QUALIFICATION TEST OF ELECTRIC CABLES UNDER A SIMULATED LOCA/DBE BY SEQUENTIAL EXPOSURE TO ENVIRONMENTS OF RADIATION, THERMAL AGING, STEAM AND CHEMICAL-SPRAY

Performed For

SAMUEL MOORE AND COMPANY, DEKORON DIVISION

Aurora, Ohio

By The

COMPONENT TESTING DIVISION

of

ISOMEDIX, INC.

Parsippany, New Jersey

JUNE 1978

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SAMUEL MOORE AND COMPANY

SECTION 1. INTRODUCTION AND SUMMARY

A qualification test on electric cables was performed in accordance with the suggestions contained in IEEE 323-1974, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations", and IEEE 383-1974, "IEEE Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations".

The samples were aged as noted in Table 1. All samples were subjected to sequential exposures of radiation, temperature and a second radiation environment, followed by a 30-day exposure to an environment of steam and chemical-spray, while electrically energized at rated voltage and current loading. This loading consisted of a potential of 600 volts (AC), between conductors and ground, and a current of 0.5 amp. Approximately 35 feet of each sample was subjected to the exposure environment.

Samples 11 and 16 (Samuel Moore designation 5C and 30) were irradiated in a Cobalt-60 field of gamma radiation at a rate resulting in a dose of 25 megarads. This was followed by thermal aging at 150°C for 7 days. After the thermal aging, the samples were again irradiated in a Cobalt-60 field of gamma radiation at a rate resulting in an additional dose of 25 megarads.

The cores of cable samples 2, 4, 5, 8, 9 and 10 were thermally aged at the facilities of Samuel Moore and Company. Cable samples 2, 5, 8 and 10 were aged at 163°C for 7 days and cable samples 4 and 9 were aged at 150°C for 7 days.

Cable samples 2, 4, 5, 7, 8, 9, 10, 12, 13 and 14 (Samuel Moore designations 1B, 2A, 2B, 3A, 4A, 5A, 5B, 6A, 7A, and 7B, respectively) were then exposed to a Cobalt-60 field of gamma radiation at a rate resulting in a dose of 25 megarads. The irradiation was followed by thermal aging at 121°C for 7 days. At the conclusion of the thermal aging, the samples were subjected to an additional exposure to Cobalt-60 gamma radiation at a rate resulting in an additional dose of 175 megarads.

Measurements of insulation resistance, made at 500 Vdc, were performed before and after each of the environmental exposure periods and periodically during the steam/chemical-spray exposure period. High voltage withstand tests were conducted at the end of the exposure period following a 40 times cable diameter mandrel bend test.

All samples, except 7 and 11, completed the 30-day LOCA simulation while electrically energized at rated voltage and current. Samples 7 and 11 completed the LOCA simulation but were de-energized early in the simulation period due to shorting of the cables conductors to ground. The shorting occurred within the epoxy-filled feed through tubes. Therefore the cables were deemed to have passed the LOCA simulation.

All the samples successfully completed post-exposure a.c. high voltage withstand tests, while immersed in water, for 1 minute at their a.c. voltage rating, 2 times their a.c. voltage rating and 5 minutes at 80 Vac/mil as per IEEE 383.

The test program was conducted during the period of April 1978, through June 1978, at Isomedix, Inc., Parsippany, New Jersey.

TABLE 1

DESCRIPTION OF CABLE SAMPLES

Isomedix Tag No.	Samuel Moore Tag No.	(Phase I) Core Thermal Aging (°C/Days) at Samuel Moore	(Phase II) First Radiation Dose (Megarads)	(Phase III) Thermal Aging Temp./ Duration (°C/Days)	(Phase IV) Second Radiation Dose (Megarads)	SAMPLE DESCRIPTION
2	1B	163/7	25	121/7	175	2/C 16 ga. 7 stranded tinned copper, 30 mils crosslinked polyolefin, 16 ga, drain and shield, 45 mil Hypalon jacke
4	2A	150/7	25	121/7	175	2/C 16 ga. 7 stranded tinned copper, 30 mils crosslinked polyolefin, 16 ga. drain and shield, 45 mil Hypalon jacke
5	2B	163/7	25	121/7	175	2/C 16 ga. 7 stranded tinned copper, 30 mils crosslinked polyolefin, 16 ga. drain and shield, 45 mil Hypalon jacke
7	3A	None	25	121/7	175	2/C Black and White 16 ga. 7 stranded tinned copper 20 mil EPDM primary insulation with 10 mils Hypalon primary jacket. 16 ga. drain and shield 45 mil Hypalon jacket
8	4A	163/7	25	121/7	175	2/C 16 ga. 7 stranded tinned copper, 30 mils FR-EPDM, 16 ga, drain and shield, 45 mil Hypalon jacket.

TABLE 1

DESCRIPTION OF CABLE SAMPLES

Isomedix Tag No.	Samuel Moore Tag No.	(Phase I) Core Thermal Aging (°C/Days) at Samuel Moore	(Phase II) First Radiation Dose (Megarads)	(Phase III) Thermal Aging Temp./ Duration (°C/Days)	(Phase IV) Second Radiation Dose (Megarads)	SAMPLE DESCRIPTION
9	5A	150/7	25	121/7	175	2/C 16 ga. 7 stranded tinned copper, 30 mils FR-EPDM, 16 ga. drain and shield, 45 mil Hypalon jacket.
10	5B	163/7	25	121/7	175	2/C 16 ga. 7 stranded tinned copper, 30 mils FR-EPDM. 16 ga.drain and shield, 45 mil Hypalon jacket.
11	5C	None	25	150/7	25	2/C 16 ga. 7 stranded tinned copper 30 mils FR-EPDM 16 ga. drain and shield 45 mil Hypalon jacket.
12	6A	None	25	121/7	175	2/C 10 ga. 7 stranded tinned copper, 30 mils FR-EPDM primary insulation with 15 mils Hypalon primary jacket, 10 ga. drain and shield, 45 mil Hypalon jacket.
13	7A	None	25	121/7	175	2/C 16 ga. 7 stranded tinned copper, 20 mils EPDM primary insulation with 10 mils Hypalon primary jacket, 16 ga. drain and shield, 45 mil Hypalon jacket.

