A Technical Evaluation of the Oyster Creek Nuclear Generating Station Analysis of Cable Ampacity Limits

A Letter Report to the USNRC

Revision 0

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Enclosure 2

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FORWARD

The United States Nuclear Regulatory Commission (USNRC) has solicited the support of Sandia National Laboratories (SNL) in the review of utility submittals associated with fire protection and electrical engineering. This letter report is the second in a series of submittal review reports related to the Oyster Creek Nuclear Generating Station (OCNGS). The submittals reviewed deal with the issues of Thermo-Lag 330-1 fire barriers, and in particular, the assessment of ampacity loads for protected cables. An initial review report was completed by SNL on June 13, 1996 based on a licensee submittal of December 8, 1995. A subsequent USNRC Request for Additional Information (RAI) was forwarded to the licensee on August 26, 1996. The current report documents an SNL review of a licensee response to this RAI as provided in a licensee document dated November 25, 1996. This work was performed as Task Order 3, Subtask 5 of USNRC JCN J-2503.

1.0 OVERVIEW AND OBJECTIVE

In response to USNRC Generic Letter 92-08, the Oyster Creek Nuclear Generating Station (OCNGS) provided initial documentation of the utility position regarding ampacity derating factors associated with its installed Thermo-Lag fire barrier systems in a submittal dated 12/8/95. SNL reviewed this submittal and provided a review findings report to the USNRC on 6/13/96. In large part as a result of this SNL review, a request for additional information (RAI) was forwarded to the licensee on 8/26/96.

The objective of this report is to document the findings and recommendations resulting from an SNL review of the licensee RAI response. The submittal reviewed was documented in a utility letter as follows:

- Letter, November 25, 1996, (item 6730-96-2336), M. B. Roche, GPU Nuclear Corp, OCNGS, to USNRC Document Control Desk (with one Attachment).

SNL was requested to review this submittal under the terms of the general technical support contract JCN J-2503, Task Order 3, Subtask 5.

2.0 UTILITY AMPACITY DERATING APPROACH

2.1 Range of Applications

One somewhat unique aspect of the OCNGS fire barriers is that all of the installed fire barrier systems are associated with either conduits or cable air drops. There are apparently no cables trays clad in Thermo-Lag fire barriers. This is one feature that simplifies the licensee's analysis problems.

It was also noted that relatively few cables are actually impacted by the fire barrier systems. In particular, because the cases generally involve conduits or air drops, the number of cables inside each barrier system is relatively small. In contrast, when a typical cable tray is clad, even though only one or two of the cables in the tray may be the actual targets of the cladding, many power cables may need to be assessed simply because they are co-located in the same tray. This, too, has led to a significant reduction in the required scope of the licensee's analyses.

2.2 Overview of Methodology

The consideration of cable ampacity loads at OCNGS is based on a very simple method. While some of the details of the assessment have been adjusted in response to the USNRC RAI questions, the overall methodology remains largely unchanged.

The licensee's general process of analysis begins by citing the base line ampacity limits for individual cables from the National Electrical Code (NEC) Handbook. While the actual tables applied are not cited by the licensee, SNL has been able to determine that all of the ampacity values apparently derive from either Table 310-16 (for 0-2000V cables) or 310-73 (for 2001-5000V cables) as identified in the 1996 version of the NEC. These values are appropriate to the licensee analysis in that all assume that the cables may be installed in a conduit. For each base line ampacity, the value is further adjusted for the assumed ambient in the plant, 40°C. (See related RAI item 3 as discussed in Chapter 3 below, and note that SNL has identified an apparent conservative error in the licensee treatment as discussed in Section 2.4 below.)

The licensee analysis of base line ampacity limits has also included application of an ACF based on the number of conductors in the conduit. The basis for the values chosen by the licensee is unclear, and this topic is discussed further in Section 2.5 below. Finally, the licensee applies an ACF factor to reflect the impact of the fire barrier system. The final result is an estimate of the fully derated ampacity limit for individual cables. Given these estimates of the derated cable ampacity limits, the utility simply compares the actual in-plant service loads to these ampacity limits. In all cases the utility has concluded that the estimated ampacity limits bound the actual in-plant service loads.

