NISTIR 7141

U.S. Department of Commerce
Technology Administration
National Institute of Standards and Technology

Office of Applied Economics
Building and Fire Research Laboratory
Gaithersburg, Maryland 20899

Firefighter Turnout Coat Configurations: Performance Data for Acquisition Decisions

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Sponsored by:
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February 2005

U.S. DEPARTMENT OF COMMERCE
Carlos M. Gutierrez, Secretary

TECHNOLOGY ADMINISTRATION
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NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
Hratch G. Semerjian, Acting Director

Abstract

This report describes the essential components of turnout coats, specifies the relevant performance tests, and documents the collected performance data that can support cost-effective acquisition and utilization decisions. A turnout coat is a system of separate components. Each component has many commercially available alternatives. Critical measures of performance are described. For each performance measure, the test method, reference, and significance are all explained. These measures fall into four categories:

1. Heat Resistance: Includes measures of resistance to heat and flame such as thermal protective performance (TPP), thermal efficiency (derived), and vertical flame char length.

2. Tactile Performance: Includes measures of weight, thickness, and bending stiffness.

3. Durability: Includes measures of outer shell durability, lightfastness, abrasion (two types), trap tear, and grab strength.

4. Comfort: Includes measures of breathability, face cloth friction, and face cloth wicking.

These performance characteristics are key to making selection decisions. Data on the performance characteristics have been compiled along with in this report. There are three distinct data sets in this report: a comprehensive universe of all suit components gathered without corresponding performance measures; and two data sets including performance data provided by Dupont and Southern Mills.

The decision support tool will help fire departments apply these data to their turnout coat selection procedures. The conceptual framework is the Analytic Hierarchy Process, a multiattribute model developed in the operations research field. The tool will implement the Analytic Hierarchy Process to help fire departments select the best turnout coats for their applications, given the relative importance they place on each of the performance characteristics presented here, and taking into account the acquisition cost. The software will be available directly on the Internet in a convenient, readily accessible form.

Key Words: firefighter, cost effective, multiattribute decision analysis, performance data, selection criteria, turnout coat

Preface

This study was conducted by the Office of Applied Economics in the Building and Fire Research Laboratory at the National Institute of Standards and Technology. This report describes the essential components of firefighter turnout coats, specifies the relevant performance tests, and documents the collected performance data that support the use of the Analytic Hierarchy Process (AHP) so that cost-effective acquisition and utilization decisions can be made. The intended audience is the National Institute of Standards and Technology as well as other government and private sector organizations that are concerned with evaluating and selecting turnout coats.

Disclaimer: Certain trade names or company products are mentioned in the text to specify adequately the experimental procedure and equipment used. In no case does such identification imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the equipment is the best available for the purpose.

Disclaimer Regarding Non-metric Units: The policy of the National Institute of Standards and Technology is to use metric units in all its published materials. Since this report is intended for U.S. users of firefighter turnout coats who evaluate performance using customary units, it is more practical and less confusing to use the customary rather than metric units to indicate turnout coat performance.

Acknowledgements

Thanks are due to Dave Evans, Randy Lawson, and Kuldeep Prasad of the Building and Fire Research Laboratory for starting this project and for their many helpful comments and suggestions on the turnout coat performance measures and data. Thanks are also given to Harold Marshall, Robert Chapman, Laura Schultz and Stephen Weber for their comments and suggestions, and to Grace Lin and Christine Izzo for data input and organization.

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1. Introduction

1.1 Background

Firefighters use a variety of equipment for protection from injury and death. Examples include self contained breathing gear, thermal imaging equipment, and protective clothing. Information about the multiple performance characteristics of such equipment is sparse and not organized for informing cost-effective decisions on acquisition and utilization. The long-range goal of this research is to develop and implement a decision support tool for the evaluation of several types of firefighters' equipment. The current effort focuses on protective clothing. This report is specifically focused on firefighter turnout coats.

The decision support tool will help fire departments apply these data to their turnout coat selection procedures. The tool will implement the Analytic Hierarchy Process (AHP), a multiattribute model, to help fire departments select the best turnout coats for their applications, given the relative importance they place on each of the performance characteristics presented here, and taking into account the acquisition cost. The software will be available directly on the Internet in a convenient, readily accessible form.

The AHP is one of a set of multiattribute decision analysis methods that considers nonmonetary attributes (qualitative and quantitative) in addition to common economic evaluation measures (such as life-cycle costing or net benefits) when evaluating project alternatives. The AHP has several significant strengths: it is well known and well-reviewed in the literature; it includes an efficient attribute weighting process of pairwise comparisons; it incorporates hierarchical descriptions of attributes, which keep the number of pairwise comparisons manageable; and it has been accepted by ASTM as a standard practice.[1]

1.2 Purpose and Scope of Approach

This report is the supporting documentation for the decision support tool. This report defines turnout coats that will be included in the decision support tool, describes the relevant performance tests, and documents the collected performance data that can support cost-effective acquisition and utilization decisions. Users of the decision support tool will need this report to develop individualized rankings of the importance of each performance characteristic.

Section 2 describes the performance tests and measures. Suit component and assembled suit selection decisions are based on performance. Section 3 explains the scope of the three data sets that were compiled. Section 3 also contains the collected data for the Dupont data set, the source data that will be used in the decision support tool. Section 4 concludes with a summary of the data, discussion of the decision support tool, and directions for future research. There are three appendices. Appendix A lists the ASTM test standards that were consulted in this report. Appendix

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[1] ASTM International, *Standard Practice for Applying Analytical Hierarchy Process (AHP) to Multiattribute Decision Analysis of Investments Related to Buildings and Building Systems*, E 1765-02, West Conshohoken, PA, 2002.

B lists most of the alternatives available for each suit component, based on an independent review of the market. Appendix C provides performance data from Southern Mills.

2. Performance Criteria

2.1 Available Performance Measures and Sources

A comprehensive investigation was completed to identify appropriate testing standards for available published test results.[2] The testing standards referenced in this report are from the National Fire Protection Association (NFPA), ASTM International, and the American Association of Textile Chemists and Colorists (AATCC).

Table 2-1. Standards Organizations

Organization	web site
National Fire Protection Association (NFPA)	www.nfpa.org
ASTM International	www.astm.org
American Association of Textile Chemists and Colorists (AATCC)	www.aatcc.org

Appendix A cites the performance tests used in this report. The major NFPA tests are outlined in NFPA 1971 and NFPA 1976. In addition, NFPA 1851 is useful for its assistance in developing selection criteria, based on the risks that emergency responders face.

The NFPA standards for turnout coats specify tests that the coats must pass in order to be labeled "compliant." Manufacturers report NFPA compliance according to these tests. The tests include Thermal Protective Performance (TPP), flame resistance, tear resistance, liquid penetration resistance, shrinkage resistance, and water absorption resistance. Manufacturers have the Underwriters Laboratories (UL) and other independent laboratories perform the tests.

In this report, the test data fall into one of four natural groupings, explained in the next chapter. Additionally, the decision support software will permit the user to enter specific cost quotes obtained from suppliers.