TABLE 1

DESCRIPTION OF CABLE SAMPLES

Isomedix Tag No.	Samuel Moore Tag No.	(Phase I) Core Thermal Aging (°C/Days) at Samuel Moore	(Phase II) First Radiation Dose (Megarads)	(Phase III) Thermal Aging Temp./ Duration (°C/Days)	(Phase IV) Second Radiation Dose (Megarads)	SAMPLE DESCRIPTION
14	7B	None	25	121/7	175	2/C 16 ga. 7 stranded tinned copper, 20 mils EPDM primary insulation with 10 mils Hypalon primary jacket, 16 ga. drain and shield, 45 mil Hypalon jacket.
16	30	None	25	150/7	25	1/C 16 ga. 7 stranded tinned copper, 30 mils FR-EPDM.

SECTION 2. TEST PROGRAM

2.1 Purpose

The purpose of the program was to provide qualification tests on electric cables in accordance with the suggestions contained in IEEE 323-1974, "IEEE Standards for Qualifying Class 1E Equipment for Nuclear Powered Generating Stations", and IEEE 383-1974, "IEEE Standard for Type Test of 1E Electric Cables, Field Splices and Connections for Nuclear Powered Generating Stations".

2.2 Discussions

2.2.1 Phase I - Core Thermal Aging

The cores of cable samples 2, 4, 5, 8, 9 and 10 were thermally aged at the facilities of Samuel Moore and Company. Cable samples 2, 5, 8 and 10 were aged at 163°C for 7 days and cable samples 4 and 9 were aged at 150°C for 7 days.

At the conclusion of this phase, the cable samples were jacketed and forwarded to Isomedix for further tests. The core thermal aging records were also forwarded and are available for inspection at Isomedix.

2.2.2 Phase II - First Radiation Aging

The cable samples were placed in a corrugated carton. The carton containing the samples was placed in a radiation facility and subjected to a Cobalt-60 source of gamma

radiation at an exposure rate of approximately 0.75 megarads per hour.

Appendix A contains complete radiation configuration and formal certification.

The carton was removed after the cables had received an accumulated dose of 25 megarads. At the conclusion of the Phase II Radiation Aging Period, IR measurements were made at room ambient conditions.

2.2.3 Phase III - Thermal Aging

Cable samples 11 and 16 were placed in a forced air oven and thermally aged at 150°C for 7 days. The oven's heater controls were adjusted to automatically maintain 150°C throughout the aging period.

Cable samples 2, 4, 5, 7, 8, 9, 10, 12, 13 and 14 were placed in a forced air oven and thermally aged at 121°C for 7 days. The heater controls on the oven were adjusted to automatically maintain 121°C throughout the 7 days.

At the conclusion of Phase III, Thermal Aging, IR measurements were made at room ambient conditions.

2.2.4 Phase IV - Second Radiation Aging

Cable samples 11 and 16 were placed in one corrugated box and cable samples 2, 4, 5, 7, 8, 9, 10, 12, 13 and 14 were placed in another corrugated box. Both boxes containing

the samples were placed in a radiation facility and subjected to a Cobalt-60 source of gamma radiation. The exposure rates were approximately 0.3 megarads per hour for cable samples 11 and 16, and 0.75 megarads per hour for the other cable samples.

Appendix A contains complete radiation configuration and formal certification.

The box containing samples 11 and 16 were removed after the samples had received an accumulated dose of 25 megarads. The other box was removed after the samples had received an accumulated dose of 175 megarads. At the conclusion of Phase IV Radiation Aging Period, IR measurements were made at room ambient conditions.

2.2.5 Phase V - LOCA Simulation (See Figure 1 and Figure 2)

At the start of the steam exposure, the cables were energized and the ambient temperature was 140°F within the pressure vessel.

To initiate the exposure, steam was rapidly admitted, raising the temperature and pressure to 340°F and 105 psig within 5 minutes. The temperature was maintained at 340°F for the remainder of the three-hour period.

At the end of this period, a controlled temperature drop was initiated that reduced the temperature to 140°F over the next two hours.

The second transient was then initiated by introducing steam that raised the environment to 340°F and 105 psig (340/105) within 5 minutes and held these parameters for the next three hours.

The temperature was then reduced to 320°F/75 psig and held for three hours before reducing the parameters to 300°F/55 psig for an additional four hours.

At that time a controlled drop was initiated that reduced the parameters to 250°F/15 psig over the next twenty minutes. The temperature was maintained at 250°F for the balance of four days, at which time the parameters were reduced over the next half hour to 200°F/10 psig nominal for the remainder of the 30-day exposure period.

Approximately 20 seconds after initiating the steam exposure, a chemical solution consisting of 3000 ppm boron as boric acid in solution with 0.064 molar sodium thiosulfate buffered with sodium hydroxide to a pH of 10 at room temperature was continuously sprayed into the vessel at a rate of 2 gpm corresponding to 0.15 gpm/ft^2 of the surface area of the mandrel.

The chemical-spray solution pH was between 9 and 11. The spray remained on throughout the Phase V LOCA simulation.

