Designation: F2668 – 16 (Reapproved 2022)

Standard Practice for Determining the Physiological Responses of the Wearer to Protective Clothing Ensembles[1]

This standard is issued under the fixed designation F2668; 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

Protective clothing ensembles such as firefighter turnout gear, HAZMAT suits, and bomb suits may impose a physiological strain on the wearer. This strain can take the form of heat stress and cardiovascular and respiratory strain, which can result in injury to the wearer. This practice provides information on the measurement of the physiological responses of a wearer to a protective clothing ensemble. The protocol is designed to allow comparisons of the physiological responses of subjects wearing different protective clothing ensembles of the same type (for example, firefighter turnout gear) and from different types (for example, firefighter ensemble versus HAZMAT suit).

1. Scope

1.1 This practice specifies the test equipment and procedures for determining the physiological responses of subjects wearing a protective clothing ensemble.

1.2 This practice covers the physiological measurement of internal body core temperature, skin temperature, exposure time, heart rate response, oxygen consumption, and whole body sweat rate to assess the physiological responses of subjects wearing a protective clothing ensemble. This practice does not measure the musculoskeletal strain on the participant imposed by the protective clothing ensemble.

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

1.3 The present standard does not attempt to determine important clothing characteristics, such as thermal insulation and evaporative resistance of the protective clothing ensemble. Test Methods F1291 and F2370 can be used for these clothing measurements.

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

1.5 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.

1.6 *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.*

1.7 *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

F2300 Test Method for Measuring the Performance of Personal Cooling Systems Using Physiological Testing

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

2.2 *Other Standards:*[3]

ISO 8996 Ergonomics—Determination of Metabolic Heat Production

ISO 9886 Ergonomics—Evaluation of Thermal Strain by Physiological Measurements

[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.

Current edition approved Feb. 1, 2022. Published February 2022. Originally approved in 2007. Last previous edition approved in 2016 as F2668 – 16. DOI:10.1520/F2668-16R22.

[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.

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

3. Terminology

3.1 *Definitions:*

3.1.1 *acclimation, n*—physiological adaptations occurring within an organism, which reduce the strain or enhance 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 reduce the strain or enhance endurance of strain, caused by stressful changes in the natural environment.

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

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

3.1.4.1 *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.

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

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

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

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

3.1.7.1 *Discussion*—Metabolic rate, as with VO_{2max}, is commonly measured by indirect calorimetry, during long-term steady-state work. 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).

3.1.8 *protective ensemble, n*—the combination of protective clothing with respiratory protective equipment, hoods, helmets, gloves, boots, communication systems, cooling devices, and other accessories intended to protect the wearer from a potential hazard when worn together.

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

3.1.10.1 *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.

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

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

3.2 IUPS Thermal Commission document[4] was referenced for the modified definitions related to thermal physiology listed above. For terms related to protective clothing used in this practice, refer to Terminology F1494.

4. Significance and Use

4.1 This practice can be used for the evaluation of the physiological response of a user to protective clothing ensembles worn under controlled conditions.

4.1.1 This practice utilizes a treadmill for the exercise protocol. This method is believed to be appropriate for the evaluation of the majority of protective clothing ensembles, especially where the user will be walking or performing similar activities. In certain situations where a protective clothing ensemble is designed to be worn where the user is performing specialized functions (for example, sitting or standing with only arm movement), alternate exercise equipment (for example, arm cycle-ergonometer) or exercise protocols should be considered for use in determining the physiological response of the subject.

4.1.2 Where evaluations include the use of personal cooling systems, refer to Test Method F2300.

4.2 This practice establishes general procedures for the physiological evaluation based on the physiological measurement of core temperature, mean skin temperature, heart rate, exposure time, oxygen consumption, and whole body sweat rate.

4.2.1 The data obtained can be used to evaluate the overall physiological response of the test participant while wearing a protective clothing ensemble.

4.2.2 The data may also be used in the research and development of advanced ensembles that are designed to reduce the physiological strain on the wearer, thereby reducing the potential injury (for example, heat injury) associated with wearing the protective clothing ensemble. Workers may be able to wear a protective clothing ensemble for a longer duration due to a reduction in the physiological strain.

[4] *The Japanese Journal of Physiology*, Vol 51, No. 2, 2001.