CERTIFIED TEST REPORT
NO. 375-02

QUALIFICATION TEST REPORT
on
EXANE II CONTROL and INSTRUMENTATION CABLE
under
SIMULATED LOCA/DBE by SIMULTANEOUS EXPOSURE
to
ENVIRONMENTS of STEAM/CHEMICAL SPRAY and GAMMA RADIATION

MARCH, 1975

performed for:

ITT SURPRENANT DIVISION
CLINTON, MASSACHUSETTS 01510

by

COMPONENT TESTING DIVISION
ISOMEDIX, INC.
PARSIPPANY, NEW JERSEY

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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."

One 7/c-12 AWG control cable and one 2/c-16 AWG shielded instrumentation cable, both unaged, were subjected to a 7 day simultaneous thermal/radiation aging exposure, followed by a 30 day simultaneous exposure to environments of radiation steam and chemical spray, while electrically energized at rated voltage and current loading. This loading consisted of a potential of 600 volts (a.c.) between conductors and a current of 21 Amps on the 7/c cable, and 15 Amps on the two conductor shielded cable.

Approximately 35 feet of each cable was subjected to the exposure environments. The samples were irradiated in a cobalt-60 field of gamma radiation at a rate resulting in a total accumulated exposure of 200 megarads, air equivalent, over the entire test period.

Measurements of insulation resistance were made periodically during the exposure period at 500 volts (d.c.). High voltage withstand tests were conducted at the end of the exposure period following a 40 diameter mandrel bend test with the cables immersed in water.

Both samples survived the entire test exposure and successfully withstood the hi-pot test at the end of the program. The test program was conducted during February and March of 1975 at the test facilities of Isomedix, Inc., in Parsippany, New Jersey.

2. Description of Cable Samples

The samples were wound in coils approximately 20 inches in diameter and were thirty-six feet long. The 7/c cable was identified as sample number 20 and the 2/c cable as number 21.

The samples are further identified as follows:

Sample No. 20

Seven-Conductor #12 AWG Control Cable 600 Volts

12 AWG 7/.0305 tinned copper, .030"nominal Exane II insulation, twisted, silicone glass barrier tape .005, .065 nominal Exane jacket.

Sample No. 21

Two-Conductor #16 AWG Signal Cable 600 Volts

16 AWG 7/.0192 tinned copper, .030 nominal Exane II insulation twisted, with a 7/.0152 bare copper drain wire, 2 mil aluminum mylar tape shield, with one .083 fiberglass filler, silicone glass barrier tape .005, .045 nominal Exane jacket.

3. Test Program

3.1 Discussion

3.1.1 Phase I - Thermal/Radiation Aging

The cable samples were installed inside a pressure vessel and placed in a radiation chamber and subjected to a seven day thermal/radiation aging environment with the temperature inside the vessel maintained at 300^{o}F. Radiation was from a cobalt-60 source of gamma radiation at an exposure rate resulting in an accumulated, equivalent air, dose of 50 megarads during this period.

3.1.2 Phase II and III - LOCA Simulation and Post-LOCA Cooldown

At the conclusion of this simulated installed-life aging cycle, the samples were exposed to a simulated loss-of-coolant accident (LOCA) environment by simultaneous application of radiation/steam and chemical-spray for a period of 30 days in accordance with the temperature profile shown in Figure A1 of Appendix A of IEEE 323 and as shown on Figure 1. The samples were continuously sprayed with a chemical solution consisting of 3000 ppm boron as boric acid in solution with 0.064 molar sodium thiosulfate and buffered with sodium hydroxide to a pH between 9 an 11 at room temperature. The spray rate was approximately 2 gpm corresponding to 0.15 gpm/ft^2 of the surface area of the mandrel.

The cable samples received an additional radiation dose of 150 megarads, air equivalent, during this portion of the test program.

3.1.3 Post-LOCA Tests

At the conclusion of the simulated LOCA event, the vessel was taken out of the radiation chamber, 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, immersed in water and subjected to high voltage withstand tests at 80v/mil (a.c.) of insulation.

4. Test Procedure

4.1 Cable Mounting

The cable samples were mounted on holding rods positioned between two end cap flanges of a vertically held metal mandrel, approximately 20 inches in diameter. Steel wire was used to hold the cables in position relative to the vertical rods. Approximately four feet of each cable end was brought up through the middle of the mandrel. These ends were brought 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.

4.2 Electrical Energizing and Interconnections

The cable ends were secured to terminal blocks mounte' on the vessel head. The lead wire, supplied by ITT, connected the energizing switch box with the test cables at the terminal block on the vessel head. The switch box contained knife switches arranged so that the cables could be individually monitored, removed from the circuit if a failure occured, or isolated during measurements of insulation resistance.

Figure 2 is a schematic diagram showing the energizing circuitry and cable connections.