In general, this approach is an acceptable means of demonstrating that cables are operating within acceptable ampacity limits. In particular, the utility analysis method is based on the comparison of individual cable loads to corresponding cable ampacity limits. However, the level of documentation provided in the utility submittal remains quite sparse. Three

complete example calculations have been provided, and SNL found no obvious errors in these three examples (beyond the apparent conservative error discussed in Section 2.4 below). The licensee has also provided a summary table of results for other applications.

While the documentation is somewhat sparse, SNL nonetheless finds that the licensee has provided adequate documentation to provide a reasonable assurance that cable ampacity limits have been given adequate consideration. In particular, the licensee has generally demonstrated a significant margin for all of the cables considered. SNL does not recommend that any follow-up is required to further clarify the general aspects of the licensee analyses. Note that Section 2.4 below discusses one apparent error in the licensee analysis that is of a conservative nature, and Section 2.5 discusses one specific aspect of the analysis for which a very limited follow-up is recommended.

2.3 Determination of Fire Barrier ACF

In the assessment of fire barrier ACF values, the licensee has directly applied the results of the Texas Utilities Electric (TUE) and Tennessee Valley Authority (TVA) ampacity derating tests. The licensee also provides an assessment of the derating impact based on the original manufacturer (TSI) tests, although these tests are no longer considered a valid basis for analysis, and hence, SNL finds these particular analyses should not be credited.

It is important to note that in its original submittal the utility did provide a comparison of the primary characteristics of the tested configurations versus those installed at OCNGS. While certain questions were raised on this issue in the RAI, SNL has concluded that the licensee extrapolations are appropriate. (See further discussion related to RAI item 1 in Chapter 3 below.) In summary, SNL finds that application of the TUE and TVA ampacity derating factors is an appropriate basis for analysis at OCNGS.

2.4 Apparent Error in Base Line Estimate for 5 kV Cables

In determining base line cable ampacity limits, the licensee has adjusted all of the NEC tabulated values using an ACF of 0.91 to reflect an assumed plant ambient of 40°C versus 30°C. Table 310-16 does assume a 30°C ambient, and hence, the adjustment of ampacities derived from this table is necessary and appropriate. However, ampacity limits derived from NEC Table 310-73 are already based on a 40°C ambient, and hence, further adjustment is unnecessary. Nonetheless all of these values have also been adjusted using the 0.91 temperature correction ACF.

As a result of this apparent error all of the cited ampacity limits for the licensee's 4160 V cables have an added, and presumably unintended, level of conservatism. This appears to impact the licensee cables identified in the supporting tables as items 15, 16, 17, and 31.

Because this apparent error has had a conservative impact on the licensee's results, SNL recommends that no formal resolution is necessary. It is, however, recommended that the apparent discrepancy be brought to the attention of the licensee. It would clearly be in the interest of the licensee to correct this apparent error in its internal documentation.

2.5 Application of NEC Diversity-Based Conduit ACF Factors

One correction applied by the licensee to the base line ampacity limits reflects a correction for the total count of current carrying conductors in a single conduit. These values are normally taken directly from the NEC, but there are two sets of values that can be used under different circumstances.

Prior to 1990, the NEC had published one set of values, but these values inherently assumed a 50% load diversity (no more than have of the conductors loaded at a given time). These values still appear in the NEC, but now appear in Appendix B as Table B-310-11, and the diversity assumption is more explicitly stated. Since 1990, the NEC has published an alternate set of more restrictive values which do not include the diversity assumption for use in general applications (see NEC 1995 Section 310-15, table under note 8a on page 70-196). The changes only impact conduits with a conductor count of 10 or higher.

It is not clear which set of values are being applied by the licensee because the licensee has not specified the total conductor count for any of the conduits considered. However, based on the limited information available, it would appear that the licensee has applied the older pre-1990 diversity-based values:

- Consider for example items 29 and 30 from the licensee's results summary table (see page 2 of 4 of Table 1 in the submittal). These two cases involve "11-1/C #8" cables apparently in a common conduit. By "backing out" the "multiple conductors in raceway" correction, it is apparent that an ACF of 0.7 has been applied in this step. This value does correspond to the ACF cited in the diversity-based ACF table for a conductor count of 7 through 24. However, the updated post-1990 values would require application of a 0.5 ACF for a conductor count of 10 through 20. Hence, if 11 is the total conductor count (it may actually be higher if there are other co-located cables but it is certainly not lower) then nominally an ACF of 0.5 should have been applied.

Any application of the older, pre-1990, diversity-based values should be accompanied by specific consideration of the available load diversity. That is, the diversity-based values should only be applied when the diversity can be either explicitly demonstrated or reasonably assumed. For many nuclear power plant applications, a reasonable assumption of diversity is possible. This would be especially true for control applications, and for certain power applications for which the equipment is never operated simultaneously. However, the licensee has not provided any discussion of diversity in its conduit loads.

SNL finds that the licensee has not provided adequate discussion of the conduit conductor count ACF factors applied to its analyses. It is recommended that the USNRC ask the licensee to explicitly state which set of NEC values has been used in the analyses. Further, it is recommended that the USNRC ask the licensee that for each case in which the NEC diversity-based values have been applied to either (1) provide an explicit justification for use of the diversity-based NEC ACF values or (2) update the analysis using the newer post-1990 NEC correction factors in which the diversity assumption has been negated.

In general, it is not anticipated that this recommendation will ultimately have a significant impact on the licensee's assessments. In particular, this observation only has the potential to impact conduits with 10 or more conductors (the factors for 4 through 9 conductors are the same in both versions of the tables). Further, for most cases it is anticipated that the available margin should be sufficient to cover a change in this particular ACF value. For example, for the two cases cited above, items 29 and 30, if 11 is the total conductor count then application of a 0.5 conductor count ACF would still result in a derated ampacity limit of 22 A, and this still exceeds the estimated load of 18.5 A. No cases can be verified with certainty, however, based of the information provided in the submittal.

3.0 LICENSEE SPECIFIC RAI RESPONSES

3.1 RAI Item 1: Physical Comparison of Tested and In-Plant Barriers

Synopsis of Question: The licensee was asked to address aspects of the configuration similarity issue related to air gaps in the conduit barrier system as tested by TVA.

Synopsis of Response: The licensee has correctly pointed out that the specific tests being cited in the analysis did involve "dry fit" and "post-buttered" barrier installations, and hence, the air gap that normally forms between the conduit and the inner surface of the fire barrier system did, in fact, existing in the TVA tests cited.

Assessment of Response: This response is fully adequate to resolve the identified concern. In fact, the licensee has identified a very important aspect of the TVA tests that had not previously been appreciated by SNL. Most of the TVA tests involved a pre-buttered installation and elimination of the air gap. However, this particular set of 3-hr barrier tests did not, and hence, will have a much broader applicability to general industry installations.

Findings and Recommendations: SNL finds that the licensee application of the TVA test results will conservatively bound the OCNGS installations as described in the submittals. No further actions on this RAI item are recommended.

3.2 RAI Item 2: Example Calculations

Synopsis of Question: The licensee was asked to provide detailed examples of its calculation process.

Synopsis of Response: The licensee has provided 3 case examples, one for a conduit with a three-hour barrier, one for a conduit with a one-hour barrier, and one for an air drop.

Assessment of Response: The licensee response is fully adequate to resolve the identified concern. SNL has reviewed the example calculations as discussed in Chapter 2 above.

Findings and Recommendations: SNL finds that the licensee has complied with the USNRC request. No further actions on this RAI item are recommended.

3.3 RAI Item 3: Ambient Temperature

Synopsis of Question: The licensee was asked to justify its assumptions of a 30°C ambient used in certain of the cable analyses.

Synopsis of Response: The licensee's updated analyses have uniformly assumed a 40°C ambient.

Assessment of Response: This response is fully adequate to resolve the identified concern.

Findings and Recommendations: SNL finds that the licensee has complied with the USNRC request, and no further actions on this RAI item are recommended.

3.4 RAI Item 4: Air Drop ADF

Synopsis of Question: The licensee assumption of an 11% ADF for air drops was not considered to represent a conservative bounding value. The licensee was asked to provide a more realistic assessment for these cases.

Synopsis of Response: The licensee has clarified that only two air drop fire barrier systems are installed in the plant. Each is only 2 to 3 feet in length. The balance of each cable is apparently contained in clad conduits. The licensee has also cited a section of the NEC that allows for limited sections of a cable to be neglected in an ampacity assessment (no more than 10% of the total length of a circuit up to a maximum of 10 feet). The licensee has also cited the available margins for these cases as well.

Assessment of Response: The licensee assessment in this regard is considered acceptable when taken as a whole. SNL has not previously encountered an invocation of this particular NEC passage, and is skeptical of it applicability to this situation. However, SNL is swayed by three points in particular:

- The licensee ampacity assessment for these applications is based on derating of conduit base line ampacity limits using conduit ACF values. This should conservatively bound the equivalent air drop treatment based on derating open air ampacity limits using air drop ACF values. That is, a "penalty" is already paid for the conduit base line ampacity as compared to the open air ampacity limit of a cable. Thus, the combined relative impact of both a conduit and a fire barrier should be more severe than the impact of a fire barrier alone. The primary concern raised by SNL was that air drops should not be assessed by derating open air ampacity limits using conduit ACF values. The licensee has clearly not done this.
- The licensee has demonstrated a significant available margin for both cables impacted by this question.
- The lengths of cable involved are very short, and hence, any localized heating effects should be mitigated to a large extent.

Findings and Recommendations: SNL finds that the licensee response is adequate to conclude that air drop applications at OCNGS have been adequately treated. No further actions on this RAI item are recommended.

3.5 RAI Item 5: Battery Charger Loads

Synopsis of Question: The licensee was asked to address the potential for higher initial battery charging current loads under conditions of initial battery discharge in its ampacity load assessments.

Synopsis of Response: The licensee has cited that conditions of battery discharge are only rarely encountered during 2-year service outages. During such periods current loads are

monitored by plant procedure. Further, the licensee has considered a potential 10% overload condition on the maximum current load.

Assessment of Response: The licensee response is adequate to resolve the identified concern. In particular the licensee has allowed for a 10% overload on a circuit that is by design current limited to the maximum rated current. Further, the licensee has cited existing plant procedures that would identify and resolve any overload conditions.

Findings and Recommendations: SNL finds that the licensee response is adequate to resolve the identified concerns. No further actions on this RAI item are recommended.

4.0 SUMMARY OF FINDINGS AND RECOMMENDATIONS

SNL finds that the licensee has adequately addressed all of the specific RAI items forwarded under USNRC cover dated August 26, 1996. Further, SNL has reviewed the licensee's example calculations, and finds that the general methodology applied is an acceptable means of assessing individual plant cable ampacity loads. Finally, SNL finds that the licensee application of both the TUE and TVA fire barrier ampacity test results has been adequately justified, and is appropriate.

SNL did identify one point of potential concern for which a follow-up RAI is recommended:

- SNL finds that the licensee has not provided adequate discussion of the conduit conductor count ACF factors applied to its analyses. It is recommended that the USNRC ask the licensee to explicitly state which set of NEC values has been used in the analyses; either the pre-1990 50% diversity based values or the post-1990 no-diversity values. Further, it is recommended that the USNRC ask that, for each case in which the NEC 50% diversity-based values have been applied, the licensee either (1) provide an explicit justification for use of the diversity-based NEC ACF values or (2) update the analysis using the newer post-1990 NEC correction factors in which the diversity assumption has been negated.

This observation will only impact clad conduits with 10 or more conductors, and it is unknown how many such conduits exist at the plant. Given that a significant level of margin has been demonstrated for most cables, it is not anticipated that this concern will ultimately have a significant impact on the licensee's assessments. It is likely that a very limited scope RAI on this one item could easily resolve the concern.

Also as a part of the review SNL noted one apparent error in the licensee applications:

- In determining base line cable ampacity limits, the licensee has adjusted all of the NEC tabulated values using an ACF of 0.91 to reflect an assumed plant ambient of 40°C versus 30°C. However, ampacity limits for the licensee's 5 kV cables appear to have been taken from NEC Table 310-73 and these values are already based on a 40°C ambient. Hence, further temperature adjustment is unnecessary.

This apparent error will impact the ampacity assessments for four specific cables; namely, licensee items 15, 16, 17, and 31. However, the apparent error has resulted in overly conservative estimates of the ampacity limits for these cables, and hence, a change would not impact the ultimate conclusions of the licensee assessments. Given the conservative nature of the error, SNL recommends that no formal resolution is necessary. It is, however, recommended that the apparent discrepancy be brought to the attention of the licensee. It would clearly be in the interest of the licensee to correct this apparent error in its internal documentation.