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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

July 1, 1980

Docket No. 50-29

Mr. James A. Kay
Senior Engineer-Licensing
Yankee Atomic Electric Company
25 Research Drive
Westborough, Massachusetts 01581

Dear Mr. Kay:

RE: SEP TOPIC VIII-4 ELECTRICAL PENETRATIONS OF REACTOR CONTAINMENT (Yankee-Rowe)

Enclosed is a copy of our evaluation of Systematic Evaluation Program Topic VIII-4, Electrical Penetrations of Reactor Containment. This assessment compares your facility, as described in Docket No. 50-29 with the criteria currently used by the regulatory staff for licensing new facilities. Please inform us if your as-built facility differs from the licensing basis assumed in our assessment within 60 days of receipt of this letter.

This evaluation will be a basic input to the integrated safety assessment for your facility unless you identify changes needed to reflect the as-built conditions at your facility. This topic assessment may be revised in the future if your facility design is changed or if NRC criteria relating to this topic are modified before the integrated assessment is completed.

Sincerely,

Dennis M. Crutchfield

Dennis M. Crutchfield, Chief
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Division of Licensing

Enclosure:
Completed SEP
Topic VIII-4

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See next page

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SEP TECHNICAL EVALUATION

TOPIC VIII-4
ELECTRICAL PENETRATIONS OF REACTOR CONTAINMENT

YANKEE ROWE NUCLEAR STATION

Yankee Atomic Electric Company

Docket No. 50-29

DATE: July 1, 1980

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SEP TECHNICAL EVALUATION

TOPIC VIII-4
ELECTRICAL PENETRATIONS OF REACTOR CONTAINMENT

YANKEE ROWE NUCLEAR STATION

1.0 INTRODUCTION

This review is part of the Systematic Evaluation Program (SEP), Topic VIII-4. Yankee Atomic Electric Company (YAEC) has provided information (Reference 1) describing typical penetrations, typical in-containment loads, and fault currents. They did not provide an analysis of their suitability in Reference 1. The objective of this review is to determine the capability of overcurrent devices to prevent exceeding the design rating of the electrical penetrations through the reactor containment during short circuit conditions at LOCA temperatures.

General Design Criterion 50, "Containment Design Basis" of Appendix A, "General Design Criteria for Nuclear Power Plants" to 10 CFR Part 50 requires that penetrations be designed so that the containment structure can, without exceeding the design leakage rate, accommodate the calculated pressure, temperature, and other environmental conditions resulting from any loss-of-coolant accident (LOCA).

IEEE Standard 317, "Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations", as augmented by Regulatory Guide 1.63, provides a basis of electrical penetrations acceptable to the staff.

Specifically, this review will examine the protection of typical electrical penetrations in the containment structure to determine the ability of these protective devices to clear the circuit during a short circuit condition prior to exceeding the containment electrical penetration test or design rating under LOCA temperatures.

2.0 CRITERIA

IEEE Standard 317, "Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations" as supplemented by Nuclear Regulatory Commission Regulatory Guide 1.63, "Electric Penetration Assemblies in Containment Structures for Light-Water-Cooled Nuclear Power Plants" provides the basis acceptable to the NRC staff. The following criteria are used in this report to determine compliance with current licensing requirements:

(1) IEEE Standard 317, Paragraph 4.2.4 -- "The rated short circuit current and duration shall be the maximum short circuit current in amperes that the conductors of a circuit can carry for a specified duration (based on the operating time of the primary overcurrent protective device or apparatus of the circuit) following continuous operation at rated continuous current without the temperature of the conductors exceeding their short-circuit design limit with all other conductors in the assembly carrying their rated continuous current under the specified normal environmental conditions."

This paragraph is augmented by 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 single random failures of circuit overload protection devices."

(2) IEEE Standard 317, Paragraph 4.2.5 -- "The 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 apparatus, during which the electrical integrity may be lost, but for which the penetration assembly shall maintain containment integrity."

3.0 DISCUSSION AND EVALUATION

In this evaluation, the results of typical containment penetrations being at LOCA temperatures concurrent with a random failure of the circuit protective devices will be analyzed.

YAEC has provided information (Reference 1) on typical penetrations. All were field manufactured. No short circuit test data is available for these penetrations. YAEC has established a qualification temperature limit for each penetration below which damage to the hermetic seal of the penetration does not occur. The initial steady state temperatures of the containment environment is up to 120°F (49°C). Under accident conditions, a peak temperature of 248°F (120°C) is expected. YAEC used the Insulated Power Cable Engineers Association publication, P-32-382, entitled "Short Circuit Characteristics of Insulated Cable" to determine limiting factors on the conductors of the penetration.