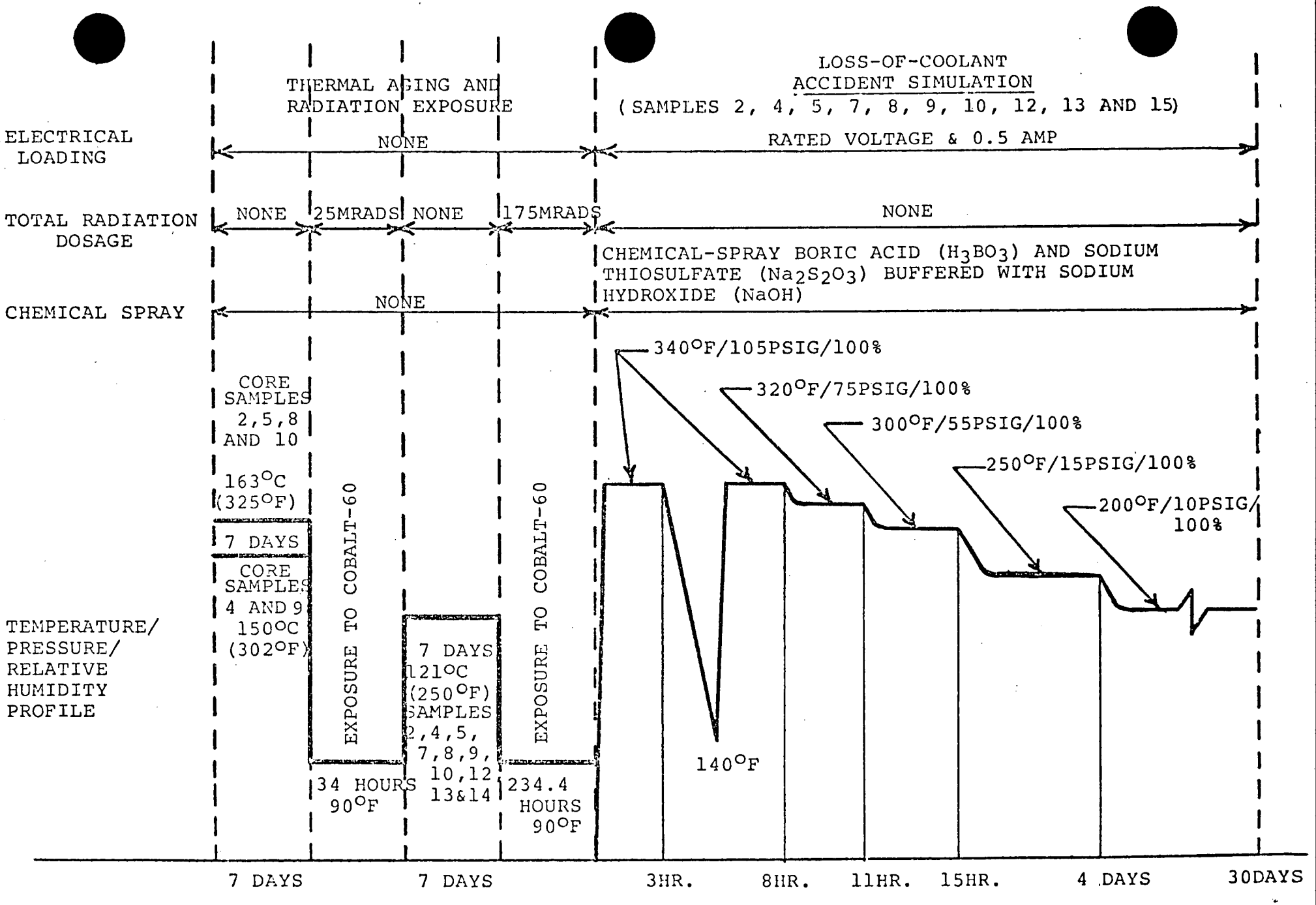
At the total test time of 30 days, the last set of insulation resistance readings were made and the system shutdown. The samples were removed from the vessel, inspected and measurements of insulation resistance made.

During the LOCA simulation exposure, the cable samples were electrically energized at a potential of 600 Vac and a current of 0.5 amperes. All the samples, except two, remained energized throughout the entire exposure period.

At an elapsed time of 17.2 hours conductors 21 and 22 of cable 11 were removed from the energizing circuitry because they shorted to ground. A short time later, at 19.5 hours elapsed time, conductor 13 of cable 7 shorted to ground and was removed from the energizing circuitry.

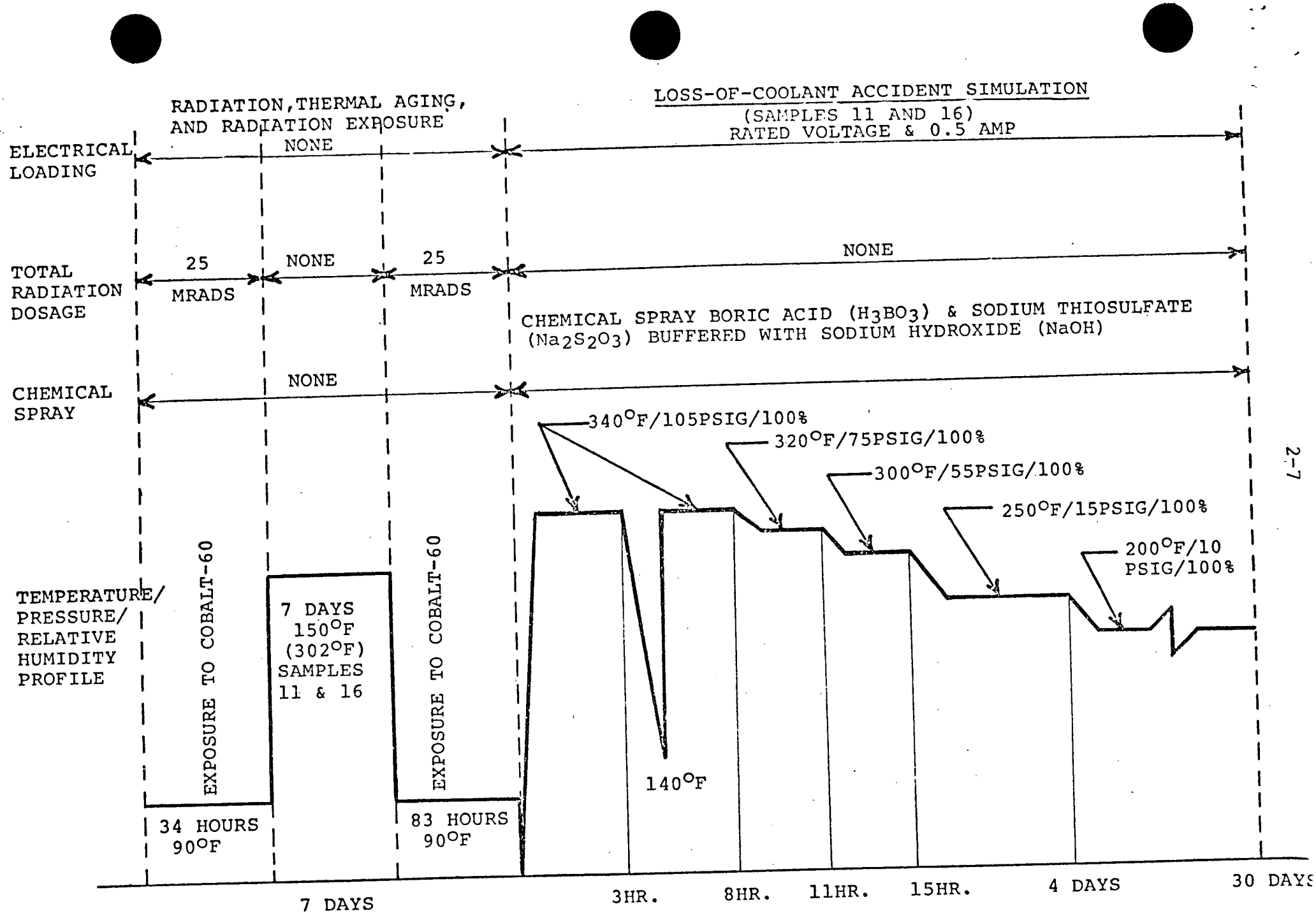
2.2.6 Phase VI - Post-LOCA Test

At the conclusion of the simulated LOCA event, the samples were removed from the mandrel, straightened and recoiled around a mandrel whose diameter was 40 times the cable diameter. While so wound, the cables were inspected for cracks and subjected to their rated a.c. voltage, twice their rated voltage and 80 Vac/mil as per IEEE 383.



