AD-A122 244 LIGHTWEIGHT ELECTRIC POWER CABLE(U) BRAND-REX DIV WILLIMANTIC CONN I N DWYER ET AL. SEP 82 DAAK70-81-C-0190 1/1

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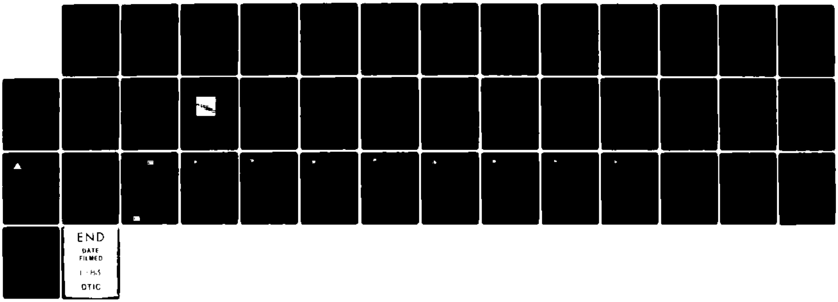

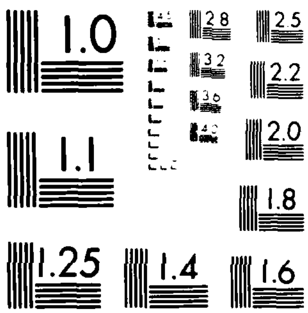

MICROCOPY RESOLUTION TEST CHART

AD A 122 244

"LIGHTWEIGHT ELECTRIC POWER CABLE"

FINAL TECHNICAL REPORT

SEPTEMBER 30, 1981 to SEPTEMBER 30, 1982

BRAND-REX COMPANY
A PART OF AKZONA
P.O. BOX 498
WILLIMANTIC, CONNECTICUT 06226

IRVING N. DWYER
CHARLES J. O'NEIL
WILLIAM G. WOOD
DAVID P. DA VIA

U. S. ARMY MOBILITY EQUIPMENT RESEARCH COMMAND
FORT BELVOIR, VIRGINIA

CONTRACT No. DAAK 70-81-C-0190

SEPTEMBER 1982

DISCLAIMER

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ABSTRACT

A TPE (Elexar 8614Z) material was selected from several candidates for evaluation in completed cable form. A second cable with higher heat resistance capability, using silicone insulation, was also evaluated. The objective was to produce a finished cable with a weight savings of 15% or better, with no loss of significant properties from the standard cable specified by Drawing #13222E8995.

A weight savings of 21% was achieved conforming to the required specification. The jacket material utilized was polyurethane, producing a thinner layered construction over the standard cable. The performance of this, as a sheath material, was excellent when tested to the requirements of MIL-C-13777G.

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I. INTRODUCTION:

The present cables used in the Patriot Missile System utilize silicone rubber with braided glass reinforcing as the primary insulation. The cable jacket is a black two layer reinforced polychloroprene (Artic Neoprene material). These cables weigh approximately two pounds per foot and are in portable use in the field. To be considered mobile with this weight factor, seventy five foot lengths are the limit that can be carried by personnel. The primary objective of this contract is to reduce the weight of the cable, thus allowing longer spans for interconnection.

One approach for reducing the weight for this large cable construction is to consider foam as the primary insulation. However, in this particular cable, where flame retardants are of great importance, a number of problems must be evaluated. Very little work has been done to foam flame retarded insulation systems. The only exceptions are the unfilled reactive systems that are inherently flame retarded. Materials like Halar (ECTFE) were looked at as candidates. For economic reasons other existing filled flame retardant systems, as well, were examined. Successfully foaming filled systems could achieve a cost reduction along with a weight reduction.

Reducing the weight of the jacket is a major part of the examination of cable weight reduction. Block copolymers that are new materials with flame retardants and other good properties for wire and cable have inherently lower specific gravity and are part of the project.

Brand-Rex has considerable research facilities for material development and testing. In addition, it has fully equipped process development and analytical laboratories. Brand-Rex also has experience in a broad field of polymer systems and manufactures a number of products using this technology.

OBJECTIVE:

The objective of this contract is to develop a power cable in the configuration of drawing #13222E8995 (See Fig. 3, P. 8) that is lighter in weight than the standard cable using silicone rubber and neoprene. The properties of the cable should not be significantly altered as determined by the qualification tests MIL-C-13777, Table II of MIL-W-16878/8, and flammability test of Appendix A, (DAAK 70-81-C-0190).

Comparison tests are to be made with neoprene/silicone constructions in the areas of abrasion and tear resistance, oil & grease resistance, flammability, low temperature flexibility, and thermal stability. The following are properties in consideration along with the above.

1. WEIGHT - Weight reduction of 15% relative to the standard cable, drawing #13222E8995. Insulation and jacket systems considered.
2. FLAMMABILITY - Cables evaluated in full scale performance tests.
3. FUEL & OIL RESISTANCE - Comparable to the performance of neoprene.
4. TOXICITY - Consideration of toxic hazard.
5. TEMPERATURE - Range of temperature for flexibility is -45°C to +71°C.
6. CURRENT CARRYING CAPACITY - Per standard cable drawing #13222E8995.

SUMMARY:

Six (6) different insulation/jacket material systems were prepared and tested as a comparison to the currently used silicone/Neoprene cable systems. Materials were selected for their inherent properties of low specific gravity and toughness that allows a design of thinner wall constructions and smaller size cable. A summary of these materials is found in Table 1. Weight and performance comparisons on candidate materials are shown in Tables 2 thru 14.

PRIMARY INSULATION:

FLUOROPOLYMERS:

A calculated weight comparison of fluoropolymers using a reduced wall revealed a reduction of 15.1% with ethylene chlorotrifluoroethylene (ECTFE-Halar) alone. (See Table 2) However, it was decided that fluoropolymers are too rigid for use in mobile power cable. Cellular ECTFE insulation improves the weight reduction up to 20.9% (See Table 7) but low strength properties (low elongation) make this form of the material unreliable. In addition, difficulty was found in processing with consistency with large conductor sizes.

ACRYLIC ELASTOMERS:

Ethylene/Acrylic elastomer, a new advanced engineering polymer, was considered for its physical and thermal capabilities as a replacement for silicone. At a lower specific gravity (1.12) and capability for reduced wall, it was evaluated and found to be suitable if the continuous operating temperature remained below 150°C, (See Table 13). However, the electrical properties are not adequate for the voltage rating in cable use.

TPE:

A block co-polymer based upon styrene-butylene-styrene with flame retardant additives, known as Elexar 8614Z was selected as the primary insulation on one of the prototype cables. Basic properties were examined and found that physical properties of this material are adequate, but thermal resistance must be considered for the application (See Product Literature P. 20 thru 22).

JACKETS:

TPE (8614Z) as a jacket was found superior in mechanical properties to neoprene but having minor deficiencies in oil resistance and tension set, (See Table 9). This consideration in jacket properties allows for a reduction in jacket sheath thickness, making it a good candidate material.

A new TPE from Monsanto (Santoprene) was considered as an improvement over the Shell TPE (Elexar). However, the low flame resistance properties required incorporating additives, which added too much weight, offering little advantage, (See Tables 10 and 11).

Another block co-polymer based upon styrene-butylene-styrene, known as Kraton G, was selected for flexibility and low specific gravity. It was formulated to improve flame resistance to an oxygen index of 27 and resulted in losses in tensile strength, tension set, and oil resistance (See Table 12). Hence, it was eliminated as a candidate.

Recent improvements in flame retardant polyurethane renew interests in this material as a replacement for neoprene. It matches or exceeds neoprene in every property catagory except oil resistance (slab analysis). Oil breakdown shows a loss of 20% compared with neoprene, but still well within the requirements of Fed-Std-228 for sheath materials. The tension set is at the limit of the specification which encompasses elastomerics. Polyurethane is classed as a TPE polymer, not a thermoset. Its physical properties far exceed neoprene for endurance and still performs at low temperature and in fire conditions, (See Table 14). This allows a 50% reduction in the sheath wall, along with a lower specific gravity, and overall cable diameter.

TABLE 1
MATERIALS EVALUATED FOR LIGHTWEIGHT CABLE (SLAB DATA)

MATERIAL	REPLACE	COMPOUND TO IMPROVE	S.G.	DEFICIENCIES
SBS (ELEXAR)-SHELL	NEOPRENE	FLAME	1.17	OIL RESISTANCE - 121°C TENSION SET
SANTOPRENE-MONSANTO	NEOPRENE	FLAME	1.31	PHYSICAL PROPERTIES
SBS (KRATON)-SHELL	NEOPRENE	FLAME	1.17	TENSILE STRENGTH OIL RESISTANCE
ETHYLENE/ACRYLIC ELASTOMER (VAMAC) DU PONT	SILICONE	AS PREPARED BY MANUFACTURER	1.12	THERMAL RESISTANCE
ECTFE (HALAR)-ALLIED	SILICONE	AS PREPARED BY MANUFACTURER	1.70	FLEXIBILITY
POLYURETHANE (ESTANE)-B.F. GOODRICH	NEOPRENE	AS PREPARED BY MANUFACTURER	1.23	TENSION SET (SLAB DATA)
REFERENCE: NEOPRENE	-	-	1.34	-

DISCUSSION AND RESULTS:

Three (3) prototype cables were built as illustrated on Page 8. They are referred to as Cables I, II and III for further discussion. Cable III is the current cable used in the field and is the reference for comparison.