[2] The National Institute of Standards and Technology (NIST) Building and Fire Research Laboratory (BFRL) fire researchers are developing new test methods to collect more data on the thermal performance of turnout coats in non-optimal conditions. A test apparatus was developed to measure heat transfer on a fabric sample that is compressed and submerged in water—a situation that might occur at a firefighter's knees or elbows. Also, heat transfer tests have been performed on turnout gear after exposure to wear (cleaning, prior exposure to heat). The Protective Clothing Performance Simulator (PCPS), developed by R. Lawson and K. Prasad, adds a skin model to the heat transfer model, and estimates the time to first degree burn and second degree burn. Kukuck and Prasad (2003), *Simulating a TPP Test for Single-Layered Fabrics* (NISTIR 6993), is an extension of earlier work by Mell and Lawson (1999) on developing a heat transfer model. In the future, the decision support tool for Fire Protective Clothing could use performance data calculated according to NIST-specified performance measures, when they are finalized and become widely available.

2.2 Introduction to Performance Tests

The performance measures listed below tend to fall into four groupings.[3]

1. Heat Resistance: Includes measures of resistance to heat and flame such as thermal protective performance (TPP), thermal efficiency (derived), and vertical flame char length.

2. Tactile Performance: Includes measures of weight, thickness, and bending stiffness.

3. Durability: Includes measures of outer shell durability, lightfastness, abrasion (two types), trap tear, and grab strength.

4. Comfort: Includes measures of breathability, face cloth friction, and face cloth wicking.

2.3 Performance Test and Measure Descriptions

Presented below is the following information for each performance test: (1) the test name, (2) what the test shows regarding performance, (3) a reference to the test standard (such as ASTM or NFPA), (4) a short description of the test, (5) the test outcome measure, (6) whether better performance is indicated by increasing or decreasing performance numbers, and (7) whether the test measure units are proportional to the impact on performance.

The mathematical framework used in the decision support tool requires that the performance measures be denominated in units that are proportional to the performance impact. Proportional units are those that are directly proportional— a measure that is twice as high indicates performance that is twice as good— and inversely proportional— a measure that is twice as high indicates performance that is half as good.

Thermal Protective Performance (TPP)

The thermal protective performance (TPP) test measures the thermal insulation of a suit. Thermal efficiency— TPP divided by the turnout coat weight—can be derived. The TPP indicates how long a firefighter can wear the suit under specific conditions before being burned. The test is referenced in NFPA 1971, Chapter 6-10, p. 43-47. The NFPA minimum requirement of a TPP rating of 35 equates to 17.5 s until second degree burn in a flashover situation. A test apparatus is described for exposing a turnout coat sample to a heat source. A calorimeter measures the heat during the exposure process. The heat exposure is described using a plot of energy versus the time to cause a second-degree burn in human tissue. The TPP rating is calculated as the product of exposure energy heat flux— calories per square centimeter per second, or $cal/(cm^2 \cdot s)$— and the time to burn in seconds (s). The resulting measure is cal/cm^2, calories per square centimeter. A suit with a higher TPP number gives the wearer more protection than a suit with a lower number. The measure is proportional, so that a suit with a TPP twice as high as another suit offers twice as much protection.

[3] The hierarchy used in the decision support tool can accommodate, at most, seven characteristics. This first version of the decision support software will allow the user to select seven performance characteristics. Future versions of the decision support tool software will use the groupings developed in this section to allow consideration of all performance characteristics.

Vertical Flame Char Length

Vertical flame char length measures the deterioration of a suit when exposed to flame. This shows the stability of the suit. The test method is given in "Standard Test Method for Flame Resistance of Textiles (Vertical Test)," ASTM Test Method D 6413-99. A specimen is positioned vertically above a controlled flame and exposed for 10 min. The fabric is folded, a weight is attached, and the fabric is lifted. Char length is the linear measure, in inches, of the tear produced. There is a linear measure of the tear along the warp (the continuous length) of the fabric, and a linear measure of the tear along the fill (the cross length) of the fabric.[4] A higher length indicates a longer tear. The measure is inversely proportional, meaning that a suit fabric that has a tear that is twice as long as another suit fabric is only half as stable.

System Mass (Weight)

System Mass (Weight) indicates how heavy the suit is. In order to simplify the terminology, "weight" should be read as "mass (weight)" throughout this report. The test method "Standard Test Method for Mass Per Unit Area (Weight) of Fabric," is provided in ASTM Test Method D 3776-96. This test measures the fabric mass per unit area (weight). A larger number— ounces per square yard, or opsy—indicates a heavier weight. The measure is inversely proportional.

System Thickness

System thickness indicates how bulky the suit is. The test method "Standard Test Method for Thickness of Textile Materials," is provided in ASTM Test Method D 1777-96 (Reapproved 2002). A specimen is placed on the base of a thickness gauge and a weighted presser foot is lowered. The displacement between the base and the presser foot is measured as the thickness of the specimen, given in mils $\left({}^{1}\!/_{1000} \text{ inch} \right)$. Higher numbers indicate greater thickness. The measure is inversely proportional.

Thermal Liner Bending Stiffness

Thermal liner bending stiffness indicates the effort of the firefighter to both put on and to move around in a suit. The test method "Standard Test Method for Stiffness of Fabrics," is provided in ASTM Test Method D 1388-96 (Reapproved 2002). The test result is the required force per inch (in grams force per inch, gf/in) to bend a sample of fabric 90°. A higher number indicates a higher force required to bend the fabric. The measure is inversely proportional, meaning that a fabric that requires twice as much force to bend compared to another fabric, is half as flexible.

Lightfastness (Colorfastness) Rating

This test measures the color change of the outer shell of the suit. Color change in some suits is an indicator of age and reduced protective performance. The test is referenced in AATCC Test Method 16-1998, "Colorfastness to Light." The test is a color shift rating after 20 h based on a grey scale color difference. Samples of the textile material to be tested are exposed to a light source under specified conditions. The colorfastness to light of the specimen is evaluated by comparison of the

[4] The decision support tool could either use the longest tear length, or it could multiply the warp and fill to get the area of the tear.

grey-scale change of the exposed portion to the masked control portion of the test specimen. The maximum lightfastness rating of 5 indicates that there was no color shift. The lowest lightfastness rating of 1 indicates that there were more than 13 AATCC Fading Units (AFU) between the exposed and unexposed fabric. The measure is proportional, meaning that a fabric with a lightfastness rating twice that of another fabric is twice as stable.

Tabor Abrasion (CS10 and H18)

Tabor abrasion measures the durability of a fabric when subjected to wear. The test method "Standard Guide for Abrasion Resistance of Textile Fabrics (Rotary Platform, Double-Head Method)" is provided in ASTM Test Method D 3884-01. A specimen is abraded using rotary rubbing action from an abrading wheel. The CS10 wheel is mildly abrasive. The H18 wheel has a medium-coarse texture. The tabor abrasion number is the number of revolutions of the specified wheel until a hole has formed in the fabric. A hole is defined as breaking both the warp and fill fibers. A higher number—more wheel revolutions—indicates a higher fabric durability. The measure is proportional, so that a fabric that requires twice as many wheel revolutions to form a hole, compared to another fabric, is twice as durable.