4.3 Dose Uniformity

Dose uniformity was obtained by repositioning the cobalt-60 source at various stages throughout the exposure cycle and by rotating the vessel. Rotation was performed 3½ days after initiating the seven day thermal/radiation aging and again fifteen days after the initiation of the steam exposure cycle.

Appendix A contains the certification of radiation exposure and describes the dose distribution and source positioning.

4.4 Measurements of Insulation Resistance (IR)

IR measurements were made peridically during the exposure cycle as a means of monitoring the relative electrical degradation of the samples.

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

1. Upon receipt of samples, prior to radiation aging.

2. Halfway through the seven day thermal/radiation aging period.

3. At the end of the thermal/radiation aging period.

4. At each dwell during the high temperature phases of the Steam/Chemical/Radiation exposure period.

5. Once each day during the four day dwell at 265^{o}F.

6. Twice per week during the balance of the 30 day period and at the conclusion of the exposure cycle.

The measurements were made after application of 500 Vdc held for one minute, unless specifically noted, by reading the odd conductors against the even conductors for the 7/c cable and between each conductor separately, and both conductors against the shield for 2/c cables.

Prior to actually making the measurements, the current and potential load were removed for approximately ten to fifteen minutes. At the conclusion of the IR measurements, the cables were put back into the circuit.

4.5 High Voltage Withstand Tests (hi-pot)

At the conclusion of the environmental exposure period, the samples were removed from the vessel, straightened and wound around a mandrel having a diameter 40 times the cable diameter.

The samples, while wound on the mandrel, were immersed in water with the ends free. The required test voltage was 80 v/mil (a.c.) of primary insulation thickness, in accordance with section 2.4.4 of IEEE 383-1974.

The procedure for performing these tests was as follows:

a) 2/c-shielded cable - one conductor connected to high voltage lead and other conductor connected to ground wire; each conductor, alternately, connected to high voltage lead with the shield grounded.

b) 7/c cable - odd conductors taken together to high voltage lead and even conductors taken together and grounded; all conductors taken together to high voltage lead against ground wire.

The specified voltage level was applied for a period of 5 minutes after which time the charging current was recorded.

5. Test Results

5.1 Actual Temperature Profile

5.1.1 Thermal/Radiation Aging

The temperature profile obtained during the actual test phases is shown in Figure 3. The test was initiated by energizing the cables and placing the cobalt source in position.

Strip heaters on the vessel were turned on approximately 1½ hours before actually starting to raise the temperature from room ambient. The vessel temperature was 240°F at the start and increased to 311°F within the next half hour. Heat from the cable current load raised the temperature to a maximum of 334°F 43 hours after starting. Heater controls and current loads were adjusted so that the temperature remained at 300 $\pm\frac{10}{5}$°F throughout the remainder of the seven day period. Three and one-half days after starting, the system was shut down so that IR measurements could be made and the vessel rotated.

The thermal/radiation aging exposure period was concluded after 168 hours had elapsed and 50 megarads, equivalent air dose, had been received. The system was shut down in order for the temperature to return to ambient prior to starting the next exposure period.

5.1.2 Phase II and III - LOCA Simulation and Post-LOCA Cooldown

At the start of the steam exposure, the cables were energized and the ambient temperature was 152°F. The cobalt source remained down until the exposure was underway.

To initiate the exposure, steam was rapidly admitted causing the temperature to rise to 280°F within twelve seconds and to 346°F within 5.4 minutes. The spray was turned on within one minute of starting at a rate of 2.5 gpm and was recirculated within seven and one-half minutes. The spray solution pH was between 9.5 and 10.5.

At an elapsed time of thirteen minutes, a pressure fitting blew out causing a rapid drop in pressure to atmospheric. The fitting was repaired, the penetration resealed and the test resumed.

The test was restarted with a slow rise in temperature and pressure reaching 346°F within 6.3 minutes.

The radiation source was raised and the exposure resumed. One and one-half hours after starting, the power was turned off to make IR measurements. At the end of the measurement period, the cables were re-energized.

At an elapsed time of 171.0 hours (ET) from the start of the thermal/radiation aging (corresponding to an ET of 3.0 hours from the start of the simultaneous exposure), the specified drop to 140°F was begun. This drop was completed by an ET of 172.8 hours. Preparations were made to initiate the second transient. The cable energizing was checked and remained on; the spray remained on and the temperature was stabilized at 138°F. Steam was again rapidly admitted increasing the temperature to 280°F within 32 seconds and to 346°F within 2.6 minutes.

The remainder of the temperature profile was followed, as shown on Figure 3.

At an ET of 527.5 hours, the system was shut down and the vessel rotated 180° to maintain uniformity of the dose distribution.

At an ET of 887.5 hours (37 days total test time), the last set of readings were made and the system shut down. The vessel was removed from the cell, the samples removed from the vessel, inspected and measurements of withstand voltage made.

