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EVALUATION OF THIN WALL SPACECRAFT WIRING

Volume I: Test Results

BY

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FINAL REPORT

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VOLUME I: TEST RESULTS

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EVALUATION OF THIN WALL SPACECRAFT ELECTRICAL WIRING

I. OBJECTIVE

The objective of this program is to determine the performance characteristi of various thin wall, spacecraft, electrical wiring under simulated spacecraft environments. The data will permit wire selection for manned spacecraft to be made on the basis of comparative performance. Further, recommendations will be made regarding the development of specifications for comparative evaluation and qualification testing of manned spacecraft electrical wire insulation.

II. EVALUATION PROGRAM

A. General

The evaluation program consisted of the following tests:

Electrical Tests

Insulation Resistance	-	Total sample immersed in water at 23°C
Voltage Withstand - 1600 volts for 1 min.	-	Total sample immersed in water
Insulation Resistance*	-	As a function of exposure time at 100% RH + dew in 15 psia pure oxygen at 50°C
Corona Start Voltage	-	In 5 psia pure dry oxygen at 93°C and in 15 psia O_2 at 100% RH + dew
Voltage Breakdown	-	In wet oxygen at 5 psia and 23°C, and at 150°C in vacuum, 10^{-6} torr
Voltage Flashover	-	In 5 psia pure oxygen at 23°C and 100% RH + dew.

*Note: Insulation Resistance and voltage breakdown are used as end point criteria of certain other tests.

Mechanical Tests

Outside Diameter	-	at 23C and 50% RH
Concentricity of Insulation	-	" " " " "
Conductor Dimensions	-	" " " " "
Weight per 1000 ft.	-	" " " " "
Stripability	-	" " " " "

Mechanical Tests (Cont'd)

Solderability	-	Solder pot at 320°C
Color Durability	-	
Marking Legibility	-	
Compatibility with Potting Compounds		
Flexibility*	-	At 23°C and -196°C
Abrasion	-	At 23C
Blocking	-	150°C and 10^{-6} torr
Cut-through	-	23°C and 150°C
Thermal Creep ("Cold" Flow)	-	23°C and 150°C
Wicking	-	In water at 23°C

*Note: Flexibility is used as an end point criterion of certain other tests.

Physical - Chemical Tests

Thermal Aging	-	At 150°C in oxygen at 15 psia and in vacuum.
Exposure to Ultra-Violet	-	Approx. 1.4 x 10^6 ergs/cm^2/sec/ equiv. at 4000 A for 1 month At 85C in wet oxygen at 15 psia and at 150C in vacuum.
Exposure to Radiation	-	10 hrs. at 6000 rads/hr at 150°C and 10^{-6} torr and 100 rads/hr at 93C in 5 psia pure O_2
Flammability Smoke, flash and fire points	-	In wet flowing oxygen at 5 psia.
Chemical Compatibility	-	

Analytical Tests

Offgassing in Oxygen	-	TGA and Analysis of Gases
Volatility in Vacuum	-	TGA and Analysis at 10^{-7} torr

B. Test Methods

Details of the various test methods have been given in Volume I of Technical Report No. 1, July 28, 1965. The minor modifications that were made in test procedures during the latter part of the program are described below.

1. X-Ray Determination of Dimensions

A great deal of effort was devoted to the application of industrial X-ray techniques to the measurement of outside diameter, conductor diameter and insulation wall thickness. Satisfactory X-ray photos could be obtained with Wires #3, 7 and 8. With other wires the coefficient of absorption was too low to permit the insulation to appear in the X-ray negative. In the case of Wire #3, the pigmented TFE dispersion, rather than the H-film, showed in the X-ray.

With the remaining wires it was necessary to apply a brushed coat of DuPont #4132 silver paint in order to obtain X-rays that showed the outer edge of the insulation wall. Many measurements were made in these X-ray negatives, but the method has not proven to be satisfactory. In addition to the error introduced by the difficulty in precisely locating the outer edge of the insulation wall, a second error is associated with the flattening of the wire when it is pressed against the X-ray film holder. This must be done to eliminate distortion.

2. Cross Sectional Examination

Measurements of the pertinent dimensions can be readily made by microscopic examination of specimens that are potted in clear plastic, cross-sectioned and then polished, using metallographic techniques. Such specimens permit a complete cross-sectional examination, which discloses any voids or oth manufacturing imperfection.

Time did not permit this procedure to be applied to all the wires in the program, but it was used with the seven most important construction types.

3. Concentricity

The concentricity values reported in Technical Report No. 1 were calculated by dividing the minimum wall thickness by the maximum wall thickness for each specimen and then averaging the results for ten specimens. This procedure leads to low values of concentricity that may not be indicative of true eccentricity. If, for instance, the insulation wall is thicker than normal along a portion of the specimen, the calculated concentricity value will be low even though the insulation thickness may be uniform across any section of the specimen.

A truer indication of concentricity can be obtained by measuring the insulation wall thickness on either side of the conductor at several points along the wire and computing the concentricity (ratio of thinner to thicker wall) for each point. This was done at three points on each of ten specimens, giving 30 values of concentricity for each wire.

Wall thickness measurements are equally as important as concentricity values. Minimum values are particularly important in determining overall wire quality. Since it was necessary to measure wall thickness in determining concentricity, the average, maximum and minimum of wall thickness have been reported.

In those cases where cross-sectioned specimens were available, concentricity was determined for each section. Such specimens provide the most meaningful concentricity data.

4. Conductor Dimension

Attempts were made to measure conductor diameter with a hand micrometer as a check on the X-ray examination. It was found, however, that consistent values could not be obtained after stripping the insulation from the stranded conductor. Since the X-ray photographs provide sharp images of the conductor, the hand micrometer measurements were discontinued.

Additional measurements were made on cross-sectioned specimens. These measurements were in reasonable agreement with the X-ray measurements.

5. Voltage Breakdown

The voltage breakdown test chamber described in Volume I of Technical Report No. 1 was used for tests in oxygen, but a separate arrangement was used for tests in vacuum. Each twisted pair specimen was placed in a 3/4 inch diameter glass tube that was sealed at one end with a removable metal cap. The other end was connected to a high vacuum pumping system. The tube was inserted in a muffle type furnace, as shown in Figure 0-1. Temperature was controlled at $150^{\circ}C \pm 5^{\circ}C$.

The removable metal cap served as the high-voltage terminal, while the glass-to-metal adapter at the other end of the tube served as the ground terminal. The twisted pair was folded over so that the active portion of the specimen was in the region of uniform temperature. The tube and a folded twisted-pairspecimen are shown in Figure 0-2.

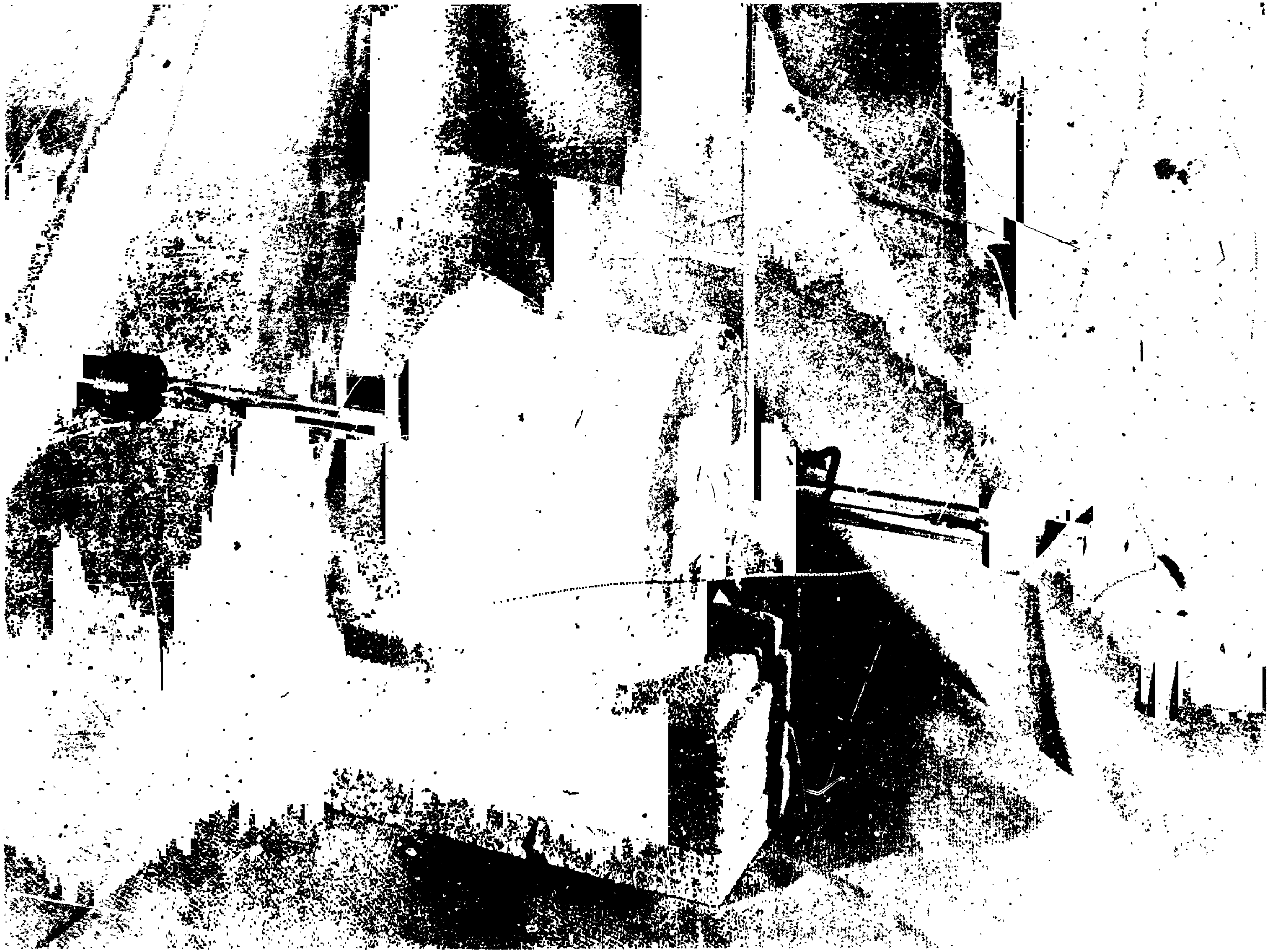
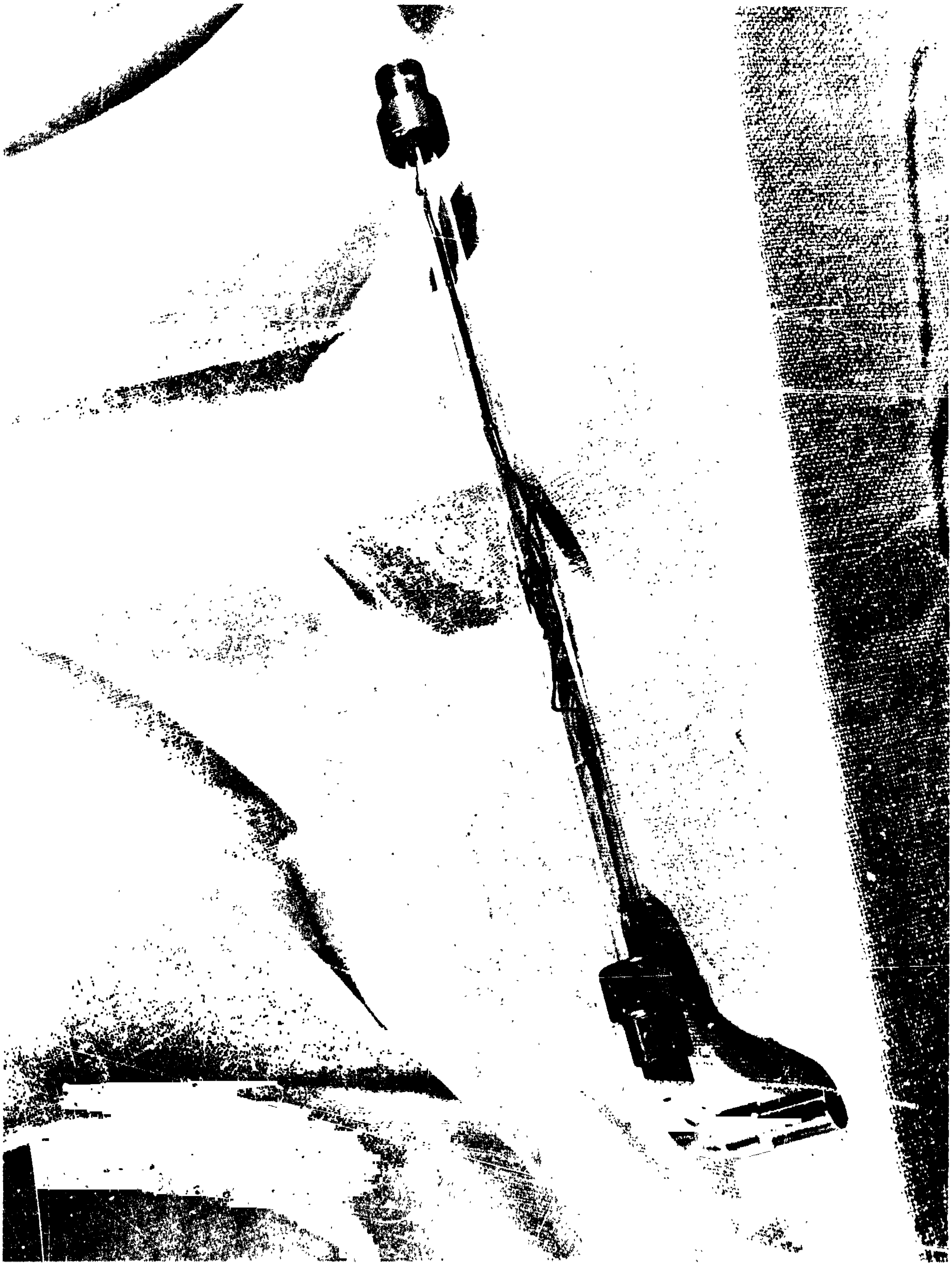


Figure 0-1 - Test Apparatus for Voltage Breakdown Tests in Vacuum at 150°C



6. Repeated Flexure Test

Inadvertently the description of the repeated flexure tests was omitted from the previous report although the results for several wires were reported and two photographs of the test equipment were included which are included also in this report as Figs. 0-3 and 0-4. The dimensions of the "nose" about which the wire is flexed is given again in Fig. 0-5.

An MIT Fold Endurance Tester has been modified for the wire evaluation program. As shown in Fig. 0-3 the wire is held under an average spring tension of 1000 grams. It is clamped in place as shown in Fig. 0-3. The aluminum nose piece is rotated back and forth 172 times per minute. When the wire breaks, the spring tension is released and the test is stopped. In some cases the conductor may break before the insulation fails and such failure is detected by the loss of electrical conductance through the wire. It is possible also that the insulation might fail before the conductor but no automatic technique was developed for detecting such failure. Careful observation never detected insulation failure prior to conductor failure in room temperature tests.

At lease three* variables are involved in the repeated flexure test.

Diameter of the bending "nose"
Total bending arc
Tension in the wire

A considerable investigation led to the arbitrary adoption of the 1000 gram load and the 1 inch bending diameter. The nose diameter was particularly important. With smaller diameters, failures occurred within such a relatively few bending cycles, even at low wire tensions, that comparisons between wires could not be made. It was apparent also from the mandrel flexibility tests that a large diameter would be necessary for low temperature tests. The 1000 gram wire tension was adopted as the best value to prevent uncontrolled "whipping" in the test.

*The frequency (cycles per second) is not believed to be an important variable so long as it is relatively low.

Considerable effort was expended in an attempt to obtain insulation rather than conduction failures in the repeated flexure test. Ultimately it was accepted for certain that at room temperature, fatigue failure would occur in the metal conductor rather than in the lower modulus insulating materials.

The effect of the total bending arc was investigated more by accident than design. It was discovered that with a 270° bending arc, rapid significant failure occurred. Decreasing the arc to 180° somewhat increased the cycles to failure but did not significantly change the order of rating. When tests were made at -162°C it was found necessary to locate the sliding mechanisms outside of the chamber and in consequence the bending arc had to be decreased again to 120°. The tests at room temperature were not repeated because a few tests indicated that the absolute values and the order of comparison would not be affected significantly.

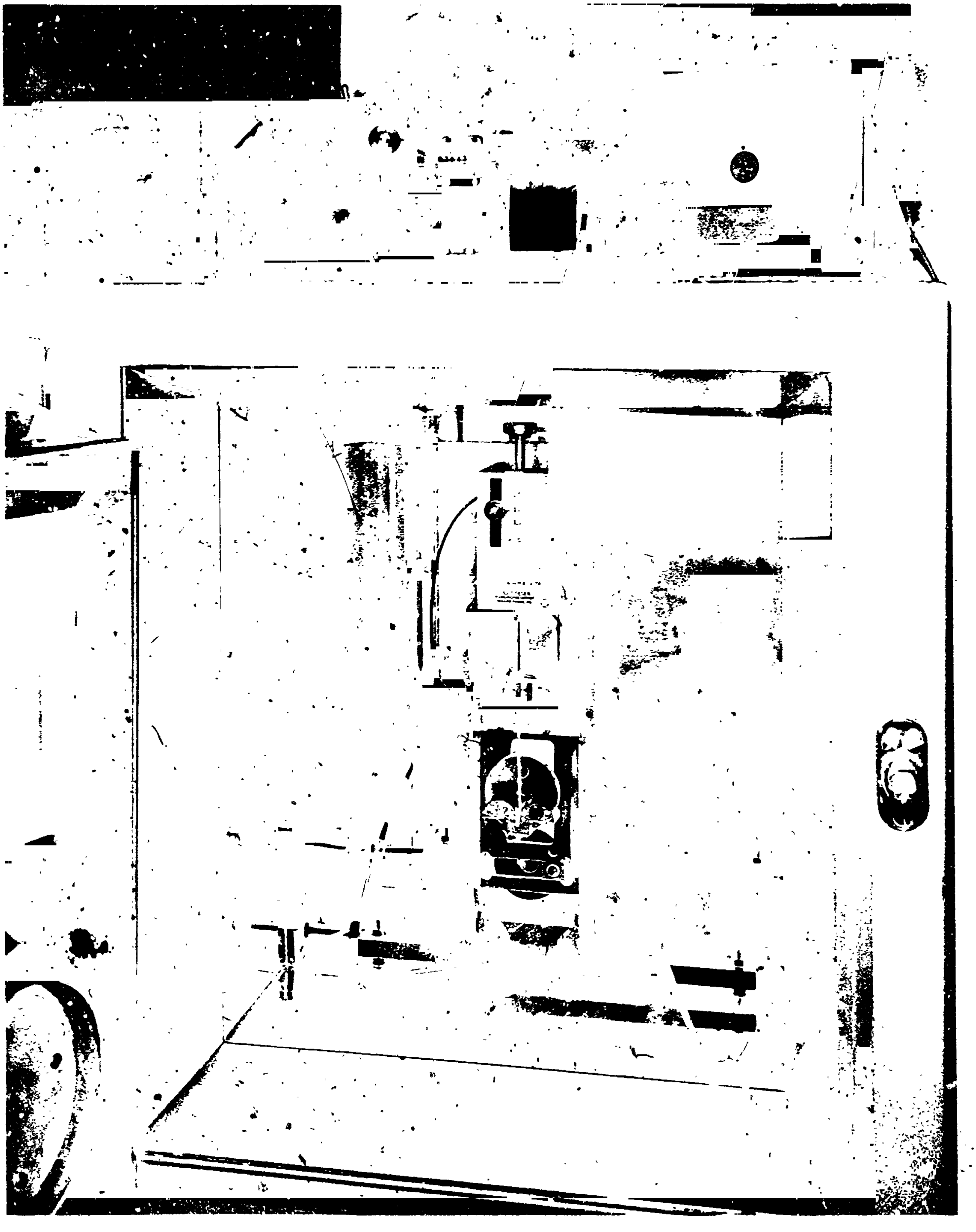


Figure 0-3 - MIT Fold Endurance Flex Tester

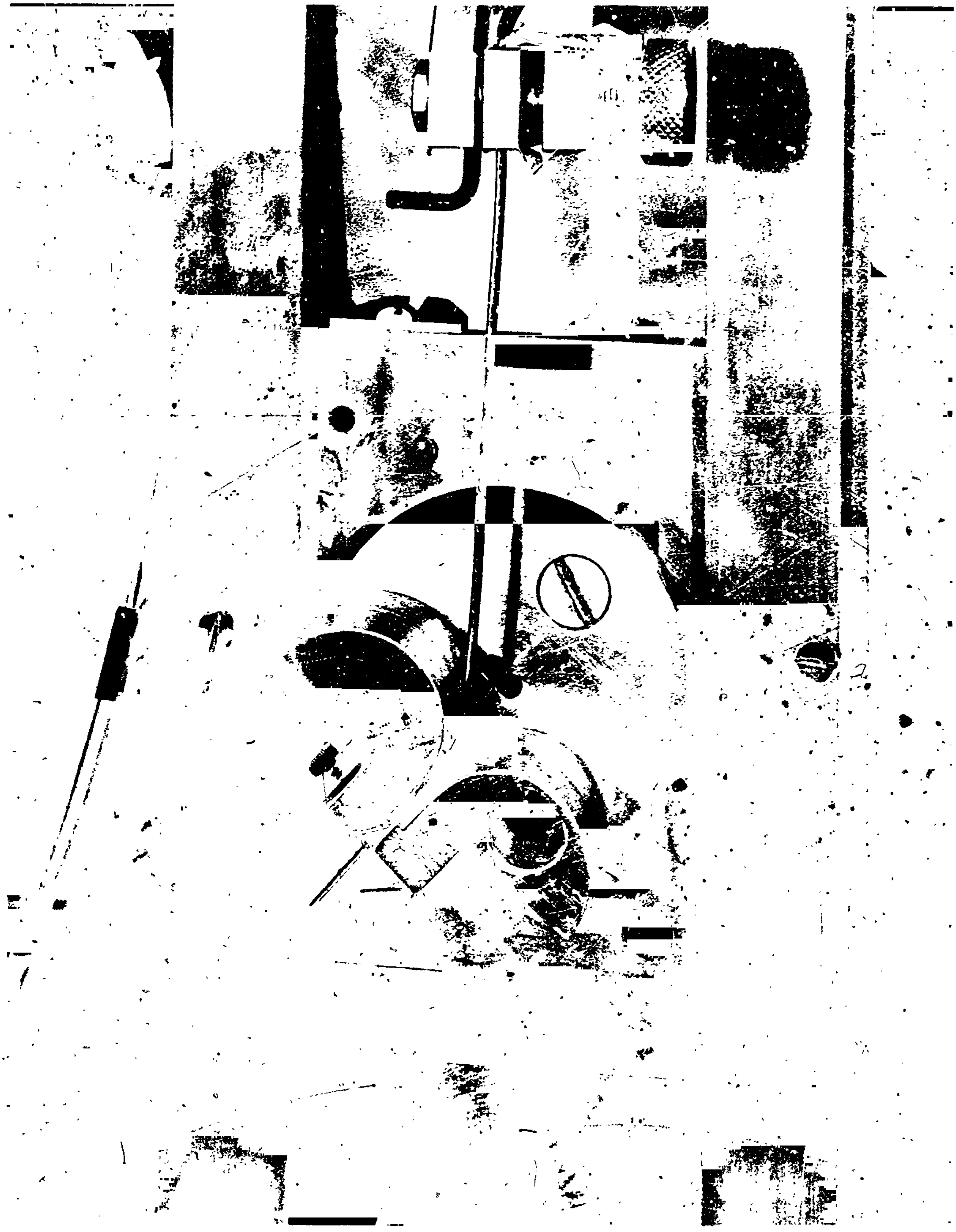


Figure 0-4 - Loading Nose for MIT Fold Endurance Flex Tester

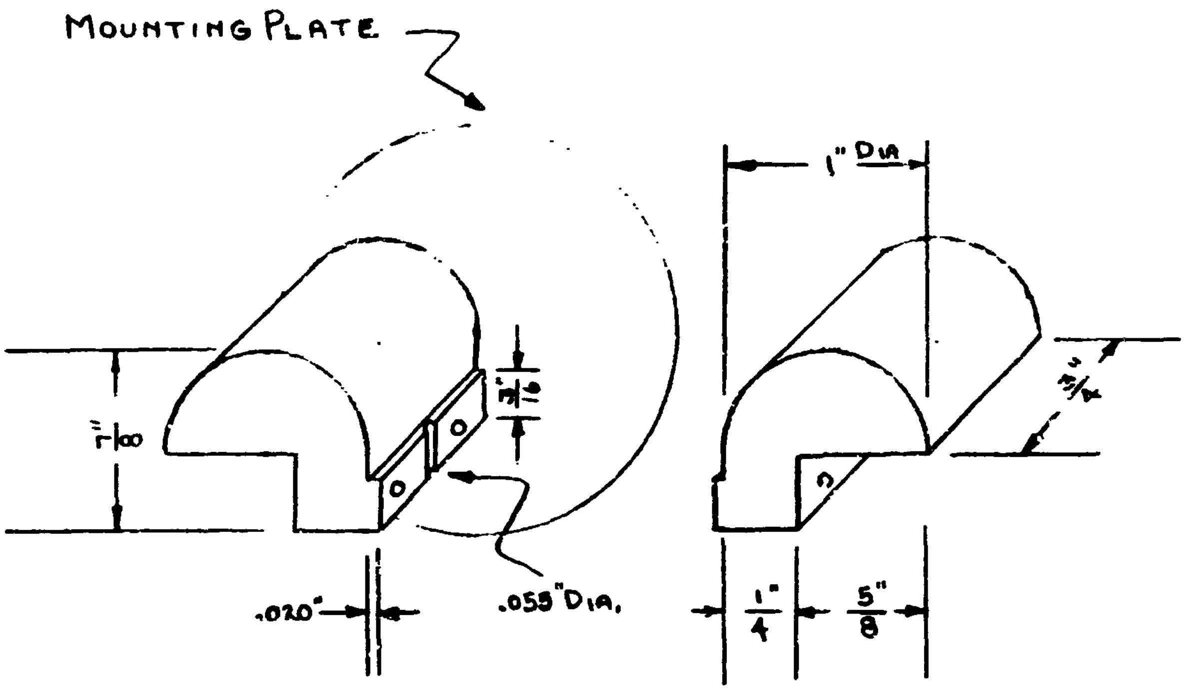


Figure 0-5: Dimensions of Modified Loading Nose for MIT Flex Tester

III. DESCRIPTION OF TEST SAMPLES

Wire No. 1

Extruded FEP nominal 5 mils with ML coating. #20 nickel plated copper 19/32 strands.

Wire No. 2

Extruded 5 mil TFE with 1 mil ML coating. #20 nickel plated copper 19/ strands.

Wire No. 3

Double wrap H-film. First wrap: ½ lap HF tape (1 mil H, ½ mil FEP); second wrap: 1/3 lap FHF tape (½ mil FEP, 1 mil H, ½ mil FEP). 6 mil wall with ½ mil TFE dispersion overcoat with red pigment. #20 nickel plated copper 19/32 strands.

Wire No. 4

Single wrap H-film. ½ lap HF tape (1 mil H, ½ mil FEP) 3 mil wall. #20 nickel plated copper 19/32 strands.

Wire No. 5

Single wrap H-film. ½ lap FHF tape (½ mil FEP, 1 mil H, ½ mil FEP) 4 mil wall. #20 nickel plated copper 19/32 strands.

Wire No. 6

Double wrap H-film. First wrap: ½ lap HF tape (1 mil H, ½ mil FEP), second wrap: ½ lap FHF tape (½ mil FEP, 1 mil H, ½ mil FEP) with ½ mil FEP dispersion overcoat. #20 silver plated copper 19/32 strands.

Wire No. 7

Irradiated modified polyolefin 9.3 mils with polyvinylidene fluoride jacket. #20 tin plated copper 19/32 strands.

Wire No. 8

Irradiated modified polyolefin 9.2 mils. #20 tin plated copper 19/32 strands.

Wire No. 9

Type E TFE per MIL-W-1687D, 9.5 mils. #20 nickel plated copper 19/32 strands.

Wire No. 10

Single wrap H-film. 2/3 lap 3 layers of HF tape (1 mil H, ½ mil FEP). #20 nickel plated copper 19/32 strands.

Wire No. 11

Single wrap H-film. ½ lap 2 layers of ½ mil H-film with 2.5 mil TFE over-wrap. #20 nickel plated copper 19/32 strands.

Wire No. 12

Extruded silicone rubber SE-9029 insulation, wall thickness 10 mils. #20 nickel plated copper, 19/32 strands.

Wire No. 13

Extruded silicone rubber (SE-9029) 10 mils, with polyvinylidene fluoride jacket 2 to 4 mils #20 nickel platted copper, 19/32 strands.

Wire No. 14

Silicone rubber (SE-9029) 10 mils, with over-wrap of H-film jacket (1 mil H, ½ mil FO ½ lap #20 nickel plated copper, 19/32 strands.

Wire No. 15

Double wrap H-film. First wrap: ½ lap HF tape (1 mil H, ½ mil FEP); second wrap: nominal 40% overlap FHF tape (½mil FEP, 1 mil H, ½ mil FEP). #20 silver plated copper 19/32 strands.

Wire No. 16

Same as Wire No. 15 with a ½ mil TFE dispersion overcoat with red pigment.

IV. TEST DATA

Detailed test data obtained during the first reporting period were recorded in Volume II of Technical Report No. 1. The present report contains a complete compilation of all test data and, therefore, supersedes the previous report. This report is presented in two volumes: Volume I contains the detailed data and Volume II contains the analysis, summary and conclusions. Many of the tables in this report are reproductions of tables that were included in Volume II of Technical Report No. 1. Data that were obtained in the latter stages of the program have been appended to the original tables. Therefore, the order in which the data are presented is not consistent in all tables.

1. Insulation Resistance - Total Sample

In the early stages of the program, wires 1 to 14 were ordered from the respective manufacturers. Arrangements were later made by NASA for wires 15 and 6 to be supplied on a no cost basis. Most of the wires were supplied in surprisingly short lengths. Table 1-1 shows the lengths that were received in each case. In addition to being inconvenient to handle so many lengths, especially in the insulation resistance tests, it is important to consider the possible reasons why such short lengths were supplied. It would appear that some of the manufacturers could not produce longer lengths that would pass the immersion test. On the other hand, the samples may have consisted of odds and ends that were accumulated during regular production runs. In any event, the reason for the apparent inability to maintain acceptable quality on long lengths should be determined before procurement specifications are established. In particular, it should be determined if the spark test and subsequent insulation resistance (3-day water immersion) followed by a 1600 volt withstand test are too severe in light of the present production capabilities and the actual application requirements.

The results of the insulation resistance measurement on immersed spools of wire are given in Tables 1-2 to 1-17. The values are given in units of ohms per 1000 feet for each spool of wire. The wire was packaged with one piece per spool.

The insulation resistance values are shown for 1 minute and 5 minute electrification times. In general, if there is no water penetration due to a defect, the five minute value will be somewhat higher than the one minute value. Sensitive measurements show this to be true even for a high resistivity, low-loss material such as TFE (see Table 1-10). In spite of the increased electrification time, which allows transient absorption currents to decay, several specimens did not pass the acceptance criterion of 3×10^{10} ohms per 1000 feet. Here again, consideration should be given to the severity of the test. Because of the difficulty encountered in obtaining samples that could pass this test, instructions were received from NASA to proceed with further evaluation of all wires despite their failure to pass the acceptance tests.

One specimen of each wire sample was tested more thoroughly at the end of the 3-day immersion to determine the resistance vs. time of voltage application (current decay) characteristics. The precise interpretation of such measurements for the subject specimens and test conditions (water immersion) is complex, but the observed changes do given an indication of the dielectric losses at very low frequencies. Such "absorption" measurements can be used as a figure of merit in the absence of data on a-c properties. They are sometimes useful in interpreting other observed behavior in terms of impurities, cure, or other processing variables.

In cases such as Wires #4 and 5, where the insulation resistance decreased continuously over the three day period, it is evident that moisture is being absorbed. Further evidence is provided by the absorption measurements, which show no large change in resistance after 20 minutes, even though the values are low at the outset. This indicates ionic conductivity caused by water absorption.

TABLE 1-1

WIRE LENGTH - AS RECEIVED (feet)

Wire #1
(1st shipment)*

610
406
245
1261

(2nd shipment)

100
100
100
100
100
100
100
100
100
145
56
56
43
55
1255

Wire #2

1135
368
1503

Wire #3

105
412
58
83
220
40
432
1350

Wire #4

165
253
944
1362

Wire #5

103
188
245
51
235
150
52
217
1241

Wire #6

55
96
573
548
1272

Wire #7

365
275
360
1000

Wire #8

1000

Wire #9

158
172
71
82
126
100
115
22
68
160
1074

Wire #10

274
311
155
434
75
1249

Wire #11**

402
371
300
158
1231

Wire #12

64
157
60
137
85
41
60
185
167
64
40
1060

Wire #13

150
177
152
202
207
195
1083

Wire #14

230
16
176
86
251
42
349
34
89
24
53
15
1365

*Shipment rejected. Faults removed by manufacturer and returned.

**Returned to manufacture
Respooled and sent back
original footage marking

(continued)

TABLE 1-1 (continued)

WIRE LENGTH - AS RECEIVED (feet)

Wire #15

264
171
184
86
173
32
163
73
1146

Wire #16

238
337
54
32
43
173
94
971

TABLE 1-2

INSULATION RESISTANCE - TOTAL SAMPLE

Wire #1

Length feet	Resistance per 1000 ft. (ohms) 1 Hour
406	6.9×10^{5}
610	7.9×10^{5}
145	1.2×10^{11}

Wire returned to vendor.

Retest

Length feet	Resistance per 1000 ft. (ohms) 1 Hour 1 minute	1 Day 1 min.	1 Day 5 min.	3 Days 1 min.	3 Days 5 min.
100	1.3×10^{11}	3.3×10^{10}	6.7×10^{10}	1.3×10^{10}	3.3×10^{10}
100	1.3×10^{11}	1.7×10^{10}	7.1×10^{10}	2.5×10^{10}	3.6×10^{10}
100	7.5×10^{10}	5.6×10^{10}	1.3×10^{11}	2.3×10^{10}	7.8×10^{10}
145	1.4×10^{11}	6.5×10^{10}	3.8×10^{11}	7.2×10^{10}	2.8×10^{11}
43	2.5×10^{11}	———	2.6×10^{11}	6.9×10^{10}	5.6×10^{11}
56	2.0×10^{11}	9.6×10^{9}	1.3×10^{10}	4.0×10^{9}	5.6×10^{9}
56	1.7×10^{11}	2.8×10^{10}	4.2×10^{10}	1.0×10^{10}	1.2×10^{10}

Resistance vs. Time of Applied Voltage

Length - 43 feet

Time Minutes	I.R. ohms/1000 ft.	Time Minutes	I.R. ohms/1000 ft.
1	6.9×10^{10}	8	1.2×10^{12}
2	1.7×10^{11}	9	9.0×10^{11}
3	3.6×10^{11}	10	1.2×10^{12}
4	4.7×10^{11}	12	1.8×10^{12}
5	5.6×10^{11}	13	1.2×10^{12}
6	7.6×10^{11}	15	1.9×10^{12}
7	1.4×10^{12}		

TABLE 1-3

INSULATION RESISTANCE - TOTAL SAMPLE

Wire #2

Length feet	Resistance per 1000 ft. (ohms) 1 Hour 1 min.	1 Hour 5 min.	1 Day 1 min.	1 Day 5 min.	3 Days 1 min.	3 Days 5 min.
262	$2.5x10^{11}$	$5.5x10^{11}$	$9.2x10^{11}$	$2.9x10^{12}$	$1.6x10^{12}$	$3.7x10^{12}$
1135	$3.2x10^{11}$	$2.0x10^{12}$	$4.5x10^{12}$	$5.7x10^{12}$	$8.5x10^{12}$	$1.0x10^{13}$

Resistance vs. Time of Applied Voltage

Length - 1135 feet

Time Minutes	I.R. (ohms/1000 ft.)
1	$8.5x10^{12}$
2	$8.7x10^{12}$
3	$9.2x10^{12}$
4	$9.6x10^{12}$
5	$1.0x10^{13}$
7	$1.1x10^{13}$
10	$1.4x10^{13}$
15	$1.8x10^{13}$
20	$2.5x10^{13}$
25	$3.2x10^{13}$
30	$4.1x10^{13}$

TABLE 1-4

INSULATION RESISTANCE - TOTAL SAMPLE

Wire #3

	Resistance per 1000 feet (ohms) (measured after 1 minute)		
Length (ft.)	1 Hour	1 Day	3 Days
40	8.7×10^{10}	1.8×10^{11}	1.2×10^{11}
83	3.0×10^{10}	4.2×10^{10}	5.2×10^{10}
58	6.7×10^{10}	1.5×10^{11}	9.3×10^{10}
220	7.8×10^{10}	1.5×10^{11}	1.2×10^{11}
412	9.8×10^{10}	7.8×10^{10}	1.2×10^{11}
432	6.8×10^{10}	2.9×10^{11}	1.4×10^{11}

Resistance vs. Time of Applied Voltage

Length - 40 feet

Time (minutes)	I.R. ohms/1000 ft.
1	1.2×10^{11}
2	2.4×10^{11}
3	4.8×10^{11}
5	9.2×10^{11}
8	1.3×10^{12}
12	1.8×10^{12}
17	1.8×10^{12}
25	2.0×10^{12}

TABLE 1-5

INSULATION RESISTANCE - TOTAL SAMPLE

Wire #4

Resistance per 1000 ft. (ohms)

Length feet	1 Hour 1 Minute	1 Day 1 min.	1 Day 5 min.	3 Days 1 min.	3 Days 5 min.
944	3.4×10^9	1.0×10^8	3.6×10^8	1.8×10^7	2.6×10^7
253	3.9×10^9	2.4×10^9	8.4×10^9	8.6×10^7	1.1×10^8
60	2.7×10^9	4.1×10^9	1.7×10^{10}	2.2×10^8	3.0×10^8

Resistance vs. Time of Applied Voltage

Length - 253 feet

Time (minutes)	I.R. (ohms/1000 ft.)
1	8.6×10^7
2	9.6×10^7
4	1.1×10^8
9	1.2×10^8
20	1.3×10^8

TABLE 1-6

INSULATION RESISTANCE - TOTAL SAMPLE

Wire #5

Resistance per 1000 ft. (ohms)

Length feet	1 Hour	1 Day		3 Days	
	1 minute	1 min.	5 min.	1 min.	5 min.
150	2.4×10^{10}	1.1×10^{10}	2.8×10^{10}	1.9×10^{8}	2.5×10^{8}
52	2.4×10^{10}	1.5×10^{10}	5.0×10^{10}	4.3×10^{8}	5.2×10^{8}
188	2.5×10^{10}	2.6×10^{10}	5.5×10^{10}	6.0×10^{8}	8.1×10^{8}
51	1.4×10^{10}	8.2×10^{9}	1.8×10^{10}	1.1×10^{8}	2.6×10^{7}
233	1.5×10^{10}	1.8×10^{9}	4.4×10^{9}	1.8×10^{7}	2.6×10^{7}
217	2.1×10^{10}	9.8×10^{9}	3.0×10^{10}	5.4×10^{8}	8.5×10^{8}
245	1.5×10^{10}	1.0×10^{10}	3.7×10^{10}	3.7×10^{8}	4.9×10^{8}

Resistance vs. Time of Applied Voltage

Length - 188 feet

Time (minutes)	I.R. ohms/1000 ft.
1	6.0×10^{8}
2	7.0×10^{8}
3	7.3×10^{8}
5	8.1×10^{8}
10	9.0×10^{8}
20	9.8×10^{8}

TABLE 1-7

INSULATION RESISTANCE - TOTAL SAMPLE

Wire #6

Length feet	Resistance per 1000 ft. (ohms) 1 Hour 1 Minute	1 Day 1 Minute	3 Days 1 min.	3 Days 5 min.
55	5.8×10^{10}	8.8×10^{10}	3.9×10^{10}	1.4×10^{11}
548	5.6×10^{10}	3.5×10^{10}	1.6×10^{10}	4.2×10^{10}
570	5.7×10^{10}	5.7×10^{10}	2.4×10^{10}	8.0×10^{10}

Resistance vs. Time of Applied Voltage

Length - 548 feet

Time (Minutes)	I.R. ohms/1000 ft.
1	1.6×10^{10}
2	2.6×10^{10}
3	3.3×10^{10}
5	4.2×10^{10}
8	5.4×10^{10}
11	6.6×10^{10}
15	7.7×10^{10}
20	8.8×10^{10}
28	1.8×10^{11}

TABLE 1-8

INSULATION RESISTANCE - TOTAL SAMPLE

Wire #7

Resistance per 1000 ft. (ohms)

Length feet	1 Hour 1 Minute	1 Day 1 min.	1 Day 5 min.	3 Days 1 min.	3 Days 5 min.
275	2.3×10^{10}	3.3×10^{10}	1.5×10^{11}	2.3×10^{10}	7.1×10^{1}[illegible]
365	1.8×10^{10}	2.9×10^{10}	8.8×10^{10}	2.3×10^{10}	5.8×10^{1}[illegible]
252	1.3×10^{10}	4.8×10^{10}	1.7×10^{11}	1.9×10^{10}	4.3×10^{1}[illegible]

Resistance vs. Time of Applied Voltage

Length - 275 feet

Time (Minutes)	I.R. ohms/1000 ft.
1	2.3×10^{10}
2	3.6×10^{10}
3	4.9×10^{10}
5	7.1×10^{10}
7	9.1×10^{10}
11	1.2×10^{11}
15	1.6×10^{11}
20	2.0×10^{11}
25	2.5×10^{11}

TABLE 1-9

INSULATION RESISTANCE - TOTAL SAMPLE

Wire #8

Length feet	1 Hour 1 Minute	1 Day 1 min.	1 Day 5 min.	3 Days 1. min.	3 Days 5 min.
		Resistance per 1000 ft. (ohms)			
892	1.3×10^{10}	2.1×10^{10}	7.9×10^{10}	1.4×10^{10}	6.8×10^{10}

Resistance vs. Time of Applied Voltage

Length - 892 feet

Time (Minutes)	I.R. ohms/1000 ft.
1	1.4×10^{10}
2	2.9×10^{10}
3	4.2×10^{10}
5	6.8×10^{10}
7	8.9×10^{10}
10	1.2×10^{11}
15	1.9×10^{11}
20	2.4×10^{11}
25	3.0×10^{11}

TABLE 1-10

INSULATION RESISTANCE - TOTAL SAMPLE

Wire #9

Length (ft.)	Resistance per 1000 feet (ohms) (measured after 1 minute) 1 Hour	1 Day	3 Days
158	3.2×10^{11}	1.2×10^{12}	9.2×10^{11}
172	4.3×10^{11}	8.8×10^{11}	1.8×10^{11}
71	1.8×10^{11}	3.0×10^{11}	3.5×10^{11}
82	2.1×10^{11}	2.2×10^{11}	3.0×10^{11}
126	6.3×10^{11}	1.5×10^{12}	7.1×10^{11}
100	8.2×10^{10}	1.4×10^{11}	1.6×10^{11}
115	3.0×10^{11}	4.5×10^{11}	3.8×10^{11}
22	4.6×10^{11}	6.8×10^{11}	3.7×10^{11}
68	2.7×10^{11}	3.1×10^{11}	2.9×10^{11}
160	3.3×10^{11}	7.3×10^{11}	6.8×10^{11}

Resistance vs. Time of Applied Voltage

Length - 100 feet

Time (Minutes)	I.R. ohms/1000 ft.
½	1.52×10^{11}
1	1.56×10^{11}
2	1.79×10^{11}
3	2.27×10^{11}
5	4.17×10^{11}
7	7.58×10^{11}
10	1.39×10^{12}
13	1.92×10^{12}
17	2.63×10^{12}
20	3.45×10^{12}

TABLE 1-11

INSULATION RESISTANCE - TOTAL SAMPLE

Wire # 10

Length feet	Resistance per 1000 ft. (ohms) 1 Hour 1 min.	1 Hour 5 min.	1 Day 1 min.	1 Day 5 min.	3 Days 1 min.	3 Days 5 min.
274	4.1×10^{10}	7.1×10^{10}	2.4×10^{10}	3.8×10^{10}	7.7×10^{9}	1.5×10^{10}
75	3.6×10^{10}	9.8×10^{10}	1.2×10^{10}	4.1×10^{10}	7.2×10^{9}	1.4×10^{10}
434	4.8×10^{10}	9.1×10^{10}	8.3×10^{9}	2.0×10^{10}	8.7×10^{8}	8.7×10^{8}
311	4.7×10^{10}	8.7×10^{10}	3.1×10^{10}	5.6×10^{10}	7.4×10^{9}	1.6×10^{10}
50	3.5×10^{10}	8.0×10^{10}	1.3×10^{10}	2.9×10^{10}	5.0×10^{9}	1.1×10^{10}

Resistance vs. Time of Applied Voltage

Length - 274 feet

Time (minutes)	I.R. ohms/1000 ft.
1	7.7×10^{9}
2	1.1×10^{10}
3	1.2×10^{10}
4	1.4×10^{10}
5	1.5×10^{10}
8	2.1×10^{10}
10	2.2×10^{10}
13	2.5×10^{10}
15	2.6×10^{10}

TABLE 1-12

INSULATION RESISTANCE - TOTAL SAMPLE

Wire #11

Length feet	1 Hour 1 min.	1 Hour 5 min.	1 Day 1 min.	3 Days 1 min.	3 Days 5 min.
	Resistance per 1000 ft. (ohms)				
300	$< 3 \times 10^{4}$	removed from test			
402	" "				
52	2.6×10^{10}	9.4×10^{10}	1.5×10^{11}	1.5×10^{11}	4.9×10^{1}
371	failed on test				

Returned to vendor

Retest

Length feet*	1 Hour 1 min.	1 Hour 5 min.	1 Day 1 min.	1 Day 5 min.	3 Days 1 min.	3 Days 5 min.
	Resistance per 1000 ft. (ohms)					
402	1.5×10^{10}	8.0×10^{10}	3.8×10^{9}	4.9×10^{9}	intermittent	short
300	2.1×10^{10}	9.3×10^{10}	4.2×10^{10}	1.8×10^{11}	4.2×10^{10}	1.4×10
371	1.9×10^{10}	9.3×10^{10}	2.2×10^{10}	9.6×10^{10}	3.7×10^{10}	1.6×10

Resistance vs. Time of Applied Voltage

Length - 371 feet*

Time (Minutes)	I.R. ohms/1000 ft.
0.5	2.0×10^{10}
1	3.7×10^{10}
2	7.0×10^{10}
3	9.6×10^{10}
5	1.6×10^{11}
8	2.3×10^{11}
10	2.6×10^{11}
15	3.7×10^{11}

*footage marked on spools returned after respooling by vendor. Same footage as returned.

Failure in original sample appeared to be the result of mechanical damage to inside wire ends caused by improper packaging.

TABLE 1-13

INSULATION RESISTANCE - TOTAL SAMPLE

Wire #12

Length Feet	1 Hour 1 min.	1 Hour 5 min.	1 Day 1 min.	1 Day 5 min.	3 Days 1 min.	3 Days 5 min.
	Resistance per 1000 ft. (ohms)					
137	$2.2x10^9$	$4.0x10^9$	$2.9x10^9$	$5.1x10^9$	$6.9x10^9$	$1.2x10^{10}$
157	$1.2x10^9$	$2.0x10^9$	$1.7x10^9$	$3.0x10^9$	$5.2x10^9$	$9.3x10^9$
60	$1.4x10^9$	$2.6x10^9$	$6.6x10^9$	$1.2x10^{10}$	$1.3x10^{10}$	$2.6x10^{10}$
64	$3.5x10^9$	$5.8x10^9$	$9.0x10^9$	$1.6x10^{10}$	$1.6x10^{10}$	$2.9x10^{10}$
60	$5.6x10^9$	$9.0x10^9$	$9.0x10^9$	$1.9x10^{10}$	$1.2x10^{10}$	$2.3x10^{10}$
185	$7.2x10^8$	$1.4x10^9$	$7.2x10^8$	$1.3x10^{10}$	$2.4x10^9$	$4.3x10^9$
85	$1.2x10^9$	$1.8x10^9$	*--			
64	$1.1x10^{10}$	$1.8x10^{10}$	$1.3x10^{10}$	$2.6x10^{10}$	$1.2x10^{10}$	$2.3x10^{10}$
44	$8.8x10^9$	$1.6x10^{10}$	$1.4x10^{10}$	$2.1x10^{10}$	$1.4x10^{10}$	$2.8x10^{10}$
40	$3.3x10^8$	$2.2x10^8$	*--			

*Intermittent short.

Resistance vs. Time of Applied Voltage

Length - 137 feet

Time (Minutes)	I.R. (ohms/1000 ft.)
1	$6.8x10^9$
2	$8.9x10^9$
3	$1.0x10^{10}$
5	$1.2x10^{10}$
8	$1.5x10^{10}$
12	$1.8x10^{10}$
16	$1.9x10^{10}$
20	$2.2x10^{10}$

TABLE 1-14

INSULATION RESISTANCE - TOTAL SAMPLE

Wire #13

Resistance per 1000 ft. (ohms)

Length feet	1 Hour 1 min.	1 Hour 5 min.	1 Day 1 min.	1 Day 5 min.	3 Days 1 min.	3 Days 5 min
195	2.1×10^9	3.9×10^9	2.3×10^9	4.3×10^9	2.3×10^9	4.3 x
202	1.0×10^9	2.2×10^9	1.1×10^9	2.0×10^9	1.4×10^9	2.4 x
201	1.5×10^9	2.6×10^9	1.8×10^9	3.4×10^9	1.3×10^9	1.0 x

Resistance vs. Time of Applied Voltage

Length - 195 feet

Time (minutes)	I.R. (ohms/1000 ft.)
0.5	2.0×10^9
1	2.3×10^9
2	3.1×10^9
5	4.3×10^9
10	5.7×10^9
20	7.6×10^9

TABLE 1-15

INSULATION RESISTANCE - TOTAL SAMPLE

Wire #14

Length feet	Resistance per 1000 ft. (ohms) 1 Hour 1 min.	1 Hour 5 min.	1 Day 1 min.	1 Day 5 min.	3 Days 1 min.	3 Days 5 min.
176	4.2×10^9	8.5×10^9	3.5×10^9	7.0×10^9	2.3×10^9	4.2×10^9
349	3.8×10^9	8.0×10^9	3.3×10^9	6.6×10^9	2.0×10^9	3.8×10^9
251	2.2×10^9	4.8×10^9	1.9×10^9	3.8×10^9	1.0×10^9	2.1×10^9
230	3.0×10^9	6.9×10^9	2.5×10^9	5.3×10^9	1.7×10^9	3.5×10^9

Resistance vs. Time of Applied Voltage

Length - 176 feet

Time (Minutes)	I.R. (ohms/1000 ft.)
1	2.3×10^9
2	3.0×10^9
3	3.3×10^9
4	3.9×10^9
5	4.2×10^9
6	4.6×10^9
10	6.5×10^9
15	8.4×10^9
20	1.1×10^{10}

TABLE 1-16

INSULATION RESISTANCE - TOTAL SAMPLE

Wire #15

Resistance per 1000 ft. (ohms)

Length feet	1 Hour 1 min.	1 Hour 5 min.	1 Day 1 min.	1 Day 5 min.	3 Days 1 min.	3 Days 5 min.
171	1.3×10^{10}	3.4×10^{10}	8.6×10^{9}	2.1×10^{10}	1.7×10^{9}	4.8 x 1
264	1.8×10^{10}	8.7×10^{10}	1.2×10^{10}	5.0×10^{10}	5.0×10^{9}	1.6 x 1
184	1.5×10^{4}		1.8×10^{4}		3.1×10^{4}	
173	1.5×10^{10}	5.7×10^{10}	1.0×10^{10}	4.0×10^{10}	3.1×10^{9}	[illegible].2 x 1
86	1.2×10^{10}	8.3×10^{10}	1.6×10^{10}	7.7×10^{10}	1.1×10^{10}	9.5 x 1
163	1.4×10^{10}	7.3×10^{10}	1.7×10^{10}	8.8×10^{10}	2.0×10^{10}	6.8 x 1

Resistance vs. Time of Applied Voltage

Length - 264 feet

Time (minutes)	I.R. (ohms/1000 ft.)
0.5	2.6×10^{9}
1	5.0×10^{9}
2	8.2×10^{9}
3	1.1×10^{10}
5	1.6×10^{10}
7	2.0×10^{10}
10	2.6×10^{10}
16	4.0×10^{10}

TABLE 1-17

INSULATION RESISTANCE - TOTAL SAMPLE

Wire #16

Resistance per 1000 ft. (ohms)

Length	1 Hour		1 Day		3 Days	
feet	1 min.	5 min.	1 min.	5 min.	1 min.	5 min.
337	8.4×10^{10}	4.4×10^{11}	6.4×10^{10}	4.7×10^{10}	5.4×10^{10}	3.7×10^{11}
94	7.8×10^{10}	4.9×10^{10}	1.1×10^{11}		1.1×10^{11}	
238	4.5×10^{10}	2.6×10^{11}	6.9×10^{10}	3.8×10^{11}	5.0×10^{10}	2.6×10^{11}
32	6.4×10^{10}		6.4×10^{10}		7.4×10^{10}	
173	4.5×10^{10}		1.1×10^{11}		6.7×10^{10}	

Resistance vs. Time of Applied Voltage

Length - 337 feet.

Time (minutes)	I.R. (ohms/1000 ft.)
0.5	3.7×10^{10}
1	5.[illegible] $\times 10^{10}$
2	1.[illegible] $\times 10^{10}$
3	1.9×10^{11}
5	3.7×10^{11}
7	4.7×10^{11}
10	5.7×10^{11}
15	7.1×10^{11}

2. Voltage Withstand

The voltage withstand test consists of applying an alternating voltage of 1600 volts for a period of one minute at the conclusion of the insulation resistance measurements. The specimens remain immersed in water, and the voltage is applied between the water and the wire conductor.

The results are summarized in Table 18. Half of the samples (wire types) passed the test. The other samples exhibited one or more failures. It should be noted that Wire No. 1 (ML coated FEP) had been rejected because it failed the insulation resistance test. The defects were removed by the manufacturer and approximately half of the original sample was resubmitted for further evaluation. The results shown in Table 18 indicate that 5 of the 7 reels that were returned failed the voltage withstand test.

After encountering numerous failures, it was agreed that the voltage withstand test would not be used as a criterion for acceptance in the evaluation program.

TABLE 2-1

Voltage Withstand Test
(1600 volts rms for 1 minute)

Wire #	Length (feet)	Observation
1	56	Intermittent failure
	43	No failure
	56	Failed after 50 sec.
	145	Failed after 15 sec.
	100	Failed after 4 sec.
	100	Failed immediately at 1600 volts
	100	No failure
3	---	No failure
4	60	No failure
	944	Failed at 1000 V.
	253	No failure
5	---	No failure
6	---	No failure
7	---	No failure
8	---	No failure
9	158	No failure
	172	No failure
	71	No failure
	82	No failure
	126	No failure
	100	No failure
	115	No failure
	22	No failure
	68	No failure
	160	Failed immediately at 1600V. Failure removed. Two remaining pieces passed 1600 volt test.
10	---	No failure
11	402	Failed
	300	No failure
	371	No failure

(continued)

TABLE 2-1 (continued)

Voltage Withstand Test

(1600 volts rms for 1 minutes)

Wire #	Length (feet)	Observation
2	--	No failure.
12	--	Two of ten samples had intermittent shorts on the I.R. test, but did not fail.
13	--	No failure.
14	--	No failure.
15	--	One of the six samples had a low I.R., but did not fail.
16	--	No failure.

3. Insulation Resistance - Cabled Specimen

Cabled specimens were aged for 15 days at 50°C in 15 psia oxygen at 100% RH with condensation. Insulation resistance was measured between the central wire and the six surrounding wires that were connected in common. Measurements were made after exposure for 1 nour, 8 hours, 1, 2, and 5 days.

Excellent agreement among specimens of the same wire was obtained, and the results are in line with those obtained in the immersion tests of the previous section.

Insulation resistance measurements are not always effective in detecting degradation or moisture absorption. Under dry conditions, d-c resistivity of most materials will increase during thermal aging, even though other properties might degrade. Under wet conditions, large changes in resistivity are observed if moisture is absorbed more or less uniformly throughout the volume of the insulating material. If there is a high resistance barrier, however, the measured value of insulation resistance will still be high because the barrier interferes with the charge transport process.

In a few cases, particularly with Wire #2, specimens exhibited low values of insulation resistance for a brief period during the 15 day exposure. This type of behavior indicates the existence of faults which affect the measurements only when water droplets form in such a way that a complete conducting path results. In the case of specimen 2-1 (see Table 3-1), the insulation resistance fell to a value less than one megohm, indicating a complete low resistance path between the central wire and at least one of the outer wires.

The single wrap H-film construction without overcoat (Wires 4, 5 and 10) showed the largest general decrease in insulation resistance with increasing exposure time. The TFE or FEP dispersion (Wires 3, 6 and 11) significantly decreased the rate of moisture absorption, as evidenced by the small effect of exposure on insulation resistance.

TABLE 3-1

INSULATION RESISTANCE - CABLED SAMPLES (OHMS)

Time in Wet Oxygen at 50C

Specimen Number	1 Hour	8 Hours	1 Day	2 Days	5 Days	15 Days
Wire 3-1	2.8×10^{13}	1.9×10^{13}	1.9×10^{13}	1.6×10^{13}	1.1×10^{13}	7.4×10^{12}
-2	3.6×10^{13}	1.7×10^{13}	1.9×10^{13}	1.4×10^{13}	1.3×10^{13}	1.1×10^{13}
-3	4.8×10^{13}	2.9×10^{13}	1.9×10^{13}	1.9×10^{13}	1.4×10^{13}	1.1×10^{13}
-4	5.3×10^{13}	1.8×10^{13}	2.0×10^{13}	1.4×10^{13}	1.1×10^{13}	7.6×10^{12}
Wire 4-1	4.0×10^{13}	1.9×10^{11}	3.7×10^{10}	3.0×10^{10}	2.2×10^{10}	2.0×10^{10}
-2	3.2×10^{13}	1.4×10^{11}	1.6×10^{10}	1.6×10^{10}	1.2×10^{10}	1.0×10^{10}
-3	2.6×10^{13}	1.7×10^{11}	3.9×10^{10}	2.8×10^{10}	2.9×10^{10}	2.8×10^{10}
-4	3.3×10^{13}	9.6×10^{11}	8.6×10^{10}	7.5×10^{10}	6.9×10^{10}	8.1×10^{10}
Wire 5-1	1.0×10^{14}	8.2×10^{11}	4.0×10^{10}	3.9×10^{10}	3.5×10^{10}	3.3×10^{10}
-2	5.4×10^{13}	2.6×10^{11}	3.5×10^{10}	3.8×10^{10}	3.7×10^{10}	3.3×10^{10}
-3	8.9×10^{13}	1.1×10^{12}	5.0×10^{10}	5.8×10^{10}	3.6×10^{10}	3.6×10^{10}
-4	1.0×10^{14}	2.9×10^{11}	5.6×10^{10}	5.8×10^{10}	6.3×10^{10}	4.5×10^{10}
Wire 6-1	1.4×10^{13}	1.9×10^{13}	2.4×10^{12}	9.6×10^{11}	9.6×10^{11}	1.1×10^{12}
-2	3.3×10^{13}	1.8×10^{13}	2.9×10^{12}	1.0×10^{12}	8.2×10^{11}	7.8×10^{11}
-3	2.4×10^{13}	2.0×10^{13}	3.5×10^{12}	1.1×10^{12}	1.0×10^{12}	1.1×10^{12}
-4	2.0×10^{13}	2.1×10^{13}	3.6×10^{12}	1.1×10^{12}	7.0×10^{11}	7.1×10^{11}

Specimen Number	1 Hours	8 Hours	1 Day	3 Days	15 Days
Wire 7-1	2.2×10^{13}	2.2×10^{13}	2.5×10^{13}	3.1×10^{13}	2.9×10^{13}
-2	1.5×10^{13}	2.3×10^{13}	1.1×10^{13}	2.[illegible]x10^{13}	1.9×10^{13}
-3	1.3×10^{13}	1.6×10^{13}	1.3×10^{13}	1.0×10^{13}	1.0×10^{13}
-4	9.8×10^{12}	1.9×10^{13}	2.0×10^{13}	1.8×10^{13}	1.4×10^{13}
Wire 8-1	8.3×10^{12}	2.9×10^{12}	9.3×10^{12}	9.3×10^{12}	1.5×10^{13}
-2	$>10^{14}$	1.4×10^{13}	1.0×10^{13}	1.0×10^{13}	1.4×10^{13}
-3	2.9×10^{13}	1.4×10^{13}	1.4×10^{13}	1.5×10^{13}	1.5×10^{13}
-4	2.2×10^{13}	1.2×10^{13}	1.2×10^{13}	1.3×10^{12}	1.3×10^{13}

(continued)

TABLE 3-1 (continued)

INSULATION RESISTANCE - CABLED SAMPLES (OHMS)

Specimen Number	1 Hour	8 Hours	1 Day	3 Days	15 Days
Wire 9-1	$>10^{14}$	$1.4x10^{14}$	$5.2x10^{13}$	$8.3x10^{13}$	$1.9x10^{14}$
-2	$>10^{14}$	$5.7x10^{13}$	$5.6x10^{13}$	$8.6x10^{13}$	$2.1x10^{14}$
-3	$>10^{14}$	$6.9x10^{13}$	$5.0x10^{13}$	$1.2x10^{14}$	$1.9x10^{14}$
-4	$>10^{14}$	$3.6x10^{13}$	$5.0x10^{13}$	$1.7x10^{14}$	$5.0x10^{14}$

Specimen Number	1 Hour	8 Hours	1 Day	2 Days	5 Days	15 Days
Wire 10-1	$1.9x10^{13}$	$6.1x10^{12}$	$2.0x10^{12}$	$1.5x10^{12}$	$1.0x10^{12}$	$5.7x10^{11}$
-2	$3.6x10^{13}$	$4.8x10^{12}$	$1.7x10^{12}$	$1.4x10^{12}$	$1.1x10^{12}$	$4.8x10^{11}$
-3	$7.8x10^{12}$	$4.5x10^{12}$	$2.0x10^{12}$	$1.6x10^{12}$	$1.0x10^{12}$	$5.7x10^{11}$
-4	$3.3x10^{13}$	$4.5x10^{12}$	$1.7x10^{12}$	$1.3x10^{12}$	$8.6x10^{11}$	$4.7x10^{11}$

Specimen Number	1 Hour	8 Hours	1 Day	3 Days	15 Days
Wire 1-1	$1.2x10^{14}$	$7.7x10^{13}$	$7.6x10^{13}$	$1.6x10^{14}$	$2.3x10^{13}$
-2	$6.8x10^{13}$	$1.9x10^{10}$	$1.0x10^{14}$	$1.5x10^{14}$	$2.2x10^{13}$
-3	$1.0x10^{14}$	$3.7x10^{13}$	$2.9x10^{13}$	$2.3x10^{13}$	$3.6x10^{12}$
-4	$5.0x10^{13}$	$1.2x10^{14}$	$9.1x10^{13}$	$9.1x10^{13}$	$2.5x10^{13}$
Wire 2-1	$2.8x10^{13}$	$3.6x10^{13}$	$1.8x10^{10}$	$2.5x10^{13}$	$2.5x10^{5}$*
-2	$2.9x10^{13}$	$3.2x10^{13}$	$3.1x10^{13}$	$9.6x10^{13}$	$5.0x10^{13}$
-3	$4.2x10^{13}$	$4.4x10^{13}$	$7.7x10^{9}$	$1.2x10^{14}$	$2.0x10^{14}$
-4	$5.4x10^{13}$	$3.6x10^{13}$	$2.1x10^{10}$	$1.0x10^{14}$	$1.6x10^{14}$
Wire 11-1	$5.9x10^{13}$	$9.3x10^{12}$	$9.3x10^{12}$	$2.6x10^{13}$	$8.3x10^{14}$
-2	$3.6x10^{13}$	$3.6x10^{13}$	$2.4x10^{13}$	$2.8x10^{13}$	$4.2x10^{14}$
-3	$3.3x10^{13}$	$3.1x10^{13}$	$2.9x10^{13}$	$2.6x10^{13}$	$3.3x10^{13}$
-4	$2.0x10^{13}$	$2.5x10^{13}$	$3.6x10^{13}$	$4.8x10^{13}$	$5.0x10^{13}$
Wire 12-1	$5.4x10^{12}$	$2.0x10^{12}$	$1.7x10^{12}$	$2.1x10^{12}$	$2.0x10^{12}$
-2	$5.7x10^{12}$	$3.1x10^{12}$	$1.3x10^{10}$	$2.3x10^{12}$	$2.6x10^{12}$
-3	$7.8x10^{12}$	$3.1x10^{12}$	$1.9x10^{12}$	$2.1x10^{12}$	$2.3x10^{12}$
-4	$5.1x10^{12}$	$2.6x10^{12}$	$2.3x10^{12}$	$2.6x10^{12}$	$3.1x10^{12}$

*Measured with Simpson Ohmmeter

(continued)

TABLE 3-1 (continued)

INSULATION RESISTANCE - CABLED SAMPLES (OHMS)

Specimen Number	1 Hour	8 Hours	1 Day	3 Days	15 Days
Wire 13-1	$5.0x10^{12}$	$1.6x10^{12}$	$1.4x10^{12}$	$1.1x10^{12}$	$1.4x10^{12}$
-2	$5.0x10^{12}$	$1.7x10^{12}$	$1.4x10^{12}$	$1.1x10^{12}$	$1.4x10^{12}$
-3	$3.3x10^{12}$	$1.2x10^{12}$	$1.0x10^{12}$	$7.8x10^{11}$	$1.0x10^{12}$
-4	$4.8x10^{12}$	$1.9x10^{12}$	$1.6x10^{12}$	$1.3x10^{12}$	$1.7x10^{12}$
Wire 14-1	$1.0x10^{13}$	$2.4x10^{12}$	$2.4x10^{12}$	$2.5x10^{12}$	$2.9x10^{12}$
-2	$1.0x10^{13}$	$1.9x10^{12}$	$1.3x10^{12}$	$1.4x10^{12}$	$1.6x10^{12}$
-3	$1.3x10^{13}$	$2.5x10^{12}$	$2.5x10^{12}$	$2.6x10^{12}$	$2.9x10^{12}$
-4	$1.2x10^{13}$	$3.3x10^{12}$	$3.1x10^{12}$	$2.9x10^{12}$	$3.1x10^{12}$

4. Corona Measurements

Corona inception voltage (c.i.v.) and corona extinction voltage (c.e.v.) was measured on the cabled specimens that were aged in wet oxygen at 15 psia for 15 days in the insulation resistance tests. The measurements were made in wet oxygen at 15 psia and a dry oxygen at 5 psia.

Corona measured in wet conditions seeks out faults and makes them evident. Whenever the corona extinction voltage drops far below corona inception voltage a fault is indicated. In this test, the c.e.v. may sometimes be observed to climb above the c.i.v. The distribution of moisture is altered by the corona itself. This is taken as evidence of a good sample, especially when the inception and extinction voltage are both high. Extreme variability of either the c.e.v. or c.i.v. is a bad indication only when some of the values are very low. The variability may be due to the particular way the moisture droplets lie on the surface of the particular sample.

The corona inception voltage and the corona extinction voltage are measured in a way that would naturally tend to make extinction voltage lower than the inception voltage. The corona inception voltage is the minimum voltage (with increasing voltage) at which continuous corona is noted. The corona extinction voltage is the maximum voltage (with decreasing voltage) at which sporadic corona is noted. The sporadic corona is judged to have ceased when none appears in a 10 second time interval. Therefore, when the c.e.v. is higher than the c.i.v., a definite change in the specimen has occurred due to the presence of corona.

Corona is known to be an extremely effective drying agent. It distorts water droplets and sprays them off the surface. Thus, in Table 4-1 when we note that for specimens #4 and #6 that c.e.v.'s are higher than c.i.v."s; this is taken as evidence of drying due to corona.

The measurements in dry oxygen at 5 psia (Table 4-2) are much more reproducible and, of course, indicate reduced inception and extinction voltages due to the lower electric strength at reduced gas pressure.

In comparing different wire samples, the insulation wall thicknesses must be considered because the voltage at which the critical field strength exists is a function of geometry. The poor showing of wires 4, 5, and 10 are probably associated with their thin walls. With wire #8, however, the two values of c.e.v. (500 and 600 V) in Table 4-1 are the result of faults in the relatively thick wall. In general, the results correlate with insulation thickness and the values are high for such thin wall insulation.

The low values of c.e.v. at 5 psia are extremely important in applications where alternating voltages exceeding 400 volts are contemplated. At lower pressures the c.e.v. would be reduced even further because of decreased gas density.

TABLE 4-1

CORONA MEASUREMENTS IN WET OXYGEN AT 15 PSIA, 23°C

Corona Inception Voltage (volts rms)

Wire 1	Wire 2	Wire 3	Wire 4	Wire 5	Wire 6	Wire 7
1000		1120	550	800	1250	2000
1300	970	1240	550	650	1000	1700
1120	1650	1400	550	700	850	1900
1300	1400	1150	500	800	1400	1250

Wire 8	Wire 9	Wire 10	Wire 11	Wire 12	Wire 13	Wire 14
1250	900	900	820	1320	2000	1300
2000	1300	770	500	1500	1750	1500
1600	1500	800	875	1720	1650	1500
1900	1800	1100	420	1500	1750	1500

Corona Extinction Voltage (volts rms)

Wire 1	Wire 2	Wire 3	Wire 4	Wire 5	Wire 6	Wire 7
1100		1120	700	700	1400	1800
1400	970	1120	770	650	1150	1650
1200	1800	1100	700	700	1300	1650
1320	1350	1300	500	750	800	1100

Wire 8	Wire 9	Wire 10	Wire 11	Wire 12	Wire 13	Wire 14
500*	900	850	875		1800	1300
1500	1200	750	650	1270	1650	14 0
600*	1100	750	500	1570	1650	1300
1500	1600	1100	920	1650	1750	1500

*Very dense corona pattern suggesting a partial breakdown.

TABLE 4-2

CORONA MEASUREMENTS IN DRY OXYGEN AT 5 PSIA O_2 23°C

Corona Inception Voltage (volts rms)

Wire 1	Wire 2	Wire 3	Wire 4	Wire 5	Wire 6	Wire 7
840		800	680	600	800	820
950	800	900	640	680	850	[illegible]20
870	1020	800	620	630	800	860
880	980	870	600	600	600	720

Wire 8	Wire 9	Wire 10	Wire 11	Wire 12	Wire 13	Wire 14
1000	1100	560	680	950	810	1150
1180	1120	560	670	1200	1000	1170
1120	1050	700	680	1250	1100	1230
1050	1070	640	680		950	1000

Corona Extinction Voltage (volts rms)

Wire 1	Wire 2	Wire 3	Wire 4	Wire 5	Wire 6	Wire 7
750		750	570	570	750	670
750	750	750	570	570	750	720
760	750	750	570	570	750	720
760	830	750	570	570	730	650

Wire 8	Wire 9	Wire 10	Wire 11	Wire 12	Wire 13	Wire 14
960	930	510	650	900	880	1180
970	970	510	650	900	950	1120
960	920	550	640	880	1050	1020
960	970	600	670		950	950

5. Voltage Breakdown - In Air, Wet PSI Oxygen and Vacuum at 150^{o}C

Values of voltage breakdown of twisted pairs at 150^{o}C in vacuum of about 10^{-6} torr and in wet oxygen at 5 PSI for all of the wire are compared in Table 5-1 for a fast rate of voltage rise (500 volts/sec.) and in Table 5-2 for a slower rate of rise (100 volts/sec.). A comparison of the results in these tables is made by means of ratios in Table 5-3. In order that these results can be compared with voltage breakdown in normal air at 23C and 50% RH, results shown in Table 5-4 have been included.

It is immediately apparent that the variability of the test results is quite great so that meaningful detailed comparison is difficult. After the program was well underway, it was noted that Wires #7, 8, 10 and 12 were badly damaged when twisted in the test fixture. In consequence, these wires were carefully twisted by hand. (Wires #13, 15 and 16 were also twisted by hand, although for them the precaution was apparently not necessary).

Many of the test specimens burned when tested in 5 PSI oxygen - particularly Wires #7 and 8 and to a somewhat lesser extent Wires #2, 12, 13 and 14. It is possible that preliminary "spitting" ignited some of the wires so that the breakdown was thereby decreased.

When tests were made in vacuum the twisted pair test specimen was heated to 150^{o}C and then the test chamber was pumped down to a pressure of about 10^{-6} torr. However, voltage breakdown was always preceded or accompanied by a blue glow in the tube. This blue glow is characteristic of electrical discharge in gases which occurs in the "glow" discharge range over a pressure range of roughly 0.1 to 10 mm pressure. This glow discharge pressure is much higher than the test pressure. It was postulated that just prior to breakdown the voltage stress in some fashion may produce outgassing in the dielectric so to locally increase the pressure to the glow discharge region. A number of voltage breakdown tests were made after first purposely achieving and holding a glow discharge for several minutes at 2 KV in a poor vacuum. Subsequently, the chamber was pumped down to a good vacuum of about 10^{-6} torr. Using this technique, a breakdown of 21.3 KV was achieved with TFE Teflon (Wire #9) which is considerably greater than all of the other values obtained in vacuum and, in fact, higher than the maximum value obtained in normal air. The voltage breakdown in vacuum for Wires #2 and 4 was also significantly improved by conditioning with a glow discharge. In contrast, the glow discharge technique did not increase the breakdown voltage at all for Wires #6, 7 and 8 and no significant increase was detected with Wires #1, 5 and 11. Time was not available to thoroughly investigate these interesting, but so far, rather fragmentary results.

It should be recognized that for some materials the voltage breakdown at 150°C will be considerably lower than at room temperature. Thus, the lowered breakdown voltage might be explained on the basis of temperature effect alone. However, it is well known that the breakdown voltage of TFE Teflon is at least, under most circumstances, not a function of temperature up to 200°C or possibly even higher. Nevertheless, it is probably impossible to separate, generally, the effects of temperature and pressure in the subject work.

Likewise, it is probably impossible to completely separate the effect of moisture and the 5 psi pressure on the voltage breakdown. It would have been more interesting to have made tests after prolonged exposure to moisture, but the test time involved would have been prohibitive. Moreover, the effect of prolonged moisture exposure is achieved in the 3 day immersion test used as a qualifying procedure. It may be assumed that the lowered breakdown voltage at 5 PSI is due primarily to the lower pressure.

TABLE 5-1

VOLTAGE BREAKDOWN IN NORMAL AIR AT 23°C AND 50% RH

Fast Rate of Rise - 500 volts/sec.

Wire #	Avg.*	Max.	Min.	Ratio-Avg. Vacuum/Air	Ratio-Avg. 5 PSI, O_2/Air
1	18.2	20.2	15.8	0.80	0.95
1**	(25.0)	(29.0)	(19.0)		
2	18.3	21.0	15.0	0.83	0.81
3	27.2	28.5	25.5	0.51	0.82
4	17.8	18.0	17.5	0.45	0.69
5	15.7	19.5	13.0	0.63	0.98
6	28.8	30.0	25.5	0.48	>0.86
7	23.7	25.5	21.0	0.52	0.74
8	27.6	29.0	26.0	0.50	0.71
9	17.5	20.5	14.5	0.85	1.04
10	20.0	23.0	18.0	0.47	0.65
11	12.3	13.5	10.5	0.88	0.86
12	17.2	18.5	16.5	0.70	1.03
13	20.1	22.4	18.0	0.63	1.02
14	23.1	25.5	20.6	0.52	0.89
15	24.1	27.5	20.0	0.43	0.94
16	26.7	30.0	24.0		0.87

* - Average of 5 values.

** - Original measurements which were later repeated - see text.

TABLE 5-2

VOLTAGE BREAKDOWN IN VACUUM AND WET O_2 AT 5 PSI

Fast Rate of Rise - 500 volts/sec.

	In Vacuum at 150°C' KV				In Wet O_2 at PSI - KV			
Wire #	Avg.*	Max.	Min.	Std. Dev.	Avg.*	Max.	Min.	Std. Dev.
1	14.5	16.5	11.0	1.85	16.4	18.5	12.0	2.9
2	15.2	16.5	14.0	0.8	14.8	17.0	13.0	1.2
3	13.9	15.5	11.8	1.25	22.4	26.5	16.5 (2.4)**	3.2
4	8.0	9.5	6.5	0.9	12.3	14.5	10.5	1.3
5	9.9	11.5	8.5	1.0	15.5	18.0	13.0	1.7
6	13.9	17.0	11.5	1.8	>24.5	>27.5	21.0	---
7	12.3	14.5	11.0	1.2	17.4	20.0	12.5	2.3
8	13.8	16.0	11.5	1.5	19.5	23.0	16.5	1.9
9	14.9	17.0	13.5	1.1	18.2	22.6	15.6	2.15
10	9.8	10.5	8.5	0.8	13.3	17.0	8.5	---
11	10.8	12.5	10.0	0.85	10.6	12.6	8.0	1.3
12	10.9	11.0	10.5	0.3	17.8	20.0	14.5	1.6
13	12.6	13.0	12.0	0.3	20.5	23.4	17.0	2.0
14	12.0	13.5	10.5	0.9	20.5	23.5	16.5	2.3
15	10.4	10.7	10.0	0.2	22.6	23.7	21.5	0.8
16					23.1	25.0	21 0	1.4

*Avg. of 5 values

**Discarded in calculations

TABLE 5-3

VOLTAGE BREAKDOWN IN VACUUM AND WET O_2 AT 5 PSI

Slow Rate of Rise - 100 Volts/sec.

	In Vacuum at 150C - Kv				In Wet O_2 at 5 PSI - Kv			
Wire #	Avg*	Max.	Min.	Std. Dev.	Avg.*	Max.	Min.	Std. Dev.
1	12.2	14.0	9.5	1.8	14.5	20.7	10.7	3.0
2	13.0	14.5	9.0	2.0	13.0	14.3	11.5	0.9
3	11.5	12.5	9.5	1.1	16.5	18.0	14.0	1.0
4					10.5	11.2	9.9 (1.2)	0.3
5					14.1	16.5	12.5	1.5
6	10.5	11.0	10.0	0.3	19.8	21.6	18.2	0.9
7	11.0	12.0	10.5	0.5	17.3	20.2	13.0	3.0
8	11.8	12.5	10.5	0.6	20.5	22.4 (17.0)	17.7	1.4
9	14.7	16.5	12.0	1.5	11.8	13.2	10.0	1.0
10					18.0	19.1	16.5	0.65
11					7.8	10.6	5.0	1.4
12					16.2	18.2	13.7	1.2
13					21.7	23.7	14.5	1.2
14					17.7	21.2	14.2	2.1
15					16.3	18.0	14.6	1.0
16					17.9	20.2	15.2	1.5

*Avg. of 5 values

TABLE 5-4

VOLTAGE BREAKDOWN RATIOS

(Average Values)

Wire #	Slow/Fast Rate of Rise in Vacuum at 150°C	Slow/Fast Rate of Rise in O_2 at 5 PSI	Vacuum/O_2 Fast Rate of Rise	Vacuum O/2 Slow Rate of Rise
1	0.84	0.88	0.88	0.84
2	0.86	0.88	1.03	1.0
3	0.83	0.74	0.62	0.70
4		0.86	0.65	
5		0.91	0.64	
6	0.76	NA	NA	0.53
7	0.89	0.99	0.71	0.63
8	0.86	1.05	0.71	0.58
9	0.99	0.65	0.82	1.25
10		1.35	0.74	
11		0.74	1.02	
12		0.91	0.61	
13		1.06	0.61	
14		0.86	0.59	
15		0.72	0.46	
16		0.77		

NA - Not Applicable

6. Voltage Flashover

Four or five test specimens were subjected to flashover in 5 psi wet oxygen. The voltage to produce flashover from a wrapping of .010 inch nichrome wire to the stripped end of the wire is recorded in Table 26, along with observations of the performance during and after flashover. It was necessary to strip these test specimens carefully by hand to avoid the mechanical damage sometimes produced by mechanical strippers. Wires damaged by wire strippers failed in erratic fashion.

The flashover voltages for the different wires as shown in Table 6-1 are more variable then would be expected from the small variations in the length of the flashover path and the thickness of the wire insulation. Thick insulation may explain the relatively high flashover voltages for wires #12, 13 and 14 but cannot explain the high flashover voltage for wire #7 which has a relatively thin insulation wall. An insulation with a low dielectric constant might be expected to have a relatively higher flashover voltage but TFE Teflon (wire #9) has the lowest dielectric constant - 2.05 - and also one of the lowest values of flashover voltage.

