BOSTRAD^{7E} CABLES

FLAME AND RADIATION RESISTANT CABLES FOR NUCLEAR POWER PLANTS

REPORT NO. B 915

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BOSTON INSULATED WIRE & CABLE CO.
65 Bay Street
Boston, Massachusetts 02125

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FIGURES

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I. INTRODUCTION

BIW Flame and Radiation Resistant Cables

BOSTRAD 7E cables with BIW's ethylene propylene rubber (EPR) insulation and BOSTRAD 7 chlorosulfonated polyethylene (CSPE) jackets have indicated life in excess of 40 years and excellent flame resistance. They are also radiation resistant, exceed LOCA environmental requirements and have excellent moisture resistance, as demonstrated by long term accelerated water absorption tests.

The outstanding performance of these cables is demonstrated by prototype tests in accordance with IEEE-383 on typical cables manufactured by BIW.

II. SUMMARY

This report describes the qualification of BOSTRAD 7E cable constructions to the requirements encountered in nuclear and fossil fueled power plants.

Type tests in accordance with IEEE 323-1974[1] and IEEE 383-1974[2] have been conducted which demonstrate the suitability of BOSTRAD 7E cables for installation in power plants. These tests include fire, LOCA, thermal endurance, radiation resistance, and water immersion.

1 IEEE Standard for Qualifying Class IE Equipment for Nuclear Power Generating Stations.

2 IEEE Standard for Type Test of Class IE Electric Cables, Field Splices and Connections for Nuclear Power Generating Stations.

III. CABLE CONSTRUCTIONS

BOSTRAD 7E cables are manufactured in accordance with BIW Specifying Standards and ICEA Standard S-68-516. Power, control and instrumentation cables are available, featuring the following construction:

Conductors	--	Class B stranded tinned copper, conforming to ASTM B8 and B33.
Insulation	--	Ethylene propylene rubber, conforming to ICEA S-68-516.
Insulation Jacket	--	BOSTRAD 7 CSPE, conforming to ICEA S-19-81.
Voltage Rating	--	1,000 V, 600 V or 300 V
Shield (if required)	--	Aluminum/polyester or copper/ polyester tape with stranded tinned copper drain wire, 100% coverage, or tinned copper braid.
Fillers (if required)	--	Flame retardant glass fiber or flame retardant synthetic rubber.
Flame Tapes(if required)	--	Flame retardant binder tapes.
Outer Jacket	--	BOSTRAD 7 CSPE, conforming to ICEA S-19-81.

Figure 1 gives typical constructions of the 2/C and 7/C cables. These cables have been subjected to the qualification tests described herein.

FIGURE 1

2 CONDUCTOR CABLE

Conductors	--	Two #16 AWG 7/.0192" tinned copper .
Dual Layer Insulation	--	25 mils ethylene propylene rubber with 15 mils BOSTRAD 7 CSPE jacket
Shield	--	Aluminum/polyester tape with #18 AWG 7/.0152" tinned copper drain wire
Jacket	--	45 mils BOSTRAD 7 CSPE

TYPICAL 7 CONDUCTOR CABLE

Conductors	--	Seven #12 AWG 7/.0305" tinned copper
Dual Layer Insulation	--	30 mils ethylene propylene rubber with 15 mils BOSTRAD 7 CSPE jacket
Outer Jacket	--	60 mils BOSTRAD 7 CSPE

IV. 40 YEAR LIFE

Long term aging tests conducted on cables indicate a life expectancy in excess of 40 years at 90C for BIW's ethylene propylene rubber insulation.

Aging was accelerated using the Arrhenius technique described below.

The aging characteristics of BIW's ethylene propylene rubber and CSPE compounds were found by monitoring the elongation of these compounds after exposure to different temperatures for varying times. This was done by placing hundreds of samples of each compound in ovens at 121C, 136C, 150C, 180C and 200C, and after prescribed intervals, removing samples from each oven and measuring ultimate elongation. The results of elongation versus time at each temperature are shown in Figure 2A.

The data in Figure 2A is transformed into a temperature versus time relationship by selecting various conditions of elongation and plotting the locus of time and temperature on semi-logarithmic paper (Figure 2B). It can be seen that for any selected value of elongation, the curves are essentially straight and parallel. Arrhenius theory in the temperature range investigated is validated by the straight line, i.e. the straight lines demonstrate a constant rate of reaction in the region. Since a rate of aging has been determined for the cable, then for any defined service condition, a line having the predetermined aging rate (slope) can be constructed through the point representing the service condition, and all points on the line will be equivalent to the defined service condition.

Elongation, however, cannot be related directly to the ability of a cable to function for a given time and temperature. However, if a cable can withstand dielectric proof testing after aging, its life is verified. Therefore, to demonstrate qualified life, BIW ages cable samples to the desired service conditions and, after this aging and bending to 40X cable OD, dielectrically proof tests the cable.

BOSTRAD 7E cables have been type tested to qualify for a 40 year, 90C service life. This has been done by constructing a line with the slope shown in Figure 2B through the desired 40 year, 90C point, as shown in Figure 3. To simulate this end life, BIW placed cable samples in air ovens at 200C, 180C, 150C, 136C and 121C. These cables were removed from the ovens periodically and subjected to a dielectric proof test of 2200 volts (twice rated voltage + 1000 in accordance with IEEE 383-1974, para. 2.3.2.). After successfully withstanding the test, the samples were returned to the oven for continued aging.

IV. 40 YEAR LIFE (Cont.)

BOSTRAD 7E cable samples aged in excess of the 40 year equivalency requirement at 200C, 180C, 150C, 136C and 121C, were bent around a 40X diameter mandrel and withstood the voltage proof test. These type tests demonstrate the capability of the cable to function after being aged to the equivalent of 40 years life at 90C.

FIGURE 2A

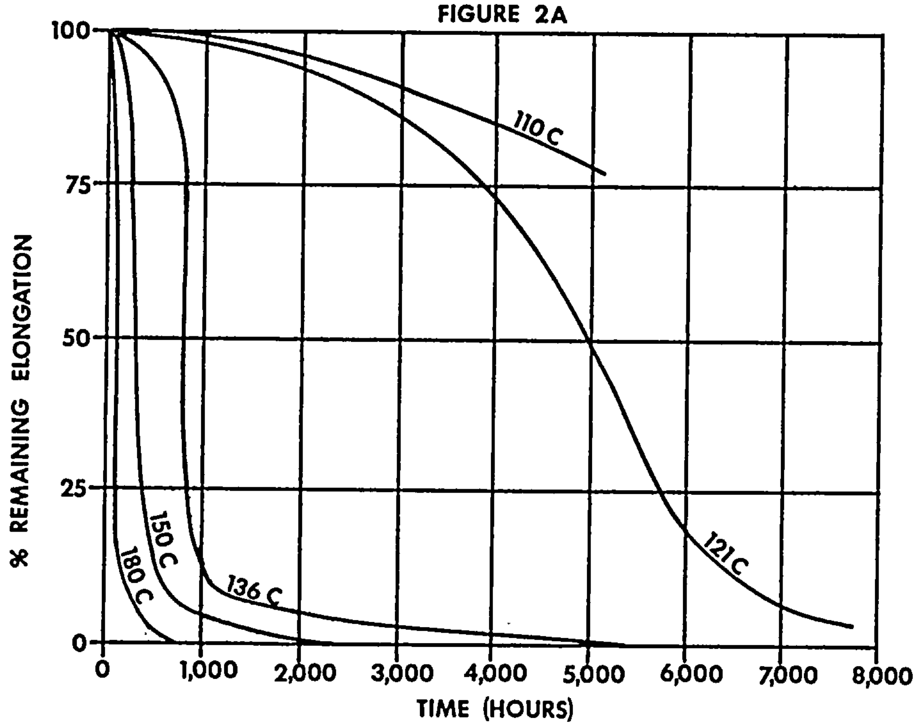


FIGURE 2B

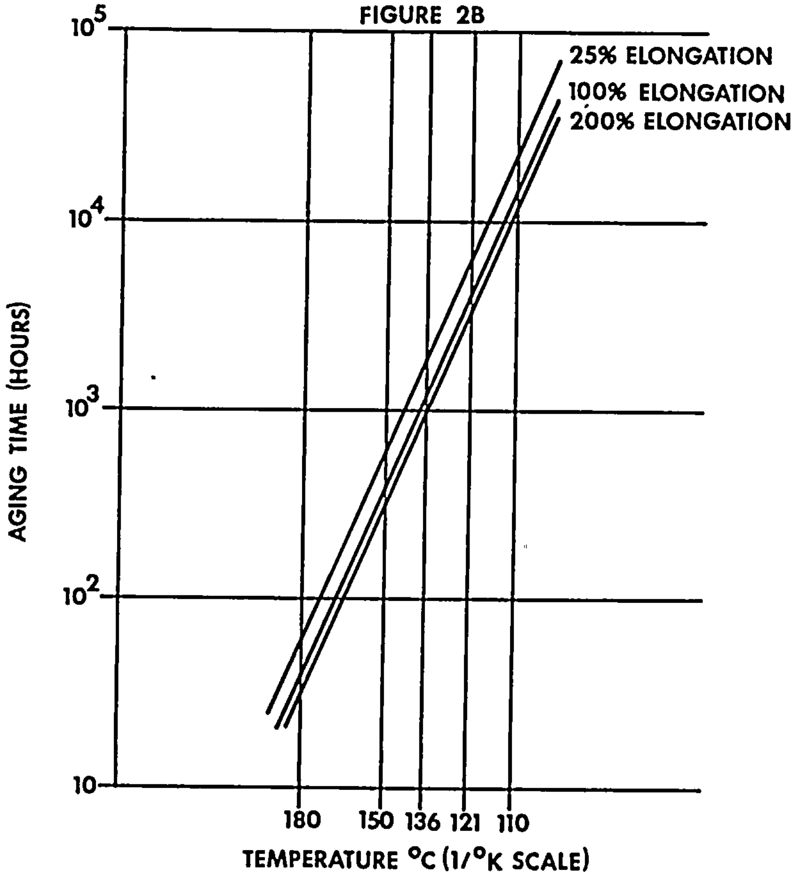
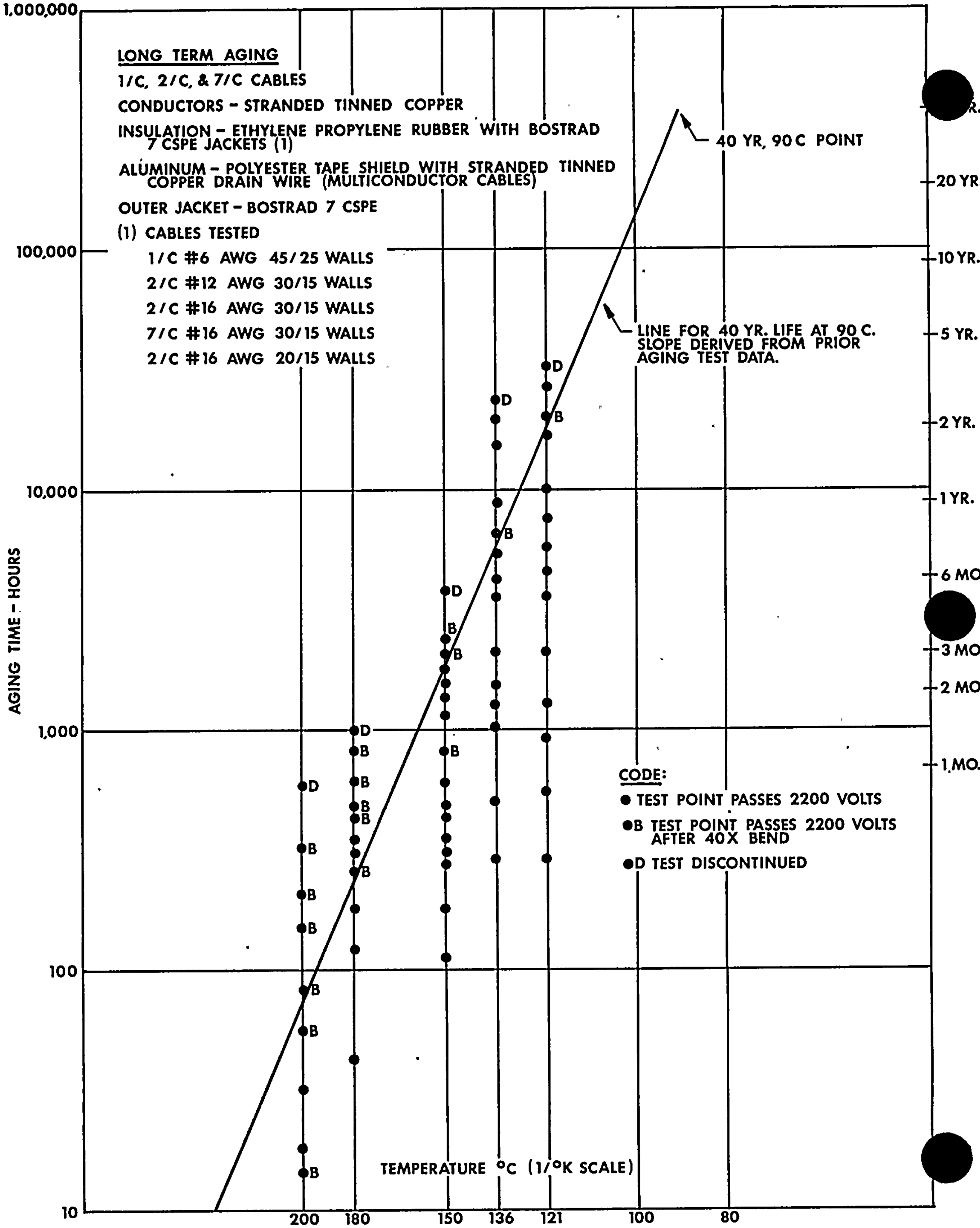