5.2 Performance of Test Cables

The cables were electrically energized at a potential of 600 Vac between conductors throughout the entire exposure period except during vessel rotation and periods when IR measurements were made.

The current loads were maintained within ± 5% of their test values, 21 Amps on cable 20 and 15 Amps on cable 21, except when these values were lowered during the seven day thermal/radiation aging period in order to control the vessel ambient temperature.

5.3 Insulation Resistance Measurements

Measurements of IR were made at the times previously mentioned and the results are shown in Table 1 as a function of the vessel temperature.

5.4 High Voltage Withstand Tests (Hi-pot)

Table 2 presents the results of the hi-pot tests performed at the conclusion of the test programs.

6. Conclusion

A 7/C #12 AWG and a 2/C #16 AWG shielded cable, manufactured by ITT Surprenant Division, were subjected to a simulated Loss-of-Coolant Accident (LOCA) test program based on the guidelines of IEEE 323-1974 and 383-1974.

The cables were subjected to a 7 day simultaneous thermal/radiation aging exposure, followed by a 30 day simultaneous exposure to environments of radiation, steam and chemical-spray while electrically energized at rated voltage and current loading. The cables received a total of 200 megarads radiation dose during the exposure that included two rapid temperature rises to 346°F and two 3-hr dwells at 346°F.

The insulation resistance was retained throughout the exposure, and the samples withstood a combination bend and high-potential withstand test (at 2.4 and 4.8 kVac) at the conclusion of the test program.

The cables demonstrated satisfactory performance throughout the simulated LOCA exposure and the Post-LOCA cooldown period. The inclusion of two LOCA transients in the temperature profile and the final bend/voltage-withstand test demonstrated that the cables withstood the test conditions, with margin, as suggested in the referenced IEEE documents.

7. Certification

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

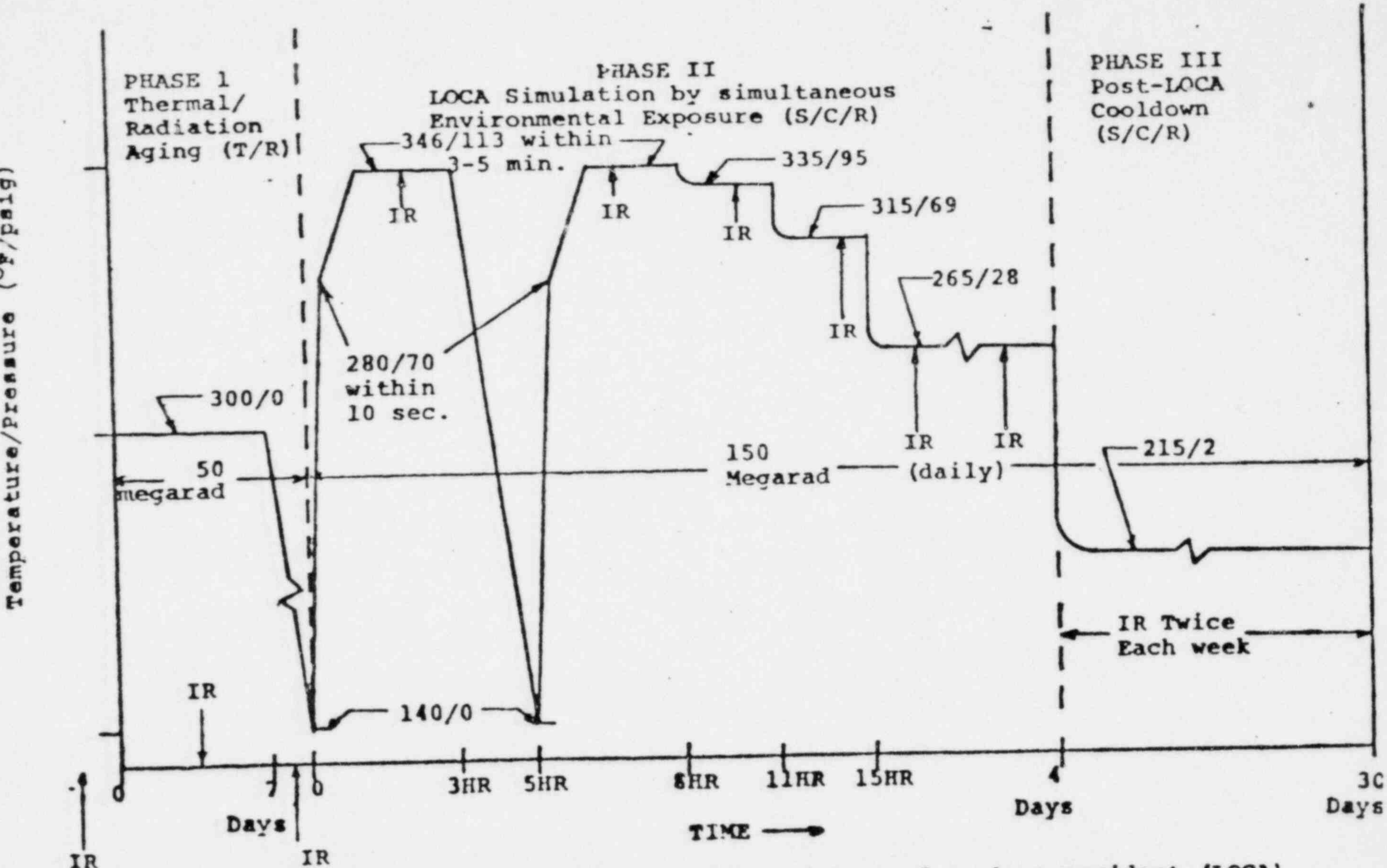
Questions relating thereto should be addressed to same.

