TENNESSEE VALLEY AUTHORITY

CHATTANOOGA, TENNESSEE 37401

830 Power Building

NOV 1 1978

Director of Nuclear Reactor Regulations
Attention: Mr. S. A. Varga, Chief
Light Water Reactors Branch No. 4
Division of Project Management
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Varga:

In the Matter of the Application of) Docket Nos. 50-390
Tennessee Valley Authority) 50-391

PWR SYS

Enclosed are five copies of a report entitled, "Qualification of Firewall III Class 1E Electric Cables." This report dated February 1, 1977, was prepared by the Rockbestos Company of New Haven, Connecticut. Also enclosed are five copies each of technical reports F-C4033-1 dated January 1975 and F-C4836-3 dated January 1978. These technical reports, prepared by Franklin Institute Research Laboratories, and the Rockbestos report are being submitted in partial response to round two question 40.60 on the Watts Bar Nuclear Plant FSAR, as requested by the NRC Power Systems Branch.

Very truly yours,

J. E. Gilleland

J. E. Gilleland
Assistant Manager of Power

Enclosures

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NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

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Qualification of Firewall III
Class 1E Electric Cables

A

QUALIFICATION OF FIREWALL® III

CLASS 1E ELECTRIC CABLES

ROCKBESTOS
PERMANENTLY INSULATED WIRES AND CABLES

THE ROCKBESTOS COMPANY
New Haven, Conn. 06504

February 1, 1977

TABLE OF CONTENTS

PURPOSE

The purpose of this test program is to demonstrate that Firewall® III electric cables will function during a loss of coolant accident (LOCA) postulated to occur at any time during 40 years of operation under conditions as prescribed by IEEE 383-1974.

TEST SAMPLE DESCRIPTIONS

Instrumentation Cable

Single Conductor #16 AWG, 300 volt , 20 mils of flame retardant XLPE insulation identified as Rockbestos Firewall® III.

*Control Cable

Single Conductor #12 AWG, 600 volt, 30 mils of flame retardant XLPE insulation identified as Rockbestos Firewall® III.

Power Cable

Single Conductor #6 AWG, 600 volt, 45 mils of flame retardant XLPE insulation identified as Rockbestos Firewall® III.

* Also qualifies Firewall SIS (NEC Type SIS).

PROCEDURE

I. Reference IEEE 383 Paragraph 2.3.3.1

Three samples ("A," "B" and "C") each made up of two 10 ft. pieces of cable, were prepared for Firewall III instrumentation, control and power cables described on Page 1. All samples were formed into test coils.

II. Reference IEEE 383 Paragraph 2.3.3.2

The "A" and "B" samples were thermally aged in a circulating air oven for 1300 hours at 150°C in order to simulate 40 year installed life at a continuous operating temperature of 90°C. This simulation was based on the attached Arrhenius data. Exposure time of 850 hours dictated by the Arrhenius slope was adjusted to 1300 hours to provide an adequate margin over specified service temperature, as required in IEEE 323, Section 6.3.1.5.

III. Reference IEEE 383 Paragraph 2.3.3.3

The "A" and "B" samples were subsequently subjected in air to gamma radiation from a cobalt 60 source at a rate of 1×10^6 rads per hour to a cumulative dosage of 5×10^7 rads.

IV. Reference IEEE 383 Paragraph 2.3.3.4

In order to demonstrate the serviceability of Firewall III after normal 40 year service conditions, the "A" samples were straightened and recoiled with an inside diameter of 20 times their O.D.'s and immersed in tap water at room temperature. While still immersed, the samples were subjected to and passed a voltage withstand test for 5 minutes at a potential of 80 V/mil AC.

V. Reference IEEE 383 Paragraph 2.4

In order to demonstrate the serviceability of Firewall III during and after a LOCA occurring during the first days of installed life, the "C" samples were first subjected to a radiation dosage of 1.5×10^8 rads and then subjected to the LOCA profile of IEEE 323 for combined PWR/BWR while energized with rated voltage and current. Following this exposure, the samples were straightened and recoiled with an inside diameter of 40 times their O.D.'s and immersed in tap water at room temperature. While still immersed, the samples were subjected to and passed a voltage withstand test for 5 minutes at a potential of 80 V/Mil AC.

In order to demonstrate the serviceability of Firewall III during and after a LOCA occurring during the last days of 40 year installed life, the "B" samples were first subjected to an additional radiation dosage of 1.5×10^8 rads, bringing the total dosage to 2×10^8 rads, and then subjected to the LOCA profile of IEEE 323 for combined PWR/BWR while energized with rated voltage and current*. Following this exposure, the samples were straightened and recoiled with an inside diameter of 40 times their O.D.'s and immersed in tap water at room temperature. While still immersed, the samples were subjected to and passed a voltage withstand test for 5 minutes at a potential of 80 V/Mil AC.

* 6 AWG: 600 VAC, 70A
12 AWG: 600 VAC, 30A
16 AWG: 300 VAC, 22A

In order to further demonstrate the serviceability of Firewall III cables after a LOCA, the "B" samples, following the post LOCA simulation test described above, were exposed to a 100% RH 200 F environment for 100 days. Following this exposure, the samples were again straightened and recoiled with an inside diameter of 40 times their O.D.'s and immersed in tap water at room temperature. While still immersed, the samples were subjected to and passed a voltage withstand test for 5 minutes at a potential of 80 V/Mil AC.

(CERTIFIED) CONCLUSION

Having successfully withstood the conditions and tests as described in the preceding procedure, we certify that Firewall III cables will function for at least 40 years at a continuous operating temperature (conductor temperature) of 90°C and after a radiation exposure of 200 megarads and during a postulated Loss-of-Coolant-Accident (LOCA) occurring at any time during the 40 years.

George S. Buettner
Chief Engineer

James R. Marth
Cable Engineer

STATE OF CONNECTICUT, COUNTY OF NEW HAVEN:
Subscribed and sworn to before me this 1st day of February 1977.

Ernestine B Natiello
Notary Public

My Commission Expires March 31, 1979

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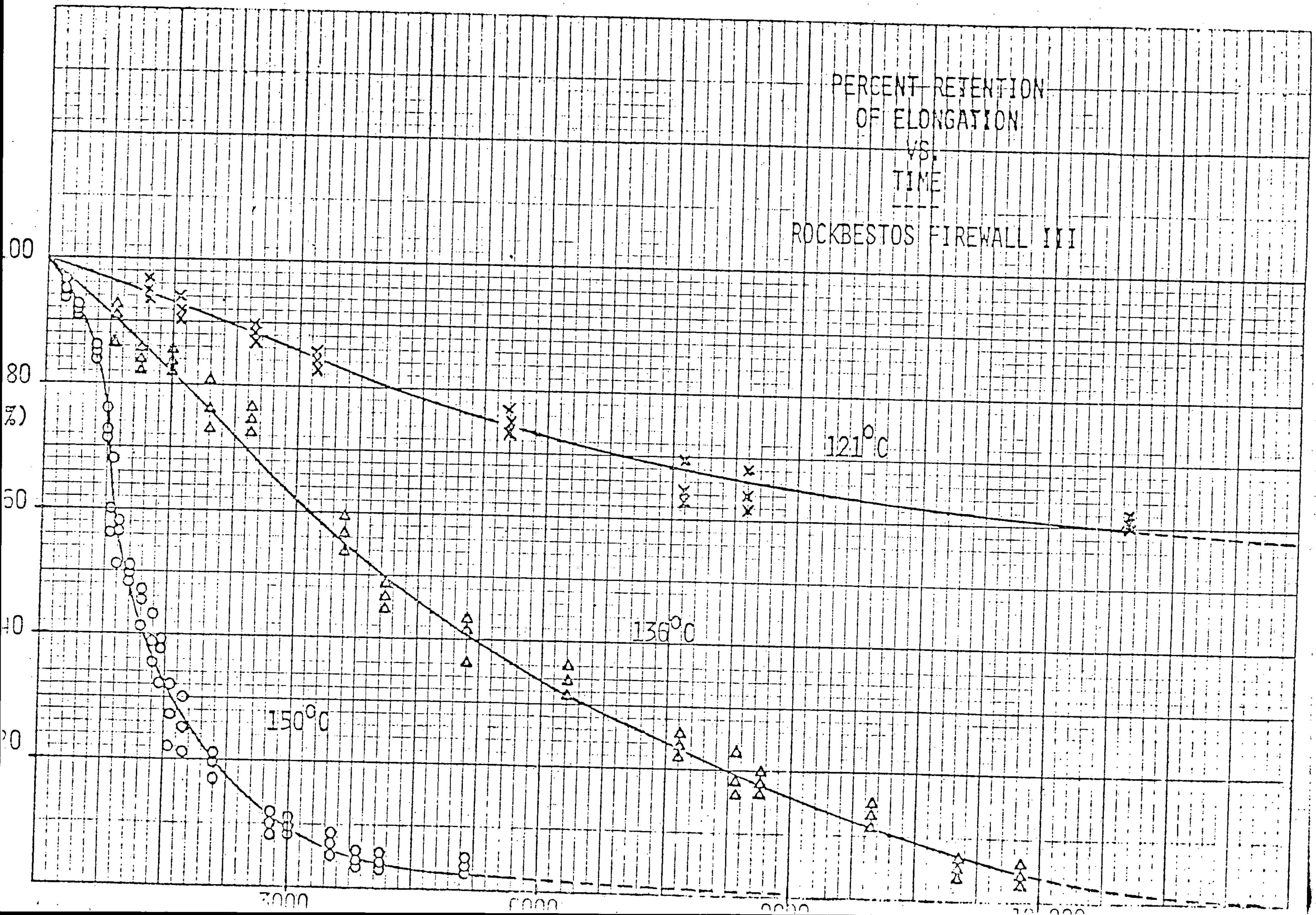
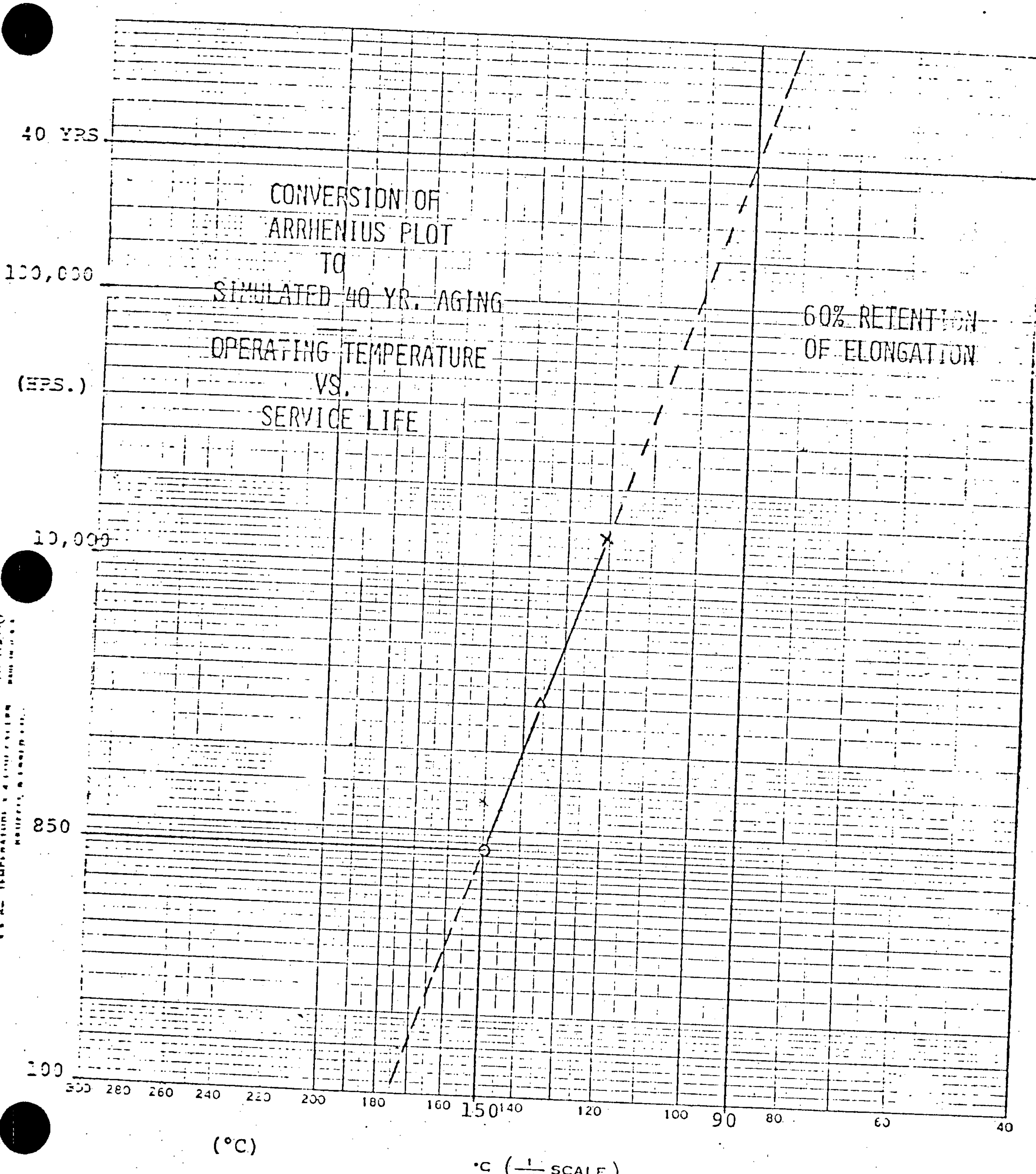
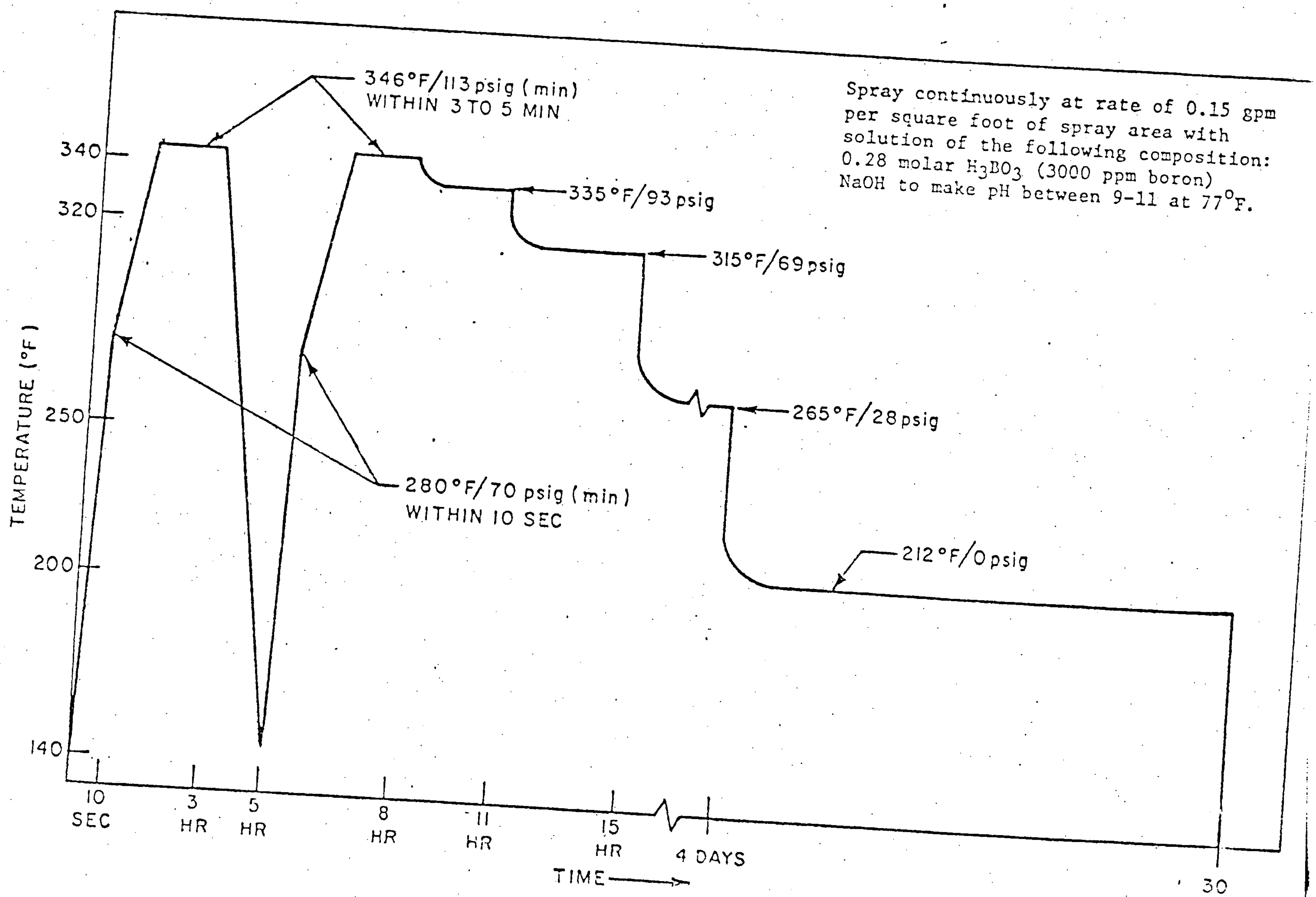


ROCKBESTOS FIREWALL III



LOCA Profile



ISOMEDIX

August 19, 1975

Mr. J. R. Marth
Cerro Wire & Cable Co.
P.O. Box 1102
New Haven, Connecticut 06504

Dear Mr. Marth:

This will summarize parameters pertinent to the irradiation of a mandrel of cable samples per your order 70572, dated July 18, 1975.

