ATTACHMENT 1 TO LAP-83-450

PROGRAM OUTLINE

Demonstration of Raychem Cable for
Qualified Use in Class 1E Service, Primary
and Secondary Containment for Brunwick
Steam Electric Plant, Units 1 and 2

CAROLINA POWER & LIGHT COMPANY

DEMONSTRATION OF RAYCHEM CABLE FOR QUALIFIED USE IN CLASS 1E SERVICE

PRIMARY & SECONDARY CONTAINMENT

FOR

BRUNSWICK STEAM ELECTRIC PLANT - UNITS 1 & 2

OUTLINE

REV. NO.	RECOMMENDED BY	CONCURRED BY	APPROVED BY	DATE
0	D. R. Rhyne	[illegible]; B. M. Parker 2/10/83	[illegible]	2/17/83
1	DRRhyne 4/6/83	B. M. Parker 4-7-83	[illegible]	4/7/83
2	DRRhyne 8/23/83	B. M. Parker 8/23/83	[illegible]	8/24/83

1. Objective:

To demonstrate by type tests that the subject cable is capable of performing its intended function as installed at BSEP under loss of coolant accident conditions specified to BSEP. Testing to be performed in accordance with applicable parts of IEEE Std 323-1974, IEEE Std 383-1974, and Regulatory Guide 1.131. Appendix A establishes CP&L's position as to the applicability of IEEE 383-1974 to this demonstration.

2. Scope

This program addresses operation during a design basis event as required in Section 2.4 of IEEE Std 383-1974. Other aspects of cable qualification for Class 1-E Service are not an issue.

3. Cable Description

Raychem-Flamtrol TM unshielded jacketed cables having combined conductor insulation and jacket wall thickness greater than .120 inches. UE&C Specification 9527-01-113-4B.

4. Cable Sample:

Test specimens to be fabricated from 7-conductor, 12 AWG, unused cable available at BSEP, selected per Appendix B.

5. BSEP Service Conditions:

a) Normal service voltage: 480 volts, maximum 528 volts.

b) Maximum service current: 12 amperes.

c) Service Life: 40 years at $66^{o}C$, 6.0×10^{7} rads.

6. BSEP Conditions To Be Simulated:

a) Normal service aging:

i) 8 years at $66^{o}C$, 1.2×10^{7} rads.

ii) 40 years at $66^{o}C$, 6.0×10^{7} rads.

b) LOCA Environment:

i) Temperature and pressure profiles as shown in Figure 1.

ii) Chemical spray: demineralized water, 24 hour duration beginning 6 hours after start of environmental exposure, .15 gallons per minute per square foot of horizontal cross-section area.

6. BSEP Conditions To Be Simulated: (Cont'd)

b) LOCA environment: (Cont'd)

iii) Radiation: 5.0×10^7 rads.

iv) Relative humidity: 100 percent after first 24 hours.

7. Performance Requirements to Be Demonstrated:

a) Ability to carry simulated rated load current and voltage during LOCA test.

8. Aging Simulation Procedure:

a) Specimen: Cable specimens mounted on 30-inch diameter mandrels, effective length not less than 10 feet.

b) Radiation Aging:

i) Gamma Radiation, cobalt-60 source.

ii) Dose rate not to exceed 1.0×10^6 rads per hours.

iii) Air equivalent dose: Condition A, 6.2×10^7 rads.
Condition B, 1.1×10^8 rads.

c) Thermal Aging: (See Appendix C)

i) Condition A: One specimen of each configuration aged at 123°C for 100 hours simulates 8 years of service at 66°C based on Arrhenius analysis of long-term thermal life data.

ii) Condition B: One specimen of each configuration aged at 140°C for 100 hours simulates 40 years life at 66°C based on Arrhenius analysis of long-term thermal life data.

9. LOCA Simulation Test:

a) Physical arrangement:

i) Mandrels with pre-aged specimens mounted in pressure vessel. Orientation depends on vessel design.

ii) Jacket ends of one specimen on each mandrel stripped to expose open ends of cable to environment inside pressure vessel. Individual components spliced to individual penetrations leads inside pressure vessel.

iii) Cable ends of remaining specimen on each mandrel sealed. Exit pressure vessel through suitable penetrations.

9. LOCA Simulation Test (Cont'd)

b) Electrical Connections:

i) Specimens continuously energized as shown in Figure 2. A, B, and C connected to 4-wire, 3-phase, Y-connected transformer with grounded neutral. Each lead fused at 0.5 amperes. Line voltage adjusted to 600 volts.

ii) Simulated load current of 20 amperes obtained as shown in Figure 2.

c) Environmental Exposure:

i) Simulated LOCA temperature and pressure profiles as shown in Figure 1.

ii) Demineralized water spray for 24 hours beginning 6 hours after start of environmental cycle. Spray directed vertically downward at minimum rate of 0.15 gallons per minute per square foot of horizontal cross-sectional area of pressure vessel.

d) Measurements:

Monitor the following parameters:

Voltage
Voltage Circuit Continuity
Load Current
Pressure
Temperature
Relative Humidity
Insulation Resistance Values

10. Bases for Acceptance - See Appendix D

11. Documentation:

To comply with IEEE Std 383-1974, Section 1.4.

