SYSTEMS INC

ENGINEERING DEPARTMENT

DOCUMENT

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TITLE

ENVIRONMENTAL QUALIFICATION REPORT FOR APPENDIX R CABLES

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1.0 SCOPE

This document provides the details of the qualitative process used to assess and evaluate the similarity of Systems Appendix R cable assemblies to similar cable assemblies Type Tested to industry standards for 1E cable systems. This evaluation provides detailed descriptions of the cable assemblies and identifies the tested cable characteristics that are identical or similar to the Appendix R cable assemblies and an analysis of test data and design basis environmental conditions.

The evaluation and analysis together with the 1E qualified cable assembly test data provide the basis for the conclusion that the similarly constructed cable can be conservatively Qualified by Similarity.

Section 1 of this document outlines the scope of the qualification document. Section 2 provides the listing of applicable standards used in the evaluation process. Section 3 presents the summary of the qualification program and includes hardware descriptions, performance criteria, and test sequence information. Section 4 is a statement that this report does provide a basis for concluding that the proposed Appendix R cable configurations can be considered as meeting the EQ requirements for 1E classification.

2.0 APPLICABLE STANDARDS

IEEE 323–1983, Qualification of Class 1E Equipment for Nuclear Power Generating Stations.

IEEE 344–1975, Recommended Practices for Seismic Qualification of class 1E Equipment for Nuclear Power Generating Stations

IEE 383-1974, Type Tests of Class 1E Cables, Field Splices, and Connections for Nuclear Power Generating Stations.

3.0 QUALIFICATION

3.1 General

The qualification testing referenced herein was performed by the Franklin Research Center in Norristown, PA and was conducted in accordance with the industry regulatory standards listed in Section 2 for Class 1E, Nuclear Safety Related Equipment. The Type Tests performed to demonstrate performance including normal and included design basis event pressure, temperature, humidity, and radiation conditions; mechanical vibration, and bending or flexing.

3.2 Appendix R Cable Configurations

The Appendix R cables that are the subject of this analysis consist of four cables each with a different conductor size and with specific numbers of conductors. The cable configuration details are defined in table 1. It is to be noted that the basic materials of construction in each cable are identical, the only difference being the number and size of the conductors. It can be further stated that the manufacturing and test methods applied to each individual cable are identical.

TABLE 1
CABLE CONSTRUCTION

Characteristic				
Part Number	300217-5	300208-5	300283-5	300286-5
Cable Diameter, inches	0.590	0.590	0.590	0.590
Outer Sheath Material	321 SST	321 SST	321 SST	321 SST
Sheath Thickness, inches	0.015	0.015	0.015	0.015
No. Conductors	4	7	8	7
Conductor Size, AWG	#8	#10	#12	#14
Conductor Spacing, inches minimum (W/W, W/Sheath)	0.055	0.055	0.055	0.055
Conductor material	Ni coated Copper	Ni coated Copper	Ni coated Copper	Ni coated Copper
Dielectric Material	SiO_2	SiO_2	SiO_2	SiO_2
Cable Clamping Length, inches	81.0	81.0	81.0	81.0
Spliced	Yes	Yes	Yes	Yes

Cable Splices in each case are accomplished by welding the corresponding conductors in each cable section to each other. The outer sleeve is then welded to the cable sheath and the chamber thus formed is filled with SiO_2 powder. The fill hole is then welded closed and the weld joints Helium leak tested. Following the leak test, each splice joint is electrically tested for continuity and withstand voltage per the prescribed test procedure.