The mandrel was placed in a cobalt-60 gamma field in an upright position, which paralleled the long axis of the radiation source. The mandrel was exposed at each of 4 quadrents, as marked with tape on its top. By integrating the dose rate at any point on the mandrel during its 4-position exposure, an average dose rate was obtained which, when multiplied by the total exposure time, yields total dose.

Phase I of the test required that the cables be exposed to 50 Mrad. They were exposed for a total of 78 hours at an average dose rate of 0.65 Mrad for a total dose of 50.7 Mrad. At this point (July 21) the mandrel was removed from the irradiator, and Cerro representatives removed several cables.

Phase II consisted of the mandrel and remaining cables being exposed to an additional 150 Mrad. Using the same procedure, they were exposed for 188 hours at an average dose rate of 0.8 Mrad per hour, for a total dose of 150.4 Mrad.

Irradiation was conducted in air at ambient temperature and pressure. Radiant heat from the source heated the samples somewhat, but the temperature did not exceed 110°f, as indicated by previous measurements on an oil solution in the same relative position.

Dosimetry was performed using a Victoreen Model 555 Integrating Dose Rate Meter and Probe. The unit was calibrated on January 15, 1974 by the Victoreen Instrument Company, using cobalt-60 and cesium-137 sources whose calibrations are traceable to the U.S. National Bureau of Standards. A copy of the calibration certificate is available. Backup dosimetry using a Red Perspex system confirmed the Victoreen readings.

Irradiation was completed on August 1, 1975, and the mandrel was picked up by your personnel.

Very truly yours,

George R. Dietz
Manager, Radiation Services

GRD:km

Tests of Raychem Flamtrol Insulated & Jacketed Electrical Cables Under Simultaneous Exposure to Heat, Gamma Radiation, Steam & Chemical Spray While Electrically Energized

Technical

Report

821043

BLW
Ins. Cond

Final Report
F-C4033-1

TESTS OF RAYCHEM FLAMTROL™ INSULATED AND JACKETED ELECTRICAL CABLES UNDER SIMULTANEOUS EXPOSURE TO HEAT, GAMMA RADIATION, STEAM AND CHEMICAL SPRAY WHILE ELECTRICALLY ENERGIZED

Prepared for

Raychem Corporation
Menlo Park, California

January 1975

THE FRANKLIN INSTITUTE RESEARCH LABORATORIES
THE BENJAMIN FRANKLIN PARKWAY · PHILADELPHIA PENNSYLVANIA 19103

CONTENTS

FIGURES

TABLES

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1. INTRODUCTION

Raychem Flamtrol insulated and jacketed electrical cables (one with a splice) submitted by Raychem were subjected to an environmental test program based on the guidelines of IEEE Standards 323-1974[1] and 383-1974[2] to determine their suitability for service within the containment of a nuclear power generating station.

The test program commenced with a seven-day combined thermal and radiation aging period consisting of 150°C (302°F) and 5 x 10^7 rads gamma radiation dose while the specimens were electrically energized. Some of the specimens had been preaged for 25 days at 150°C (302°F) and 12 days at 160°C (320° F) prior to the combined thermal and radiation aging*. These aging exposures were designed to simulate many years of normal use. The thermal and radiation period was followed by a simultaneous exposure to steam, chemical spray and gamma radiation (S/C/R). This exposure was as follows:

1. An initial dwell at >177°C (351°F) at a steam pressure of >70 psig for 10 hours.
2. 4.5 days at 135°C (275°F) at a steam pressure of 31 psig.
3. A 26 day dwell at 100°C (212°F) at a steam/air pressure of approximately 10 psig.

During the S/C/R portion of the program, the specimens were exposed to an additional gamma radiation dose of 1.5x 10^8 rads. The specimens were also electrically energized during the S/C/R exposure. This exposure simulated the in-containment environmental conditions resulting from a postulated Loss-Of-Coolant Accident (LOCA) in a generating plant having a boiling water or pressurized water reactor, and those occurring during the cooldown after the postulated LOCA. The electrical integrity of the specimens was evaluated by:

1. Insulation resistance measurements
2. The ability to maintain electrical loading during the test cycle.
3. By high-potential withstand tests performed after bending at the conclusion of the exposure.

The program was conducted by The Franklin Institute Research Laboratories (FIRL) during the period of December 1974 through January 1975.

*Preaging performed at Raychem prior to submission of specimens to FIRL (information on preaging was provided by Raychem).

2. TEST SPECIMENS

Table 1 presents a description of the specimens tested and also shows the energizing voltage and current levels.

Table 1 Test Specimens

Specimen			Electrical Loading	
Description	Number*	Length (ft)†	Voltage (Vrms - 60 Hz)	Initial Current (A)‡
Raychem Flamtrol™ 1000 V insulated wire AWG 12, 45 mil nominal wall Part No. W1TC12C10 (60C0311-12) Run No. P7-10-1-72-6	1 1X	25 22	1000	25
Raychem Flamtrol™ 1000 V insulated wire AWG 6, 45 mil nominal wall Part No. W1TC6B6 (60B0211-6) Run No. P-7-9-23-71-6	2	23	1000	65
Raychem Flamtrol™ 1000 V insulated and jacketed cable, 7 conductor, AWG 12 30 mil nominal wall insulation 60 mil nominal jacket wall Part No. J7TC12C10 Run No. P7-29-74-7	3 3X	24 22	1000	17.5
Raychem Flamtrol™ 600 V insulated and jacketed cable, 2 conductor, AWG 16 Aluminum-polyester shield wrap with AWG 18 drain wire 20 mil nominal wall insulation 45 mil nominal jacket wall Part No. F2TC16C6-C1 Run No. J14-11-6-74-6	4A 4AX	27 23	600	8
Raychem Adverse Service Coaxial Cable AWG 22 conductor 1st insulation layer - 8 mil wall of alkane-imide polymer 2nd insulation layer - 49 mil wall of Rayolin R™ radiation cross-linked polyolefin Braided copper shield Raychem Flamtrol™ jacket - 34 mil nominal wall Part No. 10483 Run No. J7-5-10-72-6	5 5X	25 25	600	0
Raychem Adverse Service Triaxial Cable AWG 26 conductor 1st insulation layer - 4 mil wall of alkane-imide polymer 2nd insulation layer - 129 mil wall of Rayfoam F™ radiation cross-linked cellular polyolefin Braided copper shield 1st jacket - 22 mils of Raychem Flamtrol™ Braided copper shield 2nd jacket - 33 mils of Raychem Flamtrol™ Part No. 10495 Run No. J7-3-1-73-6	6 6X	25 23	600	0

Table 1 Test Specimens (continued)

Specimen: Description	Number*	Length (ft)†	Electrical Loading: Voltage (Vrms - 60 Hz)	Initial Current (A)‡
(See Note 1)	7			
(See Note 1)	8			
Coaxial Cable Splice Same cable as Specimen Number 5 with splice covered with Thermofit® WCSF-N heat-shrinkable tubing splice cover (Splice illustrated in Figure 1)	9X	20	600	0
Raychem Flamtrol™ 1000 V insulated wire AWG 12, 45 mil nominal wall Part No. W1TC12B10 (Note 2) Run No. P-11-7-12-74-4	10 10X	27 18	1000	25
Same as Specimen Number 10 except preaged before test began at 150° C (302° F) for 25 days (Notes 2 and 3)	11	26	600 (Note 4)	25
Same as Specimen Number 10 except preaged before test began at 160° C (320° F) for 12 days (Notes 2 and 3)	12 12X	27 22	1000	25

* Cables with suffix "X" were mounted on the outer cable mandrel. See Section 4.4.
† Specimens cut to lengths shown. Approximately 4 ft of the length extended outside of the test vessel (2 ft on each end of the specimen).
‡ Initial currents were applied at room temperature, and allowed to drop to a lower level during combined radiation and thermal aging and simultaneous LOCA-simulation testing. See text for discussion.

Note 1 Specimens 7 and 8 were Raychem Stilan™, test results are presented in report number F-C4033-2.
Note 2 Specimens 10, 11, and 12 were an experiment to determine the effect of additional preaging. Specimen 10 was the control for the other two specimens.
Note 3 Information on preaging provided by Raychem.
Note 4 Raychem specified 1000V rms. Actual voltage used was 600V rms.
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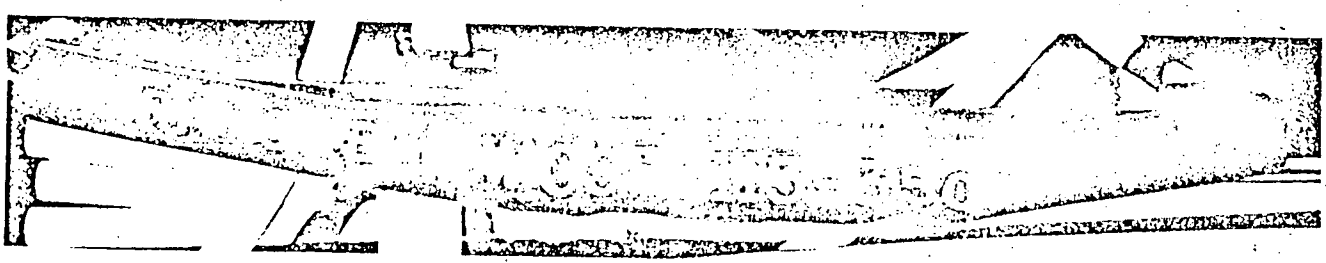

Figure 1. Raychem Flamtrol jacketed coaxial cable spliced with Raychem Thermofit WCSF-N heat-shrinkable tubing splice cover.

3. TEST PROGRAM

3.1 PRETEST INSPECTION AND PREPARATIONS

The specimens were visually inspected upon receipt, identified with stainless steel tags, and wound onto two concentric mandrels (See FIRL reports F-C4033-2 and -3) as shown in Figure 2. The mandrels were assembled with the flanged head of the 24-inch diameter pressure test vessel and the specimens were passed through pressure-sealing glands in the vessel head so that electrical measurements could be made and electric loads applied during the test exposure.

Specimens 5, 5X, 6, 6X and 9X had sections of Raychem Thermofit WCSF-N heat-shrinkable tubing over them in the immediate vicinity of the pressure-sealing glands.

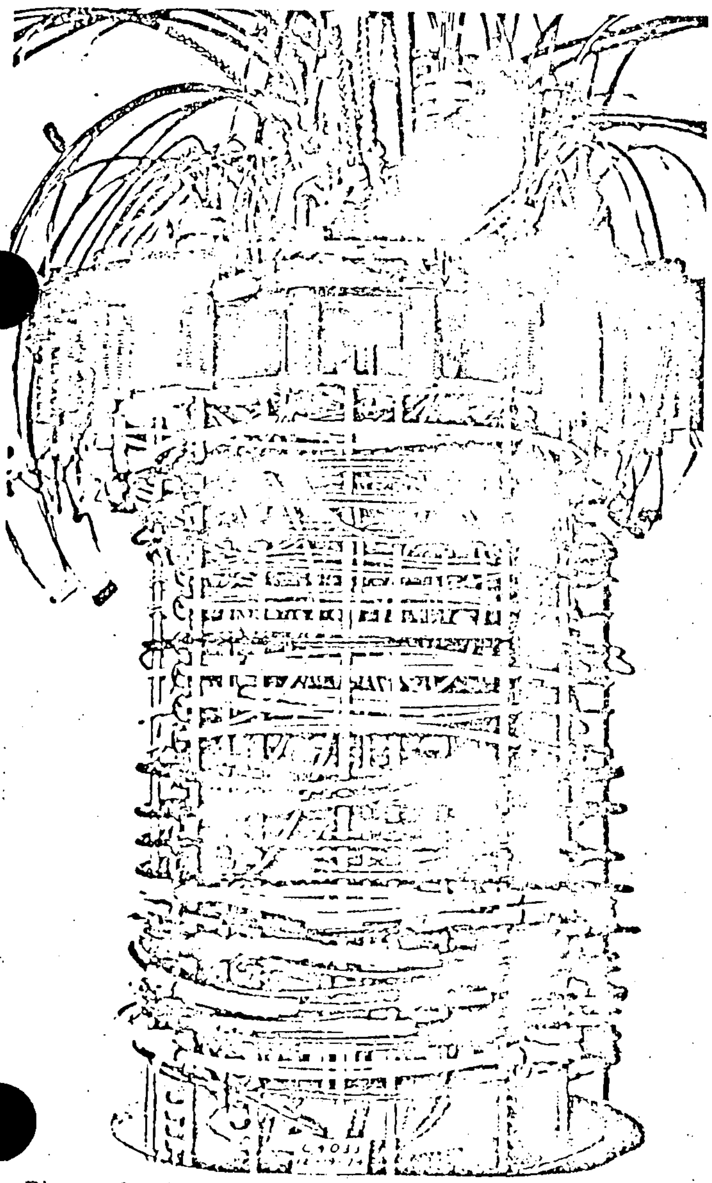

Figure 2. Pretest view of test specimens on vessel mandrels with vessel head attached.

The insulation resistance (IR) of the specimens was measured with a megohmmeter at 500V dc applied for one minute. Then the flanged head with the mandrels and the specimens attached was installed in the vessel.

3.2 ENVIRONMENTAL TEST FACILITY

The pressure vessel for the test was a 24-inch diameter by 48-inch steel chamber with a flat flange head, in which there were penetrations for the specimens (See Figures 3 and 4). A perforated steam inlet pipe extended about 7 inches down from the center of the head flange; this was surrounded by a cylindrical baffle that prevented direct impingement of steam on the specimens.

A spray system was provided to spray the specimens uniformly at an average rate of 0.15 gallons per minute (gpm) per square foot over the cylindrical area approximately midway between the two mandrels. This was accomplished by locating four wide-angle spray nozzles at each of two locations along the axis of the mandrel. The spray was directed radially outward, part of it impinging on the specimens mounted on the inner mandrel and part of it passing through the spaces between cable turns to impinge on the specimens mounted on the outer mandrel. If it is assumed that the spray is uniformly applied to the interior of an imaginary cylinder midway between the 33-inch long inner and outer mandrels, 0.15 gpm per square foot is equivalent to a total rate of 1.94 gpm. A rate of 2.5 gpm was used to assure adequate spray formation from the eight wide-angle nozzles (approximately 0.31 gpm per nozzle).

The spray solution was collected in the bottom of the vessel and was directed to a drain or returned to the pump for recirculation, as required. The spray flow rate was measured with an orifice-plate flowmeter.

The test vessel assembly with associated components was installed inside a radiation hot cell approximately 6-feet x 11-feet x 9-feet high. The cobalt-60 source consisted of pellets packed in 62-inch long pencils and arranged into a vertical cylindrical array which was moved around the vessel during the test to achieve a uniform exposure.

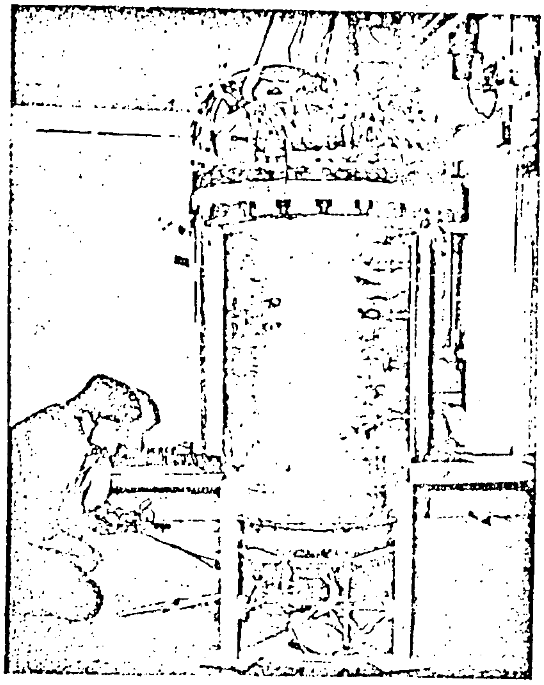

Figure 3. View of test vessel with specimens installed.

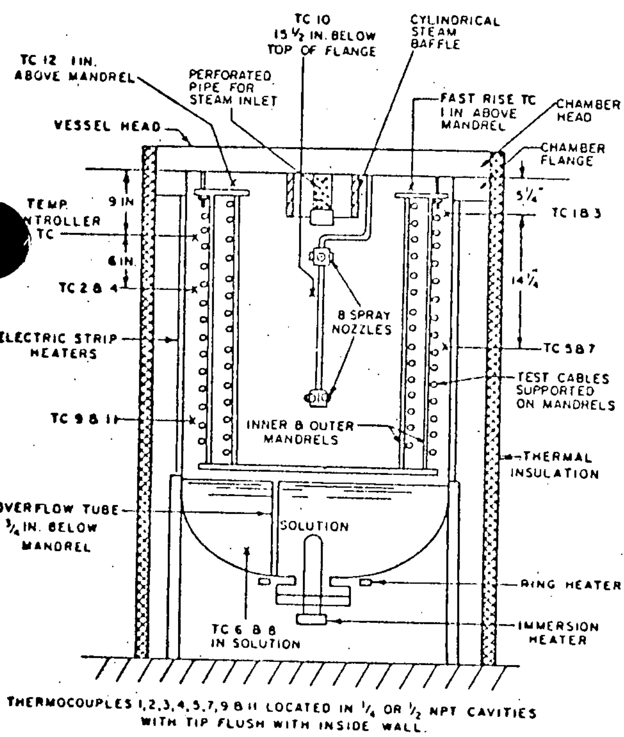

Figure 4. Diagram of pressure vessel showing salient features and location of thermocouples.

3.3 ELECTRICAL ENERGIZING

Shielded extension cables were run from the exterior of the hot cell to the top of the vessel; and connections were made at this point with the ends of the specimens which extended above the vessel. The shielding on the extension cables served to reduce the effects of radiation on measurements of insulation resistance.