It is perhaps more important to note that two of the wires flashed over the 3/16" spacing at only 780 volts (minimum value). The fires caused by flashover on the modified polyolefin wire #8 and the Kynar jacketed silicone rubber #13 are of particular concern. It is interesting to note that the Kynar jacketed polyolefin #7 did not continue to burn when power was removed but in contrast only the Kynar jacketed silicone rubber #13 burned - silicone rubber alone on wire #12 did not burn at 11!

All of the H-film taped samples - 3, 4, 5, 6, 10, 11, 14, 15 and 16 tracked. Examination showed the characteristic low resistance, black, dendritic paths on not only the surfaces of the tapes but in some instances at the interfaces between tapes as well. It was apparent that the FEP Teflon layer on H-film as well as the Teflon dispersion and tape coatings on the surface interferred to some extent with the tendency of the H-film to track. The Teflon may have been responsible for the variation in tracking tendency between different wire specimens. Unfortunately the teflon did not completely prevent the tracking.

The performance of the ML coating on wires 1 and 2 is very interesting. It is not surprising that this coating which is chemically like H-film tracked on wire #1. Why the same coating did not track on wire #2 is mystifying. The FEP Teflon substrate on wire #1 would not be expected to perform differently in this respect than the TFE Teflon substrate in wire #2.

Some study was made of the effect of the level at which repeated flashover occurred. Of course when the insulation surface tracked completely, voltage could not be reapplied. With TFE Teflon (wire #9) the arc could be held for some time and in some cases would extinguish itself so that a higher voltage was needed to restart it. Sometimes after flashover and reapplication of voltage, the subsequent flashover would occur at a somewhat lower voltage. This effect was most noted with those wires which ultimately tracked and may have indicated incipient or partial tracking.

TABLE 6-1

COMPARISON OF WIRES - FLASHOVER VOLTAGE

Initial Flashover Voltage
kv Over 3/16" Spacing in
5 PSI Wet Oxygen

Wire #	Avg.	Max.	Min.	Performance at and after Flashover
1	1.09	1.62	0.78	Tracked immediately in 3 out of 5 tests. One specimen tracked on second and one on third flashover.
2	1.34	1.44	1.26	Did not track even with repeated flashover.
3	1.51	1.61	1.32	Tracked generally after repeated flashover but immediately in two tests.
4	1.48	1.73	1.38	Tracked normally after third flashover.
5	1.80	1.92	1.68	Two specimens tracked with second flashover and two after second flashover.
6	1.91	2.16	1.80	Tracked immediately.
7	2.52	2.88	2.28	Small flame only during flashover - tracked immediately leaving black, sooty residue.
8	1.64	2.04	0.78	Flamed and continued to burn fiercely consuming total sample.
9	1.58	1.73	1.44	Does not track after repeated flashover - arc tends to extinguish.
10	1.76	1.92	1.56	Two specimens tracked immediately but two others only after repeated flashover.
11	1.36	1.42	1.25	Three specimens tracked immediately but two others only after repeated flashover.
12	2.04	2.16	1.92	Tracks immediately leaving with ash. Some smoke.
13	2.82	3.12	2.52	Flamed and continued to burn consuming total sample.
14	2.15	2.22	2.04	Three specimens tracked immediately - one tracked only after several flashovers.
15	1.77	1.92	1.08	Tracked immediately.
16	1.98	2.04	1.92	Tracked immediately.

7. Outside Diameter

Results are given for four methods of measuring outside diameter:

	Tables
Hand Micrometer	7-1 to 7-16
X-Ray Examination	7-17
Optical Comparator	7-18 to 7-31
Cross-Section Examination	7-32

As mentioned previously, page 3, difficulties were encountered in measuring outside diameter using both the X-ray techniques and the hand micrometer method. The X-ray measurements yield values that are generally greater than the hand micrometer values. With those wires that were potted and sectioned, the values fell between those obtained using the other two methods. This technique yields the most accurate dimension measurements.

The optical comparator was used to determine maximum and minimum values only. It is a convenient instrument for this purpose, and the data are reliable.

TABLE 7-1

OUTSIDE DIAMETER (MILS), HAND MICROMETER

Wire #1

Specimen	Average	Maximum	Minimum
1-1	50.57	51.8	49.8
1-2	50.76	51.5	49.8
1-3	49.72	50.3	49.3
1-4	50.38	50.9	49.8
1-5	49.88	50.7	49.6
1-6	50.17	50.7	49.8
1-7	49.80	50.6	49.3
1-8	50.42	50.9	49.3
1-9	50.23	50.7	49.9
1-10	49.69	50.3	49.4

Total Sample

Average	50.16
Maximum	51.8
Minimum	49.3

TABLE 7-2

OUTSIDE DIAMETER (MILS), HAND MICROMETER

Wire #2

Specimen	Average	Maximum	Minimum
2-1	53.13	53.4	52.8
2-2	53.00	53.5	52.6
2-3	53.40	53.7	53.2
2-4	53.30	53.8	53.0
2-5	52.88	53.3	52.1
2-6	53.10	53.4	52.9
2-7	52.83	53.0	52.6
2-8	53.17	53.3	53.0
2-9	53.50	53.8	53.1
2-10	53.18	53.4	53.0

Total Sample

Average	53.15
Maximum	53.8
Minimum	52.1

TABLE 7-3

OUTSIDE DIAMETER (MILS), HAND MICROMETER

Wire #3

<u>Specimen</u>

	Average	Maximum	Minimum
3-1	55.43	55.8	54.8
3-2	54.15	54.7	53.7
3-3	54.85	55.8	54.2
3-4	54.07	54.3	3.6
3-5	53.22	55.5	50.0
3-6	53.13	53.8	52.6
3-7	53.50	53.9	52.8
3-8	53.98	54.3	53.6
3-9	54.43	54.8	54.1
3-10	55.08	55.6	54.6

<u>Total Sample</u>

Average	54.18
Maximum	55.8
Minimum	52.6

TABLE 7-4

OUTSIDE DIAMETER (MILS), HAND MICROMETER

Wire #4

<u>Specimen</u>

	Average	Maximum	Minimum
4-1	46.28	46.8	45.7
4-2	46.45	46.9	46.1
4-3	46.25	46.7	45.7
4-4	46.33	46.7	46.2
4-5	46.52	46.7	46.3
4-6	46.15	46.5	45.9
4-7	45.68	46.0	45.4
4-8	45.70	45.9	45.4
4-9	46.45	46.9	46.2
4-10	45.47	45.8	45.1

<u>Total Sample</u>

Average	46.13
Maximum	46.9
Minimum	45.1

TABLE 7-5

OUTSIDE DIAMETER (MILS), HAND MICROMETER

Wire #5

Specimen

	Average	Maximum	Minimum
5-1	46.55	47.0	46.2
5-2	46.48	46.9	45.9
5-3	46.40	46.8	46.1
5-4	46.05	46.3	45.7
5-5	46.45	46.7	46.1
5-6	46.30	46.7	45.9
5-7	48.12	48.6	47.7
5-8	47.57	48.2	47.1
5-9	48.23	48.9	47.1
5-10	46.35	46.9	46.0

Total Sample

Average	46.75
Maximum	46.3
Minimum	45.9

TABLE 7-6

OUTSIDE DIAMETER (MILS), HAND MICROMETER

Wire #6

Specimen

	Average	Maximum	Minimum
6-1	51.23	51.6	50.8
6-2	51.75	51.9	51.5
6-3	50.82	51.1	50.5
6-4	50.77	51.2	50.5
6-5	50.72	50.8	50.6
6-6	51.03	51.6	50.4
6-7	50.70	50.9	50.5
6-8	50.95	51.5	50.4
6-9	51.33	51.4	50.1
6-10	50.73	51.1	50.4

Total Sample

Average	51.00
Maximum	51.9
Minimum	50.4

TABLE 7-7

OUTSIDE DIAMETER (MILS), HAND MICROMETER

Wire #7

<u>Specimen</u>

	Average	Maximum	Minimum
7-1	58.37	59.9	57.9
7-2	58.37	58.8	57.7
7-3	58.27	58.8	57.9
7-4	58.47	58.8	58.1
7-5	58.57	59.3	58.0
7-6	58.37	58.7	58.0
7-7	58.55	58.9	58.2
7-8	58.37	58.7	58.1
7-9	58.57	58.9	58.1
7-10	58.63	58.9	58.2

<u>Total Sample</u>

Average	58.45
Maximum	59.9
Minimum	57.7

TABLE 7-8

OUTSIDE DIAMETER (MILS), HAND MICROMETER

Wire #8

<u>Specimen</u>

	Average	Maximum	Minimum
8-1	58.43	58.6	58.0
8-2	58.30	58.8	57.6
8-3	58.57	58.7	58.3
8-4	58.42	58.8	58.1
8-5	58.57	59.0	58.3
8-6	58.35	58.7	58.1
8-7	58.52	58.7	58.3
8-8	58.50	58.9	58.2
8-9	58.46	58.7	57.9
8-10	58-45	58.7	58.0

<u>Total Sample</u>

Average	58.46
Maximum	59.0
Minimum	57.6

TABLE 7-9

OUTSIDE DIAMETER (MILS), HAND MICROMETER

Wire #9

Specimen	Average	Maximum	Minimum
9-1	59.00	59.3	58.6
9-2	59.20	59.4	58.9
9-3	58.72	59.1	58.1
9-4	58.58	59.2	57.9
9-5	58.53	59.0	58.1
9-6	59.03	59.5	58.5
9-7	58.57	59.4	57.9
9-8	58-35	58.9	57.9
9-9	59.05	59.4	58.4
9-10	58.88	59.4	58.5

Total Sample

Average	58.79
Maximum	59.5
Minimum	57.9

TABLE 7-10

OUTSIDE DIAMETER (MILS), HAND MICROMETER

Wire #10

Specimen	Average	Maximum	Minimum
10-1	47.58	48.1	47.1
10-2	47.12	47.7	46.4
10-3	46.45	46.9	46.2
10-4	46.48	46.9	46.2
10-5	47.42	47.8	47.1
10-6	47.38	47.8	47.1
10-7	46.00	46.3	45.7
10-8	46.65	46.9	46.1
10-9	46.70	47.7	46.3
10-10	47.18	47.7	46.7

Total Sample

Average	46.90
Maximum	48.1
Minimum	45.7

TABLE 7-11

OUTSIDE DIAMETER (MILS), HAND MICROMETER

Wire #11

Specimen

	Average	Maximum	Minimum
11-1	46.55	47.3	45.7
11-2	45.67	46.3	45.2
11-3	46.28	46.6	45.8
11-4	46.17	46.5	45.9
11-5	45.70	46.1	45.5
11-6	45.58	46.0	45.3
11-7	45.68	45.9	45.5
11-8	45.72	46.1	45.5
11-9	46.15	46.5	45.6
11-10	46.18	46.5	45.7

Total Sample

Average	45.97
Maximum	47.3
Minimum	45.2

TABLE 7-12

OUTSIDE DIAMETER (MILS), HAND MICROMETER

Wire #12

Specimen

	Average	Maximum	Minimum
12-1	54.87	55.2	54.5
12-2	55.00	55.7	54.4
12-3	55.47	55.8	54.9
12-4	54.77	55.3	54.3
12-5	54.75	55.2	54.0
12-6	55.07	55.7	54.6
12-7	54.87	55.3	54.3
12-8	55.07	55.6	54.6
12-9	55.00	55.3	54.7
12-10	54.92	55.2	54.7

Total Sample

Average	54.98
Maximum	55.8
Minimum	54.0

TABLE 7-13

OUTSIDE DIAMETER (MILS), HAND MICROMETER

Wire #13

Specimen	Average	Maximum	Minimum
13-1	65.03	65.5	64.6
13-2	65.62	66.1	65.2
13-3	65.08	65.6	64.7
13-4	64.67	64.8	64.4
13-5	65.95	66.4	65.0
13-6	65.60	66.1	65.3
13-7	65.25	66.1	64.5
13-8	65.37	65.7	64.8
13-9	65.18	65.5	64.8
13-10	65.48	66.1	64.8

Total Sample

Average	65.32
Maximum	66.4
Minimum	64.4

TABLE 7-14

OUTSIDE DIAMETER (MILS), HAND MICROMETER

Wire #14

Specimen	Average	Maximum	Minimum
14-1	60.92	61.9	60.1
14-2	61.03	61.4	60.4
14-3	60.67	61.3	60.2
14-4	60.63	61.4	60.2
14-5	60.68	61.2	60.1
14-6	60.65	61.2	60.1
14-7	60.93	61.3	60.6
14-8	60.38	60.1	60.7
14-9	60.65	61.2	60.3
14-10	60.68	61.4	60.2

Total Sample

Average	60.72
Maximum	61.9
Minimum	60.1

TABLE 7-15

OUTSIDE DIAMETER (MILS), HAND MICROMETER

Wire #15

Specimen	Average	Maximum	Minimum
15-1	49.1	49.8	48.6
15-2	49.1	49.3	48.8
15-3	50.3	50.5	50.2
15-4	50.0	50.6	49.1
15-5	49.3	49.9	48.7
15-6	49.4	49.9	48.8
15-7	50.0	50.3	49.7
15-8	50.3	50.5	50.0
15-9	50.1	50.5	49.8
15-10	48.9	49.2	48.6

Total Sample

Average	49.65
Maximum	50.6
Minimum	48.6

TABLE 7-16

OUTSIDE DIAMETER (MILS), HAND MICROMETER

Wire #16

Specimen	Average	Maximum	Minimum
16-1	53.5	53.9	52.9
16-2	51.1	51.7	50.5
16-3	50.9	51.4	50.4
16-4	49.3	49.6	48.6
16-5	50.3	50.5	50.2
16-6	50.5	50.8	50.1
16-7	50.9	51.6	49.9
16-8	50.9	52.4	49.9
16-9	49.9	50.2	49.7
16-10	50.5	50.5	50.4

Total Sample

Average	50.78
Maximum	53.9
Minimum	48.6

TABLE 7-17

OUTSIDE DIAMETER (MILS); X-RAY EXAMINATION WITH MEASURING MICROSCOPE (30 MEASUREMENTS PER SAMPLE)

Wire #	Average	Maximum	Minimum
1	54.8	57.9	52.8
2	56.4	59.5	52.8
3	55.2	61.4	52.4
4	51.0	56.7	48.0
5	52.9	59.1	49.2
6	55.6	58.3	52.4
7*	59.7	64.5	55.1
7	62.8	65.4	60.2
8*	58.4	61.8	51.6
9	62.2	65.4	60.2
10	52.7	58.3	49.6
11	49.8	51.6	46.9
12	69.0	78.4	64.2
13	71.2	73.2	69.3
14	79.9	86.2	76.0

*X-ray made without silver paint.

TABLE 7-18

OUTSIDE DIAMETER (INCHES), OPTICAL COMPARATOR

Wire #1

Specimen	Maximum	Minimum
1-1	.0525	.0507
1-2	.0525	.0508
1-3	.0525	.0503
1-4	.0520	.0513
1-5	.0530	.0515
1-6	.0525	.0505
1-7	.0520	.0500
1-8	.0518	.0510
1-9	.0525	.0510
1-10	.0530	.0510

Total Sample

Maximum	.0530
Minimum	.0500

TABLE 7-19

OUTSIDE DIAMETER (INCHES), OPTICAL COMPARATOR

Wire #2

Specimen	Maximum	Minimum
2-1	.0536	.0530
2-2	.0534	.0528
2-3	.0540	.0530
2-4	.0540	.0525
2-5	.0538	.0535
2-6	.0536	.0534
2-7	.0540	.0527
2-8	.0536	.0528
2-9	.0540	.0531
2-10	.0540	.0530

Total Sample

Maximum	.0540
Minimum	.0525

TABLE 7-20

OUTSIDE DIAMETER (INCHES), OPTICAL COMPARATOR

Wire #3

Specimen	Maximum	Minimum
3-1	.0567	.0561
3-2	.0567	.0554
3-3	.0559	.0550
3-4	.0554	.0549
3-5	.0557	.0547
3-6	.0563	.0556
3-7	.0567	.0550
3-8	.0567	.0564
3-9	.0567	.0556
3-10	.0555	.0545

Total Sample

Maximum	.0567
Minimum	.0545

TABLE 7-21

OUTSIDE DIAMETER (INCHES), OPTICAL COMPARATOR

Wire #4

Specimen	Maximum	Minimum
4-1	.0475	.0455
4-2	.0465	.0455
4-3	.0475	.0452
4-4	.0465	.0460
4-5	.0471	.0460
4-6	.0468	.0462
4-7	.0475	.0471
4-8	.0472	.0470
4-9	.0465	.0457
4-10	.0471	.0460

Total Sample

Maximum	.0475
Minimum	.0452

TABLE 7-22

OUTSIDE DIAMETER (INCHES), OPTICAL COMPARATOR

Wire #5

Specimen	Maximum	Minimum
5-1	.0500	.0495
5-2	.0511	.0495
5-3	.0485	.0477
5-4	.0485	.0469
5-5	.0495	.0475
5-6	.0501	.0488
5-7	.0482	.0471
5-8	.0487	.0468
5-9	.0477	.0465
5-10	.0483	.0462

Total Sample

Maximum	.0511
Minimum	.0462

TABLE 7-23

OUTSIDE DIAMETER (INCHES), OPTICAL COMPARATOR

Wire #6

Specimen	Maximum	Minimum
6-1	.0525	.0522
6-2	.0528	.0515
6-3	.0521	.0519
6-4	.0530	.0515
6-5	.0527	.0515
6-6	.0540	.0525
6-7	.0527	.0515
6-8	.0525	.0521
6-9	.0539	.0523
6-10	.0531	.0520

Total Sample

Maximum	.0540
Minimum	.0515

TABLE 7-24

OUTSIDE DIAMETER (INCHES), OPTICAL COMPARATOR

Wire #7

Specimen	Maximum	Minimum
7-1	.0550	.0545
7-2	.0549	.0543
7-3	.0550	.0546
7-4	.0547	.0540
7-5	.0550	.0543
7-6	.0551	.0545
7-7	.0547	.0542
7-8	.0555	.0547
7-9	.0545	.0539
7-10	.0552	.0543

Total Sample

Maximum	.0555
Minimum	.0540

TABLE 7-25

OUTSIDE DIAMETER (INCHES), OPTICAL COMPARATOR

Wire #8

Specimen	Maximum	Minimum
8-1	.0601	.0592
8-2	.0597	.0593
8-3	.0597	.0590
8-4	.0598	.0594
8-5	.0601	.0597
8-6	.0598	.0596
8-7	.0601	.0598
8-8	.0595	.0592
8-9	.0598	.0593
8-10	.0602	.0598

Total Sample

Maximum	.0602
Minimum	.0590

TABLE 7-26

OUTSIDE DIAMETER (INCHES), OPTICAL COMPARATOR

Wire #9

Specimen	Maximum	Minimum
9-1	.0599	.0596
9-2	.0598	.0592
9-3	.0598	.0595
9-4	.0603	.0595
9-5	.0604	.0598
9-6	.0601	.0599
9-7	.0598	.0590
9-8	.0603	.0600
9-9	.0601	.0596
9-10	.0603	.0602

Total Sample

Maximum	.0604
Minimum	.0590

TABLE 7-27

OUTSIDE DIAMETER (INCHES), OPTICAL COMPARATOR

Wire #10

Specimen	Maximum	Minimum
10-1	.0495	.0478
10-2	.0485	.0473
10-3	.0515	.0490
10-4	.0500	.0484
10-5	.0504	.0481
10-6	.0501	.0474
10-7	.0515	.0481
10-8	.0494	.0468
10-9	.0482	.0470
10-10	.0525	.0500

Total Sample

Maximum	.0525
Minimum	.0468

TABLE 7-28

OUTSIDE DIAMETER (INCHES), OPTICAL COMPARATOR

Wire #11

Specimen	Maximum	Minimum
11-1	.0485	.0471
11-2	.0474	.0468
11-3	.0473	.0462
11-4	.0473	.0468
11-5	.0474	.0469
11-6	.0480	.0464
11-7	.0481	.0454
11-8	.0490	.0474
11-9	.0472	.0467
11-10	.0472	.0460

Total Sample

Maximum	.0490
Minimum	.0454

TABLE 7-29

OUTSIDE DIAMETER (INCHES), OPTICAL COMPARATOR

Wire #12

Specimen	Maximum	Minimum
12-1	.0632	.0630
12-2	.0641	.0633
12-3	.0642	.0638
12-4	.0638	.0632
12-5	.0638	.0625
12-6	.0650	.0635
12-7	.0649	.0627
12-8	.0651	.0642
12-9	.0651	.0638
12-10	.0648	.0640

Total Sample

Maximum	.0651
Minimum	.0625

TABLE 7-30

OUTSIDE DIAMETER (INCHES), OPTICAL COMPARATOR

Wire #13

Specimen	Maximum	Minimum
13-1	.0691	.0687
13-2	.0687	.0685
13-3	.0696	.0692
13-4	.0700	.0685
13-5	.0691	.0682
13-6	.0698	.0689
13-7	.0698	.0685
13-8	.0700	.0692
13-9	.0698	.0690
13-10	.0703	.0698

Total Sample

Maximum	.0703
Minimum	.0682

TABLE 7-31

OUTSIDE DIAMETER (INCHES), OPTICAL COMPARATOR

Wire #14

Specimen	Maximum	Minimum
14-1	.0755	.0732
14-2	.0765	.0728
14-3	.0745	.0732
14-4	.0745	.0732
14-5	.0742	.0732
14-6	.0762	.0745
14-7	.0741	.0740
14-8	.0771	.0717
14-9	.0769	.0705
14-10	.0758	.0743

Total Sample

Maximum	.0771
Minimum	.0705

TABLE 7-32

OUTSIDE DIAMETER (MILS), CROSS-SECTION EXAMINATION WITH MEASURING MICROSCOPE

Wire #	Average	Maximum	Minimum
1	52.9	54.3	51.6
2	55.1	57.1	53.9
3	56.4	48.7	55.1
6	52.0	52.8	51.2
7	54.9	55.9	53.9
8	61.5	63.0	59.8
9	62.0	63.0	61.4

8. Concentricity

The results of x-ray measurements of concentricity are given in Tables 8-1 to 8-14. The values obtained using cross-section examination are summarized in Table 8-15. The inherent error in the x-ray measurements is not as important in concentricity measurements because the calculated value is a ratio of two measurements that are in error by approximately the same percentage. Therefore, the two methods yield values that do not differ greatly, although different specimens were used in each case.

The absolute value of the wall thickness measurements are more accurate for the cross-section specimens. Average, maximum and minimum values are given in Table 8-16.

The best estimate of nominal wall thickness for the remaining wire was calculated from average outside diameter as measured with a hand micrometer and average conductor diameter determined from x-ray measurements. Values obtained for all wires are given in Table 8-17, and comparison with values obtained from cross-section specimen is also shown. The values of wall thickness calculated in this way agree with the measured values much more closely than do the values obtained from x-ray measurement of outside diameter. An examination of the range of values shown in Table 8-16 indicates that closer agreement is unlikely just on the basis of statistical variation.

TABLE 8-1

CONCENTRICITY (%), X-RAY EXAMINATION WITH MEASURING MICROSCOPE

Wire #1

Specimen	Top	Center	Bottom
1-1	81.8	90.0	90.0
1-2	100.0	90.0	71.4
1-3	80.0	100.0	90.0
1-4	91.7	72.7	76.9
1-5	90.0	100.0	76.2
1-6	86.4	95.5	85.7
1-7	76.0	80.0	75.0
1-8	73.9	80.0	69.2
1-9	64.0	81.8	91.3
1-10	62.5	73.1	100.0

Total Sample

Average	83.2
Maximum	100.0
Minimum	62.5

TABLE 8-2

CONCENTRICITY (%), X-RAY EXAMINATION WITH MEASURING MICROSCOPE

Wire #2

Specimen	Top	Center	Bottom
2-1	77.3	78.3	88.9
2-2	70.0	90.5	71.4
2-3	100.0	95.5	70.8
2-4	100.0	66.7	78.6
2-5	73.9	56.7	90.5
2-6	63.0	73.1	72.7
2-7	64.3	69.2	77.3
2-8	65.4	60.7	73.3
2-9	84.2	76.9	55.2
2-10	96.7	72.0	87.0

Total Sample

Average	76.6
Maximum	100.0
Minimum	55.2

TABLE 8-3

CONCENTRICITY (%), X-RAY EXAMINATION WITH MEASURING MICROSCOPE

Wire #3

Specimen	Top	Center	Bottom
3-1	78.0	81.6	77.0
3-2	81.6	75.9	89.9
3-3	89.9	100.0	78.7
3-4	94.7	88.1	78.7
3-5	82.4	93.2	94.4
3-6	84.0	93.2	82.1
3-7	84.8	94.0	78.0
3-8	74.7	94.0	84.8
3-9	76.1	68.3	59.5
3-10	64.8	60.4	71.3

Total Sample

Average	81.8
Maximum	100.0
Minimum	59.5

TABLE 8-4

CONCENTRICITY (%), X-RAY EXAMINATION WITH MEASURING MICROSCOPE

Wire #4

Specimen	Top	Center	Bottom
4-1	85.7	68.2	92.9
4-2	100.0	91.7	92.3
4-3	73.3	70.0	91.7
4-4	58.8	100.0	91.7
4-5	69.2	66.7	100.0
4-6	56.3	77.8	100.0
4-7	87.5	62.5	75.0
4-8	52.4	64.0	78.6
4-9	70.6	66.7	76.9
4-10	90.9	64.7	76.9

Total Sample

Average	78.4
Maximum	100.0
Minimum	52.4

TABLE 8-5

CONCENTRICITY (%), X-RAY EXAMINATION WITH MEASURING MICROSCOPE

Wire #5

Specimen	Top	Center	Bottom
5-1	100.0	89.5	87.5
5-2	93.8	69.6	87.5
5-3	92.3	81.3	87.5
5-4	73.3	93.3	80.0
5-5	65.0	92.3	57.1
5-6	93.3	88.2	72.2
5-7	48.3	59.3	83.3
5-8	86.7	69.6	87.5
5-9	85.7	83.3	95.0
5-10	73.7	90.0	94.4

Total Sample

Average	82.0
Maximum	100.0
Minimum	48.3

TABLE 8-6

CONCENTRICITY (%), X-RAY EXAMINATION WITH MEASURING MICROSCOPE

Wire #6

Specimen	Top	Center	Bottom
6-1	88.0	87.0	69.2
6-2	85.7	80.0	66.7
6-3	95.5	91.3	80.0
6-4	74.1	77.8	91.7
6-5	81.8	92.0	63.3
6-6	90.0	100.0	100.0
6-7	84.0	73.1	90.0
6-8	61.5	71.4	90.9
6-9	86.4	78.3	100.0
6-10	75.0	95.5	87.0

Total Sample

Average	83.6
Maximum	100.0
Minimum	61.5

TABLE 8-7

CONCENTRICITY (%), X-RAY EXAMINATION WITH MEASURING MICROSCOPE

Wire #7

Specimen (without silver coating)

	Top	Center	Bottom
7-1	96.5	96.4	75.5
7-2	77.1	64.3	73.7
7-3	61.5	95.9	82.1
7-4	96.4	90.8	82.5
7-5	92.5	74.6	100.0
7-6	100.0	92.2	95.6
7-7	89.2	96.8	79.1
7-8	85.5	66.9	96.8
7-9	77.4	96.5	84.0
7-10	83.1	62.3	92.2

Total Sample

Average	86.3
Maximum	100.0
Minimum	61.5

Specimen (with silver coating)

	Top	Center	Bottom
7-1	79.4	96.7	90.3
7-2	67.6	87.1	96.7
7-3	77.1	86.7	71.1
7-4	78.8	89.3	100.0
7-5	96.6	90.0	73.0

Total Sample

Average	85.4
Maximum	100.0
Minimum	71.1

TABLE 8-8

CONCENTRICITY (%), X-RAY EXAMINATION WITH MEASURING MICROSCOPE

Wire #8

Specimen	Top	Center	Bottom
8-1	86.0	91.8	92.5
8-2	88.7	96.2	96.2
8-3	71.8	100.0	92.5
8-4	88.7	88.8	73.7
8-5	92.5	71.8	76.5
8-6	82.5	92.9	76.5
8-7	66.9	96.3	66.3
8-8	81.4	74.6	81.4
8-9	80.7	96.4	79.8
8-10	96.1	100.0	89.8

Total Sample

Average	85.6
Maximum	100.0
Minimum	66.3

TABLE 8-9

CONCENTRICITY (%), X-RAY EXAMINATION WITH MEASURING MICROSCOPE

Wire #9

Specimen	Top	Center	Bottom
9-1	88.2	96.6	100.0
9-2	89.7	96.4	83.3
9-3	92.6	89.3	96.6
9-4	78.1	80.0	87.1
9-5	80.0	92.9	96.8
9-6	82.8	96.6	88.2
9-7	96.3	96.2	93.8
9-8	75.0	79.3	96.4
9-9	85.7	96.3	79.3
9-10	96.9	83.9	89.3

Total Sample

Average	89.5
Maximum	100.0
Minimum	75.0

TABLE 8-10

CONCENTRICITY (%), X-RAY EXAMINATION WITH MEASURING MICROSCOPE

Wire #10

Specimen	Top	Center	Bottom
10-1	93.8	72.2	81.3
10-2	90.0	62.5	75.0
10-3	78.9	85.7	64.7
10-4	84.6	93.8	80.0
10-5	72.2	80.0	50.0
10-6	93.3	66.7	86.7
10-7	88.2	73.7	50.0
10-8	88.2	68.4	94.4
10-9	89.5	100.0	76.2
10-10	94.4	72.2	72.7

<u>Total Sample</u>

Average	79.3
Maximum	100.0
Minimum	50.0

TABLE 8-11

CONCENTRICITY (%), X-RAY EXAMINATION WITH MEASURING MICROSCOPE

Wire #11

Specimen	Top	Center	Bottom
11-1	90.9	69.2	63.6
11-2	81.8	100.0	92.9
11-3	80.0	76.5	78.6
11-4	100.0	73.3	80.0
11-5	58.8	86.7	100.0
11-6	85.7	61.1	75.0
11-7	80.0	78.6	91.7
11-8	68.8	73.3	64.7
11-9	62.5	73.3	73.3
11-10	53.3	86.7	86.7

<u>Total Sample</u>

Average	78.2
Maximum	100.0
Minimum	53.3

TABLE 8-12

CONCENTRICITY (%), X-RAY EXAMINATION WITH MEASURING MICROSCOPE

Wire #12

Specimen	Top	Center	Bottom
12-1	86.1	72.7	85.3
12-2	85.4	82.4	73.9
12-3	89.7	81.1	89.2
12-4	80.0	97.0	95.5
12-5	94.6	80.4	66.0
12-6	86.1	83.8	90.9
12-7	76.5	83.3	88.9
12-8	83.8	91.7	91.2
12-9	75.0	79.6	77.3
12-10	70.7	77.5	81.6

Total Sample

Average	83.2
Maximum	97.0
Minimum	66.0

TABLE 8-13

CONCENTRICITY (%), X-RAY EXAMINATION WITH MEASURING MICROSCOPE

Wire #13

Specimen	Top	Center	Bottom
13-1	86.4	88.1	85.7
13-2	95.0	100.0	82.2
13-3	97.7	92.7	100.0
13-4	95.0	92.7	95.5
13-5	97.4	94.7	91.9
13-6	95.0	94.9	95.1
13-7	84.4	87.8	87.8
13-8	97.4	100.0	97.4
13-9	100.0	90.2	92.7
13-10	100.0	95.0	95.0

Total Sample

Average	93.6
Maximum	100.0
Minimum	82.2

TABLE 8-14

CONCENTRICITY (%), X-RAY EXAMINATION WITH MEASURING MICROSCOPE

Wire #14

Specimen	Top	Center	Bottom
14-1	83.6	98.0	92.9
14-2	92.0	69.8	95.9
14-3	77.6	77.0	96.4
14-4	97.9	91.3	82.4
14-5	90.0	75.4	90.2
14-6	93.8	73.2	96.0
14-7	90.4	84.2	91.7
14-8	92.0	77.8	67.8
14-9	93.8	89.6	71.4
14-10	64.4	96.2	81.8

Total Sample

Average	85.8
Maximum	98.0
Minimum	64.4

TABLE 8-15

CONCENTRICITY (%), CROSS-SECTION EXAMINATION WITH MEASURING MICROSCOPE (Average of 12 Measurements)

Wire	Average	Maximum	Minimum
1	84.7	100	68.2
2	86.3	100	71.4
3	84.7	100	66.6
6	85.7	100	71.4
7	90.3	100	84.2
8	91.7	100	80.7
9	89.6	100	75.9

TABLE 8-16

INSULATION WALL THICKNESS (MILS), CROSS-SECTION EXAMINATION WITH WITH MEASURING MICROSCOPE (Average of 24 Measurements)

Wire	Average	Maximum	Minimum
1	6.7	8.7	5.5
2	6.7	8.3	5.5
3	7.1	8.3	5.5
6	6.7	8.3	5.9
7	7.4	8.7	6.3
8	9.7	10.6	8.3
9	10.6	12.2	8.7

TABLE 8-17

NOMINAL INSULATION WALL THICKNESS (MILS), CALCULATED FROM HAND MICROMETER MEASUREMENT OF O.D. AND X-RAY MEASUREMENT OF CONDUCTOR DIAMETER

Wire	Calculated Nominal Thickness	Measured on Cross-Section
1	6.0	6.7
2	6.7	6.7
3	6.5	7.1
4	2.9	---
5	3.4	---
6	6.3	6.7
7	8.0	7.4
8	9.8	9.7
9	9.3	10.6
10	8.5	---
11	8.2	---
12	7.3	---
13	12.5	---
14	10.0	---

9. Conductor Dimensions

Values of conductor diameter obtained by X-ray examination are given in Table 9-1. The values obtained from examination of cross-section specimens are given in Table 9-2. The cross-sections reveal that much of the variation in apparent conductor diameter is associated with the positioning of the individual strands. Any departure from the circular configuration results in a change in overall diameter and a corresponding change in insulation wall thickness.

TABLE 9-1

CONDUCTOR DIAMETER (MILS), X-RAY EXAMINATION WITH MEASURING MICROSCOPE (AVERAGE OF 30 MEASUREMENTS)

Wire #	Average	Maximum	Minimum
1	38.3	39.4	37.0
2	39.9	40.9	39.0
3	41.2	44.9	39.8
4	40.3	41.3	39.0
5	40.1	42.9	39.0
6	38.5	39.4	37.8
7	39.7	40.9	39.4
8	39.0	40.9	37.0
9	40.2	41.3	38.6
10	39.9	40.9	38.6
11	39.7	40.6	39.1
12	40.5	41.7	39.4
13	40.2	41.3	39.0
14	40.8	41.7	39.8

TABLE 9-2

CONDUCTOR DIAMETER (MILS), CROSS-SECTION EXAMINATION WITH MEASURING MICROSCOPE (AVERAGE OF 12 MEASUREMENTS)

Wire #	Average	Maximum	Minimum
1	39.4	40.6	38.2
2	41.7	43.3	40.6
3	42.2	44.9	41.3
6	38.6	39.4	37.4
7	40.0	40.6	38.6
8	42.2	44.5	40.9
9	40.8	42.1	39.8

10. Weight per 1000 Feet

Average maximum and minimum values of weight per 1000 feet are given in Table 10-1. In the case of Wires #1 and 2, which should be approximately the same weight, Wire #2 was significantly lighter. A check on the conductor weight per unit length indicated that one foot of the conductor used in Wire #1 weighed 1.63 grams, while that used in Wire #2 weighed 1.76 grams. In terms of pounds per 1000 feet, these values are 3.59 for Wire #1 and 3.88 for Wire #2. The conductor dimension shown in Table 9-2 also indicates that the conductor of Wire #1 is smaller than that of Wire #2.

The conductor weights of several wires were checked and the results are given in Table 10-2. The nickel plated conductors from vendors B and C varied very little in weight per unit length. The silver plated conductor of Wire #6 was somewhat lighter than the nickel plated conductors. Table 9-2 shows that it is also smaller in cross-section.

Because the conductor weight constitutes about 80% of the total weight of the wire, any significant weight differences between wires of the same construction are likely to be associated with the conductors, rather than the insulation. Undersized conductors result in higher resistance per unit length and should, therefore, be avoided. The variation in conductor size presents an argument, in addition to others, for standardizing the flammability test on the basis of currents rather than temperature. At a given current, an undersized wire will reach a higher temperature than a full sized one.

TABLE 10-1

WEIGHT PER 100C FEET (POUNDS)

Wire Number	Average	Maximum	Minimum
1	4.500	4.511	4.482
2	4.859	4.890	4.838
3	4.802	4.844	4.766
4	4.216	4.232	4.189
5	4.359	4.436	4.309
6	4.450	4.501	4.427
7	4.651	4.657	4.644
8	4.648	4.655	4.642
9	5.431	5.481	5.360
10	4.208	4.267	4.104
11	4.213	4.225	4.202
12	4.946	4.960	4.927
13	5.360	5.388	5.345
14	5.414	5.436	5.391
15	4.328	4.358	4.283
16	4.455	4.579	4.370

TABLE 10-2

CONDUCTOR WEIGHT (GMS/FT.)

Wire Number	Conductor Type	Vendor	Weight (gms/ft.)
1	Nickel Plated Copper (N/C)	A	1.63
2	N/C	B	1.76
3	N/C	B	1.76
9	N/C	B	1.74
14	N/C	B	1.77
10	N/C	C	1.72
11	N/C	C	1.73
6	Silver Plated Copper	B	1.68
8	Tin Plated Copper	D	1.70

11. Stripability

Mechanical stripping was done with an Ideal Stripmaster, Catalog No. 45-092C, Ideal Industries, Sycamore, Illinois. It was found that the cutting blades very quickly became dull when stripping the H-film wires. This lead to an erroneous observation regarding Wire #3, which was previously reported to be difficult to strip. With new cutting blades, Wire #3 was easily stripped, as indicated in Table 11-1.

Thermal stripping was done with a hot-wire stripper made by Sentry Electronics, Inc., Wewoka, Oklahoma.

The results of the stripability tests are summarized in Table 11-1. It should be noted that most of the wires were seriously damaged by the holding grip of the mechanical gripper. This damage was first detected during flashover tests, where the discharges, which should have remained on or above the surface of the insulation, actually penetrated through the insulation wall. These dielectric failures always occurred in that portion of the wire that had been held in the grips.

Wire #4 could not be stripped with the mechanical stripper, although a similar wire (#5) was easily stripped. This difference in stripability is probably caused by the fact that the wall is only 3 mils thick on Wire #4, so the cutting blade could not penetrate far enough to cause the remaining wall to fail in tension when the pulling force was applied.

TABLE 11-1

STRIPABILITY

Wire No.	Mechanical Hand Stripper	Thermal Stripper
1	Easily stripped. No conductor damage Insulation damaged from holding grip.	Easily stripped No conductor damage Melting and charring at edge of insulation.
2	Same as 1.	Same as 1.
3	Easily stripped. Some nicks and scrapes and broken wires. Outer insulation punctured by holding grip.	Slow Slight scraping of conductor. Melting and charring at edge of insulation
4	Could not be stripped with hand stripper. Insulation damaged.	Same as 3.
5	Easily stripped. Some nicks and scrapes on conductor. Insulation indented with holding grip.	Same as 3.
6	Easily stripped. Very little scraping of conductor. Insulation indented with holding grip.	Same as 3
7	Same as 6.	Easily stripped. Insulation discolored and flared at edge.
8	Easily stripped. Very little scraping of conductor. Insulation deeply indented with holding grip.	Same as 7.
9	Same as 8.	Easily stripped. Slight flare at edge of insulation.

TABLE 11-1 (continued)

STRIPABILITY

Wire No.	Mechanical Hand Stripper	Thermal Stripper
10	Same as 6.	Same as 3.
11	Could not be stripped Outer insulation punctured by holding grip.	Same as 3.
12	Easily stripped but some insulation stuck to wire. Insulation damaged from holding grip.	Same as 1.
13	Same as 12.	Same as 1.
14	Same as 12.	Same as 1.
15	Same as 6.	Same as 3.
16	Same as 3.	Same as 3.

Mechanical hand strippers rapidly became dull and would not strip samples with H-film.

12. Solderability

All wires except 15 and 16 were examined for solderability. Zinc chloride flux was used with the nickel plated conductors. All conductors were easily soldered, wetting the entire surface. No insulation damage as the result of heating was observed.

13. Color Durability

Observations on color changes are reported in the results of the various aging tests. Conclusions are summarized in Volume II of this report.

14. Marking Legibility

Specimens for marking legibility tests were marked by Kingsley Machine Co., Hollywood California. In most cases it was necessary for Kingsley to experimentally determine the best method of marking the thin walled specimens. The shortage of time and the limitations on the amount of wire that could be used for such experimenting did not always allow the optimum solution to be found.

In all cases, the markings were made with heated type pressing a marking foil onto the surface of the wire insulation. Details regarding the marking foil, machine temperature and pressure for each wire are given in Table 14-1

Wire #1 was not received in time for marked specimens to be prepared by the Kingsley Co. Marked specimens of wires 4 and 5 were received too late to be included in the test program. Marked specimens of wires 12 and 13 were received too late to be included in the 30-day ultraviolet exposure test.

Insulation resistance measurements were made on each marked specimen after immersion in water for one hour and one day. The results of these measurements are summarized in Table 14-2. Comparison of these results with the "as-received" values given in Tables 3 to 15 shows that marking caused significant decreases in insulation resistance for wires 4, 10, 11 and 12.

Voltage withstand tests were conducted at the end of the one day water immersion. Wires 10 and 11 failed this test. All of the other wires withstood 1600 volts rms for one minute.

It is not surprising that wires 4, 10, 11 and 12 were most susceptible to damage as a result of marking. Wires 4 and 10 are thin-walled, single wrap constructions, wire 11 is a single wrap with a TFE over-wrap which has proven to be easily damaged, and wire 12 has a very thin wall of silicone rubber which has poor mechanical strength.

The results of aging tests on marked specimens are summarized as follows:

15 Days in 15 psia Oxygen at 150°C

Wires 7 and 8 darkened, so that markings became difficult to read. No effect on wires 2, 3, 6, 9 10, 11, 12, 13 and 14.

15 Days in Vacuum at 150°C

No effect on marking of wires 2, 3, 6, 7, 8, 9, 10, 11, 12, 13 and 14.

30 Days of Ultraviolet Exposure in 15 psia Wet Oxygen at 85°C

Wire #2 - Marking removed.

Wire #7 - Marking faded, barely legible.

Wire #10 - Marking removed.

No effect on marking of wires 3, 6, 8, 9, 11, and 14.

30 Days of Ultraviolet Exposure in Vacuum at 150°C

No effect on marking of wires 2, 3, 6, 7, 8, 9, 10, 11 and 14.

The effects of exposing marked specimens to the various compounds used in the chemical compatibility tests described in the following section can be summarized as follows:

Oils, salt solution, glycol solutions and solvents had no effect on the markings. It is interesting to note that the drastic effects of TCE and acetone on the Kynar jacket of wire #13, which are described in the following section, did not affect the markings.

The effects of fuels and oxidizers are summarized in Table .

In all cases, effects of the various compounds on the insulation are covered in the next section.

The resistance of markings to abrasion is an important characteristic that was not investigated in the program. Tests were conducted, however, to determine if pulling the wire between the thumb and forefinger, while held tightly together, damaged the marking. None of the markings was affected after 10 passes.

It appears that satisfactory markings can be applied to all but the thinnest walled wires. In determining the legibility of these printed markings, the small size of the lettering is an important consideration. Any further reduction in outside diameter would make the markings difficult to read with the unaided eye.

TABLE 14-1

MARKING PROCESS PARAMETERS

Wire #	Kingsley Marking	Foil	Indicated Machine Temperature (°F)	Pressure (psi)
2	K-46		600	38
3	KT-29	TFE	460	38
4	KH-106		450	45
5	KH-106		450	45
6	KFP-16	FEP	600	26
7	K-46		500	26
8	K-287		450	
9	KT-26	TFE	440	40
10	K-46		550	56
11	KT-29		460	34
12	K-39		425	32
13	K-49		500	24
14	KFP-19		550	40

TABLE 14-2

INSULATION RESISTANCE OF MARKED SPECIMENS

Wire No.	Length (ft.)	Resistance per 1000 ft. (ohms) (Measured after 1 Minute) 1 Hour	1 Day
2	62	8.1×10^{11}	8.1×10^{11}
3	27	5.1×10^{10}	1.4×10^{11}
*4	50	1.6×10^{6}	8.5×10^{5}
5	42	7.1×10^{10}	2.9×10^{9}
6	21	5.3×10^{10}	5.3×10^{10}
7	29	2.0×10^{10}	1.9×10^{10}
8	43	2.1×10^{10}	1.8×10^{10}
9	35	7.0×10^{12}	7.0×10^{12}
10	52	5.2×10^{4}	2.4×10^{3}
11	16 12	1×10^{5}) 8×10^{4}) Simpson Meter	
12	52	7.3×10^{4}	7.3×10^{4}
13	52	1.5×10^{9}	1.0×10^{9}
14	62	4.6×10^{9}	3.9×10^{9}

*Two bad sections removed before test.

TABLE 14-3

EFFECT OF FUELS AND OXIDIZERS ON MARKED SPECIMENS

	Wire #										
	2	3	6	7	8	9	10	11	12	13	14
N_2H_4	R	L	L	L	L	L	R	L	L	—	L
UDMH	L	L	L	L	L	L	L	L	L	—	L
MMH	R	L	L	L	L	L	R	L	I	—	L
A-50	R	L	L	L	L	L	R	L	L	—	F
F_2	N	L	B	L	N	L	L	L	F	L	L
N_2O_4	L	F	L	L	L	L	.	L	B	L	L

L - Legible

F - Barely legible

N - Not legible

R - Marking removed

B - Insulation burned

15. Compat bility with Potting Compounds

The detailed description of the specimens used in determining compatibility with potting compounds can be found in Volume I of the First Technical Report. Briefly, they consist of twisted pairs, for insulation resistance and voltage breakdown tests after thermal aging and water immersion, and straight lengths for mechanical pull-out tests after thermal aging. The aging was carried out at 150°C in pure oxygen at 15 psia. The water immersion was for a period of three days.

Preliminary surface treatment for Wires #1, 2, 3, 4, 5, 6, 9, 10, 11 and 14 consisted of a one minute dip in Tetra-Etch* followed by rinsing in detergent water and in acetone and by drying at 60°C. Wires #7, 8 and 12 were wiped with MEL on the portion to be potted.

The detailed procedure followed for each potting compound is given below:

a) 3-M C Bristol, Pennsylvania
Silicone Sealer Material EC-1663 B/A
Primer EC-1662

The surfaces to be potted were first primed with EC-1662 per Technical Data Sheet Issue #2 dated August 17, 1960. (Apply by brush, air dry 60 minutes.)

The EC-1663 material was treated in accordance with Technical Data Sheet Issue #3 dated May 21, 1962. (Mixing Ratio = 10 parts by weight EC-1663-A to 100 parts by weight EC-1663-B. Hand mix, partially degas, apply by pressure flow gun, allow to cure 48 hours at room temperature.)

b) 3-M Co., Ridgefield, New Jersey
Scotchcast XR-5038 Resin (Epoxy)
Primer XR-5001 (Used for Wires #7, 8, 12 and 13 only.)

On the wires requiring the use of a primer it was applied in accordance with Processing Bulletin 294-7018-61. (Apply by dipping the surface to be potted in XR-5001 then air dry.)

*Trademark - W.L. Gore and Assoc., Inc.

The XR-5038 potting material was treated in accordance with Product Information Sheet Code E-EP1-5038-1 issue date 3/19/65. (Mixing Ratio = 1 part by weight of part "B" to 5 parts by weight of part "A". Hand mix, partially degas, apply by pouring, allow to cure 24 hours at room temperature.)

Comments on XR-5038 = Handles similar to most epoxies and should be treated the same, little difficulty encountered

c) Coast Pro-Seal and Mfg. Co., Los Angeles, California
Molding & Potting Compound #794 (Polyurethane base)
Primer #781

The surfaces to be potted were primed with #781 per Data Sheet dated 11/15/62. (Dip in primer and allow to air dry 1/2 hour.)

The #794 potting material was treated in accordance with Data Sheet dated 1/22/65. (Warm the #794 Part A to 180°F until it liquifies, stir well and cool to room temperature. Warm the #794 Part B to 220°F, stir well and cool to room temperature. Combine Parts A and B, hand mix, degas, pour into potting molds and cure 24 hours at room temperature.)

Comments on #794 = Time consuming procedure to get materials to the useable state, otherwise it handles like most Urethanes.

d) Products Research Company, Burbank, California
Potting & Molding Material PR-1933-2 (RTV Silicone)
Primer #PR-1903 (For all wires except #7, 8 and 13.)
Primer #PR-1904 (For wires #7,8 and 13.)
No primer is required for Wire #12 (Silicone)

Where required, the surfaces to be potted were primed with either PR-1903 or PR-1904. PR-1903 was applied in accordance with Technical Data Sheet PR-1933 issued July 1964, Page #4. (Apply by brush, air dry a minimum of one hour, all potting must be completed within 24 hours of primer application as the primed surfaces require recleaning and repriming.) Primer PR-1904 was treated the same as Primer PR-1903.

The PR-1933-2 potting material was treated in accordance with Technical Data Sheet PR-1933 issue date, July 1964. (Mixing Ratio = 20 parts by weight of base compound to 1 part by weight acceleration, hand mix, degas, apply by pressure flow gun, cure 24 hrs. at 75°F plus 48 hrs. at 120°F.)

Comments on PR-1933-2

This potting material was judged the most difficult to work with for the following reasons·

i All primed surfaced must be potted within 24 hours of priming or they require reworking.

ii The catalyzed material starts to cure while only partially degassed, making additional degassing difficult.

iii By the time the material is degassed and ready to transfer to the pressure gun, it has reacted enough to be quite rubbery and difficult to pour from the mixing container into the potting equipment.

iv It was noted that only the exterior surface of the potted samples cures in the stated room temperature cure time, and all samples potted required an additional 24 hours at room temperature before they could be handled enough to place in a 120°F oven to complete the specified cure.

Since hook-up wire must pass through the surface of potting compounds used to protect terminals and components, special problems are involved in mkaing sure that mechanical adhesion is maintained between wire and compound and that the entrance of moisture and contaminants is prevented along the interface between wire and compound. All fluorocarbon surfaces have been etched and special primers have been used as suggested by the manufacturers to obtain optimum adhesion as described in detail in the foregoing.

Three types of test have been used to determine the compatibility of the four types of potting compounds with the 14 different wire insulations. The results are reported in both tables and charts as follows:

		Table	Figure
Mechanical Pull-Out -	RTV Silicone #1933	15-1	15-1
	Silicone Cpd. #1663	15-1	15-6
	Epoxy Cpd. #XR-5038	15-2	15-11
	Polyurethane #794	15-2	15-16
Voltage Breakdown -	RTV Silicone #1933	15-3	15-2 and 15-3
	Silicone Cpd. #1663	15-5	15-7 and 15-8
	Epoxy Cpd. #XR-5038	15-1	15-12 and 15-13
	Polyurethane #794	15-[illegible]	15-17 and 15-18
Insulation Resistance -	RTV Silicone #1933	15-4	15-4 and 15-5
	Silicone Cpd. #1663	15-6	15-9 and 15-10
	Epoxy Cpd. #XR-5038	15-8	15-14 and 15-15
	Polyurethane #794	15-10	15-19 and 15-20

The tables supply more information, but the figures permit easier visualization of the rather extensive results. Both tables and figures are grouped so as to permit consideration of variations for different wires in each compound.

RTV Silicone #1933

After aging for 15 days in oxygen at 150°C, the compound is still flexible but perhaps not as tough as silicone #1663. Review of Table 15-1 indicates that with 8 of the 14 wires a shear failure occurred in the compound itself rather than just in the wire or at the interface between the compound and wire. In general, nevertheless, relatively high pull-out values are obtained. Perdominantly mechanical failure occurs within the wire structure itself or with good adhesion between insulation and compound. It is interesting that relatively poor adhesion is obtained with the TFE fused tape surface of Wire #11, but good adhesion is obtained with the extruded TFE (Wire #9). One low value with poor adhesion is obtained with Wire #5 (See Table 15-1).

As might be expected, considerable variability is obtained for many of the wires in voltage breakdown and insulation resistance as indicated by the difference between the maximum and minimum values. It is probable that with some specimens moisture did not find its way along the wire as it did with other specimens. Since the worst insulation is the important one, minimum values have been plotted in the Figures. Here too, results are expressed as ratios of the value after potting to the unexposed value measure in air. In this way the variability in initial voltage breakdown is taken into account.

For the electrical tests both "nicked" and "unnicked" twisted wire specimens were used. With unnicked specimens attack of the compound on the wire might be detected. On the other hand, with nicked specimens the ability of the compound to "heal the break" might be measured.

In order to make comparison of so many test results, the orders of merit for the wires in the #1933 compound are listed below for each type of test using minimum values:

		Voltage Breakdown		Insulation Resistance	
	Pull-Out	Unnicked	Nicked	Unnicked	Nicked
Best	3	9	12	8	8
	8	7	9	2	13
	6	12	7	7	14
	7	13	14	6	9
	5	14	6	13	7
	4	6	13	12	6
	12	2	8	10	3
	9	8	3	14	2
	1	5	2	11	4
	14	10	4	1	11
	2	4	11	4	1
	13	11	5	9	10
	10	1	10	5	5
Poorest	11	3	1	3	12

It is quickly apparent that no good correlation exists between the 5 columns above, i.e., Wire #3 has the highest pull-out value, but the lowest unnicked voltage breakdown. The correlation between the electrical tests is also poor with Wire #8 showing the highest retained value of resistance but with a relatively poor breakdown showing. Recognizing that the electrical values are intrinsically quite variable it is possible to group the three best values above the dotted line and three poorest values below the lower dotted line as follows:

Best Pull-Out Wire #	Best Electrical Values Wire #	No of Times Noted
3	7	X 3
8	9	X 2
6	12	X 2
- - - - - - -		
7	8	X 2
	2	X 1
	13	X 1
	14	X 1

Poorest Pull-Out	Poorest Electrical Values	
2	5	X 3
- - - - - - -		
13	10	X 2
10	1	X 2
11	3	X 2
	9	X 1
	12	X 1

From the above it is apparent Wires #7 and 8 show the best over-all compatibility with RTV Silicone #1933. The over-all very poor electrical performance of so many of the wires probably makes the selection of the poorest ones rather academic.

Silicone Compound #1663

The approach taken above will be followed for this and the remaining two compounds.

Unlike the RTV Silicone #1933, the adhesion of Silicone #1663 to the polyolefin Wire #8 is very poor. Adhesion is relatively poor to Wires #10 and 13 also. In general, however, pull-out values are moderately high and usually adhesion is obtained between the wire and potting compound.

The relative ratings in mechanical and electrical test are listed below for the minimum values in each case:

		Voltage Breakdown		Insulation Resistance	
	Pull-Out	Unnicked	Nicked	Unnicked	Nicked
Best	4	9	9	7	7
	3	7	2	13	8
	5	2	3	8	13
	6	12	4	2	9
	12	5	12	9	14
	1	3	6	4	1
	7	6	5	12	4
	2	8	8	3	5
	10	8	8	3	5
	14	1	14	5	3
	9	14	13	1	2
	13	4	10	10	11?
	11	10	1	14	12
Poorest	8	11	11	11	10

Best Pull-Out Wire #	Best Electrical Values Wire #	No. of Times Noted
4	7	X 3
3	9	X 2
5	2	X 2
6	13	X 2
	8	X 1

Poorest Pull-Out	Poorest Electrical Values	
9	11	X 4
13	10	X 4
11	4	X 1
8	1	X 1
	14	X 1

In considering the foregoing tabulations it is apparent from the electrical point of view that Kynar jacketed polyolefin Wire #7 and TFE Teflon Wire #9 are outstanding with Silicone #1663. While the pull-out values are moderately good, without question, the TFE over-taped wire #11 shows the poorest results and the electrical performance of wire #10 is also poor. With Wires #10 and 11 it is considered possible that moisture may penetrate along and within a relatively poorly bonded insulation rather than at the interface between insulation and potting compound.

Epoxy Compound XR-5038

By reference to Figure 2 it is apparent that moderate to very high bonding strength with XR-5038 is achieved for all of the wires except the Kynar jacketed silicone #13. It is possible that the poor adhesion of the Kynar jacket to the silicone substrate is responsible, although such very low values were not obtained with any of the other compounds. Chemical attack by the epoxy on unirradiated Kynar may be responsible since it is somewhat susceptible to certain types of chemicals (notably acetone).

The relative ratings in mechanical and electrical test are listed below for the minimum values in each case:

		Voltage Breakdown		Insulation Resistance	
	Pull-Out	Unnicked	Nicked	Unnicked	Nicked
Best	3	2	7	8	7
	4	6	2	7	8
	6	9	6	2	13
	7	14	8	13	14
	8	7	9	14	4
	5	8	3	10	10
	1	4	14	3	6
	12	13	5	6	3
	10	10	4	11	11
	2	5	10	1	12
	9	3	12	9	2
	14	11	11	4	1
	11	12	13	5	5
Poorest	13	1	1	12	9

Best Pull-Out Wire #	Best Electrical Values Wire #	No of Times noted
3	7	X 3
4	2	X 3
6	8	X 2
7	6	X 2
8	13	X 1

Poorest Pull-Out	Poorest Electrical Values	
9	1	X 3
14	11	X 2
11	12	X 2
13	5	X 2
	13	X 1
	4	X 1
	9	X 1

In considering the tabulations above it is at once apparent that the polyolefin Wires #7 and 8 show the best over-all results. ML overcoated FEP Wire #1 shows surprisingly poor electrical properties as does the silicone wire #12. The TFE overwrapped Wire #11 exhibits poor electrical <u>and</u> pull-out properties.

It is possible to look at wires which are particularly interesting such as the LEM Wire #6. XR-5038 shows excellent bond strength to the #6 wire and the electrical properties, while not the best, are actually quite good.

Polyurethane Compound #794

After aging 14 days in oxygen at 150°C the polyurethane compound #794 developed a hard crust or shell and a sticky or even viscous liquid interior under the shell. The progress of oxidation during thermal aging of this material is shown in Figure 15-21. Cross-sections of slabs aged for increasing periods of time show how oxygen diffuses into the material and changes its color. The comparison of samples aged in oxygen and air is interesting. The tests were made as carefully as possible to avoid disrupting the aged #794. While the bond strength was generally low with #794 and no very high values were obtained, the pull-out values were sometimes surprisingly high - notably with Wires #1, 4, 7, 8, and 9.

Again the relative ratings in mechanical and electrical test are listed below for the minimum values in each case.

		Voltage Breakdown		Insulation Resistance	
	Pull-Out	Unnicked	Nicked	Unnicked	Nicked
Best	8	13	4	14	13
	9	8	8	12	14
	4	7	14	13	2
	7	14	13	2	1
	1	6	11	1	12
	2	3	12	7	9
	13	5	1	10	7
	5	2	7	8	10
	3	9	6	4	8
	10	4	3	11	11
	6	12	9	3	4
	14	1	2	6	3
	11	11	10	9	6
Poorest	12	10	5	5	5

Best Pull-Out Wire #	Best Electrical Values Wire #	No. of Times Noted
8	13	X 3
9	14	X 3
4	8	X 2
7	7	X 1
	4	X 1
	12	X 1
	2	X 1

Poorest Pull-Out	Poorest Electrical Values	
6	5	X 3
14	10	X 2
11	6	X 2
12	2	X 1
	1	X 1
	9	X 1
	3	X 1
	11	X 1

The electrical values are all so bad that it is probably not significant to make tabulations such as the foregoing. Nevertheless, Wires #13 and 14 show the best even though not good electrical characteristics. With the polyurethane the performance of the polyolefin Wires #7 and 8 is relatively good. The performance of the LEM Wire #6 is poor. As with all the other potting compounds, the performance of the TFE overtaped Wire #11 is poor.

TABLE 15-1

"PULL-OUT" CHARACTERISTICS WIRES IN POTTING COMPOUNDS AGED 15 DAYS AT $150^{o}C$ IN O_2

	Pull-Out Load - Lbs.							
	Silicone Compound #1933				Silicone Compound #1663			
Wire #	Avg.	Max.	Min.	Type*	Avg.	Max.	Min.	Type*
1	12.1	12.6	11.2	1-GA, 2 & 3	11.1	12.2	9.9	3
2	9.1	9.3	8.8	1-GA & 3	9.1	10.0	8.5	1-SA & 3
3	24.2	28.0	20.4	4	12.6	14.0	12.6	1-GA
4	18.3	22.2	15.3	1-GA & 4	14.2	15.85	12.7	1-GA
5	16.0	16.5	15.5 (0.5)	4 1-NA	13.5	14.75	11.7	1-GA
6	21.3	24.3	18.6	4	15.6	18.6	12.3	1-CA
7	23.9	28.8	18.3	1-GA & 4	10.35	11.9	9.5	1-SA
8	21.6	27.7	19.2	4	3.1	3.75	2.6	1-NA
9	12.4	12.7	12.0	4	8.8	10.0	7.7	1-GA
10	8.9	11.6	6.7	1-GA & 4	10.4	12.1	8.8	1-GA
11	4.4	4.8	4.0	1-SA	4.5	4.9	3.5	1-SA
12	15.9	18.3	14.0	1-GA	12.7	13.8	11.7	1-SA
13	7.3	7.8	6.9	1-SA & 3	6.1	7.6	4.7	1-SA
14	10.3	12.0	9.5	1-CA	11.6	12.8	10.4	1-GA

*Types of failures as follows:

(1-NA) No or poor adhesion-shear between wire insulation and potting compound
(1-SA) Same adhesion-shear between wire insulation and potting compound
(1-GA) Good adhesion-shear between wire insulation and conductor
(2) Shear between insulation and conductor
(3) Shear within the wire insulation itself
(4) Potting compound sheared

TABLE 15-2

"PULL-OUT" CHARACTERISTICS WIRES IN POTTING COMPOUNDS AGED 15 DAYS AT 150°C IN O_2

	Pull-Out Load - Lbs.							
	Epoxy Compound XR 5038				Polyurethane Compound #794			
Wire #	Avg.	Max.	Min.	Type*	Avg.	Max.	Min.	Type*
1	14.4	14.8	14.2	3	11.3	12.3	9.4	1-SA & 3
2	10.4	10.9	10.1	3	8.3	8.5	8.1	3
3	39.3	41.8	33.8	2 & 3	9.4	12.8	6.0	1-GA
4	30.8	33.0	28.6	2	13.4	16.6	10.2	1-GA
5	16.5	18.2	14.9	1-SA & 2	9.4	11.4	7.0	1-SA
6	30.5	33.0	26.5	1-SA	6.8	8.4	4.9	1-GA
7	25.9	28.3	24.7	2	14.3	17.5	10.2	1-GA
8	23.7	24.9	22.2	2	13.5	15.4	12.4	1-GA
9	10.0	10.6	9.6	1-SA	11.6	12.0	11.0	1-SA
10	11.9	12.6	10.7	2	6.7	7.5	5.4	1-SA
11	3.2	3.3	3.2	1-SA	4.8	5.9	3.9	1-SA
12	12.5	13.7	11.2	1-GA	2.5	4.4	1.4	4
13	0.51	0.69	0.40	1-SA	9.5	11.0	7.6	3
14	10.1	11.4	7.4	1-SA	6.2	8.2	4.6	1-SA

*Type of failures as follows:

(1-NA) No or poor adhesion-shear between wire insulation and potting compound
(1-SA) Same adhesion-shear between wire insulation and potting compound
(1-GA) Good adhesion-shear between wire insulation and conductor
(2) Shear between insulation and conductor
(3) Shear within the wire insulation itself
(4) Potting compound sheared

TABLE 15-3

TWISTED PAIRS POTTED IN SILICONE COMPOUND #1933 AFTER 14 DAYS IN O_2 AT 150°C

Breakdown Voltage - kv

	Maximum Values			Minimum Values		
Wire #	Unnicked	Nicked	Unpotted*	Unnicked	Nicked	Unpotted*
1	0.75	<0.5	20.2	<0.5	<0.5	15.8
2	23.8	14.8	21.0	8.0	3.1	15.0
3	15.5	21.0	28.5	<0.5	6.0	25.5
4	7.5	10.2	18.0	3.5	3.0	17.5
5	9.5	9.0	19.5	5.5	<0.5	13.0
6	24.5	28.5	30.0	18.0	12.5	25.5
7	25.5(1)	25.0	25.5	24.0(1)	13.0	21.0
8	30.0	19.0(1)	29.0	11.5(1)	7.5(1)	26.0
9	27.0	24.5	20.5	22.0	9.5	14.5
10	1.2	2.5	23.0	0.7	<0.5	18.0
11	1.25	1.25	13.5	<0.5	<0.5	10.5
12	23.3	15.5	18.5	17.5	11.1	16.5
13	26.5	17.0	22.4	18.5	8.3	18.0
14	23.1	15.5	25.5	18.7	11.1	20.6

(1) Failed over surface of potting compound.
* For comparison

TABLE 15-4

TWISTED PAIRS POTTED IN SILICONE COMPOUND #1933 AFTER 14 DAYS IN O_2 AT 150°C

Insulation Resistance - Ohms

	Maximum Values			Minimum Values		
Wire #	Unnicked	Nicked	Unpotted*	Unnicked	Nicked	Unpotted*
1	1.1×10^{13}	3.1×10^{12}	2.8×10^{13}	3.3×10^{7}	1.0×10^{7}	8.6×10^{12}
2	2.9×10^{13}	1.1×10^{13}	1.6×10^{13}	1.9×10^{13}	3.9×10^{8}	9.8×10^{12}
3	2.9×10^{13}	6.2×10^{13}	6.0×10^{14}	5.0×10^{5}	1.6×10^{13}	2.5×10^{14}
4	1.0×10^{13}	4.2×10^{12}	5.0×10^{13}	5.6×10^{7}	4.2×10^{7}	3.8×10^{13}
5	1.2×10^{12}	2.2×10^{11}	2.5×10^{15}	1.7×10^{7}	1.3×10^{6}	5.9×10^{14}
6	5.6×10^{13}	5.0×10^{13}	3.6×10^{15}	1.5×10^{13}	2.4×10^{13}	2.3×10^{14}
7	1.0×10^{13}	4.6×10^{12}	8.9×10^{12}	2.5×10^{12}	3.1×10^{12}	3.6×10^{12}
8	3.1×10^{13}	2.8×10^{13}	6.3×10^{13}	2.3×10^{13}	8.3×10^{12}	8.3×10^{12}
9	8.3×10^{13}	1.2×10^{14}	1.1×10^{15}	4.2×10^{8}	4.6×10^{13}	3.6×10^{14}
10	1.7×10^{13}	7.1×10^{12}	1.0×10^{14}	5.6×10^{10}	6.6×10^{6}	1.5×10^{13}
11	2.5×10^{13}	5.0×10^{13}	$>6.0 \times 10^{14}$	2.9×10^{8}	6.2×10^{8}	$>6.0 \times 10^{14}$
12	2.8×10^{12}	2.4×10^{12}	3.5×10^{13}	1.5×10^{12}	1.8×10^{5}	1.4×10^{13}
13	3.3×10^{12}	2.8×10^{12}	7.8×10^{12}	1.3×10^{12}	1.7×10^{12}	5.0×10^{12}
14	5.0×10^{12}	7.9×10^{12}	4.5×10^{13}	2.0×10^{9}	4.5×10^{12}	3.1×10^{13}

* For comparison

TABLE 15-5

TWISTED PAIRS POTTED IN SILICONE COMPOUND #1663 AFTER 14 DAYS IN O_2 AT 150°C AND 3 DAYS IMMERSION IN WATER

Insulation Resistance - Ohms

	Maximum Values			Minimum Values		
Wire #	Unnicked	Nicked	Unpotted*	Unnicked	Nicked	Unpotted*
1	7.3×10^{11}	1.3×10^{12}	2.8×10^{13}	1.7×10^{7}	3.6×10^{11}	8.6×10^{12}
2	1.4×10^{12}	1.4×10^{12}	1.6×10^{13}	5.4×10^{11}	8.3×10^{9}	9.8×10^{12}
3	4.4×10^{12}	1.3×10^{13}	6.0×10^{14}	2.3×10^{12}	1.6×10^{12}	2.5×10^{14}
4	1.9×10^{12}	1.4×10^{12}	5.0×10^{13}	7.6×10^{11}	7.8×10^{11}	3.8×10^{13}
5	1.6×10^{12}	3.2×10^{14}	2.5×10^{15}	8.1×10^{11}	3.5×10^{11}	5.9×10^{14}
6	3.3×10^{12}	3.1×10^{12}	3.6×10^{15}	1.6×10^{12}	1.9×10^{12}	2.3×10^{14}
7	1.8×10^{12}	1.0×10^{15}	8.9×10^{12}	1.0×10^{12}	(?)	3.6×10^{12}
8	2.5×10^{12}	2.9×10^{12}	6.3×10^{13}	1.5×10^{12}	1.9×10^{12}	8.3×10^{12}
9	2.2×10^{12}	2.7×10^{12}	1.1×10^{15}	1.1×10^{12}	1.6×10^{12}	3.6×10^{12}
10	8.1×10^{11}	9.4×10^{11}	1.0×10^{14}	6.3×10^{7}	5.0×10^{6}	1.5×10^{13}
11	1.5×10^{12}	1.0×10^{12}	$>6.0 \times 10^{14}$	6.3×10^{8}	3.9×10^{9}	$>6.0 \times 10^{14}$
12	5.3×10^{11}	5.0×10^{11}	3.5×10^{13}	3.1×10^{11}	2.5×10^{7}	1.4×10^{13}
13	2.0×10^{12}	7.0×10^{11}	7.8×10^{12}	1.6×10^{12}	3.9×10^{11}	5.0×10^{12}
14	2.6×10^{12}	2.0×10^{12}	4.5×10^{13}	9.1×10^{6}	1.2×10^{12}	3.1×10^{13}

* For comparison

TABLE 15-6

TWISTED PAIRS POTTED IN SILICONE COMPOUND #1663 AFTER 14 DAYS IN O_2 AT 150°C AND 3 DAYS IMMERSION IN WATER

Breakdown Voltage - kv

	Maximum Values			Minimum Values		
Wire #	Unnicked	Nicked	Unpotted*	Unnicked	Nicked	Unpotted*
1	20.2	10.3	20.2	11.2	0.4	15.8
2	25.0	20.7	21.0	17.1	11.6	15.0
3	33.5	26.4	28.5	26.0	20.0	25.5
4	15.5	14.5	18.0	9.0	10.0	17.5
5	17.5	19.0	19.5	14.0	6.0	13.0
6	29.0	29.5	30.0	26.0	12.5	25.5
7	26.9	20.0	25.5	24.6	7.0	21.0
8	25.5	22.5	29.0	19.5	9.0	26.0
9	23.7	24.0	20.5	18.0	17.6	14.5
10	11.5	10.3	23.0	0.5	1.8	18.0
11	2.8	5.9	13.5	0.2	0.2	10.5
12	20.8	21.8	18.5	18.4	6.5	16.5
13	19.0	16.0	22.4	13.6	4.9	18.0
14	18.5	17.7	25.5	12.0	7.1	20.6

*For comparison

TABLE 15-7

TWISTED PAIRS POTTED IN EPOXY COMPOUND #XR-5038 AFTER 14 DAYS IN O_2 AT 150°C AND 3 DAYS IMMERSION IN WATER

Breakdown Voltage - kv

	Maximum Values			Minimum Values		
Wire #	Unnicked	Nicked	Unpotted*	Unnicked	Nicked	Unpotted*
1	>12.0	>10.0	<0.2	2.75	<0.5	15.8
2	22.5	20.3	21.0	19.7	12.6	15.0
3	29.0	27.5	28.5	10.0	13.5	25.5
4	12.5	11.5	12.8	9.0	7.5	17.5
5	14.5	13.7	19.5	4.5	6.0	13.0
6	35.7	29.6	30.0	25.5	16.8	25.5
7	24.8	29.0	25.5	15.7	24.0	21.0
8	30.0	27.0	29.0	16.0	15.5	26.0
9	23.5	20.5	20.5	12.8	8.0	14.5
10	13.0	11.0	23.0	8.0	7.5	18.0
11	10.5	10.5	13.5	4.0	3.0	10.5
12	9.2	9.0	18.5	4.2	5.5	16.5
13	12.1	6.0	22.4	8.6	3.1	18.0
14	18.6	16.5	25.5	16.4	10.3	20.6

*For comparison

TABLE 15-8

TWISTED PAIRS POTTED IN EPOXY COMPOUND #XR-5038 AFTER 14 DAYS IN O_2 AT 150°C AND 3 DAYS IMMERSION IN WATER

Insulation Resistance - Ohms

	Maximum Values			Minimum Values		
Wire #	Unnicked	Nicked	Unpotted*	Unnicked	Nicked	Unpotted*
1	4.6×10^{13}	2.8×10^{13}	2.8×10^{13}	1.25×10^{10}	3.3×10^{6}	8.6×10^{12}
2	5.3×10^{13}	4.5×10^{13}	1.6×10^{13}	1.2×10^{13}	3.9×10^{7}	9.8×10^{12}
3	1.0×10^{14}	1.0×10^{14}	6.0×10^{14}	4.2×10^{13}	6.8×10^{12}	2.5×10^{14}
4	2.1×10^{13}	2.2×10^{13}	5.0×10^{13}	2.3×10^{7}	1.8×10^{13}	3.8×10^{13}
5	3.1×10^{8}	1.0×10^{13}	2.5×10^{15}	2.8×10^{7}	4.5×10^{6}	5.9×10^{14}
6	8.3×10^{13}	8.9×10^{13}	3.6×10^{14}	3.0×10^{13}	2.1×10^{13}	2.3×10^{14}
7	4.5×10^{13}	2.8×10^{13}	8.9×10^{12}	6.8×10^{12}	1.3×10^{13}	3.6×10^{12}
8	4.8×10^{13}	5.6×10^{13}	6.3×10^{13}	2.9×10^{13}	2.1×10^{13}	8.3×10^{12}
9	1.3×10^{14}	1.4×10^{14}	1.1×10^{15}	4.5×10^{8}	short	3.6×10^{14}
10	1.9×10^{13}	4.2×10^{13}	1.0×10^{14}	8.1×10^{12}	5.0×10^{12}	1.5×10^{13}
11	4.6×10^{14}	6.2×10^{14}	$>6.0 \times 10^{14}$	6.7×10^{13}	1.3×10^{13}	$>6.0 \times 10^{14}$
12	1.5×10^{13}	8.9×10^{12}	3.5×10^{13}	5.0×10^{5}	1.3×10^{10}	1.4×10^{13}
13	1.3×10^{13}	1.4×10^{13}	7.8×10^{12}	5.0×10^{12}	9.1×10^{12}	5.0×10^{12}
14	4.2×10^{13}	2.5×10^{13}	4.5×10^{13}	2.8×10^{13}	1.7×10^{13}	3.1×10^{13}

*For comparison

TABLE 15-9

TWISTED PAIRS POTTED IN POLYURETHANE COMPOUND #794 AFTER 14 DAYS IN O_2 AT 150°C AND 3 DAYS IMMERSION IN WATER

Breakdown Voltage - kv

	Maximum Values			Minimum Values		
Wire #	Unnicked	Nicked	Unpotted*	Unnicked	Nicked	Unpotted*
1	9.5	13.5	20.2	0.5	3.0	15.8
2	9.7	16.0	21.0	1.7	1.5	15.0
3	28.0	28.0	28.5	3.5	3.5	25.5
4	9.5	4.5	18.0	1.6	11.3	17.5
5	6.0	7.5	19.5	1.5	<1.0	13.0
6	22.0	15.5	30.0	4.0	4.0	25.5
7	19.0	11.7	25.5	6.5	3.9	21.0
8	18.0	17.0	29.0	11.6	14.5	26.0
9	19.0	22.0	20.5	1.5	2.0	14.5
10	10.1	4.2	23.0	0 (short)	1.7	18.0
11	3.7	8.4	13.5	0 (short)	2.4	10.5
12	8.6	8.0	18.5	1.0	3.7	16.5
13	15.5	12.1	22.4	11.2	6.0	18.0
14	17.0	14.3	25.5	4.0	8.3	20.6

*For comparison

TABLE 15-10

TWISTED PAIRS POTTED IN POLYURETHANE COMPOUND #794 AFTER 14 DAYS IN O_2 AT 150°C AND 3 DAYS IMMERSION IN WATER

Insulation Resistance - Ohms

	Maximum Values			Minimum Values		
Wire #	Unnicked	Nicked	Unpotted*	Unnicked	Nicked	Unpotted*
1	3.1×10^{9}	1.0×10^{10}	2.8×10^{13}	6.2×10^{5}	3.3×10^{6}	8.6×10^{12}
2	6.4×10^{8}	1.7×10^{9}	1.6×10^{13}	1.0×10^{6}	4.5×10^{6}	9.8×10^{12}
3	1.6×10^{10}	7.6×10^{10}	6.0×10^{14}	2.0×10^{5}	2.0×10^{5}	2.5×10^{14}
4	7.8×10^{9}	3.7×10^{7}	5.0×10^{13}	1.0×10^{5}	5.0×10^{5}	3.8×10^{13}
5	3.5×10^{6}	2.0×10^{8}	2.5×10^{15}	$<2.0 \times 10^{5}$	1.0×10^{5}	5.9×10^{14}
6	5.3×10^{10}	2.1×10^{10}	3.6×10^{14}	$<2.0 \times 10^{5}$	2.0×10^{5}	2.3×10^{14}
7	4.5×10^{10}	1.7×10^{8}	8.9×10^{12}	1.0×10^{5}	$<2.0 \times 10^{5}$	3.6×10^{12}
8	2.4×10^{10}	5.9×10^{10}	6.3×10^{13}	$<2.0 \times 10^{5}$	2.0×10^{5}	8.3×10^{12}
9	3.9×10^{9}	3.5×10^{10}	1.1×10^{15}	2.0×10^{5}	1.5×10^{7}	3.6×10^{14}
10	4.2×10^{9}	6.1×10^{8}	1.0×10^{14}	6.2×10^{5}	5.6×10^{5}	1.5×10^{13}
11	2.0×10^{10}	3.6×10^{10}	$>6.0 \times 10^{14}$	7.1×10^{5}	1.4×10^{7}	$>6.0 \times 10^{14}$
12	9.6×10^{8}	9.6×10^{8}	3.5×10^{13}	2.5×10^{7}	4.2×10^{6}	1.4×10^{13}
13	3.1×10^{9}	1.1×10^{10}	7.8×10^{12}	1.0×10^{7}	9.6×10^{7}	5.0×10^{12}
14	2.4×10^{9}	1.3×10^{9}	4.5×10^{13}	4.5×10^{5}	2.5×10^{8}	3.1×10^{13}

