PEN-RLK-7-11-73

WESTINGHOUSE ELECTRIC CORPORATION
ELECTRONIC TUBE DIVISION
P. O. BOX 284
ELMIRA, NEW YORK 14902

Manufacturer's Stress Report for Electrical Penetration

Contract CP141-9521-01-118-1
Brunswick #1 and #2

Calculated by R. L. Korner
Project Engineer
Penetrations

Certified by M. Yonko, P.E.

8111020488

(M)

1. Preface

1.1 Design Parameters

These have been prescribed in design specification prepared by UE&C.

1.2 Normal Conditions

The normal operating temperature of the electrical penetration will not exceed 150°F. The internal working pressure will be 15 psig. External pressure at the containment end will vary from -0.5 psig to 2.0 psig. This is not the severest condition, hence no structural analysis will be made.

1.3 Accident Environment

First 6 hours of accident the temperature will be 340°F with a maximum external pressure of 56 psig on the inboard end of the penetration.

1.4 Pressure Temperature Rating

The penetration assembly shall be designed to a maximum pressure of 62 psig and a maximum temperature of 340°F.

1.5 Applicable ASME Code

Section III Class MC. The penetration is a continuation of the containment vessel pressure boundary. (Code stamping is not required since the containment vessel is concrete and metal, and is not subject to an existing code.)

2. Structural Analysis

The fillet weld shown in dwg. E2593 on the inboard end of the penetration is subjected to the highest stress. Penetration class A, B, C, D & F are P1 to P1 welds. Class E is a P1 to P8 weld.

D_1 = diameter over which pressure acts

P_1 = maximum external pressure (56 psig)

L_1 = length of leg of fillet

A_1 = area on which P_1 acts

F_1 = force on wled

A_2 = area of weld subjected to shear

$$A_1 = D^2 \times .784$$
$$= (10.68)^2 \times .784$$
$$= 89 \text{ sq. inches}$$

$$F_1 = P_1 \; A_1$$
$$= 62 \times 89$$
$$= 5518 \text{ lbs.}$$

$$A_2 = \pi D \times L_1$$
$$= \pi \times 10.68 \times .245$$
$$A_2 = 8.2 \text{ sq. inches}$$

$$\sigma = \frac{F_1}{A_2}$$
$$= \frac{5518}{8.2}$$
$$= 673 \text{ psi}$$

Per NE3359.1 General Requirement under (b) the allowable stress value for a fillet weld is 49% of the stress value for the vessel material.

Penetration classes A, B, C, D, F are constructed with SA333 grade 6 vessel material. Per table 1-10.1 this material has an S_m value of 16,500 psi at 360°F.

$S_{shear} = .6\ S_m = .6$. 1-,500 = 9,900 psi

$S_{allowable}$ = 49% x 9,900 = 4851 psi.

This compares with 673 psi calculated.

The design is satisfactory

FIGURE 1
View of Prototype Header (304 Conductors).

FIGURE 2
Header Mounted on Steam Chamber.

Penetration class E is constructed with an SA240 type 304 vessel material.

Per table 1-10.2, this material has an S_m value of 17,800 psi at 400°F.