FIGURE 3


LONG TERM AGING
1/C, 2/C, & 7/C CABLES
CONDUCTORS - STRANDED TINNED COPPER
INSULATION - ETHYLENE PROPYLENE RUBBER WITH BOSTRAD 7 CSPE JACKETS (1)
ALUMINUM - POLYESTER TAPE SHIELD WITH STRANDED TINNED COPPER DRAIN WIRE (MULTICONDUCTOR CABLES)
OUTER JACKET - BOSTRAD 7 CSPE
(1) CABLES TESTED
1/C #6 AWG 45/25 WALLS
2/C #12 AWG 30/15 WALLS
2/C #16 AWG 30/15 WALLS
7/C #16 AWG 30/15 WALLS
2/C #16 AWG 20/15 WALLS
40 YR, 90 C POINT
LINE FOR 40 YR. LIFE AT 90 C. SLOPE DERIVED FROM PRIOR AGING TEST DATA.
CODE:
● TEST POINT PASSES 2200 VOLTS
●B TEST POINT PASSES 2200 VOLTS AFTER 40X BEND
●D TEST DISCONTINUED
AGING TIME - HOURS
1,000,000
100,000
10,000
1,000
100
10
20 YR.
10 YR.
5 YR.
2 YR.
1 YR.
6 MO.
3 MO.
2 MO.
1 MO.
TEMPERATURE °C (1/°K SCALE)
200
180
150
136
121
100
80

V. THERMAL AND RADIATION EXPOSURE

BOSTRAD 7E cables have excellent resistance to combined exposures of heat and radiation.

Bend tests in accordance with IEEE Standard 383-1974, para. 2.3.3., are shown in Figure 4. After a gamma radiation dosage of 200 megarads and thermal conditioning of 60 days at 155C, the cable passed the required 20X bend.

The thermal aging is equivalent to 40 years at 90C as shown by Figure 3.

Additional data concerning thermal and radiation exposure may be found in Section VI, Nuclear Radiation-LOCA Environmental Performance. The LOCA simulation is regarded as a more severe performance test, and demonstrates the outstanding capability of BOSTRAD 7E to exceed the standard tests by a comfortable margin.

FIGURE 4

THERMAL AND RADIATION EXPOSURE TEST

Conditioning -- Thermal aging 155C for 60 days (1440 hours) equivalent to 40 years at 90C, followed by 2×10^8 rads gamma radiation

Cable Construction -- 2/C #16 as in Figure 1.

Test Requirements

IEEE 383-1974, para. 2.3.3.
20x Bend -- 2.0 KVAC in water for 5 minutes

Test Results

Before Bend -- Pass 2.2 KVAC dry
After 20x Bend -- Pass 2.2 KVAC in water for 5 minutes

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VI. NUCLEAR RADIATION-LOCA ENVIRONMENTAL PERFORMANCE

BOSTRAD 7E cables perform through service conditions encountered during both normal and LOCA operation in nuclear power plants, as shown by their passing the LOCA simulation tests of IEEE Standard 323-1974, Appendix A, Figure A1, and para. 2.4.3.1.

The cables were irradiated to the levels indicated in the data at ISOMEDIX, INC., Parsippany, New Jersey by exposure to a Cobalt 60 source. The cables were then subjected to the steam and pressure LOCA simulation in autoclave chambers at the Boston facility of Boston Insulated Wire & Cable Company.

Figures 5, 6, 7 and 8 demonstrate the typical performance of BIW BOSTRAD 7E cables under LOCA environmental conditions. BIW has successfully performed many LOCA tests on BOSTRAD 7E cables and continues to perform tests to verify BOSTRAD 7E's outstanding performance.

Figure 5 shows an unaged 2/C #16 AWG cable which, after a gamma radiation dose of 200 megarads, was exposed to the IEEE Std. 323-1974 LOCA environmental conditions. The cable successfully performed 367 days and then met all the requirements of the post LOCA simulation test.

Figure 6 presents data for a 2/C #16 AWG cable which, after IC[illegible] thermal aging of 168 hours at 121C (equivalent to 40 years at 50C) a[illegible] a gamma radiation dose of 200 megarads, was exposed to the LOCA environmental conditions. The cable successfully withstood these extremes for 367 days and then met all the requirements of the IEEE Std. 383-1974 post LOCA simulation test.

Figure 7 presents data for a 2/C #16 AWG cable which, after thermal aging to a condition representing 40 years life at 90C (Figure 3) and a gamma radiation dose of 200 megarads, was exposed to the LOCA environmental conditions. The cable successfully withstood these extremes for 161 days and then met all the requirements of the IEEE Std. 383-1974 post LOCA Simulation Test.

Figure 8 presents data for a 1/C #12 AWG cable containing a splice which, after heat aging to a condition representing 40 years life at 90C (Figure 3) followed by a gamma radiation dose of 200 megarads, was exposed to the LOCA environmental conditions. The cable successfully withstood these extremes for 111 days and then met all the requirements of the IEEE Std. 383-1974 post LOCA Simulation Test.

FIGURE 5

LOCA SIMULATION DATA
New Cable

Conditioning -- 2×10^8 rads, gamma

Cable Construction -- 2/C #16 as in Figure 1.

Test Requirements

Environmental Simulation Cycle per IEEE 323-1974, Appendix A, combined cycle for PWR/BWR

Cable sprayed with 0.28 molar H_3BO_3 solution adjusted to pH of 10.5 with NaOH for first 24 hours and with mineral-free water thereafter through the first 30 days only.

Test Results

	Time	Temp. °F	Pressure Psig Steam	IR Cdr - Cdr Megohms per 20 ft. test length
	0	90	0	7.0×10^5
End of	3 hrs.	340	115	3.5×10^0
	4 hrs.	160	0	1.2×10^3
	7 hrs.	340	115	3.7×10^0
	10 hrs.	320	85	7.6×10^0
	14 hrs.	300	65	1.0×10^1
	26 hrs.	250	16	1.3×10^2
	3 days	250	16	2.4×10^2
	6 days	200	0	6.0×10^4
	10 days	200	0	6.0×10^4
	35 days	200	0	7.8×10^4
	100 days	200	0	1.1×10^5 (1)
	367 days	167	0	2.2×10^4 (2)

600 volts applied between conductors throughout the test. Current of 1 amp/conductor throughout the test.

Figure 5 (Continued)

Post LOCA Tests (IEEE STD. 383-1974)

(1) The LOCA test was continued at 200F, 0 psig and 100% RH for a total of 100 days. After the 100 day cycle, the cable was subjected to a post LOCA test consisting of 40x, 20x, 10x and 5x mandrel bends. The cable withstood a 5 minute 2200 volt dielectric test after each bend.

(2) The LOCA test was continued again at 167F, 0 psig and 100% RH for a total of 367 days. The cable then passed an additional post LOCA bend test of 40x and 2200 VAC for 5 minutes in water.

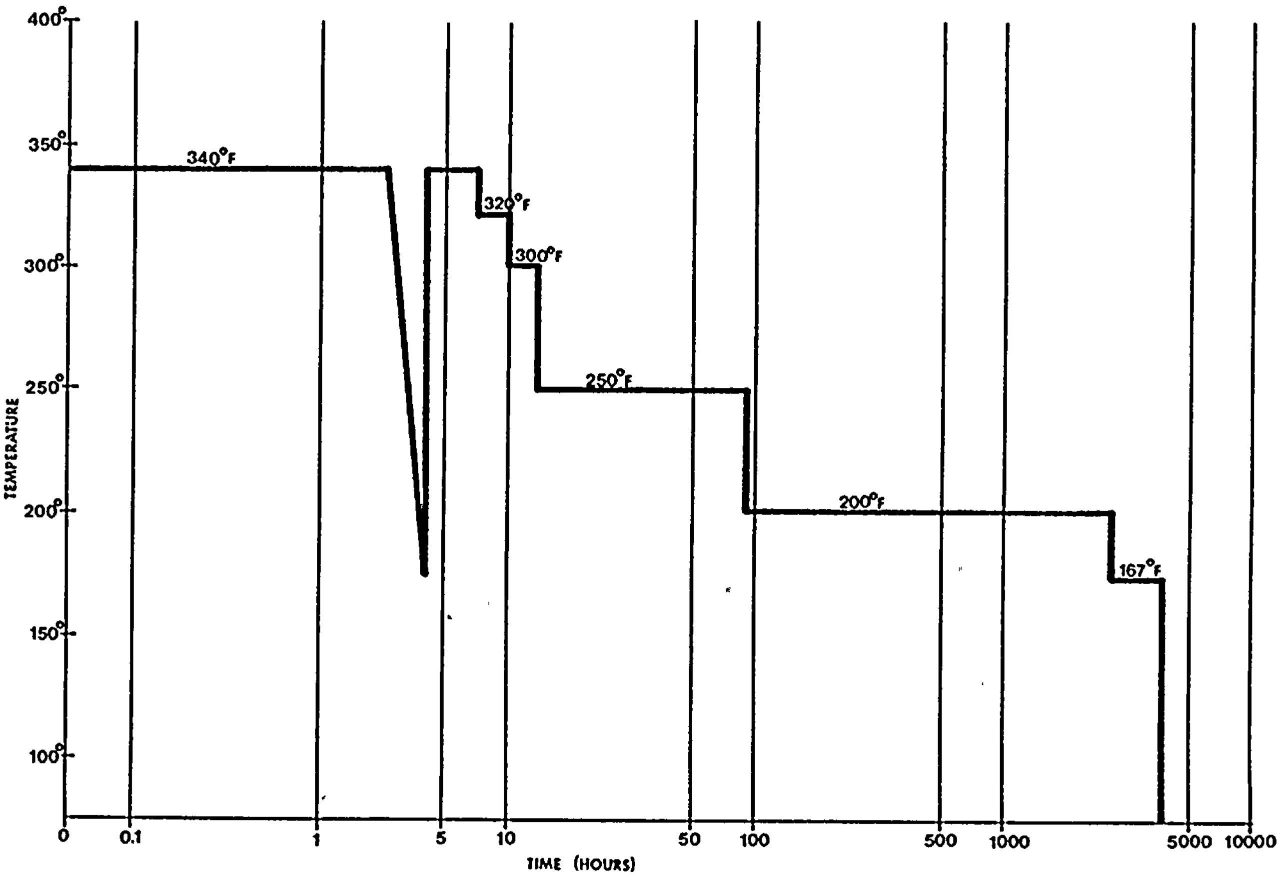

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FIGURE 6

LOCA SIMULATION DATA
Cable Aged to Equivalent of 50C for 40 Years

Conditioning --

Thermal aging at 168 hours at 121C followed by 2×10^8 rads, gamma.