A cable was built similar to Drawing #13222E 8995 (Fig. 1, P. 8) utilizing a TPE type insulation Elexar 8614 Z (See Note 1). This cable is referred to as Cable I. All primary insulation tests were performed and met the requirements of MIL-W-16878/8, except for heat resistance. The temperature requirements for the slash 8 specification are derived from silicone insulations, which are beyond the capability of TPR types. Hence, a lower aging test temperature of 160°C was added.

The sheath material used was polyurethane (Estane 58202). The prototype Cable I was manufactured to 1.340" diameter and the weight was 1556 pounds/1000 feet. The results in savings of weight was calculated as 29%; the actual weight savings measured 24%.

A silicone/neoprene cable selected from a previous production run (Drawing #13222E 8995 - Cable III) was used for a thermal performance test, in order to verify the need for high temperature materials. The test was set-up and performed at Cable Technology Laboratories, Inc. (New Brunswick, N.J.) in order to study temperature distribution at full load operating conditions; full ampacity in a 71°C ambient environment. Steady state was reached after two (2) hours and revealed temperatures up to 162°C, (See Thermal Performance Report P. 5). This is well above the safe operating level for TPR materials. However, thirty (30) minutes of continuous service would be suitable for TPR if this were actual time of operation.

NOTE 1: Elexar is a trade name for Shell Chemical Thermoplastic Elastomer.

DISCUSSION AND RESULTS (Cont'd.):

TPE primary tests - all test results are listed on page 9. Nonconforming properties were experienced in heat resistance as mentioned above and elongation on the 16 AWG yellow and green insulations. However, other performance properties were not affected as a result.

Cable Tests - Cable I did not conform to the bend and twist tests in 13777 at room temperature, however, it passed at -45°C. In every case, a 16 AWG component failed the bend test at ambient temperature. It was determined to be due to stresses caused by immobility of the smaller wire in the outer layer. It was decided not to retest Cable I, due to heat resistance deficiencies found in electrical load tests mentioned above. The performance of the polyurethane sheath was excellent in all properties tested per MIL-C-13777. The tension set property improved in the cable form, probably due to the orientation during the extrusion process.

Another cable fabricated with silicone primary insulation utilizing the same polyurethane sheath material (used in Cable I) was constructed as a comparison with the above prototype. This cable is referred to as Cable II. Historically, silicone primary insulation has performed adequately for the required sustained electrical load. Therefore, no insulation tests were performed for qualification. Finished cable tests listed under section F, on P. 10 and P. 11 were performed on Cables I and II for comparison. The small 16 AWG component failed the ambient bend test as in Cable I. Again, this component is not mobile as evidenced by fraying of glass fiber covering. The weight and diameter differential is as follows:

	WEIGHT/100 FEET		PERCENT* REDUCTION		DIAMETER	
	CALCULATED	ACTUAL	CALC.	ACTUAL	CALCULATED	ACTUAL
CABLE I TPE/URETHANE	139.7	155.6	29	24	1.320	1.340
CABLE II SILICONE/URETHANE	166.2	163.0	16	21	1.430	1.450
CABLE III SILICONE/NEOPRENE	197.1	206.0	--	--	1.650	1.690

FIRE TESTS: All Cables I, II and III met the requirements of IEEE-383 Tray Fire Test at the 70,000 BTU/Hr. input. A complete summary is given on Page 18 & 19.

* BASED UPON CABLE III.

FIGURE 1
CABLE I
1.320" OUTSIDE DIAMETER

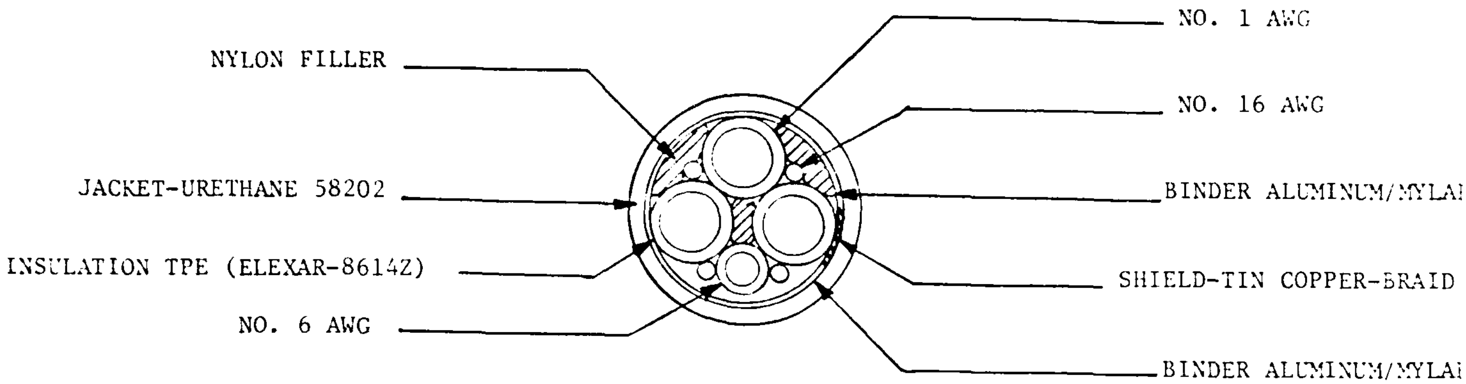


FIGURE 2
CABLE II
1.430" OUTSIDE DIAMETER

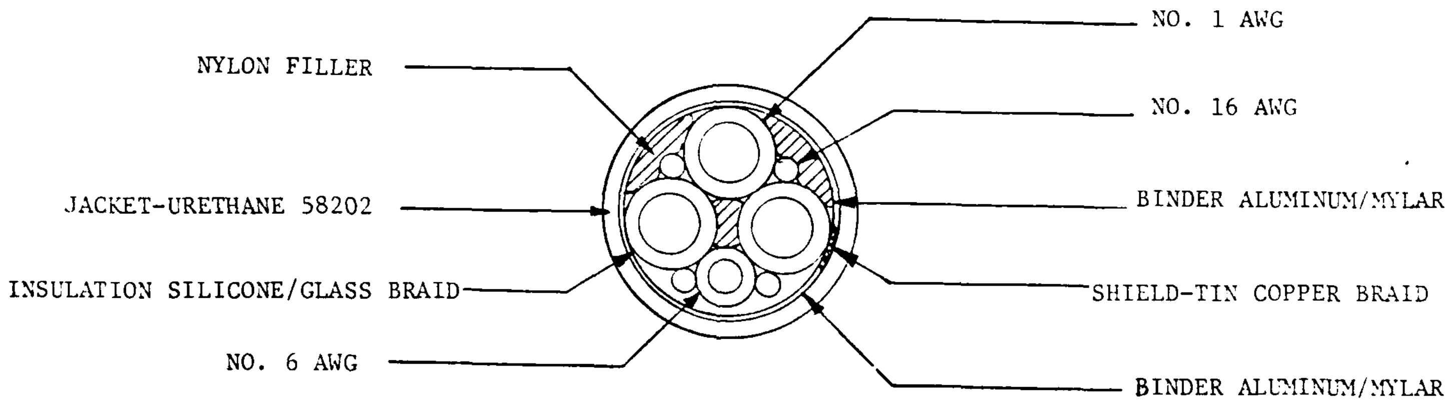
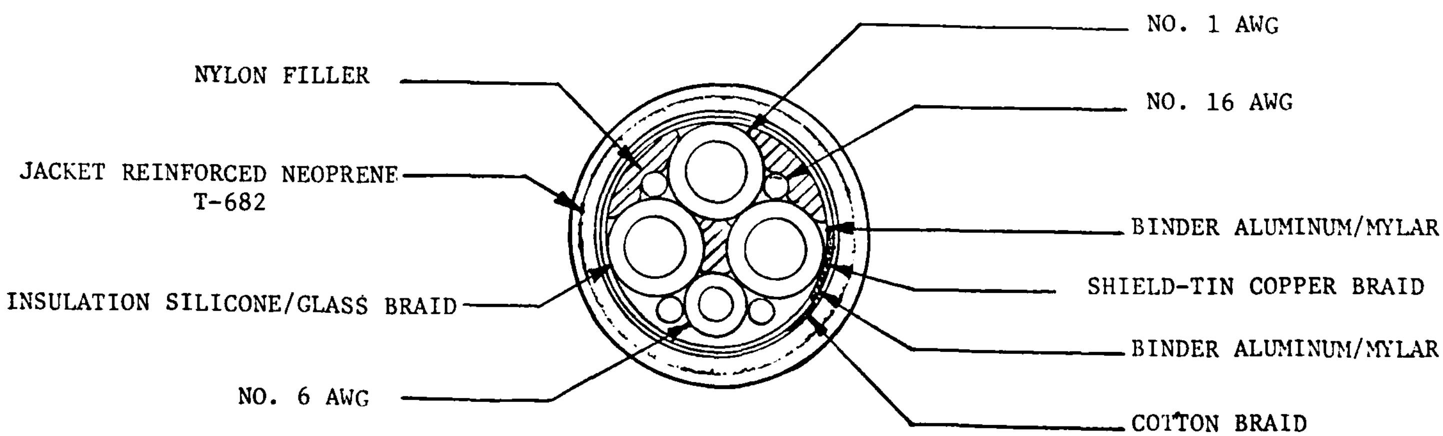


