R and D CENTER LABORATORY

TECHNICAL REPORT

NO. 12748

DESIGN, FABRICATION AND TESTING OF IMPROVED WIRING HARNESS MATERIALS FOR COMBAT VEHICLES

CONTRACT NO. DAAK30-79-C-0105

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This is a Final Report describing the investigation, selection, evaluation, environmental testing and fabrication of improved commercially available materials used to construct Combat Vehicle Wiring Harness Assemblies. The goal of this program is to achieve a 20 year field life of wiring harness assemblies used in severe/adverse combat vehicle environments.

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TABLE OF CONTENTS

1.0 Introduction

1.1 The effort of this program to evaluate cable assembly/harness designs for combat vehicles is accomplished in the three steps outlined below:

1.1.1 Determine Specifications

The main goal of this effort is to define the minimum performance requirements these assemblies must meet in application and handling. Electrical and environmental conditions are reviewed to help establish these requirements. Three field trips were made to army facilities at Amiston, Alabama, Ft. Knox, Kentucky and Ft. Hood, Texas to identify problems with M60 vehicle harnesses and to determine the most common modes of harness/cable failure.

1.1.2 Review Design and Material Selection

After establishment of design specifications, a review of alternate materials is made. Available alternate materials are examined through contacts with vendors of wire, tape, heat shrinkable tubing, jacketing materials and convoluted outer sheating. Suitable component materials are then combined in an improved cable assembly/harness. The four main categories of cable design are as follows:

Wire Harness: Open Wiring, usually with many breakouts, which have been tied together with tying tapes, lacing cords or flexible sleeving.

Molded Assem: Completely jacketed cable with molded breakouts and connector back ends providing a sealed unit.

Hybrid Assem: Cable fabricated using heat-shrinkable tubing and heat-shrinkable boots to provide an environmental seal.

Convolute Assem: Modular constructed cable with convolute tubing, metal breakouts and metal connector backshells that provide sealing characteristics.

1.1.3 Fabrication and Testing

After selection of materials and design, three sets of cables for the M1 tank are fabricated. Each set consists of three cables used in different service areas of the vehicle.

12287214 Turret Wiring Harness Assembly
12287234 Hull Wiring Harness Assembly
12287264 Engine Wiring Harness Assembly

One set of cables is tested by a local laboratory selected by Amphenol to a test plan agreeable to TACOM Engineering. The two remaining sets are shipped to TACOM for their laboratory and field testing.

2.0 Objective

The contract objective is to design, fabricate and test three sets of improved cable assemblies for the engine, hull and turret areas of a combat vehicle. The areas for improvement over current cable design are as follows:

1. Extend service life to 20 years.

2. Eliminate electrical wiring that can cause internal vehicle fires.

3. Select materials that do not support fires or produce toxic fumes.

4. Reduce possible cable chafing from vibration or installation.

5. Improve capability to withstand misuse or mis-assembly.

6. Improve electrical system interface and allow greater modification flexibility.

3.0 Conclusions

3.1 The goal of building an improved cable assembly over those currently used in combat vehicles has been accomplished. Convoluted tubing cable assemblies have proven to meet all the design parameters established at the initiation of this program. The cables have passed electrical and environmental tests per Amphenol Test Plan #123-2266 which is based on tank operations, storage and shipping. Amphenol Report 123-2289 "Thermal Life Analysis of Teflon and Tefzel" proves the materials selected for the outer sheath and wires will meet the service life goal of 20 years. The modular construction of convoluted tubing cables provides the means for repairability and circuit replacement without special tools.

4.0 Recommendations

Of the cable assembly designs examined the convoluted cable construction best meets the design requirements. It is composed of Teflon or Tefzel convoluted tubing, aluminum alloy breakouts and connector backshells and TFE or ETFE fluoropolymer insulated wires. The convoluted tubing outer sheath provides mechanical protection for the electrical circuits and environmentally seals the the unit at breakouts and connectors. Teflon and Tefzel tubing exhibit the best physical characteristics for use in combat vehicles. The backshells and breakouts have threaded connections which allow access to the back of the connectors for circuit repair and replacement. Electroless nickel plating should be used on these components rather than the cadmium plate with olive drab chromate conversion as was tested. This should help prevent blistering and flaking of

4.0 Recommendations (continued)

plating which could lead to eventual electrical failure. Wire terminations such as shields or floating shields should be accomplished with shrink sleeve material, or solder sleeves that are compatable with the temperatures and environments of the cable.