Cable Construction -- 2/C #16 AWG as in Figure 1.

Test Requirements

Environmental Simulation cycle per Appendix A, IEEE Std. 323-1974, combined cycle for PWR/BWR.

Cable sprayed with 0.28 molar H_3BO_3 solution adjusted to pH of 10.5 with NaOH for first 24 hours and with mineral-free water thereafter through the first 30 days only.

Test Results

	Time	Temp. °F	Pressure Psig Steam	IR Cdr - Cdr Megohms per 20 ft. test length
	0	125	0	2.5×10^4
End of	3 hrs.	340	105	1.2×10^0
	4 hrs.	160	0	7.3×10^2
	7 hrs.	340	105	1.6×10^0
	10 hrs.	320	85	3.0×10^0
	14 hrs.	300	60	6.4×10^0
	26 hrs.	250	16	4.0×10^1
	3 days	250	16	9.0×10^1
	4 days	200	0	1.3×10^2
	11 days	200	0	1.4×10^4
	30 days	200	0	9.4×10^4
	100 days	200	0	2.0×10^5 (1)
	367 days	167	0	8.2×10^4 (2)

600 volts applied between conductors throughout the test. Current of 1 amp/conductor throughout the test.

Figure 6 (Continued)

POST LOCA TESTS (IEEE STD. 383-1974)

(1) The LOCA test was continued at 200F, 0 psig and 100% RH for a total of 100 days. After the 100 day cycle, the cable was subjected to a post LOCA test consisting of 40x, 20x, 10x and 5x mandrel bends. The cable withstood a 5 minute 2200 volt dielectric test in water after each bend.

(2) The LOCA test was continued again at 167F, 0 psig and 100% RH for a total of 367 days. The cable then passed an additional post LOCA bend test of 40x and 2200 VAC for 5 minutes in water.

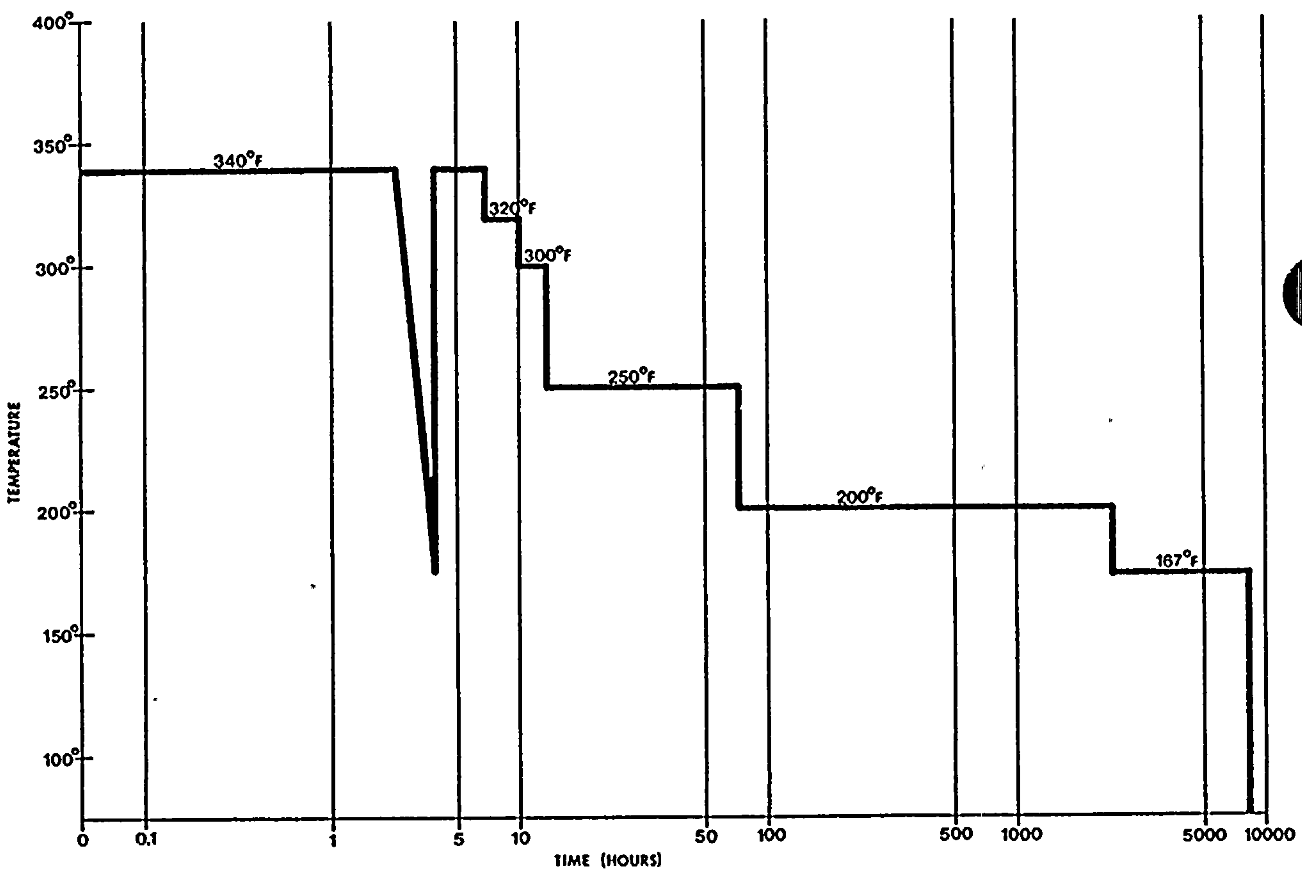


FIGURE 7

LOCA SIMULATION DATA
Cable Aged to the Equivalent of 90C for 40 Years

Conditioning --

Thermal aging of 1440 hours at 155C followed by 2×10^8 rads, gamma.

Cable Construction -- 2/C #16 AWG as in Figure 1.

Test Requirements

Environmental Simulation Cycle per Appendix A, IEEE Std. 323-1974, combined cycle for PWR/BWR.

Cable sprayed with 0.28 molar H_3BO_3 solution adjusted to pH of 10.5 with NaOH for first 24 hours and with mineral-free water continuously thereafter.

Test Results

	Time	Temp. °F	Pressure Psig Steam	IR Cdr #1 Megohms per 20 ft. test length	IR Cdr #2 Megohms per 20 ft. test length
	0	75	0	7.0×10^4	8.0×10^4
End of	3 hrs.	340	110	6.2×10^1	7.2×10
	4 hrs.	165	0	1.1×10^3	1.2×10^3
	7 hrs.	340	110	$.55 \times 10^0$	$.55 \times 10^0$
	10 hrs.	320	85	1.1×10^0	1.1×10^0
	14 hrs.	300	65	3.0×10^0	2.9×10^0
	4 days	250	20	2.0×10^1	1.7×10^1
	17 days	200	0	7.7×10^1	7.6×10^1
	45 days	200	0	8.4×10^1	8.8×10^1
	104 days	200	0	0.7×10^2	4.0×10^1
	144 days	167	0	1.0×10^0	1.7×10^0
	161 days	167	0	0.6×10^0 (1)	0.7×10^0 (1)

600 volts applied between conductors and 345 volts between conductors and shield throughout the test. Current of 1 amp/conductor throughout the test.

Figure 7 (Continued)

<u>POST LOCA BEND TEST</u> (IEEE STD 383-1974)

(1) At the conclusion of the above 161 day cycle, the cable was removed from the autoclave and successfully withstood a 40x bend followed by 2400 VAC for 5 minutes immersed in water.

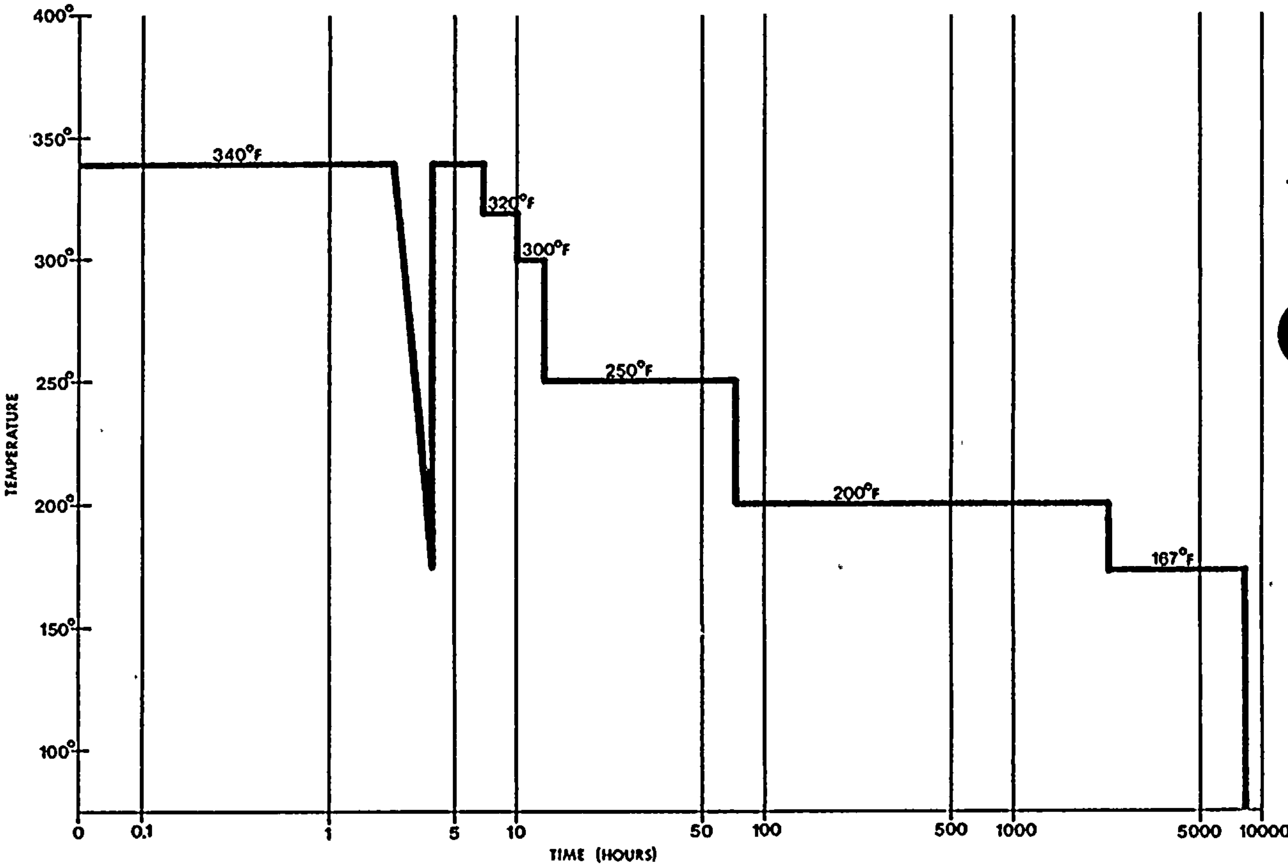


FIGURE 8

LOCA SIMULATION DATA
Cable Containing a Splice Aged to the Equivalent of 90C for 40 Years

Conditioning --

Thermal aging of 1440 hours at 155C followed by 2×10^8 rads, gamma.

Cable Construction

Conductor	--	1/C #12 AWG 7/.0305" tinned copper
Insulation	--	Ethylene propylene rubber, 30 mil wall, with BOSTRAD 7 CSPE jacket, 20 mil wall
Splice	--	Cable contained 1 splice insulated with Raychem WCSF flame retardant tubing

Test Requirements

Environmental Simulation Cycle per Appendix A, IEEE Std. 383-1974, BWR cycle, Table A2.

Cable sprayed with 0.28 molar H_3BO_3 solution adjusted to pH of 10.5 with NaOH for first 24 hours and with mineral-free water thereafter through the first 30 days only.