Trapezoidal Tear

Trapezoidal tear is a measure of fabric strength and durability. The Tear Resistance Test is referenced in section 6-12 of NFPA 1971, 2000 edition. The ASTM reference is "Standard Test Method for Tearing Strength of Fabrics by Trapezoid Procedure," ASTM Test Method D 5587-96.

The test is described as follows: An outline of an isosceles trapezoid is marked on a rectangular specimen cut for the determination of tearing strength, and the nonparallel sides of the trapezoid marked on the specimen are clamped in parallel jaws of a tensile testing machine. The separation of the jaws is continuously increased so the tear propagates across the specimen. At the same time, the force (pound-force, or lbf) developed is recorded and averaged for the test.[5] This test is performed separately along the warp direction and fill direction of the fabric.[6] A higher number indicates a greater number of pounds of force necessary to tear the fabric. The measure is proportional, so that a fabric that requires twice as much force to tear compared to another fabric, is twice as strong and durable.

Grab Strength

Grab strength is a measure of fabric strength. Grab strength is referenced in NFPA 1971, Chapter 6-50 (called the Breaking Strength Test using ASTM D5034). The test method is given in "Standard Test Method for Breaking Strength and Elongation of Textile Fabrics (Grab Test)," ASTM Test Method D 5034-95 (Reapproved 2001). In this test, a continually increasing load (pound-force, or lbf) is applied longitudinally to the specimen until the fabric ruptures. This test is performed separately along the warp direction and fill directions of the fabric. A higher grab strength indicates a greater number of pounds of force necessary to rupture the fabric. The measure is proportional, so that a fabric that requires twice as much force to rupture compared to another fabric, is twice as strong.

[5] The pound-force (lbf) is a unit of force or weight equal to a mass of one pound multiplied by the standard acceleration of gravity, approximately 32.17405 ft/s^2).

[6] For the trapezoidal tear test and the grab strength test, the decision support tool will use the lower number.

Breathability

Breathability indicates the flow of heat and moisture from the skin to the environment, by measuring the amount of energy required to maintain a constant suit temperature. The test is referenced in NFPA 1971, Chapter 6-34, p. 62-63. The specific test method "Standard Test Method for Thermal and Evaporative Resistance of Clothing Materials Using a Sweating Hot Plate," is provided in ASTM Test Method F 1868-02. Breathability is the Total Heat Loss (Q_t), which is defined as watts per square meter (W/m^2). A higher THL indicates that the suit is more breathable—it allows more flow of heat and moisture to the environment. The measure is proportional, so that a suit with a THL twice that of another suit is twice as breathable.

Face Cloth Friction

Face cloth friction indicates the ease of donning and removing fire suits over station wear. The test method is the "Standard Test Method for Static and Kinetic Coefficients of Friction of Plastic Film and Sheeting," ASTM Test Method D 1894-01, using a weighted sled (400 g) wrapped with NOMEX fabric (to simulate station wear) pulled across a length of face cloth (0.5 in/min). Face cloth friction is the coefficient of sliding friction of a suit face cloth material when sliding over a reference fabric. The measure is free of units. Larger numbers indicate more friction, and hence more difficulty in donning fire suits. The measure is inversely proportional, meaning that a fabric with twice as much face cloth friction as that of another fabric is half as easy to don.

Face Cloth Wicking

Face cloth wicking indicates the ability of the face cloth to draw heat and moisture away from the skin, improving comfort. This is a Dupont-specified test. A sample fabric (1 in x 7 in) is suspended in a pan of water containing 1.8 in ± 0.2 in water. The vertical progress of water up the fabric is measured at specific time intervals. The data in this report list the vertical height (inches) after 10 min. A higher number indicates more absorption and thus more comfort. The measure is proportional.

2.4 Summary of Performance Measures

These performance standards can be summarized as follows:

Table 2-2. Performance Measures and Direction Indicating Improved Performance

Group	Measure	Measurement Units	Test Reference	Direction Indicating Improved Performance
Heat Resistance	TPP	cal/cm^2	NFPA 1971	higher (more protection)
	Vertical Flame Char	in (per 10 min)	ASTM D 6413-99	lower (resistance to charring)
Tactile Performance	Weight	oz/yd^2	ASTM D 3776-96	lower (lighter)
	Thickness	mils	ASTM D 1777-96	lower (thinner)
	Bending Stiffness	gf/in	ASTM D 1388-96	lower (flexible)
Durability	Lightfastness Rating	index[A]	AATCC 16-1998	higher (more colorfast)
	Abrasion	cycles	ASTM D 3884-01	higher (resistance to abrasion)
	Trap Tear	lbf	ASTM D 5587-96	higher (resistance to tearing)
	Grab Strength	lbf	ASTM D 5034-95	higher (resistance to tearing)
Comfort	Breathability	W/m^2	ASTM F 1868-02	higher (body moisture escapes)
	Face Cloth Friction	dimensionless	ASTM D 1894-01	lower (less friction)
	Face Cloth Wicking	in (per 10 min)	Dupont test	higher (more wicking)

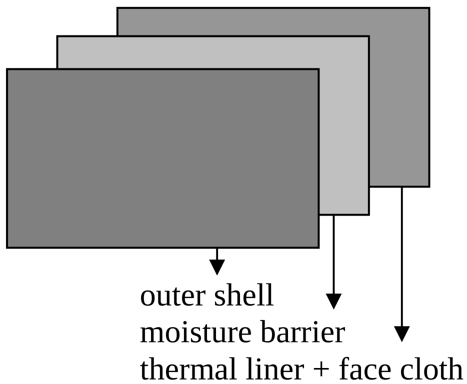
[A] Lightfastness Rating is given by an index from 1 to 5.

These performance measures will be used in the decision support tool. The tool will help users understand tradeoffs between performance measures. As an example, the standard method of increasing TPP ratings is by adding more insulation. This makes the turnout coat heavier. There is a tradeoff between weight—and perhaps associated measures such as stiffness—and the TPP rating. Again as an example, one way to reduce char length is to increase the weight of the fabric. This makes the turnout coat heavier. Again, there is a tradeoff between weight—and perhaps stiffness—and the char length rating. The decision support tool will help the user make individualized tradeoffs between weight, stiffness, TPP, char length, and other performance characteristics. The decision support tool will present the user with the best firefighter turnout coat choices based on his or her individualized performance tradeoffs and budget.

3. Data Set Organization and Collection

A firefighters' turnout coat is made of four basic components. Figure 3-1 shows these components from the interior (bottom layer) to the exterior (top layer). The first two are the face cloth and thermal liner combination, represented together in Figure 3-1. The third and fourth components are the moisture barrier and the outer shell. The face cloth is closest to the skin of the wearer and attaches to the thermal liner. The thermal liner protects against heat penetration. The integrated moisture barrier component consists of the actual moisture barrier which is a plastic-like non-fabric product laminated to a fabric liner. The moisture barrier is designed to keep water out while allowing a limited amount of moisture vapor to exit. The exterior turnout coat component is the outer shell, which protects against flames and heat. The performance of a whole turnout coat depends on the choice of each of the four components (face cloth, thermal liner, moisture barrier, and outer shell).