$S_{shear} = .6\ S_m = .6 \times 17,800 = 10,680$

$S_{allowable} = 49\% \times 10,680 = 5233$ psi

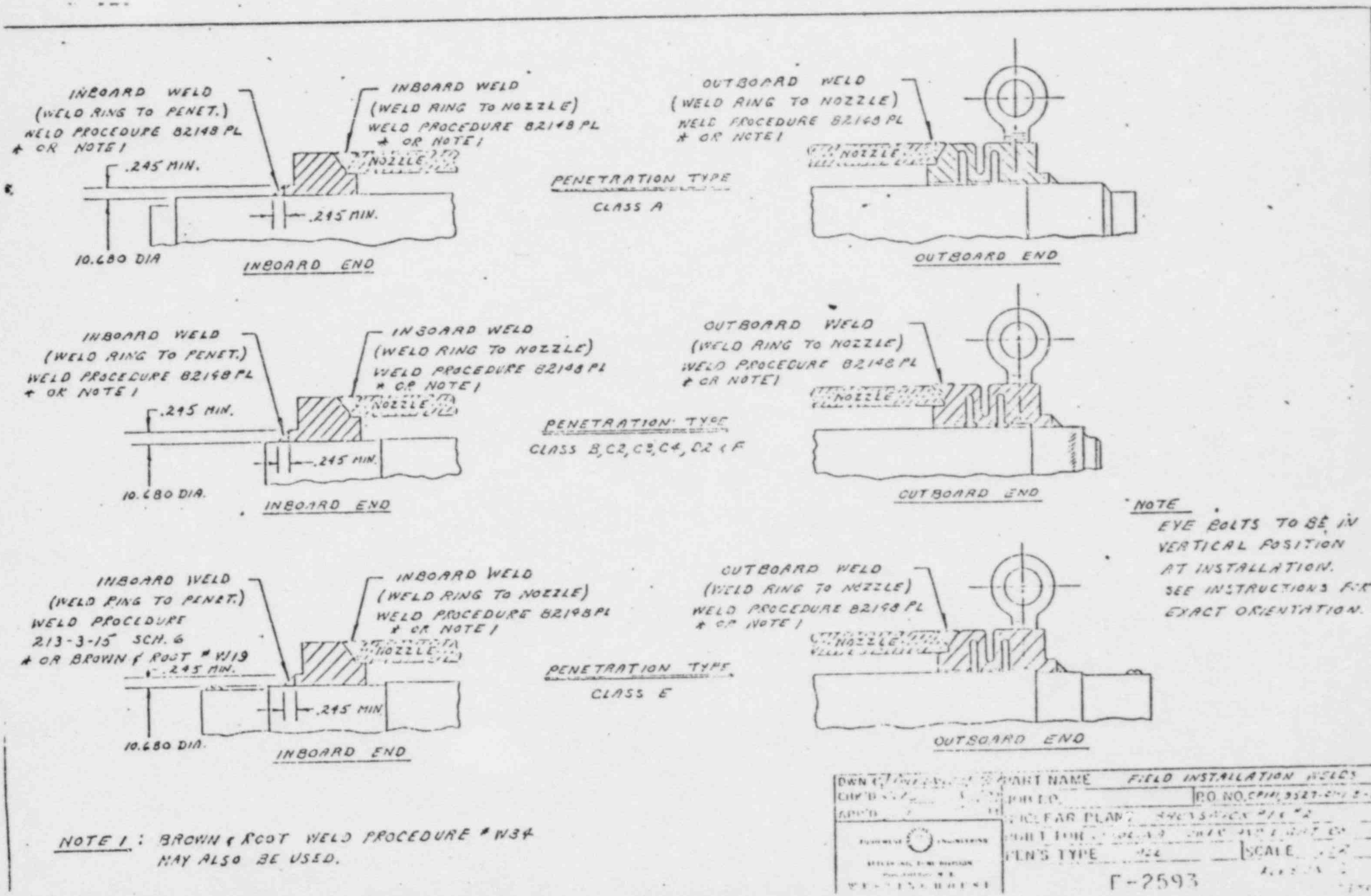
This compares with 673 psi calculated.

The design is satisfactory.

3.0 Thermal Analysis is unnecessary since the maximum temperature the assembly will be subjected to is only 340°F. S_m values for this temperature were utilized.