FIGURE 3
CABLE III
1.650" OUTSIDE DIAMETER



QUALIFICATION TESTS - COMPLETED CABLE

		REQUIRED	RESULT
	A. CONDUCTOR Per MIL-C-13777 & 13222E8995		
	1 AWG OD (IN.)	.365	.365
	DCR (Ω/1000')	.154 Max.	.128
	CMA	81,700 Nom.	88,709
	6 AWG OD (IN.)	.210	.211
	DCR (Ω/1000')	.445 Max.	.376
	CMA	26,818 Nom.	30,073
	16 AWG OD (IN.)	.057	.056
	DCR (Ω/1000')	4.81 Max.	4.45
	CMA	2,426 Nom.	2,577
	B. INSULATION Per MIL-W-16878/8 (Elexar 8614Z)		
4.6.14	Tensile Strength Method 3021 FED-STD-228 (PSI)	700 Min.	1400-1834
4.6.15	Elongation Method 3031 FED-STD-228 (%)	125 Min.	100-458
	C. INSULATED WIRE Per MIL-W-16878/8 (Elexar 8614Z)		
4.6.2.1	Spark Test Method 6211 FED-STD-228 (Kv)	5	PASS
4.6.3	Dielectric Strength 2 Hr/25°C	3 Kv-1 Minute	PASS
4.6.4	Insulation Resistance 2 Hr/25°C		
	Method 6031 FED-STD-228 (M Ω-1000')	500 Min.	190,000-409,000
4.6.10	Heat Resistance 3 X Diameter Mandrel		
	96 Hr/180°C	3 Kv-1 Minute	FAIL Softens
	96 Hr/150°C	3 Kv-1 Minute	PASS
	Shrinkage (IN.)	1/8 Max.	0-1/8
4.6.6	Cold Bend Method 2011 FED-STD-228		
	4 Hrs/-45°C	3 Kv-1 Minute	PASS
4.6.12	Solder Shrinkage Method 8231		
	FED-STD-228 Immerse 600°F (IN.)	1/8 Max.	0
4.6.11	Flammability 60° 30 Sec. Appl.		
	(Seconds Afterburn)	30 Max.	0
	(Inches Travel)	3 Max.	1.25 - 1.75
4.6.8	Surface Resistance Method 6041		
	FED-STD-228 96 Hr/25°C/95% R.H. (Ω)	5 Min.	23,000 - 500,000

		REQUIRED	RESULT
	D. CODING MATERIAL Per MIL-C-13777		
	Stripe Durability and Stripe Conductivity	N/A - All Solid Colors	
	E. SHEATH Per MIL-C-13777 (Estane 58202)		
4.5.3.1.1	Tension Set Method 4411		
	FED-STD-601 2-6 (IN.)	3/8 (Max.)	3/16-1/8
4.5.3.1.2	Ultimate Elongation Method 3031		
	FED-STD-228 (%)	300 (Min.)	716
4.5.3.1.3	Tensile Strength Method 3021		
	FED-STD-228 (PSI)	1800 (Min.)	2920
4.5.3.1.4	Tear Strength Method 3011		
	FED-STD-228 (#/IN.)	20 (Min.)	100
4.5.3.2	Accelerated Aging Method 4011		
	FED-STD-228 94 Hrs./70°C/$O_2$300 PSI 18 Hrs./121°C		
	Tensile Strength (PSI)	1600 (Min.)	2788
	Ultimate Elongation (%)	250 (Min.)	700
4.5.3.3	Oil Resistance Method 4221		
	FED-STD-228		
	Tensile Strength Retention (%)	60 (Min.)	94.7
	Elongation Retention (%)	60 (Min.)	110.4
4.5.2.4	Marking Durability .025" Diameter		
	Mandrel 500 G.M. (Cycles)	250 (Min.)	PASS at 250

	F. CABLE Per MIL-C-13777		CABLE I	CABLE II
4.5.4.1.1	Impact (6 Specimens) 48 Hrs/71°C (Cycles)	200	PASS	PASS
	48-Hrs/-45°C (Cycles)	100	PASS	PASS
4.5.4.1.1	Bend (3 Specimens) 48 Hrs/71°C (Cycles)	2000	260-1500*	300-1500*
	48-Hrs/-45°C (Cycles)	1000	PASS	PASS

	F. CABLE Per MIL-C-13777 (Cont'd.):	REQUIRED	RESULT CABLE I	RESULT CABLE II
$.%.$.L.L	Twist (3 Specimens) 48 Hrs/71°C	2000	260-704*	PASS
	48-Hrs/-45°C (Cycles)	1000	PASS	PASS
4.5.4.2.2	Voltage Test 60 H_2, 400 H_2 1 Min. (Volts)	2000	PASS	PASS
4.5.4.2.3	Insulation Resistance Method 6031			
	FED-STD-228 200 V Min.	See Part C	CONFORMS	CONFORMS
4.5.4.1.3	Cold Bend Torque 71°C/48 Hrs.			
	48-Hrs/-54°C 8.4" Diameter	N/A**	53 Ft.#	67 Ft.#
4.5.4.1.4	Ozone Resistance 11.2" Diameter Mandrel			
	ASTM-D-1149-64 (1970) (7 Days .5 RPM) 50°C	No Cracks	PASS	PASS

* In each case the cable failure resulted from loss in electrical continuity in the 16 AWG component. The conductor itself fractured without insulation or jacket failure (See Photo Page 11a). Restrictions in slippage of this component in the flex tests impairs movement and build-up of stress occurs when the surface friction is higher at the high test temerature. Variation on bend cycle failure - most failures occur on components in the proximity of the filler opposed to those next to the No. 6 AWG component. The position of these components on the mandrel is random in the test allowing variation in the results. The filler allows mobility of the No. 16 AWG wires out of position, whereas the No. 6 wire firms the position of the small components.

** No specification sheet for this construction in MIL-C-13777.

CONCLUSIONS AND RECOMMENDATIONS:

If the power cable operates at full ampacity beyond thirty (30) minutes at an ambient of 71°C, high temperature silicone insulation is adequate for the application and should continue to be used. Heat resistance of TPE is inadequate at the operating temperature examined in the tests.

Failure of the 16 AWG component is probably due to improper slippage surface to surface. Additional saturant on the silicone glass construction will improve this condition. A shorter lay length will also improve the situation, however, an increase in cable size could result and increase the weight. Additionally, the use of a strength member in the AWG #16 component may solve the failure problem in the bend test.

Urethane sheath material should be considered as a replacement of neoprene to reduce size and weight. Urethane exhibits superior properties over neoprene in most categories and the cost differential should not be significant.

FUTURE WORK:

Additional thermal load tests should be made to evaluate the effect of continuous service temperatures on the sheath material. The reduction of the wall on the cable reduces the thermal resistance and should improve the heat transfer rate, conductor to atmosphere. Another future project of interest would be to develop a silicone insulation with improved physical properties. This would allow a reduction of the wall thickness in the primary insulation and give a possible future weight saving.

TABLE 2
WEIGHT COMPARISON - SILICONE REPLACED WITH
FLUOROPOLYMER AT REDUCED WALL

CABLE COMPONENT	SILICONE	FEP	HALAR
	WEIGHT #/1,000 FT.		
I (X3)	1030.29	995.29	921.33
II (X1)	120.62	109.21	103.95
III (X4)	56.36	48.28	44.44
FILLERS, TAPES & SHIELD	228.00	214.60	214.60
NEOPRENE JACKET	611.79	452.80	452.80
TOTAL	2047.06	1780.18	1737.12
#/FT.	2.04	1.78	1.74
% LOSS	-	12.7	15.1

TABLE 3
WEIGHT COMPARISON - SILICONE REPLACED WITH
FLUOROPOLYMER AT REDUCED WALL PLUS NEOPRENE REPLACED WITH TPE

CABLE COMPONENT	SILICONE	FEP	HALAR
	WEIGHT #/1,000 FT.		
I (X3)	1030.29	955.29	921.33
II (X1)	120.62	109.21	103.95
III (X4)	56.36	48.28	44.44
FILLERS, TAPES & SHIELD	228.00	214.60	214.60
TPR JACKET	538.74	406.50	406.50
TOTAL	1974.01	1733.88	1690.82
#/FT.	1.97	1.73	1.69
% LOSS	3.5	15.3	17.4

TABLE 4
WEIGHT COMPARISON - SILICONE REPLACED WITH
FOAM FLUOROPOLYMER

CABLE COMPONENT	SILICONE	FOAMED FEP	FOAMED HALAR
	WEIGHT #/1,000 FT.		
I (X3)	1030.29	952.44	936.54
II (X1)	120.62	107.28	104.96
III (X4)	56.36	45.33	43.80
FILLERS, TAPES & SHIELD	228.00	228.00	228.00
NEOPRENE JACKET	611.79	611.79	611.79
TOTAL	2047.06	1944.84	1925.09
#/FT.	2.04	1.94	1.92
% LOSS	-	5.0	6.0