Cable Terminations are either factory or field installable. The terminations are not environmentally or seismically qualified, and must also be protected or isolated from the fire zone. Each termination consists of a dielectric plug assembly that includes the organically insulated pigtail extensions with crimp- on contacts potted into the specific configuration defined by the number and size of the cable conductors. The cable conductors are formed to match up with the dielectric plug assembly contacts and mated. A stainless steel termination shell is positioned over the end of the dielectric plug assembly bottoming out at the compression ring of the dielectric plug. Epoxy potting is then used to fill the void within the shell completely encapsulating the mated dielectric plug – cable mated interface. A seal screw is inserted into the vent hole in the sleeve. The pipe-to-tube compression fitting slides over the termination shell and the ferrule is tightened to form an environmental seal for the epoxy-potted area thereby isolating the conductor connections from the ambient environment. The threaded end of the compression fitting is attached to a junction box with the pigtail wires extending into the junction box.

3.3 Type Test Cable Assembly (Reference: Specification IEEE 383-1974)

The test series conducted by the Franklin Research Center included nine separate cable assemblies with a variety of conductor configurations, sizes and connectors. Four of these were multi-conductor cables with direct applicability to the Appendix R cables being considered in this document. In each case the manufacturing processes and materials (except that conductors included both OFHC copper and Type K thermocouples) are identical to each other. The connectors attached to the cables are not being addressed in this document because the designs and manufacturing processes used to make the connectors are not applicable to the Appendix R cable assemblies. A table detailing the cable configurations and the test parameters is an attachment to this document. A short form summary of this information is shown in tables 2 and 3.

It should be noted that the internal spacing between conductors and the spacing between conductors and sheath in all configurations maintain the same minimum distance for electrical integrity. This fact is critical to the conclusions that from an electrical standpoint, all cables are identical relative to environmental and seismic stresses seen during the test sequences.

TABLE 2
CABLE CONSTRUCTION

Characteristic	**EQ Tested Cables**				**App R**
Cable Diameter, inches	0.250	0.296	0.310	.296	0.590
Outer Sheath Material	304L SST	304L SST	304L SST	304L SST	321 SST
Sheath Thickness, inches	0.015	0.015	0.015	0.015	0.015
Number of Conductors	8	10	3	10	4 to 8
Conductor Size, AWG	#26	#26	#20	#26	#8, #10; #12; #14
Conductor material	Type K TC	OFHC Cu	Ni clad Cu	Type K TC	Ni coated Copper
Dielectric Material	SiO2	SiO2	SiO2	SiO2	SiO2
Cable Length, feet	20	20	20	20	40
Spliced	Yes	Yes	Yes	Yes	Yes

3.4 Type Test Program

The qualification program was conducted in accordance with the methodology and guidelines outlined in IEEE Standard 323-1983 and IEEE Standard 344-1975. The matrix of Appendix A and Table 3 present a summary of the test sequence and exposures for the cable system. The gray shaded areas of the matrix in Appendix A are to show the complete test history only and are not being addressed in this report.

3.4.1 Acceptance Criteria

Typical signals transmitted by the cable system were monitored continuously for evidence of transient signal error and loss of continuity during the seismic and LOCA/MSLB test events. The criteria used were:

a) High Voltage (LPRM) – Input to output signal less than 2% difference at 100 VDC in measured at output across 100K ohm resistor.

Thermocouple – Input to output ± 1.23mV (2% temperature) with input simulated over 450ºF to 2500ºF TC response.

Logic – Logic “0” output 0± 0.5V across 100 Kohm resistor
Logic “1” output 5 ± 0.5V across 270 ohm resistor.

Power – Operate (and de-energize) standard 115VAC contactor with input of 115VAC, 60 Hz.

b) There is no loss of signal continuity in the cable system during seismic and LOCA/MSLB test events. Loss of continuity is defined as the loss of the signal as recorded by a typical industrial grade strip chart recorder.

3.5 Test Sequence

3.5.1 Baseline Functional Tests

The test specimens were subjected to a series of baseline functional tests which included measurement of insulation resistance at 50 VDC, dielectric withstand test at 725 VDC, and conductor DC resistance measurements.

The baseline functional tests were performed in accordance with FRC test procedure TP-6168-2,”Test Procedure for Baseline and Functional Tests”, Revision 1, dated November 20, 1986.

