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Standard Test Method for Evaluation of Flame Resistant Clothing for Protection Against ~~Flash~~ 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 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 cal/s•cm^2), with durations up to 20 seconds.

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 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 except for 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.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D123 Terminology Relating to Textiles

D1835 Specification for Liquefied Petroleum (LP) Gases

D5219 Terminology Relating to Body Dimensions for Apparel Sizing

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

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

F1494 Terminology Relating to Protective Clothing

2.2 *AATCC Standards:*[3]

Test Method 135 Dimensional Changes of Fabrics after Home Laundering

[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.

[3] Available from American Association of Textile Chemists and Colorists (AATCC), P.O. Box 12215, Research Triangle Park, NC 27709, http://www.aatcc.org.

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, 2007 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.

3.2.1.1 *Discussion*—Burn injury in human tissue occurs when the tissue is heated above a critical temperature (44°C (317.15 K) or 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. 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 *instrumented manikin*, *n*—a structure designed and constructed to represent an adult-size human and which is fitted with thermal energy (heat flux) sensors on its surface.

3.2.4.1 *Discussion*—The manikin is fabricated to specified dimensions from a high temperature resistant material. The instrumented manikin used in fire testing of clothing is fitted with at least 100 thermal energy (heat flux) 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.

3.2.5 *predicted second-degree burn injury*, *n*—in the fire testing of clothing, a calculated second-degree burn injury to skin based on measurements made with a thermal energy sensor.

3.2.5.1 *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 assign an area to each sensor over which the same burn injury prediction is assumed to occur, others do not.

3.2.6 *predicted third-degree burn injury*, *n*—in the fire testing of clothing, a calculated third-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 third-degree burn injury is defined by the burn injury model parameters (see Section 12 and Appendix X1). Some laboratories assign an area to each sensor over which the same burn injury prediction is assumed to occur, others do not.

3.2.7 *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.

3.2.8 *second-degree burn injury*, *n*—in the fire testing of clothing, complete necrosis (living cell death) of the epidermis skin layer.

3.2.9 *thermal energy sensor*, *n*—a device capable of measuring directly the incident heat flux at its surface or one which gives an output which is used to calculate the incident heat flux.

3.2.9.1 *Discussion*—Types of sensors which have been used successfully include slug calorimeters, surface and buried temperature measurements and thin film 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

[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.

the overall manikin surface can be approximated by a minimum number of sensors. The resulting sensors 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 (see 6.2.1.1).

3.2.10 *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 that is sufficient to cause a predicted second-degree or predicted third-degree burn injury.

3.2.10.1 *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 the 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.

3.2.11 *third-degree burn injury*, *n*—in the fire testing of clothing, complete necrosis (living cell death) of the epidermis and dermis skin layers.

4. Summary of Test Method

4.1 This test method covers quantitative measurements and subjective observations that characterize the performance of single layer garments or protective clothing ensembles mounted on a stationary instrumented manikin. The conditioned test specimen is placed on the instrumented manikin at ambient atmospheric conditions and exposed to a propane-air diffusion flame with controlled heat flux, flame distribution and duration. The average exposure heat flux is 84 kW/m ^{2}(2 cal/s•cm^2) with durations up to 20 seconds.

4.2 The test procedure, data acquisition, calculation of results and preparation of parts of the test report are performed with computer hardware and software programs. The complexity of the test method requires a high degree of technical expertise in the test setup and operation of the instrumented manikin and the associated data collection and analysis software.

4.3 Thermal energy transferred through and from the test specimen during and after the exposure is measured by thermal energy sensors. The sensors are located at the surface of the manikin. They are used to measure the thermal energy absorbed as a function of time over a preset time interval. A computer based data acquisition system is used to store the time varying output from the sensors.

4.4 Computer software uses the stored data to calculate the heat flux and its variation with time at the surface of each sensor. The calculated heat flux and its variation with time at the surface is used to calculate the temperature within human skin and subcutaneous layers (adipose) as a function of time. The temperature history within the skin and subcutaneous layers (adipose) is used to predict the onset and severity of human skin burn injury. The computer software calculates the predicted second-degree and predicted third-degree burn injury and the total predicted burn injury resulting from the exposure.

4.5 The overall percentage of predicted second-degree, predicted third-degree and predicted total burn injury is calculated by dividing the total number of sensors indicating each of these conditions by the total number of sensors on the manikin. Alternately, the overall percentages are calculated using sensor area weighted techniques for facilities with non-uniform sensor coverage. A reporting is also made of the above conditions where the areas that are uncovered by the test specimen are excluded. This test method does not include the ~12 % of body surface area represented by the unsensored manikin feet and hands. No corrections are applied for their exclusion.

4.6 The visual and physical changes to the test specimen are recorded to aid in understanding overall performance and how the resulting burn injury results can be interpreted.

4.7 Identification of the test specimen, test conditions, comments and remarks about the test purpose, and response of the test specimen to the exposure are recorded and are included as part of the report.

4.8 The performance of the test specimen is indicated by the calculated burn injury area and subjective observations of material response to the test exposure.

4.9 Appendix X1 contains a general description of human burn injury, its calculation and historical notes.

5. Significance and Use

5.1 Use this test method to measure the thermal protection provided by different materials, garments, clothing ensembles, and systems to a specified fire exposure (see 3.2.2, 4.1, 10.1.3, and 10.1.4).

5.1.1 This test method does not simulate high radiant exposures, for example, those found in electric arc flash exposures, some types of fire exposures where liquid or solid fuels are involved, nor exposure to nuclear explosions.

5.2 This test method provides a measurement of garment and clothing ensemble performance on a stationary upright manikin of specified dimensions. This test method is used to provide predicted skin burn injury for a specific garment or protective clothing ensemble when exposed to a laboratory simulation of a fire. It does not establish a pass/fail for material performance.

5.2.1 This test method is not intended to be a quality assurance test. The results do not constitute a material's performance specification.

5.2.2 The effects of body position and movement are not addressed in this test method.

5.3 The measurement of the thermal protection provided by clothing is complex and dependent on 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