TABLE 5
WEIGHT COMPARISON - SILICONE REPLACED WITH
FOAM FLUOROPOLYMER PLUS NEOPRENE REPLACED WITH TPE

CABLE COMPONENT	SILICONE	FOAMED FEP	FOAMED HALAR
	WEIGHT #/1,000 FT.		
I (X3)	1030.29	952.44	936.54
II (X1)	120.62	107.28	104.96
III (X4)	56.36	45.33	43.80
FILLERS, TAPES & SHIELD	228.00	228.00	228.00
TPR JACKET	538.74	538.74	538.74
TOTAL	1974.01	1871.79	1852.04
#/FT.	1.97	1.87	1.85
% LOSS	3.5	8.6	9.5

TABLE 6
WEIGHT COMPARISON - SILICONE REPLACED WITH
FOAM FLUOROPOLYMER (REDUCED WALL)

CABLE COMPONENT	SILICONE	FOAMED FEP	FOAMED HALAR
	WEIGHT #/1,000 FT.		
I (X3)	1030.29	876.12	868.69
II (X1)	120.62	96.87	95.71
III (X4)	56.36	45.08	43.72
FILLERS,TAPES & SHIELD	228.00	214.60	214.60
NEOPRENE JACKET	611.79	442.60	442.60
TOTAL	2047.06	1675.47	1665.32
#/FT.	2.04	1.68	1.66
% LOSS	-	18.1	18.6

TABLE 7
WEIGHT COMPARISON - SILICONE REPLACED WITH
FOAMED FLUOROPOLYMER (REDUCED WALL) PLUS NEOPRENE REPLACED WITH TPE

CABLE COMPONENT	SILICONE	FOAMED FEP	FOAMED HALAR
	WEIGHT #/1,000 FT.		
I (X3)	1030.29	876.12	868.69
II (X1)	120.62	96.87	95.71
III (X4)	56.36	45.08	43.72
FILLERS, TAPES AND SHIELD	228.00	214.60	214.60
TPR JACKET	538.74	396.30	396.30
TOTAL	1974.01	1628.97	1619.02
#/FT.	1.97	1.62	1.62
% LOSS	3.5	20.4	20.9

TABLE 8
PERFORMANCE DATA - EXPANDED ECTFE (HALAR 505)

TENSILE STRENGTH	1639 PSI
ULTIMATE ELONGATION	50 %
SPARK TEST AT 3 Kv	PASS
4 Kv	PASS
5 Kv	FAIL
DIELECTRIC WITHSTAND	3.2 Kv/1 Minute

TABLE 9
PERFORMANCE COMPARISON - NEOPRENE AND TPE (ELEXAR 8614Z)

	ELEXAR 8614Z		NEOPRENE (T-682)*	
TENSILE STRENGTH (PSI)		2498		2398
ELONGATION (%)		550		317
TENSION SET (INCHES)		1-7/16		1/16
TEAR STRENGTH (#/INCHES)		36.1		17.5
OXYGEN INDEX (%)		32.0		27.8
ACCELERATED AGING (% RETENTION)				
TENSILE		80		80
ELONGATION		91		100
OIL RESISTANCE (% RETENTION)	FED.STD.	UL	FED.STD.	UL
TENSILE	55	80	100	100
ELONGATION	36	100	81	90

* Brand-Rex Designation for Artic Neoprene.

TABLE 10
PERFORMANCE COMPARISON - NEOPRENE AND TPE (SANTOPRENE COMPOUNDS)

	NEOPRENE	SANTOPRENE		
	T-682	201-73	201-80	201-87
TENSILE STRENGTH (PSI)	2173	1011	1224	1766
ELONGATION (%)	300	117	92	384
OIL RESISTANCE (% RETENTION)				
TENSILE	99	83	103	82
ELONGATION	92	100	90	52
TENSION SET (INCHES)	1/16	1-3/4	1-1/2	1-1/16
TEAR STRENGTH (#/INCHES)	20.5	17.1	26.2	48.6
OXYGEN INDEX	27.9	21.1	20.7	19.3
ACCELERATED AGING (% RETENTION)				
TENSILE	92	89	99	102
ELONGATION	117	64	82	104

TABLE 11
PERFORMANCE DATA & FORMULARITY - SANTOPRENE 200-87

MATERIALS:	COMPOUND 3L-7A	3L-7B	3L-7C
SANTOPRENE 200-87	66.5	59.5	51.5
ANTIMONY OXIDE	10.0	12.0	15.0
DECHLORANE +25	20.0	25.0	30.0
IRGANOX 1010	1.5	1.5	1.5
CYANOX LTDP	1.0	1.0	1.0
ZINC OXIDE	1.0	1.0	1.0
TOTAL	100.0	100.0	100.0
SPECIFIC GRAVITY (CALCULATED) GM/CC	1.18	1.24	1.33
SPECIFIC GRAVITY (MEASURED) GM/CC	1.14	1.21	1.31
OXYGEN INDEX	22.6	24.7	27.2

TABLE 12
PERFORMANCE DATA & FORMULARITY - KRATON G

MATERIALS:	COMPOUND 3L-8A	3L-8B	3L-8C	3L-8D
KRATON-G	62.0	42.0	39.0	32.0
POLYETHYLENE EVA	31.0	21.7	18.7	16.7
CYANOX LTDP	1.0	1.0	1.0	1.0
IRGANOX 1010	1.3	1.3	1.3	1.3
TMPTMA (X-LINKER)	3.7	3.0	3.0	3.0
AGE RITE RESIN - D	1.0	1.0	1.0	1.0
ANTIMONY OXIDE	-	10.0	12.0	15.0
DECHLORANE +25	-	20.0	24.0	30.0
TOTAL	100.0	100.0	100.0	100.0
OXYGEN INDEX (%)	19.2	25.2	27.0	30.1
TENSILE STRENGTH (PSI)	2206	1603	1640	1218
ULTIMATE ELONGATION (%)	558	525	500	458
OIL RESISTANCE (% RETENTION)				
TENSILE	21	18	20	25
ELONGATION	103	106	103	109
TENSION SET (INCHES)	5/16	8/16	9/16	10/16
TEAR STRENGTH (#/INCHES)	48.8	41.5	37.2	35.9
ACCELERATED AGING (% RETENTION)				
TENSILE	102	102	104	101
ELONGATION	98	90	92	89
SPECIFIC GRAVITY (GM/CC)	.94	1.12	1.17	1.24

TABLE 13
PERFORMANCE COMPARISON - ACRYLIC ELASTOMER (VAMAC) AND SILICONE RUBBER

	VAMAC N-123	SILICONE RUBBER
TENSILE STRENGTH (PSI)	1675	1350
ULTIMATE ELONGATION (%)	550	375
HEAT AGING 7 DAYS/200°C (% RETENTION) OF ELONG.	54	66
4 DAYS/250°C (% RETENTION) OF ELONG.	14	40
TEAR RESISTANCE (#/INCHES)	225	130

TABLE 14

PERFORMANCE COMPARISON - NEOPRENE AND POLYURETHANE (SLAB ANALYSIS)

PROPERTY	NEOPRENE T-682	ESTANE 58890	ESTANE 58202
TENSILE STRENGTH (PSI)	2168	2533	3652
ELONGATION (%)	300	600	671
OIL RESISTANCE (% RETENTION)			
TENSILE	100	86	78
ELONGATION	95	101	103
TENSION SET (INCHES)	1/16	7/16	6/16
TEAR STRENGTH (#/INCHES)	19.5	94.5	116.2
OXYGEN INDEX (%)	27.6	31.5	31.0
ACCELERATED AGING (% RETENTION)			
TENSILE	87	85	87
ELONGATION	100	106	98

BRAND-REX COMPANY
GAS BURNER TRAY FLAME TEST

SAMPLE: CABLE I DATE: 9/20/82

70,000 BTU FLAME TEST

Burning Characteristics		
Time Min.	Temperature °F	Flame Height Ft.
1	1500	2.0
2	1525	3.5
3	1525	4.0
4	1500	3.0
5	1525	2.5
6	1550	2.5
7	1525	2.0
8	1500	2.0
9	1525	2.0
10	1500	2.0
11	1500	2.0
12	1525	1.5
13	1500	1.5
14	1500	1.5
15	1500	1.5
16	1525	1.5
17	1500	1.5
18	1525	2.5
19	1500	2.0
20	1500	1.5

Time To Ignition: 0 Seconds

Maximum Flame Height: 4.0 Ft.

Flame Type (Even or Uneven): Even

Afterburn Characteristics

Time of Afterburn: 2.0 Min.

Maximum Jacket Char. Height: 37"

Maximum Insulation Char. Height: 20"

ENERGY USED

	Pressure In. of H_2O	Flow SCFH
Air	1.6	147.5
Propane	.4	29.5

2508 BTU/CU FT X 29.5 SCFH PROPANE= 73,986 BTU/HR

Start 39.375

Finish 38.250

Used 1.125

21671 BTU/HR X $\frac{1.125 \text{ Lb.}}{20 \text{ Min.}}$ X 60 Min= 73,139 BTU/HR

Test performed on unaged samples in accordance with IEEE STD 383-1974, Para. 2.5 as modified by Regulatory Guide 1.131.