Figure 5 is a diagram of the typical energizing circuitry. The energizing cabinets are illustrated in Figure 6. Table 1 gives the specified initial current loads. Current loads were adjusted to the initial specified values of Table 1 prior to the start of the environmental exposures. With the specified current, the voltage drops (resulting from conductor resistances) through the test cables and shielded extension cables were measured and recorded. Thereafter, the currents were adjusted as necessary to reestablish the initial voltage drop. The actual currents were recorded periodically as part of the test data.

This method was specified by Raychem to be in accordance with IEEE Standard 383-1974, Paragraph 2.4.3.1, which states, "....they should be energized at rated voltage and loaded with rated service current while under the average normal operating condition."

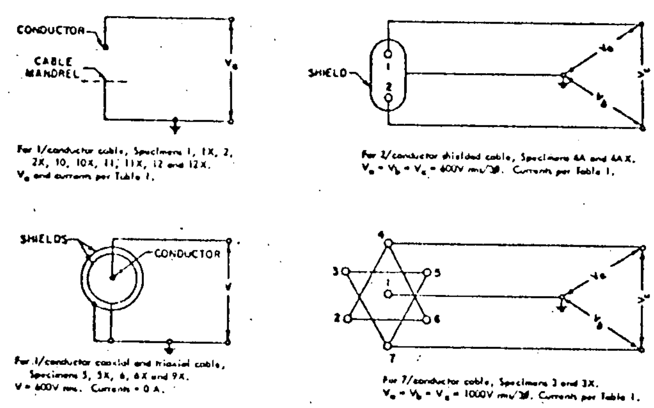

Figure 5. Electrical loading circuits for energizing specimens during environmental exposure.

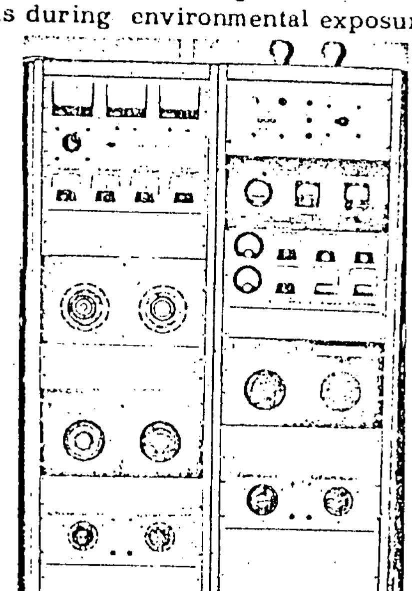

Figure 6. View of electrical energizing cabinets.

3.4 INSTRUMENTATION

Chamber temperature and pressure were monitored continuously on strip-chart recorders. The locations of the thermocouple junctions were as shown in Figure 4.

A list of the data acquisition instruments used in the test program is included as Appendix A.

Radiation Dosimetry data are included as Appendix B.

3.5 COMBINED RADIATION AND THERMAL AGING EXPOSURE

The specimens were electrically energized as stated in Section 3.3, while simultaneously thermally aged at 150°C (302°F) and irradiated to an air-equivalent dose of 5 x 10^7 rads. The vessel was electrically heated. During this exposure air was circulated through the test vessel by an external blower. Insulation resistance measurements were made during and after this exposure.

Note: *An air-equivalent dose means that the volume occupied by the specimens receives an isotropic flux of gamma radiation equivalent to the radiation dose that would result if the volume contained only air.*

3.6 LOSS-OF-COOLANT ACCIDENT (LOCA) ENVIRONMENT EXPOSURE

Following the combined radiation and thermal aging exposure, the specimens were simultaneously exposed to steam, chemical-spray and gamma radiation (S/C/R) as illustrated in Figure 7.

A chemical spray consisting of 3000 ppm boron as boric acid, 0.064 molar sodium thiosulfate and adjusted with sodium hydroxide to a pH of 10.5 at room temperature, was applied at the rate of 0.15 gpm per square foot (100 ml per second per square meter) of spray area (See Section 3.2). Fresh heated spray solution was used for the first hour of the profile. Thereafter, the spray solution was recirculated from the reservoir at the bottom of the chamber. The pH was monitored periodically and was maintained within the range of 9.5 to 11.0 by addition of fresh solution.

During the S/C/R exposure, the specimens were energized as indicated in Section 3.3.

3.7 BEND AND HIGH-POTENTIAL WITHSTAND TESTS

After the S/C/R exposure, before the test vessel was removed from the radiation hot cell, it was filled with tap water and insulation resistance measurements

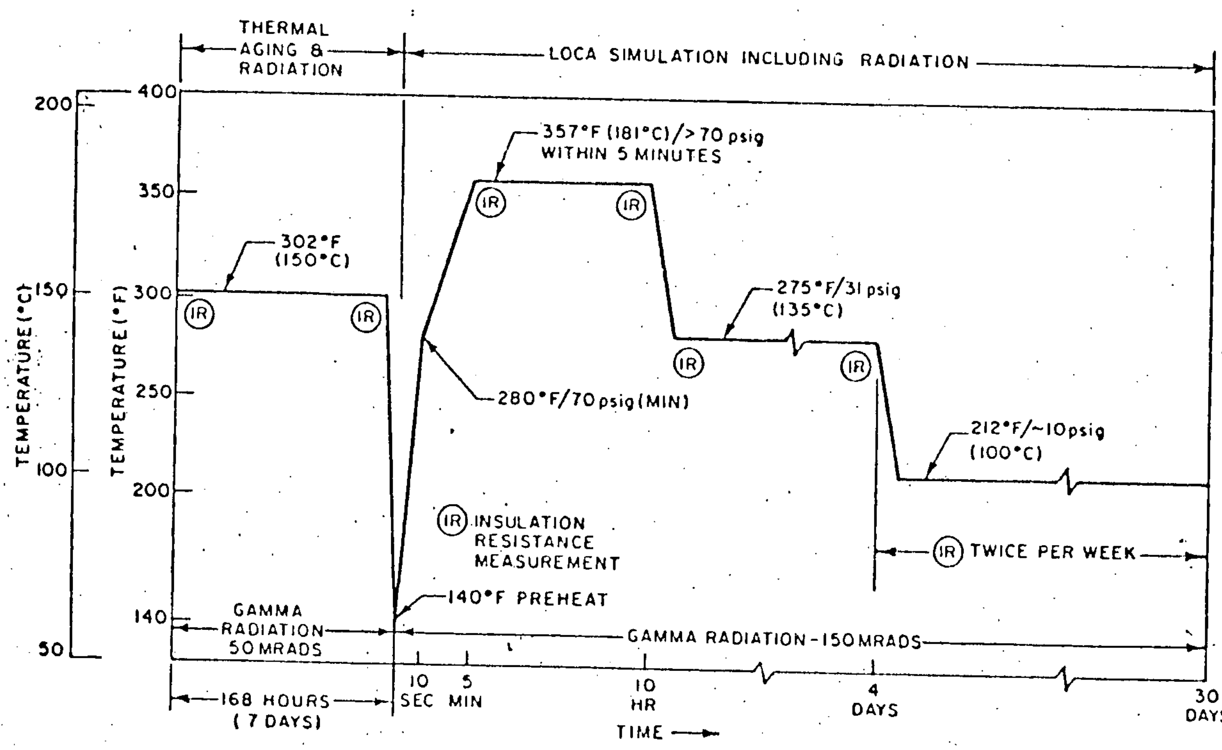

Figure 7. Temperature/pressure profile for simulation of Loss-Of-Coolant-Accident (LOCA) environment.

and preliminary high-potential withstand tests were made on all specimens at ambient temperature. The test vessel was drained, the mandrels with the specimens were removed from the vessel and the specimens were visually inspected. The specimens were then removed from the vessel mandrels and bent around test mandrels 40 times the cables' diameter. The specimens (still coiled from the test mandrel) were immersed in water and subjected to a high-potential withstand test for five minutes at the voltages shown in Section 4.4.

4. TEST RESULTS

4.1 PRETEST ELECTRICAL MEASUREMENTS

The results of insulation resistance measurements are presented in Table 2.

4.2 COMBINED RADIATION AND THERMAL AGING

The specimens were exposed to the aging environment described in Section 3.5. The average temperature near the specimens approximated or exceeded 150°C (302°F). The specimens maintained the electric loads described in Section 3.3 and Table 3. Insulation resistance measurements are included in Table 2.

4.3 LOCA ENVIRONMENT EXPOSURE

The specimens were exposed to a simultaneous steam, chemical-spray and radiation environment in general accordance with Figure 7. Minor deviations occurred as follows:

a) The temperature of 280°F was obtained in 25 seconds instead of 10 seconds.

b) The temperature drop from 357°F to 275°F was accomplished in two hours instead of one hour.

c) After nine days of the S/C/R environment, occasional clogging of the spray nozzles and filters from chemical and other deposits (possibly specimen materials) caused spray rate reductions*, which were periodically corrected by cleaning of filters and two complete replacements of the spray solutions.

Post test inspection and performance test of the spray nozzles indicated only three of the eight nozzles were spraying†. Therefore, the spray rate was in excess of 0.15 gpm per square foot of area in front of the working nozzles. Since the three working nozzles were in the upper portion of the chamber (See Figure 4), there is reasonable assurance that the impinging spray splashed and flowed onto the lower cables.

Clogging of nozzles and filters and replacements of spray solutions are not unusual occurrences for FIRL conducted tests of this type.

†*The chemical sprays tend to vaporize into steam when exiting the nozzles and leave chemical deposits leading to possible clogging of spray nozzles.*

The specimen energizing data and the results of electrical tests made during the exposure are summarized in Tables 2 and 3.

4.4 FINAL INSPECTION AND ELECTRICAL TESTS

Immediately after the S/C/R exposure, before the test vessel was removed from the radiation hot cell, it was filled with water. Insulation resistance measurements and one-minute high-potential withstand tests were made on all specimens at ambient temperature. The results indicated all specimens except 4A and 4AX were capable of withstanding appropriate high-voltage test potentials.

After removal of the vessel head and specimen mandrel from the vessel, further diagnostic tests indicated the insulation on specimens 4A and 4AX were faulted in the area of the chamber penetration. The specimens were severed immediately below the penetration before conducting the final inspection and electrical tests.

The results of the mandrel wrap test and high-potential withstand tests which followed the 30-day S/C/R environment are included in Tables 3 and 4. Figure 8 shows a typical test mandrel wrapped with a specimen. Figure 9 shows the high-potential withstand test. Post test photographs of the specimens are presented as Figures 10 and 11. The specimens on the inner mandrel (specimen numbers without the "X" suffix) were left on the mandrel and returned to Raychem for additional testing by Raychem.

Table 2. Summary of Insulation Resistance Measurements (ohms)

Elapsed LOCA Time	Temperature (°F)	Chamber Pressure (psig)	Insulation resistance (ohms)[a] of specimen number: 1	1X	2	2X	3 Even[b]	3 Odd[c]	3X Even[b]	3X Odd[c]	4A Even[b]	4A Odd[e]	4AX Even[d]	4AX Odd[e]
Pre-Test	Ambient	0	2.5×10^{12}	1.5×10^{12}	6.0×10^{11}	9.0×10^{11}	7.5×10^{11}	1.5×10^{12}	7.5×10^{11}	1.5×10^{12}	5.0×10^{12}	1.0×10^{13}	1.0×10^{13}	1.0×10^{13}
	Ambient	0	1.5×10^{10}	2.0×10^{10}	2.3×10^{9}	1.5×10^{12}	3.2×10^{9}	3.2×10^{9}	4.0×10^{9}	3.6×10^{9}	5.0×10^{9}	5.1×10^{9}	5.8×10^{9}	5.3×10^{9}
(Note f)	302	0	1.2×10^{9}	1.2×10^{8}	3.0×10^{8}	6.8×10^{8}	6.5×10^{8}	6.3×10^{8}	4.5×10^{8}	5.0×10^{8}	6.2×10^{8}	6.9×10^{8}	7.4×10^{8}	7.0×10^{8}
	262	0	1.1×10^{9}	9.2×10^{8}	2.0×10^{8}	1.1×10^{9}	3.7×10^{8}	4.0×10^{8}	8.4×10^{9}	8.4×10^{9}	8.0×10^{9}	8.6×10^{9}	8.4×10^{9}	7.6×10^{9}
	140	0	1.2×10^{8}	1.2×10^{8}	3.0×10^{7}	6.6×10^{7}	6.4×10^{7}	6.0×10^{7}	4.5×10^{7}	5.0×10^{7}	8.8×10^{7}	9.2×10^{7}	1.0×10^{8}	9.6×10^{7}
	120	0	1.2×10^{9}	1.3×10^{9}	3.7×10^{8}	8.0×10^{8}	4.8×10^{8}	8.0×10^{8}	4.5×10^{8}	5.0×10^{8}	1.4×10^{9}	1.5×10^{9}	1.0×10^{9}	1.5×10^{9}
2.2 hr	353	130	1.7×10^{7}	1.2×10^{8}	3.5×10^{7}	7.5×10^{7}	3.4×10^{8}	3.5×10^{8}	3.0×10^{8}	2.9×10^{8}	1.8×10^{7}	1.2×10^{7}	7.5×10^{7}	4.8×10^{7}
9.6 hr	358	134	7.0×10^{7}	6.0×10^{7}	2.0×10^{7}	2.6×10^{7}	2.3×10^{8}	2.5×10^{8}	2.1×10^{8}	2.1×10^{8}	1.0×10^{7}	4.0×10^{8}	2.1×10^{7}	1.1×10^{7}
14.8 hr	275	31.0	7.5×10^{7}	4.9×10^{8}	8.6×10^{7}	2.5×10^{8}	5.5×10^{8}	5.5×10^{8}	3.8×10^{8}	4.2×10^{8}	1.6×10^{8}	8.9×10^{7}	1.3×10^{8}	9.3×10^{7}
4.0 da	274	31.0	5.5×10^{8}	7.1×10^{8}	7.9×10^{7}	2.9×10^{8}	7.8×10^{8}	7.8×10^{8}	6.0×10^{8}	6.1×10^{8}	5.8×10^{7}	3.4×10^{7}	1.6×10^{7}	3.3×10^{7}
4.1 da	212	6.5	1.0×10^{9}	1.2×10^{9}	1.1×10^{8}	9.0×10^{8}	8.5×10^{8}	8.0×10^{8}	5.5×10^{8}	5.8×10^{8}	9.0×10^{7}	2.3×10^{8}	1.7×10^{7}	1.8×10^{8}
7.9 da	212	11.0	1.0×10^{8}	1.1×10^{9}	9.0×10^{7}	6.5×10^{8}	7.8×10^{8}	7.5×10^{8}	4.8×10^{8}	5.3×10^{8}	1.1×10^{7}	8.5×10^{8}	1.2×10^{7}	1.1×10^{8}
13.6 da	220	10.0	1.0×10^{9}	8.3×10^{8}	$<1.0\times10^{5}$[g]	2.4×10^{8}	8.0×10^{8}	7.4×10^{8}	5.0×10^{8}	5.5×10^{8}	1.0×10^{8}	4.5×10^{7}	1.1×10^{7}	6.5×10^{7}
17.8 da	212	12.0	9.5×10^{8}	4.2×10^{7}	3.5×10^{7}	4.0×10^{9}	7.4×10^{8}	7.0×10^{8}	4.8×10^{8}	5.3×10^{8}	1.0×10^{8}	8.0×10^{7}	3.5×10^{8}	1.3×10^{8}
21.6 da	212	12.0	9.0×10^{8}	4.0×10^{7}	3.5×10^{7}	3.5×10^{8}	7.5×10^{8}	7.0×10^{8}	4.8×10^{8}	5.3×10^{8}	1.0×10^{8}	3.0×10^{7}	$<1.0\times10^{5}$[g]	1.8×10^{7}
24.8 da	212	15.0	8.8×10^{8}	4.0×10^{7}	3.7×10^{7}	2.0×10^{8}	8.0×10^{8}	8.0×10^{8}	5.2×10^{8}	5.7×10^{8}	1.2×10^{8}	5.5×10^{8}	$<1.0\times10^{5}$[g]	2.1×10^{8}
29.9 da	212	15.0	5.5×10^{8}	2.0×10^{8}	5.0×10^{7}	2.6×10^{8}	3.7×10^{8}	4.2×10^{8}	9.0×10^{8}	1.0×10^{9}	1.2×10^{8}	4.0×10^{8}	$<1.0\times10^{5}$[g]	2.6×10^{8}
Post Test	Ambient	0	7.5×10^{9}	7.0×10^{8}	1.8×10^{9}	1.5×10^{9}	1.4×10^{10}	1.3×10^{10}	2.5×10^{10}	1.8×10^{10}	1.2×10^{10}	1.5×10^{8}	2.0×10^{6}	$<1.0\times10^{5}$[g]

