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May 26, 1982

Director, Office of Nuclear Reactor Regulation
Attention: D. M. Crutchfield, Chief
Operating Reactors Branch No. 5
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Gentlemen:

Subject: Docket No. 50-206
SEP Topic VIII-4
San Onofre Nuclear Generating Station
Unit 1

By letter dated June 30, 1981, you requested that we review and evaluate the penetrations identified in previous correspondence on this subject topic. Our evaluation is provided as an enclosure to this letter. Subsequent to your June 30, 1981 request, you transmitted to us by letter dated December 31, 1981 your contractor's final Technical Evaluation and the staff's final Safety Evaluation Report regarding this subject topic. Also included below is a discussion of our review of both evaluations.

Our evaluation of the penetrations included the low voltage penetration, the medium voltage penetration and the dc power penetration which have been identified in previous correspondence on this topic. The evaluation consisted of analyzing the penetrations in accordance with current state-of-the-art criteria to withstand a LOCA, a short circuit and failure of the primary fault clearing device without loss of containment integrity through the penetration. The results of the evaluation indicate that the medium voltage penetration is capable of withstanding the postulated event without the penetration seal temperature being exceeded. The low voltage and dc power penetration seal temperatures are exceeded. Exceeding the penetration seal temperature could result in failure of the penetration seal and the failure of containment integrity; however, it is pointed out that the loss of containment integrity would require the failure of both penetration seals. The seal inside containment is at a higher initial temperature due to the LOCA, whereas, the seal located outside containment is at a lower temperature. Therefore, failure of the seal outside containment would probably occur at some time following the failure of the seal inside containment.

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Based on our review of the Technical Evaluation and the Safety Evaluation Report, the conclusions contained therein are consistent with the results of our evaluation. However, it is noted that the Technical Evaluation utilized the peak LOCA temperature as the initial temperature of the penetration seals and as pointed out in our evaluation, a containment structural temperature was utilized. This temperature is considered to be more appropriate than the peak LOCA vapor temperature. Your letter dated December 31, 1981 indicates that the penetrations do not meet current licensing criteria. Based on NRC staff recommendations, the need to implement changes in the design of the electrical penetrations protection will be determined during the integrated safety assessment.

If you have any questions regarding this matter, please let me know.

Very truly yours,

R W Krieger

R. W. Krieger
Supervising Engineer
San Onofre Unit 1 Licensing

Enclosure

RESPONSE TO NRC INQUIRY CONCERNING
THE ADEQUACY OF ELECTRICAL PENETRATIONS
SAN ONOFRE NUCLEAR GENERATING STATION UNIT 1

March 25, 1982

1. INTRODUCTION

As requested by the NRC's letter dated June 30, 1981 regarding SEP Topic VIII-4, this report has been prepared to describe the methodology used in the evaluation of the electrical penetrations at the San Onofre Nuclear Generating Station Unit 1.

As done in previous NRC's technical evaluations the following three circuits were considered:

A. Low Voltage Penetration (No. WPC-23)

Manufacturer: Amphenol

Circuit: 480-V AC Residual Heat Removal Pump B Motor

B. Medium Voltage Penetration (Nos. JB1A0 and JB2A0)

Manufacturer: L & F Machine Company

Circuit: 4160-V AC Reactor Coolant Pump A Motor

C. Direct Current Power Penetration (No. EPC-6)

Manufacturer: Viking

Circuit: Emergency Thermal Cooling Pump Motor

The purpose of this evaluation is to assess the compliance of the electrical penetrations in the containment structure with IEEE Standard 317-1976, as augmented by Regulatory Guide 1.63, in particular Section 6.4.14 as shown in Appendix A.

These paragraphs specify that tests should verify that during the maximum design basis event Loss of Coolant Accident (LOCA), the penetrations should maintain containment integrity under rated short circuit current with the failure of the primary overcurrent protection. Containment integrity will be maintained as long as the limit temperature of the penetration seals is not exceeded, even if electrical integrity has been lost following damage of the conductor insulation.

Therefore to evaluate each of the three penetrations it should be verified that the backup protection can interrupt the short circuit current, under the above conditions, before the limit temperature of the seals is reached.

With the objective of obtaining a more realistic and more systematic evaluation, this report presents the results of the evaluation including a general overview and the major assumptions. The report then gives the Conclusions and includes the detailed description of the methodology.

