A Review of the Clinton Power Station Fire Barrier Ampacity Assessments

A Letter Report to the USNRC

Revision 0

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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 documents the results of a SNL review of a set of submittals from the Clinton Power Station (CPS) nuclear plant. These submittals deal with the assessment of ampacity loads for cable trays and conduits protected by Thermo-Lag 330-1 fire barriers. In particular, the submittals document two complementary analyses performed by CPS to support an assessment of actual in-plant cable ampacities. These documents were submitted by the utility in response to USNRC Generic Letter 92-08. This work was performed as Task Order 8, Subtask 5 of USNRC JCN J2017.

1.0 INTRODUCTION

1.1 Objective

In response to USNRC Generic Letter 92-08, the Clinton Power Station (CPS) nuclear plant provided documentation of the utility position regarding ampacity derating factors associated with its installed Thermo-Lag 330-1 fire barrier systems. The objective of this subtask was to review and evaluate these utility submittals. In particular, the submittals included documentation of analyses intended to demonstrate that the cables at CPS are operating within acceptable ampacity limits. The relevant documents reviewed are:

- Letter, November 3, 1995, J. G. Cook, Illinois Power/CPS to the USNRC Document Control Desk, item U-602512 with attachments as follows:
    - Attachment 1: Utility sworn deposition of 11/3/95.
    - Attachment 2: "Executive Summary of Illinois Power's (IP's) Position Regarding Thermo-Lag".
    - Attachment 3: "Clinton Power Station Docket No. 50-461 Follow-Up to Request for Additional Information Regarding Generic Letter 92-08 ...."
    - Attachment 4: "Followup Request for Additional Information (RAI) Regarding Generic Letter 92-08 ..."
    - Attachment 5: "50.59 Thermo-Lag Safety Evaluations"
    - Attachment 6: "Fire Endurance Calculations"

SNL was requested to review the ampacity derating aspects of these submittals under the terms of the general technical support contract JCN J-2017, Task Order 8, Subtask 5. This letter report documents the initial results of this review. The intent of this review was to provide support to the USNRC in determining the adequacy of the utility submittals, and in the potential development of a supplemental RAI. Based on the results of this review, it is recommended that such a request be pursued.

It is important to note that, consistent with the statement of work for this effort, the SNL review has been limited to those portions of the utility submittals directly related to the issue of ampacity derating only. The utility submittals include documentation of other aspects of the Thermo-Lag issue including quality control and fire performance issues. SNL has not reviewed these portions of the documents.

1.2 Overview of the Utility Ampacity Derating Approach

The consideration of ampacity derating factors for fire barriers at CPS, as currently documented by the utility in the above referenced submittals, is based on a primarily

analytical approach to the problem. The bulk of the assessment is based on fairly simple, and apparently conservative, calculations which begin with an assessment of the nominal baseline ampacity limits for the cables installed at CPS, and then compares those limits to the actual in-plant cable loads. The result is an assessment of the available margin in cable ampacity. If the available margin is sufficient to bound the ampacity derating impact of the fire barrier, the utility can appropriately conclude that the ampacity loads are acceptable.

The second part of the utility analysis involves a supplemental analysis in which the results of a single USNRC/SNL manufacturer ampacity derating replication test [1,2] are compared to in-plant ampacity loads at CSP. This calculation involves comparison of the "heat intensity" from the test to that of the in-plant cables, and to two treatments of the ICEA tables. As will be shown below, this method is, in effect, comparing the actual ampacity limits from the derating test to the in-plant ampacity loads. For a variety of reasons, SNL finds that this is not an appropriate basis for analysis and recommends that this particular aspect of the analysis not be credited.

1.3 Organization of Report

This review has focussed on a technical review of the utility documentation and the utility analysis approach. Section 2 of this report provides a more thorough discussion of the utility approach to ampacity assessments. Section 3 provides a technical review of the actual calculations documented in the utility submittals. Section 4 summarizes the SNL findings and provides recommendations regarding the need for additional information to support the final assessment of the utility analyses.

2.0 OVERVIEW OF THE UTILITY APPROACH

2.1 Overview

The utility submittals are quite involved, and document assessments for a variety of barrier issues. Those portions of the submittal which document the ampacity assessments actually represent only a small fraction of the overall documentation. It is these sections which have been reviewed here.

