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Research and Development Technical Report
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AN/VRC-12 CABLE EVALUATION

by

Frank DeNucci

July 1969

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TECHNICAL REPORT ECOM-3142

AN/VRC-12 CABLE EVALUATION

by

Frank DeNucci

Electronic Parts and Materials Division
Electronic Components Laboratory

July 1969

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US ARMY ELECTRONICS COMMAND, FORT MONMOUTH, N. J.

ABSTRACT

This study was initiated to investigate the cause of various reports of field failures of wires and cables (multi-conductor), specifically cables which are part of the AN/VRC-12 Radio Equipment.

Various types of cables, fabricated per MIL-C-3432 and similar to those reported as having failed in tactical use, were tested.

A description of each type is provided in this report along with detailed physical test data, such as tensile and elongation of conductor insulating material (aged and unaged) and mechanical tests on the cable such as, flex, impact and twist.

None of the cables tested exhibited outstanding performance in all the mechanical tests. When cables did perform very well with regard to one or two tests, they did poorly in others. All cables exhibited variations of performance and practically no correlation was obtained between the mechanical tests and the physical characteristics of the insulation.

Performance tests however, do offer some control on the construction and manufacturing variables of the cable. New design considerations are recommended based upon the evaluation. Requirements for the physical properties of the insulation are also recommended to upgrade the material and provide greater stability with respect to accelerated temperature aging. Mechanical performance tests on finished cable are recommended to provide an overall control on the constructional quality of the finished cable.

These tests will be incorporated in Military Specification MIL-C-3432 along with appropriate changes in Government inspection procedures to insure improved reliability of multi-conductor cables.

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BACKGROUND

A directive from the office of Project Manager, Selected Tactical Radios, U. S. Army Electronics Command, was forwarded to this laboratory,* stating that there exists a continuous major problem with respect to failures in wire and cable, specifically cables which are part of the AN/VRC-12 Radio Equipment. The directive stated that cable specifications are not compatible with user requirements and recommended that the entire field of wires, cables, and cable assemblies be reviewed and revised.

A meeting was arranged with representatives of the Components and Materials Division of Procurement & Production Directorate to determine: (1) What types of tactical cables were failing; (2) What types of cables were in large quantity procurement; and (3) Into what specific equipments these cables were being used. The information gained at this meeting, summed up briefly was: (1) Most cables were procured per Specification MIL-C-3432, and (2) The only known failure occurred with cables used on the AN/VRC-12 equipment.

To further investigate the Project Manager's request, a meeting was held with a representative of the Project Manager's Office to discuss cable failures in the field and to determine the type of cables failing and the cause. The items discussed were: (1) Early history of numerous failures (as much as 50 percent) of cable assemblies when Radio Equipment AN/VRC-12 was implemented in the field in October 1963 and (2) The need for more rigid specification requirements.

A meeting was arranged at Frankford Arsenal to discuss cable testing techniques, and cable testing equipment relative to multi-conductor cables and to obtain procurement information for a Frankford Arsenal Cable Testing Machine.

Tobyhanna Military Supply Depot was also queried to determine the type of cables failing and what cables were in large quantity procurement. The inquiry revealed numerous failures of cable assemblies used with AN/VRC-12 equipments. Tobyhanna reported 25,000 feet of cable as "dry-rot" cable and 20,000 cable assemblies with such defective cable.

EVALUATION PROGRAM

1. <u>Cable Sample Description</u>

Two cable samples made per Specification MIL-C-3432 were obtained from Components & Materials Division, Procurement and

*Electronic Components Laboratory

Production Directorate, and consisted of types CO-18LOF (14/22, 4/22 SI) 0500 made by the Cornish Wire Company, and CO-12LOF (12/22) 0325 made by the American Insulated Wire Company. Due to the short lengths of these samples, a complete series of tests could not be made so additional cable samples of various manufacturers were requested from Tobyhanna Supply Depot. The samples received and tested were types CO-18LOF (14/22, 4/22 SI) 0500, CO-09LOF (7/22, 2/22 SI) 0325 made by the American Insulated Wire Company, and CO-12LOF (12/22) 0325 marked Industrial Components Company (made by American Insulated Wire Company). Other cable samples were obtained from Tobyhanna which were marked "dry-rot". In order to properly evaluate cables representative of various companies' [illegible]le design and cabling techniques, a procurement was made directly to three cable manufacturers. Only one each cable type CO-18LOF (14/22, 4/22 SI) 0500, and CO-12LOF (12/22) 0325 from American Insulated Wire Company and CO-09LOF (7/22, 2/22SI)0325 from ITT Surprenant was received.

2. Test Procedures

A testing and evaluation program was immediately initiated on multi-conductor, shielded, and unshielded cables. These cables, fabricated per MIL-C-3432, were similar to the cables used with AN/VRC-12 equipment which were reported as having failed in tactical use.

Cable samples were subjected to flex, impact, and twist tests in accordance with Specification MIL-C-13777. These tests were designed, with some modification of the flex tests, to simulate field use and abuse and were performed on a Frankford Arsenal Cable Testing Machine.

The flex tests consisted of placing the cable samples between two half-inch mandrels, with the lower end of the samples fixed approximately twelve inches below the mandrels (instead of weights) to confine the flex or bend over the mandrels instead of allowing the cable sample to ride up and down over the mandrels. Cable sample length differences between cable in the vertical and horizontal position and adjustment of a ten-pound tension on the cable samples were accomplished by attaching a spring between the samples and the oscillating arm of the machine. The oscillating arm of the machine flexed the cable samples alternately over each mandrel. Starting from zero (horizontal position) and rotating through a 180 degree arc of the flexing arm and back 180 degrees to zero position constituted one cycle. This modification to the MIL-C-13777 test method was made to provide a more realistic test of the cables. The method simulates sharp bending of the cable at the back end of a connector where the cable gets the most bending abuse when it is used on an assembly and installed in equipments.

Impact tests consisted of allowing a weighted hammer to strike the cable sample which was clamped over an anvil. The weight size and height of the hammer was in accordance with MIL-C-13777 except for the types CO-12LOF (12/22) 0325 and CO-09LOF (7/22, 2/22 SI) 0325 cables. The drop height of the hammer was reduced because of the severity of the test on these smaller diameter cables which had thinner wall jackets compared to the 18-conductor cables.

Twist tests consisted of attaching one end of a cable sample to a mechanism that allowed the cable to ride up and down over a pulley. The opposite end of the cable sample was attached to a weight that applied tension and a 45 degree (each side of zero) twist to the cable.

3. Instrumentation

Cable samples for the tests were prepared by connecting the conductors in series and then terminating into a control box. Since the cable testing machine was located a considerable distance away and to eliminate constant monitoring of the flex and twist tests which were of long duration, a control box (Fig. 1) was designed and fabricated to automatically stop the cable testing machine and the cycle counter when the cable sample failed. Twenty-four volts D-C were applied through a rheostat and relay to the cable conductors, which were connected in series. The circuitry (Fig. 2) has a reset switch which closes the circuit, energizes the relay and starts the cable testing machine. Discontinuity in the cable conductors opens the circuit and stops the cable testing machine. Relay drop-out sensitivity is controlled by the "Load-Adj" rheostat.

Impact tests were controlled by a Short-Open Indicator (Fig. 3). A 110V A-C potential was applied to the conductors of the cable sample through an adjustable load to indicate 0.5 ampere. Indication on the ammeter permitted determination of failure caused by broken conductors or by short circuits between conductors. Failure due to either cause terminated the test. The electrical circuitry (Fig. 4) consisted of connecting a rheostat, ammeter, resistors (at each end of the conductors), and cable conductors all in series. Resistor values of 10 ohms were used for a cable having 18 conductors (17 resistors) to permit adjusting the control rheostat resistance in the circuit to 0.5 A.; also, to allow cables having as few as 9 conductors to be used with this indicator as there was sufficient regulation with the rheostat to adjust the load to 0.5 ampere. Small two-watt resistors were used to restrict the size of the resistor boxes. The on-off switch was a momentary type so that the circuit was closed for the short time duration necessary to read the meter at each hammer impact upon the cable sample and to prevent the resistors from overheating.

