Designation: F2733 – 09

Standard Specification for Flame Resistant Rainwear for Protection Against Flame Hazards[1]

This standard is issued under the fixed designation F2733; 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 specification establishes applicable test methods, minimum physical and thermal performance criteria, a suggested sizing guide, and suggested purchasing information for rainwear for use by workers who are potentially exposed to industrial hydrocarbon fires or other petrochemical fire hazards.

1.1.1 This specification does not apply to rainwear used for thermal electric arc flash hazards. Specification of rainwear for these electric arc flash hazards are addressed in Specification F1891.

1.2 The objective of this specification is to prescribe function and performance criteria for rainwear that meets a minimum level of thermal and physical performance when exposed to a laboratory-simulated fire exposure.

1.3 This specification is not intended to serve as a detailed manufacturing or purchasing specification, but can be referenced in purchase contracts to ensure that minimum performance requirements are met.

1.4 Controlled laboratory tests used to determine compliance with the performance requirements of this specification shall not be deemed as establishing performance levels for all situations to which wearers of this protective clothing are potentially exposed.

1.5 This specification does not attempt to establish in-service care and use of this flame resistant rainwear.

1.6 The values stated in SI units are to be regarded as standard. The values given in brackets are mathematical conversions to inch-pound or other units that are commonly used for thermal testing.

1.7 The following safety hazards caveat pertains to Sections 7 and 9 of this specification. *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D123 Terminology Relating to Textiles
D751 Test Methods for Coated Fabrics
D1117 Guide for Evaluating Nonwoven Fabrics (Withdrawn 2009)[3]
D1388 Test Method for Stiffness of Fabrics
D3393 Specification for Coated Fabrics—Waterproofness
D3776 Test Methods for Mass Per Unit Area (Weight) of Fabric
D3786 Test Method for Bursting Strength of Textile Fabrics—Diaphragm Bursting Strength Tester Method
D4391 Terminology Relating to The Burning Behavior of Textiles
D6413 Test Method for Flame Resistance of Textiles (Vertical Test)
E96/E96M Test Methods for Water Vapor Transmission of Materials
F1494 Terminology Relating to Protective Clothing
F1891 Specification for Arc and Flame Resistant Rainwear
F1930 Test Method for Evaluation of Flame Resistant Clothing for Protection Against Fire Simulations Using an Instrumented Manikin

2.2 *Federal Specifications:*[4]

FTMS 191A, Method 5516
FTMS CCC-T-191b, Method 5204

2.3 *AATCC Standards:*[5]

AATCC 135 Dimensional Changes Automatic Home Laundering of Woven and Knitted Fabrics

[1] This specification 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] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://www.dodssp.daps.mil.

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

AATCC 127 Water Resistance: Hydrostatic Pressure Test

2.4 *NFPA Standards:*

NFPA 2112 Standard on Flame-Resistant Garments for Protection of Industrial Personnel Against Flash Fire, 2007 Edition[6]

3. Terminology

3.1 *Definitions:*

3.1.1 *afterflame, n*—persistent flaming of a material after the ignition source has been removed.

3.1.2 *afterflame time, n*—the length of time for which a material continues to flame after the ignition source has been removed.

3.1.2.1 *Discussion*—During simulated laboratory fire testing of clothing, the length of time for which a specimen continues to exhibit a visible flaming as determined by a time display video recording or visual observation of the specimen during testing.

3.1.3 *break-open, n—in laboratory-simulated fire testing of clothing*, a material response evidenced by the formation of a hole in the test specimen during the thermal exposure that results in the exposure energy in direct contact with the heat sensor, the manikin surface or an undergarment.

3.1.3.1 *Discussion*—The specimen is considered to exhibit breakopen when a hole is produced as a result of the thermal exposure that is at least 3.2 cm^2 (0.5 $in.^2$) in area or at least 2.5 cm (1.0 in.) in any dimension. Single threads across the opening or hole do not reduce the size of the hole for the purposes of this test method.

3.1.4 *burn injury, n*—burn damage which occurs within human skin at various depths as a function of temperature and time and which can be described mathematically in a burn injury model.

3.1.4.1 *Discussion*—Burn injury in human tissue occurs when the tissue is heated above a critical temperature. The degree of burn injury-first, second or third degree-depends upon the level above the critical temperature, the duration above the critical temperature and the depth in the skin layers.

3.1.5 *char length, n*—in measuring flame resistance of textiles, the distance from the fabric edge which was directly exposed to the flame to the furthest point of visible fabric damage after a specified tearing force has been applied.

3.1.6 *charring, n*—the formation of carbonaceous residue as the result of pyrolysis or incomplete combustion.

3.1.7 *design test, n*—for flame resistant rainwear, one made on a sample as representative of a commercial product; these tests will not generally be repeated in quantity production.

3.1.7.1 *Discussion*—Perform the design test only when a new or modified rainwear material, substrate, coating or adhesive is used to manufacture rainwear. A change in rainwear material includes, but is not limited to, any of the following: The material composition, weight, coating, laminate, adhesive, or the supplier of the material, substrate, coating, laminate, or adhesive.

