Raychem
Energy Division

Report

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Tested by: Wyle Laboratories	Signature: (see report)	Date: July 28, 1980
Prepared by: C. F. Albertalli	Signature: C F Albertalli	Date: May 1, 1981
Approved by: R. J. Scott for Product Management	Signature: R. J. Scott	Date: 1 May 81
Approved by: G. J. Clarke for Technical Operations	Signature: G J Clarke	Date: May 1 81

Raychem Corporation
Energy Division

TEST REPORT

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP
WESTERN OPERATIONS, NORCO FACILITY

REPORT NO. 58442-3
OUR JOB NO. 58442
CONTRACT ---
YOUR P. O. NO. A01183

26 - Page Report

RAYCHEM CORPORATION
300 Constitution Drive
Menlo Park, California 94025

DATE 28 July 1980

ENVIRONMENTAL QUALIFICATION TEST REPORT

OF

RAYCHEM N-MCK NUCLEAR MOTOR CONNECTION KITS

FOR

RAYCHEM CORPORATION

MENLO PARK, CALIFORNIA

REGISTERED PROFESSIONAL ENGINEER
GEORGE D. SHIPWAY
No. 12157
MECHANICAL
STATE OF CALIFORNIA

STATE OF CALIFORNIA }
COUNTY OF RIVERSIDE } ss.

Ray C. Myrick, being duly sworn, deposes and says: That the information contained in this report is the result of complete and carefully conducted tests and is to the best of his knowledge true and correct in all respects.

Ray C. Myrick

SUBSCRIBED and sworn to before me this 30th day of July, 1980

Notary Public in and for the County of Riverside, State of California

My Commission expires 14 July, 1983

W-867A

DEPARTMENT DYNAMICS

DEPT. MGR. J.D. Anderson

TEST ENGINEER W. Franz

Registered Professional Engineer G. Shipway

DCAS-QAR VERIFICATION

QUALITY CONTROL for A. Heeseman

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1.0 SUMMARY

Six Raychem test specimens each consisting of two nuclear motor connection kits (N-MCK) were subjected to a test program based on the guidelines of IEEE Standards 323-1974[1] and 383-1974[2] to determine their suitability for service within the containment of a nuclear power generating station.

The test program consisted of:

1. Thermal aging (O, 1000, 1500 hours @ 150°C)
2. Radiation exposure (200 - 290 Mrads)
3. Simulated loss of coolant accident combined with main steamline break (LOCA/MSLB) conditions while the specimens were energized at rated current and voltage. (25 Arms, 1000 Vrms)

The electrical integrity of the specimens was evaluated by:

1. Insulation resistance measurements at 500Vd-c 2. Voltage withstand tests at 3600 Volts rms for 5 minutes 3. The ability to maintain electrical loading at rated voltage and current during the simulated LOCA/MSLB.

The N-MCK kits demonstrated satisfactory performance in this test program. All specimens had a high insulation resistance and were capable of passing a voltage withstand test at the conclusion of the test program.

The test program was conducted by Wyle Laboratories, Norco, California during the period of August, 1979 to February, 1980.

2.0 TEST SPECIMENS

Each test specimen was comprised of two nuclear motor connection kits forming a test loop as shown in Figure 1. The materials used to make the connections are also listed. A total of six specimens, or twelve N-MCKs, were used for the test program.

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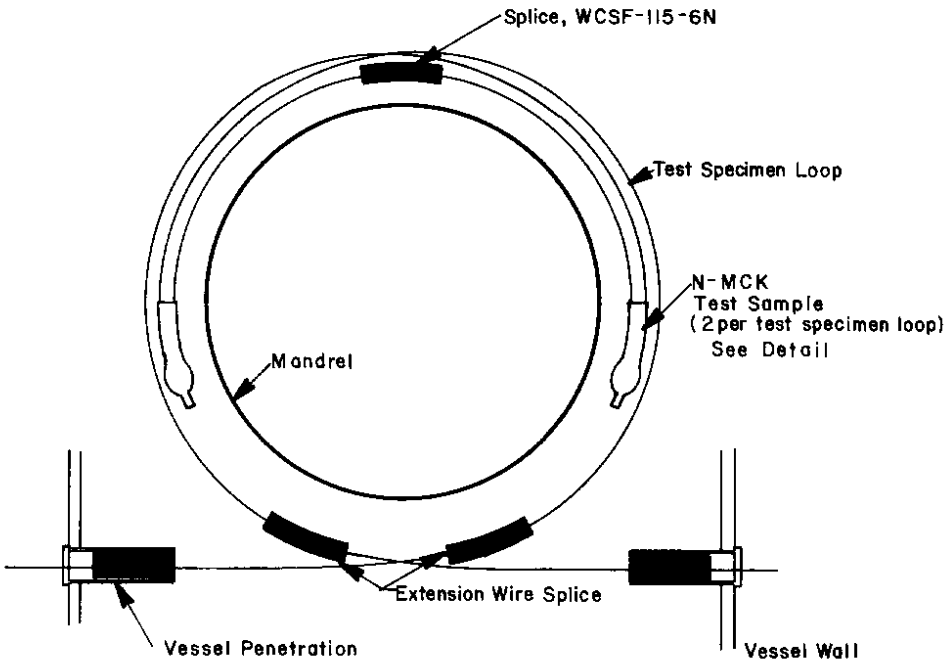

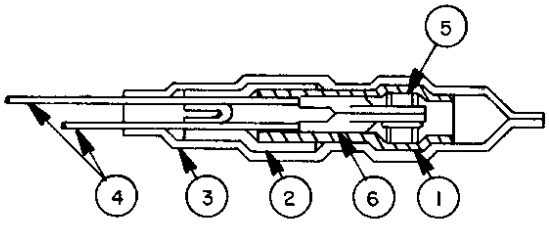

1 - WCSF-300-3U.