In supplying the value of the maximum short circuit current available (I_{sc}), YAEC supplied values for a three-phase (on a three-phase system) bolted fault; this type being able to supply the most heat into the penetration. The I_{sc} value includes in the symmetrical AC component contributions by other connected induction motors. YAEC assumed a maximum operating temperature to allow for all other penetration conductors carrying their maximum rated current.

The following formula (Reference 6) was used to determine the time allowed for a short circuit before the penetration temperature would exceed its limiting value.

$$\left[\frac{I}{A}\right]^2 t = 0.0297 \log\left[\frac{T_2 + 234}{T_1 + 234}\right]$$

$$t = \frac{0.0297\ A^2}{I_{sc}^2} \log\left[\frac{T_2 + 234}{T_1 + 234}\right] \qquad \text{(Formula 1)}$$

where

t	=	Time allowed for the short circuit - seconds
I_{sc}	=	Short circuit current - amperes
A	=	Conductor area - circular mils
T_1	=	Maximum operating temperature (120°C, LOCA condition)
T_2	=	Maximum short circuit temperature (YAEC supplied limiting factor for a given penetration).

This is based upon the heating effect of the short circuit current on the conductors.

It should be noted that the short circuit temperature-time limits of the conductors in this report vary from the values calculated by YAEC (Reference 1) even though the same methods are used. YAEC calculated an allowable current, given a temperature rise and time, where this report uses the YAEC-supplied fault current magnitude and a smaller temperature rise to calculate the maximum time allowed to clear a fault condition. Also in this report, a pre-fault penetration conductor temperature equal to the peak LOCA containment atmosphere temperature is assigned, thus simplifying while accounting for an elevated conductor temperature caused by pre-existing current flow and above normal ambient temperature.

3.1 Typical Low Voltage (0-1000 VAC) Penetration. YAEC has provided information on a penetration that is a part of a typical 480 VAC motor operated valve circuit. This penetration has a three conductor #8 mineral insulated copper sheathed cable. A brass compression seal ring is used at each end of the penetration to provide hermetic sealing. These seal rings would be damaged at a lower temperature (900°C) than any other component of the hermetic seal. The temperature limit of the hermetic seal of the mineral cable is 1080°C as supplied by YAEC (Reference 1). The maximum I_{sc} available at this penetration is 1350 rms amperes symetrical.

It is calculated that, with the 900° temperature limit of the brass seal ring, this short circuit current can be carried by the penetration for 2.25 seconds before the penetration conductors exceed 900°C in the LOCA environment.

The primary 30-ampere circuit breaker will clear this fault in .015 second. The secondary, switch gear type circuit breaker, being between the short time and long time characteristics at this fault current level, will clear the fault in between .28 and 16 seconds. Assuming that some asymmetrical fault current component exists, it would act to clear the fault in less time. At lower values of fault current, the same results occur. The secondary breaker takes longer to clear the fault current than is deemed advisable.

3.1.1 Low Voltage Penetration Evaluation. With an initial penetration temperature of 120°C (the LOCA containment temperature), the containment electrical penetration design for this low voltage penetration is not in conformance with the criteria described in Section 2.0 of this report for a three-phase fault.

3.2 Typical Medium Voltage (>1000 VAC) Penetration. YAEC has provided information on penetrations used to power the 2400 VAC main coolant pump, P-14-2. Each penetration consists of three 5/8 inch diameter tinned copper rods insulated with buna rubber. Two penetrations are used per pump. These are held in place with silicone rubber seal rings at each end of the penetration. The temperature limited element of the hermetic seal of the penetration identified by YAEC is the buna rubber which melts at 200°C. The maximum I_{sc} available due to a bolted fault at the penetration is 25,260 rms symetrical amperes. YAEC did not supply the asymetrical fault current but, at this voltage, it is typically 1.6 times the symetrical current or 40,416 rms equivalent amperes. It is noted that a portion of I_{sc} is supplied by induction motors (4550 rms amperes) which do not pass through the secondary protective device.

It is calculated that 2.51 seconds elapse after a 25,260-ampere fault occurs at a penetration temperature of 120°C (LOCA containment temperature) before the conductors exceed 200°C. It is also assumed that the silicone rubber seal ring does not fill any voids presented by the melting buna rubber insulation.