Test Results

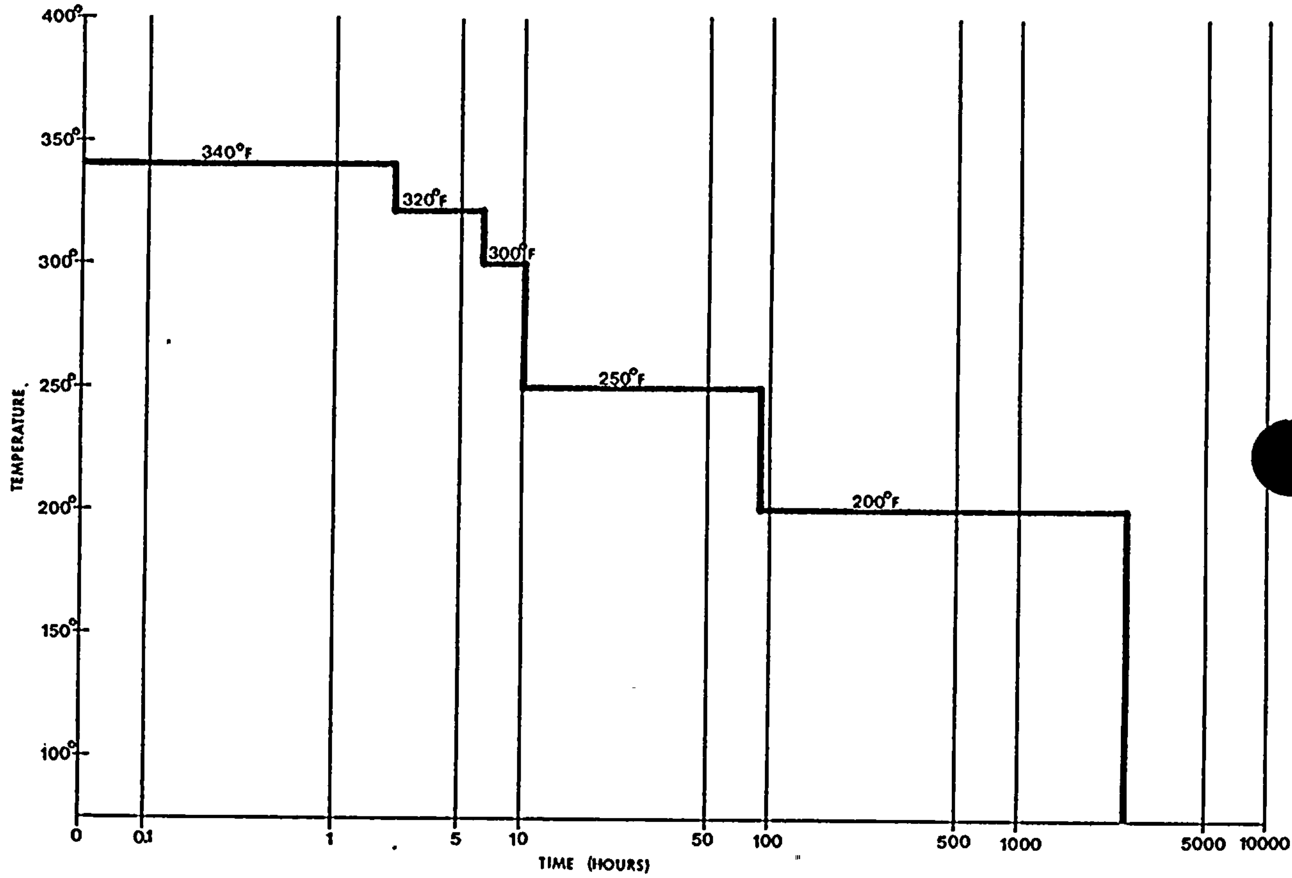
	Time	Temp. °F	Pressure Psig Steam	IR Cdr - Ground Megohms per 20 ft. test length
	0	78	0	2.2×10^5
End of	3 hrs.	340	110	$.45 \times 10^1$
	6 hrs.	320	75	1.0×10^1
	10 hrs.	300	50	1.9×10^1
	4 days	250	20	$.35 \times 10^1$
	55 days	200	0	$.8 \times 10^1$
	111 days	200	0	1.2 x 10 (1)

600 volts applied between conductor and ground throughout the test. Current of 5 amps applied continuously throughout the test.

POST LOCA TEST (IEEE STD 383-1974)

(1) The LOCA test was continued at 200F, 0 psig and 100% RH for a total of 111 days. After the 111 day cycle, the spliced cable was subjected to a post LOCA test consisting of a 40x mandrel bend. The cable and splice then withstood a 5 minute 2400 volt dielectric test immersed in water.

FIGURE 8


400°
350°
300°
250°
200°
150°
100°
TEMPERATURE
340°F
320°F
300°F
250°F
200°F
0
0.1
1
5
10
50
100
500
1000
5000
10000
TIME (HOURS)

VII. FLAME RESISTANCE - VERTICAL TRAY FIRE TESTS

BOSTRAD 7E cables successfully pass the flame test requirements of IEEE Standard 383-1974, as shown in Figures 9 and 10. The 2/C and 7/C cables self-extinguish and do not propagate flame after a 70,000 BTUh gas flame is continuously applied to the cables for 20 minutes. The excellent resistance of BOSTRAD 7E cables to burning is shown by the short distance of insulation damage and jacket char.

BOSTRAD 7E cables also pass the IEEE 383-1974 flame test requirements when a 210,000 BTUh burner is substituted for the 70,000 BTUh burner. Figure 11 demonstrates the satisfactory performance in this test.

Aging does not adversely affect the flame resistance of the cables. This is shown by Figure 12, which describes the testing of a BOSTRAD 7E cable after thermal aging of 168 hours at 121C (equivalent to 40 years at 50C). Additionally, the oxygen index of the CSPE jacket has been recorded after thermal aging. When aged to a condition beyond projected 40 year life (refer to Figure 3), the CSPE jackets show an increase in oxygen index, indicating no degradation of flame resistance.

Condition	Oxygen Index of chlorosulfonated polyethylene jacket
Initial, unaged	35
Aged 300 hrs. @ 180C	40

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FIGURE 9

VERTICAL TRAY FLAME TEST

Cable Construction -- 2/C #16 AWG as in Figure 1.

Test Requirements -- IEEE 383-1974, Paragraph 2.5.

Vertical steel ladder type cable tray, 8' long, 12" wide, 3" deep
10 cables mounted 1/2 diameter apart
10" wide, 70,000 BTU/hr ribbon burner, 1500F flame
Flame time -- 20 minutes
Gas source -- commercial gas

Cable passes if flame does not propagate and cable self-extinguishes.

Test Results

Impingement Temperature

Min	°F	Min	°F	Min	°F	Min	°F
0	1500	5	1500	10	1380	15	1360
1	1500	6	1440	11	1380	16	1360
2	1480	7	1440	12	1360	17	1400
3	1420	8	1400	13	1380	18	1460
4	1480	9	1400	14	1380	19	1400
						20	1400

	Time after Ignition
Time of burner ignition	0 min. 0 sec.
Time of burner shut-off	20 min. 0 sec.
Time flame extinguished	20 min. 0 sec.
Jacket ignition	1 min. 30 sec. (approx)
Distance of jacket char	34 inches
Distance of insulation damage	18 inches

Cables self-extinguished and did not propagate the flame -- passed test.

Insulated conductors removed from the cable also passed the flame resisting test of ICEA S-19-81, Sec. 6.19.6.

FIGURE 10

VERTICAL TRAY FLAME TEST

Cable Construction -- 7/C #12 AWG as in Figure 1.

Test Requirements -- IEEE 383-1974, Paragraph 2.5

Vertical steel ladder type cable tray, 8' long, 12" wide, 3" deep
12 cables: mounted 1/2 diameter apart
10" wide, 70,000 BTU/hr. ribbon burner, 1500F flame
Flame time -- 20 minutes
Gas source -- propane gas

Cable passes if flame does not propagate and cable self-extinguishes.

Test Results

Impingement Temperature

Min	°F	Min	°F	Min	°F	Min	°F
0	1500	5	1460	10	1780	15	1600
1	1400	6	1600	11	1600	16	1600
2	1300	7	1700	12	1600	17	1600
3	1400	8	1700	13	1620	18	1620
4	1360	9	1760	14	1600	19	1660
						20	1600

	Time after Ignition
Time of burner ignition	0 min. 0 sec.
Time of burner shut-off	20 min. 0 sec.
Time flame extinguished	20 min. 0 sec. (immediately)
Jacket ignition	1 min. 45 sec. (approx.)
Distance of jacket char	16 inches
Distance of insulation damage	0 inches

Cables self-extinguished and did not propagate the flame -- passed test.

Insulated conductors removed from the cable also passed the flame resisting test of ICEA S-19-81, Sec. 6.19.6.

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FIGURE 11

VERTICAL TRAY FLAME TEST, AGED CABLES

Cable Constructions -- 2/C #16 AWG and 4/C #16 AWG as described below.

Test Requirements -- IEEE 383-1974, Paragraph 2.5

Vertical steel ladder type cable tray, 8' long, 12" wide, 3" deep
12 cables: mounted 1/2 diameter apart
10" wide, 70,000 BTU/hr. ribbon burner, 1500 flame
Flame time -- 20 minutes
Gas source -- propane gas

Cable passes if flame does not propagate and cable self-extinguishes.

Conditioning

Cables aged 168 hours at 121C, equivalent to 40 years at 50C.

Test Results

	Time after Ignition	
	2/C #16 AWG	4/C #16 AWG
Time of burner ignition	0 min. 0 sec.	0 min. 0 sec.
Time of burner shut-off	20 min. 0 sec.	20 min. 0 sec.
Time flame extinguished	20 min. 0 sec.	20 min. 0 sec.
Jacket ignition (approx)	1 min. 45 sec.	1 min. 45 sec.
Distance of jacket char	49 inches	47 inches
Distance of insulation damage	36 inches	39 inches

Cables self-extinguished and did not propagate the flame -- passed test.

Insulated conductors removed from the cables also passed the flame resisting test of ICEA S-19-81, Sec. 6.19.6.

Cable Constructions

Conductors - #16 AWG 7/.0192" tinned copper

Insulation - 20 mils ethylene propylene rubber with 10 mils BOSTRAD7 CSPE insulating jacket.

Shield - Aluminum/polyester tape with #18 AWG 7/.0152" tinned copper drain wire

Jacket - 45 mils BOSTRAD 7 CSPE

FIGURE 12

VERTICAL TRAY FLAME TEST, AGED CABLE

Cable Construction -- 2/C #16 AWG

Test Requirements -- IEEE 383-1974, Paragraph 2.5

Vertical steel ladder type cable tray, 8' long, 12" wide, 3" deep
12 cables: mounted 1/2 diameter apart
10" wide, 70,000 BTU/hr. ribbon burner, 1500 flame
Flame time -- 20 minutes
Gas source -- propane gas

Cable passes if flame does not propagate and cable self-extinguishes.

Conditioning

Cables aged 168 hours at 150C, equivalent to 40 years at 66C.

Test Results	Time After Ignition
Time of burner ignition	0 min. 0 sec.
Time of burner shut-off	20 min. 0 sec.
Time flame extinguished	20 min. 24 sec.
Jacket ignition (approx)	1 min. 30 sec.
Distance of jacket char	39 inches
Distance of insulation damage	24 inches

Cables self-extinguished and did not propagate the flame -- passed test.

Insulated conductors removed from the cables also passed the flame resisting test of ICEA S-19-81, Sec. 6.19.6.

Cable Construction

Conductors - #16 AWG 7/.0192" tinned copper

Insulation - 25 mils ethylene propylene rubber with 15 mils BOSTRAD7 CSPE insulating jacket.

Shield - Aluminum/polyester tape with #18 AWG 7/.0152" tinned copper drain wire

Binder - Flame retardant

Jacket - 45 mils BOSTRAD 7 CSPE

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FIGURE 13

VERTICAL TRAY FLAME TEST, 210,000 BTU

Cable Construction -- 7/C #14 AWG as described below

Test Requirements -- IEEE 383-1974, Paragraph 2.5 except 210,000 BTU/hr. burner and 15' long tray

Vertical steel ladder type cable tray, 15' long, 12" wide, 3" deep
10 cables mounted 1/2 diameter apart
10" wide, 120,000 BTU/hr. ribbon burner, 1500F flame
Flame time -- 20 minutes
Gas source -- propane gas

Cable passes if flame does not propagate and cable self-extinguishes.