3.1.8 *dripping, n*—in testing thermal protective material, a response evidenced by flowing of the fiber polymer.

3.1.8.1 *Discussion*—In testing thermal protective materials, coated fabrics or laminates, dripping is a response evidenced by flowing of the fiber polymer, the fabric coating, or the fabric laminates, and the evidence of droplets from the flowing material.

3.1.9 *embrittlement, n*—the formation of a brittle residue as a result of pyrolysis or incomplete combustion.

3.1.10 *flame resistance, n*—the property of a material whereby flaming combustion is prevented, terminated, or inhibited following application of a flaming or nonflaming source of ignition, with or without subsequent removal of the ignition source.

3.1.11 *fire exposure, n—in laboratory-simulated fire testing of clothing*, a fuel rich fire generated with non-stoichiometric amounts of propane and oxygen in air leading to incomplete combustion of the propane. The fire exposure is a propane-air diffusion flame with a controlled heat flux engulfing the manikin for a controlled duration.

3.1.12 *garment ignition, n—in laboratory-simulated fire testing of clothing*, the initiation of combustion of a garment specimen that does not self extinguish for at least 10 seconds.

3.1.13 *heat energy exposure, n—in laboratory-simulated fire testing of clothing*, the total heat energy received at a surface as a direct result of a laboratory simulated fire.

3.1.13.1 *Discussion*—As related to heat energy exposure, the energy in J/cm^2 (cal/cm^2), that is transferred to the material surface is determined by multiplying the heat flux of the laboratory simulated flash fire by the duration of the laboratory–simulated flash fire.

3.1.14 *melting, n*—a material response evidenced by softening of the polymer.

3.1.14.1 *Discussion*—In testing flame resistant rainwear, melting is additionally defined as the liquefaction of material under the influence of heat.

3.1.15 *rainwear, n*—a garment which provides protection from precipitation for the head, limbs and body of the user.

3.1.16 *shrinkage, n*—a decrease in one or more dimensions of an object or material.

3.1.17 *thermal exposure, n*—the intensity of heat energy to which a fabric is exposed.

3.1.18 *thermal protection, n*—the property that characterizes the overall performance of a garment or protective clothing ensemble relative to how it prevents the transfer of heat that is sufficient to cause burn injury.

3.1.18.1 *Discussion*—Thermal protection of a garment or ensemble and the consequential predicted burn injury (second-degree and/or third-degree), is quantified from the response of manikin test thermal energy sensors. In addition to the calculated results, the physical response and degradation of the garment or protective ensemble is an observable phenomenon useful in understanding garment or protective clothing ensemble thermal protection.

[6] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, http://www.nfpa.org.

3.1.19 *thermal resistance, n*—the reciprocal of thermal transmittance.

3.1.20 *thermal material response, n—in laboratory-simulated fire testing of clothing*, the effects that are observed concurrent and subsequent to thermal exposure, which can include phenomena such as breakopen, charring, embrittlement, melting, shrinkage, etc.

3.1.20.1 *Discussion*—The thermal material response is a result of exposure to the radiant and convective energy of the laboratory-simulated fire.

3.1.21 *thermal transmittance, n*—unidirectional heat transfer per unit area, in the steady-state, between parallel planes, per unit difference of temperature of the planes.

3.2 For definitions of other textile terms used in this specification refer to Terminology D123, D4391, and F1494.

4. Significance and Use

4.1 This specification covers the minimum performance criteria for flame resistance and other requirements for rainwear used by workers with the potential to be simultaneously exposed to wet weather conditions and either hydrocarbon or petrochemical industrial fires.

4.2 The purchaser has the option to perform or have performed any of the tests required by this specification in order to verify the performance of the rainwear.

4.3 This specification for rainwear shall not be construed as a requirement for the use of any particular rainwear material.

5. Ordering Information

5.1 It is useful for the purchaser to consider the following items when buying rainwear under this specification. Include these items, as necessary, in purchasing documents:

5.1.1 Type of material,

5.1.2 Fabric weight, g/m^2 (oz/yd^2),

5.1.3 Type and material of fasteners (buttons, snaps, zippers or hook and loop fasteners),

5.1.4 Reflective material sections (optional),

5.1.5 Style and design or catalog number,

5.1.6 Hood design (attached or detachable),

5.1.7 Sizes,

5.1.8 Color,

5.1.9 Special identification markings (optional),

5.1.10 Jacket length, trouser length (if applicable), trouser/jacket overlap (if applicable), and

5.1.11 Notation of conformance to this specification.

6. Materials and Manufacture

6.1 The rainwear shall be designed and manufactured using materials and seam constructions that meet the requirements for leak resistance in 7.3.

6.2 Mechanical fastener closures, such as buttons or snaps, shall be designed and constructed so that they are covered by the rainwear outer layer material.

6.2.1 This will result in the garment having a multiple layer construction in the area of the closure. This will also prevent the closure hardware from being directly exposed to the thermal hazard.

NOTE 1—In limited testing, it has been found some uncovered closures melt and fuse. Constructing the closures so that they are covered as described above is designed to mitigate the melting and fusing observed with uncovered closures.

