Designation: ~~F1930 – 15~~ F1930 – 17

Standard Test Method for Evaluation of Flame Resistant Clothing for Protection Against Fire Simulations Using an Instrumented Manikin[1]

This standard is issued under the fixed designation F1930; 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.

1. Scope

1.1 This test method is used to provide predicted human skin burn injury for single layer garments or protective clothing ensembles mounted on a stationary upright instrumented manikin which are then exposed in a laboratory to a simulated fire environment having controlled heat flux, flame distribution, and duration. The average exposure heat flux is 84 kW/m^2 ~~(2~~ (2 cal ~~cal/s•cm~~/s·cm^2), with durations up to 20 ~~seconds.~~s.

1.2 The visual and physical changes to the single layer garment or protective clothing ensemble are recorded to aid in understanding the overall performance of the garment or protective clothing ensemble and how the predicted human skin burn injury results can be interpreted.

1.3 The skin burn injury prediction is based on a limited number of experiments where the forearms of human subjects were exposed to elevated thermal conditions. This forearm information for skin burn injury is applied uniformly to the entire body of the manikin, except the hands and feet. The hands and feet are not included in the skin burn injury prediction.

1.4 The measurements obtained and observations noted can only apply to the particular garment(s) or ensemble(s) tested using the specified heat flux, flame distribution, and duration.

1.5 This standard is used to measure and describe the response of materials, products, or assemblies to heat and flame under controlled conditions, but does not by itself incorporate all factors required for fire-hazard or fire risk assessment of the materials, products, or assemblies under actual fire conditions.

1.6 This method is not a fire-test-response test method.

1.7 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units or other units commonly used for thermal testing. If appropriate, round the non-SI units for convenience.

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

1.9 Fire testing is inherently hazardous. Adequate safeguards for personnel and property shall be employed in conducting these tests.

1.10 *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]

D123 Terminology Relating to Textiles

D1835 Specification for Liquefied Petroleum (LP) Gases

D3776/D3776M Test Methods for Mass Per Unit Area (Weight) of Fabric

D5219 Terminology Relating to Body Dimensions for Apparel Sizing

[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 F23.80 on Flame and Thermal.

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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.

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E457 Test Method for Measuring Heat-Transfer Rate Using a Thermal Capacitance (Slug) Calorimeter
E511 Test Method for Measuring Heat Flux Using a Copper-Constantan Circular Foil, Heat-Flux Transducer
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
E2683 Test Method for Measuring Heat Flux Using Flush-Mounted Insert Temperature-Gradient Gages
F1494 Terminology Relating to Protective Clothing

2.2 *AATCC Standards:*[3]
Test Method 135 Dimensional Changes of Fabrics after Home Laundering
Test Method 158 Dimensional Changes on Dry-Cleaning in Perchloroethylene: Machine Method

2.3 *Canadian Standards:*[4]
CAN/CGSB-4.2 No. 58-M90 Textile Test Methods Colorfastness and Dimensional Change in Domestic Laundering of Textiles
CAN/CGSB-3.14 M88 Liquefied Petroleum Gas (Propane)

2.4 *NFPA Standards:*[5]
NFPA 54 National Fuel Gas Code, 2009 Edition
NFPA 58 Liquefied Petroleum Gas Code 2008 Edition
NFPA 85 Boiler and Combustion Systems Hazards Code, 2007 Edition
NFPA 86 Standard for Ovens and Furnaces, 1999 Edition

3. Terminology

3.1 For definitions of terms used in this test method, use the following documents. For terms related to textiles refer to Terminology D123, for terms related to protective clothing refer to Terminology F1494, and for terms related to body dimensions refer to Terminology D5219.

3.2 *Definitions:*

3.2.1 *burn injury, n*—thermal damage which occurs to human skin at various depths and is a function of local temperature and time.

[3] Available from American Association of Textile Chemists and Colorists (AATCC), P.O. Box 12215, Research Triangle Park, NC 27709, http://www.aatcc.org.
[4] Available from Standards Council of Canada, Suite 1200, 45 O'Conor St., Ottawa, Ontario, K1P 6N7.
[5] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, http://www.nfpa.org.

3.2.1.1 *Discussion—*

Burn injury in human tissue occurs when the tissue is heated above a critical temperature ~~(44°C~~(44 °C (317.15 K) or ~~111°F).~~111 °F). Thermal burn damage to human tissue depends on the magnitude of the temperature rise above the critical value and the duration that the temperature is above the critical value. Thus, damage can occur during both the heating and cooling phases of an exposure. The degree of burn injury (second or third degree) depends on the maximum depth within the skin layers to which tissue damage occurs. The first-degree burn injury is considered minor relative to second-degree and third-degree burn injuries. It is not included in the evaluation of test specimens in this test method (see Appendix X1).

