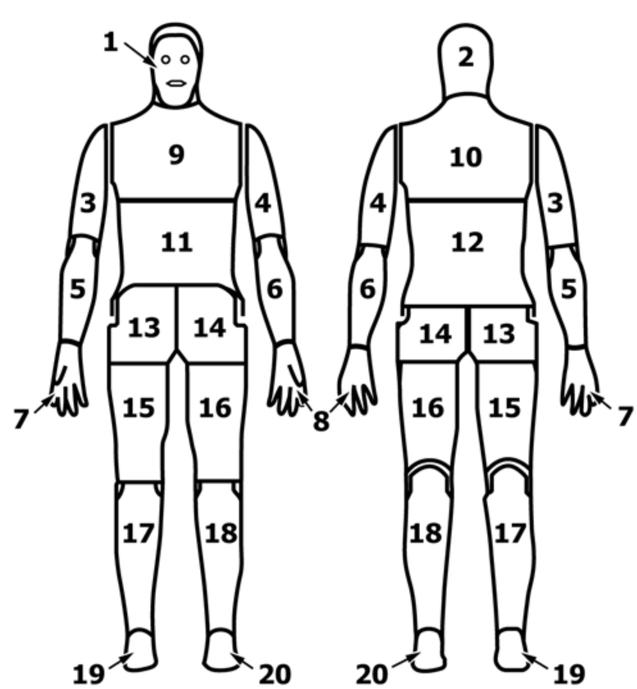

FIG. A1.1 Example of Thermal Zones on Manikin garment in addition to the whole body total evaporative resistance value for the clothing ensemble. It is calculated using the parallel method described in 9.1 and Eq 1.

A1.4 Test the garment by itself or in combination with other garments.

A1.5 Differences in garment evaporative resistance values will be more evident when the local total evaporative resistance values are compared (as opposed to ensemble evaporative resistance values).

A1.5.1 For example, compare shirts constructed of different materials in the same design using the local evaporative resistance values for the group of zones covered by the shirt.

A1.6 It is difficult to determine the increase in surface area for a group of clothed body zones (that is, the clothing area factor). Therefore, local intrinsic evaporative resistance values shall not be reported.