2. RESULTS

A. General Overview

The tests required by IEEE Standard 317-1976 to verify the compliance of the penetrations at San Onofre Unit 1 have not been conducted. In the absence of these tests, the evaluation of the three penetrations was based on an analysis using reasonable assumptions and available documented test data.

The analysis was conducted as follows:

The time t required for the penetration seals to reach their limit temperature T_2, was calculated when the selected circuit of the penetration is subjected to the rated short circuit current, assuming an initial temperature T_1. The protection total fault clearing time was then determined to verify that the short circuit current is interrupted within that time t.

B. Major Assumptions

The initial temperature T_1 of the seals is assumed to be 260°F, based on information provided to the NRC as part of the Containment Post Accident Pressure Reanalysis (SCE letter to NRC dated January 17, 1977).

The most critical assumption is the limit temperature T_2 of the penetration seal.

For the "Amphenol" and "Viking" penetrations, only continuous limits were available based on documented manufacturer's specifications or test data.

However, more realistic "short time temperature limits", higher than the continuous temperature limits should be used in this analysis since:

1. The continuous temperature limits of the penetrations provided by the manufacturer are the temperature limits of the insulation to maintain electrical integrity. Since only mechanical integrity of the containment has to be preserved, the temperature limits should be the higher temperature limits of the seal material.

2. The temperature limits of the seal material provided by the manufacturer are for continuous operation. Higher values can reasonably be used because the duration of the short circuit is at most a few cycles with operation of the primary protection, or a few seconds if the primary protection fails and the backup protection operates.

C. Evaluation Results

The following Table provides the results of the evaluation:

SAN ONOFRE UNIT 1 ELECTRICAL PENETRATIONS
INTERRUPTION OF SHORT CIRCUIT CURRENT UNDER LOCA

Penetration (Selected Circuit)	Limit Temperature of Seal T_2: Duration	Limit Temperature of Seal T_2: T_2(°C)	Time t to reach T_2 (Second)	Protection Total Fault Clearing Time (Second): Primary	Protection Total Fault Clearing Time (Second): Backup
Amphenol 480-V AC (Residual Heat Removal Pump B)	6 hours	179 (1)	0.25	0.03	1.10
L & F Machine 4.16 kV AC (Reactor Coolant Pump A	Short Time	450 (2)	10.96	0.13	1.00 (3) 0.45 (4)
Viking 125 V DC (Emergency Thermal Cooling Pump)	Continuous	149 (2)	0.38	0.03	17

NOTES:

1. Based on Documented Tests (Electrical Integrity)
2. Based on Manufacturer Specifications
3. Normal operation (circuit connected to bus 1A)
4. Cold startup operation (circuit connected to bus 1C)

Referring to the above Table the following evaluation can be made.

Under Loss of Coolant Accident (LOCA):

A. The penetrations are adequate for continuous rated current.

B. The penetrations can withstand a bolted three phase short circuit and maintain electrical integrity if the fault current is interrupted by the primary protection.

C. If, following a bolted three-phase short circuit, the primary protection fails, the performance of the penetrations is as follows:

1. The "Amphenol" penetration seal limit temperature of 355°F or 179°C is reached at 0.25 sec. The backup protection interrupts the fault at 1.10 sec.

2. The "L & F Machine" penetration will maintain mechanical integrity of the containment with the limit temperature of 450°C with a comfortable margin. The backup protection interrupts the fault within 1.0 sec. or 0.45 sec., compared to the 10.96 sec. it would take the seal temperature to reach 450°C.

3. The "Viking" penetration seal limit temperature will be reached. With a total backup protection clearing time of 17 sec., the limit temperature of penetration seals would be exceeded at 0.38 sec. with the assumed limit temperature of 149°C (300°F).

In order for the containment integrity to be violated, the Amphenol and Viking penetrations mechanical integrity must fail. This would involve failure of both the penetrations inboard and outboard seals. It is pointed out that the outbourd seal is at lower initial temperature outside containment than the inboard seal and therefore failure would occur in a longer period of time.

Also, for the "Viking" penetration, the long back up protection of 17 seconds may result in fusing the conductors, and therefore, interrupt the short circuit current before the seal is jeopardized.

3. CONCLUSIONS

The penetrations do not comply with IEEE Standard 317-1976:

First, because the required tests have not been conducted, the evaluation was based only on an analysis using reasonable and conservative assumptions:

Second, the analysis shows, that under the simultaneous occurence of LOCA, three-phase bolted short circuit current and failure of the primary protection, only the "L&F Machine" penetration seal limit temperature will not be reached and would maintain mechanical integrity. The "Amphenol" and "Viking" penetrations seal limit temperature would be reached. Although the limit temperature of their inboard seals may be exceeded, their outboard seals, exposed to a lower temperature, may maintain mechanical integrity.

