PY-CEI/NRR-1173L
Attachment 3

QUALIFICATION TESTS OF ELECTRICAL CABLES WITH EXTENDED EXPOSURE TO A LOSS-OF-COOLANT ACCIDENT ENVIRONMENT

Final Report
F-C5120-3

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Prepared for

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November 18, 1981

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1. SUMMARY OF SALIENT FACTS

FRC Project No.	Report Title:
C5120	Qualification Tests of Electrical Cables With Extended Exposure to a Loss-of-Coolant Accident Environment

Conducted and Reported by:	Conducted for:
Franklin Research Center The Parkway at Twentieth Street Philadelphia, PA 19103	Brand-Rex Company Industrial and Electronic Cable Division Willimantic, CT 06226
Report Date: November 18, 1981	Period of Test Program: May through September 1980

Objective:

To demonstrate performance of electrical cables for Class 1E service in nuclear power generating stations in accordance with guidelines presented in IEEE Stds 323-1974 and 383-1974.[1]

Equipment Tested:

Eight electrical cables (two 1/C #16 AWG, two 1/C #12 AWG, two 1/C #2 AWG, and two RG-59B/u coaxial) with crosslinked polyethylene (XLPE) insulation and jacketing materials of chlorosulfonated polyethylene (Hypalon[2]) on the coaxial cables. A complete description is provided as Table 1 herein.

Elements of Program:

The specimens were subjected to a 120-day exposure in air at a temperature of 200°F (93°C) and high humidity. During the exposure, the cables were energized with ac potentials of 600 V and currents of 10 A (#16 AWG conductors) and 25 A (#12 and #2 AWG conductors); the coaxial cables were energized with 600-V potentials only. Final tests consisted of bend tests at 40 times the cable diameters and 5-minute ac high-potential-withstand tests at 80 V per mil (3150 V/mm) of insulation.

Summary of Test Results:

All specimens remained energized throughout the 120-day exposure at 200°F (93°C) except for short periods to permit required electrical measurements or for reasons not associated with the test specimens. All specimens withstood final bend and high-potential-withstand tests with leakage/charging currents less than 8.0 mA.

[1]Full citations are provided in the text.

[2]Trademark of E.I. duPont de Nemours & Company.

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2. OBJECTIVE OF PROGRAM

The purpose of this program was to demonstrate the ability of electrical cables to perform satisfactorily for a period of 150 days (total) in a steam, humid-air, and chemical-spray exposure simulating conditions following a postulated loss-of-coolant accident (LOCA). The program of this report included a 120-day high-humidity exposure in air at 200°F (93°C). The specimens were previously exposed to a 30-day simulated steam line break (SLB) and LOCA exposure.[1]

The program was based on guidelines provided in IEEE Stds 323-1974[2] and 383-1974.[3]

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[1]FRC Final Report F-C5120-1, "Qualification Tests of Electrical Cables in a Simulated Steam Line Break (SLB) and Loss-of-Coolant Accident (LOCA) Environment," Franklin Research Center, Philadelphia, Pa., August 19, 1980.

FRC Final Report F-C5120-2, "Qualification Tests of Coaxial-Type Cables in a Simulated Steam Line Break (SLB) and Loss-of-Coolant Accident (LOCA) Environment," Franklin Research Center, Philadelphia, Pa., September 2, 1980.

[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]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.

3. IDENTIFICATION OF CABLES TESTED

Descriptions of cable specimens provided by the client are presented in Table 1 along with data on energizing potentials and currents. The cable specimens were the identical specimens previously exposed to a simulated 30-day SLB/LOCA environment.[1] The cable lengths were 13 to 21 ft (4.0 to 6.4 m; see Table 1), which are approximately 10 ft (3.0 m) shorter than the original lengths due to the method of removing samples from the 30-day test vessel. Approximately 2 ft (0.6 m) of the specimens for this program were outside the test vessel (for electrical connections), with the remaining lengths (11 to 19 ft; 3.4 to 5.8 m) within the test vessel during the humid-air exposure.

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[1]See footnote 1 on page 2.

Table 1. Identification of Test Specimens and Related Data

FRC Specimen Number	Brand-Rex Designation	Insulation/ Jacket Material(s)	No. of Conductors and Size (AWG)	Thermal Aging Temperature (Held for 168 h) (°F)/(°C)	Electrical Loading Potential (V)	Electrical Loading Current (A)	Published Insulation Thickness (in)/(mm)	Outside Diameter (OD) (in)/(mm)	Specimen Length[1] (ft)/(m)
C5120-1-2	S-1620162	XLPE	1/C-#16	Not aged	300	10	0.02/0.5	0.1/2.5	13/4.0
C5120-1-3	S-1620162	XLPE	1/C-#16	277/136	300	10	0.02/0.5	0.1/2.5	14/4.3
C5120-2-2	S-1230162	XLPE	1/C-#12	Not aged	600	25	0.03/0.8	0.15/3.8	14/4.3
C5120-2-3	S-1230162	XLPE	1/C-#12	277/136	600	25	0.03/0.8	0.15/3.8	14/4.3
C5120-3-1	S-0245162	XLPE	1/C-#2	Not aged	600	25	0.045/1.1	0.4/10	19/5.8
C5120-3-2	S-0245162	XLPE	1/C-#2	277/136	600	25	0.045/1.1	0.4/10	18/5.5
C5120-9-2	CS 75146 (RG-59B/u)	XLPE/Hypalon	Coaxial	Not aged	600	(Note 2)	0.06/1.5	0.24/6.1	15/4.6
C5120-9-3	CS 75146 (RG-59B/u)	XLPE/Hypalon	Coaxial	277/136	600	(Note 2)	0.06/1.5	0.24/6.1	16/4.9

[1] Leakage/charging current only.

[2] Approximately 2 ft (0.6 m) of the cable lengths were outside the test vessel.

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4. TEST FACILITY

The test vessel used for the humid-air exposure was a 30-in-diam (0.76-m-diam) by 48-in-long (1.2-m-long) stainless steel tank illustrated in Figure 1. A mandrel with cables (see Section 5) was supported from a loose-fitting flat cover on the vessel. The vessel was heated with a steam coil immersed in a pool of water at the bottom of the vessel and by self-induced Joule heating of the energized specimens. A sight glass located on the side of the tank indicated the level of fluids within the vessel.

The vessel was equipped with several thermocouples to measure, record, and control the temperature of vapors in the vicinity of the cables and fluids in the bottom of the vessel. A description of the thermocouples and their locations is presented in Appendix A. A list of data acquisition instruments used in the program is provided as Appendix B.

Power supplies were p[illegible]ided to energize the test cables with [illegible]oltages and currents listed in Table 1; they are schematically presented [illegible]n [illegible]ure [illegible]. The circuits included a circuit breaker that disconnected the applied potentials if the leakage/charging currents exceeded approximately 1.0 A.