Test Results

	Time after Ignition
Time of burner ignition	0 min. 0 sec.
Time of burner shut-off	20 min. 0 sec.
Time flame extinguished	20 min. 0 sec. (immediately)
Jacket ignition	1 min. 30 sec. (approx.)
Distance of jacket char	66 inches
Distance of insulation damage	58 inches

Cables self-extinguished and did not propagate the flame -- passed test.

Insulated conductors removed from the cable also passed the flame resisting test of ICEA S-19-81, Sec. 6.19.6.

Cable Construction

Conductors - #14 AWG 7/.0242" tinned copper

Insulation - 30 mils ethylene propylene rubber with 15 mils BOSTRAD 7 CSPE insulating jacket.

Jacket - 60 mils BOSTRAD 7 CSPE

FIGURE 14

VERTICAL TRAY FLAME TEST - AGED CABLE, 210,000 BTU

Cable Construction -- 2/C #16 AWG as described below

Test Requirements -- IEEE 383-1974, Paragraph 2.5 except 210,000 BTU/hr. burner and 15' long tray

Vertical steel ladder type cable tray, 15' long, 12" wide, 3" deep
7 cables: mounted 1/2 diameter apart
10" wide, 120,000 BTU/hr. ribbon burner, 1500F flame
Flame time -- 20 minutes
Gas source -- propane gas
Cable passes if flame does not propagate and cable self-extinguishes.

Conditioning

Cables aged 168 hours at 121C, equivalent to 40 years at 50C.

Test Results

	Time after Ignition
Time of burner ignition	0 min. 0 sec.
Time of burner shut-off	20 min. 0 sec.
Time flame extinguished	20 min. 42 sec.
Jacket ignition	1 min. 30 sec. (approx.)
Distance of jacket char	57 inches
Distance of insulation damage	52 inches

Cable self-extinguished and did not propagate the flame -- passed test.

Insulated conductors removed from the cable also passed the flame resisting test of ICEA S-19-81, Sec. 6.19.6.

Cable Construction

Conductors - #16 AWG 7/.0192" tinned copper

Insulation - 20 mils ethylene propylene rubber with 15 mils BOSTRAD7 CSPE insulating jacket.

Shield - Aluminum/polyester tape with #18 AWG 7/.0152" tinned copper drain wire.

Jacket - 45 mils BOSTRAD 7 CSPE

BIW

VIII. LONG TERM WATER ABSORPTION

BOSTRAD 7E cables have excellent moisture resistance as demonstrated by the stability of electrical properties after long term immersion in water. This is shown by Figure 13 for the electroendosmosis method in 90C water and by Figure 14 for EM-60 tests in 75C water.

FIGURE 15

LONG TERM ACCELERATED WATER ABSORPTION

ELECTROENDOSMOSIS METHOD IN 90C WATER

A potential of 600 volts DC negative was continuously applied to the conductor except while measurements were being performed.

Conductor -- #14 AWG 7/.0242" tinned copper
Insulation -- Ethylene propylene rubber, 30 mil wall covered with BOSTRAD 7 CSPE, 15 mil wall

TIME	SIC	POWER FACTOR, %	3300 VAC FOR 5 MIN.
1 day	3.4	3.2	pass
1 week	3.4	2.3	pass
2 weeks	3.4	2.1	pass
4 weeks	3.5	1.4	pass
8 weeks	3.5	1.6	pass
12 weeks	3.6	1.5	pass
16 weeks	3.8	1.7	pass
20 weeks	3.7	1.7	pass
24 weeks	3.7	1.4	pass
26 weeks	3.8	1.8	pass
28 weeks	3.8	1.8	pass
32 weeks	3.8	1.9	pass
36 weeks	3.9	1.6	pass
40 weeks	3.9	2.0	pass
44 weeks	4.0	2.0	pass
48 weeks	4.0	3.0	pass

BIW

FIGURE 16

LONG TERM ACCELERATED WATER ABSORPTION

ICEA S-68-516 ELECTRICAL METHOD EM-60

Conductor	--	#16 AWG 7/.0192" tinned copper
Insulation	--	Ethylene propylene rubber, 30 mil wall
Water Temperature	--	75C

Time	Increase In Capacitance (%)	Stability Factor (%)	Insulation Resistance Megohms per 1000 feet
1 day	0	0.10%	7.9×10^2
7 days	0.14	0.10	1.3×10^3
14 days	0.14	0.10	1.6×10^3
4 weeks	0.29	0.10	2.0×10^3
8 weeks	0.86	0.10	2.3×10^3
12 weeks	0.72	0.04	2.3×10^3
16 weeks	1.43	0.10	3.2×10^3
20 weeks	1.29	0.10	2.7×10^3
24 weeks	1.40	0.06	2.8×10^3
28 weeks	1.57	0.03	4.0×10^3
32 weeks	2.00	0.10	4.0×10^3
36 weeks	2.14	0.00	4.0×10^3
40 weeks	2.00	0.03	2.5×10^3
44 weeks	2.14	0.05	3.0×10^3
48 weeks	2.57	0.06	3.3×10^3
52 weeks	2.57	0.07	4.0×10^3

RG&E Reference 83-1

QUALITY ASSURANCE
EA&T
IN THE NUCLEAR INDUSTRY

ENGINEERING ANALYSIS AND TEST COMPANY, INC.

4676 ADMIRALTY WAY
MARINA DEL REY, CALIFORNIA 90291
(213) 822-0931

TEST REPORT

IEEE-323-1974 QUALIFICATION

OF

DELPHI IV HYDROGEN ANALYZER

As Manufactured By

COMSIP DELPHI, INC.

Project: 1035-1

Date: December 1980

SPECIALIZED ENGINEERING SERVICES, NUCLEAR ENGINEERING
MECHANICAL ENGINEERING • EARTHQUAKE ENGINEERING
STRUCTURAL DYNAMICS • COMPONENT QUALIFICATION
SOFTWARE DEVELOPMENT

QUALITY ASSURANCE
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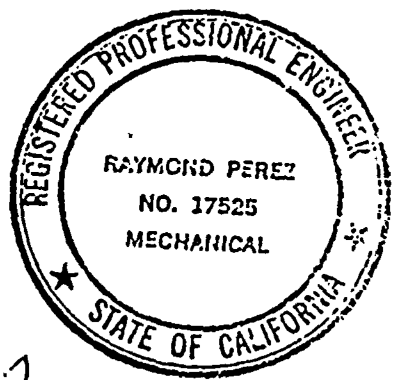
(213) 822-0931

CERTIFICATE

EA&T Company Inc. dba Engineering Analysis and Test Company performed an environmental qualification test program on a Delphi IV Hydrogen Analyzer prototype manufactured by Comsip Delphi, Inc. of South El Monte, California.

The qualification program was performed in conformance with EA&T Test Plan, Project No. 1035-1 Rev. 2 dated November 1979 and IEEE-323-1974 Standard entitled "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations", as implemented by Nuclear Regulatory Guide 1.89 entitled "Qualification of Class 1E Equipment for Nuclear Power Plants".



Raymond Perez
Professional Engineer

Michael Perez
Quality Assurance

SPECIALIZED ENGINEERING SERVICES, NUCLEAR ENGINEERING
MECHANICAL ENGINEERING • EARTHQUAKE ENGINEERING
STRUCTURAL DYNAMICS • COMPONENT QUALIFICATION
SOFTWARE DEVELOPMENT

TABLE OF CONTENTS

1.0 PURPOSE

To describe the procedure which was utilized for the environmental qualification type testing of safety related instruments for nuclear power plant applications.

2.0 SCOPE

This procedure applies to safety related instruments for which project specifications require their qualification in accordance with the requirements of IEEE-323-1974 Standard For Qualifying Class 1E Equipment For Nuclear Power Generating Stations, as implemented by Regulatory Guide 1.89, Qualification of Class 1E Equipment For Nuclear Power Plants.

3.0 DEFINITIONS

3.1 Safety Related Instruments

Instruments that are essential to emergency reactor shutdown, containment isolation, reactor core cooling, and containment and reactor heat removal, or otherwise are essential in preventing significant release of radioactive material to the environment.

3.2 Type Tests

Tests made on one or more sample instruments to verify adequacy of design and manufacturing processes.

3.3 RAD (Roentgen - Absorbed - Dose)

Absorption dose of 100 ergs/gm (material). The rad is a measure of radiated energy absorption of any form (particle or electromagnetic) in any material.

3.4 Octave

The interval between two frequencies which have a frequency ratio of two.

3.5 Operating Basis Earthquake (OBE)

That earthquake which produces the vibratory ground motion for which those features of the nuclear power plant necessary for continued operation without undue risk to the health and safety of the public are designed to remain functional (excerpted from IEEE-Std. 344-1975).

3.6 Safe Shutdown Earthquake (SSE)

That earthquake that produces the maximum vibratory ground motion for which certain structures, systems, and components are designed to remain functional.

4.0 PROCEDURE

4.1 General

4.1.1 The procedure which was followed outlines a generic environmental plan developed to qualify the Delphi Model K Hydrogen Analyzer as manufactured by Comsip Delphi, Inc. for nuclear power plant installation. The procedure describes the type tests which were performed on the instruments in a specific order. The sequence used is the one recommended by the IEEE-323-1974 Standard and briefly consists of:

4.1.1.1 Inspection and Operational Tests
4.1.1.2 Functional Tests
4.1.1.3 Thermal Aging
4.1.1.4 Functional Tests
4.1.1.5 Mechanical Cycling
4.1.1.6 Functional Tests
4.1.1.7 Irradiation
4.1.1.8 Functional Tests
4.1.1.9 Seismic Vibration
4.1.1.10 Functional Tests
4.1.1.11 Simulated Post Accident Condition
4.1.1.12 Functional Tests
4.1.1.13 Final Inspection and Operational Tests

4.1.2 The type tests were applied to one instrument from each different family. Design verification

does not require that more than one unit be tested. The instrument tested was a randomly selected production model. All of the different tests and conditions were applied to the same instrument. Appendix A of this procedure lists all of the different instruments which were subjected (one unit of each) to type tests.

4.1.3 In developing this procedure various documents, NRC Regulatory Guides, IEEE Standards etc., were consulted. Appendix G of this procedure lists all references.

4.1.4 Unless otherwise specified herein, all tests described by this procedure were performed at an atmospheric pressure of 29.92 $\pm$ 2.0 inches of mercury absolute, a temperature of 70 $\pm$ 10^{0}F and a relative humidity of 50 percent $\pm$ 25 percent.

4.1.5 Instruments were mounted in a manner and position that best simulates the expected installation. The environmental exposures and instrument performance were monitored using equipment that provides resolution for the detection of meaningful changes in the measured variables. For the LOCA exposure only, the instruments were mounted in a NEMA 12 cabinet. For seismic vibration only, the instruments were mounted on a rigid test fixture. For all other tests, simulated mounting was not required.

4.1.6 Measuring devices and test equipment utilized in the performance of the type tests were calibrated utilizing reference standards (or interim standards) whose calibration had been certified by being traceable to the National Bureau of Standards. All reference standards utilized in measuring component parameters and all test equipment calibration were supported by certificates, reports, or data sheets attesting to the data, accuracy, and conditions under which the results furnished were obtained.

4.2 Functional Tests

4.2.1 The ability of the complete Delphi Hydrogen Analyzer System to perform its Class 1E function was demonstrated by the performance of functional tests. These tests were performed initially in the program to develop a data base and were then programmed following each environmental exposure. The functional test procedure, and test results are described in Appendix C.

4.2.2 Functional tests performed extend, as a minimum, to a simulation of Class 1E performance under normal conditions. Results and data obtained from functional testing were used as a base for comparison with performance under more highly stressed conditions.

4.3 Inspection and Operational Tests

4.3.1 Instruments were subjected to inspection and operational tests to assure that there was no damage due to handling since manufacture and to verify that their performance was in accordance with equipment and project specifications. All inspections and operational tests were performed in accordance with written procedures and the test results were developed, documented and controlled in accordance with EA&T Company Inc.'s Quality Assurance Manual. Inspection and operational test results for the instruments are presented in Appendix B of this report.