*For comparison

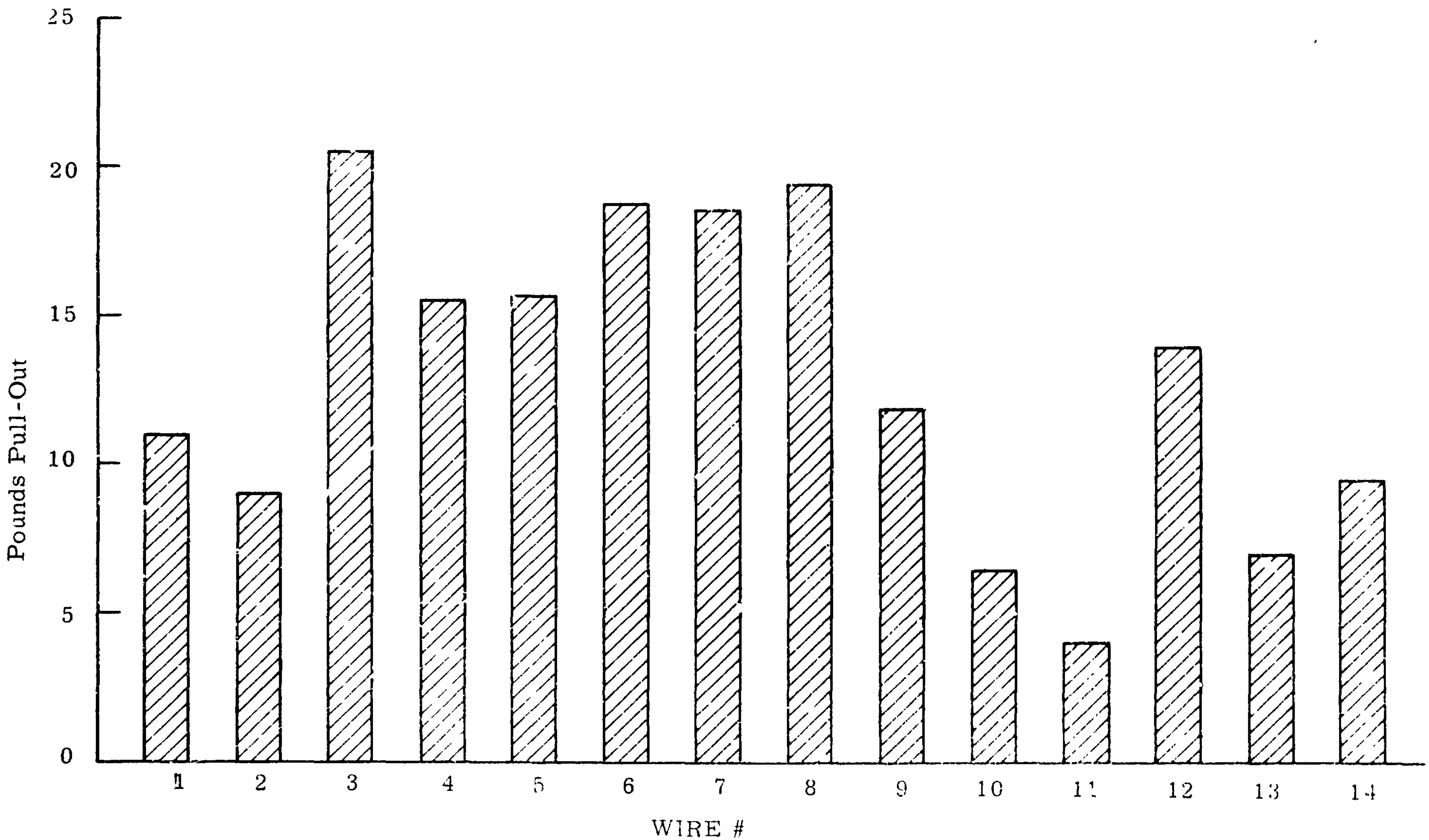


Figure 15-1 Minimum Pull-Out Silicone Compound #1933 Aged 14 Days at 150°C in Oxygen

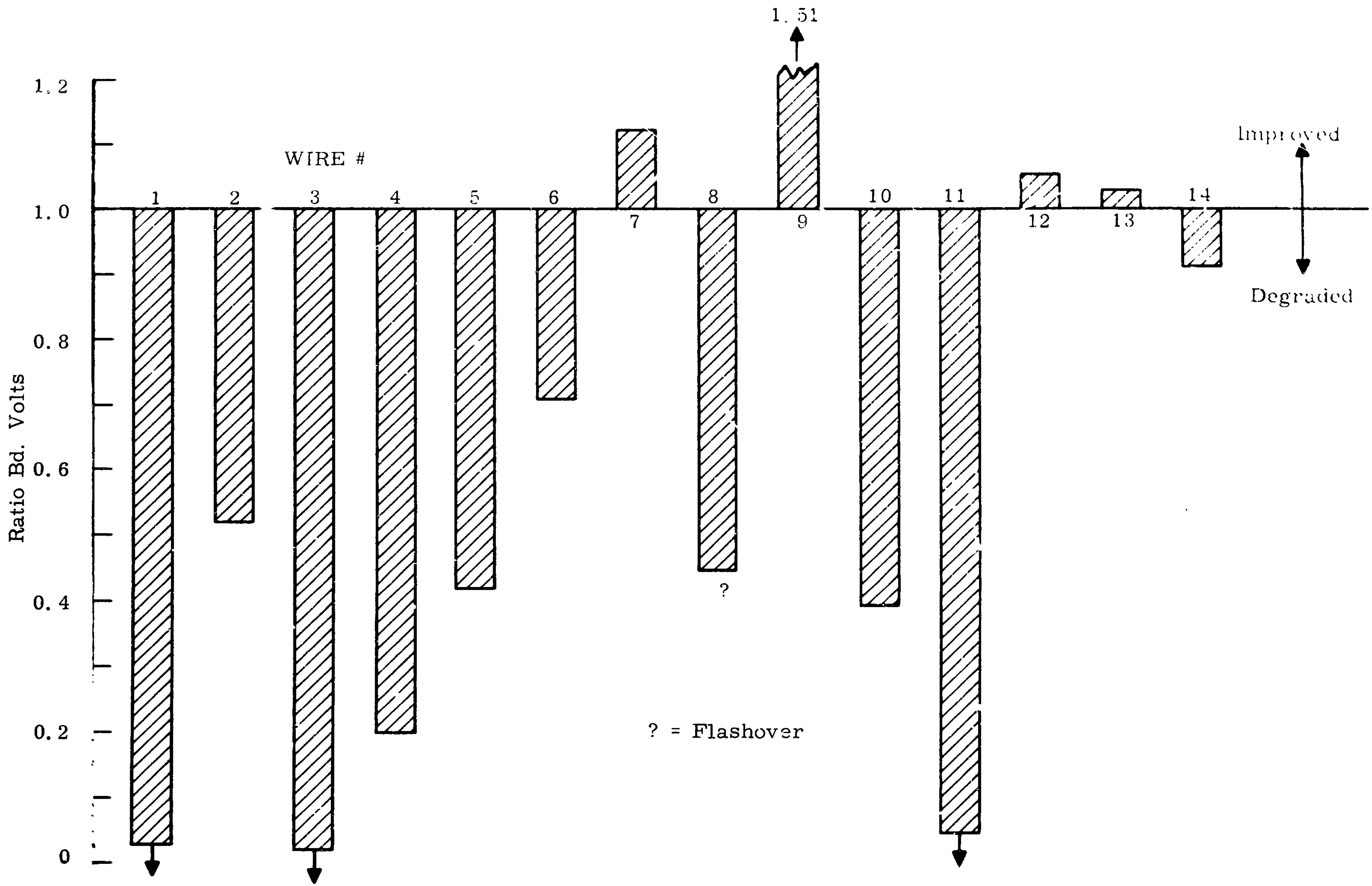


Figure 15-2 Ratio Breakdown Voltage - Potted/Unpotted, Silicone #1933 Unnicked Potted Specimens Aged 14 Days at 150°C in Oxygen and 3 Days Immersed in Water

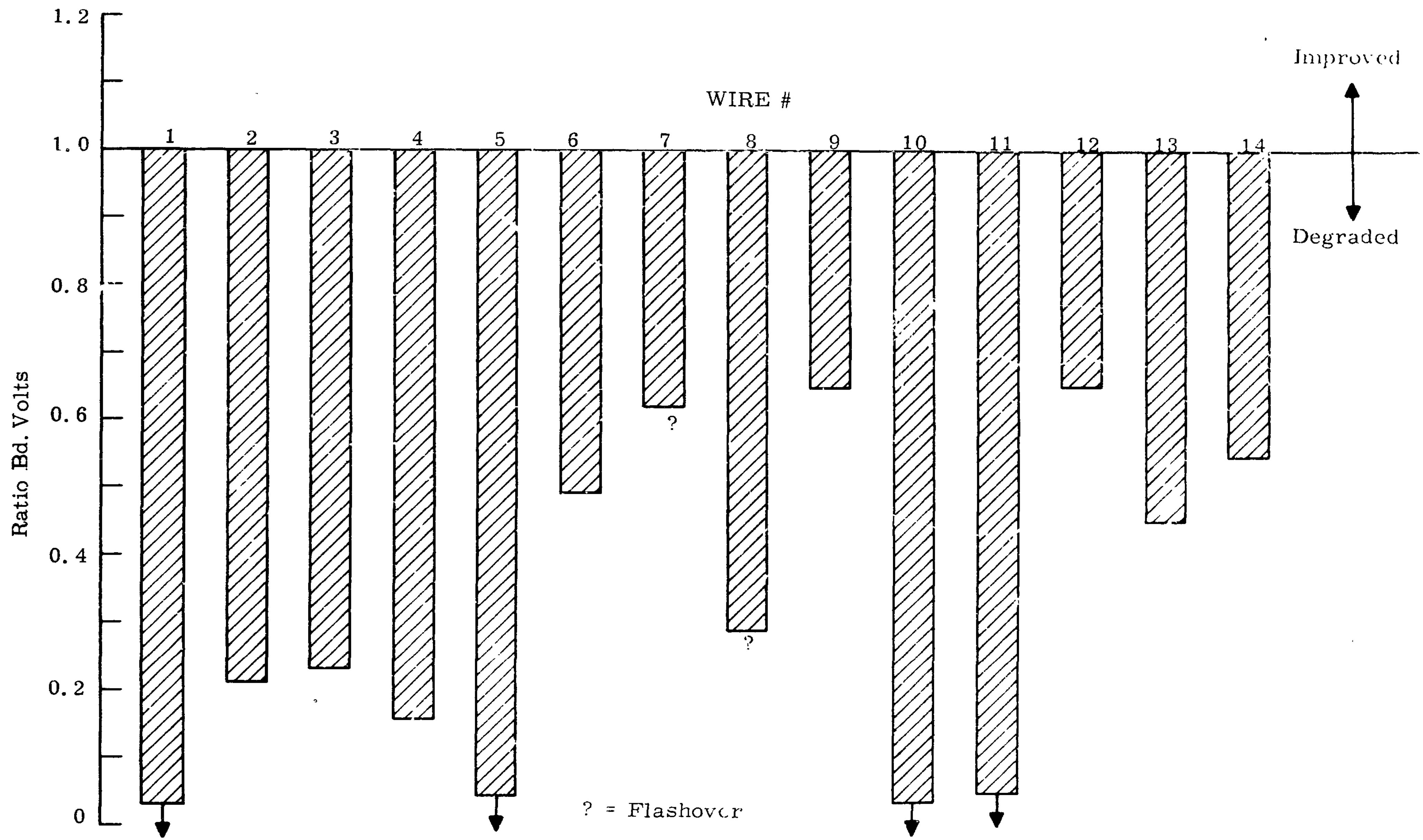


Figure 15-3 Ratio Breakdown Voltage - Potted/Unpotted, Silicone #1933 Nickel Potted Specimen Aged 14 Days at 150°C in Oxygen and 3 Days Immersed in Water

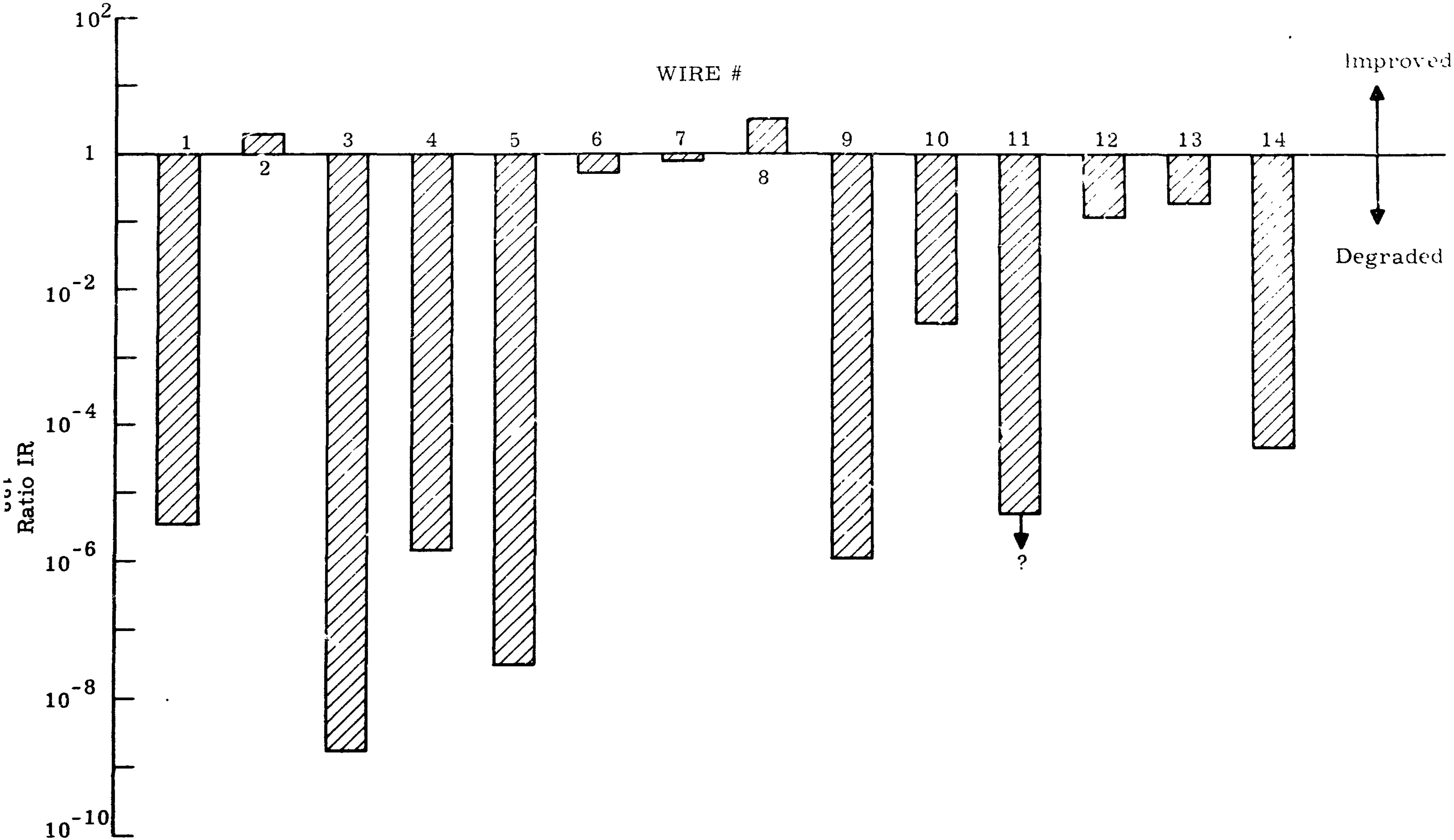


Figure 15-4 Ratio Insulation Resistance - Potted/Unpotted, Silicone #1933 Unnicked Potted Specimens Aged 14 Days at 150°C in Oxygen and 3 Days Immersed in Water

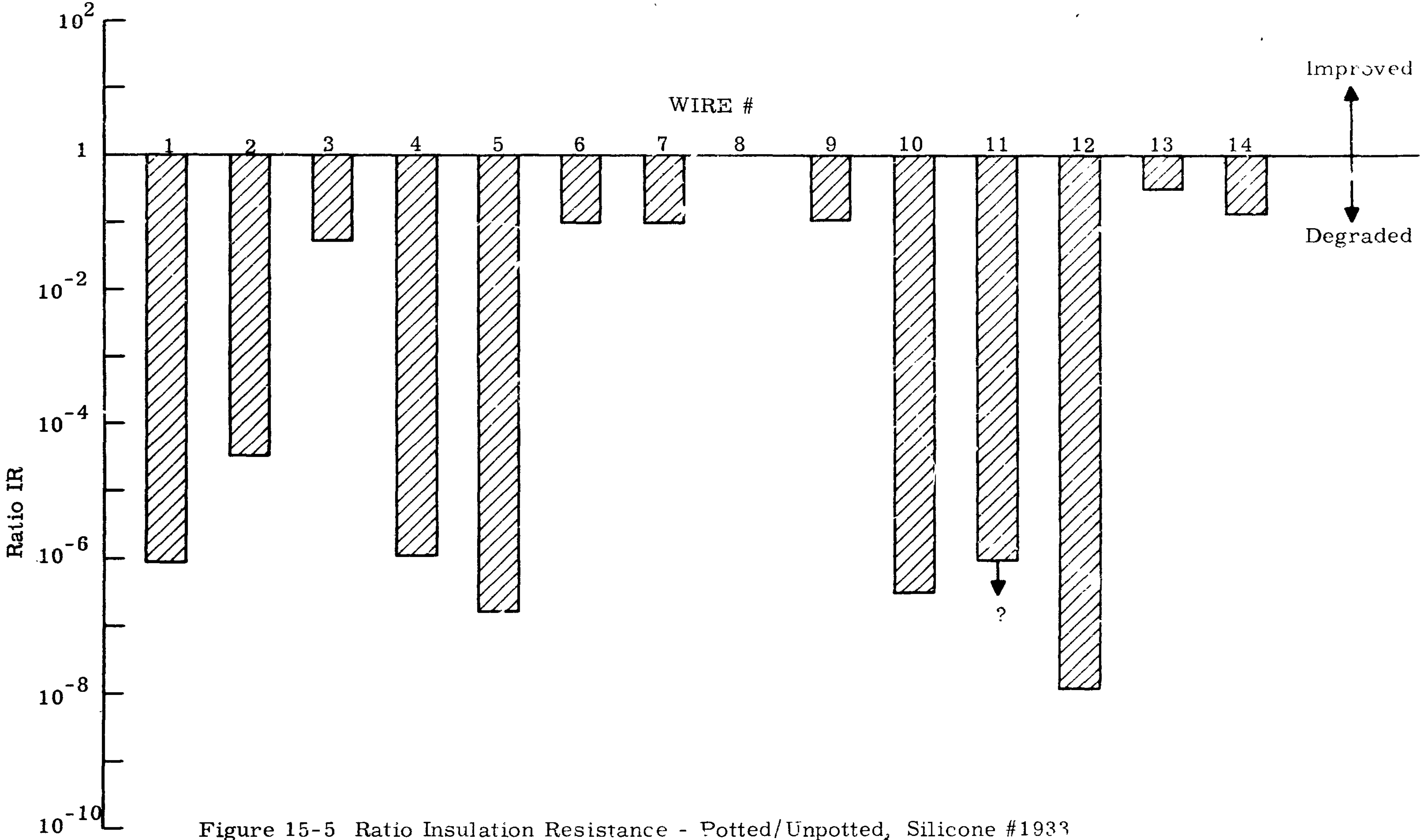


Figure 15-5 Ratio Insulation Resistance - Potted/Unpotted, Silicone #1933 Nickel Potted Specimens Aged 14 Days at 150°C in Oxygen and 3 Days Immersed in Water

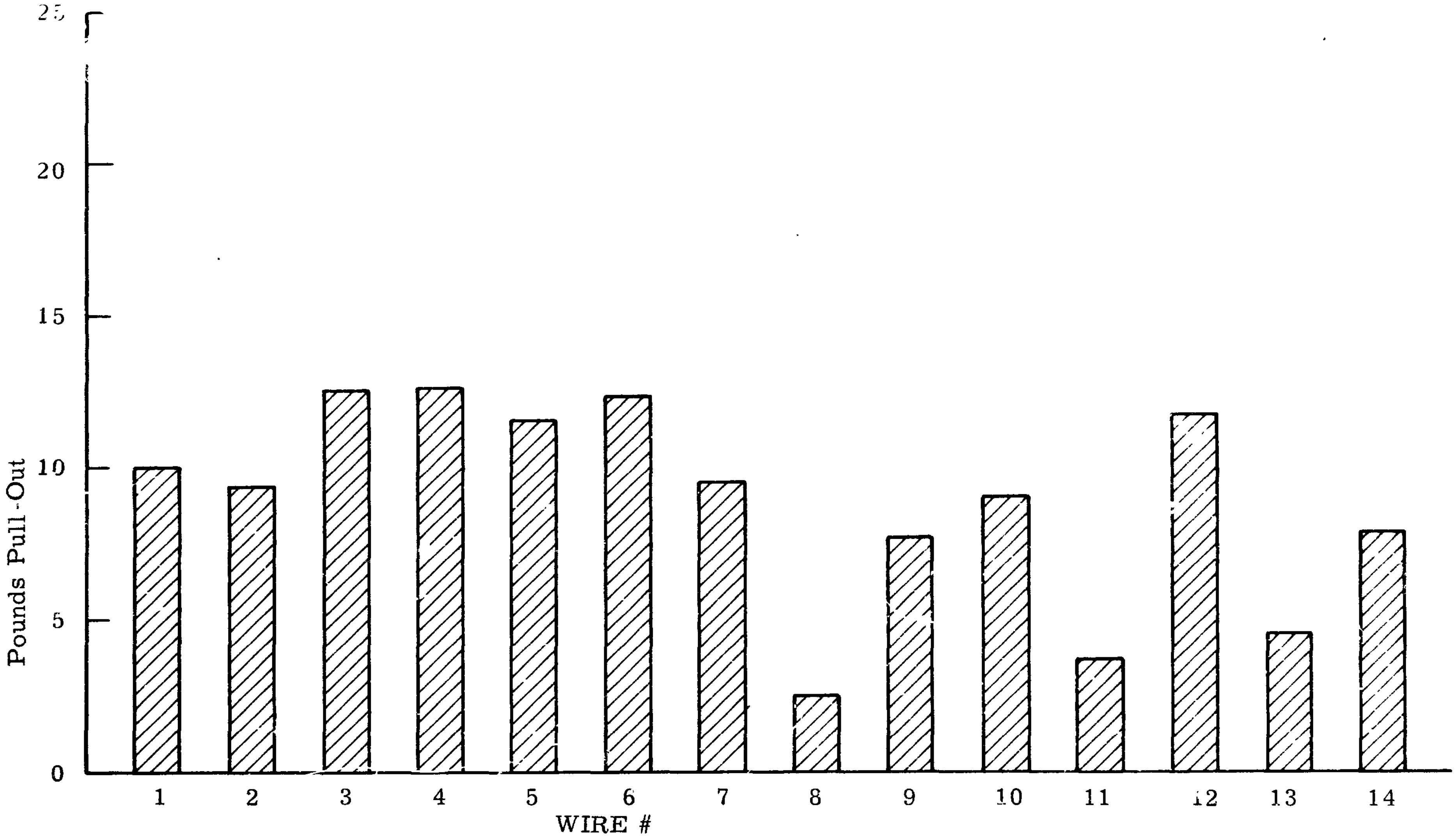


Figure 15-6 Minimum Pull-Out - Silicone Compound #1662, Aged 14 Days at 150°C in Oxygen

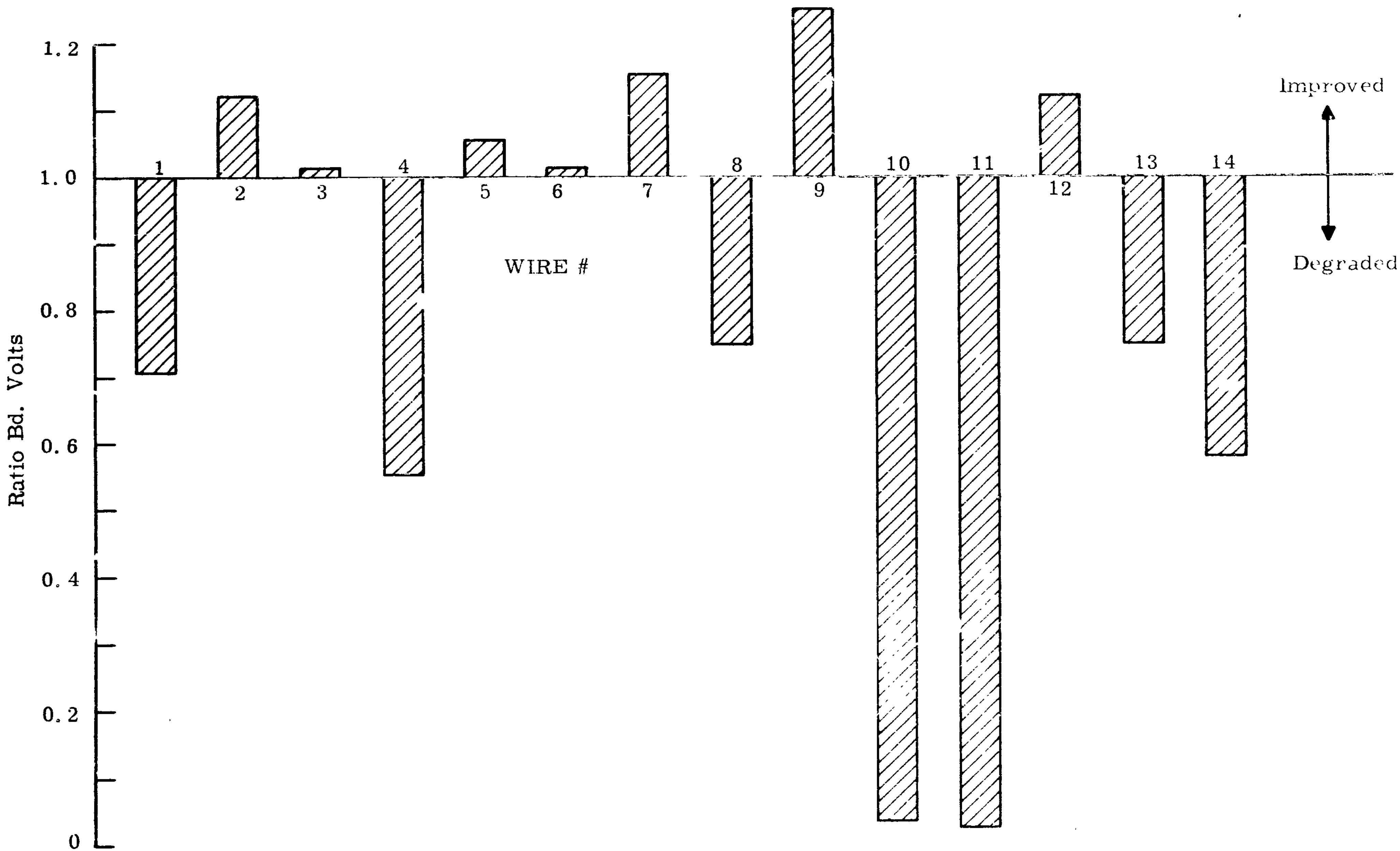


Figure 15-7 Ratio Breakdown Voltage - Potted/Unpotted, Silicone #1663 Unnicked Specimens Aged 14 Days at 150°C in Oxygen and 3 Days Immersed in Water

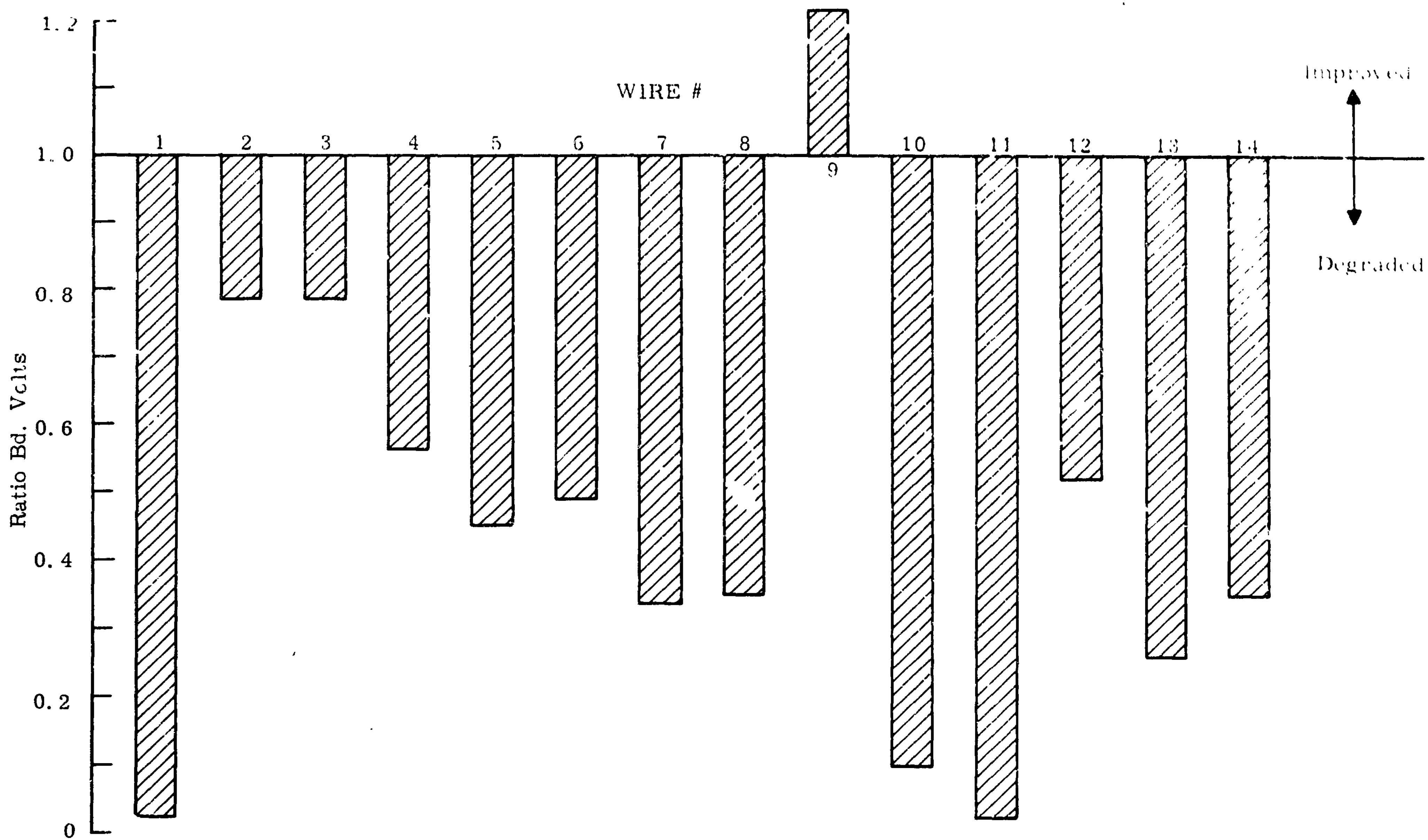


Figure 15-8 Ratio Breakdown Voltage - Potted/Unpotted Silicone (1663 Nicked Specimens Aged 14 Days at 150°C in Oxygen and 3 Days Immersed in Water

Figure 15-9 Ratio Insulation Resistance - Potted/Unpotted, Silicone #1663 Unnicked Specimens Aged 14 Days at 150°C in Oxygen and 3 Days Immersed in Water

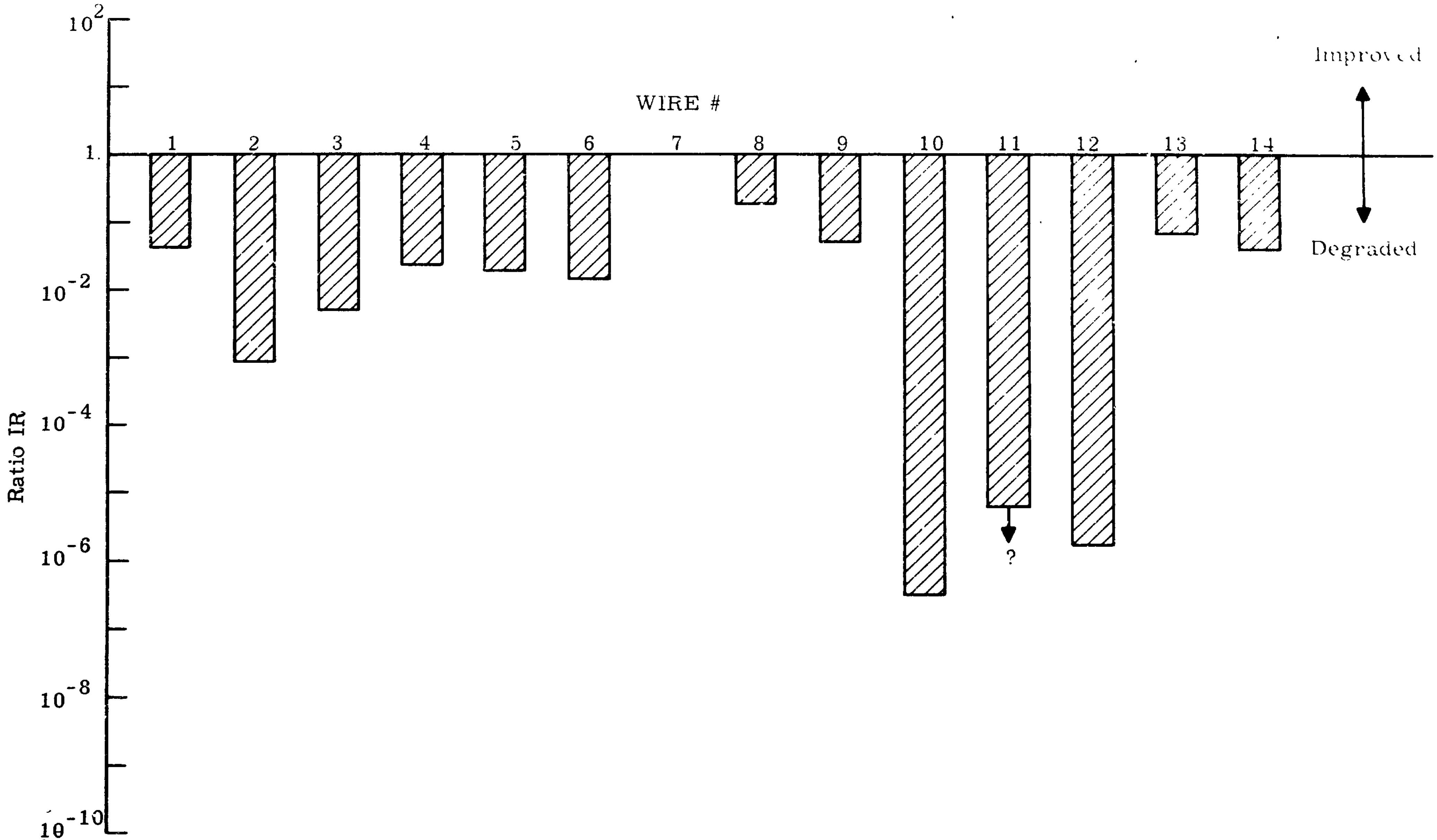


Figure 15-10 Ratio Insulation Resistance - Potted/Unpotted, Silicone #1663 Nicked Specimens Aged 14 Days at 150°C in C ygen, and 3 Days Immersed in Water

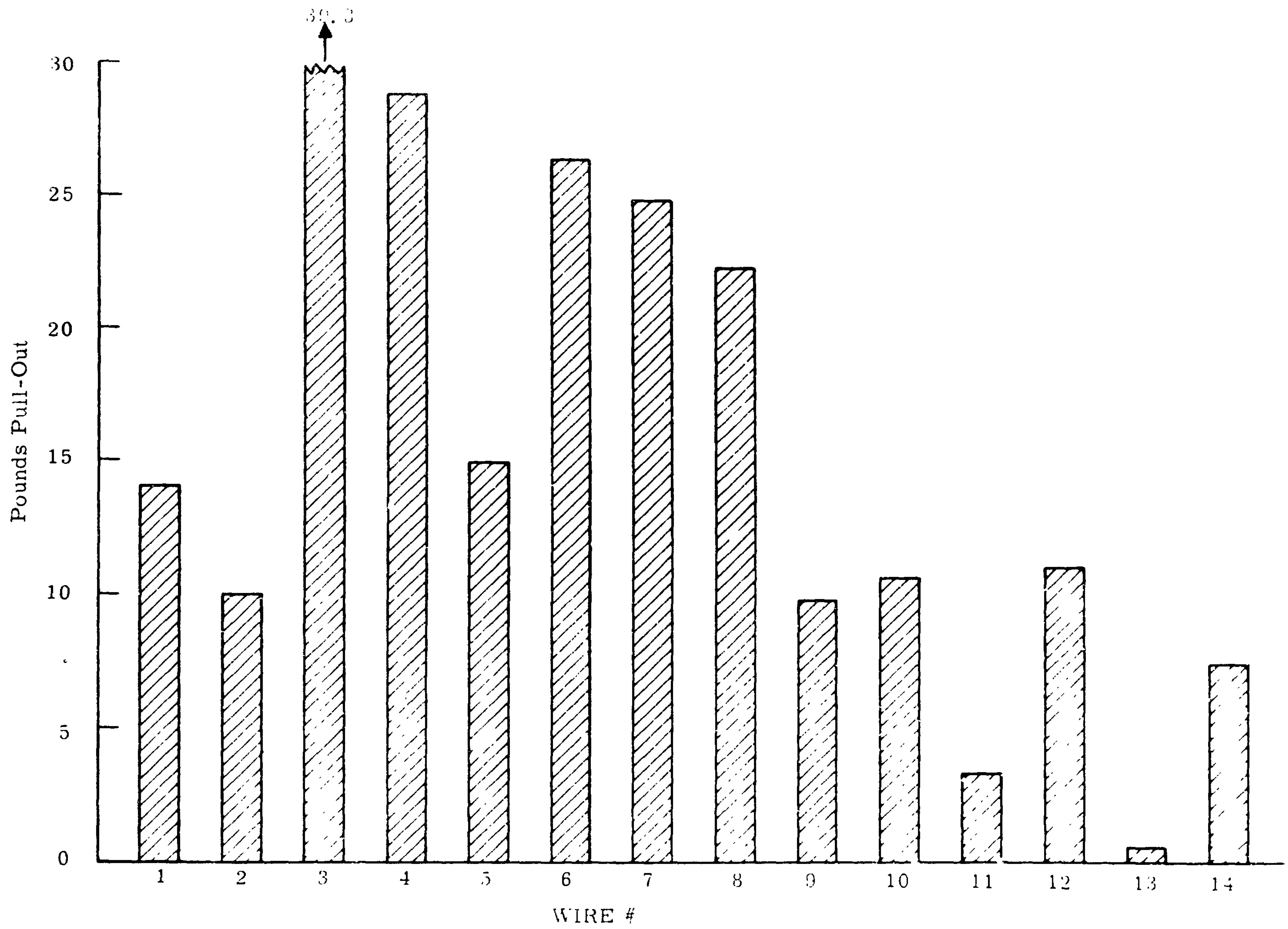


Figure 15-11 Minimum Pull-Out - Epoxy Compound XR5032 Aged 14 Days at 150°C in Oxygen.

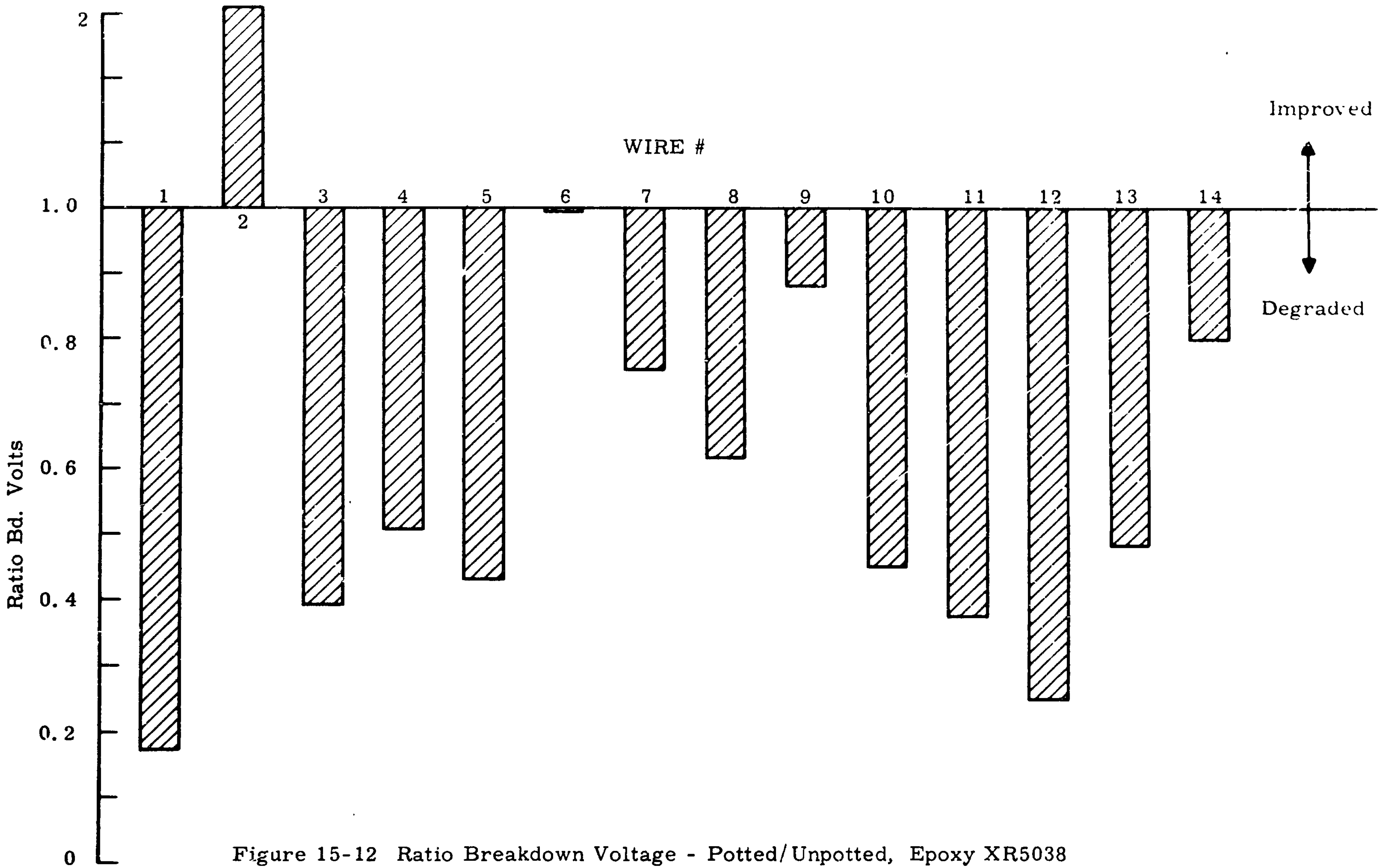


Figure 15-12 Ratio Breakdown Voltage - Potted/Unpotted, Epoxy XR5038 Unnicked Specimens Aged 14 Days at 150°C in Oxygen and 3 Days Immersed in Water

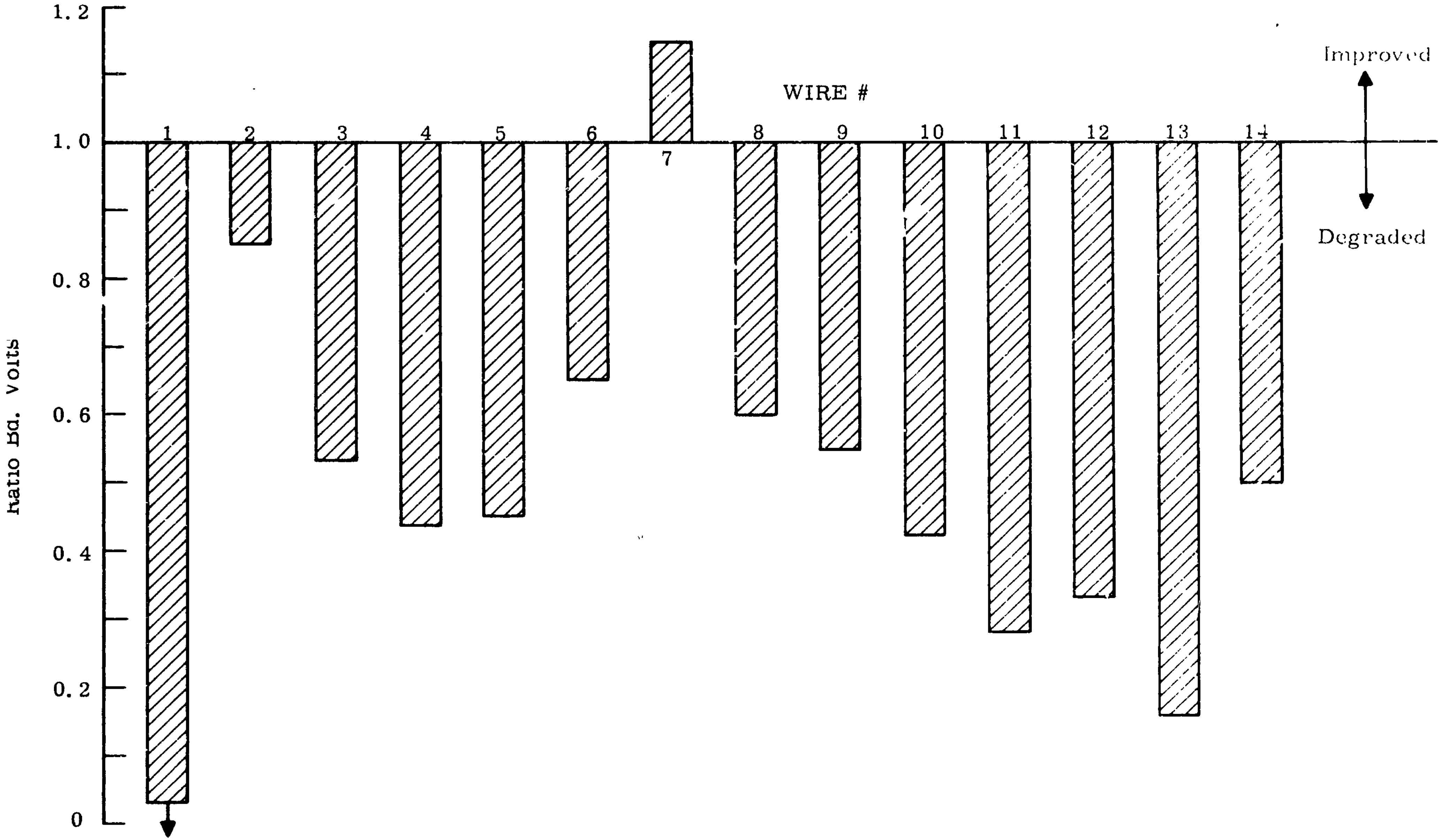


Figure 15 13 Ratio Breakdown Voltage - Potted/Unpotted, Epoxy XR5038 Nicked Specimens Aged 14 Days at 150°C in Oxygen and 3 Days Immersed in Water

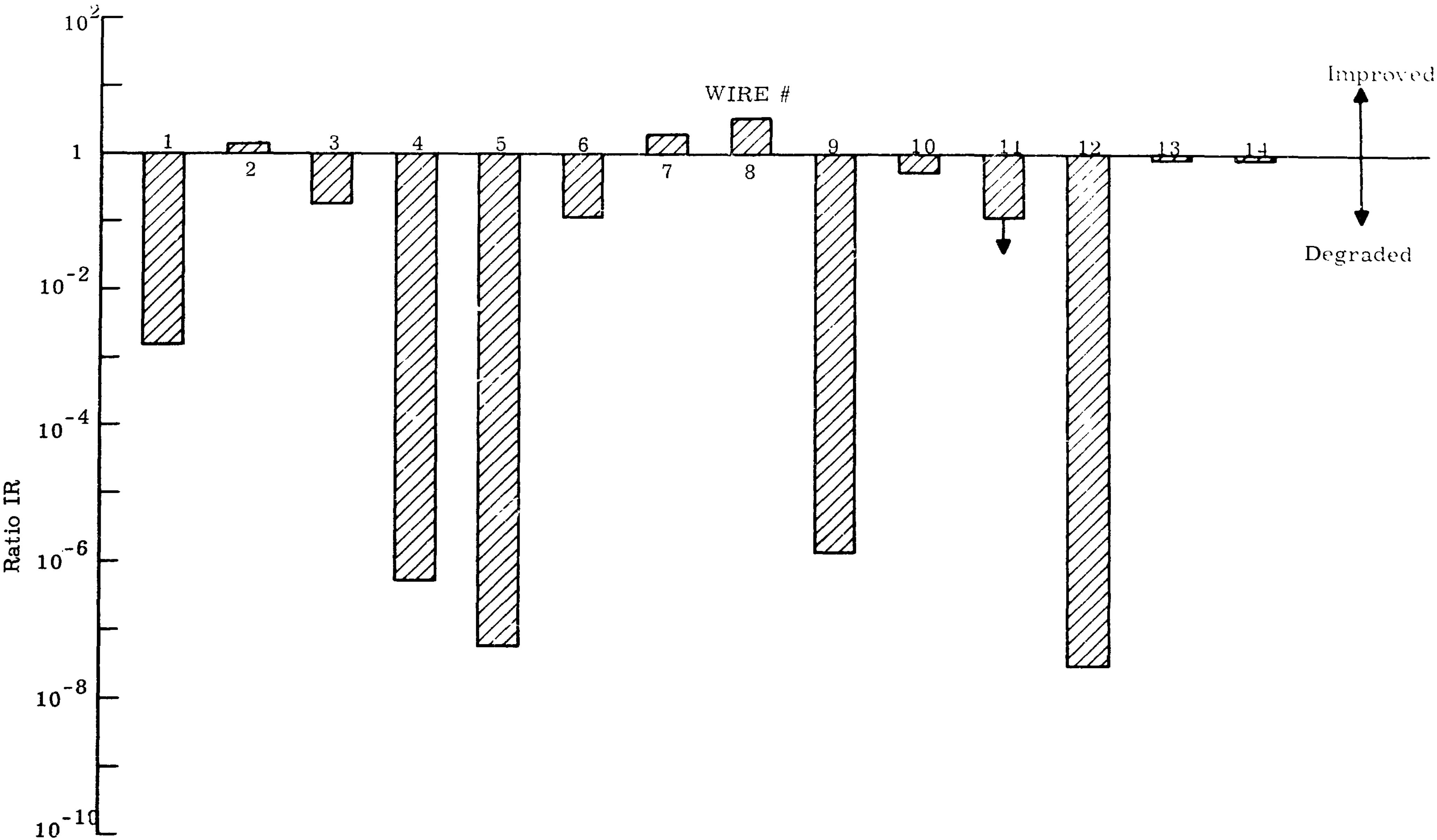


Figure 15-14 Ratio Insulation Resistance - Potted/Unpotted, Epoxy XR5038 Unnicked Specimens Aged 14 Days at 150°C in Oxygen and 3 Days Immersed in Water

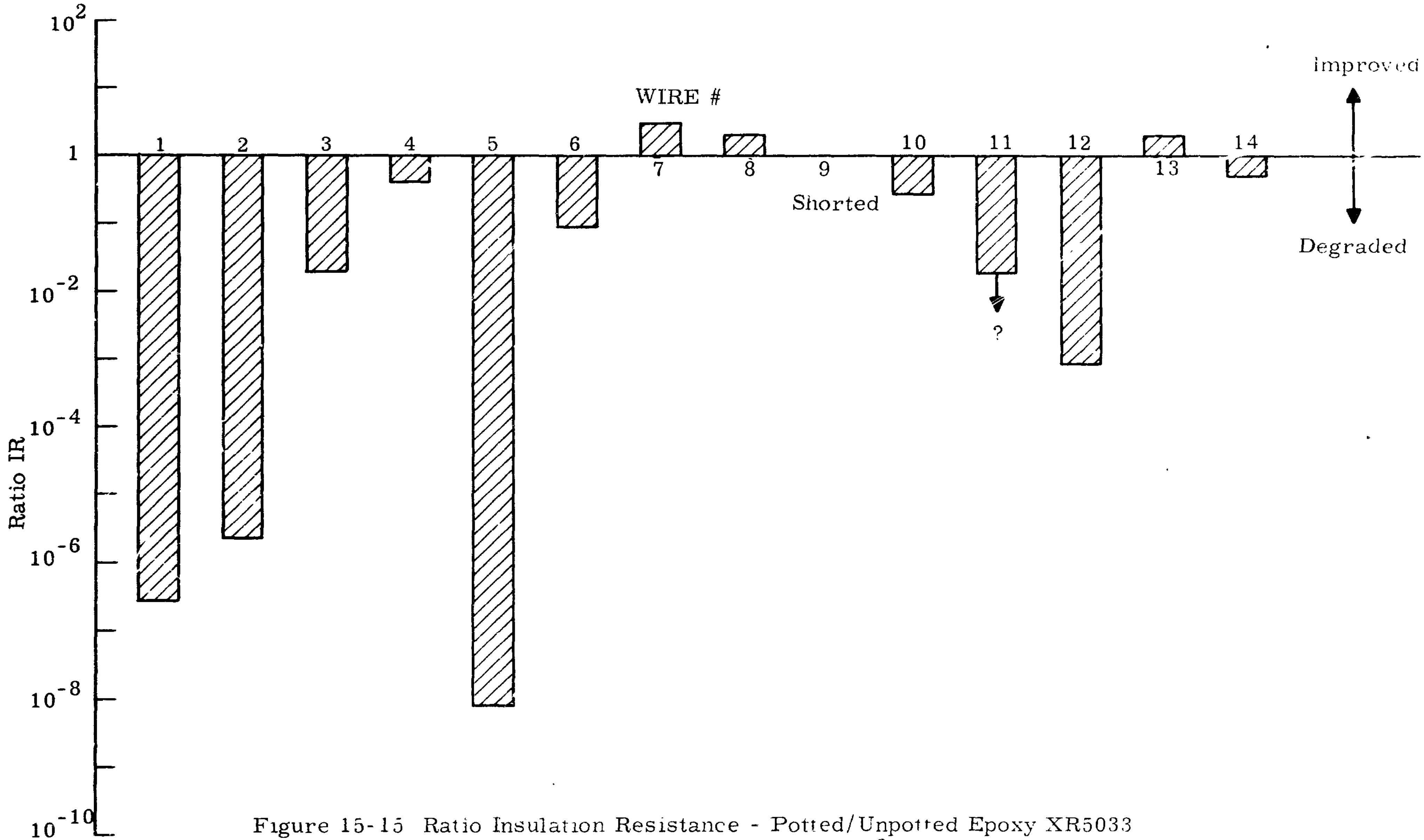


Figure 15-15 Ratio Insulation Resistance - Potted/Unpotted Epoxy XR5033 Nicked Specimens Aged 14 Days at 150°C in Oxygen and 3 Days immersed in Water

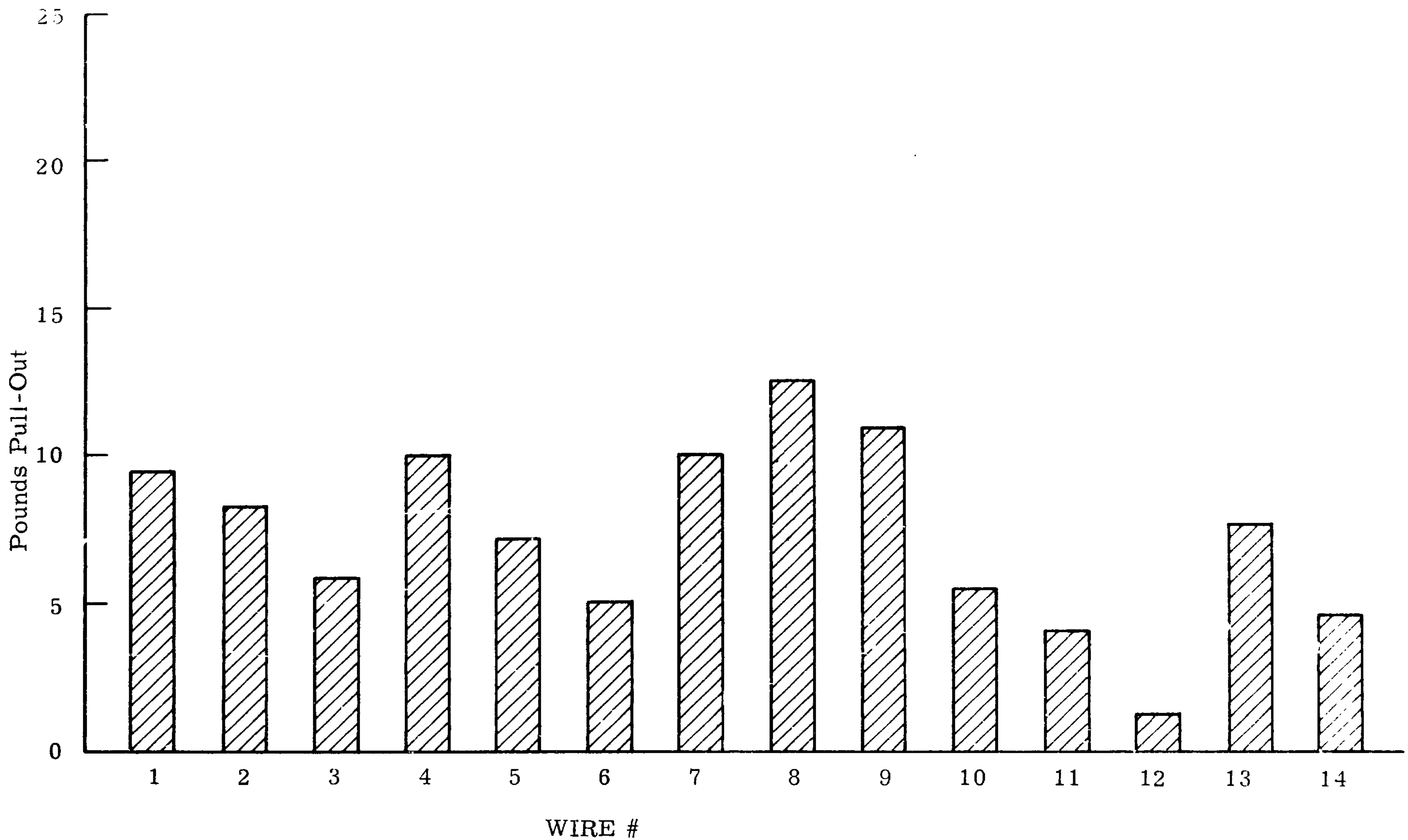


Figure 15-16 Minimum Pull-Out - Polyurethane Compound #794. Aged 14 Days at 150°C in Oxygen

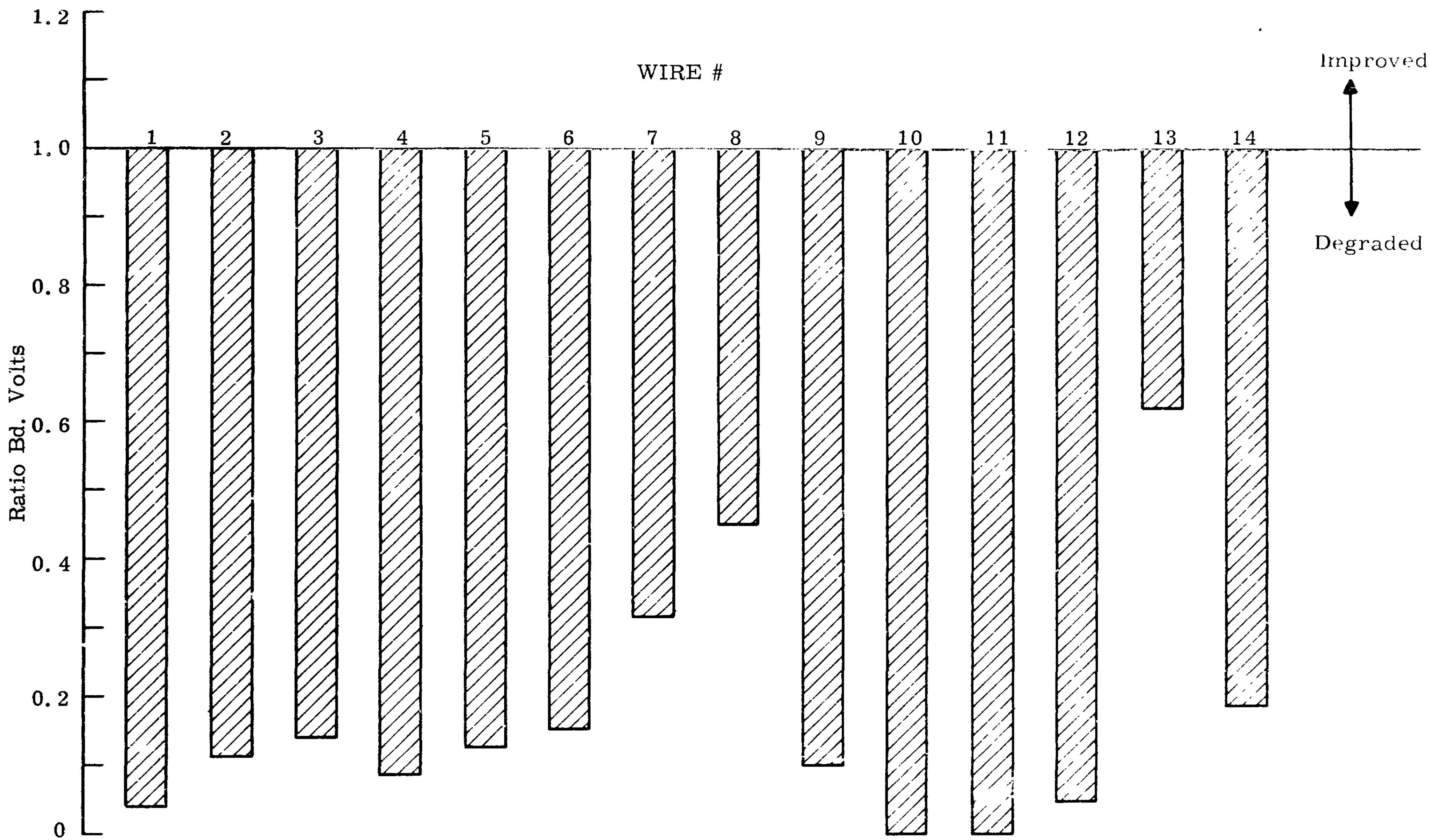


Figure 15-17 Ratio Breakdown Voltage - Potted/Unpotted, Polyurethane #794 Unnicked Specimens Aged 14 Days at 150°C in Oxygen and 3 Days Immersed in Water

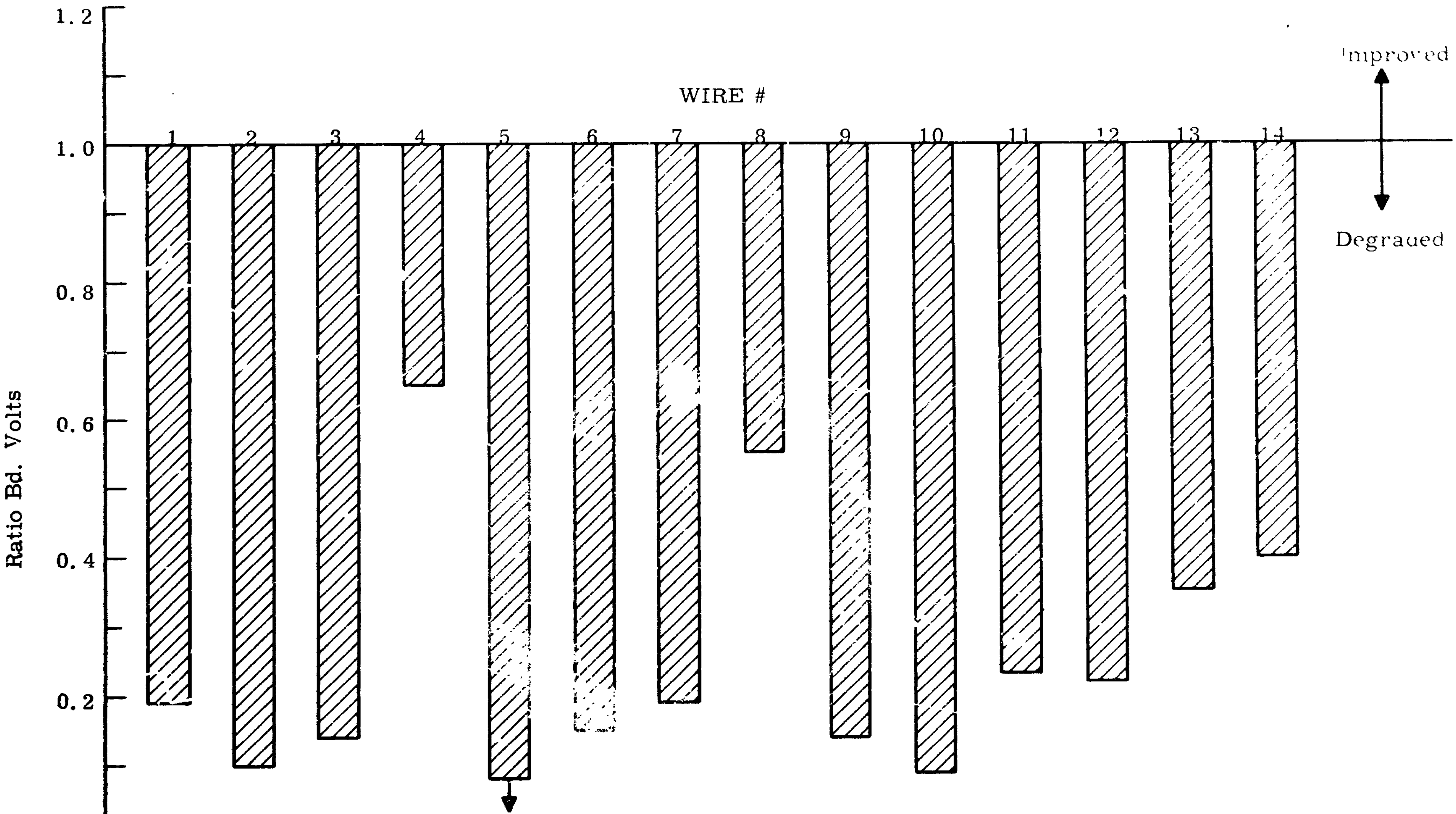


Figure 15-18 Ratio Breakdown Voltage - Potted/Unpotted, Polyurethane #794 Nicked Specimens Aged 14 Days at 150°C in Oxygen and Immersed 3 Days in Water

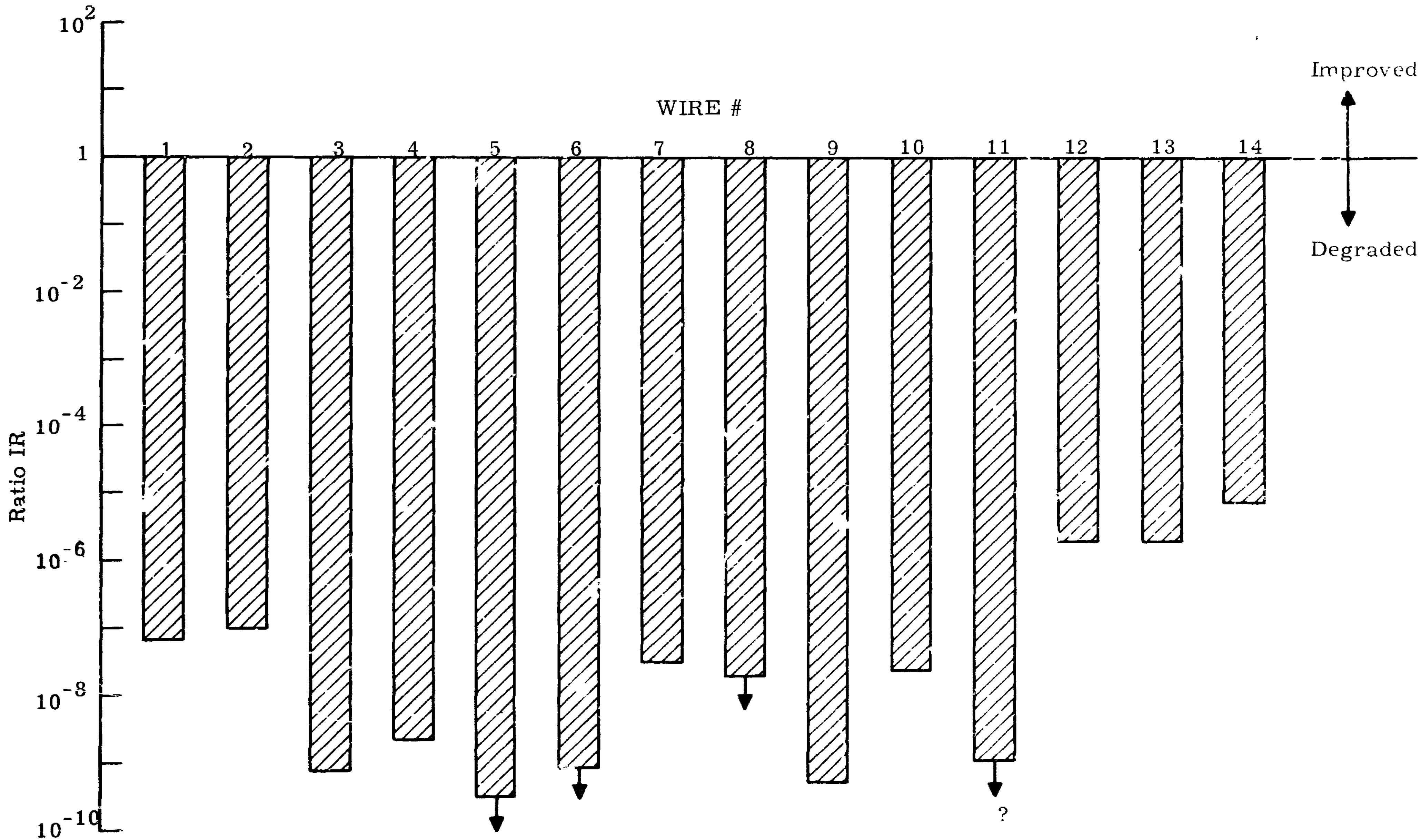


Figure 15-19 Ratio Insulation Resistance - Potted/Unpotted, Polyurethane #794 Unnicked Specimens Aged 14 Days at 150°C in Oxygen and Immersed 3 Days in Water

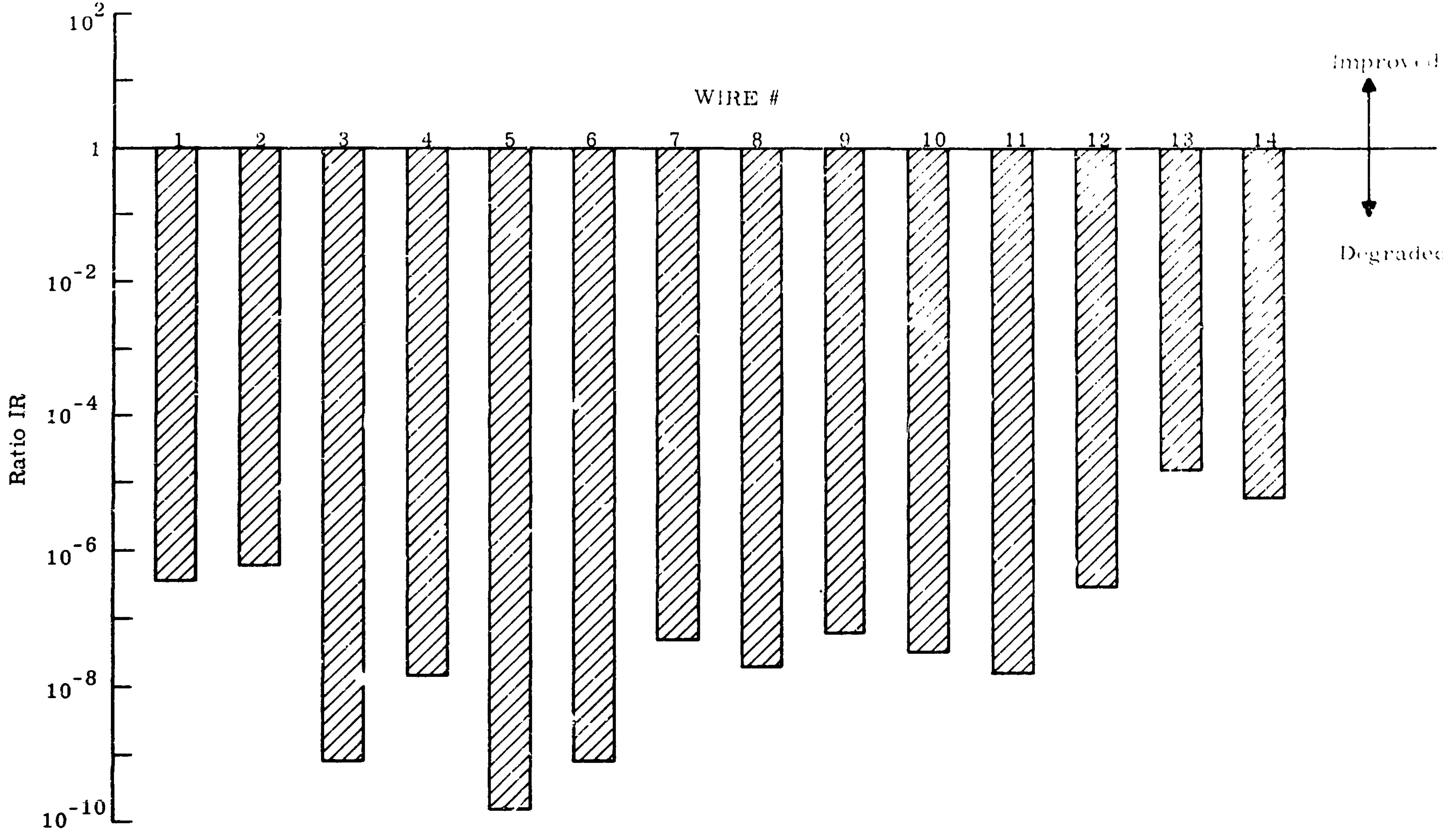


Figure 15-20 Ratio Insulation Resistance - Potted/Unpotted, Polyurethan #794 Nicked Specimens Aged 14 Days at 150°C in Oxygen and Immersed 3 Days in Water

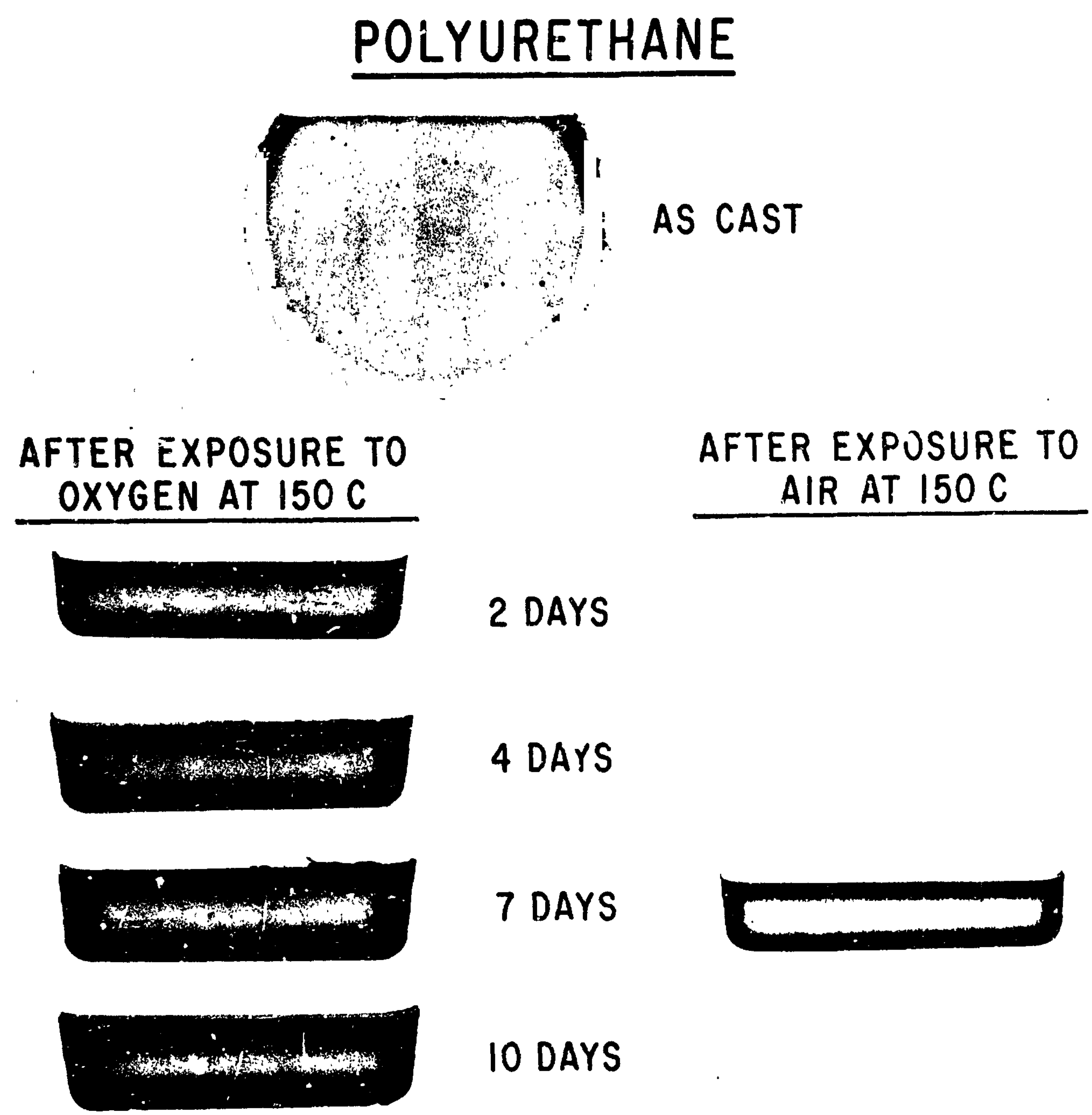


Figure 15-21 - Polyurethan #794 Aged in Air and in Oxygen

16. Flexibility

(a) Mandrel Flexibility

The mandrel flexibility test is most useful when the "kind" of failure in flexure is observed. It is difficult to code such observations into a uniform pattern. Nevertheless, the attempt has been made in Tables 16-1 and 16-2. Table 16-1 reports results of repeated mandrel flexibility tests made at room ambient. When the wires are wrapped around their own diameter (1X), the jackets of the jacketed wires sometimes craze or wrinkle. Moreover, with the exception of three wires, no damage results when the wires are bent over a .075 inch mandrel. Very slight opening or "mud-flat" cracking occurs in TFE dispersion overcoating of Wire #3 on a .075 in. diameter. The two jacketed silicone wires are more subject to failure when bent over the small mandrels.

In liquid nitrogen at -196°C considerable loss in flexibility is encountered as shown in Table 16-2. The following observations can be made:

a. Silicone rubber (Wires #12, 13 and 14) and the irradiated modified polyolefin (Wire #8) are extremely brittle at -196°C and fail even on a 3 inch mandrel.
b. The Kynar jacket (Wire #7) improves the performance of the underlying polyolefin, but silicone rubber (Wires #13 and #14) cracks under the jacket.
c. The performance of the ML overcoating over FEP Teflon (Wire #1) and TFE Teflon (Wire #2) is disappointing since ML enamel applied directly to copper has shown excellent cryogenic flexibility (see NAS 8-2442). The relatively poorer performance of Wire #2 is attributed to the better adhesion of the ML coating in this case which promotes crack propagation from the ML coating through the substrate.
d. Extruded TFE Teflon (Wire #9) shows relatively good flexibility at -196°C.
e. The H-film taped samples (Wires #3, 4, 5, 6, 10, 11, 15 and 16) all exhibit outstanding flexibility at -196°C (as was shown previously in NAS 8-2442). Differences in the flexibility of these wires can be attributed to differences in wall thickness, degree of bond and the thickness of the overcoat.

(b) Repeated Flexure

Five replicates have been used in repeated flexture tests. Results obtained at room temperature are reported in Tables 16-3 and 16-4. From Table 16-3 it is apparent that a slightly lower number of cycles cause failure with a 270° bend as compared to the 180° bend. Unfortunately, time was unavailable to make a comparison between a 120 and 180° bend. However, a few preliminary trials showed little difference. Results for Wires #15 and 16 tested at a 120° bend are little different from those for the very similar Wire #6 tested over the 180° bend. Wire tension may have a somewhat larger effect, but was not investigated in a systematic fashion.

A comparison of the results in Table 16-3 indicates that the cycles to failure for all of the nickel plated wires with the exception of #3 are lower than for silver plated wires and somewhat lower than for the tin plated wires. Thus, the nature of the wire seems more important than the insulation in determining repeated flexure failure. Differences in wire diameter and plating thickness might explain the considerable variability found even in the nickel plated wires. All of the results for nickel plated wires, except for Wire #3, (and Wire #13 which was not available when the plot was made) are plotted as a probability distribution in Figure 16-1. It is immediatel apparent that two slightly different populations are involved, but that even so, a reasonable Gaussian distribution is indicated.

With Teflon, polyolefin and silicone rubber insulation, the insulation did not fail at all or until well after conductor failure occurred as shown in Table 16-4. It is particularly interesting to note the superior performance of Wire #2 as compared to Wire #1 and the difference may well be explained by the greater adherence of the ML enamel to the TFE substrate of Wire #2.

When the repeated flexure tests are made at -162°C, much greater differences are encountered as shown in Table 16-5. While a perfect correlation does not exist with the mandrel diameter for failure at -196°C in liquid nitrogen, it is apparent that Wires #1, 2, 8, 12, 13 and 14 fail relatively rapidly and also fail on relatively large mandrel diameters at -196°C. It should be noted in addition that H-film taped Wires #4, 5, 10 and 11 as well as TFE Teflon (Wire #9) require more cycles to cause failure at -162°C than at room temperature. With Wires #9 and 10 this increase is startling. If plating of the conductor influences the results for repeated flexure at -162°C, the effects are washed out by other variables. It would seem that the conductor itself is not so likely to fail at -162°C and that the characteristics of the insulation are the controlling factor.