PROFILE OF TEST PHASES FOR SAMPLES 2, 4, 5, 7, 8, 9, 10, 12, 13 AND 14

FIGURE 1 - IEEE 323 LOCA SIMULATION PROFILE



PROFILE OF TEST PHASES FOR SAMPLES 11 AND 16
FIGURE 2 - IEEE 323 LOCA SIMULATION PROFILE

SECTION 3. TEST PROCEDURE

3.1 Cable Mounting

The cable samples were mounted on holding rods positioned between two end cap flanges of two vertically held metal mandrels, approximately 20 and 14 inches in diameter. Tie wraps were used to secure the cables in position relative to the vertical rods of each mandrel. Approximately four feet of each cable end was brought up through head penetrations in the pressure vessel, sealed and connected to the energizing lead wire. Sealing was effected by securing the cable ends in aluminum tubes with an epoxy compound. The tubes were secured to the vessel by standard tube fittings.

3.2 Electrical Energizing and Interconnections

The cable ends were secured to terminal blocks mounted on the vessel head. The lead wires were used to connect the energizing switch box with the test cables at the terminal block on the vessel head. The switch box consisted of knife switches arranged so that each cable could be individually monitored, removed from the circuit if a failure occurred, or isolated during measurements of insulation resistance.

3.3 Measurements of Insulation Resistance (IR)

IR measurements were made periodically during the exposure cycle as a means of monitoring the relative performance of the test samples.

Specifically, the IR measurements were made at the following times during the program:

1. Upon receipt at Isomedix.
2. At the end of the first radiation aging period.
3. At the end of the thermal aging period.
4. At the end of the second radiation aging period.
5. At each dwell during the high temperature phases of steam/chemical exposure period.
6. Once each day during the four-day dwell.
7. Twice weekly during the balance of the 30-day steam/chemical exposure period.
8. At the conclusion of the exposure cycle.

The measurements were made after application of 500 Vdc for one minute, by reading between the conductor and ground.

During the steam/chemical exposure period, when IR measurements were taken, prior to actually making the IR measurements, the current and potential load was removed from the cables. At the conclusion of the IR measurements, the cables were put back into the circuit.

3.4 High Voltage Withstand Tests (HI-POT)

At the conclusion of the exposure period, the samples were removed from the vessel, straightened and wound around a mandrel having a diameter 40 times the cable diameter. Each conductor of a cable sample was, in turn, subjected to a potential relative to that conductor and the other conductor connected to the drain, which was at ground potential.

SECTION 4. TEST RESULTS

4.1 Insulation Resistance Measurements

Measurements of IR were made at the times previously mentioned in Section 3, and the results are shown in Table 2.

4.2 High Voltage Withstand Tests (HI-POT)

Table 3 represents the results of the HI-POT tests performed at the conclusion of the test program.

TABLE 2

MEASUREMENTS OF INSULATION RESISTANCE (1)

Elapsed Time Hrs.	Phase (2)	Temp. (°F)	2 Conductor 3	2 Conductor 4	4 Conductor 7	4 Conductor 8	5 Conductor 9	5 Conductor 10
	As Rec'd	72	1,000,000	900,000	1,500,000	1,700,000	3,000,000	2,200,000
	After 1st Rad'n	72	690,000	430,000	830,000	790,000	1,200,000	1,100,000
	After Thermal	72	2,700,000	2,500,000	3,000,000	3,500,000	3,000,000	3,000,000
	After 2nd Rad'n	72	160,000	160,000	240,000	240,000	300,000	300,000
1.2	LOCA	340	0.4 (3)	0.47 (3)	0.27 (3)	0.26 (3)	0.65	2.0
4.5	LOCA	195	240	170	190	200	400	290
6.5	LOCA	340	0.54	0.58	0.8	0.84	1.9	1.5
8.8	LOCA	320	0.9	0.84	1.5	1.8	3.7	2.8
11.7	LOCA	300	0.9	0.847	1.6	1.8	3.7	2.9
16.6	LOCA	250	0.9	0.89	1.8	1.9	3.6	2.9
19.5	LOCA	250	17	12	19	21	35	24
43.9	LOCA	250	19	4,600,000	20	4,500,000	37	26
69.8	LOCA	250	4,000,000	4,000,000	18	22	36	26
96.7	LOCA	200	50	38	50	54	78	58
142.2	LOCA	200	70	50	120	150	150	120
191.0	LOCA	200	54	52	120	150	140	120
283.5	LOCA	200	68	54	140	190	150	130
359.0	LOCA	200	69	66	150	200	150	130
478.4	LOCA	200	68	64	140	180	150	120
547.4	LOCA	200	80	75	130	160	150	110
641.9	LOCA	200	82	80	170	220	170	150
719.5	LOCA	200	60	55	100	120	56	50
	Post-LOCA		4,400	3,900	290,000	300,000	100,000	150,000
	Post-LOCA		3,000	90,000	300,000	300,000	140,000	160,000

Notes:
1. All measurements made at 500 Vdc, held for 1 minute, all resistance values in megohms.
2. Test phase per outline described in Section 2.
3. Measurement made at 100 Vdc.