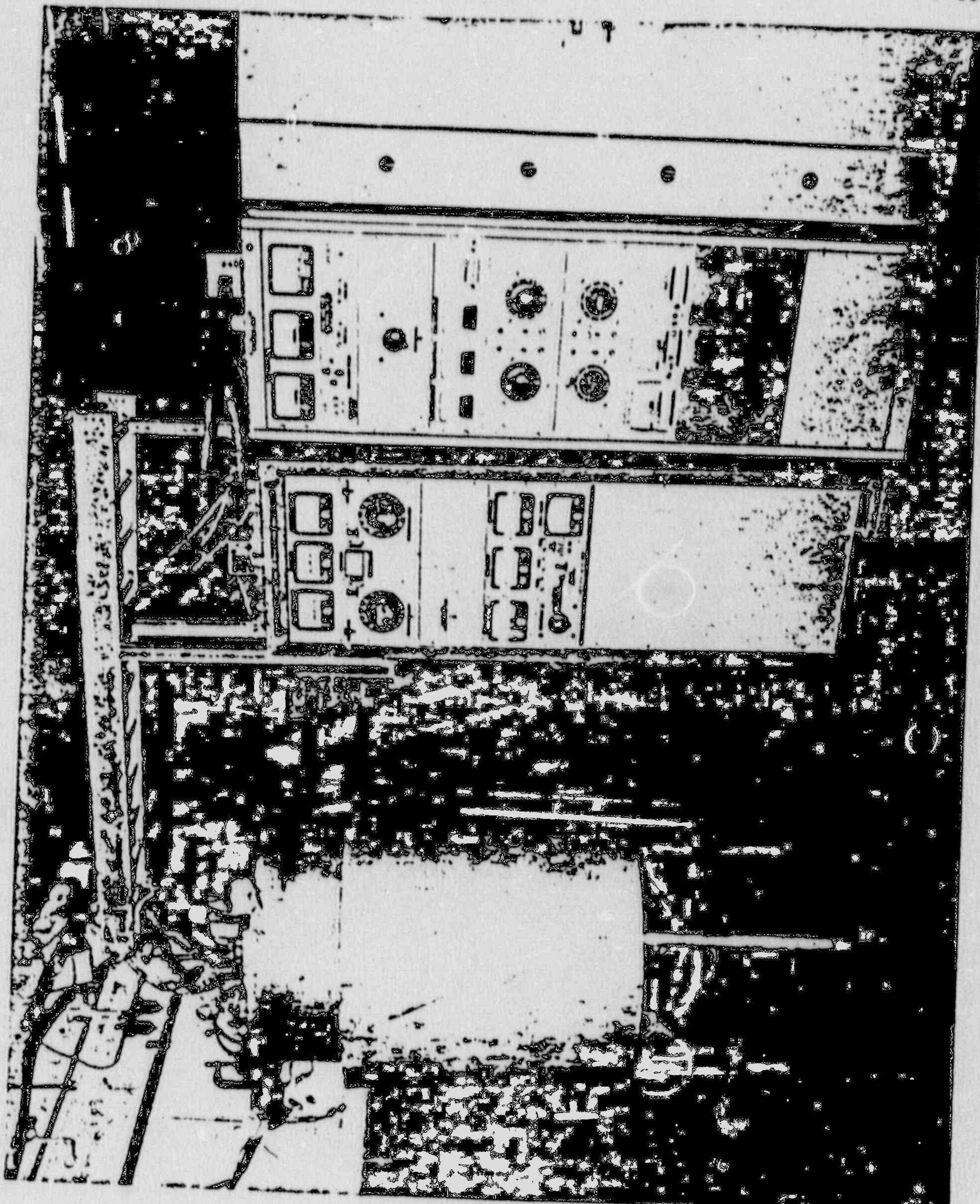

Figure 1. View of Test Facility Showing Vessel and Energizing Cabinets

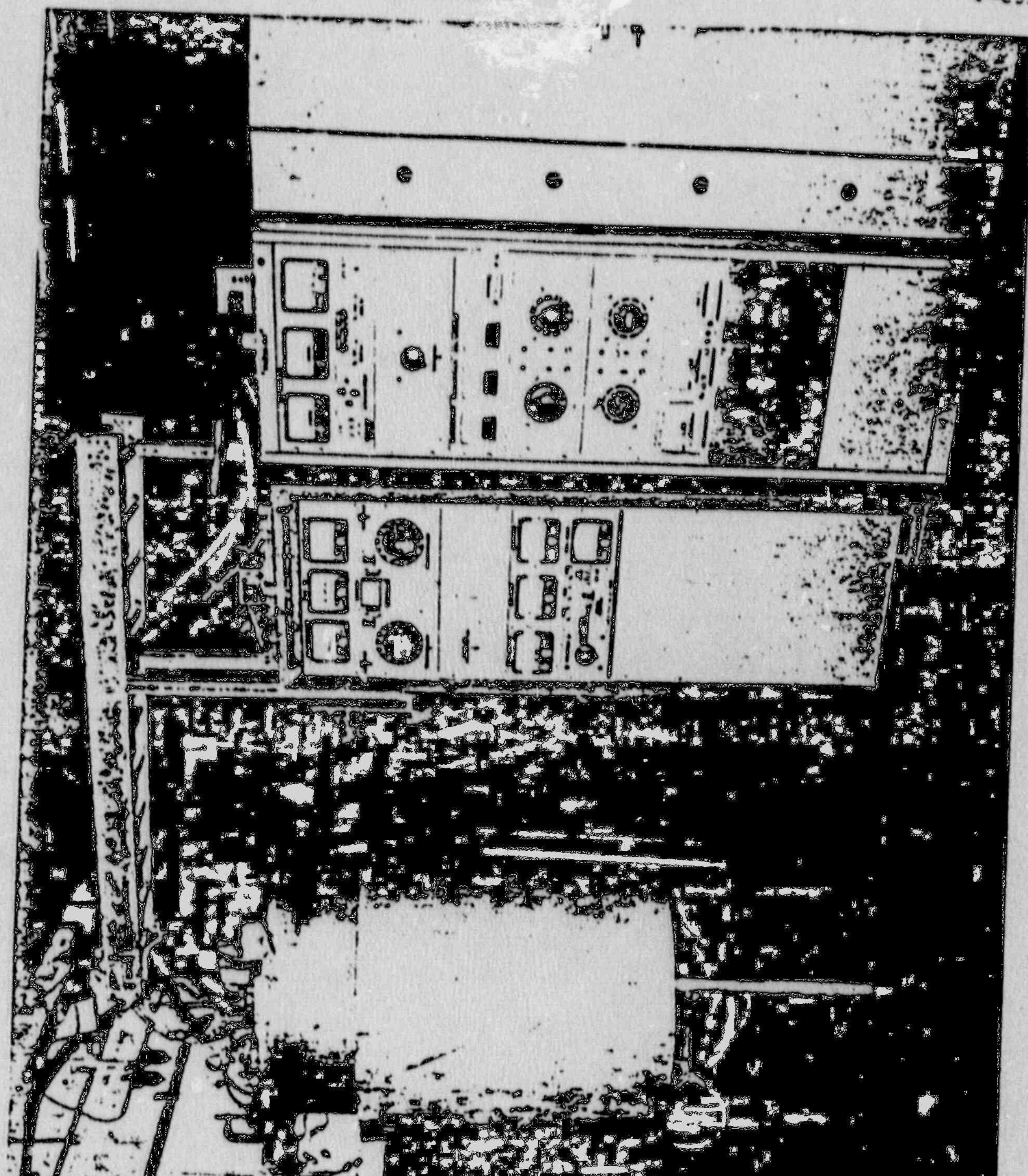

Figure 1. View of Test Facility Showing Vessel and Energizing Cabinets

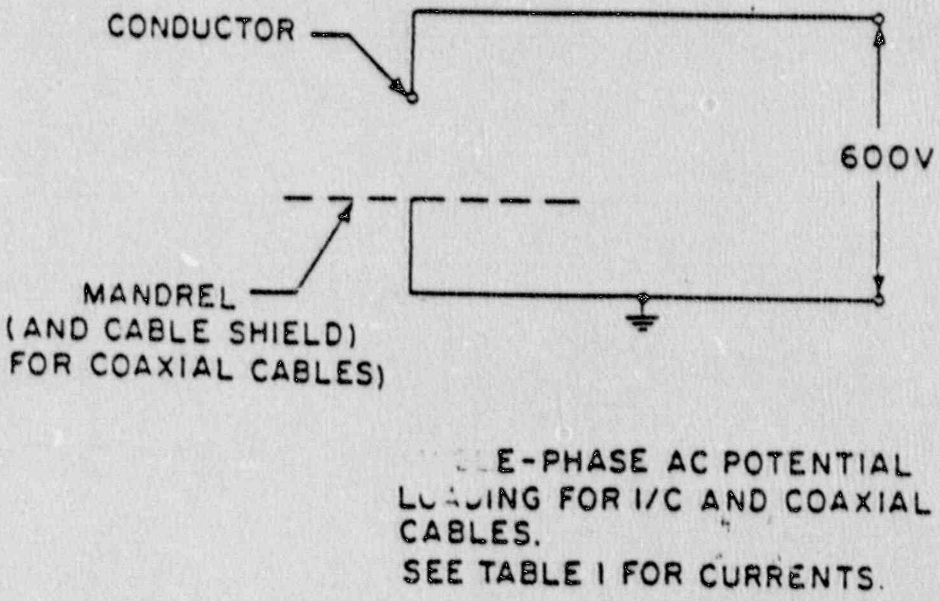

Figure 2. Electrical Loading Circuit for Energizing Cable Samples During Humid-Air Exposure

5. TEST PROGRAM

The test program was designed to extend the simulation of a cooldown period following a LOCA. The previous exposure[1] ended with a 20-day dwell at a temperature of 230°F (110°C) and a pressure of 10 lbf/in² (69 kPa); the exposure of this program provided a temperature of 200°F (93°C) for 120 days. Selection of the temperature and duration was guided by the information in Appendix A to IEEE Std 323-1974.[2]

5.1 PRETEST MEASUREMENTS AND PREPARATIONS

The cables were wrapped on one stainless steel mandrel as shown in Fig 3, with a diameter and length of 19.8 in (0.50 m) and 33 in (0.84 m), resp vely The cables were held in place with 0.5-in-diam (13-m-diam) ceramic standoffs and ties of fiberglass sleeving. Approximately two complete turns of cable were on the mandrel circumference; the cab routed up the sides of the mandrel through the flat cover of the vesse.. The cables penetrated the cover through rubber-grommeted Pyle-National cable grips.

The mandrel with cables was immersed in room-temperature tapwater for a minimum of 1 hour. The insulation resistance of the specimens was measured with a dc potential of 500 V applied for 1 minute.

5.2 TEST ARRANGEMENTS

The mandrel with cables was placed in the test vessel as shown in Figure 1. The ends of the specimen conductors were connected to electrical circuits to provide the potentials and currents indicated in Table 1 and Figure 2.

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[1]See footnote 1 on page 2.

[2]See footnote 2 on page 2.