7. Physical Performance Testing Procedures

7.1 Test rainwear material for physical performance characteristics initially as manufactured or as received from the manufacturer and after five cleaning and drying cycles unless otherwise indicated.

7.1.1 Clean and dry in accordance with care instructions from the rainwear manufacturer.

7.1.1.1 If no cleaning instructions are provided by the rainwear manufacturer, clean and dry in accordance with AATCC Method 135 (3, IV A iii)

7.1.2 For limited use or disposable rainwear with care instructions indicating the rainwear is not to be cleaned, test the rainwear material sample only as received or as manufactured.

7.2 *Weight and Weight Uniformity— Rainwear Material*

7.2.1 Determine the average weight in g/m^2 (oz/yd^2) of the rainwear material sample submitted for the material testing in 7.3, 7.4, and 7.5 (optional) in accordance with Test Method D3776, Option B. If a single sample of rainwear material is used for all of the designated tests, one average weight determination shall be done. If a different rainwear material sample is used for one or more of the tests, a separate average weight determination shall be done for each rainwear material sample.

7.2.1.1 Determine the average weight of each rainwear material sample initially as received and after five cleaning and drying cycles as described in 7.1.

7.2.2 Determine weight uniformity across the width of the rainwear material sample as received using the same temperature and humidity preconditioning as required for D3776, Option B.

7.2.2.1 For each as received rainwear material sample for which the average weight was determined in accordance with 7.2.1, take five specimens, each consisting of a circle of rainwear material 89 mm (3.5 in.) in diameter at approximately equal spaced intervals diagonally across the width of the rainwear material sample.

7.2.2.2 Determine the weight in g/m^2 (oz/yd^2) of each of the five specimens.

7.3 *Leak Resistance—Rainwear Material and Seams:*

7.3.1 Test the rainwear material in accordance with Specification D3393 at a water pressure of 207 kPa (30 psig).

7.3.2 Test the seams of the rainwear material in accordance with AATCC 127 test method at a water pressure of 20.7 kPa (3 psig) for 2 min.

7.3.2.1 Use a pump device to achieve 20.7 kPa (3 psig) if extension of the water column is not practical.

7.4 *Trapezoidal Tearing Resistance or Burst Strength:*

7.4.1 Test the rainwear material for trapezoidal tearing resistance in accordance with Guide D1117 except that the measured value shall be the average of the five highest peak loads. Appendix X3 provides detailed information for the trapezoidal tearing resistance of rainwear material in accordance with Guide D1117.

7.4.2 When the rainwear substrate fabric is a knit or a stretch woven material, it is acceptable to substitute ASTM D3786 for the trapezoidal tearing resistance test.

7.5 *Water Vapor Transmission*

7.5.1 On an optional basis, test the rainwear material for water vapor transmission (WVT) in accordance with Test Method E96/E96M using the inverted cup (BW) procedure.

8. Thermal Performance Testing Procedures

8.1 Rainwear samples for thermal tests shall be representative of the rainwear material or system. If the rainwear is constructed of a single-layer material, carry out all thermal tests on a single-layer sample of the rainwear material. If the rainwear is constructed of a multi-layer system of materials, test each layer of the multilayer system by the procedure in 8.2 and test a multi-layer sample of the rainwear by the procedures in 8.3 and 8.4.

8.2 Test the rainwear material for flame resistance in accordance with Test Method D6413.

8.2.1 Test the rainwear material initially as manufactured or as received from the manufacturer and after five cleaning and drying cycles as described in 7.1.

8.2.2 For limited use or disposable rainwear with care instructions indicating the rainwear is not to be cleaned, test the rainwear coverall specimens only as received without cleaning.

8.3 Test at least three rainwear coverall specimens made from the rainwear material sample in accordance with Test Method F1930. Fabricate the coverall specimens in accordance with the standard garment requirements specified in Test Method F1930, subsection 8.3.2.

NOTE 2—Test Method F1930 is a design test.

8.3.1 Test the three rainwear coverall specimens by the procedure in 8.3 after one cleaning and drying. Clean and dry the rainwear coverall specimens as directed by care instructions from the rainwear manufacturer.

8.3.1.1 If no cleaning instructions are provided by the rainwear manufacturer, clean and dry the rainwear coverall specimens one time in accordance with the AATCC Method 135 (3, IV A iii).

8.3.1.2 Alternatively, clean and dry the rainwear coverall specimens in accordance with the procedure required by NFPA 2112.

8.3.2 For limited use or disposable rainwear with care instructions indicating the rainwear is not to be cleaned, test the rainwear material sample only as received or as manufactured.

8.3.3 Dress the F1930 instrumented manikin in 100 % cotton briefs and a 100 % cotton crew neck T-shirt before the rainwear coverall specimens are positioned on the instrumented manikin.

8.3.4 Use a heat flux of 84 ± 4 kW/m^2 (2.0 ± 0.1 cal/cm^{2}s) and an exposure time of 3 ± 0.1 seconds as test parameters for Test Method F1930. It is acceptable to assess additional test parameters and report the results on an optional basis.

8.3.5 Determine the predicted total area of burn injury, the predicted second-degree burn area, and the predicted third-degree burn area in accordance with Test Method F1930, subsections 12.5 and 12.6. Determine the averages of these parameters for the three F1930 tests.