TABLE 16-1

MANDREL FLEXIBILITY - COMPARISON OF UNAGED WIRES TESTED IN AIR AT 23°C AND 50% RH

Wire #	Wire Dia. (1X)	Mandrel Diameter - Inches .075	0.125	0.25	0.5
1	J-Cr	OK			
2	J-W	OK			
3	MF	MF	OK		
4	W	OK			
5	W	OK			
6	OK				
7	W J-Cr	OK			
8	OK				
9	OK				
10	W LS	OK			
11	W LS	OK(1)			
12	OK				
13	J-W J-Cr	same as 1X	OK		
14				J-LS J-W	OK(2)
15	OK				
16	OK				

(1) Slight discontinuties in the outer Teflon wrap are noted in unflexed wire.
(2) The H-film jacket is loose on the wire as received.

CODE FOR FLEXIBILITY TESTS

W - Wrinkling
Cr - Crazing (Fine Cracks)
C - Cracking
S - Spalled completely off wire
Sp - Splitting Longitudinally

LS - Loosening of Wrap
J - Jacket of Coating
Slt - Slight or Some
MF - "Mud Flat" cracking opened by flexing
OK - No Damage

TABLE 16-2

MANDREL FLEXIBILITY - COMPARISON OF UNAGED WIRES TESTED IN LIQUID NITROGEN AT $-196^{o}C$

Mandrel Diameter - Inches

Wire #	.075	0.125	0.25	0.5	0.75	1.0	1.25	1.5	1.75	2.0	3.0
1				C	Slt. C J-Cr	J-Cr	OK				
2					C	C	C	C	C	OK	
3			C	J-Cr	OK						
4	Cr Slt. S	W	OK								
5	S	W LS	OK								
6			S Sp	OK							
7									C J-S	OK	
8									S	C	Slt. C
9			S	C	Slt. C	OK					
10			W Slt. C	Slt. W LS	OK						
11			C Sp.	J-C	OK						
12								S	Slt. S	C	C
13										C	C J-C
14									C	J-W C	J-W C
15				S	Cr	Slt. Cr.	OK				
16		C	Cr	Cr	OK						

CODE FOR FLEXIBILITY TESTS:

W - Wrinkling
Cr - Crazing (Fine Cracks)
C - Cracking
S - Spalled completely off wire
Sp - Splitting longitudinally

LS - Loosening of Wrap
J - Jacket of Coating
Slt - Slight or Some
MF - "Mud Flat" cracking opened by flexing
OK - No Damage

TABLE 16-3

COMPARISON OF WIRES IN REPEATED FLEXURE AT 23°C

Cycles to Conductor Failure

	180° Bend			270° Bend			
Wire #	Avg.*	Max.	Min.	Avg.*	Max.	Min.	Plating
1	2570	2630	2510				Nickel
2	2680	3360	1810				Nickel
3	5037	7802	3492	3333	4555	2654	Nickel
4	1866	2004	1785	1614	1727	1538	Nickel
5	2240	2604	1575	2098	3971	1016	Nickel
6	6081	7115	4382	5122	5448	4784	Silver
7	4332	4672	4078				Tin
8	4053	4389	3650				Tin
9	1818	2400	1520	1414	1590	1100	Nickel
10	2515	3049	1317				Nickel
11	1793	1976	1517				Nickel
12	1883	1970	1801				Nickel
13**	3323	3880	2350				Nickel
14	1513	1834	1312				Nickel
15**	6551	7293	4452				Silver
16**	6935	7960	6113				Silver

*Average of five tests.
**Tested over 120° rather than 180° bending arc.

TABLE 16-4

COMPARISON OF WIRES IN REPEATED FLEXURE AT 23°C

Wire #	Cycles to Insulation Failure Avg.	Max.	Min.	Cycles to Conductor Failure Avg.	Max.	Min.
1	2733	2833	2632	2570	2630	2510
2			>5000	2680	3360	1810
8	4065*	4076*		3890*	3650*	
9			>5000	1818	2400	1520
11			>5000			
12			>5000			
13			>5000			
14	1420**	1738**		1312**	1640**	

*Individual values with 3 other wires conductor and insulation failed at the same time.

**Silicone rubber did not fail. The H-film overwrap failed for two wires as shown. With the other 3 wires conductor and H-film wrap failed at the same time.

TABLE 16-5

COMPARISON OF WIRES IN REPEATED FLEXURE CYCLES TO CONDUCTOR FAILURE

	120° Bend, -162°C			180° Bend, 23°C			Mandrel Dia. - in.
Wire #	Avg.	Max.	Min.	Avg.	Max.	Min.	Failure at -196°C
1	506	738	214	2570	2630	2510	0.75
2	245	621	73	2680	3360	1810	1.75
3	3727	5475	2924	5037	7802	3492	0.25
4	3138	3854	2483	1866	2004	1785	.075
5	3457	7054	1353	2240	2604	1575	.075
5*	(2583)	4340	1353				
6	2633	4285	1172	6081	7115	4382	0.25
7	1771	2154	1177	4332	4672	4078	1.75
8	815	1748	422	4053	4389	3650	>3.0
9	8252	10773	4420	1818	2400	1520	0.5
10	9615	10229	8803	2515	3049	1317	0.25
11	3181	3603	2436	1793	1976	1517	0.25
12	355	493	248	1883	1970	1801	>3.0
13	577	1285	271	3323	3880	2350	3.0
14	259	381	95	1513	1834	1312	3.0
15	3783	5009	2346	6551	7293	4452	0.5
16	2159	3161	1382	6935	7960	6113	0.125

*Values in parenthesis exclude one high value.

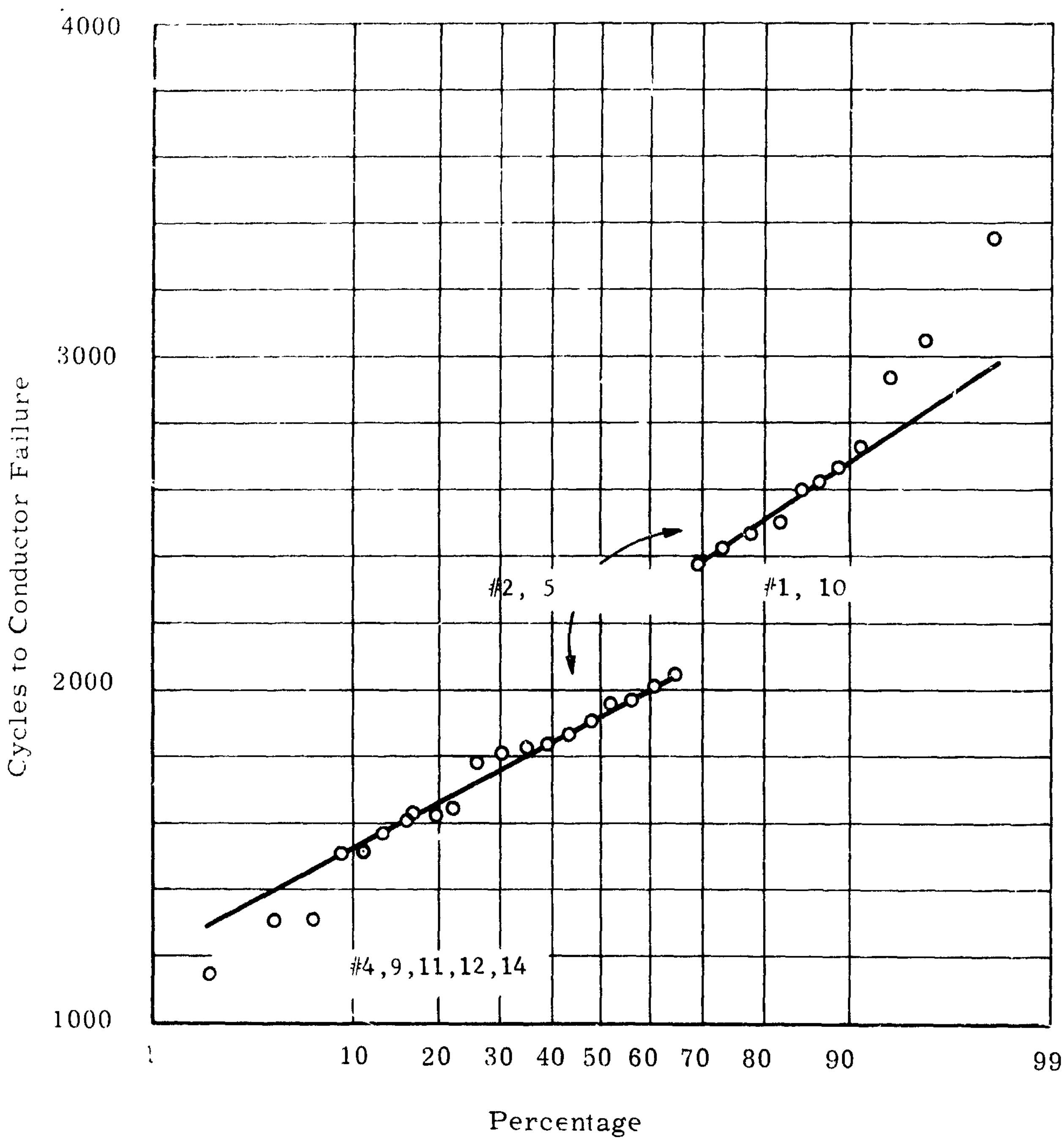


Figure 16-1 Probability Distribution - Cycles to Failure at 23°C Repeated Flexure Test

17. Scrape Abrasion

The NEMA (GE) repeated scrape abrasion tester has been used to evaluate all of the wires. Three or four test loads have been used except that only two test loads were used with Wires #13 and 14 since the extra work for these wires with loose jackets did not seem merited. At least three, and in many cases more, test results have been obtained at each load for each wire. The results, except for Wire #12, are summarized in Table 17-1. The abrasion resistance of silicone rubber (Wire #12) is so poor that lower loads had to be used to obtain reasonable values and these results for Wire #12 are summarized in Table 17-3.

Prior work with film-coated, magnet wire had indicated that the number of scrapes to failure is a power function of the load:

$$S = \frac{K}{p^n}$$

where: S = scrapes to failure
p = load in grams
K = constant
n = power function

To check this relationship for the wires in this program the log of the average scrapes to failure have been plotted verus log load in Figures 17-1, 17-2 and 17-3. The scales of these figures have been adjusted to permit plotting the rather wide range of values for the different wires. If the power function is valid, the data should be linear on such log-log plots. Reasonably linear plots are obtained for all of the wires except #1, 5, 6, 7, 8, 15 and 16. (Results for Wires #13 and 14 were not plotted because results for only two loads were available). With a little liberty, a straight line could be plotted for Wire #1 which could have a slope about like that of Wire #2. For Wires #5, 6, 8, 15 and 16 the value at the 1 Kg load are "too high". This problem is considered in Figure 17-4 for such a wire - #8 - along with Wire #7, which does seem to fit any rule, and Wire #9. In Figure 17-4 the range of values as well as the average has been plotted. When the two "out-of-line" minimum values for Wire #7 are plotted it is apparent that a reasonable straight line with a slope much like that for the other wires results. The non-linearity of Wire #8 (like #15 and 16 in Figure 17-2) remains. A little of such non-linearity can also be detected in the plot for Wire #9. It seems reasonable to assume that two mechanisms may be involved in abrasion as a function of load and that two slopes should be plotted at least for Wire #8 as shown in Figure 17-4.

It is possible to calculate the slopes for the log-log plots to obtain values of n as given in Table 17-3. Where a question exists and a double slope may be involved, both values are plotted along with a (?). It is important to understand the significance of the varying values of the slope -n. A high value means that at low loads, abrasion resistance is great, but unless the slope changes, very poor abrasion will be found at high loads. Of course, the relative position of the curves of abrasion versus load, as established by the constant K in the equation, is important also. In example, the abrasion resistance of silicone rubber is poor even at very low loads. In example, the abrasion resistance of silicone rubber is poor even at very low loads. Consequently, both the slope of the curve of abrasion versus load as well as its relative position must be established. In fact, it seems the order of merit for two wires may be reversed at different loads as shown for Wires #7 and #8 in Figure 17-4. It is also possible that the two individual values for Wire #7 at the bottom of Figure 17-4 represent a situation in which the Kynar jacket lost adhesion and ripped away so that the underlying polyolefin failed quickly.

It is recognized that the results for a non-homogeneous (jacketed) wire such as Wire #7 might well show a wide variability of results in an abrasion test. For this reason probability plots were made of individual abrasion values for the homogeneous extruded TFE Teflon (Wire #9) in Figure 17-5. As is usual when such plots are made with a few values they can be plotted in different ways as shown by the solid and dotted line for values obtained at the 700 gram load. Plot A' may be the more correct since its slope is about the same as plot B for results at the 1000 gram load. The steep slopes for these probability curves do indicate the considerable variability which may be expected in abrasion resistance with such wires for which the thickness of insulation varies considerably and processing variables are known to exist. The effect of non-homogenities may be considered once more by considering the distribution of abrasion values for ML-coated FEP Wire #1 and ML-coated TFE Wire #2 as plotted in Figure 17-6. It is known that the adhesion of the ML coating is much better on Wire #2 than Wire #1. In Figure 17-6 the one high value of 368, which is out of line for Wire #1, may be due to good adherence of the ML coating in this one instance. On the other hand, the out-of-line two low values of 50 and 89 for Wire #2 are probably due to <u>poor</u> adherence of the ML enamel in these two cases. The explanation of one very high value for Wire #2 is not obvious.

TABLE 17-1

COMPARISON OF WIRES - RESISTANCE TO SCRAPE ABRASION

Number of Scrapes to Failure

	500 Grams Load			700 Grams Load			800 Grams Load			1000 Grams Load		
Wire #	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.
I	508	579	423				54*	368 (89)	16	6(5)	10	4
2	19,947	27,800	6,975				351(7)	863	50	29(4)	42	15
3	28,119	41,024	15,213	2043(5)	3206	976	855(7)	1337	472	284(5)	305	269
4	215	236	183	55	60	46	40(7)	47	32	14(10)	18	10
5	1255(5)	1630	885	159	183	82	49(6)	78	26	68(8)	91	50
6	10,347	11,092	9,139	657	734	606	539(6)	683	452	285(5)	322	221
7	1546	1744	1384				682**	828	70	787(4)	995	26 (628)
8	6391	8522	3653				319	360	255	188	229	151
9			>50,000	12,519	19,614	6511	4325	4730	4118	941(6)	1487	445
10	386	463	326				79	86	69	23	26	19
11	33	41	26				7	9	5	4	6	3
12	2.6(5)	3	2				-	-	-	-	-	-
13							197	323	132	39	84	15
14							271	306	242	116	122	111
15	8837(4)	13,592	5079				301	364	255	114	149	67
16	11,747(4)	24,089	3833				384	427	338	167	177	160

The value in ( ) indicates the number of test values averaged. Where not noted 3 are used.

*A normal probability plot gives a probable average of 67, the max. value of 368 is not averaged.

**The minimum value of 70 is so far out of line with the remaining 3 values that it has not been averaged.

TABLE 17-2

RESISTANCE TO SCRAPE ABRASION FOR WIRE #12 (SILICONE RUBBER)

Load-grams	Number of Scrapes to Failure Avg.*	Max.	Min.
200	310	458	223
300	31	46	17
500	2.5	3	2

*Average of 4 specimens.

TABLE 17-3

CALCULATED SLOPE OF LOG SCRAPES/LOG LOAD TO FAILURE

Wire No.*	Calculated Slope = n
#2	9.1
#3	6.3
#4	4.0
#5	4.3(?) and 6.9(?)
#6	5.9(?)
#7	6.1(?)
#8	2.4(?) and 6.5(?)
#9	7.4
#10	3.9
#11	3.0
#12	5.2
#15	4.1(?) and 7.2(?)
#16	3.6(?) and 7.4(?)

$$S = \frac{K}{p^n}$$

where, S = scrapes to failure

p = load grams

K = constant

n = power function

*Significant curves could not be plotted for Wires #1, 13 and 14.

(?) See text.

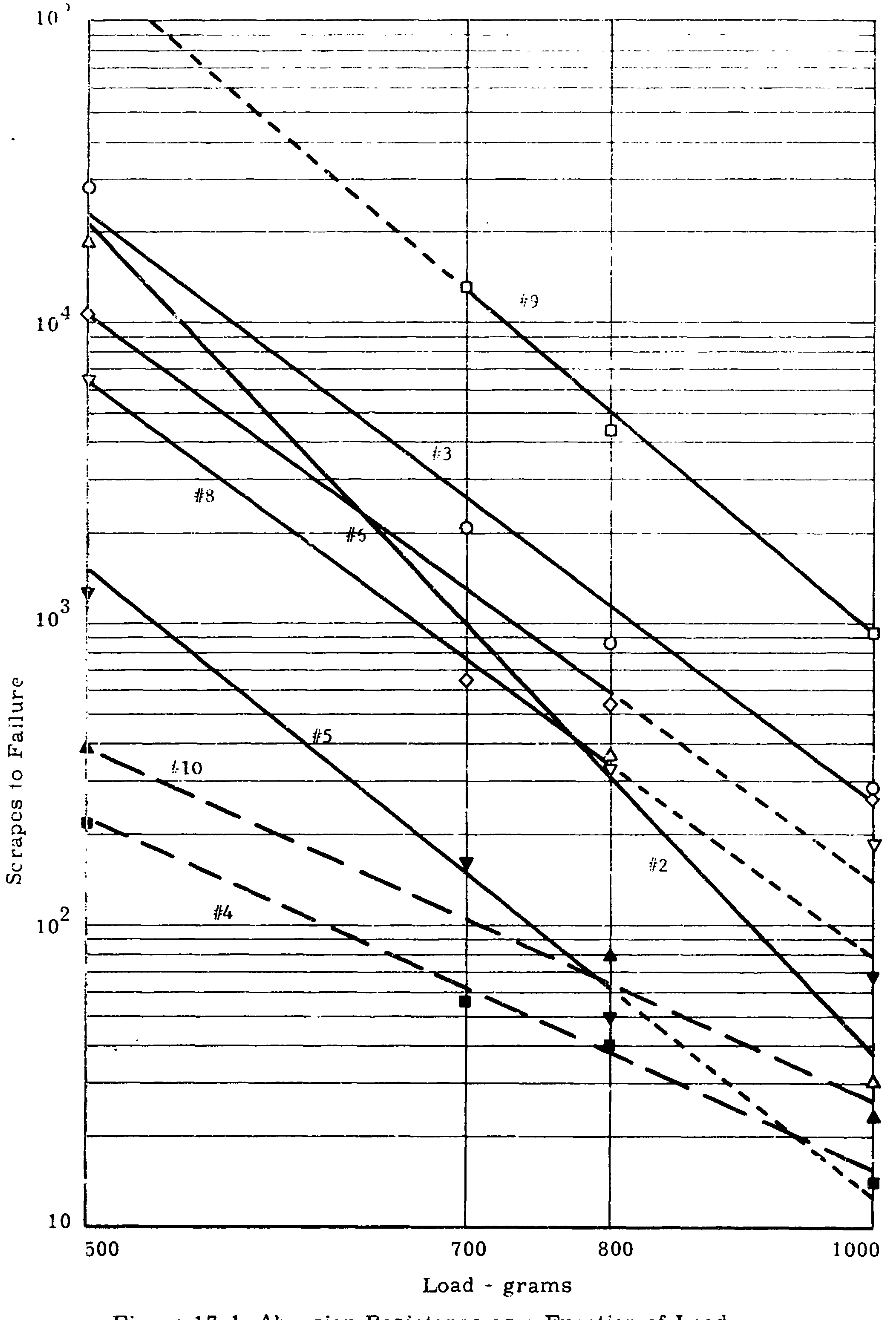


Figure 17-1 Abrasion Resistance as a Function of Load

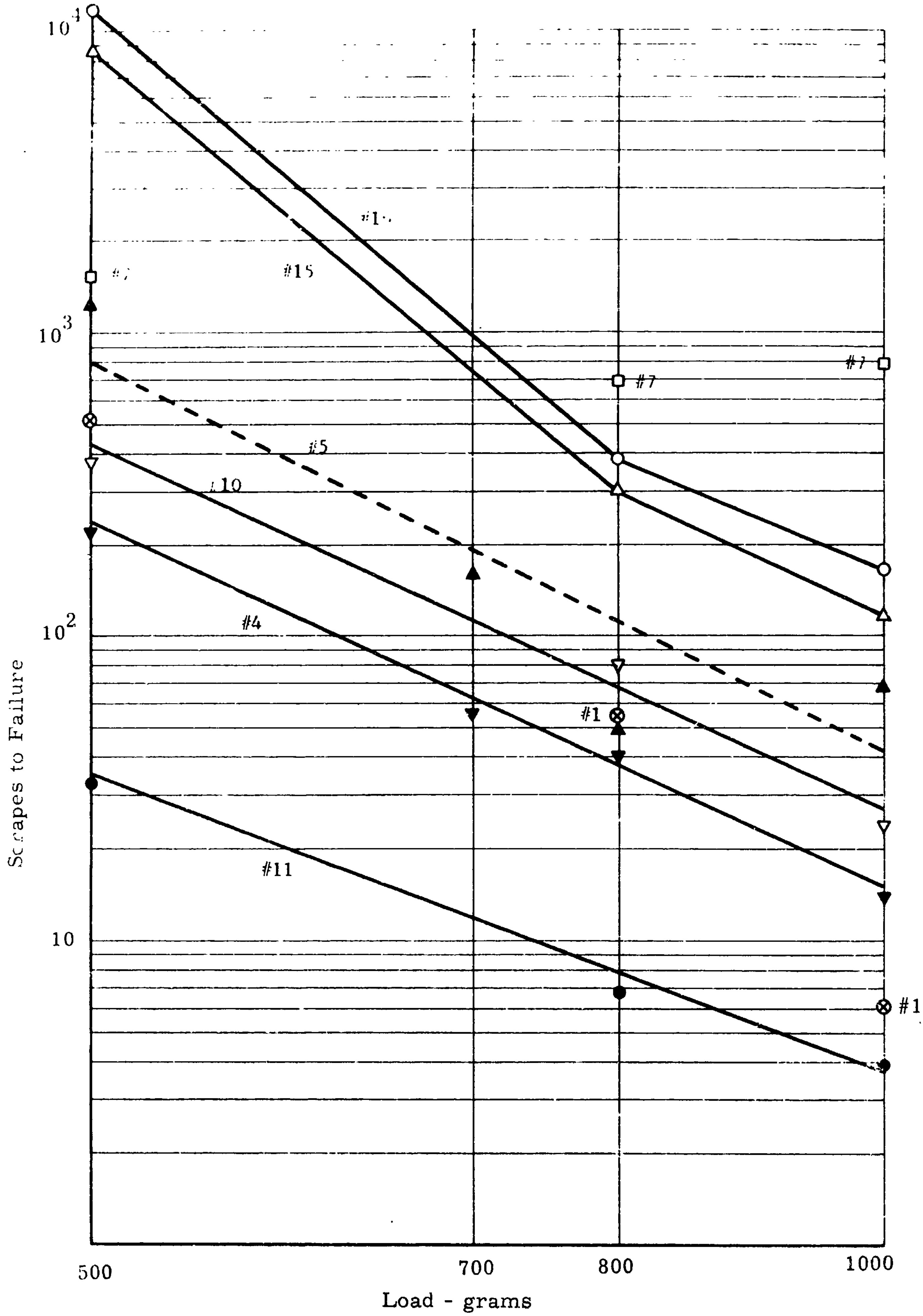


Figure 17-2 Abrasion Resistance as a Function of Load

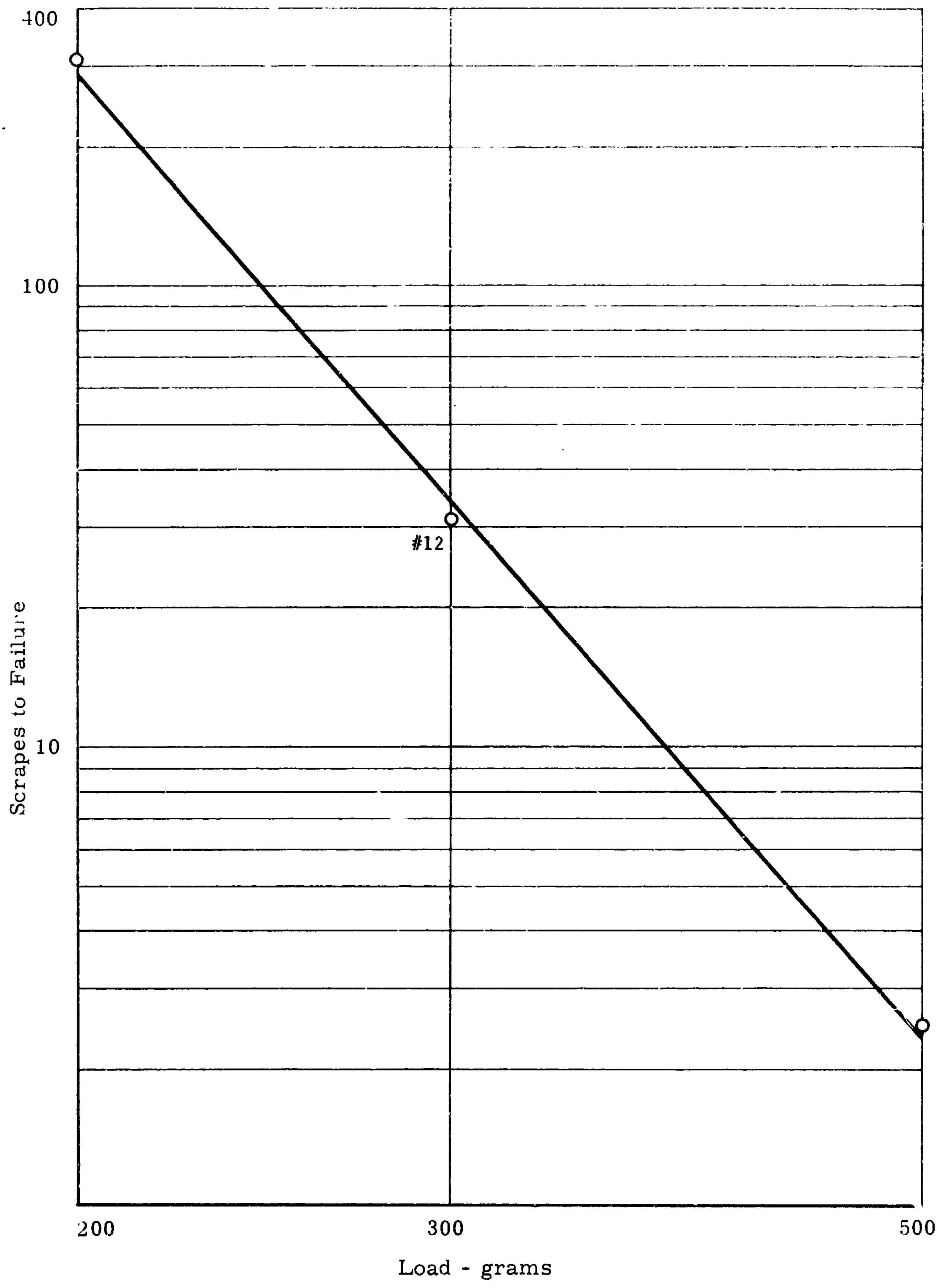


Figure 17-3 Abrasion Resistance vs Load Silicone Rubber - Wire #12

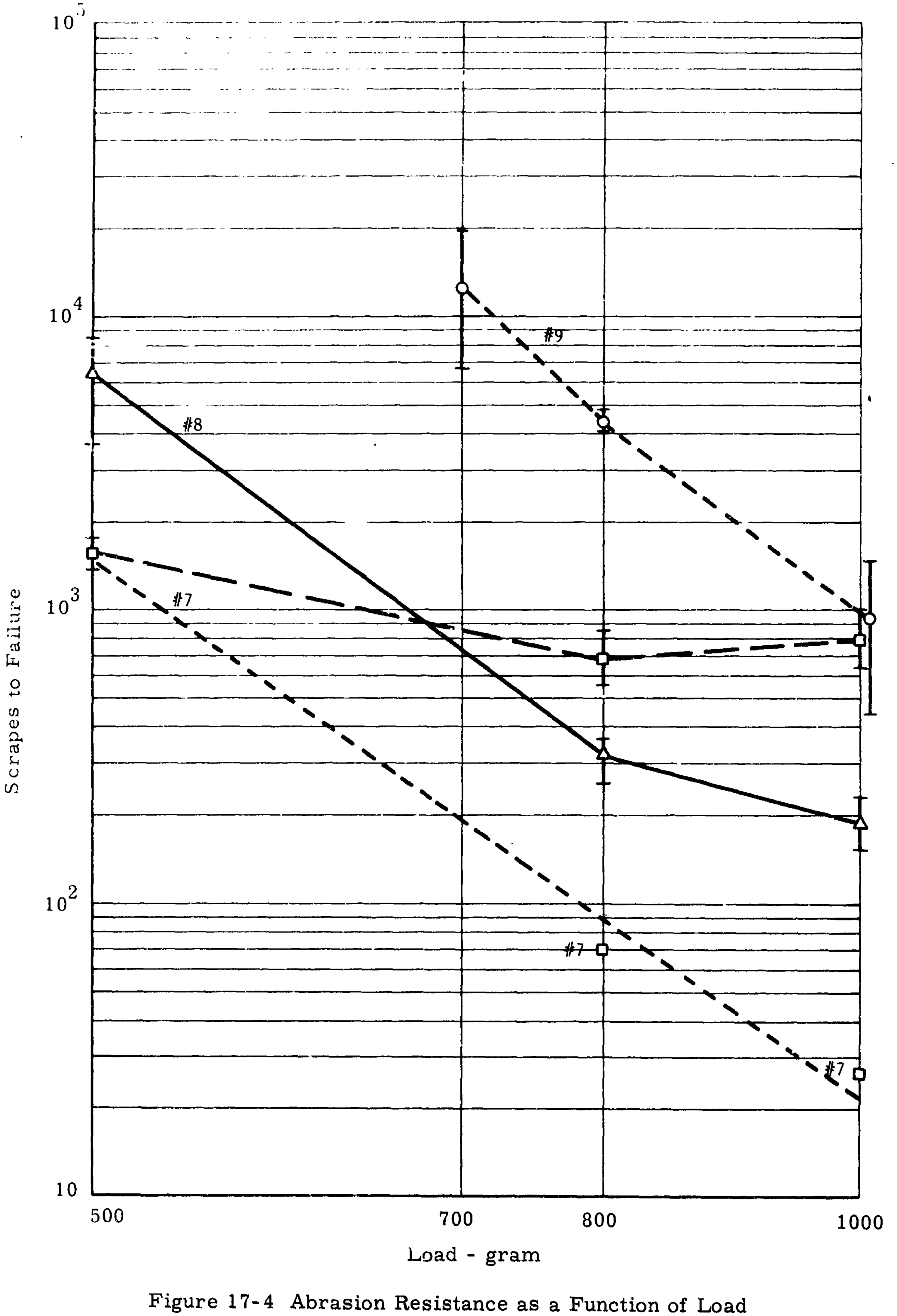


Figure 17-4 Abrasion Resistance as a Function of Load

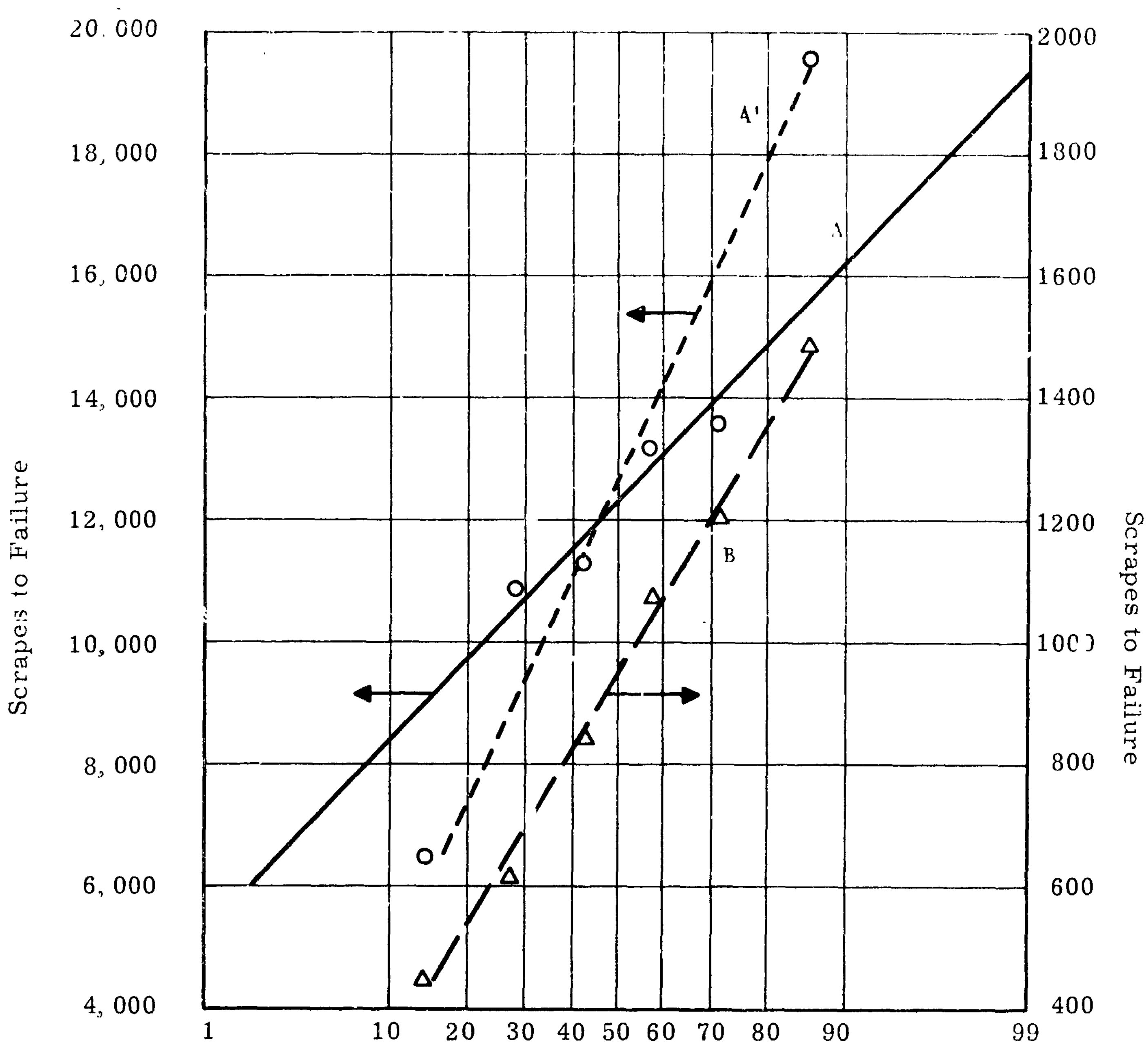


Figure 17-5 Distribution of Abrasion Results - Wire #9

A and A' = 700 gram load
B = 1000 gram load

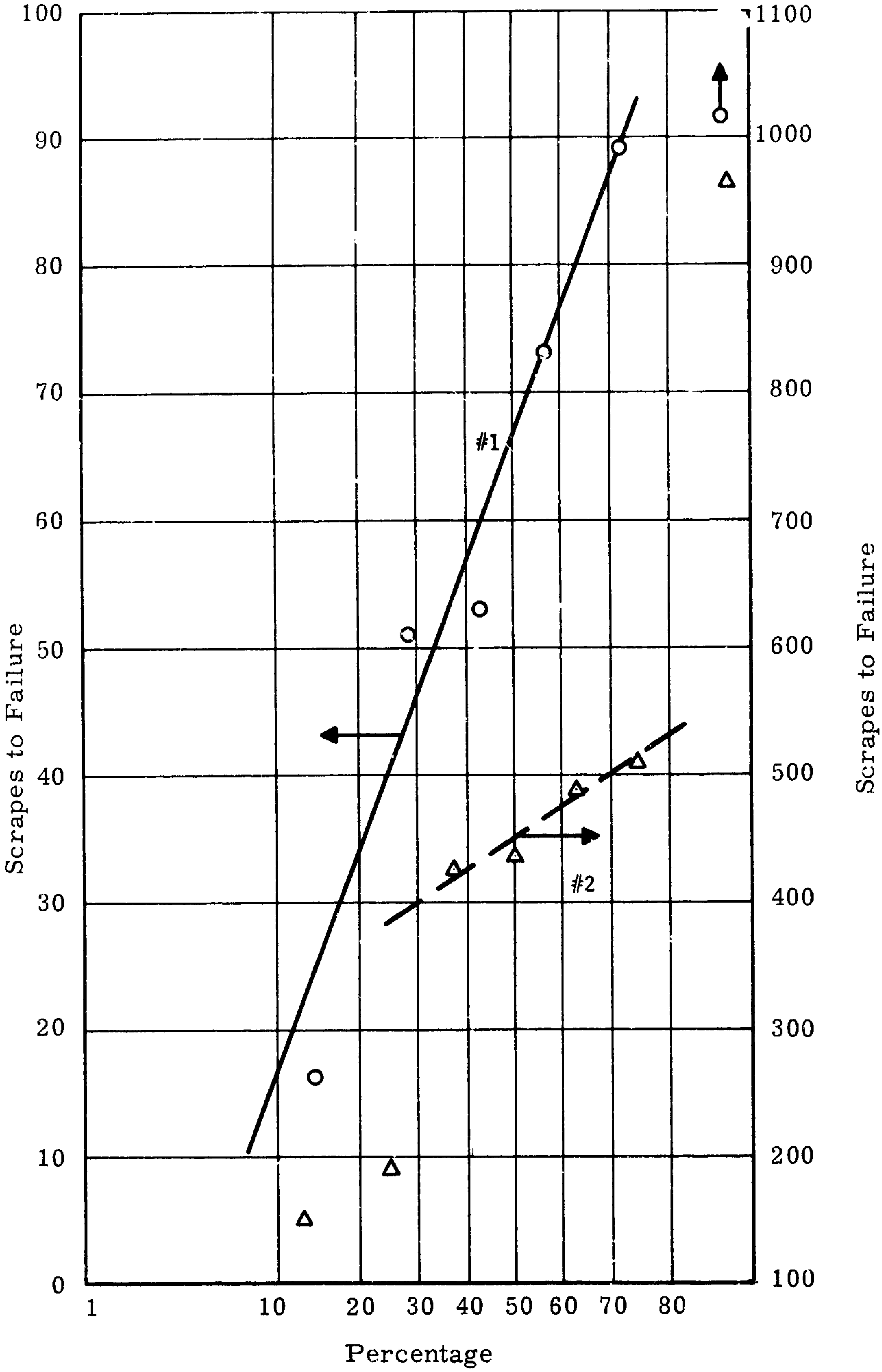


Figure 17-6 Distribution of Abrasion Values - Wires #1 and 2 - at 800 Gram Load

18. Blocking

The only cases of blocking that were observed occurred at elevated temperature with the polyolefin insulated wires. At 150°C, some blocking occurred with Wire #7 under the heat-shrinkable tubing that was used to hold the specimens together. Similar effects were observed with Wire #8 at 150°C in oxygen and in vacuum. Wires could not be separated without tearing the insulation in the region that had been compressed by the heat-shrinkable tubing.

19. Cut-Through

Cut-through results are reported as the failure load, where failure is detected by electrical continuity between the conductor and the cut-through paddle. The load is applied at a fixed cross-head speed of 0.005 inches per minute. Values are given for 23°C and 149°C. The results are summarized in Table 19-1.

Typical Load vs Deflection curves at 23°C and at 149°C are given for each sample wire (Figures 19-1 to 19-16). The curves show the effect of the wire being flattened by the crushing action of the 1/16" wide paddle. During the early stages of loading, temperature has little effect on the shape of the Load-Deflection curve. However, in the latter stages of loading, where the load steadily increases with deflection, increasing temperature causes a decrease in the slope of the curve and a significant decrease in failure load.

The results clearly show the superior cut-through strengths of the H-film construction at both 23°C and 149°C. It is likely, however, that this superiority might not be so striking if a much sharper paddle was used in applying the load. This is suggested by the ease of mechanically stripping the H-film constructions with a tool that has sharp cutting blades.

The ML coating of Wires #1 and 2 provide some improvement in cut-through strength over that of plain TFE (Wire #9), but these wires are still inferior to the H-film constructions, even when the latter have thinner insulation walls.

TABLE 19-1

CUT-THROUGH FAILURE LOAD (POUNDS), CROSS-HEAD SPEED 0.005 INCHES/MINUTE

Wire No.		23°C Failure Load (Lbs.)		149°C Failure Load (Lbs.)
1		40.0		9.6
		25.9		18.6
		41.6		19.0
	Avg.	36.0	Avg.	15.7
2		21.5		18.4
		43.0		26.0
		28.4		13.6
	Avg.	31.0	Avg.	19.3
3		106		62.1
		112		55.9
		115		41.9
	Avg.	111	Avg.	53.3
4		72.0		27.8
		91.0		34.7
		87.5		36.2
	Avg.	83.5	Avg.	32.9
5		64.2		33.0
		95.2		33.5
		39.2		35.2
	Avg.	66.2	Avg.	33.9
6		91.8		47.0
		116		57.1
		140		59.0
	Avg.	118.9	Avg.	54.4
7		20.4		3.6
		18.6		3.3
		20.0		2.0
	Avg.	19.7	Avg.	3.0
8		17.5		0.6
		17.6		0.6
		14.1		0.7
	Avg.	16.4	Avg.	0.6
9		26.6		8.1
		24.1		8.3
		24.6		7.6
	Avg.	25.1	Avg.	8.0

(Continued)

TABLE 19-1 (Cont'd)

CUT-THROUGH FAILURE LOAD (POUNDS), CROSS-HEAD SPEED .005 INCHES/MINUTE

Wire #		23°C Failure Load (Lbs.)		149°C Failure Load (Lbs.)
10		124		89.0
		103		82.3
		125		63.8
	Avg.	117	Avg.	78.4
11		51.7		34.7
		39.0		39.8
		36.4		28.8
	Avg.	42.7	Avg.	34.4
12		2.8		2.2
		2.8		2.2
		2.2		2.3
	Avg.	2.6	Avg.	2.2
13		17.5		5.9
		14.4		3.8
		26.5		4.8
	Avg.	19.5	Avg.	4.8
14		82.5		38.6
		104.0		31.5
		68.0		37.9
	Avg.	84.8	Avg.	36.0
15		72.0		66.0
		87.5		66.0
		92.5		65.8
	Avg.	84.0	Avg.	65.9
16		122.0		44.0
		116.5		71.8
		114.0		48.1
	Avg.	117.3		54.6

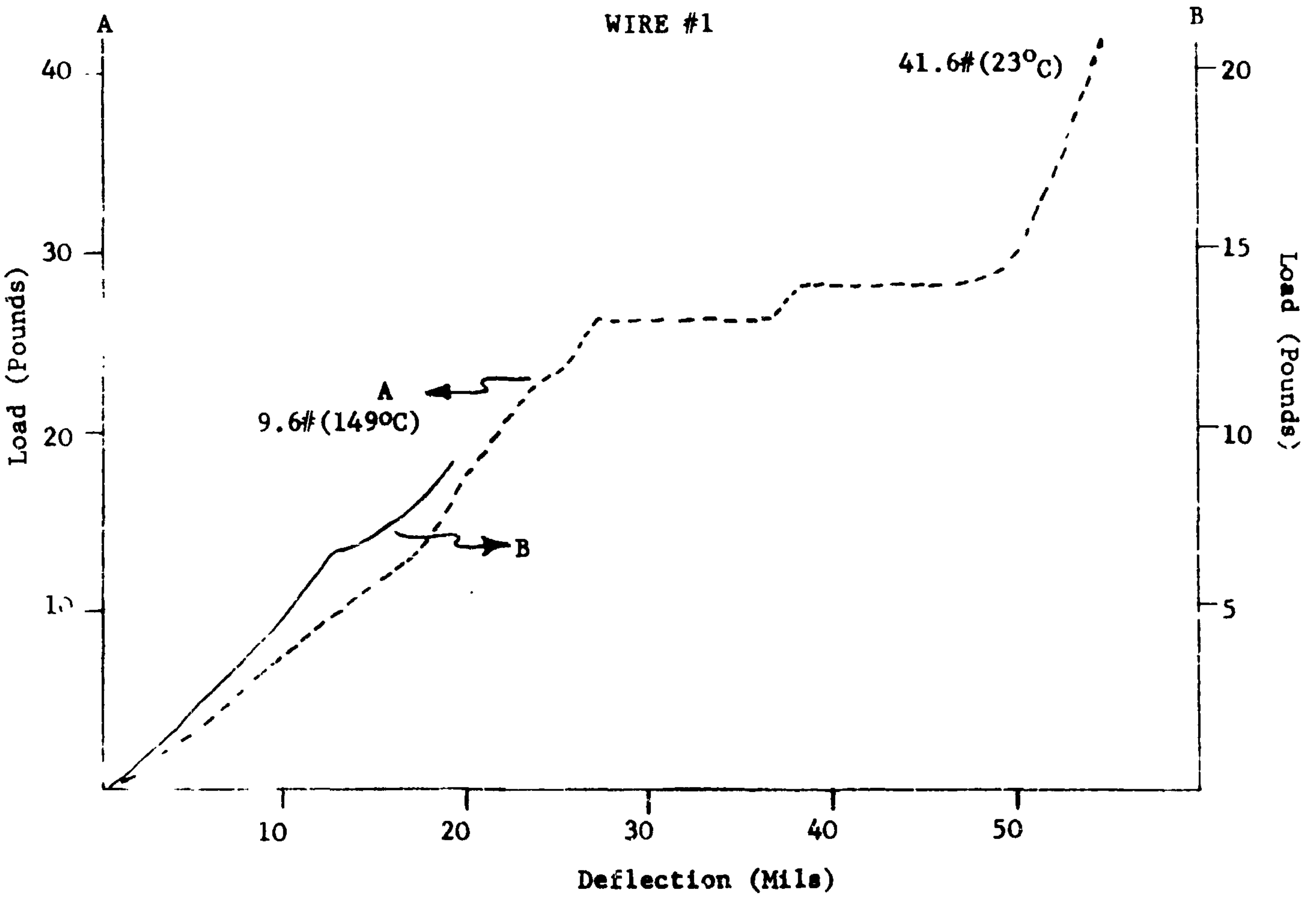


Figure 19-1: Load-Deflection Curves for Wire #1
Cross-head Speed .005 Inches per Minute

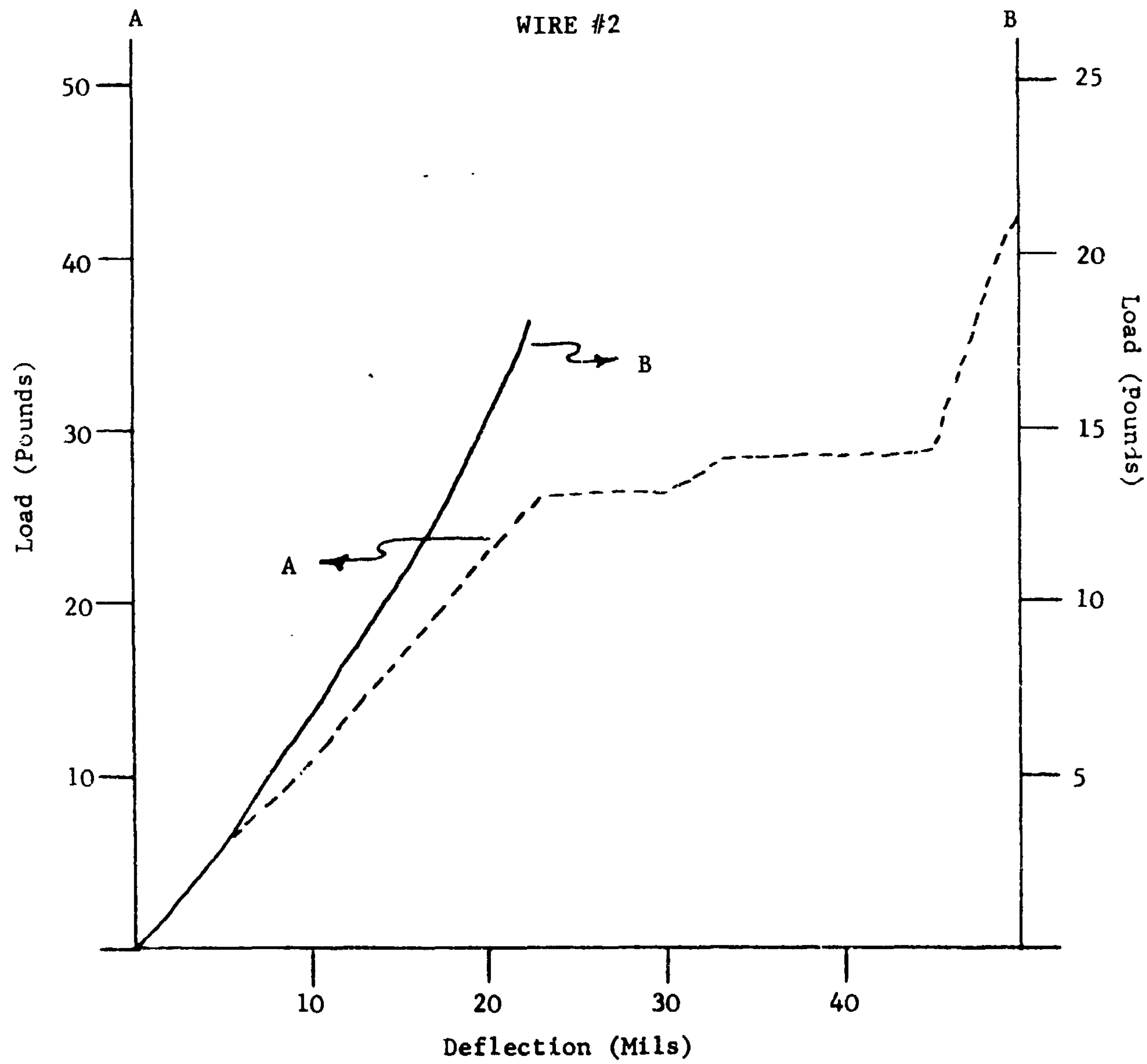


Figure 19-2: Load-Deflection Curves for Wire #2
Cross-head Speed .005 Inches per Minute

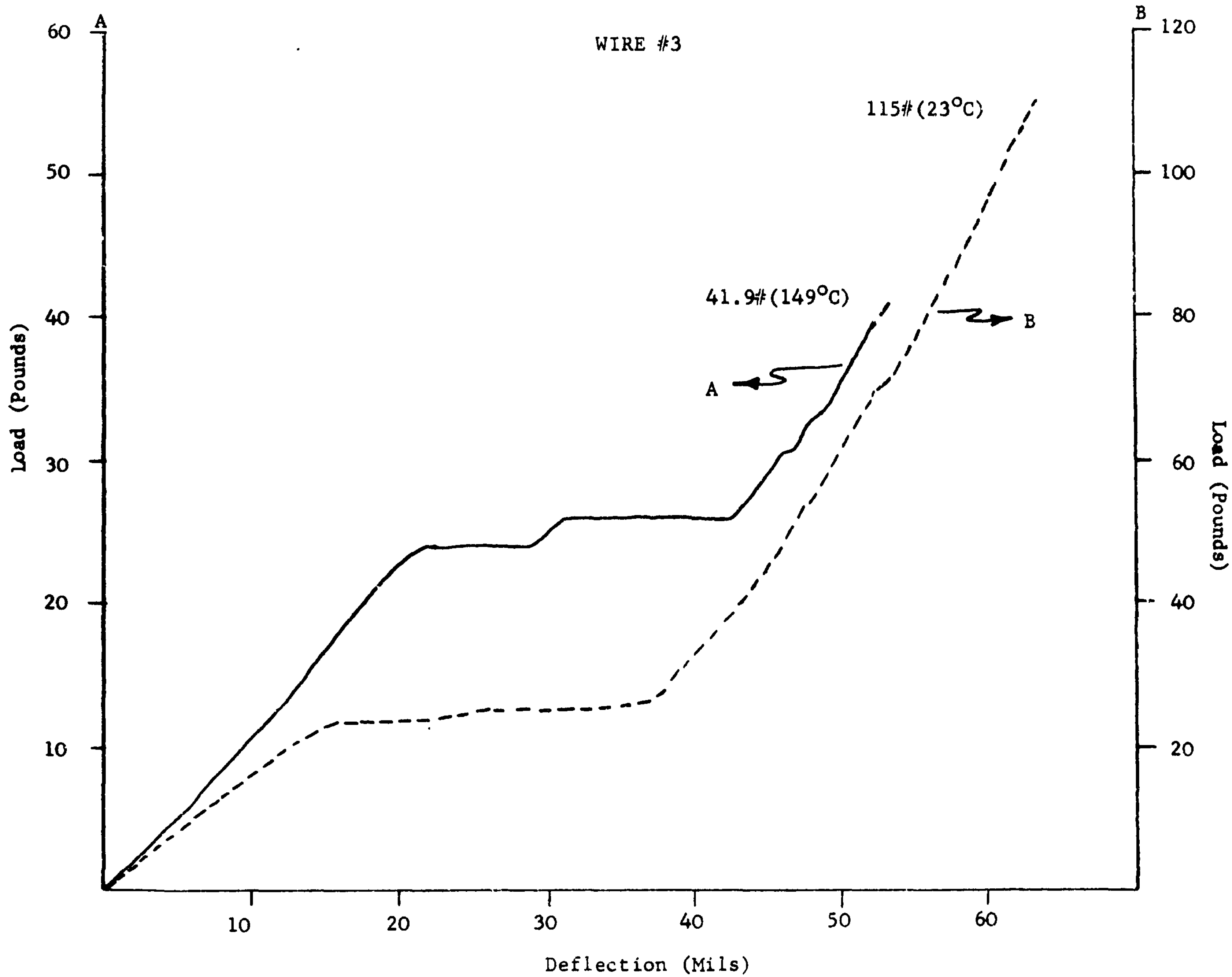


Figure 19-3: Load-Deflection Curves for Wire #3. Cross-head Speed .005 Inches per Minute

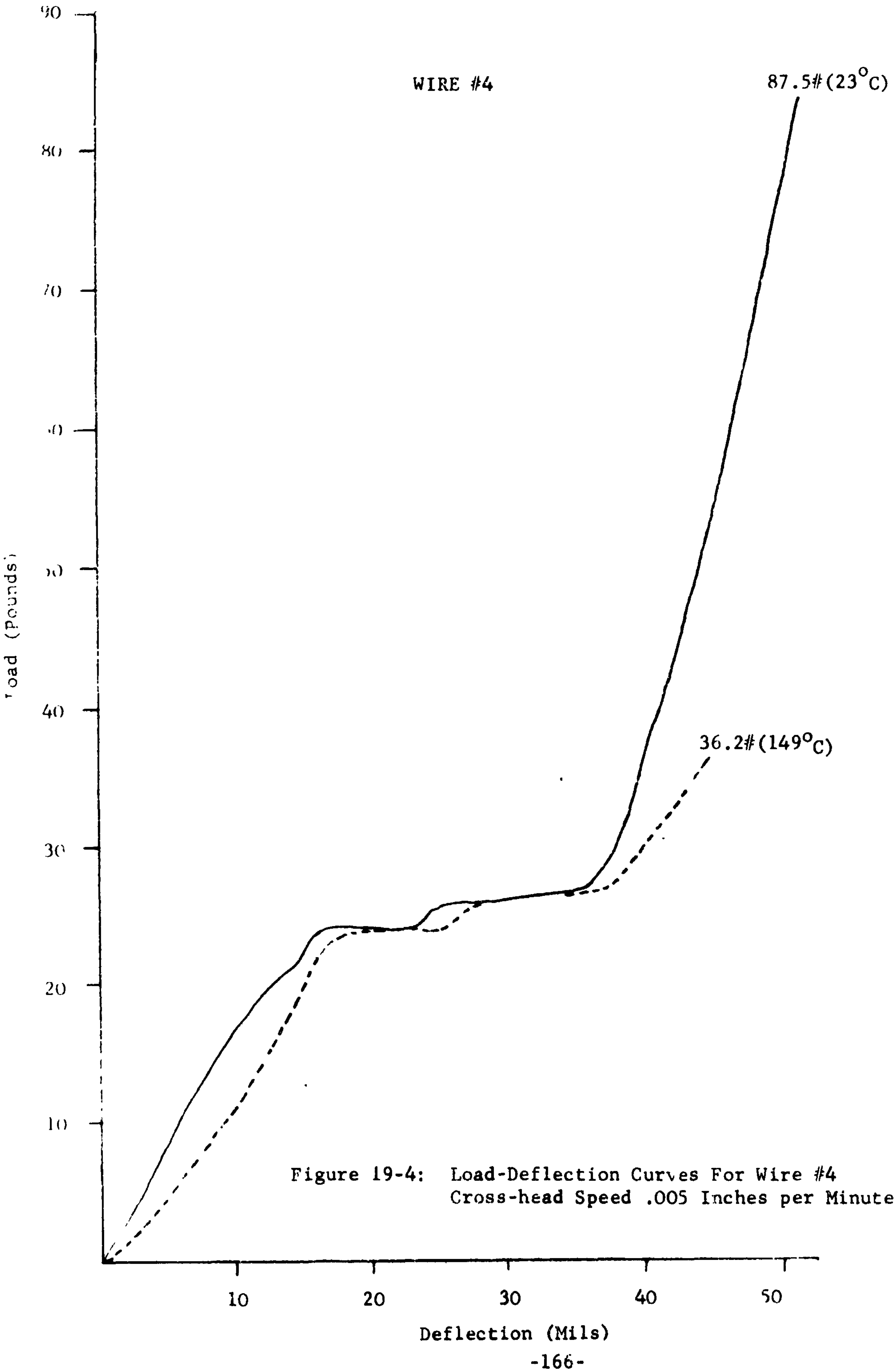


Figure 19-4: Load-Deflection Curves For Wire #4
Cross-head Speed .005 Inches per Minute

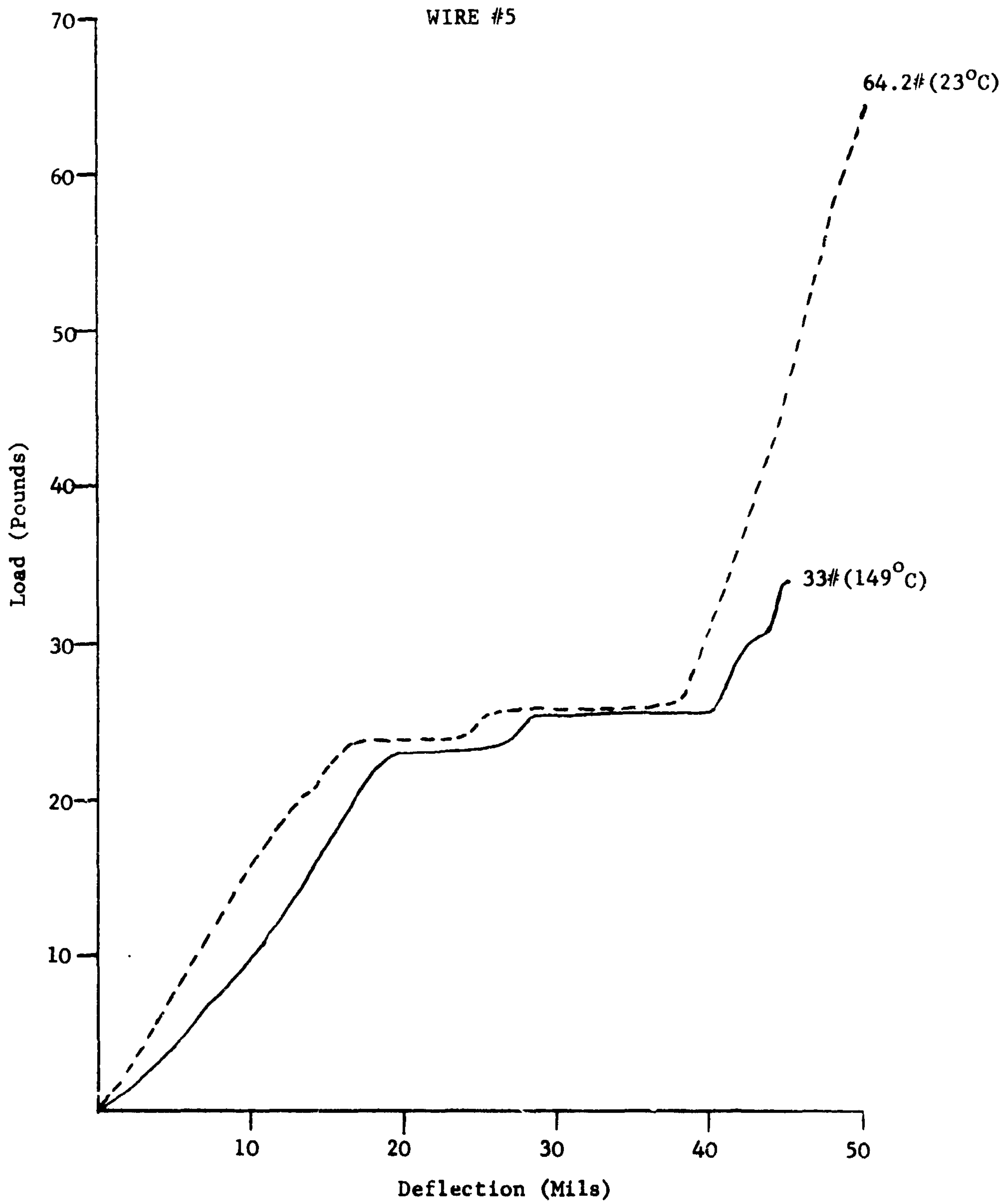


Figure 19-5: Load-Deflection Curves for Wire #5
Cross-head Speed .005 Inches per Minute

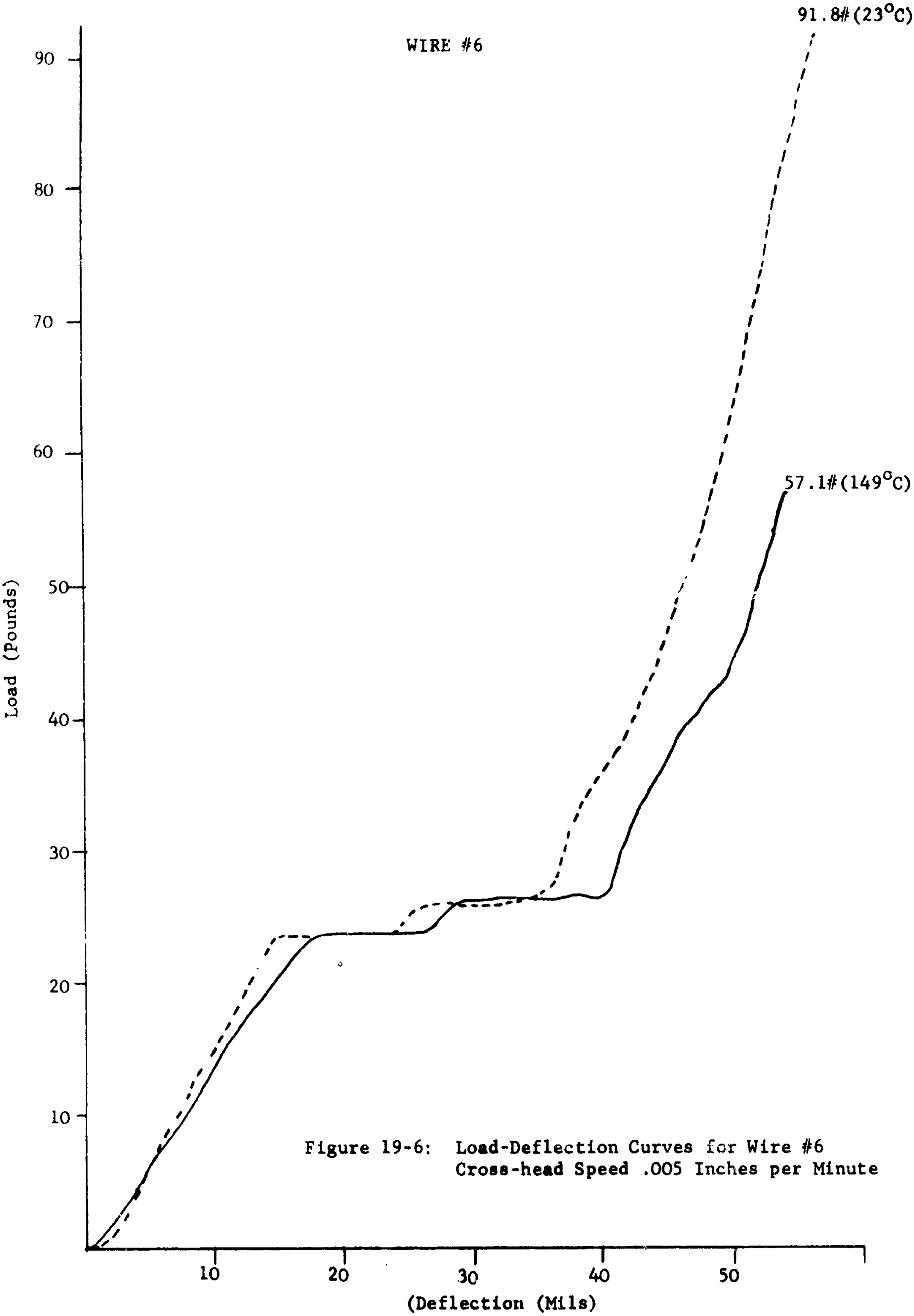


Figure 19-6: Load-Deflection Curves for Wire #6
Cross-head Speed .005 Inches per Minute

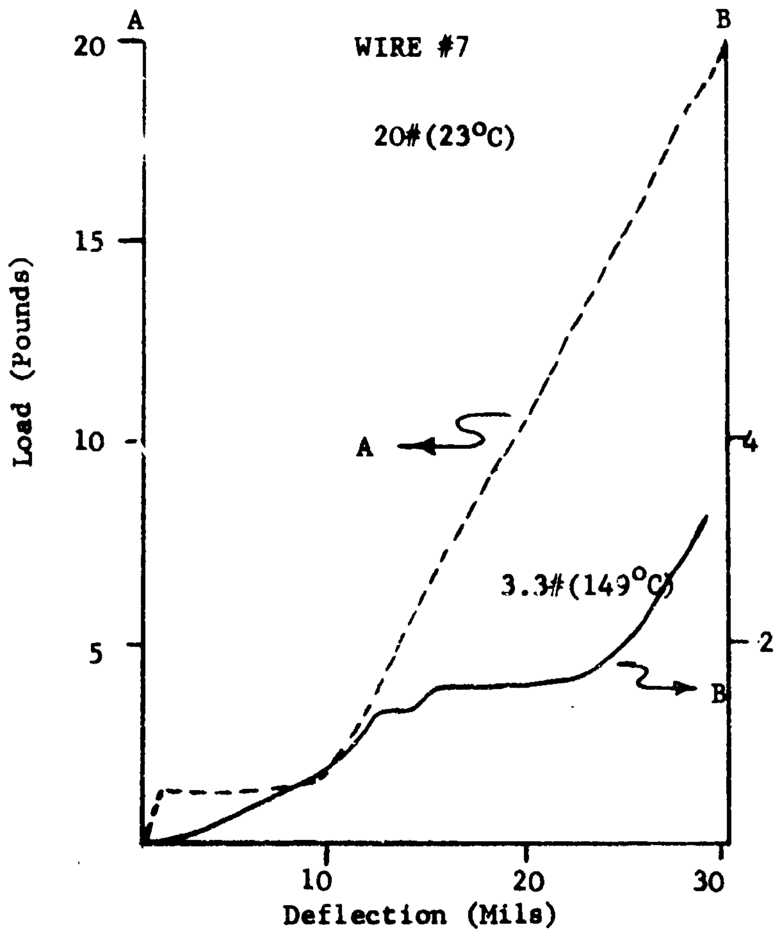


Figure 19-7: Load-Deflection Curves for Wire #7
Cross-head Speed .005 Inches per Minute

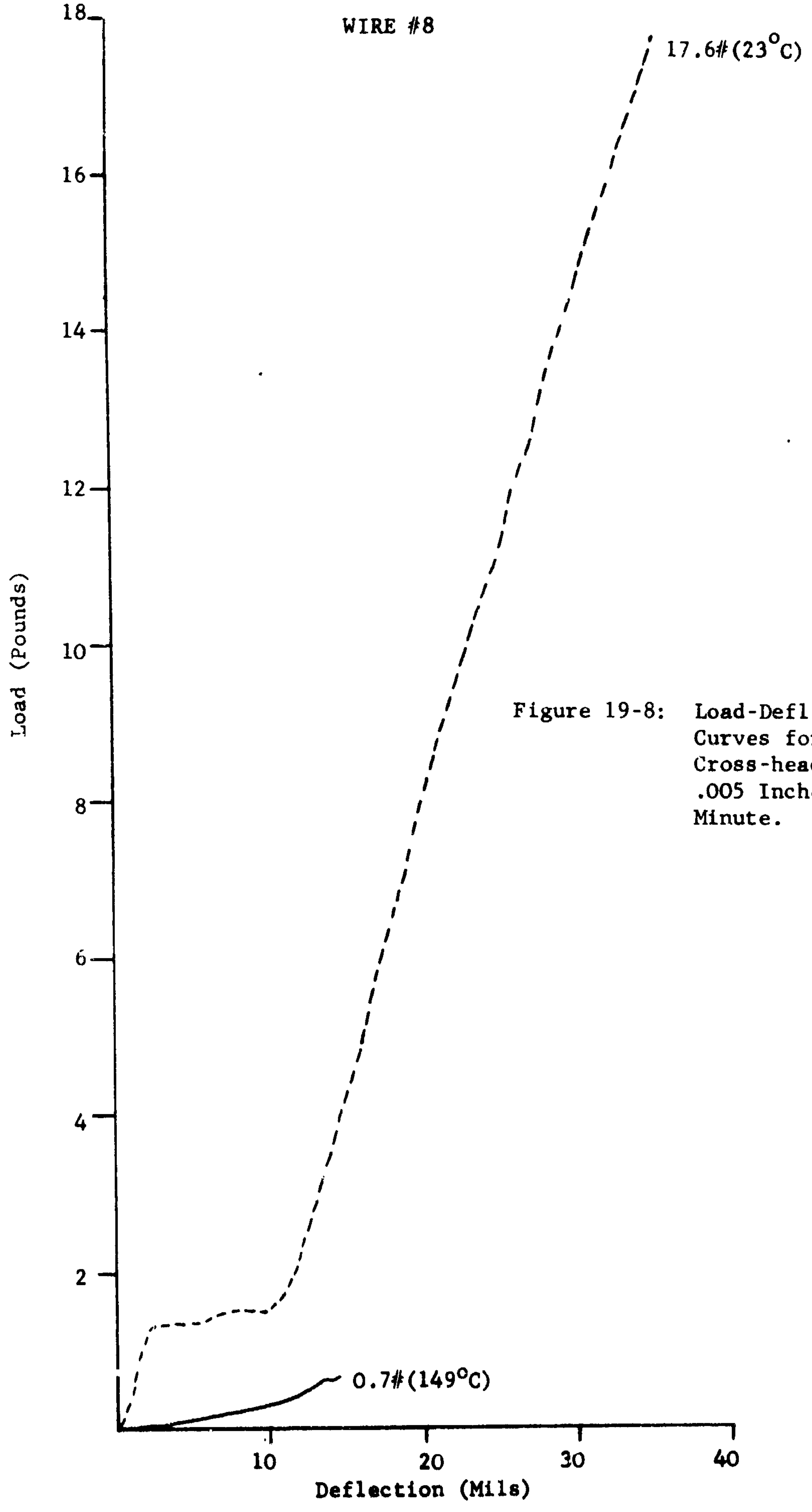


Figure 19-8: Load-Deflection Curves for Wire #8. Cross-head Speed .005 Inches per Minute.

