September 25, 1995

MEMORANDUM TO: Robert A. Capra, Director
Project Directorate III-2
Division of Reactor Projects III/IV

FROM: José A. Calvo, Chief (Original signed by J. Calvo)
Electrical Engineering Branch
Division of Engineering

SUBJECT: RESPONSE TO THE FOLLOWUP TO THE REQUEST FOR ADDITIONAL INFORMATION REGARDING GENERIC LETTER 92-08 (TAC NOS. M85521 AND M85522)

Plant: Braidwood Nuclear Station, Units 1 and 2
Licensee: Commonwealth Edison Company
Review Status: Open

By letter dated February 15, 1995, Commonwealth Edison (ComEd) Company submitted documents which were requested as a result of phone conversations between ComEd and NRR staff, related to Generic Letter (GL) 92-08, "Thermo-Lag 330-1 Fire Barriers" for the Braidwood Nuclear Power Station. Further, the licensee indicated in their response dated March 28, 1995, related to GL 92-08 that their analytical approach have been shown conservative to actual ampacity derating test results and ampacity testing is not planned for abandoned in-place Thermo-Lag fire barriers. The Electrical Engineering Branch (EELB), in conjunction with our contractor, Sandia National Laboratories, has completed our preliminary review of the licensee's analytical approach as documented in the February 15, 1995, submittal, and has identified a number of open issues and concerns (attachment) requiring clarification by the licensee.

Please treat the attachment as a request for additional information (RAI), responses to which are needed for resolving our concerns on the ComEd ampacity derating factor determinations for Braidwood Nuclear Power Station, Units 1 and 2. Please forward this RAI to the licensee.

Docket Nos.: 50-456
50-457

Attachment: As stated

CONTACT: R. Jenkins, EELB/DE
415-2985

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

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Attachment

BRAIDWOOD NUCLEAR STATION, UNITS 1 AND 2
DOCKET NOS. 50-456 AND 50-457
FOLLOWUP REQUEST FOR ADDITIONAL INFORMATION REGARDING
GENERIC LETTER 92-08
"THERMO-LAG 330-1 FIRE BARRIERS"

CABLE TRAY ANALYSIS

1. The licensee analysis as documented in Attachment 2 of the February 15, 1995 submittal, ComEd Calculation G-63, Revision 3, "Darmatt Firewrap Material Cable Ampacity Derating Factor Calculation", begins with an assumption that the open top industry ampacity tables provide an accurate representation of the ampacity values which will result in a 90°C cable conductor hot spot temperature in an open top tray. It is generally recognized that for most, although not all cases, the subject tables provide a modest margin on operating ampacity.

   Given this margin, the licensee methodology effectively assumes a lower bound value for the baseline heat load, and hence, would be expected to determine by calculation an upper bound value for the internal cable-to-cable tray thermal resistance factor. This result arises because the external resistance factors are fixed in accordance with the correlations used, and the driving temperature drop is fixed by the assumed values of cable and ambient temperature. Once the value of ampacity, i.e., heat load, is fixed then the internal resistance can be determined for the particular configuration. Hence, using a lower bound ampacity value with a downward bias would have a nonconservative effect because the higher the internal resistance estimate would lower the baseline ampacity value thereby lowering the overall ampacity derating factor for the fire barrier system.

   For the subject licensee analysis the effect of this approach would be minimal given the nature of the tray type specified, i.e., the solid bottom cable tray. In fact, the industry ampacity tables provide an accurate estimate of the open top ampacities for a solid bottom tray due to the nature of Stolpe's original experiments.

   Given that the referenced 1982 ampacity experiments were performed using solid bottom cable trays and those experimental results are bases for determining the internal resistance between the cables and the surface of a covered cable tray the subject analysis must be considered to be limited to that application. In fact, the 1982 American Power Conference paper, "Tests at Braidwood Station on the Effects of Fire Stops on the Ampacity Rating of Power Cables", makes note of the fact that the industry ampacity tables were found to be nonconservative for some of the tested configurations.

   Based on the above discussion, the licensee is requested to confirm that all of the cable trays under consideration for Braidwood Station are solid bottom trays of the type used in the original tests performed for Braidwood Station as reported in the subject 1982 paper. If other types of cable trays are applicable for Braidwood Station then a specific and detailed justification for the applicability of the licensee methodology should be submitted by the licensee.

