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1.0 INTRODUCTION

This report presents the results and findings of the Navy's technical evaluation (TECHEVAL) of the improved aluminized proximity crash-rescue coat and trouser ensemble. The TECHEVAL was performed as part of the development program sponsored by the Naval Sea Systems Command (SEA-55X24) under program element 63514N and project number S1121-SL-24737. The TECHEVAL was conducted to demonstrate that the improved aluminized proximity crash-rescue clothing ensemble meets the Navy's development test and evaluation (DT&E) and operational test and evaluation (OT&E) thresholds as given in the Test and Evaluation Master Plan (TEMP) No. XXX-OOX of 30 April 1986. Also, satisfactory results from the TECHEVAL is a prerequisite for Certification of Readiness for Operational Evaluation (OPEVAL).

The purpose of this program was to develop fire proximity suits using latest materials technology to provide greater resistance to fire penetration, increase comfort, lower cost, and extended wear life. Of particular importance is personnel protection from the radiant heat loads generated by fuel fires. Initially, the Navy Clothing and Textile Research Facility (NCTRF) evaluated various lightweight knitted fabrics of 100% spun Kevlar yarn along with subsequent aluminization data. After extensive preliminary testing, an aluminized 5.5 oz/yd² Kevlar base knit material was selected as the candidate material for the crash-rescue fire proximity suit. A development quantity of crash-rescue coats and trousers was constructed from the candidate material for a tri service evaluation at Navy and Marine Corps Air Stations, Air Force Bases, and Shipboard Crash-Rescue Stations during DT-II.

Upon completion of this wear test evaluation, it was concluded that there was an overwhelming preference for the new lighter weight garments as compared to the standard issue ensemble which is composed of an aluminized 8.0 oz/yd² Kevlar base woven fabric. Thus the new aluminized knit 5.5 oz/yd² Kevlar base material was selected for constructing the TECHEVAL garments, and only the results from this evaluation are presented in this TECHEVAL report.

This report includes the following information:

- Background/Previous Development Testing
- Material and Garment Description
- TECHEVAL Description
- TEMP DT&E Thresholds Demonstration
- TEMP OT&E Thresholds Demonstration
- TECHEVAL Questionnaire Results
- Conclusions
- Recommendations

2.0 BACKGROUND/PREVIOUS DEVELOPMENT TESTING

With the disestablishment of the Aircraft Ground Fire Suppression and Rescue Systems (AGFSRS) program, the Navy was tasked in 1977 with the responsibility for development and improvement of the Proximity Firefighters Clothing System. Although significant improvements were achieved during the tenure of AGFSRS, there was still a need for more efficient aluminized fire protective clothing. In this connection, further efforts were required for the development of new materials which were lighter; more flexible; and met the heat protection and functional needs of the crash-rescue firefighter. Accordingly, a broad based program was developed to achieve the ultimate in crash rescue fire protective clothing.

During the FY78 through FY81 time frame, NCTRF initiated a Phase I development program to evaluate various asbestos replacement fabrics for use in Firefighter's Aluminized Proximity Clothing. In this study various aluminized fabrics constructed with 100% spun Kevlar woven and knit base fabrics and fabrics made from spun Kevlar/glass core yarns and carbonized polyacrylonitrile yarns were investigated. Based on laboratory test data and a limited wear test evaluation of garments made from these fabrics, an aluminized 8 oz/yd² woven spun Kevlar base fabric was adopted as an interim replacement for the 24 oz/yd² aluminized asbestos/aramid substrate fabric employed at that time.

In FY82, NCTRF continued efforts to develop a lighter weight knitted material for eventual replacement of the 8 oz/yd² woven Kevlar interim material. Improvements desired were to increase the wearer's comfort by lowering the weight of the respective garment and to provide a higher degree of flexibility without sacrificing heat protection or durability. A summary of these development tests DT-1 through DT-IIB follows.

2.1 DT-1 Phase II Evaluation (1st Qtr FY82 through 2nd Qtr FY84)

NCTRF conducted an evaluation of lightweight knitted Kevlar fabrics of alternate constructions and finished weights, and scheduled several aluminization trial runs in order to determine the best candidate material. The base knitted fabrics evaluated were as follows:

1. 18-cut double knit, 5.5 oz/yd²
2. 20-cut warp knit, 5.5 oz/yd²

During this preliminary investigation, it was found that the yarn size was a major limiting criteria in developing extremely lightweight compact fabrics. The finest commercially manufactured spun Kevlar yarn, was a 30's singles which required using coarser gauge knitting machines and modified stitch types to obtain the desired lightweight knitted base fabrics. There were also significant development efforts required to properly aluminize the knit base fabrics. Ultimately, the 5.5 oz/yd² Kevlar warp knit laminated to a 1/4 mil aluminized polyester film on the face side of fabric only was selected for further evaluation. The aluminized knit material samples were tested in strict accordance with the finished physical requirements specified in Specification Mil-C-87076 Cloth, Coated, Aramid, Aluminized. Prototype crash-

rescue coats and trousers fabricated of the selected 5.5 oz/yd² aluminized Kevlar knit material were tested and compared with the 8 oz/yd² interim aluminized Kevlar woven material prior to initiating a full scale development effort.