The instantaneous trip fault clearing time of the primary air circuit breaker (ACB) is approximately .17 second per IEEE Standard 242-1975, Table 33, irregardless of the assymetrical fault current. The secondary ACB will clear the fault current within .51 second crediting only the symetrical component. At lower values of fault current, in all cases, both the primary and the secondary circuit breakers clear the fault quicker than the time limit imposed by Formula 1 at the same current magnitude.

3.2.1 Medium Voltage Penetration Evaluation. With an initial penetration temperature of 120°C (the LOCA containment temperature), this medium voltage penetration conforms to the criteria described in Section 2.0 of this report, and provides reasonable assurance that containment integrity will be maintained upon a random failure of a circuit protective device should a three-phase fault occur.

While parallel conductors are recognized and allowed by the National Electric Code, it is not advisable with these penetrations. Should a line break occur without faulting, the single remaining penetration does not conform to the criteria described in Section 2.0 of this report with the pump full-load current going through it.

3.3 Typical Direct Current Penetrations. YAEC has provided information for the penetration used with the solenoid pressurizer relief valve, PR-SOV-90. The penetration construction is identical to that discussed in Section 3.1 except that a seven conductor #12 mineral insulated cable is used. The temperature limit of the hermetic seal identified by YAEC is the melting point of the brass seal ring (900°C). The maximum I_{sc} available at this penetration is 555 amperes.

It is calculated that the maximum I_{sc} can be carried by this penetration for 2.08 seconds before the conductor temperature reaches 900°C. No time lag is allowed for the heat to pass from the conductor to the seal ring.

The fuse curves supplied by YAEC show that the primary fuse will clear this fault in .01 second and that the secondary fuse will independently clear this fault in less than 11 seconds. At all values of fault current less than 555 amperes, the primary fuse always cleared the fault within the time allowed by Formula 1, while the secondary fuse did not.

3.3.1 Direct Current Penetration Evaluation. With an initial penetration temperature of 120°C (the LOCA containment temperature), this direct current penetration does not conform to the criteria described in Section 2.0 of this report upon failure of the primary fuse to clear a line-to-line fault.

4.0 SUMMARY

This evaluation looks at the capability of the protective devices to prevent exceeding the design or test ratings of the selected penetrations in the event of (a) a LOCA event, (b) a fault current through the penetration and simultaneously (c) a random failure of the circuit protective devices to clear the fault. The environmental qualification tests of the penetrations is the subject of SEP Topic III-12.

This assessment neglects any heat transfer from the penetration conductor to other conductors and the containment liner. To account for initial full-rated current in the penetration conductors, an initial penetration temperature equal to the peak LOCA in-containment temperature was assigned.

With a LOCA environment inside containment, the protection of the medium voltage AC penetration conforms to the specified criteria which assumes a short circuit fault and a single random failure of the circuit protective devices. Under the same circumstances, it is expected that the temperature of the hermetic seals of the low voltage AC and the DC penetrations would exceed their respective limiting temperatures.

Should one penetration of the penetration pair used with the primary coolant pump have an open circuit in one of its three conductors, the normal operating current for the RCP would cause the remaining penetration to exceed the conductor temperature limit within 1.1 hours at an initial penetration temperature of 60°C. This condition occurs because the breaker protective setpoints disregard the fact that the use of one feeder to supply the RCP will cause conductor and penetration overheating and there is no provision to monitor the integrity of the parallel conductors.

The review of Topic III-12, "Environmental Qualification," may result in changes to the electrical penetration design and therefore, the resolution of the subject SEP topic will be deferred to the integrated assessment, at which time, any requirements imposed as a result of this review will take into consideration design changes resulting from other topics.

5.0 REFERENCES

1. Robert H. Groce, Systematic Evaluation Program (SEP), WYR 79-32, March 14, 1979, YAEC letter.

2. General Design Criterion 16, "Containment Design" of Appendix A, "General Design Criteria of Nuclear Power Plants," 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities."

3. Nuclear Regulatory Commission Standard Review Plan, Section 8.3.1, "AC Power Systems (Onsite)."

4. Regulatory Guide 1.63, Revision 2, "Electrical Penetration Assemblies in Containment Structures for Light-Water-Cooled Nuclear Power Plants."

5. IEEE Standard 317-1976, "IEEE Standard for Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations."

6. IPCEA Publication P-32-382, "Short Circuit Characteristics of Insulated Cable."

7. IEEE Standard 242-1975, "IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems."