WYLE LABORATORIES
SCIENTIFIC SERVICES & SYSTEMS GROUP
WESTERN OPERATIONS, NORCO FACILITY
1841 HILLSIDE AVENUE, NORCO, CALIFORNIA 91760
AREA CODE 714-737-0871
TWX 910-332-1204 TELECOPY (714) 737-0871

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ENVIRONMENTAL QUALIFICATION EVALUATION OF CABLE SPLICES INSIDE CONTAINMENT FOR OMAHA PUBLIC POWER DISTRICT FOR USE IN FORT CALHOUN NUCLEAR GENERATING STATION, UNIT 1

PREPARED BY: Sarkis Chaghlanian

VERIFIED BY: Bruce Matthews

APPROVED BY: CE Richardson

QUALITY ASSURANCE: L Houstead

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1.0 SCOPE

This document was prepared by Wyle Laboratories for Omaha Public Power District (The District) for safety-related cable splices installed inside containment at Fort Calhoun Nuclear Generating Station, Unit 1.

1.1 Objective

The purpose of this report is to present an environmental qualification evaluation in accordance with the requirements of IE Bulletin 79-01B, including an aging analysis of six types of cable splices for safety-related electrical equipments inside containment.

1.2 Applicable Qualification Standards, Specifications, and Documents

- Wyle Laboratories Western Test and Engineering Quality Assurance Manual 380, dated June 1, 1981
- IE Bulletin No. 79-01B, Enclosure 4, "Guidelines for Environmental Qualification of Class IE Electrical Equipment in Operating Reactors," January 14, 1980.
- IE Supplement No. 2 to Bulletin 79-01B, "Environmental Qualification of Class IE Equipment," September 30, 1980.

1.0 SCOPE (CONTINUED)

1.3 Equipment Description

The subject equipment consists of the six types of cable splices listed below for six electrical cable size and multiple conductor combinations (Table 1). For details see Tables 2 and 3 and Figure 1.

1) Cable Splices at Transmitters

2) Cable Splices at the 480 V Containment Vent Fan Motor Lead Wires

3) The 480 V Containment Vent Fan Motor Splices at the Electrical Penetrations

4) Original Plant Cable Splices at Electrical Penetrations

5) TMI Modification at Containment Penetration Lead Wire Splices (Raychem WCSF-N)

6) Cable Splices at Solenoid Valves

1.4 Safety-Related Functions

The specific safety-related functions of the cable splice components are described in the following paragraphs:

- Cable Splice: provides the electrical paths for safety-related electrical circuits.

- Insulation: provides the necessary electrical isolation to eliminate unwanted electrical paths.

- Heat Shrink Tubing: provides a vapor and liquid (chemical) seal covering the insulation of the cable and connectors. For certain splices, heat shrink tubing is also insulation.

- RTV Silicone Rubber: provides a vapor and liquid (chemical) barrier over the heat shrink tubing of the cable splice.

2.0 DEFINITION OF SERVICE CONDITIONS

The following environmental service conditions have been specified by the District[20,29,30]:

		Normal	FSAR Design Basis Event (DBE*)
o	Temperature	84F(29C)	305F(152C) Maximum **
o	Relative Humidity	90 ± 5%	100%
o	Pressure	Atmospheric	60 Psig Maximum
o	Chemical Spray	N/A	Boric Acid Solution (2500 ppm Boron)
o	Radiation	3.42×10^5	1.12×10^6 to 3.0×10^7 Rads, gamma, depending on the location (see Table 3)***
o	Time:		
	a) Transmitters	Continuous	Continuous
	b) Solenoid	Intermittent	Note 1
	c) Containment Vent Fan	Intermittent	Continuous
	d) Cable	Continuous	Continuous

Temperature and pressure profiles are given in Figures 2 and 3

* The DBE is a loss of coolant accident (LOCA).

** This is Main Steam Line Break (MSLB) temperature, used in lieu of lower 288F LOCA temperature per SER Section 3.3 Response[30].

*** This is the total calculated integrated dose for 40 years plus accident[28].

NOTE 1 After the first few seconds into a DBE situation, all the solenoids in containment move to their fail positions with the exception of the following:

The Long Term Core Cooling Solenoids (238, 239, 240) are required to operate in a DBE situation.

The Reactor Coolant Solenoid (HCV-438 A & C) moves to its fail position which is the open position, and is driven closed in a DBE.

The Auxiliary Feedwater (HCV-1107A, 1108A) move to their fail position which is their open position, and are driven closed in a DBE.

Charcoal Spray may operate intermittently in a DBE, HCV-864, 865.

Purge system, HCV-881 and 882, move to their fail position which is their open position and are driven closed in a DBE.

3.0 AGING EVALUATION CRITERIA

The following sequence of steps were used to evaluate the non-metallic materials in each splice with respect to their safety-related functions under normal and Design Basis Event (DBE) conditons.

3.1 Evaluation of Susceptibility to Radiation Degradation

The approach for evaluating the components for their radiation resistance is a four step process:

1. Review the individual materials of construction as provided on the contract specific materials list.
2. Research Wyle Laboratories Aging Library for information on threshold levels, severe damage levels, degradation characteristics, and failure criteria.
3. List threshold level for radiation damage in the aging matrix.
4. Evaluate the item based on potential degradation and ability to perform its design function after exposure to the specified radiation dose.

It is generally recognized that metallic and inorganic materials are immune to radiation degradation at the specified dose, hence, the evaluation is focused on the non-metallic (organic) materials.

3.2 Evaluation of Susceptibility to Time/Temperature Related Mechanisms

Deterioration due to thermal aging is insignificant for metallic and inorganic materials under the specified environmental conditions. Therefore, component aging is based on the non-metallic (organic) materials.

For many organic materials, it is known that the degradation process can be defined by a single temperature-dependent reaction that follows the Arrhenius equation:

$$k = A \exp(-(Ea/k_b\,T)) \qquad (1)$$

where,

k = reaction rate
A = frequency factor
$\exp$ = exponent to base e
Ea = activation energy (eV)
k_b = Boltzmann's Constant (8.617×10^{-5} eV/°K)
T = absolute temperature (°K)

3.0 AGING EVALUATION CRITERIA (CONTINUED)

3.2 Evaluation of Susceptibility to Time/Temperature Related Mechanisms (Cont'd)

It is further noted that, for many reactions, the activation energy can be considered to be constant over the applicable temperature range. Equation (1) can be transformed into a slope-intercept form of a linear equation which yields the expected life:

$$\ln(\text{life}) = (Ea/k_B)\ (1/T) + \text{Constant} \qquad (2)$$

Since the materials follow an Arrhenius relationship, the requirement at one time and temperature can be transferred to another set of time/temperature coordinates using the relationship

$$t_1 = t_2 \exp((E_a/k_B)(1/T_1 - 1/T_2)) \qquad (3)$$

where,

t_1 = Calculated life at temperature T_1
t_2 = Expected life at T_2 (Equation 2) -120
T_1 = Accident temperature (max)
T_2 = Normal service temperature

When the expected life obtained from equation(2) at the normal service temperature (84F) exceeds the specified service life (40 years) by a conservative factor of three, equation (3) is used to calculate the equivalent life at the accident temperature from the expected life minus 120 years. The factor of three is used for conservatism to account for uncertainties such as variations in the postulated temperatures and durations.

This will demonstrate life in excess of the normal service condition (conservatively estimated to be 120 years) and provide a mechanism for comparing the remaining life of a material at the accident temperature with the postulated accident duration.