8.3.5.1 If more than three rainwear coverall specimens are tested in accordance with 8.3, determine the test results and the averages of test results listed in 8.3.5 for the total number of specimens tested.

8.4 *Closure Function and Structural Seam Integrity*—Test at least two sets of as sold or finished goods rainwear subject to this standard in size "large" in accordance with Test Method F1930. This testing shall apply to all models and styles of rainwear from the rainwear manufacturer for which seams and closures of the tested as sold or finished goods rainwear are representative.

NOTE 3—A set of as sold or finished goods rainwear can consist of a jacket and pants, a jacket and bib overalls, or a coverall as long as the set of rainwear is subject to this standard and is a style or model designed and manufactured as sold to users.

NOTE 4—Test Method F1930 is a design test.

8.4.1 Test the as sold rainwear by the procedure in 8.4 after one cleaning and drying. Clean and dry as directed by care instructions from the rainwear manufacturer.

8.4.1.1 If no cleaning instructions are provided by the as sold rainwear manufacturer, clean and dry the rainwear one time in accordance with the AATCC Method 135 (3, IV A iii).

8.4.1.2 Alternatively, cleaning and dry the as sold rainwear in accordance with the procedure required by NFPA 2112.

8.4.2 For limited use or disposable as sold rainwear with care instructions indicating the rainwear is not to be cleaned, test the rainwear only as received without cleaning.

8.4.3 Dress the F1930 instrumented manikin in 100 % cotton briefs and a 100 % cotton crew neck T-shirt before the rainwear specimens are positioned on the instrumented manikin.

8.4.4 Use a heat flux of 84 ± 4 kW/m^2 (2.0 ± 0.1 cal/cm^{2}s) and an exposure time of 3 ± 0.1 seconds as test parameters for Test Method F1930. It is acceptable to assess additional test parameters and report the results on an optional basis.

8.4.5 Determine the predicted total area of burn injury, the predicted second-degree burn area, and the predicted third-degree burn area according to Test Method F1930, subsections 12.5 and 12.6. Determine the averages of these parameters for the two F1930 tests.

8.4.5.1 If more than two sets of rainwear are tested in accordance with 8.4, determine the test results and the averages of test results listed in 8.4.5 for the total number of sets of rainwear tested.

8.4.6 *Structural Seam Integrity*—Inspect structural seams of each of the sets of as sold rainwear after the exposure in 8.4.4 and before removal of the rainwear from the manikin and also before opening the rainwear closures. Determine any structural seam failure which results in a structural seam opening that exceeds 51 mm (2 in.).

8.4.7 *Closure Function After Thermal Exposure*—For each of the sets of as sold rainwear, after the exposure in 8.4.4 and before removal of the rainwear specimen from the manikin, determine whether or not all rainwear closures can be fully opened, using hands only.

9. Performance Requirements

9.1 *Material Weight and Weight Uniformity:*

9.1.1 Report the supplier's nominal weight for the rainwear material in Table 1.

TABLE 1 Rainwear Material Performance Requirements Test Report

Company Issuing Report _____
Date of Report _____

Sample description for rainwear material
Material name or designation _____
Composition of substrate _____
Coating or laminate _____
Nominal Weight, g/m^2 (oz/yd^2) _____
Color _____

	Specification F2733 Requirements	Material Performance	
	Initial and after five cleanings and dryings (except where noted)	Initial, as received	After five cleanings and dryings (except where noted)
Material Weight			
Material Average Weight determined by D3776, Option B	report	___ g/m^2 (oz/yd^2)	___ g/m^2 (oz/yd^2)
Material Weight Range as determined in accordance with 7.2.2	Within ±10 % of material as received average weight determined by D3776, Option B	Low ___ g/m^2 (oz/yd^2) __% High ___ g/m^2 (oz/yd^2) __%	NA
Leak resistance			
Leak resistance of Rainwear Material in accordance with D3393 at 207 kPa (30 psi)	no leakage	leakage or no leakage	leakage or no leakage
Leak resistance of Seams at 20.7 kPa (3 psi) for 2 min in accordance with AATCC Test Method 127	no leakage	leakage or no leakage	leakage or no leakage
Tear strength and bursting strength			
Trapezoidal Tear Strength Resistance—Guide D1117 (modified)	≥2.7 kg (6 lb) Warp	____ kg (lb) Warp	____ kg (lb) Warp
	≥2.7 kg (6 lb) Fill	____ kg (lb) Fill	____ kg (lb) Fill
Bursting strength—D3786 (Optional)	275 kPa (35 psi)	____ kPa (35 psi)	____ kPa (35 psi)
Water Vapor Transmission—E96/E96M inverted cup (BW) (Optional)	report	____ g/m^2 per 24 h	____ g/m^2 per 24 h
Flame Resistance in accordance with Test Method D6413			
Average After Flame	≤2 s	____ s Warp ____ s Fill	____ s Warp ____ s Fill
Average Char Length	≤102 mm (4 in.)	____mm (____ in.) Warp ____mm (____ in.) Fill	____mm (____ in.) Warp ____mm (____ in.) Fill
Melting and dripping	no melting and dripping	Melting and dripping or no melting and dripping	Melting and dripping or no melting and dripping
Predicted Burn Injury of rainwear material in standard coverall—Test Method F1930	After one cleaning/one drying	NA	After one cleaning/one drying
Average predicted total area burn injury from 9.6.1	≤40% Report		__%
Average predicted third-degree burn area from 9.6.2			__%
Structural seam integrity of as sold rainwear after thermal exposure of as sold rainwear—Test Method F1930	After one cleaning/one drying		After one cleaning/one drying
Number of structural seam failures with openings >51 mm (2 in.)	0 seam failures with opening >51 mm (2 in.)	NA	# of seam failures with openings >51 mm (2 in.)
Closure function after thermal exposure:	After one cleaning/one drying	NA	After one cleaning/one drying
All closures fully open by hand for as sold rainwear—Test Method F1930	All closures fully opened by hand		Number of closure not fully opened by hand
Predicted burn injury of as sold rainwear—Test Method F1930			
Average predicted total area burn injury from 9.6.5	report only	NA	__%
Average predicted third-degree burn area from 9.6.6	report only	NA	__%

