Designation: F1002 – 14

StandardPerformance Specification for Protective Clothing and Materials for Use by Workers Exposed to Specific Molten Substances and Related Thermal Hazards[1]

This standard is issued under the fixed designation F1002; 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 performance specification establishes the minimum design and performance requirements for protective clothing and protective clothing materials for both primary and secondary protection from exposure to molten substances and related thermal hazards.

1.2 This performance specification is not intended to address protection from hot liquids or from specialized forms of heat and flame protection such as any fire fighting application.

1.3 This performance specification describes the properties of specific textile materials in their material or garment composite form as tested by laboratory methods and is not intended to be used to appraise the thermal hazard or risk under actual conditions. However, it is acceptable to use information on the thermal performance of clothing made from textile materials conforming to this specification as an element in thermal risk assessment which takes into account all factors pertinent to the thermal hazard of a particular end use.

1.4 The values stated in SI units are to be regarded as standard. The values given in brackets are for information only.

1.5 *This performance specification does not purport to address all of the safety concerns, if any, associated with the use of compliant protective clothing or protective clothing materials. It is the responsibility of the persons or organizations that use this performance specification to conduct a hazard and risk assessment to determine the applicability of this performance specification to the intended application of the protective clothing or protective clothing materials, and to establish appropriate safety and health practices.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D123 Terminology Relating to Textiles

D1424 Test Method for Tearing Strength of Fabrics by Falling-Pendulum (Elmendorf-Type) Apparatus

D2724 Test Methods for Bonded, Fused, and Laminated Apparel Fabrics

D4157 Test Method for Abrasion Resistance of Textile Fabrics (Oscillatory Cylinder Method)

D5034 Test Method for Breaking Strength and Elongation of Textile Fabrics (Grab Test)

D5587 Test Method for Tearing Strength of Fabrics by Trapezoid Procedure

D6413 Test Method for Flame Resistance of Textiles (Vertical Test)

D7138 Test Method to Determine Melting Temperature of Synthetic Fibers

F955 Test Method for Evaluating Heat Transfer through Materials for Protective Clothing Upon Contact with Molten Substances

F1494 Terminology Relating to Protective Clothing

F1939 Test Method for Radiant Heat Resistance of Flame Resistant Clothing Materials with Continuous Heating

2.2 *AATCC Test Methods:*[3]

135 Dimensional Changes in 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.

Current edition approved Sept. 1, 2014. Published September 2014. Originally approved in 1986. Last previous edition approved in 2013 as F1002 - 13. DOI: 10.1520/F1002-14.

[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] AATCC Technical Manual, Current Edition available from American Association of Textile Chemists and Colorists, P.O. Box 12215, Research Triangle Park, NC 27709.

2.3 *NFPA Standard:*[4]

NFPA 1971 Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting

2.4 *Federal Standard:*[5]

MIL-C-87076A Resistance of Materials to Radiant Heat Exposure, Adhesion of Coating, and Adhesion After Wet Flexing

2.5 *ISO Standards:*[6]

ISO 9185 Protective Clothing – Assessment of Resistance of Materials to Molten Metal Splash

EN ISO 11612 Protective Clothing – Clothing to Protect Against Heat and Flame

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this performance specification, use the following documents: If the terms are related to textiles, refer to Terminology D123; if the terms are related to protective clothing, refer to Terminology F1494.

3.1.2 *breakopen*—in testing thermal protective material, a response evidenced by the formation of a hole in the material which has the potential to allow molten substance to pass through the material.

3.1.3 *charring*—the formation of a carbonaceous residue as the result of pyrolysis or incomplete combustion.

3.1.3.1 *Discussion*—Charring can be accompanied by melting, dripping, or ignition, or combinations thereof.

3.1.4 *design test, n*—one made on a sample treated as representative of a protective material; these tests will not generally be repeated in quantity production.

3.1.4.1 *Discussion*—Perform the design test only when a new or modified material is used to manufacture apparel. A modification in the material could be, but is not limited to, any of the following: the supplier, composition, weave type, weight, or dyeing and finishing process.

3.1.5 *molten substances*—metals in their liquefied, elevated temperature state, as well as related non-metallic substances also handled at elevated temperatures such as slag, dross, and salt. Excluded are liquid hot substances that may be associated with metal processing such as water, oil, and caustic solutions.

3.1.5.1 *Discussion*—For the purposes of this specification, molten metals include liquefied metals such as iron, steel, aluminum, brass, and various alloy, and non-metallic substances liquefied at elevated temperatures such as slag, dross, and salt. Hot liquid substances such as water, oil, and caustic solutions are excluded from this specification.

3.1.6 *primary protective clothing*—protective clothing designed to be worn for work activities during which significant exposure to molten substance splash, radiant heat, and flame is likely to occur.

3.1.6.1 *Discussion*—Primary protective clothing is used in work activities that include charging, tapping, and pouring, during which work is carried out in close proximity to molten substances and hot surfaces where contact with either is likely.

3.1.7 *protective clothing*—an item of clothing that is specifically designed and constructed for the intended purpose of isolating all or part of the body from a potential hazard; or, isolating the external environment from contamination by the wearer of the clothing.

3.1.7.1 *Discussion*—For the purposes of this specification, protective clothing items include full-body garments such as coats, jackets, pants, overalls, and coveralls, and partial-body clothing such as aprons, hoods, sleeves, leggings, chaps, and spats.

3.1.8 *protective clothing material*—any element, constituent, or substance from which protective clothing is composed or can be made.

3.1.8.1 *Discussion*—For the purposes of this specification, protective clothing materials include the principal material used in the construction of either primary or secondary protective clothing, and may include more than one separable layer.

3.1.9 *radiant heat*—heat communicated by energy propagated through space and transmitted by electromagnetic waves.

3.1.9.1 *Discussion*—For the purposes of this specification, radiant heat exposure occurs from close proximity to molten substances or hot surfaces containing molten substances.

3.1.10 *Radiant Heat Resistance (RHR)*—in testing of thermal protective materials, the cumulative amount of thermal exposure energy identified by the intersection of the measured time-dependent heat transfer response through the subject material to a time-dependent, empirical performance curve, expressed as a rating or value: kJ/m^2 (cal/cm^2).

3.1.11 *secondary protective clothing*—protective clothing designed for continuous wear for work activities in designated locations in which intermittent and incidental exposure to molten substance splash, radiant heat, and flame sources is possible.

3.1.11.1 *Discussion*—Secondary protective clothing is designed so that it will not continue to burn after exposure to and removal of a source of ignition that includes incidental contact with a molten substance. Limited protection against a molten substance splash and high levels of radiant heat are secondary in intent and are dependent on the extent, duration, and other circumstances related to the exposure. Primary protective clothing must supplement secondary protective clothing where more severe exposures are encountered.

3.1.12 *thermal hazard*—relates to the laboratory test methods employed to measure thermal characteristics and to predict burn injury potential for burn injury involving exposure to flame or high heat as may be encountered in the work place.

3.1.12.1 *Discussion*—For the purposes of this specification, thermal hazards include exposure high levels of radiant heat or contact with hot surfaces.

[4] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02269-9101.

[5] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[6] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

4. Significance and Use

4.1 This specification establishes minimum design, performance, and labeling criteria for both primary and secondary protective clothing for use in operations involving molten substances and related thermal hazards.

NOTE 1—Standardized molten splash testing of both primary and secondary protective materials and garments as listed in this specification utilize pure molten materials, typically iron or aluminum. In practice, users of protective clothing for metal splash protection may routinely work with alloys. Protective clothing covered by this specification may or may not perform similarly with alloys of various metals. The entity specifying the protective clothing shall determine if the protective clothing is appropriate for their specific alloy.

4.1.1 Requirements are specifically established for materials used in the construction of primary and secondary protective clothing on the basis of performance attributes that are considered important for worker protection. In some cases, different minimum levels for the same performance properties are set between primary and secondary protective clothing due to the differences in the expected performance for these two types of protective clothing.

4.1.2 Additional requirements are established for primary and secondary protective clothing items in terms of the minimum design characteristics and performance features for other materials and components used in the construction of the clothing.

4.2 This specification can be applied to either protective clothing materials or protective clothing, or both.

4.2.1 The application for protective clothing materials involves meeting the respective requirements for either primary or secondary protective clothing materials found in Section 5.

4.2.2 The application for protective clothing involves meeting the respective requirements for either primary or secondary protective clothing found in Section 6, which includes construction of the clothing with protective clothing materials that meet the requirements in Section 5.

5. Design and Materials

5.1 Clothing design shall be such to cover potentially exposed areas as completely as possible by proper interfacing of related items.

5.2 Garment design shall permit easy and rapid removal.

5.3 Garment design shall be such as to interfere the least with work function and still provide the necessary protection.

5.4 *Closures:*

5.4.1 Design closure so as to be appropriate for easy removal of garment (see 5.2).

5.4.2 Materials for closures shall be compatible with thermal resistance of material used and the protective characteristics required.

5.5 Trim, pocketing, and other auxiliary materials used in garment construction shall meet the flammability requirements of this specification (see 8.7) and shall not melt upon thermal exposure.

5.6 *Pockets:*

5.6.1 Garment design shall be appropriate as to not trap or retain molten substances.

5.6.2 Primary protective clothing shall not have external pockets.

5.7 *Thread:*

5.7.1 Sewing thread utilized in the construction of garment shall be made of an inherently flame-resistant fiber and shall not melt when tested at a temperature of 260°C (500°F) according to Test Method D7138, Method 2.

TABLE 1 Specification Requirements, Woven Materials

Characteristic	Primary		Secondary		Section Reference
	Not Coated, Laminated, or Metalized	Coated, Laminated, or Metalized	Shirt	Pants	
Breaking strength, min, N [lbf]	223 [50]	334 [75]	134 [30]	223 [50]	8.1
Tearing strength, N [lbf], min	22 [5.0]	45 [10.0]	11 [2.5]	22 [5.0]	8.2
Dimensional change, %	...	...	Report Value	Report Value	8.3
Durability to Abrasion	...	no aluminum flaking	...	...	8.4
Adhesion	...	no evidence of separation	...	...	8.5
Adhesion after wet flexing	...	no delamination or cracking		...	8.6
Flammability					
Initial					
Char length, max, mm [in].	127 [5.0]	127 [5.0]	152 [6.0]	152 [6.0]	8.7
After flame, max, s	3	3	5	5	8.7
After 25 washes/dry cleaning					
Char length, max, mm [in.]	127 [5.0]	127 [5.0]	152 [6.0]	152 [6.0]	8.7
After flame, max, s	3	3	5	5	8.7
Heat Transfer Performance	40	40	7.0	7.0	8.8.1 & 8.8.3
Radiant Heat Resistance (RHR) min.					
Molten Substance Splash	See Table 2	See Table 2	Report Value	Report Value	8.8.2 & 8.8.4

Note—There shall be no laundering for protective materials or protective garments if manufacturer's care instructions indicate "Dry Clean Only" or "Do Not Wash."

6. Requirements

6.1 The properties of protective materials used for primary and secondary protective clothing shall conform to the specification requirements in Tables 1 and 2, as tested in accordance with Section 8.

6.2 Characteristics of protective garments for both primary and secondary clothing shall conform to the specification requirements in Section 5.

7. Sampling

7.1 Material tests shall be performed on materials as they are delivered to the clothing manufacturer.

7.2 Garment requirements shall be met by finished garments as these garments will be provided to the end user.

7.3 Lot size for the initial (without laundering) flammability test shall be 4572 m (5000 yd) of manufactured material or the manufactured yardage, whichever is less. One sample of 1.0 m shall be taken from each lot.

7.4 Lot size for all other tests except design tests shall be 45720 m (50 000 yd) of manufactured material or at least every three months, whichever is more frequent. One sample of 4.0 m shall be taken from each lot.

7.5 Design test shall be run on the original material and when changes are made to materials, for example, fiber type, yarn type, weaving or knitting method, fabric weight, dyeing, or finishing procedure.

7.6 A lot size for garments shall consist of a single style (prototype) that reflects accurately the garment characteristics specified in Section 5.

8. Test Methods

8.1 *Breaking Strength (load)*—Determine the breaking strength as directed in Test Method D5034.

8.2 *Tearing Strength*—Determine the tear strength for materials for primary protective garments as directed in Test Method D5587, and for materials for secondary protective garments as directed in Test Method D1424.

8.3 *Dimensional Change*—Determine dimensional change for protective materials after laundering five times according to protective material manufacturer's or garment manufacturer's instructions. If no instructions are provided, launder five times as directed in AATCC Method 135 using Conditions 3, IV, Aiii.

NOTE 2—There shall be no laundering for protective materials or protective garments if manufacturer's care instructions indicate "Dry Clean Only" or "Do Not Wash."

8.4 *Reflectivity after Abrasion*—Determine the reflectivity after abrasion of aluminized, coated, or laminated primary materials as directed in NFPA 1971-2013 paragraph 8.51.

8.5 *Adhesion*—Determine the adhesion of aluminized materials, coated, or laminated primary materials as directed in MIL-C-87076A, paragraph 4.5.4.

8.6 *Adhesion after Wet Flexing*—Determine the adhesion after wet flexing of aluminized materials, coated, or laminated primary materials as directed in MIL-C-87076A, paragraph 4.5.5.

NOTE 3—Test Method D4157 is cited in MIL-C-87076A.

8.7 *Flammability*—The flammability shall be tested as specified in Test Method D6413 for samples both initially and after laundering as specified in 8.7.1 or dry cleaning as specified in 8.7.2. No melting and dripping of the test material is permitted.

8.7.1 *Laundering Preconditioning*—Launder materials suitable for laundering 25 times according to protective material manufacturer's or garment manufacturer's instructions. If no instructions are provided, launder 25 times as directed in AATCC Method 135, 3, IV, A iii.

TABLE 2 Pass/Fail Requirements and Average Visual Rating of Primary Protective Materials or Primary Protective Clothing Exposed to Molten Substances

Average Ratings** for Protective Materials Used for Primary Protective Clothing (Level 1 through 5, see Annex A1):	
	Rating (Level)
Molten Substance Sticking:[A] Report sticking level 1 to 5 after testing according to Test Method F955	_____
Material Charring:[B] Report charring level 1 to 5 after testing according to Test Method F955	_____
Material Shrinkage:[C] Report shrinkage level 1 to 5 after testing according to Test Method F955	_____
Material Breakopen:[D] Report Breakopen level 1 to 5 after testing according to Test Method F955	_____
A protective material intended for use in primary protective clothing fails to meet the requirements of this performance specification if any single specimen breakopen area is greater than 3.2 cm^2 (0.5 in^2).	
**The rating system uses levels one through five for sticking, charring, shrinkage, and breakopen, with "1" representing the best performance and "5" representing poorest performance. See Annex A1 for photos to be used for assigning ratings.	
Heat Transfer[E] Pass/Fail Requirement for Protective Materials Used for Primary Protective Clothing During Molten Substance Exposure (see 8.7):	
For protective materials used for primary protective clothing predicted burn injury when tested according to Test Method F955:	Yes No
If predicted burn injury based on the Stoll curve is observed for any protective material test specimen during testing according to Test Method F955, the protective material sample intended to be used for primary protective clothing fails to meet the heat transfer requirement of this performance specification.	

[A] Molten substance sticking is indicated by the visible adhesion of a solidified molten substance to a material after molten substance testing according to Test Method F955, see Annex A1.

[B] Material charring after testing according to Test Method F955, see definition of charring in 3.1.3 and also see Annex A1.

[C] Material shrinkage is the appearance of wrinkling, dimensional distortion, or change, or both, in the test specimen dimensions after testing according to Test Method F955, see Annex A1.

[D] Material breakopen after testing according to Test Method F955, see definition of breakopen in 3.1.2, also see Annex A1.

[E] Heat transfer through the protective material is determined using the Stoll curve according to Test Method F955 or Test Method F1939. For Test Method F955, heat transfer is analyzed using the Stoll curve and can either be sufficient to cause a predicted burn injury or insufficient to cause a predicted burn injury. For Test Method F1939, heat transfer is expressed as an RHR value; the higher the RHR value, the lower the level of heat transfer per unit time and the greater the protection level.