Elapsed LOCA Time	Temperature (°F)	Chamber Pressure (psig)	Insulation resistance (ohms)[a] of specimen number: 5	5X	6	6X	9X	10	10X	11	11X	12	12X
Pre-Test	Ambient	0	$>1.0\times10^{13}$	$>1.0\times10^{13}$	$>1.0\times10^{13}$	$>1.0\times10^{13}$	$>1.0\times10^{13}$	5.0×10^{12}	5.0×10^{12}	1.0×10^{12}	1.5×10^{12}	2.5×10^{12}	2.5×10^{12}
	Ambient	0	1.0×10^{11}	1.4×10^{11}	2.6×10^{11}	1.8×10^{11}	2.7×10^{11}	2.6×10^{10}	2.9×10^{10}	7.8×10^{9}	7.0×10^{9}	3.3×10^{10}	3.5×10^{10}
(Note f)	302	0	1.0×10^{9}	1.4×10^{9}	3.2×10^{9}	2.0×10^{9}	1.4×10^{9}	8.5×10^{8}	8.4×10^{8}	8.4×10^{8}	9.0×10^{8}	7.4×10^{8}	6.9×10^{8}
	262	0	2.2×10^{9}	2.6×10^{9}	1.2×10^{9}	2.8×10^{9}	6.2×10^{9}	8.4×10^{8}	8.7×10^{8}	5.4×10^{8}	5.4×10^{8}	8.8×10^{8}	3.4×10^{8}
	140	0	1.0×10^{8}	1.3×10^{8}	4.0×10^{8}	2.0×10^{8}	1.5×10^{8}	1.1×10^{9}	1.1×10^{8}	1.1×10^{8}	1.3×10^{8}	1.3×10^{8}	1.2×10^{8}
	120	0	1.5×10^{9}	1.2×10^{9}	3.6×10^{8}	2.1×10^{9}	1.4×10^{9}	1.1×10^{9}	1.1×10^{9}	1.1×10^{9}	1.2×10^{9}	1.3×10^{9}	1.2×10^{9}
2.2 hr	353	130	1.3×10^{8}	1.4×10^{8}	5.5×10^{8}	4.5×10^{8}	1.5×10^{9}	1.1×10^{8}	1.5×10^{7}	1.6×10^{7}	1.3×10^{7}	1.4×10^{7}	1.4×10^{7}
9.6 hr	358	134	1.4×10^{8}	1.6×10^{8}	3.5×10^{8}	3.2×10^{8}	1.5×10^{9}	4.5×10^{8}	6.8×10^{8}	7.6×10^{8}	6.4×10^{8}	4.3×10^{8}	7.2×10^{8}
14.8 hr	275	31.0	7.2×10^{8}	8.0×10^{8}	2.5×10^{9}	1.6×10^{9}	1.5×10^{9}	5.4×10^{7}	6.8×10^{7}	7.6×10^{7}	7.0×10^{7}	4.6×10^{7}	5.8×10^{7}
4.0 da	274	31.0	5.7×10^{8}	1.1×10^{8}	3.3×10^{9}	2.1×10^{9}	1.8×10^{9}	5.1×10^{7}	4.5×10^{7}	5.1×10^{7}	5.2×10^{7}	3.1×10^{7}	3.9×10^{7}
4.1 da	212	6.5	1.3×10^{9}	1.5×10^{8}	5.0×10^{9}	2.6×10^{9}	1.8×10^{9}	1.8×10^{8}	1.1×10^{8}	1.3×10^{8}	1.4×10^{8}	9.0×10^{7}	1.0×10^{8}
7.9 da	212	11.0	1.1×10^{9}	8.5×10^{8}	4.0×10^{9}	2.1×10^{9}	1.5×10^{9}	1.5×10^{8}	3.5×10^{7}	1.2×10^{8}	1.2×10^{8}	9.0×10^{7}	1.4×10^{7}
13.6 da	220	10.0	1.2×10^{9}	9.0×10^{8}	4.2×10^{9}	2.3×10^{9}	1.7×10^{9}	8.5×10^{7}	5.5×10^{7}	7.5×10^{7}	7.0×10^{7}	5.0×10^{7}	4.0×10^{7}
17.8 da	212	12.0	1.1×10^{9}	1.3×10^{9}	3.9×10^{9}	2.1×10^{9}	1.6×10^{9}	1.1×10^{8}	1.7×10^{7}	1.1×10^{8}	1.1×10^{8}	7.0×10^{7}	1.5×10^{7}
21.6 da	212	12.0	1.1×10^{9}	1.4×10^{9}	4.0×10^{9}	2.2×10^{9}	1.6×10^{9}	9.0×10^{7}	1.8×10^{7}	9.5×10^{7}	9.8×10^{7}	5.0×10^{7}	1.5×10^{7}
24.8 da	212	15.0	1.1×10^{9}	1.4×10^{8}	4.2×10^{9}	2.2×10^{9}	1.7×10^{9}	2.4×10^{7}	1.6×10^{7}	1.1×10^{8}	9.5×10^{7}	3.2×10^{7}	1.2×10^{7}
29.9 da	212	15.0	3.0×10^{8}	4.2×10^{8}	1.3×10^{9}	3.3×10^{9}	8.0×10^{9}	1.8×10^{7}	1.5×10^{7}	9.0×10^{7}	8.0×10^{7}	2.7×10^{7}	1.3×10^{7}
Post Test	Ambient	0	7.0×10^{11}	1.5×10^{12}	5.0×10^{12}	5.0×10^{12}	3.0×10^{12}	1.6×10^{8}	8.0×10^{8}	9.0×10^{9}	6.0×10^{9}	2.2×10^{8}	7.0×10^{8}

NOTES:

[a] Measurements made at 500V d-c for one minute, unless otherwise indicated. Measurements made during the combined thermal and radiation aging and the S/C/R include the IR effects of the extension leads. The IR of a dummy set of extension leads measured as low as 1.5×10^{8} ohms.

[b] Measurements made between conductors 2, 4 and 6 connected together; and conductors 1, 3, 5 and 7 connected together at ground potential.

[c] Measurements made between conductors 1, 3, 5 and 7 connected together; and conductors 2, 4 and 6 connected together at ground potential.

[d] Measurements made between conductor 2; and conductor 1 and shield connected together at ground potential.

[e] Measurements made between conductor 1; and conductor 2 and shield connected together at ground potential.

[f] During combined Thermal and Radiation Aging

[g] Measurements at 50V d-c

Table 3. Electrical Loading Results

Specimen Number	Energizing Voltage (Vrms)	Conductor	Actual Energizing Current (A)* Room Temp.	At 300°F#	At 355°F	At 275°F	At 212°F	Ability to Hold Electric Load During S/C/R Exposure
1	1000	1	25	17	22	24	24	Held load for 30 days
1X	1000	1	25	17	22	24	24	Held load for 30 days
2	1000	1	65	51	58	60	62	Held load for 30 days
2X	1000	1	65	51	58	60	62	Held load for 30 days
3	1000	Odd	17.5	12.5	14.9	16.2	17.3	Held load for 30 days
		Even	17.5	12.2	15.4	16.6	17.2	Held load for 30 days
3X	1000	Odd	17.5	12.5	14.9	16.2	17.3	Held load for 30 days
		Even	17.5	12.2	15.4	16.6	17.2	Held load for 30 days
4A	600	Odd	8	6.8	7.2	7.7	7.4	Load removed after 20 days†
		Even	8	6.0	7.1	7.5	7.3	Held load for 30 days
4AX	600	Odd	8	6.8	7.2	7.7	7.4	Load removed after 16 days†
		Even	8	6.0	7.1	7.5	7.3	Load removed after 14 days†
5	600	1	No current					Held load for 30 days
5X	600	1	No current					Held load for 30 days
6	600	1	No current					Held load for 30 days
6X	600	1	No current					Held load for 30 days
9X	600	1	No current					Held load for 30 days
10	1000	1	25	17	22	24	24	Held load for 30 days
10X	1000	1	25	17	22	24	24	Held load for 30 days
11	600	1	25	17	23	23	23	Held load for 30 days
11X	600	1	25	17	23	23	23	Held load for 30 days
12	1000	1	25	17	22	24	24	Held load for 30 days
12X	1000	1	25	17	22	24	24	Held load for 30 days

* See constant-voltage drop method discussed in Section 3.3.

\# Rated service currents are not required during the thermal aging phase.[2] Reduced currents prevented heat input (resistive heating from current loading) from exceeding heat losses.

†See Section 4.4 and 5 for discussion of results.

Table 4. Results of Mandrel Wrap and High-Potential Withstand Tests

Cable	Cable O.D. (in.)	Mandrel O.D. (in.)	Mandrel to Cable O.D. Ratio	Number of Turns on Mandrel	Visual Appearance of Cable	Withstand Potential[a] (Vrms)	Withstand Potential Results
1X	0.19	7.5	39.5	5.5	Flexible. Minor surface cracks.	3600	
2X	0.28	11.0	39.3	3.5	Flexible. Minor surface cracks.	5000	
3X	0.58	22.5[b]	38.3	(Note c)	No apparent damage. Portions of the cable surface has pitted texture with flake-like material which could be rubbed off.	5000[d]	
4AX	0.32	13.0	40.6	2.5	Flexible. Cable surface crinkled and crazed. Covered with flake-like material which could be rubbed off.	3200[e]	
5X	0.24	9.5	39.6	4.5	Flexible. Crinkled or raised suede texture.	2000	All cables withstood potentials for five minutes. Charging/leakage currents were less than 10 mA.
6X	0.43	17.0	39.5	2.5	Stiff but flexible (not brittle). Cable diameter collapsed to flat condition. Cable coil exhibited a "set" condition and was slumped between cable supports on chamber mandrel. Cable surface crinkled.	2000	
9X	0.24	9.5	39.6	2.5	Cable flexible. Splice intact. Cable surface crinkled.	2000	
10X	0.19	7.5	39.5	4.5	Cable flexible. No apparent damage.	3600	
11X	0.19	7.5	39.4	3.5	Cable flexible. No apparent damage.	3600	
12X	0.19	7.5	39.5	4.5	Cable flexible. No apparent damage. Sleeve intact.	3600	

[a] Potentials were applied between the cable conductors and a 55-gal metal drum of room temperature tap water (at ground potential) in which the bent (coiled) portions of the cables were immersed. Conductor shields, if present, were at ground potential.

[b] The cable was coiled to the inside diameter of the 55-gal drum which was 22.5 in. in inside diameter.

[c] The number of coil turns was not recorded but was probably two in number.

[d] Four conductors of the outer conductor lay and the center conductor were connected to ground (and water) potential.

[e] Potentials were first applied to one conductor with the other conductor and shield at ground potential, and then applied to the other conductor with the first conductor and shield at ground potential.

Figure 8. Test Mandrel wrapped with a specimen following removal from test vessel.

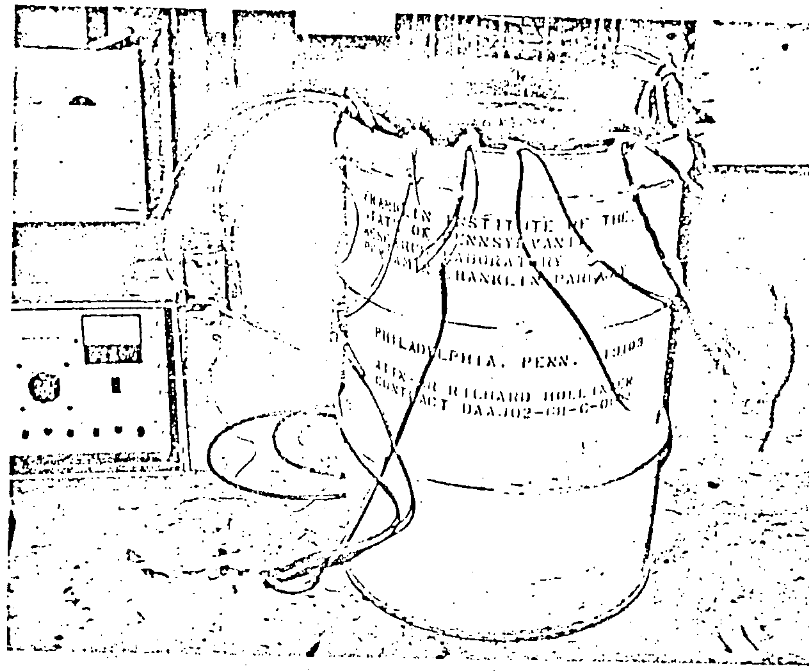

Figure 9. View of high-potential withstand testing.

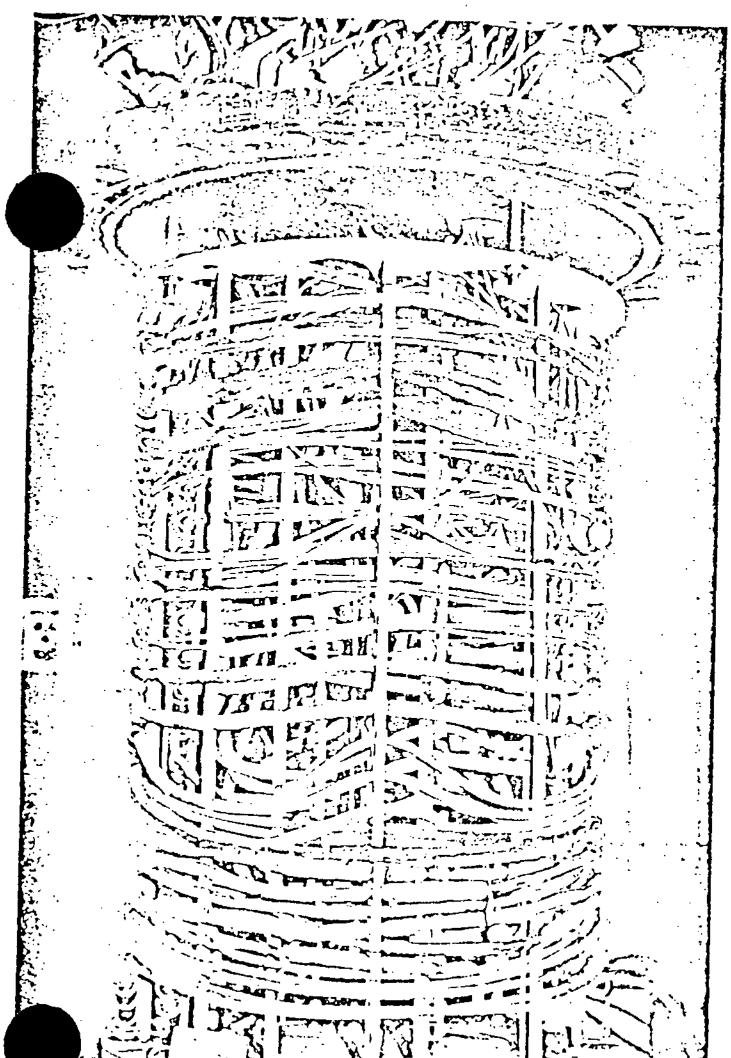

Figure 10. Post test view of specimens on vessel mandrel.

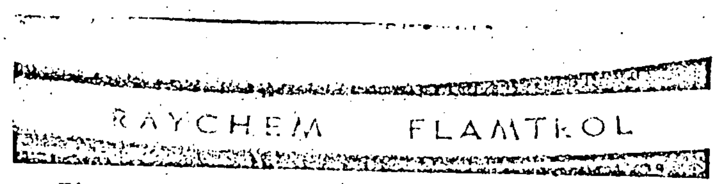

Figure 11. Close-up of one specimen after test.

5. CONCLUSIONS

Ten Raychem Flamtrol insulated and jacketed electrical cables submitted by Raychem were subjected to a test program based on the guidelines of IEEE Standards 323[1] and 383.[2] The program was designed to simulate normal service, a Loss-Of-Coolant Accident (LOCA) and the cooldown following the LOCA and included combined radiation and thermal aging with 5×10^7 rads of gamma irradiation; and a subsequent simultaneous steam, chemical-spray and radiation exposure with an additional 1.5×10^8 rads of irradiation. Throughout the exposures, the specimens were energized (except specimens which were removed from the circuits) with potentials and currents simulating field service use. At the conclusion of the above sequence of exposures, each specimen was subjected to a test mandrel wrap and high-potential withstand test.

Every specimen except 4A and 4AX demonstrated satisfactory performance during the exposures simulating normal service, a LOCA and associated cooldown; plus demonstrating a substantial margin of life remaining in the specimens by withstanding post-LOCA bends and high-potential withstand tests with the specimen immersed in water.

Based on the discussion presented below, specimens 4A and 4AX also appeared capable of demonstrating satisfactory performance during the exposures simulating normal service, a LOCA and associated cooldown; plus demonstrating a substantial margin of life remaining in the specimens by withstanding post-LOCA bends and high-potential withstand-tests with the specimens immersed in water.

The odd numbered conductor of specimen 4A, and even-numbered conductors of specimens 4A and 4AX had been removed from their energizing circuits after 20, 16, and 14 days respectively. However, a post-test inspection and analysis indicated the specimens were faulted at the point of vessel penetration and the remaining portion of the specimens within the vessel were capable of withstanding a high-potential test after being subjected to the required test mandrel bend. In addition, the vessel penetrations probably were not representative of an actual installation in a generating station.

REFERENCES

1. IEEE Standard 323-1974, IEEE Standard for Qualifying 1E Equipment for Nuclear Power Generating Stations, *The Institute of Electrical and Electronics Engineers, Inc., New York, N.Y., 1974.*

2. IEEE Standard 383-1974, IEEE Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations, *The Institute of Electrical and Electronics Engineers, Inc., New York, N.Y., 1974.*

6. CERTIFICATION

The undersigned certify that this report is a true account of the tests conducted and the results obtained.