9.1.2 *Average Weight*—For each rainwear material sample, the average weight shall be determined according to the procedure in 7.2.1 and reported in Table 1.

9.1.3 *Weight uniformity*—For each as received rainwear material sample, the highest and lowest as received weights determined in 7.2.2 shall be within ±10% of the average as received weight determined in 7.2.1. Report the highest and lowest as received weights in Table 1.

NOTE 5—In fire testing of FR rainwear material, large material weight variations have on occasion been observed. The intent of this provision is to indicate situations in which the material weight variation exceeds a total of ±5 % which would normally be expected from laundering, drying, humidity differences and normal test method error.

9.2 *Leak Resistance:*

9.2.1 The rainwear material shall not leak when tested by the procedure in 7.3.1. Report leak test result in Table 1.

9.2.2 The seams of rainwear material shall not leak when tested by the procedure in 7.3.2. Report leak test result in Table 1.

9.3 *Tear Strength or Burst Strength:*

9.3.1 Rainwear material based on woven substrates shall have a trapezoidal tearing resistance of not less than 2.7 kg (6 lb) in the warp direction and 2.7 kg (6 lb) in the fill direction when tested by the procedure in 7.4.1. Report tear strength results in Table 1.

9.3.2 Rainwear material based on a knit or stretch woven substrate fabric shall have a bursting strength of not less than 275 kPa (35 psi) if tested by the procedure in 7.4.2. If bursting strength is determined, report burst strength result in Table 1.

9.4 *Water Vapor Transmission:*

9.4.1 Report optional test results for water vapor transmission (g/m^2 per 24 hours) in Table 1 if tested by the procedure in 7.5.1.

9.5 *Flame Resistance:*

9.5.1 When tested by the procedure in 8.2, the average afterflame time shall not be more than 2 s after removal of the ignition source for specimens in both the warp and fill directions. The average char length shall be less than or equal to 102 mm (4 in.) for specimens in both the warp and fill directions. Specimens shall not melt and drip during testing. Both melting and dripping must occur for a specimen to fail. An indication of melting by itself shall not be interpreted as melting and dripping.

9.6 *Predicted Burn Injury Using Laboratory Simulated Fire and an Instrumented Manikin:*

9.6.1 The average predicted total area of burn injury for the three coverall specimens tested by the procedure in 8.3 shall be equal to or less than 40 %. Report the average predicted total burn area in Table 1.

NOTE 6—This level of burn injury indicates a minimum survival rate of approximately 70 % for burn injury victims from 20 to 60 years of age as reported in the American Burn Association Study (1991-1993).

9.6.2 Report the average predicted third-degree burn area for the three coverall specimens tested by the procedure in 8.3 in Table 1.

9.6.3 Report the material response characteristics for rainwear material, including *afterflame time, breakopen, charring, dripping, garment ignition, embrittlement, melting, and shrinkage*, for all rainwear coverall test specimens in Table 2.

9.6.4 *Structural Seam Integrity*—Structural seams of the as sold rainwear tested in 8.4 shall not exhibit a seam failure that creates a seam opening of greater than 51 mm (2 in.) after the laboratory simulated fire exposure in 8.4.

9.6.5 *Closure Function*—Closures of the as sold rainwear tested in 8.4 shall function (open only) after the simulated fire exposure in 8.4. Closures that do not fully open according to the procedure in 8.4.7 do not meet the performance requirements of this specification. Report all closures that do not fully open in Table 1.

9.6.6 Report the average predicted total area of burn injury for the two sets of as sold rainwear tested by the procedure in 8.4 in Table 1.

9.6.7 Report the average predicted third-degree burn area for the two sets of as sold rainwear tested by the procedure in 8.4 in Table 1.

9.7 *Rainwear Construction:*

9.7.1 Utilize materials, stitchings, tapes, coatings, fasteners, and closure materials that minimize heat conduction for the construction of compliant FR rainwear. Fasteners and closures used that are known to be good heat conductors, for example, zippers, snaps, buttons, etc. that are made from metals, shall be covered with a layer of rainwear material on the inside of the garment such that these items of construction will not contact undergarments or skin.