3.2.2 *fire exposure, n*—in the fire testing of clothing, the fire exposure is a propane-air diffusion flame with a controlled heat flux and spatial distribution, engulfing the manikin for a controlled duration.

3.2.2.1 *Discussion—*

The flames are generated by propane jet diffusion burners. Each burner produces a reddish-orange flame with accompanying black smoke (soot).

3.2.3 *flame distribution, n*—in the fire testing of clothing, a spatial distribution of incident flames from burners to provide a controlled heat flux over the surface area of the manikin.

3.2.4 *heat flux, n*—the heat flow rate through a surface of unit area perpendicular to the direction of heat flow (kW/m^2) ~~(cal/s•cm~~(cal/s·cm^2).

3.2.4.1 *Discussion—*

Two different heat fluxes are referred to in this test method: incident and absorbed. The incident heat flux refers to the energy striking the nude manikin, or the exterior ~~fo~~of the test specimen when mounted on the manikin, during flame engulfment. The absorbed heat flux refers to only the portion of the incident heat flux which is absorbed by each thermal energy sensor based on its absorption characteristics. The incident heat flux is used in setting the required exposure conditions while the absorbed heat flux is used in calculating the predicted skin burn injury.

3.2.5 *instrumented manikin, n*—in the fire testing of clothing, a structure designed and constructed to represent an adult-size human and which is fitted with thermal energy (heat flux) sensors onat its surface.

3.2.5.1 *Discussion*—

The manikin is fabricated to specified dimensions from a high temperature resistant temperature-resistant material (see 6.1). The instrumented manikin used in fire testing of clothing is fitted with at least 100 thermal energy sensors, distributed over the manikin surface. The feet and hands are not normally fitted with sensors. If the feet and hands are equipped with sensors, it is up to the user to define a procedure to interpret the results.

3.2.6 *predicted second-degree burn injury, n*—a calculated second-degree burn injury to skin based on measurements made with a thermal energy sensor.

3.2.6.1 *Discussion*—

For the purposes of this standard, predicted second-degree burn injury is defined by the burn injury model parameters (see Section 12 and Appendix X1). Some laboratories have unequally spaced sensors and assign an area to each sensor over which the same burn injury prediction is assumed to occur, others do not.occur; others, with equally spaced sensors, have equal areas for each sensor.

3.2.7 *predicted third-degree burn injury, n*—a calculated third-degree burn injury to skin based on measurements made with a thermal energy sensor.

3.2.7.1 *Discussion*—

For the purposes of this standard, predicted third-degree burn injury is defined by the burn injury model parameters (see Section 12 and Appendix X1). Some laboratories have unequally spaced sensors and assign an area to each sensor over which the same burn injury prediction is assumed to occur, others do not.occur; others, with equally spaced sensors, have equal areas for each sensor.

3.2.8 *predicted total burn injury, n*—in the fire testing of clothing, the manikin surface area represented by all thermal energy sensors registering a predicted second-degree or predicted third-degree burn injury, expressed as a percentage (see 13.5).

3.2.9 *second-degree burn injury, n*—complete necrosis (living cell death) of the epidermis skin layer (see Appendix X1).

3.2.10 *thermal energy sensor, n*—a device which produces an output suitable for calculating incident and absorbed heat fluxes.

3.2.10.1 *Discussion*—

Types of sensors which have been used successfully include slug calorimeters, surface and buried temperature measurements, and circular foil heat flux gauges. Some types of sensors approximate the thermal inertia of human skin and some do not. The known sensors in current use have relatively small detection areas. An assumption is made for the purposes of this method that thermal energy measured in these small areas can be extrapolated to larger surrounding surface areas so that the overall manikin surface can be approximated by a minimum number of sensors. The resulting sensor predicted sensor-predicted burn injury applies to the extrapolated coverage area. Some laboratories assign different coverage areas to each sensor over which the same burn injury prediction is assumed to apply, others do not apply; others, with equally spaced sensors, have equal areas for each sensor (see 6.2.2.1).

3.2.11 *thermal protection, n*—the property that characterizes the overall performance of a garment or protective clothing ensemble relative to how it retards the transfer of heat thermal energy that is sufficient to cause a predicted second-degree or predicted third-degree burn injury.

3.2.11.1 *Discussion*—

Thermal protection of a garment or ensemble and the consequential predicted burn injury (second-degree and third-degree), is quantified from the response of the thermal energy sensors and use of thea skin burn injury prediction model. In addition to the calculated results, the physical response and degradation of the garment or protective clothing ensemble is an observable phenomenon useful in understanding garment or protective clothing ensemble thermal protection.