2. Attachment 1 of the February 15, 1995 submittal, ComEd White Paper, February 3, 1995, "Ampacity Derating Factors for Thermo-Lag 330-1 TSI Fire Barriers" documents the licensee compares its analysis methodology to the results of an Sandia National Laboratories(SNL)/NRC ampacity derating test for the fire barrier material Thermo-Lag. The stated purpose of the White Paper is to demonstrate that the ComEd ampacity analysis methodology "yields credible and conservative results." The staff make the following observations regarding arguments presented in the licensee White Paper:

   - In a very fundamental sense, the SNL/NRC test is a poor basis for comparison. This test was performed to replicate a manufacturer's test which is considered to have fundamental and inherent weaknesses. Hence, these weaknesses were retained in the SNL tests.

   - The SNL/NRC test methodology is consistent with either IEEE P848 or with the industry accepted methodology of Stolpe. In particular, SNL treated the cable tray as a diverse load tray and made no attempts to maintain uniform current density for the three cable sizes. Both IEEE P848 and Stolpe's methodology maintain a uniform current density. The assumption of uniform power density in the licensee analysis do not reflect the actual test conditions.

   - The staff disagrees with the White Paper statements which imply that experimentally determined ampacity limits in a clad or fire barrier enclosed cable tray test can be compared to the Stolpe open air ampacity table values as an appropriate basis for the calculation of an ampacity derating factor. This position has been supported by recent changes in the draft IEEE P848 which prohibited the use of industry ampacity table values. One appropriate basis for the determination of ampacity derating factors is to derive a ratio of the baseline ampacity test value to the clad ampacity test value.

   - No details have been provided on how the fire barrier system was modeled thermally in the licensee analysis. Hence, neither SNL or the staff was able to determine if all aspects of the fire barrier system actually installed were considered (e.g., the SNL system was a double-layer system comprised of two layers of 5/8" - 3/4" thick Thermo-Lag with an air gap between layers so, for example, the assumption of a single layer 1" barrier would be inappropriate) in the licensee analysis.

   - While the SNL/NRC test involved a ladder back cable tray, the licensee analysis methodology is based on test results for a solid bottom cable tray. It would be expected that the experimentally determined open air ampacity limits for a ladder back cable tray would be somewhat higher than those which would be found for a solid bottom tray or in the industry ampacity tables. This difference is expected because of the additional impediment to heat transfer from the lower surface of the cable mass due to the bottom of a solid tray. One of the reasons that the industry ampacity tables are often cited as conservative because Stolpe's results were based on the testing of a vented solid bottom tray with a plastic sheet covering the bottom of the tray. Therefore, when ladder back trays are tested higher open air ampacities would be the expected result.

- Given the fundamental differences between the SNL/NRC and Braidwood cable trays one cannot assume that the impact of boxing a ladder back cable tray would be the same as the impact of placing a solid cover on a solid bottom trough style tray. Specifically, the thermal conditions prevailing at the bottom of the cable mass would be very different due to the differences in the extent of contact between the cable and the bottom cover. For a trough style tray nearly continuous contact would exist between the lower layer of cables and the bottom of the tray while for a ladder back tray virtually no contact would exist. The licensee analysis also credits the side rails as effective heat transfer surfaces. Here again, a solid bottom trough style tray and a ladder back tray are significantly different. In particular, the ladder back tray would form a very thick air gap (of 1" or more) between the metal side rail and the inner surface of the barrier due to the fact that the side rail is "C"-shaped with the flanges facing outward. A solid bottom trough style tray would have no such protruding flanges.

Although the licensee methodology contains many conservative features, the staff questions whether the licensee's White Paper provides an adequate basis for validation of the cable tray analysis method. Although the staff would not require a validation of the cable tray analysis assuming that the 1982 experiments performed for Braidwood Station bound Thermo-Lag cable tray types, it is recommended that these calculations be revisited with valid industry test data. There are clearly more appropriate tests for which a more representative comparison and validation can be made (e.g., Comanche Peak Steam Electric Station, Unit 2 ampacity derating tests). It would clearly be desirable to see the licensee analysis methodology validated against experimental data.

CONDUIT ANALYSIS METHODOLOGY

3. SNL noted an apparent error was made in the treatment of the air gap between the conduit and the fire barrier system. The licensee analysis utilizes a "trick" which is commonly applied to steady state rectangular geometry problems. This "trick" involves a mathematical manipulation where the air gap is converted to an equivalent thickness of Darmatt based on the ratio of their thermal conductivities:

$$X'_{air} = X_{air} \left(\frac{k_{Darmatt}}{k_{air}} \right)$$

were X'_{air}, is the modified air gap thickness, X_{air} is the actual gap thickness, and k is the thermal conductivity of the indicated material. The air gap is then treated as additional thickness of Darmatt rather than as a separate material.

Unfortunately, this approach cannot be applied directly to annular regions. The overall thermal resistance of an annular region is given by a logarithmic relationship described below:

$$R_{annulus} = \frac{1}{2\pi k} \ln\left(\frac{d_o}{d_i}\right)$$

where (d_o) and (d_i) are the outer and inner diameters of the annulus respectively, and it is implied that thermal resistance is on a per unit length basis. Hence, the conversion of an annular gap of air into an annular gap of Darmatt must be consistent with the above logarithmic form. The actual thermal resistance of the air gap and the Darmatt is the simple sum of the individual resistance values for each:

$$R_{barrier} = R_{air} + R_{Darmatt}$$

Using the actual dimensions and properties of each medium, the following expression is obtained:

$$R_{annulus} = \frac{1}{2\pi}\left[\frac{1}{k_{air}} \ln\left(\frac{d_{airgap}}{d_{cond}}\right) + \frac{1}{k_{Darmatt}} \ln\left(\frac{d^{Darmatt}}{d_{airgap}}\right)\right]$$

SNL recalculated the values for the 1 hour and 3 hour barrier systems for a 3/4" conduit using the licensee provided data in the equation above. The calculations were also repeated using the licensee's approach for converting the thermal resistance of the air gap to Darmatt equivalent value to derive total resistance for a single annular ring. The results compare as follows:

Comparison of External Thermal Resistance Values of a 3/4" Conduit		
Barrier Rating	Total External Resistance (hr-ft-°F/BTU)	
	Corrected Method	Licensee Method
1 hour	3.91	3.30
3 hours	5.54	4.81

The licensee is requested to address the above apparent discrepancy and to revise its analysis accordingly.

4. In calculating the thermal resistance between the cables and the conduit, a two part calculation has been performed. In the first part, an assessment is made of the thermal resistance for the cable insulation and jacket material using annular relationships similar to those discussed in Item 3. In the second part, the Sargent and Lundy (S&L) Standard ESA-105

used, apparently, to estimate the thermal resistance between the surface of the cable and the conduit.

Given the information provided the nature of the cable insulation and jacket resistance calculations is not clear. Specifically, the calculations presented as the top 6 lines of page 130 of Calculation G-63 require clarification. Although the calculations are attempt to account for the cable insulation and jacket regions as annular regions, why are the multipliers of 2 and 3 applied to various parts of the resistance? How does the licensee justify simply adding the various components without consideration of parallel path heat transfer and the fact that heat is not flowing from the center of each conductor radially through each individual conductor, but rather non-uniformly through the multi-conductor cable as a whole?

For this geometry, a cable resting on the bottom inside of a conduit, treatment of the problem as one of purely annular regions, which apparently are cascaded one upon another, is not correct and appears to ignore the inherent 2-dimensionality of the problem.

Based on the above discussion, the licensee is requested to submit a copy of Sargent and Lundy Standard ESA-105. Further, the licensee should explain in greater detail the full nature of the cable-to-conduit thermal resistance calculation process. This description should include a detailed explanation of both the basis and intent of calculations (e.g, the first 6 lines on page 130 of the ComEd Calculation G-63) and an explanation and justification for merging the two separate calculations into a single expression.

5. Another concern is the value assumed for the emissivity of the outer surface of the conduit. In both the cable tray and conduit analyses, a lower bound value of 0.23 is used. In the case of the cable tray analysis this was concluded to be a conservative approach. However, in the case of the conduit analysis, this approach is actually nonconservative.

   In the case of the conduit analyses, both the internal and external thermal resistance values are assumed to be known based on various thermal correlations. In calculating these "known" values, the very low value of emissivity assumed in the baseline case contributes to a relatively high external thermal resistance, and hence, to a relatively high overall thermal resistance. The total thermal resistance is then used to calculate the allowable heat load for the conduit. The higher the total thermal resistance leads to a lower allowable heat load for the baseline case. Therefore, minimizing the emissivity value in the baseline case effectively minimizes the baseline heat load and hence the baseline currents. Therefore, an emissivity value biased low is nonconservative for conduit ampacity derating estimates. For conservatism, the conduit baseline case analyses should consider the maximum possible conduit surface emissivity rather than the minimum value.

   Based on the above discussion, the licensee is requested to assess the impact on the calculated ampacity derating factors by using an upper bound emissivity value (i.e., 0.8 - 0.9) in its baseline conduit calculations.

6. The licensee did not provide any experimental validation of the analytical methodology for conduits based on actual test data. The licensee is requested to evaluate the validity of their analytical methodology using available industry test data.