RESULTS

The results of the tests are summarized in Table 1 and detailed data are tabulated in Tables A1 - A4 of the Appendix. Cornish Wire samples (Table A1) exhibited relatively high impact life, the best of all cables tested. This was attributed possibly to the addition of a textile braid over the individually insulated conductors. The braid tended to cushion the conductors from each other when the cable was subjected to impact. Although advantageous for impact, the braid tends to be a disadvantage in flexing and twisting of the cable. The textile braid restricts the insulated conductors from sliding back and forth within the cable jacket during flex and twist, possibly putting extra stress on the copper conductors. AIW 1964 cable samples (Table A2) showed relatively low impact and twist life; AIW 1963 "Dry Rot" cable samples (Table A2) showed low flex life and the poorest impact resistance of all the samples, although twist life was relatively high. Again, this may be attributed to the textile core wrap, having a similar reaction among the conductors within the cable as the textile braid over the individually insulated conductors. AIW 1966 samples (Table A2) exhibited relatively high flex, impact and twist life as compared to 1963 and 1964 samples. This was possibly due to the Mylar tape core wrap which allowed the conductors more freedom of movement during the twist test and absorbed, to some extent, the hammer blows during the impact test. Cables, type CO-12LOF (12/22) 0325 marked "Industrial Components Company" (made by AIW 1965) and AIW 1965 (Table A3) exhibited high twist life, relatively high flex life, but relatively poor impact. These cables contained no individually shielded conductors, hence there was no restriction or abrasion from shields on adjacent conductors during twist tests which would put undue stress on the copper conductors. These cables averaged relatively the same life cycles for each of the flex, impact and twist tests.

Cables, type CO-09LOF (7/22 - 2/22 SI) 0325 manufactured by ITT Surprenant (Table A4), showed relatively high impact life as compared to AIW cables. This was possibly due to the textile reinforced jacket affording some protection to the conductors by absorbing the shock from the hammer blows during the impact tests. The flex and twist life of these cables were comparable; however, the flex life is considered poor.

In order to determine if the conductor material was at fault for the low twist life of the AIW 1964 samples and the low flex life of the AIW 1963 samples labeled "dry-rot", tensile and elongation tests were performed on the copper conductors (Table 2). The tests and results were based upon requirements and values of Federal Specification QQ-W-343. The stranded #22 AWG conductor was used for these tests. Strands were not removed from the conductor because tensile strength values are not specified in the specification for this strand wire size (#34 AWG). The elongation of copper conductors for the AIW 1963 samples (labeled "A and B") and the AIW 1964 samples (labeled "From 19 and 28 cycle twist) were less than the (15% after stranding) minimum requirements of QQ-W-343. Cornish samples met the elongation requirements. All the AIW 1964, AIW 1963, and Cornish samples met the tensile requirements.

Military Specification MIL-I-3930 specifies a minimum tensile of 450 psi and 200 per cent elongation for unaged conductor insulation for wall thickness between 6 to 20 mils. For insulation walls over 20 mils, the tensile and elongation minimum requirements are 600 psi and 250 per cent respectively. Shielded conductors of the AIW 1963, 1964 and 1966 samples were tested because heat retention in the shields when the cable jacket is applied could possibly cause degradation of the shielded conductor insulation. No testing was made of the shielded conductors of the Cornish Wire samples due to insufficient cable.

Insulation elongation (unaged) values for samples of AIW 1963, and AIW 1964 (Table 3) were borderline specification values, wherein the tensile values were above specification requirements. Other cable samples passed specification requirements for tensile and elongation. AIW 1966 samples were well above the minimum requirements for both tensile and elongation.

Tensile and elongation tests were also made on insulation after air-oven conditioning for 168 hours at 100°C to possibly duplicate "dry-rot" due to overcuring. The results of these tests are also shown in Table 3. AIW 1966 samples procured directly from the manufacturer were also subjected to air-oven aging for 1/2 hour at 345°F (simulating jacket extrusion temperatures) in order to possibly duplicate "dry-rot" due to overcuring during jacket extrusion. Similar samples were subjected to air-oven aging for 1/2 hour at 400°F (also simulating possible temperature jacket extrusion) again to duplicate insulation dry-rot (Table 3).

None of these air-oven aging tests duplicated the "dry-rot" insulation (i.e., degradation to the degree that the insulation lost all its elastomeric properties and the material cracked or crumbled with no tensile load). The insulation did crumble at elongations under very small tensile stress, see Fig. 5 and 6. However, later tests of air-oven aging of insulated conductors (including an experimental cable with ethylene-propylene rubber insulation) at 100°C did result in significant deterioration after two weeks, and duplicated insulation dry rot after three weeks (See Fig. 7 and Table 3).

The repetition rate of conductor failures shown in Table 4 was not intended to indicate conductor failures due to different manufacturers or time of manufacture but rather to locate or isolate the number of failures which occurred for each conductor in respect to other conductors included in the cable. For instance, for cable type CO-18LOF(14/22 - 4/22 SI) 0500 a total of nine conductor failures were recorded for the black/white conductor and three failures for the adjacent conductor blue/black. Almost all conductors failed at least once on the impact tests. The three failures for the conductors color-coded blue, and white/black could be due to the fact that they were adjacent to the shielded conductors, and the impact hammer could possibly have driven the broken shield strands into these insulated conductors.

No pattern is discernible for the failures of conductors for the CO-12 LOF (12/22) 0325 type cables. The conductor failures resulting from flex, impact and twist tests were of relatively the same life cycle. This cable contains no shielded conductors, hence, no interaction due to conductor shields and adjacent insulated conductors. Conductor failures shown for cables, type CO-09LOF (7/22 - 2/22 SI) 0325 (Table 4) indicate a high failure rate of the white and black conductors. However, only two of the three failures were recorded for the AIW 1965 cable of the respective conductors and three and two failures for the ITT cable of the same conductors. More cable tests should be made to arrive at further conclusions.

CONCLUSIONS

Three cable types used with AN/VRC-12 were evaluated for conformance to Specification MIL-C-3432 and for performance on mechanical tests of flex, twist, and impact per MIL-C-13777. The data was analyzed to determine causes of failure and necessary revisions in specification requirements to provide greater reliability. Primary effort was directed to CO-18LOF (14/22 - 4/22 SI) 0500 because of its complexity and its failure in the field. The pertinent results of the evaluation are as follows:

1. Cable samples labeled "dry rot" did not reveal a disintegrated insulation but rather a poor grade of insulation when tested for tensile and elongation per MIL-I-3930.

2. Although the insulating material (SBR) exhibited physical characteristics after one week at 100°C greater than the initial values of MIL-I-3930,

it deteriorated rapidly after one week at 100°C and began to disintegrate at approximately three weeks at 100°C. The insulation also met requirements for tensile and elongation after 1/2 hour at 400°F, but it decreased approximately 30% in tensile from the unaged samples. The aging condition did not simulate "dry-rot".

3. EPR insulation was highly stable at 100°C, and exhibited virtually no change in physical properties for the period tested.

4. No influencing factor was apparent in determining the flex life of the cables tested other than the fatigue of the copper conductors. All failures were due to breaks in the conductors with the insulation intact.

5. None of the cables exhibited outstanding performance in all of the mechanical tests. When cables did perform very well with regard to one or two tests, they did poorly in the others. The Cornish Cable, however, was not outstanding in any one test but exceeded the requirements for all tests, and was superior to the other cables in regard to impact. The insulation in the Cornish cable also had good initial physical properties.

6. Although there were variations of performance and no established correlation between the mechanical tests and the physical characteristics of the insulation, performance tests do offer some control on the constructional and manufacturing variables of the cable.

7. The use of braided coverings over the insulation, and plastic tape wraps contributed to the outstanding performance of some of the cables in at least one of the mechanical tests.

RECOMMENDATIONS

1. The requirements of the physical properties of insulation per MIL-I-3930 should be upgraded to provide greater stability with respect to accelerated temperature aging. These upgraded requirements will improve the overall performance of cables per MIL-C-3432. Marker threads indicating month and year of manufacture should be provided under each conductor insulation to insure that conductors* are not excessively aged in storage prior to cable fabrication.

2. Mylar tape wraps should be used over and under the metallic braid of shielded conductors to prevent abrasion damage and piercing of insulation by broken strands. In multilayer cable construction the shielded

*with insulation

conductors should be in the inside layers to minimize their vulnerability to damage. The center of the cable core should be occupied by filler material rather than a conductor to eliminate excessive stresses on such a conductor.

3. Despite the variability in test results, and the evaluation limited to light duty cables, mechanical performance tests on finished cables provide an overall control on the quality of the cable with respect to numerous constructional details. The test procedures for flex, twist, and impact per MIL-C-13777 should also be incorporated into MIL-C-3432 with the following minimum requirements: 1500 flex cycles, 1500 twist cycles, and 50 impacts.