9.7.1.1 *Discussion*—If fasteners or closures, for example, zippers, snaps, or buttons, or combination thereof, are used in a manner in which they are in contact with the skin, they can increase heat transfer and predicted burn injury due to heat conduction to the skin. Using a layer of material between the conductive fastener or closure and the undergarment or skin

TABLE 2 Material Response Characteristics

	Garment Specimen #1	Garment Specimen #2	Specimen #3
After Flame Time, s Breakopen (yes/no), cm (in.) Charring (yes/no) Melting (yes/no) Dripping (yes/no) Garment Ignition (yes/no)			
Embrittlement (yes/no)			
Shrinkage, %			

can reduce heat transfer to the skin. There is no intent that this added layer of material can provide a reliable electrical insulation barrier.

9.7.2 The stitchings, thread, findings, zipper tapes, or fasteners, or combination thereof, used to manufacture the rainwear shall not degrade the flame resistance or thermal performance of the rainwear.

9.7.3 Markings and reflective materials shall be of the permanent type and shall not degrade the performance of the rainwear.

9.8 The format shown in Tables 1 and 2 shall be used to report the results for all performance requirements and test observations. This report shall be made available to the purchaser of rainwear meeting this specification by the rainwear manufacturer.

10. Stiffness of Rainwear Fabrics (Optional Test Method)

10.1 Optional test methods for determining stiffness of the rainwear are provided in Appendix X2.

11. Sequence of Testing and Inspection

11.1 The following order of testing is suggested for the evaluation of rainwear material:

11.1.1 Inspection of the fabric and seam specimen.

11.1.2 Water leakage testing; fabric and prepared seam specimen.

11.1.3 Fabric trapezoidal tearing resistance testing or burst strength testing.

11.1.4 Fabric flame resistance testing.

11.1.5 Laboratory simulated fire testing of rainwear material and zipper closures. (This is a design test.)

11.1.6 Inspection of rainwear, structural seams, style, labeling, markings, and color.

12. Compliance Certification

12.1 Rainwear material shall be tested and certified by the manufacturer or supplier to be in compliance with the requirements of this specification.

12.1.1 The user, at his expense, shall have the option to verify compliance with the requirements of this specification.

12.2 Except where noted as a design test, the rainwear material shall be tested at least every twelve months to confirm compliance with the requirements of this specification.

12.3 The rainwear supplier or manufacturer shall provide compliance testing and certification to the purchaser when a new or modified rainwear material, substrate, coating, or adhesive is used to manufacture rainwear. A change in rainwear material is considered, but is not limited to, any of the following: the composition, weight, or supplier of the substrate, coating, laminate, or adhesive, or combination thereof. The test noted as "design test" as well as all other tests shall be repeated to verify compliance with the performance requirements of this specification.

12.4 The entire shipment or lot of rainwear material shall be rejected for use under this specification if the selected samples do not meet the requirements of this specification.

13. Labeling, Identification, and Packaging

13.1 Each item of rainwear shall be permanently identified or labeled with its size, style designation or catalog number, the manufacturer's name and a statement of conformance to this specification. These shall be indelibly marked such as with an embroidered label or equivalent permanently affixed to the inside of the rainwear at the top of the back of each item of rainwear or at the bottom hem of each item of rainwear.

13.2 The statement of conformance to this specification shall be, "This rainwear meets or exceeds requirements for ASTM F2733 Standard Specification for Flame Resistant Rainwear for Fire Hazards."

13.3 A care label shall provide instructions for cleaning and drying, and the care label shall be attached so that it will remain firmly attached and readable throughout the life of the rainwear.

13.3.1 A care label indicating that the rainwear is not to be laundered or dry cleaned is acceptable for limited-use or disposable rainwear.

13.4 The method of packaging individual or bulk, shall be agreed to between the supplier and purchaser.

13.4.1 The following information shall be provided on or in the package: name of manufacturer, size, fabric material, catalog number or style of the contents, date code or date of manufacture of the rainwear, and that the rainwear meets ASTM F2733.[7]

14. Sizing

14.1 An optional sizing guide is provided in Appendix X1. Sizes shall be agreed upon between the rainwear manufacturer and the purchaser.

15. Keywords

15.1 afterflame time; fire; flame resistant; garment ignition; instrumented manikin; laboratory simulated flash fire; leak resistant; predicted second-degree burn area; predicted third-degree burn area; predicted total area of burn injury; thermal hazard

[7] Available from ASTM International Headquarters. Order Adjunct No. ADJf2733. Original adjunct produced in 1957.

APPENDIXES

X1. SIZING AND MEASUREMENTS

X1.1 Sizing Guide

X1.1.1 When placed without tension on a flat surface so that the rainwear is without creases or wrinkles, and measured at the points indicated, the rainwear conforms to the measurements shown in Table X1.1.

X1.2 Measurements

X1.2.1 Jacket Measurements—See Fig. X1.1.

X1.2.1.1 *Chest Girth (C)*—Twice the distance across the closed rainwear jacket measured 25 mm (1 in.) below the lowest points of the armhole seams. Location of the armhole seams can be approximated for designs without arm hole seams, for example, batwing designs.