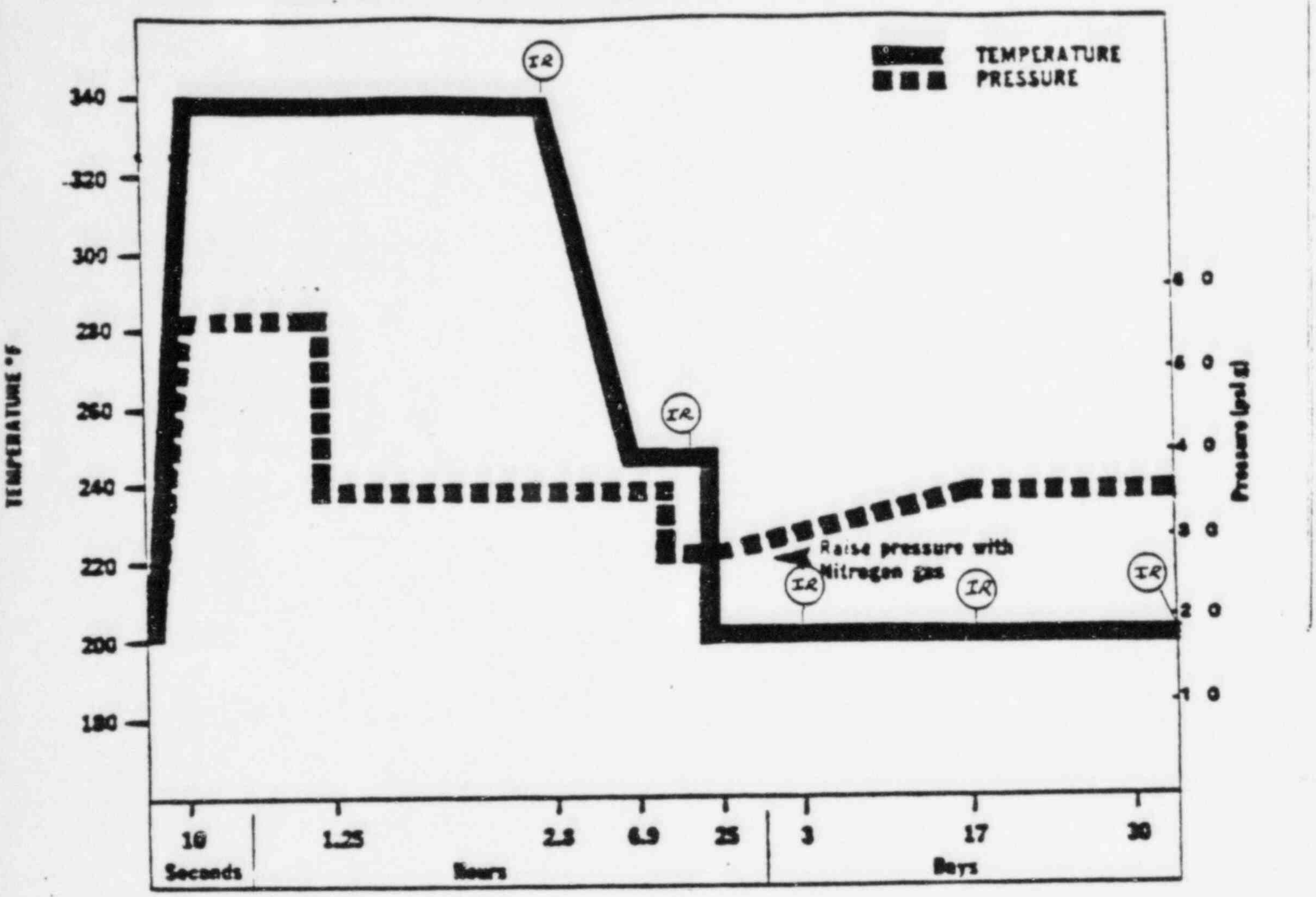
12. Appendices

A - Demonstration of Raychem Cable for use in Class 1E Service with Reference to IEEE 383-1974

B - Selection of Test Samples for Adverse Environment Testing

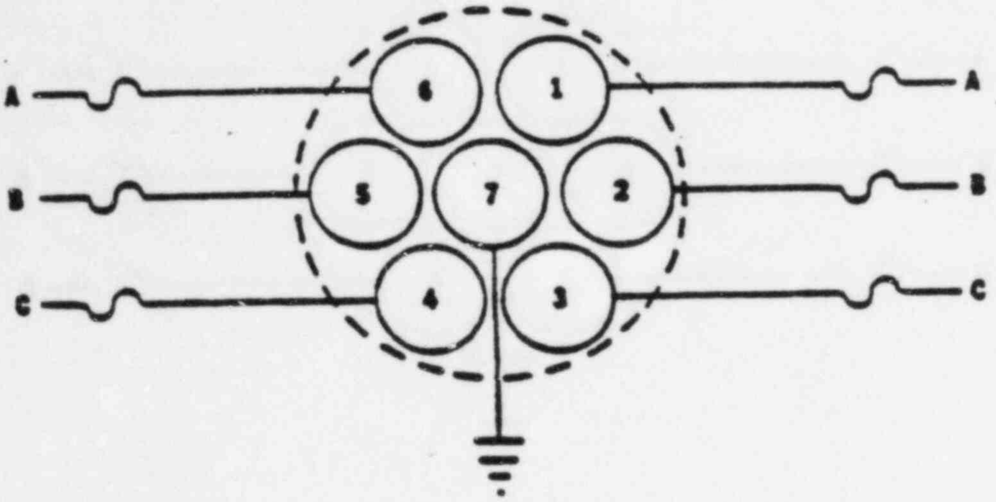
C - Method of Determining Accelerated Aging Parameters to Simulate Service Aging of Raychem-Flamtrol Cables

D - Bases for Acceptance of the Raychem Cable Through Performance of the Demonstration Program Outline, With Comments on IEEE STD 383-1974 Section 2.4.4