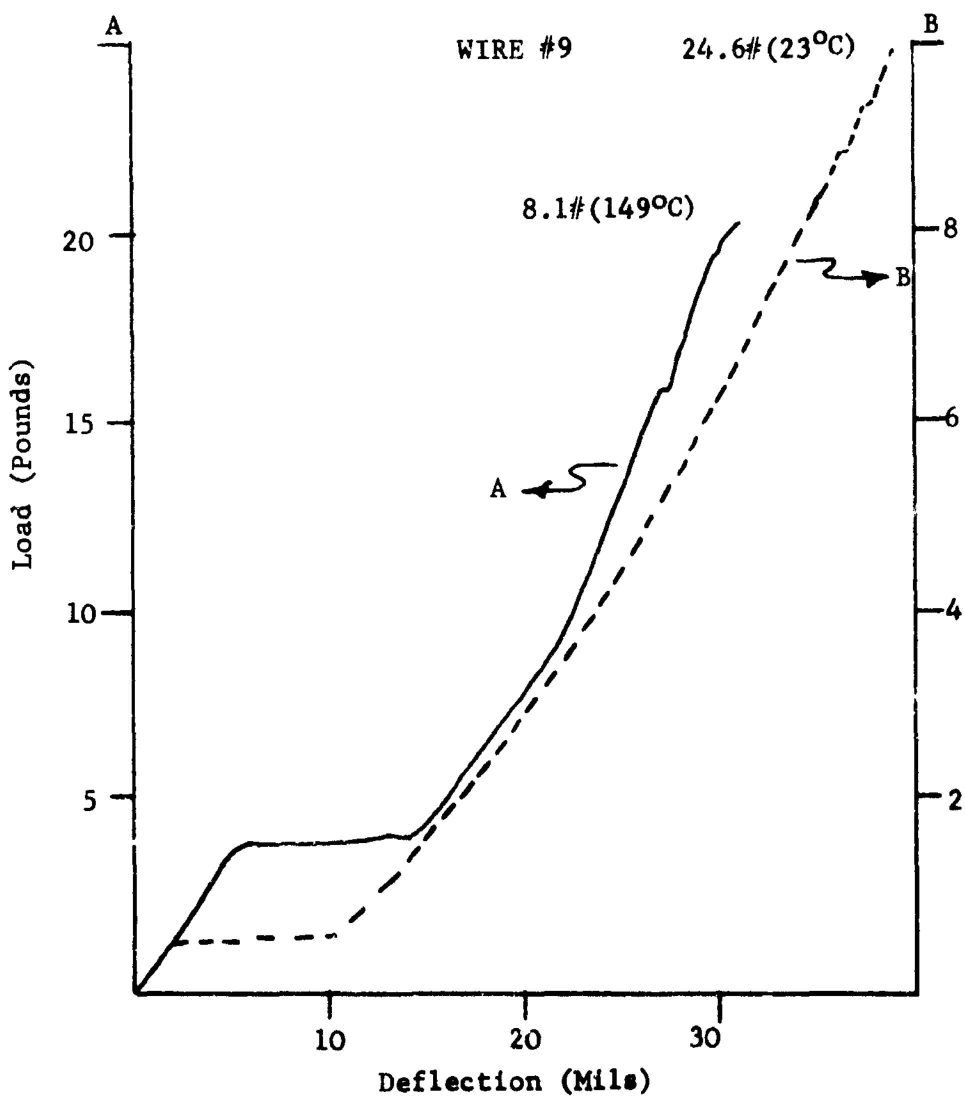


Figure 19-9: Load-Deflection Curves for Wire #9
Cross-head Speed .005 Inches per Mir ıte

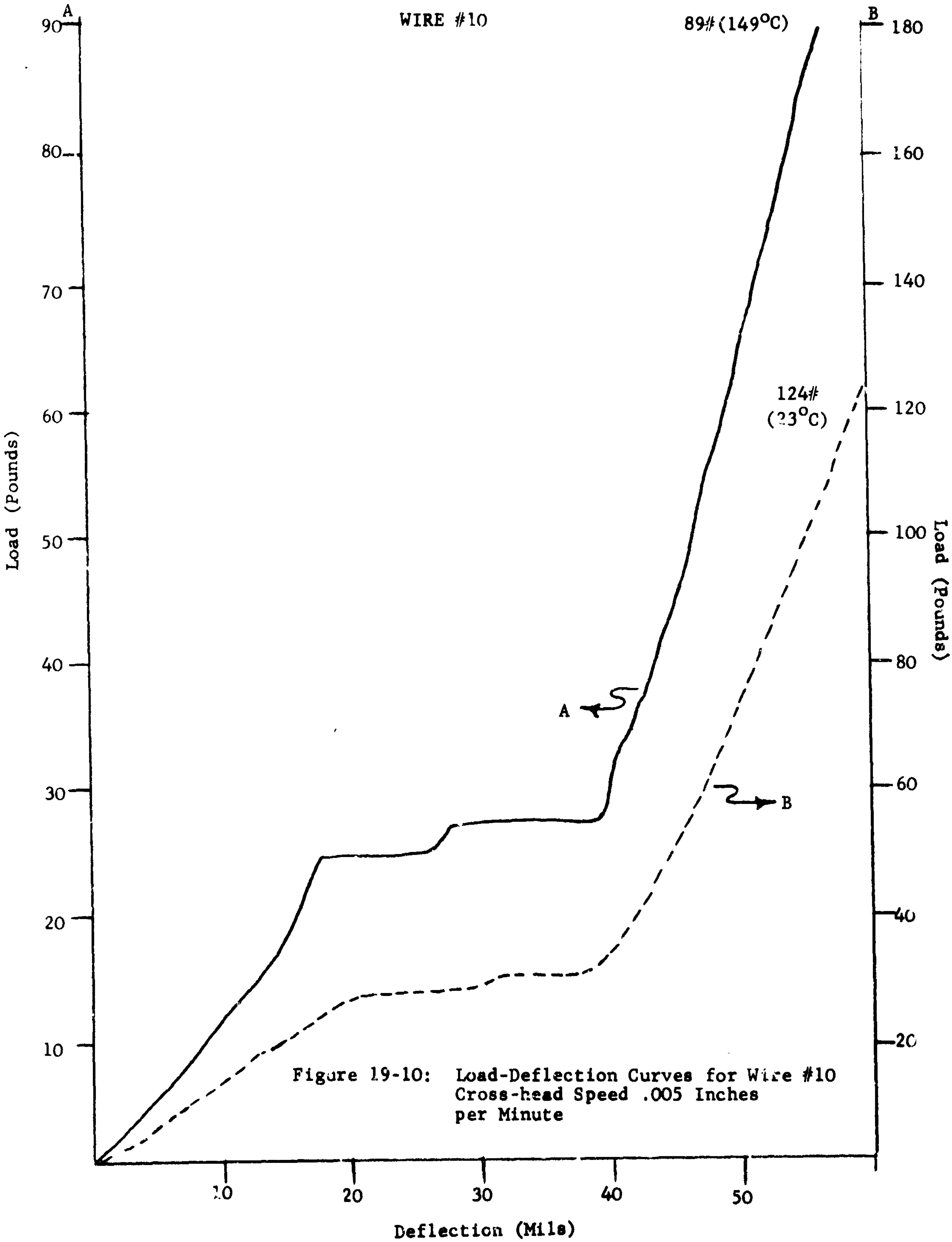


Figure 19-10: Load-Deflection Curves for Wire #10 Cross-head Speed .005 Inches per Minute

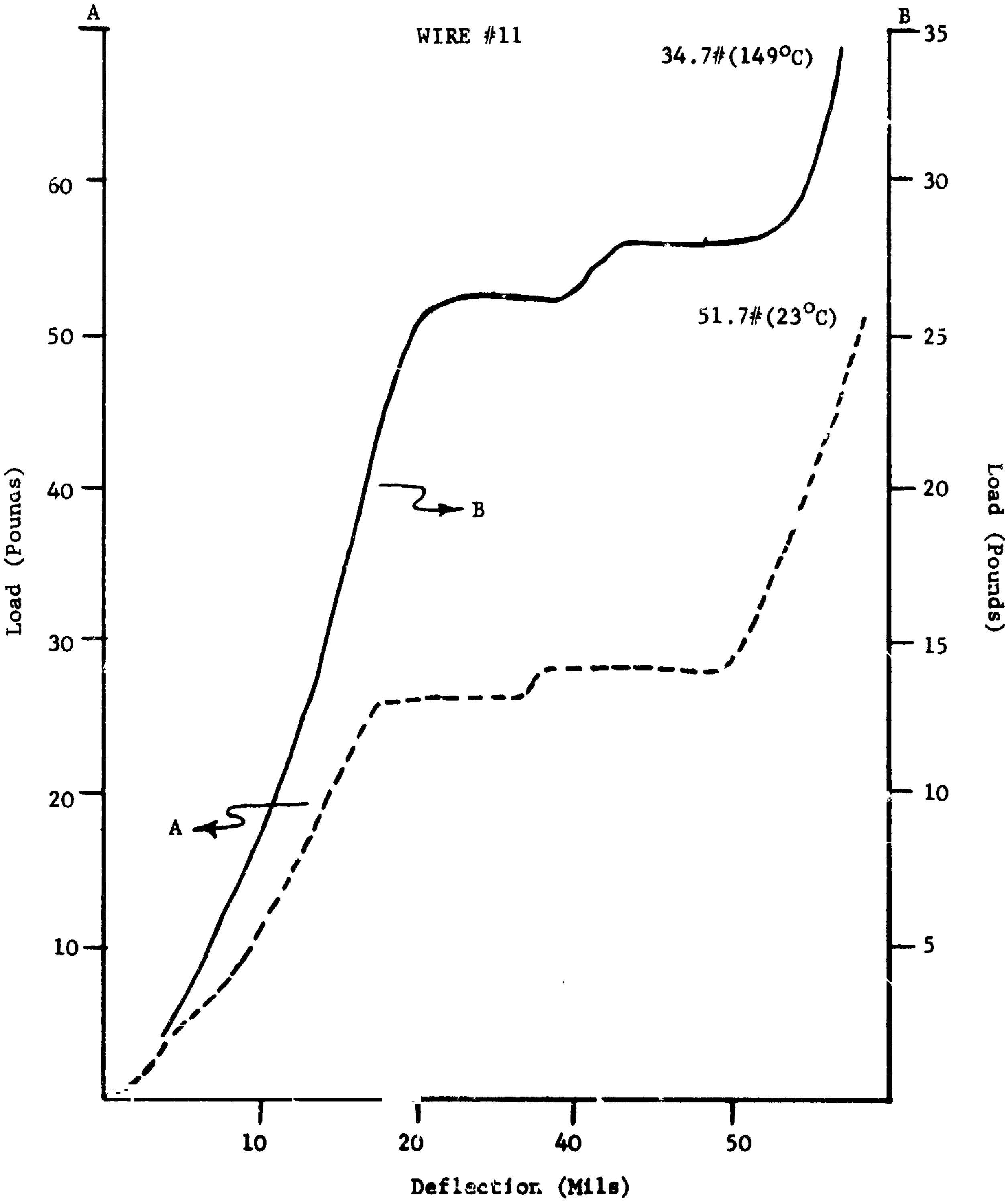
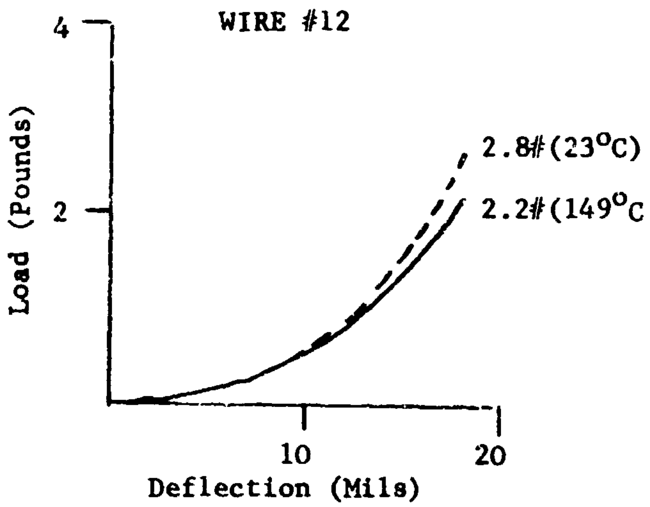


Figure 19-11: Load-Deflection Curves for Wire #11. Cross-head Speed .005 Inches per Minute



Fi ıre 19-12: Load-Deflection Curves For Wire #12
Cross-head Speed .005 Inches per Minute

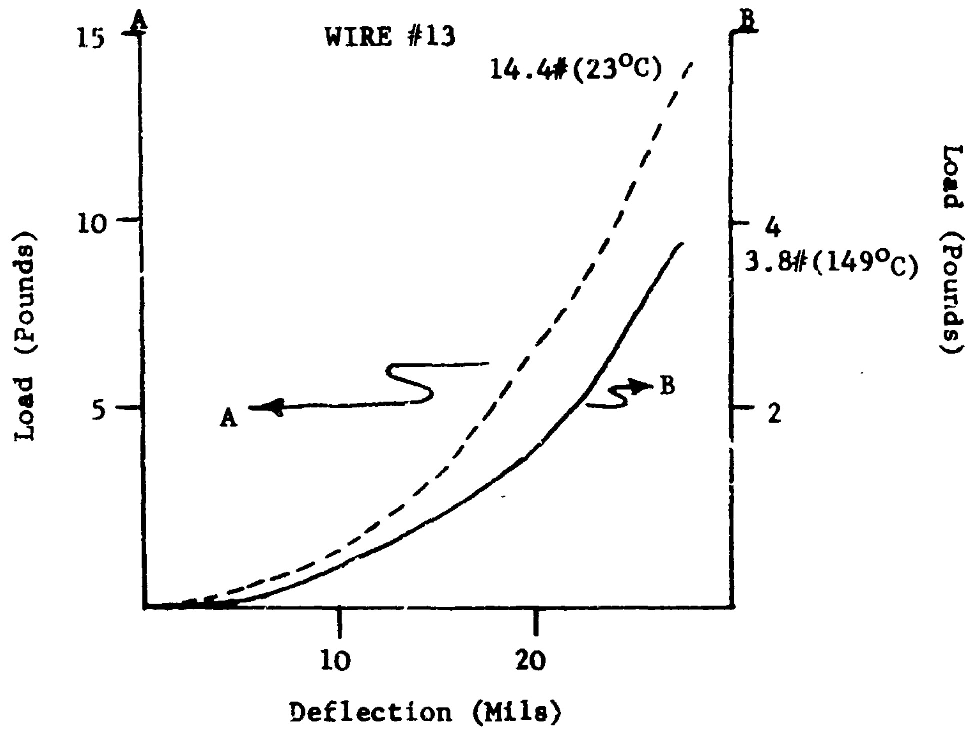


Figure 19-13: Load-Deflection Curves for Wire #13
Cross-head Speed .005 Inches per Minute

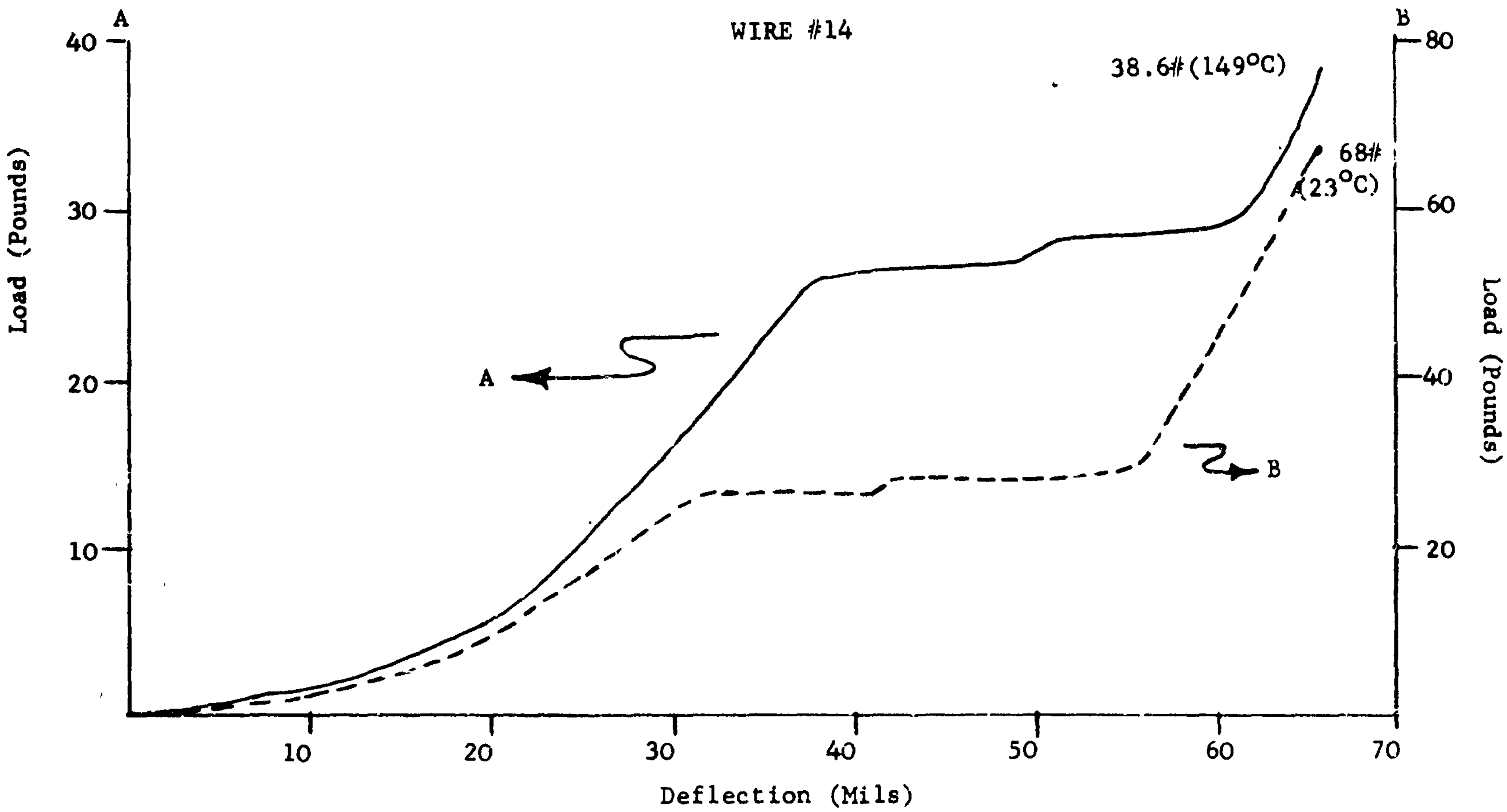


Figure 19-14: Load-Deflection Curves for Wire #14. Cross-head Speed .005 Inches per Minute

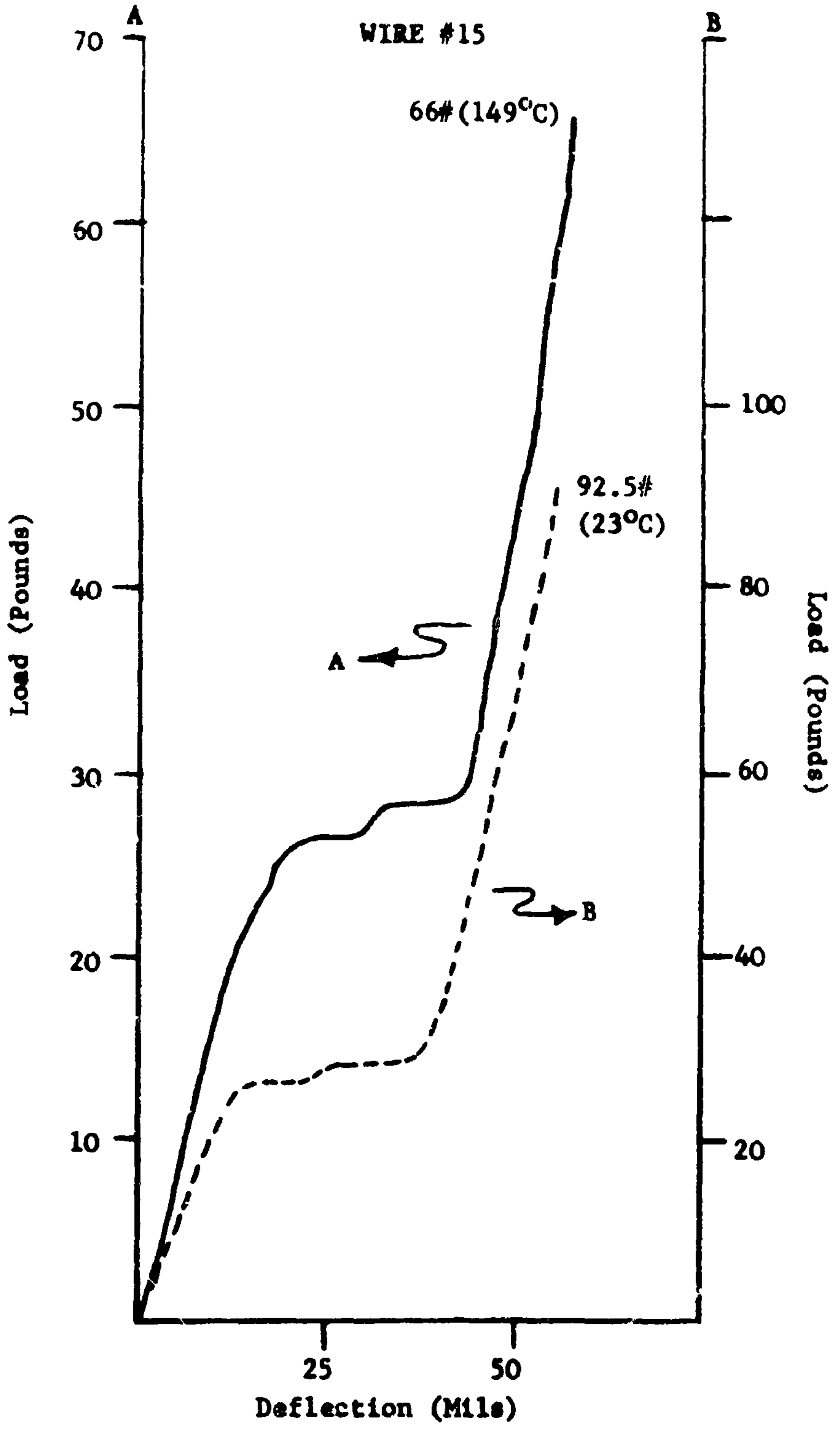


Figure 19-15: Load-Deflection Curves for Wire #15
Cross-head Speed .005 Inches per Minute

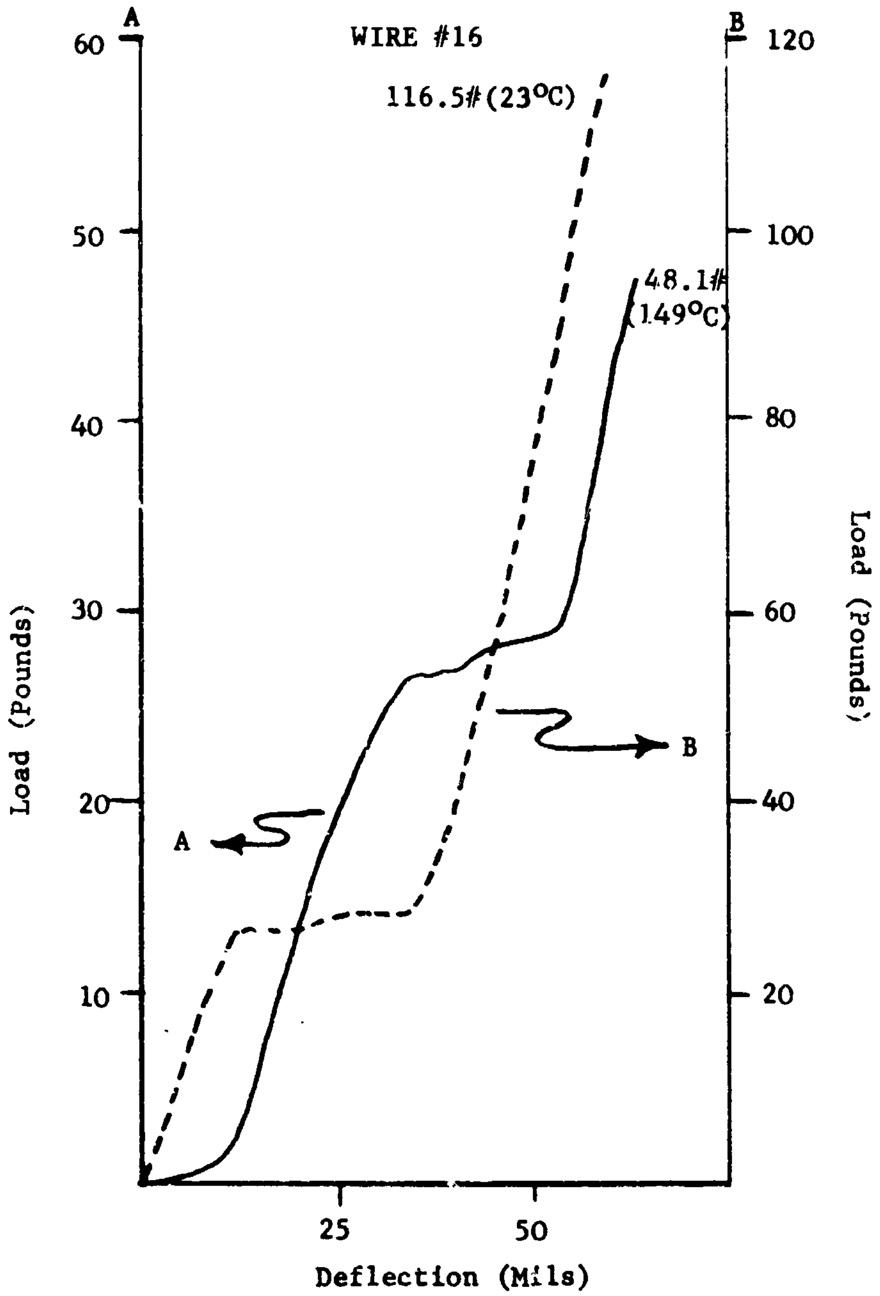


Figure 19-16: Load-Deflection Curves for Wire #16. Cross-head Speed .005 Inches per Minute

20. Thermal Creep

The suggested method of evaluating thermal creep required that a standard load be applied and the time to failure recorded. The load was defined as that which would cause Type E Teflon (Wire #9) to fail in one hour. However, the H-film constructions, with their superior cut-through strengths, would run for unreasonable lengths of time with a load that would cause TFE to fail in one hour. Therefore, the test was modified to provide comparative data and eliminate run-outs.

The standard loads, based on many tests of Wire #9, were established as 116 pounds at 23°C and 33 pounds at 149°C. Attempts were made to apply these loads to the other wires with extruded insulation. In several cases the failure occurred before the specimen was fully loaded. The results on these wires are included in Table 20-1, which summarizes the results on all of the wires.

In the case of the H-film constructions, the modified test procedure was used. This consisted of determining a short-time failure load by applying a load at a steady rate of .002 inches per minute (cross-head speed). The fixed load for the first creep test was then taken as 75% of the short-time failure load. This load was applied for one hour and, if failure did not occur, was increased in steps of about 10% at 15 minute intervals until failure occurred. In Table 20-1 the fixed load that was applied for the first hour is shown as the "Withstand" value. The failure load and the time that this last load was applied is also shown, but the incremental loads are not tabulated.

From the results obtained with the modified test procedure, estimates of the one hour failure loads can be made. These estimated values are given in Table 20-2. Although these values are only estimates, they clearly demonstrate the superior creep characteristics of the H-film construction.

Contrary to the results of the cut-through tests, the ML coatings on Wires #1 and 2 do not improve the creep behavior of these wires over that of Wire #9. It should be noted, however, that both #1 and #2 have thinner walls than #9, and with identical wall thicknesses the one hour creep loads for #1 and #2 might be somewhat higher than that for #9, particularly for Wire #2 at the higher temperature.

The creep behavior of Wire #2 (ML-TFE) is definitely better than that of Wire #1 (ML-FEP) at 149°C. This is not unexpected in view of the known effects of temperature on the mechanical properties of these materials.

Typical creep curves for a TFE insulated wire (#9) and an H-film construction (#16) are shown in Figure 20-1. The deflection during the first five minutes is not shown because this portion of the curve includes the movement of the whole wire as it is pressed against the base plate. Furthermore, the shape of this part of the curve depends on the rate at which the load was applied, and this could not be repeated excactly in each case.

With a mechanical system as complex as an insulated, stranded conductor it is not possible to analyze the creep data on the basis of per unit stress-strain relationships. The curves of Figure 20-1 show that most of the deflection occurs during the initial loading. Direct comparison of slopes is not meaningful because a different load was used in each case. In the case o Wire #16 at 23°C and Wire #9 at 149°C, where the load was increased at the end of the first hour, the curves indicate that considerably longer period would have been required to obtai the deflections observed at failure.

TABLE 20-1

THERMAL CREEP

Fixed Load Applied for Period Shown, Then Increased by Approx. 10% in 15 Minute Intervals to Failure Load.

Wire #	Temperature (°C)	Specimen	Withstood (lbs. - min.)		Failed (lbs.)
1	23	1			115 (12 min.)
		2			115 (5 min.)
		3	105	60	125 (5 min.)
1	149	1			26.5*
		2			26.8*
2	23	1	100	60	116 (5 min.)
		2			116 (7 min.)
		3			116 (3 min.)
2	149	1	33	60	50 (5 min.)
		2			40 (50 min.)
		3	40	65	50 (2 min.)
3	23	1	116	75	400
		2	116	60	350
		3	116	60	335
		4	116	60	325
3	149	1	105	60	130
		2			120 (6 min.)
		3	110	60	150
4	23	1	150	60	185
		2			170 (50 min.)
		3	160	60	175
4	149	1	85	80	115
		2			100 (36 min.)
		3			90 (47 min.)
5	23	1	200	60	275
		2	210	60	240
		3	200	60	250
5	149	1	75	60	105
		2	90	60	105
		3	90	60	100

(Continued)

TABLE 20-1 (Cont'd)

Wire #	Temperature (°C)	Specimen	Withstood (lbs. - min.)		Failed (lbs.)
6	23	1	400	60	450
		2			425 (3 min.)
		3	410	60	425
		4	410	60	450
6	149	1	185	60	245
		2	225	60	245
		3			240 (3 min.)
7	23				<96**
8	149				<23**
10	23	1			270 (3 min.)
		2	200	60	300
		3			275 (50 min.)
		4	275	60	350
10	149	1	180	60	240
		2	210	60	240
		3	225	60	270
12	23	1			20.0*
		2			20.6*
12	149	1			17.0*
		2			17.0*
13	23	1			74.0*
		2			72.2*
		3			75.5*
13	149	1			18.4*
		2			19.3*
		3			17.2*
14	23	1			116 (16 min.)
		2			116 (11 min.)
		3			116 (9 min.)
14	149	1	33	60	84
		2	65	60	75 (2 min.)
		3			70 (14 min.)
15	23	1	140	60	265
		2			200 (3 min.)
		3			185 (47 min.)
		4	185	75	275 (2 min.)
15	149	1			155 (2 min.)
		2	125	60	205 (4 min.)
		3			125 (4 min.)
		4	125	60	180 (1 min.)

(Continued)

TABLE 20-1 (Cont'd)

Wire #	Temperature (°C)	Specimen	Withstood (lbs. - min.)		Failed (lbs.)
16	23	1	370	60	425 (2 min.)
		2			400 (1 min.)
		3			375 (5 min.)
		4			375 (5 min.)
		5			350 (10 min.)
16	149	1	165	60	190 (2 min.)
		2	165	60	180 (11 min.)
		3	170	60	170 (61 min.)

*Failed at less than standard load. Values shown for short time test (.002 inches/min.)

**Failed during loading at values less than those shown.

TABLE 20-2

THERMAL CREEP

Estimated One Hour Failure Loads (Pounds)

Wire #	23°C	149°C
1	105-110	<25
2	100-110	40-45
3	300-325	110-130
4	160-170	85-100
5	210-275	90-100
6	410-425	225-240
9	116	33
10	275-300	225-240
11	175-180	70-90
15	185-200	125-140
16	350-370	170-180

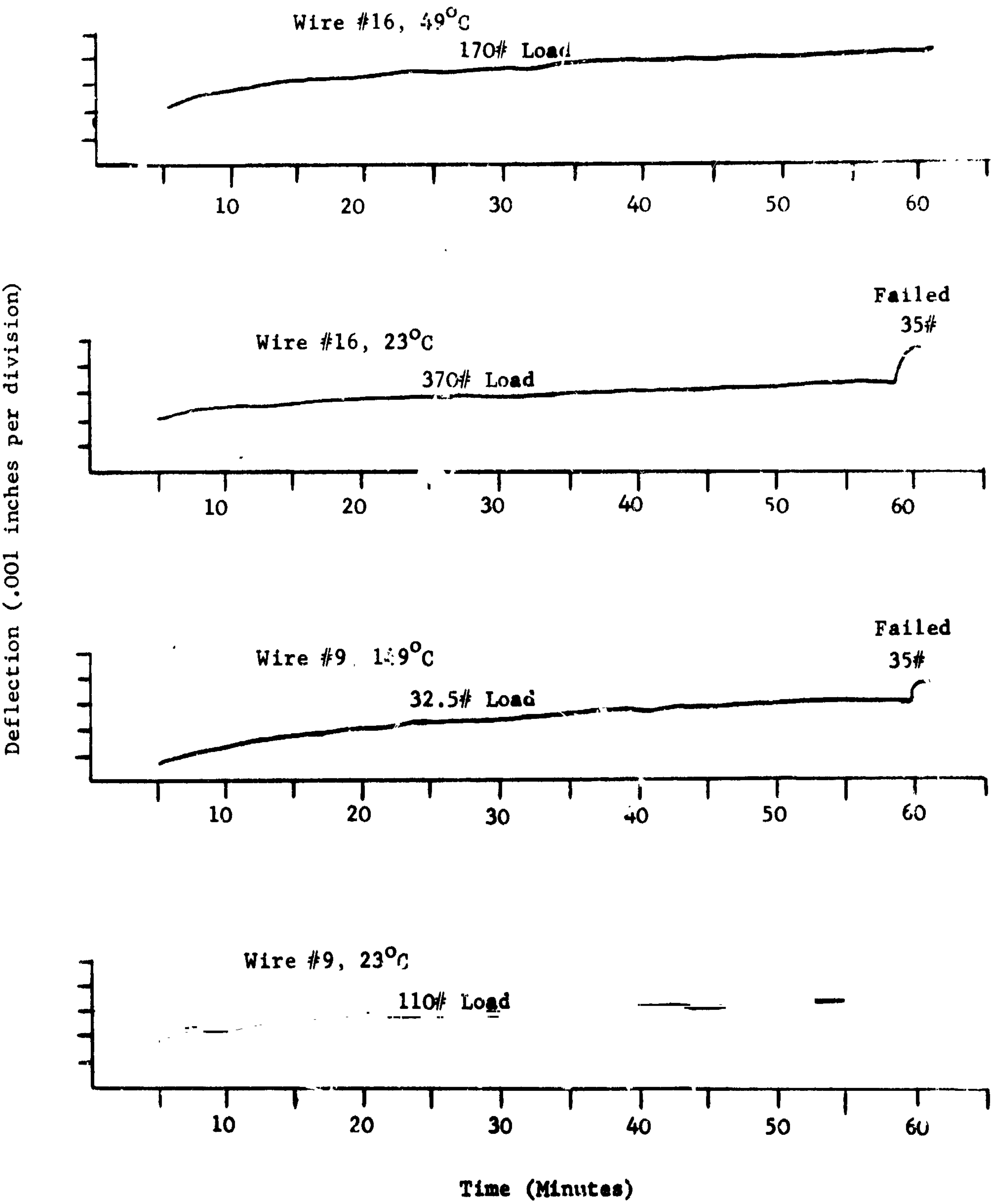


Figure 20-1: Creep Curves for Wires 9 and 16 at 23°C and 149°C

21. Wicking

The results of the wicking test are summarized in Table 21-1. The specimens were dipped in the dye solution to a depth of two inches, so those values less than two inches in Table 21-1 indicate that the solution did not even penetrate along the conductor to the liquid level in the container. This occurred with the irradiated polyolefin wires (7 and 8). In addition to having extruded insulation that is relatively well bonded to the conductor, these wires have tin plated conductors which may not have wet as readily as the nickel or silver plated conductors.

The taped specimens definitely wicked to greater lengths than the extruded wires. This is to be expected because of the absence of a bond between the insulation and the conductor.

It should be noted that the weight gain data do not correlate well with the wicking measurements. Wires 7 and 8, for instance, showed little wicking, but gained a considerable amount of weight. Moisture absorption and adsorption would be expected to increase the insulation weight of all of the specimens, even if no wicking occurred. The results show that the fluorescent dye technique is an effective means of detecting wicking.

TABLE 21-1

WICKING

Six Inch Specimen Vertically Immersed to a Depth of Two Inches

Wire No.	% Wt. Gain	Total Length Wicked (inches)
1-1	1.9	4-1/2
1-2	1.6	2-3/4
1-3	1.5	3-1/2
2-1	.59	2-1/4
2-2	.58	2-1/2
2-3	.64	2
3-1	2.1	6
3-2	1.7	5
3-3	2.2	6
4-1	2.8	6
4-2	2.1	6
4-3	2.6	6
5-1	1.3	4-1/2
5-2	1.4	4-3/4
5-3	1.2	4-1/4
6-1	.96	3-3/4
6-2	.95	3-3/4
6-3	.55	4-1/4
7-1	.99	1/8 to 1/4
7-2	.90	1/8 to 1/4
7-3	.59	1/8 to 1/4
8-1	.97	1/4
8-2	.93	1/4
8-3	1.04	1/4
9-1	.62	2-1/4
9-2	.63	2-3/8
9-3	.57	2-3/8
10-1	1.5	6
10-2	1.9	6
10-3	2.4	4
11-1	1.2	3
11-2	1.4	2-7/8
11-3	1.0	2-3/4

(continued)

TABLE 21-1 (continued)

WICKING

Six Inch Specimen Vertically Immersed to a Depth of Two Inches

Wire No.	% Wt. Gain	Total Length Wicked (inches)
12-1	.69	2-1/4
12-2	.63	2-1/4
12-3	.68	2-1/4
13-1	.56	2
13-2	.59	2-1/4
13-3	.69	2-3/4
14-1	2.0	1-3/8
14-2	1.3	2-1/4
14-3	1.1	3/4
15-1	1.8	6
15-2	1.7	6
15-3	1.8	6
16-1	1.6	6
16-2	1.4	6
16-3	1.6	6

22. Thermal Aging

In Tables 22-1 through 22-4 the effects of thermal aging for 15 days in vacuum and in 15 psia oxygen are reported on mandrel flexibility, voltage breakdown and insulation resistance. A number of observations can be made as follows:

a. Very slight decreases in flexibility occur after aging in vacuum at 150°C for Wires #1, 4, 5, 6 and 11. These changes may not be significant

b. Appreciable decrease in flexibility is noted after aging in oxygen at 15 psia for the following - ML overcoated FEP (Wire #1), Kynar jacketed polyolefin (Wire #7) and the polyolefin (Wire #8). The silicone rubber #12 was somewhat stiffened after aging but did not crack on its own diameter at 23°C.

c. Vacuum aging may have slightly decreased the voltage breakdown of the ML overcoated Wires #1 and #2 by perhaps damaging the overcoat. The voltage breakdown of the other wires is not adversely affected.

d. Aging in oxygen at 150°C has not adversely affected the voltage breakdown of any of the wires.

e. Aging at 150°C in both vacuum and oxygen generally increases insulation resistance probably by drying the specimens.

TABLE 22-1

EFFECT OF 15 DAYS EXPOSURE TO VACUUM AT 150°C ON MANDREL FLEXIBILITY

Ratio of Mandrel Diam. - Exposed / Unexposed

Wire #	No Damage Flexed at 23°C	No Damage Flexed at -196°C	Slight Damage Flexed at 23°C	Slight Damage Flexed at -196°C	Severe Damage Flexed at -196°C
1*	1X / .075	--	--	1.0 / .075	--
2	1X / .075	2.0 / 2.0	--	--	--
3	1X* / 1X	--	--	0.5 / 0.5	--
4	--	--	1X / 1X	--	.125 / .075
5	--	--	1X / 1X	.25 / .125	.125 / .075
6	1X / 1X	--	--	.50 / .25	--
7	1X / .075	--	--	--	1.75 / 1.75
8	1X / 1X	--	--	--	>3.0 / >3.0
9	1X / 1X	--	--	0.75 / 0.75	--
10	--	--	1X / 1X	0.5 / 0.25	--
11	--	--	1X / 1X	1.0 / 0.75	--
12	1X / 1X	--	--	--	>3.0 / >3.0
13	--	--	0.25 / 0.25	--	3.0 / 3.0
14	--	--	? / 0.25	--	3.0 / 3.0

*Some ML enamel appears to be eroded away.

TABLE 22-2

EFFECT OF 15 DAYS EXPOSURE TO VACUUM AT 150°C ON VOLTAGE BREAKDOWN - TWISTED PAIRS

Ratio of Breakdown Voltage (KV) - Exposed/Unexposed

Wire #	Maximum Values	Minimum Values
1	14.5 / 20.2	12.5 / 15.8
2	18.0 / 21.0	13.5 / 15.0
3	27 / 28.5	25.0 / 25.5
4	18 / 18	17 / 17.5
5	19.5 / 19.5	18 / 13.0
6	31 / 30	27 / 25.5
7	28.3 / 25.5	25.6 / 21
8	35.8 / 29	27.2 / 26
9	23.7 / 20.5	17.2 / 14.5
10	18.5 / 23	16.5 / 12
11	14.5 / 13.5	13.5 / 10.5
12	19.5 / 18.5	8.8 / 16.5
13	21.7 / 22.4	16.0 / 18.0
14	22.8 / 25.5	16.5 / 20.6

Ratio of Insulation Resistance (Ohms) - Exposed/Unexposed

Wire #	Maximum Values	Minimum Values
1	$2.0x10^{14}$ / $2.8x10^{13}$	$6.9x10^{13}$ / $8.6x10^{12}$
2	$1.3x10^{15}$ / $1.6x10^{13}$	$3.9x10^{14}$ / $9.8x10^{12}$
3	$>10^{15}$ / $6x10^{14}$	$6.3x10^{14}$ / $2.5x10^{14}$
4	$1x10^{15}$ / $5x10^{13}$	$5.0x10^{14}$ / $3.8x10^{13}$
5	$>10^{15}$ / $2.5x10^{15}$	$>10^{15}$ / $5.9x10^{14}$
6	$>5x10^{15}$ / $3.6x10^{14}$	$8.3x10^{14}$ / $2.3x10^{14}$
7	$1.1x10^{14}$ / $8.9x10^{12}$	$6.9x10^{13}$ / $3.6x10^{12}$
8	$6.3x10^{14}$ / $6.3x10^{13}$	$4.5x10^{13}$ / $8.3x10^{12}$
9	$3.6x10^{15}$ / $1.1x10^{15}$	$1.8x10^{15}$ / $3.6x10^{14}$
10	$8.3x10^{14}$ / $1x10^{14}$	$3.9x10^{13}$ / $1.5x10^{13}$
11	$>2.0x10^{15}$ / $>6.0x10^{14}$	$1.3x10^{15}$ / $>6.0x10^{14}$
12	$5.9x10^{14}$ / $3.5x10^{13}$	$1.0x10^{14}$ / $1.4x10^{13}$
13	$4.5x10^{13}$ / $7.8x10^{12}$	$2.6x10^{13}$ / $5.0x10^{12}$
14	$8.3x10^{13}$ / $4.5x10^{13}$	$4.5x10^{13}$ / $3.1x10^{13}$

TABLE 22-3

EFFECT OF 15 DAYS EXPOSURE TO 15 PSI OXYGEN AT 150°C ON MANDREL FLEXIBILITY

Ratio of Mandrel Diam. - Exposed/Unexposed

Wire #	No Damage Flexed at 23°C	No Damage Flexed at -196°C	Slight Damage Flexed at 23°C	Slight Damage Flexed at -196°C	Severe Damage Flexed at -196°C
1	--		0.25/1X	--	1.0/0.5
2	--	--	0.75/1X	--	1.75/1.75
3	1X*/1X	--	--	0.5/0.5	--
4	.075/.075	--	1X/1X	.125/.125	--
5	.075/.075	--	1X/1X	0.125/0.125	--
6	1X/1X	--	--	0.5/0.25	--
7	1X/.075	--	--	--	3.0/1.75
8	0.5/1X	--	0.25/.075	--	≥3.0/≥3.0
9	1X/1X	--	--	1.0/0.75	--
10	.125/.075	0.75/0.75	.075/1X	0.5/0.5	--
11	--	--	1X/1X	1.0/0.75	--
12	1X/1X	--	--	--	≥3.0/≥3.0
13	--	--	?/0.25	--	3.0/3.0
14	--	--	?/0.25	--	3.0/3.0

TABLE 22-4

EFFECT OF 15 DAYS EXPOSURE TO 15 PSI OXYGEN AT 150°C ON VOLTAGE BREAKDOWN - TWISTED PAIRS

Ratio of Breakdown Voltage (KV) - Exposed/Unexposed

Wire #	Maximum Values	Minimum Values
1	20.6 / 20.2	16.9 / 15.8
2	19.5 / 21.0	16.2 / 15.0
3	29 / 28.5	26 / 25.5
4	18 / 18	16.5 / 17.5
5	20 / 19.5	19.5 / 13.0
6	32 / 30	30.5 / 25.5
7	25.5 / 25.5	20.0 / 21
8	27 / 29	20 / 26
9	25.3 / 20.5	16.1 / 14.5
10	19.5 / 23	17 / 18
11	14.5 / 13.5	13.4 / 10.5
12	19.5 / 18.5	16.2 / 16.5
13	24.4 / 22.4	17.1 / 18.0
14	19.5 / 25.5	15.0 / 20.6

Ratio of Insulation Resistance (Ohms) - Exposed/Unexposed

Wire #	Maximum Values	Minimum Values
1	2.9×10^{13} / 2.8×10^{13}	1.5×10^{13} / 8.6×10^{12}
2	$>1 \times 10^{15}$ / 1.6×10^{13}	$>1.0 \times 10^{15}$ / 9.8×10^{12}
3	1.3×10^{15} / 6×10^{14}	7.7×10^{14} / 3.5×10^{14}
4	$>10^{15}$ / 5×10^{13}	$>10^{15}$ / 3.8×10^{13}
5	$>10^{15}$ / 2.5×10^{15}	$>10^{15}$ / 5.9×10^{14}
6	$>10^{15}$ / 3.6×10^{14}	$>10^{15}$ / 2.3×10^{14}
7	1.3×10^{14} / 8.9×10^{12}	5.3×10^{13} / 3.6×10^{12}
8	1.1×10^{14} / 6.3×10^{13}	3.3×10^{13} / 8.3×10^{12}
9	2×10^{16} / 1.1×10^{15}	4.2×10^{15} / 3.6×10^{14}
10	2.5×10^{14} / 1×10^{14}	7.8×10^{13} / 1.5×10^{13}
11	3.9×10^{15} / $>6.0 \times 10^{14}$	2.9×10^{14} / $>6.0 \times 10^{14}$
12	2.5×10^{14} / 3.5×10^{13}	5.7×10^{13} / 1.4×10^{13}
13	3.3×10^{13} / 7.8×10^{12}	1.5×10^{13} / 5.0×10^{12}
14	1.7×10^{14} / 4.5×10^{13}	1.0×10^{14} / 3.1×10^{13}

23. Ultraviolet Radiation

Mandrel flexibility, voltage breakdown and insulation resistance have been used to evaluate the effect of 30 days aging in vacuum at 150°C and in 15 psia wet oxygen at about 95°C. Table 23-1 through 23-3 report results in vacuum. Tables 23-4 through 23-6 report results in oxygen. The following observations can be made.

a. From Table 23-1 it is apparent that very slight and perhaps insignificant decreases in flexibility occur from the ultraviolet aging in vacuum for wires #1, 5, 6, 7, 8, 9, 10 and 11. A more significant decrease in the flexibility of the silicone rubber (wire #12) is noted.

b. From Table 23-4 it is apparent that aging in UV and oxygen considerably decreases the flexibility of the Kynar jacketed polyolefin (wire #7) and the silicone rubber (wire #12). Wires #3, 4, 5, 6, 8, 10, 11 and 14 are also more or less affected.

c. The voltage breakdown of wire #1 is slightly decreased by ultraviolet and vacuum aging but the other wires are unaffected.

d. After ultraviolet and oxygen aging the voltage breakdown of wires #1 and 13 are somewhat affected. The voltage breakdown of wires #7, 8 and 12 is drastically decreased.

e. Insulation resistance generally increases after aging, even when voltage breakdown is drastically reduced.

Much can be learned from visual observations of the wires. Color changes are reported elsewhere but do indicate, in particular, changes in the polyolefin insulated wires #7 and 8. Aging in ultraviolet and wet oxygen leads to serious physical deterioration of the Kynar jacket as shown in Figure 23-1. Although it cannot be seen in the photograph the polyolefin substrate is also visibly cracked. Another effect is shown for H-film taped wires exposed to ultraviolet and oxygen aging in Figures 23-2 and 23-3. In Figure 23-2 a slight "whitening" is visible at the interface between the lapped tapes. Figure 23-3 shows how such a wire can be untaped easily since the bond between the H-film and the FEP Teflon coating appears to have been considerably weakened. It is impossible to delaminate an unaged wire in this fashion.

TABLE 23-1

EFFECT OF 30 DAYS EXPOSURE TO UV IN VACUUM AT 150°C ON MANDREL FLEXIBILITY

Ratio of Mandrel Dia. - Exposed/Unexposed

Wire #	No Damage Flexed at 23°C	No Damage Flexed at -196°C	Slight Damage Flexed at 23°C	Slight Damage Flexed at -196°C	Severe Damage Flexed at -196°C
1	---	---	1X/1X	1.0/0.75	---
2	---	2.0/2.0	---	---	---
3*	---	---	1X/<1X	0.5/0.5	---
4*	---	---	1X/1X	0.125/0.125	---
5*	---	---	1X/1X	0.125/.075	---
6*	1X/1X	---	---	---	0.5/0.25
7**	---	---	1X/1X	---	2.0/1.75
8**	---	---	1X/<1X	---	>3.0/>3.0
9***	1X/1X	---	---	---	0.75/0.50
10	---	---	1X/1X	0.75/0.50	---
11	---	---	1X/1X	1.0/0.75	---
12	---	---	0.25/>1X	---	>3.0/>3.0
13 (1)	---	---	0.25/0.25	---	>3.0/>3.0
14 (2)	---	---	0.25/0.25	---	2.0/3.0

* Darkened slightly on exposed side
** Developed dark brown color
*** Light tan color on exposed side
(1) 23 days exposure
(2) 28 days expsoure

TABLE 23-2

EFFECT OF 30 DAYS EXPOSURE TO UV IN VACUUM AT 150°C ON VOLTAGE BREAKDOWN - TWISTED PAIRS

Ratio of Breakdown Voltage (KV) $\frac{\text{Exposed}}{\text{Unexposed}}$

Wire #	Maximum Values	Minimum Values
1*	12.5 / 20.2	10.3 / 15.8
2	19.0 / 21.0	14.6 / 15.0
3	29.5 / 28.5	23.5 / 25.5
4	18.5 / 18.0	17.0 / 17.5
5	22.5 / 19.5	19.0 / 13.0
6	34.0 / 30.0	23.5 / 25.5
7	29.0 / 25.5	19.5 / 21.0
8	33.5 / 29.0	25.5 / 26.0
9	21.5 / 20.5	16.5 / 14.5
10	21.7 / 23.0	17.5 / 18.0
11	13.9 / 13.5	9.2 / 10.5
12	20.1 / 18.5	13.8 / 16.5
13	21.5 / 22.4	16.8 / 18.0
14	24.9 / 25.5	19.0 / 20.6

*ML coating eroded away in most areas.

TABLE 23-3

EFFECT OF 30 DAYS EXPOSURE TO UV IN VACUUM AT 150°C ON INSULATION RESISTANCE - TWISTED PAIRS

Ratio of Insulation Resistance (Ohms) - $\frac{\text{Exposed}}{\text{Unexposed}}$

Wire #	Maximum Values	Minimum Values
1	4.2×10^{14} / 2.8×10^{13}	1.9×10^{14} / 8.6×10^{12}
2	3.1×10^{14} / 1.6×10^{13}	1.3×10^{14} / 9.8×10^{12}
3	4.5×10^{14} / 6.0×10^{14}	1.7×10^{14} / 3.8×10^{13}
4	2.2×10^{14} / 5.0×10^{13}	7.6×10^{13} / 3.8×10^{13}
5	7.7×10^{14} / 2.5×10^{15}	1.8×10^{14} / 5.9×10^{14}
6	2.8×10^{14} / 3.6×10^{15}	6.9×10^{13} / 2.3×10^{14}
7	1.5×10^{14} / 8.9×10^{12}	1.1×10^{14} / 3.6×10^{12}
8	2.3×10^{14} / 6.3×10^{13}	1.8×10^{14} / 8.3×10^{14}
9	1.0×10^{15} / 1.1×10^{15}	2.1×10^{14} / 3.6×10^{14}
10	3.1×10^{13} / 1.0×10^{14}	2.0×10^{13} / 1.5×10^{13}
11	4.2×10^{14} / $>6.0 \times 10^{14}$	1.2×10^{14} / $>6.0 \times 10^{14}$
12	3.3×10^{14} / 3.5×10^{13}	1.1×10^{14} / 1.4×10^{13}
13	1.8×10^{13} / 7.8×10^{12}	1.4×10^{13} / 5.0×10^{12}
14	5.0×10^{13} / 4.5×10^{13}	2.3×10^{13} / 3.1×10^{13}

TABLE 23-4

EFFECT OF 30 DAYS EXPOSURE TO UV IN WET O_2 AT 15 PSI ON MANDREL FLEXIBILITY

Ratio of Mandrel Dia. - Exposed/Unexposed

Wire #	No Damage Flexed at 23°C	No Damage Flexed at -196°C	Slight Damage Flexed at 23°C	Slight Damage Flexed at -196°C	Severe Damage Flexed at -196°C
1	---	---	1X/1X	1.0/0.75	---
2	1X/.075	2.0/2.0			
3*	---	---	0.125/<1X	---	0.75/0.25
4**	---	---	0.25/1X	---	0.75/.075
5**	---	---	0.25/1X	---	0.75/.075
6**	---	---	1X/<1X	---	0.50/0.25
7***	to deteriorated to test - see below				
8****	---	---	1X/<1X	---	>3.0/>3.0
9	1X/1X	---	---	---	0.5/0.5
10	---	---	1X/1X	---	0.75/0.25
11	---	---	1X/1X	1.0/0.75	---
12	---	---	0.5/<1X	---	>3.0/>3.0
13 (1)	---	---	0.25/0.25	---	>3.0/>3.0
14	---	---	0.5/0.25	---	3.0/3.0

* Red color has bleached slightly - coating is easily abraded with fingernail.
** FEP is easily delaminated from H-film but both appear physically OK (shows as "frosty" areas - see photo).
*** Kynar overcoat cracked and spalled before test. Substrate cracked also.
****Developed light tan color.
(1) 23 days exposure.

TABLE 23-5

EFFECT OF 30 DAYS EXPOSURE TO UV IN WET O_2 AT 15 PSI ON VOLTAGE BREAKDOWN - TWISTED PAIRS

Ratio of Breakdown Voltage (KV) - $\frac{\text{Exposed}}{\text{Unexposed}}$

Wire #	Maximum Values	Minimum Values
1(1)	12.6 / 20.2	6.1 / 15.8
2	16.4 / 21.0	11.6 / 15.0
3	30.0 / 28.5	26.0 / 25.5
4	19.0 / 18.0	15.0 / 17.5
5	22.0 / 19.5	14.0 / 13.0
6	31.5 / 30.0	28.5 / 25.5
7	1.25/ 25.5	<0.5 / 21.0
8*	16.0 / 29.0	2.0 / 26.0
9	21.0 / 20.5	16.0 / 14.5
10	26.6 / 23.0	21.2 / 18.0
11	13.0 / 13.5	11.7 / 10.5
12	3.3 / 18.5	1.8 / 16.5
13	17.0 / 22.4	10.9 / 18.0
14	24.5 / 25.5	18.1 / 20.6

*Flame at breakdown
(1) ML eroded away in many areas

TABLE 23-6

EFFECT OF 30 DAYS EXPOSURE TO UV IN WET O_2 AT 15 PSI ON INSULATION RESISTANCE - TWISTED PAIRS

Ratio of Insulation Resistance (Ohms) - $\frac{\text{Exposed}}{\text{Unexposed}}$

Wire #	Maximum Values	Minimum Values
1	1.4×10^{13} / 2.8×10^{13}	6.4×10^{12} / 8.6×10^{12}
2	2.2×10^{13} / 1.6×10^{13}	1.4×10^{13} / 9.8×10^{12}
3	4.2×10^{15} / 6.0×10^{14}	1.8×10^{15} / 2.5×10^{14}
4	2.3×10^{15} / 5.0×10^{13}	7.8×10^{14} / 3.8×10^{13}
5	4.2×10^{15} / 2.5×10^{15}	2.3×10^{14} / 5.9×10^{14}
6	1.8×10^{15} / 3.6×10^{15}	5.7×10^{14} / 2.3×10^{14}
7	7.1×10^{12} / 8.9×10^{12}	7.8×10^{11} / 3.6×10^{12}
8	6.7×10^{13} / 6.3×10^{13}	5.2×10^{11} / 8.3×10^{11}
9	4.2×10^{15} / 1.1×10^{15}	6.4×10^{14} / 3.6×10^{14}
10	2.0×10^{13} / 1.0×10^{14}	7.7×10^{12} / 1.5×10^{13}
11	6.3×10^{14} / $>6.0 \times 10^{14}$	1.2×10^{14} / $>6.0 \times 10^{13}$
12	1.3×10^{13} / $3.5 \times 10^{1[illegible]}$	8.2×10^{12} / 8.2×10^{12}
13	2.0×10^{13} / 7.8×10^{12}	7.7×10^{12} / 5.0×10^{12}
14	1.6×10^{14} / 4.5×10^{13}	3.9×10^{13} / 3.1×10^{13}

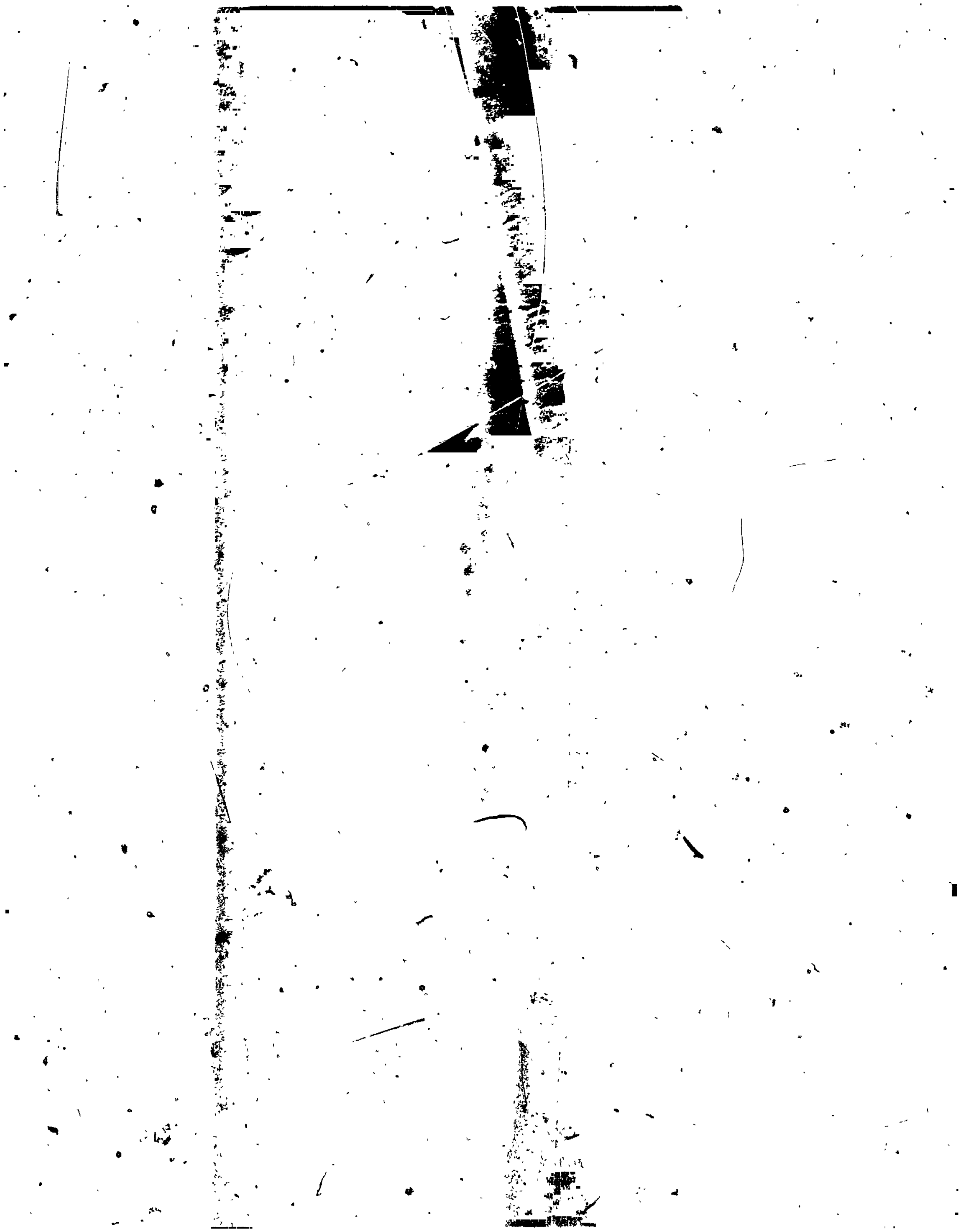


Figure 23-1 - Damage to Kynar Jacket of Wire #7 after Aging 30 Days at 95°C in Wet Oxygen while Exposed to Ultraviolet Radiation

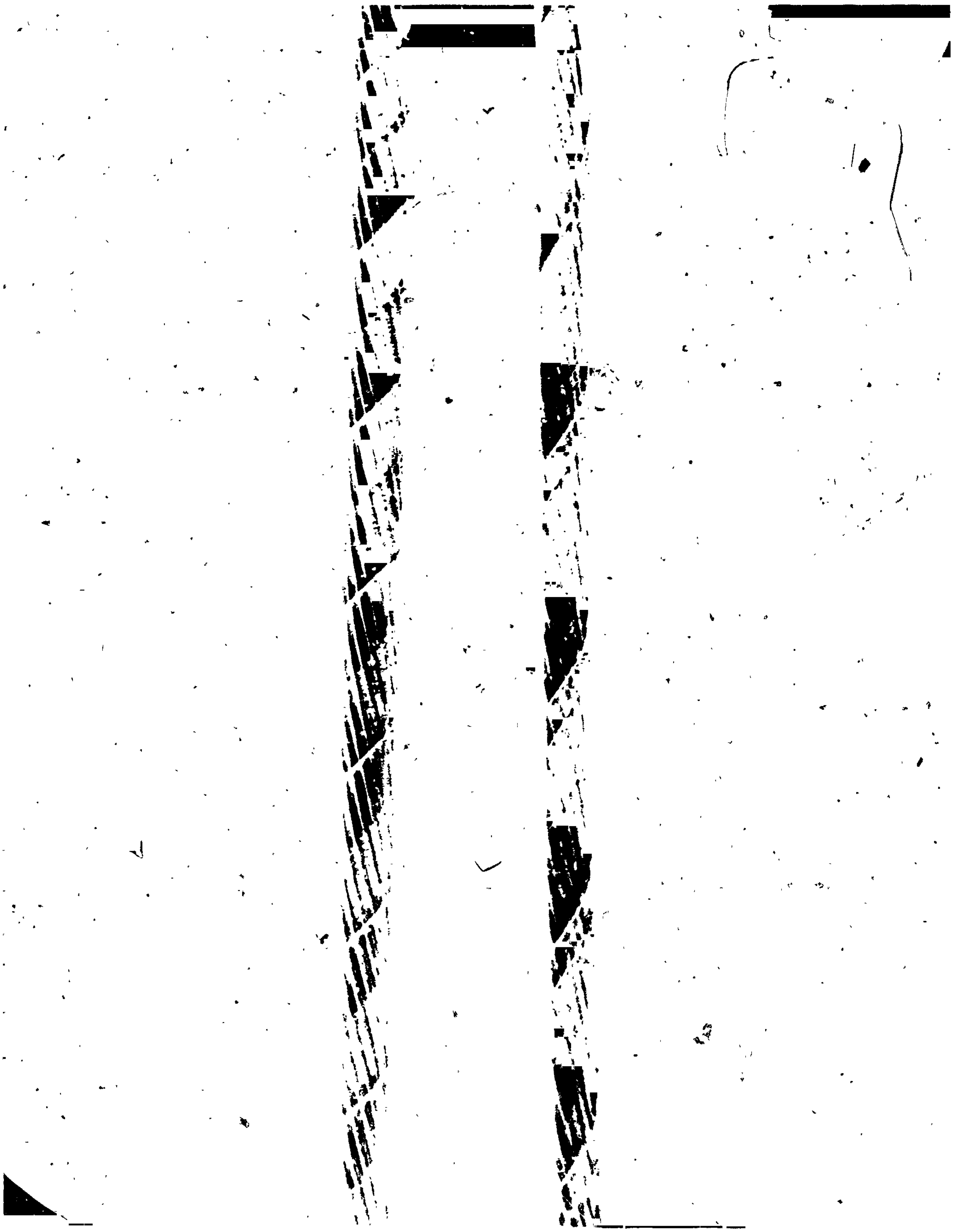


Figure 23-2 - Whitening of Interface between H-film Overlap after Aging 30 Days at 95°C in Wet Oxygen while Exposed to Ultraviolet Radiation

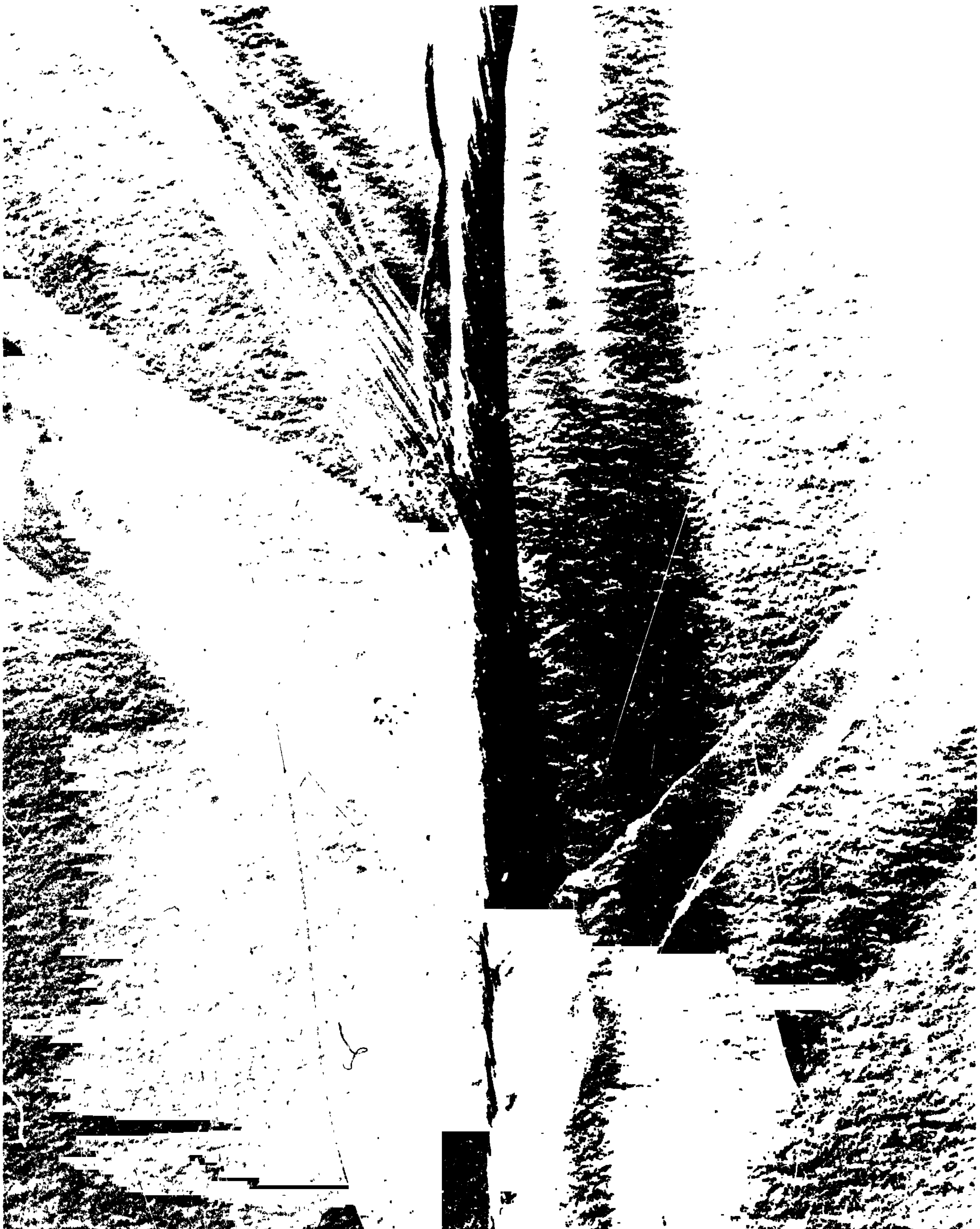


Figure 23-3 - H-film Delaminated from FEP Layer after Aging 30 Days at 95°C in Wet Oxygen while Exposed to Ultraviolet Radiation

24. X-Ray Irradiation

As required with RFP all wires #1-14 were exposed to x-rays as follows:

a. 10 hours - 6000 rads/hr. at 150°C (in vacuum).

b. 2 hours - 500 rads/hr. at 90°C (in 5 psia oxygen).

On the basis of previous work these levels or irradiation are very low.

Tables 24-1 to 24-3 report the effect of radiation in vacuum and Tables 24-4 to 24-6 report result of exposures in oxygen. As in the other aging program very small and probably non-significant changes occurred in cryogenic flexibility. The voltage breakdown of wire #1 decreased somewhat after exposure in vacuum but this may also have been due to chance. No other significant changes can be observed. Insulation resistance increases as is usual in aging studies.

TABLE 24-1

EFFECT OF 10 HOURS EXPOSURE TO 6000 RADS/HR. X-RAY AT 150°C IN VACUUM ON MANDREL FLEXIBILITY

Ratio of Mandrel Dia. - $\frac{\text{Exposed}}{\text{Unexposed}}$

Wire #	No Damage Flexed at 23°C	No Damage Flexed at -196°C	Slight Damage Flexed at 23°C	Slight Damage Flexed at -196°C	Severe Damage Flexed at -196°C
1	---	---	1X/1X	1.0/0.75	---
2	---	---	1X/1X	---	2.0/1.75
3	---	---	1X/1X	0.5/0.5	/0.25
4	---	---	1X/1X	0.250/0.125	0.125/.075
5	---	---	1X/1X	0.250/0.125	0.125/.075
6	1X/1X	---	---	0.50/0.50	/0.25
7	1X/.075	---		---	1.75/1.75
8	1X/1X	---	---	---	≥3.0/>3.0
9	1X/1X	---	---	---	0.5/0.5
10	---	---	1X/1X	0.50/0.50	/0.25
11	---	---	1X/1X	1.0/0.75	/0.25
12	1X/1X	---	---	---	≥3.0/>3.0
13	---	---	0.25/0.25	---	3.0/3.0
14	---	---	0.25/0.25	---	2.0/3.0

TABLE 24-2

EFFECT OF 10 HOURS EXPOSURE TO 6000 RADS/HR. X-RAY AT 150°C IN VACUUM ON VOLTAGE BREAKDOWN - TWISTED PAIRS

Ratio of Breakdown Voltage (KV) - $\frac{\text{Exposed}}{\text{Unexposed}}$

Wire #	Maximum Values	Minimum Values
1	14.2 / 28.2	9.1 / 15.8
2	20.0 / 21.0	14.1 / 15.0
3	29.4 / 28.5	27.2 / 25.5
4	18.1 / 18.0	11.9 / 17.5
5	20.1 / 19.5	12.7 / 13.0
6	31.5 / 30.0	27.9 / 25.5
7	26.4 / 25.5	21.6 / 21.0
8	40.0 / 29.0	29.0 / 26.0
9	20.0 / 20.5	17.5 / 14.5
10	27.5 / 23.0	20.1 / 18.0
11	13.1 / 13.5	11.6 / 10.5
12	19.0 / 18.5	15.3 / 16.[illegible]
13	21.5 / 22.4	17.9 / [illegible]
14	22.5 / 25.5	17.6 / 20.6

TABLE 24-3

EFFECT OF 10 HOURS EXPOSURE TO 6000 RADS/HR. X-RAY AT 150°C IN VACUUM ON INSULATION RESISTANCE - TWISTED PAIRS

Ratio of Insulation Resistance (Ohms) - $\frac{\text{Exposed}}{\text{Unexposed}}$

Wire #	Maximum Values	Minimum Values
1	1.0×10^{15} / 2.8×10^{13}	5.3×10^{13} / 8.6×10^{12}
2	7.1×10^{14} / 1.6×10^{13}	2.3×10^{14} / 9.8×10^{12}
3	3.9×10^{14} / 6.0×10^{14}	1.3×10^{14} / 2.5×10^{14}
4	6.3×10^{14} / 5.0×10^{13}	3.3×10^{14} / 3.8×10^{13}
5	$>2.5 \times 10^{15}$ / 2.5×10^{15}	$>2.5 \times 10^{15}$ / 5.9×10^{14}
6	2.0×10^{15} / 3.6×10^{15}	5.9×10^{13} / 2.3×10^{14}
7	1.2×10^{15} / 8.9×10^{12}	1.4×10^{14} / 3.6×10^{12}
8	3.1×10^{14} / 6.3×10^{13}	7.0×10^{13} / 8.3×10^{12}
9	$>2.0 \times 10^{15}$ / 1.1×10^{15}	$>2.0 \times 10^{15}$ / 3.6×10^{14}
10	2.1×10^{13} / 1.0×10^{14}	8.1×10^{12} / 1.5×10^{13}
11	$>1.0 \times 10^{15}$ / $>6.0 \times 10^{14}$	$>1.0 \times 10^{15}$ / $>6.0 \times 10^{14}$
12	5.6×10^{14} / 3.5×10^{13}	1.0×10^{14} / 1.4×10^{13}
13	2.9×10^{13} / 7.8×10^{12}	1.9×10^{13} / 5.0×10^{12}
14	5.0×10^{13} / 4.5×10^{13}	3.6×10^{13} / 3.1×10^{13}

TABLE 24-4

EFFECT OF 2 HOURS EXPOSURE TO 500 RADS/Hr. X-RAY IN 5 PSI OXYGEN AT 90°C ON MANDREL FLEXIBILITY

Ratio of Mandrel Dia. - Exposed / Unexposed

Wire #	No Damage Flexed at 23°C	No Damage Flexed at -196°C	Slight Damage Flexed at 23°C	Slight Damage Flexed at -196°C	Severe Damage Flexed at -196°C
1	---	---	1X/1X	1.0/0.75	---
2	---	---	1X/1X	1.75/2.0	---
3	---	---	1X/1X	0.5/0.5	---
4	---	---	1X/1X	0.25/.125	0.125/.075
5			1X/1X	0.25/0.125	0.125/0.075
6	1X/1X	---	---	0.50/0.50	---
7	---	---	1X/1X	---	1.75/1.75
8	1X/1X	---	---	---	3.0/>3.0
9	1X/1X	---	---	---	0.5/0.5
10	---	---	1X/1X	0.50/0.50	---
11	---	---	1X/1X	1.0/0.75	---
12	1X/1X	---	---	---	>3.0/>3.0
13	---	---	0.25/0.25	---	3.0/3.0
14	---	---	0.25/0.25	---	3.0/3.0

TABLE 24-5

EFFECT OF 2 HOURS EXPOSURE TO 500 RADS/HR. X-RAY IN 5 PSI OXYGEN AT 90°C ON VOLTAGE BREAKDOWN - TWISTED PAIRS

Ratio of Breakdown Voltage (KV) - $\frac{\text{Exposed}}{\text{Unexposed}}$

Wire #	Maximum Values	Minimum Values
1	20.1 / 20.2	17.5 / 15.8
2	18.9 / 21.0	14.7 / 15.0
3	29.1 / 28.5	27.0 / 25.5
4	17.9 / 18.0	11.8 / 17.5
5	20.0 / 19.5	19.0 / 13.0
6	34.5 / 30.0	30.7 / 25.5
7	27.0 / 25.5	23.4 / 21.0
8	31.9 / 29.0	25.8 / 26.0
9	17.8 / 20.5	15.7 / 14.5
10	25.6 / 23.0	18.7 / 18.0
11	14.0 / 13.5	12.5 / 10.5
12	20.2 / 18.5	15.3 / 16.5
13	21.8 / 22.4	19.0 / 18.0
14	23.4 / 25.5	20.1 / 20.6

TABLE 24-6

EFFECT OF 2 HOURS EXPOSURE TO 500 RADS/HR. X-RAY IN 5 PSI OXYGEN AT 90°C ON INSULATION RESISTANCE - TWISTED PAIRS

Ratio of Insulation Resistance (Ohms) - $\frac{\text{Exposed}}{\text{Unexposed}}$

Wire #	Maximum Values	Minimum Values
1	$1.1 \times 10^{14} / 2.8 \times 10^{13}$	$3.6 \times 10^{13} / 8.6 \times 10^{12}$
2	$2.8 \times 10^{14} / 1.6 \times 10^{13}$	$3.3 \times 10^{13} / 9.8 \times 10^{12}$
3	$1.3 \times 10^{15} / 6.0 \times 10^{14}$	$3.6 \times 10^{14} / 2.5 \times 10^{14}$
4	$5.0 \times 10^{15} / 5.0 \times 10^{13}$	$3.9 \times 10^{14} / 3.8 \times 10^{13}$
5	$2.0 \times 10^{15} / 2.5 \times 10^{15}$	$3.3 \times 10^{14} / 5.9 \times 10^{14}$
6	$1.0 \times 10^{15} / 3.6 \times 10^{15}$	$1.9 \times 10^{14} / 2.3 \times 10^{14}$
7	$2.8 \times 10^{14} / 8.9 \times 10^{12}$	$5.0 \times 10^{13} / 3.6 \times 10^{12}$
8	$2.4 \times 10^{13} / 6.3 \times 10^{13}$	$6.6 \times 10^{12} / 8.3 \times 10^{12}$
9	$>1.0 \times 10^{15} / 1.1 \times 10^{15}$	$>1.0 \times 10^{15} / 3.6 \times 10^{14}$
10	$5.6 \times 10^{12} / 1.0 \times 10^{14}$	$2.2 \times 10^{12} / 1.5 \times 10^{13}$
11	$>1.0 \times 10^{15} / >6.0 \times 10^{14}$	$>1.0 \times 10^{15} / >6.0 \times 10^{14}$
12	$1.3 \times 10^{14} / 3.5 \times 10^{13}$	$3.6 \times 10^{13} / 1.4 \times 10^{13}$
13	$1.2 \times 10^{13} / 7.8 \times 10^{12}$	$8.8 \times 10^{12} / 5.0 \times 10^{12}$
14	$4.2 \times 10^{13} / 4.5 \times 10^{13}$	$2.4 \times 10^{13} / 3.1 \times 10^{13}$

25. Flammability

In conducting the flammability tests, it was recognized that many possible variables existed. Consequently, an effort has been made to vary the different tests somewhat (particularly the replicates) so as to investigate the effect of small variations in the test procedure. At the same time, the procedures were standardized sufficiently so as to permit comparisons between wires.

As described under methods of test, three types of procedure have been used.

I. An external heater around the wire brings the wire temperature up to between 480 and somwhat over 500°C. After 5 minutes, sufficient current is passed through the wire to bring the wire up to at least 600°C.

IIA. A suddenly applied fixed value of current (usually 40, 45 or 50 amperes) brings the wire very rapidly to a very high temperature which depends primarily on the current but also apparently on other factors. The very rapid rise in temperature after a 50 ampere current starts to flow is illustrated in Figure 25-1.

IIB. The current is increased in steps to nominal 20, 30, 32.5, 35, 37.5, 40, 42.5, 45, 47.5 and sometimes 50 amperes. Actual recorded current and the associated voltage drop (for a 1 inch section of wire) for a typical test is shown in Figure 25-2. The measured wire temperature is given in Figure 25-3. The temperature rises more slowly to a maximum value in about 3 minutes.

It is apparent that the temperature does not increase uniformily as shown in Figure 25-3. After some study of visual observations correlated with measurements made by both the voltage drop and thermocouple techniques it became apparent that many variables influenced the temperatures observed and gave question to the values of temperature reported. Several observations on the problem of temperature measurement can be made:

a. Oxidation and perhaps diffusion of plated coatings change the wire resistance so that the voltage drop technique is inherently inaccurate for the measurement of high wire temperatures.

b. A fine wire thermocouple can be inserted in the conductor adequately only by first cutting the insulation, untwisting the wire strands and then retwisting them after inserting the thermocouple junction. In consequence an artificial discontinuity is introduced in both wire and insulation at the hottest point.

c. Fine thermocouple junctions are fragile and also may not maintain consistent thermal contact with the wire during test. They are also subject to errors introduced by radiation. Consequently the thermocouple results lack relaible accuracy.

d. Current and time alone do not determine the wire temperature. At a specific value of current while the insulation adheres to the wire radiation may be relatively great and the temperature is low. When the insulation comes loose but still surrounds the wire, the conductor temperature increases rapidly. When the insulation finally falls off, the temperature may again decrease somewhat. The emissivity of the degraded insulation probably is also a factor. Finally, of course, it is really the temperature of the insulation rather than the conductor which should be determined.

It is apparent that temperature measurements in flammability test remain as an unsolved problem. Temperature values provide the most significant way of evaluating the performance of the insulation. On the other hand the values of current have more functional significance in terms of operational requirements. Consequently both current and measured temperature are reported in the following. Thermocouple measurements were used from the beginning for Type I tests in which a heater coil was used. Thermocouples have been used also for the other two types of test with Wires #1, 2, 7, 8, 10, 11, 12, 13, 14, 15 and 16 since on balance this approach seems somewhat better than the voltage drop technique which was used in the first tests with Wires #3, 4, 5, 6 and 9.

Flammability results for all the wires are summarized for the three types of test in Tables 25-1 through 25-3. Although it was not a contract responsibility, the flammability of the polyolefin Wires #7 and 8 have been evaluated in air with results summarized in Table 25-4. The detailed test results are appended to this section.

Despite the summation in the tables, the many factors involved make it desirable to summarize even further in a number of observations as follows:

a. Type I tests with a hot external heater coil combined with spark ignition produce fires in many kinds of insulation which normally do not burn. TFE Teflon (Wire #9) burns with an almost invisible blue flame as pictured in Figure 25-4. In several additional tests not reported here, the flame in TFE Teflon has progressed both up and down the vertical wire and movies have been made of the process. When the H-film taped wires such as Wires #15 and 16 burn, it appears likely that the Teflon coatings are primarily involved but that the H-film may also contribute since in such cases the flame appears to become more yellow.

b. In a very few cases with several wires, a continuing fire in the form of a "glow" rather than a flame occurred. The glow often progressed along the surface of the wire.

c. In some cases a small fire would start and then extinguish itself quickly. In other cases the gases given off would cause a flickering near the spark and in some cases a quick flash would occur. Flickers and flashes have not been classed as fires.

d. H-film taped wires #4, 5, and 6 have never glowed or burned in any of the flammability tests. It should be recognized that subtle variables are involved and more tests might change this observation.

e. The polyolefin wires #7 and 8 and the silicone Wire #12 burn quite easily in all three types of test. (One specimen of #12 glowed in the Type II-B progressive current test.) A fire in wire #8 is shown in Figure 25-5.

f. Jacketing changes the flame resistance of the polyolefin and silicone insulations but sometimes in a surprising fashion. In many cases a Kynar jacket appears to confine the decomposition gases until they suddenly burst out in great volume and are then easily ignited. In consequence a Kynar jacket may often <u>decrease</u> the flammability resistance. On the other hand the H-film jacket over the silicone rubber in Wire #14 did seem to improve its performance.

g. Both Kynar jacketed polyolefin (Wire #7) and the unjacketed wire #8 will burn even in normal air. The other wires have not been tested in air.

h. The spark-gap is essential in producing ignition. Much of the observed variability in the test results can be traced to bowing of the wire specimens away from the spark gap during test. It is suggested that in future work this problem can be avoided by maintaining a slight tension on the wire during test.

i. Considerable variability in smoke production amongst the various wires is shown in the summary tables and the appended detailed test results. In particular H-film taped Wires #4, 5, and 6 as well as TFE Teflon (Wire #9) seldom, if ever, evolved visible smoke. However, all of these wires did give off invisible vapor which caused more or less white deposit throughout the test chamber. It is suggested that this deposit is formed of Teflon polymer fragments and it was observed with the other wires which also contained Teflon.

j. Considerable information about the physical state of the wires during the progress of the flammability tests can be found in the appended tabulation of detailed results. These observations are much too varied to be readily summarized so only initial color change is given in the tables. It should be noted that Wires #11, 12 and 13 are initially black in color so that with them color change is difficult to detect.

k. H-film chars in the flammability test but does not appear to soften. FEP Teflon does melt and sometimes form "beads" of resin on the wire. The H-film tends to unwrap when the FEP softens and melts. TFE Teflon does not truly melt but does appear to soften. It becomes transparent at its transition temperature of 325°C.

TABLE 25-1

SUMMARY FLAMMABILITY TESTS IN 5 PSI OXYGEN

Heater Coil Energized - Test Type I

Wire #	Wire Discolors I Amps.	Wire Discolors Temp.* °C	First Heavy Smoke I Amps.	First Heavy Smoke Temp.* °C	Fire or Complete Degradation (SE = self-extinguished) Status	Time Min.	I Amps.	Max. Temp.* °C
1	---	---	37.5	850	No fire	13	37.5	870
1	0	573	52	?	No fire	6.25	52	?
1	0	522	---	---	Fire - SE	6	37.5	870
2	0	562	---	---	Flash	8	39	745
2	---	---	37.5	744	Glow-No flame	5.5	37.5	835
2	---	---	---	---	Flash	6	40	709
3	0	568	---	---	Flash	2.5	?	568
3	---	528	34	>600	No fire	2.5	3.4	>600
3	0	504	---	---	Flash	8	26	>600
4	0	492	---	---	Flash	13	26	>660
4	26	600	--	---	Flicker	7.25	26	634
4	23	640	---	---	No fire	8	23	644
5	0	541	---	---	No fire	12	23	646
5	30	646	53	>646	No fire	13.5	53	>646
5	30	625	38	704	Flash	18	38	704
6	34	?	---	---	No fire	10	34	?
6	0	505	---	---	No fire	12	30	654
6	30	572	---	---	No fire	11	375	634
7	---	---	0	?	Fire	0.67	0	488
7	---	---	0	?	Fire	1.0	0	496
7	---	---	0	?	Fire	0.75	0	460
8	0	?	0	?	Fire	<0.5	0	389
8	0	330	0	330	Fire	1	0	330
8	0	?	0	?	Fire	<0.5	0	485
9	---	---	---	---	Blue Fire	6	37.5	>660
9	---	---	---	---	Blue Fire	9	37.5	645
9	---	---	---	---	No fire	17.5	45	>660
10	0	506	37.5	516	Fire - SE	6	37.5	877
10	0	613	37.5	793	No fire	9.5	37.5	802
10	0	549	---	---	No fire	10	38	818

(continued)

*The accuracy of the temperature measurements is questioned. - See text.

TABLE 25-1 (continued)

SUMMARY FLAMMABILITY TESTS IN 5 PSI OXYGEN

Heater Coil Energized - Test Type I

Wire #	Wire Discolors I Amps.	Wire Discolors Temp.* °C	First Heavy Smoke I Amps.	First Heavy Smoke Temp.* °C	Fire or Complete Degradation SE = self-extinguished Status	Time Min.	I Amps.	Max Temp.* °C
11	---	---	---	---	No fire	9	37.5	>61
11	---	---	45	803	No fire	12	49	>803
11	---	---	---	---	No fire	7	44	>928
12	---	---	0	273	Fire	5	37.5	480
12	---	---	0	?	Fire	0.33	0	550
12	---	---	0	?	Fire	<0.33	0	611
13	---	---	0	?	Fire	1.75	0	295
13	---	---	0	?	Fire	0.75	0	231
13	---	---	0	?	Fire	0.75	0	234
14	---	---	0	?	Fire	4	45	758
14	---	---	0	?	Fire	4.25	40	800
14	---	---	0	?	Fire	5.5	40	854
15	0	454	0	?	Fire	5.25	40	699
15	---	---	0	?	Fire	5.5	40	546
15	---	---	0	?	Fire	3.3	0	747
16	---	---	---	---	Fire	3.3	40	616
16	---	---	40	?	Fire	3.25	40	911
16	---	---	---	---	Glow	3.3	40	434

*The accuracy of the temperature measurements is question. See text.