D V Paulson /for
L.E. Witcher
Test Engineer

D. V. Paulson
D.V. Paulson, P.E.
Project Leader

APPROVED

Zenons Zudans
Zenons Zudans, Director
Engineering Department

W. H. Steigelmann
W.H. Steigelmann, P.E., Manager
Energy Engineering Laboratory

Appendix

A

LIST OF DATA ACQUISITION INSTRUMENTS

INSTRUMENT NUMBER	18132
INSTR AND MFR	MEYLAND STOPWATCH, ELAPSED TIME METER
TYPE/MODEL NUMBER	
SERIAL NUMBER	
RANGE/FEATURES	0-9999.9 HR
DATE CALIBRATED	NOT REQUIRED

INSTRUMENT NUMBER	18260
INSTR AND MFR	SIMPSON AC VOLTMETER
TYPE/MODEL NUMBER	RECTIFIER
SERIAL NUMBER	
RANGE/FEATURES	0 TO 1.5 KVAC 20 VAC DIV
DATE CALIBRATED	12 21 74

INSTRUMENT NUMBER	18261
INSTR AND MFR	SIMPSON AC MILLIAMMETER
TYPE/MODEL NUMBER	
SERIAL NUMBER	
RANGE/FEATURES	0-100 MAAC 2MA DIV
DATE CALIBRATED	REFERENCE ONLY

INSTRUMENT NUMBER	18262
INSTR AND MFR	SIMPSON AC MILLIAMMETER
TYPE/MODEL NUMBER	
SERIAL NUMBER	
RANGE/FEATURES	0-100 MA AC 2MA DIV
DATE CALIBRATED	REFERENCE ONLY

INSTRUMENT NUMBER	18264
INSTR AND MFR	MIDWEST AC AMMETER
TYPE/MODEL NUMBER	
SERIAL NUMBER	
RANGE/FEATURES	0-100A WITH CURRENT XFMR
DATE CALIBRATED	12 21 74

INSTRUMENT NUMBER	18265
INSTR AND MFR	MIDWEST AC AMMETER
TYPE/MODEL NUMBER	
SERIAL NUMBER	
RANGE/FEATURES	0-100A WITH CURRENT XFMR
DATE CALIBRATED	12 21 74

INSTRUMENT NUMBER	18266
INSTR AND MFR	MIDWEST AC AMMETER
TYPE/MODEL NUMBER	
SERIAL NUMBER	
RANGE/FEATURES	0-100A WITH CURRENT XFMR
DATE CALIBRATED	12 21 74

INSTRUMENT NUMBER	18267
INSTR AND MFR	MIDWEST AC AMMETER
TYPE/MODEL NUMBER	
SERIAL NUMBER	
RANGE/FEATURES	0-100A WITH CURRENT XFMR
DATE CALIBRATED	12 21 74

INSTRUMENT NUMBER	18196
INSTR AND MFR	SIMPSON, AMMETER
TYPE/MODEL NUMBER	7016
SERIAL NUMBER	
RANGE/FEATURES	0-1 A AC 0.02 A/DIV
DATE CALIBRATED	04 29 74

INSTRUMENT NUMBER	18027
INSTR AND MFR	SIMPSON, AMMETER
TYPE/MODEL NUMBER	
SERIAL NUMBER	7016
RANGE/FEATURES	0-1.0 A AC
DATE CALIBRATED	04 29 74

INSTRUMENT NUMBER	18193
INSTR AND MFR	SIMPSON VOLTMETER
TYPE/MODEL NUMBER	
SERIAL NUMBER	
RANGE/FEATURES	0-750 VAC 10V/DIV
DATE CALIBRATED	12 21 74

INSTRUMENT NUMBER	18268
INSTR AND MFR	GE AC AMMETER
TYPE/MODEL NUMBER	
SERIAL NUMBER	
RANGE/FEATURES	0-100A F.S. 2 DIV WITH CURRENT XFMR
DATE CALIBRATED	12 21 74

INSTRUMENT NUMBER	18118
INSTR AND MFR	WESTINGHOUSE, AMMETER
TYPE/MODEL NUMBER	NT-35
SERIAL NUMBER	
RANGE/FEATURES	0-10 A
DATE CALIBRATED	12 21 74

INSTRUMENT NUMBER	18271
INSTR AND MFR	GE AC AMMETER
TYPE/MODEL NUMBER	
SERIAL NUMBER	
RANGE/FEATURES	0-100A F.S. 2 DIV WITH CURRENT XFMR
DATE CALIBRATED	12 21 74

INSTRUMENT NUMBER	18272
INSTR AND MFR	GE AC AMMETER
TYPE/MODEL NUMBER	AD-91 FS 5A
SERIAL NUMBER	
RANGE/FEATURES	0-100A F.S. 2 DIV WITH CURRENT XFMR
DATE CALIBRATED	12 21 74
INSTRUMENT NUMBER	18273
INSTR AND MFR	MIDWEST AC AMMETER
TYPE/MODEL NUMBER	
SERIAL NUMBER	
RANGE/FEATURES	0-100A F.S. 2 DIV WITH CURRENT XFMR
DATE CALIBRATED	12 21 74
INSTRUMENT NUMBER	18172
INSTR AND MFR	ESTERLINE ANGUS 2-PEN RECORDER
TYPE/MODEL NUMBER	SPEED SERVO II L11025
SERIAL NUMBER	908424
RANGE/FEATURES	0-400 DEGREES F TYPE T T/C 0-10 MVDC 1-960 IN/HR
DATE CALIBRATED	10 11 74
INSTRUMENT NUMBER	4215152
INSTR AND MFR	DATSTROM INSTRUMENT, MULTIPOINT RECORDER
TYPE/MODEL NUMBER	6702
SERIAL NUMBER	205830
RANGE/FEATURES	0-400 DEGREES F TYPE J T/C
DATE CALIBRATED	10 11 74
INSTRUMENT NUMBER	18235
INSTR AND MFR	GENERAL RADIO MEGOHMMETER
TYPE/MODEL NUMBER	1864
SERIAL NUMBER	4368-1075
RANGE/FEATURES	50K TO 5T OHMS 10-1000 V DC
DATE CALIBRATED	11 26 74
INSTRUMENT NUMBER	18007
INSTR AND MFR	HIPOTRONICS, MEGOHMMETER
TYPE/MODEL NUMBER	M3A
SERIAL NUMBER	3900-1032 P/N 1626
RANGE/FEATURES	10 MILLION MEGOHMS 50,100,500,1000 VDC
DATE CALIBRATED	11 06 74
INSTRUMENT NUMBER	18258
INSTR AND MFR	HIPOTRONICS AC DIELECTRIC TEST SET
TYPE/MODEL NUMBER	705-2
SERIAL NUMBER	74-21040 UNIT 2
RANGE/FEATURES	0 TO 5 KVA 2KVA
DATE CALIBRATED	12 21 74

INSTRUMENT NUMBER	18039
INSTR AND MFR	MORIDEN METAV, PRESSURE GAGE
TYPE/MODEL NUMBER	ACHAGAGE AISI 316 TUBE
SERIAL NUMBER	1006
RANGE/FEATURES	0-200 PSIG 1 PSI/DIV
DATE CALIBRATED	11 19 74
INSTRUMENT NUMBER	18247
INSTR AND MFR	AMETEK PRESSURE TRANSDUCER
TYPE/MODEL NUMBER	5060200EC2X24
SERIAL NUMBER	40227-1
RANGE/FEATURES	0-200 PSIG 0-1 V DC 60 OHM LOAD
DATE CALIBRATED	08 23 74
INSTRUMENT NUMBER	18248
INSTR AND MFR	BARTON INSTRUMENTS MANOMETER
TYPE/MODEL NUMBER	227
SERIAL NUMBER	227-82967
RANGE/FEATURES	0-100 IN. WATER
DATE CALIBRATED	09 26 74
INSTRUMENT NUMBER	18249
INSTR AND MFR	DANIEL INDUSTRIES ORIFICE FLOW SECTION
TYPE/MODEL NUMBER	
SERIAL NUMBER	
RANGE/FEATURES	0.375 IN. DIA ORIFICE 0.750 IN. DIA PIPE
DATE CALIBRATED	10 07 74
INSTRUMENT NUMBER	18175
INSTR AND MFR	ASHCROFT, PRESSURE GAGE
TYPE/MODEL NUMBER	
SERIAL NUMBER	1003
RANGE/FEATURES	0-160 PSIG
DATE CALIBRATED	REFERENCE ONLY
INSTRUMENT NUMBER	18254
INSTR AND MFR	MULTI-AMP AC AMMETER
TYPE/MODEL NUMBER	165
SERIAL NUMBER	2102
RANGE/FEATURES	MULTI RANGE 10 TO 10000 MA AC
DATE CALIBRATED	11 11 74
INSTRUMENT NUMBER	18274
INSTR AND MFR	AMPROBE AC VOLT-AMMETER PROBE
TYPE/MODEL NUMBER	RS-3
SERIAL NUMBER	DO 4216504
RANGE/FEATURES	0-6/15/40/100/300AAC 0-150/300/600 VAC 25 OHM MS
DATE CALIBRATED	08 16 74

Appendix

B

CERTIFICATION OF RADIATION

ISOMEDIX

February 20, 1975

Mr. William Steigelmann
Performance Qualification Laboratory
Franklin Institute Research Laboratories
20th and Cherry Street
Philadelphia, Pennsylvania 19103

Dear Mr. Steigelmann:

This will summarize the parameters pertinent to the recent simultaneous steam, chemical spray and radiation exposure test conducted for the Raychem Company, under your Project C-4033.

Test cables were mounted on a mandrel by FIRL, assembled into a pressure vessel, installed in the irradiation chamber, and appropriately connected to an electrical load. Irradiation for the Phase I 7 day test was begun on December 21, 1974 and concluded on December 30, 1974. Approximately three days after the start of irradiation, we were instructed to extend the irradiation over a nine day period, yet still accumulate a 50 Mrad average dose. This was accomplished by moving the source further from the target for the remaining time. During Phase I, the cables received a minimum dose of 48.4 Mrad and maximum of 54.0 Mrad. Where possible, we utilized the irradiator to process other products concurrently with the test, which necessitated occasional short periods where the radiation field was reduced to zero. The log sheet reflecting times of source exposure is included as Encl. 1, and the details of source positioning, dose rates and total dose is shown in Fig. 1.

Phase II of the test began on December 30, 1974 and concluded on January 30, 1975. During the approximately 720 hour exposure, cables received an additional minimum dose of 149.3 Mrad and maximum dose of 155.6 Mrad. The log sheets reflecting exposure times is in Encl. 2, and details of irradiation in Fig. 2.

In summary, total doses to the cables over the 39 day period ranged from 197.7 Mrad (position F) to 209.8 Mrad (position A), with an estimated source positioning error of ± 5% in dose rate.

Isomedix Inc. • 25 Eastmans Road, Parsippany, New Jersey (201) 887-4700
Mailing Address: Post Office Box 177, Parsippany, New Jersey 07054
CHICAGO DIVISION • 7828 Nagle Ave., Morton Grove, Illinois 60053 (312) 966-1150

Dosimetry was performed using a Victoreen Model 555 Integrating Dose Rate Meter and Probe. The unit was calibrated on January 15, 1974 by the Victoreen Instrument Company, using cobalt-60 and cesium-137 sources whose calibrations are traceable to the U.S. National Bureau of Standards. A copy of the calibration certificate is available. Backup dosimetry using a Red Perspex system provided by Atomic Energy of Canada, Ltd. confirmed the Victoreen readings.

During the sequence, Isomedix recorded the various test parameters and IR readings as designated in your test plan. These, together with other recorded data, were provided to you under separate cover.

Upon completion of irradiation, the chamber was removed from the irradiator by your personnel at which time our role was completed.

Very truly yours,

George R. Dietz
Manager, Radiation Services

Enclosures

GRD:km

The Franklin Institute Research Laboratories (FIRL) was established in 1946 as the research division of The Franklin Institute, which was founded in 1824.

As a not-for-profit organization, FIRL undertakes research, development, and engineering projects for both government agencies and private industry in the United States and abroad.

The Research Laboratories has a technical staff of approximately 300. It is organized into 20 laboratories and other subdivisions, grouped into four operating Departments: Physical and Life Sciences, Engineering, Systems Science, and Science Information Services. The Laboratories also maintain full support services which include a publications group, photographic laboratory, instrument repair and calibration shop, and a large machine shop.

Qualification Tests of FR-EP/CPE Instrumentation Class 1E Electric Cables In a Simulated Steam-Line-Break & LOCA Environment

Technical

F-C4836-3

Report

QUALIFICATION TESTS OF FR-EP/CPE INSTRUMENTATION CLASS 1E ELECTRIC CABLES IN A SIMULATED STEAM-LINE-BREAK AND LOSS-OF-COOLANT ACCIDENT ENVIRONMENT

Prepared for

The Anaconda Company

January 1978

THE FRANKLIN INSTITUTE RESEARCH LABORATORIES
THE BENJAMIN FRANKLIN PARKWAY • PHILADELPHIA, PENNSYLVANIA

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FIGURES

TABLES

1. INTRODUCTION

A group of electrical cables submitted by The Anaconda Company were subjected to a qualification test program in general accordance with IEEE standards[1,2] including thermal aging (150°C for 168 h), gamma irradiation (200 Mrad) and simulation of a combined steam-line-break (SLB) accident and loss-of-coolant accident (LOCA)[3] while electrically energized. This report deals specifically with four cables, identified as FREP/CPE instrumentation cable, and single conductor FREP low voltage power and control cable.

The simulation of the combined SLB/LOCA lasted 16-days; it included a rapid rise in temperature to 385°F/66 psig, a dwell at this superheated-steam condition for 10 min, a saturated-steam exposure at several lower temperatures and a final dwell at 230°F/6 psig for 9 days. The electrical integrity of the cables was evaluated by means of insulation resistance measurements, ability to maintain electrical loading during the steam/chemical-spray exposure, and by post-test mandrel-bend and high-potential-withstand tests.

The program was conducted by The Franklin Institute Research Laboratories (FIRL) during the period from October 1977 through January 1978.

1. IEEE Std 383-1974, IEEE Standard for Type Test of Class IE Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations, The Institute of Electrical and Electronics Engineers, Inc., New York, NY, 1974.
2. IEEE Std 323-1974, IEEE Standard for Qualifying Class IE Equipment for Nuclear Power Generating Stations, The Institute of Electrical and Electronics Engineers, Inc., New York, NY, 1974.
3. Simulated SLB and LOCA exposure requirements were selected by the client. See Section 3.3.

2. SPECIMEN DESCRIPTION

Descriptions of the cable specimens and their required energizing potentials and currents are presented in Table 1.

Table 1. Cable Specimens and Electrical Loading

CABLE SPECIMEN NUMBER	CABLE DESCRIPTION AND FORMULATION (a)(b)(c)	NOMINAL OUTSIDE DIAMETER (in.)(c)	MEASURED OUTSIDE DIAMETER (in.)	REQUIRED ELECTRICAL LOADING (Vac/A)
23.01 23.02	Category 23 Low Voltage Power and Control Cable 1/C No. 12 AWG 7/W Tinned Copper Conductor, 30-mil Flame Resistant Cross-Linked Ethylene Propylene Rubber Insulation (FREP), length = 30 ft.	0.160 0.160	0.158 0.158	480/25 480/25
26.4 26.5	Category 26 Instrumentation Cable, 2/C No. 16 AWG 7/W Tinned Copper Conductor, 25-mil Flame Resistant Cross-Linked Ethylene Propylene Rubber Insulation (FREP), Twist, Silicone/Glass Tape, Tinned Copper Drain Wire, Aluminun/Mylar Tape, 30-mil Chorinated Polyethylene Jacket (CPE), length = 30 ft.	0.325 0.325	0.300 0.300	480/10 480/10

NOTES: (a) Cable descriptions were provided by the Anconda Company
(b) Conductor material was copper in all cases.
(c) Nominal thicknesses and diameters were provided by the client.

3. TEST PROGRAM

The test program consisted of thermal aging, gamma radiation exposure, simulated SLB/LOCA and post-accident tests. It was based on the guidelines of IEEE Std 383-1974[4] and IEEE Std 323-1974[4], which are used for qualification testing of safety-related electrical cables for service within the containment of nuclear power generating stations.

3.1 THERMAL AGING

The cables were visually inspected prior to being coiled around a 20-in. diameter mandrel. A view of the cables on the mandrel is presented as Figure 1. The cables and mandrel were immersed in tap water at room temperature for 1 h before the insulation resistance (IR) of each cable was measured. Following the IR measurement, the cables were thermally aged at 150°C (302°F) for 168 h in a forced-air-convection oven. A view of the cables in the oven is provided as Figure 2. Following the thermal aging, the cables were re-inspected and the IR was again measured with the cables in tap water at room temperature.

3.2 GAMMA RADIATION EXPOSURE

The cables mounted on the 20-in. diameter mandrel, as shown in Figure 1, were exposed to gamma radiation from a cobalt-60 source to an accumulated air-equivalent dose of 200 Mrad at an average dose rate of 1.0 Mrad per hour. This radiation dose is based on guidelines provided by IEEE Standards 323 and 383 and is intended to encompass the radiation dose received during normal operation (ie., 50 Mrad per IEEE 383, Section 2.3.3.3) plus the dose received during one typical LOCA exposure described in IEEE 323 Appendix A (per IEEE 383, Section 2.4.2). The combined dose in accordance with these guidelines is 200 Mrad.

4. Refer to footnotes 1 and 2 on page 1-1.

3.3 STEAM/CHEMICAL-SPRAY EXPOSURE WITH ELECTRICAL LOADING

The four cable specimens were transferred from the 20-in. diameter mandrel used during thermal aging and radiation exposure to a set of two concentric mandrels (16-in. and 20-in. diameters).[5] The cables on the mandrels were installed into a 24-in.-diameter test vessel (autoclave). The cables were passed to the outside of the vessel through metal tubes and sealed with epoxy potting compound. Approximately 20 ft of each cable were contained within the test vessel. The ends of the cables were attached to electrical energizing circuits through knife switches, which facilitated disconnection for IR measurements or other analysis. Figure 3 is a pretest view of the cables on the mandrels, and Figure 4 is a typical view of the test arrangement including the energizing cabinets. The required electrical energizing levels are provided in Table 1 and the potential loading arrangements are shown in Figure 5.