5.0 Discussion

5.1 Based on investigations and observations from the review of tank environmental conditions, the following parameters are established as guidelines for material selection:

Environmental Requirements

Temperature: Engine Compartment: -55°C (-67°F) to 150°C (302°F)

Crew Compartment: -55°C (-67°F) to 60°C (140°F)

Fluid Immersion: (20 continuous hours)

Diesel Fuel V-V-F-80 50°C
Turbin Fuel MIL-T-5624 23°C
Hydraulic Fluid MIL-H-46170 100°C
Lubricating Oil MIL-T-23699 23°C

Humidity: MIL-STD-810, Method 507, Procedure I
Salt Fog: MIL-STD-810, Method 509, Procedure I
Dust: MIL-STD-810, Method 510, Procedure I
Shock: MIL-STD-810, Method 516.1, Procedure I
Vibration: MIL-STD-810, Procedure VIII; Table 5142-VI
Steam Exposure: 45 psi at 12 to 24 inches.

5.2.1 Analysis of alternate materials is accomplished by individual component reviews such as conductors, primary insulation and jacketing (outer sheath). It becomes apparent that Teflon and Tefzel exhibited the most durability in the environments examined. The reason for selecting these materials and type of design is based on the following analysis.

5.2.2 Wiring harnesses as used in the M60 tank have proven to be incompatible with the known environments. This is due in part to the materials available at the time. Extending beyond the material previously used and selecting wire insulation (Teflon) that is compatible and tapes or ties that would maintain the configuration, the problem still exists with sealing back ends of connectors. Special backshells would be needed to provent moisture entering through the connector back end, but this would increase the harness cost and therefore lose the main advantage of wiring harnesses. Additionally, the wire insulation has no protection, and unwanted splicing can be performed at any location in the vehicle.

5.2.3 The disadvantage of using a molded cable assembly is that the cable is not field repairable, and most materials used in this type of design do not possess fuel compatibility, temperature range, abrasion resistance, and expectant life in any one combination. The advantage of this assembly lies in its ability to more accurately locate breakouts and connector molds. The offsetting disadvantages restrict use of molded cable assemblies to special areas.

5.2.4 An advantage of using a hybrid jacketed cable design is the ease of fabrication. Hybrid cables are similar to harnesses, with the addition of shrink tubes and boots. Manufacturing personnel must be trained for assembly work to provide the necessary sealed environment around the tubing and boot interface and boot-to-connector backshell. Due to the shrink tubing sheath the cable loses some flexibility. Material selection for lower temperature areas does not ensure a 20-year life expectancy and, for the higher temperature areas, preliminary data indicates storage life of 20 years may be attainable. Although this cable design is considered repairable, there is a requirement for special tools, adhesives, and accessory hardware.

5.2.5 Convoluted tubing cable assemblies maintain the greatest advantage in meeting a 20-year life expectancy. The materials (Teflon and Tefzel) involved will meet all environmental and electrical requirements of design. One disadvantage is the size limitations for a convolute tubing design. Metal breakouts may be too large due to wire complement requirements and cause installation problems that may require relocation or redressing those cables in the area preventing stack-up. Convolute cable was selected as the design for an improved cable assembly for combat vehicles and was tested to verify its suitability.

5.3 Sample Harnesses and Testing

5.3.1 Although, three cable assembly sets were to be fabricated from the design recommended, a change of scope evolved. Six cable assemblies were required for use on the ATEPS vehicle and were substituted for two sets of hull, engine, and turret cables for the MI tank to be shipped to TACOM engineering. Connectors ordered for the sample cables were not usable for the ATEPS cables, and it was decided to have Chrysler supply the connectors. Amphenol would use the wire from the sample cable stock. Icore and Raychem would fabricate convolute tubing and hardware at the same cost charged for two shippable sets required per contract. Amphenol assigned ATEPS cables 2W104-X, 2W106-X and 2W159-X to Icore's design. Cables 2W105-X, 2W111-X, and 2W160-X were assigned to Raychem. Connectors and wire were sent to Icore and Raychem to fabricate complete assemblies. Raychem delivered hardware to Chrysler on July 15, 1981, for use on the ATEPS project. Icore's convolute cable assemblies were shipped to Chrysler on July 23, 1981. The following is a record of the substitution.