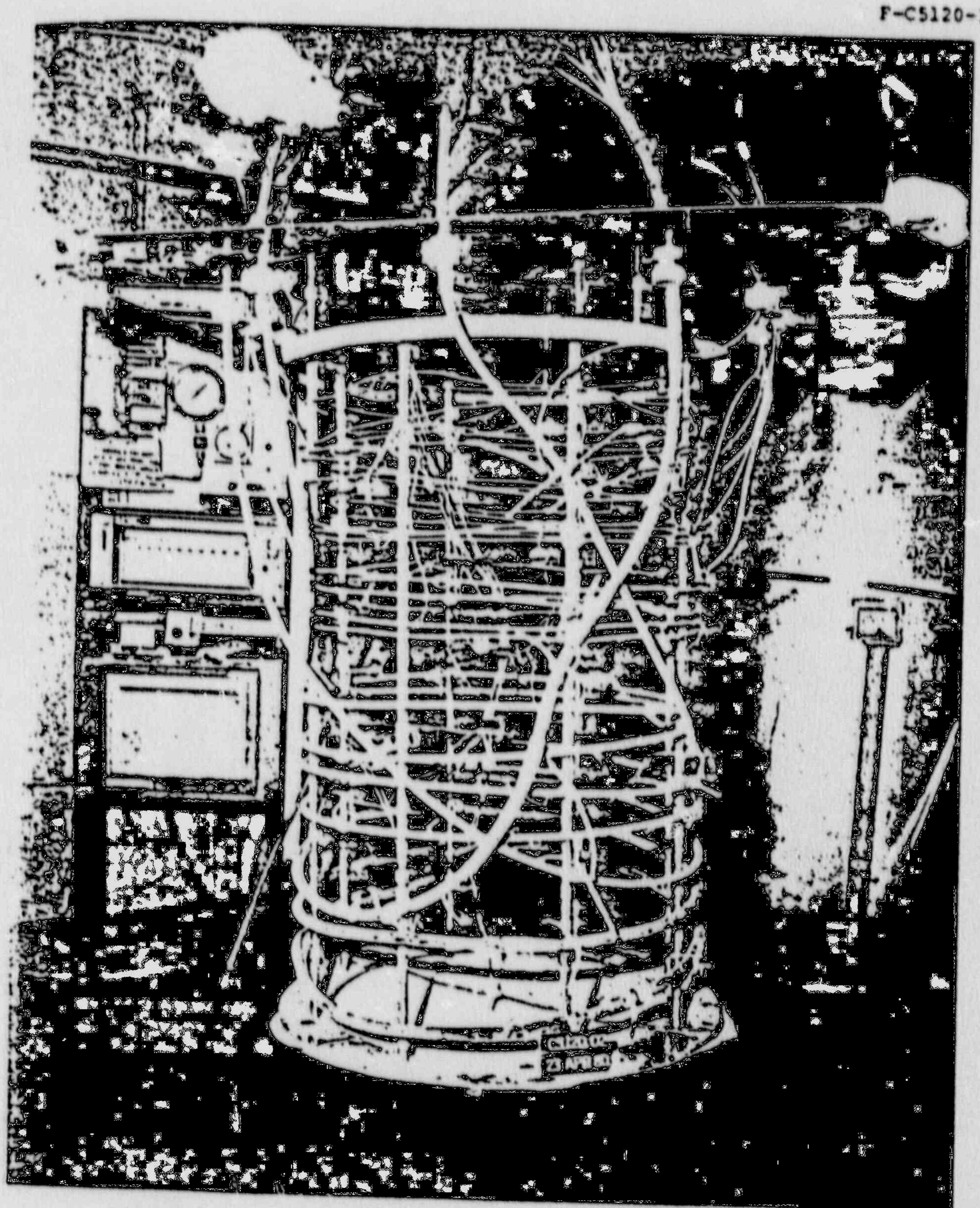

Figure 3. Pretest View of Cables on Stainless Steel Mandrel
(This view includes a cable not discussed in this report.)

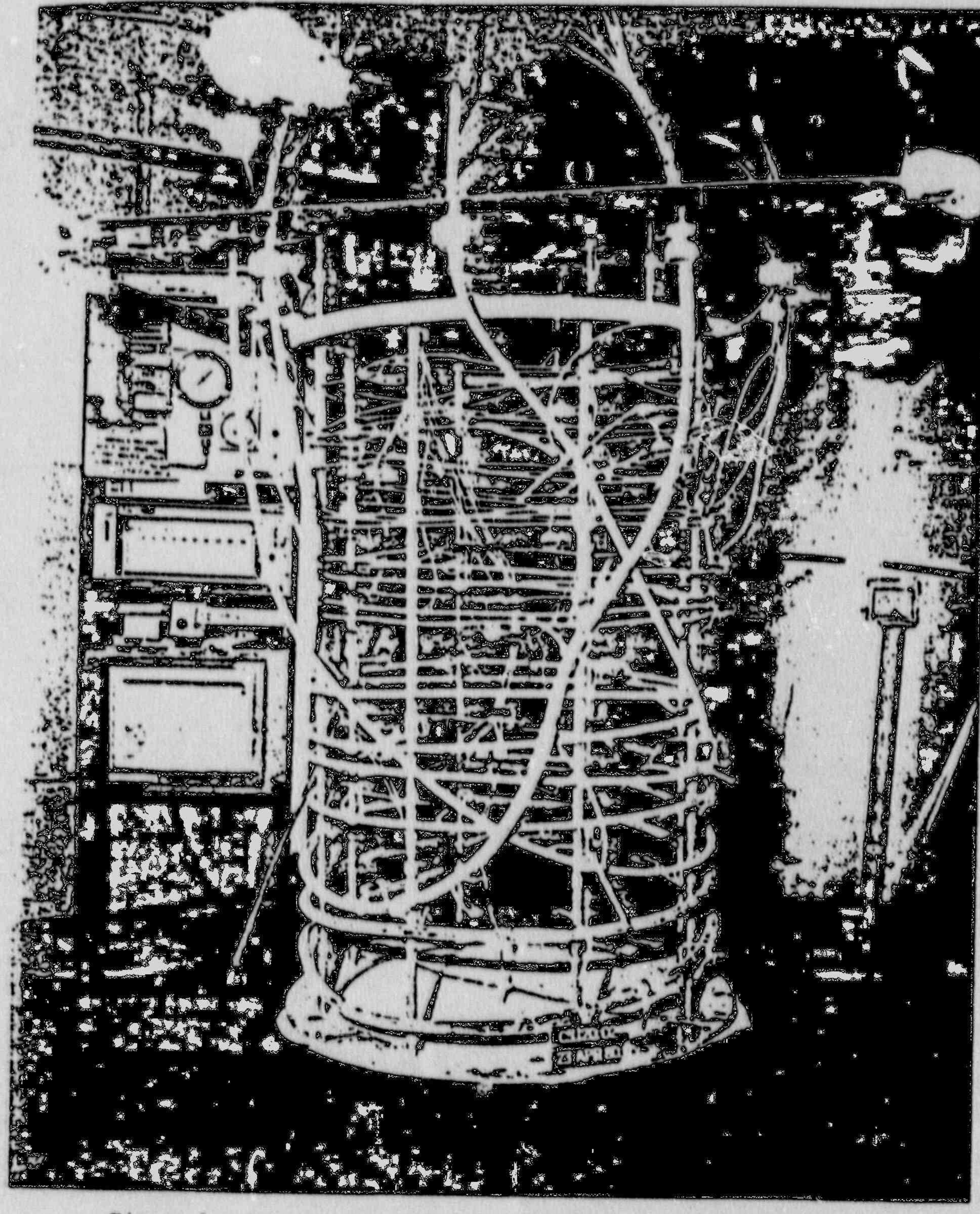

Figure 3. Pretest View of Cables on Stainless Steel Mandrel
(This view includes a cable not discussed in this report.)

5.3 HUMID-AIR EXPOSURE

The cables were subjected to a humid-air exposure at 200°F (93°C) and atmospheric pressure for a period of 120 days. The humid-air environment was provided primarily by heating a pool of water in the bottom of the vessel. This method provided a very humid condition in the vicinity of the cables; however, the relative humidity (RH) was not measured.[1]

The pH of the water in the bottom of the tank was maintained at a value of approximately 9.0 by periodic addition of sodium hydroxide.

The cables were electrically energized with the potentials and currents of Table 1 and Figure 2 during the exposure. If the levels of potential and current drifted, they were readjusted to the specified values. If faulting in a cable or conductor caused tripping of the power supplies, the cable or conductor was disconnected from the circuit, and the potentials and currents were restored to the remaining cables or conductors.

The insulation resistance (IR) of the specimens was measured once per week during the 120-day exposure. The energizing potentials and currents were removed from all of the specimens as required to perform the IR measurements.

5.4 FINAL INSPECTION AND TESTS

Following the humid-air exposure, the cables were removed from the test vessel and wrapped around a mandrel having a diameter 40 times the cable diameter (see Tables 1 and 3). While bent, the cables were inspected for cracks and tears.

While coiled at bend test diameters, the cables were immersed in room-temperature tapwater for 1 hour (minimum) and then subjected to high-potential-withstand tests at ac potentials of 80 V per mil (3150 V per mm) of insulation held for 5 minutes. At the end of 5 minutes, the leakage/charging currents were measured.

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[1]See footnote 1 on page 14.