3.5.2 Thermal Aging

The test specimens were placed in a loosely coiled arrangement in the thermal aging oven and thermally aged for a period of 430 hours (18 days) for 20-year samples and 860 hours (36 days) for 40-year samples at a temperature of 260ºF (+5, -0) [127ºC (+3, -0)]. The thermal aging simulation was as specified in Hanford Engineering Development Laboratories document "Test Requirements for the Qualification Testing of Whittaker Cable/Connector Assemblies", February 10 1986. , and was based upon Arrhenius modeling using an activation energy of 1.0 eV, a normal service temperature of 135ºF (57ºC), and an expected service life of approximately 20 or 40 years respectively. The thermal aging simulation was performed in accordance with FRC test procedure TP-6168-3, "Test Procedure for Thermal Aging of Whittaker/ERD Cable and Connectors", Revision O, December 9, 1986.

3.5.3 Irradiation Aging

The test specimens delineated as 40-year samples were exposed to an air-equivalent dose of 50 Mrads of gamma radiation from a source of cobalt-60 at a dose rate of less than 0.5 Mrads/h. The 20-year test specimens were exposed to an air-equivalent dose of 25 Mrads. The 25 Mrads and 50 Mrads represent the gamma radiation exposure anticipated during a 20 and 40-year service life respectively of the test specimens. All test specimens were exposed to a total integrated dose of 165 Mrads to simulate the exposure postulated from a LOCA plus a 10% margin. The dose rate for the 165 Mrads exposure was less than 1 Mrad/hr. The gamma irradiation was performed in accordance with FRC test procedure TP-6168-5, "Test Procedure for Gamma Irradiation of MSSI Cable and Connectors", Revision O, dated December 9, 1986, and FRC Purchase Specification S-6168-2, "Specification for Gamma Irradiation of Whittaker/ERD SI Cables", dated January 28, 1987.

3.5.4 Vibration Aging

The test specimens were mounted on a Triaxial shaker table and subjected to a sinusoidal vibration of 0.75 g at the base of the test fixture as the frequency was swept from 5 to 200 to 5 Hz at a rate of 2 octave/min. The vibration was applied for 90 minutes along each of two orthogonal axes of the test specimen. During the vibration testing, the test specimens were continuously energized and the circuit was monitored using an FM recorder. The testing was performed at Wyle Laboratories in accordance with FRC test procedure TP-6168-6, "Test Procedure for Seismic/Vibration Susceptibility Testing of SI Cables", Revision 1, dated April 21, 1987.

3.5.5 Seismic Testing

The test specimens were subjected to a series of five operating basis earthquakes (OBE's), each of 30-s duration, which enveloped the required response spectra (RRS) of Figure 1. The seismic testing was conducted at Wyle Laboratories in accordance with the requirements of FRC test procedure TP-6168-6, "Test Procedure for Seismic/Vibration Susceptibility Testing of SI Cables", Revision 1, dated April 21, 1987. During the seismic testing, the test specimens were continuously energized and the circuit was monitored with am FM recorder.

Due to the differences in the jacket materials and diameters of the cables used for the Type Test Cable Assemblies and the cables that a subject of qualification, MSSI Engineering decided to perform the seismic stress analysis for one of Appendix R cable configurations.

The structural analysis is performed for the cable P/N 300286-5 based on Operating Basis Earthquake (OBE), the Safe Shutdown Earthquake (OBE) requirements and the corresponding loading spectra specified in FRC test procedure TP-6168-6. Two typical cases of the cable installation are analyzed:

1) Straight cable with the splice in the middle installed using 81-inch support clamping span.

2) Cable is bent 90° with bend radius of 6 inches and supported at 36 inches of the bend point in two places.

Based on the observation that all margins of safety are greater than zero, it is concluded that the analyzed cable is structurally adequate with respect to the specified earthquake loading test requirements. See Foster Engineering Report in Appendix B.

3.5.6 BWR LOCA Exposure

The test specimens were exposed to steam, demineralized water spray and high humidity in accordance with the profile specified in Figure 2.