For example for Polyolefin, with a degradation parameter of 86% loss of electrical strength (Table 3, item No. 1):

Normal calculated life = $\exp((E_a/k_B)(1/T) + (\text{Intercept}))$
where, E_a = 0.86 eV
Intercept = -15.04707

For a baseline temperature of 84F (29C) (normal service condition)

T = 29C + 273 = 302K

life = $\exp((9980.2716)(1/302) - 15.04707)$

life = 6.56×10^7 hours (7,496 years)

3.0 AGING EVALUATION CRITERIA (CONTINUED)

3.2 Evaluation of Susceptibility to Time/Temperature Related Mechanisms (Cont'd)

Then 7,496 years - 120 years = 7,376 years

For an accident temperature of 305F (152C) (accident service condition)

t_1 = t_2 exp ((slope) ($1/T_1 - 1/T_2$))

t_1 = equivalent calculated accident life at 305F

t_2 = 7,376 years

T_1 = 152C + 273 = 425K

T_2 = 29C + 273 = 302K

then

t_1 = (7,376 years x 365 days/year) exp ((9980.2716) (1/425 - 1/362))

t_1 = 189 days

Based on the above calculation, it is demonstrated:

a) Calculated normal life of 120 years at 84F (29C)
b) Calculated accident life of 189 days at 305F (152C) in addition to 120 years normal life.

If the calculated life at the normal operating temperature does not exceed the service life (40 years) by a multiple of 3, then a case by case analysis will be carried out.

4.0 EVALUATION

4.1 Aging

An aging analysis was done to determine the susceptibility to time/temperature and radiation related mechanisms.

Damage levels and calculated lives for normal operation and DBE conditions were determined solely on the individual effects of radiation and time/temperature related mechanisms.

Contract specific materials lists were provided by The District for the purpose of evaluation.

4.1.1 TIME/TEMPERATURE EFFECTS

The Aging Matrix (Table 3) contains a list of the non-metallic materials used in each splice, the data used in this evaluation, and the calculated lives (normal and accident) for each of the splices.

A review of calculated lives, normal and accident, (Table 3) indicates insignificant thermal aging at the specified normal and accident environmental temperatures. Certainly, calculated expected life is only a theoretical life, but it demonstrates that each material will have a qualified life, for a normal service, of greater than 40 years, plus accident and post accident life.

4.1.2 RADIATION EFFECTS

4.1.2.1 Gamma Radiation Effects

The threshold levels for radiation induced damage were determined per section 3.1. The radiation threshold level of each material was compared to the required dose specified in Table 3. Where the radiation threshold level of a material is greater than the required dose by a margin of +25%, or test data exists where test conditions envelop the required dose, the effects of radiation exposure were judged to be insignificant.

A review of Table 3 indicates insignificant radiation aging.

4.1.2.2 Beta Radiation Effects

The following analysis is based on the methodology presented in the DOR Guidelines.

4.0 EVALUATION (CONTINUED)

4.1 Aging (Cont'd)

4.1.2.2 Beta Radiation Effects (Cont'd)

The beta dose is reduced by a factor of ten within 30 mils of the surface of electrical cable insulation. An additional 40 mils (for a total of 70 mils) results in another factor of ten reduction in dose. Any structures or other equipment in the vicinity of the equipment of interest would act as shielding to further reduce beta doses.

If the plant specific beta radiation dose is not available, the generic dose of 2×10^8 rads could be used.

It can be shown, by assuming a conservative unshielded surface beta dose of 2.0×10^8 rads and considering the shielding factors discussed above, that the beta dose to radiation sensitive equipment internals would be less than or equal to 10% of the total gamma dose to which an item of equipment has been qualified. Then that equipment may be considered qualified for the total radiation environment (gamma plus beta). If this criterion is not satisfied the radiation service condition should be determined by the sum of the gamma and beta doses.

4.1.2.2.1 Cable Splices at Transmitters

These cables splices are located inside conduits which shield them from beta radiation. Therefore, the effects of beta radiation would be insignificant.

4.1.2.2.2 Cable Splices at the 480 V Containment Vent Fan Motor Lead Wires.

These cable splices are located inside terminal boxes[20] and covered with RTV 3145 which shield them from beta radiation. Therefore, the effects of beta radiation would be insignificant.

4.1.2.2.3 The 480V Containment Vent Fan Motor Lead Splices at the Electrical Penetration

These cable splices are exempted from the effect of beta radiation because of the R.T.V. covering. Since the R.T.V is about 1/8 inch thick[2] (125 mils), the beta dose is reduced by a factor of 1000. The beta dose is then 2×10^5 rads. This beta dose is less than ten percent of the gamma dose and the effects of beta radiation are considered insignificant.

4.1.2.2.4 Original Plant Cable Splices at Electrical Penetrations

The effects of beta radiation are considered insignificant due to the RTV coating as in 4.1.2.2.3.

4.0 EVALUATION (CONTINUED)

4.1.2.2.5 TMI Modification at Containment Penetration Lead Wire Splices (Raychem WCSF-N)

The effects of beta radiation are considered insignificant because this cable splice was tested to gamma radiation of 2.0×10^8 (Ref. 3), which is greater than the total integrated gamma plus beta dose.

4.1.2.2.6 Cable Splices at Solenoid Valves

These cable splices are located inside condulets[20] which shield them from beta radiation. Therefore, the effects of beta radiation would be insignificant.

4.2 Relative Humidity Effects

Relative humidity is not considered a significant aging mechanism for the subject splices.

For insulation systems, humidity is usually not the primary failure mechanism. As noted in Reference 25, with respect to motor insulations, "In most cases, moisture plays only a secondary role in the failure. It does not produce the damage in the insulation. The insulation wears away or cracks for other reasons. Moisture merely provides a direct electrical pathway between these matured devices and ground." Therefore, effect of humidity was considered insignificant for this application.

In addition to the above it is judged that the combination of high temperature/pressure steam and chemical spray is a more severe environment than 100% relative humidity. Original Plant Cable Splices at the Electrical Penetrations and TMI Modification at Containment Penetration Lead Wire Splices (Raychem WCSF-N) were subjected, without failure, to a LOCA test (high temperature/pressure steam) with chemical spray environments. Therefore, immunity to relative humidity was demonstrated by more severe test conditions.

For the Cable Splices at the Transmitters, Cable Splices at the 480 V Containment Vent Fan Motor Lead Wires and the 480 V Containment Vent Fan Motor Splices at the Electrical Penetrations, the RTV coating provides an excellent seal over the splice thus causing the effects of humidity to be insignificant.

The splices at Solenoid Valves are double Pentube heat shrink tubing and are located inside a condulet system[20]. Therefore, the effects of humidity are considered insignificant.

4.0 EVALUATION (CONTINUED)

4.3 Design Basis Event (DBE)

The DBE is a Loss of Coolant Accident (LOCA).

Each splice was evaluated for the following LOCA environments:

1. Thermal Aging
2. Radiation Aging
3. Temperature
4. Pressure
5. Chemical Spray
6. Relative Humidity
7. Submergence

A summary of these evaluations is given in Tables 4 through 9.

4.3.1 THERMAL AGING

Based on the evaluation presented in Section 4.1, the effects of thermal aging during a LOCA are insignificant.

4.3.2 RADIATION AGING

Each cable splice was evaluated for the total integrated dose plus accident (LOCA), Section 4.1.2.

Based on the evaluation presented in section 4.1.2, the effects of radiation aging during a LOCA are insignificant.

TMI modification at Containment Penetration Lead Wire Splices (Raychem WCSF-N), and Original Plant Cable Splices at Electrical Penetrations interface with teflon insulated cables. The effects of 1.12×10^6 (Table 8) and 1.36×10^7 (Table 7) rads gamma respectively on teflon must be addressed by test because the Raychem test[3] and Franklin Institute[(1)] tests were conducted without teflon insulated cables.

Because of the high radiation level, a test, in lieu of analysis, must be used to demonstrate qualification of the interface.

4.0 EVALUATION (CONTINUED)

4.3 Design Basis Event (DBE) (Cont'd)

4.3.3 TEMPERATURE

Figure 4 shows the SER Section 3.3 response 305F temperature profile. The shaded area is the MSLB 305F temperature profile, in excess of peak LOCA temperature. The estimated duration of this hypothetical condition will not be greater than 5 minutes.

A review of calculated lives for the materials used in each type of cable splice showed that each individual material is capable of withstanding 305F far longer than 5 minutes as shown in Table 3.

4.3.3.1 Cable Splices at Transmitters

As indicated in Section 4.3.5.1, these splices are covered with a LOCA qualified Dow Corning 3145 RTV adhesive/sealant[4]. This RTV has good dielectric properties over a wide temperature range and will withstand long term exposure at 482F (250C)[27].

The sealant will also withstand steam (to 200C) and has withstood a 100,000 hour aging test at 200C[4]. Dow Corning has reported "Steam at 245F could, in time, soften Dow Corning 3145, but 20 minutes would be considered a minor exposure"[4]. Because the exposure to high temperature is for only a short time, there should be no adverse effects on the Dow Corning 3145 RTV.

4.3.3.2 Cable Splices at the 480V Containment Vent Fan Motor Lead Wires

Dow Corning 3144 RTV adhesive/sealant's ability to stand up to the adverse conditions of a LOCA is documented by the Fisher Controls Company valve actuator tests[7]. Test parameters included temperatures in excess of 288F, pressure in excess of 60 psig, and a 100% saturated steam environment.

Furthermore, 3144 RTV will withstand long term exposure at 250C (482F)[27].

It is concluded that the short time exposure at high temperature will not have an adverse effect on this splice.

4.3.3.3 The 480V Containment Vent Fan, Motor Lead Splices at the Electrical Penetrations

This cable splice will withstand the short time exposure of 305F per analysis presented in section 4.3.3.1 above.

4.0 EVALUATION (CONTINUED)

4.3 Design Basis Event (DBE) (Cont'd)

4.3.3.4 Original Plant Cable Splices at Electrical Penetrations

Figure 4 includes the Franklin Test estimated average temperature of 297F. The 17F increase (305F-288F) over the calculated LOCA temperature curve is plotted as the SER Section 3.3 MSLB Temperature Curve. By inspection, it can be seen that the amount of heat added during testing was significantly greater than that required by the hypothetical SER Section 3.3, MSLB Temperature Curve (LOCA curve plus 17F). Note the logrithmatic scale and that Area B is a major increase over Area A. Therefore, the Franklin Tests are judged to be conservative compared to the DBE temperature profile with its 305F imposed peak temperature.

Some test temperatures reached 302F while others were as low as 295F. This represents a range of undershoot from 3 to 8 degrees. Since the SER Section 3.3, use of 305F was established for the upper regions of the containment, and the electrical penetation splices are in the lower-middle elevations, the 3 to 8 degree difference for about 52 seconds can be taken into account by establishing the materials capability to withstand higher temperatures.

The material evaluation in Section 4.3.1 and 4.3.3.1 shows the capability to withstand 305F temperatures so materials in the splice should withstand a short exposure at 305F.

4.3.3.5 TMI Modification at Containment Penetration Lead Wire Splices (Raychem WCSF-N)

These splices have been tested to temperatures up to 390F which exceeds the required temperature by 85F[3].

4.3.3.6 Cable Splices at Solenoid Valves

The material evaluation in Section 4.3.1 and 4.3.3.1 shows the capability to withstand 305F temperatures so materials in the splice should withstand a short exposure at 305F.

4.3.4 PRESSURE

No accident pressure test data exists for the cables splices listed below:

a) Cable Splices at Transmitters

b) Cables Splices at the 480V Containment Vent Fan Motor Lead Wires

c) The 480V Containment Vent Fan Motor Splices at the Electrical Penetrations

d) Cables Splices at Solenoid Valves

4.0 EVALUATION (CONTINUED)

4.3 Design Basis Event (DBE) (Cont'd)

4.3.4 PRESSURE (Cont'd)

The effects of pressure are significant when chemical spray is present to cause shorting of the conductors due to voids or poor adhesive properties of the splice. The splice construction technique should minimize the possibility of voids. RTV alone exhibits excellent adhesive properties[4,7].

Original plant Cable Splices at Electrical Penetrations and TMI Modification at Containment Penetration Lead Wire Splices have been tested for a LOCA condition with a pressure equal or greater than 60 psig[1,3].

4.3.5 CHEMICAL SPRAY

4.3.5.1 Cable Splices at Transmitters

These splices are potted with Dow Corning RTV 3145 adhesive/sealant[4]. The sealant will withstand steam up to 392F (200C), and chemical spray for the DBE conditions specified in section 2.2.

Each cable splice is sealed in a condulet which prevents chemical spray from getting to the splices[20].

A chemical spray environment during a LOCA should be insignificant.

4.3.5.2 Cable Splices at the 480V Containment Vent Fan Motor Lead Wires

These splices are covered with Dow Corning RTV 3144 adhesive/sealant. Due to the RTV sealant, the splice system will not be subjected to chemical spray during a LOCA (Ref. 7).

The RTV 3144 sealant will effectively seal off all environments from the underlying Scotch brand tapes and the splice, except for radiation. The RTV 3144 also is not adversely affected by boric acid solutions in excess of 5%[7].

These splices are contained within a sealed NEMA conduit and terminal box system[20]. The physical layout of the conduit is such that chemical spray would have to travel against the direction of gravity inside the conduit to reach the splices during the 2 to 3 hours operating time requirement[20].

The effects of a chemical spray environment during a 2 to 3 hour LOCA should be insignificant.

4.0 EVALUATION (CONTINUED)

4.3.5.3 The 480V Containment Vent Fan Motor Splices at the Electrical Penetrations

These splices use G.E. RTV silicone to seal the final end tabs of the Irrasil tape. A layer of Scotch #33 tape is installed over the entire splice. An investigation of this splice indicates that its composition would allow it to withstand the effects of chemical spray during a LOCA[5].

The SPT has an outstanding resistance to steam and hot water[5]. It also has excellent resistance to acids. The silicone tape and RTV both exhibit good, high-temperature characteristics and chemical resistance.

To insure operability of the splice, the splices are coated with Dow Corning RTV 3145 adhesive/sealant[4]. This mitigates the chemical spray from attacking the splice. Therefore, the effects of chemical spray environment during a 2 to 3 hour LOCA should be insignificant.

4.3.5.4 Original Plant Cable Splices at Electrical Penetrations

The effects of chemical spray environment during the LOCA should be insignificant per Section 4.3.5.1 above.