5.5 ACCEPTANCE REQUIREMENTS

The test specimens were considered to have met the requirements of IEEE Std 383-1974,[3] Section 2.4, if they (a) remained energized with rated potential and current during the humid-air exposure and (b) passed the final bend and high-potential-withstand tests. It was assumed that the first criterion was met if the total leakage/charging current of the specimens connected to an energizing source did not exceed approximately 1.0 A.[4]

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[3]See footnote 3 on page 2.

[4]Each energizing source supplied its potential to a circuit containing one or more cable specimens and extension wires. When the specimens are performing satisfactorily, the total leakage/charging current for each circuit, including extension wires, is usually less than 10 mA, or 100 times less than the assumed acceptance criterion of 1.0 A. A failing specimen usually exhibits dramatic fluctuations and increases in leakage/charging currents which culminate in the tripping of energizing circuits (1.0 A maximum). The failing specimen is usually incapable of being reenergized without continued or sporadic tripping of the energizing circuits.

6. TEST RESULTS

6.1 INSULATION RESISTANCE

Results of IR measurements obtained during the test program are summarized in Table 2. IR measurements made during the 200°F (93°C) exposure included the IR effects of extension cables and terminal blocks used to connect the specimens to energizing circuits; the effects usually cause a negligible reduction in measured IR except when the specimen IR is very high (in which case the reduction is not significant to program objectives).

6.2 HUMID-AIR EXPOSURE

The 200°F (93°C) temperature and humid condition was provided for 120 days (minimum) with the following deviations:

- The vessel temperature decreased to 140°F (60°C; minimum temperature) on one occasion when the building electrical power was turned off for scheduled maintenance of power distribution equipment. Time that elapsed while temperatures were below 200°F (i.e., the time for temperature to drift downwards to 140°F, plus the time necessary to regain the temperature of 200°F) was approximately 6 hours. Approximately 0.5 day at 200°F was added to the 120-day exposure (120.5 days total) to compensate for this 6-hour period and to add to the conservatism of the program.

- The temperatures indicated at various locations within the test vessel differed by +6°, -6°F (+3°, -3°C) from the average temperature. The differences were caused by the stagnant condition of vapors within the vessel (i.e., the vapors were not stirred or circulated).

- The median temperature (i.e., the median of several indicated temperatures at any one time) was maintained within a span of 190° to 210°F (88° to 99°C) for approximately 95% of the time; see next comment below.

- On a few occasions (e.g., during a weekend when the test was not being monitored), the water in the bottom of the vessel evaporated to a level where temperature control was not completely effective. At these times, vessel temperatures climbed as high as 224°F (107°C; one thermocouple; one location). Conditions were corrected on the next working day; the addition of fresh water temporarily lowered the temperature to 190°F (88°C) until restabilization at 200°F (93°C) was reestablished. In general, these situations added to the conservatism of the test.

- Temperatures drifted downward approximately 10°F (6°C) when the cables were deenergized for IR measurements (i.e., of 1-hour durations, once per week). The drift was caused by the loss of Joule heating normally contributed by the energized cables.

A humid condition was verified by a thermocouple immersed in the solution in the bottom of the vessel. The temperature indicated was approximately equal to the median of temperatures indicated by thermocouples located in the vessel vapors.[1]

The specimens were electrically energized throughout the 120-day (minimum) exposure except as follows:

- All cables were deenergized for approximately 1 hour every week as required to permit IR measurements.
- All cables were deenergized for approximately 5 hours when the building power supply was turned off for scheduled maintenance of power distribution equipment.
- During a period of 19 hours or less after 50 days of elapsed time, the circuit breaker controlling the 600-V potential tripped to the off position during the night while the test was unattended. The tripping of the breaker was caused by a specimen not discussed in this report. The potential was restored after removing the faulting specimen from the circuit.

6.3 FINAL TESTS

Results of final tests and inspections are presented in Table 3.

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[1] For reference only, a 10°F (6°C) difference between wet- and dry-bulb temperatures over a dry-bulb temperature span of 190° to 210°F (88° to 99°C) indicates an RH of 80 to 81%; a lesser difference in temperatures indicates a higher RH.

Table 2. Summary of Insulation Resistance Measurements[a]
(All values are in ohms.)[b]

ELAPSED TIME (days)	CABLE NUMBER							
	1-2	1-3	2-2	2-3	3-1	3-2	9-2	9-3
Pretest[c]	5.0 E+12	4.0 E+12	9.6 E+12	8.6 E+12	2.4 E+12	2.4 E+12	1.3 E+13	1.5 E+13
<0.1[d]	9.4 E+08	[illegible]	1.2 E+09	1.1 E+09	3.5 E+09	3.0 E+09	1.7 E+10	1.4 E+10
15.9	6.6 E+08	5.4 E+08	2.8 E+09	1.2 E+09	3.0 E+09	1.9 E+09	1.4 E+10	1.0 E+10
43.9	5.6 E+08	5.8 E+08	2.2 E+09	1.6 E+09	4.0 E+09	3.0 E+09	1.5 E+10	1.1 E+10
50.8	5.6 E+08	5.8 E+08	2.0 E+09	1.7 E+09	4.0 E+09	2.8 E+09	1.4 E+10	1.0 E+10
57.0	5.6 E+08	5.6 E+08	1.4 E+09	1.2 E+09	4.0 E+09	3.0 E+09	1.3 E+10	8.2 E+09
70.8	4.0 E+08	4.0 E+08	1.4 E+09	1.3 E+09	3.0 E+09	2.2 E+09	8.4 E+09	7.2 E+09
85.8	4.5 E+08	4.5 E+08	1.1 E+09	1.0 E+09	3.5 E+09	2.6 E+09	1.2 E+10	8.4 E+09
101	4.5 E+08	4.5 E+08	1.0 E+09	1.0 E+09	2.6 E+09	3.0 E+09	1.1 E+10	7.6 E+09
120	5.4 E+08	5.8 E+08	1.2 E+09	1.2 E+09	1.7 E+09	1.5 E+09	1.4 E+10	9.6 E+09
Post-test[e]	1.0 E+12	1.5 E+11	2.0 E+12	8.2 E+09	4.0 E+11	2.8 E+10	7.0 E+12	8.4 E+12

NOTES:

a. Insulation resistance (IR) measured at a dc potential of 500 V for 1 minute unless otherwise indicated; specimens wrapped on a mandrel in the test vessel at 200°F (93°C) unless otherwise indicated. IR measurements of the specimens in the test vessel include the IR effects of extension cables.

b. The values of ohms are written as a number followed by the letter E (for exponent), a plus symbol, and two digits which indicate the power of 10 by which the number must be multiplied to obtain the correct value. For example, 1.2 E+09 is 1.2×10^9 or 1,200,000,000.

c. Immersed in 60°F (16°C) tapwater.

d. At approximately 1.7 hours of elapsed time.

e. After wrapping on bend-test mandrel and 1-hour immersion in 77°F tapwater; no extension cables are involved except the guarded test lead of the megohmmeter.

