NFPA 2112®-2012
Standard on Flame-Resistant Garments for Protection of Industrial Personnel Against Flash Fire
TIA Log No. 1105
Reference: Various
Comment Closing Date: June 14, 2013
Submitter: Jeffrey O. Stull, International Personnel Protection, Inc.

1. Revise 3.3.6, A.3.3.6, and 3.3.20, and add a new A.3.3.20 to read as follows:

3.3.6* Cold Weather Insulation Material. A fabric that consists of one or more nonseparable layers that is used for protection in a low-temperature environment. A cold weather insulation material is not an interlining (see interlining).

A.3.3.6 Cold Weather Insulation Material. Examples of insulation materials ~~are~~ include textile battings(s) alone or batting(s) that are attached to a face cloth. For example, an insulation material consisting of two layers are considered nonseparable by the attachment that combines the two layers. The insulation material may or may not have a face cloth. Cold weather insulation materials generally are provided within the garment such that their area of coverage coincides with the majority of garment area covering the wearer's body.
Cold weather insulation material as defined in this standard does not preclude the use of intermediate layers for additional protection against thermal hazards.

3.3.20* Interlining. Any textile that is incorporated into any garment as a layer between outer and inner layers that only covers a small portion of the overall garment. ~~[**1975**, 2009]~~

A.3.3.20 Interlining. The outer and inner layers are compliant to the fabric requirements of this standard. Examples of an interlining are a fabric layer used to stiffen the waist band in a pair of pants or a facing fabric used inside the closure flap of a coverall. Interlining materials do not come in contact with the wearer's skin or underclothing.

2. Revise subsections 5.1.2, 5.1.9(7), and 5.1.12, and add a new 5.1.13 to read as follows:

5.1.2 At least one product label shall be conspicuously located inside each flame-resistant garment. ~~when the item is properly assembled with all layers and components in place.~~

5.1.9(7) Fiber content for each primary fabric layer including cold weather insulation materials, but excluding interlinings and labels.

5.1.12 Garments with multiple layers, including an outer layer and removable cold weather insulation layer, shall specify the certified ~~wearable configurations on the label~~ configuration and include a warning on the label stating that all layers must be properly secured and worn in accordance with the manufacturer's instructions.

5.1.13 For garments with multiple layers that include an outer layer and a removable cold weather insulation layer, a label shall be conspicuously attached to the removable insulation layer that states "DO NOT WEAR THIS LINER BY ITSELF. FOR COMPLIANCE WITH THE FLASH FIRE REQUIREMENTS OF NFPA 2112, THE COMPLETE GARMENT MUST BE WORN. FOR COMPLIANCE INFORMATION, SEE THE PRODUCT LABEL ON OUTER GARMENT."

3. Add new Section 6.4 and subsections 6.4.1, and A.6.4.1 to read as follows:

6.4 Use of a Liner for Cold Weather Insulation. Garments shall be permitted to include liners in their construction including cold weather insulation materials where the liner is either integral to the garment or removable.

6.4.1* Where garments incorporate a cold weather insulation material as part of a removable lining system, the garment shall be designed such that the removable liner consisting of the cold weather insulation material cannot be independently worn.

A.6.4.1 Removable liners are permitted to be worn separately if the liner material(s) independently meets the appropriate fabric requirements in Chapter 7 including 7.1.1 for heat transfer performance and 7.1.5 for overall flash fire performance. If the liner contains cold weather insulation materials that are not evaluated to 7.1.1 and 7.1.5 and do not pass the thermal shrinkage resistance requirement in 7.1.3, then the manufacturer must label the liner as specified in 5.1.13 and provide a design that does not allow separate wearing of the liner without the outer layer. This may be demonstrated by the absence of a means of closure for the closure area of shirts, pants, and coveralls.

4. Add new subsections 7.1.1.1 and 7.1.1.2 to read as follows:

7.1.1.1 Where the flame-resistant garment consists of multiple and separable layers intended to be worn separately, the outer layer and the inner layer or layers shall be separately tested.

7.1.1.2 Where the flame-resistant garment consists of multiple layers intended only to be worn together, only the outer layer shall be tested.

5. Revise subsections 7.1.2 and 7.1.3 to read as follows:

7.1.2 Fabric, cold weather insulation material, and reflective striping utilized in the construction of flame-resistant garments shall be tested for flame resistance as specified in Section 8.3, and shall have a char length of not more than 100 mm (4 in.) and an after-flame of not more than 2 seconds, and shall not melt and drip.

7.1.3 Fabric utilized in the construction of flame-resistant garments, excluding manufacturer's labels, interlinings, and cold weather insulation materials, shall be individually tested for thermal shrinkage resistance as specified in Section 8.4, and shall not shrink more than 10 percent in any direction.

6. Delete existing subsection 7.1.3.1 as follows:

~~**7.1.3.1** Cold weather insulation materials utilized in the construction of flame-resistant garments shall be tested in accordance with Section 8.4 and shall not shrink more than 20 percent in any direction.~~

7. Revise subsection 7.1.4 to read as follows:

7.1.4 Fabric, cold weather insulation materials, other textile materials, and reflective striping other than those items described in 7.1.4.1 and 7.1.4.2, used in the construction of flame-resistant garments shall be individually tested for heat resistance in their original form as specified in Section 8.4, and shall not melt and drip, separate, or ignite.

8. Add a new subsection 8.3.1.7 to read as follows:

8.3.1.7 Modifications to this test method for testing cold weather insulation materials shall be as specified in 8.3.13.

9. Revise subsections 8.3.3.1, 8.3.3.2, and 8.3.3.3 to read as follows

8.3.3.1 For fabrics and cold weather insulation materials that are designated on the flame-resistant garment label to be washed, specimens shall be tested before and after 100 cycles of washing and drying as specified in 8.1.3.

8.3.3.2 For fabrics and cold weather insulation materials that are designated on the flame-resistant garment label to be dry-cleaned, specimens shall be tested before and after 100 cycles of dry cleaning as specified in 8.1.4.

8.3.3.3 For fabrics and cold weather insulation materials that are designated on the flame-resistant garment label to be either washed or dry-cleaned, specimens shall be tested before and after 100 cycles of washing and drying as specified in 8.1.3, or after 100 cycles of dry cleaning as specified in 8.1.4.

10. Add new subsections to 8.3.13 to read as follows:

8.3.13 Specific Requirements for Testing Cold Weather Insulation Materials.

8.3.13.1 Samples for wash or dry-clean conditioning shall be prepared by cutting a 66-cm × 66-cm (26-in. × 26-in.) panel of the cold weather insulation material. A similar-sized piece of 200-g/m^2 to 270-g/m^2 (6.0-oz/yd^2 to 8.0-oz/yd^2) flame-resistant fabric meeting all requirements of this standard shall be sewn around the perimeter of the cold weather insulation material such that the batting side is covered by the fabric.

8.3.13.2 Following wash or dry-clean conditioning, 5 specimens measuring 75 mm × 300 mm (3 in. × 12 in.) from each of the warp and filling direction shall be removed from the cold weather insulation material layer of the conditioned panels.

