A Supplemental Technical Evaluation of the South Texas Project 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 third in a series of submittal review reports related to the Houston Lighting and Power Co. South Texas Project (STP). The submittals being reviewed by SNL 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 28, 1996 based on a licensee submittal of April 24, 1995. A second round of SNL review was performed and included a USNRC Request for Additional Information (RAI) dated September 11, 1996, the corresponding licensee response dated November 6, 1996, and an SNL review findings and recommendations letter report dated April 24, 1997. A third round of reviews was initiated by a supplemental USNRC RAI dated May 9, 1997. On July 7, 1997, the licensee responded to this RAI, and the current report documents the SNL findings and recommendations based on a review of the licensee response to this most recent RAI. This work was performed as Task Order 2, Sub-task 5 of USNRC JCN J-2503.

1.0 OVERVIEW AND OBJECTIVE

1.1 Background

In support of the USNRC, SNL has been involved in the review of licensee submittals from the Houston Lighting and Power Co. South Texas Project (STP) associated with the licensee's assessment of ampacity loads for fire barrier clad cables. The following illustrates the history of this effort:

- April 24, 1995: In response to USNRC Generic Letter 92-08, STP provided initial documentation of the utility position regarding ampacity derating factors associated with its installed Thermo-Lag fire barrier systems.
- June 28, 1996: SNL issues a review findings letter report to the USNRC
- September 11, 1996: A request for additional information (RAI) is forwarded to the licensee by the USNRC.
- November 6, 1996: The licensee responds to the USNRC RAI of 9/11/96.
- April 24, 1997: SNL issues a second review findings and recommendations letter report.
- May 9, 1997: The USNRC issues another RAI to the licensee.
- July 7, 1997: The licensee responds to the 5/9/97 RAI.

The current report documents the SNL findings and recommendations based on a review of the licensee July 7, 1997 submittal.

1.2 Objective

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

- Letter, July 7, 1997 (item ST-HL-AE-5685), T. H. Cloninger, Houston Lighting and Power Co., STP, to the USNRC Document Control Desk (with one Attachment).
  - Attachment 1: "Attachment - Reassessment of the Ampacity Derating Analysis for Remaining Cable Trays"

SNL was requested to review this submittal under the terms of the general technical support contract JCN J-2503, Task Order 2, Subtask 5.

1.3 Overview of the Licensee Submittal

In the previous SNL review report (4/24/97) SNL found that the ampacity assessments for 24 specific cable trays, 13 for unit 1 and 11 for unit 2, were inadequate and that the acceptability of the ampacity loads for the cables in those trays was indeterminate. Consistent with the recommendations made by SNL, the licensee has provided more detailed ampacity assessments for these 24 trays based on a direct ampacity margins approach to assessment.

For each of the 24 trays, a table is provided that characterizes each tray and the installed barrier system, identifies each of the cables in the tray, states the actual ampacity load for each cable, applies a load factor (LF) of 1.25 to the actual ampacity load, and cites the maximum allowable ampacity load for each cable. The initial assessment of acceptability is based on a direct comparison of the actual load (including the LF) versus maximum allowable ampacity load.

For each cable that does not pass this initial screening, a specific argument of acceptability is provided. Such discussions are provided for 13 Unit 1 and 17 Unit 2 cables. The licensee has ultimately concluded that none of the cables has been subject to excessive or unacceptable aging degradation. The basis for these assessments has included the crediting of several mitigating factors; namely, identification of intermittent loads for MOVs, relaxation of the LF to 1.0 for control components and resistive heating loads, credit taken for non-continuous and/or seasonal loading conditions, relaxation of the LF margin for certain pumps and motors, identification of non-Appendix R systems and cables, and removal of the fire barrier system for future operation.

1.4 Report Organization

Chapter 2 provides a cable by cable assessment of the licensee analyses including SNL insights and findings. Chapter 3 summarizes SNL's findings and recommendations.