4.3.5.5 TMI Modification at Containment Penetration Lead Wire Splices (Raychem WCSF-N)

These splices are LOCA qualified per Wyle Report No. 58442-1[3].

The tested chemical spray consisted of 6200 ppm of boron, 50 ppm of hydrazine buffered to a pH of 10.5 with trisodium phosphate.

The test conditions far exceed the required plant conditions specified in Section 2.2.

4.3.5.6 Cable Splices at Solenoid Valves

These cable splices are covered with double heatshrink tubing and are contained within a sealed NEMA condulet and conduit system[20]. The physical layout of the conduit is such that chemical spray would have to travel against the direction of gravity inside a conduit to reach the splices during the LOCA which prevents chemical spray from getting to the splice.

4.3.6 RELATIVE HUMIDITY

Based on the evaluation presented in Section 4.2, the effects of relative humidity during a LOCA are insignificant.

4.0 EVALUATION (CONTINUED)

4.3.7 SUBMERGENCE

As reported by The District, the cable splices are above flood level (SCEW Sheets p. 5-49 through 5-52), therefore no effects of submergence are considered in this report.

4.4 In-Containment Inspection

On November 5 and 6, 1981, an inspection of splices was performed for the purpose of the "as constructed" splices at Fort Calhoun[8]. The District's Licensing Action Log, Item 00266, commitment to perform the inspection during the 1981 refueling outage was completed. The significant results of the District's and Wyle's in-containment inspection are as follows:

Original Plant Cable Splices at Electrical Penetration

The inspection of a splice after disassembly verified that the pertinent design data of the "as constructed" equipment conforms to document FSK-E-329, Sheet 3, the Fort Calhoun Construction Inspection Data Report (CIDR) of 1973 and the test specimen description of Test Report F-C3348[8]. The pertinent design data which was selected to verify the assumptions of Wyle Preliminary Report[9] include, but are not limited to the following:

1. Double heat shrink tubing over butt splice
2. Drain wire has boot and associated splice in double heat shrink
3. Relative spacing between butt splices
4. Materials
    a. RTV
    b. GE Irrathene
    c. Scotch 33

In addition, subsequent discussions with the District's Field Maintenance Electricians on November 5, 1981, pointed out that the materials of Items 4a, b, c, were recognizable and identifiable as the proper materials. These District personnel participated in construction and start up of Fort Calhoun.

The first purpose of the cable splice disassembly was to ensure continued plant operation by demonstrating that assumptions 2, 3, 4, and 5 of Reference 9 regarding the penetration lead wires were met. Specifically, the "as constructed" penetration lead wire splices were similar to those used in the April, 1972 Franklin Institute Test, Report F-C3348, by having two layers of heat shrink over each butt splice in lieu of one layer (including the drain wire), and the drain wire had a boot of heat shrink over it. The second purpose was to gather sufficient data to assist in the evaluation/verification of the cable splice similarity analysis (tested specimens versus installed splices) of assumption 1 of Reference 9.

4.0 EVALUATION (CONTINUED)

4.5 Test Specimens Similarity Evaluation

Industry experience regarding cable splice qualification, suggests that the multiconductor cable splice is the limiting case. The sealing or pressure boundary function of keeping liquid/chemical spray out of the conductor area is more difficult to obtain for a multiconductor splice than for a single conductor or lesser number of conductors splice.

4.6 Evaluation Summary

See Tables 4 through 9 for details.

Effects of LOCA environment are considered negligible for Cable Splices at the Solenoid Valves for a one minute LOCA operating time requirement. However, the District must take exception to the one hour margin criterion of the DOR Guideline. Otherwise a test or replacement must be considered. Material analysis shows no adverse effects. Also, the solenoids fail in a safe position. Accordingly, continued plant operation is justified, and if the one hour criterion with the requirement for accident test data is envoked, then a test or replacement program must be considered.

For the Cable Splice at the Transmitter taking into account the single heat shrink tube potted with RTV inside an enclosed condulet, the LOCA operational time requirement of 1000 hours and the material analysis shows no adverse effects. Continued plant operation is justified. As no accident test data is available, a test or replacement program must be considered.

TMI Modification at Containment Penetration Lead Wire Splices, Raychem WCSF-N, meet IEEE-323-1974. The Original Plant Cable Splices at Electrical Penetrations meet the DOR Guidelines by a combination test and analysis. However, because neither was tested with Teflon insulated cable, a test program is needed to demonstrate qualification for the Teflon interface at the levels indicated in Tables 7 and 8.

Cable Splices at the 480V Containment Vent Fan Motor Lead Wires and the 480V Containment Vent Fan Motor Splices at the Electrical Penetrations evaluation shows good use of RTV to seal the splices. The material analysis shows that the individual splice components have no adverse effects from normal and accident conditions and continued plant operation is justified. As no accident test data exists, a test plan or replacement is needed.

5.0 CONCLUSIONS

1. Based upon the inspection at Fort Calhoun and the engineering evaluation done to date, it has been determined that insufficient accident test data is available to support full qualification in strict accordance with DOR Guidelines of IE Bulletin 79-01B for the cable splices listed below. The specific deficiency is lack of accident test data on the splice.

   a) Cable Splices at the 480V Containment Vent Fan Motor Lead Wires (LER 80-007)

   b) The 480V Containment Vent Fan Motor Splices at the Electrical Penetrations (LER 80-007)

   c) Cable Splices at Solenoid Valves except for HCV-238, 239, and 240)

   d) Cable Splices at Transmitters (LER 80-006)

   As presented in Section 4.0 above, from an engineering and analysis point of view, the above splices are capable of safe operation before, during, and after a LOCA for the time period required to operate. Therefore continued operation is justified.

2. Original Plant Cable Splices at containment penetration using original plant double heat shrink splices tested per April, 1972 Franklin Institute Test Report F-C3348[1] are qualified except for interface with teflon insulated cable which must be tested.

3. Containment penetration lead wire splices using Raychem splices are qualified per May, 1980, Wyle Test Report No. 58442-1[3], except for the interface with Teflon insulated cable which must be tested.

REFERENCES

1. Qualification Tests of Cable Splices Under Simulated Reactor Containment Service Conditions, Franklin Institute Final Report F-C3348, dated April 1972.

2. Fort Calhoun File No. FC-643-80, dated 6 June , 1980.

3. Environmental Qualification Test Report of Raychem WCSF-N nuclear in-line cable splice assemblies for Raychem Corporation, Menlo Park, California, Wyle Report No. 58447-1, dated 15 May, 1980.

4. Dow Corning letter dated March 24, 1980; Subject: Dow Corning 3145 RTV and adhesive/sealant integrity.

5. LER 80-007, Fort Calhoun Station, Unit 1, Docket No. 05000285, attachment No. 1.

6. Standard Handbook for Electrical Engineers, Tenth Edition.

7. Enclosure 9, Containment Fan Cooler Motor Splices. Omaha Public Power District, Fort Calhoun Station, Unit 1, Electrical Equipments Evaluation Report.

8. Wyle Quality Inspection Record by E.J. Gerloff; subject: Penetration Splice, dated November 11, 1981.

9. Wyle Report, 26333-02; subject: Preliminary Assessment Report on Cable Splices Inside Containment for Fort Calhoun Station, Unit 1, dated January 29, 1981.

10. Enclosure 8, Material Analysis of Containment Penetration Cable Splices for Radiation Effects, for Fort Calhoun Station, Unit 1, Electrical Equipments Evaluation Report.