The demineralized water spray was applied at an intensity of 0.15 gpm/ft squared (6.1 (L/min)/m squared) from approximately 3 hour elapsed time (ET) of the second transient until 28 hour ET. Fresh spray solution was used for the first hour; thereafter, the spray solution was recirculated from a pool of solution collected in the bottom of the vessel.

During the BWR LOCA exposure, the test specimens were subjected to operational test to confirm compliance with the Acceptance Criteria defined in 4.3.1 herein. At various times, the signal to the cable was changed to simulate an input change. The input and output voltages of the cable were monitored with a data logger. Operational tests were performed approximately one hour before the start of the LOCA exposure; during the dwell at the peak temperature/pressure of each transient; during the dwell at 320ºF (160ºC)/75 psig (172 kPa); and once per day thereafter until completion of the exposure.

The test was extended beyond the original plan by 10 days at a temperature of 230ºF (110ºC). The test specimens were continuously energized during this period.

The BWR LOCA exposure was performed in accordance with FRC test procedure TP-6168-7, "Test Procedure for LOCA Exposure of Whittaker/ERD Cable and Connectors", Revision 1.

TABLE 3
TEST SEQUENCE AND EXPOSURES

TEST CONDITION	EXPOSURE
Radiation Aging	50 X 10^6 Rads, Gamma
Mechanical Aging	50 Mate/Demate Cycles
Thermal Aging	260ºF for 860 hours for 40 year life specimens
	260ºF for 430 hours for 20 year life specimens
Vibration Aging	Sinusoidal .75g from 5 to 200 Hz at a Rate of 2 Octave/Min.
Seismic	Figure 1
Accident Irradiation	165 X 10^6 Rads, Gamma
LOCA/MSLB	See Figure 2

4.0 CONCLUSIONS

The qualification test program for the Silicon Dioxide cable system was conducted in accordance with the methodology and guidelines outlined in IEEE Standard 323-1983 and IEEE Standard 344-1975 for the normal and accident conditions as described in this report.

The results of these tests provide empirical evidence that the steel jacketed, SiO2 insulated cables tested meet the acceptance criteria for signal and control cable operation in both a normal and post-LOCA environments postulated for nuclear power plants. The Type Test results support the conclusion that other cables of similar configurations but with the same basic construction and materials can be considered qualified by similarity.

For purposes of this evaluation and analysis this report addresses only the data pertinent to the basic cable and splices and is not meant to include the connectors in the tested assembly. Appendix A, a tabulation of all of the pertinent aspects of the test program is included to provide as a handy reference summary of the program.