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

Specimen Number	Visual Appearance Before and During Bend Test	Mandrel Diameter (in)/(cm)	Mandrel/ Cable Diameter Ratio	Number of Cable Turns	Applied Alternating Potential[a] (V)	Leakage/ Charging Current (mA)	Remarks
C5120-1-2	Cable surface appears very rough; no cracking of surface present. Evidence of surface abrasions, discolorations, and chemical stains.	4.0/10	40	10	1600	1.8	Withstood potential. (Specimens connected together for test.)
C5120-1-3	Same as Specimen 1-2 above.	4.0/10	40	10	1600		
C5120-2-2	No apparent damage except minor surface abrasions, discolorations, and chemical stains.	6.0/15	40	3	2400	2.6	Withstood potential. (Specimens connected together for test.)
C5120-2-3	Same as Specimen 2-2 above.	6.0/15	40	3	2400		
C5120-3-1	Cable surface appears rough, discolored, and chemically stained, but free of damage.	16/41	40	<3[b]	3600	7.8	Withstood potential. (Specimens connected together for test.)
C5120-3-2	Same as Specimen 3-1 above.	16/41	40	<3[b]	3600		
C5120-9-2	Jacket has many circumferential [illegible] mostly [illegible] within 2 ft (0.6 m) from each end. Jacket has rough appearance, and is discolored and stained with chemicals.	9.5/24	39.6	3	4800	2.2	Withstood potential. (Specimens connected together for test.)
C5120-9-3	Similar to Specimen 9-2 above except that jacket is split longitudinally for a length of approximately 18 in (0.46 m) exposing metallic braid underneath. Metallic braid also visible in another area of approximately 0.5-in (13-mm) diameter.	9.5/24	39.6	3	4800		

NOTES:

a. Potentials applied for 5 minutes after specimens had been immersed in room-temperature tapwater for a minimum of 1.0 hour. The ground terminal of the test instrument was connected to a bare copper conductor in the water and the metallic braid of specimens C5120-9-2 and C5120-9-3 where applicable.

b. The length of the specimen did not permit three full turns while the specimen ends were being kept above the surface of the water.

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7. CONCLUSIONS

Based on the results of this program, it is concluded that all of the nine specimens met the test criteria of IEEE Stds 323[1] and 383,[2] as demonstrated by their ability to maintain their electrical load for a simulated post-LOCA condition at 200°F (93°C) for 120 days beyond the original 30-day simulated SLB/LOCA exposure previously reported.[3]

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[1]See footnote 2 on page 2.

[2]See footnote 3 on page 2.

[3]See footnote 1 on page 2.

8. CERTIFICATION

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

D. V. Paulson — 11-17-81
D. V. Paulson
Project Engineer
Date

APPROVED:

S. P. Carfagno — 11-18-81
S. P. Carfagno, Manager
Nuclear Engineering
Date

M. M. Reddi — 11-18-81
M. M. Reddi
Vice President and Director
Engineering & Sciences Dept.
Date

F-C5120-3

DESCRIPTION OF THERMOCOUPLES AND LOCATIONS

APPENDIX A

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Table A-1. List of Thermocouples and Locations in the Test Vessel

Thermocouple Identification[a]	Approximate Location and Remarks[b]
1	On center line of vessel; 4.5 in (11 mm) below bottom flange of mandrel.
2	On center line of vessel; 18 in (460 mm) above bottom flange of mandrel.
3	0.5 in (13 mm) inside mandrel; 4.5 in (11 mm) below upper flange of mandrel.
4	0.5 in (13 mm) inside mandrel; 4.5 in (11 mm) below upper flange of mandrel.
5	0.5 in (13 mm) inside mandrel; 13 in (330 mm) below upper flange of mandrel.
6	0.5 in (13 mm) inside mandrel; 13 in (330 mm) below upper flange of mandrel.
7	0.5 in (13 mm) inside mandrel; 6 in (152 mm) above bottom flange of mandrel.
8	0.5 in (13 mm) inside mandrel; 6 in (152 mm) above bottom flange of mandrel.
9	On center line of vessel; 4.5 in (11 mm) below bottom flange of mandrel.
10	On center line of vessel; 16 in (410 mm) below upper flange of mandrel.
11	On center line of vessel; 16 in (410 mm) below upper flange of mandrel.

a. Thermocouple nos. 1 through 8 were type T (copper-constantan) #20 AWG insulated with polyvinyl chloride. Junctions were soft soldered. Thermocouple nos. 9, 10 and 11 were type T (copper-constantan) sheathed in 0.063-in-diam (1.6-mm-diam) inconel or stainless steel tubing (i.e., some were inconel and some were stainless steel), grounded junction.

b. See accompanying sketch for additional description of thermocouple locations.

