Designation: F2300 – 10 (Reapproved 2022)

Standard Test Method for Measuring the Performance of Personal Cooling Systems Using Physiological Testing[1]

This standard is issued under the fixed designation F2300; 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

Individuals in various occupations are exposed to high heat stress resulting from increased metabolism, or the environment, or both. Environmental heat stress can be especially severe when individuals are required to wear Personal Protective Equipment (PPE), which impairs or prevents evaporation of sweat from the skin, and thus nullifies the body's principal means of removing metabolic heat. Failure to dissipate this heat can dramatically limit work capacity and heat tolerance, thereby increasing the risk of heat-related illness. To reduce this risk, workers are wearing Personal Cooling Systems (PCS) to extend their exposure time to thermal stress. These systems are intended to limit the effects of external environmental heat and the internally generated metabolic heat on the body. For this purpose, standards that objectively quantify the effectiveness of PCS are essential. Therefore, tests that measure important physiological variables, such as core temperature, are essential in evaluating PCS applications and increasing worker's health and safety.

1. Scope

1.1 This test method covers the physiological measurement of internal body core temperature, skin temperature, thermal exposure time, heart rate response, oxygen consumption, and whole body sweat rate, to assess the effectiveness of personal cooling systems (PCS) in reducing the effects of thermal stress.

1.1.1 To increase safety during physiological testing, this dynamic test requires the use of human participants who exhibit specific health and physical fitness requirements.

1.2 This test incorporates the use of protective clothing ensembles (outer garments) used in conjunction with or worn over top of the PCS. This scope is therefore oriented to industrial rather than athletic applications.

1.2.1 The effectiveness of different PCS will be quantified with the same protective clothing ensemble. Therefore, the physiological values obtained apply only to the cooling systems, the particular protective outer garment, and the specific test conditions.

1.2.2 When a protective outer garment is not provided, this test method requires that PCS shall be tested with the standard outer garment defined within this test method.

1.2.3 The present standard does not attempt to determine important clothing characteristics, such as thermal insulation and evaporative resistance, of the PCS or of the garments worn with the PCS. Test Methods F1291 and F2370 can be referenced for these clothing measurements.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 It is the responsibility of the test laboratory to obtain the necessary and appropriate approval(s) required by their institution for conducting tests using human participants.

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

[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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1.6 *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

F1494 Terminology Relating to Protective Clothing

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

2.2 *Other Standards:*

ISO 8996 Ergonomics—Determination of Metabolic Heat Production[3]

ISO 9886 Ergonomics—Evaluation of Thermal Strain by Physiological Measurements[3]

The Commission for Thermal Physiology of the International Union of Physiological Sciences (IUPS Thermal Commission) Glossary of Terms for Thermal Physiology[4]

U.S. Food and Drug Administration (FDA) Cleared Sterilants and High Level Disinfectants with General Claims for Processing Reusable Medical and Dental Devices (March 2009)[5]

3. Terminology

3.1 *Definitions:*

3.1.1 *acclimation, n*—physiological adaptations occurring within an organism, which reduces the strain or enhances endurance of strain, caused by artificially or experimentally induced stressful changes in particular environmental conditions.

3.1.1.1 *Discussion*—Acclimation describes the adaptive changes that occur within an organism in response to artificially induced changes in particular climatic factors such as ambient temperature and humidity in a controlled environment.

3.1.2 *acclimatization, n*—physiological adaptations occurring within an organism, which reduces the strain or enhances endurance of strain, caused by stressful changes in the natural environment.

3.1.3 *clo, n*—unit of thermal resistance defined as the insulation required to keep a resting man (producing heat at the rate of 58 W/m^2) comfortable in an environment at 21 °C, air velocity 0.1 m/s, or roughly the insulation value of typical indoor clothing.

3.1.3.1 *Discussion*—Numerically the clo is equal to 0.155 K·m^2/W, which is equal to 0.18°C·m^2·h/kcal.

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

3.1.5 *core temperature, n*—the mean temperature of the thermal core.

3.1.5.1 *Discussion*—Core temperature is commonly represented by rectal temperature, or by the more rapidly responding esophageal temperature. Core temperature is also measured by ingested telemetric thermometers in the form of a capsule.

3.1.6 *garment, n*—a single item of clothing (for example, shirt).

3.1.7 *maximum oxygen consumption (VO_{2max}), n*—the highest rate at which an organism can take up oxygen during aerobic metabolism.

3.1.7.1 *Discussion*—Determination of VO_{2max} requires very high motivation of the individual and is expressed in mL per min or as a term relative to body mass in mL per kg per min. Maximum oxygen consumption is often referred to as maximal aerobic power (MAP).

3.1.8 *metabolic rate, n*—the rate of transformation of chemical energy into heat and mechanical work by aerobic and anaerobic activities within an organism.

3.1.8.1 *Discussion*—Metabolic rate, as with VO_{2max}, is commonly measured by indirect calorimetry, during long-term steady-state work, and is typically expressed in Watts (W). Metabolic rate, also referred to as energy expenditure, is usually expressed in terms of unit area of the total body surface (W/m^2) or of total body mass (W/kg) when comparisons are made between individuals.

3.1.9 *thermal core, n*—the deep tissues of the brain, neck, and torso whose temperatures are not changed in their relationship to each other by circulatory adjustments.

3.1.9.1 *Discussion*—These deep tissues comprise the most thermally protected tissues of the body and are most critical to temperature regulation. The thermal core is distinct from changes in heat transfer to the environment that affects the appendages and other tissues of the body.

3.1.10 *thermal insulation, n*—the resistance to dry heat transfer by way of conduction, convection, and radiation.

3.1.11 *thermal strain, n*—any deviation of body temperature induced by sustained thermal stress that cannot be fully compensated by temperature regulation.

3.1.11.1 *Discussion*—Thermal strain results in the activation of thermoeffector activities that causes sustained changes in the state of non-thermal regulatory systems. Thermal strain is measurable by an increased heart rate and whole body sweat rate, as determined by pre and post nude mass loss.

3.1.12 *thermal stress, n*—any thermal change between a temperature regulator and its environment, which if uncompensated by temperature regulation, would result in hyperthermia.

3.1.12.1 *Discussion*—Thermal stress is often referred to as heat stress.

[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.

[4] Available from Physiology & Biophysics School of Medicine, Case Western Reserve University, 10900 Euclid Avenue Cleveland, OH 44106-4970, http://www.iups.org.

[5] Available from U.S. Food and Drug Administration (FDA), 10903 New Hampshire Ave., Silver Spring, MD 20993, http://www.fda.gov.