Number of cables in tray: 4 (1 Layer)

Cable description:

Tested By : 23

Page 1 of 1

BRAND-REX COMPANY
GAS BURNER TRAY FLAME TEST

SAMPLE: CABLE II DATE: 9/21/82

70,000 BTU FLAME TEST

Burning Characteristics		
Time Min.	Temperature °F	Flame Height Ft.
1	1500	2.5
2	1525	2.5
3	1500	3.5
4	1500	3.0
5	1500	3.0
6	1450	3.0
7	1475	3.5
8	1500	2.5
9	1525	2.5
10	1500	2.5
11	1500	3.0
12	1500	3.5
13	1550	3.0
14	1550	2.5
15	1500	2.0
16	1500	2.0
17	1550	2.0
18	1525	2.0
19	1500	2.0
20	1500	2.0

Time To Ignition: 0 Seconds

Maximum Flame Height: 3.5 Ft.

Flame Type (Even or Uneven): Even

Afterburn Characteristics

Time of Afterburn: 90 Seconds

Maximum Jacket Char. Height: 4 Ft. 1"

Maximum Insulation Char. Height: 27"

ENERGY USED

	Pressure In. of H_2O	Flow SCFH
Air	1.6	147.5
Propane	.4	29.5

2508 BTU/CU FT X 29.5 SCFH PROPANE= 73,986 BTU/HR

Test performed on unaged samples in accordance with IEEE STD 383-1974, Para. 2.5 as modified by Regulatory Guide 1.131.

Start 33,750

Finish 32,625

Used 1.125

$$21671 \text{ BTU/HR} \times \frac{1.125 \text{ Lb.}}{20 \text{ Min.}} \times 60 \text{ Min} = 73,140 \text{ BTU/HR}$$

Number of cables in tray: 4 (1 Layer)

Cable description:

NOTE: Cable has dripping, burning particles @ 4 Minutes Into Test.

Test witnessed by Bill Wood. Pictures taken of test.

Tested By : 4

Page 1 of 1

REFERENCE ELEXAR COMPOUNDS

	Test Method	Conditions	Units	Specimen Type*	Grade 8431Z	8421Z	8712Z	8313Z	8623Z	8614Z	8821Z
I. General Properties											
Density	Calculated	–	gm/cc		0.91	0.99	1.10	1.29	1.16	1.17	1.00
Specific Gravity	Air Pycnometer	Room Temp	Ratio range	IM	0.885-0.915	0.965-0.995	1.085-1.115		1.14-1.17	1.17-1.20	0.97-1.00
Hardness	ASTM D2240 Durometer	23°C, 10 sec	Shore A/D	IM	A67±5	A89±5	A65±5	D52	A95±2	A95±2	A86±2
Melt Flow	ASTM D1238	Condition G	gm/10 min	Nibs	7±3	18±4	6±3	-	3±2	3.5±1.5	-
Color	Visual	—		Nibs	translucent	translucent	Lt Gray	Lt Gray	White	White	White
Physical Form	Visual	—	Pellet size	Cut Strand	Nom ¼"	Nom ¼"	Nom ¼"	Nom ¼"	Nom ¼"	Nom ¼"	Nom ¼"
II. Strength/Mechanical Abuse											
Properties @ 25°C											
Tensile Strength at Break	UL 62		psi(MPa)	WI(18-20/30)	2700(18.6)	2100(14.5)	1600(11.0)	3750(25.9)*	2450(16.9)	2300(15.9)	2600(17.9)
100% Modulus			psi(MPa)	IM, WI	400(2.8)	850(5.9)	355(2.4)	2085(14.4)	1100(7.6)	1050(7.2)	
Tensile Modulus			psi(MPa)	IM, WI	600(4.1)	1200(8.3)		2675(18.4)	1650(11.4)	1450(10.0)	
Elongation at Break	UL 62		%	WI(18-20/30)	675	600	650	540	530	500	510
Tear Strength	ASTM D624	Die C	lb/in(kg/cm)	IM, 1/8 flow	275(49)	470(84)	190(34)	570(102)	450(81)	380(69)	300(53)
Abrasion Resistance	MIL T-5438	SAE J1128,	inches of tape	WI(18/30)	—	—	—		66/54		—
		1 lb wt	raw ave (adj. ave)	WI(20/30)	-	-	—		57/54	50/48	—
	MIL T-5438	SAE J1128,	inches of tape	WI(14/30)	-	65/48	—		—	-	—
		3 lb wt	raw ave (adj. ave)		*23 mil wall						
III. Environmental Properties											
A. Thermoxidative/Thermal											
Aging at 136°C	Air circulating	7 days on bare copper	% retention, T_B/E_B	WI(14/45)	95/100	98/96	100/100		-	100/77	
Aging at 136°C	Air circulating	90 days on bare copper	% retention, T_B/E_B	WI(18-20/30)	100/67	100/78	—		90/80	96/70	
Aging at 158°C	Air circulating	7 days on bare copper	% retention, T_B/E_B	WI(18-20/30)	100/100	91/81	100/98		68/70	75/56	
Oxygen Bomb	ASTM D572	150 hrs, 80°C, 300 psi	% retention, T_B/E_B	IM	100/90	100/90	100/100(J)		95/90	95/90	
	ASTM D572	300 hrs, 80°C, 300 psi	% retention, T_B/E_B	IM	83/83	96/91	—		97/91	98/91	
Air Bomb	UL Subj. 758	52 hrs, 127°C, 80 psi	% retention, T_B/E_B	WI(20/30)	—		—		95/93	94/87	
		42 hrs, 127°C, 80 psi	% retention, T_B/E_B	IM	100/100	90/80 87/74(WI)	75/94(J)		—	—	
Conductor Corrosion	Visual	After aging 158°C	--	WI	none	none	none		none	none	
Deformation	UL 44/62/83	121°C, 500gm	% initial	WI(14/45)	0.89	1.00	0.91		—	-	—
		121°C, 400gm	wall	WI(18/30)	0.71	0.83	—		—	--	-
		121°C, 2000gm	retained	J, IM	0.96	0.99	—		—	—	-
		158°C, 500gm		WI(18-20/30)	—	—	—	0.89	0.70	0.70	0.85
B. Cold Temperature Properties											
Mandrel Bend	UL type	1" Mandrel	min. passing temp., °C	WI(14/80)	-75°C	—	-75°C	—	—	-	—
	UL 62	2×OD Mandrel	min. passing temp., °C	WI(18/30)		—	-	—	—	-80°C	—
Impact Resistance	Falling weight	Flat impact surface ¼" mandrel	Passing temp., °C/ft lb impact	WI(14/80)	51°C/40	—	--	—	—	--	--
				WI(20/100)	--	--	-50/.25	—	—	--	—
Brittleness	ASTM D746		50% failure temp., °C	IM	100	-86	-60(J)	—	-56	-50	—
Torsional Stiffness	MIL-I-3930	23°C/-54°C	23°C Angle	IM, T-50 die cut specimens	86	25.3			7.7	8.3	
			23°C TS Factor		1.09	6.14			22.6	20.7	
			-54°C Angle		70	10.0			5.7	5.3	
			-54°C TS Factor		1.56	17.5			31.0	33.0	
			TS Ratio (-54°C/23°C)		1.45	2.83			1.38	1.59	
C. Use and Life Temperature											
Operating Range											
Static	--	Cold Bend, Aging & Deformation	Temperature Range	WI, J	-75°C/105°C	-/105°C	-75°C/105°C		-/125°C	-80°C/125°C	
Dynamic		Cold Impact, Aging & Deformation	Temperature Range	WI, J	51°C/105°C	-/105°C	-50°C/105°C		-/125°C	125°C	
Thermal Rating	UL Rating [illegible]	Retention of T_B, E_B in 90 day		WI	125°C	125°C	125°C		125°C	[illegible]	