2.2 DT-IIA (3rd Qtr FY84- 1st Qtr FY85)

Engineering development models (EDMs) were manufactured and subjected to both laboratory and a Tri-Service wear test to evaluate durability, fit, comfort, and ability of personnel to perform normal working duties with minimal restrictions. Fifty-five (55) aluminized Kevlar knit coat/trouser ensembles were wear tested at the following Navy and Marine Corps Air Stations, Air Force Bases, and Shipboard crash-rescue stations during DT-IIA:

Marine Corps Air Station, Cherry Point, N.C.
Naval Air Station, Miramar, Calif.
Naval Air Station, Oceana, Va.
Naval Air Station, Whidbey Island, Oak Harbour, Was.
Andrews AFB, Washington, D.C.
Kirkland AFB, Albuquerque, New Mexico
Offutt AFB, Omaha, Nebraska
U.S.S. America
U.S.S. Constellation

Based on the overall test data, it was concluded that the durability of the clothing was not effected using the lightweight Kevlar knit fabric. Accordingly, additional aluminized Kevlar knit coat/trouser ensembles were manufactured for physiological and fire pit testing in DT-IIB and for further tri-service evaluation during DT-IIC (TECHEVAL). A summary of the DT-IIA/DT-IIB testing is provided as Appendix A.

3.0 Aluminized Proximity Coat/Trouser Proximity Description

This section provides a description of the improved aluminized garments (TECHEVAL ITEMS).

3.1 Coat, Firemen's, Aluminized, Proximity The improved aluminized coat as shown in figure 1, was constructed in strict accordance with the standard Military Specification Mil-C-29145 Coat, Firemen's, Aluminized, Proximity except the new lightweight 5.5 oz/yd² aluminized Kevlar knit material was utilized in lieu of the interim standard 8 oz/yd² woven spun Kevlar fabric. The standard issue coat consists of a highly reflective aluminized coated outershell, fabricated from an aluminized mylar/woven Kevlar laminate and a vapor barrier inner lining of neoprene coated nylon which provides waterproofness and steam protection. The outershell as shown on figure 2, features a snap-in quilted innershell liner which is provided for thermal insulation. The quilted liner is fabricated from a 7 oz/yd² aramid batting sandwiched between pajama check aramid and rayon outer fabrics. The coat is also constructed with a corduroy top collar, sleeves with leather bound bottom edges, and side patch pockets with flaps. The front closure consists of a protective flap secured by means of three snaps and dee rings.

3.2 Trousers, Firemen's, Aluminized, Proximity The improved aluminized trousers as shown in figure 3, were constructed in strict accordance with the standard Military Specification Mil-T-29146 Trousers, Firemen's, Aluminized, Proximity except the new lightweight 5.5 oz/yd² aluminized Kevlar knit material was utilized in lieu of the interim standard 8 oz/yd² woven spun Kevlar fabric. The standard issue trousers consist of a highly reflective aluminized coated outershell, fabricated from an aluminized mylar/woven Kevlar laminate and a vapor barrier inner lining which provides waterproofness and steam protection. The outershell as shown in figure 4, features a snap-in quilted liner which is provided for thermal insulation. The quilted liner is fabricated from a 7 oz/yd² aramid batting sandwiched between pajama check aramid and rayon outer fabrics. The trousers are constructed with the leg bottoms bound with leather. The front fly closure is secured by means of three snap fasteners stitched to the waistband at the front and back of the garment.

4.0 TECHEVAL DESCRIPTION

TECHEVAL (DT-IIC) was conducted during the 4th Qtr FY86 through the 1st Qtr FY87. A total of 74 aluminized Kevlar knit crash/rescue coat and trouser ensembles were distributed to 15 Navy, Marine Corps, and Air Force Bases Stateside; 6 Oversea Bases; and 4 Aircraft Carriers. Instruction sheets and test questionnaires were furnished with each garment ensemble. A briefing was conducted with the designated test monitors at each of the 15 U.S. Bases and 4 Aircraft Carriers prior to starting the test. Our objective was to discuss and/or clarify the overall wear test program, and to solicit initial reactions from the selected test participants relative to comfort, fit, and design features.