8.3.13.3 If applicable, all specimens shall be prepared for testing by trimming the scrim material, batting, or other layer(s) away from the face cloth by 50 mm ± 3 mm (2.0 in. ± 1/8 in.) such that the face cloth can be folded back covering the scrim, batting, or other layer(s) by 50 mm ± 3 mm (2.0 in. ± 1/8 in.); the folded specimen shall be secured in the specimen holder.

8.3.13.4 Testing shall be performed as described in 8.3.2 through 8.3.7.

11. Revise subsection 8.4.1 and add new subsections 8.4.1.1 through 8.4.1.5 to read as follows:

8.4.1 Application. ~~The heat and thermal shrinkage resistance test method shall apply to flame-resistant garment fabrics, components, and hardware.~~

8.4.1.1 This test method shall apply to flame-resistant garment fabrics, components, hardware, and cold weather insulation materials.

8.4.1.2 Modifications to this test method for testing flame-resistant garment textile materials shall be as specified in 8.4.8.

8.4.1.3 Modifications to this test method for testing other flame-resistant garment materials, including reflective striping, shall be as specified in 8.4.9.

8.4.1.4 Modifications to this test method for testing hardware shall be as specified in 8.4.10.

8.4.1.5 Modifications to this test method for testing cold weather insulation materials shall be as specified in 8.4.11.

12. Revise subsections 8.4.2.1 and 8.4.3.1 through 8.4.3.3 to read as follows:

8.4.2.1 Only heat resistance testing shall be conducted on not fewer than three specimens for each hardware item, label material, ~~and~~ other flame-resistant garment fabrics, and cold weather insulation materials not listed in 8.4.2.2 and 8.4.2.3.

8.4.3.1 For fabrics and cold weather insulation materials that are designated on the flame-resistant garment label to be washed, specimens shall be tested before and after three cycles of washing and drying as specified in 8.1.3.

8.4.3.2 For fabrics and cold weather insulation materials that are designated on the flame-resistant garment label to be dry-cleaned, specimens shall be tested before and after three cycles of dry-cleaning as specified in 8.1.4.

8.4.3.3 For fabrics and cold weather insulation materials that are designated on the flame-resistant garment label to be either washed or dry-cleaned, specimens shall be tested before and after three cycles of washing and drying as specified in 8.1.3, after three cycles of dry-cleaning as specified in 8.1.4.

13. Delete existing subsection 8.4.8.2 and renumber 8.4.8.3 to 8.4.8.2 to read as follows:

~~**8.4.8.2** Measurements of cold weather insulation material thermal shrinkage shall be made on the side of the fabric facing the wearer as used in the construction of the garment.~~

~~**8.4.8.3**~~ **8.4.8.2** Testing shall be performed in accordance with 8.4.2 through 8.4.7.

14. Add new subsection 8.4.11 to read as follows:

8.4.11 Specific Requirements for Testing Cold Weather Insulation Materials.

8.4.11.1 Samples for wash or dry-clean conditioning shall be prepared by cutting a 50-cm × 20-cm (20-in. × 8-in.) panel of the cold weather insulation material. A similar-sized cloth piece of 200-g/m^2 to 270-g/m^2 (6.0-oz/yd^2 to 8.0-oz/yd^2) flame-resistant fabric meeting all requirements of this standard shall be sewn around the perimeter of the cold weather insulation material such that the batting side is covered by the fabric .

8.4.11.2 Following wash or dry-clean conditioning, 3 specimens measuring 152 mm × 152 mm (6 in. × 6 in.) shall be removed from the cold weather insulation material layer of the conditioned panel.

8.4.11.3 Testing shall be performed in accordance with 8.4.2 through 8.4.7, and thermal shrinkage shall not be measured.

Submitter's Substantiation: The current criteria in NFPA 2112-2012 are not workable to support the inclusion of cold weather insulation materials that provide safe and effective protection of flame resistant garments used for protection of workers against accident flash fires. Changes were made to the 2012 edition of NFPA 2112 without the benefit of a full validation effort. An effort intended to meet this purpose has now been completed by a task group under the direction of the Technical Committee where several prospective cold weather insulation materials were evaluated using existing and proposed test methods that included both current and modified flame resistance and heat/thermal shrinkage resistance testing. Additional evaluations were carried out using full scale manikin testing with garments incorporating the selected cold weather insulation materials in jackets of a simple design to assess effects of simulated flash fires on the clothing and insulation materials.

This effort produced the following two primary findings:

1. One of the cold weather insulation materials included in the investigation exhibited average afterflame times in excess of the 2-second requirement using the current flame resistance test procedures. When tested according to the proposed modified flame resistance test procedures, afterflame times were compliant or near compliant. In addition, the manikin-based testing for the same fabric exhibiting extended afterflame times, showed no unusual burning behavior during manikin testing of full garments where the liner consisted of the cold weather insulation material or showed shrinkage that differed radically from garments using materials that qualify to current NFPA 2112 performance criteria. Based on these findings, the modified flame resistance testing can be utilized for the evaluation of cold weather insulation materials.

   It was observed that after flame times were observed to be generally shorter when a 50 mm folded edge was used as compared to a 25 mm folded edge. It was also rationalized that more consistent results would be provided with the 50 mm folded edge for the modified flame test because the specimen is positioned 19 mm into a 38 mm high flame leaving only a 6 mm space between the top of the flame and the beginning of the unprotected (by the folded edge) batting. It was therefore reasoned and consistent with the observed test results that the modified flame resistance test should use a 50 mm folded edge.

   Specific changes to NFPA 2112 have been proposed in proposed modifications shown in Section 8.3.

2. Certain cold weather insulation materials exhibited significant distortion in heat/thermal shrinkage resistance testing and thermal shrinkage. Yet, these same materials when employed in the form of a liner in a flame resistant jacket utilizing a lightweight shell material did not show significant differences in their shrinkage (of the liner) with materials that would otherwise pass the NFPA 2112-2013 thermal shrinkage resistance criteria. This further included testing with the jacket samples inverted (turned inside out)

representing a “worst case” exposure and wearing configuration where no adverse safety issues were observed. From these results, the exemption of cold weather insulation materials from the thermal shrinkage resistance requirement can be justified. Specific changes to NFPA 2112 implementing these modifications are provided as in paragraphs 7.1.3, 7.1.3.1 (deletion), 7.1.4, and Section 8.4.

It is important to point out that the cold weather insulation material is required to meet a heat resistance requirement and is always covered by an outer (shell) material (paragraph 7.1.4). If it is not, it would not qualify as a cold weather insulation material. It is also important to point out that while these changes were based on testing that did not show any safety of the protective garment to be compromised when presented to a simulated flash fire, conditions may exist for which cold weather insulation materials (and other garment materials) will fail to provide intended levels of protection.

The following substantiations are proposed for the additional changes in this amendment to address cold weather insulation material definitions, labeling, design criteria, performance criteria, and test methods:

- A clarification was added to the definition of cold weather insulation material to indicate that the material is not an interlining. Additional language was also added to distinguish an interlining that is not tested for heat resistance or thermal shrinkage resistance from a cold weather insulation material, which is tested for heat resistance but not thermal shrinkage resistance (paragraphs 3.3.6, 3.3.20, A.3.3.6, and A.3.3.20).