4. Appropriate changes should be made in the inspection test procedures to incorporate the accelerated temperature aging of insulation and the mechanical performance tests to assure improved reliability of the finished cable to be delivered to prime contractors.

Implementation of the specification revisions will be undertaken by the Electronic Components Laboratory of this Command in coordination with the Procurement & Production Directorate. However, the procurement agency must exercise adequate inspection surveillance to achieve the benefits of the upgraded specification requirements.

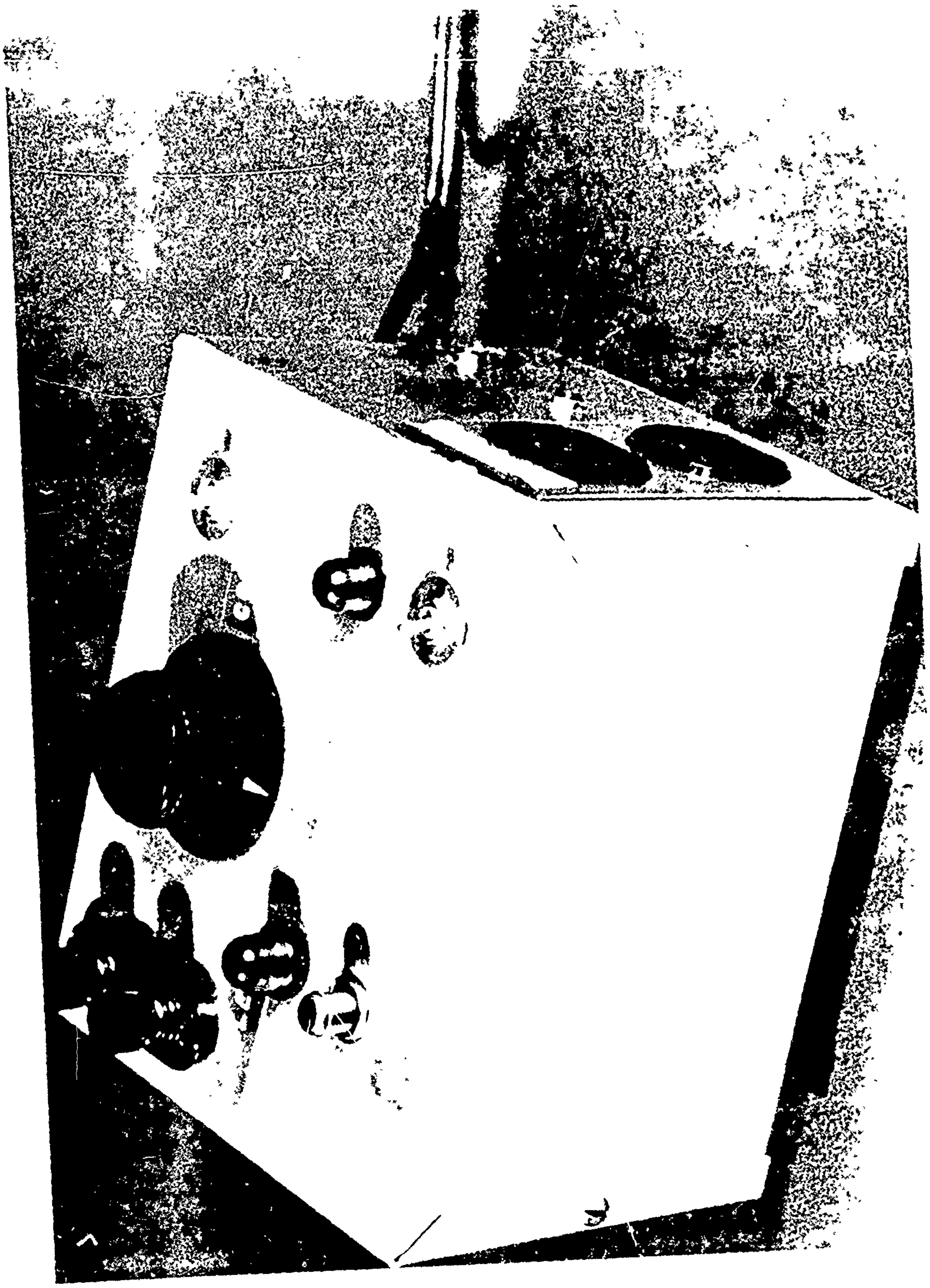
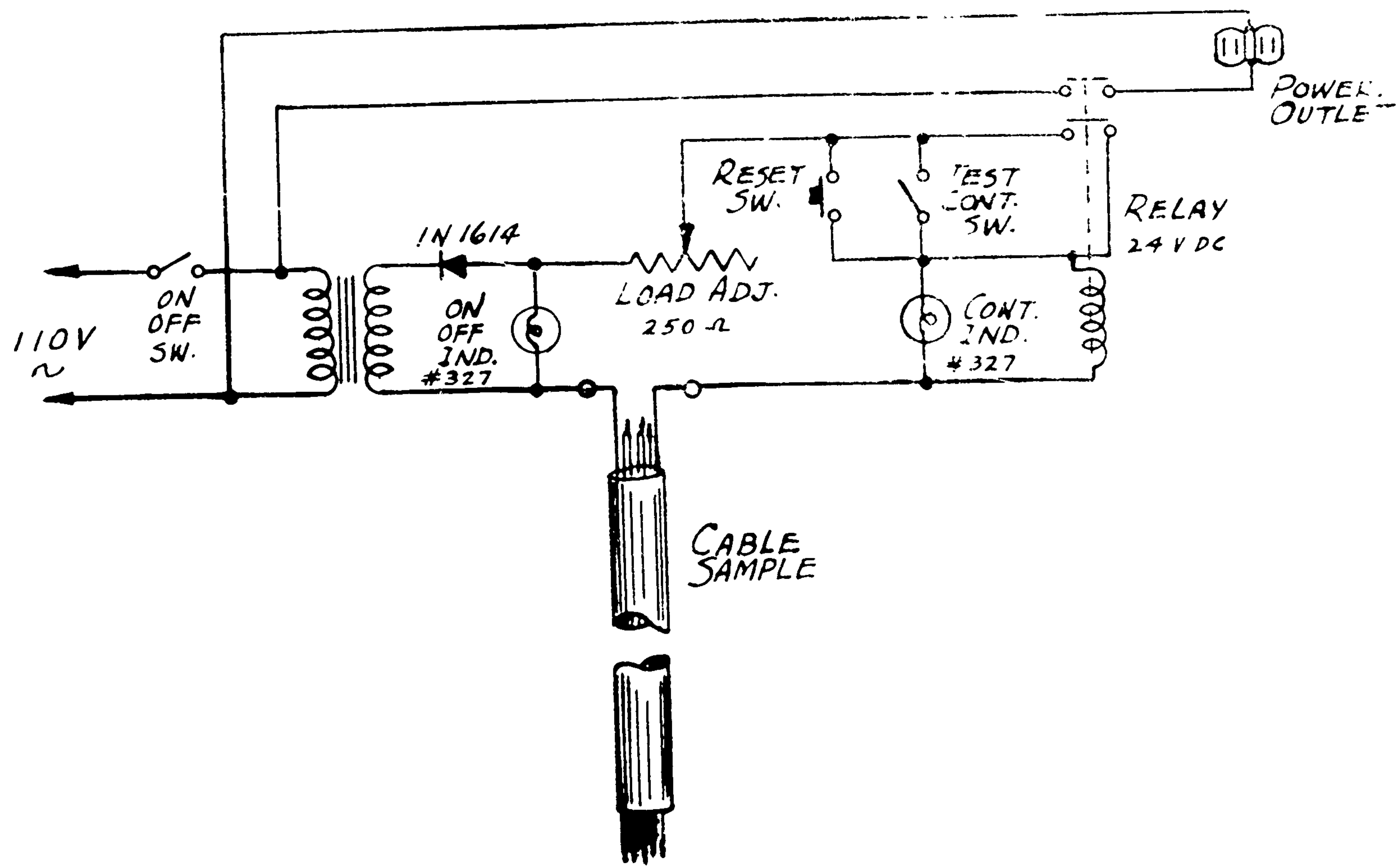