Figure 3-1. Components of Firefighters' Turnout Coat



Three data collection efforts were undertaken for this project. The first effort resulted in a data set, presented in Appendix B, describing the composition of turnout coats, by component. It is a detailed description of the composition of available thermal liners, moisture barriers, and outer shells; and provides the most comprehensive picture available of all possible suit configurations. No performance data are included for this data set. The second data set, obtained from Southern Mills, denotes a complete suit as the combination of four components: the face cloth, thermal liner, moisture barrier, and the outer shell. The third data set, obtained from Dupont, denotes a complete suit as the combination of three components, because the face cloth is considered part of the thermal liner. The Dupont data will be used in this first version of the decision support tool. Therefore, these data are presented in the body of this report, specifically Section 3.5 Table 3-1.

3.1 Composition of Fire Turnout Coats, by Component

The first data set, available in Appendix B, was compiled from company-provided specifications on available products on the market. Information sources included web sites, brochures, and corporate documents. The face cloth, thermal liner, moisture barrier, and outer shell are the separate components that must be combined to produce a complete suit. The face cloth and thermal liner combination is treated as a single component in this data set. Information such as fabric type, fabric blends, weight, weave, and finishes were compiled for thermal liners and outer shells. In Appendix B, the first table lists the available fibers. The second table details fabrics used in thermal liners and outer shells. Because both components use the same fabrics, they were combined into one table for ease of presentation. The third table details moisture barriers.

The component-level approach has many advantages. Component-level evaluation provides more flexibility to the data set user. Protective clothing can be specified as any combination of components—not just the combinations that were tested together. Second, gathering component performance data is more efficient and more cost effective than collecting turnout coat performance data. The number of choices for each component results in a large number of possible combinations of turnout coats. Turnout coats are often made to custom specifications, and the performance information on all possible completed turnout coats is not available.

This approach also has some deficiencies. Not all tests are performed or disclosed by the manufacturer for each component. The cooperation of the manufacturer is needed to obtain specific measures when they are not presented in the published product literature.

Second, because the data are limited to tests on individual turnout coat components and not entire suits, some performance measures are not available. Simple additive measures such as weight and thickness are possible to construct, and some single-component performance tests can indicate the whole turnout coat performance. For example, a moisture penetration test performed on the moisture barrier component indicates the moisture penetration performance of a whole suit. Also, the tabor abrasion tests and lightfastness tests performed on the outer shell component will indicate the durability of the whole turnout coat. There are, however, performance tests that require all the suit components to be tested together—such as the thermal protective performance (TPP) test. For the TPP, it is necessary to either locate actual test data for the suit or to estimate performance data based on the components used. Performance algorithms being developed at the NIST may eventually be able to calculate the TPP performance of the whole turnout coat from the performance of each individual component.[7]

3.2 Fiber and Fabrics in the Component-Level Data Set

Any specific turnout coat component, such as an outer shell, is created using specific steps that may involve several companies. For example, one manufacturer might make the fiber, a second weave the fiber into fabric, and a third use the fabric to make one or more of the components of a turnout coat. The most basic element of the turnout coat is the fiber, followed by the fabric. Both the fiber and fabric manufacturers provided performance information.

Properties of fabrics include weight, fiber, and fiber blends. This information was compiled separately for outer shells, moisture barriers, and thermal liners. In the data set, the moisture barrier component is entered as a single unit, typically a combination of the moisture barrier and a backing fabric.

Data on the composition of fire turnout coats, by component, are presented in Appendix B. Identified are 55 thermal liner and face cloth combinations, 22 moisture barriers, and 91 outer shell variations. Moisture barriers are a combination of the moisture barrier and a liner. Components are differentiated when they change fiber blends, when they have unique trade names or product names,

[7] See footnote 2.

and when they have weave or finish variations. Entries are identified by product name, trade name, fiber content and blend, and manufacturer name.

Currently, these performance data are incomplete because components do not have performance data for all tests. The models for estimating thermal performance are not currently available and data are not available at the component level. Due to incomplete manufacturer testing information, the performance of components cannot be reliably compared.

To compensate for unavailable performance data, a new data collection effort was undertaken. The strategy was to look for data from a single-source that had several full turnout coat combinations and performance measures, where all the turnout coat combinations had been tested thoroughly and consistently. The collected data were compiled into the second (Southern Mills) and third (Dupont) data sets.

3.3 The Southern Mills Data Set

The second data set, presented in Appendix C, is from performance data provided by Southern Mills, a textile manufacturer. Southern Mills provides information on 50 suits that are the combinations of 5 thermal liners (with face cloths), 2 moisture barriers, and 5 outer shells. The performance measures used by Southern Mills are TPP, weight, thickness, and a price index (these data are shown in Appendix C).

Because of data limitations, it is not possible to combine the Southern Mills and Dupont data into a single, usable, data set.[8]

3.4 The Dupont Data Set

The third data set is from performance data provided by Dupont. The information contained in the Dupont data set is available on the Internet using the Dupont EZ-Spec configuration program (http://www.dupont.com/nomex/ezspec/splash.html). This data set includes 13 measures of performance on a total of 41 complete suits.[9] Dupont uses a well-documented standard set of tests on all suits. The performance results of one suit can be meaningfully compared with those of another suit. One notable omission in these performance tests is the radiative protective performance (RPP) measure. The Dupont performance data presented are from tests of whole turnout coats. The Dupont data used in the decision support tool are presented in their entirety in Section 3.5, Table 3-1.

The multiattribute decision analysis algorithm requires a fully-populated data matrix. As more data become available, these data sets will be expanded and, where possible, merged. When relevant NIST models are developed, the data sets will incorporate these NIST-developed performance measures.

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[8] In order to use the analytic hierarchy process, all suit choices must have measures for all performance criteria. Because the Dupont data and Southern Mills data do not share all suit choices or all performance measures, it is not possible to combine them for use in the decision support tool.

[9] Two tests in the Dupont data were omitted from this report. The Thermal Efficiency test is TPP divided by weight, and so may be constructed without a separate entry. The "Thermo-Man" test uses a Dupont-specific method that estimates percent of estimated burn. This test was omitted because it is not a required test and it is not often reported for other turnout coats that might be added to the this data set in the future, thus eliminating its usefulness as a standard of comparison.

3.5 Complete Turnout Coat Performance Data for Internet Decision Tool

The following table lists the performance data from Data Set 3 (Dupont Data) for the 41 turnout coat combinations tested. These data will be used in the decision support tool. Table 3-1 column headings refer to the performance measures explained in Section 2.

