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SYSTEMATIC EVALUATION PROGRAM TOPIC VIII-4, ELECTRICAL PENETRATIONS OF REACTOR CONTAINMENT, R. E. GINNA NUCLEAR STATION, UNIT NO. 1

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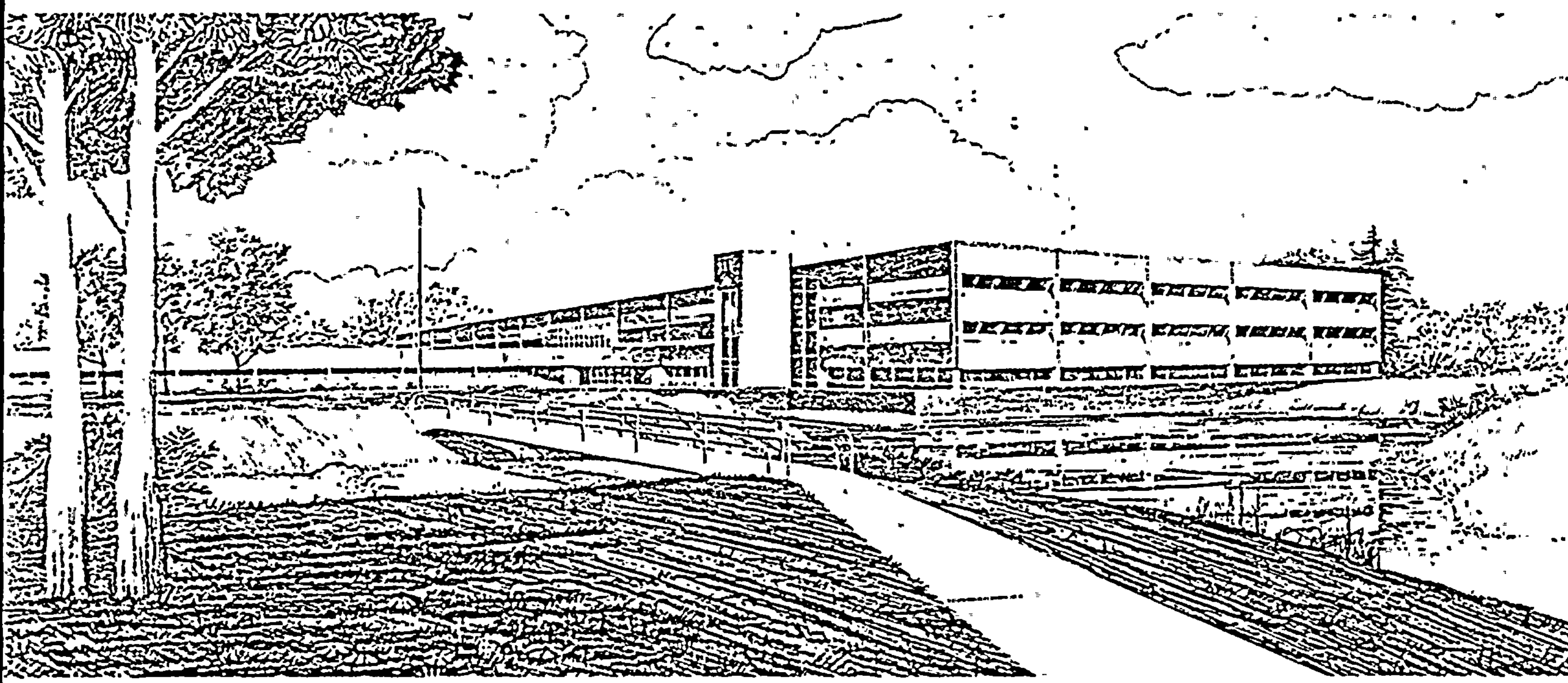

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INTERIM REPORT

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SYSTEMATIC EVALUATION PROGRAM

TOPIC VIII-4
ELECTRICAL PENETRATIONS OF REACTOR CONTAINMENT

R.E. GINNA NUCLEAR STATION, UNIT NO. 1

Docket No. 50-244

September 1981

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ABSTRACT

This SEP technical evaluation, for the R. E. Ginna Nuclear Station, Unit No. 1 reviews the capability of the overcurrent protection devices to protect the electrical penetrations of the reactor containment for postulated fault conditions concurrent with an accident condition.

FOREWORD

This report is supplied as part of the "Electrical, Instrumentation, and Control Systems Support for the Systematic Evaluation Program (II)" being conducted for the U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, Division of Licensing by EG&G Idaho, Inc., Reliability & Statistics Branch.