5.3.1 (Continued)

Original Requirements:

Qty	Part No.	Usage
2	12287264	Engine Wiring Harness
2	12287234	Hull Wiring Harness
2	12287214	Turret Wiring Harness

Substitutions:

Qty	Part No.	Usage	Vendor P/N
1	2W104-X	RFRT Fire Ext.	250588*
1	2W105-X	RFRT RF Sensor & Periscope	CHO-0319-001*
1	2W106-X	Driver Control Panel	250587*
1	2W111-X	LFRT	CHO-0319-002**
1	2W159-X	Rear Remote Term. Left Eng. Comp.	250589*
1	2W160-X	Rear Remote Term. Right Eng. Comp.	CHO-0319-003**

* Icore International Inc.
** Raychem Corporation

5.3.2 One set of cables to be fabricated per the original requirement and retained by Amphenol for laboratory testing was also changed. At a design review meeting in February, 1981, it was agreed to fabricate three simpler convolute cables of Icore's design and three of Raychem's design. Additionally, three control cables were fabricated using materials and construction presently used in the MI tank and M60 tank. Amphenol prepared Test Plan 123-2266 outlining the test sequence for each cable assembly (see Table I). Amphenol selected National Technical Systems (NTS) Laboratory to perform the electrical, environmental, and physical tests. Nine sample test cables with test gear harnesses were submitted to NTS laboratory October, 1981.

5.3.3 The test plan was divided into three sample groups with five cables being subjected to tests approximating conditions within a tank vehicle during operation. A second group of two cables was subjected to high and low temperatures and fluid immersion with a final flammability test to gain knowledge of what the cable design can withstand after fire. The third group of two cables was subjected to tests normally expected during shipping and handling.

5.4 Test Analysis

5.4.1 Three control cables were subjected to a test sequence patterned after conditions normally existing during tank operations. Control cable SK-71781 (Test Cable No. 9) contained wire (M13486/1) used in harnesses on the M60 tank in both the hull and engine compartments. The test results showed wire failure as early as the completion of the first test for high temperature. Eventually three of the four circuits failed. The PVC tape wrap cracked during high temperature and disintegrated during vibration. All neoprene wire insulation was cracked, and even the non-metallic braid underneath had deteriorated. Wire M13486/1 has proven to be unacceptable for high temperature (150°C) and fluid immersion.

5.4.2 Within test cable No. 9 were two wires per M27500-16RE-2N06 that were recommended for use in the convoluted tubing cable assemblies. The two wires were unprotected during testing and maintained their insulation resistance values through high temperature, low temperature, and all fluid immersion tests. Insulation values dropped during humidity testing, but that was attributed to connector design, not wire selection. No deterioration was noted after completion of testing. The wire satisfactorily performed its electrical and environmental function.

5.4.3 Also, within test cable No. 9 were five wires of Boston insulation wire "no-smoke" that performed well through high temperature, low temperature and JP4 fluid immersion tests. Insulation resistance values kept dropping through subsequent tests leading to failure below 500 megaohms during humidity. After humidity testing and drying of wires, the insulation resistance values more than doubled. The failure was attributed to swelling of the silicone inner wire insulation during fluid immersion.

5.4.4 After completion of sample cable testing, Raychem personnel disclosed the identification of two control cables was in error. A letter from Roger Goodrich, Raychem's national sales manager, is attached here to. The cables involved are Test Cable No. 1 (SK-82880-04) and Test Cable No. 2 (SK-82880-03) as identified in Amphenol Test Plan 123-2266. The reversal of identification tags resulted in the neoprene heat shrink tubing construction (SK-82880-04) being subjected to high temperature tests beyond its limit. Conversely, the Viton heat shrink tubing construction (SK-82880-03) was not tested to its full capacity during the high temperature test. Retesting was performed by Raychem per their test report TSL821255.