4.0 Fatigue evaluation is also unnecessary since only a few cycles will be experienced in the forty year plant life.

5.0 Seismic analysis has been treated by actual test conducted on each class of penetration.


INBOARD WELD
(WELD RING TO PENET.)
WELD PROCEDURE 82148 PL
* OR NOTE 1
.245 MIN.
10.680 DIA
INBOARD WELD
(WELD RING TO NOZZLE)
WELD PROCEDURE 82148 PL
* OR NOTE 1
NOZZLE
.245 MIN.
INBOARD END
PENETRATION TYPE
CLASS A
OUTBOARD WELD
(WELD RING TO NOZZLE)
WELD PROCEDURE 82148 PL
* OR NOTE 1
NOZZLE
OUTBOARD END
INBOARD WELD
(WELD RING TO PENET.)
WELD PROCEDURE 82148 PL
* OR NOTE 1
.245 MIN.
10.680 DIA.
INBOARD WELD
(WELD RING TO NOZZLE)
WELD PROCEDURE 82148 PL
* OR NOTE 1
NOZZLE
.245 MIN.
INBOARD END
PENETRATION TYPE
CLASS B, C2, C3, C4, D2 & F
OUTBOARD WELD
(WELD RING TO NOZZLE)
WELD PROCEDURE 82148 PL
* OR NOTE 1
NOZZLE
OUTBOARD END
NOTE
EYE BOLTS TO BE IN
VERTICAL POSITION
AT INSTALLATION.
SEE INSTRUCTIONS FOR
EXACT ORIENTATION.
INBOARD WELD
(WELD RING TO PENET.)
WELD PROCEDURE
213-3-15 SCH. 6
* OR BROWN & ROOT #W19
.245 MIN.
10.680 DIA.
INBOARD WELD
(WELD RING TO NOZZLE)
WELD PROCEDURE 82148 PL
* OR NOTE 1
NOZZLE
.245 MIN
INBOARD END
PENETRATION TYPE
CLASS E
OUTBOARD WELD
(WELD RING TO NOZZLE)
WELD PROCEDURE 82148 PL
* OR NOTE 1
NOZZLE
OUTBOARD END
NOTE 1: BROWN & ROOT WELD PROCEDURE #W34
MAY ALSO BE USED.
PART NAME FIELD INSTALLATION WELDS
PEN'S TYPE
SCALE
F-2593

MEMORANDUM

united engineers & constructors inc.

No.	9527-058	OFFICE:	PHILADELPHIA
DEPT.	Reliability & Quality Assurance	DATE:	October 17, 1980
TO:	S. Rubin/R.N. Brey 11U0	COPIES:	JB Silverwood/RH Leonard BB Scott RR Cerzosimo 14U3 DC Marr 14U4 Project File
FROM:	D. M. Kelly/W. Majkowski 14U6		File H-338-3 QA File 14U5

SUBJECT: Carolina Power & Light Company
Brunswick Steam Electric Plant
TRANSMITTAL OF MATERIALS EVALUATION
OF WESTINGHOUSE ELECTRICAL
PENETRATION ASSEMBLIES

The materials of construction of the Westinghouse electrical penetration assemblies listed in the attached materials evaluation report have been reviewed.

All of the electrical penetration assemblies evaluated have been judged acceptable for 30 day post-LOCA service.

W. Majkowski
W. Majkowski
Materials Engineer

WM/fbh

Reviewed By: R.E. Moore
R.E. Moore
Supervising Engineer
Corrosion Engineering

MATERIALS ENGINEERING EVALUATION
OF ELECTRICAL PENETRATION ASSEMBLIES
FOR 30 DAY Post-LOCA SERVICE

The electrical penetration materials of construction, excluding the metals, have been qualification tested per Reference 1 for steam, pressure, temperature, flammability, corrosive outgassing and radiation. Tests for flammability, corrosive outgassing and radiation are complete and acceptable for all penetrations for the planned 40 year life of the plant. The evaluation of the materials suitability for 30 day post-LOCA service therefore must be judged on the basis of 24 hour tests for steam, pressure and temperature as reported in Reference 1, the 24 hour tests of the prototype penetration modules as reported in References 2, 3, 4, 5 and basic materials properties which are available from manufacturers' literature and materials handbooks as referenced herein. The metallic components are relatively insensitive to the limits of the parameters being considered here and are therefore judged acceptable.

Testing of components per Reference 1 was performed at 175°C (347°F) for 6 hours at 90 psig steam pressure followed by 18 hours at 150°C (302°F) at a steam pressure of 55 psig. Testing per References 2, 3, 4, 5, as applicable to the respective types of penetrations was performed at 340°F for 6 hours at 56 psig followed by 18 hours at temperatures ranging from 200°F to 302°F and reduced pressures.