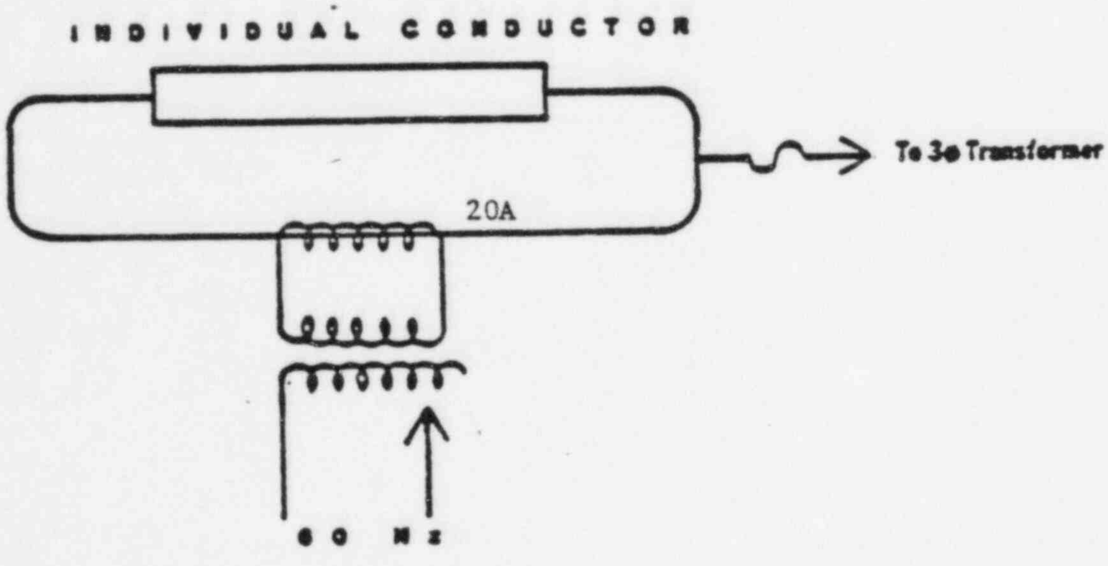


TIME	TEMPERATURE (F)	PRESSURE (PSIG)
0 to 10 s	200 ramps to 340	17 ramps to 56
10 s to 1.25 h	steady at 340	steady at 56
at 1.25 h	steady at 340	56 steps to 35
1.25 h to 2.8 h	steady at 340	steady at 35
2.8 h to 6.9 h	340 ramps to 250	steady at 35
6.9 h to 8.3 h	steady at 250	steady at 35
at 8.3 h	steady at 250	35 steps to 25
8.3 h to 25 h	steady at 250	steady at 25
at 25 h	250 steps to 200	steady at 25
25 h to 17 d	steady at 200	25 ramps to 34
17 d to 33 d	steady at 200	steady at 34

Figure 1



CONDUCTOR DETAIL



TEST ENERGIZATION CIRCUIT (TYPICAL)

Figure 2

APPENDIX A

CAROLINA POWER & LIGHT COMPANY
BRUNSWICK STEAM ELECTRIC PLANT - UNITS 1 & 2
DEMONSTRATION OF RAYCHEM CABLE FOR USE IN CLASS 1E SERVICE
WITH REFERENCE TO IEEE STD 383-1974

FORWARD

A program outline has been prepared to demonstrate the capability of the Raychem cable installed in the Brunswick Plant to perform its function through the harsh environment of a design basis event. The program has been developed with guidance from IEEE Std 383-1974, modified as applicable for the plant specific environment at Brunswick. The sections of IEEE Std 383-1974 as they apply to this program are defined as follows, following the format of the standard.

1. General Provisions

1.1 Scope: Applicable as noted herein. The cable is installed in the Brunswick Plant for Class 1E application in primary and secondary containment.

1.2 Definitions: Applicable. Cable type for testing is representative of the installed cable and justification for selection of the test specimens is provided in Raychem report, "Selection of Test Samples for Adverse Environmental Testing Brunswick Steam Electric Plant", dated February 1983, which forms a part of the documentation for this program. Other definitions as given in this section are satisfied as they apply to this program. The profile for the design basis event is in accordance with the concepts in IEEE Std 323-1974.

1.3 Type Tests As Qualification Method: Applicable, with the exception that performance under normal conditions is not at issue and is not a part of this program.

1.3.1 Cable Description: Applicable. The program outline provides a description of the cable and documentation for selection of the test specimen is provided iin the Raychem Report of February 1983 noted in 1.2.

1.3.2 Field Splice or Connection Description: Not applicable to this program.

1.3.3 Description of Significant Environmental Conditions: Applicable, with the exception that normal operation is not at issue. The cable will be subjected to the environmental conditions postulated for primary and secondary containments during a design basis event. The Mechanical (section 1.3.3.4) and Fire (section 1.3.3.5) conditions are not at issue and are not part of this program.

1.3.4 Operating Requirements

1.3.4.1 Meeting Service Conditions: The cable has been shown to meet normal service conditions and is not at issue for this program.

1.3.4.2 Design Basis Event Conditions for Qualifying Cable: This program has been developed to demonstrate the capability of the cable to perform its function throughout a Loss of Coolant Accident (LOCA). This will be satisfied by the cable exhibiting no electrical breakdown when energized at 600 volts AC and 20 amperes, throughout exposure to the harsh environment of a LOCA in primary containment. These levels are based upon providing margin in the test program over maximum operating conditions this cable experiences in service at Brunswick. The maximum service conditions at the plant for this cable are 480 volts AC ± 10%. (528 volts AC max.) and 12 amperes. Compliance with this criterion for the primary containment will also demonstrate the capability of the cable to perform its function in the less severe environment of secondary containment.

1.3.5 Type Test Conditions and Sequences

1.3.5.1 General: Applicable. This program will demonstrate the capability of the cable to function under the conditions of a design basis event.

1.3.5.2 Aging: Applicable. The specimens will be irradiated to the levels of exposure for the operating conditions in the plant to a total integrated dose to include the design basis event. Additionally, the specimens will be aged to current life and the 40 year life of the plant using standard and accepted Arrhenius techniques. The method is described in Raychem Report, "Method of Determining Accelerated Aging Parameters to Simulate Service Aging of Raychem Cables Installed at Brunswick Steam Electric Plant" (Revision A), dated February 1983. This report forms a part of the documentation for this program.

1.3.5.3 Test Design Basis Event: Applicable, except that the specimens will be aged to present life (8 years) and end of life (40 years). Test conditions will simulate environmental extremes including margin for temperature and pressure thru the initial transient and margin in the duration of the test (33 days).

1.4 Documentation: Applicable. Documentation will be provided including cable description, program outline, test results and evaluation.