4.3.2 The equipment was operated to the extremes of all performance and electrical characteristics given in the equipment specifications. Included in the equipment specification is the requirement for operation of the instruments at 110 V $\pm$ 10%.

4.4 Service Condition Simulation and Aging

4.4.1 The objective of aging was to put the instruments in a condition equivalent to their end-of-life condition in order to verify that they would perform their function after being subjected to normal environments during their design life.

4.4.2 These type test exposures may be catagorized in two phases. The first phase consisted of exposure to elevated temperature to simulate the effects of chemical reactions on the materials over the design life. The second phase consisted of accelerated operational cycling of instruments to simulate the expected mechanical wear and electrical contact degradation of the instruments being tested.

Table D-I of Appendix D of this procedure provides a schedule of the design life, baseline temperature, aging time, and aging temperature under which thermal aging was performed.

Table D-II of Appendix D of this procedure lists all instruments, the number and rate of cycles as well as comments on how cycling was performed on parameters which are directly related to the operation of each instrument.

4.4.3 At the completion of the Service Condition Simulation and Aging, the Delphi IV Hydrogen Analyzer System was inspected and functionally tested and results were documented as described in paragraph 4.2 above. Performance data was compared with that which was previously obtained and any deviations were evaluated.

4.4.4 Thermal Aging temperatures listed in Table D-I of Appendix D were established based on material specifications as provided by the manufacturer, the baseline temperature of the instruments, an assumed design life of 5 or 10 years and the 10°C rule.

4.5 Irradiation

4.5.1 The objective of the irradiation exposure was to subject the test instruments to radiation doses anticipated in the design life, and as a minimum, one Design Basis Event. The irradiation test dose was the total of normal and abnormal doses.

4.5.2 Irradiation was performed in a radiation chamber with Co-60 source pencils. The exposure was of Gamma radiation.

4.5.3 The components were arranged in the chamber and then the chamber was loaded with Co-60 source pencils. The chamber temperature was maintained at approximately 70°F and the pressure was one atmosphere. The dose rate was limited to less than 1.0 Mrad/hour. After the irradiation tests were completed, the system was functionally tested as described in paragraph 4.2 above.

4.5.4 The total integrated service life radiation dose varies with instrument location in the Nuclear Power Plant. The radiation dose to the Delphi K-IV Hydrogen Analyzer for this generic environmental plan is given in Table D-III of Appendix D.

4.5.5 The total integrated service life radiation dose is the sum of the normal in-service radiation exposure and the post accident in-service radiation exposure.

4.6 Seismic Vibration

4.6.1 The objective of Seismic Vibration was to verify that the operation of the instruments would not be impaired, when subjected to a minimum of five (5) Operating Basis Earthquakes (OBE), followed by one (1) Safe Shutdown Earthquake (SSE).

4.6.2 The test items' primary mounting point was the normal mounting attachment provided on the test items which simulates the actual in-service mounting. The test items were attached to a rigid fixture (natural frequency > 33 cps) and then the fixture was attached to the exciter shake table. The fixture was designed to transmit the vibratory inputs without any degradation to seismic requirements as well as to maintain the test item in its correct attitude.

4.6.3 Testing consisted of vibration inputs in two axes simultanously and independently such that a purely rectilinear motion does not result. During the two axes simultaneous vibration, testing was conducted in the following configuration:

Vertical - Horizontal (longitudinal) #1 axis
Vertical - Horizontal (lateral) #2 axis

4.6.4 A continuous sine wave resonance search was conducted in each axis. The rate of change of frequency (1 Hz to 40 Hz) was approximately one octave per minute, or that frequency change necessary to acquire suitable response. The input level was 0.2 g peak. Only one axis at a time had vibration applied.

4.6.5 Seismic Qualification was performed using a complex random motion. Testing was performed in two steps with the test items principal horizontal axis first positioned parallel with the test table motion, then rotated 90° in the horizontal plane for the second step.

The test items were subjected to 5 O.B.E.'s of not less than 30 seconds each and 1 S.S.E. of not less than 40 seconds.

4.6.6 In establishing the required input acceleration, the following considerations were given. The test instruments are panel mounted. Therefore, the required response motion for all directions

was that shown in Figure E-1 for Generic Qualification. The test response spectra enveloped the required response spectra to the extent capable, given limitations of the test table.

4.6.6.1 The Control Panel was seismically qualified to IEEE-344-1975 Sec. 7.2 by a combined test and analysis program. The test report documenting this program is EA&T Report No. 1035-2, dated July 1980. The Required Response Spectrum for all directions is shown in Figure E-II of Appendix E of this report.

4.6.6.2 The test instruments were mounted on the shake table in a manner that dynamically simulated the recommended mounting. If the instrument was intended to be mounted on a control panel, the response at the instrument mounting location was monitored during an assembled control panel sine sweep test and the instrument was mounted directly to the shake table with the in-service excitation simulated.

4.6.7 A control accelerometer was mounted adjacent to each input mounting point.

4.6.8 During the performance of the seismic tests, the control accelerometers and response accelerometers were permanently recorded.

The control accelerometers output for the complex random tests was routed through a shock spectrum analyzer and the data presented as a peak response of frequency.

4.6.9 All instruments were energized (as applicable) during the performance of the seismic tests. Output response (such as pressure, current, position, etc.) was monitored throughout the test. Relays, hand switches, temperature and pressure switch contacts were monitored for

chattering using a chatter detector with a chatter gate time of 1 msec.

4.6.10 Upon completion of the seismic vibration tests all instruments were functionally tested and results were documented as described in paragraph 4.2 above. Performance data was compared with that which was previously obtained and any deviations were evaluated.

4.7 Simulated Post Accident Condition

4.7.1 The objective of this environmental exposure was to verify the capability of the equipment to operate under a postulated Design Basis Accident. The Simulated Post Accident Condition exposure consisted of exposure to radiation, pressure, temperature and humidity. The post accident exposure to radiation was combined with the expected in-service radiation exposure as described in paragraph 4.5 Irradiation.

4.7.2 The Simulated Post Accident Condition exposure was performed in a controlled environmental chamber. Appendix F lists the test variables (i.e., temperature, humidity, pressure) and time profile.

4.7.3 All instruments were periodically monitored during the performance of these tests. Upon completion, the K-IV Hydrogen Analyzer was functionally tested and results were recorded as described in paragraph 4.2.

4.7.4 The instruments and equipment were mounted and connected in a manner that simulated their installation when in actual use. Throughout the LOCA Post Accident Condition exposure, the venting path of all pneumatic devices were via all components that are installed during normal operation.

4.7.5 The K-IV Hydrogen Analyzer withdrew a sample gas simulating its actual operation under a postulated Design Basis Accident. The sample gas temperature and pressure are indicated in Table F-1.

4.8 Failure Analysis Criteria

4.8.1 In the evaluation of the qualification test results, any sample equipment was assumed to have failed when the equipment did not perform Class 1E functions required by the equipment specifications.

4.8.2 If a failure occurred during the qualification test process, this did not necessarily constitute a failure to qualify. It has to be determined whether the failure was random or an end-of-life failure. True random failures by definition do not impact qualified life.

4.8.3 If end-of-life or random failure was established as the cause of failure, a replacement plan was to be initiated for the component which failed if such replacement was feasible. If such replacement was not feasible, then the equipment was considered to have reached end-of-life.

4.8.4 If the appropriate component replacement plan was to be implemented, the qualified life of the equipment was not degraded.

4.9 Acceptance Criteria

4.9.1 To meet the provisions set forth by IEEE-323-1974, the qualification program was to be accompanied by a detailed report documenting all the tests, data, etc., and the acceptance.

4.9.2 The acceptance criteria for Service Condition Simulation and Aging exposure was the successful simulation of the design life. The Delphi IV Hydrogen Analyzer was required to perform after the simulated accelerated aging process without the loss of Class 1E function and structural integrity.

4.9.3 The acceptance criteria for Simulated Post Accident Conditions exposure required that loss of Class 1E performance did not occur, loss of input and output did not occur, structural integrity be maintained, and spurious signals were not produced. The addition of setpoint securing devices were not to aid in maintaining setpoint accuracy.

4.9.4 The acceptance criteria for Seismic exposure required that structural integrity be maintained, and that loss of Class 1E performance did not occur during or after the excitation of one Safe Shutdown Earthquake and five Operating Basis Earthquakes.

4.9.5 A qualification report was to be prepared and certified by a registered professional engineer. The report was to contain all the detailed test procedures, measurements, description of test instrumentation, fixtures, calibration data and interpretations, and data on, and explanation of any anomalies. The qualified life of the particular component instruments was to be delineated as the period of time for which satisfactory performance could be demonstrated for the specified set of service conditions.

5.0 Qualification Test Results

5.1 Summary

The sequence of environmental qualification type tests performed on the Delphi IV Hydrogen Analyzer prototype was completed on 10/26/80, at the conclusion of the 100 day Post LOCA exposure.

Two anomalies were observed as a result of these tests.

At the 42nd day of the Post LOCA exposure, the Sample Pump bearings were observed to be fixed, preventing the actuator arm from moving. The bearings were replaced and the pump resumed operation. The reason for this occurance is under investigation. It has not been determined whether the causal factor was random or end of life.

Following the 100th day of Post LOCA exposure the Sample Pump diaphrams were observed leaking. This anomaly is also under investigation. It is currently unknown whether the leakage is the result of random or end of life conditions.

Operational tests of the individual components will be performed at a later date. The Hydrogen Analyzer unit has not been dissassembled at this time, so that interested observers may witness the unit's functional operation.

Functional test results are presented in Appendix C.

APPENDIX A

LIST OF SAFETY RELATED INSTRUMENTS

TABLE A-1

List Of Safety Related Instruments

Item	Description
1	Entry Exit Valve Hoke Model 4251 G6Y Serial No. 2190
2	Moisture Separator Armstrong Model 11-AV Serial No. 1793
3	Gas Manifold Serial No. 3
4	Air Cooled Heat Exchanger Serial No. 4
5	Flowmeter Brooks Model 1350 Tube No. 196A Serial No. 2189-5
6	Flowmeter Brooks Model 1350 Tube No. 5-65A Serial No. 2189-6
7	Pressure Indicator Marshalltown Model 52B Serial No. 0195
8	Sample Pump Serial No. 1882
9	H2 Analyzer Serial No. 371
10	Analyzer Electronics Serial No. 10
11	Flow Orifice Serial No. 3356

TABLE A-1

List Of Safety Related Instruments (continued)

Item	Description
12 A&B	Differential Pressure Switch Static O-Ring Model No. 15R3-K2-VYIC Serial No. 78-4-1097
13	Down Stream Regulator Conoflow Model H21XT-XXX R1 Serial No. 3204-15
14	Down Stream Regulator Conoflow Model H21XT-XXX R2 Serial No. 3204-16
15	Down Stream Regulator Conoflow Model H21XT-XXX R3 Serial No. 1791
16A	Down Stream Regulator Conoflow Model H21XT-XXX-RB Serial No. 2191-16A
16B	Down Stream Regulator Conoflow Model H21XT-XXX-RB Serial No. 2191-16B
17	Calibration & Reagent Valve ASCO Catalog No. THT8262C7E Serial No. 93415D
18 A,B, C	Check Valve NUPRO Model SS-4CA-3 Serial No. 2187
19	Temperature Switch Fenwall Model 22800 Serial No. 7901
20	Temperature Bulb Fenwall Model 22800 Serial No. 21918

TABLE A-1

List Of Safety Related Instruments (continued)

Item	Description
21	Lights GE Model Et-16 Serial No. 0165A7844P5
22	Relay Potter Brumfield Model KRP11AG Serial No. 174414
23	Relay Potter Brumfield Model KRP14AG Serial No. 173308
24	Relay GE Model CR2810A 14AJ Serial No. 22D135
25	Magnetic Motor Starter GE Model CR206B0 Serial No. 15D21G2
26	Switch GE Model CR2940U201 Serial No. 26
27	Terminal Strip GE Model EB5 Serial No. 27
28	Circuit Breaker ITE Pushmatic Model P1515 Serial No 614
29	Fittings Hoke Gyrolok Model 6CM6-316 Serial No. 29
30A	Cal Rod Strip Heater (4 EA) GE Model 2A907A102 Serial No. SS2041-30A
30B	Cal Rod Strip Heater (4 EA) GE Model 2A907A102 Serial No. SS2041-30B

TABLE A-1

List Of Safety Related Instruments (continued)

Item	Description
30C	Cal Rod Strip Heater (4 EA) GE Model 2A907A102 Serial No. SS2041-30C
30D	Cal Rod Strip Heater (4 EA) GE Model 2A907A102 Serial No. SS2041-30D
31	Sample Pump Motor (1) Reliance ID No. 1YF882640A20 NE Serial No. 31
32	Current Transmitter AGM Model CD-4000 Serial No. 38-320
33	Trip Switch AGM Model CD-4004-1 Serial No. 38-213
34	Matheson Flowmeter Tube No. 600 Serial No. 34
35	Matheson Flowmeter Tube No. 601 Serial No. 35
36	Flowmeter Brooks Model 1350 Tube No. 459 Serial No. 36
37A	Terminal Strip Allied Barrier Block Model 750R1503 Serial No. 37A
37B	Terminal Strip Allied Barrier Block Model 750R1503 Serial No. 37B

Note: (1) Sample Pump Motor is purchased as prequalified to IEEE-323-1974 by manufacturer.