The Reference 1 temperature-pressure profile is far more severe than that to which the materials would be exposed during an actual LOCA where the maximum temperature in containment peaks at less than 300°F at a maximum steam pressure of 50 psig and drops to about 170°F at 12-15 psig within twenty minutes. Pressure and temperature subsequently decay asymtotically to ambient values at an assumed relative humidity of 100%.

The more severe temperature-steam-pressure exposures cited above can be considered an accelerated test program for the materials of construction and for the configuration of the penetration assemblies. Based on a thorough evaluation of the referenced test data, the materials and penetrations are judged acceptable for 30 days of post-LOCA service. However, further consideration to justify this conclusion is presented in the following discussion of the various classes of penetrations for those materials unique to that penetration class.

CLASS B AND C PENETRATIONS

Westinghouse drawing Nos. E-2453, E-2455, E-2456

Class B Plant Id. Nos.: X-105B, X-105C, X-105D, X-105E, X-105G, X-105H, X-105K, X-105J

Class C Plant Id. Nos.: X-102A, X-102B, X-102C, X-102E, X-102F, X-102H

The non-metallic materials used in the construction of Class B and C penerations, common to both penetrations, consist of the following:

1. Polyform 105 heat shrinkable tubing
2. Kynar heat shrinkable tubing
3. Scotchcast XR-5126 epoxy potting compound
4. Sylgard 185 epoxy potting compound
5. Polyplate (polyester fiberglass filled) bracing disk
6. Silicone rubber fiberglass insulation
7. Okonite EPR insulation with neoprene jacket

These materials have been individually evaluated with respect to water absorption, resistance to 100% relative humidity and maximum recommended service temperatures. (Reference 8) These materials are relatively insensitive to moisture and their maximum service temperatures exceed the 170°F maximum temperature following the LOCA extreme conditions for which they were previously qualified.

CLASS E PENETRATION ASSEMBLIES

Westinghouse drawing No. E-2458

Plant Id. Nos.: X-100A, B, C, D, E, F, G, H

The materials unique to Class E penetrations are:

1. Kovar - glass seal assemblies
2. Raychem Coax and Triax cables
3. Coax connectors (Amphenol)

The glass and Kovar (29 Ni - 17 Co - Fe alloy) are not sensitive to moisture so the seal assemblies are not affected by the 30 day exposure to high humidity at the stated time-temperature profile. Raychem Flamtrol Coax and Triax cables are qualfication tested by Raychem per their Specification No. 60, Para. 4.3.3.3 at times, temperatures and steam pressures as follows:

24 hours at $340^{o}F \, {}^{+18}_{-0}$ at 60 psig

30 days at $200^{o}F \, {}^{+5}_{-0}$ at atmospheric pressure

Insulation testing of the cables is performed during and after this temperature-steam-pressure exposure. These cables are therefore considered suitable for 30 days post-LOCA service.

Amphenol Coax connectors consisting of Amphenol No. 82-503 (special) jack and No. 28650 (special) plug were subjected to LOCA temperature-pressure-humidity tests with the prototype penetration module (Reference 3) but were not subjected to radiation exposure. Detailed evaluation of the materials of construction of these Amphenol connectors disclosed that the internal insulator in these connectors is radiation cross linked polyethylene (XLPE) as denoted by the "special" following the Amphenol part number. XLPE has performed satisfactorily after being irradiated to 1.256×10^{8} rads (Reference 1).

CLASS F PENETRATION

Westinghouse drawing Nos. E-2459, E-2842

Plant Id. Nos.: X-104A, F

The non-metallic materials used in the Class F penetrations are:

1. Polyform 105 heat shrinkable tubing
2. Scotchcast XR-5126 epoxy potting compound
3. Scotchcast XR-5237 epoxy potting compound
4. Stycast 2850FT epoxy potting compound
5. "Q" resin epoxy potting compound
6. Polyplate (polyester fiberglass filled) bracing disk
7. Polysulfone insulation
8. Amphenol connectors (Silicone rubber insert)

These materials have been individually evaluated with respect to water absorption, resistance to 100% relative humidity and maximum recommended service temperatures. (Reference 8) These materials are relatively insensitive to moisture and their maximum service temperatures exceed the 170°F maximum temperature following the LOCA extreme conditions.