Table 3-1. Dupont Fire Suit Performance Data

Outer Shell	Moisture Barrier	Thermal Liner	Face Cloth	TPP (cal/cm^2)	Vertical Flame: Char Length (in)	Trap Tear (lbf)	Grab Strength (lbf)	Tabor Abrasion		Lightfastness Rating	Face Cloth Friction	Face Cloth Wicking (in)	System Weight (oz/yd^2)	System Thickness (mils)	Breathability (W/m^2)	Thermal Liner Bending Stiffness (g/in)
								CS10 (cycles to hole)	H18 (cycles to hole)							
Nomex/Kevlar (Advance)	Breathe-Tex Plus/E89	3 Layer Nomex E89	Nomex Woven	47.7	0.8 x 0.8	31 x 22	233 x 178	740	165	1	0.47	2.2	19.7	147	~174	2.3
Nomex/Kevlar (Advance)	Breathe-Tex Plus/E89	Aralite	Caldura	45.5	0.8 x 0.8	31 x 22	233 x 178	740	165	1	0.37	2.8	20.2	166	~145	4.1
Nomex/Kevlar (Advance)	Breathe-Tex Plus/E89	Aralite	Nomex Woven	43.1	0.8 x 0.8	31 x 22	233 x 178	740	165	1	0.47	2.2	19.6	160	~145	3.0
Nomex/Kevlar (Advance	Crosstech/ E89	2 layer Nomex E89	Caldura	41.3	0.8 x 0.8	31 x 22	233 x 178	740	165	1	0.37	2.8	18.4	125	~250	2.8
Nomex/Kevlar (Advance)	Crosstech/ E89	3 layer Nomex E89	Nomex Woven	44.3	0.8 x 0.8	31 x 22	233 x 178	740	165	1	0.47	2.2	19.0	135	~217	2.3
Nomex/Kevlar (Advance)	Crosstech/ E89	Aralite	Caldura	43.8	0.8 x 0.8	31 x 22	233 x 178	740	165	1	0.37	2.8	19.0	151	~200	4.1
Nomex/Kevlar (Advance)	Crosstech/ E89	Aralite	Nomex Woven	45.3	0.8 x 0.8	31 x 22	233 x 178	740	165	1	0.47	2.8	18.7	168	~200	3.0
Nomex/Kevlar (Duralite)	Crosstech/ E89	SMS	200 Denier	40.4	0.6 x 0.6	90 x 108	288 x 262	861	292	3	0.27	2.5	16.4	140	N/A	2.1
Nomex/Kevlar (Fusion)	Breathe-Tex Plus/E89	3 Layer Nomex E89	Nomex Woven	43.1	0.9 x 0.8	44 x 32	363 x 313	1233	247	2/3	0.32	4.0	19.6	125	174	2.3
Nomex/Kevlar (Fusion)	Crosstech/ E89	2 Layer Nomex E89	Glide	36.1	0.9 x 0.8	44 x 32	363 x 313	1233	247	2/3	0.32	4.0	17.9	101	~250	1.9
Nomex/Kevlar (Fusion)	Crosstech/ E89	3 Layer Nomex E89	Nomex Woven	43.1	0.9 x 0.8	44 x 32	363 x 313	1233	247	2/3	0.50	1.9	20.5	140	225	2.3

Table 3-1. Dupont Fire Suit Performance Data, continued

Outer Shell	Moisture Barrier	Thermal Liner	Face Cloth	TPP (cal/cm^2)	Vertical Flame: Char Length (in)	Trap Tear (lbf)	Grab Strength (lbf)	Tabor Abrasion		Lightfastness Rating	Face Cloth Friction	Face Cloth Wicking (in)	System Weight (oz/yd^2)	System Thickness (mils)	Breathability (W/m^2)	Thermal Liner Bending Stiffness (g/in)
								CS10 (cycles to hole)	H18 (cycles to hole)							
Nomex/Kevlar (Fusion)	Crosstech/ E89	Aralite	Nomex Woven	41.9	0.9 x 0.8	44 x 32	363 x 313	1233	247	2/3	0.47	2.2	18.7	153	~200	3.0
Kevlar/Basofil	Crosstech/ E89	2 Layer Nomex E89	Caldura	45.8	0.3 x 0.3	23 x 43	185 x 146	1042	137	2	0.38	2.8	19.8	120	~250	2.8
Kevlar/Basofil	Crosstech/ E89	Aralite	Caldura	47.7	0.3 x 0.3	23 x 43	185 x 146	1042	137	2	0.38	2.8	20.2	165	~200	4.1
Kevlar/Basofil	Crosstech/ E89	Aralite	Nomex Woven	47.5	0.3 x 0.3	23 x 43	185 x 146	1042	137	2	0.47	2.2	19.2	170	~200	3.0
Kevlar/Basofil	Crosstech/ E89	Basofil Felt	FRT Cotton	53.5	0.3 x 0.3	23 x 43	185 x 146	1042	137	2	0.50	3.0	24.1	170	N/A	3.3
Kevlar/PBI (Gold)	Crosstech/ E89	2 Layer Nomex E89	Caldura	39.3	0.3 x 0.2	30 x 35	258 x 234	870	119	3	0.38	2.8	18.7	120	250	2.8
Kevlar/PBI (Gold)	Crosstech/ E89	3 Layer Nomex E89	Nomex Woven	43.0	0.3 x 0.2	30 x 35	258 x 234	870	119	3	0.47	2.2	19.6	135	217	2.3
Kevlar/PBI (Gold)	Crosstech/ E89	Aralite	Caldura	43.5	0.3 x 0.2	30 x 35	258 x 234	870	119	3	0.38	2.8	20.0	153	~200	4.1
Kevlar/PBI (Gold)	Crosstech/ E89	Aralite	Nomex Woven	41.4	0.3 x 0.2	30 x 35	258 x 234	870	119	3	0.47	2.2	18.7	150	~200	3.0
Kevlar/PBI (Gold)	Crosstech/ E89	Rebound	Slick	50.0	0.3 x 0.2	30 x 35	258 x 234	870	119	3	0.27	2.5	22.3	N/A	120	4.6
Kevlar/PBI (Gold Plus)	Breathe-Tex Plus/E89	3 Layer Nomex E89	Glide	43.2	0.5 x 0.5	38 x 40	239 x 248	862	183	3	0.32	4.0	19.8	128	~170	2.4