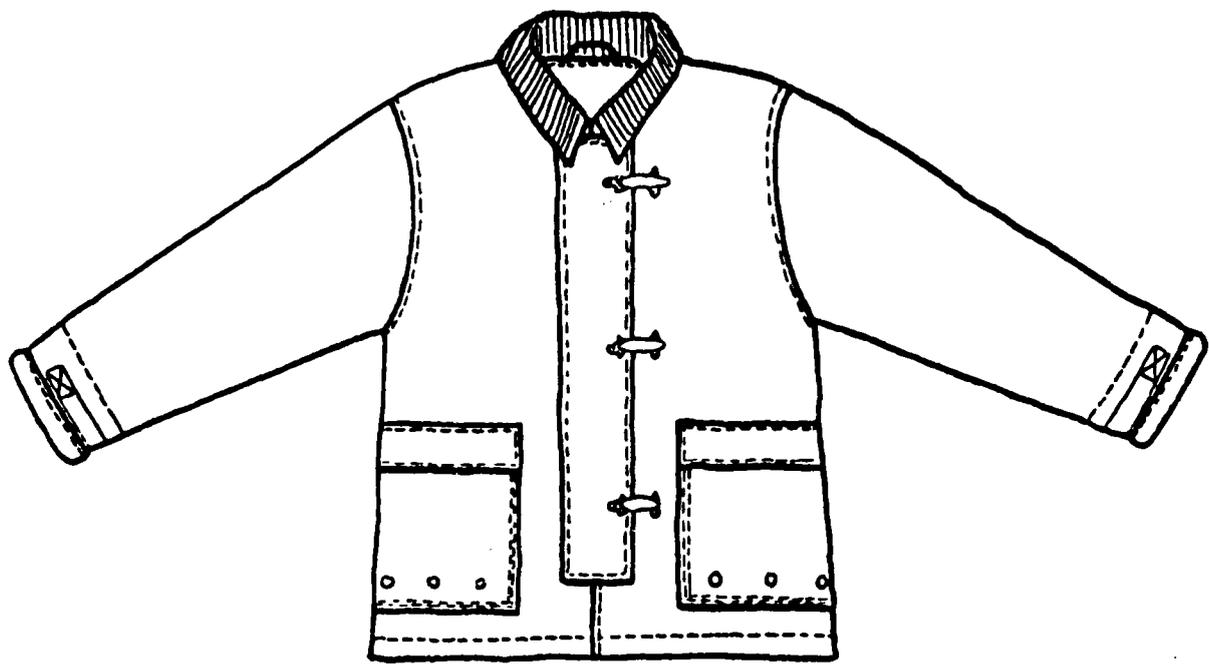
5.0 TEMP DT&E THRESHOLDS DEMONSTRATION

This section presents the tests/efforts that were performed on the new aluminized proximity Kevlar knit crash-rescue (APCR) coat/trouser ensembles, to demonstrate compliance with the DT&E Threshold parameters as given in the TEMP. These threshold parameters are:

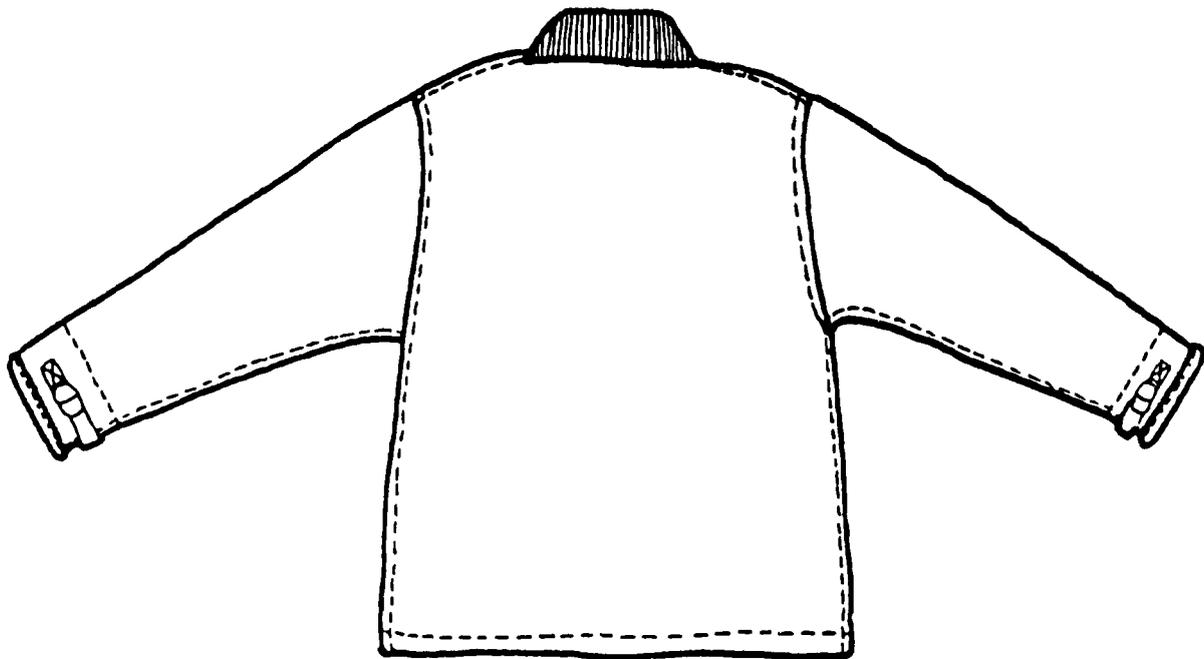
- Flammability
- Burn Injury
- Radiant Heat Penetration
- Compatibility
- Durability
- Anthropometric Population
- Don Time
- Mission Time

In general, the following sequence is presented for each of the parameters:

