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<p>The Navy Clothing and Textile Research Facility (NCTRF) evaluated potential fire-retardant (FR) candidate replacement fabrics for the Navy's 65/35 polyester/cotton poplin khaki shirt and twill trouser fabrics for application in all Officer and CPO khaki shipboard work uniforms. Based on laboratory and wear test data, the most reasonable option for a fire-retardant Officer/CPO work uniform is the 100% fire-retardant-treated cotton (precondensate/ammonia cure treatment) shirt and trouser ensemble. (U)</p> <p><i>Keywords: fire protective clothing (KT)</i></p>					
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FIRE RETARDANT OFFICER/CPO WORK UNIFORM

EXECUTIVE SUMMARY

The Navy Clothing and Textile Research Facility (NCTRF) was directed by the Naval Military Personnel Command (NMPC) to conduct an evaluation of potential fire retardant (FR) candidate replacement fabrics for the Navy's 65/35 polyester/cotton poplin khaki shirt and twill trouser fabrics for application in all Officer and CPO khaki shipboard work uniforms.

The evaluation included:

- a. The selection of commercially available twill fabrics (shirting weight: 4.5 - 5.5 oz/yd², trouser weight: 7.0 - 8.0 oz/yd²) having the following characteristics:
 - (a) 100% Fire Retardant Treated (FRT) cotton, finished with a phosphorous base-ammonia cured treatment, Navy shade khaki
 - (b) 100% Fire Retardant Treated (FRT) cotton, finished with a brominated base treatment in a latex binder, Navy shade khaki
 - (c) 95/5% Nomex/Kevlar inherently fire retardant (FR), producer-colored, Navy shade khaki
- b. Laboratory tests to determine material physical characteristics and appearance, time to burn injury (TBI) and dimensional stability properties after multiple launderings
- c. Laboratory tests of representative uniforms manufactured from the selected fabrics to determine their appearance properties after multiple launderings and dry cleanings
- d. User evaluation of FR Officer/CPO work khaki uniforms in selected candidate fabrics at 13 test sites selected by NMPC
- e. Full scale fire envelopment testing of the candidate uniforms to determine their protective burn injury characteristics for a two second exposure to a 1500 - 2200°F fire was delayed because of weather conditions.

Results of these evaluations indicated:

- (a) Under laboratory test conditions, all candidate fabrics performed similarly when characteristics such as flame resistance, TBI, dimensional stability and colorfastness are grouped. The Nomex/Kevlar fabrics had better physical properties than the FRT cotton and standard polyester/cotton materials with respect to strength and seam efficiency. The precondensate ammonia cured FRT cotton fabrics were rated slightly better in physical properties than the standard polyester/cotton and brominated FRT cotton fabrics.
- (b) Based on appearance, the FRT cotton fabrics were rated significantly lower than the standard polyester/cotton and Nomex/Kevlar fabrics. The cotton fabrics had a non-press appearance after laundering while the Nomex/Kevlar fabrics had a smooth finish appearance after laundering and before pressing. In garment configuration, appearance ratings dropped for the FRT cotton uniforms while appearance ratings for the standard polyester/cotton and Nomex/Kevlar uniforms remained the same. Thus, the overall appearance characteristics of the standard polyester/cotton and Nomex/Kevlar uniforms were superior to the FRT cotton uniforms.
- (c) User evaluation of the FR candidate materials in the khaki work uniform configuration indicated the FRT cotton precondensate/ammonia cure fabrics were perceived as being more comfortable than the FRT cotton brominated finish and Nomex/Kevlar uniforms. The Nomex/Kevlar uniform had better appearance characteristics after laundering and required less ironing than both FRT cotton uniforms (precondensate/ammonia cure and brominated treated).
- (d) Overall preference was similar for both the Nomex/Kevlar and ammoniated FRT cotton uniforms, 34 and 35 percent respectively. Cost acceptability was greatest for the ammoniated FRT cotton uniform. However, only 23 percent found the \$40.00 cost for the uniform acceptable.

Conclusions

- a. The Nomex/Kevlar candidate materials performed somewhat better than the FRT cotton candidates when laboratory tested for physical properties. The physical characteristics of all the FR candidate materials were approximately equal to or better than the current standard polyester/cotton fabrics. The standard polyester/cotton uniform was rated higher in appearance characteristics after laundering/dry cleaning than the FRT cotton uniforms and only slightly higher than the Nomex/Kevlar uniforms.

- b. Laboratory flame resistance and radiant heat exposure tests indicate that the FRT cotton fabrics provide suitable fire and heat protection similar to that of the current fire retardant utility uniform for enlisted personnel.
- c. Overall results from the user evaluation indicated the Nomex/Kevlar and FRT cotton precondensate ammonia treated uniforms as the preferred test candidates over the current polyester/cotton work uniform although only approximately one-third of the respondents preferred these uniforms. The results indicated that the Nomex/Kevlar uniforms had better appearance qualities after cleaning and required less ironing than the ammoniated FRT cotton uniforms while the ammoniated FRT cotton uniforms were more comfortable than the Nomex/Kevlar uniforms. In terms of cost acceptability, the ammoniated FRT cotton uniforms were preferred over the other test candidates. However, only 23 percent of the respondents were willing to pay \$40.00 for this uniform.

Recommendations

Based on laboratory and wear test data, it appears that the most reasonable option for a fire retardant Officer/CPO work uniform is the 100% Fire Retardant Treated Cotton (precondensate/ammonia cure treatment) shirt and trouser ensemble. The principal deficiency of this uniform compared to the current standard polyester/cotton khaki work uniform and Nomex/Kevlar candidate uniform is its poor appearance after laundering. The benefits to be derived are short term heat/fire protection and the comfort afforded by 100 percent cotton fabrics, at a cost increase of approximately 18 percent with respect to the current polyester/cotton uniform.

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FIRE-RETARDANT OFFICER/CPO WORK UNIFORM

INTRODUCTION

At the direction of the Naval Military Personnel Command (NMPC), the Navy Clothing and Textile Research Facility (NCTRF) initiated a program in July 1985 to evaluate potential fire retardant (FR) candidate replacement fabrics for the Navy's Officer/CPO khaki work uniform.

The evaluation involved the selection of commercially available FR khaki fabrics that based on their physical and finish characteristics, would potentially meet the functional requirements for Navy Officer/CPO work uniform fabrics.

The candidate FR materials selected for the khaki uniforms were composed of a 95/5% Nomex/Kevlar, and 100% FRT cotton, utilizing two types of fire retardant finishes (1. precondensate/ammonia cure, 2. brominated base with a latex binding).

All candidate shirt and trouser fabrics were of a twill weave construction to alleviate previous problems in obtaining a good vertical shade match as a result of construction differences in the current standard polyester/cotton fabrics (poplin shirt and a twill trouser) used in the khaki work uniform.

The candidate materials were evaluated in the laboratory to determine their physical characteristics and appearance, flame resistance, heat protection, and dimensional stability properties after multiple launderings.

Uniforms manufactured from the selected fabrics were also laboratory evaluated to determine their appearance after multiple launderings and dry cleanings. In addition, the candidate uniforms were evaluated at 13 test sites selected by NMPC to determine their acceptability by Naval personnel. Full scale fire envelopment testing of the candidate FR fabrics in uniform configuration to determine their protective burn injury characteristics after being subjected to a two second exposure in a 1500 - 2200°F fire were delayed due to weather conditions. An addendum report will be prepared regarding the performance of the test uniforms to this threat by December 87.

As a result of this evaluation, the following was determined:

- a. Based on laboratory data, all of the candidate FR fabrics had strength characteristics equal to or better than the current standard polyester/cotton khaki materials.
- b. Based on laboratory/user data, all candidate fabrics exhibited dimensional stability characteristics equal to the standard polyester/cotton fabrics.

- c. Based on flat appearance ratings used to evaluate smoothness appearance of fabrics after laundering, the FRT cotton uniforms had a non-dressed appearance after laundering, while the Nomex/ Kevlar uniforms had a smooth finished appearance after laundering and were rated significantly better than the FRT cotton uniforms for this characteristic.
- d. Radiant heat exposure tests indicate that the FRT cotton fabrics and Nomex/Kevlar fabrics provide suitable heat protection similar to that of the current fire retardant utility uniform for enlisted personnel. Protection time was directly related to the weights of the fabric and not the fiber composition.
- e. Regarding overall preference, the FRT cotton precondensate ammonia treated and Nomex/Kevlar uniform were the most preferred (35 percent and 34 percent, respectively). The current polyester/cotton work uniform was preferred by 25 percent of the test participants and the FRT cotton brominated finish uniform was preferred by only 6 percent of the test participants.
- f. In terms of cost acceptability, the ammoniated FRT cotton uniforms were preferred over the other test candidates. However, only 23 percent of the respondents were willing to pay the \$40.00 cost for this uniform.