TABLE 25-2

SUMMARY FLAMMABILITY TESTS IN 5 PSI OXYGEN

High Current - No Heater Coil Used - Test Type IIA

	Wire Discolors		First Heavy Smoke		Fire or Complete Degradation SE = self-extinguished			Max.
Wire #	I Amps.	Temp. * °C	I Amps.	Temp.* °C	Status	Time Min.	I Amps.	Temp.* °C
1	40	315(?)	45	503	Fire	7	44	1051
1	41	576	41	590	No fire	6.3	41	700
1	38	513	38	570	Fused-No fire	9.5	52.5	808?
2	40	435	45	549	No fire	8	46	>515
2	45	523	45	580	No fire	8	46.5	677
2	43.5	541	43.5	541	No fire	5.5	40	700
3	50	?	50	?	Glow	2.75	50	900?
3	50	?	50	?	Glow	2.75	50	900?
3	---	---	51	590	Flash	3.75	51	>590
4	40	393	---	---	No fire	9	45	655
4	41	395	---	---	Flash	8.0	45	673
4	45	615	---	---	No fire	5	45	>800
5	40	308	---	---	No fire	9	45	533
5	39	385	---	---	Flicker	10	45	520
5	40	340	---	---	No fire	10	45	560
6	40	?	---	---	Flicker	24	50	875
6	40	408	---	---	No fire	18	50	465
6	50	?	50	?	No fire	2.25	51	680
7	40	346	37.5	417	Fire - SE	4.75	45	402
7	39	364	38	439	Fire	2.5	37.5	676
7	40	?	40	445	No fire	6	45	718
8	---	---	40	?	Fire	1.5	40	680
8	40	?	40	?	Fire	1	40	445
8	40	?	40	?	Fire	1	40	545
9	---	---	---	---	Fused-No fire	11.75	49	>800
9	---	---	---	---	Fused-No fire	12.75	56	>800
9	---	---	---	---	No fire	5	45	765
10	40	?	40	>532	No fire	5.25	45	725
10	37.5	709	37.5	709	No fire	7.25	44	>1000
10	---	---	42.5	859	No fire	4	43.5	859

(continued)

*The accuracy of the temperature measurements is questioned. - See text.

TABLE 25-2

SUMMARY FLAMMABILITY TESTS IN 5 PSI OXYGEN

High Current - No Heater Coil Used - Test Type IIA

Wire #	Wire Discolors I Amps.	Wire Discolors Temp.* °C	First Heavy Smoke I Amps.	First Heavy Smoke Temp.* °C	Fire or Complete Degradation (SE = self-extinguished) Status	Time Min.	I Amps.	Max. Temp.* °C
11	40	470	45	611	No fire	8	46	706
11	40	554	45	682	No fire	6	45	682
11	40	510	43.5	646	Fused-No fire	9	52.5	>935
12	---	---	38	462	No fire	10	46.5	880
12	---	---	40	?	Fire	1.75	40	?
12	---	---	40	255	Fire	8	52.5	673
13	---	---	40	406	Fused-Fire	9.25	62	>844
13	---	---	40	301	Fire	1.7	40	488
13	---	---	40	390	Fire	1.3	40	457
14	---	---	38	368	No fire	11	51	7[illegible]1
14	45	558	45	301	Fused-No fire	9	52.5	>691
14	49	660	41	470	Fire	9	52.5	708
15	40	400	49	766	No fire	8.5	49.5	766
15	45	435	4[illegible]	550	Fused-No fire	5.3	60	856
15	44	614	44	607	Fused-No fire	5	60	920
16	---	---	45	506	Glow	9	60	871
16	---	---	45	837	Fused-fire	3.3	60	1193
16	---	---	46	628	Fused-No fire	2.3	60	968

*The accuracy of the temperature measurements is questioned. See text.

TABLE 25-3

SUMMARY FLAMMABILITY TESTS IN 5 PSI OXYGEN

Current Progressively Increased - No Heater Coil Used - Test Type IIB

Wire #	Wire Discolors I Amps.	Wire Discolors Temp.* °C	First Heavy Smoke I Amps.	First Heavy Smoke Temp.* °C	Fire or Complete Degradation (SE = self-extinguished) Status	Time Min.	I Amps.	Max. Temp.* °C
1	37.5	441	40.5	500	No fire	21	45	680
1	37.5	450	42.5	680	No fire	23	48.8	965
1	35	441	40	581	No fire	16.5	42.5	628
2	41	474	45	593	No fire	22	49	767
2	39	457	43.5	593	No fire	22	47	750
2	37.5	364	45	532	No fire	19	48	655
3	37.5	310	---	---	Fire-SE	23	47	715
3	---	---	---	---	Flicker	21	49	>800
3	37.5	288	---	---	No fire	19	46	>800
4	35	318	---	---	No fire	19	44	590
4	38	470	---	---	No fire	17.5	45	760
4	41	600	---	---	No fire	19	45	760
5	34.5	312	---	---	No fire	18.5	42	650
5	33	252	---	---	No fire	20	45	605
5	37.5	350	---	---	No fire	19.5	45	>512
6	37.5	435	---	---	No fire	22	48	>800
6	37.5	377	---	---	Fused-No fire	21	49.5	>800
6	37	453	---	---	No fire	22.5	50	>800
7	31	273	36	382	Fire	11	37.5	529
7	32	275	35	386	No fire	10	44	491
7	31	285	37	390	Fire	13.5	38	470
8	30	425	34	560	Fire	10.6	37.5	750
8	32	458	33	535	Fire	10.75	38	605
8	35	353	40	555	Fire	13	40	555
9	---	---	---	---	No fire	18	46.5	420?
9	---	---	---	---	No fire	19.25	45	620
9	---	---	---	---	No fire	19	45	758
10	32	465	---	---	Flash	17	43	960
10	34.5	502	---	---	No fire	17	43	901
10	33	437	---	---	No fire	18	45	754

(continued).

*The accuracy of the temperature measurements is questioned. See text.

TABLE 25-3

SUMMARY FLAMMABILITY TESTS IN 5 PSI OXYGEN

Current Progressively Increased - No Heater Coil Used - Test Type IIB

	Wire Discolors		First Heavy Smoke		Fire or Complete Degradation SE = self-extinguished			Max.
Wire #	I Amps.	Temp.* °C	I Amps.	Temp.* °C	Status	Time Min.	I Amps.	Temp.* °C
11	---	---	45	646	No fire	21.25	47.5	>726
11	---	---	44	496	No fire	21	48	817
11	---	---	45	580	No fire	20	49	664
12	---	---	32.5	283	Fused-No fire	35	63.8	>950
12	---	---	30	233	No fire	28	52.5	793
12	---	---	31	264	Glow	16.3	44	570
13	---	---	42.6	395	Fire	17.75	45	542
13	---	---	40	523	No fire	19	44	762
13	---	---	---	---	Fire	9.5	37	355
14	34.5	281	43	422	Fire	15.7	43	462
14	33	328	41	452	No fire	27	32.5	>900
14	34.5	359	43	532	Fused-No fire	23.5	62	>758
15	34.5	340	---	---	No fire	23.5	50	871
15	37.5	>317	---	---	Fused-No fire	20.5	56	901
15	35	386	---	---	No fire	20	45	621
16	---	---	45	692	No fire	21	49	790
16	---	---	45	654	No fire	22	47	744
16	---	---	---	---	No fire	18.5	49	744

*The accuracy of the temperature measurements is questioned. See text.

TABLE 25-4

SUMMARY FLAMMABILITY TESTS IN NORMAL AIR

Current Progressively Increased - No Heater Coil Used - Test Type IIB

	Wire Discolors		First Heavy Smoke		Fire or Complete Degradation SE = self-extinguished			
Wire #	I Amps.	Temp. °C	I Amps.	Temp. °C	Status	Time Min.	I Amps.	Max. Temp. °C
7	33	355	---	---	Fire	7.5	37.5	522
7	33	283	---	---	Fire-SE	6.5	37.5	>355
8	---	---	30	228	Fire	6.75	32.5	300
8	---	---	---	---	Fire	2.75	30	?

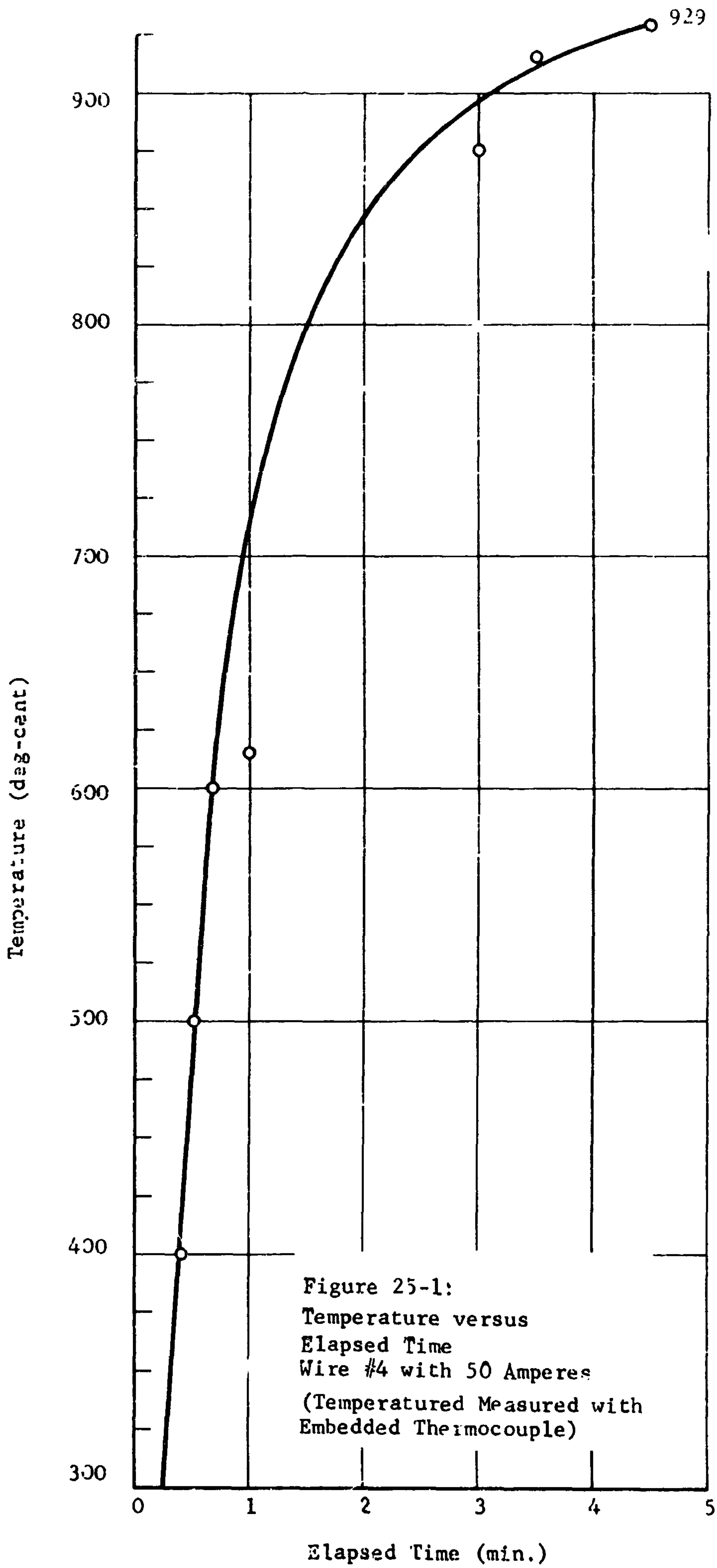


Figure 25-1:
Temperature versus
Elapsed Time
Wire #4 with 50 Amperes
(Temperatured Measured with
Embedded Thermocouple)

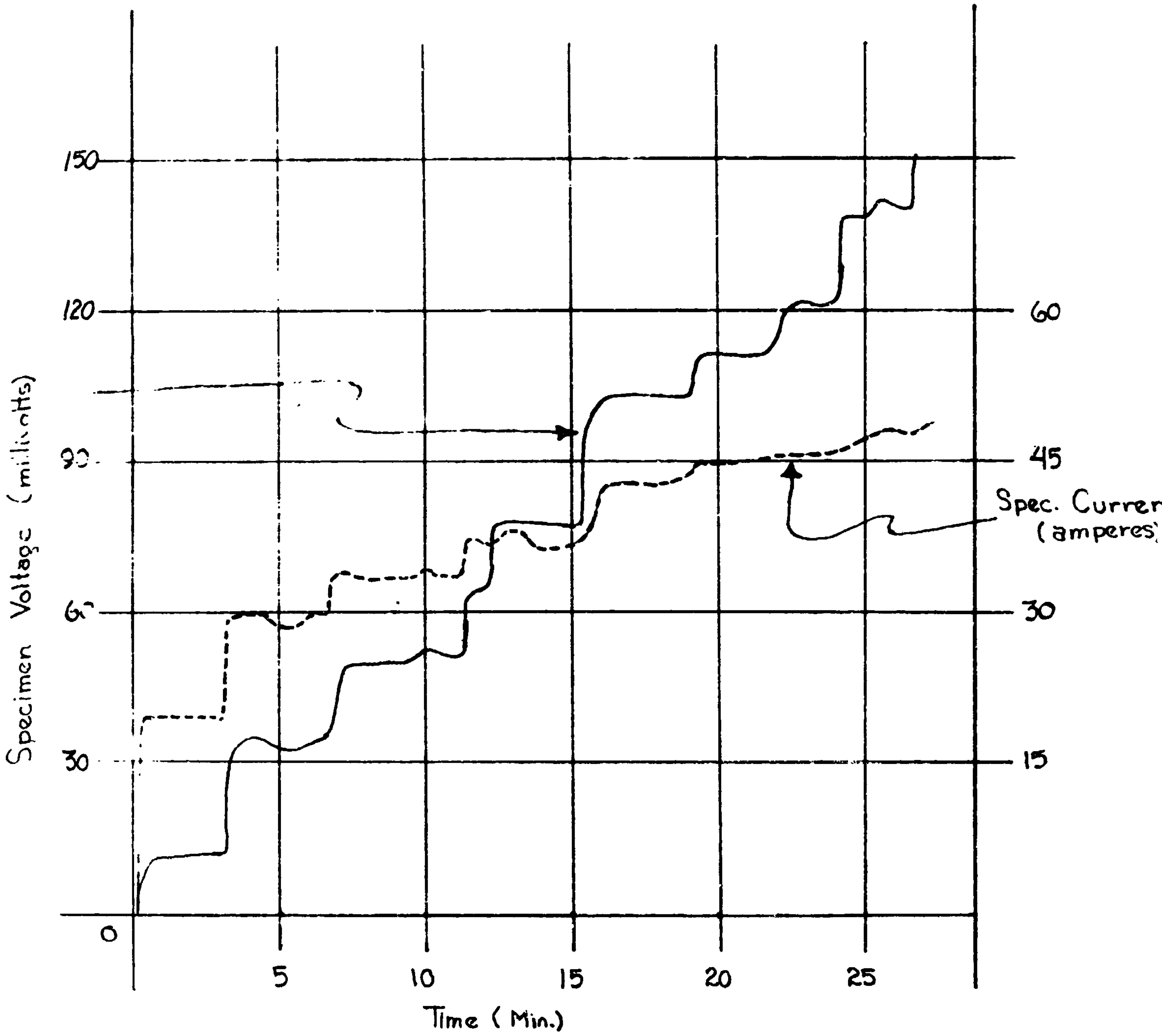


Figure 25-2: **Typical Chart of Current and Voltage Drop versus Elapsed Time**
Test Type IIB

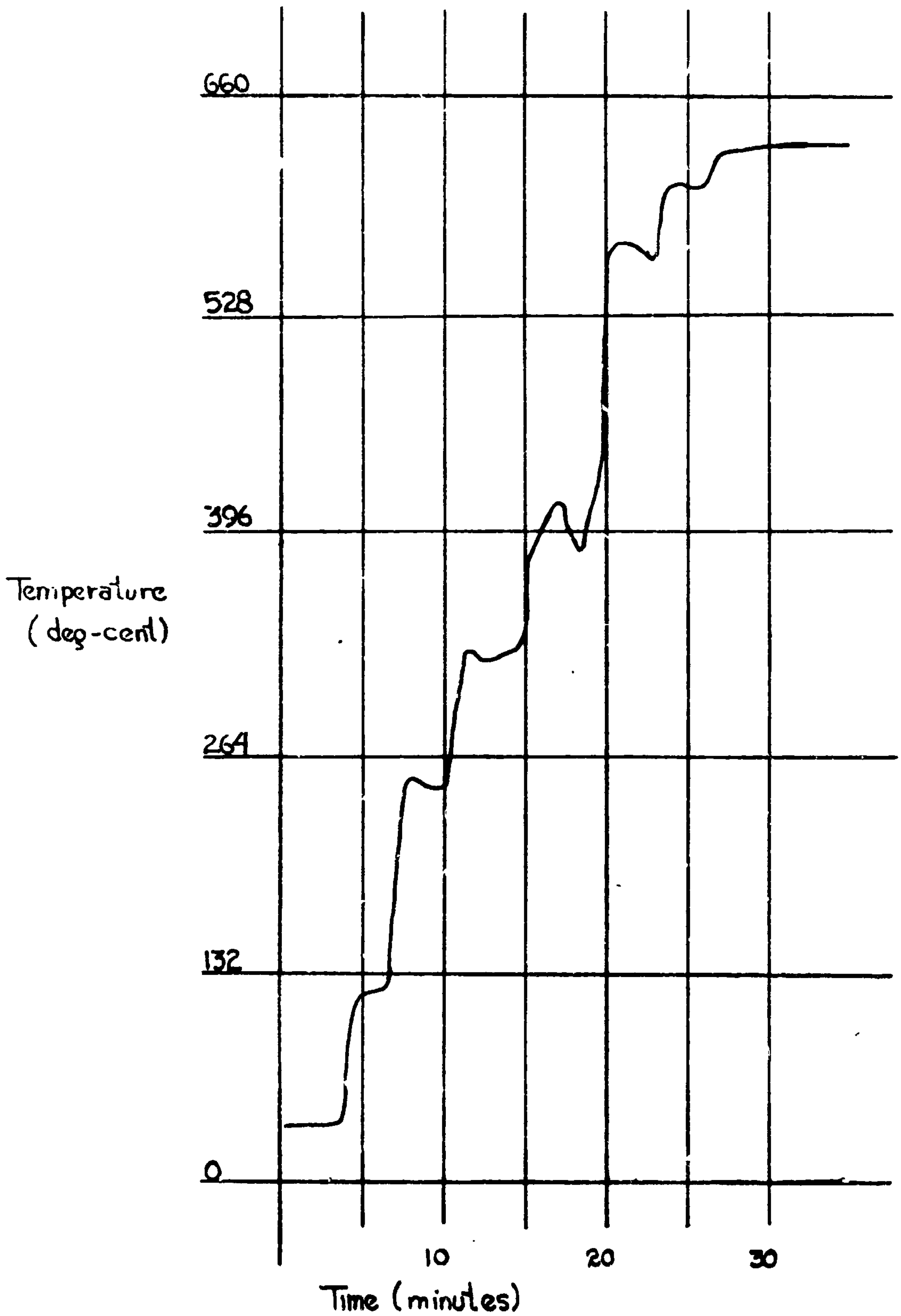


Figure 25-3: **Chart of Temperature versus Elapsed** Time for the Test Described in Figure 25-2. Test Type IIB.

Figure 25-4 - Flaming TFE Teflon Insulation Wire #9 in 5 PSIA Oxygen.
The Teflon Burns Completely

Figure 25-5 - Flaming Polyolefin Insulation Wire (#8) in 5 PSIA Oxygen

Wire No. 1 (1-I-1)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start			
0.5		500	
1.5		635	Insulation directly under coil completely destroyed-- bare wire showed--very little smoke
10	37.5		
10.25		850	Heavy smoke--insulation fell on incandescent wire did not ignite
13	Off	870	

Wire No. 1 (1-I-2)

Chamber Pressure - 254
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start			
0.25		543	Beads of FEP (?) formed on wire
1		573	Discolored
1.5		573	
2		570	Darkened
3		570	
4		568	
5.45		550	
5.5	37.5		
6			Heater coil failed
6.25	51.6		Very heavy smoke Insulation stripped off, wire glowed

Wire No. 1 (1-I-3)

Chamber Pressure - 254
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start			
0.5		475	Beads of FEP (?) formed on wire
1		522	Discolored
2		493	
3		514	
4		508	
4.5		496	
5	37.5	510	Fire--self extinguished
6	37.5	870	Wire glowed
7	Off		

Fire started near the top of the incandescent heater coil, progressed upward and extinguished itself rapidly.

Wire No. 2 (2-I-1)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start			
0.5		567	
1		562	
2		564	
3		562	Discolored
5		532	Temperature recorder became erratic
6		505	Temperature recorder became erratic
6.5	40		
7	36	800	Very dark
8	39	745	Section enclosed by coil completely bared--when section fell off it struck the incandescent coil, flashed but did not burn
9	37.5	745	Bare section progressed up wire--insulation melted
10	37.5	745	
10.25			Thermocouple failed
10.5			Wire glowed brightly
11	42		Bare section progressed both up and down
12	Off		

Wire No. 2 (2-I-2)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start			
35 sec.		346	
1.5		462	
2.5		452	
3		500	
4		514	Insulation enclosed by coil disappeared
5	37.5		
5.25	37.5	744	Heavy smoke
5.5	37.5	835	A glow developed in the insulation immediatel above the heater coil. This smoldering fire traveled rapidly up the insulation without flaming. When it extinguished attempts were made with the spark gap to reinitiate the fir but these proved fruitless.

Wire No. 2 (2-I-3)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed time (min.)	I (amperes)	Temp. (^oC)	Remarks
Start			
25 sec.		479	
1		514	
2		508	
3		510	
4		510	
5		514	
6	40		Insulation stripped off the wire quite rapidly--Bare conductor sagged against the heater coil. There was a flash and most of the insulation
		709	was destroyed. The heater coil melted.
8	Off		

Wire No. 3 (3-I-1)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I* (amperes)	Max. Temp. (°C)	Remarks
Start		489	The wire temperature increased to 489C and held -- spark gap energized periodically
2.5			A flash occurred -- extinguished immediately
5		568	Temperature increased to at least 568C when current was passed through the wire -- specimens charred and shriveled -- bare sections of wire show where the insulation had flaked off
11	Off		No fire -- insulation destroyed around entire center section

*In this first test, current was applied after five minutes of test but was not recorded as it was in the tests to follow.

Wire No. 3 (3-I-2)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start		528	The wire temperature increased to 528C within 30 sec. -- no visible effect
3.5			Some slight darkening
5	28.5	>600	Temperature increased to greater than 600C -- the wire sagged against the heater coil
15	33.8		White smoke appeared then disappeared almost immediately
25	33.8		Specimen was badly damaged near the coil area
25	Off		

Wire No. 3 (3-I-3)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start			Coil temperature was raised to indicate 489C then rose slowly to 504C
2		504	Slight darkening
5	26.2	600	
6			Wire insulation is black and blistered with white deposit on insulation inside coil
8			Flickering occurs at spark gap
10			Off

Wire No. 4 (4-I-1)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start			Temperature increased to 489C and then overshot to 528C. Heater voltage was reduced slightly
2.5		492	
2.75			Discoloration
4.5			Electrode burn-off
5.5	24	603	
7			Insulation quite dark, beads form on surface
8		580	
9	21	566	
10	26.2	624	
11			Electrode burns off*
13			Temperature is greater than 660C flashes appear on heater coil
15	Off		Insulation completely removed from the center of the specimen

*Apparently volatilized material deposits on the spark-plug electrodes, sparks and burns off. The spark does not propogate and the gases do not burn. This phenomenon occurred in many of the tests to follow.

Wire No. 4 (4-I-2)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start			
1			Temperature increased to 490C in 20 sec.
1.5			Electrode burn off
3		475	
5.25	30	620	
5.75	26.2	655	
6			Specimen very dark
7		634	
.25			Flicker at spk. gap electrode
8	26.2	600	
9	30	660+	
10			Bare spots on conductor show
11	Off		

Wire No. 4 (4-I-3)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start			Temperature increased to 489C in 45 sec.
1		497	
2		499	
4		490	
5		483	
5.5	23.2	640	
6			Specimen very dark
6.5			Insulation black, but intact
7.5		623	Temperature varys
8			Insulation removed from the wire
8 min. 22 sec.	Off	644	No flashing at electrodes -- no smoke, insulation removed near center of wire

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Max. Time (°C)	Remarks
Start			Temperature reached 528C in 35 sec.
1		539	
2		540	
3		541	Slight discoloration
4			Shrinking about area surrounded by coil
8			No spark gap reaction
9			Very dark, but intact
10	22.5	646	
11			Specimen still in fair physical shape
12	Off		Beads formed around insulation

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Max. Temp. (^oC)	Remarks
Start			Temperature reached 488 in 25 sec. overshot to 527C. Heater coil voltage reduced
1		488	
2.5			Little discoloration
3		486	
5.5	30.7	646	
6			Insulation darkening
6.5	30	634	
6.75			Shrinks
7.5	28.5	625	
8	31.5	646	
8.75			Take wrap lossens
10			Immediately adjacent to upper part of heater coil there is bubbling on surface
10.5			No reaction to spark
11			Thermocouple leads have failed
12			Insulation strips away from specimen
12	42.7		Smoke -- wire glows
13.5	52.5		Wire became brilliant and melted, some smoke present, no ignitable products -- insulation almost completely gone -- no flame

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start			Temperature reached 495C in 15 sec.
1		528	
4		489	
5.5	30	625	
6			Specimen darkens
7			Very dark -- shrinking
7.5	30	614	
9.5			Beads form between wraps below coil -- not bubbling
12		601	
13	37.5		
13.5		704	Bubbles at wraps
15			Insulation flakes off
18			With the current in the specimen at 45 amperes the temperature increased to approx. 810C. Smoke and vapors appeared which flashed in the spark gap but were not affected by the now incandescent heater wire -- self extinguishing when the spark gap was de-energized
18.3			Insulation was almost completely destroyed -- test off

Wire No. 6 (6-I-1)

Chamber Pressure - 242 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start	0	482	Wire temperature increased rapidly to 482C no effect on wire surface
5	33.8	*	Darkening of insulation
6			Shrinking inside of coil, spark gap caused no ignition of off-gassing products
10	Off		

A whitish material flowed around a thermocouple lead and solidified

*Thermocouple broke before temperature could be measured.

Wire No. 6 (6-I-2)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil Energized

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start			Wire temperature increased with heating coil to 505C
2		505	No apparent surface effect
4			Discoloration around center of wire
5	26.3		
6		594	
7			Quite dark near center
7.75			One flash when spark gap was energized
8		600	Very dark near center
9			Almost black at the center
10	30		
11		646	
12	Off	654	Black at center

No smoke, no flame, apparent deposit burned off electrode when spark gap was energized. After the test there were whitish drops on the insulation surface.

Wire No. 6 (6-I-3)

Chamber Pressure - 267 mm.
Current - As Specified Below
Heater - Energized

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start			Temperature reached 490C in 25 sec.
3		496	No reaction to spark plug
5	30		
6		572	
6.5			Insulation discolored
6.75	37.5		
7.5		626	Insulation black, electrode burned off some deposited material
9	37.5	634	
10.5			Insulation sagged
11	Off		

Beads of a whitish material appeared around the wire near the area of the coil.

Wire No. 7

(7-I-1)
(7-I-2)
(7-I-3)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
40 sec.	0	488	Spec. 7-I-1 Fire -- continued to burn
62 sec.	0	496	Spec. 7-I-2 Fire -- continued to burn
45 sec.	0	462	Spec. 7-I-3 Fire -- continued to burn

Wire No. 8 (8-I-1)

Chamber Pressure - 228 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	None	389	With 7V applied to the heater coil the wire temperature rose quickly to 389 C. Ignition spark started a fire which continued with the spark gap de-energized. Temperature continued to climb until it reached 567 C.

Wire No. 8 (8-I-2)

Chamber Pressure - 228 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start			
0.5		330	Specimen darkened
1.			Spark gap was energized and specimen started to burn and continued to burn although the heater coil and the spark gap were de-energized. Temperature climbed rapidly to >650 C.

Wire No. 8 (8-I-3)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (^oC)	Remarks
Start			
0.25			Specimen darkened
<.50		485	
			The temperature increased to 485 C, when the spark gap was energized at 25 sec., the whole specimen blazed and continued to burn with the coil power and the spark gap de-energized.

Wire No. 9 (9-I-2)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start			
1		264	Insulation swelled
2		438	
3		488	
4			A section of insulation fell away--exposing a fresh section--the wire insulating appeared as an outer skin had fallen off.
5		482	
6	37.5	>660	

Temperature increased to greater than 660C. When the spark gap was energized a very blue flame appeared and progressed up the insulation. The flame was quite like a hydrogen flame in color and general appearance and was not extinguished until all three sources of heat were de-energized. Small bright sparks accompanied the burning gas.

Wire No. 9 (9-I-3)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start			Temperature increased to 488C in 15 sec.
0.5		528	
1.5		541	
2			Conductor has sagged against heater coil
3		535	
4.5			Several turns of heater coil shorted by sagging conductor, temperature increased to >650C
5.75			Shorted turns opened and temperature decreased
6.5	27		Current was passed through wire
7		653	
7.5			Insulation stripps away
8	24.8	645	
8.5	37.5		
8.75-9.25			Insulation stripped away and shreds fell on incandescent heating coil. Spark gap was energized and a very blue flame resulted and progressed down the insulation until all sources were removed.

Wire No. 9 (9-I-4)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start			Temperature reached 489C after 0.5 min.
2-4			Spark gap causes no reaction, temperature has increased to 531C
5	32.5	581	Electrode burns off, Insulation splits
7.5	35	660	
9	37.5	>660	Insulation strips badly
12	40		Insulation hangs in shreds
15	42.5		Entire center section is bare -- pieces of hanging insulation are melting
17.5	45		Within 30 seconds the conductor melted -- no fire resulted

Spark gap showed some burn off -- but no fire or flame resulted.

Wire No. 10 (10-I-1)

Chamber Pressure - 254
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start			
27 sec.		479	
.75		506	
1.25			Beads formed near heating coil
2		506	Darkened
4		506	
5	37.5	516	Smoke formed almost immediately Small fire observed at upper end of coil but extinguished almost immediately
6		877	Most of insulation disappeared -- wire glowed
6.25	Off		

The spark gap did not ignite the smoke nor did it restart the fire.

Wire No. 10 (10-I-2)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (ampere)	Temp. (°C)	Remarks
Start			
27 sec.		546	
1.5		613	
2		613	
2.25			Bead formed near the top of the ccil
2.5			Insulation darkened near the coil
4		611	
5	37.5		
5.25		785	Very dark
5.5	33.8	802	Charred -- bare wire glowed
6.5	30.6	745	
7.5	37.5	793	Smoke
8.5	36	793	Smoke disappeared
9.5	36	772	Off

Much of the wire was bare.
Unwrapping was apparent on specimen near terminal blocks.

Wire No. 10 (10-I-3)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (ampere)	Temp. (°C)	Remarks
Start			
1		549	Discolored
2			Insulation unwrapped -- bead formed
3		546	
4		479	
5	37.5		
5.5			Unwrapped badly Wire glowed
6		691	Black
6.5		797	
7	36	818	
8	34.5	807	
9	38.2	797	
10	Off		Heater coil failed

Fairly heavy white deposit was observed in the chamber after type I tests with no. 10 wire.
Most of wire bared.

Wire No. 11 (11-I-1)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (^{o}C)	Remarks
Start			
35 sec.		510	
1.25		541	
1.5			Blistered near coil
2		541	
3		533	
4		536	
5		532	
5.25	37.5		
5.5			Badly blistered Insulation fell off
6	33.8	700	
6.25			Much bare wire -- glowed brightly
6.75	37.5	758	
7.5	36.8	761	
8.5	37.5	761	Center insulation completely disappeared
9	Off		

Wire No. 11 (11-I-2)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start			
23 sec.		628	
1		691	
1.75		646	
2		645	
3		633	
4		620	
5.25	37.5	613	
5.5		790	Blistered
5.75			Insulation melting and falling away
6		767	
6.75	36	778	
8	38	803	Insulation fell away from heater coil -- wire glowed
9	45		
9.5			Thermocouple failed wire very bright, smoke formed
10.5	48.8		Wire glowed brightly Insulation almost completely destroyed
12	Off		

Wire No. 11 (11-I-3)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start			
1.5		647	Blistered
2		647	Blistering continued
4		628	
5	40		
5.25		790	
5.5		>928	
5.75	44		Wire glowed -- insulation stripped of
7	Off		

Almost all of insulation was destroyed.
Pieces which dropped off onto incandescent coil did not burn.

Wire No. 12 (12-I-1)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start			
25 sec.		273	Smoke
1		391	
1.5			Heavy white deposit
2		408	
2.5		429	Smoke -- disappeared
3.5		470	
4		468	
5	37.5	480	Very heavy smoke observed immediately, flame was initiated by the incandescent coil and continued after the coil was de-energized.

Wire No. 12 (12-I-2)

Chamber Pressure - 254
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start			
0.33		550	Burned -- completely destroyed

Wire No. 12 (12-I-3)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start			
<.33		611	Burst into flame -- temperature had increased to 611C

Wire No. 13 (13-I-1)

Chamber Pressure - 254 mm.
Current - See Footnote*
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (^oC)	Remarks
Start			
27 sec.		283	Kynar jacket shrunk
1		295	
1 min. 42 sec.		295	Fire initiated by spark gap

Wire No. 13 (13-I-2)

Chamber Pressure - 254 mm.
Current - See Footnote*
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (^oC)	Remarks
25 sec.		216	Kynar jacket shrunk
42 sec.		231	Fire initiated by spark gap

Wire No. 13 (13-I-3)

Chamber Pressure - 254 mm.
Current - See Footnote*
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (^oC)	Remarks
50 sec.		234	Fire initiated by spark gap

*Specimens all failed before period when current would have been applied.

Wire No. 14 (14-I-1)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start			
0.25		611	
1		496	
1.5		532	
3		532	
4	45	758	Fire within 10 sec.

Wire No. 14 (14-I-2)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start			
1		462	White deposit formed on electrodes and upper part of test specimen
2		466	
3		466	
4	40		
4.25		800	Fire
4.5			Fire extinguished
5.25	37.5	769	Fire
5.4	45	860	Fire extinguished
	Off	860	

Wire No. 14 (14-I-3)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start			
1		496	
2		496	
3		488	
5		532	
5.25	40		
5.5		854	Fire -- insullation burned

Wire No. 15 (15-I-1)

Chamber Pressure - 254
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (^oC)	Remarks
Start			
1		355	
2		454	Dark brown color around heater coil
4		433	
5	40		
5.25		699	Fire started at bottom of heater coil when heater coil fused. The flame traveled down the wire for a short distance before being extinguished.

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start			
0.5		300	
1		369	
1.5		390	
2		371	
3		409	
3 min. 50 sec.		419	Very small fire started when specimen sagged against upper turn of incandescent heater coil. It went out almost immediately.
5	40	419	
5.5		546	Fire started again at upper end of the heater coil and progressed upward a short distance before being extinguished.

Wire No. 15 (15-I-3)

Chamber Pressure - 254
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start			
.5		371	
.75		412	
1.5		492	
2		492	
2.5		492	
3		492	
3 min. 20 sec.		747	Insulation burned with first blue and then a yellow flame.

Wire No. 16 (16-I-1)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start			Blisters formed immediately
0.5		300	
1		390	
2		480	
2.5		487	
3		506	
3.25	40		
3 min. 20 sec.		616	Fire - a blue and yellow flame progressed upward along the wire.

Wire No. 16 (16-I-2)

Chamber Pressure - 254 mm.
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start			
0.5		372	
1		372	
2		372	
2.5		372	
3	40		
3.25		911	Smoke - blistered Wire fused when temperature reached 911C - no flames were observed although a glowing fire progressed up the specimen.

Wire No. 16 (16-I-3)

Chamber Pressure - 254
Current - As Specified Below
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start			
1		300	
2		410	
2.75		417	
3	40		
3 min. 20 sec.		434	Wire fused -- no flame resulted although a glowing fire progressed up the specimen.

A wrapped layer of film loosened and came off in spirals along with the residue of the dispersion coating which remained bonded to the H-film.

A very strong, acrid odor was evident when the test chamber was opened. A white deposit had formed in the chamber.

Wire No. 1 (1-IIA-1)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	40		
0.5			Beads of FEP (?) formed on wire
1	39.8	315	Discolored
4	39.8	515	
5	38.2	503	
5.25	45		
5.75			Heavy smoke - dripped
6		794	
6.25	43.6		Wire glowed red -- insulation black, flaked
7		1051	Flamed -- wire very bright yellow
9			Off

Wire No. 1 (1-IIA-2)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	42.5		
0.5	41.3	391	Beads of FEP (?) formed on wire
1	41.3	576	Discolored
1.25		590	Smoke
1.5			Insulation black and swelled
2	42	620	Heavy smoke
3	39.8	584	Smoke stopped
4	41.3	624	
5		610	
5.75			Heavy smoke
6.20		700	Wire glowed -- insulation in shreds.

Wire No. 1 (1-IIA-3)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	42.5		
0.5	36	320	Beads formed
1	38.3	513	Swelled
1.25			Darkened
1.75	37.5	502	
2			Smoke
2.5	38.6	570	
3.5	38.3	561	Black, shrunk
4.5	40.5	613	Heavy smoke
6.5	39	595	
7.5	41.9	620	
8	45		
8.5		808	Wire glowed, insulation flaked off
9.5	52.5		Wire fused -- no fire

After all 1-IIA tests a white deposit covered the upper parts of the test chamber.

Wire No. 2 (2-IIA-1)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (^oC)	Remarks
Start	40		
0.5		283	
1	38.2	364	
2	39.8	435	Darkened
3	39	435	
4	39.8	417	
5	45		
5.5			Unwrapped
5.75			Smoke
6	46.5	549	
6.25		515	Wire glowed
7	45.8		Insulation unwrapped and fell off
7.5			Thermocouple reading erratic
8	Off		

Much of center section (2") was bare.

Wire No. 2 (2-IIA-2)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	45		
0.5		355	
1	45	523	Darkened
1.25			Very dark
1.33			Smoke
2	45	580	Smoke disappeared
2.5			Smoke again
3	45.8	597	
3.75			Wrap shriveled
4	45	592	Smoke disappeared
5	43.5	566	
5.25	48.8		Wire glowed immediately
5.75	48.8	664	
6.33			Dripped Unwrapped - flaked and fell off
7	46.5	677	
7.5			About 2 in. of center section bare -- glowed red
7.75	46.5	673	
8	Off		

Wire No. 2 (2-IIA-3)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	45		
0.5		364	
1	43.5	541	Discolored -- shriveled
1 min. 5 sec.			Smoke -- very dark
1.5	45.8	620	
1.75			Heavy smoke
2	45	584	A little smoke
2.25		589	Dripped
2.75			Wire glowed
3	45.8	651	
3.5			Dripped -- bubbled
4	43.5	620	
4.5			Bared area grew larger Insulation fell off
5	46.5	700	
5.25			Upper part unwrapped
5.5	45.8	691	About 2 in. completely bare Glowed
	Off		

A white deposit in the chamber was noticed after all IIA and IIB tests on this wire.

Wire No. 3 (3-IIA-1)

Chamber Pressure - 267 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start	50		
12 sec.	50		Shrinks
20 sec.	50		Melts
30 sec.	50		Flashes at spark gap
40 sec.	50		Flashes at spark gap
1	51	590	
1 min. 20 sec.	51		Smoke
1 min. 30 sec.	51		Conductor glows red
1 min. 45 sec.	51		Flashing at spark gap
2 min. 35 sec.	51		Insulation falls off
3 min. 40 sec.		Off	

White powder deposited -- some acrid odor from decomposition products was noted.

Wire No. 3 (3-IIA-2)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Max.* Temp. (°C)	Remarks
Start	50		
25 sec.	50		Shrinks
29 sec.	50		Swells
40 sec.	50		Insulation melts
56 sec.	50		Chars
66 sec.	50		Smoke
1 min. 25 sec.	50		Flashes at spark gap
1 min. 30 sec.	50		Conductor glows red
1 min. 45 sec.	50		
2 min.	50		
2 min. 45 sec.	50		Yellow flame -- self ignited appears as a glow in pieces of insulation separated slightly from the conductor

*Temperature rose too rapidly to be recorded accurately. Maximum temperature at the conclusion of the test is about 900°C.

Wire No. 3 (3-IIA-3)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp.* (°C)	Remarks
Start	50		
20 sec.	50		Black
55 sec.	50		Smoke
1 min. 10 sec.	50		Much smoke
2 min.	50		Insulation almost entirely gone at this time
2 min. 50 sec.	50		Insulation glows and appears to burn at intervals

During these tests a very distinctive acrid odor was noticed.

*Temperature rose too rapidly to be recorded accurately. Maximum temperature at the conclusion of the test is about 900°C.

Wire No. 4 (4-IIA-1)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start	40		
4	40.5	395	Slight darkening
7	45		
7.5	45		Increased darkening, bright flashes appear when spark gap is energized
8.0		673	
8.5	46.4		
10	Off		Wrap is coming off

Wire No. 4 (4-IIA-2)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	40		
0.5		393	
1	40		Discoloration of surface
2	40		Increased darkening
2.5		510	
4		510	
5	45		No reaction to spark discharge
5.5	45		Very dark -- swelling
5.75	45		Unwrapping of surface
6.5		620	
7.5	45		Wrap opens to expose bare conductor at upper section
8	45		Insulation flakes off
9	Off	655	Insulation continues to flake off until test is concluded

Wire No. 4 (4-IIA-3)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (^{o}C)	Remarks
Start	45		
1	45	685	Very dark -- unwrapping no gap reaction to spark discharge
2	43.5	725	
2.5	44.2	750	Shrinks where drop leads are attached
3			Pressure decreased to 127 mm.
5	45	>800	Insulation almost completely destroyed at center of the specimen

Whitish deposit on the terminal blocks was noticed after all tests on this type wire.

Wire No. 5 (5-IIA-1)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (^{o}C)	Remarks
Start	40		
.5		225	
0.75			Darkens
1	40.1	308	Shrinks
5	40.9	475	Continues to darken
5.25	45		
5.5	45	490	Very black, starting to unwrap
6			Insulation is very black, shrunken badly, no flaking and seems not to unwrap further
7.5	45	533	Unwraps at bottom section
9	Off		White deposit on specimen terminal blocks

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start	40		
0.5	39.4	385	Darkens
1.5	39.2	402	Shrinks
2		410	
2.5			Very dark -- starting to unwrap
3	39.7	395	
4		430	
5	40.1	435	
5.25	42.5		
6	42.8	520	Very black -- starting to swell -- continues to unwrap
7		508	
7.5	45		Drop lead broke
9			Flickers at spark gap electrodes
10	Off		

Whitish deposit on specimen terminal blocks. Beads of material formed on surface of the insulation.

Wire No. 5 (5-IIA-3)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Energized

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start	40		
1	39.7	340	Darkens
2	39.8	380	Shrinks
4	40.4	380	Wrap loosens
5	42.5		
5.5	42.4	468	Very dark -- unwrapping
7.5	45		
8		560	
8.25			Wrap loosens badly -- conductor glows
9	45	560	Spark gap -- no reaction
10	Off		

Wire No. 6 (6-IIA-1)

Chamber Pressure - 254 mm
Current - Steady
Heater - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start	40		
1	40		Darkens - drop leads failed
3.5	40		Shrinks
13	40		Wire quite dark nearer center
15	42.5	*665	No change
17.5	45		No change
20	47.5	*875	No change
20.5			Appears to shrivel
20.75			Drips
21			Bare wire shows
21.5			Spark discharge ignites a by-product
23	50		
24			Off

No flame at any time - apparently the FEP melts and allows the H-film to unwrap.

*Maximum temperature has been estimated from current-temperature plot.
Voltage drop leads burned off.

Wire No. 6 (6-IIA-2)

Chamber Pressure - 242 mm.
Current - Steady
Heater - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start	40		
2			Center portion and lower portion darkens - no reaction to spark discharge.
5	40		Continues to darken.
6.5	39.8	408	
7.5			Very dark.
9.0	42.8	477	
12	43.4	473	
15	42.7	465	
17	50		Very black - starts to drip - bare wire shows through dripping area - no reaction to spark discharge
18			Off

No flame, no reaction to spark discharge.

Wire No. 6 (6-11A-3)

Chamber Pressure - 254 mm
Current - Steady
Heater - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start	50		
0.33	50		Center darkens.
55 sec.	50		Smoke
1 min. 25 sec.	50		Shrinks - very black
1.5	51		
2		680	Insulation flakes off - very black
2.25			Wire glows.

No flame, no reaction to spark discharge. After each of the three tests, a white powdery deposit was noticed around the upper block of the specimen holder.

Wire No. 7 (7-IIA-1)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	40		
0.5	39.8	346	
.75		390	Discolored
1	37.5	417	Smoke
1.5			Heavy Smoke
2.5	39.8	505	
3			Much of wire bare, insulation melted, some hanging in shreds
4	38.2	462	
4.5	45		
4.75			Very heavy smoke Flame -- self extinguished
5.5	45	611	
5.75			Off Insulation almost completely removed from specimen

Wire No. 7 (7-IIA-2)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	40		
0.5	39	364	Discolored
1	38.2	439	Ins. black - heavy smoke
1.5			Ins. melting
2	37.5	435	
2 min. 25 sec.		676	Caught fire and continued to burn

Wire No. 7 (7-IIA-3)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	40		
0.5	39.8	206	
55 sec.			Discolored
1.25			Brown
1.5			Bubbled
1.75			Very dark
2		445	Smoke
2.5			Black
5	45	460	Immediately very dense smoke -- almost entire chamber filled -- very difficult to see
6	Off	718	Wire almost completely bare

Wire No. 8 (8-IIA-1)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	40		
55 sec.			Smoked
1 min. 25 sec.		680	Flamed and continued to burn

Wire No. 8 (8-IIA-2)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	40		
0.75			Darkened -- insulation split away near voltage drop leads
1	40	445	When spark gap was energized, specimen burned

Wire No. 8 (8-IIA-3)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	40		
0.5			Insulation shrunk
0.75			Darkened and sagged (not dripping)
50 sec.			Very black
1		545	Fire ignited by spark gap

Wire No. 9 (9-IIA-1)

Chamber Pressure - 254 mm. O_2
Current - Steady
Heater - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start	40		
1	37.5	325	Shrinks
5	40.1	425	Electrode burnoff.
6.0	45		
6.5	45	532	Rapid shrinking
6.75			Insulation splits.
8			Insulation slipped and rests on lower drop lead.
9	43.1	560	Conductor glows.
10.25	48.8	>800	Conductor glows brightly.
11.75			Conductor melted No flame - test off

The insulation first shrunk from around the area split to receive the drop leads. As the temperature increased, the insulation split longitudinally and slipped down the conductor until it was stopped by the lower drop lead. It finally split away until the entire 1 inch center section was bare, meanwhile the insulation split above and below the drop leads until the conductor melted. The spark discharge indicated that a residue was formed and this "burned off" the electrodes when energized. There was no apparent smoke or falme at any time.

Wire No. 9 (9-IIA-2)

Chamber Pressure - 254 mm. O_2
Current - Steady
Heater - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start	40		
1	39.4	485	Shrinks
1.25			Electrode burn-off
6	45.8	612	Rapid shrinking Insulation splits
7	43.5		Insulation slipped
7.25			Insulation falls off, conductor has a dull red glow
8		745	
8.5	44.6		Wire glows brightly
9	45.4	>800	Insulation is in shreds - spark discharge still indicates burn-off, no flame
10.75	48.8	>800	Insulation melts away from upper part
12	54	>800	Wire very brillant - insulation is almost completely gone for entire length except near terminal blocks.
12.75	56.2	>800	Conductor melted - no flame

The insulation reacted very similar to the first replicate. Current was increased until the conductor melted. At failure there was no smoke or flame.

Wire No. 9 (9-IIA-3)

Chamber Pressure 254 mm. O_2
Current - Steady
Heater - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (^oC)	Remarks
Start	45		
25 sec.	45		Shrinks
0.5	44.2	440	
1.0		598	
1.13			Splits around center
1.75	45	665	
2			Shrinks
2.5			Center slipped down
3	44.2	705	Insulation falling off - conductor shows red - bare spots.
3.75		740	
4.5	45		Insulation continues to split and fall off - no flame
5			Off

This specimen was tested with a constant current of 45 amperes which would produce a temperature of 765^oC at the center of the conductor. From the previous two tests at steady current condition, it was apparent that rapid degradation of the insulation would occur.

Wire No. 10 (10-IIA-1)

Chamber Pressure - 254 mm.
Current Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (^oC)	Remarks
Start	40		
.25			Black in color
<1			Smoked
1.25			Insulation bubbled
1.5	39.7	532	
2	40.5	522	
2.75			Wire glowed
3	40.5	593	Insulation flaked off leaving large bare areas
4	40.5	607	
4.5	45		
5.25	Off	725	Entire center part of wire bared

Wire No. 10 (10-IIA-2)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (^oC)	Remarks
Start	40		
1	37.5	709	Smoked -- insulation almost black in color -- smoke not ignited by spark gap
2	38.6	745	"Beads" formed on insulation
2.5			Smoked
3	39	754	
3.25			Smoke disappeared
4	39.8	812	
5	39.8	817	Black -- insulation flaked
5.25	45		Wire glowed -- smoke
6	44.2	>1000	
7.25	Off		Entire center section of wire was bared

Wire No. 10 (10-IIA-3)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	42.5	859	Heavy smoke started almost immediately -- it would not ignite -- current shot up to 48.7 amps momentarily
2.5	43.5	790	Insulation charred and flaked off very rapidly -- conductor glowed very red -- no fire
4	Off	766	

After all tests with wire no. 10 there was a slight whitish deposit on all the upper components of the chamber.

Wire No. 11 (11-IIA-1)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	40		
0.5			Teflon shrunk rapidly exposing H-film underneath
3	39.8	470	H-film turned very dark in color where exposed to the oxygen atomosphere
4	40.5	536	
5	40.5	549	
5.5	45	576	Blisters formed on surface
6	45	576	Badly blistered
6.75			Smoked
7	45.8	611	Insulation fell off -- wire glowed -- smoked
8	Off	706	Center part of specimen completely bared

Wire No. 11 (11-IIA-2)

Chamber Pressure - 254 mm.
Current Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	40		
35 sec.		421	Teflon shrunk
1	40	479	
1.25		554	Exposed H-film became very dark
1.75	40	557	
2			Blistered
2 min. 5 sec.		549	
3	39.8	549	
4.75	40.5	558	
5	45		
5 min. 10 sec.		673	Glowed
5.5	45	682	Smoked -- insulation fell off
6	Off		

Wire No. 11 (11-IIA-3)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (^oC)	Remarks
Start	40		
1	36.8	415	
1.25			Teflon shrunk
2	40.5	510	H-film darkened
3	39	488	
4	40.5	519	
5	40.5	523	Small blisters formed
5.5	45		
6	44.2	642	Large blisters formed
6.25	43.5	646	Insulation split -- smoked Exposed wire glowed dully
7	45	726	
7.5	44.2	740	Bright glow observed
8	45	763	
8.5	52.5	>935	Heavy smoke -- very bright glow
9	Off		Almost all of insulation destroyed -- wire fused -- no fire resulted

Wire No. 12 (12-IIA-1)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	40		
0.25			Smoke
1	38.2	462	Heavy smoke
2	37.5	480	Chamber very smoky
3.5	39.8	487	
4	41.2	517	Still smoked heavily
5	45		
6.25	45	588	Spark gap ignited gases but did not start fire
7	45	621	Chamber filled with smoke
8	48.8		
9	46.5	735	
10			Off

Just prior to the end of the test the current was increased to 56.6 amperes. The temperature increased to 880C. Smoke filled the chamber. When the spark gap was energized the gases appeared to be combustible but fire did not continue. At this time the entire length of wire was covered with a dark powdery residue which fell off when the specimen was removed from test.

Wire No. 12 (12-IIA-2)

Chamber Pressure - 254 mm.
Current-Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	40		
0.5			Heavy smoke
1.75			Fire started at the spark gap but the flame disappeared and a glow progressed both up and down the insulation leaving a white residue on the specimen and in the chamber.

It is noted that the smoke was very dense and the spark was in very close proximity to the wire when the flame occurred.

Wire No. 12 (12-IIA-3)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	40		
0.25		255	Smoke
.75	36	342	Very heavy smoke
2	38.2	408	
3.25	40.5	462	
4	40.5	448	Gases burned but did not start fire
5	39	426	
5.25	45		
6	43.5	527	
7	44.2	588	
8	52.5	673	Insulation burned

Wire No. 13 (13-IIA-1)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	40		
20 sec.		331	Kynar jacket shrunk
45 sec.	36.8	372	Smoked
1			Jacket blistered
1.5	39.8	466	Heavy smoke
2.5	41.2	519	
2.75			Rubber deformed
3.5	41.2	589	Smoked heavily
4.5	42	602	Gases ignited with spark
5	45		
5.25		660	Heavy smoke
5.75		683	Wire glowed
6		681	Chamber filled with smoke
6.5			Long shreds of insulation hung from wire
7.25			About 2" of wire was bared
7.5	45.8	762	
7.75	48.8		
8.25		844	
9.25	62		Current increased until wire fused -- fire started at lower end of the specimen -- near the terminal block

This specimen sagged away from the spark gap during test.

Wire No. 13 (13-IIA-3)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	40		
20 sec.	40		Shrunk
40 sec.	40	301	
45 sec.	40		Smoked
1.5	40	448	
1 min. 40 sec.	40	488	Fire initiated by spark gap

Wire No. 13 (13-IIA-4)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	40		
20 sec.			Shrunk
35 sec.		390	Smoked
1 min. 20 sec.		457	Fire initiated by spark gap

Note -- It was apparent with the tests on wire 13 that the proximity of the spark gap to the insulation surface was a major factor in the time at which a fire would start. Although the spark gap was initially placed 1/32" away from the wire, the spacing varied considerably as the wire heated.

Wire No. 14 (14-IIA-1)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	40		
1	38.2	368	Smoke
2	39	426	
3.5	38.2	390	
4	39.8	413	
5	39.8	426	
5.25	45		Heavy smoke
6.5	44.2	554	
7.5	47.2		
8	47.2	664	Chamber filled with smoke
9	48.8	656	Specimen unwrapped
10	51	767	Entire center section glowed Smoked heavily
11	51	771	Insulation flaked and fell off

Wire No. 14 (14-IIA-2)

Chamber Pressure 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	45		
0.33		301	Smoke
50 sec.		505	Very heavy smoke
1.5	45	532	
2.5	45	558	Outer wrap dark but intact
4.5	45	571	
5.5	45	580	Quite dark in color
6	48.8		
7	48.8	691	
8.25	52.5	t.c. failed	Unwrapped -- wire glowed brightly -- flaked off
10	52.5		Glowed very red beneath silicone rubber remnants. Wrap came off in large flakes -- 2-2½" completely removed.
11.5	58.5		
12.5	60		Taping disappeared except at extreme ends near terminal blocks -- silicone rubber residue still present on most of the conductor
15	63.8		Wire fused -- no fire resulted

Wire No. 14 (14-IIA-3)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	45		
1	41.2	470	Heavy smoking within 30 sec.
2	45	606	
3	45	571	
3.5	48.8		
4.5	48.8	660	Wire glowed -- wrap very dark -- unwrapped
5.5	48.8	686	
6	52.5		
7.5	52.5	704	Flaked -- much of wire glowed red .
8.25		704	
9		708	Fire

Wire No. 15 (15-IIA-1)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	40		
35 sec.		364	Specimen overcoat started to shrink -- still transparent
1		400	Discolored
2	39.8	534	Brown in color
3	39.8	550	Dark brown
4	39.8	550	
5	45		
5.5	45	647	
5.75			Wrap loosened
6.5	44.2	633	
.	48.8		
7.75		766	Smoked -- wire glowed
8.25	49.5	735	
8.5	Off	720	Much of the wire was bare

Wire No. 15 (15-IIA-2)

Chamber Pressure - 254 mm.
Current - Steady

Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (^oC)	Remarks
Start	45		
.5	45	435	
.75			Smoked -- dark brown color -- shrunk
1	42.8	550	
1.5	45.8	611	Black -- wrap loosened
2	45	611	
3	45.8	621	Bare section about 1/2 in. along center portion -- insulation flaked off
3.5	45.8	628	
4.5	45.8	628	
5	60		Current increased rapidly until wire fused
5 min. 20 sec.		856	Wire fused -- no fire resulted

Wire No. 15 (15-IIA-3)

Chamber Pressure - 254 mm.
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (^oC)	Remarks
Start	45		
0.5	45	496	Shrunk
1	44.2	614	Dark brown -- wrap loosened
1.5	44.2	628	
1.75	44.2	607	Smoke
2	44.2	621	
2.5			Smoke disappeared
3	44.2	614	
3.5			Wrap was very loose -- appeared to flake
4	45	659	
4.5	45	659	
5	60		
5 min. 10 sec.		920	Wire fused -- no fire resulted

Wire No. 16 (16-IIA-1)

Chamber Pressure - 254

Current - Steady

Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	40		
50 sec.			Dispersion overcoat shrunk
1	39.8	436	Marks from the wire stripper on the jacket were accentuated
2	39	426	
3	38.2	405	
3.5	38.2	405	
4	45		
4.25		506	Smoke
4.5		550	Blistered
5.25	45.8	602	Overcoat and film unwrapped
6	45	583	Smoke disappeared
6.75	44.2	567	
7	47.5		
7.25		628	Smoke formed again
7.5		654	Wire glowed -- insulation flaked off
8.5	47.6	673	Glowed
9	60		
9 min. 9 sec.		871	Wire fused and initiated a fire -- the glow progressed up the specimen for a short distance

Wire No. 16 (16-IIA-2)

Chamber Pressure - 254
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	45		
25 sec.		480	Shrunk
40 sec.		837	Smoke
1.5		904	
1.75			Smoke disappeared
2.25		921	
3 min. 20 sec.	60	1193	Wire fused starting a small fire

Wire No. 16 (16-IIA-3)

Chamber Pressure - 254
Current - Steady
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	45		
25 sec.		410	Shrunk
45 sec.			Smoked
1	45.8	628	
1.25			Badly blistered
1.5	45	637	Insulation fell off
2	60		
2 min. 18 sec.		968	Wire fused without starting a fire

Wire No. 1 (1-IIB-1)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (^{o}C)	Remarks
Start	20		
1	18.4	107	
4	28.5	260	
5.5			Beads on insulation surface
6	31	309	
10.5	37.5	441	Discolored
13	40	521	Beads flowed together
14.75	40.5	500	Smoke
15	42.5		Heavy smoke
15.5			Charred, insulation flaked off Bare wire glowed
16	42.4	525	
17	42	575	
20	45		Wire glowed brilliantly
21	45	680	Insulation almost all disappeared
	Off		

White deposit formed on upper electrode terminals and upper part of chamber. Solidified FEP apparent where it has run down the specimen and cooled nearer the terminal blocks.

Wire No. 1 (1-IIB-3)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
2.5	30		
6	29.2	272	
6.5	32.5		Bead started to form
7	31.6	346	
10	37.5		
12	37.5	450	Discolored
14	40.5	564	Very dark color
15	42.5		
15.25			Black -- smoke
17		680	
17.25	42.6		
18.5	45	784	Wire glowed red, black char
19	45	790	White deposit formed on electrodes
20.75	47.1	865	
22	48.8	965	Much smoke
23	Off		

Wire No. 1 (1-IIB-4)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
2.5	30		
4	27.8	287	Beads formed
5.5	32.5		
6	33.6	335	Beads became much larger
7.5	35		
9	35	441	Discolo[illegible]
10	37.5		
10.5	36	478	Darkened (10.75 [illegible]
11	37.5	498	
12.5	40		
13	40.2	562	Very dark
13.75		581	Smoke
15	42.5		
15.25		628	Heavy smoke
16.5	42.5	628	Wire glowed red -- insulation flaked off

After all 1-IIB tests a white deposit covered the upper parts of the test chamber.

Wire No. 2

(2-IIB-1)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
2	19.9	108	
2.75	30		
4.5	30	260	
5	32.5		
7	32.2	292	
7.5	35		
9.5	34.5	328	
10	37.5		
12	37.5	399	
12.5	42.5		
13.5	41.2	474	Darkened
15	45		
15.5			Darkened
16	45	576	Swelled
16.25		593	Smoke
17.5	47.5		Very dark - unwrapped
18		691	Insulation split
18.5	48	718	Wire glowed
19.5	46.9	709	Large bare spot -- glowed
20	49.5		
20.25		719	Smoke
20.75			Insulation fell off in large pieces
21	48.8	767	
22	Off		

Center 3½" - 4" section completely bare
No fire -- still smoking at end of test
White deposit formed in chamber

Wire No. 2 (2-IIB-2)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
1	18.8	116	
2.5	30		
4	30	260	
5	32.5		
7	32.2	337	
7.5	35		
9.5	34.5	390	
11	39	457	Slightly darkened
12.5	40		
14.5		461	
16	43.5	593	Quite dark -- smoke
17	44.2	636	
17.5	45		
18			Unwrapped
18.5	44.2	637	
19.5	45.8	668	Continued to unwrap -- very dark
20	47.5		
21	47.2	750	Bare -- wire glowed -- insulation fell off
22	Off		

Wire No. 2 (2-IIB-3)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
1	20.2	103	
2.5	30		
4	30	228	
5	35		
7	35.2	310	
7.5	37.5		
9.5	36	341	
10	37.5		
10.25		364	Darkened
12	39.8	421	
12.5	42.5		
13		470	Quite dark -- unwrapped
14		488	Very dark
15	45		
15.25		532	Smoke
16	45	572	Bare wire showed Unwrapped badly -- smoked
17.5	47.5		Wire glowed
18	48	652	Insulation fell off
18.5	48	655	Glowed brightly
19	Off		

Large bare section -- insulation fell off

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start	20		
2.5	30		
5.0	32.5		
7.5	35		
10.0	37.5		Slight darkening
11	37.5	310	Spark discharge causes gap flickering
12.5	40		Dark [illegible] wells
15	42.5	340	Bare spot showing at center
18	45		Drips formed
20	47.5		
20.5	47.2	655	Conductor glows
21	47.2	715	Very small yellow flame appeared - extinguished itself
23	Off		

Wire No. 3 (3-IIB-2)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start	20		
		115	
2.5	30		
5	32.5		
7.5	35		
9	35	347	Shrinks
10	37.5		
12	37.5	457	Drips
12.5	40		
14	40	490	Swells
15	42.5		
16	43.1	573	Surface appears uneven - insulation loosening at wraps
17	42.4		
17.5	45		Flicker at spark gap electrode
18	45	608	Shrivels and chars
19	45		Very black - flakes
20	47.5		
21	48.8	>800	Large bare spots - wire glows

Wire No. 3 (3-IIB-3)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start	20		
2.5	30		
5	32.5	192	
7.5	35	212	Shrinks
10	37.5		Some darkening
11	37.5	288	Blisters or drips
12.5	40		
13	40.5	355	Splitting of portion above upper drop lead
15	42.5		Sputtering around electrode of spark gap
17	42	568	
17.5	45		
18.5	45		Insulation flaking off-glowing
19	45.8	>800	

Note: Some strands of the conductor were damaged during stripping

Wire No. 4 (4-IIB-1)

Chamber Pressure - 229 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C) Calculated	Max. Temp. (°C) Measured*	Remarks
Start	20			
3	30			
5.0	32.5			
7.5	35			
8.5	34.9	318		Slight darkening
10	37.5		425	
12.5	40		570	
13		448		Dark brown - shrinks at drop leads
15	42.5		656	
16		475		
16.5	42.5			Unwraps at the lower end
17		543		
17.5	43.5			Unwrapping continues
18.5	44.2	590	760	Insulation almost gone at center
19	Off			

*The "measured" temperatures are taken from a calibration run with #4 wire. The differences between the measured temperatures and those calculated from the voltage drop points up the problem involved in temperature measurements. See the text for more details.

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (^{o}C) Calculated	Measured*	Remarks
Start	20			
2.5	30			
5	32.5			
7.5	35			
10	37.5		470	
12	38.2	218		Discoloration
12.5	40		570	
14.5		253		
15	42.5		656	Quite dark - shrinking - unwrapping
16	42	333		
16.25				Shrinks - unwrapping - very dark
17		373		
17.5	45		760	Wire appearance increased from dull to bright red as current to 50.2 amperes was increased
	Off			

*See comment on previous chart, 4-IIB-1

Wire No. 4 (4-IIB-3)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C) Calculated	Measured*	Remarks
Start	20			
2.5	30			
5.0	32.5			
7.5	35			
10	37.5			
12.5	40			
13	41.2		600	Darkening - shrinks
14	40.5			No spark gap reaction
15	42.5			
15.5				Very dark
16	42.4		659	Swells - black
17	42			Unwraps
17.5	45		760	
18	45	@800		Badly unwrapped - almost black - conductor glows
19	Off			

*See comment on previous chart, 4-IIB-1

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start	20		
2.5	30		
4.5		205	
5.0	32.5		
7.5	35		
8	34.5	312	Slight darkening
9	37.5		Tape unwraps - darkens
11	37.5	370	Continues to unwrap
11.5	40		
12.5	39.8	440	Shrinks
14	42.5		
16.5	45		
17.5	42	650	Very black - wire glows, insulation appears to glow
18.5	Off		Insulation is almost totally destroyed.

White beads have formed on the insulation surface

Wire No. 5 (5-IIB-2)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start	20		
2.5	30		
5.0	32.5		
6	33	252	Slight darkening
7	33	258	Some loosening of wrap
7.5	35		
10	37.5		
11	36	280	Shrinks
12.5	40		
13	39.8	385	Quite dark
14	39	375	Insulation loosens
15	42.5		
16	42.8	525	Center is black
17	42.8	505	White beads have formed
18			Wire glows - dull red
18.25	45	600	Unwrapping progresses as wire blackens
19	45	605	Insulation appears almost fluid
20			Off

White beads again have formed

Wire No. 5 (5-IIB-3)

Chamber Pressure - 254 mm.
Current - Increasing
Heating Coil - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start	20		
2.5	30		
5.0	32.5		
7.5	35		
9.0		240	
10	37.5		Slight discoloration
12.5	40		
13	39.8	350	Darkening - unwrapping
14		397	
15	42.5		Very dark, shrinking at ends loosening
17.5	45		No apparent beading
18		512	
18.25	45		Whitish beads forming an insulation surface
18.5	45		Wire glowing
19.5	Off		

Spark gap energized through tests - showed no reaction except a burn-off of deposits on electrode tips

Chamber Pressure - 254 mm.
Current - Increasing
Heater - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start	20		
2		212	
2.5	30		
4		333	
5	32.5		
6		340	
7.5	35.5		
10	37.5		
12		435	
12.5	40		
15	42.5		Wire dark at center
17.5	45		Shrinks - black
19		655	
20	47.5		Very black - bare wire shows through - shrinking
21		>800	
22	48		Off

Spark gap energized periodically throughout the test - no reaction apparent

Wire No. 6 (6-IIB-2)

Chamber Pressure - 267 mm.
Current - Increasing
Heater - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start	20		
2		125	
2.5	30		
5	32.5		
7.0		358	
7.5	35		
9		377	
10	37.5		Slight darkening
14	40		Quite dark
15	42.5		Very dark
16	43.1		Wrap appears loose
17.5	45		
18.5	45	688	Conductor showing - insulation black
20	49.5		Unwrapping badly - FEP
21	Off	>800	Wire melted - no reaction to spark discharge ignition

Wire No. 6 (6-IIB-3)

Chamber Pressure - 254 mm.
Current - Increasing
Heater - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start	20		
2		226	
2.5	30		
5	32.5		
6		358	
7.5	35		
10	37.5		
11	36.8	453	Specimen darkening
12.5	40		
13	40.9	555	Very dark
15	42.5		Shrinks
17. 5	45		
18	45	626	Very black - drips
19	45		Unwraps
20	47.5		
20.5	47.2	790	Bare conductor shows where insulation is unwrapped
22	48.0	>800	Badly unwrapped
22.5	50.1		Considerable conductor shows - wire glows - no smoke - no ignition with spark discharge

Wire No. 7 (7-IIB-1)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
1	21.8	130	
2	20.2	214	
2.5	30		
3.5	29.2	227	
4.5	30.8	273	Discolored
5	32.5		
6	31.5	283	Darkened
7		314	
7.5	35		
8.5	35.2	390	Very dark brown
9.5	36	382	
9.75			Black -- smoked
10	37.5		Melted -- bubbled
10.25		426	Dense smoke
10 min. 52 sec.		529	Spark gap initiated fire which completely consumed the insulation

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
1	18	111	
2.5	30		
3.5	30	275	
4			Slight discoloration
5	32.5		
5.25			Darkened
6	32.2	336	
6.5			Overcoat shrunk Polyolefin intact
7.5	35		
8.5	34.5	386	Brown color -- overcoat pulled back further
10	37.5		
10.25			Blackened
10.5			Smoke
11			Heavy smoke
11.75	36.8		
12.5	40		
14	39.8	479	
15	42.5		
16	44.2	491	
	Off		

Wire was almost completely bare.

Wire No. 7 (7-IIB-3)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
1	18.8	112	
2.5	30		
3.5	30.8	274	
4.5		285	Slight Discoloration
5	32.5		
6.5	33	319	Darkened
7.5	35		
8	36	373	Brown
9	36	381	Dark brown
10.25	37.5		
10.5			Blackened
11	36.8	400	
11.25		390	Heavy smoke
12	38.2	470	Black, dripped
13.5			Caught fire and continued to burn

Wire No. 8 (8-IIB-1)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (^oC)	Remarks
Start	20	205	
2.5	30		
4		425	Darkened
5	32.5		
7.5	35		
8-9	34.4	560	Smoked, blackened, insulation dripped from wire
9.5	34.6	540	Heavy smoke
10	37.5		
10.6		750	Burned

Wire No. 8 (8-IIB-2)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (^oC)	Remarks
Start	20		
2.5	30	200	
5.0	32.5	410	
5.5	32.4	458	Darkened
6	31.9	483	Quite dark, shrinking
7.5	34.7	535	Black
9	33.0		Smoke
10	37.5		
10.5	38.3	600	
10 min. 40 sec.		605	Heavy smoke -- hot spot appeared on the wire -- extinguished itself
10 min. 44 sec.			Hot spot reformed and instantly entire specimen was enveloped in flames.

Wire No. 8 (8-IIB-3)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
2	20	95	
4.5	29.4	245	
7	33	283	
8	35	353	Darkened
10.5	37.1	392	
12	38.2	423	Specimen black in color Slight flame occurred at spark gap
12.5	40		
13	40	555	Smoke followed very quickly by flame -- insulation burned

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start	20		
2.5	30		
3.0		158	
5	32.5		
5.5 - 6.5		259	Insulation swells
7.5	35		
8		292	Insulation shrinks
10	37.5		
10.25			Shrinks rapidly
12.5	40		
14		427	
15	42.5		
15.5			Insulation at center slid down conductor - stopped at lower voltage drop lead
16	48.8		Current jumped to this value momentarily electrode burn-off,insulation is stripping rapidly
17.5	45		Current was reduced immediately from 48.8 to 42.5, then the rate of increase was resumed
18	46.5	420	Wire - cherry red

At the lower current (32.5 amps.) the insulation swelled - this was apparent from the decrease in width of the slits in the insulation made to accommodate the voltage drop leads. Then at a temperature very little above that causing swelling, shrinkin occurred slowly and then at the next step much more rapidly. There was no flame, smoke or any indication of ignitable gases. The only noticeable effect of the spark gap was to burn off what was apparently a deposit that was formed on the electrode.

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start	20		
2.5	30		
3.5		195	
5	32.5		
5.5			Insulation swells
6.5		248	
7.5	35		
7.75			Insulation shrinks
10	37.5		
12		370	
12.5	40		Rapid shrinking continues
15	42.5		
17		537	
17.5	45		
17.75			Insulation melts -- splits along axis of wire -- conductor red
18.5		620	
18.75			Entire center section of insulation is gone -- rest hangs in long shreds
19.25	Off		

No flames or smoke apparent with spark gap energized periodically throughout test.

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Max. Temp. (°C)	Remarks
Start	20		
2.5	30		
3.5		215	Possible start of swelling
5	32.5		
6		292	Insulation swells
7.5	35	430	Insulation shrinks immediately
9		322	
10	37.5	412	
12.5	40		Shrinking continues through last two steps
14		535	
15	42.5		Insulation at center slipped
16		662	
16.25			Insulation strips off -- turns translucent
17			
17.5	45	758	Electrodes burn-off with discha ge
17.75			Insulation almost completely gone -- wire glows
19			Remaining insulation is in strips

Wire No. 10 (10-JIB-1)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
1	18.8	150	
2.5	30		
3	30	286	
5	32.5		
6	32.3	465	Slightly Discolored
7.5	35		
7.75			Brown in color
8	34.2	536	
8.5			Darkened - shrunk in length, Swelled in dia.
9	34.9	584	
9.5			Black - beads formed on insulation
10	37.5		
13	41.3	740	Black - charred - wire glowed
15	42.5		Wire glowed red
15.5	42.8	960	Insulation fell off Very bright flash occurred at the spark gap electrodes
17	Off		

Insulation started to unwrap where cut to accept the thermocouple. Continued to unwrap throughout the test after the 37.5 amp. step had been reached.

Slight whitish deposit observed around upper terminal block.

Wire No. 10 (10-IIB-2)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
1	18.8	142	
2.5	30		
4	30	381	
5	32.5		
5.5			Discolored
6	34.5	502	
7	33	513	Black, beads formed, shrunk in length
8	36	572	Tape unwrapped
10	37.5		
10.5	38	629	Beads formed along with bubbling in the insulation
12.5	40		
13	39.8	681	Wire glowed, insulation charred and flaked away
14	41.3	817	
15	42.5		
17	42.7	901	

Most of wire bared, some insulation stayed on wire near terminal blocks.

Wire No. 10 (10-IIB-3)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	27		
1	26.8	241	
2.5	30		
3.5	29.2	337	
4.5			Discolored
5	32.5		
7	33	437	
7.5	35		
8	34.5	479	Dark brown color
8.45		479	Bead formed
10	37.5		Wrap loosened
10.5			Beads appeared to boil
11	37.2	522	White deposit formed
12	38.8	546	
12.5	40		
13	40.5	598	Black
15	42.5		Conductor glowed
15.5	42.7	663	
15.75			Insulation flaked off
16	41.3	632	
17.5	45		Wire bright red
18	45	754	

Most of the insulation disappeared after 18 min., the current was then increased until the wire melted. At this point there was no flame.

Wire No. 11 (11-IIB-1)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
2	19.8	125	
2.5	30		
4.5	28.9	260	
5	32.5		
7	31.6	330	
7.5	35		
9	35.2	366	
10	37.5		
12	38.2	430	
12.5	40		
14.5	39.8	460	
15	42.5		
15.25			Surface deformed
15.5			Insulation swelled
16	43.1	526	
17	42.4	523	Blisters appeared
17.5	45		
18	45	646	Smoke -- insulation bubbled and fell off -- wire glowed
19	45	726	White deposit formed
20	47.5		
21.25	Off		

Specimen almost completely bare except near terminal blocks.

Wire No. 11 (11-IIB-2)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
2	18	102	
2.5	30		
4	29	228	
5	32.5		
7	32.6	283	
7.5	35		
8.5	36.8	328	
10	37.5		
12	37.1	346	
12.5	40		
14.5	42	431	
15	42	439	Small blisters or pits observed
17	40.5	41[illegible]	
17.75			Smoke
18	44.2	496	
18.5			Wire red -- insulation fell off
19	45.8	762	Smoke still apparent
21	47.6	817	Almost all insulation was gone -- current was increased until wire fused -- no flame resulted

Wire No. 11 (11-IIB-3)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
2	18.8	112	
	30		
4.5	30.8	267	
5	32.5		
7	33	314	
7.5	35		
9.5	35.2	355	
10	37.5		
12	37.5	393	
12.5	40		
14	39.6	435	
15	42.5		
16	42.8	488	Small blisters or pits observed
17	43.5	511	Change in surface appeared along a 2" space at the center of the wire
17.5	45		
18.25		580	Smoke
19	45	636	Wire red -- insulation fell off
19.5	45.8	664	
20			Insulation almost completely disappeared
	Off		

With these specimens it is apparent that the temperature stays fairly constant at the set current until the insulation falls off or is burned away, then with the current still fairly constant at the same value the temperature increases at a rapid rate.

Wire No. 12 (12-IIB-1)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
2	18.8	116	
2.5	30		
4.5	30.8	28.3	
5.25	32.5		Smoke
6.5	33.8	323	Smoke
7.5	35		
9	32.6	355	
10	37.5		
10.25			Heavier smoke
10.75	39	465	
12	38.2	455	Smoke disappeared
12.5	40		
13			Smoke
14	40.4	515	
15	42.5		
15.5	44.2	624	Smoked heavily
17	45	664	Blistered -- chamber filled with smoke
19.5	45.8	682	
22	47.6	754	Insulation appeared crazed
22.75			Wire glowed beneath material remaining on surface
23.5	49.1	818	Smoked heavily
24.75	51	844	
25	52.5		Wire glowed very brightly -- remnants of insulation still on wire
29.5	55.5	951	
35	63.8	>950	Wire fused -- no fire resulted -- charred remnants of insulation still adhered to the wire

Wire No. 12 (12-IIB-2)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
1.25	21	120	
2	20.2	118	
2.5	30		
3		200	
3 min. 5 sec.			Smoke
3.5	30	233	
5	32.5		
5.5			Heavier smoke
7	33	305	
7.5	35		
9.5	36	331	
10	37.5		
12	36.8	347	
14	39.8	426	Heavy smoke
14.5			Gases appear to be slightly combustible ignited with spark gap
15	42.5		
15.5			Very dense smoke
16	42.5	483	
17.5	45		
19	45.8	606	Chamber filled with smoke
21.5	46.5	655	
22	46.5	637	
22.75			Wire started to glow through remnants of insulation
23.5	49.5	713	Some insulation cracked away -- wire glowed
25.5	51.8	767	Wire glowed brightly -- several bare spots formed on wire
27.5	52.5	793	
28	Off		

Wire No. 12 (12-IIB-3)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
2	18.8	109	
2.5	20		
3.5	29.2	237	
4			Smoke (wisps)
4.5	30.8	264	
5	32.5		
5.25			Heavier smoke (light in color)
6	33	315	
7.5	35		
8.5	35.2	355	
9.5	36	351	
10	37.5		
12	37.5	395	
12.5	40		
13	40.5	443	Smoke
14.5	39.4	435	
15	42.5		
15.25		420	Heavy smoke
16	44.2	562	
16.33		570	Chamber filled with smoke. When spark gap was energized, specimen started to flame and then extinguished itself when current and the spark gap were de-energized. The specimen continued to glow and the glow progressed both up and down the specimen until it almost reached the terminal blocks. A white residue remained where the wire had burned.

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
2	19.2	89	
2.5	30		
4.5	29.2	213	
5	32.5		
7	32.3	251	
7.5	35		
9.5	33	269	
10.25	37.5		
12	37.5	364	Small blisteres formed Outer coat shrunk
13	40		
14.5	39.7	381	
15	42.5		
15.5		395	Smoke Blisters spread to cover 2-2½" of insulation over center portion of the wire
17	41.3	436	
17.5	45	534	Heavy smoke
17.75		542	Fire initiated by spark gap

Wire No. 13 (13-IIB-2)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
2	19.9	107	
2.5	30		
2.75		180	Overcoat shrunk rapidly insulation split longitudinally
3.75	30	237	Large blisters formed
4.5	29.2	241	
5	32.5		
7	33	301	
7.5	35		
9.5	35.2	355	
10	37.5		
11.5		430	Smoke blisters formed
12	38.2	435	
12.5	40		Wire sagged away from spark gap
12.75		523	Smoke
14.5	41.6	541	
15	45		Smoke filled chamber
16	45	762	Wire glowed
16.5		726	Insulation peeled and fell away
18.5	44.2	674	Smoke disappeared
19	Off		

Center of specimen bared -- white "ashes" adhere to remainder of the conductor.

Wire No. 13 (13-IIB-3)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
2	18	108	
2.5	30		
2.75		190	Kynar jacket shrunk
3			Large blisters formed
4	30	242	
5	32.5		
7	32.2	292	
7.5	35		
9	34.5		
9.5	36.8	355	Fire started by the spark -- progressed upward -- very slowly after first initiated

Wire No. 14 (14-IIB-1)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
2	20.2	89	
2.5	30		
4.5	30	206	
5	32.5		
7	32.2	242	
7.5	35		
8.5	34.5	281	Darkened -- swelled
10	37.5		
11	36.8	296	Wrap appeared to shrink logitudinally
12	36.8	301	
12.5	40		
13.5	40.1	368	
14.5	40.5	373	
15	42.5		
15.25	42.8	422	Smoke
15.66		462	Fire started by the spark extinguished when current was reduced

Since very little damage to the specimen could be observed the same current (I) was reapplied (42.5 amps.) Fire was not restarted with the spark until the thermocouple indicated approximately the same temperature as that at which the first fire occurred.