136°C & 7 day, 158°C Aging

D. Flame Resistance											
Limiting Oxygen Index	ASTM D2863		L.O.I.	WI (tube)	18	18	21.5	24	24	32	17.7
VW-1	UL 62	Vertical wire flame	Pass/Fail	WI(4 [illegible])	F	F	P		P	P	F
VW-1	UL 62	Vertical wire flame	Pass/Fail	WI(20 30)	F	F	F		F	P	F
CSA	C 22.2 No. 0.3	Vertical wire flame	Pass/Fail	WI(20 30)	F	F	F	P	P	P	F
Horizontal Burn	UL Subj. 758 (AWM)	Horizontal wire (rate)	Pass/Fail	WI(18 20 30)	F	F	F		P	P	F
Horizontal Burn	UL Subj. 758 (AWM)	Horizontal wire (rate)	Pass/Fail	WI(14 30)	F	F	P		P	P	F
Horizontal Burn	UL 44	Horizontal wire (distance)	Pass/Fail	WI(14 30)	F	F	F		P	P	F
Horizontal Burn	SAE J1128	Horizontal wire (time)	Pass/Fail	WI(18 23 30)	F	F	F	P	P	P	F
E. Resistance to Solvents, Fluids, Water & Oil											
Moisture Absorption	ASTM D570	7 days 80°C	mg/in²	IM	2.1	1.7	1.2(J)		[illegible]	3.3	
		24 hrs 80°C			0.6	1.0	–		1.4	1.5	
Stress Cracking	ASTM D1693	90 days 10% Igepal rm temp	Cracking	IM	none	none	–		none	none	
	ASTM D1693	21 days 100% Igepal 100°C	Cracking	IM	none	none			none	none	
	ASTM D1693	21 days 50% Igepal 50°C	Cracking	IM	none	none			none	none	
ASTM #2 Oil Aging	UL 62	7 days 60°C	% retention T_B E_B	WI(18 30)	45/85	90/98	53/81(J)		–	93/100	
	UL 83	4 days 100°C	% retention T_B E_B	WI(18 30)	–	66/70	–			80/100	
	UL 83	60 days 75°C	% retention T_B E_B	WI(14 30)					77/95		
Brake Fluid	ASTM D471	72 hrs 100°C	% retention T_B E_B % vol inc	IM	95/95/–15	80/90/7			85/90/4	80/[illegible]/3	
Ethylene glycol	ASTM D471	72 hrs 100°C	% retention T_B E_B % vol inc	IM	55/60/3	95/90/2			90/90/2	9[illegible]/4	
Methanol	ASTM D471	[illegible] 100°C	% retention T_B E_B % vol inc	IM	75/90/3	95/90/0			90/[illegible]/3	[illegible]/0	
Silicone Oil	ASTM D471	72 hrs 100°C	% retention T_B E_B % vol inc	IM	100/100/5	100/80/14			95/8[illegible]/8	10[illegible]/85/7	
5% Salt Water	ASTM D471	72 hrs 100°C	% retention T_B E_B % vol inc	IM	100/85/2	80/100/1			90/80/0	9[illegible]/2	
Vegetable Oil	ASTM D471	18 hrs 121°C	% retention T_B E_B % vol inc	IM	40/65	60/70			70/70	65/6[illegible]	
Animal Fat	ASTM D471	18 hrs 121°C	% retention T_B E_B % vol inc	IM	40/95	70/75			70/7[illegible]	70/60	
10W 40 Motor Oil	ASTM D471	72 hrs 100°C	% retention T_B E_B % vol inc	IM	20/40/90	50/55/25	13/38/+96(J)		60/40/20	60/5[illegible]/18	
Gasoline	ASTM D471	Refluxing	% retention T_B E_B % vol inc	IM	20/10/16	40/35/17	12/18/+28(J)		40/2[illegible]/24	40/2[illegible]/23	
Transmission Oil	ASTM D471	72 hrs 100°C	% retention T_B/E_B/% vol inc	IM	15/60/100	50/50/32	12/34/+109(J)		55/60/23	55/40/25	
F. Ozone/Weathering											
Ozone Resistance	ASTM D1171	150 pphm, 60°C, 1000 hrs	Cracking	IM	none	none	none	–	none	none	–
U.V. Stability											
Weatherometer	UL 62	720 exposure hrs	% retention T_B E_B	J	80/100**	U.V. absorber and/or carbon black pigment recommended for outdoor exposure and use; consult your Shell Chemical Sales representative for information.					
Florida Exposure	—	5° South, 1 yr.	% retention T_B/E_B	IM	100/100**						
IV. Electrical Properties											
Dielectric Constant @ 25°C	ASTM D150	60 HZ	Ratio	IM	2.1	2.4			2.7	2.8	2.35
		1 KHZ	Ratio	IM	2.1	2.4			2.7	2.8	2.35
		1 MHZ	Ratio	IM	2.1	2.3			2.3	2.3	2.35
Dissipation Factor @ 25°C	ASTM D150	60 HZ	Loss angle tangent	IM	< 0.0001	0.0008			0.002	0.002	0.002
		1 KHZ	Loss angle tangent	IM	< 0.0001	0.0008			0.002	0.002	0.003
		1 MHZ	Loss angle tangent	IM	< 0.0001	0.0005			0.004	0.005	0.01
Dielectric Strength	ASTM D149	Short time	V/mil	IM	[illegible]	660			650	625	
Volume Resistivity	ASTM D257	500 V.D.C.	Ohm-cm	IM	9.1×10^{16}	3.5×10^{16}			2.6×10^{16}	2.2×10^{16}	9×10^{15}
Surface Resistivity	ASTM D257	500 V.D.C.	Ohm	IM	9.5×10^{16}	6.2×10^{16}			3.5×10^{16}	3.5×10^{16}	2×10^{16}
Insulation Resistance	UL/IPCEA	After 23 hrs. in H_2O at rm. temp., 1 hr., 15.6°C	Megohms/1000 feet	WI(14/30 47)	1×10^{6}	9×10^{4}			2.1×10^{6}	4.5×10^{5}	7.5×10^{4}(22°C)
Insulation Resistance Constant	UL/IPCEA	15.6°C 500 V.D.C.	—	WI(14/30 47)	2.5×10^{6}	2.3×10^{6}			6.8×10^{4}	1.2×10^{6}	2.5×10^{4}(22°C)
EM 60	IPCEA S-19-81	75°C water									
SIC	IPCEA S-19-81	At 75°C 80 V/mil, 1 day		WI(14 30 47)	2.22						2.6
Capacitance Increase	IPCEA S-19-81	1-14 days, 80 V/mil	%	WI(14 30 47)	1.21						0.5
Power Factor	IPCEA S-19-81	At 14 days, 80 V/mil	%	WI(14 30 47)	0.19						0.44
Stability Factor	IPCEA S-19-81	At 14 days	Power Factor Difference, %	WI(14 30 47)	0.15						0.04

*IM – Injection Molded Plaque

WI = Wire Insulation. Numbers in parenthesis are gauge size/wall thickness

J = Specimen taken from jacket or jacketed cable specimen

**U.V. Stabilized grades

Estane Polyurethanes

Product Data

ESTANE 58202-021

Flame Retarded Thermoplastic

Poly (Ether) Urethane

	Typical Properties	ASTM Test Procedure
Tensile, psi	4700	D412
100% Modulus, psi	850	
300% Modulus, psi	1350	
Elongation, %	570	
Graves Tear, pli	370	D624
Crescent Tear, pli	460	D624
Hardness, A-C-D	87-58-41	D2240
Taber Abrasion, mgm loss		
CS-17 wheel, 1000 gm, 1000 cycles	6.2	
Vicat B, °C	94	D1525
Brittleness Temp - Below	-70°C	D746
Gehman RT Modulus	1250	D1053
T_2	-15°C	
T_5	-31°C	
T_{10}	-37°C	
T_{50}	-51°C	
T_{100}	----	
Freeze Point	-51°C	
Compression Set, 22 hours, RT	23%	D395
Compression Set, 22 hours, 70°C	66%	
Specific Gravity	1.226	
**UL Vertical 94 Flame Test	V-0	

The BFGoodrich Company, Chemical Group/6100 Oak Tree Blvd., Cleveland, Ohio 44131

BFGoodrich Chemical Group

GLOSSARY

BLOCK CO-POLYMER

Regular, repeating segments of different monomers in a polymer chain.

ECTFE

(Ethylene Chlorotrifluoroethylene) - A class of fluoropolymer material used for insulation. Reference Halar 505.

ELASTOMER

Natural or synthetic polymers with elastic or rubbery properties.

ETHYLENE ACRYLIC ELASTOMER

Copolymer of ethylene and methyl acrylate plus a cure site monomer. Used in applications where heat resistance, oil resistance and low temperature are needed. Reference Vamac.

FLUOROPOLYMER

Paraffinic structured polymers with fluorine atom in place of hydrogen. Notably teflon.

POLYCHLOROPRENE

(Neoprene) - Synthetic elastomeric material. Vulkanized by heat to crosslink. T-682 Neoprene is a Brand-Rex compounded low temperature material.

POLYURETHANE

Urethane polymer formed from isocyanates. Considered as a TPE. Most frequently used as a jacket material.

SILICONE

Semiorganic polymer with elastomeric properties. Vulcanized by heat to crosslink.

TPE

(Thermoplastic Elastomer) - Polymers having elastomeric properties. Used as thermoplastics - melt formed by heat.

CABLE TECHNOLOGY LABORATORIES, INC.

REPORT

THERMAL PERFORMANCE OF

PATRIOT MISSILE CABLE

INVESTIGATION PERFORMED FOR

BRAND-REX COMPANY

WILLIMANTIC, CONNECTICUT

Report No. 82-012 Composed of Eight (8) pages Order No. 57891 dated 4/19/82 New Brunswick, May 24, of 1982	Main Investigator(s) J. Dyndul Approved by: C. Katz

Triangle Road off Jersey Avenue — P.O. Box 707 — Telex 844426
New Brunswick, N.J. 08903 Tel. (201) 745-5600

THERMAL PERFORMANCE OF PATRIOT MISSILE CABLE

PURPOSE

To report the results of tests performed to determine the temperature rise of cables manufactured in accordance with MIS-20076/1 subjected to maximum specified current carrying capacity when operating in an environment of 71°C.