- Objective
- Procedure
- Results
- Conclusions



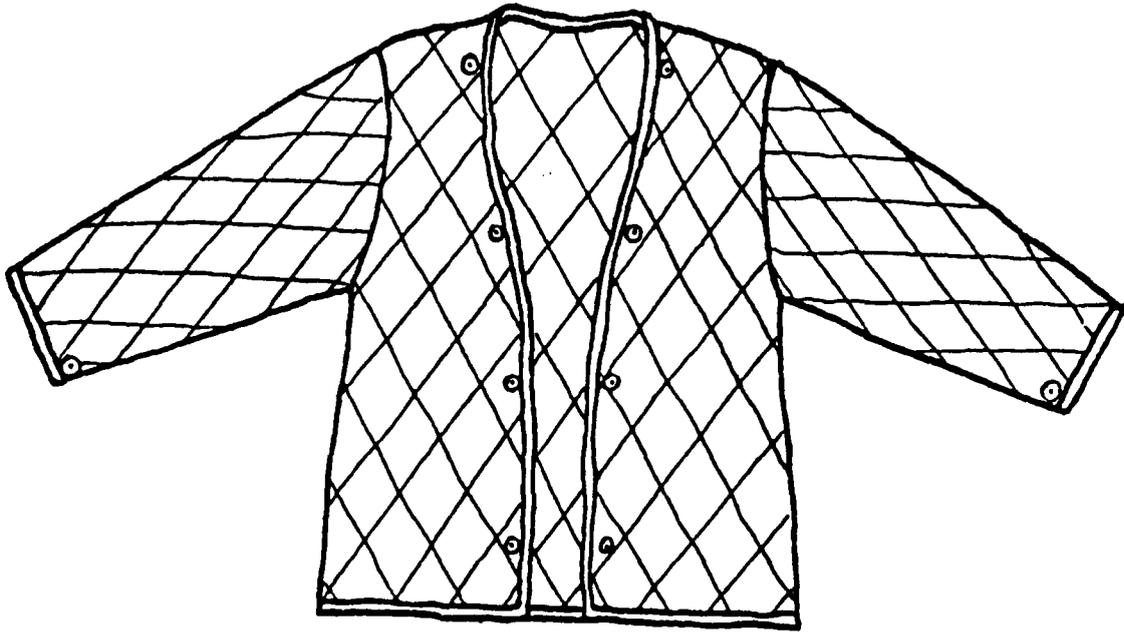
Front View



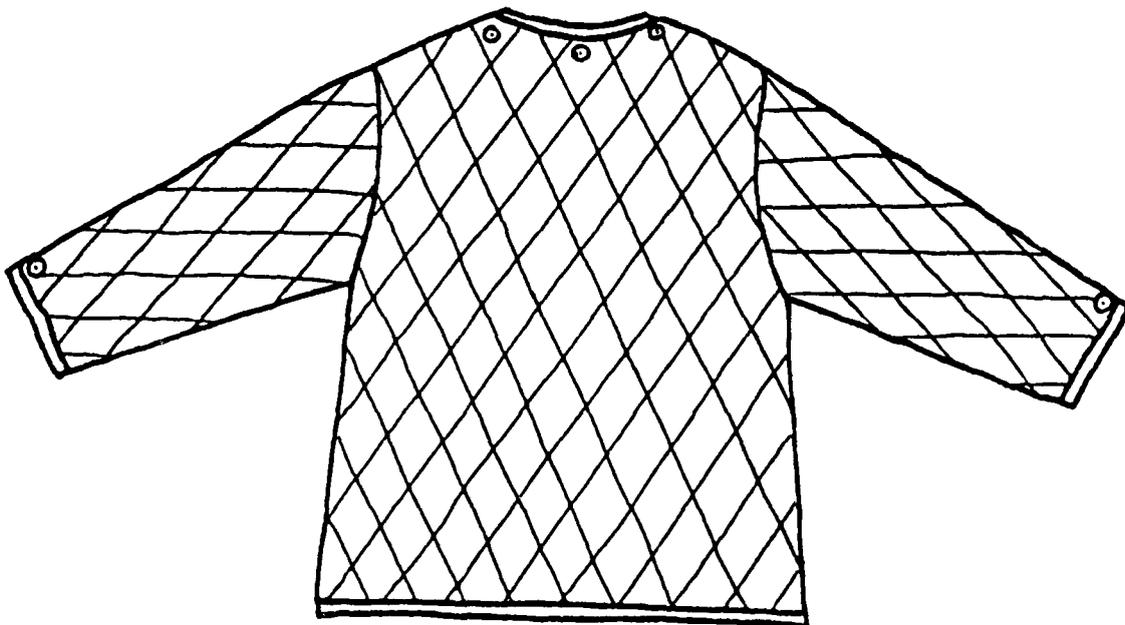
Back View

FIGURE 1