Following a set of IR measurements with the cables immersed in tap water at room-temperature and atmospheric pressure, the cables were energized and exposed to a steam/chemical-spray (S/C) environment for 16 days in accordance with the profile illustrated in Figure 6.[6] The test conditions correspond to superheated steam during the first 10 min and to saturated steam thereafter. The IR was measured at the times indicated in Figure 6. After the cooldown period which followed the end of the SLB/LOCA exposure, the IR of the cables on the mandrel was re-measured and the specimens were re-inspected.

A list of the equipment used to monitor temperature, pressure and electrical load is given in Appendix A.

---

5. This transfer was necessary because the selection of a test autoclave was changed after the gamma irradiation.

6. Margin was added for pressure and temperature in accordance with IEEE Std 323-1974. See footnote 2 on page 1-1.

3.4 MANDREL BEND TEST

At the conclusion of the S/C exposure described in Section 3.3, all of the cables were cut from the interior side of the vessel closure, below the sealing tubes, then removed from the mandrels and straightened. The central portion of each sample was coiled around a mandrel having a diameter of approximately 40 times the cable outer diameter (OD).[7] That portion of cable wound on the mandrels was visually inspected for evidence of cracks or other breaks in the jacket or insulation.

3.5 HIGH-POTENTIAL WITHSTAND TEST

The coiled cables, after being removed from the concentric mandrels mentioned in Section 3.4, were immersed in tap water at room temperature for a period of one hour prior to the 5-min application of the high voltages discussed in Section 4.6.

The conductor of the single-conductor (1/C) cables was connected to the energized lead of the high-potential test set with the ground lead of the test set connected to the shield (if one existed) and to a copper tube immersed in the tank of water containing the test specimens.

Conductor 1 of the shielded two-conductor (2/C) cables was initially connected to the energized lead of the test set with the ground lead of the test set connected to conductor 2, the shield and the immersed copper tube. After the 5-min test period, the test set leads were reversed so that the energized lead was connected to conductor 2 while the shield, conductor 1 and copper tube were all connected to the ground lead.

7. The actual ratios of mandrel diameter to measured cable OD are reported in Section 4.

Figure 1. Pretest View of Cables and Mandrel
(Some cables shown in this view are not discussed in this report.)

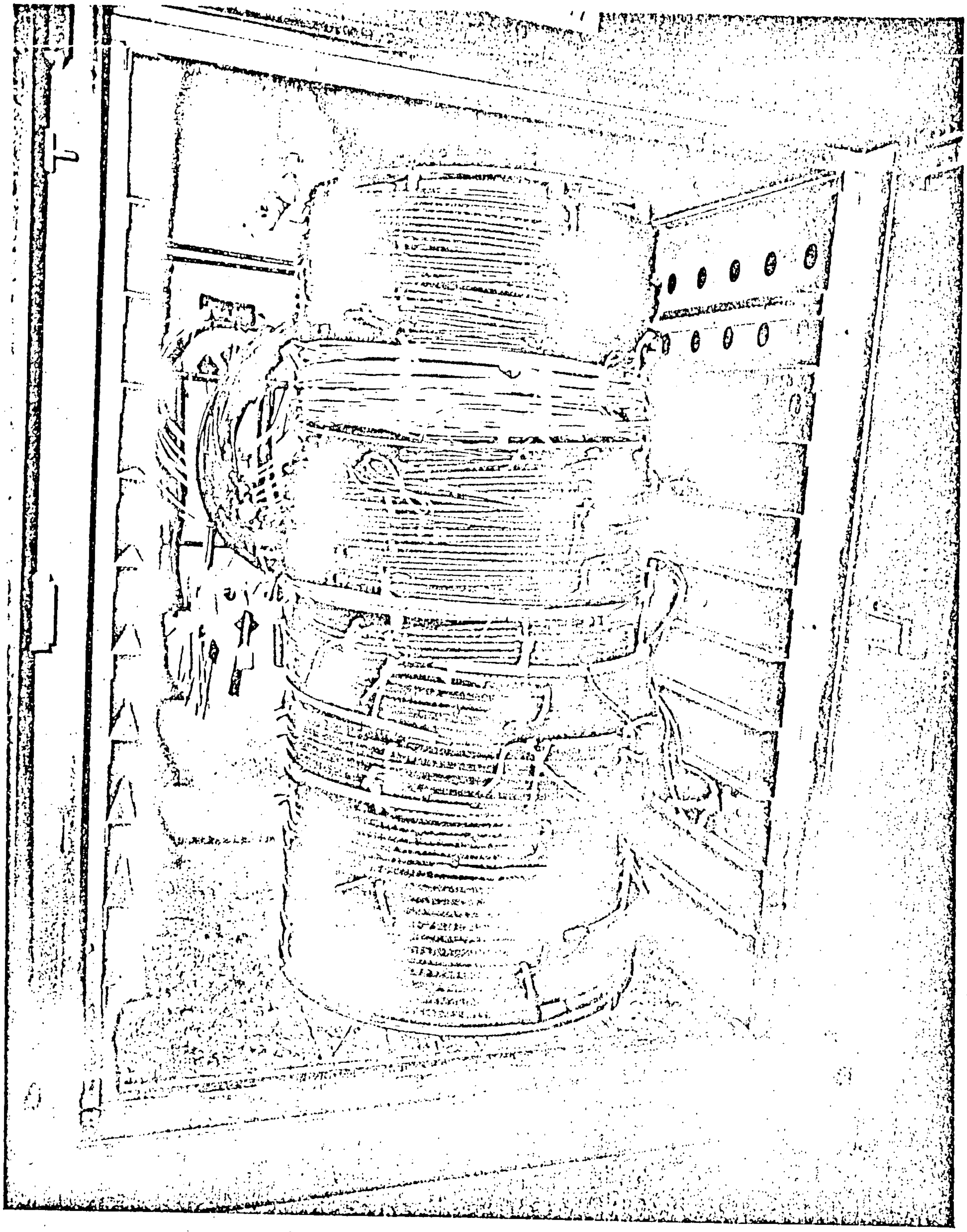

Figure 2. View of Specimens in Thermal Aging Oven
(Some cables shown in this view are not discussed in this report.)

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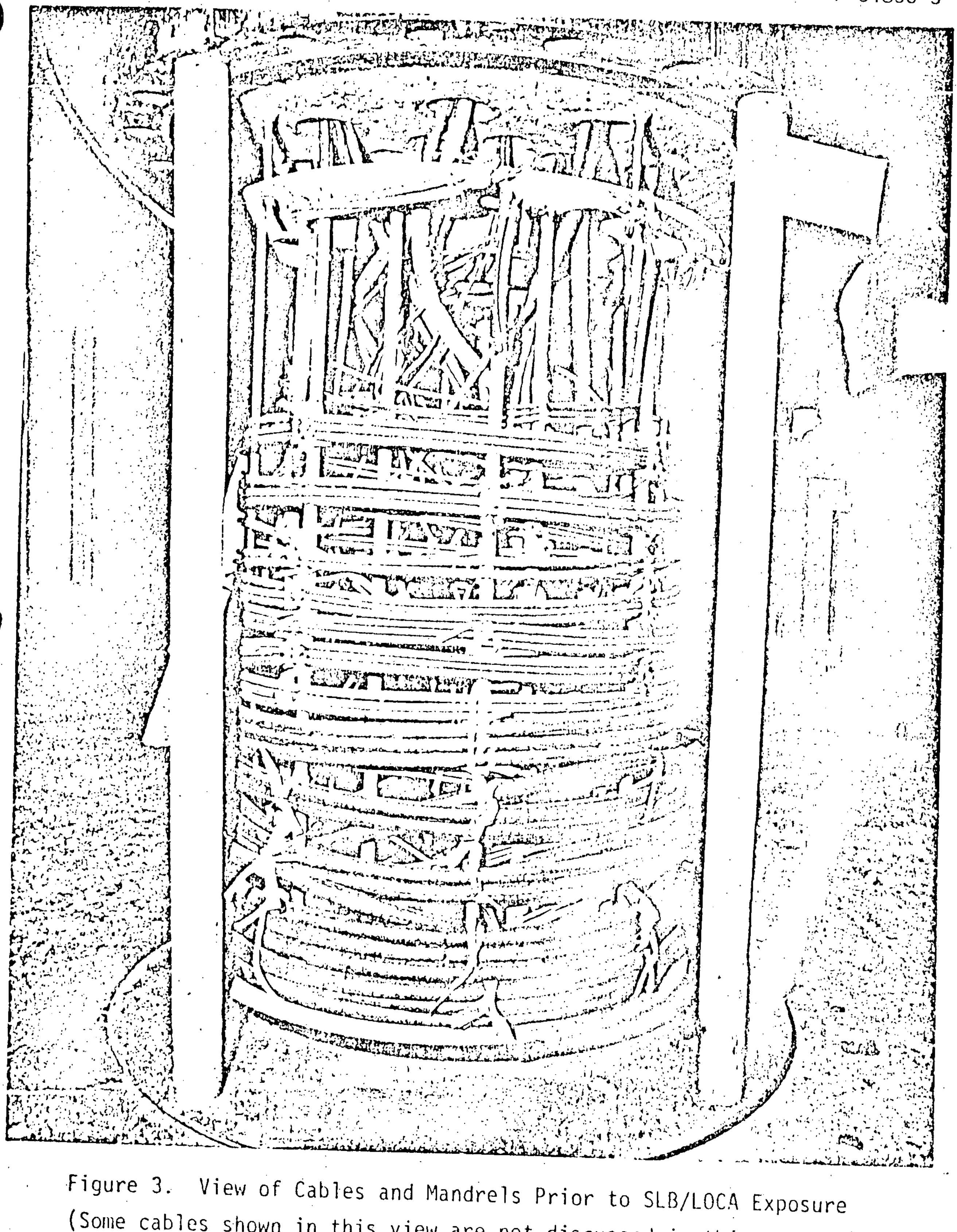

Figure 3. View of Cables and Mandrels Prior to SLB/LOCA Exposure (Some cables shown in this view are not discussed in this report.)

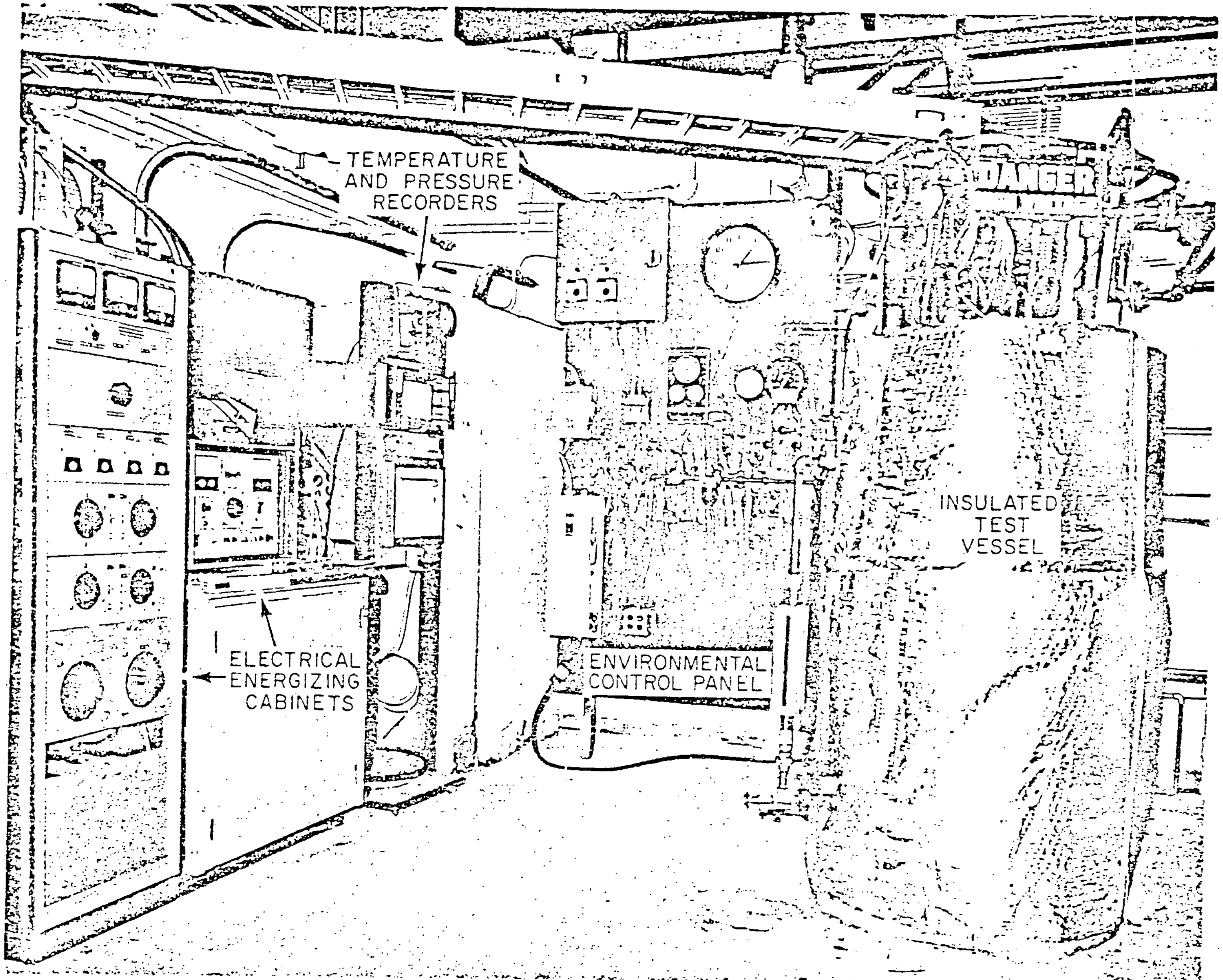

Figure 4. Typical FIRL Facility for Qualification Testing of Electrical Cables

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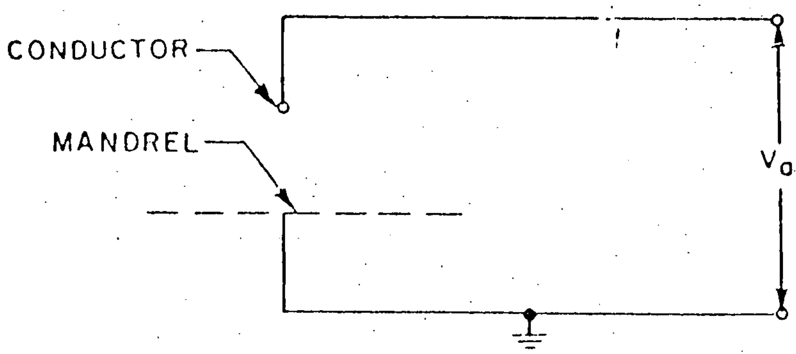
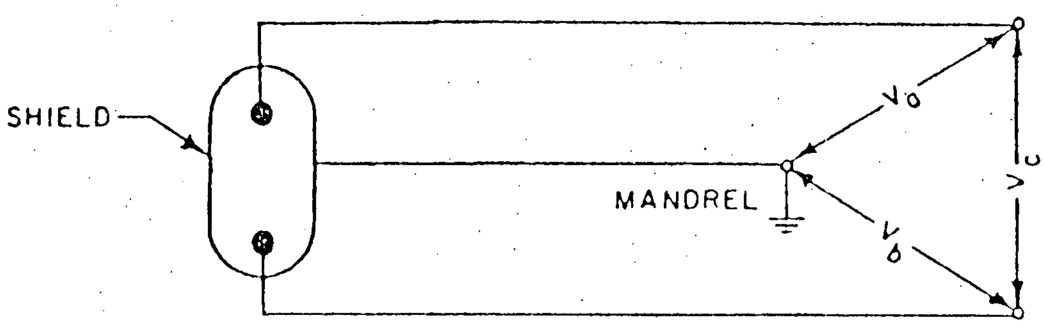


Single-phase potential loading for 1/C cables

V_a = 2.9 kVac (#2 AWG) or 480 Vac (#12 AWG)

Current load = 170 A (#2 AWG) or 25 A (#12 AWG)

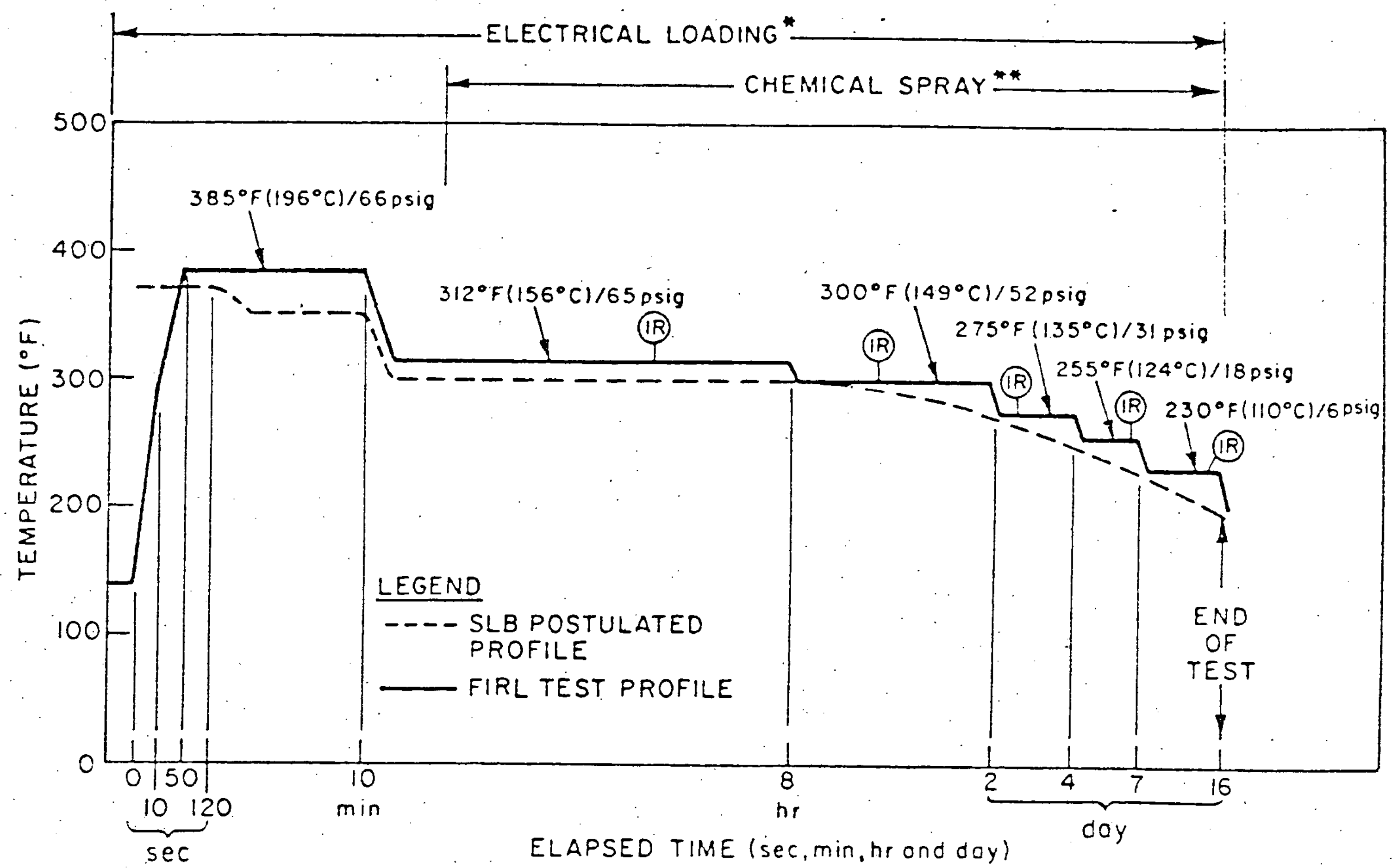


Three-phase potential loading connections for 2/C shielded cables

$V_a = V_b = V_c$ = 480 Vac

Current load = 10 A

Figure 5. Electrical Loading Circuits for Energizing Cable Samples During Environmental Exposures



(IR) REFERS TO INSULATION RESISTANCE MEASUREMENTS

*Electrical loading interrupted for short periods to permit IR measurements.