X1.2.1.2 *Sleeve Length (A)*—The distance from the vertical centerline of the jacket at the base of the collar band or hood attachment seam to the end of the sleeve.

X1.2.1.3 *Sleeve at Elbow Girth (E)* —Twice the distance across the sleeve at a point midway along the underarm length of the sleeve.

X1.2.1.4 *Jacket Length (L)*—The distance from the base of the collar band or hood attachment seam at the vertical centerline of the jacket to the bottom of the jacket shall be 75 cm (30 in.) as standard. Optional lengths may be specified upon agreement between the manufacturer and purchaser.

X1.2.2 *Trousers Measurements*—See Fig. X1.2.

X1.2.2.1 *Waist Girth (W)*— Twice the distance across the waist at a distance of 20 cm (8 in.) above the crotch for trousers with bib front and suspenders.

X1.2.2.2 *Knee Girth (K)*— Twice the distance across the leg at a position midway between the crotch and the bottom of the leg.

X1.2.2.3 *Leg Inseam (I)*— The distance from the crotch along the leg seam to the bottom edge of the leg.

X1.3 Permissible Measurement Tolerances

X1.3.1 *Girth Measurements*—Table X1.1 value ±25 mm (±1 in.).

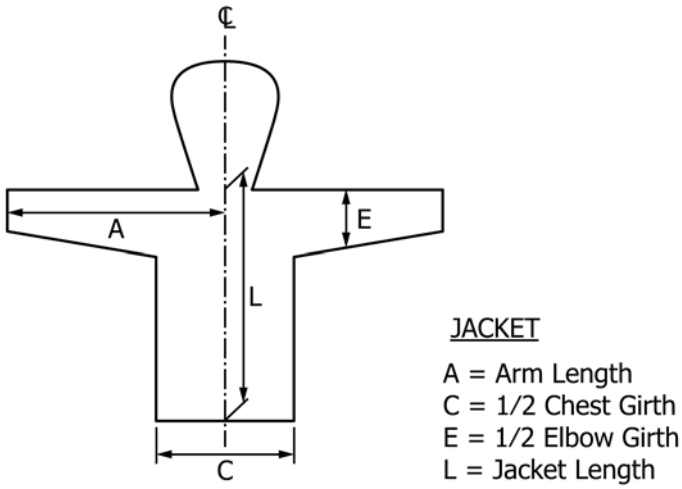

FIG. X1.1 Jacket Measurements

X1.3.2 *Length Measurements*—Table X1.1 value ±15 mm (±0.6 in.).

NOTE X1.1—Table X1.1 provides measurements for regular length rainsuits. Short and tall sizes are typically provided by changing the sleeve and leg lengths of the regular length measurements. Short sizes typically have 51 mm (2 in.) subtracted from the sleeve and leg lengths listed in Table X1.1. Tall sizes typically have 51 mm (2 in.) added to the sleeve length and leg lengths as listed in Table X1.1. Girth measurements for short and tall heights generally conform to Table X1.1 measurements. It is appropriate for additional special sizes to be agreed to between user and manufacture.

X1.4 Measurement of Fabric Thickness and Mass (Optional)

X1.4.1 Fabric thickness and mass is determined by the procedure included in Test Methods D751.

TABLE X1.1 Two Piece Rainsuit Measurements

Jacket—Measurements in Centimeters (Inches)			
Size	Chest Girth (C)	Sleeve Length (A)—See Note X1.1	Sleeve at Elbow Girth (E)
Small	114 (45)	81 (32)	48 (19)
Medium	124 (49)	84 (33)	48 (19)
Large	135 (53)	86 (34)	48 (19)
X-Large	145 (57)	89 (35)	51 (20)
XX-Large	152 (60)	91 (36)	51 (20)
XXX-Large	64 (163)	36 (91)	20 (51)
Trousers—Measurements in Centimetres (Inches)			
Size	Waist Girth (W)	Leg Inseam Length (I)—See Note X1.1	Knee Girth (K)
Small	107 (42)	74 (29)	53 (21)
Medium	114 (46)	76 (30)	56 (22)
Large	122 (48)	78 (31)	58 (23)
X-Large	130 (51)	78 (31)	61 (24)
XX-Large	137 (54)	81 (32)	64 (25)
XXX-Large	145 (57)	81 (32)	66 (26)