5.4.5 Test Cable No. 1 (SK-82880-04) was refurbished with new neoprene heat shrink tubing and boots. This cable was then subjected to sample No. 1 test sequence except for vibration and steam exposure. The cable successfully passed insulation resistance requirements with a slight drop in values after humidity cycling but well within the 500 - megaohm minimum requirement. The disadvantage of neoprene heat-shrinkable tubing and boots is that the life expectancy of the

5.4.5 (Continued)

material is 5 to 10 years per Military Standard Handbook 695. The 20 year goal could not be achieved with this cable design. Additionally, the cable design is not conducive to field repair due to the special equipment necessary for any repair beyond the connector termination.

5.4.6 Control Cable No. 4 (SK-82880-05) having a hybrid construction with Tefzel convolute tubing and Viton boots and sleeving was tested for vibration and steam exposure before the mislabeling error was discovered. Additional testing for humidity, salt fog, sand, and dust was performed by Raychem. This cable maintained high insulation resistance values through humidity and salt fog. The insulation resistance values were much higher than after completion of fluid immersion tests performed by NTS Laboratory and are not explainable. The disadvantage of this assembly is the same as SK-82880-04, i.e., it is not conducive to field repair.

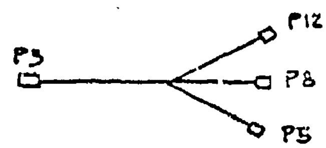
5.4.7 Test Cables SK-82880-02 and SK-82680-03 experienced a drop in insulation resistance during fluid immersion and humidity tests but remained above the 500 mega ohm minimum requirement. Leakage of fluid into the system contributed to the insulation resistance drop. However, even with this condition the cables performed satisfactorily.

5.4.8 Test cables SK-82880-05 and SK-82780-01 were also subjected to flammability testing. Cable SK-82880-01 maintained insulation resistance values and experienced no flame penetration. Cable SK-82880-05 self-extinguished after 15 seconds and experienced no dripping, burn rate, or after glow. Burn length was 2 inches and flame penetration to outer sheath was only 0.1 x 0.3 inch. The inner sheath was not damaged.

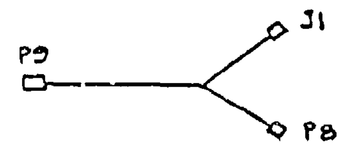
5.4.9 Test cables SK-82880-01 and SK-82680-02 were subjected to thermal shock test. Insulation resistance dropped on both cables but was well within the minimum of 500 mega-ohms. Both cables withstood the test without discontinuity of circuitry or damage to hardware.

5.4.10 The following charts outline the tests performed and the results of each test. Additional comments are noted on any adverse conditions resulting from the tests.

TEST ANALYSIS
TEST SEQUENCE No. 1



SK-82880-02



SK-82680-03

Tests Performed	Raychem	Icore
Initial		
Continuity	ok	ok
Insulation Resistance	ok	ok
Dielectric Strength	ok	ok
High Temperature		
Visual	Slight discoloration connector ends	Discoloration connector ends
Insulation Resistance	ok	ok
Low Temperature		
Visual	ok	ok
Insulation Resistance	ok	ok
Fluid Immersion		
JP4 - Visual	Slight discoloration. Convolute less resilient	Darkening of copper sleeve. Corrosion signs connector assemblies
- IR	ok	ok
Lub Oil - Visual	ok	ok
- IR	ok	ok
Diesel No. 2 - Visual	ok	ok
- IR	ok	ok
Hydr Fluid - Visual	ok	ok
- IR	ok	ok
Humidity		
IR During	ok	ok
IR After	ok	ok
Salt Fog	ok	ok
Sand & Dust - DS	ok	ok

	SK-82880-02				SK-82680-03		
Vibration	ok				ck		
Steam Exposure	ok				ok		
Observation							
Connectors	P3	P12	P8	P5	P9	J1	P8
Plating	ok	ok	ok	ok	ok	ok	ok
Front Insert	ok	ok	ok	②	ok	ok	ok
Rear Grommet	③	③	③	③	①	ok	ok
Backshell	④				Slight oil evident in all backshells		
Plating	ok	ok	ok	ok	P8 backshell, 50% plating removed to bare metal		
Breakout	Considerable oil in area				Slight oil on wire		
Plating	ok				One coupling ring, plating removed to bare metal		
Convolute Sheath	Slightly stiffer than original				J1 outer braid damaged at backshell		
Internal Wire	ok				ok		
Shrink Sleeve - Shields	ok				N/A		

① Silicone grommet torn.