This report includes background information relating to this investigation, description of all candidate fabrics employed, the approach and procedures used to evaluate the candidate fabrics, results obtained, and the conclusions and recommendations derived from these results.

BACKGROUND

In June 1985, the NMPC tasked NCTRF to develop a fire retardant working uniform for Officer/CPO personnel since the current work uniform does not have fire retardant characteristics. Because one of the Navy's prime objectives is for all shipboard clothing to be fire retardant, it was necessary to develop a Officer/CPO FR working uniform which would be equivalent in fire protection to the enlisted FR utility uniform. These garments would be designed to the extent possible to meet the functional characteristics of the present standard polyester/cotton khaki work uniform while incorporating fire retardancy.

APPROACH

Fabrics

Commercially available fire retardant fabrics in khaki shades, having physical and performance properties potentially suitable for use in Officers/CPO khaki work uniforms were selected. The present fabrics are made from 65/35 polyester/cotton fibers. Table I lists the materials selected and their general characteristics. Also listed are the general characteristics of the standard polyester/cotton, khaki fabrics.

With the exception of the FRT cotton brominated base fabrics with the latex binding, all of the candidate fabrics (FRT cotton phosphorus base-ammonia cured and Nomex/Kevlar) weighed between 4.5 and 5.0 oz/sq yd for the shirting materials, and between 7.0 and 7.5 oz/sq yd for the trouser materials. The brominated base FRT cotton fabrics were the heaviest of the candidate fabrics (5.8 oz/sq yd for the shirt and 9.0 oz/sq yd for the trousers).

All candidate shirt and trouser fabrics were of a twill weave construction to alleviate previous problems in obtaining a good vertical shade match caused by construction differences in the shirt and trousers of the current polyester/cotton fabrics used in the Officer/CPO Work Uniform (poplin construction for the shirt and a twill weave construction for the trouser). Even when the color in these two fabrics is the same, their appearance is different because of changes in light reflection due to the different constructions. Similar fabric constructions for both the shirt and trousers should minimize this problem.

Work uniform candidate materials were limited to 100% cotton (as employed in the enlisted FR chambray shirt and denim trouser work uniform), and the 95/5 Nomex/Kevlar material (used in the FR engineering coverall). For the 100% cotton materials, two durable treatments were considered. One was a phosphorous type-ammonia cured treatment identical to that used in the FR enlisted work uniform and the other a bromine type treatment with a latex binder.

The phosphorous treatment results in the chemical being imparted and subsequently cross-linked by an ammonia vapor cure within the interstices of the cotton fiber yarn. This treatment produces a durable treatment with good FR properties (short after flame and after glow times and small char lengths upon removal of the flame source). The treatment does not effect strength properties and is not subject to direct physical abrasion because of its location within the cotton yarn.

The bromine treatment, cross-linked with a latex, is adhered to the surface of the cotton fabric much like a surface coating. This treatment also produces a finish durable to laundering similar to the phosphorous finish. Initial problems were encountered with this finish related to FR properties (long glow time) and the hand of the material (rubbery feel). Changes in formulation and application techniques resulted in improved FR characteristics and hand (the coating was drawn internally to the fabric by vacuum methods, reducing the amount of coating on the surface).

Cotton fabrics finished with these types of fire retardant treatments (FRT) exhibit the same poor after laundering appearance characteristics normally associated with non-resin treated cotton fabrics. Attempts to use durable press resin treatments in combination with the FR treatment to improve appearance were not very effective because the treatment physically blocks some of the cross-linking action necessary to obtain good durable press characteristics. The 95/5 Nomex/Kevlar candidate fabrics are inherently flame retardant and require no additional add-on FR treatments. Furthermore, like other synthetic fabrics, Nomex/Kevlar fabrics exhibit good after laundering appearance characteristics because they can be heat set (autoclaved) to remove any residual stresses in the fabric during finishing.

Sufficient quantities of each candidate fabric were obtained to conduct laboratory physical and performance evaluations and to construct uniforms from these fabrics for both laboratory and user performance evaluations.

The laboratory evaluations of the candidate fabrics determined their physical characteristics and appearance performance after multiple launderings and dry cleanings with respect to wrinkling behavior.

Table II shows the fabric codes assigned to each of the candidate fabrics. The code descriptors represent the following:

- NK - Nomex/Kevlar, 4.5 oz/sq yd shirt and 7.2 oz/sq yd trouser
- CA - FRT Cotton (precondensate/ammonia cure), 4.7 oz/sq yd shirt and 7.0 oz/sq yd trouser
- CB - FRT Cotton (brominated), 5.8 oz/sq yd shirt and 9.0 oz/sq yd trouser
- SPC - Standard 65/35% Polyester/Cotton, 4.6 oz/sq yd shirt and 6.8 oz/sq yd trouser
- S - Shirt
- T - Trouser
- E - Ensemble

Table I - General Characteristics of Candidate Replacement Materials and the Current Polyester/Cotton Fabrics

Blend (%)	Shade	Weight (oz/sq yd)	Construction (Weave)	Fire Retardant Finish
100% FRT Cotton	Khaki	4.7	2 X 1 Twill	Precondensate/ Ammonia Cure
	Khaki	7.0	2 X 1 Twill	Precondensate/ Ammonia Cure
100% FRT Cotton	Khaki	5.8	2 X 1 Twill	Brominated/ Latex Binder
	Khaki	9.0	2 X 1 Twill	Brominated/ Latex Binder
95/5% Namex/Kevlar	Khaki	4.5	2 X 1 Twill	Inherent
	Khaki	7.2	2 X 1 Twill	Inherent
65/35% Polyester/Cotton	Khaki	4.6	Poplin	N/A
	Khaki	6.8	2 X 1 Twill	N/A

Table II - Fabric Codes Assigned to Candidate Fabrics

Code	Item (Garment)	Weight (oz/sq yd)	Fabric Blend (%)	Fire Retardant Finish
NKS	shirt	4.5	95/5 Nomex/ Kevlar	Inherent
NKT	trouser	7.2	95/5 Nomex/ Kevlar	Inherent
NKE	shirt/trouser	N/A	95/5 Nomex/ Kevlar	Inherent
CAS	shirt	4.7	100% FRT Cotton	Precondensate/ Ammonia Cure
CAT	trouser	7.2	100% FRT Cotton	Precondensate/ Ammonia Cure
CAE	shirt/trouser	N/A	100% FRT Cotton	Precondensate/ Ammonia Cure
CBS	shirt	5.8	100% FRT Cotton	Brominated
CBT	trouser	9.0	100% FRT Cotton	Brominated
CBE	shirt/trouser	N/A	100% FRT Cotton	Brominated
SPCS	shirt	4.6	65% Polyester/ 35% Cotton	N/A
SPCT	trouser	6.8	65% Polyester/ 35% Cotton	N/A
SPCE	shirt/trouser	N/A	65% Polyester/ 35% Cotton	N/A

Uniforms

Men's and women's long sleeve shirts and trousers/slacks were constructed from the candidate fabrics. None of the uniforms possessed any type of durable press or crease resistant finish. A FR silicone resin finish is available, however, and may be applied to the creases of the trousers. This resin is cured (cross-linked) during the formation of the creases to obtain a durable, sharp crease appearance. Compatibility of the resin finish with the FR finish would require verification.

Laboratory evaluations of the uniform items determined their appearance performance after multiple launderings and dry cleanings with respect to wrinkling behavior.

Full scale fire envelopment testing of the uniforms to determine their protective burn injury characteristics after being evaluated for a two second exposure to a 1500^oF-2200^oF fire was delayed. Data from these tests will be provided in an addendum report by December 87.

User evaluations were also conducted on the candidate fabrics to determine acceptability by Naval personnel. Table III indicates the test sites selected, the fabric combinations compared for each type of uniform evaluated and the number of uniform combinations compared.

Because of the limited nature of the user evaluation, only a small percentage of women evaluators were available for the wear test and the data available were limited. Therefore, the data reported represents the combined responses of both the men and women evaluators. A total of 93 volunteers were fitted with the experimental uniforms in the user evaluation.