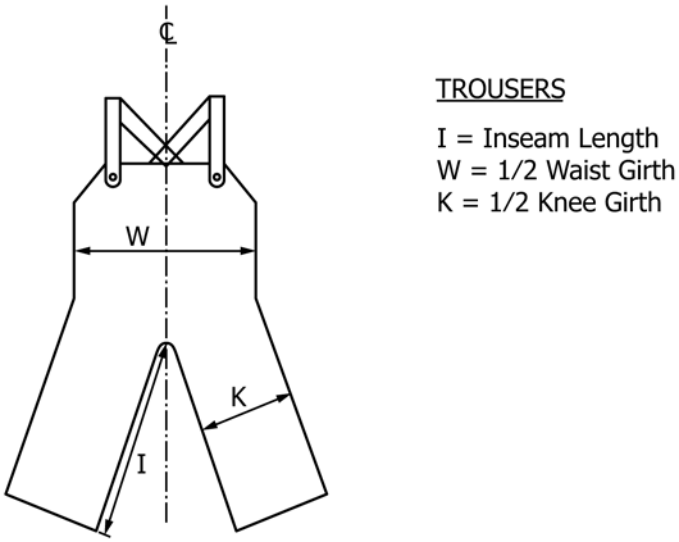

FIG. X1.2 Trouser Measurements

X2. DRAPE STIFFNESS

X2.1 Perform the drape stiffness test in a manner similar to the method specified in Test Method D1388. Use Option A, Cantilever Test, of Test Method D1388 as the test method. Drape stiffness is a measure of how a material will bend under its own weight, and is referred to as "bending length" in Test Method D1388.

X2.1.1 A25 by 150 mm (1 by 6 in.) rectangular specimen may be used for testing typical rainwear fabrics.

X2.1.2 Test five specimens from each sample lot. The test may be performed over a range of temperatures between –12 ± 2°C (10 ± 4°F) and 43 ± 2°C (110 ± 4°F). Condition the specimen and the test device for at least 4 h at each of these temperatures prior to the performance of the test. The test shall be conducted at the same temperature used to condition the fabric specimens.

X2.2 An alternative test method, Federal Test Method Standard (FTMS) No. CCC-T-191b Method 5204, the Clark Stiffness Tester, may also be used to determine flexural rigidity.

X3. TRAPEZOIDAL TEARING RESISTANCE

X3.1 Test Methods D751, D1117, trapezoidal tearing resistance test information for testing rainwear material, is provided as general assistance and clarification to the test laboratory.

X3.1.1 The specimen shall be a 76 by 152 mm (3 by 6 in.) rectangle. The long dimension shall be parallel to the warp for warp tests and parallel to the filling for filling tests. No two specimens for warp tests shall contain the same filling yarns. The specimen shall be taken to avoid the selvage of the cloth. An isosceles trapezoid having an altitude of 76 mm (3 in.) and bases of 25.4 and 102 mm (1 and 4 in.) in length, respectively, shall be marked on each specimen with the aid of a template. A cut ⅜ in. (9.5 mm) in length shall then be made in the center of a line perpendicular to the 25 mm (1 in.) edge.

X3.1.2 Apparatus shall consist of a straining mechanism, two clamps for holding specimens, and load and elongation recording mechanisms, wherein the specimen is held between two clamps and strained by a uniform movement of the pulling clamp. The test machine shall be operated at a rate of 305 mm/min (12 in./min). The apparatus shall be constant-rate-of-extension (CRE) device.

X3.1.2.1 Straining mechanism shall be of such capacity that the maximum load required to break the specimen shall be not greater than 85 % or less than 15 % of the rated capacity of the straining mechanism as specified by the manufacturer.

X3.1.2.2 Clamps shall be designed such that the 170 g (6 oz) of weight are distributed evenly across the complete width of the sample. The clamps shall have two jaws on each clamp. The design of the clamps shall be such that one gripping surface or jaw shall be permitted to be an integral part of the rigid frame of the clamp or be fastened to allow a slight vertical movement, while the other gripping surface or jaw shall be completely moveable. The dimensions of the immovable jaw of each clamp parallel to the application of the load shall measure 1 in. (25 mm), and the dimension of the jaw perpendicular to this direction shall measure 76 mm (3 in.) or more. The face of the moveable jaw of each clamp shall measure 25 by 76 mm (1 by 3 in.). Each jaw face shall have a flat, smooth gripping surface. All edges that might cause a cutting action shall be rounded to a radius of not more than 0.4 mm (1/64 in.). In cases where a cloth tends to slip when being

tested, the jaws shall be faced with rubber or other material to prevent slippage. The distance between the jaws shall be 25 mm (1 in.) at the start of the test.

X3.1.2.3 Recorder shall consist of a calibrated dial, scale, or chart used to indicate applied load and elongation. Error shall not exceed 2 % up to and including a 22.7 kg (50 lb) load and 1 % over a 22.7 kg (50 lb) load at any reading within its loading range. All machine attachments for determining maximum loads shall be disengaged during the test.

X3.1.3 The specimen shall be clamped along the nonparallel sides of the trapezoid so that these sides lie along the lower edge of the upper clamp and upper edge of the lower clamp with the cut halfway between the clamps. The short trapezoid base shall be held taut, and the long trapezoid base shall lie in the folds. The strain mechanism shall be started, and the force necessary to tear the cloth shall be observed by means of the recording device. Five specimens in each of the warp and filling directions shall be tested from each sample unit. If a specimen slips between the jaws, breaks in or at the edges of the jaws, or, if for any reason attributable to faulty technique, an individual measurement falls markedly below the average test results for the sample unit, such result shall be discarded and another specimen shall be tested.

X3.1.4 The trapezoidal tearing resistance shall be the average of the five highest peak loads of resistance registered. The tear strength shall be reported to the nearest 45.4 g (0.1 lb). The standard deviation shall also be determined and reported.