2 - 302A812-52/144(S-1119 Adhesive).

3 - MCKF-500/144 (S-1119 Adhesive).

4 - 1/C-12 AWG XLPE Insulation, Rockbestos Firewall III (.030inch insulation thickness).

5 - 3/8" DIA x 3/4" Long Bolt.

6 - Ring tongue Terminals.

FIGURE 1. SAMPLE CONSTRUCTION

3.0 TEST PROGRAM

3.1 Pretest Inspection

The specimens were visually inspected upon receipt at Wyle Laboratories. There was no evidence of damage due to shipping.

3.1.1 Functional Test (Baseline Data)

Each specimen was immersed in water and given a voltage withstand test of 3.6kVrms a-c for five minutes. Both N-MCK's on each specimen loop were immersed during this test. The voltage was applied between the specimen conductor and the grounded tank or vessel. All specimens passed the test.

While still immersed for the above test, the insulation resistance (IR) of each specimen was measured at 500V d-c. These results are given in Table 1 on page 14.

The continuity of each specimen loop was also verified with a low voltage ohmmeter.

3.2 Thermal Aging

Two of the six specimen loops were wrapped onto a 20-inch diameter stainless steel mandrel and tied in place. The mandrel and specimens were placed in an air-circulating oven operating at 150°C (302°F) for 500 hours. At that time, two additional specimen loops were added to the mandrel, and the oven aging continued for another 1000 hours. After removal from the oven, the two remaining specimen loops were then added to the mandrel.

Specimen No.	Thermal Aging (Hours at 150°C)[1]
3-1	1500
3-2	1500
3-3	1000
3-4	1000
3-5	Unaged
3-5	Unaged

After the thermal aging, it was observed that the factory sealed end had disbonded on one of the two N-MCKs on specimens 3-1 and 3-3. The two affected N-MCKs were removed, and the specimen loop spliced together to continue the test. The splice in the specimen loop where the N-MCK was removed was insulated with WCSF-N heat shrinkable tubing. Therefore, only one N-MCK motor connection was left on specimen loops 3-1 and 3-3 for the remainder of the test program. The modified specimen loops are shown in Figure 2.

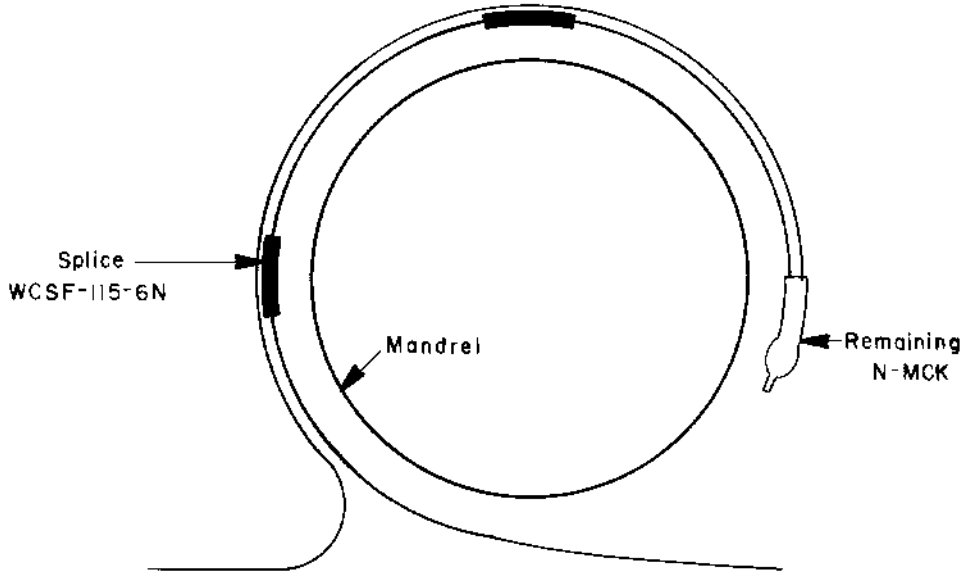

FIGURE 2. Modified Specimen Loop

1. Both 1000 and 1500 hours exceed the required aging times to simulate 40 year life for the cable.

A discussion of the cause of the disbondment of the N-MCKs is included in Appendix C (provided by Raychem).

The mandrel, with the specimens in place, is shown in Figure 3.