1.5 Modifications: Not applicable to this program.

2. EXAMPLES OF TYPE TESTS

2.1 Introduction: Applicable. This program will demonstrate that the cable is qualified to perform its function at the Brunswick Plant. The levels (600 volts AC and 20 amperes) to which the cable will be energized while under test, provide margin over the maximum conditions of operation for the cable installed in the plant. The environmental conditions for the test cover the envelope with margin for the postulated LOCA. Where applicable, previous tests will be referenced in the documentation.

2.2 Type Test Samples: Applicable for the tests to be performed.

2.3 Testing to Qualify for Normal Operation: The capability for this cable to perform under normal operations has been demonstrated and is not at issue for this program. This section and subsections are, therefore, not applicable.

2.4 Testing for Operation During Design Basis Event:

2.4.1 General: The objective of this program is to demonstrate that Raychem-Flamtrol unshielded, jacketed cables having combined conductor insulation and jacket wall thickness equal to or greater than .120 inches is qualified for service as installed in the Brunswick Plant. This program will qualify this cable for Class 1E service inside primary containment, and secondary containment boundaries under a LOCA or High Energy Line Break (HELB) condition specific to the Brunswick Plant. The program outline, "Demonstration of Raychem Cable for Use in Class 1E Service" has been prepared to describe the details of the program and forms a part of the required documentation.

2.4.2 Radiation Exposure: Applicable. The cable samples will be irradiated to levels of exposure equivalent to present life (8 years), and end of life (40 years), to a total integrated dose to include exposure to the LOCA or HELB.

2.4.3 LOCA Simulation: Applicable. The cable samples will be operated under the maximum voltage and ampere load for plant service conditions, plus margin, while exposed to the harsh environment profile of the LOCA. The capability of the cable to satisfactorily perform under rated voltage and current throughout these conditions will demonstrate that the cable is qualified for its function at Brunswick.

2.4.4 Post LOCA Simulation Test: Not Applicable. The criteria for acceptance will be demonstrated by the ability of the cable to function under rated voltage and current throughout the harsh environmental exposure of a LOCA as described in section 2.4.3. The justification for the acceptance criteria is delineated in the statement entitled, "Criteria fcr Acceptance with Comments on IEEE Std 383-1974, Section 2.4.4", which forms a part of the documentation for this test program.

2.5 Flame Tests - Not applicable for this test program. The ability of this cable to resist fire has been previously demonstrated and satisfied and is not at issue in this test program. Reference for Flame Tests may be found in report titled, "Raychem-Flamtrol Qualification to IEEE Std 383-1974".

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APPENDIX B

SELECTION OF TEST SAMPLES

FOR ADVERSE ENVIRONMENT TESTING

BRUNSWICK STEAM ELECTRIC PLANT

February, 1983

Raychem Corporation
300 Constitution Drive

SELECTION OF TEST SAMPLES

FOR ADVERSE ENVIRONMENT TESTING

BRUNSWICK STEAM ELECTRIC PLANT

Cable samples to be used in adverse environment testing will be taken from the inventory of unused cable available at BSEP. Constructions on hand include 7-, 10- and 12-conductor unshielded, jacketed cable. For reasons described below, testing of the 7-conductor construction will yield results that are applicable to the other constructions.

The conditions necessary for space charge effects to occur during jacket irradiation of unshielded jacketed cables with a high-energy electron beam are not dependent on the number of conductors in the cable. If the electrons cannot penetrate the jacket and component insulation walls so that a highly ionized path to at least one grounded conductor is formed, space charge will develop and the phenomenon will occur.

In a 7-conductor cable, six component wires are helically wrapped around a center component wire to form a full and uniform outer layer, as shown in Figure 1. This regular configuration ensures that each component wire in the outer layer is in intimate contact with three other component wires and with the inner surface of the jacket. Therefore, among the constructions available, the 7-conductor configuration presents a geometrical arrangement with the greatest potential for space charge effects to occur in a way that reduces the distances between affected components to a minimum, which results in a worst case situation from an electrical breakdown point of view.

If the required adverse environment testing is performed on 7-conductor cables which have been shown by pre-test inspection to contain components affected by space charge, the conclusions drawn from such testing will be applicable to 10- and 12-conductor cables as well. If the affected components in a 7-conductor cable perform their intended function during adverse environment testing, there is no reason to believe that a 10- or 12-conductor cable would not yield the same result.

For the following reasons, it is more practical to test the 7-conductor configuration:

(a) It has the smallest outside diameter (.765 inch max) which permits the use of a 30-inch diameter (40X) mandrel, whereas the 10- and 12-conductor cables would require 39- and 40-inch diameter mandrels respectively. The larger diameter mandrels are more difficult to handle and require larger ovens and pressure vessels for testing. At Wylie Norco, a 42-inch diameter pressure vessel is available which can accomodate a 30-inch diameter mandrel with specimens mounted (approximately 32-inch diameter overall), but could not accomodate the larger mandrels. Their next larger vessel is 72 inches in diameter and has a volume too large to permit the required supersaturated steam conditions to be maintained in accordance with the proposed LOCA profile.

(b) Pressure vessel penetrations are much more complicated and require more space as the number of conductors is increased.

(c) The amount of instrumentation and auxilary electrical equipment required increases as the number of conductors is increased.

(d) If it was necessary to test 10- or 12-conductor cables, dealing with the disadvantages mentioned in (a), (b) and (c) above would increase the cost and, perhaps, delay the start of testing.

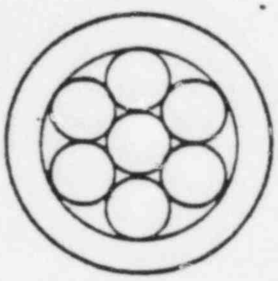

Figure 1. 7-Conductor cable.