TABLE F-I

SIMULATED POST ACCIDENT CONDITIONS
DELPHI IV HYDROGEN ANALYZER
GENERIC QUALIFICATION

LOCA Ambient Conditions At Control Cabinet Location

Time, Days	0-100
Temperature, °C	66 (150°F)
Pressure, in Hg	29.92 ± 2
Relative Humidity, %	90 ± 5

LOCA Ambient Conditions at Sample Withdrawn Point

Time	Temperature	Pressure
0-15 Min.	N/A	N/A
15 Min. - 10 Hours	150°C (300°F)	483 KPA (70 PSI)
10 Hours - 4 Days	99°C (210°F)	276 KPA (40 PSI)
4 Days - 100 Days	75°C (167°F)	35 KPA (5 PSI)

NOTE: All specified parameters include margins of + 8°C (15°F) for temperature, + 10% of gauge pressure and + 10% of period of time equipment is qualified to operate following design basis event.

At 10 HRS, 4 Days then every 10 Days thereafter investigate readout @ 4.5% H_2 in air then in steam at histogram point.

NOTE: Instruments mounted in simulated NEMA 12 Cabinet.
60 PSI back pressure on Comsip Delphi Supplied Boiler System.

FROM ENGINEERING ANALYSIS AND TEST COMPANY (EA+T)
TEST REPORT "IEEE-323-1974 PROTOTYPE QUALIFICATION SUPPLEMENTARY TEST OF HYDROGEN ANALYZER SAMPLE PUMP FOR HYDROGEN ANALYZER SYSTEMS K-III AND K-IV
PROJECT-1035-8
SEPT 1982

ABSTRACT

This final test report describes the qualification test procedures and test results which were performed on the Hydrogen Analyzer Sample Pump for the Hydrogen Analyzer Systems K-III and K-IV.

A prototype of this pump was previously subjected to an environmental qualification test sequence during which certain anomalies were observed (see EA&T Test Report 1035-1, dated September 1981). Subsequently, the Hydrogen Analyzer Sample Pump was subjected to supplemental IEEE-323-1974 environmental type tests described in this report.

TABLE OF CONTENTS

1.0 PURPOSE

To describe the procedure which was utilized for the environmental qualification type testing of safety related instruments for nuclear power plant applications.

2.0 SCOPE

This procedure applies to safety related instruments for which project specifications require their qualification in accordance with the requirements of "IEEE-323-1974 Standard For Qualifying Class 1E Equipment For Nuclear Power Generating Stations", as implemented by Regulatory Guide 1.89, "Qualification of Class 1E Equipment For Nuclear Power Plants." This procedure is in accordance with the guidance of NUREG-0588 "Interim Staff Position on Environmental Qualification of Safety Related Electrical Equipment," dated September 1979.

3.0 DEFINITIONS

3.1 Safety Related Instruments

Instruments that are essential to emergency reactor shutdown, containment isolation, reactor core cooling, and containment and reactor heat removal, or otherwise are essential in preventing significant release of radioactive material to the environment.

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Tests made on one or more sample instruments to verify adequacy of design and manufacturing processes.

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3.5 Operating Basis Earthquake (OBE)

That earthquake which produces the vibratory ground motion for which those features of the nuclear power plant necessary for continued operation without undue risk to the health and safety of the public are designed to remain functional (excerpted from IEEE Std. 344-1975).

3.6 Safe Shutdown Earthquake (SSE)

That earthquake that produces the maximum vibratory ground motion for which certain structures, systems, and components are designed to remain functional.

4.0 PROCEDURE

4.1 General

The Hydrogen Analyzer Sample Pump extracts sample gases from points within the containment building for Hydrogen gas concentration determination. The pump is a small reciprocating dual stage unit. The pump is powered by a 1 Hp electric motor. The normal, abnormal and design basis accident conditions to which this pump will be subjected are identified in this section of the Test Plan.

4.1.1 The procedure which was followed outlines a generic environmental plan developed to qualify the Delphi Model K Hydrogen Analyzer Sample Pump as manufactured by Comsip,Inc. for nuclear power plant installation. The procedure describes the type tests to be performed on instruments in a specific order. The sequence used is the one recommended by the IEEE-323-1974 Standard and briefly consists of:

4.1.1.1 Inspection and Operational Test
4.1.1.2 Functional Tests
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4.1.1.4 Functional Tests
4.1.1.5 Mechanical Cycling
4.1.1.6 Functional Tests
4.1.1.7 Irradiation
4.1.1.8 Functional Tests
4.1.1.9 Seismic Vibration
4.1.1.10 Functional Tests
4.1.1.11 Simulated Post Accident Condition
4.1.1.12 Functional Tests
4.1.1.13 Final Inspection and Operational Tests

4.1.2 Appendix A of this procedure list the five sample pumps which were tested, and describes the previous environmental testing performed on Sample Pump No. 1 Motor, Reliance I.D. No. IYF 882640A20 NE.

4.1.3 In developing this procedure various documents, NRC Regulatory Guides, IEEE Standards, etc., were consulted. Appendix G of this procedure lists all references.

4.1.4 Unless otherwise specified herein, all functional tests described by this procedure were performed at an atmospheric pressure of 29.92 $\pm$ 2.0 inches of mercury absolute, a temperature of 70 $\pm$ 10°F and a relative humidity of 50 percent $\pm$ 25 percent.

4.1.5 The Sample Pump was mounted in a manner and position that best simulates the expected installation. The environmental exposures and instrument performance were monitored using equipment that provides resolution for the detection of meaningful changes in the measured variables.

4.1.6 Measuring and test equipment utilized in the performance of the type tests were calibrated utilizing reference standards (or interim standards) whose calibration had been certified by being traceable to the National Bureau of Standards. All reference standards utilized in measuring and all test equipment calibration is supported by certificates, reports, or data sheets attesting to the data, accuracy, and conditions under which the results furnished were obtained.

4.2 Functional Tests

4.2.1 The ability of the Delphi Hydrogen Analyzer Sample Pump to perform its Class 1E function was demonstrated by the performance of functional tests. These tests were performed initially in the program to develop a data base and then following each environmental exposure. The functional test procedure is described in Appendix C.

4.2.2 The functional tests performed extend, as a minimum, to a simulation of Class 1E performance under normal conditions. Results and data obtained from functional testing was used as a base for comparison with performance under more highly stressed conditions.

4.3 Inspection and Operational Tests

4.3.1 The Sample Pump was subjected to inspection and operational tests to assure that there was no damage due to handling since manufacture and to verify that its performance was in accordance with equipment and project specifications. All inspections and operational tests were performed in accordance with written procedures and the test results were documented. Inspection and test procedures were developed, documented and controlled in accordance with EA&T Company, Inc.'s Quality Assurance Manual. Inspection and operational test procedures for the instruments are presented in Appendix B of this procedure.

4.3.2 The Sample Pump was operated to the extremes of all performance and electrical characteristics given in the equipment specifications.

4.4 Service Condition Simulation and Aging

4.4.1 The objective of aging is to put instruments in a condition equivalent to their end-of-service-life condition in order to verify that they shall perform their function after being subjected to normal environments during their design life.

4.4.2 These type test exposures may be categorized in two phases: The first phase consisted of exposure to elevated temperature to simulate the effects of chemical reactions on the materials over the design life. The second phase consisted of accelerated operational cycling of instruments to simulate the expected mechanical wear and electrical surge degradation of the instruments being tested.

Table I of Appendix D of this procedure provides a schedule of the design life, baseline temperature, aging time, and aging temperature under which thermal aging was performed.

Table II of Appendix D of this procedure lists all instruments, the number and rate of cycles as well as comments on how cycling was performed on parameters which are directly related to the operation of each instrument.

4.4.3 At the completion of the Service Condition Simulation and Aging, the Delphi IV Hydrogen Analyzer Sample Pump was inspected and functionally tested and results were documented as described in paragraph 4.2 above. Performance data was compared with those that were previously obtained and any deviations were evaluated.

4.4.4 Thermal Aging temperatures listed in Table I of Appendix D were established based on material specifications as provided by the manufacturer, the baseline temperature of the instruments, an assumed design life of 5 or 10 years for the pump diaphrams and pump bearings, respectively. Arrhenius Methodology was used to establish aging temperatures.

4.5 Irradiation

4.5.1 The objective of the irradiation exposure was to subject the test instruments to radiation doses anticipated in the design life, and as a minimum, one Design Basis Event. The irradiation test dose was the total of normal and abnormal doses.

4.5.2 Irradiation was performed in a radiation chamber with Co-60 source pencils. The exposure was of Gamma radiation.

4.5.3 The Sample Pump was placed in the chamber and then the chamber was loaded with Co-60 source pencils. The chamber temperature was at approximately 70°F and the pressure was one atmosphere. After the irradiation tests were completed, the system was functionally tested as described in paragraph 4.2 above.

4.5.4 The total integrated service life radiation dose varies with instrument location in the Nuclear Power Plant. The radiation dose given to the Hydrogen Analyzer Sample Pumps for this generic environment plan is stated in Table III of Appendix D.

4.5.5 The total integrated service life radiation dose is the sum of the normal in-service radiation exposure and the post accident in-service radiation exposure.

4.5.6 To account for any effects unique to beta radiation one diaphragm was additionally exposed to beta radiation as indicated in Table III of Appendix D.

4.6 Seismic Vibration

4.6.1 The objective of Seismic Vibration was to verify that the operation of the instruments was not impaired, when subjected to a minimum of five (5) Operating Basis Earthquakes (OBE), followed by one (1) Safe Shutdown Earthquake (SSE).

4.6.2 The Sample Pumps primary mounting point was the normal mounting attachment provided on the test items which simulate the actual in-service mounting. The Sample Pump was attached to a rigid fixture (natural frequency > 33 cps) and then the fixture was attached to the exciter shake table. The fixture was designed to transmit the vibratory inputs without any degradation to seismic requirements, as well as, to maintain the test item in its correct attitude.

4.6.3 Testing consisted of vibration inputs in two axes simultaneously and independently such that a purely rectilinear motion did not result. During the two axes simultaneous vibration, testing was conducted in the following configuration:

Vertical - Horizontal (longitudinal) #1 axis
Vertical - Horizontal (lateral) #2 axis

4.6.4 A continuous sine wave resonance search was conducted in each axis. The rate of change of frequency (1 Hz to 40 Hz) was approximately one octave per minute, or that frequency change necessary to acquire suitable response. The input level was 0.2g peak. Only one axis at a time had vibration applied. Transmissibility plots were obtained and recorded for each orthogonal mounting orientation (i.e. longitudinal, lateral and vertical directions). The transmissibility plots show in amplitude the ratio of the response of an accelerometer mounted near the center of gravity of the pump to the input as measured by an accelerometer mounted on the table for each of the three orthogonal axes.