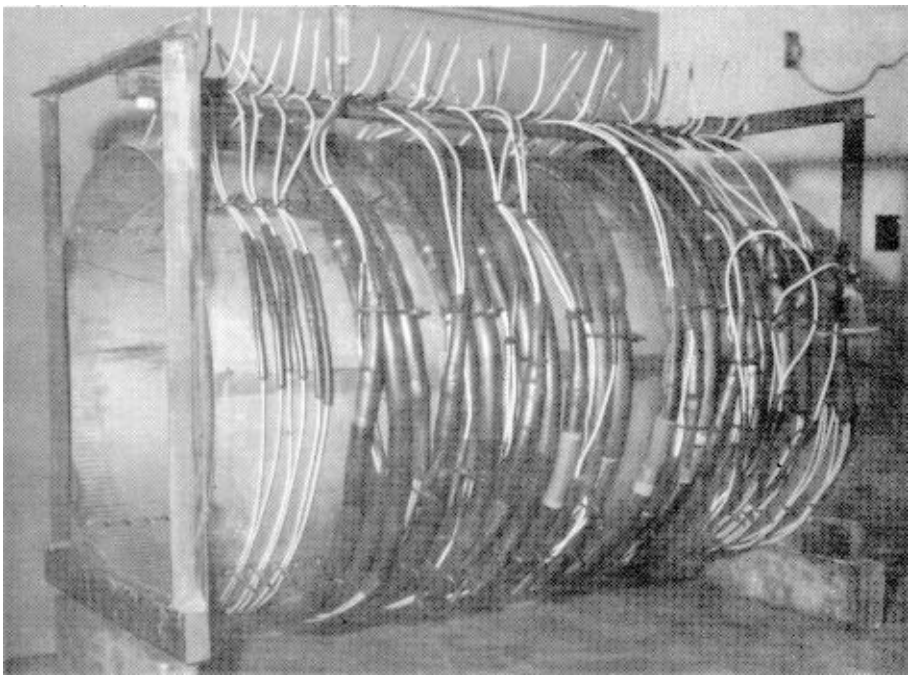

FIGURE 3. Mandrel and Samples (Specimens 3-1 through 3-6 are located at the extreme right of the mandrel.)

Note Several other types of product specimens were also tested in this program and are shown on the mandrel along with the N-MCK specimens. This report covers only the N-MCK specimens. The other specimens are the subject of separate reports.

3.2.1 Functional Tests

The mandrel with the specimens in place was immersed in water, and the insulation resistance measurements made. This was accomplished by splicing long extension leads to each end of the test loops. The splices between the specimens and the extension leads were covered with WCSF-N heat shrinkable tubing. The mandrel immersed in water is shown in Figure 4.

All specimens again passed the five minute, 3.6kV a-c voltage withstand test. The insulation resistance values are given in Table 1 on page 14.

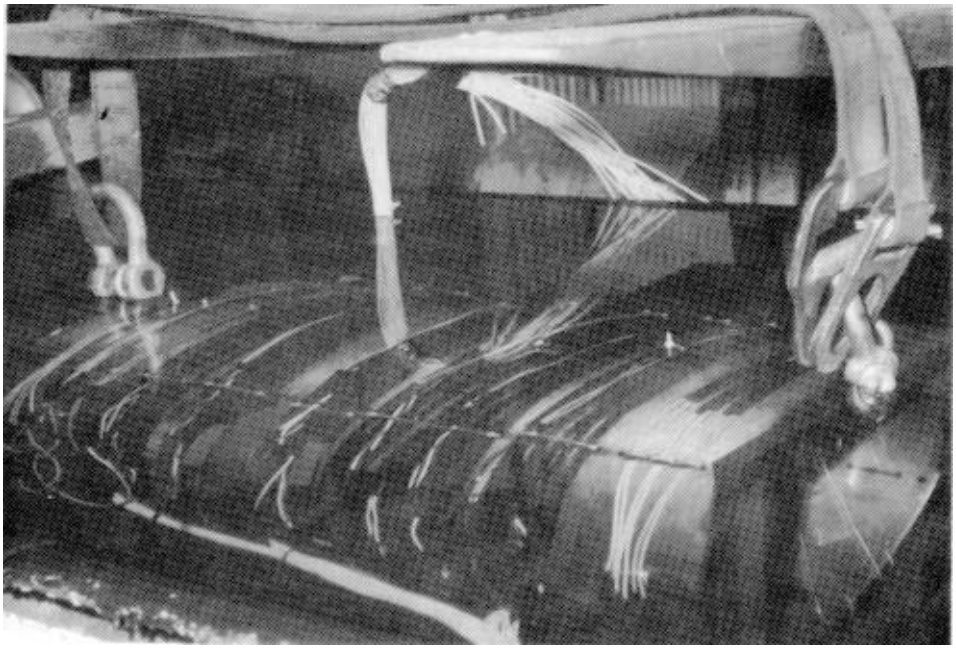

FIGURE 4. Mandrel and Samples Immersed in Water

3.3 Radiation Exposure

The specimens, while still on the mandrel, were subjected to gamma radiation from a Cobalt-60 source. The total dose given the specimens ranged from 2.0×10^8 to 2.9×10^8 rads. The dose rate was between 0.32 and 0.47×10^6 rads per hour. The certificate of radiation dose is shown in Appendix A.

3.3.1 Functional Tests

The functional tests were again performed as described in 3.1.1. All specimens passed the voltage withstand test. The insulation resistance values are given in Table 1.