Wire No. 14 (14-IIB-2)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start			
1	18.8	121	
2.5	30		
3.5	29.2	264	
5	32.5		
6	32.6	328	Darkened
8	35		
8.5			Swelled
9	34.5	381	Rubber swelled particularly around the thermocouple junction
12.5		413	
12.5	40		
13	41.2	452	Smoke (wisps)
15	42.5		
16	42.8		Smoke (light)
17.5	45		
17.75			Heavy smoke
19			Film shrunk considerably very black smoked
20	47.5		Smoke poured from specimen
21			Unwrapping -- conductor glowed
22.5	49.5		
23	50.2	754	Wire glowed -- smoked lower part of specimen unwrapped -- upper part flaked and fell away conductor still covered by ash from silicone rubber
27	52.5	>900	
	Off		

Wire No. 14 (14-IIB-3)

Chamber Pressure - 254 mm.
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
1	20.6	108	
2.5	30		
3.5	29.2	232	
5	32.5		
6.5	33	297	
7.5	35		
9	34.5	359	Darkened -- swelled
10	37.5		
11	37.5	386	Wrap loosened
12.5	40		
13.5	40.5	452	
14.5	40.5	452	Very dark
15	42.5		
16	42.7	53	Chamber filled with light smoke
17.5	45		
18.5	44.2	576	
19.5	45	571	
20	47.5		
21	48	668	Large puff of smoke from lower end of specimen
22	47.2	664	Chamber filled with dense smoke
22.5	49.5		Lower portion unwrapped wire glowed through decomposed insulation at center -- smoked heavily
23.5	50.2	758	Continued to unwrap -- rubber appeared to be an ash like material

The current was increased until the wire fused. Fusing current was 62 amps. No flame occurred. During the test the specimen sagged until a sizeable gap between the wire and the spark gap developed. If this had not occurred it is felt that a fire would have developed when the specimen was smoking heavily.

Wire No. 15 (15-IIB-1)

Chamber Pressure - 254
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
2	18.8	112	
2.5	30		
4.5	286	246	
5	32.5		
7	32.2	297	
7.5	35		
9.5	34.5	340	
10	37.5		Discolored
12	36.8	386	
12.5	40		Darkened
14.5	40.9	476	
15	42.5		Very dark brown
17	42	482	
17.5	45		Outside wrap shrunk
19.5	43.5	553	Almost black
20	47.5		
21			Unwrapped
22	47.2	652	Flaked -- fell off
22.5	50		Red glow -- smoke
23.5		871	Center section bared -- wire glowed brightly -- wire fused at 61.5 amperes -- no fire resulted

Wire No. 15 (15-IIB-2)

Chamber Pressure - 254
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (^{o}C)	Remarks
Start	20		
2	19.5	120	
2.5	30		
4.5	29.2	236	
5	32.5		
7	33	350	
7.5	35		
9.5	33.8	319	
10	37.5		
10.5			Discolored
12.5	40	443	Outer wrap shrunk
14	42	511	Wrap loosened
15	45		Very dark brown
16.5	45	596	
17.25		607	Flaked
17.5	48		
17.75		654	Wire glowed
18.25			About 1 in. around center portion was bare
18.5	47.2	692	
19		694	Wire continued to flake off
20	46.5	682	
20.5	56	901	Wire fused -- smoke -- no fire resulted

Wire No. 15 (15-IIB-3)

Chamber Pressure - 254
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
2	17.2	98	
2.5	30		
4.5	29.2	263	
5	32.5		
7	32.6	334	
7.25			Dispersion overcoat shrunk
7.5	35		
8			Discolored
9.5	34.9	386	
10	37.5		
10.5		436	Continued to darken and shrink
11	38.2	462	
2	38.2	476	
12.5	40		
14	39.8	496	
15	42.5		Overcoat stripped back about ½ inch -- may have shrunk this much -- under layer still was bonded to wire -- very dark brown
17	42	558	
17.5	45		Wrap loosened especially around upper part
18.5			Very dark
19		612	Flaked off
20	Off	621	

Tests with wire no. 15 produced a white deposit in the chamber.

Wire No. 16 (16-IIB-1)

Chamber Pressure - 254
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
2	18	107	
2.5	30		
4.5	31.5	292	
5	32.5		
7	33	345	
7.5	35		
7 min. 50 sec.		372	Dispersion overcoat started to shrink
9.75	36	381	
10	37.5		
10.25		426	Shrunk faster
12	36.8	431	
12.5	40		
13.5		522	Flim wrap loosened A split developed in the overcoat which followed the wrap spiral -- blistered
15	42.5		Film was very dark where it was exposed through the open overcoat
16	42.8	550	
16.5			Blistering spread along the length of the wire
17	42	550	
17.5	45		
18 min. 25 sec.		692	Smoke
18 min. 55 sec.		725	Glowed -- insulation flaked off
19.5	46.5	735	About 1 inch around center bared -- insulation blackened and flaked off
20	48.8		
21	Off	790	Much of the wire was bared

Wire No. 16 (16-IIB-2)

Chamber Pressure - 254
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
2	18.8	124	
2.5	30		
4.75	28.5	236	
5	32.5		
7.25	32.2	309	
7.5	35		
7 min. 55 sec.		372	Dispersion overcoat shrunk a little
9.5	35.6	390	
10	37.5		
12	37.9	452	
12.5	40		
13.5		513	Overcoat wrinkled
14		541	Blistered
14.5	40.5	522	Exposed film became black
15	42.5		
16.5		576	Blistered over approximately 3 inches
17	41.2	558	
17.5	45		Film unwrapped
17 min. 50 sec.		654	Smoked
18.5		664	Wire glowed dully -- insulation flaked off
19.5	45	664	Insulation did not ignite even though strips hung directly in spark gap
20	47.2		
21	47.2	725	Wire glowed -- insulation fell off in large flakes
22	Off	744	

Wire No. 16 (16-IIB-3)

Chamber Pressure - 254
Current - Increasing
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
2	18	111	
2.5	30		
4.5	29.2	270	
5	32.5		
5.75		338	Shrunk very slightly
7.25	34.5	372	
7.5	37.5		
8.25		421	Surface deformed -- general pattern of underlying wrap became evident
9.5	36.8	436	
10	40		
10.5		496	Exposed film became quite dark
11.25		511	Surface continued to wrinkle
12	39.8	492	Blisters formed
12.5	42		
14.5	42.8	588	Large blisters formed -- cracks opened along film wrap "line" -- exposed film became black
15	45.8		
15.5		692	Wire glowed -- insulation fell off
16.5	45.8	699	
17.25	44.6	664	
17.5	48.8		
17.75	48.8	744	Wire glowed brightly -- insulation flaked off
18.5	Off	735	

All number 16 specimens have a strong acrid odor after test and form white deposits in the chamber.

Wire No. 7 (7-C-1)

Chamber Temperature - 27C
Chamber Pressure - Atmospheric - Room Air
Current - As Specified
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	30		
2	29.2	304	
2.5	32.5		
4.5	33.0	355	Discolored -- some odor
5	35		
6	34.5	329	Light brown color
6.5	37.5		
7 min. 23 sec.		522	Fire -- initiated by spark gap continued to burn without current flow

Wire No. 7 (7-C-2)

Chamber Temperature - 27C
Chamber Pressure - Atmospheric - Room Air
Current - As Specified
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	30		
2.25	29.2	214	
2.5	33		
3.5		283	Slight discoloration
4.75	32.2	264	
5	37.5		
5.5		329	Light brown
5.75		355	Flame started -- not self sustaining -- required spark gap to ignite it
6.5			Fire -- initiated by spark gap continued for a short distance up the specimen then extinguished itself

Wire No. 8 (8-C-1)

Chamber Temperature - 27C
Chamber Pressure - Atmospheric - Room Air
Current - As Specified
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
2	19.5	111	
2	30		
3			Smoked
4.5		228	
4.75	32.5	273	Smoked heavily
6.75		300	Fire initiated by spark gap -- black smoke, insulation continued to burn with no power applied This test specimen sagged to within 1/4 in. of the spark gap -- considerable smoke observed before ignition

Wire No. 8 (8-C-2)

Chamber Temperature - 27C
Chamber Pressure - Atmospheric - Room Air
Current - As Specified
Heater Coil - Not Used

Elapsed Time (min.)	I (amperes)	Temp. (°C)	Remarks
Start	20		
1.5	19.5	125	
2	30		
2.75			Fire was initiated by the spark gap and continued to burn with no power applied accompanied by considerable black smoke

26. Chemical Compatibility

The effect of exposing wire to chemicals and contaminants has been investigated by measuring voltage breakdown and insulation resistance of twisted pairs and also mandrel flexibility at 23C and -196C before and after exposure to the chemical.

Degradation from Exposure to Fuels and Oxidizers

The degradation resulting from four fuels and two oxidizers is reported in tables as follows:

Chemical	Mandrel Flexibility	Voltage Breakdown	Insulation Resistance
UDMH	26-1	26-2	26-2
MMH	26-3	26-4	26-4
Hydrazine	26-5	26-6	26-6
A-50	26-7	26-8	26-8
Nitrogen Tetraoxide	26-9	26-10	26-11
Fluorine	26-12	26-13	26-14

The results have been plotted also as ratios in Figures as follows:

Chemical	Voltage Breakdown	Insulation Resistance
UDMH	26-1	26-2
MMH	26-3	26-4
Hydrazine	26-5	26-6
A-50	26-7	26-8
Nitrogen Tetraoxide	26-9	26-10
Fluorine	26-11	26-12

The average of the ratio of the maximum and minimum values has been plotted for voltage breakdown. For insulation resistance, a log average has been used.

A number of observation can be made in respect to these results:

a. Only N_2O_4 appears to degrade Teflon.

b. MMH, N_2O_4 and A-50 (hydrazines) degrade H-film (Wires #3, 4, 5, 6, 10, 11 and 14). To a greater or less extent, the FEP coating on the H-film, overcoating Teflon dispersion (#3 and 6) and overcoating TFE tape (#11) protect the H-film from attack. The TFE dispersion coating on Wire #3 is particularly effective in preventing such attack.

c. UDMH does not appear to cause significant attack on H-film.

d. Except for fluorine all of the fuels and oxidizers seriously attack the irradiated modified polyolefins (Wires #7 and 8) even when protected with a Kynar jacket (Wire #7).

e. All of the materials attack the silicone rubber in Wires #12, 13 and 14. Curiously, the attack on Wire #13 with a Kynar jacket and on #14 with an overcoating of FEP bonded H-film is often greater than on the silicone rubber alone (Wire #12). It is conjectured that the contaminant may collect at the interface between the rubber and the jacket. In addition, the jacket may slow down the volatilization of the contaminant out of the rubber.

f. The fuels improve the cryogenic flexibility of Wires #1 and #2 because they attack and largely remove the ML overcoating which limits flexibility in liquid nitrogen.

g. It was difficult to obtain exposure in fluorine without starting a fire. After experimental problems were overcome it became apparent that fire was initiated at some spots and not at others on the surface of the wire. It was surmised that surface contaminant was responsible - perhaps human perspiration.

h. As noted in the tables, many of the wire specimens burned at the time of voltage breakdown because of residual absorbed or trapped fuel. It is remarkable how persistently some of the wires retained the fuel. Unfortunately, time did not permit a quantitative study.

Degradation from Exposure to Oils, Salt and Glycol Solutions

The effect of exposure to lubricating oil (MIL-L-7808), a hydraulic oil (MIL-H-5606), 5% sodium chloride in distilled water, salt fog (MIL Std. 810) and ethylene glycol (67.5%) and water (32.5%) with inhibitors per Air Res. Spec. RS-89 is reported in tables as follows:

Exposed to	Mandrel Flexibility	Voltage Breakdown	Insulation Resistance
Lube Oil	26-15	26-16	26-17
Hydraulic Oil	26-18	26-19	26-20
5% NaCl	26-21	26-22	26-23
Salt Fog	26-24	26-25	26-26
Ethylene Glycol/ water	26-27	26-28	26-29

Since degradation is not severe or general (as with the fuels and oxidizers) comparative figures have not been plotted. The following detailed observations are made:

a. Silicone rubber, Wire #12, is badly swelled by hydraulic oil and the Kynar jacket of Wire #13 does not provide protection against the oil. The fused FEP - H-film wrap of Wire #14 does provide protection against the degradation of the oil.

b. Both lube and hydraulic oil appear to penetrate wires #4, 5, 6, 7 and 11 and adversely affect flexibility at -196°C. Conversely, the absorption of the oil sometimes improves voltage breakdown.

c. Lube and hydraulic oils both increase voltage breakdown in silicone rubber (Wire #12) despite and perhaps because of the sweeling they cause. Even though hydraulic oil swells silicone rubber so badly that the Kynar jacket splits, the voltage breakdown surprisingly is not adversely affected.

d. The absorbed oils produced fires at voltage breakdown in several wires, as noted in the tables. It is interesting that wires overcoated with ML enamel (#1 and 2) both burn at voltage breakdown after exposure to lube oil. It is difficult to account for the flame with these wires.

e. The 5% sodium chloride solution appears to affect significantly only the voltage breakdown of the irradiated polyolefin (Wire #8). Why the insulation resistance is also not adversely affected is difficult to explain. It is conjectured that the rather highly filled material absorbs the solution. The salt fog exposure produces similar results with Wire #8.

f. Salt fog exposure severely degrades Wires #4 and 5 and appears to adversely affect Wires #6 and 11 to some extent. It is considered probable that hydrolytic instability of the H-film is involved. The dispersion coating appears to protect Wire #3. The absence of attack with Wire #10 is difficult to explain.

Curiously, the cryogenic flexibility of Wires #1 and 2 is also adversely affected after salt fog exposure. Probably hydrolytic instability of the ML coating is involved in this case also.

g. The ethylene glycol solution appears to degrade significantly only the silicone rubber.

Degradation from Exposure to Solvents

The effect of exposure of the wires to a variety of solvents is shown in tables as follows:

Solvent	Mandrel Flexibility	Voltage Breakdown	Insulation Resistance
Ethyl Alcohol	26-30	26-31	26-31
JP-4	26-32	26-33	26-33
Freon 114	26-34	26-35	26-35
Trichloroethylene	26-36	26-37	26-37
Acetone	26-38	26-39	26-39
Freon 113	26-40	26-41	26-41

The detailed observations can be made as follows:

a. Ethyl alcohol appears to penetrate wires #4, 5, 6, 7 and 11 so as to decrease flexibility when measured at -196°C. Otherwise, the alcohol appears to cause no significant degradation.

b. All of the other solvents, like alcohol, decrease cryogenic flexibility with Wires #4, 5, 6, 7 and 11.

c. Silicone rubber is considerably swollen by exposure to JP-4, Freons 113 and 114, and tricholoroethylene. These solvents penetrate the Kynar jacket of Wire #13 so that the wire swells and splits the jacket. With Wire #14, either the H-film overcoat prevents the penetration of sufficient solvent to cause damage or the tape is strong enough to prevent damage. Some swelling of the rubber under the H-film is apparent in that the overcoat is noticeably tighter.

d. Acetone attacks the Kynar jacket of Wire #13 directly, producing "shreds" f polymer. The acetone does not appear to appreciably attack or swell the silicone rubber.

e. Acetone does not attack the Kynar jacket of Wire #7. It is suggested that irradiation of the Kynar in this case has improved its resistance to acetone.

f. JP-4 quite markedly improves the voltage breakdown of silicone rubber #12 and the irradiated polyolefin #8. Yet these same wires with a Kynar jacket, #13 and #7, show a decrease in breakdown with exposure to JP-4. The increase in breakdown voltage may be due to swelling or possibly impregnation. The reason for the decrease with the Kynar jacketed wires is unexplained.

g. Exposure to Freons 113 and 114 and trichloroethylene markedly increases the voltage breakdown in the polyolefin Wire #8, but does not significantly improve the silicone ruber #12. Exposure to Freon 113, like JP-4, does decrease the voltage breakdown in the Kynar jacketed silicone rubber (Wire #13). However, in contrast, Freon 113 does not adversely affect the Kynar jacketed polyolefin (Wire #7) and the Freon 114 as well as trichloroethylene do not damage either of the Kynar jacketed wires (#7 and #13).

h. The increase in voltage breakdown for extruded TFE Teflon (Wire #9) with exposure to all of the solvents is surprising. After exposure to acetone the value of voltage breakdown almost doubles! Apparently impregnation of the sintered structure is involved. It is difficult to explain why acetone exposure causes the most marked increase. It is obvious that the sintering of the Teflon is quite incomplete. Such variations in the homogenity of the TFE extrusion may well account for the considerable variability in Wire #9.

i. Exposure to all of the solvents increase the tendency for several of the wires - particularly the jacketed ones - to flame or burn at the time of voltage breakdown. While JP-4 and acetone exposure produce the greatest tendency for the wires to burn, it is surprising that the Freons and trichloroethylene also increase the tendency to flame. Many subtle differences between the various wires and different solvents exist and the data in the tables may be examined in this respect.

TABLE 26-1

EFFECT OF 20 HOURS EXPOSURE TO UDMH ON MANDREL FLEXIBILITY

Ratio of Mandrel Diam. - Exposed/Unexposed

Wire #	No Damage Flexed at 23°C	No Damage Flexed at -196°C	Slight Damage Flexed at 23°C	Slight Damage Flexed at -196°C	Severe Damage Flexed at -196°C
1	---	---	1X/1X	---	1.75/0.5
2*	---	---	1X/1X	---	2.0/1.75
3	1X**/1X	---	---	0.5/0.5	---
4	---	---	0.25/1X	1.0/.125	---
5	---	---	1X/1x	0.50/.125	0.25/.075
6	1X/1X	---	---	---	0.25/0.25
7	---	---	.075/1X	---	3.0/1.75
8	1X/1X	---	---	---	>3.0/>3.0
9	1X/1X	---	---	---	0.50/
10			1X/1X		1.0/0.25
11			1X/1X	1.0/0.5	
12	Swelled and eroded - dried to flaky material - no test possible.				
13	Kynar jacket discolored "brown", but appears to protect rubber physically.		1X/1X		>3.0/>3.0
14			0.25/1X		>3.0/>3.0

*ML softened and in some areas partly eroded away.

**"Mud flat" cracking in the unflexed FEP coating opens with flexing.

Note: Color changes are recorded elsewhere.

TABLE 26-2

EFFECT OF 20 HOURS EXPOSURE TO UDMH - TWISTED PAIRS

Ratio of Breakdown Voltage (KV) - Exposed/Unexposed

Wire #	Maximum Values	Minimum Values
1	22.5 / 20.2	18.0 / 15.8
2	18.3 / 21.0	15.1 / 15.0
3	30.5 / 28.5	29.5 / 25.5
4	18.5 / 18.0	16.5 / 17.5
5	23.0 / 19.5	14.3 / 13.0
6	33.2 / 30.0	30.5 / 25.5
7	12.5 / 25.5	7.0 / 21.0
8	3.5 / 29.0	2.2 / 26.0
9	23.4 / 20.5	21.2 / 14.5
10	25.5 / 23.0	13.5 / 18.0
11	15.0 / 13.5	12.5 / 10.4
12	8.8 / 18.5	7.6 / 16.5
13	7.0 / 22.4	6.5 / 18.0
14	28.0 / 25.5	22.0 / 20.6

Wires #1, 7, 8 and 11 ignite and continue to burn when power is removed.

Ratio of Insulation Resistance (Ohms) - Exposed/Unexposed

1	$7.7x10^{13}$ / $2.8x10^{13}$	$1.6x10^{13}$ / $8.6x10^{12}$
2	$2.6x10^{12}$ / $1.6x10^{13}$	$1.6x10^{11}$ / $9.8x10^{12}$
3	$6.6x10^{14}$ / 6×10^{14}	$3.1x10^{14}$ / 2.5×10^{14}
4	$1.4x10^{14}$ / 5×10^{13}	$9.6x10^{13}$ / $3.8x10^{14}$
5	$1.4x10^{13}$ / $2.5x10^{15}$	$4.2x10^{12}$ / $5.9x10^{14}$
6	$1.2x10^{14}$ / $3.6x10^{14}$	$5.3x10^{13}$ / $2.3x10^{14}$
7	$2.8x10^{9}$ / $8.9x10^{12}$	$6.7x10^{8}$ / $3.6x10^{12}$
8	$6.3x10^{7}$ / $6.3x10^{13}$	$2.3x10^{5}$ / $8.3x10^{12}$
9	$9.3x10^{14}$ / $1.1x10^{15}$	$4.2x10^{14}$ / $3.6x10^{14}$
10	$3.6x10^{10}$ / $1.0x10^{14}$	$1.0x10^{10}$ / $1.5x10^{13}$
11	$2.3x10^{14}$ / $>6.0x10^{14}$	$1.1x10^{14}$ / $>6.0x10^{14}$
12	$8.3x10^{10}$ / $3.5x10^{13}$	$3.1x10^{10}$ / $1.4x10^{13}$
13	$3.0x10^{7}$ / $7.8x10^{12}$	$1.6x10^{7}$ / $5.0x10^{12}$
14	$1.4x10^{13}$ / $4.5x10^{13}$	$2.2x10^{12}$ / $3.1x10^{13}$

TABLE 26-3

EFFECT OF 20 HOURS EXPOSED TO MMH ON MANDREL FLEXIBILITY

Ratio of Mandrel Diam.- Exposed/Unexposed

	No Damage Flexed at		Slight Damage Flexed At		Severe Damage Flexed at
Wire #	23°C	-196°C	23°C	-196°C	-196°C
3	1X*/1X	---	---	0.5/0.5	---
4	Too damaged to tests- H-film degraded to a yellow-green powder				
5	Too damaged to tests- H-film degraded to a yellow-green powder				
6	.075/1X	---	---	0.50/0.25	---
9	1X/1X	---	---	---	0.50/0.50

*"Mud flat" cracking in the unflexed FEP coating opens with flexing.

Note: Wire #6 exhibits small yellow spots of degraded H-film.

(continued)

TABLE 26-3 (continued)

EFFECT OF 20 HOURS EXPOSURE TO MMH ON MANDREL FLEXIBILITY

Ratio of Mandrel Diam. - Exposed/Unexposed

Wire #		No Damage Flexed at 23°C	No Damage Flexed at -196°C	Slight Damage Flexed at 23°C	Slight Damage Flexed at -196°C	Severe Damage Flexed at -196°C
1*		1X / .075	---	---	---	0.25 / 0.50
2*		1X / .075	---	---	---	0.75 / 1.75
7		---	---	0.125 / 1X	---	2.0 / 1.75
8		1X / 1X	---	---	---	>3.0 / >3.0
10	H-film decomposed to greenish-yellow powder - no tests.					
11	TFE overwrap protects H-film only in limited areas where tests were made.	1X / 1X	---	1.0 / 0.5		Some H-film areas became a green-yellow powder.
12		1X / 1X (swelled in some areas - color reddish brown)				>3.0 / >3.0
13	Silicone rubber softened somewhat			1X / 1X	---	>3.0 / >3.0
14	H-film decomposed to yellow-green powder - silicone rubber soft - no tests					

*ML overcoat eroded away almost completely.

Note: Color changes are recorded elsewhere.

TABLE 26-4

EFFECT OF 20 HOURS EXPOSURE TO MMH - TWISTED PAIRS

Ratio of Breakdown Voltage (KV) - Exposed/Unexposed

Wire #	Maximum Values	Minimum Values
1*	17.5 / 20.2	15.5 / 15.8
2	16.5 / 21	15.6 / 15
3	29.2 / 28.5	28.2 / 25.5
4	1.5 / 18.0	1.0 / 17.5
5	4.1 / 19.5	2.0 / 13.0
6	26.0 / 30.0	23.0 / 25.5
7	9.0 / 25.5	7.5 / 21
8	2.5 / 29	2.5 / 26
9	20.8 / 20.5	17.0 / 14.5
10	<0.5 / 23	<0.5 / 18
11	7.0 / 13.5	3.5 / 10.5
12	6.5 / 18.5	6.0 / 16.5
13	9.0 / 22.4	6.0 / 18.0
14	5.0 / 25.5	3.0 / 20.6

*ML overcoat eroded away in most areas.

Note: Wires 1, 5, 7, 8, 10, 11, 13 and 14 ignite and continue to burn when power is removed.

Ratio of Insulation Resistance (Ohms) - Exposed/Unexposed

Wire #	Maximum Values	Minimum Values
1	3.6×10^{13} / 2.8×10^{13}	1.2×10^{13} / 8.6×10^{12}
2	5.0×10^{13} / 1.6×10^{13}	1.9×10^{13} / 9.8×10^{12}
3	1.3×10^{14} / 6×10^{14}	7.8×10^{13} / 2.5×10^{14}
4	2.2×10^{12} / 5×10^{13}	1.2×10^{11} / 3.8×10^{14}
5	3.9×10^{12} / 2.5×10^{15}	2.3×10^{11} / 5.9×10^{14}
6	1.5×10^{14} / 3.6×10^{14}	5×10^{13} / 2.3×10^{14}
7	6.7×10^{9} / 8.9×10^{12}	1.8×10^{8} / 3.6×10^{12}
8	8.0×10^{7} / 6.3×10^{13}	5.1×10^{7} / 8.3×10^{12}
9	1.5×10^{15} / 1.1×10^{15}	1.1×10^{15} / 3.6×10^{14}
10	Shorted / 1.0×10^{14}	Shorted / 1.5×10^{13}
11	3.3×10^{14} / $>6.0\times10^{14}$	2.1×10^{14} / $>6.0\times10^{14}$
12	4.2×10^{10} / 3.5×10^{13}	1.1×10^{13} / 1.4×10^{13}
13	1.0×10^{5} / 7.8×10^{12}	7.0×10^{4} / 5.0×10^{12}
14	1.0×10^{7} / 4.5×10^{13}	1.0×10^{7} / 3.1×10^{13}

TABLE 26-5

EFFECT OF 20 HOURS EXPOSURE TO HYDRAZINE ON MANDREL FLEXIBILITY

Ratio of Mandrel Diam. - $\frac{\text{Exposed}}{\text{Unexposed}}$

Wire #	No Damage Flexed at 23°C	No Damage Flexed at -196°C	Slight Damage Flexed at 23°C	Slight Damage Flexed at -196°C	Severe Damage Flexed at -196°C
3	1X*/1X	-	-	0.5/0.5	-
4	Too damaged to test - H-film degraded to a yellow powder.				
5	Too damaged to test - H-film degraded to a yellow powder.				
6	.50/1X	-	-	.50/.25	-
9	1X/1X	-	-	.75/.75	-

*"Mud flat" cracking in the unflexed FEP coating opens with flexing.

(continued)

TABLE 26-5 (continued)

EFFECT OF 20 HOURS EXPOSURE TO HYDRAZINE ON MANDREL FLEXIBILITY

Ratio of Mandrel Diam. - Exposed / Unexposed

Wire #	No Damage Flexed at 23°C	No Damage Flexed at -196°C	Slight Damage Flexed at 23°C	Slight Damage Flexed at -196°C	Severe Damage Flexed at -196°C
1*	1X / .075	---	---	---	0.25* / 0.50
2*	1X / .075	---	---	---	0.50 / 1.75
7	---	---	.075 / 1X	---	2.0 / 1.75
8	1X / 1X	---	---	---	>3.0 / >3.0
10	H-film decomposed to yellow (with spots of orange) colored pow_er, Too damaged to test.				
11	Nearly all H-film is decomposed to orange colored powder,	visible when TFE overcoat is removed.	1X / 1X	1.0 / 0.5	---
12	1X / 1X	(Developed brown color with some purple areas)			>3.0 / >3.0
13	Liquid at interface between jacket and rubber. Silicone rubber is brown, but turns to purple color when exposed to air.		1X / 1X	---	>3.0 / >3.0
14	H-film decomposed to orange past - silicone rubber is purple color and swelled - no test.				

*ML overcoat eroded away - almost completely.

Note: Color changes recorded elsewhere.

TABLE 26-6

EFFECT OF 20 HOURS EXPOSURE TO HYDRAZINE - TWISTED PAIRS

Ratio of Breakdown Voltage (KV) - Exposed/Unexposed

Wire #	Maximum Values	Minimum Values
1*	20.5 / 20.2	14.5 / 15.8
2*	21.4 / 21.0	17.0 / 15.0
3	29.5 / 28.5	26.5 / 25.5
4	4.1 / 18.0	3.6 / 17.5
5	5.1 / 19.5	3.0 / 13.0
6	16.6 / 30.0	15.3 / 25.5
7	16.0 / 25.5	9.5 / 21.0
8	10.0 / 29.0	7.5 / 26.0
9	22.4 / 20.5	17.0 / 14.5
10	<0.5 / 23.0	<0.5 / 18.0
11	3.0 / 13.5	1.5 / 10.5
12	7.0 / 18.5	6.5 / 16.5
13	3.7 / 22.4	3.6// 18.0
14	12.0 / 25.5	2.0 / 20.6

Wires #4, 5, 7, 8, 10, 11, 13 and 14 ignite and continue to burn when power is removed.

Ratio of Insulation Resistance (Ohms) - Exposed/Unexposed

1*	$5.6x10^{13}$ / $2.8x10^{13}$	$9.6x10^{12}$ / $8.6x10^{12}$
2*	$4.2x10^{13}$ / $1.6x10^{13}$	$3.1x10^{13}$ / $9.8x10^{12}$
3	$5.6x10^{14}$ / $6 x 10^{14}$	$2.9x10^{14}$ / $2.5x10^{14}$
4	$5x10^{13}$ / $5 x 10^{13}$	$2.3x10^{13}$ / $3.8x10^{13}$
5	$2.5x10^{13}$ / $2.5x10^{15}$	$2x10^{10}$ / $5.9x10^{14}$
6	$7.8x10^{13}$ / $3.6x10^{14}$	$3.9x10^{12}$ / $2.3x10^{14}$
7	$1.0x10^{11}$ / $8.9x10^{12}$	$1.0x10^{8}$ / $3.6x10^{12}$
8	$1.4x10^{11}$ / $6.3x10^{13}$	$2.3x10^{8}$ / $8.3x10^{12}$
9	$3.6x10^{15}$ / $1.1x10^{15}$	$1.2x10^{15}$ / $3.6x10^{14}$
10	Shorted / $1.0x10^{14}$	Shorted / $1.5x10^{13}$
11	$2.3x10^{14}$ /$>6.0x10^{14}$	$1.9x10^{8}$ / $>6.0x10^{14}$
12	$2.3x10^{7}$ / $3.5x10^{13}$	$6.8x10^{6}$ / $1.4x10^{13}$
13	$7.1x10^{6}$ / $7.8x10^{12}$	$3.3x10^{5}$ / $5.0x10^{12}$
14	$6.0x10^{4}$ / $4.5x10^{13}$	$5.0x10^{4}$ / $3.1x10^{13}$

*ML overcoat eroded away in most areas.

TABLE 26-7

EFFECT OF 20 HOURS EXPOSURE TO A-50 ON MANDREL FLEXIBILITY

Ratio of Mandrel Diam. - $\frac{\text{Exposed}}{\text{Unexposed}}$

Wire #	No Damage Flexed at 23°C	No Damage Flexed at -196°C	Slight Damage Flexed at 23°C	Slight Damage Flexed at -196°C	Severe Damage Flexed at -196°C
3	1X*/1X	-	-	0.5/0.5	-
4	Too damaged to test - H-film degraded to a brigh yellow powder.				
5	Too damaged to test - H-film degraded to a yellow-gold powder.				
6	1X/1X	-	-	0.25/0.25	-
9	1X/1X	-	-	-	0.50/0.50

*"Mud flat" cracking in the unflexed FEP coating opens with flexing.

Note: Wire #6 exhibits yellow spots of degraded H-film plus extensive crazing in the yellow areas.

(continued)

TABLE 26-7 (continued)

EFFECT OF 20 HOURS EXPOSURE TO A-50 ON MANDREL FLEXIBILITY

Ratio of Mandrel Diam. - $\frac{\text{Exposed}}{\text{Unexposed}}$

Wire #	No Damage Flexed at 23°C	No Damage Flexed at -196°C	Severe Damage Flexed at 23°C	Severe Damage Flexed at -196°C	Severe Damage Flexed at -196°C
1*	1X/.075	---	---	---	0.125*/0.50
2*	1X/.075	---	---	---	0.50/1.75
7	---	---	1X/1X	---	3.0/1.75
8	1X/1X	---	---	---	>3.0/>3.0
10	H-film decomposed to yellow (with spots of deep orange) colored powder. Too damaged to test.				
11	Nearly all H-film is decomposed to orange colored powder, visible when TFE overcoat is removed.		1X/1X	1.5/0.5	---
12	(Developed brown color with purple spots)		1X/<1X	---	>3.0/>3.0
13	Rubber appears to be damaged.		1X/1X	---	>3.0/>3.0
14	H-film decomposed to orange paste, silicone rubber is a purple color - No test.				

*ML overcoat eroded away almost completely.

Note: Color changes are recorded elsewhere.

TABLE 26-8

EFFECT OF 20 HOURS EXPOSURE TO A-50 - TWISTED PAIRS

Ratio of Breakdown Voltage (KV) - Exposed/Unexposed

Wire #	Maximum Values	Minimum Values
1*	20.5 / 20.2	14.0 / 15.8
2	17.6 / 21.0	14.3 / 15.0
3	28.4 / 28.5	24.0 / 25.5
4	4.4 / 18.0	4.0 / 17.5
5	4.1 / 19.5	2.0 / 13.0
6	23.0 / 30.0	15.5 / 25.5
7	6.5 / 25.5	6.0 / 21.0
8	4.0 / 29.0	1.5 / 26.0
9	22.3 / 20.5	18.4 / 14.5
10	<0.5 / 23.0	<0.5 / 18.0
11	11.0 / 13.5	5.0 / 10.5
12	8.3 / 18.5	5.7 / 16.5
13	6.7 / 22.4	5.6 / 18.0
14	2.1 / 25.5	1.5 / 20.6

*Wires #7, 11, 13 and 14 burn continuously - Wire #8 flame goes out when power is removed.

Ratio of Insulation Resistance (Ohms) - Exposed/Unexposed)

Wire #	Maximum Values	Minimum Values
1	1.0×10^{12} / 2.8×10^{13}	3.3×10^{11} / 8.6×10^{12}
2	1.9×10^{13} / 1.6×10^{13}	1.0×10^{13} / 9.8×10^{12}
3	1.4×10^{14} / 6×10^{14}	6.6×10^{13} / 2.5×10^{14}
4	1.4×10^{12} / 5×10^{13}	5×10^{10} / 3.8×10^{13}
5	2.3×10^{11} / 2.5×10^{15}	8.9×10^{10} / 5.9×10^{14}
6	6×10^{13} / 3.6×10^{14}	1.8×10^{13} / 2.3×10^{14}
7	Shorted / 8.9×10^{12}	Shorted / 3.6×10^{12}
8	3.2×10^{8} / 6.3×10^{13}	8.1×10^{7} / 8.3×10^{12}
9	1×10^{15} / 1.1×10^{15}	6×10^{14} / 3.6×10^{14}
10	Shorted / 1.0×10^{14}	Shorted / 1.5×10^{13}
11	5.9×10^{14} / $>6.0\times10^{14}$	1.5×10^{13} / $>6.0\times10^{14}$
12	3.9×10^{6} / 3.5×10^{13}	1.5×10^{6} / 1.4×10^{13}
13	3.0×10^{6} / 7.8×10^{12}	1.5×10^{6} / 5.0×10^{12}
14	4.8×10^{4} / 4.5×10^{13}	2.6×10^{4} / 3.1×10^{13}

TABLE 26-9

EFFECT OF 20 HOURS EXPOSURE TO N_2O_4 ON MANDREL FLEXIBILITY

Ratio of Mandrel Dia. - Exposed/Unexposed

	No Damage Flexed at		Slight Damage Flexed at		Severe Damage Flexed at
Wire #	23°C	-196°C	23°C	-196°C	-196°C
1			1X/1X		0.5/0.5
2	1X/1X	ML decomposed to yellow powder		0.75/2.0	
3*	1X/1X				1.0/0.25
4			0.25/1X		3.0/.075
5			0.25/1X		2.0/.075
6			0.25/<1X		2.0/0.25
7			0.25/1X		3.0/1.75
8**	1X/1X				>3.0/>3.0
9	1X/1X				0.5/0.5
10			0.50/1X		2.0/0.25
11***	1X/.075				1.75/0.25
12	Completely destroyed				
13	Rubber swelled sufficiently to split Kynar jacket		.125/1X		3.0/3.0
14	Rubber appears like dried paste - too damaged to test				

* Red color faded
** Tinted green
*** N_2O_4 trapped under jacket is released when wire is cut

TABLE 26-10

EFFECT OF 10 HOURS EXPOSURE TO N_2O_4 ON VOLTAGE BREAKDOWN - TWISTED PAIRS

Ratio of Breakdown Voltage (KV) - $\frac{\text{Exposed}}{\text{Unexposed}}$

Wire #		Max. Values	Min. Values
1*		13.4/20.2	10.2/15.8
2		4.8/21.0	3.6/15.0
3		19.0/28.5	17.5/25.5
4		1.0/18.0	0.8/17.5
5		2.5/19.5	1.0/13.0
6		16.2/30.0	13.8/25.5
7*		11.0/25.5	8.5/21.0
8**		17.5/29.0	15.0/26.0
9		18.5/20.5	12.5/14.5
10		2.9/23.0	1.5/18.0
11		7.5/13.5	3.5/10.5
12	Completely destroyed		
13		7.6/22.4	3.3/18.0
14		9.5/25.5	6.0/20.6

* Flamed briefly
**Burned fiercely

TABLE 26-11

EFFECT OF 10 HOURS EXPOSURE TO N_2O_4 ON INSULATION RESISTANCE - TWISTED PAIRS

Ratio of Insulation Resistance (Ohms) - $\frac{\text{Exposed}}{\text{Unexposed}}$

Wire #		Max. Values	Min. Values
1		$5.0 \times 10^{12} / 2.8 \times 10^{13}$	$6.4 \times 10^{9} / 8.6 \times 10^{12}$
2		$4.2 \times 10^{10} / 1.6 \times 10^{13}$	$1.3 \times 10^{10} / 9.8 \times 10^{12}$
3		$9.3 \times 10^{11} / 6.0 \times 10^{14}$	$6.9 \times 10^{11} / 2.5 \times 10^{14}$
4		$2.5 \times 10^{13} / 5.0 \times 10^{13}$	$1.0 \times 10^{6} / 3.8 \times 10^{13}$
5		$1.7 \times 10^{10} / 2.5 \times 10^{15}$	$8.6 \times 10^{8} / 5.9 \times 10^{14}$
6		$4.2 \times 10^{11} / 3.6 \times 10^{15}$	$1.0 \times 10^{10} / 2.3 \times 10^{14}$
7		$1.1 \times 10^{10} / 8.9 \times 10^{12}$	$5.6 \times 10^{8} / 3.6 \times 10^{12}$
8		$8.3 \times 10^{9} / 6.3 \times 10^{13}$	$4.4 \times 10^{8} / 8.3 \times 10^{12}$
9		$1.3 \times 10^{15} / 1.1 \times 10^{15}$	$4.5 \times 10^{14} / 3.6 \times 10^{14}$
10		$1.9 \times 10^{8} / 1.0 \times 10^{14}$	$8.9 \times 10^{7} / 1.5 \times 10^{13}$
11		$2.6 \times 10^{14} / >6.0 \times 10^{14}$	$7.7 \times 10^{12} / >6.0 \times 10^{14}$
12	Completely destroyed		
13		$2.3 \times 10^{10} / 7.8 \times 10^{12}$	$1.7 \times 10^{9} / 5.0 \times 10^{12}$
14		$6.7 \times 10^{8} / 4.5 \times 10^{13}$	$1.5 \times 10^{8} / 3.1 \times 10^{13}$

TABLE 26-12

EFFECT OF 20 HOURS EXPOSURE TO FLUORINE ON MANDREL FLEXIBILITY

Ratio of Mandrel Dia. - $\frac{\text{Exposed}}{\text{Unexposed}}$

	No Damage Flexed at		Slight Damage Flexed at		Severe Damage Flexed at
Wire #	23°C	-196°C	23°C	-196°C	-196°C
1*	1X/1X				0.5/0.5
2	1X/1X				1.75/1.75
3	1X/1X			0.5/0.5	
4			0.25/1X		0.25/.075
5			0.25/1X		0.5/.075
6**	1X/1X				0.5/0.25
7			.075/1X		3.0/1.75
8	1X/1X				>3.0/>3.0
9	1X/1X				0.75/0.50
10			1X/1X	0.75/0.50	
11			1X/1X	1.5/0.75	
12(1)	Too damaged to test				
13	Started to burn - flushed with nitrogen - no test				
14			0.25/1X		>3.0/>3.0

* Areas of ML overcoat completely eroded away, some spalling also. Results are for FEP only.

** Some areas of surface are charred (apparently at fingerprints?). Sample flushed with nitrogen after only 5 minutes exposure to extinguish fire.

(1) Caught fire after 5 minutes exposure and was flushed with nitrogen - no tests.

TABLE 26-13

EFFECT OF 10 HOURS EXPOSURE TO FLUORINE ON VOLTAGE BREAKDOWN - TWISTED PAIRS

Ratio of Breakdown Voltage (KV) - $\frac{\text{Exposed}}{\text{Unexposed}}$

Wire #	Max. Values	Min. Values
1*	23.5/20.2	21.0/15.8
2	20.0/21.0	18.0/15.0
3	31.5/28.5	24.5/25.5
4	9.0/18.0	7.0/17.5
5	10.0/19.5	10.0/13.0
6**	32.5/30.0	27.5/25.5
7	30.5/25.5	21.0/21.0
8	29.0/29.0	26.0/26.0
9	18.5/20.5	17.5/14.5
10	18.5/23.0	13.5/18.0
11	14.5/13.5	10.0/10.5
12**	Too damaged to test	
13	Started to burn - flushed with nitrogen - no test	
14	13.8/25.5	9.9/20.6

* ML enamel overcoat is completely eroded away in some areas.

** Caught fire after 5 minutes exposure and was flushed with nitrogen

TABLE 26-14

EFFECT OF 10 HOURS EXPOSURE TO FLUORINE ON INSULATION RESISTANCE - TWISTED PAIRS

Ratio of Insulation Resistance (Ohms) - $\frac{\text{Exposed}}{\text{Unexposed}}$

Wire #		Max. Values	Min. Values
1*		8.3×10^{12}/ 2.8×10^{13}	1.9×10^{12}/ 8.6×10^{12}
2		3.6×10^{13}/ 1.6×10^{13}	2.1×10^{13}/ 9.8×10^{12}
3		1.2×10^{13}/ 6.0×10^{14}	1.9×10^{12}/ 2.5×10^{14}
4		4.2×10^{13}/ 5.0×10^{13}	7.6×10^{10}/ 3.8×10^{13}
5		2.6×10^{11}/ 2.5×10^{15}	8.6×10^{12}/ 5.9×10^{14}
6**		1.4×10^{13}/ 3.6×10^{15}	8.6×10^{12}/ 2.3×10^{14}
7		2.0×10^{13}/ 8.9×10^{12}	5.6×10^{12}/ 3.6×10^{12}
8		3.5×10^{13}/ 6.3×10^{13}	7.0×10^{12}/ 8.3×10^{12}
9		1.2×10^{15}/ 1.1×10^{15}	5.6×10^{14}/ 3.6×10^{14}
10		9.1×10^{11}/ 1.0×10^{14}	5.6×10^{10}/ 1.5×10^{13}
11		4.5×10^{13}/$>6.0 \times 10^{14}$	3.2×10^{13}/$>6.0 \times 10^{14}$
12***	Too damaged to test	/ 3.5×10^{13}	/ 1.4×10^{13}
13	Started to burn - flushed with nitrogen - no test		
14		3.6×10^{11}/ 4.5×10^{13}	1.3×10^{11}/ 3.1×10^{13}

* Areas of ML enamel overcoat are completely eroded away.

** Caught fire after 5 minutes exposure (apparently at fingerprints) and was flushed with nitrogen.

*** Caught fire after 5 minutes exposure and was flushed with nitrogen - no tests

TABLE 26-15

EFFECT OF 16 DAYS EXPOSURE TO LUBE OIL ON MANDREL FLEXIBILITY

Ratio of Mandrel Diam. - Exposed/Unexposed

	No Damage Flexed at		Slight Damage Flexed at		Severe Damage Flexed at
Wire #	23°C	-196°C	23°C	-196°C	-196°C
3	1X/1X	---	---	0.5/0.5	---
4	---	---	1X/1X	.25/.125	---
5	---	---	1X/1X	.50/.125	0.25/.075
6	1X/1X	---	---	0.50/0.25	---
7	1X/.075	---	---	---	3.0/1.75
8	1X/1X	---	---	---	3.0/3.0
9	1X/1X	---	---	---	0.5/0.5
1			1X/1X		1.5/0.5
2		2.0/2.0	1X/1X		
10			1X/1X	0.50/0.50	
11			1X/1X		0.75/0.25
12	1X/1X	Swelled slightly			≥3.0/>3.0
13	Penetration of oil between rubber and jacket.		1X/1X		≥3.0/>3.0
14			1X/1X		≥3.0/>3.0

TABLE 26-16

EFFECT OF 14 DAYS EXPOSURE TO LUBE OIL ON VOLTAGE BREAKDOWN - TWISTED PAIRS

Ratio of Breakdown Voltage (KV) - Exposed/Unexposed

Wire #	Max. Values	Min. Values
3	31 / 28.5	27.4/ 25.5
4	26 / 18	24.4/ 17.5
5	20.8/ 19.5	14 / 13
6	38.4/ 30	35.2/ 25.5
7	23 / 25.5	18 / 21
8	34 / 29	29 / 26
9	21.5/ 20.5	19.5/ 14.5
1	20.7/ 20.2	16.1/ 15.8
2	18.4/ 21.0	15.1/ 15.0
10	24.8/ 23.0	18.0/ 18.0
11	16.2/ 13.5	15.0/ 10.5
12	24.3/ 18.5	19.8/ 16.5
13	23.3/ 22.4	17.6/ 18.0
14	24.5/ 25.5	21.4/ 20.6

Small flame occurred with wire # 1, 2, 12, 13 and 14

TABLE 26-17

EFFECT OF 14 DAYS EXPOSURE TO LUBE OIL ON INSULATION RESISTANCE - TWISTED PAIRS

Ratio of Insulation Resistance (ohms) - Exposed/Unexposed

Wire #	Max. Values	Min. Values
3	$2.0 \times 10^{13}/6 \times 10^{14}$	$1.4 \times 10^{13}/2.5 \times 10^{14}$
4	$6 \times 10^{12}/5 \times 10^{13}$	$4.2 \times 10^{12}/3.8 \times 10^{13}$
5	$1.3 \times 10^{13}/2.5 \times 10^{15}$	$8.9 \times 10^{12}/5.9 \times 10^{14}$
6	$3.6 \times 10^{13}/3.6 \times 10^{14}$	$2.2 \times 10^{13}/2.3 \times 10^{14}$
7	$2.3 \times 10^{13}/8.9 \times 10^{12}$	$2.2 \times 10^{12}/3.6 \times 10^{12}$
8	$1.3 \times 10^{13}/6.3 \times 10^{13}$	$3.6 \times 10^{12}/8.3 \times 10^{12}$
9	$3.9 \times 10^{13}/1.1 \times 10^{15}$	$23 \times 10^{13}/3.6 \times 10^{14}$
1	$9.8 \times 10^{12}/2.8 \times 10^{13}$	$2.6 \times 10^{12}/8.6 \times 10^{12}$
2	$1.7 \times 10^{13}/1.6 \times 10^{13}$	$1.4 \times 10^{13}/9.8 \times 10^{12}$
10	$1.1 \times 10^{13}/1.0 \times 10^{14}$	$7.1 \times 10^{12}/1.5 \times 10^{13}$
11	$3.9 \times 10^{13}/>6.0 \times 10^{14}$	$3.6 \times 10^{13}/>6.0 \times 10^{14}$
12	$1.9 \times 10^{10}/3.5 \times 10^{13}$	$1.6 \times 10^{10}/1.4 \times 10^{13}$
13	$3.6 \times 10^{12}/7.8 \times 10^{12}$	$2.9 \times 10^{12}/5.0 \times 10^{12}$
14	$7.1 \times 10^{12}/4.5 \times 10^{13}$	$6.4 \times 10^{12}/3.1 \times 10^{13}$

TABLE 26-18

EFFECT OF 14 DAYS EXPOSURE TO HYDRAULIC OIL ON MANDREL FLEXIBILITY

Ratio of Mandrel Diam. - Exposed/Unexposed

	No Damage Flexed at		Slight Damage Flexed at		Severe Damage Flexed at
Wire #	23°C	-196°C	23°C	-196°C	-196°C
3	1X/1X	---	---	0.5/0.5	---
4	---	---	1X/1X	.25/.125	---
5	---	---	1X/1X	.25/.125	---
6	1X/1X	0.50/0.50	---	---	---
7	1X/.075	---	---	---	3.0/1.75
8*	1X/1X	---	---	---	3.0/3.0
9	1X/1X	---	---	---	0.5/0.5
1	---	---	1X/1X	---	1.5/0.5
2	---	---	1X/1X	---	2.0/1.75
10	---	---	1X/1X	0.5/0.5	---
11	---	---	1X/1X	---	0.75/0.25
12	Badly swelled - no test				
13	Rubber swelled and Kynar split				
14	---	---	1X/1X	---	>3.0/>3.0

*Insulation stained - pink color

TABLE 26-19

EFFECT OF 14 DAYS EXPOSURE TO HYDRAULIC OIL ON VOLTAGE BREAKDOWN - TWISTED PAIRS

Ratio of Breakdown Voltage (KV) - Exposed/Unexposed

Wire #	Max. Values	Min. Values
3	31.4/28.5	28.9/25
4	23.7/18	19.3/17.5
5	25 /19.5	20 /13
6	36.2/30	35 /25.5
7	25.2/25.5	18.4/21
3	35.1/29	30 /26
9	19.9/20.5	18.7/14.5
1	21.4/20.2	17.6/15.8
2	24.3/21/0	17.3/15.0
10	20.1/23.0	17.0/18.0
11	16.5/13.5	14.6/10.5
12	21.0/18.5	18.5/16.5
13	23.3/22.4	18.0/18.0
14	25.5/25.5	21.5/20.6

Small flame occurred in wires #2, 11. Wires #7, 12, 13 and 14 burned with a bright flame.

TABLE 26-20

EFFECT OF 14 DAYS EXPOSURE TO HYDRAULIC OIL

Ratio of Insulation Resistance (ohms) - Exposed/Unexposed

Wire #	Max. Values	Min. Values
3	$1.4 \times 10^{13} / 6 \times 10^{14}$	$8.9 \times 10^{12} / 2.5 \times 10^{14}$
4	$1.1 \times 10^{13} / 5 \times 10^{13}$	$6.1 \times 10^{12} / 3.8 \times 10^{13}$
5	$9.8 \times 10^{12} / 2.5 \times 10^{15}$	$8.3 \times 10^{12} / 5.9 \times 10^{14}$
6	$1.1 \times 10^{13} / 3.6 \times 10^{14}$	$6.8 \times 10^{12} / 2.3 \times 10^{14}$
7	$2.3 \times 10^{13} / 8.9 \times 10^{12}$	$1.5 \times 10^{13} / 3.6 \times 10^{12}$
8	$1.6 \times 10^{13} / 6.3 \times 10^{13}$	$1.4 \times 10^{13} / 8.3 \times 10^{12}$
9	$2.9 \times 10^{13} / 1.1 \times 10^{15}$	$2.0 \times 10^{13} / 3.6 \times 10^{14}$
1	$1.6 \times 10^{13} / 2.3 \times 10^{13}$	$1.0 \times 10^{13} / 8.6 \times 10^{12}$
2	$1.5 \times 10^{13} / 1.6 \times 10^{13}$	$1.1 \times 10^{13} / 9.8 \times 10^{12}$
10	$1.0 \times 10^{13} / 1.0 \times 10^{14}$	$5.1 \times 10^{12} / 1.5 \times 10^{13}$
11	$6.9 \times 10^{13} / >6.0 \times 10^{14}$	$3.9 \times 10^{13} / >6.0 \times 10^{14}$
12	$2.9 \times 10^{12} / 3.5 \times 10^{13}$	$2.2 \times 10^{12} / 1.4 \times 10^{13}$
13	$4.5 \times 10^{12} / 7.8 \times 10^{12}$	$2.6 \times 10^{12} / 5.0 \times 10^{12}$
14	$9.3 \times 10^{12} / 4.5 \times 10^{13}$	$5.0 \times 10^{12} / 3.1 \times 10^{13}$

TABLE 26-21

EFFECT OF 14 DAYS EXPOSURE TO 5% NaCl ON MANDREL FLEXIBILITY

Ratio of Mandrel Diam. - Exposed/Unexposed

	No Damage Flexed at		Slight Damage Flexed at		Severe Damage Flexed at
Wire #	23°C	-196°C	23°C	-196°C	-196°C
3	1X/1X	---	---	0.50/0.50	---
4	---	---	1X/1X	0.25/.125	---
5	---	---	0.25/1X	---	0.25/.075
6	1X/1X	---	---	0.25/0.25	---
7	1X/.075	2.0/2.0	---	---	---
8	1X/1X	---	---	---	3.0/3.0
9	1X/1X	---	---	---	0.5/0.5
1	---	---	1X/1X	1.0/0.75	---
2	---	---	0.250/1X	---	2.0/1.75
10	---	---	1X/1X	0.5/0.5	---
11	---	---	1X/1X	1.5/0.50	---
12	1X/1X	---	---	---	>3.0/>3.0
13	Developed blue-white blotches underneath jacket		1X/1X	---	>3.0/>3.0
14	---	---	1X/1X	---	>3.0/>3.0

TABLE 26-22

EFFECT OF 14 DAYS EXPOSURE TO 5% Na Cl ON VOLTAGE BREAKDOWN - TWISTED PAIRS

Ratio of Breakdown Voltage (kv) - Exposed/Unexposed

Wire #	Max. Values	Min. Values
3	26.5/ 28.5	25.5/ 25.5
4	16.6/ 18	8.7/ 17.5
5	15 / 19.5	12.5/ 13
6	29.5/ 30	27 / 25.5
7	20.5/ 25.5	19.5/ 21
8	24 / 29	17 / 26
9	20.5/ 20.5	17.5/ 14.5
1	20.5/ 20.2	16.5/ 15.8
2	19.6/ 21.0	16.1/ 15.0
10	26.5/ 23.0	19.0/ 18.0
11	12.0/ 13.5	12.0/ 10.5
12	19.1/ 18.5	17.1/ 16.5
13	20.5/ 22.4	19.5/ 18.0
14	24.5/ 25.5	21.4/ 20.6

TABLE 26-23

EFFECT OF 14 DAYS EXPOSURE TO 5% NaCl ON INSULATION RESISTANCE - TWISTED PAIRS

Ratio of Insulation Resistance (ohms) - Exposed/Unexposed

Wire #	Max Values	Min. Values
3	2.1×10^{14}/ 6×10^{14}	7.8×10^{13}/ 2.5×10^{14}
4	1.9×10^{13}/ 5×10^{13}	2.8×10^{12}/ 3.8×10^{13}
5	1.6×10^{12}/ 2.5×10^{15}	8.6×10^{11}/ 5.9×10^{14}
6	3.5×10^{13}/ 3.6×10^{14}	2.3×10^{13}/ 2.3×10^{14}
7	2.5×10^{13}/ 8.9×10^{12}	1.7×10^{13}/ 3.6×10^{12}
8	6.3×10^{13}/ 6.3×10^{13}	1.9×10^{13}/ 8.3×10^{12}
9	7.1×10^{14}/ 1.1×10^{15}	2.9×10^{14}/ 3.6×10^{14}
1	3.3×10^{12}/ 2.8×10^{13}	3.3×10^{11}/ 8.6×10^{12}
2	5.0×10^{4} / 1.6×10^{13}	3.9×10^{13}/ 9.8×10^{12}
10	3.1×10^{12}/ 1.0×10^{14}	6.9×10^{11}/ 1.5×10^{13}
11	2.3×10^{14}/$>6.0 \times 10^{14}$	1.4×10^{14}/$>6.0 \times 10^{14}$
12	7.8×10^{12}/ 3.5×10^{13}	6.0×10^{12}/ 1.4×10^{13}
13	3.6×10^{12}/ 7.8×10^{12}	2.0×10^{12}/ 5.0×10^{12}
14	4.5×10^{12}/ 4.5×10^{13}	3.3×10^{12}/ 3.1×10^{13}

TABLE 26-24

EFFECT OF 14 DAYS EXPOSURE TO SALT FOG ON MANDREL FLEXIBILITY

Ratio of Mandrel Dias. - Exposed / Unexposed

	No Damage Flexed at		Slight Damage Flexed at		Severe Damage Flexed at
Wire #	23°C	-196°C	23°C	-196°C	-196°C
1	---	---	1X / 1X	---	1.0 / 0.5
2	---	---	0.75 / 1X	---	2.0 / 1.75
3	1X / 1X	---	---	0.75 / 0.50	---
4	---	---	0.25 / 1X	---	1.75 / .075
5	---	---	.075 / 1X	---	1.0 / .075
6	1X / 1X	---	---	1.0 / 0.25	---
7	.075 / .075	---	---	---	1.75 / 1.75
8	1X / 1X	---	---	---	>3.0 / >3.0
9	1X / 1X	---	---	---	0.5 / 0.5
10	---	---	1X / 1X	0.50 / 0.50	---
11	---	---	1X / 1X	0.75 / 0.50	---
12	1X / 1X	---	---	---	>3.0 / >3.0
13	---	---	0.25 / 1X	---	>3.0 / >3.0
14	---	---	1X / 1X	---	>3.0 / >3.0

TABLE 26-25

EFFECT OF 14 DAYS EXPOSURE TO SALT FOG ON VOLTAGE BREAKDOWN - TWISTED PAIRS

Ratio of Breakdown Voltage (kv) - Exposed/Unexposed

Wire #	Max. Values	Min. Values
3	27 / 28.5	21.5 / 25.5
4	2 / 18	1.25 / 17.5
5	6 / 19.5	2.5 / 13
6	23 / 30	21.5 / 25.5
7	21 / 25.5	18 / 21
8	15 / 29	15 / 26
9	24 / 20.5	22 / 14.5
10	18.5 / 23	17 / 18
1	20.5 / 20.2	14.5 / 15.8
2	17.5 / 21.0	15.5 / 15.0
11	14.2 / 13.5	11.8 / 10.5
12	16.6 / 18.5	12.7 / 16.5
13	23.5 / 27.4	21.0 / 18.0
14	20.0 / 25.5	19.3 / 20.6

TABLE 26-26

EFFECT OF 14 DAYS EXPOSURE TO SALT FOG ON INSULATION RESISTANCE - TWISTED PAIRS

Ratio of Insulation Resistance (ohms) - Exposed/Unexposed

Wire #	Max. Values	Min. Values
3	3.9×10^{13} / 6×10^{14}	2.5×10^{13} / 2.5×10^{14}
4	2.3×10^{9} / 5×10^{13}	3.9×10^{8} / 3.8×10^{13}
5	1.5×10^{13} / 2.5×10^{15}	1.9×10^{9} / 5.9×10^{14}
6	1.7×10^{13} / 3.6×10^{14}	5.9×10^{11} / 2.3×10^{14}
7	2×10^{13} / 8.9×10^{12}	1.9×10^{13} / 3.6×10^{12}
8	3.9×10^{13} / 6.3×10^{13}	1.8×10^{13} / 8.3×10^{12}
9	$> 10^{14}$ / 1.1×10^{15}	$> 10^{14}$ / 3.6×10^{14}
10	4.2×10^{13} / 1×10^{14}	2.9×10^{11} / 1.5×10^{13}
1	1.8×10^{13} / 2.8×10^{13}	1.4×10^{13} / 8.6×10^{12}
2	1.9×10^{13} / 1.6×10^{13}	1.4×10^{13} / 9.8×10^{12}
11	$>1.0 \times 10^{15}$ / $>6.0 \times 10^{14}$	5.0×10^{14} / $>6.0 \times 10^{14}$
12	2.5×10^{13} / 3.5×10^{13}	1.8×10^{13} / 1.4×10^{13}
13	3.1×10^{12} / 7.8×10^{12}	1.9×10^{12} / 5.0×10^{12}
14	2.3×10^{13} / 4.5×10^{13}	1.9×10^{13} / 3.1×10^{13}

TABLE 26-27

EFFECT OF 14 DAYS EXPOSURE TO ETHYLENE GYLCOL/WATER ON MANDREL FLEXIBILITY

Ratio of Mandrel Dia. - Exposed/Unexposed

	No Damage Flexed at		Slight Damage Flexed at		Severe Damage Flexed at
Wire #	23°C	-196°C	23°C	-196°C	-196°C
1	---	---	1X/1X	---	1.5/0.5
2	---	---	1X/1X	3.0/2.0	---
3	1X/1X	---	---	0.5/0.5	---
4	---	---	1X/1X	0.125/0.125	---
5	---	---	1X/1X	0.125/0.125	---
6	1X/1X	---	---	---	0.25/0.25
7	1X/.075	---	---	---	2.0/1.75
8	1X/1X	---	---	---	>3.0/>3.0
9	1X/1X	---	---	---	0.5/0.5
10	---	---	1X/1X	0.75/0.50	---
11	---	---	1X/1X	1.5/0.75	---
12	---	---	1X/1X	---	>3.0/>3.0
13	Fluid trapped under H-film		1X/1X	---	>3.0/>3.0
14	---	---	1X/1X	---	>3.0/>3.0

TABLE 26-28

EFFECT OF 14 DAYS EXPOSURE TO ETHYLENE GLYCOL/WATER ON VOLTAGE BREAKDOWN - TWISTED PAIRS

Ratio of Breakdown Voltage (KV) - $\frac{\text{Exposed}}{\text{Unexposed}}$

Wire #	Max. Values	Min. Values
1	21.0 / 20.2	17.5 / 15.8
2	16.8 / 21.0	14.0 / 15.0
3	30.0 / 28.5	28.0 / 25.5
4	22.5 / 18.0	21.5 / 17.5
5	23.5 / 19.5	16.0 / 13.0
6	38.0 / 30.0	33.0 / 25.5
7	23.5 / 25.5	21.5 / 21.0
8	33.0 / 29.0	30.0 / 26.0
9	22.0 / 20.5	18.0 / 14.5
10	20.0 / 23.0	17.1 / 18.0
11	13.5 / 13.5	13.0 / 10.5
12	12.0 / 18.5	10.6 / 16.5
13	20.0 / 22.4	15.0 / 18.0
14	24.5 / 25.5	20.2 / 20.6

TABLE 26-29

EFFECT OF 14 DAYS EXPOSURE TO ETHYLENE GLYCOL/WATER ON INSULATION RESISTANCE - TWISTED PAIRS

Ratio of Insulation Resistance (Ohms) - $\frac{\text{Exposed}}{\text{Unexposed}}$

Wire #	Max. Values	Min. Values
1	$9.4 \times 10^{13} / 2.8 \times 10^{13}$	$5.0 \times 10^{12} / 8.6 \times 10^{12}$
2	$5.0 \times 10^{12} / 1.6 \times 10^{13}$	$1.8 \times 10^{12} / 9.8 \times 10^{12}$
3	$7.1 \times 10^{13} / 6.0 \times 10^{14}$	$5.3 \times 10^{13} / 2.5 \times 10^{14}$
4	$9.6 \times 10^{12} / 5.0 \times 10^{13}$	$2.3 \times 10^{12} / 3.8 \times 10^{13}$
5	$>2.0 \times 10^{15} / 2.5 \times 10^{15}$	$7.1 \times 10^{11} / 5.9 \times 10^{14}$
6	$3.8 \times 10^{13} / 3.6 \times 10^{15}$	$1.4 \times 10^{13} / 2.3 \times 10^{14}$
7	$5.0 \times 10^{13} / 8.9 \times 10^{12}$	$5.6 \times 10^{11} / 3.6 \times 10^{12}$
8	$>1.0 \times 10^{15} / 6.3 \times 10^{13}$	$>1.0 \times 10^{15} / 8.3 \times 10^{12}$
9	$>2.0 \times 10^{15} / 1.1 \times 10^{15}$	$4.5 \times 10^{13} / 3.6 \times 10^{14}$
10	$5.8 \times 10^{13} / 1.0 \times 10^{14}$	$1.7 \times 10^{12} / 1.5 \times 10^{13}$
11	$7.8 \times 10^{13} / >6.0 \times 10^{14}$	$3.3 \times 10^{13} / >6.0 \times 10^{14}$
12	$4.5 \times 10^{11} / 3.5 \times 10^{13}$	$1.7 \times 10^{9} / 1.4 \times 10^{13}$
13	$3.6 \times 10^{12} / 7.8 \times 10^{12}$	$2.4 \times 10^{12} / 5.0 \times 10^{12}$
14	$9.1 \times 10^{12} / 4.5 \times 10^{13}$	$4.5 \times 10^{12} / 3.1 \times 10^{13}$

TABLE 26-30

EFFECT OF 14 DAYS EXPOSURE TO ETHYL ALCOHOL ON MANDREL FLEXIBILITY

Ratio of Mandrel Diam. - Exposed/Unexposed

Wire #	No Damage Flexed at 23°C	No Damage Flexed at -196°C	Slight Damage Flexed at 23°C	Slight Damage Flexed at -196°C	Severe Damage Flexed at -196°C
1	---	---	1X/1X	---	0.75/0.50
2	---	---	0.125/1X	---	1.75/1.75
3	1X/1X	---	---	0.5/0.5	---
4	---	---	1X/1X	0.5/.125	---
5	---	---	1X/1X	---	0.25/.075
6	1X/1X	---	---	0.50/0.25	---
7	.075/.075	---	---	---	2.0/1.75
8	1X/1X	---	---	---	≥3.0/≥3.0
9	1X/1X	---	---	---	0.5/0.5
10	---	---	1X/1X	0.5/0.5	---
11	---	---	1X/1X	---	0.50/0.25
12	1X/1X	---	---	---	≥3.0/≥3.0
13	Blue-white blotches at interface between rubber and jacket.		1X/1X	---	≥3.0/≥3.0
14	---	---	1X/1X	---	≥3.0/≥3.0

TABLE 26-31

EFFECT OF 14 DAYS EXPOSURE TO ETHYL ALCOHOL - TWISTED PAIRS

Ratio of Breakdown Voltage (KV) - Exposed/Unexposed

Wire #	Maximum Values	Minimum Values
1*	21.0 / 20.2	16.9/ 15.8
2	20.1 / 21.0	17.0/ 15.0
3	29.0 / 28.5	28.0/ 25.5
4	18.0 / 18.0	16.5/ 17.5
5	18.0 / 19.5	15/0/ 13.0
6	32.0 / 30.0	29.5/ 25.5
7	27.7 / 25.5	25.2/ 21.0
8	21.9 / 29.0	21.2/ 26.0
9	23.0 / 20.5	18.0/ 14.5
10	21.9 / 23.0	21.2/ 18.0
11*	14.7 / 13.5	11.6/ 10.5
12	17.7 / 18.5	13.7/ 16.5
13	20.0 / 22.4	15.0/ 18.0
14*	21.5 / 25.5	17.6/ 20.6

*Flame at breakdown.

Ratio of Insulation Resistance (Ohms) - Exposed/Unexposed

1	$6.7x10^{13}$ / $2.8x10^{13}$	$4.2x10^{13}$ / $8.6x10^{12}$
2	$2.0x10^{13}$ / $1.6x10^{13}$	$1.4x10^{13}$ / $9.8x10^{12}$
3	$1.1x10^{15}$ / $6.0x10^{14}$	$2.1x10^{14}$ / $2.5x10^{14}$
4	$2.4x10^{14}$ / $5.0x10^{13}$	$1.0x10^{14}$ / $3.8x10^{13}$
5	$8.3x10^{14}$ / $2.5x10^{1[illegible]}$	$4.2x10^{14}$ / $5.9x10^{14}$
6	$3.1x10^{14}$ / $3.6x10^{14}$	$1.4x10^{14}$ / $2.3x10^{14}$
7	$1.9x10^{13}$ / $8.9x10^{12}$	$1.1x10^{13}$ / $3.6x10^{12}$
8	$1.4x10^{14}$ / $6.3x10^{13}$	$1.0x10^{14}$ / $8.3x10^{12}$
9	$4.2x10^{14}$ / $1.1x10^{15}$	$3.6x10^{14}$ / $3.6x10^{14}$
10	$3.1x10^{13}$ / $1.0x10^{14}$	$2.4x10^{13}$ / $1.5x10^{13}$
11	$>1.0x10^{15}$ / $>6.0x10^{14}$	$>1.0x10^{15}$ / $>6.0x10^{14}$
12	$1.3x10^{13}$ / $3.5x10^{13}$	$1.3x10^{13}$ / $1.4x10^{13}$
13	$3.6x10^{12}$ / $7.8x10^{12}$	$2.4x10^{12}$ / $5.0x10^{12}$
14	$3.6x10^{13}$ / $4.5x10^{13}$	$1.3x10^{13}$ / $3.1x10^{13}$

TABLE 26-32

EFFECT OF 14 DAYS EXPOSURE TO JP-4 ON MANDREL FLEXIBILITY

Ratio of Mandrel Diam. - Exposed / Unexposed

Wire #	No Damage Flexed at 23°C	No Damage Flexed at -196°C	Slight Damage Flexed at 23°C	Slight Damage Flexed at -196°C	Severe Damage Flexed at -196°C
1	---	---	.075 / 1X	1.0 / 0.75	---
2	---	---	.125 / 1X	---	1.75 / 1.75
3	1X / 1X	---	---	0.5 / 0.5	---
4	---	---	1X / 1X	.250 / .125	---
5	---	---	1X / 1X	.250 / .125	---
6	1X / 1X	---	---	0.50 / 0.25	---
7	1X / .075	---	---	---	2.0 / 1.75
8	1X / 1X	---	---	---	2.0 / >3.0
9	1X / 1X	---	---	---	0.5 / 0.5
10	---	---	1X / 1X	0.5 / 0.5	---
11	---	---	1X / 1X	1.0 / 0.5	---
12	Too badly swollen to test.				
13	Rubber is swelled and Kynar jacket split - no test				
14	---	---	1X / 1X	---	>3.0 / >3.0

TABLE 26-33

EFFECT OF 14 DAYS EXPOSURE TO JP-4 - TWISTED PAIRS

Ratio of Breakdown Voltage (KV) - Exposed/Unexposed

Wire #	Maximum Values	Momimum Values
1	25.3 / 20.2	18.5 / 15.8
2	19.5 / 21.0	16.7 / 15.0
3	27.5 / 28.5	26.5 / 25.5
4	18.0 / 18.0	17.5 / 17.5
5	23.0 / 19.5	21.5 / 13.0
6	31.0 / 30.0	27.5 / 25.5
7	18.5 / 25.5	16.5 / 21.0
8	35.0 / 29.0	32.5 / 26.0
9	24.0 / 20.5	17.5 / 14.5
10	21.0 / 23.0	20.3 / 18.0
11	15.7 / 13.5	12.7 / 10.5
12*	24.0 / 18.5	18.5 / 16.5
13*	17.7 / 22.4	12.6 / 18.0
14*	23.2 / 25.5	22.0 / 20.6

*Flame at breakdown.

Ratio of Insulation Resistance (Ohms) - Exposed/Unexposed

1	$1.1x10^{14}$ / $2.8x10^{13}$	$5.0x10^{13}$ / $8.6x10^{12}$
2	$2.5x10^{13}$ / $1.6x10^{13}$	$1.5x10^{13}$ / $9.8x10^{12}$
3	$6.3x10^{14}$ / $6 x 10^{14}$	$3.6x10^{14}$ / $2.5x10^{14}$
4	$1.3x10^{14}$ / $5 x 10^{13}$	$5.6x10^{13}$ / $3.8x10^{13}$
5	$5x10^{13}$ / $2.5x10^{15}$	$3.2x10^{13}$ / $5.9x10^{14}$
6	$9.8x10^{13}$ / $3.6x10^{14}$	$1.5x10^{12}$ / $2.3x10^{14}$
7	$8.9x10^{13}$ / $8.9x10^{12}$	$2x10^{13}$ / $3.6x10^{12}$
8	$2.4x10^{14}$ / $6.3x10^{13}$	$2.3x10^{14}$ / $8.3x10^{12}$
9	$4.2x10^{14}$ / $1.1x10^{15}$	$3.1x10^{14}$ / $3.6x10^{14}$
10	$2.3x10^{13}$ / $1.0x10^{14}$	$6.3x10^{12}$ / $1.5x10^{13}$
11	$>1.0x10^{15}$ / $>6.0x10^{14}$	$>1.0x10^{15}$ / $>6.0x10^{14}$
12	$9.1x10^{12}$ / $3.5x10^{13}$	$3.9x10^{12}$ / $1.4x10^{13}$
13	$2.8x10^{12}$ / $7.8x10^{12}$	$2.1x10^{12}$ / $5.0x10^{12}$
14	$1.6x10^{13}$ / $4.5x10^{13}$	$1.4x10^{13}$ / $3.1x10^{13}$

TABLE 26-34

EFFECT OF 14 DAYS EXPOSURE TO FREON 114 ON MANDREL FLEXIBILITY

Ratio of Mandrel Diam. - Exposed/Unexposed

Wire #	No Damage Flexed at 23°C	No Damage Flexed at -196°C	Slight Damage Flexed at 23°C	Slight Damage Flexed at -196°C	Severe Damage Flexed at -196°C
1	---	---	1X/1X	1.0/0.75	---
2	---	---	1X/1X	---	1.75/1.75
3	1X/1X	---	---	0.5/0.5	---
4	---	---	1X/1X	.125/.125	---
5	---	---	1X/1X	.125/.125	---
6	1X/1X	---	---	.05/0.25	---
7	1X/1X	---	---	---	2.0/1.75
8	1X/1X	---	---	---	>3.0/>3.0
9	1X/1X	---	---	---	0.75/0.50
10	---	---	1X/1X	0.5/0.5	---
11	---	---	1X/1X	---	1.0/0.25
12*	1X/1X	---	---	---	>3.0/>3.0
13	Rubber swelled sufficiently to split Kynar jacket				
14 (H-film wringled before test)			1X/1X		>3.0/>3.0

*swelled in solvent but recovered on being removed

TABLE 26-35

EFFECT OF 14 DAYS EXPOSURE TO FREON #114 - TWISTED PAIRS

Ratio of Breakdown Voltage (KV) - Exposed/Unexposed

Wire #	Maximum Values	Minimum Values
1*	16.3 / 20.2	13.7 / 15.8
2	18.4 / 21.0	17.0 / 15.0
3	27 / 28.5	24.5 / 25.5
4	19 / 18	17.5 / 17.5
5	24 / 19.5	13.5 / 13
6	31 / 30	29.5 / 25.5
7*	24.5 / 25.5	22.0 / 21.0
8	30.0 / 29.0	22.0 / 26.0
9	24 / 20.5	15.5 / 14.5
10	21.5 / 23.0	18.4 / 18.0
11	12.8 / 13.5	12.5 / 10.5
12	19.3 / 18.5	18.1 / 16.5
13	24.0 / 22.4	21.5 / 18.0
14	27.7 / 25.5	22.5 / 20.6

*Flame at breakdown.

Ratio of Insulation Resistance (Ohms) - Exposed/Unexposed

1	$2.8x10^{13}$ / $2.8x10^{13}$	$1.7x10^{13}$ / $8.6x10^{12}$
2	$1.1x10^{13}$ / $1.6x10^{13}$	$9.6x10^{12}$ / $9.8x10^{12}$
3	$5.6x10^{14}$ / $6x10^{14}$	$2.9x10^{14}$ / $2.5x10^{14}$
4	$3.8x10^{13}$ / $5x10^{13}$	$1.1x10^{13}$ / $3.8x10^{13}$
5	$3.1x10^{14}$ / $2.5x10^{15}$	$1.1x10^{14}$ / $5.9x10^{14}$
6	$2.3x10^{14}$ / $3.6x10^{14}$	$6.4x10^{13}$ / $2.3x10^{14}$
7	$1.4x10^{13}$ / $8.9x10^{12}$	$9.3x10^{12}$ / $3.6x10^{12}$
8	$4.4x10^{14}$ / $6.3x10^{13}$	$1.6x10^{13}$ / $8.3x10^{12}$
9	$>10^{15}$ / $1.1x10^{15}$	$8.3x10^{14}$ / $3.6x10^{14}$
10	$3.9x10^{13}$ / $1.0x10^{14}$	$1.9x10^{13}$ / $1.5x10^{13}$
11	$8.3x10^{14}$ / $>6.0x10^{14}$	$7.1x10^{14}$ / $>6.0x10^{14}$
12	$1.1x10^{13}$ / $3.5x10^{13}$	$7.7x10^{12}$ / $1.4x10^{13}$
13	$4.2x10^{12}$ / $7.8x10^{12}$	$1.7x10^{12}$ / $5.0x10^{12}$
14	$1.5x10^{13}$ / $4.5x10^{13}$	$9.1x10^{12}$ / $3.1x10^{13}$

TABLE 26-36

EFFECT OF 14 DAYS EXPOSURE TO TRICHLOROETHYLENE ON MANDREL FLEXIBILITY

Ratio of Mandrel Diam. - Exposed / Unexposed

Wire #	No Damage Flexed at 23°C	No Damage Flexed at -196°C	Slight Damage Flexed at 23°C	Slight Damage Flexed at -196°C	Severe Damage Flexed at -196°C
3	1X / 1X	---	---	0.5 / 0.5	---
4	---	---	1X / 1X	---	1.0 / .075
5	---	---	1X / 1X	---	0.125 / .075
6	1X / 1X	---	---	0.75 / 0.25	---
7	.075 / .075	---	---	---	2.0 / 1.75
8	1X / 1X	---	---	---	3.0 / 3.0
9	1X / 1X	---	---	---	0.5 / 0.5
1*	1X / .075	---	---	---	1.0 / 0.5
2	---	---	1X / 1X	---	2.0 / 1.75
10	---	---	1X / 1X	0.75 / 0.50	0.50 / 0.25
11	---	---	1X / 1X	0.75 / 0.50	---
12	Swelled, peeled and split - no test				
13	Rubber badly swelled and Kynar jacket split - no test				
14	Rubber somewhat swollen		1X / 1X	---	>3.0 / >3.0

*ML overcoat appeared to be eroded and perhaps softened.

TABLE 26-37

EFFECT OF 14 DAYS EXPOSURE TO TRICHLOROETHYLENE - TWISTED PAIRS

Ratio of Breakdown Voltage (KV) - Exposed/Unexposed

Wire #	Maximum Values	Minimum Values
1*	26.0 / 20.2	21.4 / 15.8
2*	17.7 / 21.0	17.4 / 15.0
3	26.5 / 28.5	24.5 / 25.5
4	17 / 18	15 / 17.5
5	22 / 19.5	12.5 / 13
6	34 / 30	27.5 / 25.5
7	35.0 / 25.5	28.0 / 21
8	46.0 / 29.0	45.0 / 26.0
9	27.5 / 20.5	22 / 14.5
10	17.7 / 23.0	17.1 / 18.0
11	13.4 / 13.5	11.8 / 10.5
12*(1)	18.4 / 18.5	15.0 / 16.5
13*	26.2 / 22.4	19.8 / 18.0
14*	28.2 / 25.5	25.1 / 20.6

*Flame at breakdown. (1)No physical damage in twist area.