REFERENCES

1. Design Approval Tests on Materials Used in Westinghouse Penetrations for the Brunswick Station of Carolina Power and Light Company.

2. Westinghouse Accident Environment Test Report for Class B, C, D Penetrations, PEN-RLK-3-16-01, March 1973.

3. Westinghouse Accident Environment Test Report for Class E Penetration, PEN-RLK-02, March 1973.

4. Westinghouse Accident Environment Test Reports for Class F Penetration, PEN-RLK-5-24-73, March 1975, with Addendum and Report #AB - 11/12/73.

5. Westinghouse Report - The Qualification of a Modular Type Electric Penetration Following the Requirements of IEEE Standard #317 - 1972, PEN-TR-75-6, March 1975 with Addendum 1 and 2.

6. Raychem Wire and Cable Division Specification 60, August 1973.

7. Materials in Design Engineering, July 1960; How Radiation Affects Engineering Materials, Richard E. Bowman; Radiation Effects Information Center, Battelle Memorial Institute.

8. Materials Engineering/Materials Selector 1972, 1975, 1976, 1979.

9. Engineering Alloys, 5th Edition, Woldman & Gibbons.

10. EPRI NP - 1558, A Review of Equipment Aging Theory and Technology, September 1980.

(22)

BOSTON INSULATED WIRE & CABLE CO.

General Data Sheet

TEST: Autoclave Test:	SPEC: --	PAR: L.O.C.A. Conditions	TEST NO.: 871
CONDITIONING: Sample received radiation dose of 10^8 rads.			DATE: Jan. 14, 1972
PART, TYPE NO.: LSS 1727D (See construction below.)			TESTED BY: W. Barnes
CUSTOMER:			LAB. SUP. CHECK:
TEST REQUIREMENTS: Boric Acid Spray -- 0.20 molar boron as boric acid with a 0.019 molar solution of sodium hydroxide to give a pH of 8-8.5 Rate of flow less than but not greater than 1 quart/min.			TIME: IN OUT TEMP.: RH:

1. Cable Construction:
   (a) Two conductors (#16 AWG, 19/29 TC XLPE insulated 0.124") cabled with #01 glass filler and #16 AWG, solid TC drain wire
   (b) Aluminum-Mylar shield 1" x 0015", 2 lap 0.255"
   (c) T-91 flame tape, 3 lap 0.275"
   (d) Neoprene jacket 0.420"

2. Autoclave Cycle

Temp. °F	Time & Temp.	Pressure P.S.I.	Voltage volts	IR cond to cond MΩ/15 Ft	IR cond to cond MΩ/Ft	IR conds to shield MΩ/15 Ft	IR cond to shield MΩ/Ft
60	Start	0	500	2.7×10^5	4.05×10^6	2×10^5	3×10^6
310	10-15'	80	"	1.5×10^3	2.25×10^4	0.8×10^2	1.2×10^3
284	10 min.	55	"	1.1×10^3	1.65×10^4	0.61×10^2	9.15×10^2
290	10 min.	55	"	0.9×10^3	1.35×10^4	0.6×10^2	9.0×10^2
295	10 min.	[illegible]	"	0.93×10^3	1.39×10^4	0.57×10^2	8.55×10^2
287	10 min.	50	"	0.9×10^3	1.35×10^4	0.57×10^2	8.55×10^2
291	10 min.	53	"	0.85×10^3	1.27×10^4	0.53×10^2	7.95×10^2
291	10 min.	55	"	0.86×10^3	1.29×10^4	0.51×10^2	7.65×10^2
210	1 hr.	0	"	0.63×10^4	9.45×10^4	1.6×10^2	2.4×10^3
212	1 hr.	0	"	0.5×10^4	7.[illegible]	1.4×10^2	2.1×10^3
212	17 hrs.	0	"	0.93×10^3	[illegible]	0.35×10^2	5.25×10^2
212	[illegible] hrs.	0		0.93 [illegible]	[illegible]	0.39×10^2	5.85×10^2