Nissen M. Burstein
Manager, Component Testing

SONYA R. SAPOSNIK
NOTARY PUBLIC OF NEW JERSEY
My Commission Expires March 18, 1979

FIGURE 1

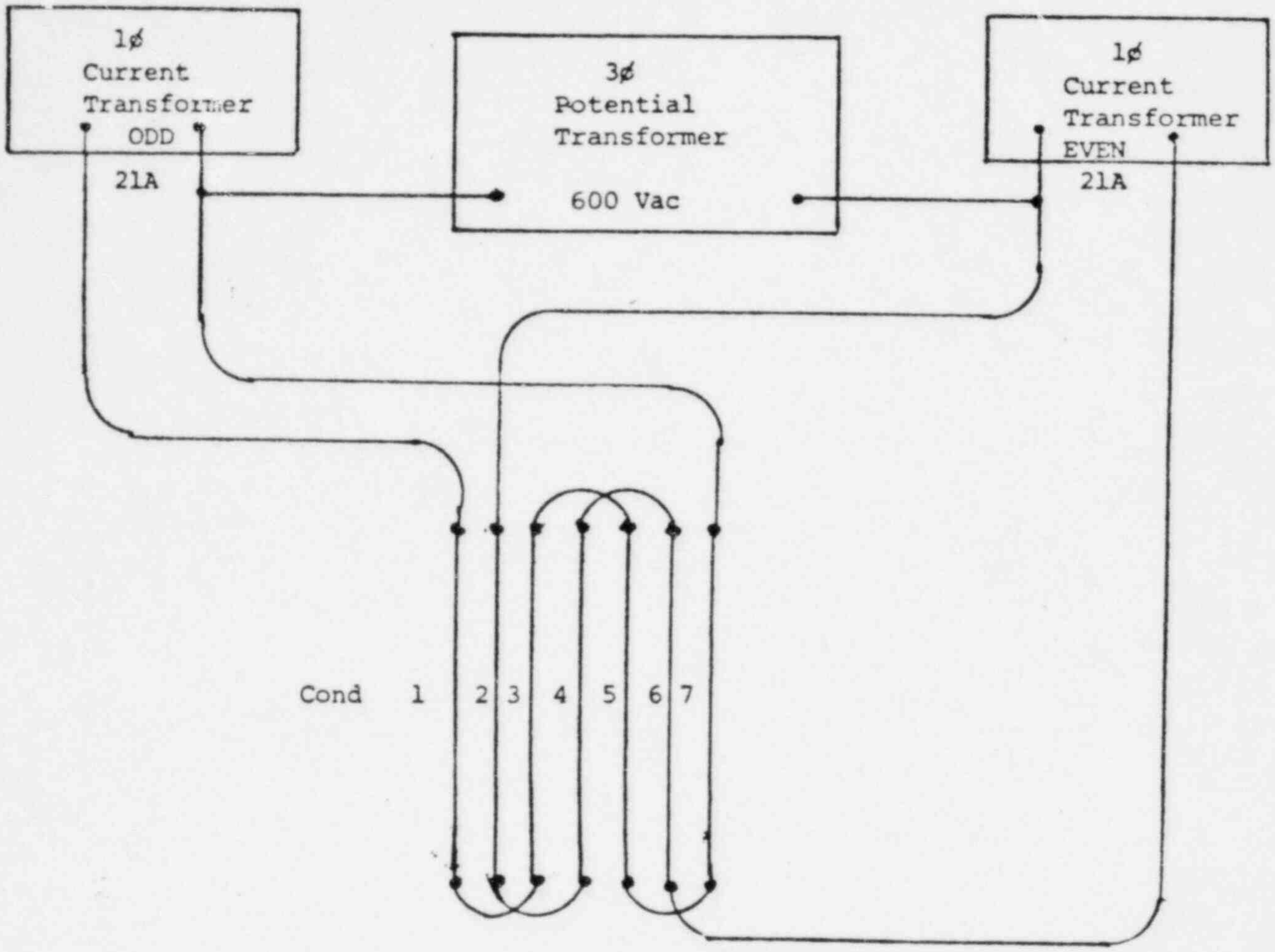
Fig. 1: Temp/Pressure Profile



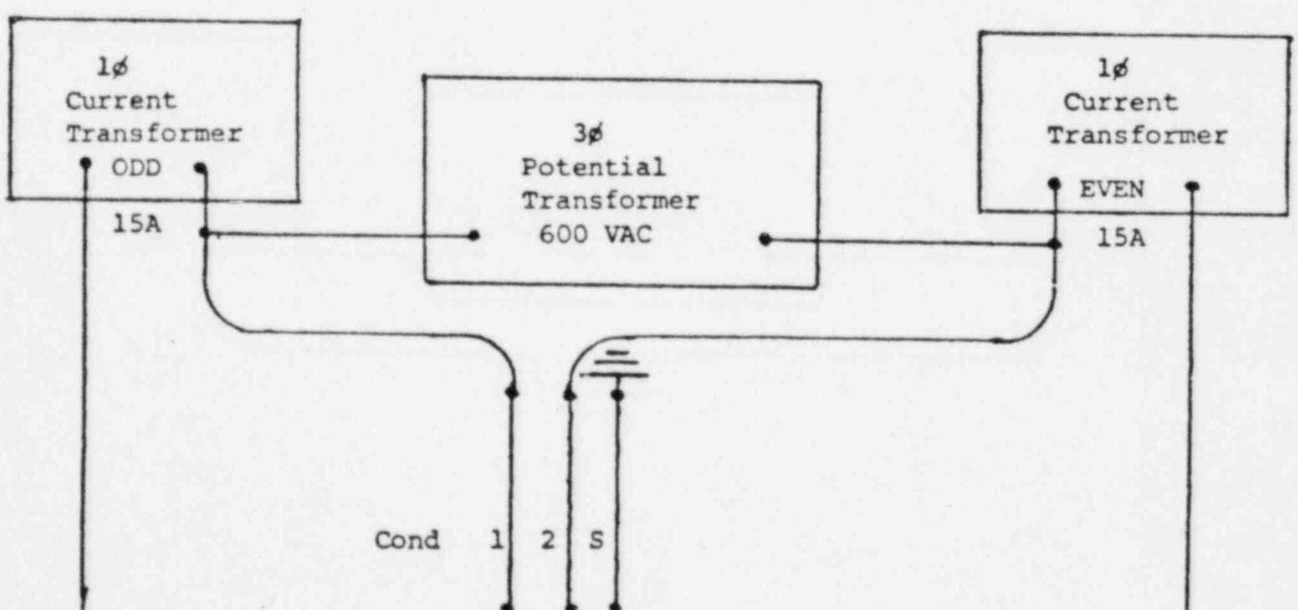
Temperature/pressure profile for simulation of loss-of-coolant accident (LOCA) design basis event (DBE) by simultaneous steam/chemical-spray/radiation environmental exposure (after IEEE 323-1974 figure A1 of Appendix A)

Isomedix Inc.

Fig. 2: SCHEMATIC REPRESENTATION OF ENERGIZING CIRCUITRY



CABLE NO. 20 - 7/C #12 AWG



CABLE NO. 21 - 2/C #16 AWG SHLD.