The utility ampacity analysis is performed in two parts using two different methods of analysis. These parts/methods can be summarized as follows:

> Part 1 / Method 1: The utility assesses the baseline ampacity limits of its installed cables using the tabulated ampacity values from ICEA P-54-440 for cables in cable trays [3]. These values are then compared to the actual in-plant ampacity loads, and an available ampacity margin is determined. If this margin is sufficient to bound the ampacity derating impact of its installed fire barriers, then the utility appropriately concludes that the in-plant ampacity loads are acceptable.
>
> Part 2 / Method 2: The utility compares the measured performance of the cables in a single USNRC/SNL manufacturer replication test to the in-plant cable ampacity loads. In this analysis, the utility has calculated the "heat intensity" of the tested cables and compares this to the "heat intensity" of the in-plant cables, and the "heat intensity" associated with two treatments of the ICEA tables. It is typically concluded by the utility that "since the heat intensity of the cables with the smallest margin is lower than the heat intensity of the derated cables of IEIN 94-22, all of the cables within the Thermo-Lag are acceptable." As discussed further below, this part of the analysis is, in effect, comparing the actual measured ampacity limits of the tested cables to the ampacity loads of the in-plant cables. A number of technical concerns are identified related to this part of the analysis, and overall, the basis of this part of the analysis is considered questionable.

Each of these two methods will be reviewed in detail in the sections which follow. There are several factors which will significantly influence the utility analyses, and the final assessment of the adequacy of the utility submittals. The most significant of these factors are as follows:

- The utility states that all of its cables are rated for an operating temperature of 90°C. This is a typical value for modern insulation types used in the nuclear industry. However, the utility has not stated the ambient temperature assumed in its baseline ampacity calculations. Based on the values cited, it would appear that an ambient of 40°C has been assumed for all areas. The utility should explicitly identify its assumptions in this regard.

- Design practice at CPS included the segregation of control, instrument, and power cables into separate cable trays. Hence, for the power cables of concern

to the ampacity analysis, there should be no instrument or control cables collocated in the same tray.

- In its original plant design, the utility sized its cables assuming that the cables would be installed in cable trays with a depth of fill of 2". The utility notes several cases in which the actual depth of fill is significantly lower than this nominal value. Since the ampacity limits of a cable in a cable tray will decrease with increasing depth of fill, this design practice should provide an additional source of ampacity margin at CPS, provided that the actual depth of fill does not exceed 2" for any power cable tray.

- The utility analysis has not considered control or instrumentation cables as a thermal source in its ampacity calculations. This is consistent with general practice and is considered appropriate for the assessments at CPS, especially given the segregation of power cables from other cable types.

- Ampacity loads for cables are apparently based on actual in-plant service loads using the rated power of connected devices (as compared to breaker settings e.g.). This is generally considered an appropriate practice although the utility will derive no conservatism from this treatment.

2.2 The CPS Margins Analysis

In Attachment 5 of the utility submittal, as identified in Section 1.1 above, the utility has documented its assessment of the available ampacity margin in power cables protected by Thermo-Lag fire barrier systems. This assessment is based on a simple comparison of the actual in-plant ampacity loads to tabulated ampacity limits from the ICEA ampacity tables. The objective of this type of analysis is to show that the available margin is sufficient to bound the potential impact of the fire barrier system.

In general, the utility calculations appear to have been performed in an appropriate manner. However, because only very limited information is provided regarding the physical characteristics of the various cables, no information of the ampacity correction implemented by the utility (such as for ambient temperature or cable diameter), and no ambient temperature has been specified, SNL has been unable to verify the base ampacity limits cited by the utility. A check of the values did reveal nominal consistency with the ICEA tables, SNL was unable to obtain one-to-one correspondence for many of the CPS ampacity values. In order to complete the review the base ampacity values assumed by the utility should be verified. It is expected that the utility supporting calculations which are cited in the study would provide the needed information, and hence, these supporting documents should be obtained and reviewed. (Section 4.4 identified the four specific utility documents which should be obtained for review.)

The overall ampacity margins approach taken by the utility is generally an acceptable means of resolving the ampacity derating questions. In fact, this type of margins analysis is potentially the most simple and straight-forward approach to the assessment of fire barrier ampacity derating issues. That is, provided that the utility can

demonstrate adequate margin in its cable ampacities to cover any anticipated fire barrier impact, then they could correctly assume that their ampacity values are acceptable. However, the acceptability of this approach in the final analysis rests on the comparison of available ampacity margins to appropriate estimates of the fire barrier derating impact. As discussed further in Section 2.3 below, it is this aspect of the margins analysis which is considered lacking in the utility submittal. The final assessments provided by CPS are currently based on the comparison of in-plant cable loads to tested ampacity limits. This approach as applied by CPS is considered technically flawed and, in addition, an inappropriate data set has been used as the basis for comparison. Using an alternate basis for the final assessment of the adequacy of its available ampacity margins, it is expected that the utility could, with relatively little additional effort, demonstrate the acceptability of its current cable loading factors (for example, comparing margins directly to ampacity derating factors from either the TU or TVA tests).