11. Fort Calhoun Station, Unit 1, File No. 11405-E-150, 151, Cable and Conduit Schedule, Fort Calhoun.

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27. Information about Silicone Elastomers, 3145 RTV, Dow Corning Corporation, Form No. 61-34913-80.

28. Enclosure 11, Expected Radiation Dose Levels In-Containment Omaha Public Power District, Fort Calhoun Station, Unit 1, Electrical Equipments Evaluation Report.

29. Telecon of Jim Thompson, Wyle Laboratories, Norco, Ca., and Mike Capella, Omaha Public Power District, Omaha, Nebraska, April 21, 1982. Subject: Containment Temperatures for Fort Calhoun Nuclear Generating Station, Unit 1.

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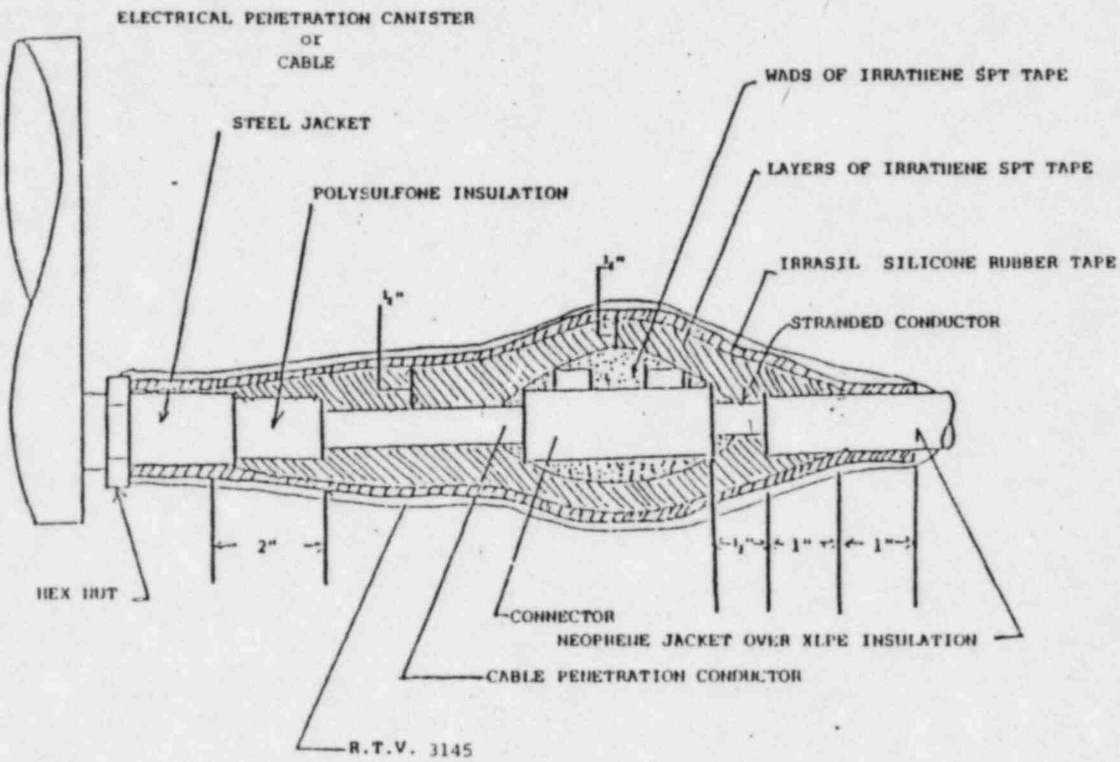