FIGURE 3 ACTUAL TEMPERATURE PROFILE OBTAINED DURING LOCA SIMULATION

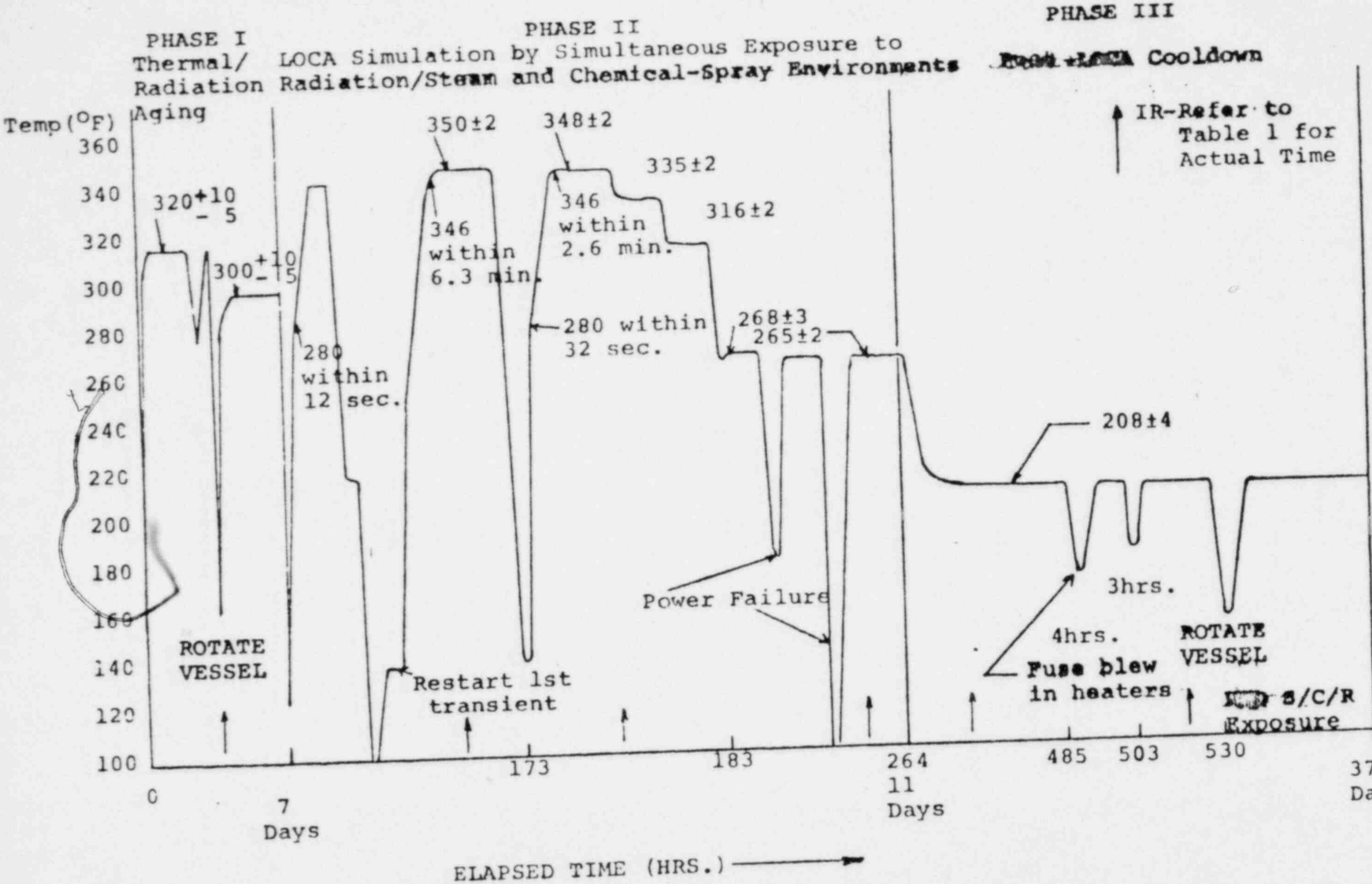


TABLE 1

MEASUREMENTS OF INSULATION RESISTANCE (1)

Elapsed Time (hrs.)	Phase	Temp. (^{o}F)	PSIG	Cable Samples (3) 21 (2/c)		Cable Samples (3) 20 (7/c)
-	Pre-Test	68	0	45×10^5	13×10^5	9×10^5
84.1	I	320	0	3.2×10^2	1.65×10^2	2×10^2
168.1	Post I	160	0	7.4×10^2	4×10^2	9×10^2
170.4	II	354	102	7.8	3.8	11
174.4	II	353	102	1.35×10^1	8.5	1.25×10^1
177.5	II	335	75	3.0×10^1	1.45×10^1	2.15×10^1
180.6	II	315	55	5.4×10^1	2.4×10^1	2.85×10^1
183.5	II	265	18	2.5×10^2	1.35×10^2	8.0×10^1
198.2	II	265	18.5	4.2×10^2	2.1×10^2	1.6×10^2
222.5	II	265	13	2.6×10^2	1.32×10^2	12×10^1
246.3	II	268	19	2.5×10^2	1.3×10^2	1.1×10^2
265.5	III	212	4.5	9.9×10^2	5.2×10^2	7.0×10^2
384.3	III	205	1.3	5.0×10^2	3.3×10^2	3.6×10^2
510.0	III	200	1	8.1×10^2	4.6×10^2	7.2×10^2
582.0	III	205	2.5	1.8×10^3	12×10^2	7.5×10^2
678.1	III	205	4.5	2×10^3	14×10^2	10×10^2
750.8	III	202	11	1.93×10^3	11×10^2	8×10^2
846.5	III	203	9	2.05×10^3	1.08×10^3	8×10^3
887.5	III	206	9	2×10^3	12×10^2	7.9×10^2

(1) All measurements made at 500 Vdc, held for 1 minute, and all resistance values in megohms, unless otherwise noted.

(2) Elapsed Time (ET) total test time from the start of T/R aging.

(3) Sample 21 read between conductors first then between the shield against the conductors taken together; Sample 20 read taking odd conductors against the even conductors.