**Continuously sprayed radially outward from the center of the cable mandrel for entire test at a rate of approximately 0.15 (gal/min)/ft^2 (6.1 (liters/min)/m^2) at the cable location. The chemical solution was composed of:

6200 parts per million boron as H_3BO_3
50 parts per million hydrazine (NH_2NH_2)
Na_3PO_4 added to make the pH between 8.6 and 10.0 at 77°F in fresh solution storage tank.

Figure 6. Temperature/Pressure Profile for a Simulated SLB/LOCA Steam/Chemical-Spray Exposure With Electrical Loading

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4. TEST RESULTS

4.1 THERMAL AGING

All of the cable samples were thermally aged at 150°C (302°F) for 168 h prior to gamma radiation exposure. The results of the IR measurements made after thermal aging are included in Table 2. The thermal aging had little visible effect on cables 23.01 and 23.02 (except that the jackets were slightly stuck together in spots) but did result in cables 26.4 and 26.5 having increased stiffness and the cable jackets having small radial splits at the surface printing, which slightly exposed the shield in spots.

4.2 GAMMA RADIATION EXPOSURE

The certification of the 200-Mrad gamma radiation exposure, with information on dose rate, temperature and dosimetry, is included in Appendix B. There was no visible change in the cables as a result of the gamma radiation exposure.

4.3 STEAM/CHEMICAL-SPRAY EXPOSURE: INSULATION RESISTANCE MEASUREMENTS

The SLB/LOCA, steam/chemical-spray exposure was provided in accordance with the profile outlined in Figure 6. Figure 7 illustrates the actual temperature and pressure history during the first 40 s of the superheated-steam exposure.

Following the first 10 min of superheated-steam exposure, the chemical spray was initiated and the required saturated-steam temperature/pressure dwells were provided for 16 days. Fresh solution (pH = 9.5) from a storage tank was sprayed onto the cables for the first 8 h of the test after which the solution was recirculated in a closed loop from the autoclave sump to the autoclave spray nozzles. As the chemical solution in the autoclave sump was diluted by steam condensate, the pH dropped, necessitating the periodic replacement of the recirculated solution with fresh solution. The pH was measured twice daily except on weekends when one measurement was made daily. Occasionally, the measured pH was below the minimum specified level of 8.6 after several hours of unattended operation (e.g., overnight).

The results of the IR measurements are included in Table 2.

4.4 ELECTRICAL LOADING

All cables held their electrical loading throughout the 16 day SLB/LOCA simulation except when the power was removed to permit IR measurement.

4.5 VISUAL INSPECTION FOLLOWING STEAM/CHEMICAL-SPRAY EXPOSURE

From a visual inspection of the cables following the steam/chemical-spray exposure, immediately after the mandrels and cables were lifted out of the test vessel, it appeared that the cables were in good condition but had chemical deposits over most of their lengths. A view of the cables is shown in Figure 8.

4.6 BEND AND HIGH POTENTIAL WITHSTAND TESTS

The results of the bend and high-potential withstand tests are summarized in Table 3. From a visual inspection at the time of the high-potential withstand test, it appeared that the cables were in good condition.

Table 2. Summary of Insulation Resistance Measurements[a]

(All resistances are in ohms.)

ELAPSED TIME OR EVENT	TEMPERATURE (°F)	PRESSURE (psig)	CABLE SPECIMEN					
			23.01	23.02	26.4		26.5	
			(b)	(b)	(c)	(d)	(c)	(d)
Pre-thermal Aging	66[e]	0	3.0×10^{12}	3.5×10^{12}	1.5×10^{12}	9.6×10^{11}	1.9×10^{12}	1.2×10^{12}
Pre-Irradiation	64[e]	0	5.0×10^{12}	3.5×10^{12}	4.5×10^{12}	3.0×10^{12}	1.1×10^{13}	1.2×10^{13}
Post-Irradiation[f]	78[e]	0	1.2×10^{12}	1.2×10^{12}	5.2×10^{11}	4.5×10^{11}	5.4×10^{11}	5.1×10^{11}
Pre-SLB/LOCA[g]	60[e]	0	6.8×10^{10}	6.8×10^{10}	8.8×10^{11}	2.5×10^{11}	9.0×10^{11}	7.5×10^{11}
Second Plateau[h][i] (4.4 h)	312	68	1.3×10^{8}	1.4×10^{8}	2.0×10^{7}[j]	1.2×10^{7}	8.2×10^{7}	8.4×10^{7}
Third Plateau[i] (1.9 d)	300	51	3.5×10^{8}	3.5×10^{8}	1.5×10^{7}[j]	2.4×10^{8}	3.0×10^{8}	2.8×10^{8}
Fourth Plateau[i] (2.8 d)	275	33	1.0×10^{9}	1.0×10^{9}	8.8×10^{7}[j]	6.8×10^{8}	8.4×10^{8}	7.6×10^{8}
Fifth Plateau[i] (5.8 d)	255	18	3.0×10^{9}	3.0×10^{9}	3.0×10^{8}	1.9×10^{9}	2.6×10^{9}	2.2×10^{9}
Sixth Plateau[i] (15.9 d)	230	6	1.3×10^{10}	1.3×10^{10}	1.5×10^{9}	7.4×10^{9}	1.0×10^{10}	8.2×10^{9}
Post-SLB/LOCA (17.8 d)	46[g]	0	4.5×10^{11}	4.5×10^{11}	8.6×10^{8}	2.6×10^{11}	2.0×10^{11}	2.2×10^{11}

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Table 2. Summary of Insulation Resistance Measurements [a] (Cont.)

NOTES

a. Measurements were made after the cable was held at 500 Vdc for one minute unless otherwise indicated.

b. Measurements were made between conductor and ground (mandrel).

c. Measurements were made between conductor 2 (-) and conductor 1 plus the drain wire (+) at ground (mandrel) potential.

d. Measurements were made between conductor 1 (-) and conductor 2 plus the drain wire (+) at ground (mandrel) potential.

e. Cables were placed in water for a period of 1 h prior to IR measurement.

f. IR measurements were made prior to installation of cables in the test vessel and connected to the energizing cabinet.

g. IR measurements were made after the cables were installed in the test vessel and connected to the energizing cabinet.

h. The IR was not measured during the duration of the first plateau of the SLB/LOCA because insufficient time was available. Plateaus are shown on Figure 6.

i. Cables were energized at rated voltage, unless otherwise noted, except when the IR measurements were made.

j. Erratic meter indications.

Table 3. Summary of Bend and High-Potential Withstand Tests

CABLE NO.	MEASURED CABLE OD (in.)	MANDREL OD (in.)	OD RATIO[a]	NUMBER OF TURNS ON MANDREL	VISUAL APPEARANCE OF CABLE[b]	MAXIMUM APPLIED POTENTIAL[c] (Vac)	CHARGING LEAKAGE CURRENT[c] (mA)
23.01	0.158	6.0	38.0	9	No apparent damage.	2400	1.6
23.02	0.158	6.0	38.0	10	No apparent damage.	2400	1.8
26.4	0.300	11.0	36.7	6	Jacket broken and separated from cable at intervals along the length.	2000	1.6
26.5	0.300	11.0	36.7	6	Jacket cracked along entire length	2000	1.6

NOTES: a. Ratio of outside diameter (OD) of bend-test mandrel to OD of cable.

b. All cables had salt deposits on the exterior surfaces.

c. Unless otherwise indicated, the potentials were applied in the manner described in Section 3.5 and maintained for 5 minutes. Leakage/charging currents were measured after 5 minutes.

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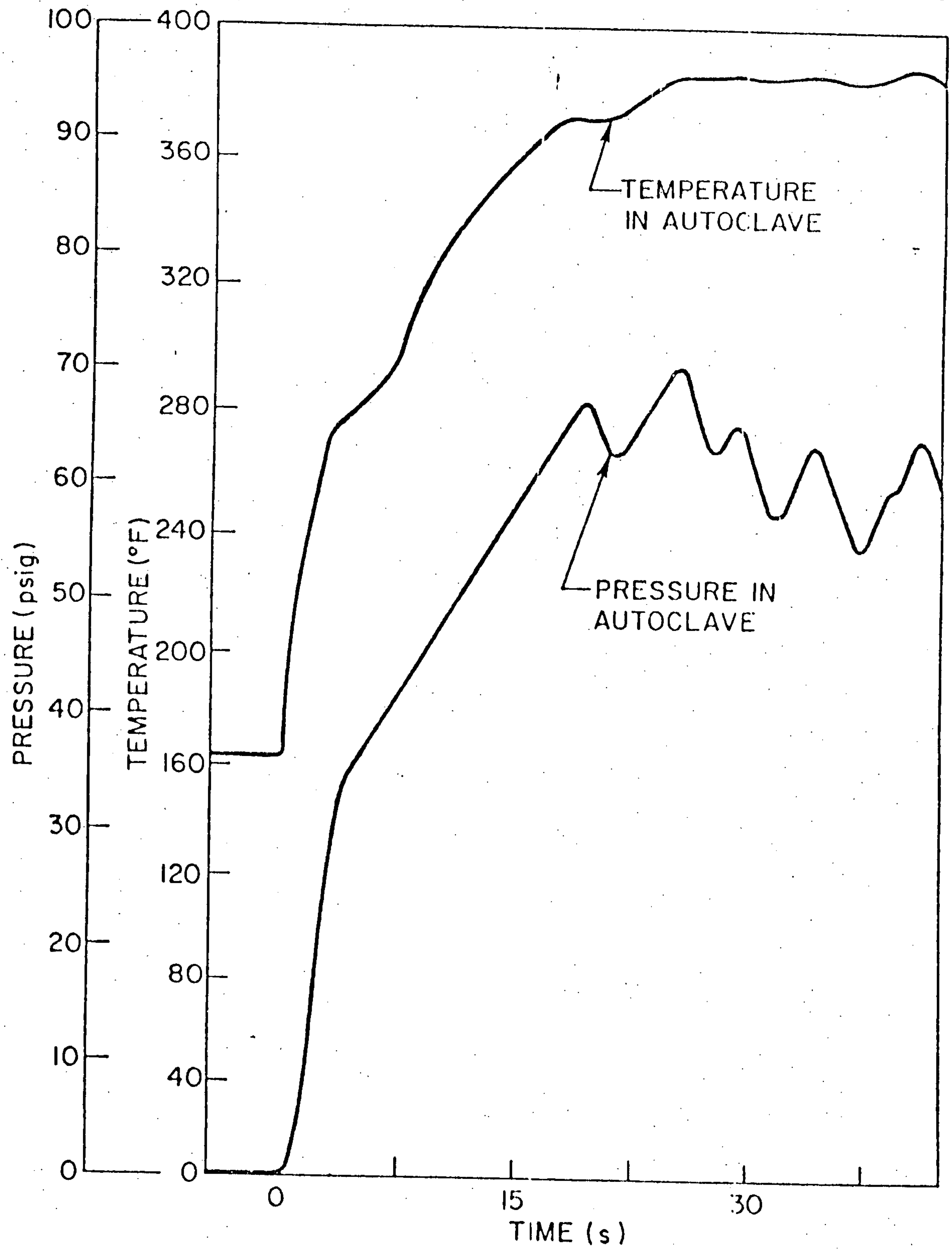


Figure 7. Initial Temperature and Pressure Rise of Simulated SLB/LOCA

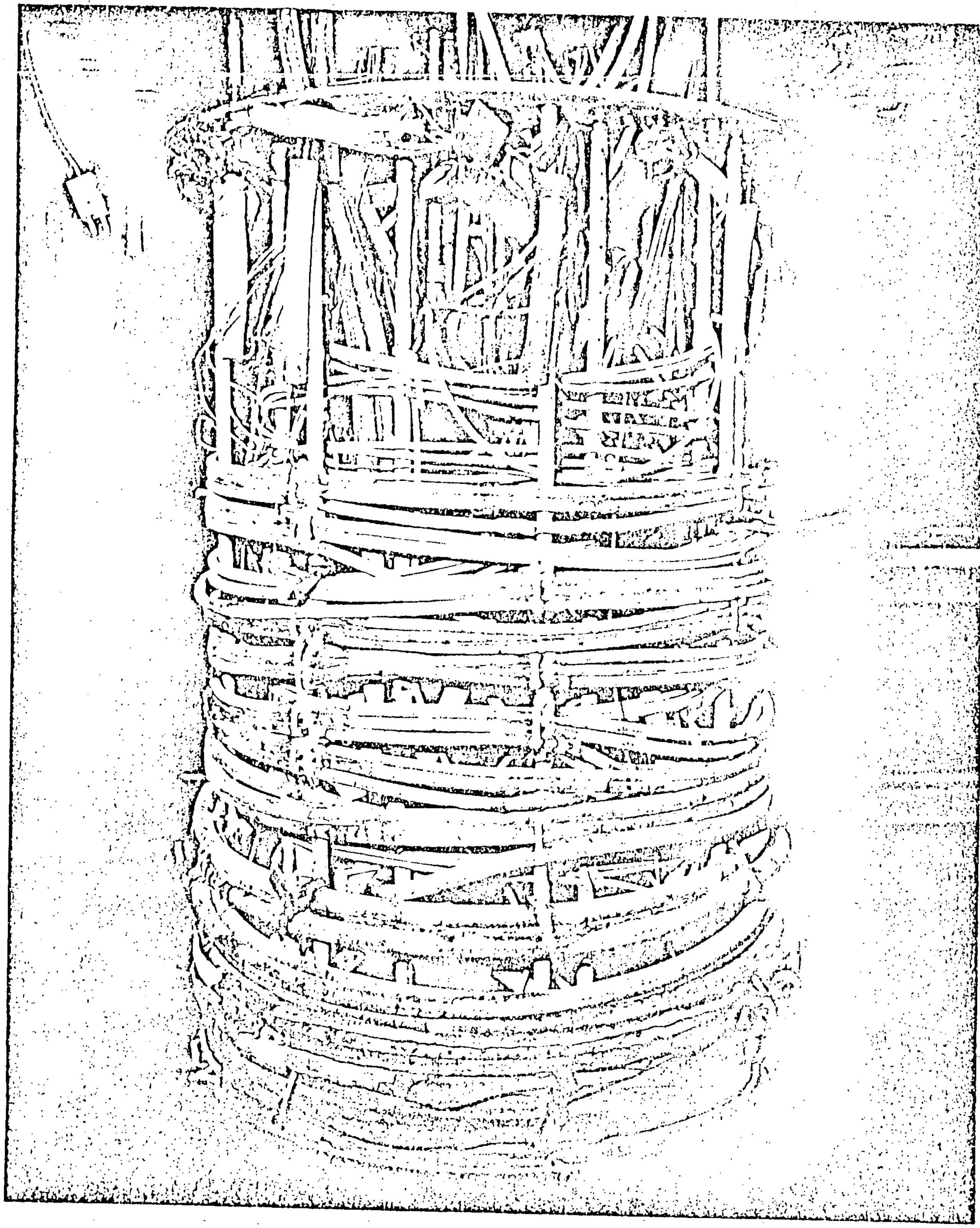


Figure 8. Post-Test View of Cables and Mandrels
(Some cables shown in this view are not discussed in this report.)

5. CONCLUSIONS

Four samples of electrical power and control cable provided by The Anaconda Company were subjected to a test program based on the guidelines of IEEE Standards 383 and 323.[8] The program was designed to simulate a combined steam-line-break (SLB) and loss-of-coolant accident (LOCA) and the cooldown period following the accident; it included thermal aging (168 h @ 150°C), gamma irradiation (200 Mrad) and a 16-day exposure to superheated-steam and saturated-steam/chemical-spray conditions including an initial 10-min dwell at superheated-steam conditions of 385°F/66 psig.