FIGURE 1

INSULATION OF "E" CABLE CONNECTIONS
FOR
CONTAINMENT VENT FAN

FIGURE 1*

INSULATION OF "E" CABLE CONNECTIONS

*Reference 24

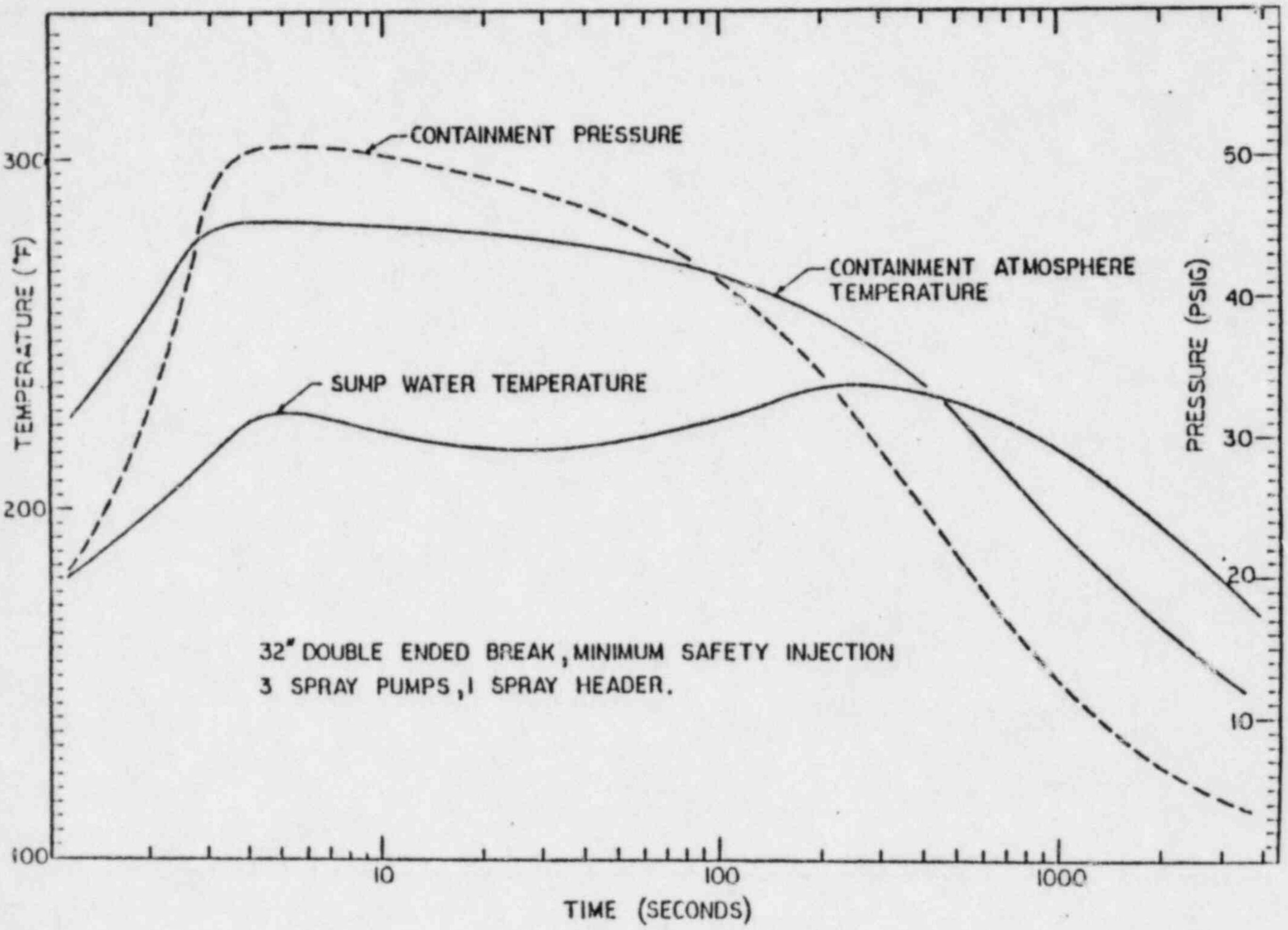

FIGURE 2

CONTAINMENT TEMPERATURES
FOLLOWING LOCA

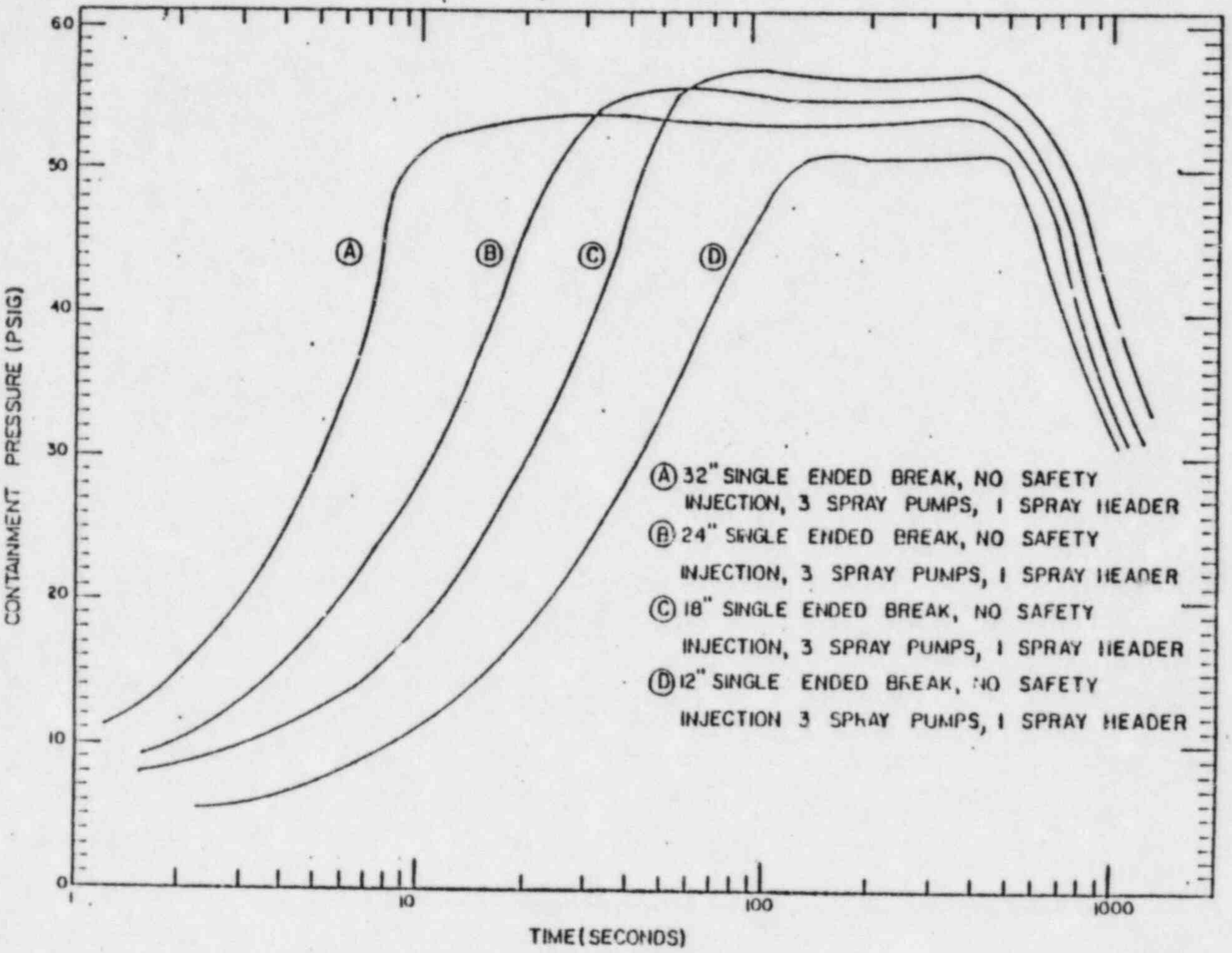

FIGURE 3

CONTAINMENT PRESSURE

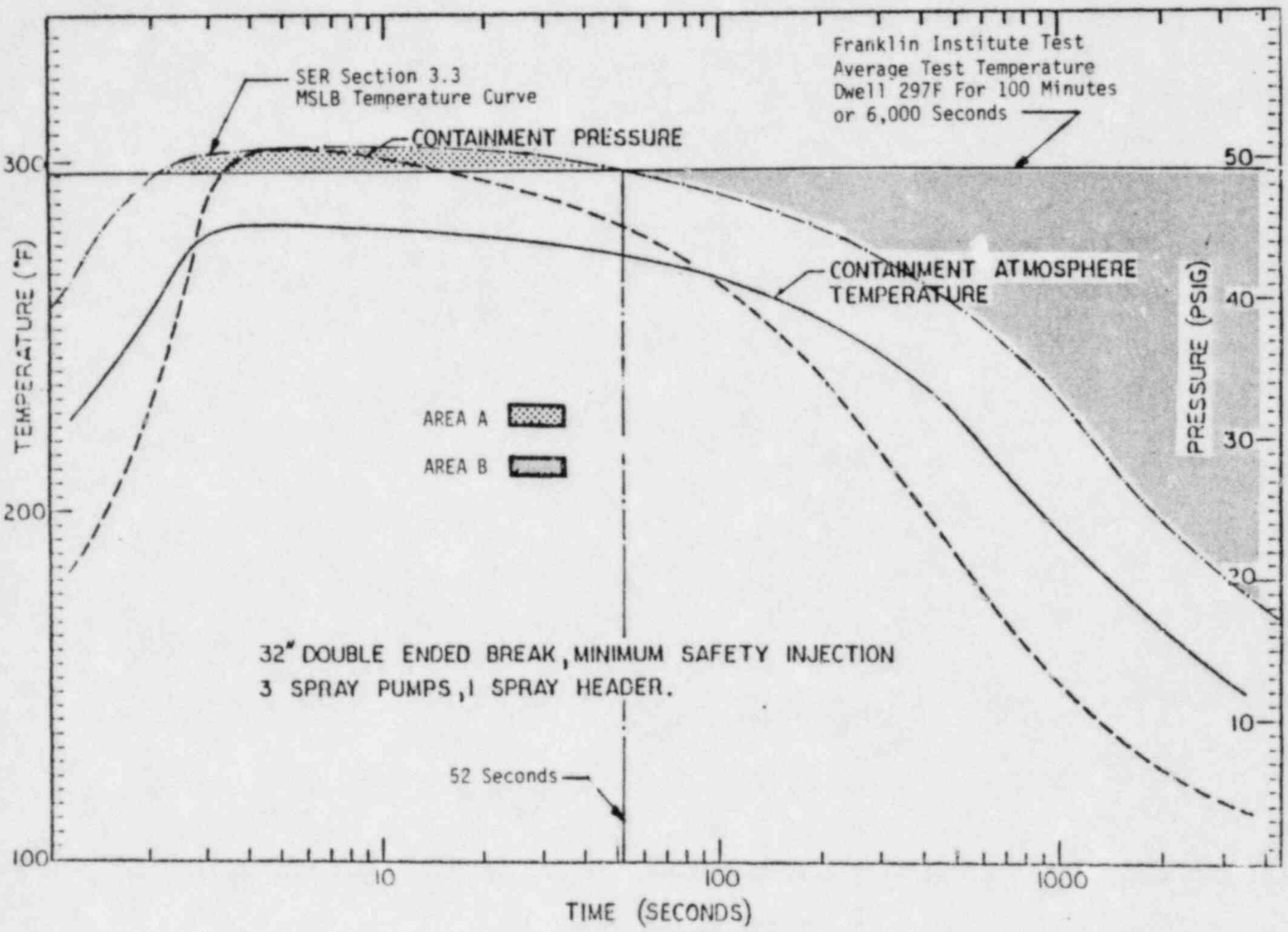

FIGURE 4

SER SECTION 3.3
MSLB TEMPERATURE CURVE

TABLE 1

CABLE DESCRIPTION

I.D. No.	Cable No.	Type	Function
319	W-10	1/C 300 MCM	Containment Vent Fan Motors
325	W-21	3/C #10	480 V, 3 Ø Power for Motor Operated Valves (MOV)
328	W-38	3/C #12	120 V, 1 Ø Control for MOV and 120 VDC on PC1849
330	W-40	4/C #12	120 VDC Control to Solenoids and Limit Switches
331	W-41	7/C #12	120 V, 1 Ø Control for MOV and HCV 1107A and HCV 1108A
323	W-57	2/C #14 TS Pair	Drain Wire Using all Instruments

TABLE 2

CABLE SPLICE IDENTIFICATION

Item No.	I.D. No.	(Cable Splices) Materials	Cable No. Type	(Cable Splices) Description	(Cable Splices) Manufacturer	Exposure to Containment Atmosphere#	Screws+ Page No.	Reference No.
1	330 323	Polyolefin Dow Corning 3145 RTV Clear	W-40 4/C #12 W-57 2/C #14 TS Pair	Splices at Transmitter (Single heat shrink splice)	Amp & American Pamcor	No*	6-50	(Enc. #8, LER-80-006) 10,4
2	319A	1.Scotch Tape #70 2.Bishop Tape #3 3.Scotch Tape #88 5.Dow Corning 3144 RTV	W-10 1/C 300 MCM	Cable Splices at the 480V Containment Vent Fan Motor Lead Wires (VA-3A, 313, 7C, 7D)	3M Company & Bishop	No **	6-51	(Enc. #9) 7
3	319B	1.Irrathane SPT Tape 2.Irrasil Tape 3.Scotch Tape #33 4.Dow Corning 3145 RTV	W-10 1/C 300 MCM	The 480V Containment Fan Motor Lead Splices at the Electrical Penetration	General Electric	Yes	6-52	(LER 80-007) 5
4	325 328 330 331 323	Polyolefin Neoprene Dow Corning 3145 RTV Clear	W-21 3/C #10 W-38 2/C #12 W-40 4/C #12 W-41 7/C #12 W-57 2/C #14 TS Pair	Original Plant Cable Splices at Electrical Penetrations, (double heat shrink)	Amp & Penntube	Yes	6-49	(Enc. #8 XA-545E-462) 10
5		Cross-linked Polyolefin S-1119 Adhesive (Hotmelt Polyethylene Copolymer)		TMI Modification at Containment Penetration Lead Wire Splices	WCSF-N Raychem	Yes	N/A	3
6		Polyolefin	W-40 4/C #12 W-57 2/C #14 TS Pain	Splices at Solenoid Valves (double heat shrink splice)	Amp & American Pamcor	No*	6-49	

* Inside Condulets
**Inside Terminal Box

#Reference 11
+System Component Evaluation Work Sheet

TABLE 3

AGING MATRIX

ITEM NO	ITEM MANUFACTURER	SERVICE CONDITIONS		NONMETALLIC MATERIALS AND ACTIVATION ENERGIES (eV)	THRESHOLD LEVEL FOR RADIATION DAMAGE (RADS)	CALCULATED LIFE (YEARS)		REMARKS
		NORMAL	ACCIDENT			NORMAL	ACCIDENT	