CABLE DESCRIPTION

Flexible power cable utilized for distribution of energy and control consisting of:

(a) Three (3) #1 AWG conductor made of #30 AWG tin coated copper strands.

(b) One (1) #6 AWG conductor made of #27 AWG tin coated copper strands.

(c) Four (4) #16 AWG conductor made of #29 AWG tin coated copper strands.

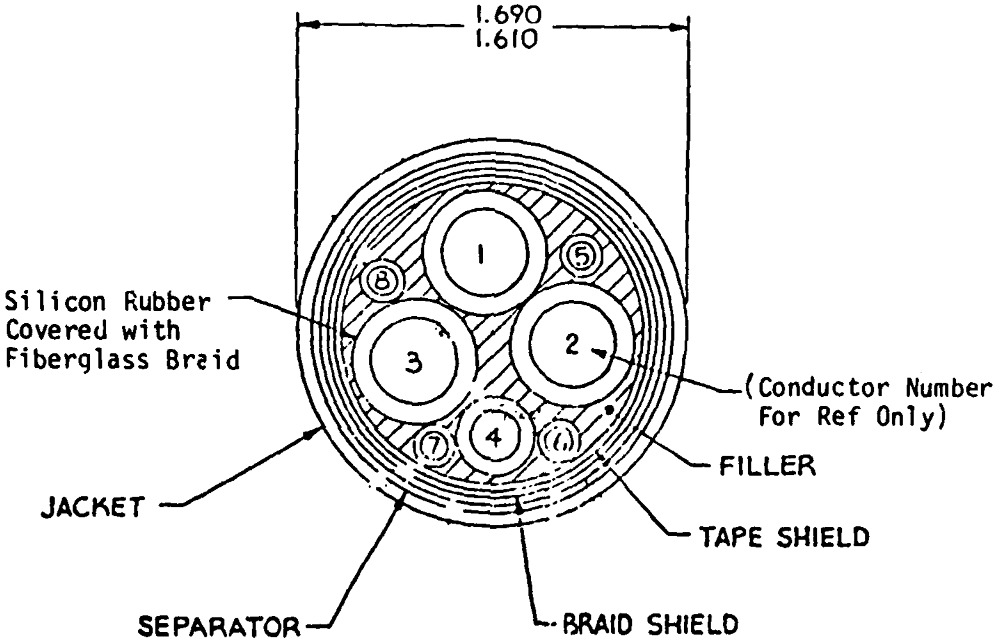
The above conductors were rated to carry maximum currents as follows:

Conductor Size	Maximum Current-Amp.
#1 AWG	163
#6 AWG	75
#16 AWG	20

Each conductor was silicon rubber insulated covered with a fiberglass braid jacket followed by a braided shield of tinned copper strands. The overall cable was jacketed by a two layer reinforced black polychloroprene (artic neoprene) having a nominal wall thickness of 0.156". The insulation of the conductors was rated to withstand the following voltages:

Conductor Size	Test Voltage-kV
#1 AWG	20
#6 AWG	18
#16 AWG	15

The following drawing provides a graphic description of the cable submitted for tests.



TEST REQUIREMENTS

Brand-Rex Company requested CTL to determine and plot the increase in temperature of the described cable and to establish the steady state temperature when the described cable, operating in an environment of 71°C, is loaded simultaneously with the following currents:

163 Amperes circulating through each #1 AWG conductor
75 Amperes circulating through each #6 AWG conductor
20 Amperes circulating through each #16 AWG conductor

PROCEDURE

A long, non-magnetic cylindrical enclosure was prepared capable of maintaining constant thermal conditions. After verifying that the temperature inside this enclosure could be maintained at a constant 71°C the 15 ft. long sample supplied by Brand-Rex was introduced into the enclosure, after providing it with two groups of thermocouples.

Preliminary heating runs allowed to establish that the temperature at the location of measurements was not affected by the test set-up configuration. Additional runs were performed to establish uniformity, reproducibility and accuracy. After all requirements were satisfied the final loading runs, with results as reported herein, were executed.

DATA

Table 1 - Temperatures Recorded During Final Test

Fig. 1 - Location of Thermocouples

Fig. 2 - Temperature Increase with Time for First Group of Thermocouples

Fig. 3 - Temperature Increase with Time for Second Group of Thermocouples

CONCLUSIONS

1. The maximum temperature rise of the cable operating in a 71°C environment with specified currents circulating continuously are:

Time From Start	Temperature Rise	Cable Temperature
30 Minutes	55°C	126°C
1 Hour	75°C	146°C
2 Hours	90°C	161°C

2. Steady state temperature for this cable is reached after approximately two hours of maximum current circulation.

TABLE 1

TEMPERATURES RECORDED DURING FINAL TEST

Start Time From (min.)	Thermocouple No. 1	2	3	4	5	6	7
	Temperature (°C)						
0	90	89	84	71	92	90	84
10	96	95	89	71	98	97	90
20	112	111	103	71	113	112	102
30	125	124	114	71	126	125	113
40	133	133	122	73	134	134	121
50	140	139	128	74	140	140	127
60	145	144	132	75	145	145	131
70	148	147	135	76	148	149	134
80	153	152	139	77	153	153	138
90	156	155	141	78	156	156	140
100	158	156	142	77	158	159	141
110	158	157	143	76	159	160	142
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140	160	159	144	72	161	162	144