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APPENDIX C

METHOD OF DETERMINING ACCELERATED AGING PARAMETERS TO SIMULATE SERVICE AGING OF RAYCHEM-FLAMTROL™ CABLES INSTALLED AT BRUNSWICK STEAM ELECTRIC PLANT

Revision A

February 1983

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INTRODUCTION

Certain qualification test procedures are intended to determine if components will perform satisfactorily during transient adverse environmental conditions that may occur at any time during the design life of the component. To satisfy such test requirements, it is necessary to pre-condition some of the test specimens in a way that produces degradation equivalent to that which would occur over the service period of interest. To accomplish such pre-conditioning in a reasonable time, accelerated aging techniques are used where specimens are aged at a temperature above the applicable service temperature for a relatively short period.[1] The purpose of this discussion is to describe the analysis used to determine the appropriate accelerated aging condition (time and temperature) for simulating thermal aging of Raychem-Flamtrol™ cables at 66°C for 8 years and 40 years.

GENERAL BACKGROUND

In accordance with chemical reaction rate theory, the relationship between time to failure (L), as defined by a specified test end point, and absolute exposure temperature (K) is given by the Arrhenius equation: $\log(L) = A - BE(1/K)$, where A and B are constants and E is the activation energy of the rate controlling mechanism. Therefore, a typical plot of thermal aging data, where logarithmic average life is plotted against the reciprocal absolute temperature, results in a straight line, as shown in Figure 1, over the temperature range where E is constant. Because B, which is the reciprocal of the gas constant, is the same for all materials, the slope of the thermal life curve is determined by E, the activation energy. Therefore, in the temperature range where the straight line relationship is applicable (constant slope), the activation energy is constant, so each point on the curve represents a condition (time and temperature) which results in the same degree of degradation. In Figure 2, for example, the effect of thermal aging over a period L_1 at a temperature

GENERAL BACKGROUND (Cont'd)

T_1 can be duplicated by aging for a much shorter period L_2 at a higher temperature T_2.

In the present case, it is necessary to determine the accelerated aging conditions that will produce the same degree of degradation that will be caused by thermal aging at service temperature for prescribed periods. In Figure 3, the point (L_3, T_3) represents the service aging condition, which lies below the thermal life curve. This means that the component will not have reached end of life, as defined above, during its service life L_3 at a temperature T_3. To simulate the amount of thermal degradation that it would experience during its service life, an accelerated aging test can be performed at condition (L_4, T_4) which lies on a straight line parallel to the thermal life curve and passing through the point (L_3, T_3), as shown in Figure 4. This process is merely an application of the Arrhenius equation, keeping activation energy constant, but defining the end point as the amount of thermal degradation occurring in service (L_3, T_3) rather than the end of life criterion used in developing the thermal life curve. Although any point on the service aging curve can be used in selecting the accelerated aging test parameters, some standards require that the temperature be chosen so as to make the aging time no less than 100 hours.[2]

DETAILED ANALYSIS

The following analysis was used to determine the appropriate aging temperature to be used in a 100-hour accelerated aging period to simulate service aging at 66°C for 8 and 40 years respectively. It consists of applying the procedure described above to the actual thermal life data for Raychem-Flamtrol.[3] The applicable portion of the Arrhenius plot is shown in Figure 5.*

The coordinates of points A and B in Figure 5 were determined by a regression line analysis of the thermal aging data. Point C represents the service condition of 40 years at 66°C. The service aging curve passes through point C and is parallel to the thermal life curve. The point at which the service aging curve intersects the 100-hour line represents the aging temperature required to produce the same degree of thermal degradation in 100 hours that would occur in 40 years at a service temperature of 66°C. It can be seen that the required temperature is about 140°C.

It is more rigorous to calculate the temperature by applying analytical geometry to the following known information:

	Point A	Point B	Point C	Point D
time	215 days	1850 days	40 years	100 hours
temperature	150°C	127°C	66°C	—

Converting time to hours and degrees Celsius to Kelvin, gives

	Point A	Point B	Point C	Point D
log (hrs)	3.713	4.647	5.545	2.000
$10^5/K$	236	250	295	x

**At temperatures higher than 150°C, the rate controlling mechanism is oxygen diffusion, rather than thermal oxidation, and the slope of the curve changes to reflect the lower activation energy of the diffusion process. However, this phenomenon does not enter into the present analysis.*

Therefore, the slope, m, of the thermal life curve, which passes through A and B, is given by

$$m = \frac{3.713 - 4.647}{236 - 250} = .0667$$

Because the service life curve, which passes through the points C and D, must have the same slope, it follows that

$$.0667 = \frac{5.545 - 2.000}{295 - X}$$

and

$$X = 241.85$$

Substituting $10^5/K$ for X, and solving for K gives

$$10^5/K = 241.85$$
$$K = 413.4$$
$$^oC = K - 273 = 140.4$$

Therefore, the appropriate accelerated aging condition corresponding to 40 years at 66°C is 100 hours at 140°C.

A similar calculation to determine the appropriate temperature required to simulate 8 years at 66°C yields

$$.0667 = \frac{4.846 - 2.000}{295 - X}$$

where 4.846 is the log (hrs) corresponding to 8 years. Solving for X gives

DETAILED ANALYSIS (Cont'd)

$$X = 252.3$$

$$10^5/K = 252.3$$

$$K = 396.4$$

$$^{\circ}C = 123.4$$

so the appropriate accelerated aging condition is 100 hours at 123°C.

REFERENCES

1. IEEE Std 383-1974, IEEE Standard for Type Test of Class 1E Electric Cables, Field Splices and Connections for Nuclear Power Generating Stations.