Coat, Firemen's, Aluminized Proximity



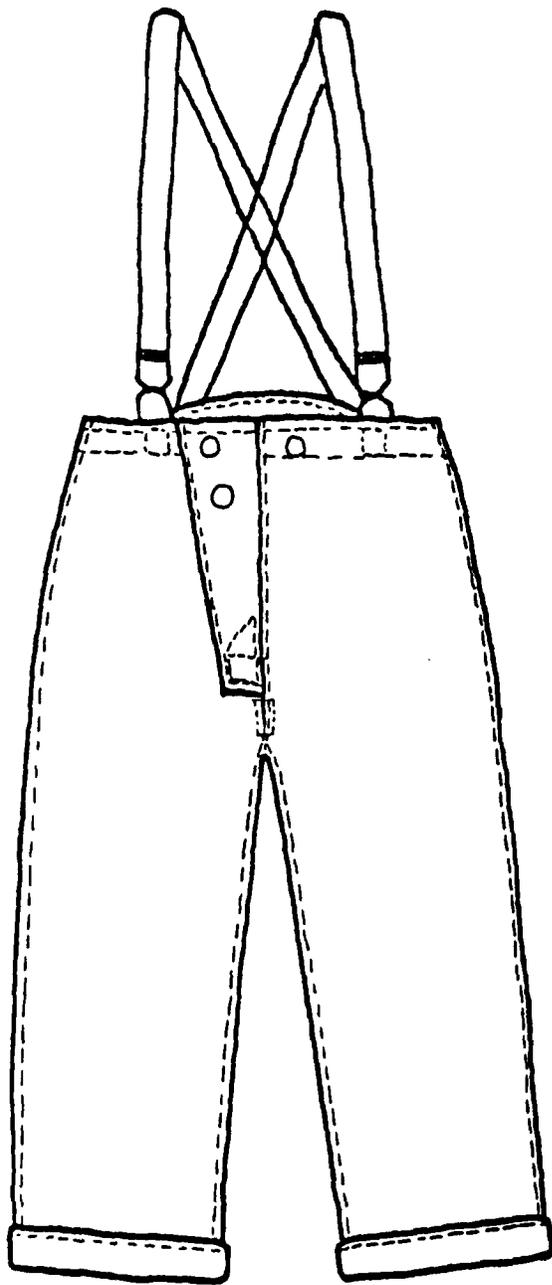
Front View



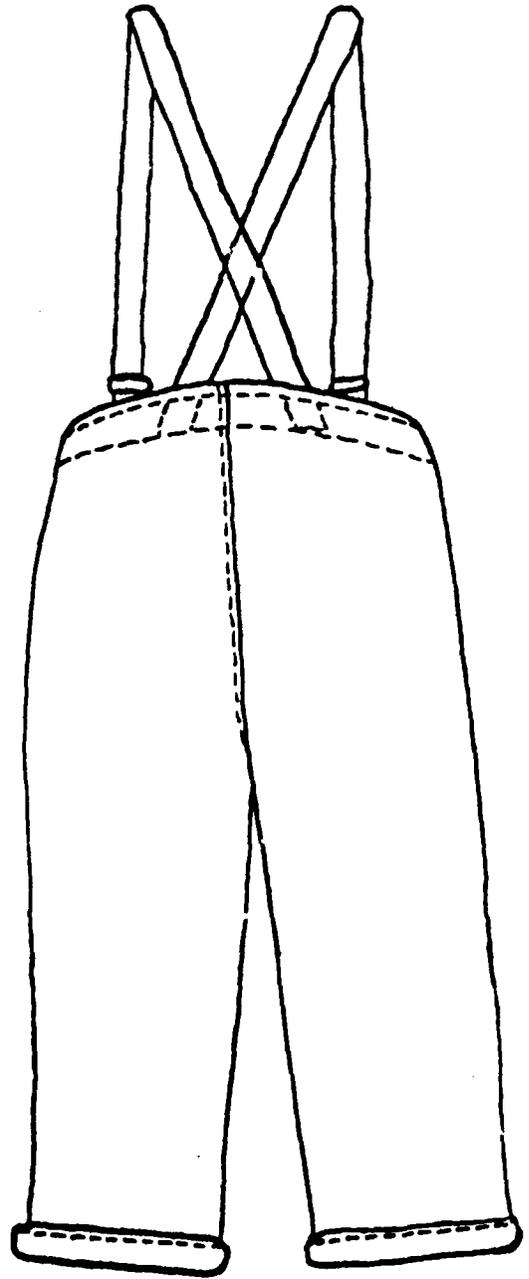
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FIGURE 2