Figure 1
Discontinuity Automatic Control



Schematic - Discontinuity Automatic Control

Figure 2

Fig. 3

Short-Open Indicator Box and Resistor Terminals

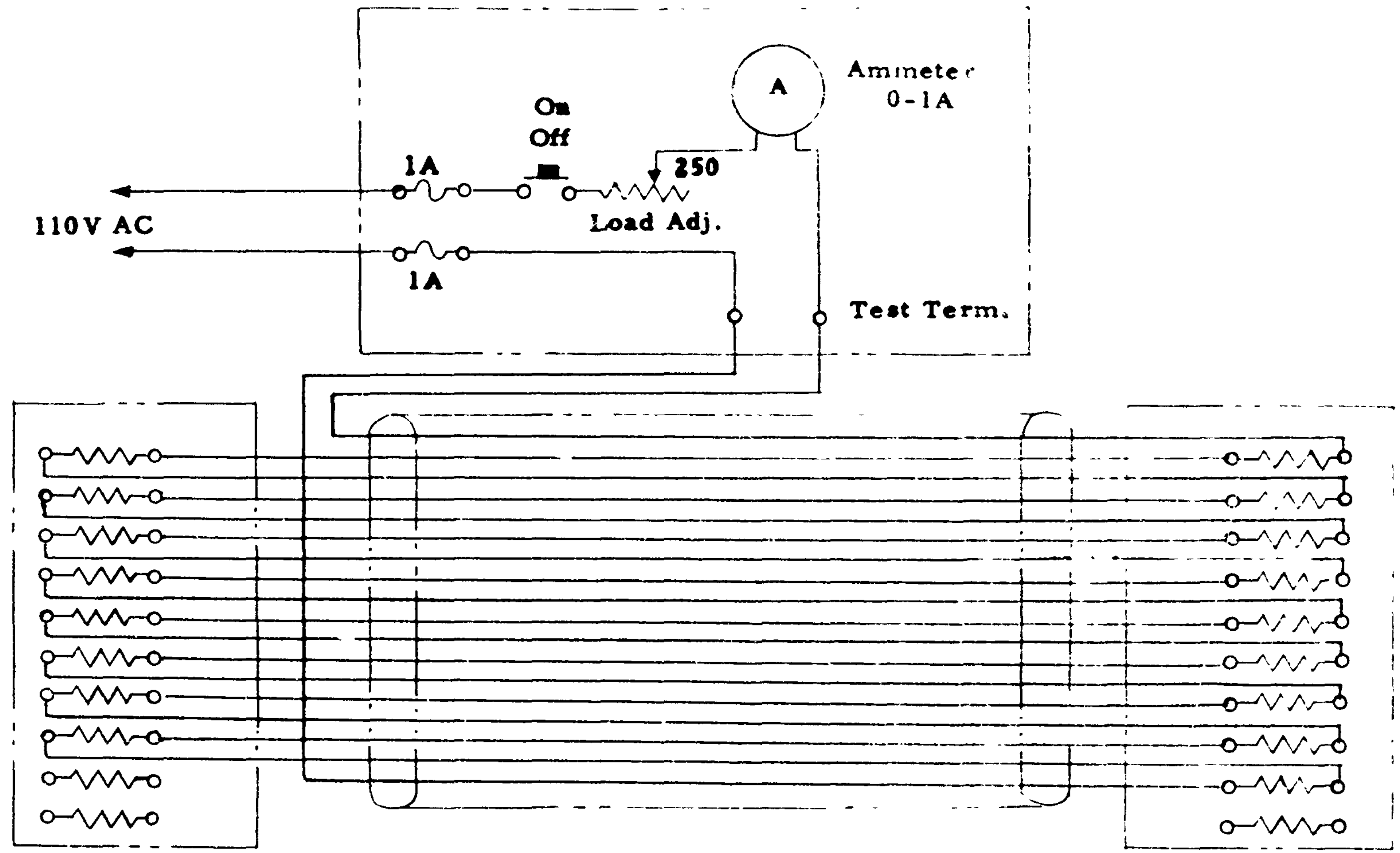
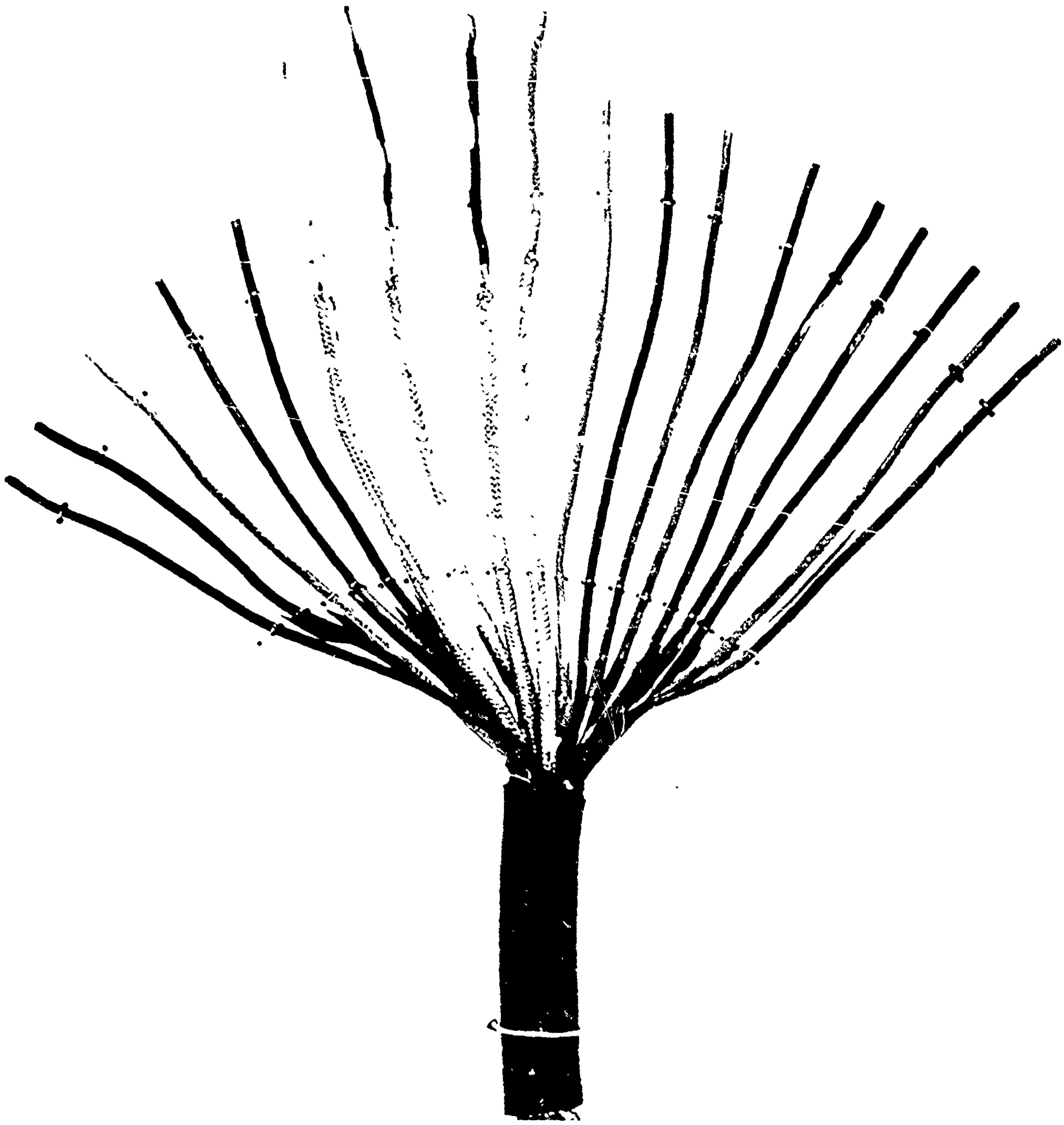
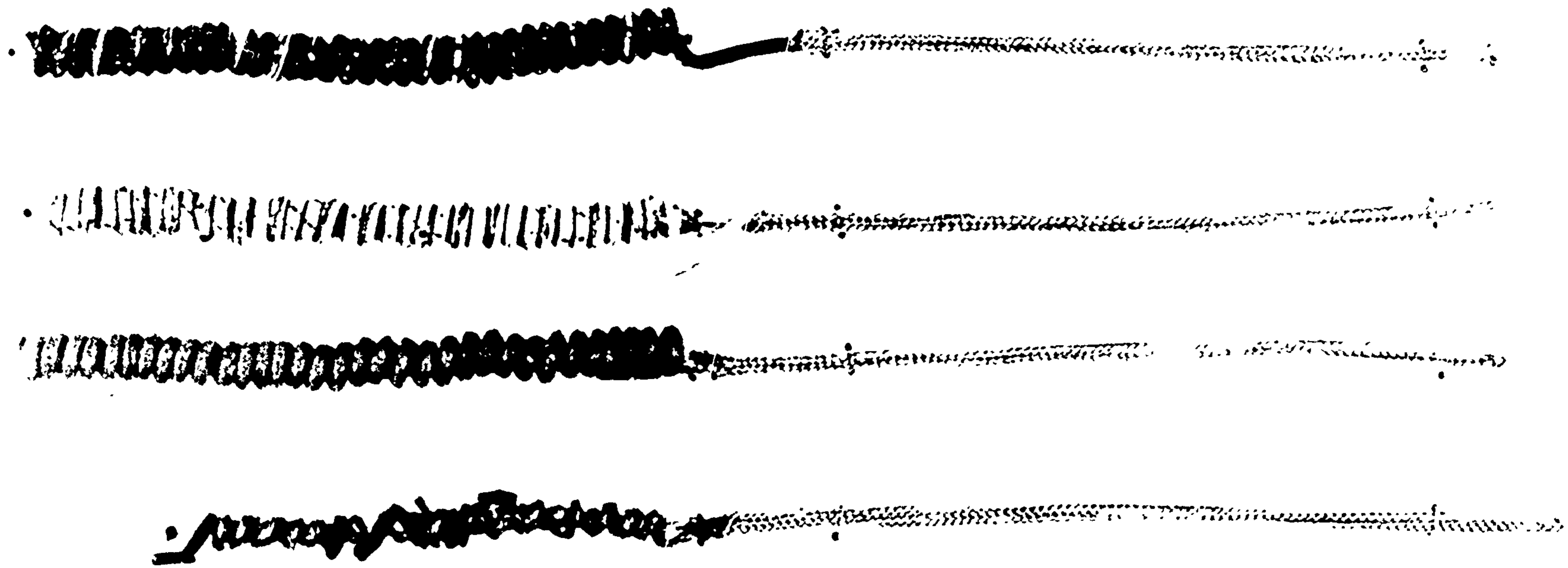