These penetrations are being evaluated as part of the ongoing equipment qualification program at San Onofre Unit 1.

4. DETAILED METHODOLOGY

For each penetration the following methodology was used:

A. Outline

Following a short circuit on the selected circuit at the penetration, during a LOCA condition, with an initial temperature T_1, the time t required for the penetration seals to reach their limit temperature T_2

is calculated. The protection total fault clearing time is then determined to verify that the short circuit current is interrupted within that time t.

B. Assumptions

B.1 Initial Temperature T_1 - LOCA Conditions

The initial temperature T_1 of the seal, prior to the short circuit is assumed to be equal to the surface temperature of the containment structure. Although the exact value can only be known with a thermal simulation of the complete penetration, this assumption is made because it is estimated that within the penetration there is a balance between the heat generated in the cables prior to the short circuit, and the heat lost through the penetration toward the outside of the penetration (heat sink).

The surface temperature of the containment structure under LOCA conditions is assumed to be approximately 260°F for 24 hours, as shown by Case II in attached Figure 1 obtained from the Containment Post Accident Reanalysis transmitted by SCE letter to NRC, dated January 17, 1977. This temperature is lower than the temperature of the containment vapor as shown by attached Figure 2 which was previously assumed.

B.2 Limit Temperature T_2 of Penetration Seals

Continuous Limit Temperatures

The continuous temperature limits of the penetrations are indicated below:

"Amphenol" penetrations, which have a EPR (ethylene propylene rubber) seal material, were tested by the manufacturer in 1977 to withstand 355°F (179°C) for 6 hours, while maintaining electrical integrity. A higher rating of 400°F (204°C) for one hour has been indicated by the manufacturer, but the reference in which it is documented is not available. The use of this higher rating has a negligible impact on the time t required to reach this temperature. t will be increased from 0.25 seconds to 0.35 seconds.

The "L & F Machine Penetrations" have seals consisting of glass bushings guaranteed to withstand temperatures of up to 450°C as indicated by General Electric Publication GET-3363.

The Viking Penetrations were reported to have seal material (Butyl Rubber) with a continuous rating of 300°F (149°C) as indicated in Wyle Laboratories Engineering Report dated October 29, 1980. (Qualification Assessment Analysis of Viking Penetrations for San Onofre Unit 1.)

These temperatures would not be exceeded by the post-LOCA containment structural temperature of 260°F or the peak vapor temperature of 291°F.

"Short Term" Limit Temperatures

A documented "short time" limit temperature of 450°C is available only for the "L & F Machine" penetrations as indicated by General Electric Publication GET-3363.

C. Time versus Temperature Calculations

The time t for the penetration seal temperature to increase from the initial temperature T_1 = 260°F = 126.7°C, to the limit temperature T_2 was determined by using the following formula:

$$t = \frac{A^2}{I^2} (.0297) \log_{10} \frac{T_2 + 234}{T_1 + 234}$$

With: I = Short Circuit Current (Amperes)
A = Conductor Area (Circular Mils)
t = Time of short circuit (second)
T_1 = Initial temperature = 126.7°C
T_2 = Penetration Seal Limit Temperature

This formula was published by IPCEA in Publication P-32-382 for insulated copper conductor cables. T_1 and T_2 are conductor temperature. It is assumed here that the conductor temperature is the same as the penetration seal temperature.

Discussion

a. This formula, derived for insulated copper conductors under conservative assumptions, is only an approximation for electrical penetrations. Quoting the Publication P-32-382, "The formula is based on the heat content of the conductor material and the temperature limit of the insulation with the assumption that the time is so short that the heat developed during short circuit is contained in the conductor."

Therefore, this formula is conservative, especially when it is used for long short circuit durations. As remarked in IEEE Paper 31 TP-67-179 by R. C. Mildner, C. B. Arends, and P. C. Woodland, the heat dissipation outside the conductor cannot be neglected.

b. For the ac circuits (480-V and 4.16 kV), because of the fast decrement of the short circuit dc component, the short circuit current I asymmetrical value should be replaced with the symmetrical value if the time t exceed 8 cycles (0.133 sec.).