TABLE 2

MEASUREMENTS OF INSULATION RESISTANCE (1)

Elapsed Time Hrs.	Phase (2)	Temp. (°F)	7 Conductor 13 (Black)	7 Conductor 14 (White)	8 Conductor 15	8 Conductor 16	9 Conductor 17	9 Conductor
	As Rec'd.	72	500,000	500,000	3,000,000	2,500,000	1,400,000	1,000,000
	After 1st Rad'n	72	370,000	360,000	1,250,000	900,000	580,000	1,200,000
	After Thermal	72	900,000	920,000	4,000,000	3,600,000	2,200,000	2,200,000
	After 2nd Rad'n	72	5	50,000	500,000	500,000	500,000	500,000
1.2	LOCA	340	0.5	0.51 (4)	10	5 (4)	0.02 (5)	350
4.5	LOCA	195	50	52	14,000	17,000	22,000	16,000
6.5	LOCA	340	0.28 (3)	0.55	11	50	420	350
8.8	LOCA	320	0.7	0.94	150	92	720	600
11.7	LOCA	300	0.7	0.94	140	94	720	700
16.6	LOCA	250	0.7	0.98	170	97	740	680
19.5	LOCA	250	(6)	5	2,200	480	35	1,600
43.9	LOCA	250	(6)	3,500,000	4,000,000	1,100	300	840
69.8	LOCA	250	(6)	5.4	640	780	940	1,300
96.7	LOCA	200	(6)	12	1,200	300	2,000	1,100
142.2	LOCA	200	(6)	28	5,200	70	1,800	2,200
191.0	LOCA	200	(6)	26	5,000	54	2,200	1,800
283.5	LOCA	200	0.012(7)	23	5,000	18	2,200	1,700
359.0	LOCA	200	0.006(7)	17	4,200	44	1,900	1,200
478.4	LOCA	200	0.019(7)	9	2,500	37	1,600	1,000
547.4	LOCA	200	0.015(7)	7.2	2,300	48	1,500	1,100
641.9	LOCA	200	0.0090(7)	6.4	4,200	33	2,600	1,200
719.5	LOCA	200	0.009 (7)	3.6	1,200	36	1,900	750
	Post-LOCA		0.028(7)	150	260,000	0.26(7)	440	1,100
	Post-LOCA		1,300	140	2,200	500,000	300	950,000

1. All measurements made at 500 Vdc, held for 1 minute, all resistance values in megohms.
2. Test phase per outline described in Section 2.
3. Measurement made at 100 Vdc.
4. Measurement made at 400 Vdc.
5. Measurement made with Simpson meter.
6. Conductor out of energizing circuit. No reading with megohmmeter.
7. Measurement made with Simpson meter. Conductor out of energizing circuit-LOCA exposure.

TABLE 2

MEASUREMENTS OF INSULATION RESISTANCE (1)

Elapsed Time Hrs.	Phase (2)	Temp. (°F)	10 Conductor 19	10 Conductor 20	11 Conductor 21	11 Conductor 22	12 Conductor 23	12 Conductor
	As Rec'd.	72	1,600,000	1,200,000	1,200,000	1,700,000	260,000	260,000
	After 1st Rad'n	72	1,200,000	1,200,000	1,400,000	1,320,000	170,000	200,000
	After Thermal	72	2,600,000	2,800,000	2,000,000	1,900,000	370,000	370,000
	After 2nd Rad'n	72	500,000	500,000	2,400,000	2,400,000	500,000	500,000
1.2	LOCA	340	300	400	17	22	28	28
4.5	LOCA	195	26,000	24,000	7,500	4,500	4,800	5,800
6.5	LOCA	340	320	440	17	7.8	11	11
8.8	LOCA	320	620	840	30	5	21	22
11.7	LOCA	300	700	800	32	5.6	21	22
16.6	LOCA	250	620	870	30	8	24	24
19.5	LOCA	250	4,900	8,200	(3)	(3)	260	280
43.9	LOCA	250	3,800	8,500	(3)	(3)	300	300
69.8	LOCA	250	2,800,000	8,500	(3)	(3)	2,800,000	3,500,00
96.7	LOCA	200	8,000	14,000	(3)	(3)	760	800
142.2	LOCA	200	15,000	20,000	(3)	(3)	2,500	2,700
191.0	LOCA	200	13,000	17,000	(3)	(3)	2,600	2,800
283.5	LOCA	200	14,000	19,000	0.014(4)	0.019(4)	2,900	2,900
359.0	LOCA	200	11,000	15,000	0.033(4)	0.031(4)	2,500	2,700
478.4	LOCA	200	7,800	9,200	0.0030(4)	0.030(4)	2,100	2,200
547.4	LOCA	200	7,800	9,000	0.0028(4)	0.060(4)	1,800	2,000
641.9	LOCA	200	13,000	16,000	0.0080(4)	0.080(4)	2,400	2,500
719.5	LOCA	200	6,400	7,900	0.0040(4)	0.070(4)	1,100	1,200
	Post-LOCA		340,000	430,000	0.016 (4)	4.5	190,000	190,000
	Post-LOCA		400,000	460,000	600,000	680,000	180,000	180,000

1. All measurements made at 500 Vdc, held for 1 minute, all resistance values in megohms.
2. Test phase per outline described in Section 2.
3. Conductor out of energizing circuit. No measurement with megohmmeter.
4. Measurement made with Simpson meter. Conductor out of energizing circuit during LOCA phase.

TABLE 2

MEASUREMENTS OF INSULATION RESISTANCE (1)

Elapsed Time Hrs.	Phase (2)	Temp. (°F)	13 Conductor 25	13 Conductor 26	14 Conductor 27	14 Conductor 28	16 Conductor 30
	As Rec'd	72	220,000	220,000	210,000	200,000	5,000,000
	After 1st Rad'n	72	190,000	210,000	167,000	175,000	3,100,000
	After Thermal	72	540,000	560,000	560,000	600,000	7,800,000
	After 2nd Rad'n	72	450,000	480,000	500,000	500,000	9,000,000
1.2	LOCA	340	370	340	300	340	62
4.5	LOCA	195	6,400	9,400	22,000	18,000	22,000
6.5	LOCA	340	15	15 (3)	260	280	58
8.8	LOCA	320	2,200	2,200	4,600	4,800	1,300
11.7	LOCA	300	2,200	2,200	4,600	4,800	1,300
16.6	LOCA	250	2,200	2,200	4,600	4,800	1,300
19.5	LOCA	250	270	200	4,900	5,000	1,500
43.9	LOCA	250	400	400	5,000	5,000	6,600,000
69.8	LOCA	250	320	300	5,000	5,000	0.64 (4)
96.7	LOCA	200	4,000	370	9,000	7,800	26
142.2	LOCA	200	7,900	7,400	17,000	12,000	3
191.0	LOCA	200	10,000	8,000	13,000	10,000	3,000
283.5	LOCA	200	15,000	7,600	16,000	14,000	5,200
359.0	LOCA	200	11,000	6,500	13,000	9,400	4,700
478.4	LOCA	200	6,200	6,200	8,200	6,000	3,500
547.4	LOCA	200	6,000	6,000	8,000	6,000	980
641.9	LOCA	200	12,000	11,000	15,000	12,000	780
719.5	LOCA	200	5,200	5,200	6,600	5,000	450
	Post-LOCA		260,000	110,000	310,000	150,000	19
	Post-LOCA		50,000	50,000	400,000	400,000	65,000