2.0 UTILITY AMPACITY ASSESSMENTS

2.1 Introductory Comments

It is important to note that the licensee submittal states that, with a single exception, all of the Thermo-Lag based cable tray fire barriers will be removed. Hence, in the current context the primary objective is to ensure that formerly protected cables have not been subjected to excessive premature aging. In contrast, a typical assessment is intended to ensure that continued performance at the cited ampacity levels will not be a long-term aging problem.

In its ampacity assessments for cable trays, the licensee has applied a 32% derating factor for 1-hour barriers (based on testing by TUE) and a 48% derating for 3-hour barriers (based on testing by TVA). SNL has previously cited that these values are appropriate. No new information that might call this earlier finding into question was identified. Hence, the cited derating factors remain valid.

In the SNL report of 4/24/97, the most significant SNL finding was that the licensee applied Watts-per-foot approach to cable tray ampacity assessment was inadequate and inappropriate. The current licensee assessments still report a cable tray overall heating rate derived from the Watts-per-foot methodology. However, none of the final assessments has been based on these results. This fully resolves the SNL review findings regarding the Watts-per-foot method in the context of the STP assessments.

In certain cases, the licensee has "resolved" cable loads by relaxing the assumed load factor (LF) from 1.25 to 1.0 for circuit loads that are subject to overload conditions of operation (i.e., pumps and motors). The licensee states that "typical industry practice does not include consideration of undervoltage or overload conditions in ampacity assessments. Consequently, a load factor of 1.0 applies."[1] SNL does not concur with this assumption. Typical industry practice does include consideration of overload conditions in an ampacity assessment. Indeed, load factors have no other purpose than to ensure that the ampacity assessment allows for all conditions of operation. If no allowance is made for the LF, then in actual overload or undervoltage conditions, a severe cable overheating problem could easily occur. To entirely dismiss load factor corrections is inconsistent with accepted industry practice and is inappropriate as a general ampacity practice. However, in this specific case we are dealing with life to date cable aging assessments for fire barriers that are being removed. Hence, SNL does consider it appropriate to include some allowances for the likely nature of the life-to-date operation. In our assessments of the cables impacted by this assumption, SNL has considered the actual "LF margin" that is available, and the adequacy of that margin to ensure that premature aging has not been realized. In all cases SNL found this margin to be adequate. However, it should be recognized that SNL's evaluation criteria was somewhat different, and more stringent, than that applied by the licensee.

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[1] See for example the top of page 6 of the licensee submittal.

As a final note, the licensee discussions have occasionally cited that a given cable is not an Appendix R cable, and hence, "the adequacy of the cable ampacity is not a concern from an Appendix R standpoint." SNL has not credited this argument in its review. In particular, SNL is unaware of any specific criteria that ampacity need only be considered for identified plant Appendix R safe shutdown systems. Rather, it has been SNL's assumption that ampacity derating assessments are required for all cables impacted by a fire barrier cladding, regardless of their safety significance. Fortunately, in all such cases the licensee has provided alternate arguments for acceptability that are more reasoned and can be credited. No specific actions on this point have been recommended.

2.2 Unit 1 Cable Assessments

The licensee has provided ampacity reassessments for 13 cable trays in Unit 1. The results have been provided in the form of 13 individual tables, one for each tray. The tables identify each of the cables in each tray, cite the characteristics of the tray and fire barrier, and provides information on the actual ampacity loads and maximum allowable ampacity loads for each cable. An initial assessment of the acceptability is made by comparing the in-plant service load to the maximum allowable ampacity load. It is important to note that this initial assessment uniformly includes a load factor (LF) of 1.25 for all cables.

SNL reviewed the information provided in the tables, and found no specific discrepancies. SNL was not able to fully verify the cited baseline ampacity limits because the cable tray size (in particular the available fill depth) was not specified. However, in our previous reviews SNL was able to verify a range of licensee baseline cable ampacity calculations, and no discrepancies in those earlier efforts were identified. Hence, no specific adverse findings in this regard have been made.

The initial STP assessments identified a total of 13 Unit 1 cables that did not pass this initial screening assessment. (The fact that 13 cables fail the initial ampacity screening and that 13 trays were under analysis is coincidental. Most cables appear in more than one tray, and several trays have more than a single cable that does not pass the ampacity screening.) For each of these 13 cables a supplemental discussion is provided. In each case the licensee has concluded that no excessive premature aging impact has been realized by the cables. SNL has reviewed each of these individual cable assessments for acceptability. SNL's findings are documented in the sub-sections that follow.

2.2.1 Cable B1S1ALC1LC

This cable is cited as an MOV power cable with an intermittent load. On the basis of the intermittent load the licensee concludes that "no premature aging concern exists."

SNL finds that this assessment is acceptable. In particular, the cited ampacity load of 44 A, which includes a 1.25 LF, is only nominally greater than the 41 A allowable continuos load. Given the intermittent nature of the load, ampacity driven heating is not a serious concern for this or other MOV cables.

2.2.2 Cable C1CHABC3LA

The most severe ampacity limit for this cable is 28A. The actual cable load is 25A, but when a LF of 1.25 is applied the service load (31A) exceeds the ampacity limit. The licensee concluded that the 1.25 LF is not appropriate for the types of control devices serviced by the cable, and instead cites that a 1.0 LF should be applied. Comparison of the 25A actual load to the 28A limit indicates acceptability, and the licensee therefore concludes that "no premature aging concern exists."

SNL finds that this assessment is acceptable. Relaxation of the conservative 1.25 LF is justified in this case given the nature of the components served, control components.

2.2.3 Cable C1CHABC3LB

The analysis of this cable is identical to that described in 2.2.2 above (relaxation of LF for control components). SNL finds that this assessment is acceptable.

2.2.4 Cable C1SIAMC1LC

The analysis of this cable is identical to that described in 2.2.1 above (MOV case). SNL finds that this assessment is acceptable.

2.2.5 Cable N1DBATC3SAA

This cable was apparently mis-identified in the original licensee analyses, and is discussed only in this context. It is cited as carrying only a very minor ampacity load, 3.5 A versus an ampacity limit of 39 A, and is clearly acceptable. SNL finds that this assessment is acceptable.

2.2.6 Cable N1DBATC3SAB

The discussion of this cable is virtually identical to that described in 2.2.5 above. SNL finds that this assessment is acceptable.

2.2.7 Cable N1HCAUC1HD

This cable services a resistive heating element. Hence, the licensee relaxes the LF from 1.25 to 1.00. On this basis, the service load is within the most severe cable tray ampacity limit for this cable.

SNL finds that this assessment is acceptable. In particular, resistive loads are not subject to under-voltage or start-up current overloads; hence, application of a 1.0 LF is appropriate.

2.2.8 Cable N1HFADC1HA

The analysis of this cable is virtually identical to that described in 2.2.7 above (relaxation of LF for resistive loads with some margin available). SNL finds that this assessment is acceptable.

2.2.9 Cable N1HFADC1HB

The analysis of this cable is virtually identical to that described in 2.2.7 above (relaxation of LF for resistive loads with some margin available). SNL finds that this assessment is acceptable.

2.2.10 Cable N1HMAKC1HB

The initial analysis of this cable is similar to that described in 2.2.7 above (relaxation of LF for resistive loads). However, in this case even assuming a 1.0 LF the cable service load still exceeds the worst-case ampacity limit by about 5%. The licensee argues that:

- this is "an intermittent or semi-intermittent load since it is used to heat air as necessary, particularly when considering the regional climatological characteristics at the South Texas Project,"
- the fire barrier is to be removed (hence, only potential life-to-date operation is of potential concern), and
- this is not an Appendix R system or cable (the argument is not credited by SNL as discussed in Section 2.1 above).

The licensee concludes on this basis that "the subject cable is deemed adequate for the installation and operating conditions."

This case is not as clear-cut as many of the other cases considered, and requires some special consideration. The fact that the cable serves a resistive load does justify relaxation of the LF. However, the cable is still nominally overloaded. SNL also notes that the cable trays housing this cable contain numerous relatively heavily loaded power cables so that diversity should not be credited. Hence, during actual operation the cable was likely operating at a temperature that exceeded its nominal rating.

SNL finds that there are two important mitigating factors in this case: (1) this is a seasonal heating circuit that has only been operated sporadically (apparently only during rare periods of extended cold weather), and (2) the fire barrier system is to be removed. In this case, the cable has been subjected to a 5% overload condition during peak operation. This would correspond to an estimated cable temperature of about 95°C compared to the normal condition of 90°C.[2] A rough "rule of thumb" states that an increase of 10°C will double the aging rate of a typical cable. Hence, during operation this cable was subject to aging at significantly less than 2 times the normal aging rate. Given the nature of the load, a winter heating load only, the cable can certainly be assumed to have operated for less than one-half of its overall lifetime (probably less than 10% of its lifetime in reality).

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[2]Based on IPCEA P-45-426 temperature correction factor equation 5a.

Hence, it is reasonable to conclude that this cable has experienced far less thermal aging than it would have if it had operated continuously at its full rated ampacity limit.

On this basis, SNL finds that the licensee assessment is acceptable. One can conclude that the operating experience of this cable has not resulted in any adverse aging impact. Removal of the fire barrier system will render moot any concerns for the future operation of this service load as the ADF for the fire barrier will no longer apply.

2.2.11 Cable N1KMAVC3SA

The analysis of this cable is virtually identical to that described in 2.2.7 above (relaxation of LF for resistive loads with some margin available). SNL finds that this assessment is acceptable.

2.2.12 Cable N1PWAVC2SB

The analysis of this cable is quite similar to that of the cable described in 2.2.10 above, although it is not clear wether or not this is a seasonal load. The cable is a resistive water heater load cable that remains nominally overloaded even when a LF of 1.0 is applied. In this case the overload is about 11%. At this level of overload, the cables operating temperature when energized was likely about 101°C, or about 11°C above its nominal rated temperature. Hence, this cable was likely subject to aging at about twice the normal rate during its actual operation.

It is unclear how often this cable was actually in operation. This is apparently not a seasonal load. However, given that this is a water heater load, it appears reasonable to assume that the cable has been energized for no more than one-half its total lifetime. Hence, it is reasonable to conclude that this cable has experienced aging that is no more severe than would have been experienced if the cable had been operated at its full rated current for its entire lifetime to date. Further, the licensee cites that the fire barrier will be removed. On this basis, SNL finds that the licensee assessment is acceptable.

2.2.13 Cable N1CVBCC1HA

This cable services a 75HP pump; hence, it is subject to some potential for overload due to start-up surges or under-voltage operation. The licensee analysis demonstrated a margin of 15% in comparison to the nominal service load. This would correspond to a nominal available LF of 1.15 versus the 1.25 value used in the screening assessment.

The fire barrier in question will be removed, hence, future operating conditions are not of concern, only the aging impact for the life-to-date operation. It is unlikely that any extended periods of operation at overload conditions would have been experienced by this cable in its life-to-date operations. Indeed, the available 15% margin is sufficient to allow for any occasional periods of modest overload operation that may have been experienced by this cable. It appears quite reasonable to conclude that this cable has not experienced any significant acceleration of its normal aging process. On this basis, SNL finds the licensee assessment to be acceptable.

2.3 Unit 2 Cable Assessments

The assessments for Unit 2 were essentially identical to those for Unit 1 as described in Section 2.2 above, and SNL has reviewed these assessments to essentially the same level of detail. A total of 17 cables were identified as nominally overloaded for Unit 2. The following subsections discuss the assessments for each of these 17 cables.

2.3.1 Cable B2SIALC1LC

The assessment of this cable is essentially identical to that discussed in Section 2.2.1 above (MOV case). SNL finds that this assessment is acceptable.

2.3.2 Cable C2VF01C3SS

The assessment of this cable is essentially identical to that discussed in Section 2.2.2 above (relaxation of LF for control component service loads with some margin). SNL finds that this assessment is acceptable.

2.3.3 Cable C2CHABC3LA

The assessment of this cable is essentially identical to that discussed in Section 2.2.2 above (relaxation of LF for control component service loads with some margin). SNL finds that this assessment is acceptable.

2.3.4 Cable C2CHABC3LB

The assessment of this cable is essentially identical to that discussed in Section 2.2.2 above (relaxation of LF for control component service loads with some margin). SNL finds that this assessment is acceptable.

2.3.5 Cable C2CVAMC1LA

The assessment of this cable is nominally identical to that discussed in Section 2.2.13 above (relaxation of LF for motors/pumps with some margin available). In this case, there is an available margin of about 17%. A further mitigating factor in this case is that the load in question is a boric acid transfer pump which is only subject to occasional intermittent operation. Consistent with the discussion presented in Section 2.2.13 above, SNL finds that this assessment is acceptable.

2.3.6 Cable C2HMAGC1LA

The assessment of this cable is nominally identical to that discussed in Section 2.2.13 above (relaxation of LF for motors/pumps with some margin available). In this case, there is an available margin of about 16%. Consistent with the discussion presented in Section 2.2.13 above, SNL finds that the licensee assessment of this case is acceptable.

2.3.7 Cable C2HMAGC1LB

The assessment of this cable is nominally identical to that discussed in Section 2.2.13 above (relaxation of LF for motors/pumps with some margin available). In this case, there is an available margin of about 16%. Consistent with the discussion presented in Section 2.2.13 above, SNL finds that the licensee assessment of this case is acceptable.

2.3.8 Cable C2HMAMC1LD

The assessment of this cable is nominally identical to that discussed in Section 2.2.13 above (relaxation of LF for motors/pumps with some margin available). In this case, there is an available margin of about 16%. Consistent with the discussion presented in Section 2.2.13 above, SNL finds that the licensee assessment of this case is acceptable.

2.3.9 Cable N2HMADC1HA

The assessment of this cable is nominally identical to that discussed in Section 2.2.13 above (relaxation of LF for motors/pumps with some margin available). In this case, there is a somewhat smaller available margin, about 9%. However, the load is associated with an air exhaust fan, and such fans are less likely to be subject to overload conditions than are other pumps and motors. This is because air handling fans are routinely designed with somewhat oversized motors and rarely run at their full rated power. STP has based the assumed in-service ampacity load on the rated motor output; hence, this assessment is likely conservative in comparison to the actual operating load. Given this circumstance, SNL finds that the licensee assessment of this case is acceptable.

2.3.10 Cable N2HMAKC1HB

The assessment of this cable is nominally identical to that discussed in Section 2.2.10 above (a seasonal resistance heater load that exceeds the cable rating by about 11%). In fact, in this particular case it is quite clear that the cable has likely not seen a service factor that approaches 50%. Hence, as in the prior case, SNL finds that the licensee assessment in this case is acceptable.

2.3.11 Cable N2BRAUC1HA

The assessment of this cable is nominally identical to that discussed in Section 2.2.13 above (relaxation of LF for motors/pumps with some margin available). In this case, there is an available margin of about 15%. Consistent with the discussion presented in Section 2.2.13 above, SNL finds that the licensee assessment of this case is acceptable.

2.3.12 Cable N2CVBCC1HA

The assessment of this cable is nominally identical to that discussed in Section 2.2.13 above (relaxation of LF for motors/pumps with some margin available). In this case, there is an available margin of about 18%. Consistent with the discussion presented in Section 2.2.13 above, SNL finds that the licensee assessment of this case is acceptable.

2.3.13 Cable N2HCAUC1HB

The assessment of this cable is nominally identical to that discussed in Section 2.2.13 above (relaxation of LF for motors/pumps with some margin available). In this case, there is an available margin of about 16%. Consistent with the discussion presented in Section 2.2.13 above, SNL finds that the licensee assessment of this case is acceptable.

2.3.14 Cable N2HCAUC1HC

The assessment of this cable is nominally identical to that discussed in Section 2.2.13 above (relaxation of LF for motors/pumps with some margin available). In this case, there is an available margin of about 16%. Consistent with the discussion presented in Section 2.2.13 above, SNL finds that the licensee assessment of this case is acceptable.

2.3.15 Cable N2HCAUC1HD

The assessment of this cable is quite similar to that discussed in Section 2.2.12 above (a non-seasonal resistance heater load that exceeds the cable ampacity limit). However, in this case the nominal overload is less than 1%. Given the nature of the load as non-continuous and the very small nominal overload, it is unlikely that this cable has been subject to excessive aging. Further, the licensee states that the fire barrier will be removed. Hence, SNL finds that the licensee assessment in this case is acceptable.

2.3.16 Cable N2HFADC1HA

This case is nominally similar to that discussed in Section 2.2.10 above (a seasonal building heating load that nominally exceeds the cable ampacity limit). In this case, the nominal overload is about 4%. SNL recommends that the licensee assessment is acceptable.

2.3.17 Cable N2HFADC1HB

This case is nominally similar to that discussed in Section 2.2.10 above (a seasonal building heating load that nominally exceeds the cable ampacity limit), and is identical to that discussed in 2.3.16 above. SNL recommends that the licensee assessment is acceptable.

3.0 SUMMARY OF FINDINGS AND RECOMMENDATIONS

SNL finds that the licensee has resolved all of the outstanding technical items identified in SNL's previous reviews. In particular, the licensee has abandoned the Watts-per-foot methodology in favor of a more conventional margins approach. This was the most significant point of concern raised by SNL. Abandoning of the Watts-per-foot approach fully addresses those concerns in the context of the STP assessments.

The licensee has provided specific ampacity assessments for the 24 cable trays that were previously accepted on the basis of the Watts-per-foot method. Screening ampacity margins assessments identified a total of 30 individual cables requiring further consideration. Individual assessments were provided for each of these 30 cables. SNL found that all of these assessments were acceptable.

SNL did take exception to two aspects of the licensee case assessments as follows:

- The licensee stated that "typical industry practice does not include consideration of undervoltage or overload conditions in ampacity assessments." As a result, for several motor and pump cases, the licensee resolved a nominal ampacity overload by relaxing the LF from 1.25 to 1.0. SNL does not concur with this assumption. Indeed, load factors have no other purpose than to ensure that the ampacity assessment allows for all conditions of operation and they are considered in typical industry practice. Ultimately, this finding had no impact on the final SNL assessment of acceptability. In all of the impacted cases SNL found that the available "LF margin" was adequate, given that the fire barriers are being removed, to ensure that no adverse life-to-date aging has been realized.

- The licensee discussions occasionally cited that a given cable is not an Appendix R cable; hence, "the adequacy of the cable ampacity is not a concern from an Appendix R standpoint." SNL has not credited this argument in its review. It is SNL's assumption that ampacity should be considered for all fire barrier clad circuits, not just the plant Appendix R safe shutdown systems. Fortunately, in all such cases the licensee has provided alternate arguments for acceptability that are more reasoned and can be credited.

Ultimately these two points had no impact on SNL's final assessment findings. In all cases there was sufficient information provided by the licensee to conclude that no adverse aging impact had been experienced by the cables independent of these two points. Hence, no specific actions on either point has been recommended.

It should be noted that SNL has recommended that certain cables that have been operated at overload conditions in the past will remain acceptable for future operation. This assessment has been based on two points in particular. First, the licensee has stated that the subject fire barriers will be removed and this will relieve any potential overload problems during future operations. Second, an assessment was made by SNL of the worst-case life impact of the cables for life-to-date operation at the cited overload

conditions, and no cases were identified for which a more severe than normal aging impact was likely.

On this basis, SNL finds that the licensee has adequately addressed the ampacity derating concerns as applicable to STP. No further actions on the part of the USNRC in this regard are recommended.