4.6.5 Seismic qualification was performed using a complex random motion. The frequency content and range of input waveform was displayed as Test Tesponse Spectra (TRS) Shock Response Spectrum for both the Operating Basis Earthquake (OBE) and Safe Shutdown Earthquake (SSE) for all three orthogonal axes. Testing was performed in two steps with the test items' principal horizontal axis first positioned parallel with the test table motion, then rotated 90° in the horizontal plane for the second step.

The Sample Pump was subjected to 5 O.B.E.'s of not less than 30 seconds each and 1 S.S.E. of not less than 40 seconds.

4.6.6 In establishing the required input acceleration, the following considerations were given. The Sample Pump is panel mounted. Therefore, the required response motion for all directions is that shown in Figure E-1 for Generic Qualification. The test response spectra enveloped the required response spectra to the extent capable given limitations of the test table.

4.6.6.1 The Sample Pump was mounted on the shake table in a manner that dynamically simulates the recommended mounting. A photograph showing mounting details is provided.

4.6.7 A control accelerometer was mounted adjacent to an input mounting point.

4.6.8 During the performance of the seismic tests the control accelerometers and response accelerometers were recorded.

The control accelerometers output for the complex random tests was routed through a shock spectrum analyzer and the data was presented as a peak response of frequency. One representative OBE and SSE TRS was plotted at 5% damping for a longitudinal/vertical and lateral/vertical test run. The location of each input and response accelerometer is identified on the plot of the shock response spectra.

4.6.9 The Sample Pump was energized (as applicable) during the performance of seismic tests. Output response (such as pressure, current, position, etc.) was monitored throughout the test.

4.6.10 Upon completion of the seismic vibration tests the Sample Pump was functionally tested and results were documented as described in paragraph 4.2 above. Performance data was compared with those that were previously obtained and any deviations were evaluated.

4.7 Simulated Post Accident Condition

4.7.1 The objective of this environmental exposure was to verify the capability of the equipment to operate under a postulated Design Basis Accident. The Simulated Post Accident Condition exposure consisted of exposure to radiation, pressure, temperature and humidity. The post accident exposure to radiation was combined with the expected in-service radiation exposure as described in paragraph 4.5 Irradiation.

4.7.2 The Simulated Post Accident Condition exposure was performed in a controlled environmental chamber. Appendix F lists the test variables (i.e., temperature, humidity, pressure) and time profile.

4.7.3 The Sample Pumps were periodically monitored during the performance of these tests. Upon completion, the K-IV Hydrogen Analyzer Sample Pumps were functionally tested and results were recorded as described in paragraph 4.2.

4.7.4 The Sample Pumps were mounted and connected in a manner that simulates their installation when in actual use.

4.7.5 The Sample Pumps were operated continuously during the Post Accident exposure.

4.8 Failure Analysis

4.8.1 In the evaluation of the qualification test results, any sample equipment was assumed to have failed when the equipment did not perform Class 1E functions required by the equipment specifications.

4.8.2 If a failure occurred during the qualification test process, this would not necessarily constitute a failure to qualify. It must be determined if the failure was random or an end-of-life failure. True random failures by definition do not impact qualified life.

4.8.3 If end-of-life or random failure was established as the cause of failure, a replacement plan was initiated for the component which failed if such replacement was feasible. If such replacement was not feasible, the equipment was considered to have reached end-of-life.

4.8.4 If the appropriate component replacement plan was to be implemented, the qualified life of the equipment was not degraded.

4.9 Acceptance Criteria and Qualification Report

4.9.1 To meet the provisions set forth by IEEE-323-1974, the qualification program was to be accompanied by a detailed report documenting all tests, data, etc., and the acceptance criteria.

4.9.2 The acceptance criteria for Service Condition Simulation and Aging exposure was successful simulation of the design life. The Hydrogen Analyzer Sample Pump was required to perform after the simulated accelerated aging process without the loss of Class 1E function and structural integrity.

4.9.3 The acceptance criteria for Simulated Post Accident Conditions exposure required that loss of Class 1E performance did not occur, and structural integrity was maintained.

4.9.4 The acceptance criteria for Seismic exposure required that structural integrity was maintained, loss os Class 1E performance did not occur during or after the excitation of one Safe Shutdown Earthquake and five Operation Basis Earthquakes.

4.9.5 A qualification report would be prepared and certified by a registered professional engineer. The report contains all of the detailed test procedures, measurements, description of test instrumentation, fixtures, calibration data and interpretations, and data on, and explanation of any anomalies. The qualified life of the

particular component instruments shall be delineated as the period of time for which satisfactory performance can be demonstrated for the specified set of service conditions.

5.0 Qualification Test Results

5.1 Summary

The environmental qualification type tests, described in Section 4.0 of this report were performed in sequence, as recommended by Std. IEEE-323-1974. The 100 day Simulated Post Accident Condition environmental test concluded on 9/17/82, and the Functional Test and Final Inspection and Operational Tests were performed on 9/20/82. All five test items, Pump #1 through Pump #5, were found to be completely functional and free of any degradation preventing the performance of their Class 1E function.

44. RG&E Correspondence Concerning Limit Switches, March 3, 1978
45. Design Approval Test on Material Used in Westinghouse Penetrations for the Brunswick Station of Carolina Power and Light Company - August 11, 1972
46. Test Data for Coleman and Rome Cable
47. Aging Failure Detection Program, May 6, 1980
48. Valcor Solenoid Valve: Vendor Data.
49. WCAP-9001, A Controlled Combination System to Prevent H_2 Accumulation following a LOCA
50. Westinghouse Terminal Blocks Qualification - Superseded
51. Cable Identification and Qualification Supplement, Including F-C5074 (Supplement) Concerning Coleman Silicone-Rubber-Insulated Cable Qualification
52. Wide-Range Sump Level Switch Specification - Superseded. See 81.
53. Limitorque Valve Operator Data, Including Limitorque Report B0003 and Section 4.1.4 of B0058
54. Containment Electrical Penetration Analysis, RG&E Letter dated 4/12/79
55. Kerite Letter, June 26, 1980
56. IE Inspections 78-20 and 78-21 - Reports Concerning Installation of Splice Sleeves
57. Control Valve Specification SP-513-044666-000, September 27, 1974, Concerning Standby AFW Valves - Mild
58. Westinghouse 10/10/80 Letter Concerning Crouse-Hinds Electrical Penetrations
59. Evaluation of Aging Effects on Organic Materials used in Crouse-Hinds Electrical Penetrations
60. Westinghouse Terminal Block Information on Aging and Radiation - Superseded
61. Aging Evaluation of Westinghouse Electrical Penetrations
62. Raychem Splice Sleeve Aging Information
63. Kerite Cable Aging Information
64. Containment Fan Cooler Motor Splices
65. Safety-Related Motor Bearings - Maintenance and Lubrication, including extracts from Ginna Maintenance Procedure A-1011
66. Deleted.
67. Safety-Related Motor Characteristics (Insulation)
68. WCAP-8754, Environmental Qualification of Class IE Motors for Nuclear Out of Containment Use
69. Westinghouse Research Report 71-1C2-RADMC-R1, December 31, 1970 (Revised April 10, 1971), Concerning "The Effect of Radiation on Insulating Materials Used in Westinghouse Medium Motors" - extracts
70. WCAP-7829, "Fan Cooler Motor Unit Test"
71. WCAP-7706-L, An Evaluation of Solid State Logic in Reactor Penetration in Anticipated Transients
72. Maintenance/Surveillance for Aging Program at Ginna
73. Valcor Report QR 52600-5540-2
74. LVDT
75. Namco Limit Switch
76. EPRI Report 1707-3
77. Similarity Analysis for Valcor Solenoids (PRZR PORV and head vent PORV)
78. Kerite Cable Report for Ginna - Proprietary
79. Conax RTD Test Report Summary
80. Chevron NRRG Grease and Portions of A-1011
81. TransAmerica (GEM) DeLaval Sump B Level, including connecting BIW cable
82. Post-accident sampling system, SOV 955.
83. Comsip, Inc. Hydrogen Monitors, including hydrogen pump.
84. Mobil Oil radiation data.

RG&E Reference 84

Mobil Oil Corporation

670 WHITE PLAINS ROAD
SCARSDALE, NEW YORK 10583

February 2, 1984

Mr. George Wrobel
Rochester Gas & Electric
49 East Avenue
Rochester, New York 14649

Dear Mr. Wrobel:

This confirms the information given to you on the radiation tolerances for specific Mobil products.

Mobil Product	Maximum Rad Levels
Mobil DTE 25	3×10^8
Mobil DTE 26	3×10^8
Mobilux EP1	3×10^8
Mobilux EP2	3×10^8

The values quoted for Mobil DTE 25, 26 are the radiation effects based on an 18% change in their viscosities. Values for Mobilux EP1 and EP2 are based on a 15-20% change in penetration. For your further information, our Gamma irridation studies were carried out in a 5MW reactor under static conditions immediately after reactor shutdown. Typical dosage rate varied between 2×10^8 rad/hour to 2×10^6 rad/hour.

Please advise if we can be of any assistance.

Very truly yours,

D. Magana (om)
D. Magana
Chief Engineer
Northeast Commercial Division

DM:lac
2099L/3

CC: D.C. Stanek
J.M. Blesedell
L.W. Cline

GINNA STATION

(DOCUMENTATION REFERENCE)

1. Crouse-Hinds Penetration Test Report
2. Gilbert Spec. 520 - Standby AFW Pumps - Mild
3. Gilbert Spec. 711 - Standby AFW Pumps Motors - Mild
4. Gilbert Spec. 5201 - Large Motors
5. Deleted. Included in Reference 51
6. Gilbert Spec. 5342 - HVAC Throughout Ginna - Mild
7. Gilbert Spec. RO-2239 - Diesel Generators - Mild
8. Gilbert Spec. RO-2267 - Auxiliary Feedwater Pumps - Mild
9. Gilbert Spec. RO-2400 - Batteries - Mild
10. IPCEA Std. S-61-402, Sect. 3.8 and 4.3.1 - PVC Cable
11. Kerite Cable - Memo 7/22/68
12. NEMA Std. SG-3, Low Voltage Circuit Breakers - Mild
13. Westinghouse Spec. 676258 - Motor Operated Valves
14. Westinghouse Spec. 676270 - Control Valves
15. Westinghouse Spec. 676370 - Auxiliary Pumps
16. Westinghouse Spec. 676427 - Auxiliary Pump Motors
17. WCAP 7343, Irradiation Testing of Reactor Containment Fan Cooler Motor Insulation, June, 1969
18. WCAP 7410-L, Environmental Testing of Engineered Safety Features Related Equipment, Vol. I & II, 12/70
19. WCAP 7744, Environmental Testing of ESF Related Equipment (Non-Proprietary), Vol. I & II, 12/70
20. WCAP 9003, Fan Cooler Motor Unit Test, January, 1969
21. Deleted. Included in Reference 45
22. Westinghouse Terminal Blocks - Superseded
23. Report NS-CE-775, Fail-Safe Operation of ASCO Solenoids - Superseded
24. Copes-Vulcan Solenoid Valves - Superseded
25. Vendor Data on Laurence Solenoid - Superseded
26. Vendor Data on Versa Solenoid - Superseded
27. WCAP 7153, Investigation of Chemical Additives for Reactor Containment Sprays
28. Deleted. Included in Reference 45
29. Gilbert Spec. 504 - Westinghouse Electrical Penetrations
30. Technical Proposal for Electric Penetration for Ginna Containment Structure by Westinghouse - September 4, 1974
31. WCAP 7354-L, Supplier Post Accident Testing of Process Instrumentation
32. Vendor Data on Gould Batteries - Mild
33. Westinghouse Spec. Sheets for Foxboro Transmitters - Superseded
34. Vendor Data on Barton 289 Transmitter - Superseded
35. Rosemont RTD Spec. - Superseded
36. Vendor Data on Raychem Splice Sleeves
37. June 16, 1975 Letter to R. A. Purple from L. D. White on Containment Flooding
38. April 4, 1979 FRC Final Report F-C5074, Raychem Splice Sleeves and Kerite Cable

39-
42. Deleted.
43. Design Criteria - Standby Aux. Feedwater System - October 24, 1974 - Mild

Note 1: "Mild" environment equipment is defined in 10 CFR 50.49.

Note 2: References designated as "superseded" are for items which have been replaced by other environmentally qualified equipment.