- Additional labeling language was added to require the identification of the cold weather insulation material fiber content, the inclusion of a warning that garments with cold weather insulation materials must be properly secured and that a separate label must be provided on the liner if detachable, that indicates that the liner must not be worn by itself. These changes are covered in paragraph 5.1.2, 5.1.9, 5.1.12, and 5.1.13).

- Design criteria were added to permit garment with sewn-in or detachable liners that utilize cold weather insulation materials but that manufacturers must design removable liners so that the liner cannot be worn without the outer layer (paragraphs 6.4 and A.6.4).

- Changes were made in the performance criteria to clarify to which requirements cold weather insulation materials are tested (paragraphs 7.1.2, 7.1.3, and 7.1.4).

- A clarification was provided to specify that the cold weather insulation material is not tested for thermal protective performance (paragraphs 7.1.1.1 and 7.1.1.2).

- Specific procedures were added to address the modified testing of the cold weather insulation material as specified in U.S. Air Force purchase description NCTRF PD N2-01-3A, *Batting, Quilted, Aramid*, involving the removal of 50 mm of batting and folding of the face cloth over the remaining batting, as supported by the test information provided above (paragraph 8.3.1.7 and Section 8.3.13). Additional instructions were provided for preparing samples for conditioning by sewing a layer of flame resistant fabric to the cold weather insulation material prior to laundering with its removal following laundering or dry cleaning (paragraphs 8.3.13.1 and 8.3.13.2).

- Modifications for the heat and thermal shrinkage resistance test method were made to clarify that the cold weather insulation materials are not evaluated for thermal shrinkage resistance as supported by the test information above (paragraphs 8.4.1.1 through 8.4.1.5, paragraph 8.4.2.1, and section 8.4.11). Additional instructions were provided for preparing samples for conditioning by sewing a layer of flame resistant fabric to the cold weather insulation material prior to laundering with its removal following laundering or dry cleaning (paragraphs 8.4.3.1 through 8.4.3.3).

For supporting documentation see the doc info pages at www.nfpa.org/2112.

Emergency Nature: The proposed TIA intends to correct a circumstance in which the revised NFPA Standard has resulted in an adverse impact on a product or method that was inadvertently overlooked in the total revision process or was without adequate technical (safety) justification for the action. As currently written, NFPA 2112 includes

criteria that create a bias against cold weather insulation materials that is inconsistent with their use and in consistent with demonstrated levels of safety.

The OSHA interpretation of March 2010 encouraging employers to provide their employees with garments certified to a consensus standard like NFPA 2112 has created a need and demand for outerwear garments for cold weather protection that are certified to the NFPA 2112 standard. The current edition of the NFPA 2112 standard does not provide clear methods to properly test and certify garments that incorporate insulation for additional protection from cold weather.

Anyone may submit a comment by the closing date indicated above. To submit a comment, please identify the number of the TIA and forward to the Secretary, Standards Council, 1 Batterymarch Park, Quincy, MA 02169-7471.

Supporting Material for TIA 1105 (2112)

This study was carried out by a task group under the direction of the technical committee to investigate and the safety of various cold weather insulation materials that can be used in conjunction with flame resistant garments for protection of industrial personnel against flash fire hazards. The objectives of this study were to specifically evaluate the different cold weather insulation materials for key properties currently provided in the 2012 edition of NFPA 2112 and compare this performance against the results of thermal instrumented manikin tests, which simulate actual exposure of garments to flash fire. The study also included an investigation for the modification of the existing flame resistance test to specifically address observed issues for performance with cold weather insulation materials.

Cold weather insulation materials tested in this study are listed in Table 1.

Table 1 – Cold Weather Insulation Materials Evaluated as Part of Validation Effort

Mat'l. Desig.	Generic Description	Relevance for Study
A	130 g/m^2 Aramid needle punch batting quilted to 115 g/m^2 Aramid face cloth	Used as control (known ability to comply with current NFPA 2112 requirements)
B	155 g/m^2 80% reprocessed Aramid/ 20% FR Rayon batting quilted to115 g/m^2 50% Aramid/ 50% FR Modacrylic face cloth	Material has facecloth that could exhibit increased shrinkage during thermal shrinkage test
C	170 g/m^2 FR Modacrylic batting quilted to 180 g/m^2 100% FR cotton face fabric	Material includes batting that could exhibit high levels of shrinkage in thermal shrinkage resistance test
D	120 g/m^2 55% Modacrylic /30% Aramid/ 15% polyester with 100% Nylon scrim quilted to 185 g/m^2 flame-resistant 88% cotton/12% Nylon fabric	Same as above
E	339 g/m^2 90% reprocessed virgin Aramid fibers/10% 10% FR viscose needle punch batting quilted to 100% Aramid face cloth	Material includes polyester scrim support layer that exhibit afterflaming
F*	475 g/m^2 100% Aramid nonwoven batting quilted with light scrim and breathable wind barrier quilted to 100% Aramid face cloth	Similar as above material, but also includes additional breathable wind barrier layer as part of overall material

* This material was not evaluated in all tests.

The following tests were carried out for each material:

- Flame resistance as currently specified in NFPA 2112, Section 8.3 with the exception that the cold weather insulation material samples were only laundered a total of 3 times as specified in 8.1.3 of NFPA 2112 and protected by a layer of 150 g/m^2 100% Aramid fabric during laundering.

- Flame resistance in accordance with Section 8.3 of NFPA 2112 but including the modification of where either 25 or 50 mm of insulation batting was removed from the exposure edge of the specimen and the face cloth was folded 25 mm over the insulation material and stapled along the sides of the specimen as specified in U.S. Air Force purchase description NCTRF PD N2-01-3A, *Batting, Quilted, Aramid*; cold weather insulation material samples were laundered a total of 3 times as specified in 8.1.3 of NFPA 2112 and protected by a layer of 150 g/m^2 100% Aramid fabric during laundering. Replicate tests were split by the participating laboratories between the 25 and 50 mm folded edge procedures for most samples.

- Heat and thermal shrinkage resistance testing in accordance with Section 8.4 of NFPA 2112; cold weather insulation material samples were protected by a layer of 150 g/m^2 100% Aramid fabric during laundering.

- Instrumented thermal manikin testing was performed in accordance with ASTM F1930, *Standard Test Method for Evaluation of Flame Resistant Clothing for Protection Against Fire Simulations Using an Instrumented Manikin*, using a 3-second exposure without any underclothing on the manikin; jackets were constructed using each of the cold weather insulation materials a sewn in lining with a 100% 150 g/m^2 shell material. Jackets were considered to be a worst case product because of the potential for flame to come underneath the bottom hem of the jacket at the mid-torso length. Waist-length, long-sleeved jackets were constructed to be devoid of pockets but included a knit Aramid collar and sleeve end cuffs, a 4-snap front closure in a size to fit the thermal-instrumented manikin. The jacket design included a bottom hem with drawstring feature to control the gap between the lower hem of the jacket and the manikin body. Sample jackets were tested in three configurations – (1) with jacket front closure fully secured, (2) with jacket front closure open, and with the jacket turned inside out to observe effects directly on the cold weather insulation material-based liner as an absolute worst case wearing configuration. Portions of the manikin not covered by the jacket were exposed to the simulated flash fire. In addition to the prescribed measurement of predicted 3rd degree and total burn injury, measurements of shrinkage on the face cloth side of each jacket were made in the locations shown in Figure 1.