Liner Removable



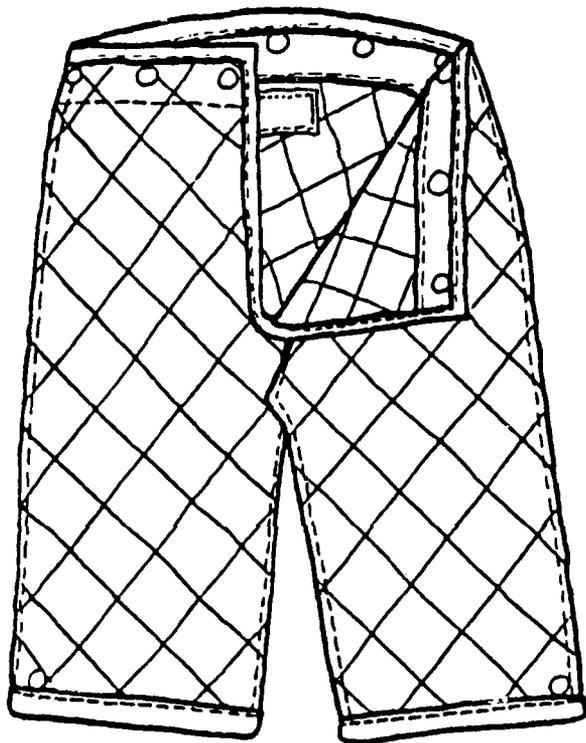
Front View



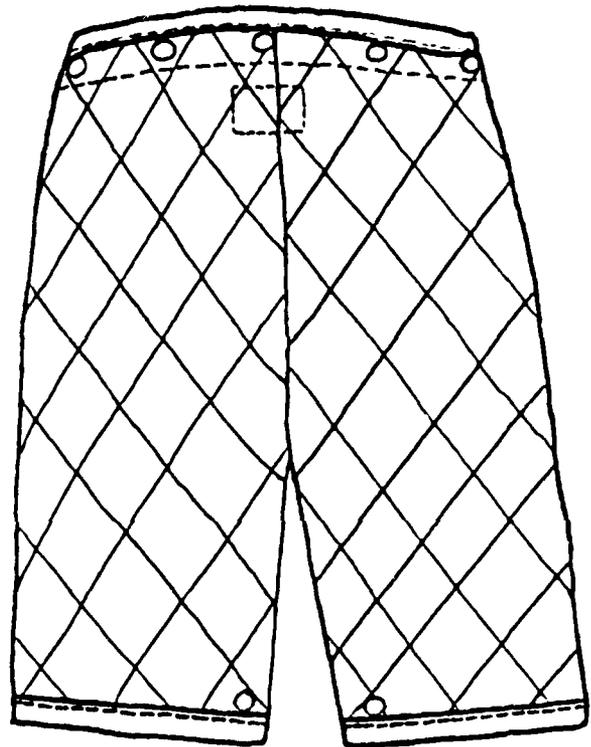
Back View

FIGURE 3

Aluminized Trousers Firemen's



Front View



Back View

FIGURE 4

Snap-In-Liner

5.1 Flammability

5.1.1 Objective To demonstrate that the new APCR coat/trouser ensembles will protect the user against burn injury.

5.1.2 Procedure Laboratory and full scale fuel fire pit tests were conducted.

Laboratory Test Aluminized Kevlar knit material samples were tested for vertical flame resistance in strict accordance with specified requirements of Mil-C-87076 Cloth, Coated, Aramid, Aluminized. In order to determine the resistance of the aluminized knit material to flame, glow propagation, and tendency to char, a material sample is exposed to a flame for a given/set time period of twelve seconds in accordance with Test Method 5903 of Fed-STD-191. After the twelve seconds, the flame source is removed and the material's after flame time is recorded. Once the flame extinguishes, the after glow time and char length of the material are determined and recorded. The following requirements are specified:

After Flame Time, Seconds	2.0 (Maximum)
After Glow Time, Seconds	40.0 (Maximum)
Char Length, inches	1.5 (Maximum)

Full Scale Fire Pit Test This test involves exposure of a dressed manikin to flames for 5 seconds in a 1500-2200^oF open pit fuel fire. Temperature sensitive paper tape patches are attached to the manikin at several discrete body sites. The tapes were previously calibrated to equate tape temperatures to skin temperatures at which second degree burns would occur. The percent of body area that would have sustained second degree burns is determined from the number of tape sensors which are activated at or above the second degree burn temperature level. The degree of burn injury and the self extinguishing properties of the ensemble are determined after the 5-second exposure.

5.1.3 Results

Laboratory Test The aluminized knit material self extinguished, and had an average glow time of 30.6 seconds and a char length of 0.5 inches. There was no evidence of after flame.

Full Scale Fire Pit Test The new APCR coat/trouser ensembles self extinguished after exposure to flames in an open pit fuel fire and no burn injury was sustained by the test manikin.

5.1.4 Conclusion The new APCR coat/trouser ensembles met the flammability threshold criteria specified in Mil-C-87076 and the full scale fire pit test requirements.

5.2 Radiant Heat Penetration

5.2.1 Objective To demonstrate that the new aluminized knit material used in the fabrication of the APCR coat/trouser ensembles, will protect the user against radiant heat penetration after abrasion.

5.2.2 Procedure In order to determine the effectiveness of the reflectivity of the aluminized knit material after abrasion, a 25 second exposure of material samples to a high temperature quartz lamp radiant heat source following 300 abrasion cycles was performed in accordance with Military Specification Mil-C-87076.

5.2.3 Results The aluminized knit material showed no evidence of flaking on the coated surface, and there was no discoloration of the blotting paper.

5.2.4 Conclusion The new aluminized knit material met the radiant heat penetration threshold criteria specified in Mil-C-87076.

5.3 Compatibility

5.3.1 Objective To demonstrate that the new APCR coat and trousers are compatible with the standard issue thermal insulating liner.

5.3.2 Procedure No specific test was required to demonstrate its compatibility with the standard snap-in liner, since the new APCR coat and trousers are made from the same range of patterns as the standard aluminized coat (Mil-C-29145) and the standard aluminized trousers (Mil-T-29146). However, during both Phase II and TECHEVAL wear test evaluations, all selected test participants were requested to furnish their own snap-in liner and comment on their compatibility with the outershell garment.

5.3.3 Results The new APCR coat/trouser ensembles have been worn by over 120 test participants during Phase II and TECHEVAL wear test evaluations, and no evidence of incompatibility with the standard snap-in liner was observed or reported.

5.3.4 Conclusion The new APCR coat and trousers is compatible with the respective standard issue snap-in liner.

5.4 Durability

5.4.1 Objective To demonstrate that the new aluminized knit crash-rescue coat and trousers can withstand both shipboard and shore base operational wear.

5.4.2 Procedure Aluminized Kevlar knit material samples were tested in strict accordance with the specified requirements of Mil-C-87076 Cloth, Coated, Aramid, Aluminized. In addition, a durability test was conducted during Phase I and TECHEVAL wear test evaluations at designated Navy, Marine Corps, and Air Force Bases along with four (4) Aircraft Carriers. A questionnaire was used to record the test participants wear time and duties. The worn test garments were examined for any major or critical failures (tears, rips, excessive abraded areas, etc.).

5.4.3 Results Based on overall test data, the aluminized knit material met all specified requirements of Mil-C-87076 and 91% of the APCR coat/trouser ensembles satisfactorily withstood the 6 months wear test.