Fig. 4

Schematic - Short-Open Indicator

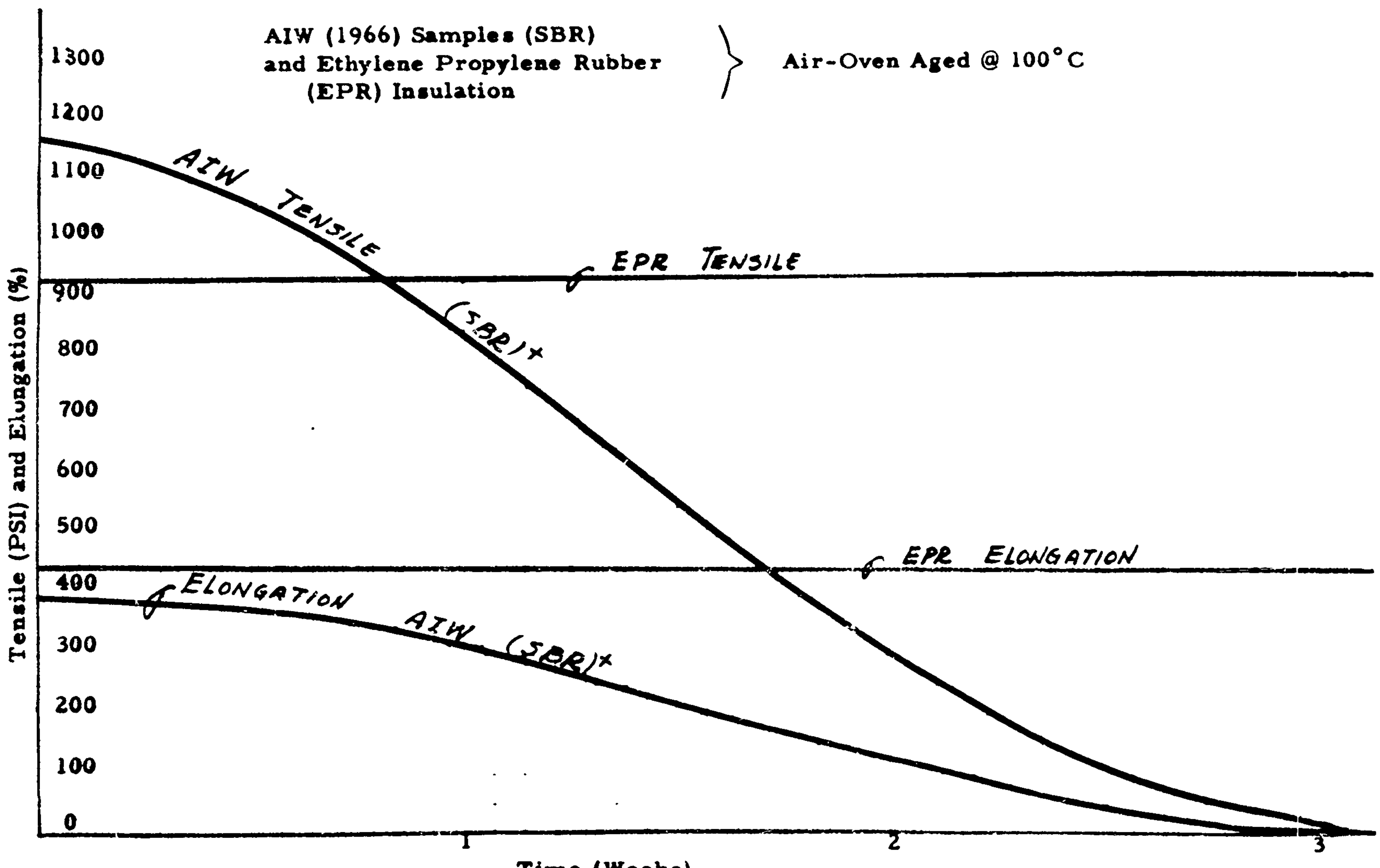


DEFECTIVE CABLE FROM
TOBYHANNA TYPE CO-18LOF
(14/22, 4/22 SI) 0500 PER
MIL-C-3432 AND SIMILAR TO
CABLE USED ON AN/VRC-12
EQUIPMENT



INSULATED CONDUCTORS
FROM DEFECTIVE CABLE

Fig. 6



* = Recent Tests
\+ = (SBR) Styrene Butadiene Rubber

Fig. 7
*Tensile and Elongation (SBR & EPR Insulation)