Table 3-1. Dupont Fire Suit Performance Data, continued

Outer Shell	Moisture Barrier	Thermal Liner	Face Cloth	TPP (cal/cm^2)	Vertical Flame: Char Length (in)	Trap Tear (lbf)	Grab Strength (lbf)	Tabor Abrasion		Lightfastness Rating	Face Cloth Friction	Face Cloth Wicking (in)	System Weight (oz/yd^2)	System Thickness (mils)	Breathability (W/m^2)	Thermal Liner Bending Stiffness (g/in)
								CS10 (cycles to hole)	H18 (cycles to hole)							
Kevlar/PBI (Gold Plus)	Breathe-Tex Plus/E89	Aralite	Caldura	44.1	0.5 x 0.5	38 x 40	239 x 248	862	183	3	0.38	2.8	20.0	162	142	4.1
Kevlar/PBI (Gold Plus)	Crosstech/ E89	3 Layer Nomex E89	Nomex Woven	44.5	0.5 x 0.5	38 x 40	239 x 248	862	183	3	0.47	2.2	20.3	142	217	2.3
Kevlar/PBI (Gold Plus)	Crosstech/ E89	Aralite	Nomex Woven	45.6	0.5 x 0.5	38 x 40	239 x 248	862	183	3	0.47	2.2	19.5	169	200	3.0
Nomex	Crosstech/ E89	Nomex/ Kevlar Batt	Nomex Woven	42.0	3.2 x 3.2	63 x 41	295 x 256	1442	270	3	0.50	1.9	18.9	172	~207	2.5
Nomex	Crosstech/ E89	Aralite	Caldura	41.8	3.2 x 3.2	63 x 41	295 x 256	1442	270	3	0.37	2.8	19.7	186	~207	4.1
Nomex	Crosstech/ E89	Aralite	Nomex Woven	42.8	3.2 x 3.2	63 x 41	295 x 256	1442	270	3	0.47	2.2	19.3	178	207	3.0
Nomex	Crosstech/ E89	Q9-Aramid	Nomex Woven	46.0	3.2 x 3.2	63 x 41	295 x 256	1442	270	3	0.47	2.2	20.9	226	~207	4.0
Nomex	Neoprene	Q9-Aramid	Nomex Woven	54.1	3.2 x 3.2	63 x 41	295 x 256	1442	270	3	0.47	2.2	31.0	213	97	4.0
Z200	Aquatech	2 Layer Nomex E89	Nomex Filament - 100 Denier	46.6	0.4 x 0.5	28 x 26	215 x 200	890	117	3	0.26	1.2	18.5	124	228	1.9
Z200	Aquatech	3 Layer Nomex E89	Nomex Filament - 100 Denier	54.0	0.4 x 0.5	28 x 26	215 x 200	890	117	3	0.26	1.2	20.0	140	207	2.3
Z200	Breathe-Tex Plus/E89	2 Layer Nomex E89	Nomex Filament - 100 Denier	46.2	0.4 x 0.5	28 x 26	215 x 200	890	117	3	0.26	1.2	18.8	100	235	1.9

Table 3-1. Dupont Fire Suit Performance Data, continued

Outer Shell	Moisture Barrier	Thermal Liner	Face Cloth	TPP (cal/cm^2)	Vertical Flame: Char Length (in)	Trap Tear (lbf)	Grab Strength (lbf)	Tabor Abrasion: CS10 (cycles to hole)	Tabor Abrasion: H18 (cycles to hole)	Lightfastness Rating	Face Cloth Friction	Face Cloth Wicking (in)	System Weight (oz/yd^2)	System Thickness (mils)	Breathability (W/m^2)	Thermal Liner Bending Stiffness (g/in)
Z200	Crosstech/ E89	2 Layer Nomex E89	Nomex Filament - 100 Denier	44.0	0.4 x 0.5	28 x 26	215 x 200	890	117	3	0.26	1.2	17.0	96	251	1.9
Z200	Crosstech/ E89	3 Layer Nomex E89	Nomex Filament - 100 Denier	52.0	0.4 x 0.5	28 x 26	215 x 200	890	117	3	0.26	1.2	18.5	108	230	2.3
Z200	Crosstech on Slick	2 Layer Nomex E89	Nomex Filament - 100 Denier	40.9	0.4 x 0.5	28 x 26	215 x 200	890	117	3	0.26	1.2	17.6	100	257	1.7
Z200	Crosstech on Slick	3 Layer Nomex E89	Nomex Filament - 100 Denier	49.0	0.4 x 0.5	28 x 26	215 x 200	890	117	3	0.26	1.2	19.7	120	220	2.3
Z200 Isodri	Crosstech/ E89	2 Layer Nomex E89	Glide	44.0	0.5 x 0.5	28 x 25	217 x 178	900	137	4	0.32	4.0	18.8	120	~250	2.1
Z200 Isodri	Crosstech/ E89	2 Layer Nomex E89	Nomex Filament - 100 Denier	41.3	0.5 x 0.5	28 x 25	217 x 178	900	137	4	0.26	1.2	18.5	98	250	1.9
Z200 Isodri	Crosstech/ E89	3 Layer Nomex E89	Glide	50.5	0.5 x 0.5	28 x 25	217 x 178	900	137	4	0.32	4.0	20.7	155	~230	2.4
Z200 Isodri	Crosstech/ E89	3 Layer Nomex E89	Nomex Filament - 100 Denier	48.2	0.5 x 0.5	28 x 25	217 x 178	900	137	4	0.26	1.2	18.4	142	250	2.3

4. Summary and Suggestions for Future Research

4.1 Summary

The Firefighter Protective Clothing project has successfully developed a data framework and collected data to be used in the decision support tool for Firefighter Protective Clothing. The data set framework consists of four firefighter turnout coat elements: the face cloth, thermal liner, moisture barrier, and outer shell. Three data sets were created. In the first data set, the different product choices for each suit component were collected and entered into a comprehensive data set (available electronically from the author). When populating the data set with performance data, complications arose. Data on the performance of specific fire fighting gear, when available, did not cover the broad combination of suits that could be produced by combining the various choices of outer shell, thermal liner, moisture barrier, and face cloth. Second, when merging performance data from different sources, or even across different suit types, differences in test methods or in the way test results are reported, cause meaningful comparisons to be impossible. A second data set was obtained from Southern Mills. This data set provides four turnout coat performance measures for 50 suits (5 outer shells, 2 moisture barriers, and 5 thermal liners). A third source of data, the Dupont EZ-Spec Machine, included 13 performance measures on a total of 41 suits.

The decision support tool will help the user make individualized tradeoffs between weight, stiffness, TPP, char length, and other performance characteristics. The decision support tool will present the user with the best firefighter turnout coat choices based on his or her individualized performance tradeoffs and budget.

4.2 Suggestions for Future Research

The decision support tool, in the future, could incorporate additional performance tests and more combinations of turnout coat components. BFRL fire researchers are developing mathematical models to estimate heat transfer, time to skin burn, and TPP measures. The decision support tool for Firefighter turnout coats will be able to add performance data calculated according to new NIST-specified performance measures.

The decision support software could be revised. Based on input from users, the interface could add new functions that would provide an informative report on selected coats, or screen the coats for certain user-input criteria, such as a performance threshold. The decision support tool could also be expanded to encompass other protective clothing items such as helmets, gloves, pants, and boots. Lastly, the tool could be modified to encompass biological or chemical protective gear. A universal database would need to be developed to facilitate the use of different clothing items as well as clothing items that protect the wearer from different types of threats.

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Appendix A
Test Standards

American Association of Textile Chemists and Colorists (AATCC), "Color Fastness to Light," Test Method 16-1998.

ASTM International, "Standard Test Method for Stiffness of Fabrics," Test Method D 1388-96 (Reapproved 2002).

ASTM International, "Standard Test Method for Tearing Strength of Fabrics by Falling-Pendulum Type (Elmendorf) Apparatus," Test Method D 1424-96.

ASTM International, "Standard Test Method for Static and Kinetic Coefficients of Friction of Plastic Film and Sheeting," ASTM Test Method D 1894-01.