**Table III - Uniform Distribution Sites and Fabric Comparison
Information for User Evaluation**

Test Site	Uniform Combinations Compared	Number of Uniforms Combinations Compared
USS Yellowstone (Norfolk)	NKE - CAE NKE - CAE - CBE	5 2
Submarine/Tenders (San Diego)	NKE - CAE NKE - CAE - CBE	13 11
USS Recovery (Norfolk)	NKE - CAE NKE - CAE - CBE	2 3
USS Platte (Norfolk)	NKE - CAE	1
USS San Diego (Norfolk)	NKE - CAE NKE - CAE - CBE	1 2
USS Savannah (Norfolk)	NKE - CAE	3
USS Canisteo (Norfolk)	NKE - CAE NKE - CAE - CBE	2 1
USS Juneau (San Diego)	NKE - CAE	5
USS Tarawa (San Diego)	NKE - CAE NKE - CAE - CBE	6 1
USS Tuscaloosa (San Diego)	NKE - CAE NKE - CAE - CBE	1 1
Amphibious Squadron One (San Diego)	NKE - CAE	2
Submarine/Tenders (New London)	NKE - CAE NKE - CAE - CBE	23 6
USS Schenectady (San Diego)	NKE - CAE NKE - CAE - CBE	1 1
Totals	NKE - CAE NKE - CAE - CBE	65 28

PROCEDURE

Fabrics

Table IV lists the test procedures employed in evaluating the candidate materials in the laboratory.

Physical Characteristics

The physical characteristics of the candidate materials (weight, yarn ply, construction, break and tear strength, etc.) were determined using visual or the specified test methods noted in Table IV.

Flame Resistance Characteristics

The flame resistance of the FR materials was determined using the specified test method noted in Table IV. After flame and after glow times, as well as char length, were recorded initially and after 25 launderings.

Radiant Heat Exposure

Radiant heat exposure tests were conducted on the FR materials by recording the amount of heat transferred through the fabric when exposed to a radiant heat source. Measurements of the radiant heat exposure levels and the heat transferred through the fabrics were made with a water cooled heat flux transducer. The data were used to calculate the exposure time required to produce a second degree burn injury (TBI) for different radiant heat flux levels. The burn injury time estimations were determined using burn injury data developed by Stoll and Chianta, Naval Air Development Center (Figure 1). Radiant heat flux challenge levels of 0.5, 0.8, and 1.2 cal/sq cm/sec were used and heat flux measurements of the heat transferred through the specimen were taken with the heat flux transducer against the test specimen.

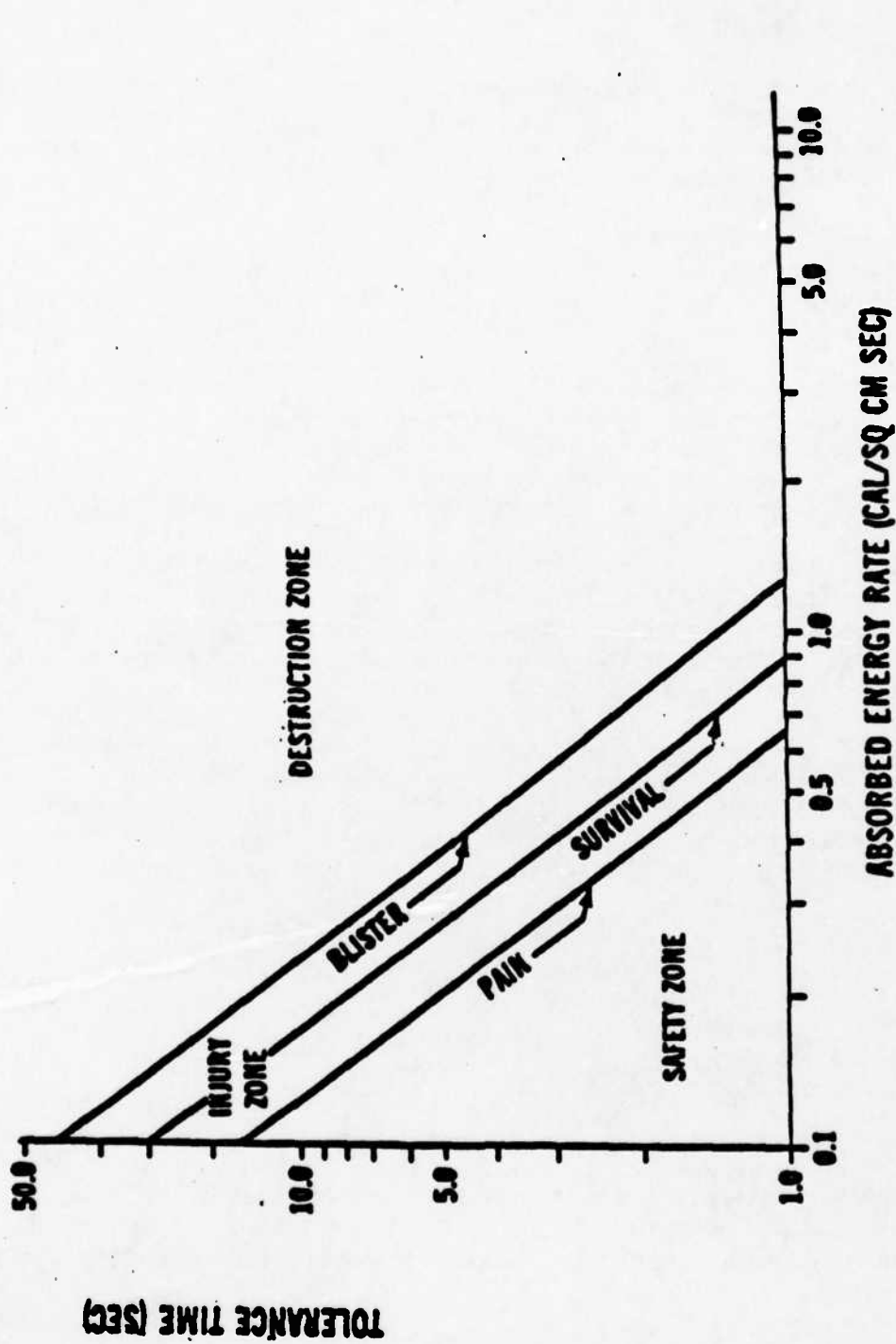
Dimensional Stability Characteristics

The dimensional stability of the FR materials was determined using the specified test method noted in Table IV. The data were recorded after the initial laundering, and after every five launderings, up to 25 launderings.

Table IV - Material/Garment Laboratory Test Methods

Characteristic	Test Method *
Fiber Identification	1200
Yarn Ply	Visual
Weave	Visual
Labile Sulfur	2020
Colorfastness to Light	5660
Colorfastness to Laundering (3 cycles)	10
Colorfastness to Perspiration	5680
Colorfastness to Crocking	5651
Weight	5041
Yarns per Inch	5050
Break Strength	5100
Tearing Strength	5132
Stiffness	5202
Air Permeability	5450
Seam Efficiency	5110
pH	2811
Flame Resistance	5903
Flame Resistance after 25 Launderings	5556 & 5903
Radiant Heat	NCTRF
Dimensional Stability (25 cycles)	5550
Flat Appearance	AATCC-124
Wrinkle Recovery	AATCC-88
Crease Recovery	AATCC-86

* Federal Standard for Textile Test Methods
No. 191 A, except where noted.



HUMAN SKIN TOLERANCE TIME TO ABSORBED THERMAL ENERGY DELIVERED IN A RECTANGULAR HEAT PULSE.

FIGURE 1

EVALUATION OF THERMAL PROTECTION STOLL AND CHIANTA

Performance Characteristics

In determining the performance characteristics of the candidate materials (flat appearance, wrinkle recovery, and crease recovery) all methods employed in the tests conformed to the American Association of Textile Chemist and Colorist (AATCC) procedures as shown in Table IV.

1. Flat Appearance - This test method is used to evaluate smoothness appearance of fabrics after laundering. Appearance was determined under home laundering machine wash condition III (140° + 5F), and drying procedure B (tumble drying) before pressing. The rating scale was as follows:

1. Crumpled, Creased, and Severely Wrinkled Appearance
2. Ruffled, Obviously Wrinkled Appearance
3. Mussed, Non-Pressed Appearance
4. Smooth Finished Appearance
5. Very Smooth, Pressed, Finished Appearance

2. Wrinkle Recovery - This test method is used for determining the appearance of materials after induced wrinkling. The rating scale standard No. 5 represents the smoothest appearance and best retention of original appearance, while a No. 1 rating represents the poorest appearance and poorest retention of original appearance.

3. Crease Recovery - This test method is designed for evaluating the retention of pressed-in creases. Appearance was determined under home laundering machine wash condition III (140°F), and drying procedure C (tumble drying). The rating scale standard No. 5 represents the best level of appearance of crease retention, while No.1 represents the poorest appearance.

Uniforms

Performance Characteristics

In determining the performance characteristics of the candidate uniforms and the current working khaki uniform, combinations of specific laundering and dry cleaning conditions were employed with the flat appearance test method listed in Table IV. Table V reflects how these different conditions were combined, depending upon the particular characteristics being rated.

Flat Appearance - Ratings were performed similarly to the method used for materials, except upper garments were viewed on hangers and lower garments draped from clamps (appearance ratings for the shirt and trousers were combined and reported as a uniform ensemble). The performance properties measured on the candidate uniforms and the standard polyester/cotton uniform were appearance before and after pressing in the laundering tests, and appearance before and after pressing in the dry cleaning tests.