TABLE 2

Results of Hi-Pot Tests at Conclusion of 37 Day Environmental Exposure

Sample No.		Voltage Required	(KVAC) Actual	Charging Current (MA)	Comments
20(7/c)	1,3,5,7, to 2,4,6	4.8	4.8	10	Hold for 5 min.
	All cond to gnd	4.8	4.8	0	Held for 5 min.
21(2/c)	cond 1-to-cond 2	4.8	4.8	0	Held for 5 min.
	cond 1-to-shld	2.4	2.4	0	Held for 5 min.
	cond 2-to-shld	2.4	2.4	0	Held for 5 min.

ISOMEDIX

APPENDIX A

RADIATION CERTIFICATION

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ISOMEDIX

May 8, 1975

Inter Company Memo

To: Nissen M. Burstein
Manager, Qualification Testing

From: George R. Dietz
Manager, Service Irradiation

This will summarize the parameters pertinent to the recent simultaneous steam, chemical spray and radiation exposure test conducted for ITT Surprenant.

Irradiation for the Phase I 7 day test was begun on February 14, 1975 and concluded on February 22, 1975. During Phase I, the cables received a minimum dose of 52.5 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 details of source positioning, dose rates and total dose is shown in Figure 1.

Phase II of the test began on February 22, 1975 and concluded on March 27, 1975. During the approximately 720 hour radiation exposure, with simultaneous steam/chemical spray per your profile, cables received an additional minimum dose of 148.9 Mrad and maximum dose of 155.2 Mrad. The details of irradiation are shown in Figure 2.

In summary, total dose to the cables over the entire test period ranged from 201.4 to 209.2 Mrad, with an estimated source positioning error of ± 5% in dose rate.

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 whose calibrations are traceable to the U.S. National Bureau of Standards. Backup dosimetry using a Red Perspex system provided by Atomic Energy of Canada, Ltd. confirmed the Victoreen readings.

George R. Dietz
George R. Dietz
Manager, Radiation Services

Enclosures
GRD:km

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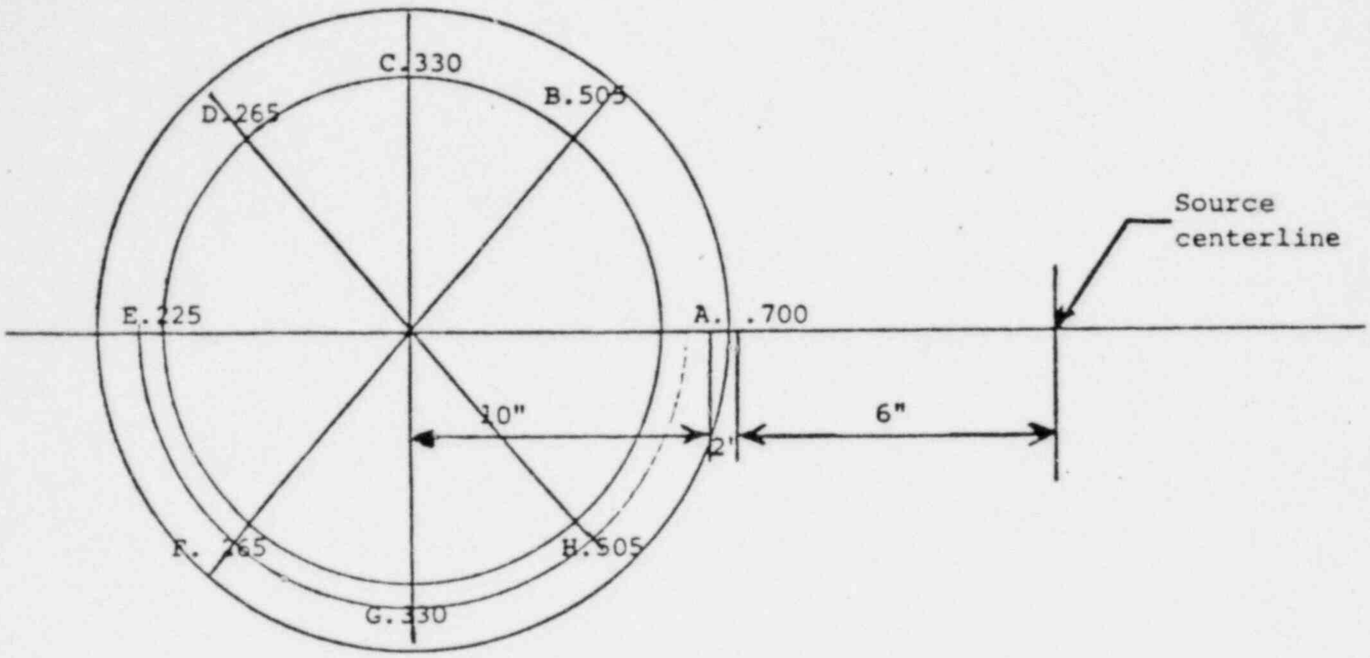
Fig.A-1 Dose - 50 Mrad

Dose Rates and Total Dose



Numbers on figure represent dose rates (kilorad/hr) at lettered points when the source is located as shown, relative to the cables.