② Front insert appears to be recessed.

③ Grommet discolored from fluids and considerable oil at grommet area and on wires.

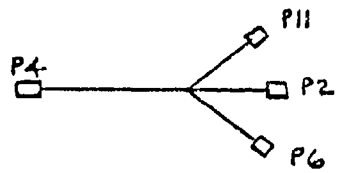
④ Removed shrink boots - ("Y" breakout-P3 leg oil, P5 leg dry, P12 leg oil)
P5 - oil under sleeve
P12 - dry
P8 - considerable oil under sleeve
P3 - dry

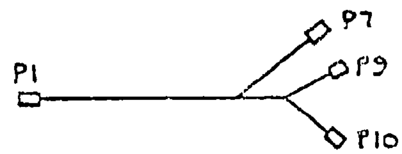
Insulation resistance maintained on Icore (SK-82680-03) cable through high temperature, low temperature, and fluid immersion on the J1 and P8 legs. IR values dropped on P9 leg after first fluid immersion test indicating the mating connector did not provide the seal necessary to exclude the fluids. Even though insulation values dropped during humidity testing, they were within the minimum 500-megohm requirement. The decrease in values can be attributed to normal connector characteristics.

Insulation resistance on Raychem (SK-82880-02) cable was maintained through high temperature, low temperature, JP4, and diesel No. 2 before values decreased. Considerable oil was found in all legs of the assembly that seemed to occur during the lubricating oil immersion, when the IR values dropped. Some evidence that the leak path could have been under the shrink sleeves at P5 and P8 termination. During the remaining sequence of tests the IR values dropped more but never below the minimum 500-meg ohm requirement. A mechanical termination is superior to a shrink sleeve junction between the convoluted tube and shield by reducing the possibility of bond or adhesive failure.

TEST ANALYSIS

TEST SEQUENCE No. 1





Tests Performed	SK-82880-04 Raychem	SK-82880-05 Raychem
Initial		
Continuity	ok	ok
Insulation Resistance	ok	ok
Dielectric Strength	ok	ok
High Temperature		
Visual		Slight discoloration connector ends
Insulation Resistance	ok	ok
Low Temperature		
Visual		ok
Insulation Resistance	ok	ok
Fluid Immersion		
JP4 - Visual		Slight discoloration
- IR	ok	ok
Lub Oil - Visual		ok
- IR	ok	ok
Diesel No. 2 - Visual		ok
- IR	ok	ok
Hydr Fluid - Visual		ok
- IR	ok	ok
Humidity		
IR During	ok	ok
IR After		ok
Salt Fog	ok	ok
Sand & Dust - DS	ok	ok

Observations	SK-82880-04				SK-82880-05			
Connectors	P4	P11	P2	P6	P1	P7	P9	P10
Plating	①	ok	ok	ok	ok	ok	ok	ok
Front Insert	ok	②	ok	ok	ok	ok	ok	ok
Rear Grommet	④	ok	④	③	ok	⑧	ok	⑧
Backshell								
Plating	⑦	ok	⑤	⑥	ok	ok	ok	ok
Breakout	Boot ok				ok			
Plating	N/A				ok			
Outer Sheath								
Internal Wire	ok				Scored insulation P7 & P10			
Shrink Sleeve - Shields	ok				ok			

① Connector Plating has blisters, rear area of shell shows corrosion.

② Front insert recessed.

③ Grommet torn at pin 4; grit on grommet.

④ Dust and grit inside connector and on grommet.

⑤ Plating chipped at safety wire hole.

⑥ Plating chipping and bare metal exposed.

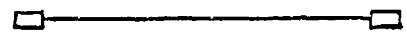
⑦ Considerable grit on connector threads and OD of grommet.

⑧ Wire impression in rear grommet due to high heat and limited space in backshell.