2. IEE Std 323-1974, IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations.

3. Raychem-Flamtrol Thermal Aging Study, Final Report, Raychem Laboratory Report No. 5160, April 1980.

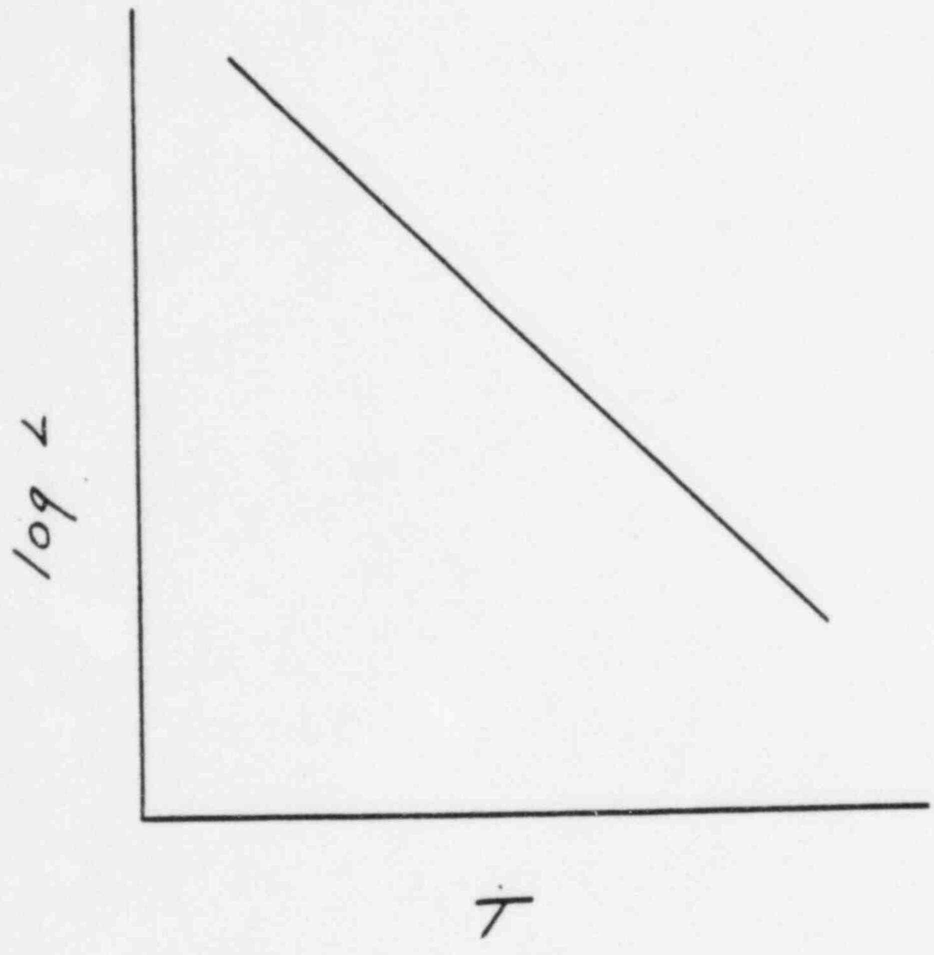

Figure 1. Model Arrhenius plot. Logarithmic average life vs. temperature. (Inverse, absolute, reciprocal seale)

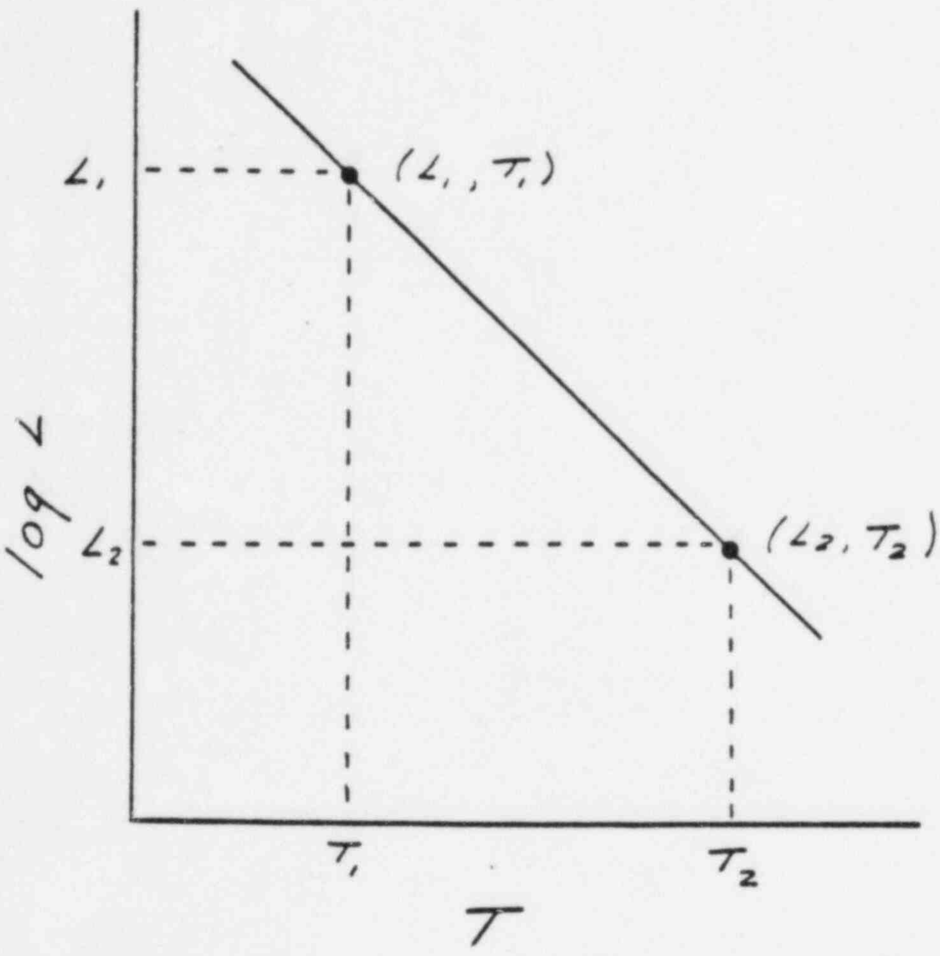

Figure 2. Model Arrhenius plot. Aging conditions (L_1, T_1) and (L_2, T_2) produce the same degree of thermal degradation.