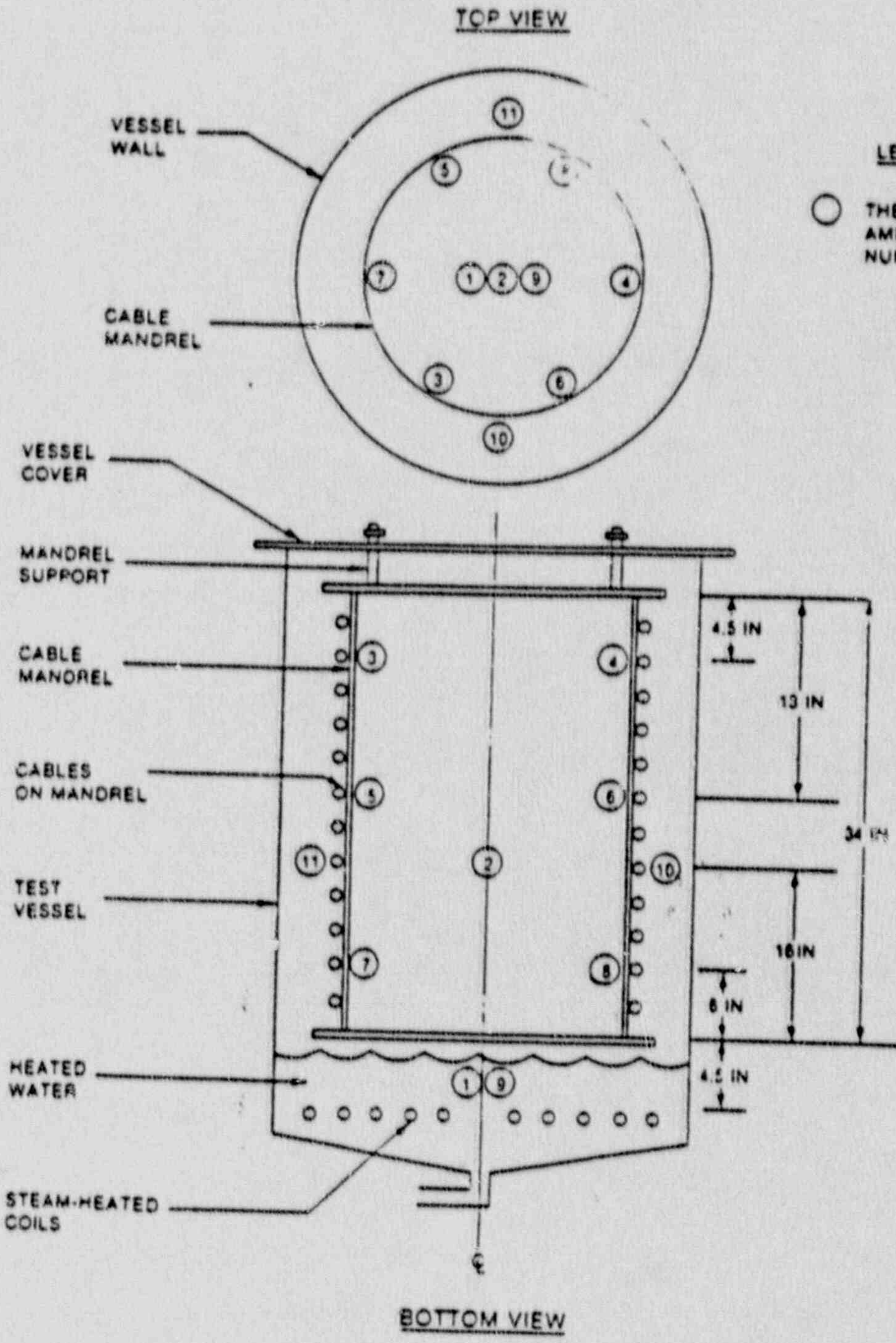

Figure A-1. Schematic of Thermocouple Locations

F-C5120-3

LIST OF DATA ACQUISITION INSTRUMENTS

APPENDIX 3

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GENERAL FRC PROCEDURE FOR CALIBRATION OF INSTRUMENTS TO MEASURE TEMPERATURE, ELECTRICAL CURRENT AND LIQUID FLOW RATE

A *List of Data Acquisition Instruments* (hereafter called *Instrument List*) used to measure or record data obtained during this test program is appended. The following remarks are offered to assist the reader in understanding FRC practice for calibrating instruments to measure temperature, electrical current and liquid flow rate.

1. Temperature Measurement

In general, environmental temperatures provided during oven exposures and simulated SLB/LOCA conditions (e.g., steam exposures) are sensed by thermocouples; their signals are displayed and recorded by strip chart recorders with appropriate electronic reference-junction compensation. FRC uses thermocouples and thermocouple wire purchased from vendors who comply with ANSI Standard MC96.1-1975, "Temperature Measurement by Thermocouples," for limits of error (e.g., ± 3/4% over 200°-to-700°F range for ANSI type T). FRC maintains its temperature recorders through a service contract with recorder suppliers who routinely clean, service and calibrate the recorders, traceable to NBS, a minimum of once every four months. The reports of calibration are on file at FRC.

To further substantiate the validity of temperature measurements by thermocouples, FRC maintains special calibrated thermocouples (calibrated at 32°, 212° and 400°F) which are used according to the following procedure:

> On the day a test is started, a calibrated thermocouple is substituted for one of the ANSI-standard-quality thermocouples at the specified oven or test vessel location. (The thermocouples are connected to the recorders with ANSI-standard thermocouple extension wires; Jones-type terminal strips are occasionally included with appropriate thermocouple-metal connecting links.) The calibrated thermocouple is placed in a dewar bath of stirred ice-water for approximately 30 s and then into an insulated flask of actively boiling water for approximately 30 s. If the recorder indicates the temperatures of freezing and boiling water within a tolerance of ± 2°F, the temperature measuring/recording system is considered adequately calibrated for the purposes of the test program. The above *system calibration* procedure is repeated after completion of the oven aging or SLB/LOCA exposure.

2. Electrical Measurement

All electrical measurements are made by instruments with calibrations traceable to NBS. Special circuits are frequently provided to supply current levels requiring *power*-current transformers. In these cases, *instrument*-current transformers are used in conjunction with 5-A movement ammeters to indicate the currents present in the test circuits. These panel-mounted ammeters are calibrated on a program-by-program basis against calibrated ammeters of higher quality.

3. Liquid Flow Rate Measurement

FRC calibrates its liquid flowmeters according to the following procedure:

> The flowmeter is installed in the FRC flow calibration station, which has provisions for adjusting and controlling the flow rate of tap water through the flowmeter. The water is collected in a tank which rests on a beam balance. After steady flow is established, the time for a predetermined mass of water to flow through the flowmeter is measured; time measurements are made with an automatic electric timer.

Most FRC flowmeters are of a concentric orifice-plate type (e.g., Daniel Flow Tube) with a differential-pressure manometer (e.g., Barton Dial Manometer). The orifice and manometer are calibrated *as a system*, although the instruments are identified by separate FRC item numbers. Both the manometer and the orifice are listed in the *Instrument List*.

4. Strip Chart Recorders

As noted in Section 1 above, strip chart recorders are serviced and calibrated a minimum of once every four months. Some recorders respond to voltage inputs other than thermocouple signals and the amount of pen response can be controlled by adjustment of front-panel controls. For these recorders, pen-response calibration is obtained on a program-by-program basis for the specific parameters being recorded. For example, to record pressure the pressure transducer and the recorder are calibrated *as a system* by applying known levels of pressure to the sensor and then recording the amount of recorder pen response. After calibration, the recorder input-amplifier controls remain unchanged, except for occasional minor zero-drift adjustments. The actual calibrations appear on the strip chart. The full-span calibration level (e.g., 0 to 200 psig full scale) is included among the data provided in the *Instrument List*.

LIST OF DATA ACQUISITION INSTRUMENTS

INSTRUMENT NUMBER	18207
INSTRUMENT AND MANUFACTURER	MIDWEST ELECTRIC PRODUCTS AMMETER
TYPE/MODEL NUMBER	PANEL, TRANSFORMER TYPE
SERIAL NUMBER	NONE
RANGE/FEATURES	0 TO 100 PERCENT, 2 PCT/DIV
ACCURACY	3.0 PERCENT OF F.S.
DATE CALIBRATED	4-30-80 TO 12.6 A F.S.
CALIBRATION DUE	10-30-80

INSTRUMENT NUMBER	18206
INSTRUMENT AND MANUFACTURER	MIDWEST ELECTRIC PRODUCTS AMMETER
TYPE/MODEL NUMBER	PANEL, TRANSFORMER TYPE
SERIAL NUMBER	NONE
RANGE/FEATURES	0 TO 100 PERCENT, 2 PCT/DIV
ACCURACY	3.0 PERCENT OF F.S.
DATE CALIBRATED	4-30-80 TO 25A F.S.
CALIBRATION DUE	10-30-80