3.4 Loss of Coolant Accident and Main Steamline Break (LOCA/MSLB) Environmental Exposure

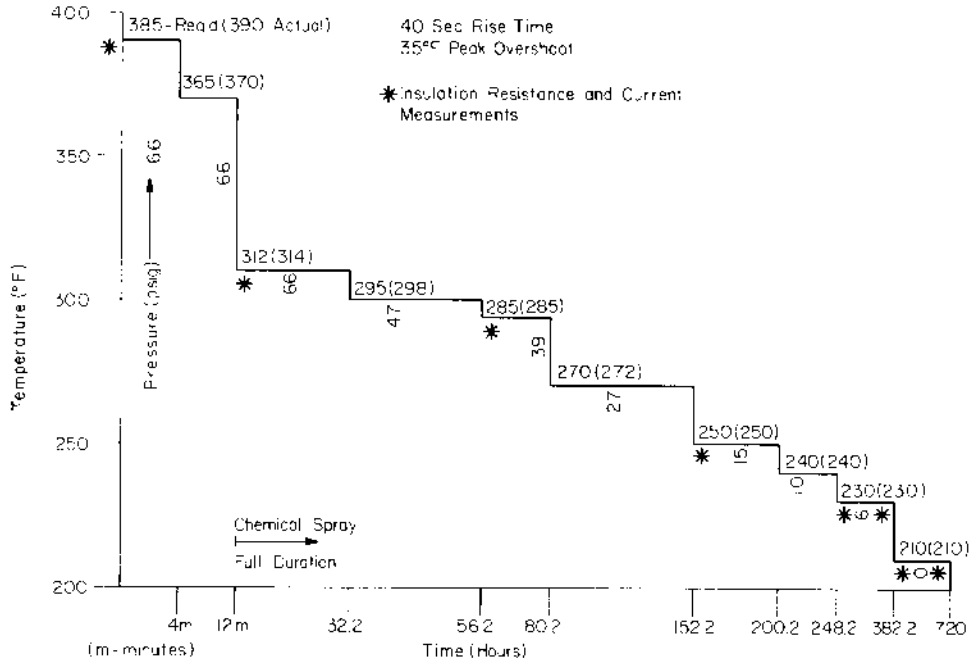

Figure 5 Temperature/Pressure Profile For Simulation of LOCA/MSLB Environment

3.4 Loss of Coolant Accident and Main Steamline Break (LOCA/MSLB) Environmental Exposure (continued)

The specimens on the mandrel were placed in a test chamber capable of exposing the specimens to the steam and chemical spray environment shown in Figure 5.

The extension leads were brought out through penetrations in the vessel to allow the specimens to be energized during the exposure. The specimens were energized at 1.0kV a-c to ground and carried a current of 25 amperes at 25°C ambient at the start of the simulated accident. The current was allowed to drop as the resistance in the conductors increased at elevated temperatures. Current values during the test are recorded in Table 2 on page 15.

Fuses were installed in each specimen circuit so that during the exposure a breakdown in the insulation of one specimen would not affect the voltage applied to the others. Schematics of the test chamber and energizing circuit are given in Figures 6 and 7 respectively. All data acquisition instruments used in the test program are listed in Appendix B.

The chemical spray consisted of 6200 ppm of boron, 50 ppm of hydrazine buffered to a ph of 10.5 with trisodium phosphate. The spray was applied at the top of the vessel through a horizontal spray header at a rate in excess of 0.15 gpm/ft2 (actual flow varied from .26 to .81 gpm/ft2).