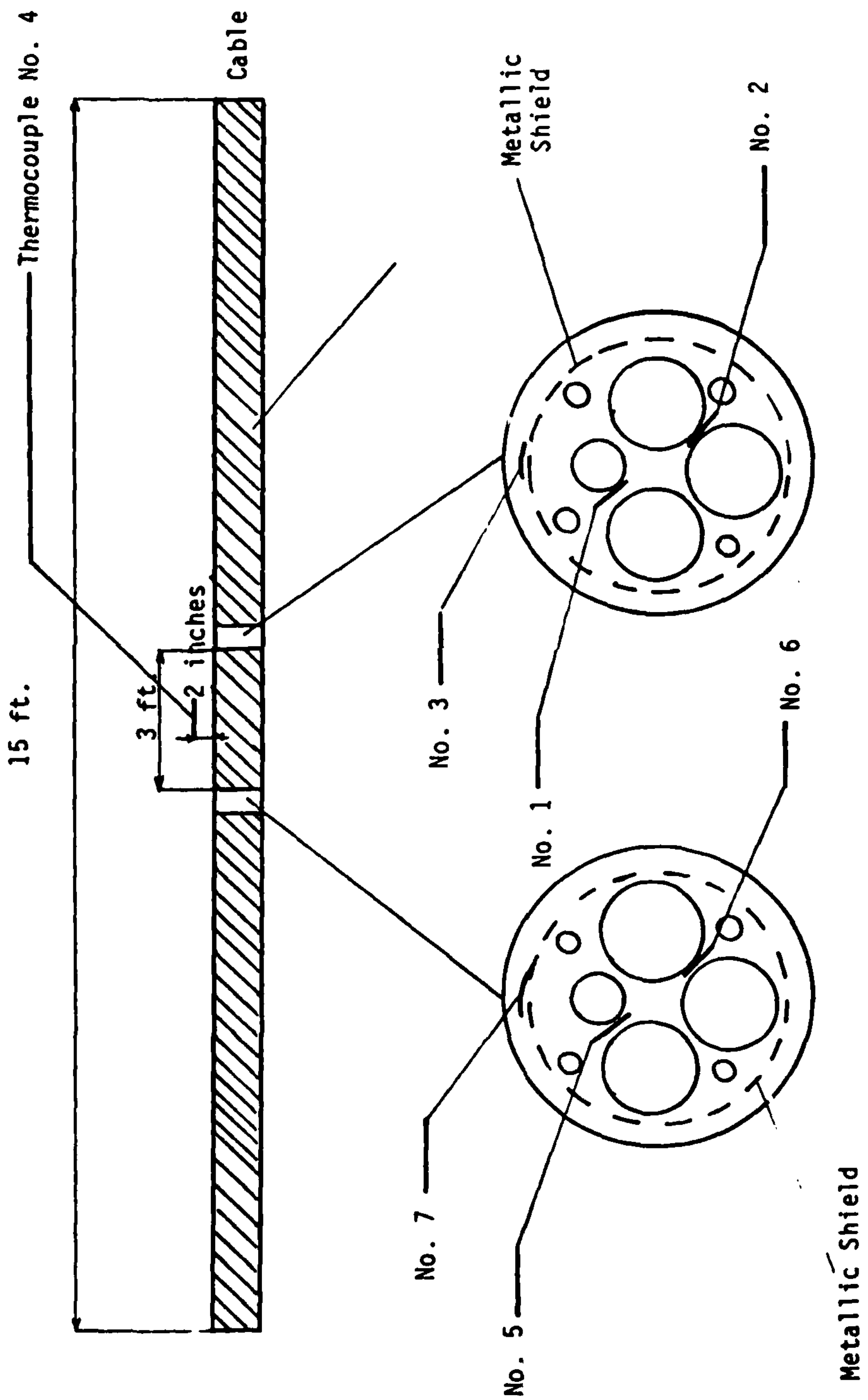

Figure 1 - Thermocouple Location

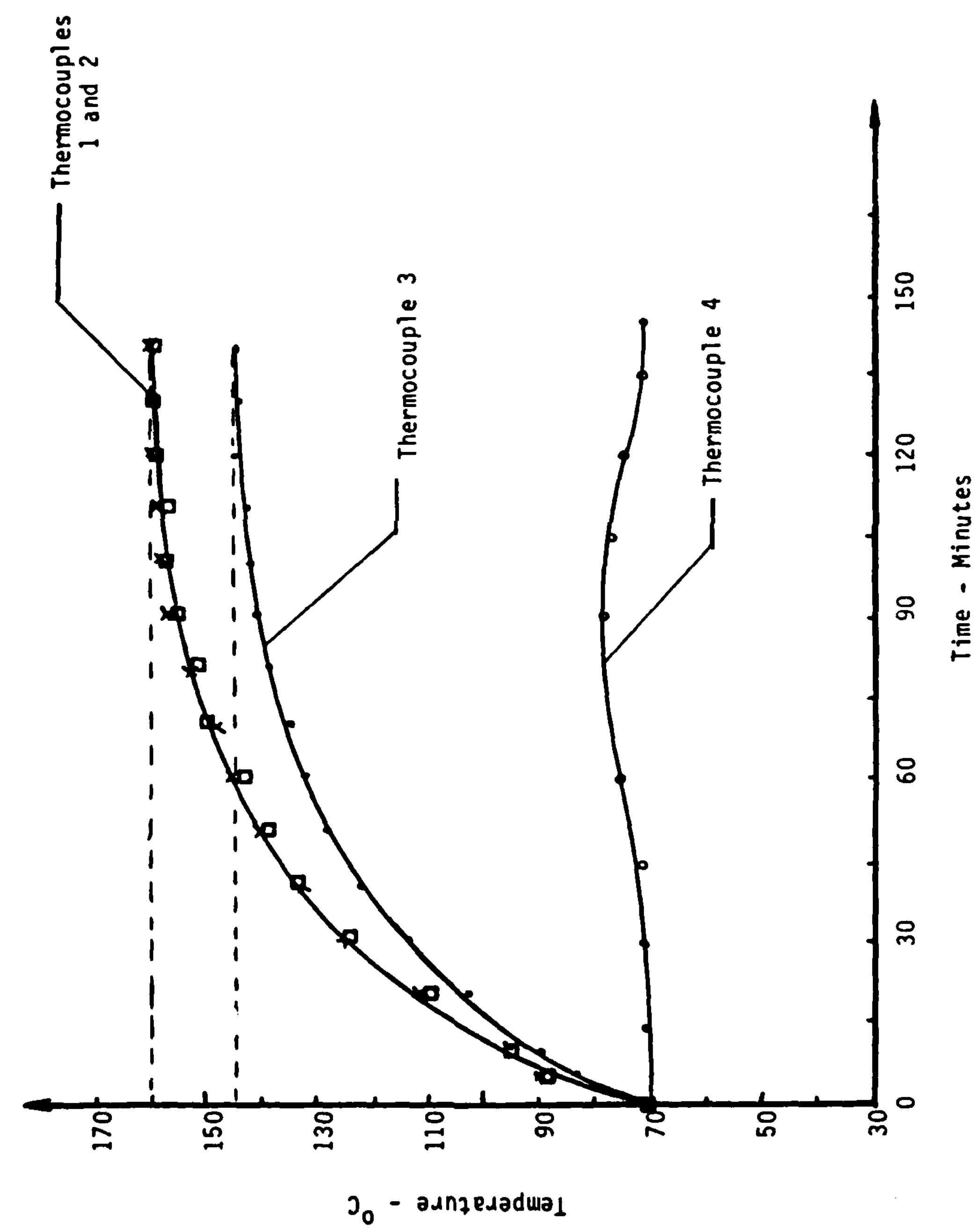

Figure 2 - Temperature Increase with Time for First Group of Thermocouples

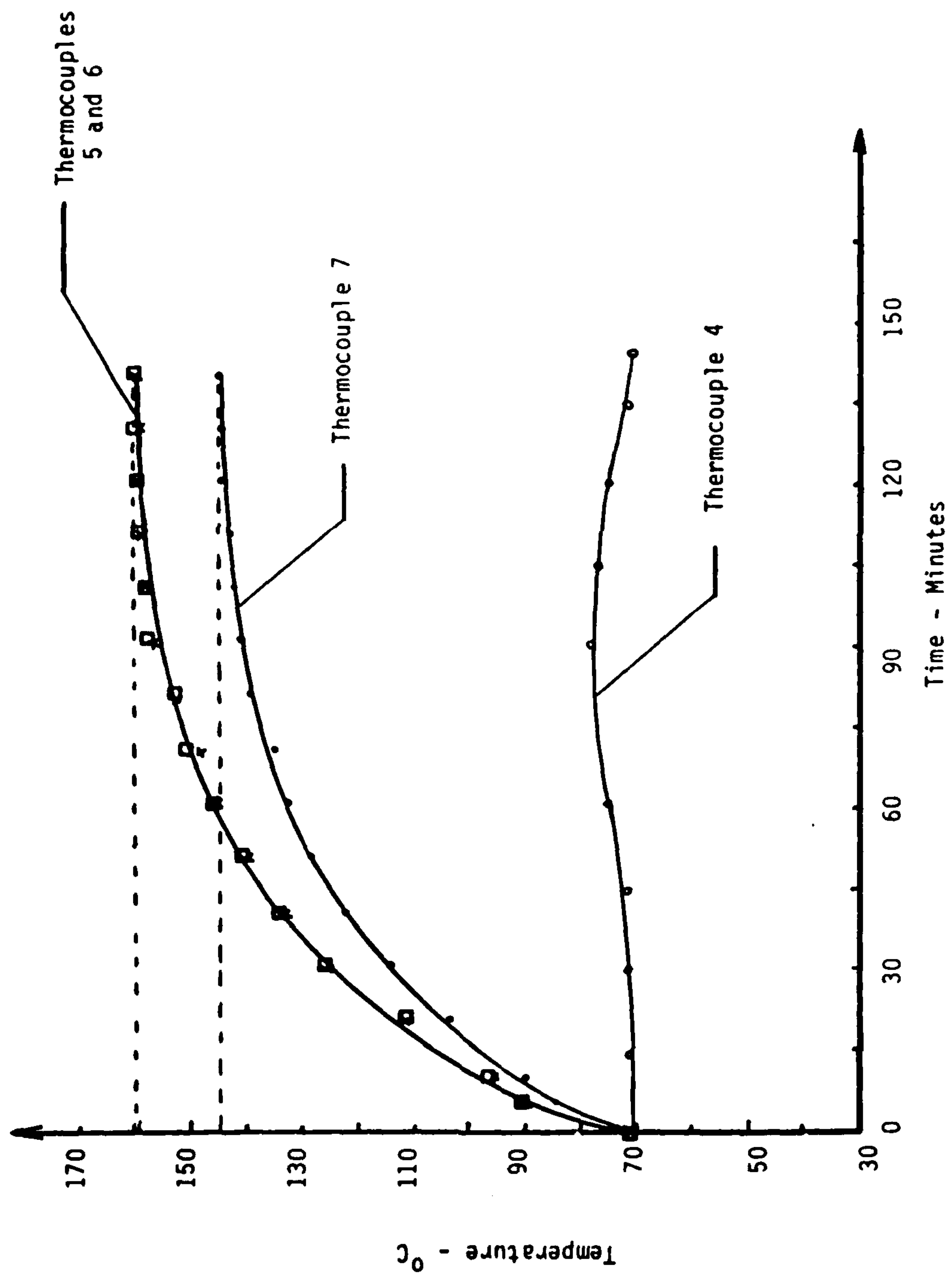

Figure 3 - Temperature Increase with Time for Second Group of Thermocouples

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		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) IRVING N. DWYER, CHARLES O'NEIL, WILLIAM G. WOOD, DAVID P. DA VIA		8. CONTRACT OR GRANT NUMBER(s) DAAK 70-81-C-0190
9. PERFORMING ORGANIZATION NAME AND ADDRESS BRAND-REX COMPANY P.O. BOX 498 WILLIMANTIC, CONNECTICUT 06226		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. ARMY MOBILITY EQUIPMENT RESEARCH AND DEVELOPMENT COMMAND PROCUREMENT & PRODUCTION DIRECTORATE FORT BELVOIR, VA. 22060		12. REPORT DATE September 1982
		13. NUMBER OF PAGES
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ELECTRICAL INSULATIONS
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ELASTOMERS

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A TPE (Elexar 8614Z) material was selected from several candidates for evaluation in completed cable form. A second cable with higher heat resistance capability, using silicone insulation, was also evaluated. The objective was to produce a finished cable with a weight savings of 15% or better, with no loss of significant properties from the standard cable specified by Drawing #13222E8995.

A weight savings of 21 to 24% was achieved conforming to the required specification. The jacket material utilized was polyurethane, producing a thinner layered construction over the standard cable. The performance of this, as a sheath material, was excellent when tested to the requirements of MIL-C-13777G

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