3. Dielectric Test

After 25 hrs. at 212°F and 0 psig, the following tests were done:

(a) 600 VAC 5 min cond to cond - OK

(b) 600 VAC 5 min conductors to shield - OK

(c) 1.5 KVAC, 5 min. cond to cond - OK

(d) 1.5 KVAC, 5 min. conductors to shield - OK

Test No. 8714

CONTAINMENT TEST

Loss-of-Coolant Accident Evaluation

1. Irradiate a sufficient length of shielded cable by gamma radiation to a dose of 1×10^8 rads.

2. Place a length of irradiated cable in an autoclave with at least eight feet exposed to the autoclave environment.

3. Expose the cable to the following autoclave conditions. Throughout the autoclave cycle, the cable shall be sprayed with a solution of 0.23 molar boron as boric acid with the pH adjusted to 5.0 (min.) to 9.0 (max.) with lithium hydroxide (0.03 molar max.). The relative humidity throughout the test shall be maintained at 100%.

   (a) Raise the temperature to 280F and the pressure to 60 psia (45 psig) minimum with the relative humidity at 100%. Maintain this condition for 60 minutes. After the cable has been at these conditions for at least 30 minutes, measure the insulation resistance at 500 volts dc between adjacent conductors and between all conductors connected together and the shield.

   (b) Reduce the temperature to 205 - 215F and the pressure to 14.7 psia, maintaining the relative humidity at 100%. Maintain this condition for 24 hours.

   At the end of the 24 hour period, measure the insulation resistance at 500 volts dc between adjacent conductors and between all conductors and the shield. Also, apply 600 volts ac for 5 minutes between conductors and between all conductors together and the shield. The cable shall be considered to meet the containment test if no breakdown occurs. The voltage test shall be repeated at 1.5 kV ac for information only.

The insulation resistance and voltage tests shall be made while the cable is still in the autoclave with the temperature at 205 - 215F at 14.7 psia and 100% relative humidity.

FORM 3500

H-338-1

MEMORANDUM

(51)

united engineers & constructors inc

ɜ No.	9527.058	OFFICE:	Philadelphia
DEPT.	Reliability & Quality Assurance	DATE:	October 15, 1980
TO:	S. Rubin/R.N. Brey 11U0	COPIES:	JB Silverwood/RH Leonard BB Scott RR Cerzosimo 14U3 DC Marr 14U4 ~~Project File~~ File H-338-1 File(QA) 14U5
FROM:	W. Majkowski 14U6		

SUBJECT: Carolina Power & Light Co.
Brunswick Steam Electric Plant
Transmittal of Materials Evaluation
of Boston Insulated Wire & Cable Co.
Instrumentation Cables

The following instrumentation cables fabricated by Boston Insulated Wire & Cable Company are similar in construction and use common materials of construction. Materials were evaluated for the "worst" case in-containment condition.

These materials have been evaluated based on BIW test data for radiation exposure and 26 hour exposure to temperature-pressure-humidity data which exceed the initial 24 hour LOCA conditions. This data was supplemented by data from other sources for generically similar materials and general materials properties data.

On the basis of the above criteria, these cables are judged acceptable for 30 days post-LOCA service.

Cable Plant I.D. Nos. MA 16, MC 16, TC 16
XA 16, & XE 16

W. Majkowski

W. Majkowski
Materials Engineer

WM/dbm

Reviewed By: R.E. Moore

R.E. Moore
Supervising Engineer
Corrosion Engineering

EVALUATION OF BOSTON INSULATED WIRE
AND CABLE CO. INSTRUMENT CABLES FOR
30 DAY POST-LOCA SERVICE

Plant ID Nos. - MA 16, MC 16, TC 16
XA 16 & XE 16

The subject cables are similar in construction and utilize the following common non-metallic materials:

1 - Flame Retardent, cross-linked polyethylene (XLPE) insulation

2 - Aluminum/Mylar Film Tape (shield)

3 - eoprene/Glass Tape

4 - Neoprene jacket(s) (external covers)

RADIATION

As reported in BIW Test No. 8714 (attached) a two conductor cable constructed of these materials was exposed to 1×10^8 rads of gamma radiation and was subsequently subjected to a 26 hour LOCA time-temperature-pressure profile at 100% relative humidity for insulation resistance tests as follows:

10 minutes at 310°F - 80 PSIG
1 hour at 284-291°F - 50-55 PSIG
2 hours at 210-212°F - 0 PSIG
23 hours at 212°F - - 0 PSIG

Since cable No. TC 16 is used in containment which represents the worst case condition for all the subject cables, justification for 30 day post LOCA service for this cable should qualify all of these cables.