Since:

(Asymmetrical Short Circuit Current) = 1.6 x (Symmetrical short circuit current)

This correction is important. For long total fault clearing times of backup protection it results in multiplying the time t previously calculated in NRC audit by $(1.6)^2 = 2.56$.

Values of A and I used for these calculation, as shown in Appendix B, were obtained from the information provided in SCE letter from J. G. Haynes to D. L. Ziemann, of the NRC dated June 15, 1979.

D. Total Fault Clearing Times of Primary and Backup Protection

Using the above information, the total fault clearing times provided by primary and backup protection were determined for the selected circuits of the three penetrations as shown in Appendix B.

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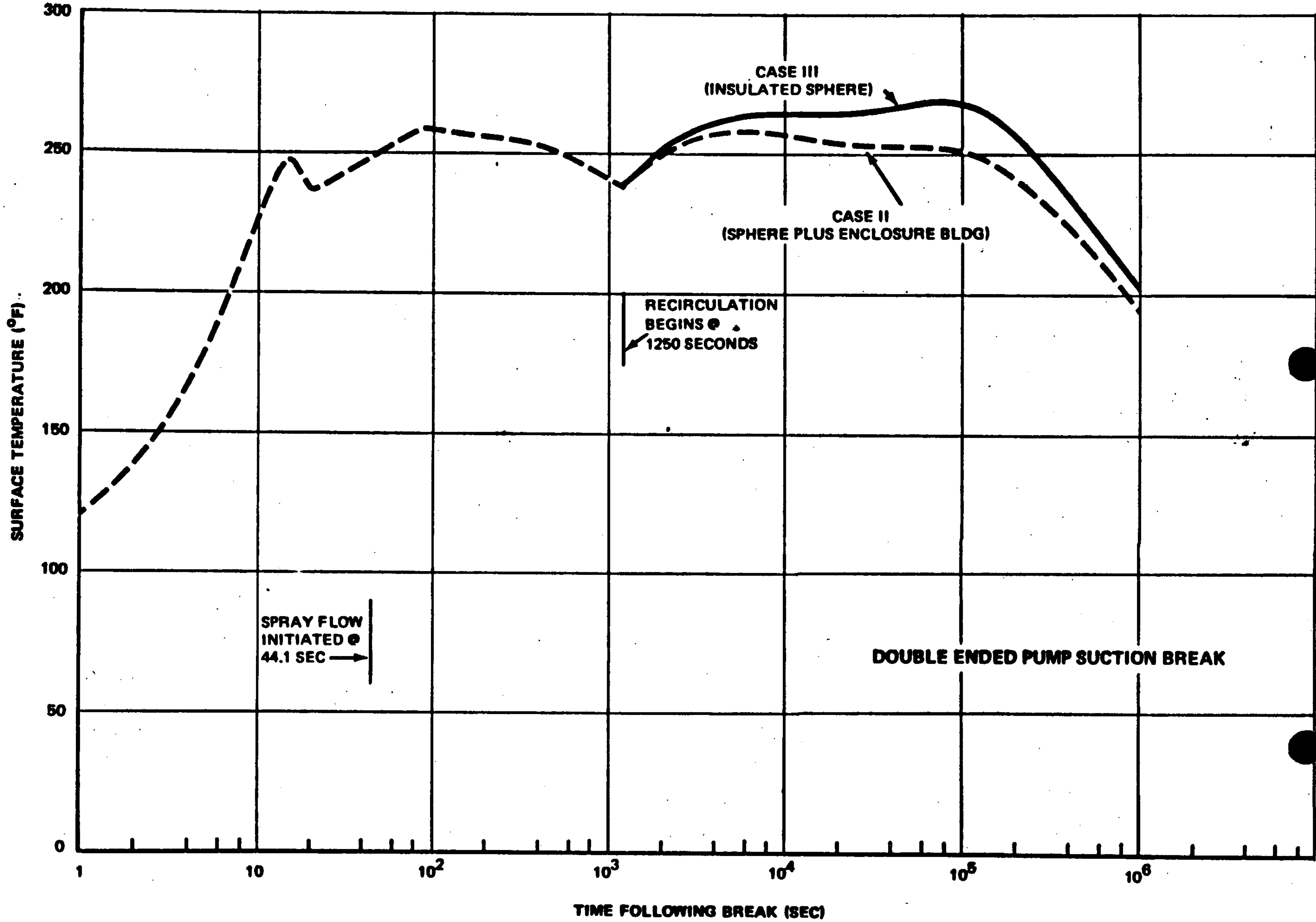