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SYSTEMATIC EVALUATION PROGRAM

TOPIC VIII-4
ELECTRICAL PENETRATIONS OF REACTOR CONTAINMENT

R.E. GINNA NUCLEAR STATION, UNIT NO. 1

1.0 INTRODUCTION

This review is part of the Systematic Evaluation Program (SEP), Topic VIII-4. The evaluation provided by Rochester Gas and Electric (RGE)[1] has demonstrated the adequacy of the penetrations and the circuit protective devices during normal operation. A letter of July 21, 1980[2] provides additional information on the penetration designs. The objective of this review is to determine the capability of the overcurrent protective 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 the protective devices to clear the circuit during a short circuit condition prior to exceeding the containment electrical penetration test or design ratings with initial assumed 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."

Additional clarification of these criteria was provided to RGE on March 30, 1981.[3]

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.

RGE has provided information[1,2] on typical penetrations. Additional material, submitted as a result of this review was provided on June 9, 1981[4] and July 14, 1981.[5] All penetrations but one were manufactured by Crouse-Hinds, who no longer makes these penetrations. Crouse Hinds supplied RGE with test data, where available, and calculated data with a 10x safety factor where test data was not available.

RGE has established that before damage to the hermetic seal of the penetration occurs, melting of the solder in the hermetic seal of the penetrations must occur (361°F, 180°C). A silver braze is used for penetrations CE-21, CE-25 and CE-27 instead of solder (1100°F, 600°C). This temperature is used because it is the lowest temperature that affects the penetration seal. Other materials, while affecting the strain relief of the penetration at lower temperatures, do not affect the hermetic seal. The limiting temperature is determined by the analysis of the construction of the penetrations rather than testing. The Ginna 1 Technical Specification allows for initial steady state temperatures of the penetration environment up to 120°F (49°C). Under accident conditions, a peak temperature of 285°F (140°C) is expected.

In those penetrations with conductors larger than #2 copper, the limit was not heat input but mechanical forces generated by electromagnetic coupling, and the limits put on these was determined by tests, with no mechanical failure of the penetration. Smaller penetration conductors are not subject to failure by mechanical forces when used within their maximum current rating.

RGE also used the Insulated Power Cable Engineers Association publication, P-32-382, entitled "Short Circuit Characteristics of Insulated Cable"

to determine separate limiting factors on the conductors of the penetration. Where these figures were more conservative than the Crouse-Hind figures, they were used instead.

In supplying the value of the maximum short circuit current available (I_{sc}), RGE 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 supplied by RGE takes both the symmetrical AC component and the peak DC offset component. In the RGE analysis, the I_{sc} was held to the maximum value for all phases when only one phase can have the full initial offset, and despite the fact that the DC component decays. This provides an additional safety factor in their calculations. RGE did not assume that all other penetration conductors were carrying their maximum rated current, but applied the normal operating current.

The following formula[6] was used to determine the time allowed for a short-circuit before the penetration conductor temperature would exceed the melting point of solder.

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

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

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 (140°C, LOCA condition)
- T_2 = Maximum short circuit temperature (180°C, temperature for melting solder).

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 RGE[1] even though the same methods are used. RGE has utilized an initial temperature of 40°C while this review uses an initial temperature of 140°C (LOCA condition) for the penetration. 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) Penetrations. RGE has provided information on three typical low-voltage AC penetrations.[1]

3.1.1 Penetration Number AE-6. This penetration has #2 AWG conductors and was type-tested to 37,400 amperes for 3 cycles by the manufacturer, Crouse-Hinds. The I_{sc} available on the identified 480-V circuit is 9600 amperes. Using Formula 1, this current can be carried for 0.06 second before the penetration conductor temperature exceeds the melting point of solder while under a LOCA environment. The primary circuit breaker responds within this time (.018 second). The secondary circuit breaker does not. For smaller fault currents, both the allowable time before the hermetic seal is damaged increases and the fault clearing time increases. At all fault current levels, the primary breaker cleared, while the secondary breaker did not clear the fault within the allowable time.

As a result of this review, RGE has proposed to install a 70 ampere backup circuit breaker in series with the primary circuit breaker.[4] RGE has shown that the response of this new circuit breaker is properly coordinated to protect the AE-6 penetration under any postulated fault condition.

3.1.2 Penetration Number AE-5. This penetration has #8 AWG conductors and is calculated by the manufacturer to be able to withstand 1400 amperes for 0.54 second (including the Crouse-Hinds-supplied 10x

safety factor). RGE does not expect mechanical damage at less than 4662 amperes (this is equal to 1400 x 3.33 or 1/3 of the original safety factor). The identified 480 VAC circuit is capable of supplying a maximum I_{sc} of 3500 amperes into the penetration. The primary breaker can clear this fault in 0.018 second, while the secondary fuse clears the fault in 0.002 second. The backup device will clear the fault before the primary protective device at this level of fault current.

