



Designation: F3672 – 23

Standard Test Method for Measuring the Evaporative Resistance of Clothing Items Using Heated Manikin Body Forms¹

This standard is issued under the fixed designation F3672; 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 reappraisal. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reappraisal.

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 thermal resistance (insulation) and evaporative resistance provided by a clothing ensemble are measured on full-body, life-size manikins according to Test Methods F1291 and F2370, respectively. These standards also discuss measuring the local total resistance values of garments by using only a few body parts (zones) covered by the clothing. However, more detailed data can be obtained from a dedicated body part manikin with several zones than from a full-body manikin where only one or two zones are used to take measurements. This detailed information about extremities is important, as they impact human thermal comfort and are often vulnerable to thermal injury. Test Method F3426 offers a means by which to measure detailed thermal resistance values of clothing items intended to be worn on the extremities, but detailed evaporative resistance values for these clothing items provide additional indicators of product performance. This is particularly true in end-use scenarios where latent heat transfer is the dominant mechanism for thermoregulation. The resistance values measured using body part manikins are dependent upon the designs and materials used in the component garments, the amount of body surface area covered by clothing, distribution of the fabric 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.

1. Scope

1.1 This test method covers the determination of the evaporative resistance of clothing items that cover only the head (Option 1), a hand (Option 2), or a foot (Option 3). It describes the measurement of the resistance to evaporative heat transfer from a heated sweating thermal manikin form to the testing environment.

1.1.1 This is a static test that provides a baseline clothing measurement on a stationary head manikin form (Option 1), hand manikin form (Option 2), or foot manikin form (Option 3).

1.1.2 The effects of body form position, movement, and contact with other surfaces are not addressed in this test method.

1.2 The evaporative resistance values obtained apply only to the particular clothing items evaluated and for the specified environmental conditions of each test.

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.

Current edition approved Nov. 1, 2023. Published November 2023. DOI: 10.1520/F3672-23.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*²

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

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.

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

F3426 Test Method for Measuring the Thermal Insulation of Clothing Items Using Heated Manikin Body Forms

2.2 *ASHRAE Standard*.³

ASHRAE 55 Thermal Environmental Conditions for Human Occupancy

2.3 *ISO Standard*.⁴

ISO 9920 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 ensemble, n*—a group of garments worn together on the body at the same time (for example, sock and boot).

3.1.2 *clothing item, n*—a garment or product worn as part of the clothing ensemble or separately.

3.1.2.1 *Discussion*—This standard only addresses clothing items or ensembles worn on the head, a hand, or a foot. Clothing ensembles may be comprised of a single clothing item or a system of multiple clothing items. For example, some handwear systems consist of multiple gloves (for example, liner and shell), mittens, or both. Clothing ensembles comprised of multiple distinct items may be evaluated using this test method.

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

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

3.1.4.1 *Discussion*—The evaporative resistance in units of $\text{kPa}\cdot\text{m}^2/\text{W}$ can be calculated for several different cases:

R_{ea} = evaporative resistance of the air layer on the surface of the sweating nude manikin body form,

R_{et} = total evaporative resistance of the clothing and surface air layer around the manikin body form, and

R_{ecl} = intrinsic evaporative resistance of the clothing.

3.1.4.2 *Discussion*—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 clothing item (or ensemble).

4. Significance and Use

4.1 This test method can be used to quantify and compare the evaporative resistance imposed by different clothing items or ensembles as long as each test is conducted using the same

experimental procedures and test conditions. For example, variations in the design and material used in gloves can be evaluated. The effects of layering, closures, and fit can also be measured.

4.2 The measurement of the evaporative resistance imposed 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

5.1 Manikin Body Forms:

5.1.1 Option 1 – Head Manikin:

5.1.1.1 *Manikin*—Use a manikin head form that is the size and shape of a representative human and heated to a constant, average surface temperature.

5.1.1.2 *Size and Shape*—The manikin head shall be constructed to simulate the head of a human being; that is, it shall consist of a head, chin, and nose. Ear protrusions are not required. Total surface area shall be $0.134 \text{ m}^2 \pm 15 \%$.

5.1.1.3 *Manikin Zones*—Construct the manikin head form with no less than four independent temperature-controlled zones. At a minimum the top of the head, the back of the head, the eye/forehead area, and the mouth area shall be independent zones.

5.1.1.4 *Guard Zone*—Construct the manikin head form with a guard zone butting up against the terminus of the head/neck (where the head form would connect to the rest of a body if it were a full-body manikin). Heat this zone to the same constant temperature as all other zones to prevent unwanted heat loss from the manikin head form into the apparatus or environment. This zone shall not be included as one of the four required manikin zones.

5.1.2 Option 2 – Hand Manikin:

5.1.2.1 *Manikin*—Use a hand manikin form that is the size and shape of a representative human's left or right hand and heated to a constant, average surface temperature.

5.1.2.2 *Size and Shape*—The hand manikin shall be constructed to simulate the hand and wrist/forearm of an adult human being; that is, it shall consist of a wrist/forearm, palm and back of hand, four finger digits, and a thumb digit with fingers extended to allow gloves to be worn. Total surface area of form shall be $0.069 \text{ m}^2 \pm 15 \%$.

NOTE 1—Based on the specified manikin dimensions, use appropriately sized glove specimens approximately size 8 to 10 (medium to large).

5.1.2.3 *Manikin Zones*—Construct the manikin hand form with no less than four independent temperature-controlled zones. At a minimum the palm, the fingers, the back of the hand, and the wrist shall be independent zones.

³ Available from American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 180 Technology Pkwy., NW, Peachtree Corners, GA 30092, <http://www.ashrae.org>.

⁴ Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, <https://www.iso.org>.