User Evaluation

As shown in Table III, user evaluations were conducted on Officer/CPO khaki work uniforms in the fabric candidates indicated. There were 93 test participants who evaluated 214 uniforms (93 Nomex/Kevlar uniforms, 93 precondensate/ammonia cure FRT cotton uniforms, and 28 brominated FRT cotton uniforms). The test uniforms were worn over a period of nine months during the August 1986 to April 1987 timeframe.

Briefings were held with most test participants prior to the start of the evaluation and occasionally during the nine month evaluation period. Arrangements were made with various uniform tailor shops to permit alterations of the uniforms prior to their wear in the evaluation.

Questionnaire forms (Appendix B) were provided each participant to develop information relative to the following characteristics:

- a. Fit
- b. Times Uniforms Worn
- c. Cleaning Methods Employed
- d. Degree of Dimensional Change
- e. Need for Pressing after Cleaning
- f. Ease of Stain Removal
- g. Comfort
- h. Durability
- i. Appearance after Wear/Cleaning
- j. Comparability to Current Khaki Polyester/Cotton Uniform
- k. Preference
- l. Cost Acceptability

Table V - Cleaning Procedures of Uniforms for Laboratory Flat Appearance Evaluation

Cleaning Method	Procedure	
<u>Laundering</u> Method Wash Temp (°F) Drying Method Drying Temp (°F) Press. Method Press. Temp (°F) Number of cycles	<u>(A)</u> NAVEDTRA Formula II 140 Tumble 140-180 Flat Bed 275-300 15	<u>(B)</u> Home Wash 140 Tumble 140-180 Flat Bed 275-300 15
<u>Dry Cleaning</u> Method Drying Method Pressing Method Number of cycles	Commercial Dry Cleaners Tumble Flat Bed three	

RESULTS

Laboratory/Fabrics

Physical Characteristics

Table VI shows the physical characteristics of the candidate materials. All of the candidates were found to possess suitable physical properties with respect to fabric weight, stiffness, colorfastness to laundering, perspiration, and crocking. Colorfastness to light was rated worse for the Nomex/Kevlar fabric, which is noted for poor light fastness, and the bromine treated FRT cotton because of its finish. The pH for all fabrics was essentially neutral.

The Nomex/Kevlar fabrics had higher physical properties than the FRT cotton materials for equivalent weight fabrics with respect to break and tear strengths, and seam efficiency. The phosphorous/ammonia cured FRT cotton rated slightly higher in physical properties than the brominated FRT cotton based on their relative tear strengths. The strength characteristics for both the Nomex/Kevlar and phosphorous/ammonia cured FRT cotton fabrics were suitable. The tear strengths for the brominated FRT cotton fabrics in the filling direction were marginal.

Air permeability results were directly related to the weight and finish of the fabrics. The heavier fabrics possessed lower air permeability values. Values were as low as 20 ft³/min/ft² for the 9.1 oz/sq yd bromine treated FRT cotton and as high as 99 ft³/min/ft² for the 4.5 oz/sq yd Nomex/Kevlar fabric.

Flame Resistance Characteristics

Flame resistance was generally within normal specification limits for the types of fabrics evaluated. There were no substantial differences in flame resistance after 25 launderings in comparison to initial results for all candidate fabrics. Those exceeding normal specification limits for this characteristic were the brominated FRT cotton materials where after glow readings were over 30 seconds before and after laundering. Specification limits normally established for these types of fabrics are as follows:

	Nomex Fabrics	FRT Cotton Fabrics
After Flame (seconds)	2.0	2.0
After Glow (seconds)	25.0	5.0
Char Length (inches)	3.5	5.0

Radiant Heat Exposure

Table VII indicates the time to burn injury (TBI) for the candidate materials with the sample placed directly against the sensor. At the highest heat flux challenge level of 1.2 g cal/sq cm/sec , all of the fabrics provided at least 6.4 seconds of protection. The TBI times measured for all fabrics were primarily dependent on the weight of the fabrics rather than their fiber content.

Dimensional Stability Characteristics

Table VIII indicates the percentage change in fabric dimensions initially, and after every five cycles, up to twenty-five launderings.

Dimensional stability results were within normal specification limits (2 percent maximum) after one laundering for all candidate shirt and trouser fabrics evaluated. However, progressive shrinkage did occur with the FRT cotton materials, with significant changes starting at the tenth cycle for both the shirt and trouser materials. Shrinkage for the FRT cotton materials ranged as high as 3.7% for the ammonia cured shirting fabric, and 4.4% for both the ammonia and brominated type trouser fabrics. Progressive shrinkage is a typical characteristic for all cotton fabrics. The Nomex/Kevlar materials remained under 2% through 25 laundering cycles. Figures 2 and 3 depict the dimensional changes in the shirting and trouser materials, respectively, with regards to the number of laundering cycles.

Table VI - Physical Characteristics of Candidate Materials

Characteristic	Fabrics					
	NKS	NKT	CAS	CAT	CBS	CBT
Yarn Ply	2 ply	2 ply	singles	singles	singles	singles
Weave	twill	twill	twill	twill	twill	twill
Labile Sulfur	pass	pass	pass	pass	pass	pass
Colorfastness to:						
Light (40 hrs)	fair	fair	good	good	fair	fair
Laundering	good	good	good	good	good	good
Perspiration	excel	excel	excel	excel	excel	excel
Crocking	excel	excel	good	good	good	good
Weight (oz/sq yd)	4.5	7.2	4.7	7.0	5.8	9.1
Yarns / inch (W / F)	75/51	99/46	114/52	90/48	111/52	93/48
Break Strength (lbs. W / F)	173/92	300/128	147/62	239/98	167/63	233/95
Tearing Strength (lbs. W / F)	12/9	15+/8	8/6	10/8	6/4	7/4
Stiffness (30°) (in/lbs)	.0021	.0030	.0020	.0029	.0020	.0025
Air Permeability (ft ³ /min/ft ²)	99	31	80	33	65	20
Seam Efficiency (% str. retained)	100	100	91	90	86	91
pH	6.6	6.8	6.5	6.7	6.8	7.8
Flame Resistance:						
Initial						
after flame (sec)	1.9	0.0	0.0	0.0	0.0	0.0
after glow (sec)	0.0	8.7	0.4	0.0	30+	30+
char length (in)	2.8	2.5	4.1	4.6	2.9	2.5
After 25 Washes						
after flame (sec)	0.0	0.0	0.0	0.5	0.0	0.0
after glow (sec)	7.0	4.4	0.0	0.0	30+	30+
char length (in)	3.3	2.8	4.7	3.8	3.6	3.4

Table VII - Time to Burn Injury (TBI) Protection Provided by Candidate Materials for Different Radiant Heat Flux Challenge Levels

Fabric	Wt (oz/yd ²)	Heat Flux (g cal/cm ² /sec)	TBI (sec)
NKS	4.5	0.5	14.3
		0.8	9.5
		1.2	6.6
NKT	7.2	0.5	17.6
		0.8	12.0
		1.2	8.6
CAS	4.7	0.5	15.0
		0.8	9.2
		1.2	6.4
CAT	7.0	0.5	17.2
		0.8	10.9
		1.2	8.1
CBS	5.8	0.5	16.0
		0.8	10.9
		1.2	7.5
CBT	9.0	0.5	19.1
		0.8	12.6
		1.2	9.2

Table VIII - Dimensional Stability Characteristics of Candidate Materials

No. Washings*	Dimensional Change (%)					
	NKS	NKT	CAS	CAT	CBS	CBT
1 W	1.0	0.6	1.2	0.8	0.6	1.0
F	1.4	1.0	1.5	1.2	1.4	1.6
5 W	1.7	1.5	2.1	1.7	0.6	1.5
F	1.2	0.6	1.7	0.0	1.9	1.9
10 W	1.2	1.4	2.8	2.9	1.8	2.8
F	0.6	0.2	2.5	0.3	2.4	0.2
15 W	1.2	1.6	3.7	3.7	2.3	3.6
F	0.7	0.3	2.7	0.3	3.3	0.6
20 W	1.3	1.8	3.4	4.0	2.7	4.0
F	0.8	0.2	1.7	0.0	2.4	0.0
25 W	1.6	1.9	3.6	4.4	3.0	4.4
F	0.9	0.3	2.0	0.2	2.6	0.0