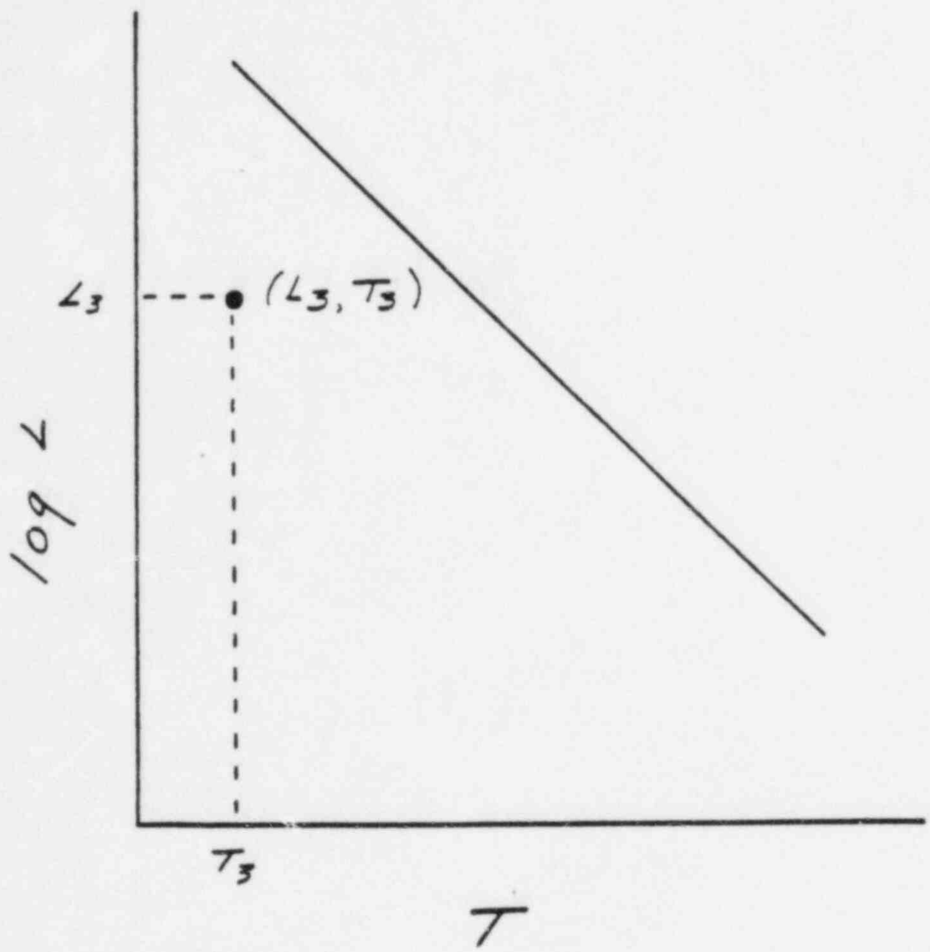

Figure 3. Model Arrhenius plot. Point (L_3, T_3) represents service aging condition.

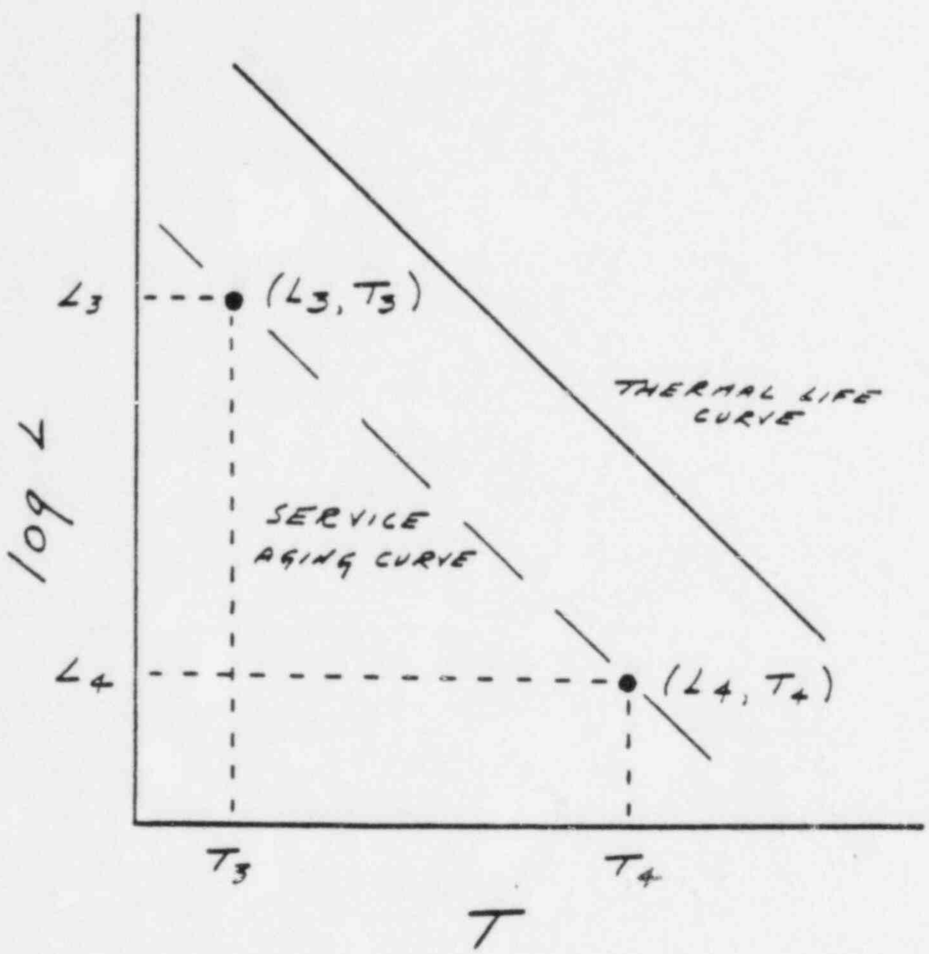

Figure 4. Accelerated aging condition (L_4, T_4) lies on service aging curve which is drawn through service aging condition (L_3, T_3) and parallel to thermal life curve.