Notes
1. All measurements made at 500 Vdc, held for 1 minute, all resistance values in megohms.
2. Test phase per outline described in Section 2.
3. Measurement made at 100 Vdc.
4. Measurement made at 50 Vdc.

TABLE 3

RESULTS OF HIGH VOLTAGE WITHSTAND TEST PERFORMED AT CONCLUSION OF 30 DAY ENVIRONMENTAL EXPOSURE

CABLE/ CONDUCTOR	TIME VOLTAGE HELD (MINUTES)	APPLIED A.C. VOLTAGE (VOLTS)	LEAKAGE CURRENT (MA)* IN WATER
2/3	1	600	<50
2/4	1	600	<50
2/4	1	1200	<50
2/3	1	1200	<50
2/3	5	2400	<50
2/4	5	2400	<50
4/7	1	600	<50
4/8	1	600	<50
4/8	1	1200	<50
4/7	1	1200	<50
4/7	5	2400	<50
4/8	5	2400	<50
5/9	1	600	<50
5/10	1	600	<50
5/10	1	1200	<50
5/9	1	1200	<50
5/9	5	2400	<50
5/10	5	2400	<50
7/13	1	600	<50
7/14	1	600	<50
7/14	1	1200	<50
7/13	1	1200	<50
7/13	5	2400	<50
7/14	5	2400	<50
8/15	1	600	<50
8/16	1	600	<50
8/16	1	1200	<50
8/15	1	1200	<50
8/15	5	2400	<50
8/16	5	2400	<50
9/17	1	600	<50
9/18	1	600	<50
9/18	1	1200	<50
9/17	1	1200	<50
9/17	5	2400	<50
9/18	5	2400	<50

* No meter movement observed

TABLE 3

RESULTS OF HIGH VOLTAGE WITHSTAND TEST PERFORMED AT CONCLUSION OF 30 DAY ENVIRONMENTAL EXPOSURE

CABLE/ CONDUCTOR	TIME VOLTAGE HELD (MINUTES)	APPLIED A.C. VOLTAGE (MINUTES)	LEAKAGE CURRENT (MA)* IN WATER
10/19	1	600	<50
10/20	1	600	<50
10/20	1	1200	<50
10/19	1	1200	<50
10/19	5	2400	<50
10/20	5	2400	<50
11/21	1	600	<50
11/22	1	600	<50
11/22	1	1200	<50
11/21	1	1200	<50
11/21	5	2400	<50
11/22	5	2400	<50
12/23	1	600	<50
12/24	1	600	<50
12/24	1	1200	<50
12/23	1	1200	<50
12/23	5	2400	<50
12/24	5	2400	<50
13/25	1	600	<50
13/26	1	600	<50
13/26	1	1200	<50
13/25	1	1200	<50
13/25	5	2400	<50
13/26	5	2400	<50
14/27	1	600	<50
14/28	1	600	<50
14/28	1	1200	<50
14/27	1	1200	<50
14/27	5	2400	<50
14/28	5	2400	<50
16/30	1	600	<50
16/30	1	1200	<50
16/30	5	2400	<50

* No meter movement observed

SECTION 5. CONCLUSION

Cable Samples 2, 5, 8 and 10 successfully completed the 30 day LOCA simulation after exposure to a total accumulated dose of 200 megarads of Cobalt-60 gamma radiation, core conditioning at 163°C for 7 days and cable aging of 121°C for 7 days.

Cable Samples 4 and 9 successfully completed the 30 day LOCA simulation after exposure to a total accumulated dose of 200 megarads of Cobalt-60 gamma radiation, core conditioning at 150°C for 7 days and cable aging of 121°C for 7 days.

Cable Samples 7, 12, 13 and 14 successfully completed the 30 day LOCA simulation after exposure to a total accumulated dose of 200 megarads of Cobalt-60 gamma radiation and a conditioning of 121°C for 7 days.

Cable Samples 11 and 16 successfully completed the 30 day LOCA simulation after exposure to a total accumulated dose of 50 megarads of Cobalt-60 gamma radiation and a conditioning of 150°C for 7 days.

At the conclusion of the LOCA period, a high-voltage withstand test was performed with the cable samples wrapped around a mandrel whose diameter was 40 times the diameter of the individual cable. The high voltage a.c. withstand was performed in water. The samples successfully completed post-exposure a.c. high potential withstand tests for 1 minute at rated a.c. voltage, 1 minute at twice rated a.c. voltage and 5 minutes at 80 Vac/mil as per IEEE 383.

The difficulties experienced, during the LOCA simulation, with cables 7 and 11 were attributed to the means of sealing and securing of the cables where they passed through the penetrations in the pressure vessel.

SECTION 6. CERTIFICATION

The undersigned certifies that this report presents a true account of the test conducted and the results obtained.

Tejinder S. Sachdeva
Manager, Component Testing

APPENDIX A

RADIATION CERTIFICATION

ISOMEDIX

June 8, 1978

To : Tejinder S. Sachdeva
Manager, Component Testing

From : David P. Constantine
Radiation Production Manager

Subject: Radiation Exposure of Samuel Moore & Co. Cables, Phase I

This will summarize the parameters pertinent to the irradiation of 19 electric cable samples for Samuel Moore & Co. Reference Order A09581. Cable identification is noted elsewhere in your report.

The cables were placed in a corrugated carton and then placed in a Cobalt-60 gamma field such that the dose rate was .75 Megarads per hour. The cables were exposed for 34.0 hours yielding a minimum dose of 25.5 Megarads. The cables were rotated every 8.5 hours to obtain the most even dose distribution.

Dosimetry was performed using an Atomic Energy of Canada, Ltd. (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 in-house 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.

