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Standard Test Method for Measuring the Thermal Insulation of Clothing Using a Heated Manikin[1]

This standard is issued under the fixed designation F1291; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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 insulation provided by 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. Insulation measurements made on fabrics alone do not take these factors into account. Measurements of the resistance to dry heat loss provided by clothing can be used to determine the thermal comfort or stress of people in cold to comfortable environments (see Practice F2732, ASHRAE 55-2013, and ISO 7730:2005). However, the moisture permeability of clothing is more important in environmental conditions where heat balance can only be achieved by the evaporation of sweat.

1. Scope

1.1 This test method covers the determination of the insulation value of clothing ensembles. It describes the measurement of the resistance to dry heat transfer from a heated manikin to a relatively calm, cool environment. Information on measuring the local thermal 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 insulation values obtained apply only to the particular ensembles evaluated and for the specified environmental conditions of each test, particularly with respect to air movement.

1.3 The values stated in either clo or SI units are to be regarded separately as standard. Within the text, the SI units are shown in parentheses. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other.

1.4 The evaporative resistance of a clothing ensemble can be measured in accordance with Test Method F2370.

1.5 *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 consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1518 Test Method for Thermal Resistance of Batting Systems Using a Hot Plate

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

F2370 Test Method for Measuring the Evaporative Resistance of Clothing Using a Sweating Manikin

F2732 Practice for Determining the Temperature Ratings for Cold Weather Protective Clothing

2.2 *ASHRAE Standards:*[3]

ASHRAE 55-2013 Thermal Environmental Conditions for Human Occupancy

[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 Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329, http://www.ashrae.org.

2.3 *ISO Standards:*[4]

ISO 7730:2005 Moderate Thermal Environments—Determination of the PMV and PPD Indices and Specification of the Conditions for Thermal Comfort

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 *clo, n*—unit of thermal resistance (insulation) equal to 0.155 K m^2/W.

3.1.1.1 *Discussion*—The value of the clo was selected as roughly the insulation value of typical indoor clothing, which should keep a resting man (producing heat at the rate of 58 W/m^2) comfortable in an environment at 21°C, air movement 0.1 m/s.

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

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

3.1.4 *thermal insulation, n*—the resistance to dry heat transfer via conduction, convection, and radiation.

3.1.4.1 *Discussion*—The following insulation values can be determined in this method using SI units:

R_a = thermal resistance (insulation) of the air layer on the surface of the nude manikin.

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

R_{cl} = intrinsic thermal resistance (insulation) of the clothing.

When the measurements are expressed in clo units, the symbol I is used instead of R.

I_a = thermal resistance (insulation) of the air layer on the surface of the nude manikin.

I_t = total thermal resistance (insulation) of the clothing and surface air layer around the manikin.

I_{cl} = intrinsic thermal resistance (insulation) of the clothing.

Total insulation values are measured directly with a manikin. Intrinsic clothing insulation values are determined by subtracting the air layer resistance around the clothed manikin from the total insulation value for the ensemble. Intrinsic clothing insulation values are used in several thermal comfort and clothing standards (see 2.1, 2.2, and 2.3).

4. Significance and Use

4.1 This test method can be used to quantify and compare the insulation provided by different clothing systems. For example, variations in the design and fabric used in component garments can be evaluated. The effects of garment layering, closure, and fit can be measured for clothing ensembles. The insulation values for ensembles can be used in models that predict the physiological responses of people in different environmental conditions. Garment insulation values can be compared as well (see Annex A1).

4.2 The measurement of the insulation provided by clothing is complex and dependent on 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, temperature, 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.

4.3 Report the insulation values in SI units or clo units as standard procedure. Conversion factors to other units are given in Test Method D1518.

5. Apparatus[5]

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 skin 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 *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 skin 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

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

[5] Information on laboratories with thermal manikins can be obtained from the Institute for Environmental Research, Kansas State University, Manhattan, KS 66506.

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 skin 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 temperatures shall be area-weighted when calculating the mean surface (skin) temperature. Distributed sensors must 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 ±1.0°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. The value of the mean air velocity must be reported, however. 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.

6.2 *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 insulation value than small air layers. Therefore, garments that do not have the appropriate fit on the manikin (that is, are 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 Manikin

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

7.1.1 The intrinsic clothing insulation value of the calibration ensemble (R_{cl}) is 0.122 °C·m^2/W or (I_{cl}) 0.79 clo, 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.[6] 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.[6]

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.

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.

8. Test Procedure

8.1 *Environmental Test Conditions*—The test conditions given below shall be standard for all tests.

8.1.1 *Air Temperature*—The air temperature shall be at least 12°C lower than the manikin's mean temperature (that is, 23°C) during a test. When ensembles with high insulation values are tested (for example, cold weather clothing), the air temperature shall be lowered so that a minimum heat flux of 20 W/m^2 from the manikin's segments is maintained.

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

8.1.3 *Relative Humidity*—Select a level between 30 and 80 % relative humidity ±5 %, preferably 50 %. The relative humidity has no effect on measurements of insulation under steady-state conditions.

8.1.4 If it is necessary to test the clothing ensembles in different environmental conditions (air temperature, air velocity, or relative humidity), the conditions must be clearly defined and reported.

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 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).

8.3.1 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 %).

8.3.2 After the manikin system reaches equilibrium conditions, record the manikin's surface temperatures, the air temperature, 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 insulation value.