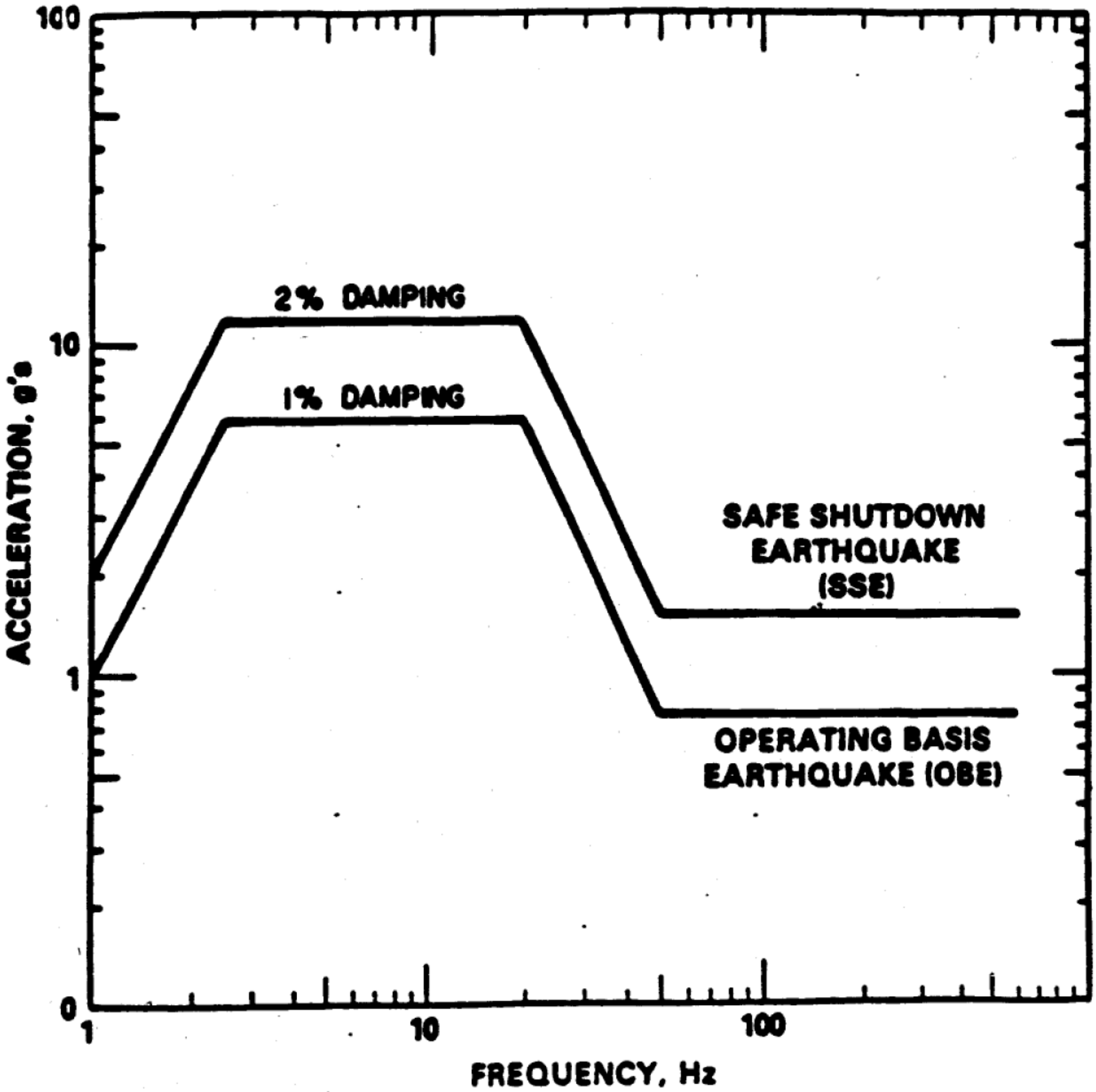

Figure 1, required response Spectra for Multifrequency Seismic Test
(Vertical and Horizontal)