ASTM International, "Standard Test Method for Air Wicking of Tire Fabrics, Tire Cord Fabrics, Tire Cord, and Yarns," Test Method D 2692-98.

ASTM International, "Standard Test Method for Mass Per Unit Area (Weight) of Fabric," Test Method D 3776-96.

ASTM International, "Standard Guide for Abrasion Resistance of Textile Fabrics (Rotary Platform, Double-Head Method)," Test Method D 3884-01.

ASTM International, "Standard Test Method for Trapezoid Tearing Strength of Geotextiles," Test Method D 4533-01 (Reapproved 1996).

ASTM International, "Standard Test Method for Grab Breaking Load and Elongation of Geotextiles," Test Method D 4632-91 (Reapproved 1996).

ASTM International, "Standard Test Method for Breaking Strength and Elongation of Textile Fabrics (Grab Test)," Test Method D 5034-95 (Reapproved 2001).

ASTM International, "Standard Test Method for Tearing Strength of Fabrics by Trapezoid Procedure," ASTM Test Method D 5587-96.

ASTM International, "Standard Test Method for Tearing Strength of Nonwoven Fabrics by the Trapezoid Procedure," Test Method D 5733-99.

ASTM International, "Standard Test Method for Flame Resistance of Textiles (Vertical Test)," Test Method D 6413-99.

ASTM International, "Standard Test Method for Thermal and Evaporative Resistance of Clothing Materials Using a Sweating Hot Plate," Test Method F 1868-02.

ASTM International, "Standard Guide for Measuring and Reporting Friction Coefficients," Test Guide G 115-98.

Appendix B
Composition of Fire Turnout Coats, By Component

The performance of a turnout coat is primarily based on fabric characteristics. The fabric used to make a turnout coat component has inherent properties such as weight, thickness, stiffness, resistance to abrasion/tearing, and protection from heat and flame. There can be more than one way to manufacture a fabric. Different blends have different properties. The fabric may be made into different styles of turnout coats that have different layering, stitching, sleeve design, and closures that affect performance.

Table B-1 identifies the different fibers that are available for manufacturing turnout coat components. Outer shells and thermal liners (with face cloth, if specified) are described in Table B-2. Table B-3 describes moisture barriers. The moisture barriers are laminated or cross-stitched to the fabrics in Table B-2. There is no performance data in this data set.

Table B-1. Fibers Used In Outer Shells, Moisture Barriers, And Thermal Liners

Fiber Trade name	Manufacturer	Web Address
Basofil	BASF	www.basofil.com
Kevlar (para-aramid fiber)	Dupont	www.kevlar.com
PBI	Hoechst Celanese	
Nomex (meta-aramid fiber)	Dupont	www.dupont.com/nomex/firefighterprotection
Zylon	Toyobo Co., Ltd.	www.zylon.com
P84	Inspec Fibres	www.p84.com
Lenzing FR	Lenzing Fibres	www.lenzing.com
Conex	Teijin	www.teijin.co.jp
Kermel	Rhodia	www.kermel.com
N330	Dupont	www.dupont.com/nomex/firefighterprotection
N301	Dupont	www.dupont.com/nomex/firefighterprotection
N302	Dupont	www.dupont.com/nomex/firefighterprotection
N305	Dupont	www.dupont.com/nomex/firefighterprotection
N307	Dupont	www.dupont.com/nomex/firefighterprotection
N308	Dupont	www.dupont.com/nomex/firefighterprotection
N310	Dupont	www.dupont.com/nomex/firefighterprotection

Table B-2. Outer Shells and Thermal Liners

Fabric	Description
not specified	X % Nomex, Y % Kevlar batting with Chambray face cloth
not specified	X % Nomex, Y % Kevlar batting with Glide II face cloth
not specified	X % Nomex E89 Araflo with Glide II face cloth
not specified	X % Nomex E89, with 100 denier filament face cloth
Advance, ripstop weave (7.0 oz)	40 % Nomex IIIA (93 % Nomex, 5 % Kevlar, 2 % P-140), 60 % Kevlar with Shelltite or Super Shelltite finish
Araflo	Nomex E89 with spunlaced fabric
Araflo Dri	not specified
Aralite	X % Kevlar, Y % Nomex batting with spun face cloth
Aralite Gold	80 % Kevlar, 20 % PBI batting with spun face cloth
Aramax, x weave (x.x oz)	60 % Kevlar, 40 % Nomex III (Core of Kevlar/ Sheath of Nomex III)
AtEase, plain weave (4.5, 6.0, or 7.5 oz)	100 % Nomex IIIA with Wickwell finish
Barrage, ripstop weave (7.5 oz)	40 % Basofil, 60 % Kevlar with Hypel or Super Shelltite finish
Brigade	X % Nomex IIIA
Caldura	X % Nomex, Y % Kevlar batting with spun aramid face cloth
Caldura SL	2 layers Nomex E89 with aramid face cloth
Chambray	50 % Kevlar, 50 % Nomex virgin batting with 100 % Nomex face cloth
Chambray Araflo	3 layers of E89 with 100 % Nomex face cloth
Chambray Pure Quilt	50 % Kevlar with 100 % Nomex face cloth
Crusader	60 % Kevlar, 40 % Nomex
Defender 600, ripstop weave (6.0 oz)	100 % Nomex IIIA (93 % Nomex, 5 % Kevlar, 2 % P-140) with Shelltite finish
Defender 750, plain (duck) weave (7.5 oz)	100 % Nomex IIIA (93 % Nomex, 5 % Kevlar, 2 % P-140) with Shelltite finish
Defender, twill weave (7.0 oz)	100 % Nomex IIIA (93 % Nomex, 5 % Kevlar, 2 % P-140) with Shelltite finish
Delta T	75 % Nomex, 23 % Kevlar, 2 % P140
Duralite	50 % Kevlar, 50 % Nomex
FE-289	3 layers of Nomex E89 with Nomex filament face cloth
FE-389	2 layers of Nomex E89 with Nomex filament face cloth
Fireflite	X % Kevlar, Y % Wool