After the 16-day exposure, the cables were removed from the test vessel and subjected to final mandrel-bend and high-potential withstand tests.

All of the cables mentioned in this report performed satisfactorily during the program, including a demonstration of substantial margin of remaining life, by withstanding post-accident, mandrel-bend tests at approximately 40 times the cable OD and final high-potential withstand tests at 80 Vac per mil of insulation.

8. See footnotes on page 1-1

6. CERTIFICATION

The undersigned certify that this report is a true account of the tests conducted and the results obtained.

G. C. Gambs, Jr.
Project Leader

D. V. Paulson, Chief
Environmental Testing Section

APPROVED:

M. M. Reddi, Vice President
Engineering

S. P. Carfagno, Manager
Performance Qualification Laboratory

Appendix

A

DATA ACQUISITION INSTRUMENTS

LIST OF DATA ACQUISITION INSTRUMENTS

INSTRUMENT NUMBER	18006
INSTR AND MFR	GENERAL ELECTRIC, AMMETER, AC
TYPE/MODEL NUMBER	A092 CURRENT TRANSFORMER
SERIAL NUMBER	NONE
RANGE FEATURES	0-100 A AC
ACCURACY	2.0 PERCENT OF F.S.
DATE CALIBRATED	12 08 77
CALIBRATION DUE	06 08 78

INSTRUMENT NUMBER	18221
INSTR AND MFR	ESTERLINE ANGUS SPEED SERVO II
TYPE/MODEL NUMBER	L1102S
SERIAL NUMBER	908001
RANGE FEATURES	0.5 MILLIVOLT - 100 V.
ACCURACY	0.25 PERCENT OF SPAN
DATE CALIBRATED	10 10 77
CALIBRATION DUE	02 10 78

INSTRUMENT NUMBER	18037
INSTR AND MFR	NORDEN KETAY, PRESSURE GAGE
TYPE/MODEL NUMBER	ACRAGAGE AISI 316 TUBE
SERIAL NUMBER	A6
RANGE FEATURES	0-200 PSIG 1 PSI/DIV
ACCURACY	1.0 PERCENT OF FULL SCALE
DATE CALIBRATED	10 17 77
CALIBRATION DUE	10 17 78

INSTRUMENT NUMBER	18062
INSTR AND MFR	AMETEK, PRESSURE TRANSDUCER
TYPE/MODEL NUMBER	50G0200BC2X24
SERIAL NUMBER	20583-1 R3081-1
RANGE FEATURES	0-50, 100, 200 PSIG
ACCURACY	0.25 PERCENT OF 200 PSIG
DATE CALIBRATED	10 17 77
CALIBRATION DUE	10 17 78

INSTRUMENT NUMBER	18297
INSTR AND MFR	JOHN FLUKE MFG CO DIGITAL MULTIMETER
TYPE/MODEL NUMBER	8800A
SERIAL NUMBER	36076
RANGE FEATURES	200MV-1200V DC 2V-1200V AC 200-20M OHMS
ACCURACY	0.02 PERCENT OR BETTER
DATE CALIBRATED	05 13 77
CALIBRATION DUE	05 13 78

LIST OF DATA ACQUISITION INSTRUMENTS

INSTRUMENT NUMBER	18254
INSTR AND MFR	MULTI-AMP AC AMMETER
TYPE/MODEL NUMBER	165
SERIAL NUMBER	2102
RANGE FEATURES	MULTI RANGE 10 TO 10000 MA AC
ACCURACY	0.5 PERCENT OF F.S.
DATE CALIBRATED	10 10 77
CALIBRATION DUE	04 10 78

INSTRUMENT NUMBER	18183
INSTR AND MFR	BARTON INSTRUMENT, PRESSURE GAGE
TYPE/MODEL NUMBER	STAINLESS STEEL
SERIAL NUMBER	227-19714
RANGE FEATURES	0-100 IN. WATER 6000 PSIG STATIC
ACCURACY	0.5 PERCENT OF FS DIFF PRESS
DATE CALIBRATED	09 02 77
CALIBRATION DUE	09 02 78

INSTRUMENT NUMBER	18213
INSTR AND MFR	SIMPSON VOLTMETER
TYPE/MODEL NUMBER	MODEL 59
SERIAL NUMBER	04309
RANGE FEATURES	0-750 VOLTS AC
ACCURACY	2.0 PERCENT OF F.S.
DATE CALIBRATED	12 28 77
CALIBRATION DUE	06 28 78

INSTRUMENT NUMBER	18207
INSTR AND MFR	MIDWEST ELECTRIC PRODUCTS AMMETER
TYPE/MODEL NUMBER	CURRENT TRANSFORMER
SERIAL NUMBER	NONE
RANGE FEATURES	0-100 A AC 2A/DIV
ACCURACY	2.0 PERCENT OF F.S.
DATE CALIBRATED	12 08 77
CALIBRATION DUE	06 08 78

INSTRUMENT NUMBER	18206
INSTR AND MFR	MIDWEST ELECTRIC PRODUCTS AMMETER
TYPE/MODEL NUMBER	CURRENT TRANSFORMER
SERIAL NUMBER	NONE
RANGE FEATURES	0-100 A AC 2A/DIV
ACCURACY	2.0 PERCENT OF F.S.
DATE CALIBRATED	12 08 77
CALIBRATION DUE	06 08 78

LIST OF DATA ACQUISITION INSTRUMENTS

INSTRUMENT NUMBER	18200
INSTR AND MFR	MIDWEST ELECTRIC PRODUCTS AMMETER
TYPE/MODEL NUMBER	CURRENT TRANSFORMER
SERIAL NUMBER	NONE
RANGE FEATURES	0-100 A AC 2A/DIV
ACCURACY	2.0 PERCENT OF F.S.
DATE CALIBRATED	12 08 77
CALIBRATION DUE	06 08 78

INSTRUMENT NUMBER	18137
INSTR AND MFR	GENERAL ELECTRIC, AMMETER A.C.
TYPE/MODEL NUMBER	CURRENT TRANSFORMER/A092
SERIAL NUMBER	NONE
RANGE FEATURES	0-100 A AC
ACCURACY	2.0 PERCENT OF F.S.
DATE CALIBRATED	12 08 77
CALIBRATION DUE	06 08 78

INSTRUMENT NUMBER	4217802
INSTR AND MFR	GENERAL RADIO MEGOHMMETER
TYPE/MODEL NUMBER	1864
SERIAL NUMBER	4368-1075
RANGE FEATURES	50K TO 5T OHMS 10-1000 V DC
ACCURACY	5.0 PCT OR LESS DEPNG ON SPAN
DATE CALIBRATED	07 15 77
CALIBRATION DUE	01 15 78

INSTRUMENT NUMBER	4217507
INSTR AND MFR	BECKMAN INST., INS. AND BREAKDOWN TEST SET
TYPE/MODEL NUMBER	1600-AC/DC ITS
SERIAL NUMBER	77145
RANGE FEATURES	10 KV AC/DC 10 MA AC/DC
ACCURACY	3.0 PERCENT OF F.S.
DATE CALIBRATED	09 12 77
CALIBRATION DUE	03 12 78

INSTRUMENT NUMBER	18299
INSTR AND MFR	HIPOTRONICS AC DIELECTRIC TEST SET
TYPE/MODEL NUMBER	715-10
SERIAL NUMBER	76-26386
RANGE FEATURES	0-15 KVAC 750 MA
ACCURACY	2 PERCENT AT 2/3 OF SPAN
DATE CALIBRATED	09 28 77
CALIBRATION DUE	03 28 78

LIST OF DATA ACQUISITION INSTRUMENTS

INSTRUMENT NUMBER	4217779
INSTR AND MFR	HONEYWELL-BROWN, MULTIPOINT TEMP. RECORDER
TYPE/MODEL NUMBER	ELECTRONIK 16.1630 3856
SERIAL NUMBER	S0355 779001
RANGE FEATURES	0-500 DEGREES F TYPE T T/C 0.125-1.0 IN/MIN
ACCURACY	0.25 PERCENT OF SPAN
DATE CALIBRATED	10 17 77
CALIBRATION DUE	02 17 78

INSTRUMENT NUMBER
INSTR AND MFR
TYPE/MODEL NUMBER
SERIAL NUMBER
RANGE FEATURES
ACCURACY
DATE CALIBRATED
CALIBRATION DUE

INSTRUMENT NUMBER
INSTR AND MFR
TYPE/MODEL NUMBER
SERIAL NUMBER
RANGE FEATURES
ACCURACY
DATE CALIBRATED
CALIBRATION DUE

INSTRUMENT NUMBER
INSTR AND MFR
TYPE/MODEL NUMBER
SERIAL NUMBER
RANGE FEATURES
ACCURACY
DATE CALIBRATED
CALIBRATION DUE

INSTRUMENT NUMBER
INSTR AND MFR
TYPE/MODEL NUMBER
SERIAL NUMBER
RANGE FEATURES
ACCURACY
DATE CALIBRATED
CALIBRATION DUE

Appendix

B

CERTIFICATION OF RADIATION

ISOMEDIX

December 27, 1977

Dr. S. Carfagno
Performance Qualification Laboratory
Franklin Institute Research Laboratories
20th and Cherry Streets
Philadelphia, PA 19103

Dear Dr. Carfagno:

This will summarize parameters pertinent to the irradiation of two mandrels wrapped with cable samples, per your Order 32096 dated November 16, 1977. This is FIRL Project No. C4836.

The mandrels were placed in a cobalt-60 gamma field and exposed at each of 4 quadrants, as marked with tape on the tops. By integrating the dose rate at any point on the mandrel during its 4-position exposure, an average dose rate was obtained which, when multiplied by the total exposure time, yields total dose.

The mandrels were exposed for a period of 200 hours at an average dose rate of 1.0 Mrad per hour, yielding a minimum dose of 200 Mrad. The mandrels were rotated at 50-hour intervals.

Irradiation was conducted in air at ambient temperature and pressure. Radiant heat from the source heated the samples somewhat, but the temperature did not exceed 110^{o}F, as indicated by previous measurements on an oil solution in the same relative position.

Dosimetry was performed using an Atomic Energy of Canada Limited (AECL) Red Perspex system with Type BC-2 readout. Calibration of the Perspex is made by AECL using Ceric dosimetry traceable to the U. S. National Bureau of Standards. Isomedix regularly cross-calibrates its AECL system with an inhouse Harwell Perspex system, and makes semi-annual calibrations directly with NBS, using the NBS Radiochromic Dye system. A copy of the dosimetry correlation report is available upon request.

Radiation was completed on December 3, 1977.

Very truly yours,

George R. Dietz
Manager, Radiation Services

GRD:of

The Franklin Institute Research Laboratories (FIRL) was established in 1946 as the research division of The Franklin Institute, which was founded in 1824.

As a not-for-profit organization, FIRL undertakes research, development, and engineering projects for both government agencies and private industry in the United States and abroad.

The Research Laboratories has a technical staff of approximately 300. It is organized into 20 laboratories and other subdivisions, grouped into four operating Departments: Physical and Life Sciences, Engineering, Systems Science, and Science Information Services. The Laboratories also maintains full support services which include a publications group, photographic laboratory, instrument repair and calibration shop, and a large machine shop.

ATTACHMENT

TO

FIRL TECHNICAL REPORT F-C4836

THE QUALIFIED LIFE QUALIFICATION PROCEDURE

AND

THE BASIS FOR ESTABLISHING TIME & TEMPERATURE CONDITIONS FOR QUALIFIED LIFE SIMULATION

DATE: JANUARY, 1978

BY: T.H. LING

(Submitted in reference to TVA Contract 76K587232 and FIRL Report F-C4836-3)

8.1.1.2

Long Term Physical Aging Properties (Arrhenius Plot)

(A) Air oven with end-point at 50% elongation.

Test Specimen: Insulation in Tube-form procured from FR-EP insulation cable

Test Procedure: Air Oven Test (IPCEA S-68-516, Section 6.10.3)

The aging times required to obtain the respective 50% elongation are:

Aging Temperature	Time Period
150°C	410 hours
135°C	1080 hours
121°C	5200 hours

(B) Arrhenius Plot

The temperature & time relationship is plotted as shown in Figure I. The line obtained shows that the insulation possesses 40 years life, if the insulation is continuously aged around 90°C. This line also passes the point i.e. 150°C with 168 hours.

(C) Conclusion (Qualified Cable Life)

Based on Arrhenius technique, Anaconda FR-EP insulated cable possesses 40 years qualified life, provided the cable is operated at 90°C or less.

Furthermore, also based on Arrhenius Plot, the aging at 150°C with 168 hours, is equivalent to the life of 90°C for 40 years. This is the basis to use 150°C with 168 hours, as aging condition for qualified life simulation.

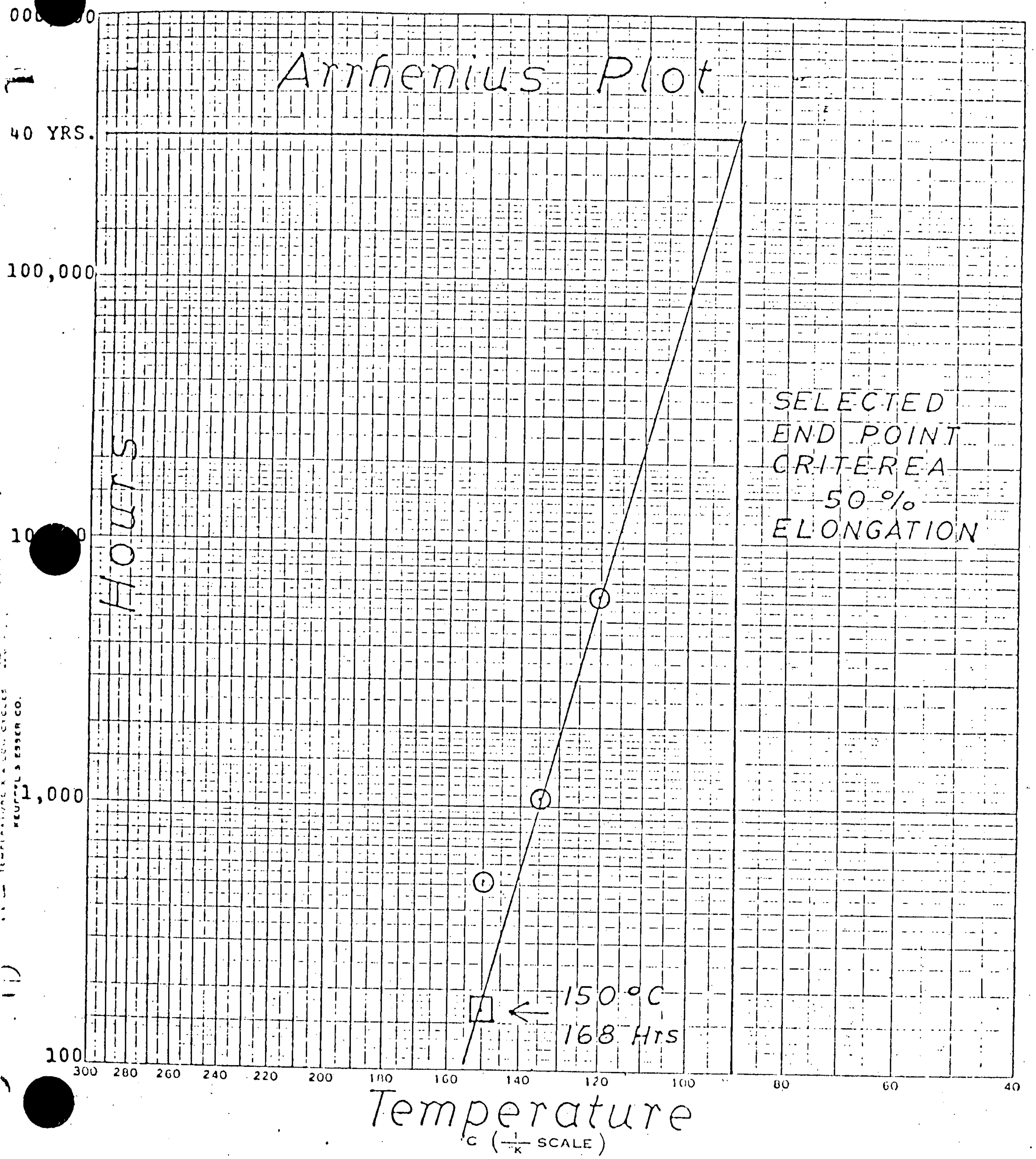
(D) Remarks:

(1) As stated in IEEE-383-1974, Section 2.3.2, "Aging data should be submitted to establish long term performance of the insulation". This is the reason that tube-form specimens of insulation, procured from FR-EP insulated cable, were used in the aging test.

(D) Remarks: (Cont'd)

(2) The method adopted by IEEE Standard 383-1974 to determine the end point of cable life is 1) bending the aged sample around a mandrel with 20 times the cable O.D., then 2) immersing in water at room temperature 3) applying ac stress of 80 VPM for 5 minutes. The method was utilized in our LOCA qualification test as reported in FIRL Technical Report F-C4836. However, the life is influenced not only by status of aging, but will also be effected by other factors involved in the testing. Based on these reasons, we trust that the slope developed based on elongation is a better and reproducible method for the prediction of cable life.

FIGURE I


Arrhenius Plot
40 YRS.
100,000
1,000
100
Hours
SELECTED
END POINT
CRITEREA
50 %
ELONGATION
150 °C
168 Hrs
300
280
260
240
220
200
180
160
140
120
100
80
60
40
Temperature
°C (1/K SCALE)