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 85°F, as indicated by previous measurements on an oil solution in the same relative position.

Irradiation was started on April 5, 1978, and completed on April 7, 1978. Following the first stage, the cables were returned to you for further testing.

David P. Constantine

David P. Constantine
Radiation Production Manager

DPC:km

ISOMEDIX

June 8, 1978

To : Tejinder S. Sachdeva
Manager, Component Testing

From : David P. Constantine
Radiation Production Manager

Subject: Radiation Exposure of Samuel Moore & Co. Cables
Phase II

This will summarize the parameters pertinent to the irradiation of 19 electric cable samples for Samuel Moore & Co. Reference Order A09581. Cable identification is noted elsewhere in your report.

Six (6) of the cables were placed in a corrugated carton and then placed in a Cobalt-60 gamma field such that the dose rate was 0.3 megarad per hour. The cables were exposed for 83 hours, yielding a minimum dose of 24.9 megarad. The cables were rotated approximately every 21 hours to obtain the most even dose distribution.

Thirteen (13) of the cables were placed in a corrugated carton and then placed in a Cobalt-60 gamma field such that the dose rate was 0.75 megarads per hour. The cables were exposed for 234.4 hours yielding a minimum dose of 175.8 megarads. The cables were rotated approximately every 59 hours to obtain the most even dose distribution.

Dosimetry was performed using an Atomic Energy of Canada, Ltd. (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 in-house 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.

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 85°F, as indicated by previous measurements on an oil solution in the same relative position.

Irradiation was started on April 20, 1978, and completed on April 25, 1978 (6),and May 4, 1978 (13), respectively.

Following completion of Phase II, the cables were returned to you for your disposition.

David P. Constantine
Radiation Production Manager

DPC:km

APPENDIX B

ISOMEDIX TEST EQUIPMENT LIST

ISOMEDIX TEST EQUIPMENT LIST

Name	Manufacturer	Model	S/N	Range	Accuracy	Calibration Frequency
Dead Weight Pressure Tester	Amthor Inst. Co.	460	14233	0-300 Psi	0.1%	Annually
Pyrotest	Gulton	9-B		Room Temp to 570°F	0.17% of Span	Prior to Test
Temp. Recorder	Westronics	RM11B	1435	0-400°F	±2.5 % of Span	Prior to Test
Pressure Recorder	Westronics	RM11B	1434	0-150 psig	±2.5 % of Span	Prior to Test
Air Gages	U.S. Gage (3)			0-200	1% of Span	Prior to Test
Thermocouples	Omega Eng.	Type T			3/4%	Prior to Test
Hi-Pot Tester	Bendix, Inc.	60B4-1-A		0-10,000 Vac or Vdc	±2% ±2%	Annually
Megohmeter	General Radio	1864	5652	10-1090Vdc .5-2x10^{14}ohm	±2%	Annually
Multimeter	Simpson	260		0-20 Mohm	±2°of scale ARC	Annually
Temp.Recorder	Esterline-Angus	E1124E		0-400°F	±0.25% of Span	Annually
Amprobe	Amprobe Instruments			0-6/15/40/100 Amps	±3% Full Scale	Annually

ISOMEDIX TEST EQUIPMENT LIST

SUPPORT EQUIPMENT

	NAME	SERIAL #
CLOCKS	Cramer	1948
	Meylan	161
	Edwards	248
DOSIMETERS	Eon	4274
	Johnson	617
	Jordan	2241
	Victoreen	HCM IM

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ISOMEDIX

September 19, 1978

Samuel Moore and Company
Dekoron Division
Aurora, Ohio 44202

Gentlemen:

This letter forms an addendum to our June 1978 report for 12 cables tested for Samuel Moore and Company for qualification by sequential exposure to Thermal Aging, Radiation and Steam/ Chemical loss-of-coolant accident (LOCA) environment.

Six of the 12 cables, labelled 5, 7, 10, 12, 13 and 14, were subjected to further tests of a 70 day extension of the steam/ chemical loss-of-coolant accident (LOCA) environmental exposure and post-LOCA high voltage withstand tests.

The cables were coiled around a 20 inch diameter mandrel and placed in a pressure vessel. The cable ends were brought out through the head penetrations of the vessel and secured in the penetrations by epoxy filled tubes. The odd and even conductors of the cables were connected in two series circuits for energizing at a potential of 600 Vac and current loading of 0.5 amperes.

Strip heaters were mounted on the sides of the vessel and piping was installed for the spraying and circulation of a chemical solution. This chemical solution consists of 3000 ppm boron as boric acid in solution with 0.064 molar sodium thiosulfate buffered with sodium hydroxide to a pH between 9 and 11 at room temperature. The spray rate was to be approximately 2 gallons per minute (gpm) corresponding to 0.15 gpm/ft^2 of the surface area of the mandrel.

The temperature inside the vessel during the 70 days was maintained at 200°F. An air supply was used to provide 10 pounds of pressure during this period.

Before starting the 70 day LOCA extension, Insulation Resistance (IR) of each conductor of the six cables was measured. The measurement was made after applying 500 Vdc for one minute by reading between the conductor and ground.

To initiate the 70 day extension, the cables were energized at 600 volts and 0.5 amps, the heaters were turned on and the inside of the vessel was heated to 200°F. When the vessel reached 200°F the chemical-spray and an elapsed time clock were started. Also, at the same time, the air supply was turned on to obtain the 10 pounds of pressure on the inside of the vessel.

During the 70 day extension, one noteworthy event occurred. At approximately 67.1 hours elapsed time, cable 5 conductor 9 and cable 7 conductors 13 and 14 shorted to ground thus causing the leakage current protection fuses to blow. These conductors were removed from the electrical energizing circuitry as the points of breakdown could not be isolated and corrected.

The conductors of cables 10, 12, 13 and 14 and conductor 10 of cable 5 remained energized, throughout the entire 70 day extension period, at 600 volts A.C. and 0.5 amps.

When the insulation resistance measurements were made during the extension period, the cables were removed from the energizing circuitry. Measurements of IR were made once a week during the exposure and at the end of the exposure period. Table I-1, attached, contains the IR values recorded.