INSTRUMENT NUMBER	18204
INSTRUMENT AND MANUFACTURER	MIDWEST ELECTRIC PRODUCTS AMMETER
TYPE/MODEL NUMBER	PANEL, TRANSFORMER TYPE
SERIAL NUMBER	NONE
RANGE/FEATURES	0 TO 100 PERCENT, 2 PCT/DIV
ACCURACY	3.0 PERCENT OF F.S.
DATE CALIBRATED	4-30-80 TO 25A F.S.
CALIBRATION DUE	10-30-80

INSTRUMENT NUMBER	18213
INSTRUMENT AND MANUFACTURER	SIMPSON VOLTMETER
TYPE/MODEL NUMBER	59 PANEL
SERIAL NUMBER	04309
RANGE/FEATURES	0 TO 750 Vac
ACCURACY	2.0 PERCENT OF F.S.
DATE CALIBRATED	1-15-80
CALIBRATION DUE	7-15-80

INSTRUMENT NUMBER	18356
INSTRUMENT AND MANUFACTURER	SIMPSON VOLTMETER
TYPE/MODEL NUMBER	NONE
SERIAL NUMBER	NONE
RANGE/FEATURES	0 TO 300 Vac
ACCURACY	2 PERCENT OF F.S.
DATE CALIBRATED	5-5-80
CALIBRATION DUE	11-5-80

INSTRUMENT NUMBER	18131
INSTRUMENT AND MANUFACTURER	LEEDS-NORTHRUP RECORDER
TYPE/MODEL NUMBER	524-101-000-0999-6-511
SERIAL NUMBER	E 72-54S07-1-1
RANGE/FEATURES	0 TO 400 DEG F, TYPE T T/C, 24 POINTS
ACCURACY	0.25 PERCENT OF F.S.
DATE CALIBRATED	4-25-80 AND 8-27-80
CALIBRATION DUE	12-27-80

INSTRUMENT NUMBER	18253
INSTRUMENT AND MANUFACTURER	MULTIAMP INSTR. CORP. MILLIAMMETER
TYPE/MODEL NUMBER	165
SERIAL NUMBER	2104
RANGE/FEATURES	0 TO 10,000 mA
ACCURACY	0.5 PERCENT OF F.S.
DATE CALIBRATED	12-10-79 AND 7-30-80
CALIBRATION DUE	1-31-81

INSTRUMENT NUMBER	4217802
INSTRUMENT AND MANUFACTURER	GENERAL RADIO MEGOHMMETER
TYPE/MODEL NUMBER	1864
SERIAL NUMBER	4368-1075
RANGE/FEATURES	200 TERAOHMS AT 10-1000 Vdc
ACCURACY	7.0 PERCENT OR LESS DEPENDING ON SPAN
DATE CALIBRATED	1-22-80
CALIBRATION DUE	7-22-80

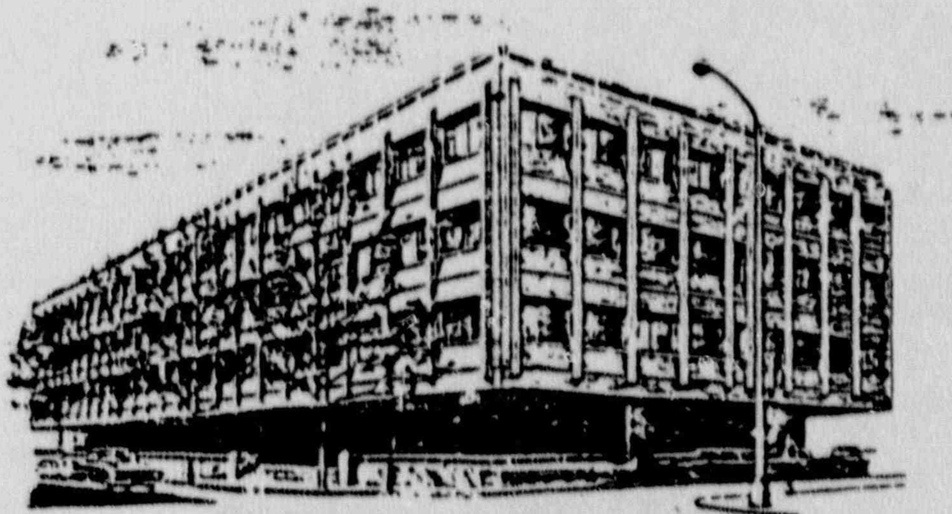
INSTRUMENT NUMBER	18254
INSTRUMENT AND MANUFACTURER	MULTIAMP INSTRU. CORP. MILLIAMMETER
TYPE/MODEL NUMBER	165
SERIAL NUMBER	2102
RANGE/FEATURES	0 TO 10,000 mA
ACCURACY	0.5 PERCENT OF F.S.
DATE CALIBRATED	1-14-80 AND 9-10-80
CALIBRATION DUE	3-10-81

INSTRUMENT NUMBER	4218030
INSTRUMENT AND MANUFACTURER	GENERAL RADIO MEGOHMMETER
TYPE/MODEL NUMBER	1864
SERIAL NUMBER	3137
RANGE/FEATURES	50K OHMS TO 500K OHMS, 10 TO 1000 Vdc
ACCURACY	5.0 PERCENT OR LESS DEPENDING ON SPAN
DATE CALIBRATED	4-10-80
CALIBRATION DUE	10-10-80

INSTRUMENT NUMBER	4229663
INSTRUMENT AND MANUFACTURER	SIMPSON MULTIMETER
TYPE/MODEL NUMBER	6M
SERIAL NUMBER	3-711589
RANGE/FEATURES	1000 Vac & Vdc, 2 Mohm, 10 Adc
ACCURACY	3 PERCENT OF F.S.
DATE CALIBRATED	6-13-80
CALIBRATION DUE	6-13-81

INSTRUMENT NUMBER	4217507
INSTRUMENT AND MANUFACTURER	BECKMAN INS. AND BREAKDOWN TEST SET
TYPE/MODEL NUMBER	1600
SERIAL NUMBER	77145
RANGE/FEATURES	10 kV AC/DC, 10 mA AC/DC
ACCURACY	3.0 PERCENT OF F.S.
DATE CALIBRATED	9-5-80
CALIBRATION DUE	3-5-81

INFORMATION ONLY



INFORMATION ONLY

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The principal areas of effort at Franklin include mechanical and electrical engineering; development and application of sophisticated analytical methods; electronic design; failure analysis; product and process development; acoustics; energy conservation; design of data processing systems; information services; market and economic analyses; and a broad spectrum of research in health and safety.

FRC maintains full support services, which include a publications group, photographic laboratory, computer center, instrument calibration and repair shop and a machine shop.

In addition to the headquarters in Philadelphia, U.S. offices are maintained in Washington, D.C., Silver Spring, Maryland, Jefferson, Arkansas, and Oak Ridge, Tennessee. Foreign offices are maintained in Tokyo, Munich, and Luxembourg.

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ATTACHMENT 4