5.4.4 Conclusion The service life of the new APCR coat/trouser ensembles is directly related to the frequency and severity of normal everyday work functions. Under the various conditions the ensembles were subjected to during the wear test, service life would be expected to be greater than 6 months for most of the scenarios encountered.

5.5 Anthropometric Population

5.5.1 Objective To demonstrate that the new APCR coat/trouser ensembles can fit an anthropometric population within the 5 th to 95 th percentile as described in Mil-STD-1472.

5.5.2 Procedure No specific test was required to demonstrate compliance since the improved aluminized knit crash-rescue coat and trousers are made from the same range of patterns as the standard aluminized coat (Mil-C-29145) and the standard aluminized trousers (Mil-T-29146).

5.5.3 Results During Phase II and TECHEVAL wear test evaluations, a total of 149 aluminized knit crash-rescue coat and trouser ensembles were issued to selected test participants at Navy, Marine Corps, and Air Force Bases. No cases were reported where a firefighter could not be properly fitted with either the aluminized coat or trousers. In addition, there is no historical data which indicates that there are fitting problems associated with the crash rescue suits.

5.5.4 Conclusion The new APCR coat/trouser ensembles will fit an anthropometric population within the 5 th to 95 th percentile.

5.6 Don Time

5.6.1 Objective To demonstrate that the new APCR coat and trousers can be donned in two minutes without assistance.

5.6.2 Procedure Test participants were observed/timed while donning the aluminized knit crash-rescue coat and trousers. For this test, the trousers were positioned rolled down over their boots to simulate actual readiness conditions.

5.6.3 Results Don time for the new APCR coat and trousers was 90 seconds or less.

5.6.4 Conclusion The new APCR coat/trouser ensembles met the two minute maximum don time threshold criteria.

6.0 TEMP OT&E THRESHOLDS DEMONSTRATION

6.1 Suitability-Shelf Life

6.1.1 Objective To demonstrate that the shelf life for the new APCR coat/trouser ensemble is at least 5 years.

6.1.2 Procedure There is no suitable test to determine shelf life, and compliance is based on the inherent properties of aluminized Kevlar knit materials and experience with the current aluminized Kevlar crash-rescue coat/trouser ensemble in the military supply system.

6.1.3 Results/Conclusion Based on the inherent stability of the new APCR coat/trouser ensemble materials and that current items made of similar materials have been in the military stock system for a number of years without any shelf life problem, the new APCR coat/trouser ensemble is projected to meet the five year shelf life requirement.

6.2 Suitability-Mission Time

6.2.1 Objective To demonstrate that the new APCR coat/trouser ensemble can be worn for at least 8 hours/per day while performing normal firefighting duties.

6.2.2 Procedure The mission time/wear time of test participants during TECHEVAL was recorded.

6.2.3 Results Data collected during TECHEVAL indicated that the new APCR coat/trouser ensemble was worn 4 to 8 hours per day by the test participants without any problems indicated. The average wear time was 4 hours per day.

6.2.4 Conclusion The new APCR coat/trouser ensemble can meet the 8 hour per day OT mission time requirement under temperate temperature/humidity conditions. As with other types of protective clothing ensembles, mission time would be substantially reduced under high temperature/humidity conditions.

7.0 TECHEVAL QUESTIONNAIRE RESULTS

7.0.1 Objective To wear the new APCR coat/trouser ensembles during actual performance of duties and record observations on furnished questionnaires.

7.0.2 Procedure The new APCR coat/trouser ensembles were distributed in approximately equal numbers to 21 Navy, Marine Corps, and Air Force Bases along with 4 Aircraft Carriers. Instruction sheets and survey questionnaires were furnished with the ensembles.

7.0.3 Results The TECHEVAL questionnaire results are indicated in Table I. The data/information results are based on a 180-day wear test period, 74/78 (95%) of the test participants responding.

Table I- TECHEVAL Questionnaire Results

<u>Characteristic</u>	<u>Rating (%)</u>
Number of times worn:	
Up to 15	4/74 (5%)
15-30	12/74 (16%)
30-60	16/74 (22%)
60-100	14/74 (19%)
Over 100	28/74 (38%)
Comparing comfort of new APCR ensemble to standard APCR ensemble:	
Better than	68/74 (92%)
Equal to	6/74 (8%)
Comparing fit of new APCR ensemble to standard APCR ensemble:	
Better than	50/74 (68%)
Equal to	24/74 (32%)
Comparing ability to work in of the new APCR ensemble to the standard APCR ensemble:	
Easier than	69/74 (93%)
Equal to	5/74 (7%)

Table I- TECHEVAL Questionnaire Results (Cont'd)

Characteristic	Rating (%)
Evidence of aluminized knit material fabric failures:	
(a) Cracking	
Yes	6/74 (8%)
No	68/74 (92%)
(b) Flaking or Peeling	
Yes	23/74 (31%)
No	51/74 (69%)
(c) Delamination at seam	
Yes	5/74 (9%)
No	69/74 (93%)
(d) Cut from sharp object	
Yes	7/74 (9%)
No	67/74 (91%)
(e) Fraying or wear- through	
Yes	7/74 (9%)
No	67/74 (93%)
(f) Tearing at flex points	
Yes	1/74 (1%)
No	73/74 (99%)
Preference of the new APCR ensemble to the standard ensemble	Yes (100%)

1/ Evidence of aluminized knit fabric failures were observed in most cases to be concentrated in stress areas of the respective garment, i.e. elbow areas of the coat and on the knee and seat areas of the trousers.