Ratio of Insulation Resistance (Ohms) - Exposed/Unexposed

1	1.1×10^{14} / 2.8×10^{13}	4.5×10^{13} / 8.6×10^{12}
2	8.8×10^{13} / 1.6×10^{13}	3.9×10^{13} / 9.8×10^{12}
3	1.3×10^{15} / 6×10^{14}	1.8×10^{14} / 2.5×10^{14}
4	1.3×10^{14} / 5×10^{13}	3.6×10^{13} / 3.8×10^{13}
5	5×10^{14} / 2.5×10^{15}	2.5×10^{14} / 5.9×10^{14}
6	3.6×10^{14} / 3.6×10^{14}	9.3×10^{13} / 2.3×10^{14}
7	1.7×10^{13} / 8.9×10^{12}	1.6×10^{13} / 3.6×10^{12}
8	1.8×10^{14} / 6.3×10^{13}	5.0×10^{13} / 8.3×10^{12}
9	4.8×10^{14} / 1.1×10^{15}	2.6×10^{14} / 3.6×10^{14}
10	1.0×10^{13} / 1.0×10^{14}	7.0×10^{12} / 1.5×10^{13}
11	$>1.0\times10^{15}$ / $>6.0\times10^{14}$	$>1.0\times10^{15}$ / $>6.0\times10^{14}$
12	1.4×10^{13} / 3.5×10^{13}	3.6×10^{11} / 1.4×10^{13}
13	1.3×10^{13} / 7.8×10^{12}	5.4×10^{12} / 5.0×10^{12}
14	3.1×10^{13} / 4.5×10^{13}	2.3×10^{13} / 3.1×10^{13}

TABLE 26-38

EFFECT OF 14 DAYS EXPOSURE TO ACETONE ON MANDREL FLEXIBILITY

Ratio of Mandrel Diam. - $\frac{\text{Exposed}}{\text{Unexposed}}$

Wire #	No Damage Flexed at 23°C	No Damage Flexed at -196°C	Slight Damage Flexed at 23°C	Slight Damage Flexed at -196°C	Severe Damage Flexed at -196°C
1	---	---	1X/1X	0.75/0.75	---
2	---	---	1X/1X	---	1.75/1.75
3	.075/1X	---	---	0.50/0.50	---
4	---	---	1X/1X	0.50/.125	---
5	---	---	1X/1X	0.25/.125	---
6	1X/1X	---	---	0.50/0.25	---
7	---	---	0.25/1X	3.0/2.0	2.0/1.75
8	1X/1X	---	---	---	>3.0/>3.0
9	1X/1X	---	---	---	0.5/0.5
10	---	---	1X/1X	0.75/0.50	---
11	---	---	1X/1X	1.5/0.5	---
12	1X/1X	---	---	---	>3.0/>3.0
13	Acetone attacks Kynar jacket but does not seem to swell rubber				
14	Rubber somewhat swelled.		1X/1X		>3.0/>3.0

TABLE 26-39

EFFECT OF 14 DAYS EXPOSURE TO ACETONE - TWISTED PAIRS

Ratio of Breakdown Voltage (KV) - Exposed/Unexposed

Wire #	Maximum Values	Minimum Values
1*	17.2 / 20.2	13.8 / 15.8
2*	17.9 / 21.0	15.8 / 15.0
3	25.0 / 28.5	23.0 / 25.5
4	16.0 / 18.0	16.0 / 17.5
5	18.0 / 19.5	11.0 / 13.0
6	31.0 / 30.0	28.5 / 25.5
7*	29.0 / 25.5	22.5 / 21.0
8*	20.0 / 29.0	19.0 / 26.0
9	38.0 / 20.5	27.5 / 14.5
10	19.1 / 23.0	18.6 / 18.6
11*	14.3 / 13.5	13.2 / 10.5
12	18.5 / 18.5	15.6 / 16.5
13*	7.5 / 22.4	5.0 / 18.0
14*	16.5 / 25.5	14.8 / 20.6

*Flame at breakdown.

Ratio of Insulation Resistance (Ohms) - Exposed/Unexposed

1	$7.6x10^{13}$ / $2.8x10^{13}$	$5.6x10^{13}$ / $8.6x10^{12}$
2	$1.2x10^{13}$ / $1.6x10^{13}$	$1.0x10^{13}$ / $9.8x10^{12}$
3	$1.7x10^{15}$ / $6x10^{14}$	$6.3x10^{14}$ / $2.5x10^{14}$
4	$7.1x10^{13}$ / $5x10^{13}$	$1.6x10^{13}$ / $3.8x10^{13}$
5	$5x10^{13}$ / $2.5x10^{15}$	$4.2x10^{13}$ / $5.9x10^{14}$
6	$5x10^{13}$ / $3.6x10^{14}$	$3.3x10^{13}$ / $2.3x10^{14}$
7	$3.7x10^{12}$ / $8.9x10^{12}$	$2.7x10^{12}$ / $3.6x10^{12}$
8	$2.8x10^{13}$ / $6.3x10^{13}$	$1.7x10^{12}$ / $8.3x10^{12}$
9	$7.1x10^{15}$ / $1.1x10^{15}$	$5.9x10^{15}$ / $3.6x10^{14}$
10	$3.1x10^{13}$ / $1.0x10^{14}$	$5.0x10^{12}$ / $1.5x10^{13}$
11	$>1.0x10^{15}$ / $>6.0x10^{14}$	$>1.0x10^{15}$ / $>6.0x10^{14}$
12	$1.7x10^{13}$ / $3.5x10^{13}$	$8.6x10^{12}$ / $1.4x10^{13}$
13	$1.3x10^{7}$ / $7.8x10^{12}$	$5.0x10^{6}$ / $5.0x10^{12}$
14	$3.6x10^{3}$ / $4.5x10^{13}$	$1.1x10^{13}$ / $3.1x10^{13}$

TABLE 26-40

EFFECT OF 14 DAYS EXPOSURE TO FREON 113 ON MANDREL FLEXIBILITY

Ratio of Mandrel Diam. - $\frac{\text{Exposed}}{\text{Unexposed}}$

	No Damage Flexed at		Slight Damage Flexed at		Severe Damage Flexed at
Wire #	23°C	-196°C	23°C	-196°C	-196°C
3	1X/1X	---	---	0.5/0.5	---
4	---	---	1X/1X	0.5/.125	---
5	---	---	1X/1X	0.25/.125	---
6	1X/1X	---	---	0.25/0.25	---
7	1X/1X	---	---	---	2.0/1.75
8	1X/1X	---	---	---	3.0/3.0
9	1X/1X	---	---	---	0.75/0.50
1	---	---	1X/1X	1.0/0.75	---
2	---	---	1X/1X	---	2.0/1.75
10	---	---	1X/1X	0.75/0.50	---
11	---	---	1X/1X	1.0/0.5	---
12	Swells, cracks and peels - no tests possible				
13	Rubber swelled sufficiently to split Kynar jacket - no test				
14	Rubber slightly swelled.		1X/1X		>3.0/>3.0

TABLE 26-41

EFFECT OF 14 DAYS EXPOSURE TO FREON 113 - TWISTED PAIRS

Ratio of Breakdown Voltage (KV) - Exposed/Unexposed

Wire #	Maximum Values	Minimum Values
1*	24.7 / 20.2	17.6 / 15.8
2*	20.0 / 21.0	17.5 / 15.0
3	29.0 / 28.5	26.0 / 25.5
4	18.5 / 18.0	18.0 / 17.5
5	22.0 / 19.5	16.0 / 13.0
6	33.0 / 30.0	29.5 / 25.5
7*	29.5 / 25.5	24.0 / 21.0
8	37.0 / 29.0	35.0 / 26.0
9	24.0 / 20.5	21.5 / 14.5
10	21.5 / 23.0	18.4 / 18.0
11	15.0 / 13.5	14.3 / 10.5
12**	19.5 / 18.5	13.1 / 16.5
13	17.0 / 22.4	13.5 / 18.0
14	28.5 / 25.5	25.8 / 20.6

*Flame at breakdown.
**Undamaged in twist area.

Ratio of Insulation Resistance (Ohms) - Exposed/Unexposed

1	$4.8x10^{13}$ / $2.8x10^{13}$	$2.6x10^{13}$ / $8.6x10^{12}$
2	$5.0x10^{14}$ / $16.x10^{13}$	$3.9x10^{13}$ / $9.8x10^{12}$
3	$4.2x10^{13}$ / $6x10^{14}$	$7.8x10^{13}$ / $7.5x10^{14}$
4	$1.8x10^{14}$ / $5x10^{13}$	$8.5x10^{13}$ / $3.8x10^{13}$
5	$5.0x10^{14}$ / $2.5x10^{15}$	$1.9x10^{14}$ / $5.9x10^{14}$
6	$1.8x10^{14}$ / $3.6x10^{14}$	$8.5x10^{13}$ / $2.3x10^{14}$
7	$2.4x10^{14}$ / $8.9x10^{12}$	$7.6x10^{13}$ / $3.6x10^{12}$
8	$4.2x10^{14}$ / $6.3x10^{13}$	$2.3x10^{14}$ / $8.3x10^{12}$
9	$>10^{15}$ / $1.1x10^{15}$	$6.7x10^{14}$ / $3.6x10^{14}$
10	$3.9x10^{13}$ / $1.0x10^{14}$	$1.9x10^{13}$ / $1.5x10^{13}$
11	$5.0x10^{14}$ / $>6.0x10^{14}$	$3.6x10^{14}$ / $>6.0x10^{14}$
12	$1.5x10^{13}$ / $3.5x10^{13}$	$9.3x10^{12}$ / $1.4x10^{13}$
13	$2.2x10^{13}$ / $7.8x10^{12}$	$3.6x10^{12}$ / $5.0x10^{12}$
14	$2.9x10^{13}$ / $4.5x10^{13}$	$2.5x10^{13}$ / $3.1x10^{13}$

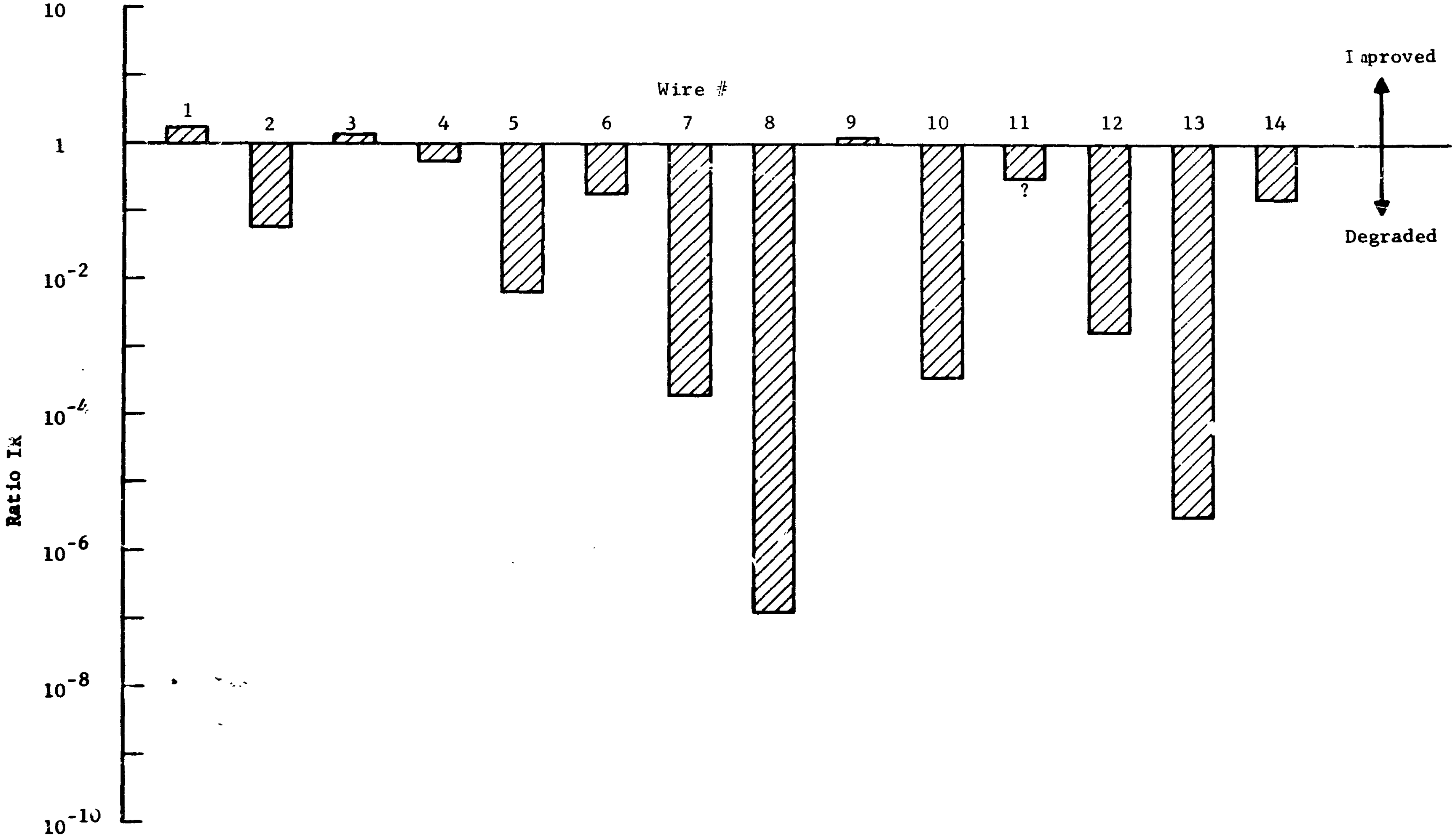


Fig. 26-1 - Ratio of Insulation Resistance - Exposed/Unexposed 20 Hours in Unsymmetrical Dimethylhydrazine (UDMH)

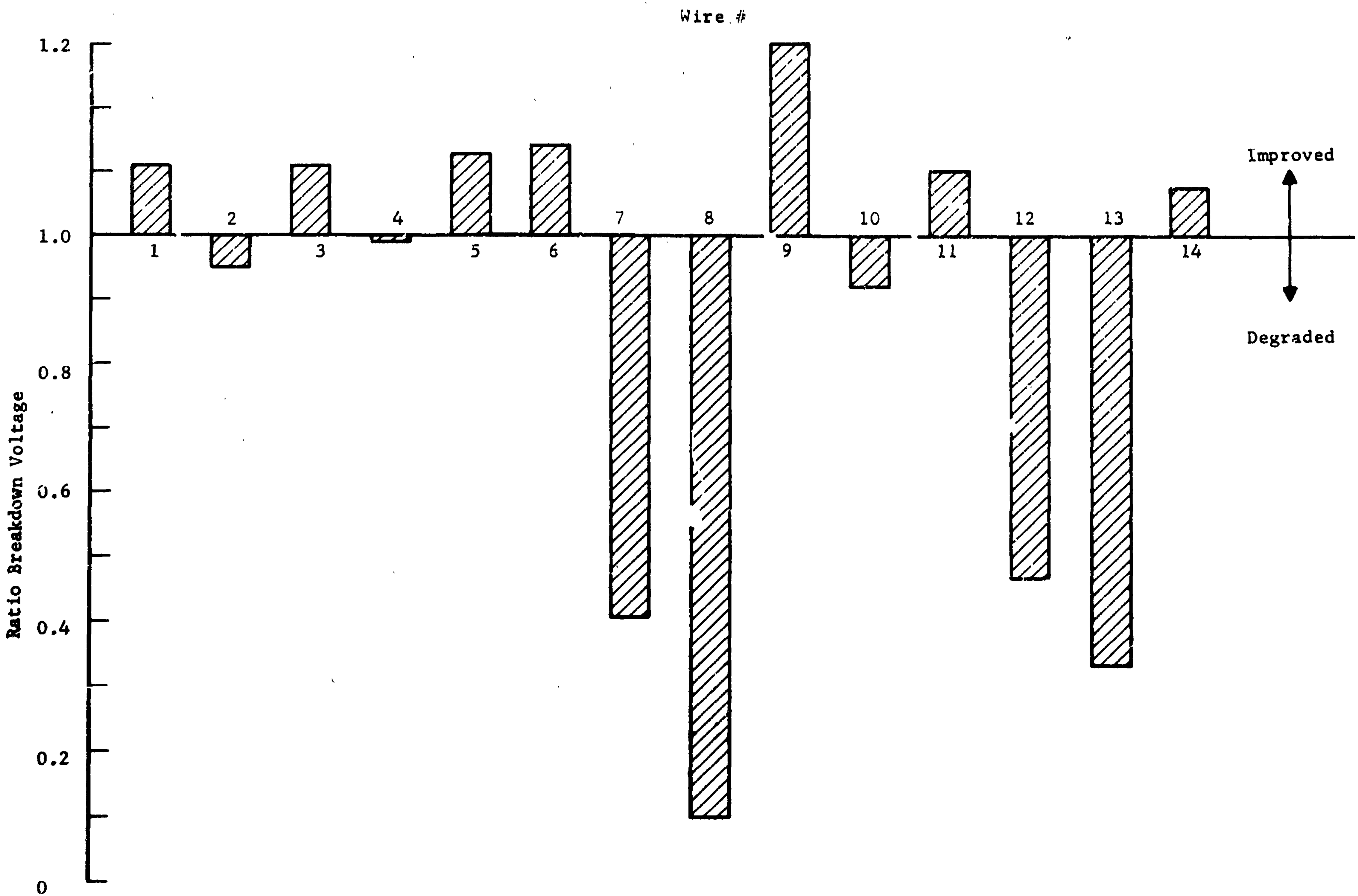


Fig. 26-2 - Ratio of Breakdown Voltage - Exposed/Unexposed 20 Hours in Unsymmetrical Dimethylhydrazine (UDMH)

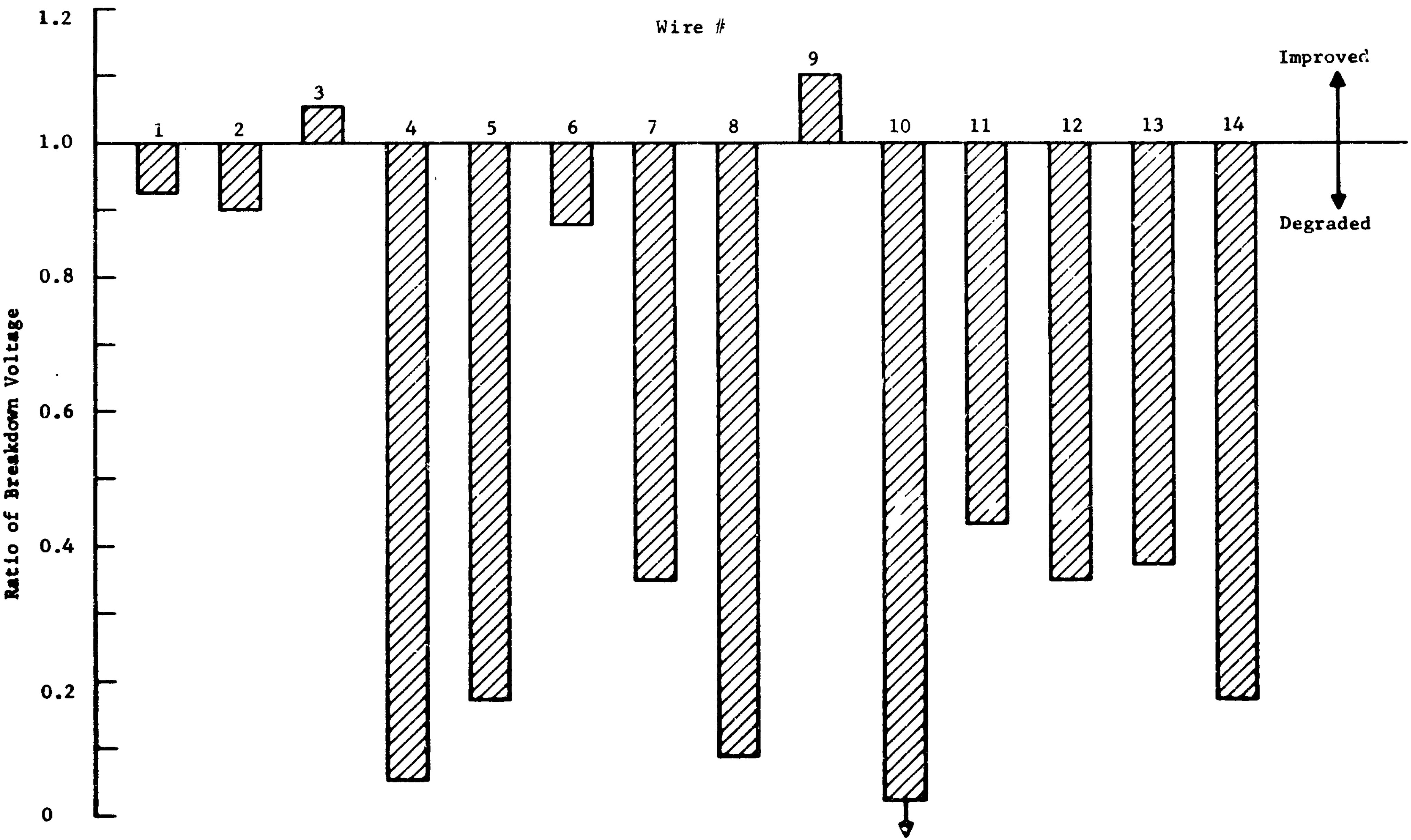


Fig. 26-3 - **Ratio of Breakdown Voltage - Exposed/Unexposed 20 Hours in Monomethylhydrazine (MMH)**

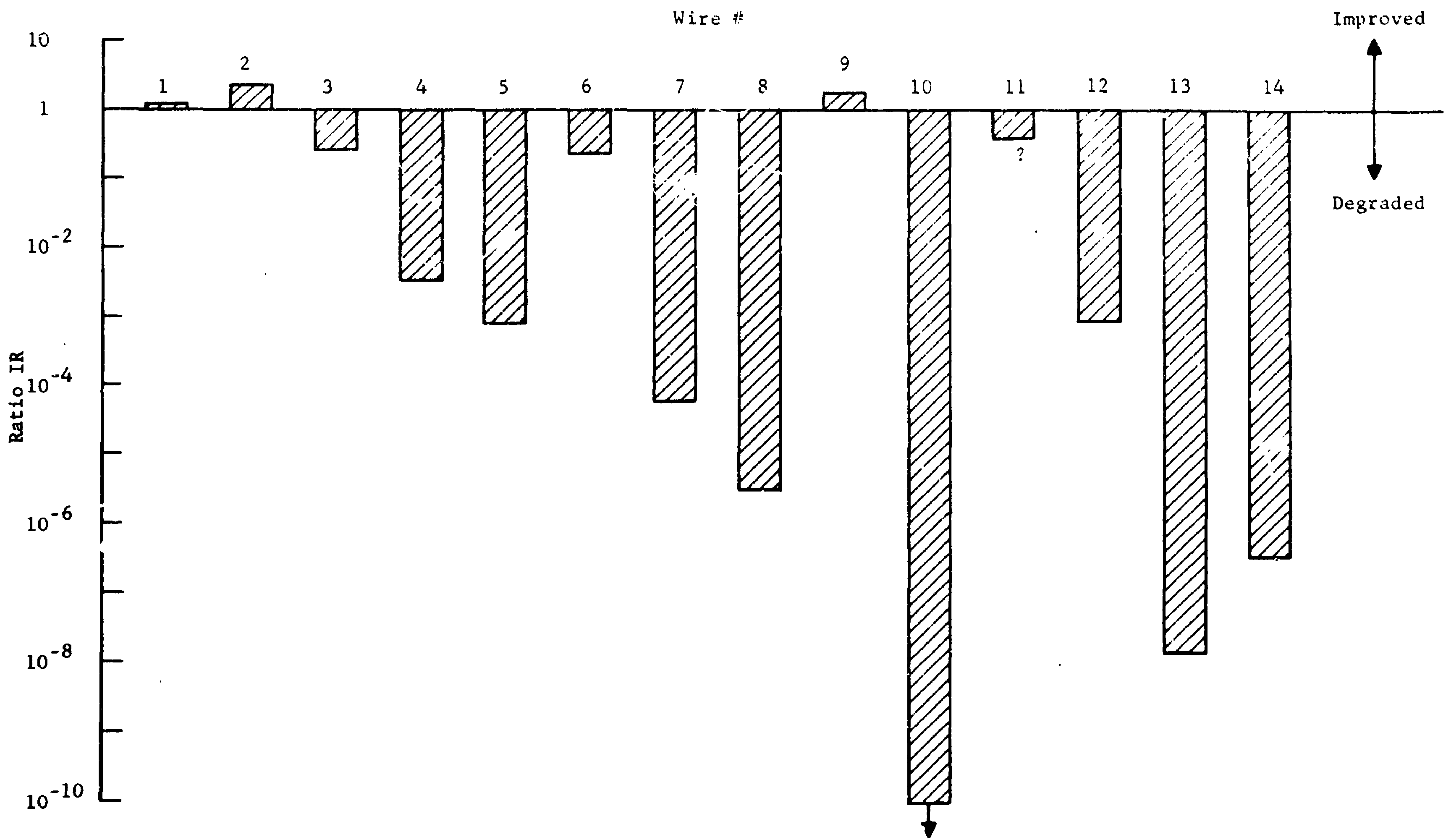


Fig. 26-4 - Ratio of Insulation Resistance - Exposed/Unexposed 20 Hours in Monomethylhydrazine (MMH)

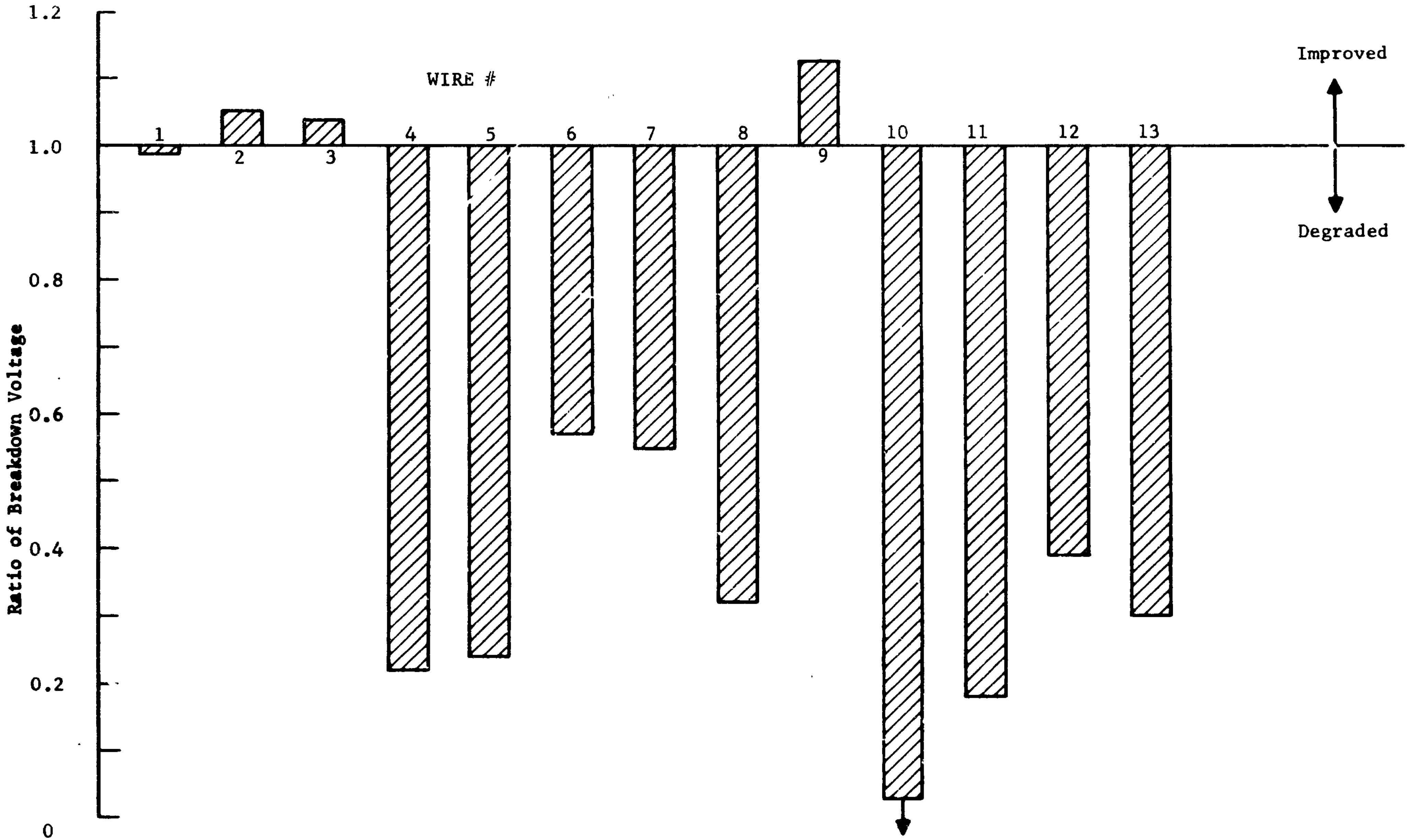


Fig. 26-5 - Ratio of Breakdown Voltage - Exposed/Unexposed 20 Hours in Hydrazine

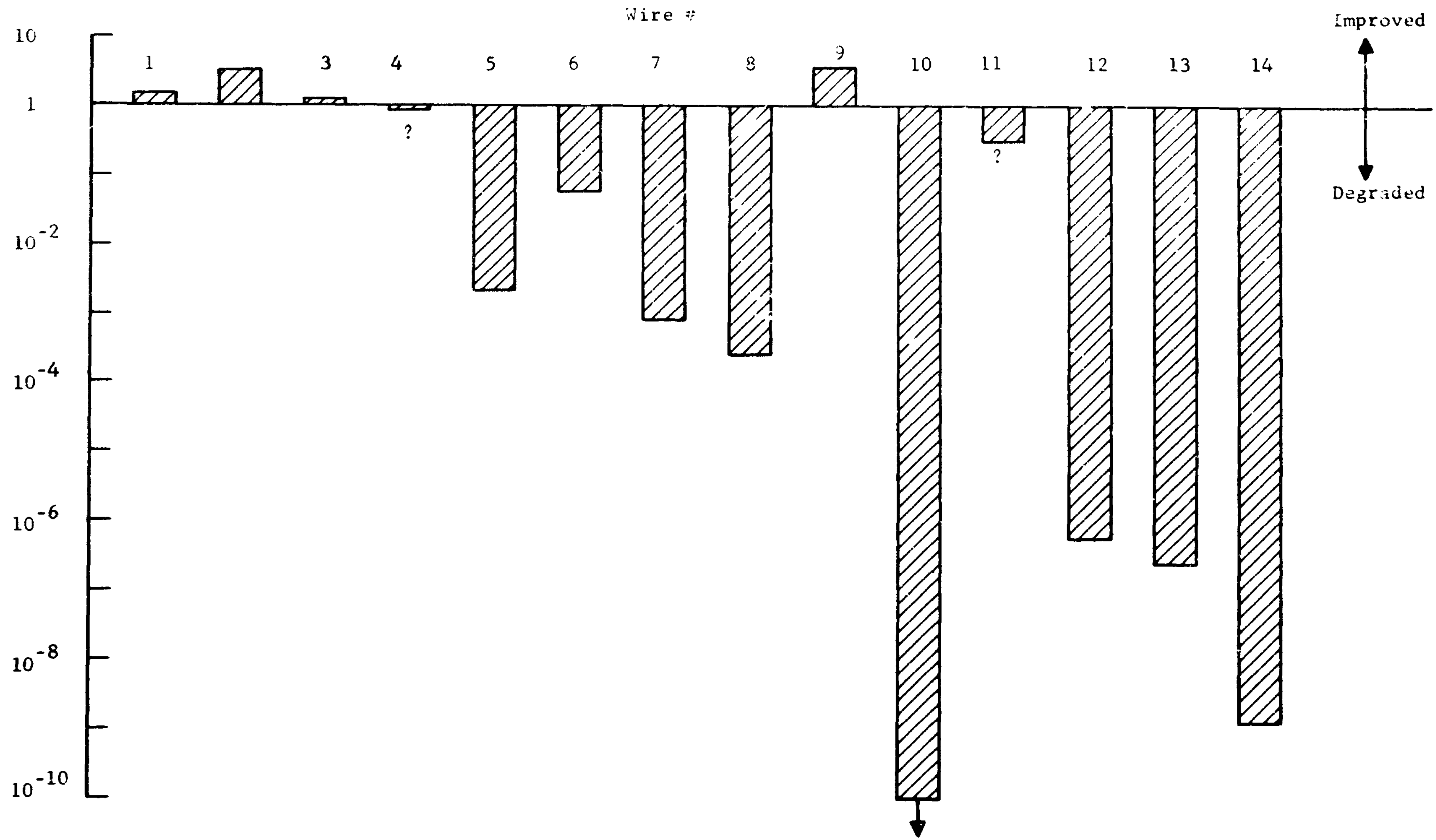


Fig. 26-6 - Ratio of Insulation Resistance - Exposed 20 Hours in Hydrazine

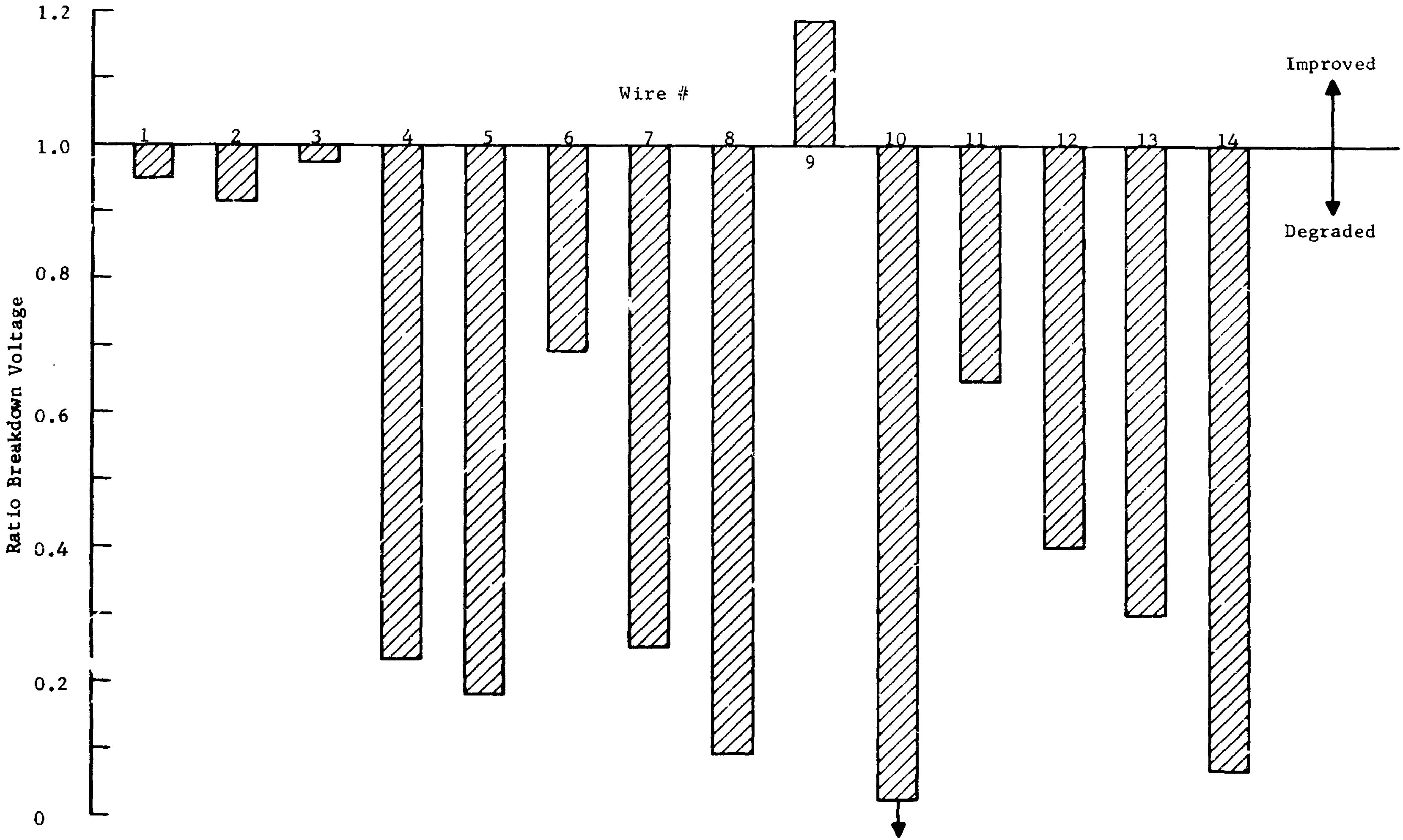


Fig. 26-7 - Ratio of Breakdown Voltage - Exposed/Unexposed 20 Hours in A-50

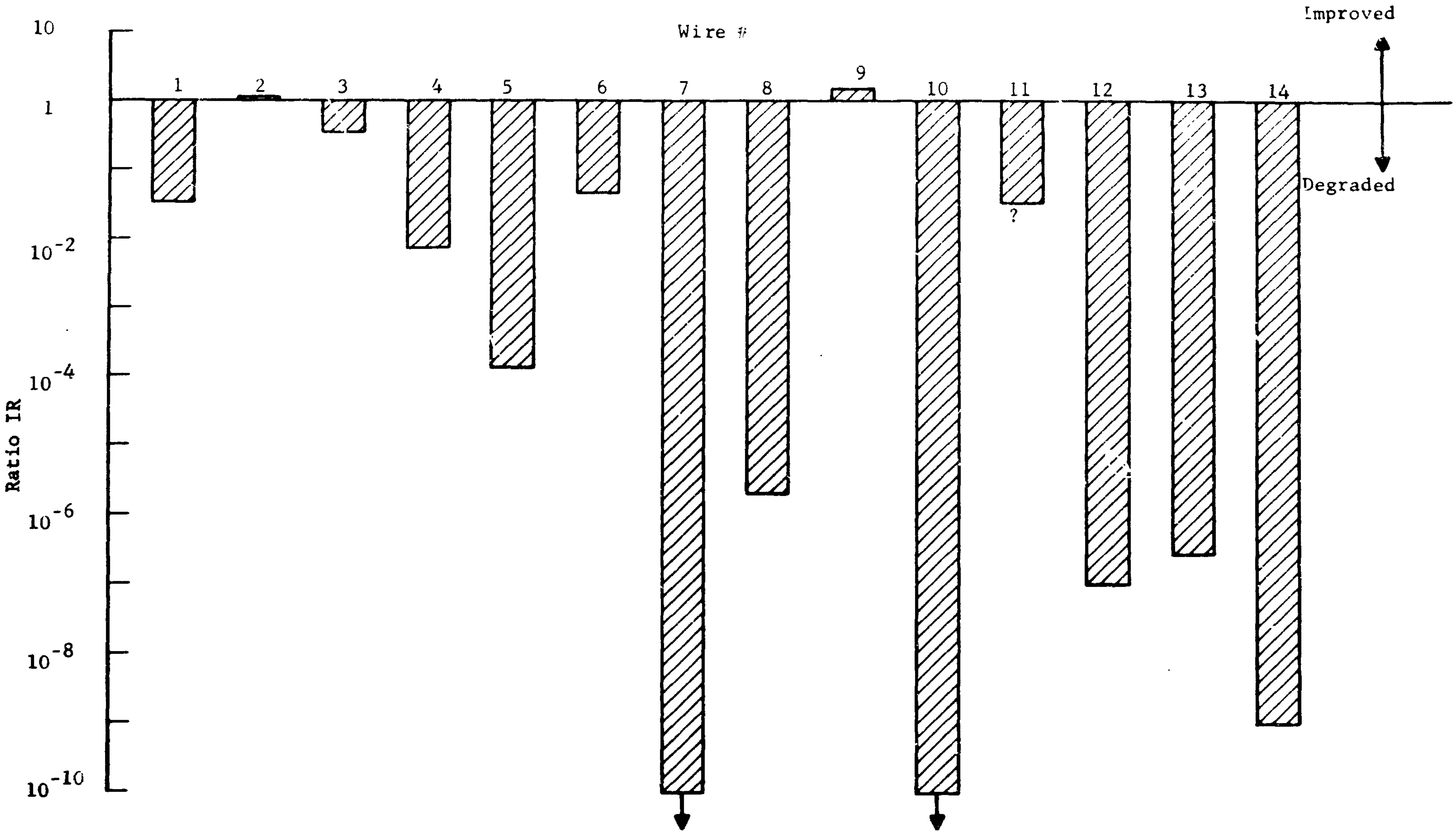


Fig. 26-8 - Ratio of Insulation Resistance - Exposed/Unexposed - 20 Hours in A50

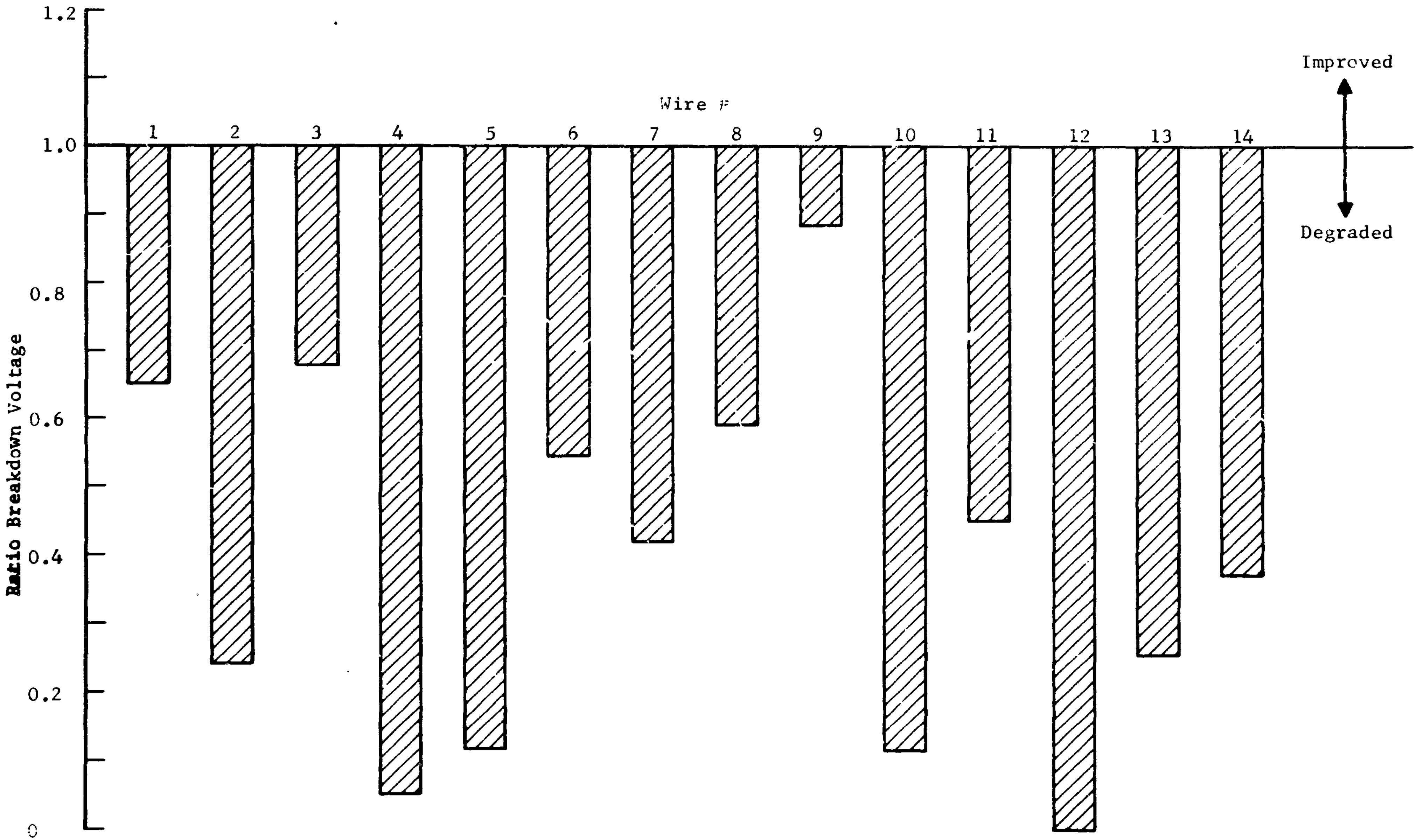


Fig. 26-9 - Ratio of Breakdown Voltage - Exposed/Unexposed 20 Hours in Nitrogen Tetroxide (N_2O_4)

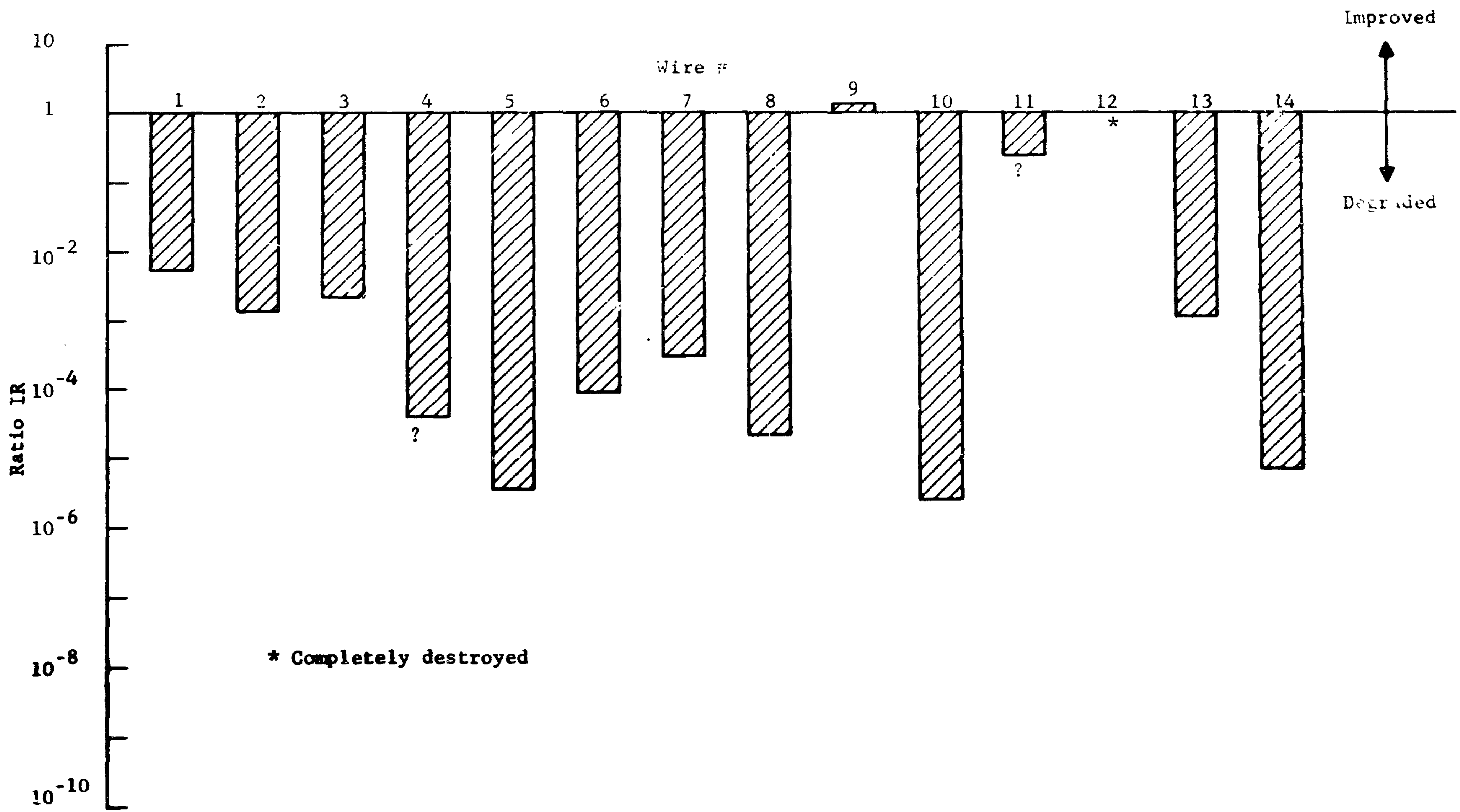


Fig. 26-10 **Ratio of Insulation Resistance - Exposed/Unexposed 20 Hours in Nitrogen Tetroxide (N_2O_4)**

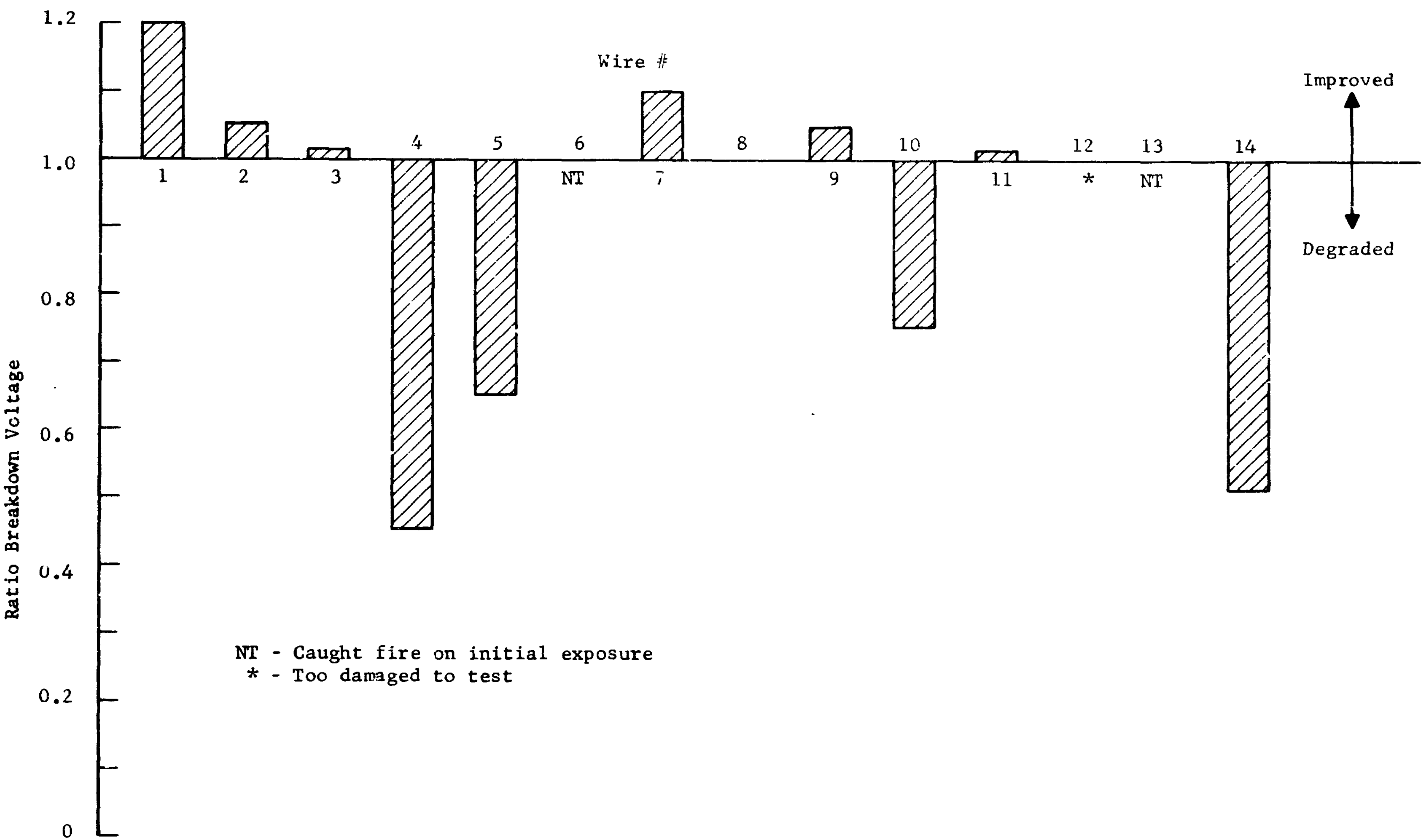


Fig. 26-11 - Ratio of Breakdown Voltage - Exposed/Unexposed 20 Hours in Fluorine

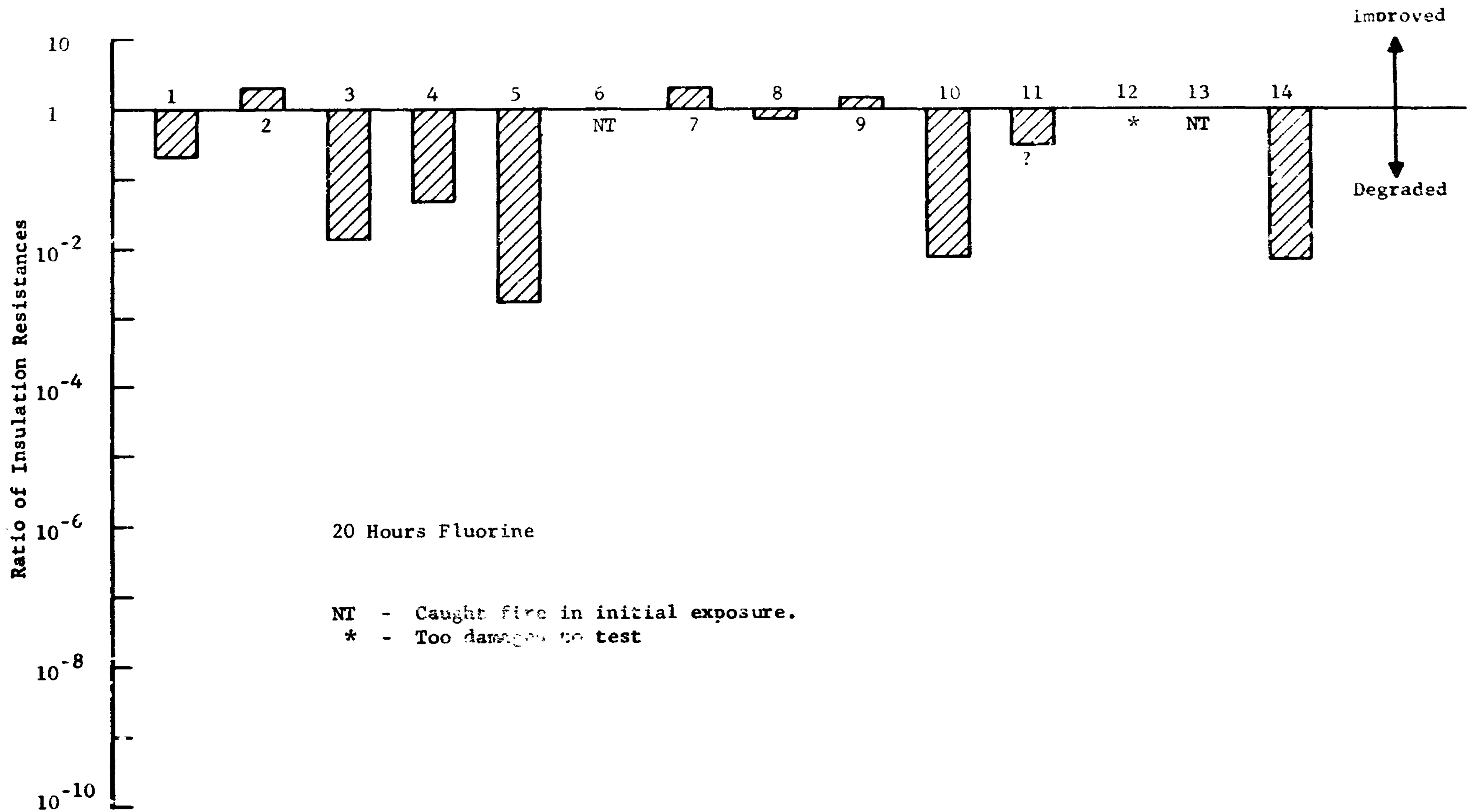


Fig. 26-12 - Ratio of Insulation Resistance - Exposed/Unexposed - 20 Hours in Fluorine

27. Offgassing in Oxygen

The % weight loss at 150°C in 5 psi oxygen, based on the weight of the wire, is given in Table 27-1. A similar table - 27-2 - is based on the weight of the insulation. The cumulative loss after about ¼, 1½ and 15 hours is recorded (actual experimental times are shown). Finally, the estimate rate of loss at 15 hours is included. This rate is based on values running from about one to several hours beyond the 15 hour time, but the accuracy of the result is limited. At any rate, the rate is measurable only with the polyolefin Wires #7 and 8 and the silicone rubber Wires #12, 13 and 14. For these wires also the actual amount of gas evolved is relatively large. The jackets about the silicone rubber in Wires #13 and 14 do seem to decrease the weight loss somewhat. In contrast, the amount of gas evolved for Wires #9 and 11 is very low.

Some idea of weight loss at 300°C was obtained by increasing the temperature in about 1.5 hours to 300°C and then holding the temperature as long as the test time schedule would permit. The additional weight loss is tabulated in Table 27-3. The comparative order of results is about the same as at 150°C.

TABLE 27-1

CUMULATIVE % WEIGHT LOSS AT 150°C IN 5 PSI OXYGEN
(Based on Total Weight of Wire)

Wire	Elapsed Time	% Loss	Elapsed Time	% Loss	Elapsed Time	% Loss	Estimated Rate after 15 hrs.%/hr.
1	14 min.	.025	1.5 hrs.	.050	14.5 hrs.	.038 (1)	*
1	14	.025	1.5	.038	14.5	.028	*
2	18	.037	1.5	.049	15.25	.049	*
2	18	.025	1.5	.050	15.25	.050	*
3	17	.049	1.0	.061	14.5	.043 (1)	*
3	17	.049	1.0	.049	14.5	.025 (1)	*
3	15	.049	2.0	.098	14.5	.098	*
4	15	.037	1.5	.037 (1)	14.25	.037	*
4	15	.075	1.5	.086 (1)	14.25	.075	*
5	15	.062	1.5	.062	14.5	.025 (1)	*
5	15	.037	1.5	.049	14.5	.00 (1)	*
6	15	.098	1.5	.098	15.5	.027 (1)	*
6	15	.074	1.5	.086	15.5	.037 (1)	*
7	13	.098	1.5	0.195	14.5	0.282	.012
7	13	0.110	1.5	0.193	14.5	0.258	.012
8	15	.086	1.5	0.184	16	0.273	.0065
8	15	.049	1.5	0.172	16	0.258	.0041
9	18	.027	1.5	.037	14.25	.00 (1)	*
9	18	.012	1.5	.012	14.25	.00 (1)	*
10	17	.050	1.5	.050	13.5	.037 (1)	*
10	17	.037	1.5	.050	13.5	.037 (1)	*
11	14	.012	1.5	.025	14.5	.012 (1)	*
11	14	.00	1.5	.00	14.5	.00	*
12	15	.123	1.5	0.308	14.75	0.295	(?)
12	15	.098	1.5	0.295	14.75	0.28	.01
12	13	.150	1.5	0.375	14.5	0.388	(?)
12	13	.222	1.5	0.345	14.5	0.345	.005
13	16	.037	1.5	0.112	15.5	0.233	(?)
13	16	.049	1.5	0.136	15.5	0.235	.012
14	15	.062	1.5	.099	15.5	0.136	(?)
14	15	.049	1.5	.099	15.5	0.123	.011

* Too low to measure.

(1) Increase or decrease is not significant.

TABLE 27-2

CUMULATIVE % WEIGHT LOSS AT 150°C IN 5 PSI OXYGEN
(Based on Weight of Insulation)

Wire #	Elapsed Time Minutes	Loss %	Elapsed Time Hours	Loss %	Elapsed Time Hours	Loss %	Estimated Rate After 15 hrs. %/hr.
1	14	0.12	1.5	0.24_5	14.5	0.18^5 (1)	*
1	14	0.12	1.5	0.18^5	14.5	0.13 (1)	*
2	18	0.17	1.5	0.22	15.25	0.22	*
2	18	0.11	1.5	0.23	15.25	0.23	*
3	17	0.25	1.0	0.31	14.5	0.22 (1)	*
3	17	0.25	1.0	0.25	14.5	0.13 (1)	*
3	15	0.25	2.0	0.50	14.5	0.50	*
4	15	0.29^5	1.5	0.29^5	14.25	0.29^5	*
4	15	0.60	1.5	0.69	14.25	0.60 (1)	*
5	15	0.41	1.5	0.41	14.5	0.17 (1)	*
5	15	0.25	1.5	0.33	14.5	0.00 (1)	*
6	15	0.58	1.5	0.58	15.5	0.16 (1)	*
6	15	0.44	1.5	0.51	15.5	0.22 (1)	*
7	13	0.52	1.5	1.03	14.5	1.48	.063
7	13	0.58	1.5	1.02	14.5	1.38	.063
8	15	0.45	1.5	0.97	16	1.44	.034
8	15	0.26	1.5	0.91	16	1.36	.022
9	18	0.11	1.5	0.14	14.25	.00 (1)	*
9	18	.046	1.5	.046	14.25	.00 (1)	*
10	17	0.50	1.5	0.50	13.5	0.37 (1)	*
10	17	0.37	1.5	0.50	13.5	0.37 (1)	*
11	14	0.12	1.5	0.25	14.5	0.12 (1)	*
11	14	.00	1.5	0.00	14.5	.00	*
12	15	0.65	1.5	1.62	14.75	1.56 (1)	(?)
12	15	0.52	1.5	1.56	14.75	1.48 (1)	.05
12	13	0.79	1.5	1.98	14.5	2.10	(?)
12	13	1.17	1.5	1.82	14.5	1.82	.026
13	16	0.13	1.5	0.41	15.5	0.85	(?)
13	16	0.18	1.5	0.50	15.5	0.86	.044
14	15	0.22	1.5	0.35	15.5	0.49	(?)
14	15	0.17	1.5	0.35	15.5	0.44	.039

* Too low to measure.

(1) Increase or decrease is not significant.

TABLE 27-3

ADDITIONAL % WEIGHT LOSS AT 300°C IN 5 PSI OXYGEN

	Based on Weight of Wire			Based on Weight of Insulation		
	Increased to 300°C	at 300°C		Increased to 300°C	at 300°C	
Wire #	% Loss	Min.	% Loss	% Loss	Min.	% Loss
1	.050	150	.062	.25	150	.30
1	.062	15	.062	.30	15	.30
2	.086	155	.074*	.39	155	.34*
2	.086	15	.086	.39	15	.39
3	.098	150	.111	.50	150	.57
3	.124	10	.124	.63	10	.63
3	.123	150	.148	.63	150	.76
4	.025	157	.025	.20	157	.20
4	.049	15	.049	.39	15	.39
5	.037	150	.037	.24	150	.29
5	.049	15	.061*	.33	15	.41*
6	.025	165	.037	.147	165	.22
6	.049	15	.049	.29	15	.29
7	.63	30	1.21	3.3	30	6.4
7	.60	30	1.32	3.15	30	6.9
8	Not run					
8	Not run					
9	.050	150	.050	.19	150	.19
9	.037	15	.037	.14	15	.14
10	.050	165	.050	.50	165	.50
10	.037	15	.037	.37	15	.37
11	.037	150	.025*	.37	150	.25*
11	.025	15	.025	.25	15	.25
12	.333	135	.435	1.75	135	2.28
12	.355	15	.321	1.87	15	1.95
12	.301	--	--	1.59	--	--
12	.307	10	.333	1.62	10	1.75
13	.480	155	.613	1.75	155	2.23
13	.480	15	.508	1.75	15	1.84
14	.210	160	.445	0.75	100	1.59
14	.236	18	.295	0.85	18	1.05

*Increase or decrease over time indicated is not significant.

28. Volatility in Vacuum

The % weight loss at 150°C in vacuum based on the weight of the wire is given in Table 28-1. A similar table - 28-2 - is based on the weight of the insulation. The cumulative loss after ½, 1 and 15 hours is recorded as well as the rate of loss at 15 hours. This rate is measurable only with the polyolefin Wires #7 and 8 and the silicone rubber Wires #12, 13 and 14. Since the loss was large for the silicones, results are shown also at 23°C. It is perhaps unfortunate that similar tests at 23°C were not made with the polyolefin wires #7 and 8, which showed a relatively very high loss at 150°C. As in oxygen, the weight loss with Wires #9 and 11 is the lowest of all.

Because of time and somewhat greater experimental problems, no attempt was made to measure weight loss in vacuum at 300°C.

TABLE 28-1

CUMULATIVE % WEIGHT LOSS AT 150° IN VACUUM

(Based on Total Weight of Wire)

Wire after	¼ hr.	1 hr.	15 hrs.	Estimated Rate after 15 hrs. %/hr.
1	.041	.063	.077	<.0006
1	.038	.054	0.1015	<.00025
2	.0074	.016	.049	<.00033
2	.0049	.025	.049	<.00025
3	.045	.050	.051	<.00025
3	.017	.052	.055	<.00033
4	.018	.022	.026	<.0002
4	.035	.035	.035	<.0002
5	.060	.063	.079	<.0002
5	.074	.087	0.10	<.0002
6	.060	.064	.074	<.0002
6	.072	.075	.078	<.0002
7	0.343	0.503	0.772	.0067
7	0.408	0.629	0.985	.0041
8	0.333	0.492	0.713	.0037
8	0.370	0.535	0.769	.0024
9	.011	.017	.035	<.00025
9	.020	.030	.035	<.00025
10	.047	.0542	.0542	<.00025
10	.052	.0595	.0595	<.00015
11	.0111	.0185	.0234	<.0003
11	.0346	.0592	.0931	<.00025
12 at (23°C)	.00995	.0248	0.1305	.0021
12 at 150°C	0.313	0.472	0.572	(?)
12 at 150°C	0.273	0.485	0.562	(?)
13	0.293	0.493	0.567	(?)
14 at (23°C)	.0187	.0432	.0553	.0019
14 at (100°C)	.0111	.0493	0.142	.0017
14 at (150°C)	0.128	0.278	0.671	.0017

TABLE 28-2

CUMULATIVE % WEIGHT LOSS AT $150^{\circ}C$ IN VACUUM

(Based on Weight of Insulation)

Wire # after	¼ hr.	1 hr.	15 hrs.	Estimated Rate after 15 hrs. %/hr.
1	0.20	0.31	0.38	<.003
1	0.19	0.26	0.495	<.0012
2	.034	.073	0.22	<.0015
2	.022	0.114	0.22	
3	0.23	0.26	0.26	<.0013
3	.087	0.27	0.28	<.0017
4	0.14	0.18	0.21	<.0016
4	0.28	0.28	0.28	<.0016
5	0.40	0.42	0.53	<.0013
5	0.49	0.58	0.67	<.0013
6	0.35	0.38	0.44	<.0018
6	0.42	0.44	0.46	<.0018
7	1.81	2.66	4.07	.035
7	2.15	3.30	5.10	.022
8	1.76	2.60	3.76	.0195
8	1.95	2.82	4.05	.013
9	.042	.065	0.13	<.001
9	.077	0.116	0.13	<.001
10	0.47	0.54	0.54	<.0025
10	0.52	0.60	0.60	<.0015
11	0.11	0.19	0.23	<.003
11	0.35	0.59	0.93	<.0025
12*	.052	0.13	0.69	.011
12	1.64	2.48	3.01	(?)
12	1.48	2.50	2.96	(?)
13	1.06	1.79	2.06	(?)
14*	.068	0.154	0.20	.007
14**	.040	0.176	0.51	.006
14	0.465	1.01	2.44	.006

* at $23^{\circ}C$
**at $150^{\circ}C$

29. Analysis of Evolved Gas

The analysis of the gases evolved from hook-up wire at high temperature is important in at least several ways:

a. The likelihood that such gases will introduce operational hazards may be considered.
b. The possible toxicity may be estimated.
c. The mechanism of chemical change and aging in the insulation may be studied.

Both vacuum and 5 PSI oxygen ambients are common spacecraft environments and have, therefore, been used in this program. A temperature of 150°C is the top temperature expected in normal spacecraft applications. A 300°C test temperature has been included.also to provide some idea of the character of the off-gassing under wire overload conditions.

Results at 150°C have been summarized in Table 29-1. It is immediately apparent that the gas evolved is largely absorbed water in most cases with some nitrogen and CO_2, both of which are most likely dissolved in the insulation rather than the result of chemical decomposition. The large amount of water and also the oxygen in this atmosphere decrease the discriminating capability of the test. In order to make comparison easier, results have been plotted with the nitrogen, water, and oxygen subtracted from the total.

The larger amount of CO_2 in the oxygen atmosphere is probably due to the fact that it was absorbed and has not been pumped out of the insulation. It is, of course, still possible that some decomposition takes place. It is possible, too, that some of the gas reported as nitrogen might actually be carbon monoxide (CO) which has the same mass peak. When a sufficient quantity of the gas was present to make measurements worthwhile, the gas was shown to be nitrogen rather than CO.

At 150°C, except for water, the total outgassing is small, as shown in the values at the bottom of Figure 29-1. As noted before, the greater outgassing in oxygen may be due simply to the fact that dissolved gases are not pumped out. In support of this view, the jacketed wires #1, 7, 13 and 14 appear to trap gas. Moreover, ML overcoated Wire #2, which is known to have a tightly adherent coating evolves less gas than Wire #1 with a loose ML coating.

It should be noted that outgassing in Wires #9 and 11 is particularly low, but that the others are roughly comparable. Very small amounts of organic components of several kinds are noted, particularly hydrocarbons. Such hydrocarbons may be due to oily contamination or may come from binders or extrusion lubricants such as those used with TFE Teflon (Wire #9). In some cases very small amounts of low molecular weight polymer fragments may come off, i.e., silanes from the silicone rubber in Wires #12, 13 and 14. The amines and the ethyleneamines from Wires #1, 3, 4, 5, 6 and 10 are probably unreacted constituents from the polyimide polymerization or perhaps decomposition products from such unreacted or partially reacted constituents.

The picture at 300°C is much more complicated, as shown in Tables 29-2A and 29-2B. In Table 29-2A it is noted that the amount of gas evolved is generally greater at 300 than at 150°C even though much less water is evolved. In this case much of the water is undoubtedly a product of polymerization or degradation reactions, since most of the absorbed water should have been pumped off when tests were made on the same specimens at 150°C prior to exposure at 300°C. It is interesting to note also that with a few exceptions, the total amount of gas evolved is greater in oxygen than in vacuum*. The amount of CO_2 evolved is also greater (with two exceptions) in oxygen as compared to vacuum. Undoubtedly, oxidation is involved and the insulation is literally "burning-up". Curiously, and in contrast, the amount of water is proportionately less in the oxygen atmosphere than in vacuum. Apparently carbon rather than hydrogen "burns" and water results from condensation or other reactions which do not depend upon an oxygen atmosphere.

From the toxicity point of view the presence of carbon monoxide (CO) is important**. Unfortunately, the oxygen in this atmosphere tended to "swamp out" the detection of small amounts. Moreover, CO appears to be a common component of the evolved gas from all of the wires. It appears generally to be more prevalent, where detection was possible, in the oxygen atmosphere. However, oxygen does not appear to change the CO_2/CO ratio

*This contradicts a popularly held notion that outgassing will be greater in vacuum.

**Here again the mass spectrograph may cause confusion because it is difficult to separate N_2 from CO. However, most of the absorbed nitrogen was evolved at 150°C.

in a significant fashion.

In Table 29-2B it can be seen that many organic compounds are evolved. Polymer fragmentaion, further condensation and polymerization as well as other types of degradation are obviously involved. It should be noted that the silicone tetrafluoride (S_iF_4) undoubtedly comes from the reaction of the HF evolved with the silica walls of the equipment. It is possible that other materials evolve and combine in the gaseous phase.

In the oxygen atmosphere very small quantities of the same materials, which were detected under vacuum conditions, may have been present, but could not be detected. Keeping the lack of sensitivity for the measurements in oxygen, a number of observations concerning gases evolved at 300°C can be made:

a. Hydrocarbons (C_2 to C_8) are evolved in both vacuum and oxygen with all of the wires. There is generally less in the oxygen atmosphere perhaps because oxidation takes place. The hydrocarbons may be traced for TFE Teflon (Wire #9) to the lubricant used in the extrusion process. The relatively large amount with Wire #3 may be traceable to residues from the dispersion coating process.

b. While the amount of gas evolved from Wires #7 and 8 is relatively high, the composition seems to be relatively simple. In addition to the hydrocarbons, some oxygenated hydrocarbons are noted. With Wire #7 the polyvinyldene fluoride jacket apparently breaks down to give a relatively large amount of HF which is reported as SiF_4 and also some CF_4.

c. The gas from TFE Teflon (Wire #9) show, in addition to the hydrocarbons, some formaldehyde, which is unexplained. However, the absence of fluorocarbons is remarkable and indicates how very little decomposition occurs with TFE Teflon at 300°C. The TFE taped overcoat of Wire #11 also shows no evidence of decomposition.

d. The SiF_4 from Wire #2 indicates either that the TFE Teflon is breakdown down in this case or that some FEP may have been used to achieve adhesion to the ML coating. The SiF_4 in the spectra from Wires #1, #5 and #6 may be traceable to the FEP Teflon bond. It is difficult to explain no evidence of fluorocarbons from Wires #3 and #4 which also contain some FEP Teflon bond. The absence of hexafluoropropylene with Wire #1 at 300°C is rather surprising since it was indicated at 150°C. Perhaps it was physically absorbed and was all "pulled off" at 150°C.

e. The hydrazine noted in the spectra from the polyimide ML coatings on Wires #1 and 2 may be a decomposition product of the polymer, but is more likely a decomposition product of unreacted or partially reacted residual constituents from the polymerization. The nitric oxide and amines in the polyimide H-film taped Wires #3, 4, 5, 6, 10 and 11 probably can be traced also to unreacted constituents in the polymer.

f. The silanes from the silicone rubber (Wire #12) are expected, but their absence for the silicone in Wires #13 and 14 is unexplained. (They were noted at 150°C). However, both methanol and formaldehyde in the spectra of Wires #12, 13 and 14 can be explained as oxidation of the methyl groups in the silicone rubber.

TABLE 29-1

COMPARISON - MASS SPECTROGRAPHIC ANALYSIS OF GAS EVOLVED AT 150°C

(1) +2.5% Hydrogen
(2) +10.5% of nitric oxide
(3) +7.5% of Ethyleneimine
(4) +15% of #98-99

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
CC of gas evolved/ gram of insulation	In Vac.	.096	0.12	3.2	0.93	7.05	5.4	0.41	0.26	.020	2.37	0.10	0.11	0.87	2.55
	In O_2	.096	.028	1.8	1.66	0.75	5.1	0.59	0.14	.052	1.70	1.04	0.53	.020	.039
Mole % Water	In Vac.	58	78.2	94.7	94.2	97.9	95.1	79.3	98.2	71.3	97.0	85	89.1	95	96.6
	In O_2	65	7	99.3	98.6	47	98.6	75.0	83.6	77.0	98.8	100	95.8	-	21.6
Excluding Water															
Mole % Nitrogen	In Vac.	-	0.9 (1)	72	69	65.5	67		11	54	54.5	49	46	34	30
Mole % Oxygen	In Vac.	-	-	11	8.5	9.5	10	-	-	6	-	-	-	6	12
Excluding Water, Nitrogen, Oxygen and Hydrogen															
Mole % Carbon Dioxide	In Vac.	36	44	65	38	96	100	68.5	79.5	70	66	78.5	85	33<	20
	In O_2	69	87	73	100	100	94		55	100	100		88	100	60
Mole % Hydrocarbons	In Vac.	17	41 (4)	35	24.5	-	-	23.5	8.5	30	7.5	21.5	1	10	-
	In O_2	14	13	-	-	-	4.5	17	32	-	-	-	-	-	-
Mole % Methylamine or dimethylamine	In Vac.	14	-	-	37.5	4	-	4	6.5 (2)		15 (3)	-	-	-	-
	In O_2	-	-	23	-	-	1.5	-	-	-	-	-	-	-	-
Mole % Benzene	In Vac.	-	-	-	-	-	-	-	-	-	-	-	-	17	15
	In O_2	-	-	-	-	-	-	-	0.6	-	-	-	12	-	3
Mole % Oxygenated Hydrocarbons	In Vac.	-	-	-	-	-	-	4	-	-	4	-	-	30	60
	In O_2	-	-	3	-	-	-	6	6.7	-	-	-	-	-	34
Mole % Silanes	In Vac.	-	-	-	-	-	-	-	-	-	-	-	14	10	5
	In O_2	-	-	-	-	-	-	-	-	-	-	-	-	-	3
Mole % in Hexafluoropropylene	In Vac.	33	-	-	-	-	-	-	-	-	-	-	-	-	-
	In O_2	17	-	-	-	-	-	-	-	-	-	-	-	-	-
CC of gas/gram of Insulation	In Vac.	.040	.0044	.029	.014	.035	.048	.083	.0032	.0027	.032	.0081	.0065	.026	.050
	In O_2	.033	.026	.013	.040	0.39	.086	0.15	.023	.012	.021	.00	.022	.018	.031

TABLE 29-2A

COMPARISON - MASS SPECTROGRAPHIC ANALYSIS OF GAS EVOLVED AT 300°C IN VACUUM AND IN 5 PSI OXYGEN (Oxygen Excluded)

	Wire No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
CC of gas evolved/	In Vac.	0.54	0.60	2.8	0.51	1.54	0.66	2.61	7.6	.06	1.19	.02	3.18	1.09	1.84
gram of insulation	In O_2	1.08	0.65	1.03	1.38	0.74	2.29	20.6	21.8	.18	2.05	0.12	10.5	5.75	3.70
	Ratio-Vac/O_2	0.50	0.36	2.7	0.37	2.08	0.29	0.13	0.35	0.33	0.56	0.17	0.30	0.19	0.50
Mole % Water	In Vac.	27	67.7	40.6	63.1	44.2	66	45.7	17.8	38.5	71.9	32.6	50.4	53.6	60.6
	In O_2	10.5	45.0	25.2	28.7	14.0*	27.3	10.7	10	25.2	48.9	23.0	36	36.5	20
	Ratio-Vac/O_2	2.6	1.5	1.6	2.2	31.5*	2.4	4.3	1.8	1.5	1.5	1.4	1.4	1.5	3.0
Mole % Carbon Dioxide	In Vac.	46.6	20.6	24.6	24.7	22.8	23.0	19.8	63.0	28.4	16.1	31.5	8.8	18.0	16.2
	In O_2	84	51.7	60.6	69.7	97.3*	72.7	41.8	54	71.0	50.0	13.6	52	60	69
	Ratio-Vac/O_2	0.56	0.40	0.41	0.36	0.24	0.32	0.48	1.16	0.41	0.32	0.43	0.17	0.30	0.24
Mole % Carbon Monoxide	In Vac.	17.0	3.8	5.7	7.9	3.6	1.5	7.9	4.6	32	4.3	16.6	2.9	3.4	1.6
	In O_2	5.5	?	?	?	?	?	46.2	30	?	?	?	8	10	8.5
	Ratio-Vac/O_2	3.1	---	---	---	---	---	0.17	0.15	---	---	---	5.36	0.34	0.19
Ratio CO_2/CO	In Vac.	2.7	5.4	4.3	3.1	6.3	15.3	2.5	1.4	0.9	3.8	1.9	3.1	5.3	10.1
	In O_2	1.5	---	---	---	---	---	0.9	1.8	---	---	---	6.5	6.0	8.1

? - Too small to be measured in the presence of oxygen.

* - Figures do not agree with others from non-condensed fraction and should be questioned.

TABLE 29-2B

MASS SPECTROGRAPHIC ANALYSIS OF GAS EVOLVED AT 300°C IN VACUUM AND 5 PSI OXYGEN

(Oxygen Excluded)

Mo. %	Wire #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Hydrogen	In Vac.	5.1	-	-	-	--	0.2	-	1.1	-	4.7	16.6	-	0.7	0.5
	In O_2	-	-	-	-	-	-	0.2	-	-	-	-	-	-	-
Methane	In Vac.	-	-	-	-	-	-	-	0.6	-	0.5	-	1.5	2.2	0.8
	In O_2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Benzene	In Vac.	-	-	-	-	-	-	-	0.3	-	-	-	18.3	10.4	7.3
	In O_2	-	-	-	-	-	-	-	-	-	-	-	1.3	2.0	0.7
Hydro-carbons	In Vac.	2.9	4.0	18.9	3.3	8.8	2.7	4.2	8.4	1.1	1.0	2.7	5.8	2.2	3.2
	In O_2	3.3	1.5	10.5	0.9	0.1	-	3.8	5.7	0.3	0.8	2.2	-	-	0.6
Oxygen-ated Hydro-carbons	In Vac.	-	-	9.5	-	-	-	0.8	4.2	-	0.5	-	-	-	-
	In O_2	-	-	2.6	-	-	-	0.8	2.2	-	-	0.3	-	-	-
Methanol	In Vac.	-	-	-	-	-	-	-	-	-	-	-	10.2	9.0	8.1
	In O_2	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-
Formal-dehyde	In Vac.	-	-	-	-	-	-	-	-	-	-	-	1.3	1.1	1.0
	In O_2	-	-	-	-	1.1	-	-	-	2.9	-	-	4.5	2.8	1.8
Acetic Acid	In Vac.	-	-	-	-	1.3	1.2	-	-	-	-	-	-	-	-
	In O_2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NO	In Vac.	-	-	-	-	1.0	-	-	-	-	-	-	-	-	-
	In O_2	-	-	-	-	-	-	-	-	-	0.3	0.9	-	-	-
Methyl and Di-methyl-amine	In Vac.	-	-	0.8	1.1	8.7	2.9	-	-	-	1.0	-	-	-	-
	In O_2	-	-	1.1	0.7	-	-	-	-	-	-	-	-	-	-
Hydra-zine	In Vac.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	In O_2	0.5	0.3	-	-	-	-	-	-	-	-	-	-	-	-
SiF_4	In Vac.	0.8	0.3	-	-	7.5	2.0	21.6	-	-	-	-	-	-	-
	In O_2	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-
CF_4	In Vac.	-	-	-	-	2.1	0.5	-	-	-	-	-	-	-	-
	In O_2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silanes	In Vac.	-	-	-	-	-	-	-	-	-	-	-	1.3	-	-
	In O_2	-	-	--	-	-	-	-	-	-	-	-	0.3	-	-