* FED STD 191 #5550

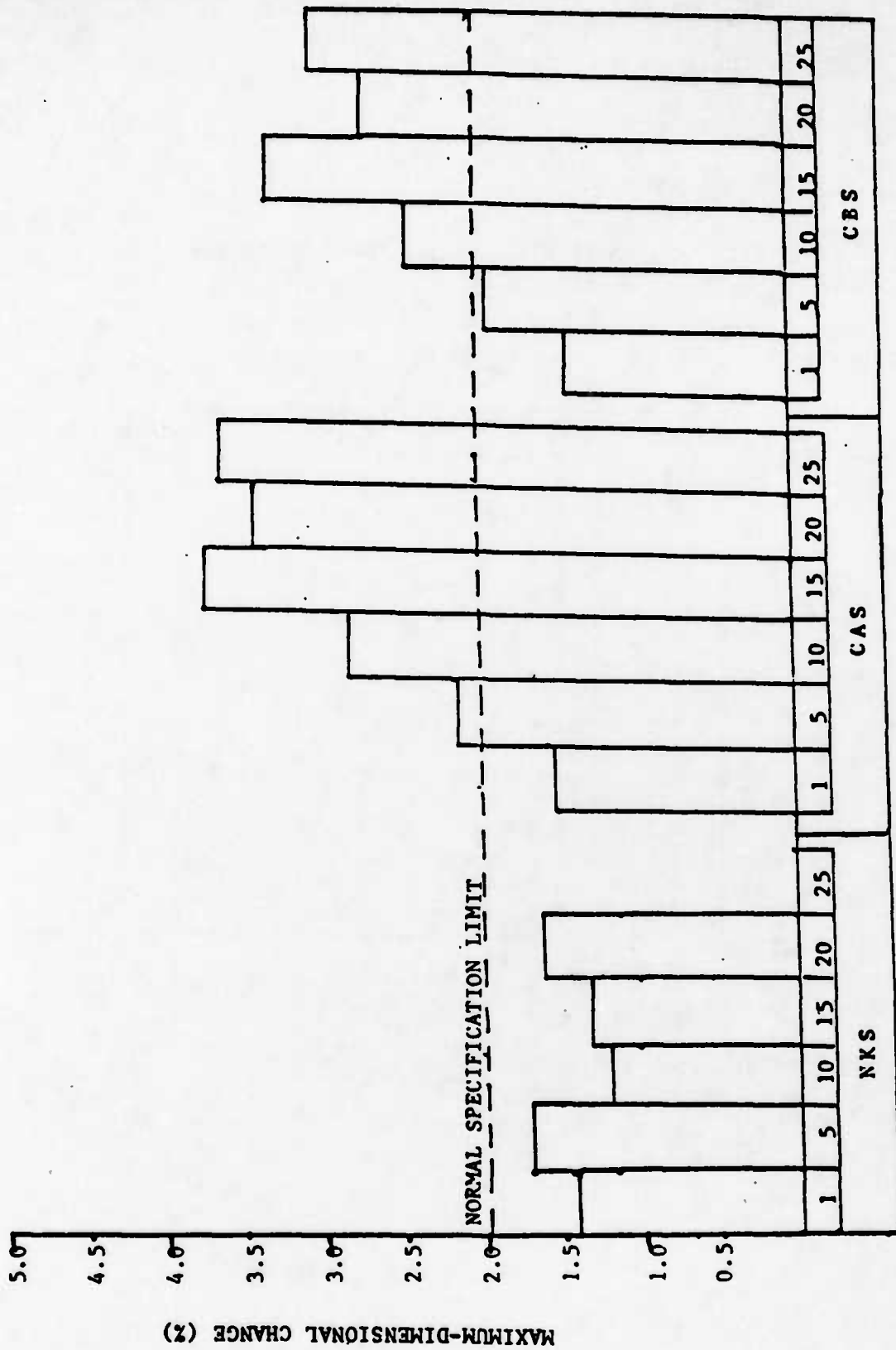
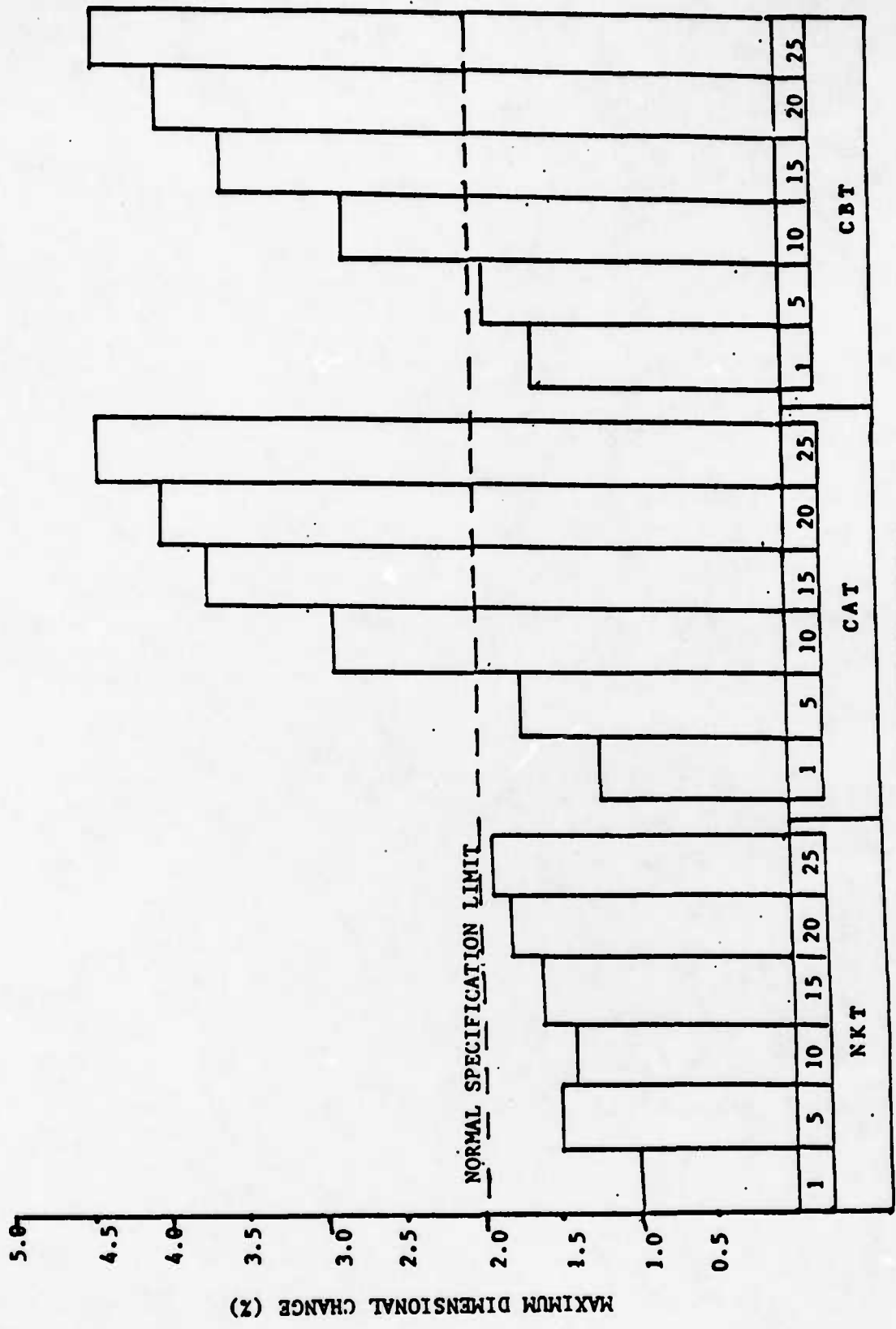


FIGURE 2 PROGRESSIVE SHRINKAGE CHARACTERISTICS OF CANDIDATE SHIRTING MATERIALS



LAUNDERING CYCLES
FIGURE 3 PROGRESSIVE SHRINKAGE CHARACTERISTICS OF
 CANDIDATE TROUSER MATERIALS

Performance Characteristics

Table IX shows the performance characteristics of the candidate materials for Flat Appearance, Wrinkle Recovery and Crease Recovery before pressing.

Flat Appearance

The Nomex/Kevlar fabrics showed the best performance for this property. The rating (3.3 for the shirt and 3.5 for the trouser fabrics) indicated an appearance between non-pressed and a smooth finish. The FRT cotton materials ratings were similar, averaging 2.3 for the shirt fabrics and 3.0 for the trouser fabrics (rumped appearance for the shirt fabrics and a non-pressed appearance for the trouser fabrics).

Wrinkle Recovery

Wrinkle recovery data indicated a large difference in ratings between the Nomex/Kevlar and cotton fabrics. The NKE was rated highly for both shirt and trouser materials (4.2 and 4.0), representing a smooth appearance and good retention of original appearance. Both FRT cotton fabrics (CAF and CBE) were rated consistently low in appearance, having a wrinkle recovery rating of no higher than 2.5 (rumped to non-pressed appearance).

Crease Recovery

Crease recovery results were essentially poor for all the candidate materials in retaining pressed-in creases. The FRT cotton fabrics were somewhat better than the Nomex/Kevlar when considered as ensembles, with the brominated cotton ensemble showing the best performance.