SUMMARY OF TESTS TABLE 1

CABLE TYPE & MFR.	FLEX No. of Cycles	FLEX Fault (Cond.)	IMPACT No. of Cycles	IMPACT Fault (Cond)	TWIST No. of Cycles	TWIST Fault (Cond)	[illegible]	CABLE CONSTRUCTION
CO-18LOF(16/22, 4/22SI)0500								
1. CORNISH 1962	1429	O/R (SH)	154	BK/R (SH)	3048	[illegible]		Conductor [illegible] .0063" T.C. [illegible] [illegible] Core wrap textile Jacket [illegible] (TABLE A1)
2. " "	1094	O/R (SH)	149	O/R (SH)		No [illegible] cable	[illegible]	
3. " "	1649	BK/R (SH)	186	O/R (SH)				
1. AMER. INS. WIRE 1964	2223	R/BK	17	BLU/BK, O	19	[illegible]		Conductor [illegible] Insulation SBR [illegible] wall avg Shield cond [illegible] tape wrap [illegible] TC BR [illegible] Core wrap textile Jacket Polychlor .055" thk avg (TABLE A2)
2. " "	2116	W/R (SH), BK W	20	W/BK, G/BK, W/BK, R/W	27	[illegible]	[illegible]	
3. " "	1100	BK, W	25	O, G, BLU, W, BK, BK/W, W & SH		No [illegible] cable		
1. AMER. INS. WIRE 1966	1647	W	88	G/BK, O/BK, BK/W	15,650	[illegible] BK, W BK		Conductor [illegible] T.C. Insulation SBR .034" wall avg Shield cond Mylar tape, 65 .005 TC BR shld Core wrap Mylar tape Jacket Polychlor .055" thk (avg) (TABLE A2)
2. " (FROM AIW)	1788	R/W	71	R	20,379	No Failure	4 1/2	
3. "	1312	O	65	BLU	17,540			
1. AMER. INS. WIRE 1963	588	G/W	6	See Table #2	1551	R BK G BK		Conductor [illegible] .0063" T.C. Insulation SBR .035" wall avg) Core wrap textile [illegible] same as 1964 [illegible] Jacket Polychlor .055" thk avg, TABLE A2)
2. " LABELED	329	W	12	BLU BK W			4	
3. " "DRY-ROT"	556	R	15	[illegible] BLU		No [illegible] cable		
CO-12LOF (12/22) 0325								
1. AMER. INS. W. 1965	3614	G, G/BK	15 †	G		No [illegible] cable	3 1/2	Conductor [illegible] .0063" T.C. Insulation SBR .021" thk avg) Core wrap textile Jacket Polychlor .046" thk avg) TABLE A3)
2.	947	BLU, G/BK, O BK	26 †	BK/W, BLU BK				
3.	1245	G	53 †	C, BLU				
1. INDUSTRIAL COMP. (AIW) 1965	853	BLU	21 †	BLU, G BK	18,990	No Failure	3 1/2	Conductor [illegible] .0063" T.C. Insulation SBR .021" wall avg) Core wrap textile Jacket Polychlor .046" thk (avg) (TABLE A3)
2. "	1653	G BK, BK/W	25 †	BLU, BK/W	16,705	"		
3. "	2029	G, BK, W, W BK	19 †	G, R, BK	15,000	"		
1. AMER. INS. WIRE 1965	996	W BK	40 †	G BK R BK	23,166	No Failure	3 1/4	Conductor 16/.0063" T.C. Insulation SBR .046" wall avg Core wrap Mylar tape Jacket: Polychlor .046" thk avg, (TABLE A3)
2. " (FROM AIW)	1101	C/BK	20 †	[illegible] BK	18,500	"		
3. "	2086	G, O	35 †	No Failure	15,000	"		
CO-39LOF (7/22, 2/22SI) 0325								
1. AMER. INS. WIRE 1965	56	[illegible]	12 †	R [illegible] BK, W BK BLU [illegible] G shields	5243	BK	4 1/2	Conductor 16/.0063" T.C. Insulation SBR .020" wall (avg) Shield cond - Mylar tape, 65 .005 TC BR shld Jacket - Polychlor .042" thk (avg (TABLE A4)
2. "	139	R BK [illegible] BK	22 †	R, G, W, shields	3201	BK		
3. "	323	R BK SH	19 †	R, [illegible], BK shields	5861	~		
1. I.T.T. SURPRENANT 1965	77	R	98 †	W, BLU	6156	W, R, G, O, BLU, BK		Conductor 16/.0063" T.C. TABLE A4) Insulation SBR .023" wall avg) Shield cond Mylar tape, 65 .005 TC BR shld Jacket Polychlor textile reinforced [illegible]
2. "	537	R, G W	121 †	W BLU	4467	R, BLU/BK, W/BK	3 1/2	
3. "	500	O	94 †	W	5638	~		

† 2" HAMMER, [illegible] SEE TEXT

TABLE 2 - TEST RESULTS

Tensile & Elongation of Copper Conductors

TENSILE		ELONGATION	
FORCE BREAK (LBS)	PSI	EXT'D LENGTH (IN.)	%
AIW 1964 COND. FROM 19 CYCLE TWIST TEST			
19.0	32700	4.25	6.25
17.5	30120	4.25	6.25
20.0	34440	4.31	7.7
17.25	29690	4.25	6.25
16.5	28399	x	x
19.5	33560	4.31	7.7
AIW 1964 COND. FROM 28 CYCLE TWIST TEST			
20.5	35280	4.25	6.25
17.0	29260	4.5	12.5
18.0	30980	4.25	6.25
19.0	32700	4.25	6.25
17.0	29260	4.5	12.5
16.5	28400	4.25	6.25
AIW 1963 LABELED "DRY-ROT" (LOT A)			
21.0	36140	4.25	6.25
20.5	35280	4.50	12.5
20.7	35628	4.375	9.4
20.0	34420	4.375	9.4
20.2	34760	4.25	6.25
20.5	35280	4.375	9.4
AIW 1963 LABELED "DRY-ROT" (LOT B)			
20.0	34420	4.375	9.4
20.5	35280	4.25	6.25
19.0	32700	4.25	6.25
18.5	31840	4.125	3.1
20.3	34390	4.375	9.4
21.3	36660	4.25	6.25
CORNISH			
17.0	29260	4.75	18.7
17.5	30120	4.75	18.7
17.0	29260	4.375	9.4
17.5	30120	x	x
17.0	29260	4.75	18.7

TEST RESULTS TABLE 3

TENSILE & ELONGATION

SAMPLE CABLE YEAR OF MFR COND. COLOR	UNAGED TENSILE LBS	UNAGED TENSILE PSI	UNAGED ELONGATION IN.	UNAGED ELONGATION %	AGED 168 HRS @ 100°C TENSILE LBS	AGED 168 HRS @ 100°C TENSILE PSI	AGED 168 HRS @ 100°C ELONGATION IN.	AGED 168 HRS @ 100°C ELONGATION %	AGED ½ HR @ 345°F TENSILE LBS	AGED ½ HR @ 345°F TENSILE PSI	AGED ½ HR @ 345°F ELONGATION IN.	AGED ½ HR @ 345°F ELONGATION %	AGED ½ HR @ 400°F TENSILE LBS	AGED ½ HR @ 400°F TENSILE PSI	AGED ½ HR @ 400°F ELONGATION IN.	AGED ½ HR @ 400°F ELONGATION %
AMER. INS. 1963																
G	1.13	536	11.9	197	1.8	[illegible]25	11.0	175					[illegible]	323	[illegible]3	[illegible]07
O/BK	[illegible]	612	12.6	215	2.0	615	10.8	170					[illegible]	[illegible]	[illegible]5	[illegible]12
W/BK	1.98	642	12.5	212	2.0	[illegible]	11.7	190					[illegible]	373	3.6	240
BK/W	1.12	703	13.5	237	x	x	x	x					[illegible]	385	4.6	[illegible]65
AMER. INS. 1964 ✝																
G	2.7	739	10.2	155	2.0	675	11.1	190								
O/BK	4.3	1002	19.5	388	2.0	650	10.8	170					2.55	598	16.4	[illegible]
W/BK	5.9	1329	19.7	392	2.0	700	x	x					2.42	1028	19.7	3[illegible]2
BK/W					1.5	530	x	x								
O/R (SHIELDED)	5.0	1141	15.8	295									[illegible].10	736	15.6	290
BK/R "	5.05	1180	13.9	247									[illegible].13	976	14.2	25[illegible]
BLU/W "	6.45	1369	19.6	390									[illegible].78	802	16.0	30[illegible]
W/R "	7.05	1396	20.0	400									[illegible].40	871	15.5	287
AMER. INS. 1966																
G	5.0	1272	19.9	397									3.15	801	18.3	355
O/BK	5.3	1292	19.9	397									x			
W/BK	5.35	1427	19.4	385									3.50	933	19.1	380
BK/W	4.85	1439	18.0	358									x			
O/R (SHIELDED)	4.2	1014	16.1	302	4.2	1020	18.0	350	4.5	1090	16.0	300	3.25	785	18.5	362
BK/R "	6.3	1503	19.6	390	3.8	1000	19.0	370	4.0	1050	17.0	320	3.10	740	16.4	310
BLU/W "	4.9	1276	18.2	355	3.9	1140	17.0	325	3.7	1080	[illegible]0	200	3.20	833	17.5	338
W/R "	5.7	1512	19.6	390	4.6	1300	19.0	370	4.2	1190	16.0	300	2.93	777	17.3	332
AMER. INS 1966	UNAGED				AGED 168 HRS @ 100°C				AGED 2 WKS @ 100°C				AGED 3 WKS @ 100°C			
#G	4.7	1342	16.5	412	3.0	857	12.5	312	.7	274	22	56	INSULATION CRACKED WHEN BENT OVER MANDREL, SIMILAR TO DRY-ROT.			
#W	4.2	1024	14.5	350	3.6	878	13.5	337	1.3	455	3.9	[illegible]				
#R	4.0	1176	16.5	412	2.5	735	12.5	317	.35	222	[illegible]	34				

x No Results Due To Faulty Tester Rejected Sample

✝ Unshielded Conductors were Tested Because the Insulation is Directly Exposed To Oven Temperature.