1	Cable splices at Transmitter AMP & American Pamcor	Temperature 84F (29C) Relative Humidity 90 ± 5% Pressure Atmospheric Radiation 3.42 x 10^5 rads	Temperature 305F (152C) Relative Humidity 100% Pressure Max. 60 psig Radiation 3.0 x 10^7 rads	(1)Polyolefin 0.86 (Ref. 12)	(1)5.0 x 10^8 (Ref. 13)	120	189 (days)	(2)
				(2)3145 RTV 1.67 (Ref. 14)	(2)2.5 x 10^7 (Ref. 4)	120	> 120	
2	Cable Splices at the 480V Containment Vent Fans Motor Lead Wires 3M Company & Bishop Electric	Temperature 84F (29C) Relative Humidity 90 ± 5% Pressure Atmoshperic Radiation 3.42 x 10^5 rads	Temperature 305F (152C) Relative Humidity 100% Pressure Max. 60 psig Radiation 1.92 x 10^7	(1)Scotch Tape #70 (silicone rubber) 1.64 (Ref. 16)	(1)1.0 x 10^6 (Ref. 15)	120	> 120	(3)
				(2)Bishop Tape #3 (polyethylene base) assumed polyethylene 1.11 (Ref. 21)	(2)2.0 x 10^8 (Ref. 23)	120	52 (days)	
				(3)Scotch Tape #88 Vinyl plastic (poly- vinyl chloride assumed) 1.19 (Ref. 17)	(3)1.9 x 10^7 (Ref. 15)	120	73 (days)	(3)
				(4)3144 RTV (assumed clear RTV 3145) 1.67 (Ref. 14)	(4)1.02 x 10^8 (Ref. 7)	120	>120	(4)

TABLE 3

AGING MATRIX

ITEM NO	ITEM MANUFACTURER	SERVICE CONDITIONS		NONMETALLIC MATERIALS AND ACTIVATION ENERGIES (eV)	THRESHOLD LEVEL FOR RADIATION DAMAGE (RADS)	CALCULATED LIFE (YEARS)		REMARKS
		NORMAL	ACCIDENT			NORMAL	ACCIDENT	
3	The 480V Containment Vent Fan Motor Splices at the Electrical Penetration General Electric	Temperature 84F (29C) Relative Humidity 90 ± 5% Pressure Atmospheric Radiation 3.42 x 10^5 rads	 305F (152C) 100% Max. 60 psig 1.12 x 10^6 rads	(1)Irrathene SPT Tape (Ethylene Propylene Rubber) 1.34 (Ref. 22)	(1)5.0 x 10^7 (Ref. 23)	120	34 (days)	
				(2)Irrasil Silicone Rubber Tape (irradiated silicone rubber) 1.64 (Ref. 16)	(2)1.0 x 10^6 (Ref. 15)	120	>120	(5,3)
				(3)Scotch Tape #33 Vinyl plastic (Polyvinyl chloride assumed) 1.19 (Ref. 17)	1.6 x 10^7 (Ref. 15)	120	73 (days)	
				(4)3145 RTV 1.67 (Ref. 14)	2.5 x 10^7 (Ref. 4)	120	>120	
4	Original Plant Cable Splice at Electrical Penetrations Amp. & Penntube	Temperature 84F (29C) Relative Humidity 90 ± 5% Pressure Atmospheric Radiation 3.42 x 10^5 rads	 305F (152C) 100% Max. 60 psig 2.5 x 10^7	(1)Polyolefin 0.86 (Ref. 12)	(1)5.0 x 10^8 (Ref. 13)	120	189 (days)	
				(2)Neoprene 1.05 (Ref. 18)	(2)1.0 x 10^6 (Ref. 15)	120	4 (days)	(6)
				(3)3145 RTV 1.67 (Ref. 14)	(3)2.5 x 10^7 (Ref. 4)	120	>120	
5	TMI Modification at Containment Penetration Lead Wire Splices Raychem WCSF-N	All the conditions are the same as item No. 3 above		(1)Polyolefin Crosslinked 1.29 (Ref. 19)	(1)5.0 x 10^8 (Ref. 13)	120	55 (days)	(7)
				(2)Adhesive (Hotmelt Polyethylene Copolymer) 1.11 (Ref. 21)	(2)8.7 x 10^7 (Ref. 15)	120	52 (days)	
6	Cable Splices at Solenoid Valves Amp - American Pancor	All the conditions are the same as item No. 4 above		Polyolefin 0.86 (Ref. 12)	5.0 x 10^8 (Ref. 13)	120	189 (days)	