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

8.5 *Nude Test*—Measure the insulation (R_a) provided by the air layer surrounding the nude manikin by conducting a test in the same environmental conditions used for the clothing tests. However, if a low temperature is being used to test cold weather clothing, it is feasible that the nude manikin's skin temperature will not be able to reach the 35°C set point. In this case, a higher air temperature is acceptable for the nude test. 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 thermal resistance (insulation) 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 thermal insulation of the clothing system, including the air layer resistance (R_t), using Eq 1:

$$R_t = (T_s - T_a)A/H \tag{1}$$

where:

R_t = total thermal resistance (insulation) of the clothing and surface air layer around the manikin (°C·m^2/W),
A = manikin's surface area (m^2),
T_s = manikin's surface temperature (°C),
T_a = air temperature (°C), and
H = power required to heat the manikin (W).

9.2 Determine the average total insulation value (R_t) 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 Convert the average R_t in SI units to I_t in clo units by multiplying R_t by 6.45.

[6] The sole source of supply of 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.

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

9.4 Determine the average intrinsic insulation value of the clothing alone (R_{cl}) using the mean R_t value and Eq 2:

$$R_{cl} = R_t - \frac{R_a}{f_{cl}} \tag{2}$$

where:

R_{cl} = intrinsic thermal resistance (insulation) of the clothing (°C·m²/W),
R_t = total thermal resistance (insulation) of the clothing and surface air layer around the manikin (°C·m²/W),
R_a = thermal resistance (insulation) of the air layer on the surface of the nude manikin (°C·m²/W),
f_{cl} = clothing area factor (dimensionless).

9.4.1 Estimate the f_{cl} by using values in Table 1 or ISO 9920:2007 or measure them using a photographic method.[7]

9.5 Convert the average R_{cl} in SI units to I_{cl} in clo units by multiplying R_{cl} by 6.45.

10. Report

10.1 State that the clothing ensembles were tested as directed in Test Method F1291.

10.2 Report the following information:

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

10.2.2 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 1—It is recommended to include a photograph of the manikin dressed in each clothing ensemble in the report.

10.2.3 Report the average total thermal resistance (insulation) value (R_t) or (I_t) of the clothing and surface air layer around the manikin.

10.2.4 Report the average intrinsic thermal resistance (insulation) value (R_{cl}) or (I_{cl}) of the clothing and the clothing area factor (f_{cl}) used to calculate it.

10.2.5 Report the thermal resistance (insulation) value of the air layer on the surface of the nude manikin (R_a) or (I_a).

10.2.6 Specify the environmental test conditions listed in 8.1.

10.2.7 Explain any departures from the specified apparatus or procedure.

10.2.8 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 insulation value for the calibration ensemble. Six labs had a sample of the calibration garments that fit their manikin. Three replications of the test were conducted. One labs' data were omitted from the statistical analysis because they were greater than 10 % from the mean. The intrinsic insulation value of the calibration ensemble (R_{cl}) was 0.122 °C·m²/W and (I_{cl}) was 0.79 clo. The 95 % repeatability limit (r) for data taken at a single lab was 0.009 °C·m²/W, and the 95 % reproducibility limit (R) was 0.024 °C·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 instruments. It is recommended that the insulation value 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 thermal insulation has no bias because the value can be defined only in terms of a test method.

12. Keywords

12.1 clothing insulation; protective clothing; thermal insulation; thermal manikin

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

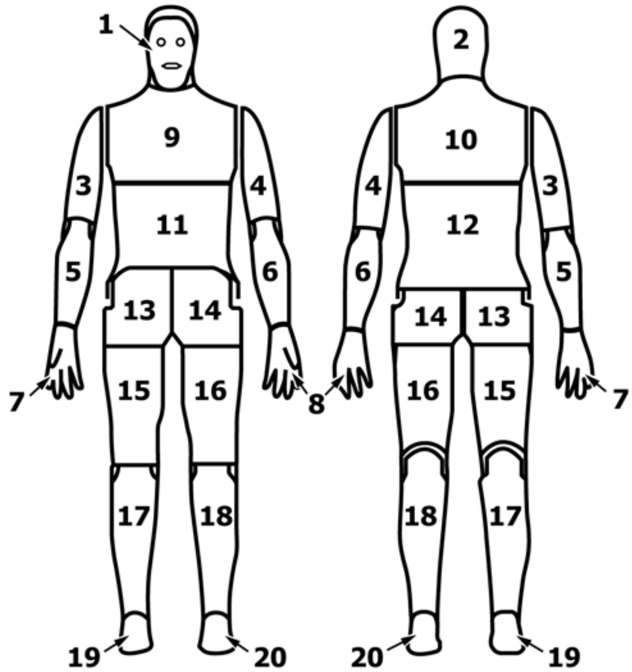

FIG. A1.1 Example of Thermal Zones on Manikin

ANNEX

(Mandatory Information)

A1. LOCAL THERMAL RESISTANCE DATA

A1.1 Most thermal 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 thermal resistance value for each body zone in addition to the whole body total insulation value for the clothing ensemble. Each local total thermal 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 insulation values shall not be reported.

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

A1.2.3 Use caution in the interpretation of local total thermal insulation data. Heat moves 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 thermal resistance value for a group of zones covered by a garment in addition to the whole body total insulation 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.

NOTE A1.1—If thick garments are placed on the nude manikin, there will be a large difference in the heat flux from the manikin's zones. It may be difficult to select an air temperature that will result in adequate power to the covered and uncovered parts of the manikin.

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

A1.5.1 For example, compare jackets constructed of different filling materials in the same design using the local total thermal resistance values for the group of zones covered by the jacket.

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 insulation values shall not be reported.