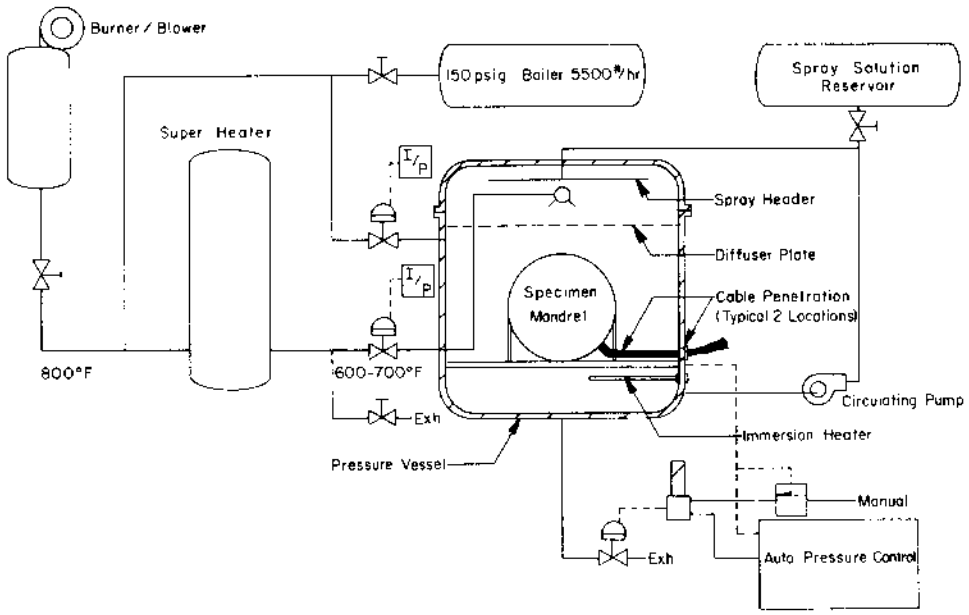

FIGURE 6. LOCA/MSLB Pressure Vessel and Auxiliary Equipment

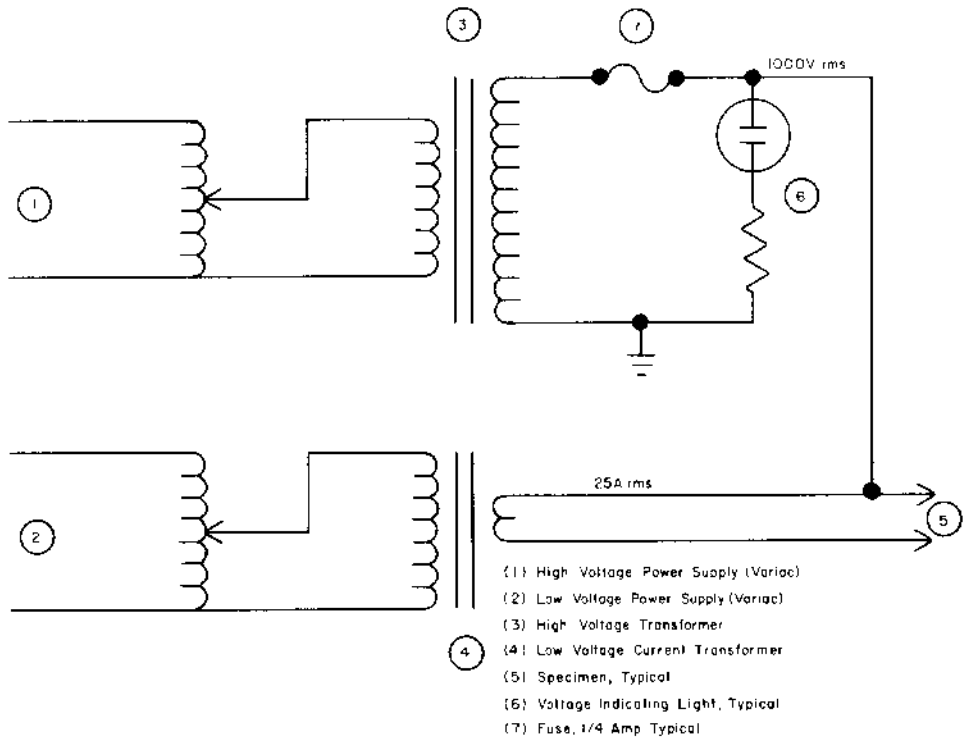

FIGURE 7. Test Schematic for Energizing Specimens

3.4.1 Test Results

During the course of the LOCA/MSLB environment exposure, all specimens held the rated current. The capability to supply voltage continuously throughout the test was impaired due to insulation failures in the test loop other than at the splice specimens themselves. The 1.0kV a-c was necessarily terminated on these specimens when the fuse opened. A complete discussion of the anomalies associated with the loss of voltage is given in 3.4.2.

Insulation resistance values measured at selected times during the LOCA/MSLB exposure are given in Table 1 on page 14.

3.4.2 Post LOCA/MSLB Inspection

At the conclusion of the test profile (Figure 5), the test vessel was flooded with tap water. The specimens were then given a voltage withstand test, and the insulation resistances measured. The results of the insulation resistance tests are given in Table 1. The vessel was then opened, and the cause for some of the specimens being unable to hold rated voltage investigated. The test vessel with the specimens in place is shown in Figures 8 and 9.

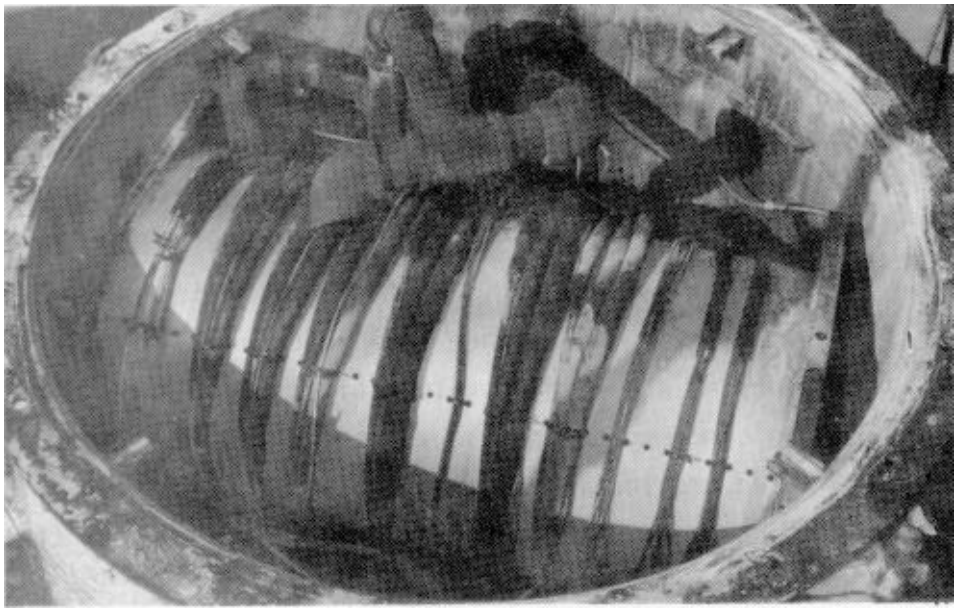

FIGURE 8. Test Chamber and Samples

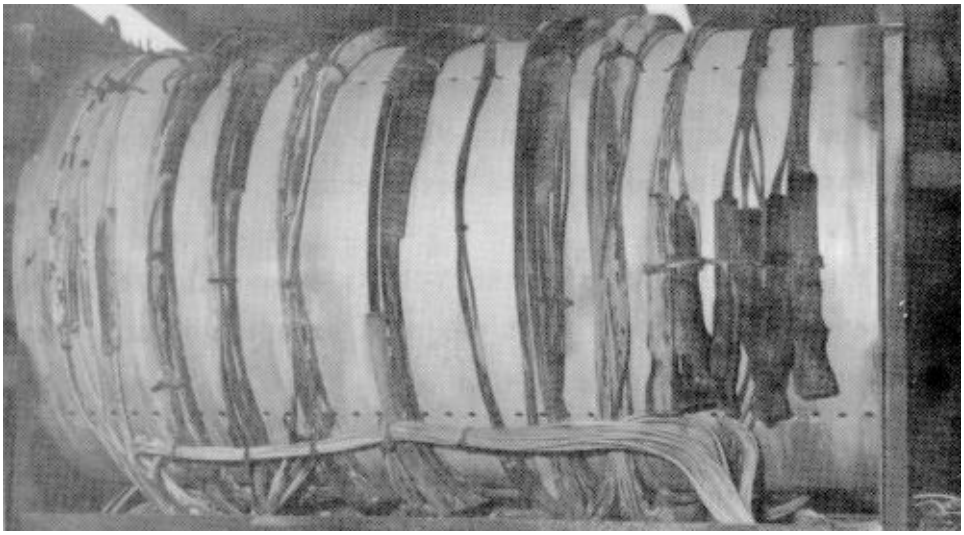

FIGURE 9. Mandrel After Removal from Vessel

3.4.2 Post LOCA/MSLB Inspection (continued)

The extension wires were cut inside the vessel so that the mandrel could be removed. This also allowed the penetrations to be inspected. It was found that some of the wires in the penetration had a low insulation resistance and would not pass the 3.6kV a-c voltage withstand test. The specimens associated with the penetration wires having a low insulation resistance were retested. The retest of specimen 3-3 showed high values of insulation resistance, and the specimen passed the voltage withstand test. The low value previously measured on this specimen can therefore be attributed to the penetration and not the specimen.

Specimen loops 3-1, 3-2, and 3-4 had cracks in the wire insulation near the N-MCK samples. These loops were removed from the mandrel and tested with the N-MCK's immersed in water. The cracked wire insulation was kept above the water for these tests. All the N-MCK's yielded a high insulation resistance value and passed the voltage withstand test thereby demonstrating that the previously low insulation resistance values were caused by insulation failure elsewhere in the test loops.

Visual examination of the N-MCK's showed surface degradation and some crazing. This was most apparent in specimens 3-5 and 3-6.

A summary of the findings is given in Table 3 on page 16.

4.0 CONCLUSIONS

Six test specimen loops, each containing two N-MCKs (except 3-1 and 3-3 which had only one N-MCK), were subjected to an extensive test program including thermal aging, radiation exposure, and simulated LOCA/MSLB environmental exposure. During the LOCA/MSLB exposure, the specimens were energized at rated current and voltage.

All specimens demonstrated satisfactory electrical performance at the conclusion of the test program. Wire insulation cracks and low resistance of some wires in the test vessel penetrations caused apparent low values in some of the specimens, but subsequent testing substantiates the ability of these N-MCKs to maintain electrical integrity throughout the test program. All specimens had high insulation resistance values and passed the voltage withstand test at the conclusion of the program.

The results of this comprehensive test program confirm, by type testing, the adequacy and suitability of the Raychem N-MCK nuclear motor connection kits for use on Class IE systems within the containment of a nuclear power generating station.

REFERENCES

(1) IEEE Standard 323-1974, "IEEE Standard for Qualifying IE Equipment for Nuclear Power Generating Stations".

(2) IEEE Standard 383-1974, "IEEE Standard for Type Test of Class IE Electric Cables, Field Splices, and Connections for Nuclear Power Generation Stations."

TABLE 1

INSULATION RESISTANCE (OHMS)

Test Conditions		Temperature (°F)	Temperature (°C)	Pressure (psig)	Specimen Number 3 - 1	3 - 2	3 - 3	3 - 4	3 - 5	3 - 6
Initial (Baseline)	(1)	Ambient	-	-	5.0×10^{10}	$>5.0 \times 10^{10}$	$>5.0 \times 10^{10}$	$>5.0 \times 10^{10}$	$>5.0 \times 10^{10}$	$>5.0 \times 10^{10}$
After Aging	(2)	Ambient	-	-	$>1.0 \times 10^{8}$	$>1.0 \times 10^{8}$	$>1.0 \times 10^{8}$	$>1.0 \times 10^{8}$	$>1.0 \times 10^{8}$	$>1.0 \times 10^{8}$
After Irradiation	(1)	Ambient	-	-	$>5.0 \times 10^{10}$	$>5.0 \times 10^{10}$	$>5.0 \times 10^{10}$	$>5.0 \times 10^{10}$	$>5.0 \times 10^{10}$	$>5.0 \times 10^{10}$
In Test Vessel	(1)	Ambient	-	-	3.0×10^{10}	3.0×10^{10}	4.5×10^{10}	3.0×10^{10}	3.0×10^{10}	3.0×10^{10}
During Simulated LOCA/MSLB Test (See Figure 5)										
After 12 minutes		314	157	66	7.5×10^{6}	6.8×10^{6}	1.5×10^{7}	1.7×10^{7}	1.5×10^{7}	1.2×10^{7}
After 56.2 hours		285	141	39	(3)	(3)	2.2×10^{7}	2.1×10^{7}	2.2×10^{7}	1.9×10^{7}
After 152.2 hours		250	121	15			5.4×10^{7}	4.7×10^{7}	5.0×10^{7}	3.4×10^{7}
After 248.2 hours		230	110	6			(4)	1.0×10^{8}	1.1×10^{8}	7.2×10^{7}
After 381 hours		230	110	6				1.0×10^{8}	1.1×10^{8}	8.0×10^{7}
After 383 hours		210	99	0				2.1×10^{8}	2.9×10^{8}	2.1×10^{8}
After 720 hours		210	99	0				(3)	2.2×10^{8}	1.6×10^{8}
Test Vessel Filled with Water		-	-	-					2.8×10^{9}	9.0×10^{9}
Specimens Removed from Mandrel and Tested in Water					2.0×10^{9}	1.5×10^{7}	3.6×10^{10}	1.0×10^{10}		

(1) 5.0×10^{10} is the maximum insulation resistance readable at 500 V d-c with the specific test equipment.

(2) 1.0×10^{8} is the maximum insulation resistance readable at 500 V d-c with the specific test equipment.

(3) Subsequent test showed low value due to cracks in wire insulation.

(4) Subsequent test showed low value due to penetration in vessel.

Note: All specimens passed a voltage withstand test of 3.6kV a-c for 5 minutes at each test point excluding post aging and during the simulated event.

TABLE 2

CURRRENT MONITORING OF SPECIMENS

DURING SIMULATED LOCA/MSLB ENVIRONMENT

Test Conditions	Temperature (°F)	Temperature (°C)	Pressure (psig)	CURRENT (Amperes) 3 - 1	3 - 2	3 - 3	3 - 4	3 - 5	3 - 6
Before Start of Test	Ambient	-	-	25.0	25.0	24.8	25.5	25.5	25.6
During Test (See Figure 5)									
12 minutes	314	157	66	21.5	21.7	21.6	22.1	22.0	22.1
56.2 hours	285	141	39	22.3	22.5	22.5	22.8	22.8	22.8
152.2 hours	250	121	15	23.1	23.4	23.4	23.8	23.8	23.9
248.2 hours	230	110	6	23.6	23.8	23.8	24.5	24.4	24.2
381 hours	230	110	6	23.4	23.5	23.6	24.0	23.9	23.9
383 hours	210	99	0	23.7	23.9	23.9	24.4	24.3	24.3
720 hours	210	99	0	23.5	23.6	23.6	24.0	24.0	24.0

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TABLE 3

POST LOCA/MSLB INVESTIGATION SUMMARY

Specimen Loop No.	Aging Time at 150°C	Time Voltage Was Applied	Results
3 - 1	1500 Hours	1 Day	Penetration failure and hole in wire insulation. Passed subsequent immersion and VWT.
3 - 2	1500 Hours	1 Day	Cracks in wire insulation. Passed subsequent immersion and VWT.
3 - 3	1000 Hours	11 Days	Penetration failure. Passed subsequent immersion and VWT.
3 - 4	1000 Hours	20 Days	Hole in wire insulation. Passed subsequent immersion and VWT.
3 - 5	Unaged	Completed Test	--
3 - 6	Unaged	Completed Test	--

* VWT - Voltage Withstand Test

APPENDIX A

CERTIFICATION OF RADIATION DOSE

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Atomics International Division
8900 De Soto Avenue
Canoga Park, California 91304
(213) 341-1000

Rockwell International

CERTIFICATE OF GAMMA RADIATION DOSE

CUSTOMER Wyle Laboratories

PURCHASE ORDER NO. 8057
Wyle Job No. NDQ 58442

DATE IN October 26, 1979

TIME IN 11:00 AM

DATE OUT November 21, 1979

TIME OUT 8:00 AM

MINIMUM DOSE 2.0×10^8 RADS

MAXIMUM DOSE 2.9×10^8 RADS

Signature RKPaschall

APPENDIX B

LIST OF DATA ACQUISITION INSRUMENTS

SPECIMEN SPLICES

CUSTOMER RAYCHEM CORPORATION

PART NO. SEE RECEIVING INSP.

S/N SEE RECEIVING INSP.

TEST: BASELINE FUNCTIONAL

JOB NO. 58442

DATE 7/31/79

TEST BY T. Knight

WITNESS -

WYLE LABORATORIES

EQUIPMENT	MANUFACTURER	MODEL NO.	RANGE	WYLE NO.	CALIBRATION LAST	CALIBRATION DUE	ACCY.
A. C. Hipot	Associated Research	5/33	0-6kV	5086	06-27-79	01-13-80	±3%
Insulation Tester	Arizona Inst.	N/A	3MΩ - 50KMΩ 0-500 VDC	51027	03-01-79	09-02-79	±4%
Digital Voltmeter	Fluke	8000A	0-2 Ohms	7317	07-10-79	07-13-80	Mfg. Spec.

W 614 C Q.C. Approval

SHEET OF

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WYLE LABORATORIES

SPECIMEN: SPLICES

CUSTOMER: RAYCHEM CORPORATION

PART NO.: SEE REC. INSP.

S/N: SEE REC. INSP.