Both flame resistance and heat/thermal shrinkage resistance testing was conducted by two separate laboratories that provide testing services for the certification of garment to NFPA 2112 including Intertek Testing Services (“Intertek”) and Underwriters Laboratories (“UL”). The average results using both standard and modified flame resistance test methods are reported in Table 2 (room temperature) and Table 3 (after laundering) while the heat and thermal shrinkage resistance test results are provided in Table 4. The manikin testing for this effort was conducted by DuPont. Results from this testing are shown in Tables 5 and 6.

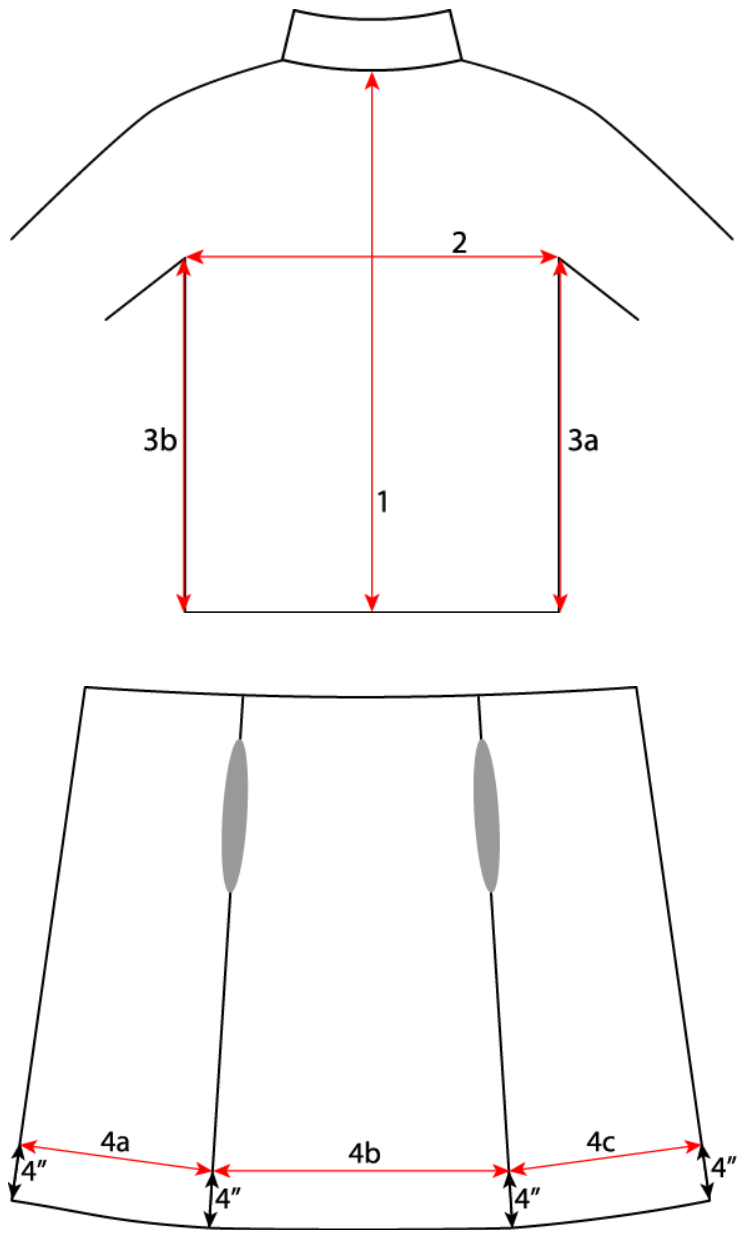


Figure 1 – Measurement Locations for Determining Shrinking of Cold Weather Insulation Material (all measurements made on face cloth side of material)

Table 2 – Flame Resistance Data for Selected Cold Weather Insulation Materials Subjected to Room Temperature Conditioning*

Mat'l	Lab	Method	Afterflame (sec) †		Char length (mm) †		Melting or dripping? †	
			Warp	Fill	Warp	Fill	Warp	Fill
A	ITS	Standard	0	0	54	51	No	No
		Modified‡	0	0	48	54	No	No
	UL	Standard	0.61	0.49	46	37	No	No
		Modified	0.78	0.58	35	33	No	No
B	ITS	Standard	0	0	78	69	No	No
		Modified‡	0	0	42	39	No	No
	UL	Standard	0.44	0.59	73	61	No	No
		Modified	0.67	0.77	42	62	No	No
C	ITS	Standard	0	0	57	57	No	No
		Modified‡	0	0	36	36	No	No
	UL	Standard	0.51	0.66	21	34	No	No
		Modified	0.54	0.5	20	24	No	No
D	ITS	Standard	0	0	6	9	No	No
		Modified‡	0	0	9	9	No	No
	UL	Standard	0.68	0.64	6	9	No	No
		Modified	0.81	0.71	7	7	No	No
E	ITS	Standard	6.4	2.3	34	32	No	No
		Modified‡	0.3	3.4	26	29	No	No
	UL	Standard	3.46	2.78	27	25	No	No
		Modified‡	0.83	0.87	16	14	No	No
F	ITS	Standard	1.8	0.6	5	3	No	No
		Modified‡	1.2	1.6	8	3	No	No
	UL	Standard	1.2	1.03	5	5	No	No
		Modified‡	1.27	1.18	3	3	No	No

* Testing in accordance with NFPA 2112-2012, Section 8.3; room temperature conditioning and laundering per 8.1.2; all data are the average of 5 replicates in each direction.

** Lining material descriptions provided in Table 1.

† NFPA 2112-2012 requires fabrics have after flame times that do not exceed 2 seconds in either direction, char lengths that do not exceed 100 mm in either direction, and that specimens not exhibit melting or dripping.

‡ A portion of the replicates tests using the modified test procedures were evaluated with specimens having a 50 mm folded edge with the remainder of the specimens used a 25 mm folded edge.

Table 3 – Flame Resistance Data for Selected Cold Weather Insulation Materials After 3 Cycles of Industrial Laundering*

Mat'l **	Lab	Method	Afterflame (sec) †		Char length (mm.) †		Melting or dripping? †	
			Warp	Fill	Warp	Fill	Warp	Fill
A	ITS	Standard	0	0	45	45	No	No
		Modified‡	0	0	36	42	No	No
	UL	Standard	0.97	0.68	44	47	No	No
		Modified	0.74	0.68	34	43	No	No
B	ITS	Standard	0	0	81	63	No	No
		Modified‡	0	0	36	51	No	No
	UL	Standard	0.61	0.66	75	66	No	No
		Modified	0.63	0.53	66	47	No	No
C	ITS	Standard	0	0	30	39	No	No
		Modified‡	0	0	33	30	No	No
	UL	Standard	0.79	0.65	36	40	No	No
		Modified	0.66	0.63	21	22	No	No
D	ITS	Standard	0	0	3	3	No	No
		Modified‡	0	0	9	9	No	No
	UL	Standard	0.83	0.87	5	5	No	No
		Modified	0.59	0.61	5	5	No	No
E	ITS	Standard	1.9	5.0	29	32	No	No
		Modified‡	0.9	0.5	11	18	No	No
	UL	Standard	1.87	5.47	19	27	No	No
		Modified‡	0.83	0.87	16	14	No	No
F	ITS	Standard	0.9	0.9	3	5	No	No
		Modified‡	0.3	0.6	5	3	No	No
	UL	Standard	0.86	0.92	4	4.8	No	No
		Modified‡	0.94	0.97	3	4	No	No

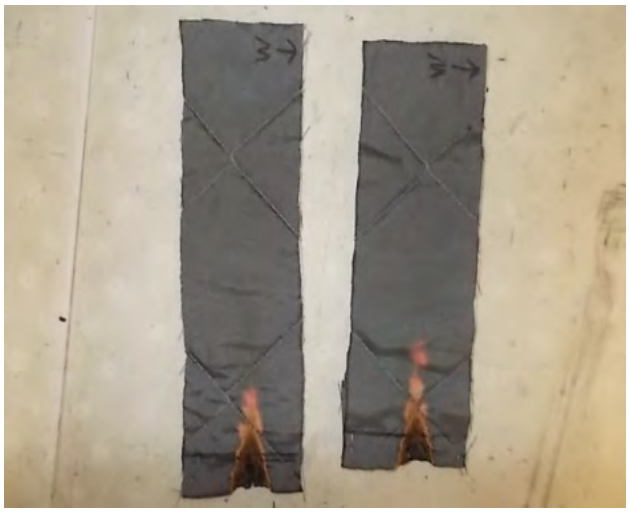
* Testing in accordance with NFPA 2112-2012, Section 8.3; room temperature conditioning and laundering per 8.1.3 but using 3 cycles instead of 100 cycles; samples for conditioning were also prepared by sewing a layer of 150 g/m^2 to the batting side of cold weather insulation material; all data are the average of 5 replicates in each direction.

** Lining material descriptions provided in Table 1.

† NFPA 2112-2012 requires fabrics have after flame times that do not exceed 2 seconds in either direction, char lengths that do not exceed 100 mm in either direction, and that specimens not exhibit melting or dripping.

‡ A portion of the replicates tests using the modified test procedures were evaluated with specimens having a 50 mm folded edge with the remainder of the specimens used a 25 mm folded edge.

Photographs of representative tested samples appear in Figures 2 and 3.



(a) Face Cloth Side **(b) Batting Side**

Figure 2 – Material E Specimens Showing Post-Test Condition for 25 mm and 50 mm Folded Edge Configuration

(a) Face Cloth Side **(b) Batting Side**

Figure 3 – Material F Specimens Showing Post-Test Condition for 25 mm and 50 mm Folded Edge Configuration

Table 4 – Heat and Thermal Shrinkage Resistance Data for Sample Lining Materials*

Mat'l **	Lab	Heat Resistance†		% Thermal Shrinkage Resistance‡			
		Melting, Ignition, Dripping or Separation; Other Observations		Room Temp. Conditioning		After 3X Laundry Cycles	
		Room Temp. Conditioning	After 3X Laundry Cycles	Warp	Fill	Warp	Fill
A	ITS	No	No	>10	>10	>10	>10
	UL	No	No	>10	>10	>10	>10
B	ITS	No	No	>10	>10	>10	>10
	UL	No	No	>10	>10	>10	>10
C	ITS	No	No	-2.71	-2.97	-3.08	-3.78
	UL	No	No	-2.4	-3.6	-4.2	-4.3
D	ITS	No	No	-0.48	-0.26	0.61	0.17
	ITS	No	No	-0.7	-1.7	-0.3	0.1
E	ITS	No	No	-3.63	-3.58	-3.57	-5.42
	UL	No	No	-2.5	-3.1	-4.7	-4.5
F	ITS	Dripping	Dripping	0.4	-0.79	0.79	-0.92
	UL	Melting / Dripping	Melting / Dripping	1.8	-1.2	-0.1	-1.7

* Testing in accordance with NFPA 2112-2012, Section 8.4; room temperature conditioning and laundering per 8.1.2 and 8.1.3, respectively; all data are the average of 3 replicates.
** Lining material descriptions provided in Table 1.
† NFPA 2112-2012 requires fabrics not to melt, ignite, drip or separate during and after heat resistance testing in a forced air circulating oven at 500°F (260°C for 5 minutes).
‡ NFPA 2112-2012 requires fabrics not to exhibit shrinkage of more that 20% in either direction; shaded boxes represent non-compliant results.

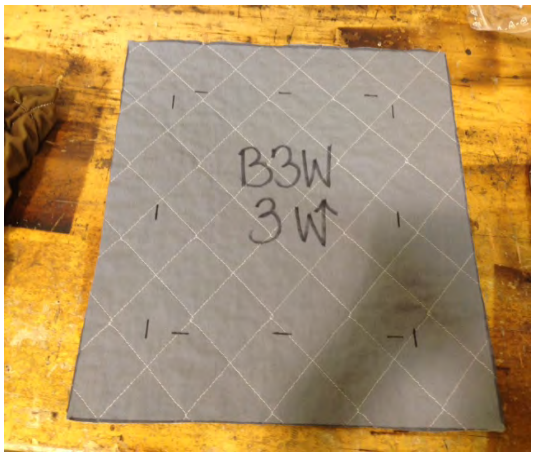
Copies of the laboratory reports for the flame resistance and heat/thermal shrinkage resistance are available from NFPA Headquarters.

Photographs of representative tested samples appear in Figures 4 through 7.

(a) Before exposure

(b) After exposure

Figure 4 – Material B Face Cloth Side Before and After 5-minute 260°C Heat Exposure



(a) Before exposure

(b) After exposure

Figure 5 – Material C Face Cloth Side Before and After 5-minute 260°C Heat Exposure

(a) Before exposure (face cloth side)

(b) After exposure (face cloth side)

(c) After exposure (batting side)

Figure 6 – Material D Before and After 5-minute 260°C Heat Exposure

(a) Front before exposure

(b) Back before exposure

(c) Front after exposure

(d) Back after exposure

Figure 7 – Material F Before and After 5-minute 260°C Heat Exposure

Table 5 – Test Data and Observations from Evaluation of Jackets Using Cold Weather Insulation Material-Based Liners in Instrumented Manikin Testing*

Liner Mat'l **	Wearing Config.†	Predicted Burn Injury		After-flame Time (sec)	Observations‡		
		3rd Degree	Total***		Break-open	Melt/ Stick	Other
A	Secured	36.9	45.1	0			Outer shell shrinkage
	Open	36.9	58.2	0			
	Inverted	38.5	44.3	0	Yes		Sleeve broke open; face cloth only
B	Secured	34.4	44.3	0		Yes	Batt to outer shell
	Open	36.1	54.9	0		Yes	Shrinkage near hem; Batt to outer shell
	Inverted	n/a	n/a	n/a	n/a	n/a	n/a
C	Secured	36.1	44.3	5		Yes	Puckering; batt to outer shell
	Open	35.2	51.1	5			Batt to outer shell
	Inverted	33.6	44.3	8.5			Activation of face cloth
D	Secured	32.8	43.4	0		Yes	Batt to outer shell
	Open	36.9	54.1	0		Yes	Batt to outer shell
	Inverted	32.8	44.3	2.8			Activation of face cloth on sleeves
E	Secured	44.3	45.9	1.8			Puckering bottom edge
	Open	45.6	56.6	1.9			Puckering bottom edge
	Inverted	35.2	45.1	2.4	Yes		Puckering bottom edge

* Testing performed in accordance with ASTM F1930 with 3-second exposure; no undergarments were worn on manikin underneath jacket or on exposed areas of garment not covered by jacket

** Lining material descriptions provided in Table 1; Material tested as sewn-in liner inside jacket comprising a 150 g/m^2 shell, zipper front closure, regular sleeves, standard collar, no pocket, and with a hem that included a drawstring to maintain a uniform gap between the jacket bottom hem and the manikin surface.

*** Large portions of 3rd degree burn attributed to portions of instrument manikin not covered by jacket including legs and head.

† Secured – jacket front closure fully closed; Open – jacket front closure open; Inverted – jacket turned inside out.

‡ If no observation was made, no information was noted; when reported, afterflame pertained to that area of the garment with longest observed afterflame; "batt to outer shell" refers to materials exhibiting melting or sticking – these observations were made only on portions of the jacket; activation of face cloth means that flaming occurred at that part of the garment (when inverted).

Representative output from the manikin testing is provided in Figures 8 through 10. Photographs of representative tested samples for Materials A through E appear in Figures 11 through 24.

Thermo-Man® File Name	Predicted Burn Injury
°R130325E	45.1 % Total
	8.2 % 2nd
Nomex IIIA Shell	36.9 % 3rd Degree
Exposure Information	Use Deprecated Burn Model ☐

Program Version:	6
Time Stamp:	2013-03-25 10:42:30 -0400
System Identity:	SPRUANCE (SN 50920114538)
Run ID:	Demonstration
Sensor Calibration File Name:	SensorInfo-R.bdat
Exposure Time, seconds:	3.0
Acquisition Time, seconds:	60.0
Scan Interval, seconds:	0.1 (601 Total Temperature Scans)
Garment Identity:	Nomex IIIA Shell

Misc Garment Information:
Nomex IIIA Shell, 4.5 opsy, Dupont(R), NB, 44R, AR
Airlite Liner Closed & snapped

Pre-Run Information:
Temp: 40 Wind: 04 Hum: 84 Bar: 29.69in

Post-Run Information:
1.7 sec afterflame front left arm

Garment Type:	Other
Head Unprotected:	Yes
Arms Unprotected:	No
Other Unprotected Sensors:	
Number of Sensors:	122

Survival Rate by Age Group (2012 ABA National Burn Repository Data)

20-29.9	30-39.9	40-49.9	50-59.9
87.5%	89.9%	75.7%	60.2%

ASTM F1930-2012 Burn Injury Prediction Model

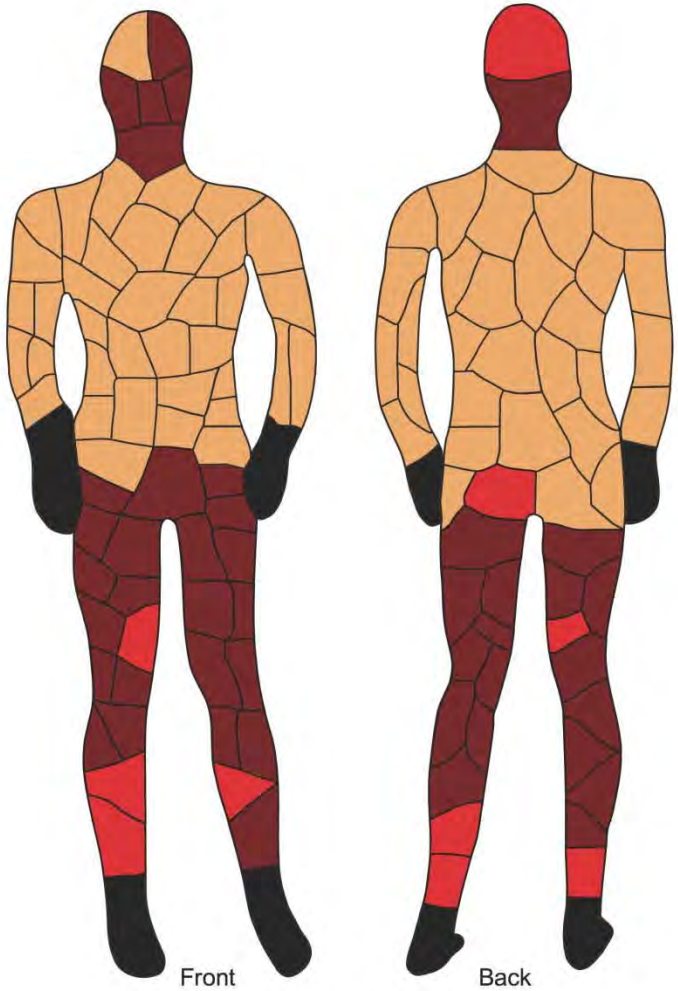


Figure 8 – Instrumented Manikin Test Output for Material A Garment – Closure Secured

Thermo-Man® File Name	Predicted Burn Injury
°R130325F	58.2 % Total
	21.3 % 2nd
Nomex IIIA Shell	36.9 % 3rd Degree

Exposure Information — Use Deprecated Burn Model ☐

Program Version:	6
Time Stamp:	2013-03-25 10:54:02 -0400
System Identity:	SPRUANCE (SN 50920114538)
Run ID:	Demonstration
Sensor Calibration File Name:	SensorInfo-R.bdat
Exposure Time, seconds:	3.0
Acquisition Time, seconds:	60.0
Scan Interval, seconds:	0.1 (601 Total Temperature Scans)
Garment Identity:	Nomex IIIA Shell

Misc Garment Information:
Nomex IIIA Shell, 4.5 opsy, Dupont(R), NB, 44R, AR
Airlite Liner Coat Open

Pre-Run Information:
Temp:40F Wind: 04 Hum: 84 Bar: 29.69in

Post-Run Information:
General afterflame

Garment Type:	Other
Head Unprotected:	Yes
Arms Unprotected:	No
Other Unprotected Sensors:	
Number of Sensors:	122

Survival Rate by Age Group (2012 ABA National Burn Repository Data)

20-29.9	30-39.9	40-49.9	50-59.9
79.3%	71.3%	60.0%	42.6%

ASTM F1930-2012 Burn Injury Prediction Model

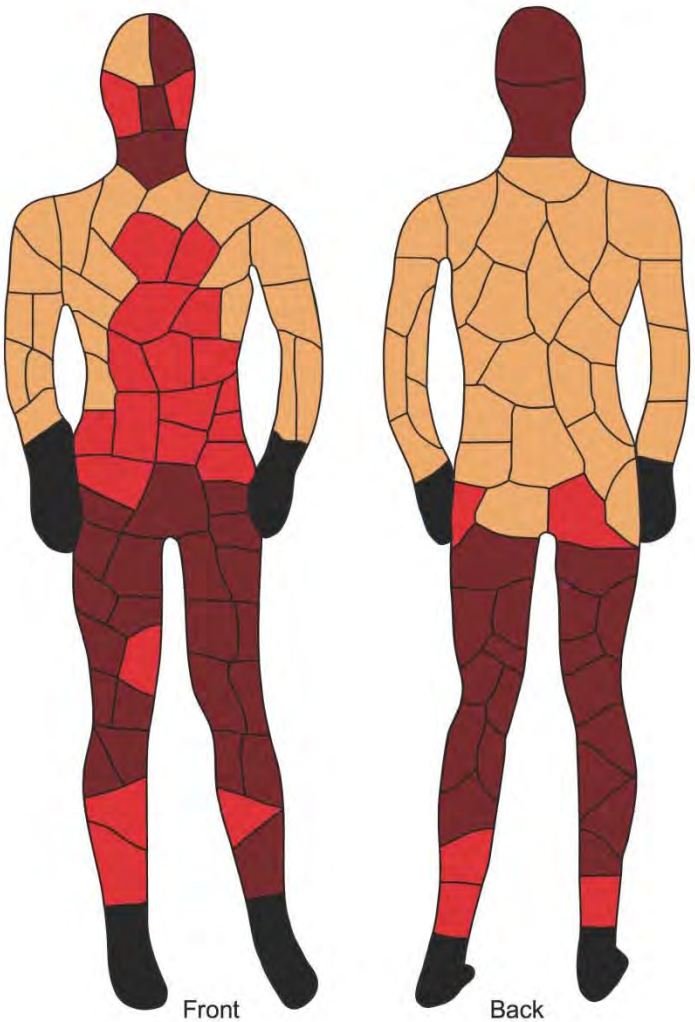


Figure 9 – Instrumented Manikin Test Output for Material A Garment – Closure Open

Thermo-Man® File Name	Predicted Burn Injury
°R130325G	44.3 % Total
	5.7 % 2nd
Nomex IIIA Shell	38.5 % 3rd Degree

Exposure Information — Use Deprecated Burn Model ☐

Program Version:	6
Time Stamp:	2013-03-25 11:07:08 -0400
System Identity:	SPRUANCE (SN 50920114538)
Run ID:	Demonstration
Sensor Calibration File Name:	SensorInfo-R.bdat
Exposure Time, seconds:	3.0
Acquisition Time, seconds:	60.0
Scan Interval, seconds:	0.1 (601 Total Temperature Scans)
Garment Identity:	Nomex IIIA Shell

Misc Garment Information:
Nomex IIIA Shell, 4.5 opsy, Dupont(R), NB, 44R, AR
Airlite Liner Shell closed & snapped (inside out)

Pre-Run Information:
Temp:41F Wind: 00mph RH:83 % Bar: 29.69inHg

Post-Run Information:
general afterflame

Garment Type:	Other
Head Unprotected:	Yes
Arms Unprotected:	No
Other Unprotected Sensors:	
Number of Sensors:	122

Survival Rate by Age Group (2012 ABA National Burn Repository Data)

20-29.9	30-39.9	40-49.9	50-59.9
88.1%	90.7%	77.1%	61.6%

ASTM F1930-2012 Burn Injury Prediction Model

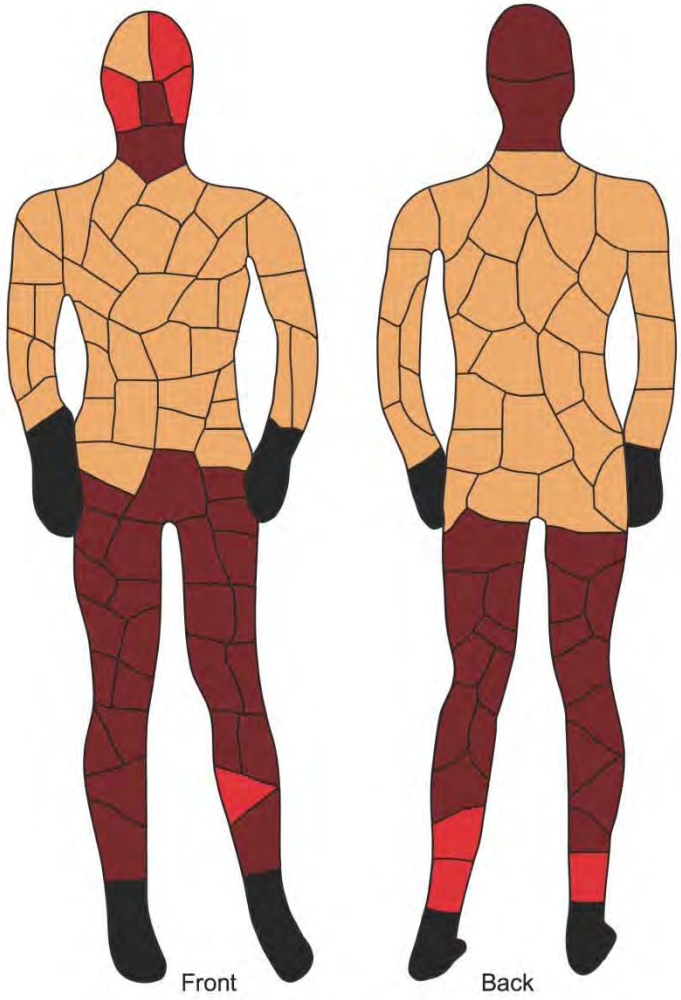


Figure 10 – Instrumented Manikin Test Output for Material A Garment – Inverted

(a) Front of Jacket - Before Exposure

(b) Back of Jacket - Before Exposure

(c) Front of Jacket - After Exposure

(d) Back of Jacket - After Exposure

(e) Drawstring Area - After Exposure

(f) Jacket Interior - After Exposure

Figure 11 – Simulated Flash Fire Exposure of Jacket with Material A – Closure Secured

(a) Front of Jacket - Before Exposure

(b) Back of Jacket - Before Exposure

(c) Front of Jacket - After Exposure

(d) Back of Jacket - After Exposure

(e) Drawstring Area - After Exposure

(f) Jacket Interior - After Exposure

Figure 12 – Simulated Flash Fire Exposure of Jacket with Material A – Closure Open

(a) Front of Jacket - Before Exposure

(b) Back of Jacket - Before Exposure

(c) Front of Jacket - After Exposure

(d) Back of Jacket - After Exposure

(e) Drawstring Area - After Exposure

(f) Jacket Inverted Exterior - After Exposure

Figure 13 – Simulated Flash Fire Exposure of Jacket with Material A – Jacket Inverted

(a) Front of Jacket - Before Exposure

(b) Back of Jacket - Before Exposure

(c) Front of Jacket - After Exposure

(d) Back of Jacket - After Exposure

(e) Drawstring Area - After Exposure

(f) Jacket Interior - After Exposure

Figure 14 – Simulated Flash Fire Exposure of Jacket with Material B – Closure Secured

(a) Front of Jacket - Before Exposure

(b) Back of Jacket - Before Exposure

(c) Front of Jacket - After Exposure

(d) Back of Jacket - After Exposure

(e) Drawstring Area - After Exposure

(f) Jacket Interior - After Exposure

Figure 15 – Simulated Flash Fire Exposure of Jacket with Material B – Closure Open

(a) Front of Jacket - Before Exposure

(b) Back of Jacket - Before Exposure

(c) Front of Jacket - After Exposure

(d) Back of Jacket - After Exposure

(e) Drawstring Area - After Exposure

(f) Jacket Interior - After Exposure

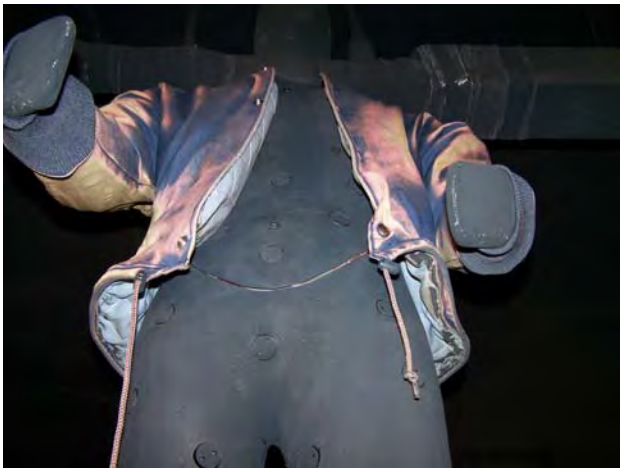
Figure 16 – Simulated Flash Fire Exposure of Jacket with Material C – Closure Secured

(a) Front of Jacket - Before Exposure

(b) Back of Jacket - Before Exposure

(c) Front of Jacket - After Exposure

(d) Back of Jacket - After Exposure



(e) Drawstring Area - After Exposure

(f) Jacket Interior - After Exposure

Figure 17 – Simulated Flash Fire Exposure of Jacket with Material C – Closure Open

(a) Front of Jacket - Before Exposure

(b) Back of Jacket - Before Exposure

(c) Front of Jacket - After Exposure

(d) Back of Jacket - After Exposure

(e) Drawstring Area - After Exposure

(f) Jacket Inverted Exterior - After Exposure

Figure 18 – Simulated Flash Fire Exposure of Jacket with Material C – Jacket Inverted

(a) Front of Jacket - Before Exposure

(b) Back of Jacket - Before Exposure

(c) Front of Jacket - After Exposure

(d) Back of Jacket - After Exposure

(e) Drawstring Area - After Exposure

(f) Jacket Interior - After Exposure

Figure 19 – Simulated Flash Fire Exposure of Jacket with Material D – Closure Secured

(a) Front of Jacket - Before Exposure

(b) Back of Jacket - Before Exposure

(c) Front of Jacket - After Exposure

(d) Back of Jacket - After Exposure

(e) Drawstring Area - After Exposure

(f) Jacket Interior - After Exposure

Figure 20 – Simulated Flash Fire Exposure of Jacket with Material D – Closure Open

(a) Front of Jacket - Before Exposure

(b) Back of Jacket - Before Exposure

(c) Front of Jacket - After Exposure

(d) Back of Jacket - After Exposure

(e) Drawstring Area - After Exposure

(f) Jacket Inverted Exterior - After Exposure

Figure 21 – Simulated Flash Fire Exposure of Jacket with Material D – Jacket Inverted

(a) Front of Jacket - Before Exposure

(b) Back of Jacket - Before Exposure

(c) Front of Jacket - After Exposure

(d) Back of Jacket - After Exposure

(e) Drawstring Area - After Exposure

(f) Jacket Interior - After Exposure

Figure 22 – Simulated Flash Fire Exposure of Jacket with Material E – Closure Secured

(a) Front of Jacket - Before Exposure

(b) Back of Jacket - Before Exposure

(c) Front of Jacket - After Exposure

(d) Back of Jacket - After Exposure

(e) Drawstring Area - After Exposure

(f) Jacket Interior - After Exposure

Figure 23 – Simulated Flash Fire Exposure of Jacket with Material E – Closure Open

(a) Front of Jacket - Before Exposure

(b) Back of Jacket - Before Exposure

(c) Front of Jacket - After Exposure

(d) Back of Jacket - After Exposure

(e) Drawstring Area - After Exposure

(f) Jacket Inverted Exterior - After Exposure

Figure 24 – Simulated Flash Fire Exposure of Jacket with Material E – Jacket Inverted

Table 6 – Liner Shrinkage Data from Evaluation of Jackets Using Cold Weather Insulation Material-Based Liners in Instrumented Manikin Testing*

Liner Mat'l **	Wearing Config.†	Measured Shrinkage (%) by Location						
		1	2	3a	3b	4a	4b	4c
A	Secured	5.58	3.09	2.94	0.00	6.81	7.29	9.53
	Open	5.06	3.03	4.39	2.90	17.71	2.58	10.64
	Inverted	10.15	10.77	13.00	8.91	11.96	15.00	10.71
B	Secured	5.00	-0.12	3.07	0.97	7.29	11.30	11.83
	Open	4.31	4.45	1.94	11.32	17.53	1.05	8.47
	Inverted	n/a	n/a	n/a	n/a	n/a	n/a	n/a
C	Secured	9.69	14.65	7.69	12.38	9.13	16.16	13.05
	Open	6.69	8.59	3.85	10.05	15.79	11.62	31.77
	Inverted	0.50	5.97	+0.97	+0.96	10.42	5.43	9.57
D	Secured	5.70	4.69	6.73	7.69	16.30	2.54	15.43
	Open	10.45	8.40	12.46	15.00	13.68	12.47	12.59
	Inverted	2.81	1.75	0.00	0.48	2.70	2.03	3.21
E	Secured	7.84	2.17	9.26	3.70	14.89	8.16	10.42
	Open	9.80	2.22	5.45	9.43	26.09	10.20	18.37
	Inverted	5.88	0.00	9.09	9.62	8.51	7.07	14.89

* Testing performed in accordance with ASTM F1930 with 3-second exposure; no undergarments were worn on manikin underneath jacket or on exposed areas of garment not covered by jacket

** Lining material descriptions provided in Table 1; Material tested as sewn-in liner inside jacket comprising a 150 g/m^2 shell, zipper front closure, regular sleeves, standard collar, no pocket, and with a hem that included a drawstring to maintain a uniform gap between the jacket bottom hem and the manikin surface.

† Secured – jacket front closure fully closed; Open – jacket front closure open; Inverted – jacket turned inside out.

+ Indicates garments increased in this dimension after thermal exposure