



Designation: F2732 – 23

Standard Practice for Determining the Temperature Ratings for Cold Weather Protective Clothing¹

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INTRODUCTION

Manufacturers of cold weather protective clothing want consumers to be thermally comfortable when wearing their products. Therefore, they want to indicate the amount of warmth (that is, insulation) their products will provide to consumers at the point of sale. This is often expressed as a temperature rating on product labels and in product descriptions in catalogs. A temperature rating is commonly understood to mean the lowest air temperature at which the average adult person will have an acceptable level of thermal comfort when wearing the product. Although it is not always stated on labels or in catalogs, manufacturers are assuming that consumers will wear the appropriate amount of clothing with the cold weather garments.

Heated manikins are used to measure the thermal resistance (insulation) and evaporative resistance of clothing ensembles in accordance with Test Methods **F1291** and **F2370**, respectively. The thermal insulation value of a cold weather protective ensemble is used in heat loss models to estimate the thermal comfort of people in cold environments. This approach is also used for sleeping bags (see ISO 23537-1).

1. Scope

1.1 This standard practice covers the determination of the temperature rating of a cold weather protective clothing garment or system of garments when worn with one of two base ensembles. It involves measuring the thermal resistance (insulation) value of a clothing ensemble (base ensemble plus the garment or garment system being evaluated) with a heated manikin in accordance with Test Method **F1291**. The result is used in a heat loss model to predict the lowest environmental temperature for comfort.

1.2 The predictive model used in this standard estimates the evaporative heat loss from a person wearing cold weather clothing as opposed to measuring the evaporative resistance on a sweating manikin. If a person is active and gets overheated in a cold environment, he/she is usually able to adjust the garments to dissipate excess heat.

1.3 The temperature ratings estimated by this standard practice are guidelines for thermal comfort, determined from a whole-body heat loss model (see **Annex A1**). Therefore,

localized cooling, discomfort, and even frostbite could still occur at extremely low temperatures because clothing insulation is not evenly distributed over the body surface. In addition, some body parts (for example, ears, fingers, toes) have a high surface area relative to their mass, and consequently lose heat at a faster rate than other parts of the body.

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**

¹ This practice 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.

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

2.2 Other Standards:

ISO 23537-1 Requirements for Sleeping Bags—Part 1: Thermal, Mass and Dimensional Requirements for Sleeping Bags Designed for Limit Temperatures of -20°C and Higher³

ASHRAE 55-2020 Thermal Environmental Conditions for Human Occupancy⁴

3. Terminology

3.1 Definitions:

3.1.1 *clo*, *n*—a unit of thermal resistance (insulation) equal to $0.155^{\circ}\text{C}\cdot\text{m}^2/\text{W}$.

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 person (producing heat at the rate of 58 W/m^2) comfortable in an environment at 21°C , air movement 0.1 m/s . When *clo* was developed, typical indoor clothing consisted of a three-piece suit and light underclothes.

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 *temperature rating*, *n*—the lowest environmental temperature at which a person can remain thermally neutral while wearing a particular clothing ensemble.

3.1.5 *thermal comfort*, *n*—that condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation (see ASHRAE 55-2020).

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

3.1.6.1 Discussion—The following insulation values can be determined with a thermal manikin:

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 ensemble and surface air layer around the manikin, and

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

R_a , R_t , and R_{cl} are typically used for SI units, while I_a , I_t , and I_{cl} are typically used with *clo* units. 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.

4. Significance and Use

4.1 This practice is used to measure the insulation provided by a cold weather clothing garment or garment system using a heated manikin (see Test Method **F1291**) and to predict the

temperature rating for comfort at two activity levels using whole-body heat loss models.

4.1.1 The temperature rating is for an ensemble—not an individual garment. However, manufacturers want to label cold weather garments or garment systems with a temperature rating to help consumers select the product that will best meet their needs. Therefore, the insulation of a garment or garment system is measured with a standard base ensemble. Furthermore, the standard is limited to garments that cover a substantial amount of body surface area such as jackets, coats, insulated pants, coveralls, or snow suits. The temperature ratings of headwear, footwear, and handwear cannot be determined with this practice.

4.1.2 The temperature predictions determined by this standard practice are for adults only. The physiology of children is significantly different from that of adults, so a modified heat loss model needs to be used to predict the comfort of children wearing outdoor clothing.⁵

4.1.3 The temperature ratings determined by this standard practice and listed on garment labels are only guidelines for comfort and will be affected by the garments consumers wear with them, their activity level during wear, and individual differences in the physiological characteristics of people (for example, gender, age, body mass, etc.).

5. Calibration of Manikin

5.1 *Manikin*—Use a thermal manikin as described in Test Method **F1291**.

5.2 *Calibration*—Calibrate the manikin using the procedures in Test Method **F1291**.

5.2.1 The intrinsic clothing insulation value of the Test Method **F1291** calibration ensemble (R_{cl}) shall be within $\pm 10\%$ of the reference value before proceeding with this method.

6. Base Ensembles

6.1 A cold weather garment or garment system is typically worn with other garments as part of an ensemble. Therefore, garment or garment systems shall be tested with a base ensemble to determine the temperature for comfort. All cold weather jackets, coveralls, and jacket/pant sets (where the jacket/pant sets are worn together) shall be tested with a lightweight base ensemble that represents the minimum amount of clothing that a reasonable person might wear with the cold weather clothing (Base Ensemble #1). All cold weather pants shall be tested with a base jacket added to the base ensemble (Base Ensemble #2). The size of the garments shall be selected based on the measurements of the manikin.

6.2 The garments used in Base Ensemble #1 are:

6.2.1 *Shirt*—Long-sleeve mock turtleneck shirt, 214 g/m^2 (6.3 oz/yd^2) $\pm 10\%$; worn with shirttail over jeans.

6.2.2 *Jeans*—Denim jeans, 397 g/m^2 (11.7 oz/yd^2) $\pm 10\%$.

6.2.3 *Men's Underwear Briefs*—Jersey knit briefs, 180 g/m^2 (5.3 oz/yd^2) $\pm 10\%$; jockey style that fits snugly at the

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

⁴ Available from American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 180 Technology Parkway, Peachtree Corners, GA 30092, <http://www.ashrae.org>.

⁵ McCullough, E. A., Eckels, S., and Harms, C., “Determining Temperature Ratings for Children’s Cold Weather Clothing,” *Applied Ergonomics*, Vol 40, 2009, pp. 870–877.