TABLE 4

Repetition Rate of Conductor Failures for all Cable Samples Flex, Impact & Twist Tested

CABLE TYPE: CO-18LOF(14/22 - 4/22 SI) 0500

Conductor (Color)

TESTS	NUMBER OF FAILURES	W	R	G	BK	BLU	O	W/BK	G/W	R/W	BLU/W (SH)	BK/R (SH)	W/R (SH)	O/R (SH)	R/BK	G/BK	O/BK	BLU/BK	BK/W
FLEX	1	✓	✓				✓		✓	✓		✓	✓	✓	✓				✓
	2	✓								✓			✓	✓					✓
	3																		✓
IMPACT	1		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	2					✓	✓	✓				✓	✓			✓		✓	✓
	3					✓		✓											✓
	4																		✓
TWIST	1		✓	✓				✓	✓	✓			✓		✓	✓	✓	✓	✓
	2								✓						✓		✓		✓

CABLE TYPE: CO-12LOF(12/22) 0325

TESTS	NUMBER OF FAILURES	W	R	G	BK	BLU	O	W/BK	G/W	R/W	BLU/W (SH)	BK/R (SH)	W/R (SH)	O/R (SH)	R/BK	G/BK	O/BK	BLU/BK	BK/W
FLEX	1			✓		✓	✓	✓	X	X	X	X	X	X		✓	✓		✓
	2			✓		✓		✓								✓	✓		
	3			✓												✓			
	4			✓															
	5																		
IMPACT	1			✓	✓	✓	✓	✓	X	X	X	X	X	X	✓	✓	✓	✓	✓
	2			✓		✓		✓							✓	✓		✓	✓
	3			✓		✓												✓	✓
	4			✓															
TWIST		**Discontinued test @ high life cycle. Also insufficient samples.**																	

CABLE TYPE: CO-09LOF(7/22 - 2/22 SI) 0325

TESTS	NUMBER OF FAILURES	W	R	G	BK	BLU	O	W/BK	G/W	R/W	BLU/W (SH)	BK/R (SH)	W/R (SH)	O/R (SH)	R/BK	G/BK	O/BK	BLU/BK	BK/W
FLEX	1	✓	✓	✓			✓		X	X	X		X	X	SH ✓	✓	X	X	X
	2		✓												✓				
	3		✓																
IMPACT	1	✓	✓	✓	✓	✓	✓	✓	X	X	X		X	X	X		X	X	X
	2	✓	✓	✓		✓	✓	✓											
	3	✓	✓			✓													
	4	✓																	
	5	✓																	
TWIST	1	✓	✓	✓	✓	✓	✓	✓	X	X	X		X	X	X	(SH) ✓	X	X	X
	2		✓		✓	✓													
	3				✓														
	4				✓														
	5				✓														

X = no conductor of corresponding color
✓ = Failure

APPENDIX

ABBREVIATIONS

Cond	Conductor
Ins	Insulation
Str	Strand(s)
Text	Textile
T C	Tinned Copper
SBR	Styrene Butadiene Rubber
Sh, Sh'ld	Shield(s)(ed)
AIW	American Insulated Wire Company
Bk/W	Black solid color with White tracer
G/W	Green " " " " "
R/W	Red " " " " "
Blu/W	Blue " " " " "
Bk/R	Black " " " Red "
W/R	White " " " " "
O/R	Orange " " " " "
R/Bk	Red " " " Black "
G/Bk	Green " " " " "
O/Bk	Orange " " " " "
Blu/Bk	Blue " " " " "
W/Bk	White " " " " "
W	White solid color
R	Red " "
G	Green " "
Bk	Black " "
Blu	Blue " "
O	Orange " "

TABLE A1

TEST RESULTS

Cable Type: CO-18LOF (14/22, 4/22 SI) 0500
Manufacturer: Cornish Wire
Date of Mfr: 1962
*Description of Cable:
Received From: Components & Materials Division, Coles Area

Wrap: Cotton
Jacket: Polychloroprene
Conductors: 14 Cond. #22 AWG, consisting of 16 Str. #34 AWG (.0063") Tin. Copper
4 Cond. #22 AWG, Shielded cond. 16/#34 AWG Shielded Braid consisting of 65 Str. .005 ± in. T C
Insulation: SBR with Textile Braid

Cable Sample No.	No. of Cycles	Fault (Conductor)	*Remarks
FLEX TESTS			
1	1094	O/R (Sh'ld)	Cond. broken; ins=OK; Text. braid=OK; Appr ox 50% of Sh. Str. broken
2	1429	O/R (Sh'ld)	Same as above
3	1649	Bk/R (Sh'ld)	Same as above
IMPACT TESTS 15# Hammer Weight 6" Hammer Drop			
1	149		Short only on impact; exam. did not reveal fault; Text. braid over ins. frayed; ins=OK; Almost all of sh. broken indicating possibly that short was due to sh'ld str. being driven into ins. to cond.
2	167 to 186		First indication of short @167~. To definitely locate fault, test was continued to 186~. Exam.
		G/Bk	showed ins. frayed to bare cond. but not shorting due to good ins. of adjacent R/Bk, R, G & O/Bk cond.
		O	Braid frayed; ins. broken; no short due to good ins. on adjacent cond. (Bk & R/W).
		R, G/W, R/W, Bk, W	Braid frayed; ins=OK
		O/R (Sh'ld)	All sh'ld str. broken; possibly sh'ld str. penetrated thru ins. or to adjacent Blu/W (Sh) cond. or below to O/R(Sh) and directly below blow of impact hammer.
		W/R (Sh)	Same as above O/R (sh)
		Bk/R (Sh)	Same except this cond. is on the outside of O/R (Sh) and adjacent to Blu/W (Sh)
		Blu/W (Sh)	Same except this cond. was on the bottom (next to anvil) & was exposed to broken sh'ld str. of all the other sh'ld cond.

Table A1 (continued)

Cable Sample No.	No. of Cycles	Fault (Conductor)	*Remarks
3	154	Bk/R (Sh)	Cond. broken; all sh'ld str. broken; text. braid frayed; Bk/W, G/W, R/W, Blu/W (Sh) Cond. are on the bottom.
		G/W, Bk/W R/Bk, O, Bk W/Bk, W, W/R (Sh), O/R (Sh)	Text. braid frayed thru; cond=OK; ins=OK
TWIST TESTS		40# Weight	
1	3698	W/R (Sh)	Cond. broken; few sh'ld str. broken
2		(No more cable)	

*See List of Abbreviations

TABLE A2

TEST RESULTS

Cable Type: CO-18LOF (14/22, 4/22 SI) 0500

Description of Cable:

Conductors: 14 cond. #22 AWG, consisting of 16 str. #34 AWG (.0063") T C
4 cond. #22 AWG, sh'ld cond. 16/#34 AWG sh'ld braid consisting of 65/.005± in. T C (Mylar tape under sh.)

Insulation: SBR

Binder and Wrap: Cotton

Jacket: Polychloroprene

(1) Manufacturer: American Ins. Wire (AIW) Date of Mfr: 1964
Received from: Components & Materials Division, Coles Area

Cable Sample No.	No. of Cycles	Fault (Conductors)	Remarks
FLEX TESTS			
1	2976	W/R (Sh) Bk/W	Cond. broken, ins=OK; few sh. str. broken
2	3101	Bk/W, R/W, W/R (Sh)	Same as above
		Shields	Approx. 50% of str. broken
3	2223	R/Bk	Cond. broken; ins=OK
4	1100	Bk/W	Same as above
		Shields	Few str. broken
IMPACT TESTS 15# Hammer Weight			6" Hammer Drop
1	20	W/Bk, G/Bk R/Bk	Cond. broken; ins=OK
		R/W	Cond. broken; ins. split
2	25	Bk/W, Blu/Bk	Pinhole in ins; probably from sh. str.
		O, G, Blu Bk/W	Cond. broken; ins=OK
		W/R (sh), W/Bk	Same as above
		Shields	Almost all str. broken
3	17	Blu/Bk, O	Cond. broken; ins=OK
		Shields	Few str. broken
TWIST TESTS 40# Weight			
1	19	Bk/W, Blu/Bk, O/Bk	Cond. broken; ins=OK
		G/W, G, R	Same as above
2	28	O/Bk, G/W R/W	Same as above
		Shields	OK

Table A2 (continued)

(2) Manufacturer American Ins. Wire (AIW) Date of Mfr: 1963
Cables Labeled Dry-Rot" (see text)
Received from. Tobyhanna Military Depot