Table B-2. Outer Shells and Thermal Liners, continued

Fabric	Description
Flame Quilt	100 % Indura, 50 % FR rayon, 50 % Basofil
Fusion	40 % Nomex, 60 % Kevlar, Teflon F/PPE
Genesis	Nomex IIIA with proprietary finishing procedure
Gladiator	60 % Kevlar, 40 % Basofil
Glide II	50 % Kevlar, 50 % Nomex virgin batting with 100 % Nomex face cloth
Glide Pure	50 % Kevlar with 100 % Nomex face cloth
Guardian	60 % Kevlar, 40 % PBI
Iso-dri	X treated with Teflon
Isolator	X % Kevlar, Y % Nomex batting with spun face cloth
Isolator Plus	X % Kevlar, Y % Nomex batting with spun face cloth
Kermel HTA	X % Kermel, Y % Kevlar
Kombat 600, ripstop weave (6.0 oz)	60 % Kevlar, 40 % PBI with Shelltite or Super Shelltite finish blend
Kombat 750, ripstop weave (7.5 oz)	60 % Kevlar, 40 % PBI with Shelltite or Super Shelltite finish
Millenia, twill weave (7.5 oz)	60 % Technora, 40 % Zylon with Super Shelltite finish
Nomex E89	Spunlaced, X % Nomex, Y % Kevlar
OMNI 45	40 % Basofil, 60 % Kevlar
OMNI Quilt, 1 layer	100 % Nomex, 1 layer Basofil spunlace fiber
OMNI Quilt, 2 layer	100 % Nomex, 2 layers Basofil spunlace fiber
OMNI Quilt, 3 layer	100 % Nomex, 3 layers Basofil spunlace fiber
PBI Gold	60 % Kevlar, 40 % PBI blend
PBI Gold Plus	60 % Kevlar, 40 % PBI
PBI Lightweight Gold	50 % Kevlar, 50 % PBI blend
PJ	
Pleatpak	X % Nomex SL E89
Power PBI Gold Plus	60 % Kevlar, 40 % PBI
Protective Comfort	Indura face cloth with spun Basofil
Q-9	X % Kevlar, Y % Nomex batting with Nomex face cloth
Quattro-tech	Nomex filament face cloth with Kevlar fleece

Table B-2. Outer Shells and Thermal Liners, continued

Fabric	Description
Rebound SRS	SRS Rebound with Chambray face cloth
Reliant, x weave (x.x oz)	x % x, x % x with x finish
Slick	200 denier Nomex
Stretch Kombat	X % Kevlar, Y % PBI, Z % Lycra, S % Nomex E89
Synergy, x weave (x.x oz)	100 % Nomex III (95 % Nomex, 5 % Kevlar)
UltraFlex	X % Kevlar, Y % Nomex batting with 200 denier filament
XTRA-LITE	X % Nomex, Y % Kevlar batting
Z-200, x weave (7.5 oz)	x % Nomex with Teflon F/PPE finish

Table B-3. Moisture Barriers

Fabric	Manufacturer	Web Address
Crosstech	W.L. Gore & Associates, Inc.	www.goretex.com/activities/fireserv.html
Gore-Tex	W.L. Gore & Associates, Inc.	www.goretex.com/activities/fireserv.html
Tetratex	W.L. Gore & Associates, Inc.	www.goretex.com/activities/fireserv.html
FR-Neoprene	Tetratec Corporation	www.tetratex.com
Neo-Guard	Southern Mills	www.southernmills.com
Breathe-Tex Plus	Aldan Industries, Inc.	www.aldan-ind.com
Aquatech	Aldan Industries, Inc.	www.aldan-ind.com
FR Xalt	Burlington Performance Fabrics	
Stedair2000	Stedfast	www.stedfast.com/english/protection/firefighter.html

Appendix C
Southern Mills Fire Suit Performance Data

Column headings are explained in Section 2.

Table C-1. Southern Mills Fire Suit Performance Data

Outer Shell	Moisture Barrier	Thermal Liner	composite price index	composite TPP rating (cal/cm^2)	composite weight (oz/yd^2)	composite thickness
Millenia	ComfortZone	Caldura SL	81	35-38	20.0	0.115
Millenia	ComfortZone	3-Layer E-89	81	41-44	21.5	0.127
Millenia	ComfortZone	Caldura	79	39-42	21.4	0.151
Millenia	ComfortZone	Aralite	73	35-38	20.8	0.200
Millenia	ComfortZone	Q-9	70	45-48	23.3	0.183
Millenia	Crosstech	Caldura SL	93	35-38	19.5	0.102
Millenia	Crosstech	3-Layer E-89	93	37-40	21.1	0.128
Millenia	Crosstech	Caldura	91	37-40	20.4	0.137
Millenia	Crosstech	Aralite	85	36-39	20.3	0.172
Millenia	Crosstech	Q-9	82	42-45	22.9	0.171
Kombat	ComfortZone	Caldura SL	80	39-42	20.1	0.126
Kombat	ComfortZone	3-Layer E-89	80	44-47	21.0	0.156
Kombat	ComfortZone	Caldura	78	39-42	21.0	0.163
Kombat	ComfortZone	Aralite	72	38-41	20.0	0.157
Kombat	ComfortZone	Q-9	69	48-51	22.7	0.204
Kombat	Crosstech	Caldura SL	92	37-40	19.4	0.104
Kombat	Crosstech	3-Layer E-89	92	42-45	21.3	0.130
Kombat	Crosstech	Caldura	90	39-42	20.9	0.154
Kombat	Crosstech	Aralite	84	37-40	20.4	0.185
Kombat	Crosstech	Q-9	81	45-48	21.7	0.188
Advance	ComfortZone	Caldura SL	61	41-44	19.8	0.122
Advance	ComfortZone	3-Layer E-89	61	48-51	20.7	0.150
Advance	ComfortZone	Caldura	60	45-48	20.6	0.160
Advance	ComfortZone	Aralite	53	40-43	20.4	0.168
Advance	ComfortZone	Q-9	51	49-52	23.0	0.211
Advance	Crosstech	Caldura SL	73	36-39	19.0	0.103
Advance	Crosstech	3-Layer E-89	73	45-48	20.4	0.133
Advance	Crosstech	Caldura	72	40-43	20.1	0.136
Advance	Crosstech	Aralite	66	44-47	19.6	0.129
Advance	Crosstech	Q-9	63	49-52	21.8	0.180
Barrage	ComfortZone	Caldura SL	64	no data	no data	no data
Barrage	ComfortZone	3-Layer E-89	64	no data	no data	no data
Barrage	ComfortZone	Caldura	63	no data	no data	no data
Barrage	ComfortZone	Aralite	56	no data	no data	no data
Barrage	ComfortZone	Q-9	54	no data	no data	no data
Barrage	Crosstech	Caldura SL	77	no data	no data	no data
Barrage	Crosstech	3-Layer E-89	77	no data	no data	no data

Table C-1. Southern Mills Fire Suit Performance Data, continued

Outer Shell	Moisture Barrier	Thermal Liner	composite price index	composite TPP rating (cal / cm2)	composite weight (oz per sq yd)	composite thickness
Barrage	Crosstech	Caldura	75	no data	no data	no data
Barrage	Crosstech	Aralite	69	no data	no data	no data
Barrage	Crosstech	Q-9	66	no data	no data	no data
Defender	ComfortZone	Caldura SL	56	35-38	21.3	0.179
Defender	ComfortZone	3-Layer E-89	56	38-41	21.0	0.142
Defender	ComfortZone	Caldura	54	36-39	20.6	0.129
Defender	ComfortZone	Aralite	48	35-38	20.6	0.156
Defender	ComfortZone	Q-9	45	39-42	23.2	0.198
Defender	Crosstech	Caldura SL	68	37-40	20.3	0.112
Defender	Crosstech	3-Layer E-89	68	44-47	20.8	0.154
Defender	Crosstech	Caldura	67	39-42	21.3	0.140
Defender	Crosstech	Aralite	60	42-45	20.2	0.162
Defender	Crosstech	Q-9	58	49-52	23.0	0.180