8.0 Conclusions

Based on the development test and evaluation (DT&E) results reported herein, it is concluded that the new APCR coat/trouser ensembles consistently met or exceeded the development test (DT) thresholds established by TEMP XXX-00X.

9.0 Recommendations

Based on the findings and conclusions of the new APCR coat/trouser ensembles, it is recommended that the new APCR coat/trouser ensemble fabricated from the new lightweight aluminized knit material (Mil-C-24929) be adopted by NAVSEA for fleet procurement.

APPENDIX A. SUMMARY OF DT-IIA/B TESTING

1.0 Introduction

A summary of the development testing (DT-IIA and DT-IIB) of the new Aluminized Proximity Crash-Rescue (APCR) coat/trouser ensembles is presented, and includes procedure; criteria; and results. In addition, discussion of the results is also included.

2.0 Test Description

2.1 Flammability A laboratory vertical flammability resistance test was conducted in accordance with Method 5903 of FED-STD-191. The requirement for this test is that the fabric be self extinguishing, and have a maximum after flame time of 2.0 seconds, a maximum after glow time of 40.0 seconds, and a char length of no more than 1.5 inches. In addition, a full scale (fuel fire pit test) of these items was conducted at the Naval Air Development Center (NADC), Warminster, Pa. The requirement of this test is that both the coat and trousers self extinguish after a 5 second exposure to a 1500-2200^oF J-P-4 fuel fire and that the degree of heat penetration measured would result in no burn injury based on the Stoll-Chianta criteria.

2.2 Radiant Heat Penetration A laboratory test was conducted in accordance with Military Specification Mil-C-87076. The test requirement is that a material sample after 300 abrasion cycles and a 25 second exposure to a high temperature quartz lamp radiant heater shall show no evidence of flaking and/or cracking of the outer aluminized film surface and no discoloration of the blotting paper used to indicate the degree of heat penetration.

2.3 Compatibility This determination was made via our test questionnaire submitted to the selected test participants, requesting comment as to whether the standard issue snap-in liner fit the respective coat and trousers.

2.4 Durability The durability (resistance to tears, rips, excessive abraded areas, etc.), of the new APCR coat/trouser ensemble was examined during shipboard and shore base operational wear trials. The new APCR ensembles were worn for 6 months by firefighting personnel performing their normal assigned duties.

2.5 Anthropometric Population This test was conducted to determine if there was a sizing problem which would prevent proper fitting of shipboard and shore base firefighting personnel.

2.6 Don Time The amount of time required to don the new APCR coat/trouser ensemble was measured. A maximum don time of two minutes without assistance was required.

2.7 Mission Time This test was a determination through actual wear trials, as to whether the new APCR coat/trouser ensemble is capable of being worn for 8 hours while performing normal firefighting operations.

3.0 Test Results

The test results of the new APCR coat/trouser ensembles are as follows:

Table II- Results of aluminized knit crash-rescue coat/trouser ensembles (DT-IIA/B)

Test Characteristics	Results
Flammability, Vertical Resistance (TM 5903) (Aluminized knit material)	
After Flame (sec)	0.0
After Glow (sec)	30.6
Char Length (inches)	0.5
Self Extinguishing (NADC Fire Pit)	Yes
Burn Injury (NADC Fire Pit)	None
Radiant Heat Penetration (Aluminized knit material)	Pass
Compatibility	Pass
Durability (% of Significant Failure)	9% (See Table I-Techeval Questionnaire Results)
Anth Population (Fit 5th to 95th Percentile)	Pass (No problem occurred in outfitting test participants)
Ease of Donning (minutes)	Pass (90 seconds- maximum)
Mission Time (OT-8 hours)	Pass

4.0 Discussion/Conclusions

4.1 Flammability

4.1.1 Laboratory Test- Vertical Flammability Resistance

The basic aluminized knit material self extinguished once the flame source was removed from the fabric after a 12 second exposure. The after glow time (30.6 seconds) and char length (0.5 inches), were well below the specified requirements. There was no after flame observed.

4.1.2 Field Test-Fuel Fire Pit

The new APCR coat/trouser ensemble self extinguished after a 5 second exposure to a 1500-2200^oF fire pit test, and no burn injury was sustained by the test manikin.

4.2 Radiant Heat Penetration

The basic aluminized knit material was examined for its reflectivity after abrasion, and there was no evidence of cracking and/or flaking of the aluminized film and no evidence of discoloration of the blotting paper.

4.3 Compatibility

The new APCR coat and trousers were found to be compatible with the respective standard issue snap-in liner.

4.4 Durability

The new APCR coat and trousers encountered some major failures such as rips or tears in the stress areas (elbows and knees) of the respective garments. The failures were characterized as critical, and were removed from further testing.

4.5 Anthropometric Population

The new APCR coat/trouser ensemble sizing was sufficient to fit all test participants. It is concluded that the APCR coat and trousers are satisfactorily sized to fit Military firefighting personnel.

4.6 Ease of Donning

The new APCR coat/trouser ensembles were donned between 60 to 90 seconds, well within the required 2 minute time frame.

4.7 Mission Time

The new APCR coat/trouser ensembles met the mission time requirement of 8 hours under temperate temperature/humidity. As with other types of protective clothing ensembles, mission times could be substantially reduced under temperature/humidity conditions.