At the conclusion of the LOCA exposure period, the mandrel (containing the cables) was removed from the vessel. The six cables were unwound from the mandrel, straightened, and rewound on another mandrel having a diameter 40 times the cable diameter. The cables were inspected and their jackets, except for cable 12, were observed to be intact. Cable 12's jacket was found to have a crack. The mandrel was then immersed in water at room temperature and the cable ends were kept out of the water. After stabilizing for a few minutes, the cables, except cable 12, were subjected to high voltage withstand tests at 600, 1200 and 2400 volts A.C. for periods of 1, 1 and 5 minutes, respectively. Cable 12 was subjected to high voltage withstand tests at 600, 1200 and 3600 volts A.C. for periods of 1, 1 and 5 minutes, respectively. Cable samples 5, 7, 10, 12 and 13 completed post LOCA exposure A.C. high potential withstand test for 1 minute at rated voltage, 1 minute at twice rated voltage and 5 minutes at 80 VAC/mil as per IEEE 383. Both legs 27 and 28 of cable sample 14 completed the post LOCA exposure AC high potential withstand test for 1 minute at rated voltage and 1 minute at twice rated voltage. Leg 27 held 2400 volts A.C. or 80 Vac/mil for 5 minutes and leg 28 held 2400 volts A.C. or 80 Vac/mil for 2 minutes and 20 seconds. It can be concluded that cable sample 14 demonstrates cable functionality. The results of the voltage withstand tests are in the attached Table I-2.

Since the dielectric withstand test results were satisfactory on samples 5 and 7, it can be concluded that the difficulties experienced during the 70 day LOCA extension can be attributed to the

termination procedures for lead wires penetrating the pressure vessel openings rather than the conductors inside the vessel. From the above results it can be concluded that cable samples 5, 7, 10, 12, 13 and 14 successfully completed the 70 day LOCA extension.

At the completion of the exposure period and all testing, the six cables and the potted aluminum tubes were shipped to Samuel Moore and Company, Aurora, Ohio.

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

Tejinder S. Sachdeva /RJP

Tejinder S. Sachdeva
Manager, Component Testing

Attachments
JP:km

TABLE I-1

MEASUREMENTS OF INSULATION RESISTANCE (1)

psed e Hrs.	Temp. °F	Pressure PSIG	Cable 5 Conductor 9	Cable 5 Conductor 10	Cable 7 Conductor 13	Cable 7 Conductor 14	Cable 10 Conductor 19	Cable 10 Conductor 20
0	80	0	4,400	4,000	160	88	3,600	3,000
3.0	200	10	52	150	4.3	1.6	3,800	4,100
67.1	200	10	100*	1.7	25,000*	550*	6,500	6,800
243.0	200	10	60*	130	100,000*	10,000*	4,000	4,500
430.4	200	10	62*	120	150,000*	12,000*	4,100	4,400
651.0	200	10	60*	92	0.058+	7,600*	3,500	3,600
816.6	200	10	65*	84	90,000*	14,000*	2,800	2,800
006.4	200	10	63*	72	75,000*	19,000*	3,500	3,500
154.4	200	10	70*	60	105,000*	18,000*	2,800	2,400
320.5	200	10	180*	57	13,000*	36,000*	3,400	3,500
464.3	200	10	90*	50	21,000*	15,000*	3,500	3,700
633.4	200	10	100*	50	18,000*	16,000*	3,000	3,000
t-70 Day	76	0	6,500*	14,000	1.6*	36,000*	280,000	200,000

- Measurements made at 500 Vdc, held for 1 minute, all resistance values in megohms.

- Measurement in ohms made with Simpson meter.

- Measurement made at 30 Vdc, held for 1 minute, resistance values in megohms.

TABLE I-1

MEASUREMENTS OF INSULATION RESISTANCE (1)

Elapsed Time Hrs.	Temp. °F	Pressure PSIG	Cable 12 Conductor 23	Cable 12 Conductor 24	Cable 13 Conductor 25	Cable 13 Conductor 26	Cable 14 Conductor 27	Cable 14 Conductor
0	80	0	1,400	1,600	4,000	5,000	4,000	4,400
3.0	200	10	1,700	1,900	3,500	5,200	4,500	5,000
67.1	200	10	2,000	2,700	6,500	10,000	8,000	9,000
243.0	200	10	1,600	1,800	4,000	1,500	5,200	5,600
430.4	200	10	1,500	1,800	4,600	1,800	5,000	5,600
651.0	200	10	1,450	1,600	2,400	500	5,000	5,300
816.6	200	10	1,200	1,500	3,000	300	450	4,500
1006.4	200	10	1,300	1,400	3,000	150	940	50,000
1154.4	200	10	700	900	1,500	300	1,000	3,400
1320.5	200	10	520	500	2,100	420	560	4,100
1464.3	200	10	260	350	2,500	150	480	4,500
1633.4	200	10	150	120	1,500	300	500	3,000
Post-70 Day	76	0	250	180	20,000	140	450	8,000

1 - Measurements made at 500 Vdc, held for 1 minute, all resistance values in megohms.

* - Measurement in ohms made with Simpson meter.

TABLE I-2

RESULTS OF HIGH VOLTAGE WITHSTAND TEST PERFORMED AT CONCLUSION OF 70 DAY EXTENSION OF ENVIRONMENTAL EXPOSURE

Cable/ Conductor	Applied A.C. Voltage (Volts)	Time Voltage Held (Minutes)	Leakage Current in Water (MA)*
5/9	600	1	<50
5/10	600	1	<50
5/10	1200	1	<50
5/9	1200	1	<50
5/9	2400	5	<50
5/10	2400	5	<50
7/13(B)	600	1	<50
7/14(W)	600	1	<50
7/14	1200	1	<50
7/13	1200	1	<50
7/13	2400	5	<50
7/14	2400	5	<50
10/19	600	1	<50
10/20	600	1	<50
10/20	1200	1	<50
10/19	1200	1	<50
10/19	2400	5	<50
10/20	2400	5	<50
12/23	600	1	<50
12/24	600	1	<50
12/24	1200	1	<50
12/23	1200	1	<50
12/23	3600	5	<50
12/24	3600	5	<50
13/25	600	1	<50
13/26	600	1	<50
13/26	1200	1	<50
13/25	1200	1	<50
13/25	2400	5	<50
13/26	2400	5	<50
14/27	600	1	<50
14/28	600	1	<50
14/28	1200	1	<50
14/27	1200	1	<50
14/27	2400	5	<50
14/28	2400	2:20	<1000

* No meter movement at 50 MA.