Table IX - Average Performance Characteristics of Candidate Materials for Flat Appearance, Wrinkle Recovery, and Crease Recovery Before Pressing (one cycle)

Characteristic	Fabric					
	NKS	NKT	CAS	CAT	CBS	CBT
Flat Appearance Home Laundering 140°F	3.3	3.5	2.4	3.0	2.2	3.0
Wrinkle Recovery Induced Wrinkling	4.2	4.0	2.2	2.5	2.5	2.0
Crease Recovery Home Laundering 140°F	1.2	1.8	1.7	2.3	2.3	2.3

Uniforms

Performance Characteristics

Figure 4 indicates the flat appearance ratings for the candidate fabric ensembles and the current polyester/cotton khaki work uniform after 15 shipboard and home launderings and after three dry cleanings, before and after pressing.

The best overall performance (after home/shipboard launderings and dry cleanings) before pressing was achieved with the standard khaki polyester/cotton uniform (SPCE) and the Nomex/Kevlar uniform (NKE). Values ranged from 3.5 to 4.5. The other candidate fabrics (FRT cotton fabrics CAE and CBE) had lower appearance ratings, ranging between 1.0 and 2.0 for both shirts and trousers.

After pressing, the appearance ratings for all fabrics improved. The largest increase in appearance from before pressing to after pressing was the FRT cotton ensembles. However, the Nomex/Kevlar uniforms still had a better rating than the FRT cotton uniforms (a rating of 4.0 compared to 3.0 or less for the cotton) indicating that a smooth finish appearance could be achieved with the Nomex/Kevlar uniforms while the cotton uniforms would still have a mused appearance even after pressing. This indicates that the cotton uniforms cannot be restored to an acceptable military appearance easily. The current standard polyester/cotton khaki uniform was ranked better for appearance than any of the candidate uniforms, having a rating of 5.0, indicating a very smooth pressed appearance.

User Evaluation

Results of the user evaluation are shown in Table X. The data shown indicate as a percentage the total response to a particular characteristic addressed for each candidate uniform evaluated.

Initial Fit - Depending upon the particular candidate fabric, uniform responses indicated the fit of the uniforms was considered acceptable by as few as 65 percent and as many as 82 percent. The low fit results with the brominated finish cotton uniform (65 percent) was due in part to the fact that only 28 uniforms of this type were available versus 93 each of both the Nomex/Kevlar and ammoniated cotton uniforms.

Cleaning Methods - Responses indicated that shipboard laundering was the method used by most participants to clean their uniforms. Depending on the particular uniform, 53 to 57 percent of the personnel subjected their test uniforms to shipboard laundering. For the remaining responses, 29 to 31 percent indicated the uniforms were home laundered, while 8 to 14 percent indicated the uniforms were dry cleaned. Four percent of the responses indicated the uniforms were cleaned by a commercial launderer.

Degree of Dimensional Change - The majority of the responses, 91 percent or more, indicated that participants did not observe any dimensional changes in their test uniforms for any candidate fabric. Those who did felt the changes were slight.

Appearance After Wear/Cleaning - The only candidate ensemble that had an appearance rating similar to the standard uniform (98 percent - good/excellent) was the Nomex/Kevlar uniform (87 percent). Both FRT cotton uniforms were rated less than 60 percent as having good to excellent appearance after wear and cleaning.

Ironing Required - For all candidate uniforms, the majority of the responses indicated that ironing was required to achieve an acceptable appearance. For the FRT cotton uniforms, 76 to 83 percent of the responses indicated ironing was required and 55 percent of the responses indicated the Nomex/Kevlar uniform required ironing.

Stain Removal - Most responses for the FRT cotton uniforms, (87 to 88 percent), indicated that stain removal was easy, while 92 percent of the responses indicated that the Nomex/Kevlar uniform had good stain removal characteristics.

Comfort - Responses indicated that the ammoniated FRT cotton uniform was perceived to be more comfortable than the other candidate uniforms. Forty two percent felt the comfort of this uniform was cool to excellent while only 23 percent felt the brominated FRT cotton uniform was cool to excellent and only 22 percent felt the Nomex/Kevlar uniform was cool to excellent.

Durability - The majority of the responses, (91 percent or more), indicated that all candidate uniform fabrics were durable.

Comparison to the Standard Polyester/Cotton Khaki Uniform - At least 46 percent of the responses indicated that the Nomex/Kevlar and ammoniated FRT cotton candidate uniforms were equal to or better than the current polyester/cotton work uniform. Only 31 percent of the responses indicated the brominated FRT cotton uniform was equal to or better than the current uniform.

Preference - Preference for the Nomex/Kevlar and ammoniated FRT cotton uniform was similar, 34 and 35 percent, respectively and both were preferred to the brominated FRT cotton uniform (6 percent) and the standard polyester/cotton uniform (25 percent).

Cost Acceptability - Based on the cost estimates for each of the candidate uniforms (\$60 Nomex/Kevlar, \$40 ammoniated FRT cotton, and \$42 brominated FRT cotton), the maximum "yes" response was 23 percent for the ammoniated FRT cotton uniform. Less than 10 percent of the responses indicated that the Nomex/Kevlar or brominated FRT cotton uniforms would be purchased at the cost associated with these uniforms.

BP - before pressing
 AP - after pressing
 SL - shipboard laundering - 15 cycles
 HL - home laundering - 15 cycles
 DC - dry cleaning - 3 cycles