It is calculated that the maximum I_{sc} can be carried by this penetration in a LOCA environment for 0.029 second before the penetration conductor temperature exceeds the melting point of solder. Both protective devices will clear the fault within this time. At lower levels of fault current, both devices clear the fault in time to prevent solder melting.

3.1.3 Penetration Number CE-21. This penetration has 500 MCM conductors and was type-tested by the manufacturer and extrapolated by RGE to withstand 44,000 amperes for 10 cycles. The 480 VAC circuit identified by RGE as typical can supply a maximum I_{sc} of 20,000 amperes. Both the primary and secondary breakers will clear the postulated fault within 0.45 and 0.50 second, respectively.

It is calculated that the 20,000-ampere fault current can be carried by this penetration in a LOCA environment for 6.46 seconds before the penetration conductor temperature exceeds the melting point of the silver braze. Both the primary and the secondary circuit breaker will act in time to prevent damage to the hermetic seal of this penetration at this current level. Both circuit breakers respond faster than the penetration heat build-up limit for all current levels.

Since all in-containment components of this identified circuit are environmentally qualified for class 1E service,[5] NRC position 2[3] can be applied. This position requires only a single class 1E circuit breaker for penetration protection where all components served by that penetration are qualified to class 1E requirements.

3.1.4 Low-Voltage Penetration Evaluation. With the initial temperature of the penetrations at 140°C (LOCA), penetrations AE-5 and

CE-21 are designed and utilized within the criteria described in Section 2.0 of this report. The protective devices for penetration AE-6, while not designed and utilized within the criteria described in Section 2.0 of this report, supply power for class 1E components, and therefore, are acceptable per NRC position 2.[3]

3.2 Typical Medium Voltage (≥1000 VAC) Penetration. Penetration numbers CE-25 and CE-27 have been identified by RGE[1] as typical of medium-voltage (4160 V) penetrations. These penetrations are used in parallel to supply power to one 6000 horsepower (HP) reactor coolant pump (RCP). These pumps are the only medium-voltage load within containment.

Construction of these penetrations is of the same materials and methods as discussed in Section 3.0. The hermetic seal is silver brazed (T_2 = 600°C). Each penetration, containing three 750,000-MCM conductors, was type-tested by the manufacturer and found to have no damage at 80,000 amperes for 10 cycles (0.167 second).

The maximum I_{sc} available (including that available from the source and from the subtransient and transient response of the 6000 HP motor fed back through the single remaining penetration and cable) is 46,000 asymmetrical/36,800 symmetrical amperes. The primary breaker overcurrent relay trips in 0.018 second, and the backup breaker overcurrent relay trips in 0.17 second should the primary breaker not clear the fault (both values based on 36,800 amperes).

It is calculated that the available 46,000-ampere asymmetrical fault current can be carried by this penetration for 2.75 second before penetration seal failure would occur. Using the time-current characteristics, assuming 46,000 amperes is constant throughout the clearing time, the primary breaker overcurrent will clear the fault in 0.018 second while the secondary breaker overcurrent will clear the fault in 0.17 second.

3.2.1 Medium Voltage Penetration Evaluation. Penetrations CE-25 and CE-27 are designed and utilized within the criteria described in Section 2.0 of this report.

Additionally, RGE has committed to improve the protection characteristics for low magnitude fault currents.[4] This will be accomplished by installing a redundant set of overcurrent relays between the primary protective relays and the penetration. This set of relays will actuate the backup breaker. RGE has shown that with this additional set of relays, the response of the circuit protective devices is properly coordinated to protect the CE-25 and CE-27 penetrations under any postulated fault conditions.

3.3 <u>Typical Direct Current Penetrations</u>. RGE has provided information of three typical direct-current power penetrations.[1] These penetrations are of the same construction as in Section 3.0, and the same methods of determining the limiting heating factors were used.

3.3.1 <u>Penetration Number CE-18</u>. This penetration, constructed with number 2 conductors, provides 125 V DC power to the lift coil and was type-tested to be able to withstand a current in excess of 30,000 amperes for 3 cycles with no mechanical damage. The maximum I_{sc} available to this penetration is identified as 270 amperes. At this 270-ampere current, the two primary (both + and - leads) 50-ampere fuses will clear the line-to-line fault in 0.18 second or, should these fuses fail, the secondary 150-ampere fuse will clear the fault in 0.576 second.