The reported 1×10^8 rads of radiation exposure testing as reported by BIW does not meet the specification requirement of 1.1×10^8 rads. However, supplementary data for the same generic material proves the respective material satisfactory for this application as follows:

1 - Neoprene was irradiated to 1.17×10^8 rads per Reference 1 without significant effect on elastomeric properties.

2 - Per Reference 2, XLPE as primary insulation was irradiated to 2.0×10^8 rads without significant loss of resistance or ductility. Reference 2 states that tensile strength of polyethylene at 10^{12} ergs per gram (C) ($\sim 10^{10}$ rads) is 25% lower than initial tensile strength so that physical properties of the material are not seriously impaired by radiation doses of 1.1×10^8 rads.

3 - Mylar film exhibits no change in tensile strength or elongation at doses up to 3×10^9 ergs per gram (C) ($\sim 3 \times 10^7$ rads). At about 1×10^8 rads, Mylar tends to darken and become embrittled. However, in this application as an aluminumized tape beneath the neoprene jacket, the loss of ductility of the Mylar is not pertinent to the electrical performance of the cable (Reference 3).

The effect on glass of radiation doses of 1 to 2×10^8 rads is one of discoloration only which is not significant to the performance of the neoprene/glass tape used in this cable (Reference 3).

PRESSURE - TEMPERATURE - HUMIDITY EXPOSURE

The LOCA time-temperature profile consists of rapid heating to a peak temperature of about 290°F at 50 psig and drops to about 170°F at 12-15 psig within 20 minutes followed by subsequent temperature and pressure decay to near ambient values. Relative humidity (R.H.) is assumed to remain at 100%.

The BIW test temperature-pressure-relative humidity profile of 310°F for 10-15 minutes at 80 psig followed by one hour at 284-291°F at 50-55 psig far exceeds the LOCA peaks of 290°F at 50 psig for less than 20 minutes. This constitutes a far more severe test than the LOCA conditions. Reference 1 certifies that a neoprene (Okoprene) jacketed cable "will pass an exposure to steam at 90 psig and 340°F for six hours and still satisfactorily function". These conclusions are drawn from resistance tests between shield and conductor as well as conductor-to-conductor.

Actually impairment of cable performance would require moisture penetration through the neoprene jacket, through the aluminized mylar wrap and through the primary insulation of XLPE. Permeation of moisture through the neoprene jacket alone would not result in a cable failure. Neoprene's resistance to surface degradation is demonstrated by the following exerpt from Reference 4. "An early jacketed cable that has been kept on an outdoor test rack in a stressed condition since 1935 has yet to show detectable surface degradation". The resistance of XLPE to the temperature-pressure humidity condition can be seen from Raychem Specification 60 for testing wire and cable insulation wherein generically similar insulation is tested at 340°F at a steam pressure of 60 psig for 24 hours followed by exposure at 200°F for 30 days.

On the basis of the tests performed and the above information, this cable is judged acceptable for 30 day post-LOCA Service.

REFERENCES

1 - Westinghouse Electric Corp Report; Design Approval Tests on Materials used in Westinghouse Penetrations for the Brunswick Station of Carolina Power and Light Company; The Okonite Company, Certification No. 1, Certification for Nuclear Environments.

2 - Raychem Corporation Catalog; Coax Data Sheets 10481 and 10483

3 - Materials in Design Engineering, July 1960; How Radiation Effects Engineering Materials, Richard E. Bowman; Radiation Effects Information Center

4 - DuPont Catalog No. A86651, "DuPont Neoprene", Part 1, Page 4