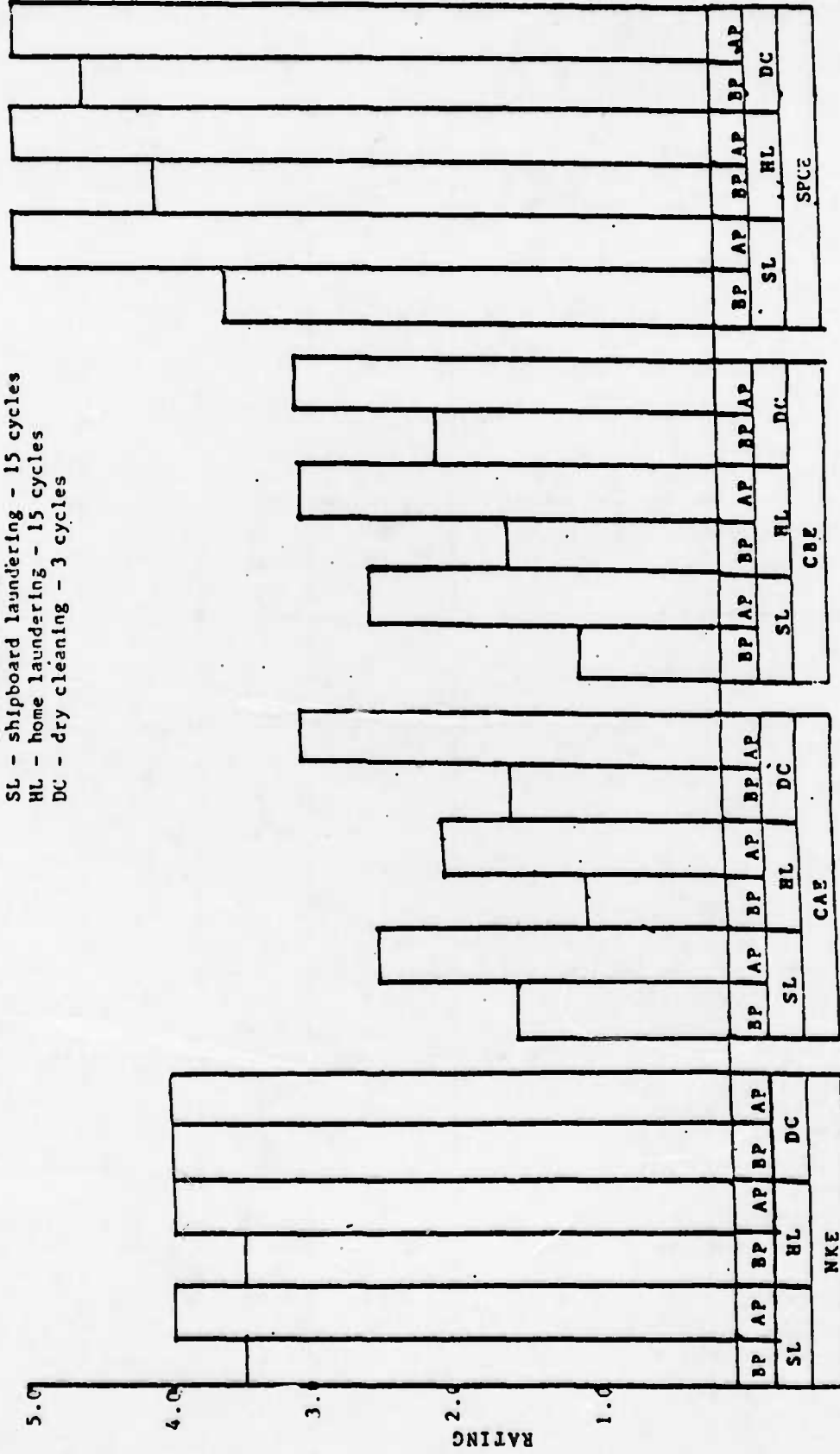


FIGURE 4: FLAT APPEARANCE RATINGS

Table X - Questionnaire Data for FR Work Khaki Uniform

Characteristic	Descriptor	Total Responses (%)			
		NKE	CAE	CBE	SPCE
Fit	Good/Excellent	77	82	65	N/A
	Poor	23	19	35	N/A
Cleaning Method	Home Laund.	29	30	31	N/A
	Shipboard Laund.	53	53	57	N/A
	Commercial Laund.	4	4	4	N/A
	Dry Clean	14	13	8	N/A
Dimensional Stability	Yes	4	6	9	N/A
	No	96	94	91	N/A
Appearance Wear/Cleaning	Good/Excellent	87	59	53	98
	Poor	13	41	47	2
Ironing Required	Yes	55	76	83	N/A
	No	45	24	17	N/A
Stain Removal	Yes	92	88	87	N/A
	No	8	12	13	N/A
Comfort	Hot	27	13	12	0
	Warm	51	45	60	20
	Cool	16	32	23	60
	Excellent	6	10	5	20
Durability	Good/Excellent	93	94	91	N/A
	Poor	7	6	9	N/A
Comparision to Std. Poly/Ctn	Better	12	6	1	N/A
	Same	36	40	30	N/A
	Worse	52	54	69	N/A
Overall Preference	1st Choice	34	35	6	25
Cost Acceptability	Yes	4	23	9	N/A
	No	96	77	91	N/A

DISCUSSION OF RESULTS

Table XI reflects the relative ratings for the candidate and current standard fabrics. A five point rating system was employed, with a rating of "5" being the highest rating and a rating of "1" being the lowest. The criteria used in developing the ratings are given in Appendix B. Whole number ratings were used. For example, a rating of "3.5" was rounded to "4", a rating of "3.4" was rounded to "3".

Strength/Durability - Based upon laboratory data, all of the candidate fabrics had strength characteristics equal to or better than the current polyester/cotton khaki material. The user data indicated that all the candidate materials had good durability during the wear trials and all were rated "5" (laboratory rating was based on tear strength data).

Air Permeability - The candidate Nomex/Kevlar shirting fabric was rated "5" for this property and was similar to the standard polyester/cotton shirting fabric. The air permeability of the cotton shirting fabrics was also high ("4" rating). All candidate trouser fabrics had air permeability values equal to or better than the standard polyester/cotton trouser fabric.

Flame Resistance - Based on char length after 25 launderings, all materials were rated "4" with the exception of the ammoniated FRT cotton shirting fabric, which rated "3". All candidate materials had good self-extinguishing properties.

Radiant Heat - All candidate fabric/ensemble components had equivalent burn injury protection levels, with ratings of "4" for the shirts and "5" for the trousers.

Dimensional Stability - Based on the laboratory tests after 25 launderings, the Nomex/Kevlar candidate materials were superior to the cotton fabrics regarding this property ("4" rating) and similar to the standard polyester/cotton materials. Depending upon the ensemble component, the cotton material ratings ranged from "1" to "2". In the user tests, all fabrics were found highly acceptable regarding this property and were assigned a "5" rating. The difference in laboratory and user results suggests that laundering conditions and the number of launderings the field garments were exposed to were not as severe as the laboratory conditions employed.

Appearance - The pressed appearance of the candidate Nomex/Kevlar garments in both the laboratory and user tests were superior to the cotton garments ("4" rating laboratory - "5" rating user tests) and similar to the standard polyester/cotton fabrics in this respect, implicating a smooth pressed finished appearance. Both the ammoniated and brominated cotton garments had a "3" rating in both the laboratory and the user tests, indicating at best a mussed, non-pressed appearance.

Ironing Required - Based on this criteria, the Nomex/Kevlar uniform rated a "3" (41 to 60 percent indicated ironing was required). These uniforms, however, did require less ironing than the FRT cotton uniforms which were rated a "2" (61 to 80 percent indicated ironing was required) for the ammoniated FRT cotton, and a "1" (81 to 100 percent indicated ironing was required) for the brominated FRT cotton uniforms.

Stain Removal - All candidate uniforms were rated "5", since 81 to 100 percent of the responses indicated that stain removal was easy.

Comfort - This characteristic was rated on the basis of the percentage of total responses indicating "cool to excellent" comfort. The Nomex/Kevlar and brominated FRT cotton uniforms were rated "2" (21 to 40 percent of the responses indicated that participants were comfortable). The ammoniated FRT cotton uniform was rated best of all candidates, having a rating of "3" (41 to 60 percent) of the responses indicated participants were comfortable. The standard polyester/cotton uniform had a comfort rating of "4" (61 to 80 percent of responses indicated participants were comfortable).

Comparison to the Standard Khaki (polyester/cotton) - This characteristic was rated on the basis of the percentage of total responses indicating that the FR candidate uniforms were "equal to or better" than the current standard khaki uniform. The Nomex/Kevlar and ammoniated FRT cotton uniforms were rated "3" (41 to 60 percent of the responses indicated the uniforms made from these fabrics were equal to or better than the standard). The brominated FRT cotton uniform was rated "2" (21 to 40 percent of the responses indicated this fabric was equal to or better than the standard).

Cost Acceptability - This characteristic was rated on the basis of the percentage of total responses indicating "yes" to purchasing the FR uniforms at the following prices; NKE-\$68, CAE-\$40, CBE-\$42. Of all the FR candidate ensembles, the FRT cotton CAE rated the highest with a "2" (21 to 40 percent of the responses indicated that the ensemble was worth the price listed and would purchase the FR uniform if it were to become the new standard). The NKE and CBE rated "1" (less than 20 percent would purchase these uniforms at the prices indicated).

Preference - These rankings reflect the relative preference for the candidate and current khaki work uniforms. The Nomex/Kevlar, ammoniated FRT cotton and standard polyester/cotton uniforms were rated "2", having a preference percentage between 21 and 40 percent, while the brominated FRT cotton uniform was rated "1", having a preference percentage between 0 and 20 percent.

Table XI - Relative Rating for Candidate and Current Standard Fabrics/Uniforms

Characteristic	Type of Evaluation	Uniform Ensemble									
		NKE		CAE		CBE		SPCE			
		S	T	S	T	S	T	S	T	S	T
Strength/ Durability	Lab	4	4	3	4	2	3	2		2	2
	User	5		5		5		-			
Air Permeability	Lab	5	2	4	2	4	1	5		1	
Flame Resistance Char Length	Lab (after 25 laundering)	4	4	3	4	4	4	-		-	
Radiant Heat (sample 0" from sensor) TBI	gcal/cm ² /sec 1.2	4	5	4	5	4	5	-		-	
Dimensional Stability	Lab (25 laundering)	4	4	2	1	2	1	4		4	
	User	5		5		5		5			
Pressed Appearance	Lab/Gar (15 laundering)	4		3		3		5			
	User	5		3		3		5			
Ironing Required	User	3		2		1		-			
Stain Removal	User	5		5		5		-			
Comfort Cool/Excellent	User	2		3		2		4			
Comparison to Std. poly/ctn Same or Better	User	3		3		2		-			
Cost Acceptability	User	1		2		1		-			
Overall Preference Ranking	User	2		2		1		2			

OVERALL RATING

Table XII indicates the rank order for all candidate fabrics based on the characteristics indicated in Table XI, combining the laboratory and user results. A ranking of "1", "2", or "3" was applied with "3" indicating the best and "1" indicating the worst of the candidate uniform types.

For most of the physical/performance indicators, the Nomex/Kevlar uniform fabrics were superior or equivalent to the FRT cotton uniform fabrics, except for comfort where the ammoniated cotton fabrics were rated the best. The brominated cotton fabrics were not found superior to the other two candidates for any indicator.

The only differences between the Nomex/Kevlar and cotton uniforms which were considered significant were the poor appearance of the cotton uniforms after laundering and the amount of pressing required to achieve even a marginally acceptable appearance when compared to the superior after-laundering appearance of the Nomex/Kevlar uniform. The one characteristic where the ammoniated cotton uniform outperformed the Nomex/Kevlar uniform was comfort, which is also an important concern.