Insulation resistance valves for SK-82880-04 cable were maintained at consistent values throughout all tests except humidity where there was a drop, but never below the minimum of 500 megohms. Insulation resistance values for SK-82880-05 cable were considerably higher at initial testing than on all other cables tested. Values dropped after humidity testing but maintained higher values than previously witnessed. The cables met all requirements. A few connectors exhibited corrosion and plating chipping that was not observed on other cables but the cause could be because the cables were handled more during testing.

TEST ANALYSIS

TEST SAMPLE NO. 1



SK-71781

Tests Performed	M13486/1 Circuits	BIW No-Smoke Circuits	M27500-16RE-2N06 Circuits
Initial	5,6,12,13,14&15	1,2,3,4&7	8&9,10&11
Continuity	ok	ok	ok
Insulation Resistance	Circuit 5&14 failed	ok	ok
Dielectric Strength	ok	ok	ok
High Temperature			
Visual	Tape dried and cracked	ok	ok
Insulation Resistance	Omitted 5&14. Circuit 15 failed	ok	ok
Low Temperature			
Visual	ok	ok	ok
Insulation Resistance	Omitted 5,14&15. Circuit 13 failed	ok	ok
Fluid Immersion			
JP4 - Visual	ok	ok	ok
- IR	Omitted 5,13,14&15	ok	ok
Lub Oil - Visual	Additional cracking of tape & insulation	ok	ok
- IR	same	ok	ok
Diesel No. 2 - Visual	ok	ok	ok
- IR	same	ok	ok
Hydr Fluid - Visual	ok	ok	ok
- IR	same	ok	ok
Humidity			
IR During	Additionally circuit 12 failed	Circuits 1,2,3 and 7 failed	ok
IR After	same	ok	ok

	SN-7178		
Salt Fog	ok	ok	ok
Sand & Dust - DS	ok	ok	ok
Vibration	Tape & insulation is cracking & disintegrating	ok	ok
Steam Exposure	Further cracking of insulation	ok	ok

Observation

The intial insulation resistance tests of circuits 5 and 14 showed they failed the 500-megohm requirement and were even below 100 megohms, which is usually considered an acceptable level. These two circuits could not be investigated for cause of failure due to the epoxy potting compound at the rear of the connector. The two circuits were dropped from testing which still left four circuits of M13486/1 wire available for further testing and evaluation.

After high temperature testing, circuit 15 dropped below the 500-megohm requirement, and the PVC tape dried and cracked.

After low temperature testing, circuit 13 dropped below the 500-megohm requirement. During humidity circuit 12 failed.

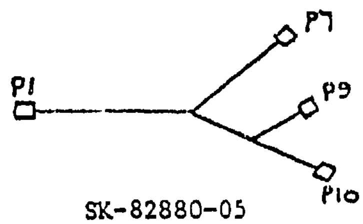
The M13486/1 wire was used in various areas of the M60 tank, and field trips indicated potential problems using neoprene insulation on wires and PVC tape wrap in high temperature or fluids. This test verified the materials are not compatible with the environment when a greater proportion of the tape cracked and disintegrated and each wire insulation cracked including deterioration of the non-metallic braid beneath the insulation. Three of the four circuits failed insulation resistance during some sequence of testing.

BIW no-smoke wire generally was acceptable, but insulation resistance decreased after diesel immersion which evidently swelled the inner insulation material (silicone based). During humidity, four of the five circuits failed IR but recovered after drying and maintained good IR valves after steam exposure.

M27500 wire exhibited no deterioration through high temperature, low temperature, and fluid immersion. Reduced IR values during humidity may be attributed to normal connector design or a leak path around the wires through the epoxy to the grommet.

TEST ANALYSIS

TEST SEQUENCE No 2

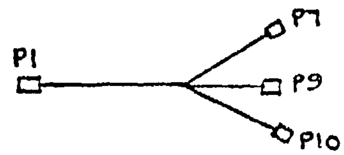
	 SK-82880-05	 SK-82780-01
Tests Performed	Raychem	Icore
Initial		
Continuity	ok	ok
Insulation Resistance	ok	ok
Dielectric Strength	ok	ok
High Temperature		
Visual	Slight discoloration connector ends	Slight discoloration connector ends
Insulation Resistance	ok	ok
Low Temperature		
Visual	ok	ok
Insulation Resistance	ok	ok
Fluid Immersion		
JP4 - Visual	Slight discoloration	Darkening of copper sleeve. Signs of corrosion at conn.
- IR	ok	ok
Lub Oil - Visual	ok	ok
- IR	ok	ok
Diesel No. 2 - Visual	ok	ok
- IR	ok	ok
Hydr Fluid - Visual	ok	ok
- IR	ok	ok
Flammability		
Flame Penetration	0.01 x 0.03 inches limited to outer sheath	none