FIGURE 1

STRUCTURE SURFACE TEMPERATURE

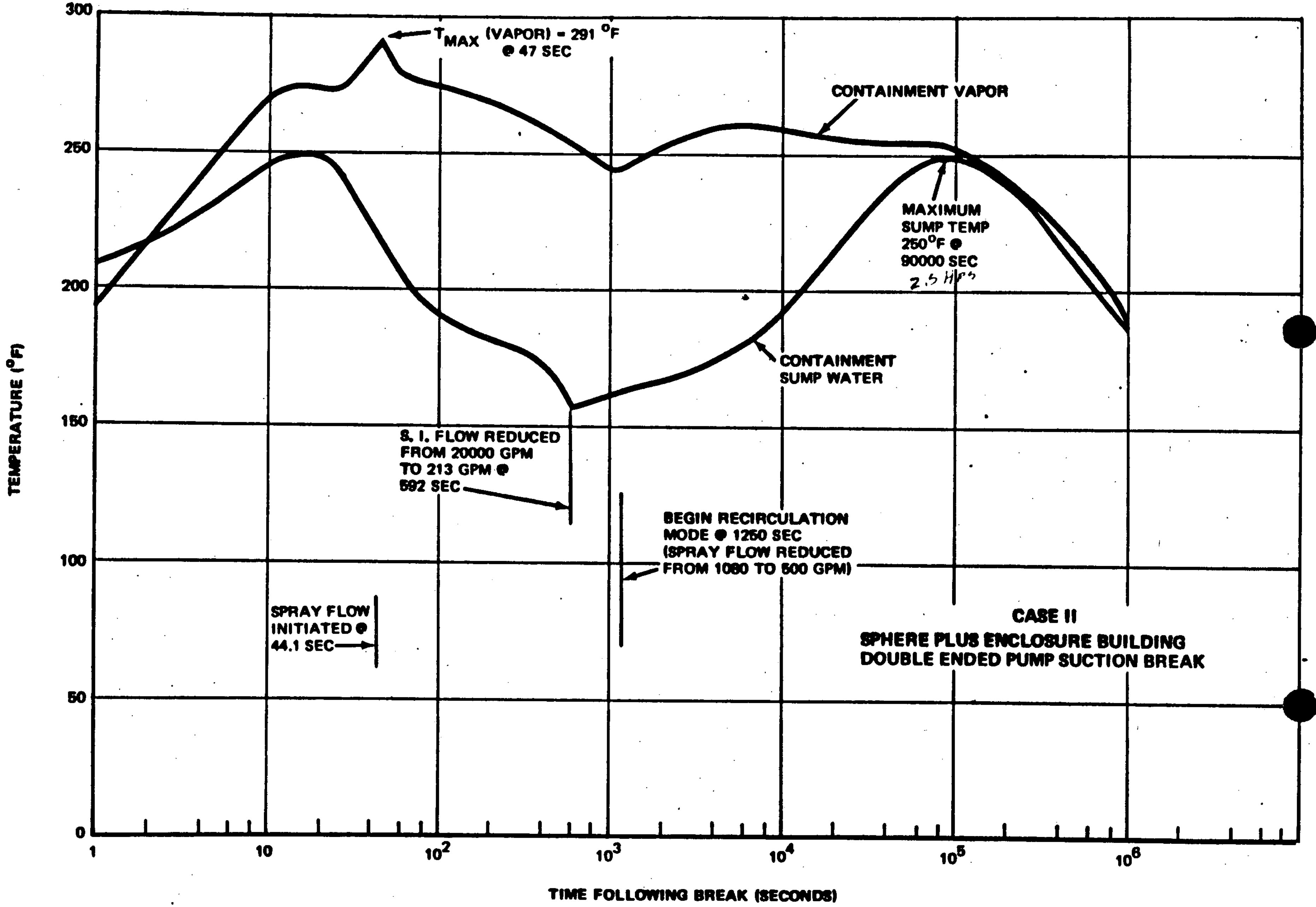

FIGURE 2

CONTAINMENT TEMPERATURE

APPENDIX A

EXCERPTS OF IEEE STANDARD 317-1976

"6.4.14 Rated Maximum Duration of Rated Short Circuit Current Test

The maximum duration of rated short-circuit current shall be verified by test. The test shall be conducted at maximum design basis event: temperature, pressure, and relative humidity. The test current and duration shall be in accordance with Section 4.2.5 plus margin (Rated Current: +5%, Rated Voltage: +10%, Temperture +8°C).