Cable Sample No.	No. of Cycles	Fault (Conductors)	Remarks
FLEX TESTS			
1	588	G/W	Cond. broken, ins, etc. OK
2	329	W	Same as above
3	556	R	Same as above
IMPACT TESTS	15# Hammer Weight		6" Hammer Drop
1	6	-	Failure not visible, probably short to sh.
2	12	Blu, Bk/W	Short. Ins. cut thru exposing cond. to sh.
3	15	W/Bk, Bk	Same as above
TWIST TESTS	40# Weight		
1	8027	R/Bk, G/Bk	Cond. broken, ins OK; sh. str. almost all brkn at several places
	No More Cable		

(3) Manufacturer: American Ins. Wire (AIW) Date of Mfr: 1966
Wrap: Mylar Tape
Received from: Manufacturer

Cable Sample No.	No. of Cycles	Fault (Conductors)	Remarks
FLEX TESTS			
1	1647	W	Cond. broken; ins, sh, wrap = OK
2	1788	R/W	Same as above
3	1312	O	Cond. broken; ins. OK; some sh. str. broken
IMPACT TESTS	15# Hammer Weight		6" Hammer Drop
1	88	G/Bk, O/Bk, Bk/W	Cond. broken; ins-OK; Mylar wrap broken; all sh. str. broken
2	71	R	Ins. cut thru and shorted to adjacent shield of frayed "O/R" cond.
3	65	Blu	cond. broken; ins - OK
TWIST TESTS	40# Weight		
1	15,650	W/Bk, R/Bk(Sh)	Cond. broken; Mylar wrap broken; ins. worn thru and cond. exposed; approx. 50% of sh. str. broken
2	20,379		No Failures
3	17,540		No Failures

TABLE A3
TEST RESULTS

Cable Type: CO-12LOF (12/22) 0325
Description of Cable:
Conductors: 12 #AWG; Each cond.consisting of 16/#34 AWG (.0063") TC
Insulation: SBR
Binder: Cotton
Wrap: Mylar Tape
Jacket: Polychloroprene

(1) Manufacturer: American Ins. Wire (AIW) Date of Mfr: 1965
Received from: Manufacturer

Cable Sample No.	No. of Cycles	Fault (Conductor)	Remarks
FLEX TESTS			
1	986	W/Bk	Cond. broken; ins=OK; Mylar wrap broken
2	1701	O/Bk	Same as above
3	2066	G, O	Same as above
IMPACT TESTS 15# Weight 2" Hammer Drop			
1	46	G/Bk, R/Bk	Cond. broken; ins=OK
2	26	O/Bk	Same as above
3	35	-	No Failure
TWIST TESTS 40# Weight			
1	23,066	-	No Failure
2	18,500	-	No Failure
3	15,000	-	No Failure

(2) Manufacturer: American Ins. Wire(AIW) Date of Mfr: 1965
Wrap: Cotton
Received from: Components & Materials Division, Coles Area

FLEX TESTS			
1	3614	G, G/Bk	Cond. broken; ins=OK
2	947	Blu, G/Bk O/Bk	Same as above
3	1245	G	Same as above
IMPACT TESTS 15# Hammer Weight 2" Hammer Drop (2)			
1	53	O, Blu	Cond. broken; ins=OK
2	26	Bk/W, Blu/Bk	Same as above
3	15	G	Same as above
TWIST TESTS			
No More Cable			

Table A3 (Continued)

(3) Manufacturer: Industrial Components Co. (Actually AIW) Date of Mfr: June 1965

Received from: Tobyhanna Military Depot

Cable Sample No.	No. of Cycles	Fault (Conductors)	Remarks
FLEX TESTS			
1	853	Blu	Cond. broken; ins, etc. = OK
2	1653	Bk/W, G/Bk	Same as above
3	[illegible]	G, W, Bk	Same as above
IMPACT TESTS	15# Hammer Weight	3" Hammer Drop (1)	
1	2	Blu/Bk, W/Bk, G	Cond. broken; ins, etc. = OK
2	3	Bk/W, G Bk, Blu/Bk	Same as above
3	6	W/Bk	Same as above
IMPACT TESTS	15# Hammer Weight	2" Hammer Drop (2)	
1	21	Blu, G/Bk	Cond. broken; ins, etc. = OK
2	25	Bk/W, Blu	Same as above
3	19	R/Bk, G	Same as above
TWIST TESTS	40# Weight		
1	13,890	NF (3)	Mylar tape frayed thru
2	14,960	NF	Same as above
3	13,600	NF	Same as above

NOTE:
(1) 3" Hammer drop too severe for this light-duty, small dia. cable
(2) Hammer drop reduced to 2" drop
(3) NF = No Failure

TABLE A4

TEST RESULTS

Cable Type: CO-09LOF (7/22, 2/22 SI) 0325

Description of Cable:

Conductors: 7 Cond. #22 AWG, consisting of 16 Str./#34 AWG (.0063")TC
2 Cond. #22 AWG, sh'ld cond. 16/#34 AWG sh'ld braid consisting of 65/.005± in. TC (Mylar tape under sh)

Insulation: SBR

Binder: Cotton

Wrap: Mylar Tape

Jacket: Polychloroprene

(1) Manufacturer: American Insulated Wire (AIW) Date of Mfr: 1965
Received from: Tobyhanna Army Depot

Cable Sample No.	No. of Cycles	Fault (Conductors)	Remarks
FLEX TESTS			
1	86	R	Cond. broken; ins. - OK
2	179	Bk/R (Sh), G/Bk	Same as above
3	303	Bk/R (Sh)	Same as above
		Shields	Few strands broken
IMPACT TESTS	15# Hammer Weight	2" Hammer Drop	
1	12	R, W, Bk, W/Bk, Blu, O, G	Cond. broken; ins. - OK
		Shields	All str. broken; Mylar wrap broken
2	22	R, G, W	Cond. broken; ins. - OK
		Shields	All str. broken; Mylar wrap broken
3	19	R, O, W/Bk	Cond. broken; ins. - OK
		Shields	All str. broken; Mylar wrap broken
TWIST TESTS	40# Weight		
1	5243	Bk	Cond. broken; ins. - OK; some sh. str. broken
2	3201	Bk	Same as above
3	5821	-	

Manufacturer: ITT Surprenant Date of Mfr: 1966

Wrap: Textile Reinforced Polychloroprene Jacket

Received from: Manufacturer

FLEX TESTS			
1	77	R	Cond. broken; ins, etc. OK
2	509	R, W, G	Same as above
3	500	O	Same as above

Table A4 (continued)

Cable Sample No.	No. of Cycles	Fault (Conductors)	Remarks
IMPACT TESTS		15# Hammer	2" Hammer Drop
1	98	W, Blu	Cond. ins. broken & cond. exposed & shorted to sh; sh. str. all broken; cond. under sh. protected from shorting to sh. by Mylar wrap
2	112	W, Blu	
3	94	W	
TWIST TESTS		40# Weight	
1	6156	W, R, G, O, Blu, Bk	Cond. broken; ins. - OK; sh. str. all broken
2	4167	R, Blu, Bk W/Bk	Same as above
3	5608	Bk, G/Bk(Sh)	Same as above

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13. ABSTRACT

This study was initiated to investigate the cause of various reports of field failures of wires and cables (multi-conductor), specifically cables which are part of the AN/VRC-12 Radio Equipment.

Various types of cables, fabricated per MIL-C-3432 and similar to those reported as having failed in tactical use, were tested.

A description of each type is provided in this report along with detailed physical test data, such as tensile and elongation of conductor insulating material (aged and unaged) and mechanical tests on the cable such as, flex, impact and twist.

None of the cables tested exhibited outstanding performance in all the mechanical tests. When cables did perform very well with regard to one or two tests, they did poorly in others. All cables exhibited variations of performance and practically no correlation was obtained between the mechanical tests and the physical characteristics of the insulation.

Performance tests, however, do offer some control on the construction and manufacturing variables of the cable. New design considerations are recommended based upon the evaluation. Requirements for the physical properties of the insulation are also recommended to upgrade the material and provide greater stability with respect to accelerated temperature aging. Mechanical performance tests on

Cable, multiconductor Cable, Extra flexible Cable, Electrical Cable, Light duty			

finished cable are recommended to provide an overall control on the constructional quality of the finished cable.

These tests will be incorporated in Military Specification MIL-C-3432 along with appropriate changes in Government inspection procedures to insure improved reliability of multi-conductor cables.