	SK-82880-05				SK-82780-01	
Observations						
Connectors	P1	P7	P8	P10	P1	P3
Plating	ok	ok	ok	ok	ok	ok
Front Insert	ok	ok	ok	ok	ok	ok
Rear Grommet	ok	(1)	ok	(1)	ok	ok
Backshell						
Plating	ok	ok	ok	ok	Slight blistering. Plating off internal threads	
Breakout	P9/P10 "Y" branch split					
Plating	ok				N/A	
Convolute Sheath					Copper shield discolored	
Internal Wire	Scored insulation P7 & P10				ok	
Shrink Sleeve - Shields	ok				ok	

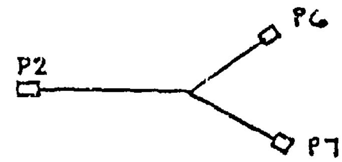
(1) Wire impression in rear grommet due to high heat and limited space in backshell.

Icore (SK-82780-01) maintained insulation resistance values throughout all the test sequences. Raychem (SK-82880-05) insulation resistance dropped approximately 75 percent after the first fluid immersion (JP4) which is attributed to a leak path at P7 and P10 when wire was pinched against the rear grommet. Connector backshells used on Raychem cables require more rear area for storage of wires and shield terminations similar to Icore's design. Backshell design must allow for wire termination and ensure proper area to effectively seal the rear of connector. The insulation resistance values remained above the minimum 500-megohm requirement even with this condition. Icore cable withstood the flammability test without any detrimental effect to copper shield or convolute tubing. Raychem cable outer convolute tubing split at the point of flame concentration, but no effect was noticed to the inner shield.

TEST SEQUENCE No. 3



SK-82880-01



SK-82680-02

Tests Performed	Raychem	Icore
Initial		
Continuity	ok	ok
Insulation Resistance	ok	ok
Dielectric Strength	ok	ok
Thermal Shock		
Visual	ok	ok
Insulation Resistance	ok	ok
Shock		
Continuity	ok	ok
Observations		
Connectors	P1 P7 P9 P10	P2 P6 P7
Plating	ok ok ok ok	ok ok ok
Front Insert	ok ok ok ok	ok ok ok
Rear Grommet	ok ok ok ok	ok ok ok
Backshell		
Plating	ok ok ok ok	ok ① ①
Breakout		
Plating	ok	Slight blistering on coupling rings & metal particles on threads
Convolute Sheath	Slightly stiffer than originally	Slightly stiffer than originally
Internal Wire	ok	ok
Shrink Sleeve - Shields	ok	ok

① Wear shown on internal threads of backshell with small particles of metal probably from plating on threads.

Raychem (SK-82880-01) insulation values dropped approximately 66 percent of their original values and Icore (SK-82880-02) dropped approximately 70 percent, but both cables were well within the minimum 500-megohm requirements. The decrease in insulation resistance may be attributed to normal connector deterioration under thermal shock conditions.

TABLE I

TEST CABLE IDENTIFICATION

CABLE ASSEMBLY	DESCRIPTION
SK82680-02	Teflon convoluted outer sheath from Icore International
SK82680-03	Teflon convoluted outer sheath from Icore International
SK8270-01	Teflon convoluted outer sheath from Icore International
SK82880-01	Tefzel convoluted outer sheath from Raychem Corporation
SK82880-02	Tefzel convoluted outer sheath from Raychem Corporation.
SK82880-03	Viton (VPB) heat shrink tubing outer sheath from Raychem Corp.
SK71781	Open Harness with single conductor wires of Boston Insulated Wire low smoke insulation, MIL-C-13486 wire wrapped with PVC tape and wires per U.S. Automotive Tank Command Drawing 12273950
SK82880-04	Neoprene (NT-FR) heat shrink tubing outer sheath from Raychem Corp.

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