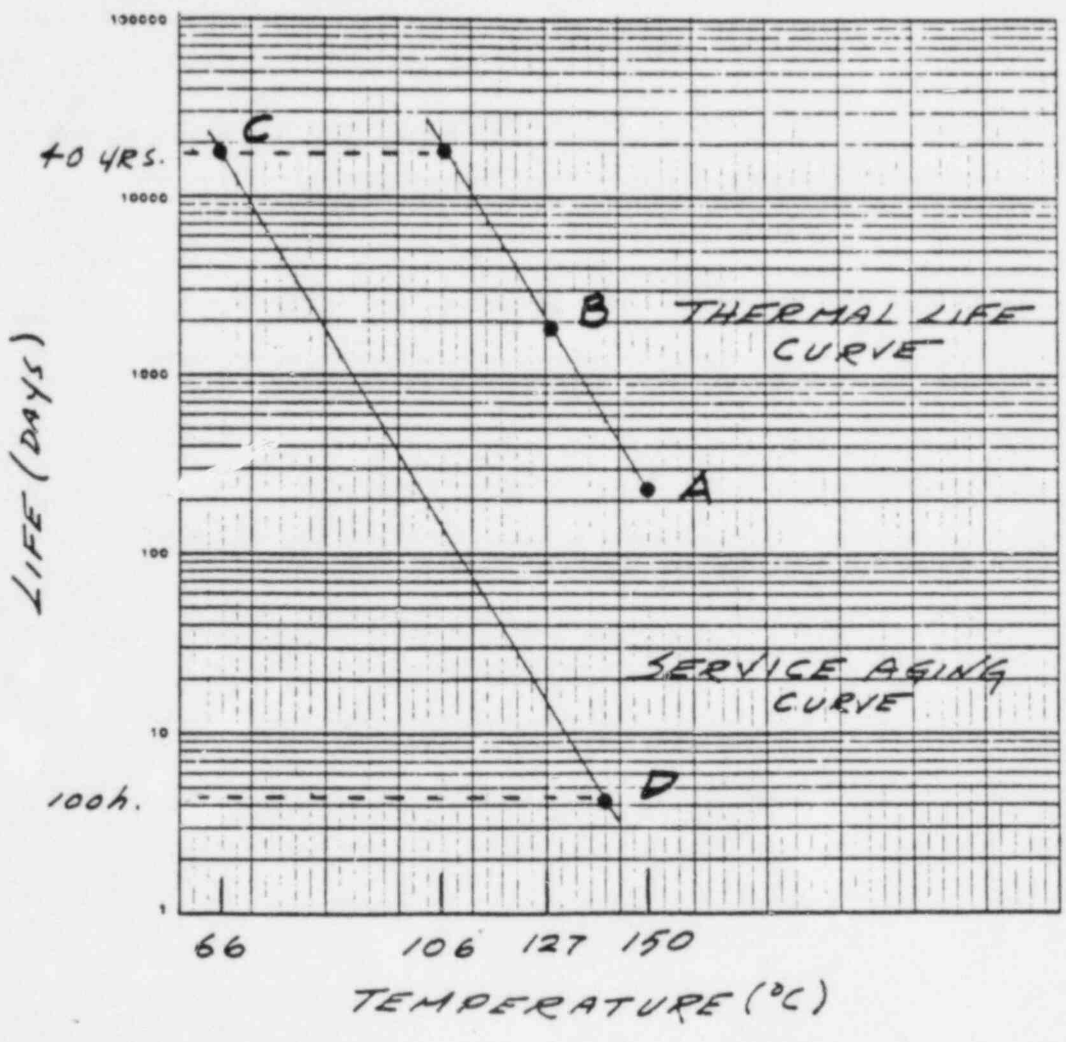

Figure 5. Accelerated aging condition (Point D) to simulate service aging at 66°C for 40 years (Point C) based on thermal life curve for Raychem-Flamtrol (E = 31.4 kcal/mole).

APPENDIX D

BASIS FOR ACCEPTANCE WITH COMMENTS ON IEEE STD 383-1974 SECTION 2.4.4

The primary objective of this program is to assure and demonstrate that the affected Raychem cable installed in the Brunswick plant will perform its function throughout the harsh environment of a LOCA. This program is based upon accepted concepts for equipment qualification and will demonstrate the capability of this cable to perform the function of sustaining plant operating voltage and current throughout the LOCA.

The cables in the plant are installed in trays, raceways, and conduit and as such, mechanical durability is not an issue. Therefore, the key factors in this test program to assure a realistic and meaningful test of this cable are:

1. Aging and radiation exposure of test specimens to the current life and a 40 year expected life of the plant.

2. Physical configuration of specimens simulating the possible extremes could be found in the plant i.e., jacket intact and jacket open exposing the primary insulation of the 7 individual conductors.

3. Conservatism in the operating parameters to demonstrate the capability of the cable to perform its function. The cable will be energized throughout the test at 600 volts AC and 20 amperes. This provides margin for voltage and current.

4. Conservatism in duration by extending the event through 33 days and with a margin in the temperature and pressure profile through the initial transient in accordance with IEEE Std. 323-1974.

It is significant to note that this cable has been subjected to standard production (voltage withstand/acceptance) testing by Raychem before delivery to the site. Additionally, Franklin Institute Research Laboratory conducted a series of electrical tests (reference Report F-C4408) on cables after delivery to the site. These tests included 5.5KV AC voltage tests, insulation resistance measurements at 500VDC and 16.5KV DC voltage tests after the cables were immersed in water for a minimum of 24 hours. Voltage levels were applied and held for 5 minutes with satisfactory results.

The Post LOCA Simulation Test described in IEEE Std 383-1974, Section 2.4.4, introduces mechanical stress and conditions which are not a practical representation of the environment in which the cable will function. The straightening and then recoiling of the cable and handling could introduce mechanical degradation which cannot occur in service. Additionally, the subjecting of the cable to a voltage gradient seven times greater than that which it will experience in performing its function, and repeating this stress for each conductor, introduces conditions into this program which are not indicative of plant conditions. This repeated stressing could cause an electrical breakdown to occur which would not occur in service.

The capability of the cable to perform its design function will be fully demonstrated by successful completion of the program as described.

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