Based on user preference data where both the Nomex/Kevlar and ammoniated cotton fabric uniforms were considered equal, it would appear that any advantage the Nomex/Kevlar fabric uniform had over the ammoniated cotton fabric uniform with respect to appearance was neutralized by the better comfort of the ammoniated cotton fabric uniform. In addition, since the ammoniated cotton fabric uniform was found more cost acceptable than the Nomex/Kevlar uniform in the user test, it suggests there would be more acceptability for this uniform over the Nomex/Kevlar uniform by the Naval Officer/CPO community.

Table XII - Overall Rating - Rank Order

Characteristic	Uniform Ensemble		
	NKE	CAF	CBF
Strength/Durability	3	2	1
Air Permeability	3	2	1
Flame Resistance	3	2	3
Radiant Heat Protection	3	3	3
Dimensional Stability	3	2	2
Pressed Appearance	3	2	2
Ironing Required	3	2	1
Stain Removal	3	3	3
Comfort	2	3	2
Comparison to Standard Polyester/Cotton	3	3	2
Overall Preference	3	3	2
Cost Acceptability	2	3	2
Overall Rating Avg.	2.8	2.5	2.0

CONCLUSIONS

1. Of the physical and performance differences between the Nomex/Kevlar and FRT cotton candidate fabrics, the two most important functional differences were appearance after laundering and comfort. The Nomex/Kevlar fabrics are superior to the FRT cotton fabrics with respect to appearance after laundering while the ammoniated cotton fabrics are superior to the Nomex/Kevlar and brominated FRT cotton fabrics with respect to comfort.

2. With respect to heat and flame protection, both the Nomex/Kevlar and the ammoniated and brominated cotton fabrics were considered suitable, with heat protection being a function of the weight of the fabric, rather than the fiber content.

3. Based on user preference data, both the Nomex/Kevlar and ammoniated cotton fabrics were equally liked. However, when cost acceptability is considered, the ammoniated cotton fabrics are the most practical choice for an Officer/CPO fire retardant uniform.

RECOMMENDATIONS

Since the preference for both the Nomex/Kevlar and the precondensate ammonia cure FRT cotton were similar, their heat protection and flame resistance properties suitable, and the cotton fabric uniforms more cost acceptable (\$28 less than the Nomex/Kevlar uniform), it is the recommendation of this Facility that the 100% Fire Retardant Treated Cotton (precondensate ammonia cure treatment) shirt and trouser ensemble be considered as the replacement for the current standard polyester/cotton khaki Officer/CPO work uniform.

(APPENDIX A)

QUESTIONNAIRE
FIRE RETARDANT WORKING KHAKI UNIFORM
MEN AND WOMEN

NAME: _____ RANK: _____

SHIP/ACTIVITY: _____

UNIFORM #/SIZE

SHIRT: _____ TROUSER/SLACKS: _____

1. How did uniforms fit when issued?

	<u> A </u>	<u> B </u>	<u> C </u>
EXCELLENT:	_____	_____	_____
GOOD:	_____	_____	_____
POOR:	_____	_____	_____

If poor, where was fit improper? Please indicate uniform by code letter.

2. How many times were the uniforms worn to date?

<u> A </u>	<u> B </u>	<u> C </u>
_____	_____	_____

3. What method of cleaning was used (1. Home laundry; 2. Shipboard laundry; 3. Commercial laundry; 4. Drycleaned) and number of times cleaned to date?

	<u> A </u>	<u> B </u>	<u> C </u>
METHOD:	<u> 1 </u> <u> 2 </u> <u> 3 </u> <u> 4 </u>	<u> 1 </u> <u> 2 </u> <u> 3 </u> <u> 4 </u>	<u> 1 </u> <u> 2 </u> <u> 3 </u> <u> 4 </u>
NO. TIMES:	_____	_____	_____

4. Did uniforms shrink after cleaning? YES: _____ NO: _____
If YES, designate which uniform(s) by code letter and explain where shrinkage occurred.

5. Did uniforms require any ironing after cleaning? YES: _____ NO: _____
If YES, designate which uniform(s) by code letter and explain where ironing was needed.

6. Were spots/stains easily removed in cleaning? YES: _____ NO: _____
If NO, designate which uniform(s) by code letter and explain type of stains, etc.

7. How do you rate comfort of the uniforms?

	<u>A</u>	<u>B</u>	<u>C</u>	<u>STANDARD</u>
HOT:	_____	_____	_____	_____
WARM:	_____	_____	_____	_____
COOL:	_____	_____	_____	_____
EXCELLENT:	_____	_____	_____	_____

If HOT or WARM, please indicate the temperature and humidity relating to these conditions and types of discomfort. Indicate which uniform(s) by code letter.

8. How durable were the uniforms to abrasion, rips/tears, etc.?

	<u>A</u>	<u>B</u>	<u>C</u>
EXCELLENT:	_____	_____	_____
GOOD:	_____	_____	_____
POOR:	_____	_____	_____

If POOR, please explain and indicate uniform(s) by code letter.

9. What was overall appearance of uniforms after repeated wear/cleaning?

	<u>A</u>	<u>B</u>	<u>C</u>	<u>STANDARD</u>
EXCELLENT:	_____	_____	_____	_____
GOOD:	_____	_____	_____	_____
POOR:	_____	_____	_____	_____

If POOR, please explain and indicate uniform(s) by code letter.

10. How do these uniforms compare to current khaki uniforms?

	<u>A</u>	<u>B</u>	<u>C</u>
BETTER:	_____	_____	_____
SAME:	_____	_____	_____
WORSE:	_____	_____	_____

If WORSE, please explain and indicate which uniform(s) by code letter.

11. Which uniform (if more than one issued) do you prefer? (select 1st and 2nd choice):

 A B C STANDARD

Please list reasons for preference and indicate uniform(s) by code letter.

_____.

12. The current working khaki uniform costs approximately \$34.00. Since the FR uniforms would ultimately be more expensive, would you purchase these uniforms at the following prices?

<u>A @ \$68.00</u>	<u>B @ \$40.00</u>	<u>C @ \$42.00</u>
YES ___ NO ___	YES ___ NO ___	YES ___ NO ___

Please list reasons.

_____.

13. Additional comments:

_____.

Signature: _____.

Date: _____.

APPENDIX B

Rating Criteria for Various Fabric/Uniform Characteristics

<u>Characteristic</u>	<u>Rating Criteria</u>				
<u>1. Strength</u>	<u>Rating</u>				
Lab	1	2	3	4	5
Tear (lbs)					
Warp	1-3	4-6	7-9	10-12	13-15
Filling	1-3	4-6	7-9	10-12	13-15
<u>2. Durability</u>	<u>Rating</u>				
User	1	2	3	4	5
(%) Good/Excellent	0-20	21-40	41-60	61-80	81-100
<u>3. Air Permeability</u>	<u>Rating</u>				
Lab	1	2	3	4	5
(ft ³ /min/ft ²)					
Trousers Fabric	0-20	21-40	41-60	61-80	81-100
Shirting Fabric	0-20	21-40	41-60	61-80	81-100
<u>4. Dimensional Stability</u>	<u>Rating</u>				
(%)	1	2	3	4	5
Lab (25 launderings)	4.1-5.0	3.1-4.0	2.1-3.0	1.1-2.0	0.0-1.0
User (no)	0-20	21-40	41-60	61-80	81-100

5. Appearance

Pressed after Shipboard Launderings (15 cycles)

Rating

Lab/ Garment	1 - Crumpled, creased and severely wrinkled appearance
	2 - Rumpled, obviously wrinkled appearance
	3 - Mussed, non-pressed appearance
	4 - Smooth finished appearance
	5 - Very smooth pressed finished appearance

User	<u>Rating</u>				
(%)	1	2	3	4	5
Good/Excellent	0-20	21-40	41-60	61-80	81-100

6. Ironing Required

Rating

User	1	2	3	4	5
(%) yes	81-100	61-80	41-60	21-40	0-20

7. Stain Removal

Rating

User	1	2	3	4	5
(%) yes	0-20	21-40	41-60	61-80	81-100

8. Comfort

Rating

User	1	2	3	4	5
(%) Cool/Excellent	0-20	21-40	41-60	61-80	81-100

9. Comparison to Std.

Rating

User	1	2	3	4	5
(%) Same/Better	0-20	21-40	41-60	61-80	81-100

10. Cost Acceptability

Rating

User	1	2	3	4	5
(%) Yes	0-20	21-40	41-60	61-80	81-100

11. Preference

Rating

User	1	2	3	4	5
(%)	0-20	21-40	41-60	61-80	81-100

12. Radiant Heat

Rating

Lab	1	2	3	4	5
TBI (sec)	0-2	2.1-4	4.1-6	6.1-8	8.1-10
(1.2 qcal/cm ² /sec)					

13. Flame Resistance

Rating

Lab (25 launderings)	1	2	3	4	5
char length (in)	8-10	6-8	4-6	2-4	0-2

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