It is calculated that the 270-ampere fault current can be carried by this penetration for 79.2 seconds before damage to the hermetic seal of the penetration occurs. The primary and secondary fuses will clear this fault and all faults of less magnitude before the penetration temperature exceeds its qualification limit.

3.3.2 <u>Penetration Number CE-17</u>. This penetration, constructed with number 8 conductors, provides 125 V DC power for the rod drive circuit, and is calculated to be able to withstand 1400 amperes for 0.54 second. The maximum I_{sc} available to this penetration is 260 amperes. At this current, the primary fuse will clear the line-to-line fault in 0.0004 second or, should this fuse fail, the secondary fuse will clear the fault in 0.0043 second.

It is calculated that the 260-ampere fault current can be carried by this penetration for 5.28 seconds before damage to the hermetic seal of the penetration occurs. Both the primary and the secondary fuses will clear this fault and all faults of less magnitude before the penetration temperature exceeds its qualification limit.

3.3.3 Penetration Number CE-23. This penetration, constructed with #10 conductors, provides 125 V DC control power and is calculated to be able to withstand 1250 amperes for 0.27 second. The maximum I_{sc} available at the penetration is 600 amperes. At this current, the primary fuse will clear the fault in 0.014 second. The secondary fuse will not melt in time to prevent damage to the penetration (700 seconds operating time at 600 amperes).

It is calculated that the 600-ampere fault current can be carried by this penetration for 0.39 second. The primary fuse will, and the secondary fuse will not, clear this fault and all faults of less magnitude before the temperature of the penetration will exceed the melting point of solder.

As a result of this review, RGE has proposed to install a new primary fuse (25A).[4] The existing primary fuse (30A) will then be the secondary fuse. The two fuses will be in series with penetration number CE-23. RGE has shown that the response times for these two fuses are properly coordinated to protect the CE-23 penetration under any postulated fault condition.

3.3.4 Direct Current Penetration Evaluation. With the initial temperature of the penetrations at 140°C as expected with a LOCA, penetrations CE-17, CE-18 and CE-23 are designed and utilized within the criteria described in Section 2.0 of this report.

3.4 Other Penetrations. RGE also provided information on penetration numbers AE-10, CE-1, and CE-8.[1] Penetration numbers AE-10 and CE-1 are part of instrumentation (10-50 mADC) current loops. The transmitters of these are current-limited to 50 milliamperes while each penetration conductor is rated at 12 amperes continuous. Penetration number CE-19 is triaxial

instrumentation signals, and the circuit described is equipment-limited to less than 200 watts (i.e., the source of the signal would fail before 200 watts output is reached). A maximum I_{sc} of 1 ampere would be carried on a penetration conductor rated at 10 amperes continuous. No mechanical failures are postulated for these penetrations (construction and materials similar to the power penetrations previously described) even under accident conditions within containment.

A recent modification installed a low-voltage power, control, and instrumentation penetration that is IEEE-Standard-317-1972-qualified for an in-containment television monitor system. This penetration, for which application data was not submitted, is none the less qualified to IEEE Standard 317-1972, assuming it is being used within specification limits.

4.0 SUMMARY

This evaluation looks at the capability of the protective devices to prevent exceeding the design 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.

The penetrations identified with power-limited instrumentation circuits are deemed suitable under all postulated conditions.

After the proposed modifications to the circuit protective devices are completed, with a LOCA environment inside containment all penetrations are designed and utilized within the criteria described in Section 2.0 of this report which assumes a short circuit and random failure of circuit protective devices.

RGE is investigating improvements for the protection of other penetration circuits as a result of this SEP topic.[4] No completion date has been established, but any modifications are expected to be similar to those discussed in this report and in reference 4.

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. RGE letter, Harry G. Saddock, Systematic Evaluation Program Topic VIII-4, "Electrical Penetrations of Reactor Containment", R.E. Ginna Nuclear Power Plant, Unit No. 1, Docket No. 50-244, April 12, 1979.

2. RGE letter, C. D. White, Jr., to Director of Nuclear Reactor Regulation, U.S. NRC, "SEP Topic VII-4--Electrical Penetration of Reactor Containment," July 21, 1980.

3. NRC letter to RGE, "SEP Topic VIII-4," March 30, 1981.

4. RGE letter, J. E. Maier to Director of Nuclear Reactor Regulation, NRC, "SEP Topic VIII-4, Electrical Penetrations," June 9, 1981.

5. RGE letter, J. E. Maier to Director of Nuclear Reactor Regulation, NRC, "SEP Topic VIII-4, Electrical Penetrations," July 14, 1981.

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

7. 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."

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

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

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