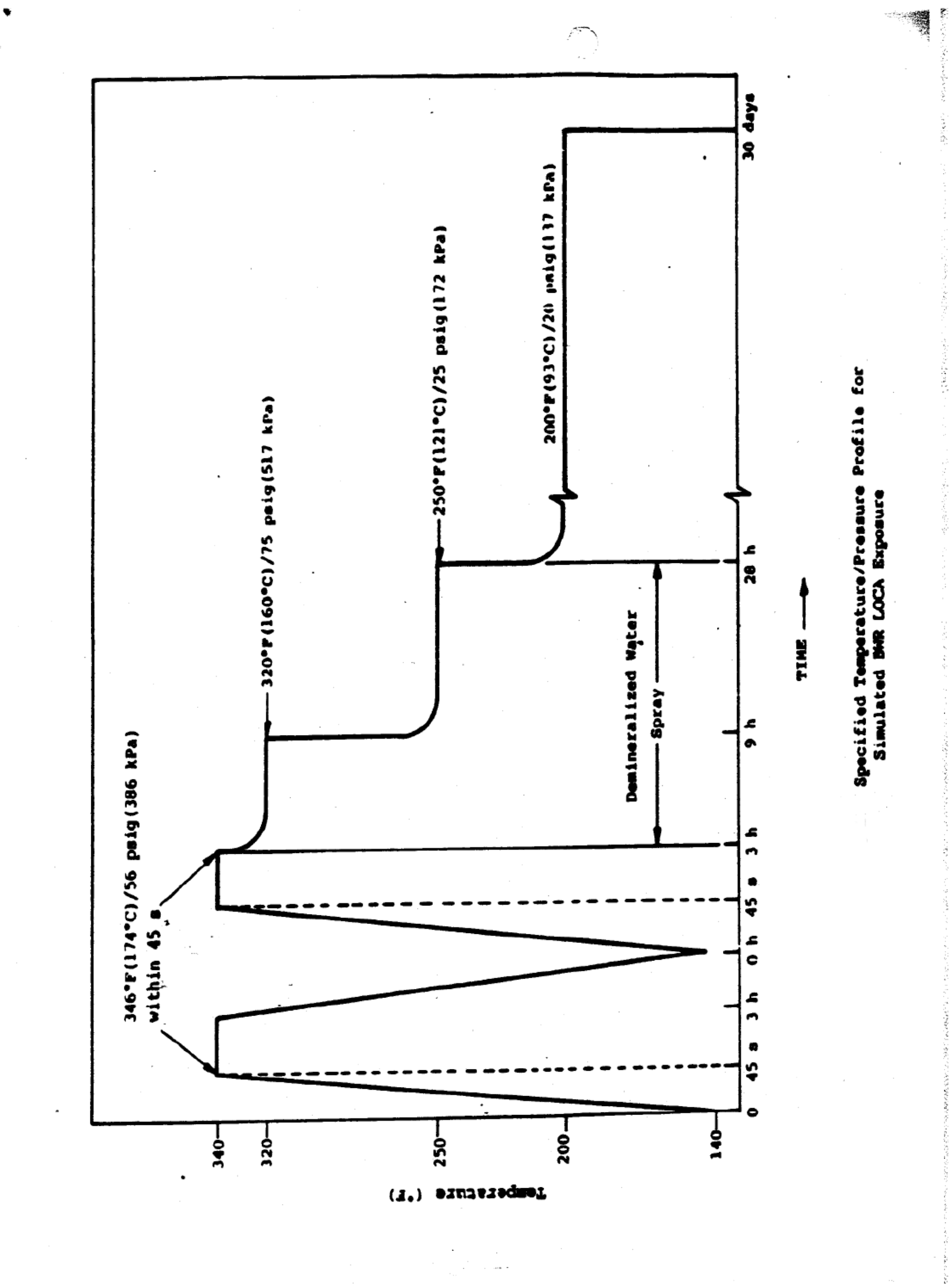

Figure 2, LOCA Profile

APPENDIX A

Class 1E-Qualification Summary

(2 pages)

CLASS 1E – QUALIFICATION TEST SUMMARY

FRC REPORT #	ERD PART NO	CONFIGURATION DETAIL	INTERFACIAL SEAL (NOTE1)	QUAL LIFE	TEST RESULTS	FUNCTIONAL REQUIREMENTS	THERMAL AGING HRS. AT 260	MECHANICAL AGING MATES/DEMATES	NUCLEAR IRRADIATION	HYDRODYNAMIC VIBRATION	SEISMIC	LOCA
6168-1	16-99-00540	Coax cable, Quick latch connector	Organic	20	P*	Input to output voltage less than 2% difference	430	50	25 Mrads + 165 Mrads	.75g's,5-200-5Hz, 90 minutes, 2 orthogonal axes	50 OBE, 1 SSE per axis 30 sec. Ea. Per Fig. 5 (6g's, 12g's)	Steam, Pressure, Temp per BWR profile 40 days
6168-2	16-99-00540	Coax cable, Quick latch connector	Organic	40	P*	Input to output voltage less than 2% difference	860	50	50 Mrads + 165 Mrads	.75g's,5-200-5Hz, 90 minutes, 2 orthogonal axes	50 OBE, 1 SSE per axis 30 sec. Ea. Per Fig. 5 (6g's, 12g's)	Steam, Pressure, Temp per BWR profile 40 days
6168-3	16-99-00500	Coax cable, Quick latch connector	Organic	20	P*	Input to output voltage less than 2% difference	430	50	25 Mrads + 165 Mrads	.75g's,5-200-5Hz, 90 minutes, 2 orthogonal axes	50 OBE, 1 SSE per axis 30 sec. Ea. Per Fig. 5 (6g's, 12g's)	Steam, Pressure, Temp per BWR profile 40 days
6168-4	16-99-00470	10-wire Thermocouple, multi-pin connector	Organic	40	TXXX	±1.23MV (2% of temp range 450° to 2500°F)	860	50	50 Mrads + 165 Mrads	.75g's,5-200-5Hz, 90 minutes, 2 orthogonal axes	50 OBE, 1 SSE per axis 30 sec. Ea. Per Fig. 5 (6g's, 12g's)	Steam, Pressure, Temp per BWR profile 40 days
6168-5	16-99-00460	8-wire thermocouple, multi-pin connector transition to four - 2-wire thermocouples	Organic	20	P*	±1.23MV (2% of temp range 450° to 2500°F)	430	50	25 Mrads + 165 Mrads	.75g's,5-200-5Hz, 90 minutes, 2 orthogonal axes	50 OBE, 1 SSE per axis 30 sec. Ea. Per Fig. 5 (6g's, 12g's)	Steam, Pressure, Temp per BWR profile 40 days
6168-6	16-99-00450	10-wire logic, multi-pin connector, transition to 10-coax, 10-wire splice	Organic	20	P*	Logic 0 (100K Ohm load) 0 ± 0.5V Logic 1 (270 Ohm load) 5 ± 0.5V	430	50	25 Mrads + 165 Mrads	.75g's,5-200-5Hz, 90 minutes, 2 orthogonal axes	50 OBE, 1 SSE per axis 30 sec. Ea. Per Fig. 5 (6g's, 12g's)	Steam, Pressure, Temp per BWR profile 40 days
6168-7	16-99-00430	3-wire power, multi-pin connector, 3-wire splice	Inorganic	40	O**	Actuate/de-actuate std 110V contactor	860	50	50 Mrads + 165 Mrads	.75g's,5-200-5Hz, 90 minutes, 2 orthogonal axes	50 OBE, 1 SSE per axis 30 sec. Ea. Per Fig. 5 (6g's, 12g's)	Steam, Pressure, Temp per BWR profile 40 days
6168-8	16-99-00420	10-wire Thermocouple, multi-pin connector, 10-wire splice	Organic	40	P*	±1.23MV (2% of temp range 450° to 2500°F)	860	50	50 Mrads + 165 Mrads	.75g's,5-200-5Hz, 90 minutes, 2 orthogonal axes	50 OBE, 1 SSE per axis 30 sec. Ea. Per Fig. 5 (6g's, 12g's)	Steam, Pressure, Temp per BWR profile 40 days
6168-9	16-99-00480	Coax cable, Quick latch connector	Organic	20	P*	Input to output voltage less than 2% difference	430	50	25 Mrads + 165 Mrads	.75g's,5-200-5Hz, 90 minutes, 2 orthogonal axes	50 OBE, 1 SSE per axis 30 sec. Ea. Per Fig. 5 (6g's, 12g's)	Steam, Pressure, Temp per BWR profile 40 days

P* - Meets all test pass/fail requirements

O** - Open conductor on leg A after Seismic
TXXX – TC 4A – 4B out of tolerance during LOCA
Note 1: Organic – (Compound EPDM 3957 supplied by Precision Rubber Products, Lebanon, Tenn.)
Inorganic – (Grafoil T Graphite Gasket supplied by Crane Packing Co., Morton Grove, Ill.)

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APPENDIX B

Seismic Stress Analysis

(15 pages)