Irradiation was conducted by locating the source at 4 quadrants of the irradiation chamber, with a typical location shown above. When equal irradiation times are administered in each of the source locations, the average dose rate at a point is the average of the sum of the dose rates received in each position. Rotation of the vessel and positioning the source in two quadrants each time had the same effect as if the source were relocated four times.

Average Dose rates at A,C,E and G are:

$1/4\sum A,C,E,G = 1/4\sum 700+330+330+225 = \frac{1585}{4} = 396$ Krad/hr

and at B,D,F and H

$1/4\sum B,D,F$ and $H, = 1/4\sum 505+265+505 = \frac{1540}{4} = 385$ Krad/hr

Considering irregularities in the actual containment vessel, a 12% absorption factor was applied. Hence actual dose rates at A,C,E and G were .88x396 or 348.5 Krad/hr (maximum dose rate) and at B,D,F and H, .88x385 or 339 Krad/hr (minimum dose rate).

The minimum dose administered over the 7 day period to positions B,D,F and H from the 155 hour exposure was

$155 \text{ hr} \times .339 \frac{\text{Mrad}}{\text{hr}} - 52.5 \text{ Mrad}$

and the maximum dose, to positions A,C,E and G, was

$155\frac{1}{2} \text{ hr} \times 348.5 \frac{\text{Mrad}}{\text{hr}} = 54.0 \text{ Mrad}$

Attenuation or buildup factors for the contents of the chamber (mandrel, cables, etc.) were not considered in the above because of the randomness of their locations.

EXANE II 600 VOLT SINGLE LAYER

1.0 Insulation: Exane II

The insulation shall consist of irradiated cross-linked thermosetting compounds with wall thickness shown in Table I. The insulation layer shall fit snugly over the conductor, but shall strip freely in at least a half-inch length using either automotive or manual stripping tools.

a. Physical Properties - Unaged

When tested in accordance to par. 6.4.11 of IPCEA S-66-524, the minimum values measured on the insulation removed from the conductor shall be as follows:

Minimum Tensile Strength, psi	1500
Minimum Elongation, %	150

b. Physical Properties After Air Oven Aging at 121°C

When tested according to par. 6.4.12 of IPCEA S-66-524, the insulation which has been removed carefully from the conductor and then aged in a circulating air oven for 168 hours at 121°C shall retain the following minimum physical property values:

Tensile Strength Retention (% of unaged)	90
Elongation Retention (% of unaged)	75

c. Heat Distortion at 121°C

When tested according to par. 6.4.14 of IPCEA S-66-524, distortion of the insulation shall not exceed 30% of the unaged value.

d. Copper Mirror Corrosion Test - Corrosivity by Insulation

When tested in accordance with the procedure outlined in ASTM 267-1, the insulation shall not create sufficient corrosive outgassing products to remove any copper from the test mirror after 16 hours at 175°C.

2.0 Insulated Conductors

a. Dimensions: The insulated conductor dimensions shall be as specified in Table I.

b. 100% Dielectric Test: 100% of all footage made to this specification shall either withstand the water immersion test of par. 5.2

of shall withstand a 100% impulse dielectric test using an impulse dielectric test using an impulse test voltage of 17.5 KV shall consist of a Slaughter Co. Series 656 Pulse Ionization Tester or equivalent.

c. Insulation Resistance - 25°C Water: Any 25 foot sample, chosen at random from production, shall pass the dielectric test and the insulated conductor shall have an insulation resistance not less than the value of R calculated as follows:

$$R = K \log 10 \frac{D}{d}$$

Where:

R = Insulation resistance in Megohms - 1000'
K = Constant for the insulation
D = Diameter over insulation
d = Diameter under insulation

The minimum value of K is 20,000 @ 15.6°C (60°F)

IR Test Method: The center 20 foot section of 25 foot coils shall be immersed in a 5% salt water solution at a bath temperature less than 25° for a period of 24 hours. Use Table 6-10 of IPCEA S-66-524, column 1.03, for temperature correction factors for Insulation Resistance.

d. IPCEA Vertical Flame Test

When tested according to the vertical flame test of par. 6.19.6, IPCEA S-19-81, the requirements of par. 6.19.6.3, IPCEA S-19-81 shall be met.

e. Gravimetric Water Absorption

When tested in accordance with the procedure of par. 6.7.3 of IPCEA S-61-420, the finished wire shall have a maximum water absorption of 5 milligrams per square inch.

f. 75°C Capacitance Stability

When tested according to para. 6.9.2 of IPCEA S-19-81, in water which is maintained at 75°C ± 1°C, the following minimum requirements shall apply:

Maximum Initial SIC = 3.3
Maximum Change 1 to 14 days - 3.0%
Maximum Change 7 to 14 days - 1.5%
Stability Factor (Maximum) - 1.0%