Section 4.2.5:

Rated Maximum Duration of Rated Short Circuit Current shall be the maximum time that the conductors of a circuit can carry rated short circuit current based on the operating time of the backup protective device or appratus, during which the electrical integrity may be lost but for which the penetration assembly shall maintain containment integrity.

The test duration shall be not less than the time required for the backup overcurrent protection device to function."

NRC REGULATORY GUIDE 1.63 - PARAGRAPH C-1

"The electric penetration assembly should be designed to withstand without loss of mechanical integrity the maximum possible fault current versus time conditions that could occur given a single randum failure of circuit overload protection devices."

APPENDIX B

Using the data provided by SCE letter from J. G. Haynes to D. L. Ziemann, NRC dated June 15, 1979:

A. TIME VERSUS TEMPERATURE CALCULATIONS - DATA

	Electrical Penetration		
	Amphenol 480V AC	L & F Machine 4.16 kV AC	Viking 125-V DC
Conductor Size	4/0	2 x 500 MCM	2/0
Conductor Area (CMIL)	211.6×10^3	10^6	133.1×10^3
Short Circuit Current I (Amps)			
Asymmetrical	27,500	43,825	5,953
Symmetrical	17,187	27,391	--

B. PROTECTION TOTAL CLEARING TIMES

B.1 Low voltage penetration - Amphenol
Circuit: 480-V AC Residual Heat Removal Pump B Motor

Primary Protection: 480-V breaker 1222

For I = 27,500 A
Series trip IT = 1,500 A
Instantaneous trip T = 0.03 sec.
From the Breaker Curve.

Backup Protection: 480 V breaker 1202

C09 Relay

CT Ratio 2000/5
Time: 1 sec. at 51 A or for tap value

$$\frac{51}{5} = 10.2$$

From the relay curve Tap Dial Setting: 7

$$I = 17{,}187 \text{ A} \times \frac{5}{2{,}000} \times \frac{1}{5} = 8.6$$

multiple of tap value.

With tap dial setting of 7 the total clearing time is: T = 1.1 sec.

B.2 Medium Voltage Penetration - L & F Machine Company
Circuit: 4.16 kV Reactor Coolant Pump (RCP) Motor

Primary Protection: 4.16 kV Breaker 11A03 Bus 1A

C09 Relay

CT Ratio 800/5
Time: 24 sec. at 18 A or for tap value

$$\frac{18}{5} = 3.6$$

From the relay curve Time dial setting: 6.5

$$I = 43{,}825 \text{ A} \times \frac{5}{300} \times \frac{1}{5} = 54 \text{ multiple}$$

of tap value
Instantaneous trip T = 0.133 sec.

Backup Protection: 4.16 kV Breaker 11A04 Bus 1A (Normal)

C08 Relay

CT Ratio 2000/3.33
Time 1 sec. at 36 A or for tap value

$$\frac{36}{3.33} = 10.8$$

From the relay curve Time dial setting: 4.5

$$I = 27{,}391 \text{ A} \frac{3.33}{2000} \quad \frac{1}{3.33} = 13.7 \text{ multiple}$$

of tap value
With 4.5 dial setting curve the total clearing time is: T = 1.0 sec.

Backup Protection: 4.16 kV Breaker 11C01 Bus 1C (Cold Startup)

C011 Relay

CT Ratio 2000/5
Time 0.5 sec. at 54 A or for tap value

$$\frac{54}{5} = 10.8$$

From the Relay Curve Time dial setting: 7.5

$$I = 27{,}391 \text{ A} \frac{5}{2000} \quad \frac{1}{5} = 13.7 \text{ multiple}$$

of tap value
With 7.5 time dial setting the total clearing times T = 0.45 sec.

B.3 Direct Current Power Penetration - Viking
Circuit: Emergency Thermal Cooling Pump Motor 125-V DC

Primary Protection: 125-V DC Breaker 72-120

100 AF/100 AT molded case breaker
For I = 5,953 A instantaneous trip
Total clearing time T = 0.03 sec.

Backup Protection: 125-V DC Breaker 72-144

Trip Coil 1600 A
Long time trip 1600 A
Instantaneous trip at 8000 A or 500% of rating
Time 20 sec. at 4800 A or 300% of rating
From the corresponding relay curve
Total clearing time to interrupt 5,953 A (372% of rating) T = 17 sec.

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