TEST: FUNCTIONAL

JOB NO.: 58442

DATE: 10/25/79

TEST BY: T. Knight

WITNESS:

EQUIPMENT	MANUFACTURER	MODEL NO.	RANGE	WYLE NO.	CALIBRATION LAST	CALIBRATION DUE	ACCY.
Megohmmeter	Freed Trans. Co.	1620	1MΩ to >200KMΩ	2248	12-10-79	06-15-80	±5%
Digital V.O.M.	Fluke	8000A	0-1200 VAC 0- 200 mA-AC	7684	05-03-79	05-04-80	Mfg. Spec.
Amp Probe	Fluke	N/A	1000:1 Ratio	7691	06-25-79	06-29-80	±3%
A. C. Hipot	Associated Research	5133	0-6kV AC	5086	06-27-79	01-13-80	±3%
A. C. Hipot	Associated Research	5133	0-6kV AC	5086	01-17-80	07-20-80	±3%

W 614 C Q.C. Approval

SHEET OF

SPECIMEN: SPLICES
CUSTOMER: RAYCHEM CORPORATION
PART NO.: SEE RECEIVING INSP.
S/N: SEE RECEIVING INSP.
TEST: ACCIDENT SIMULATION

JOB NO.: 58442
DATE: 1/3/80
TEST BY: N. Schmitz
WITNESS:

WYLE LABORATORIES

EQUIPMENT	MANUFACTURER	MODEL NO.	RANGE	WYLE NO.	CALIBRATION LAST	CALIBRATION DUE	ACCY.
Electrostatic Voltmeter	Electrical Instrum. Ser.	University	0-1000 Volt	8416	11-30-79	03-20-80	±1.0%
Powerstat	Superior Elect. Co.	1258C	0- 28 Amp 0-280 VAC	N/A	SYSTEM CALIBRATION		
Transformer	Westinghouse	6C9B-071	240/480 VAC 12KVA 12KVOut	N/A	SYSTEM CALIBRATION		
Digital Multimeter	Fluke	8010A	0- 200 mA 0-2000 VAC	8188	11-12-79	11-12-80	±0.5%
Amp Probe	Fluke	N/A	1000:1 Ratio	7691	06-25-79	06-29-80	±3.0%
Shunt	Weston	0041218	50Amp/50mV	8183	01-15-79	01-20-80	±0.5%
Shunt	Weston	0041218	50Amp/50mV	8184	01-15-79	01-20-80	±0.5%
Shunt	Weston	0041218	50Amp/50mV	8185	01-15-79	01-20-80	±0.5%
Powerstat (Typ. 3)	Superior Elect. Co.	1258C	0- 28 Amp 0-280 VAC	N/A	SYSTEM CALIBRATION		
Transformer (Typ. 3)	UNK.	N/A	1000:6 Ratio	N/A	SYSTEM CALIBRATION		
Venturi	Barco	550	1-300 gpm	8166	12-16-79	12-16-80	±1%
Pressure Transducer	Validyne	DP15	0-100 psi	7460	SYSTEM CALIBRATION		±.25%
Recorder	H.P.	7132A	0-500 mV	7613	SYSTEM CALIBRATION		±0.2%
Recorder	H.P.	7132A	0-500 mV	7612	SYSTEM CALIBRATION		±0.2%
Delta Press. Gauge	Barton	D4-49053-1	0-80 in W.C.	7784	09-03-79	01-03-80	±.25%
Dig. Thermometer	Fluke	2160A	-328 to +750°F	8290	09-04-80	09-07-80	±2°F
Dig. Thermometer	Fluke	2160A	-328 to +750°F	8401	10-12-79	10-12-80	±2°F
Dig. Thermometer	Fluke	2160A	-328 to +750°F	8032	08-13-79	08-17-80	±2°F

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APPENDIX C

DISCUSSION OF DISBONDMENT

R

DISCUSSION OF DISBONDMENT

At the conclusion of the thermal aging portion of the environmental qualification test program conducted by Wyle Laboratories (Wyle Job Number NDQ-58442), it was observed that two of the twelve N-MCK cap samples being aged evidenced disbonding of the factory sealed end. The two affected N-MCK's were removed from the test, and the testing continued. The ten remaining N-MCK nuclear motor connection kits successfully completed the LOCA environmental qualification program. This discussion summarizes the results of Raychem's investigation into the cause and nature of the disbonding and the subsequent actions taken.

The bonded end cap for the N-MCK consists of a length of WCSF tubing which has been factory sealed or bonded at one end. The bonded cap is coated with Raychem's nuclear grade adhesive and functions as an insulating and sealing cap for the motor connection kit. The same type bonded end cap has been used in the commercial version of the MCK product since 1978.

The investigation conducted by Raychem involved analysis of the two samples returned from Wyle in conjunction with tests conducted on large numbers of samples taken from inventory and production. All aspects of the bonding process were evaluated.

R

DISCUSSION OF DISBONDMENT, (continued)

The investigative efforts led to the following conclusions:

- The disbonding of the N-MCK caps during heat-aging in the Wyle test program was anamolous. The cause of the disbonding resulted from a deviation from the specified manufacturing process.

- Improvements in the control of the process were necessary to preclude deviations from the manufacturing specification which could result in unsatisfactory bonds.

Corrective actions to incorporate quality control improvements have been implemented. The manufacturing specification has been rewritten for N-MCK bonded caps incorporating beneficial changes in the process that were discovered during the investigation to further improve bond strength and reliability. All testing subsequent to implementing the modified manufacturing procedures has confirmed consistently good bonds with no evidence of disbonding, including tests to duplicate the accelerated aging conditions under which the initial samples disbonded.

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DISCUSSION OF DISBONDMENT, (continued)

In summary, ten of the twelve N-MCK nuclear motor connection kits successfully completed the LOCA environmental qualification program conducted by Wyle Laboratories (Test Report No. 58442-3) confirming the adequacy and suitability of the Raychem N-MCK design. The investigation, conducted to determine the cause and significance of the disbonding of two of the twelve bonded N-MCK caps, resulted in improvements to the bonding process and control of the manufacturing methods used to produce the N-MCK caps.

All caps supplied by Raychem for N-MCKs are manufactured using these improved methods.

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