TABLE 3 REMARKS

(1) Unless otherwise noted, Calculated Accident Life listed is in addition to 120 years Calculated Normal Life.

(2) Has shown to exhibit excellent radiation resistance when irradiated to levels of 5.0×10^7 rads, gamma (Ref. 10).

(3) Satisfactory test results were obtained when subjected to radiation fields in the neighborhood of $30\text{-}100 \times 10^6$ (Ref. 7).

(4) Dow Corning no longer manufactures RTV 3144; the replacement product is RTV 3145 clear, which is basically the same product (Ref. 26, 27).

(5) An investigation of this splice indicates that its composition would allow it to withstand the LOCA conditions (Ref. 5).

(6) Has been irradiated to levels of 5, 10, and 25×10^6 rads by the Penntube Plastics Co., with no evidence of degradation as a result of these exposures (Ref. 10).

(7) This splice system has been tested to a radiation dose up to $200\text{-}290 \times 10^6$ with satisfactory results (Ref. 3).

TABLE 4
EVALUATION SUMMARY

EQUIPMENT: Cable Splices at Transmitters

	EVALUATION RESULTS			
PARAMETER	PLANT	TEST	ANALYSIS	REMARKS
Thermal Aging	40 years (Normal and DBE)	--	120 years at 84F plus DBE at 305F	Section 4.1.1
Radiation Aging (Rads)	3.0×10^7	--	5.0×10^7	Section 4.1.2
Temperature (F)	305	--	305	Section 4.3.3
Pressure (psig)	60	--	60	Section 4.3.4
Chemical Spray	2500 ppm Boron		Protected by RTV 3145	Section 4.3.5
Relative Humidity %	100	--	100	Section 4.2
Submergence	Flood level Elev. 1000.9'	--	Above Flood Level	SCEW Sheet p. 6-50

TABLE 5
EVALUATION SUMMARY

EQUIPMENT: Cable Splices at the 480V Containment Vent Fan Motor Lead Wires

EVALUATION RESULTS

PARAMETER	PLANT	TEST	ANALYSIS	REMARKS
Thermal Aging	40 years (Normal and DBE)	--	120 years at 84F plus DBE at 305F	Section 4.1.1
Radiation Aging (Rads)	1.92×10^7	--	1.0×10^8	Section 4.1.2
Temperature (F)	305	--	305	Section 4.3.3
Pressure (psig)	60	--	60	Section 4.3.4
Chemical Spray	2500 ppm Boron	--	Boric acid in excess of 5%	Section 4.3.5
Relative Humidity %	100	--	100	Section 4.2
Submergence	Flood level Elev. 1000.9'	--	Above flood level	Scew Sheet p. 6-51

TABLE 6
EVALUATION SUMMARY

EQUIPMENT: The 480V Containment Vent Fan Motor Splices at the Electrical Penetrations

	EVALUATION RESULTS			
PARAMETER	PLANT	TEST	ANALYSIS	REMARKS
Thermal Aging	40 years (Normal and DBE)	--	120 years at 84F plus DBE at 305F	Section 4.1.1
Radiation Aging (Rads)	1.12×10^6	--	1.6×10^6	LER 80-007 Section 4.1.2
Temperature (F)	305	--	305	Section 4.3.3
Pressure (psig)	60	--	60	Section 4.3.4
Chemical Spray	2500 ppm Boron	--	Protected by RTV 3145	Section 4.3.5
Relative Humidity %	100	--	100	Section 4.2
Submergence	Flood level Elev. 1000.9'	--	Above flood level	SCEW Sheet p. 6-52

TABLE 7
EVALUATION SUMMARY

EQUIPMENT: Original Plant Cable Splices at Electrical Penetrations

PARAMETER	PLANT	TEST	ANALYSIS	REMARKS
	EVALUATION RESULTS			
Thermal Aging	40 years (Normal and DBE)	--	120 years at 84F plus DBE at 305F	Section 4.1.1
Radiation Aging*	1.36×10^7*	--	2.5×10^7	Section 4.1.2
Temperature (F)	305	285-295	305	Section 4.3.3
Pressure (psig)	60	60		Section 4.3.4
Chemical Spray	2500 ppm Boron	1% pH 9.5	Protected by RTV 3145	Section 4.3.5
Relative Humidity %	100		100	Section 4.2
Submergence	Flood level Elev. 1000.9'	--	Above flood level	SCEW Sheet p. 6-49

*Application has teflon insulated lead wires as interface. Need test to confirm splice will perform safety function under radiation.

TABLE 8
EVALUATION SUMMARY

EQUIPMENT: Containment Penetration Lead Wire Splices (Raychem WCSF-N)

	EVALUATION RESULTS			
PARAMETER	PLANT	TEST*	ANALYSIS	REMARKS
Themal Aging	40 years	1500 hours at 150C	120 years at 84F plus DBE at 305F	Section 4.1.1
Radiation Aging**	1.12×10^{6}**	2.0 - 2.9 $\times 10^{8}$	5.0×10^{8}	Section 4.1.2
Temperature (F)	305	390	305	Section 4.3.3
Pressure (psig)	60	66		Section 4.3.4
Chemical Spray	2500 ppm Boron	6200 ppm Boron		Section 4.3.5
Relative Humidity %	100	100	100	Section 4.2
Submergence	Flood level Elev. 1000.9'	--	Above flood level	SCEW Sheet p. 6-52

*Wyle Test Report No. 58442-1 (Ref. 3)

**Application has teflon insulated lead wires as interface. Need test to confirm splice will perform safety function under radiation.

TABLE 9
EVALUATION SUMMARY

EQUIPMENT: Cable Splices at Solenoid Valves

EVALUATION RESULTS

PARAMETER	PLANT	TEST	ANALYSIS	REMARKS
Themal Aging	40 years	1500 hours at 150C	120 years at 84F plus DBE at 305F	Section 4.1.1
Radiation Aging	1.36×10^7	--	5×10^8	Section 4.1.2
Temperature (F)	305	--	305	Section 4.3.3
Pressure (psig)	60	--	60	Section 4.3.4
Chemical Spray	2500 ppm Boron	--	Protected by NEMA condulet and conduit system	Section 4.3.5
Relative Humidity %	100	--	100	Sectin 4.2
Submergence	Flood Level Elev. 1000.9'	--	Above flood level	Scew Sheet p. 6-49

ATTACHMENT