2.3 The CPS Analysis of IEIN 94-22/SAND94-0146

Upon completion of the initial margins analysis, no further consideration is given to cables that are shown to have an available ampacity margin of 50% or more. However, for all of the other cables, the final assessments of the acceptability of ampacity load factors are based on a comparison of the in-plant cable loads to those measured in the USNRC/SNL manufacturer reproduction test as documented in USNRC IE Information Notice (IEIN) 94-22 and SAND94-0146. This final comparison is based on an assessment of the "heat intensity" for the test, for the actual in-plant cable loads, and for two treatments of the ICEA cable tray ampacity values.

While the utility compares only the "heat intensity" values, it is relatively easy to show that, in effect, CPS is comparing the actual in-plant cable loads to the measured ampacity limits in the clad test of the USNRC/SNL test set. First, note that the "heat intensity" is defined as the rate of heat generation per unit cross section of the cable, per unit length of cable tray or conduit, or more simply, the volumetric rate of heat generation in the cables (heat rate/unit volume).

The concept of heat intensity derives directly from the original work of Stolpe [4]. He found that a rough correlation existed between the ampacity limits of a given cable and the "heat intensity" of the cable mass which could largely account for differences in cable size. In his thermal model, the cable mass was treated as a single homogeneous region, and the "heat intensity" was used to characterize the rate of heat generation in that cable mass. As a result, Stolpe's work and the ICEA tables can be viewed with equal validity as establishing limits on the allowable "heat intensity" or limits on cable ampacities. Because of the nature of Stolpe's thermal model in particular, the terms are directly related in a very real technical sense. In effect, the "heat intensity" factor became Stolpe's means of normalizing his test and analysis results.

However, it must also be recognized that this was an expedient simplification of a relatively complex thermal geometry implemented by Stolpe in order to make his thermal calculations possible. The assumption that "heat intensity" is the overriding

"In general, it must be noted that the TSI test protocol was quite poor. The greatest inherent difficulty derives from the complex nature of the test article which uses three different cable circuits in a single test specimen. Further complications are introduced because of the 'U'-shaped cable tray." (pg. 64)

"(T)he complex configuration used by TSI, and hence by SNL also, introduces quite complicated radiative exchange behaviors between the upper and lower legs of the tray which are inconsistent from cable to cable. It is suspected that this had a significant impact on the results." (pg. 65)

"It should be noted that because of these experimental shortcomings, SNL does not consider the ampacity derating test results reported here to represent a reliable assessment of the ampacity derating factors which would be encountered in actual applications. It is recommended that ampacity derating assessments be based on alternative tests utilizing test articles which are geometrically more simplistic ..., and for which a less inter-dependent temperature control is possible ..." (pg. 61)

The intent of these statements is clear. The USNRC/SNL test suffered from certain inherent shortcomings. Because the test was meant to reproduce one of the original manufacturer tests, these shortcomings could not be overcome without compromising the objective of the tests. The use of this test as the basis for the assessment of actual in-plant installations is inappropriate.

Beyond this fundamental shortcoming in the utility analysis methodology, there are additional technical concerns related to the general methodology of analysis employed by the utility. That is, even if the utility were to apply the same methodology to an alternate data set, there are additional technical concerns which must be resolved.

First, the utility chose to compare the USNRC/SNL test values to the ICEA 1.5" depth of fill. This is because the depth of fill calculated by CPS for the USNRC/SNL test was 1.41" and the closest tabulated values were for the 1.5" depth of fill. Further comparisons are then made to the CPS original design limits which were based on a 2" depth of fill, and to the actual in-plant values for the particular cable under consideration (where depth of fill might vary significantly). This is a inappropriate. Recall that in the open tray ampacity tables of ICEA P-54-440 the allowable "heat intensity" varies with the depth of fill. That is, as the depth of fill increases, the limiting "heat intensity" decreases. This result derives directly from the work of Stolpe.

Given this, it is not at all surprising that the values of heat intensity vary from case to case. Nor is it surprising that the USNRC/SNL values exceed the ICEA tabulated values which in turn exceed the plant design values. This is because the depth of fill for the SNL tests was the lowest, and that assumed in the original plant design was the highest. Correction for depth of fill should fully reconcile any differences between the ICEA table values at 1.5" and the CPS original design values because the original CPS design was based on the ICEA tables. A similar correction would not be expected to fully account for differences between the test data and the other values because the

thermal parameter of interest does introduce a certain error, in particular because the thermal conductivity and thermal diffusivity of the cable mass will vary with cable size (due to changes in the insulation-to-copper mass and volume ratios). Stolpe's work provides only a very minimal examination of this error. However, it was at least partly in recognition of this limitation that Stolpe incorporated a certain degree of conservatism into his work.

In the CPS analysis, the "heat intensity" is calculated in a very straight-forward manner. The ampacity-driven heating rate per foot of cable is simply divided by the cross-sectional area of the cable itself:

$$Heat\ Intensity = \left(I^2 \times \frac{R}{L}\right) \times \frac{1}{A_{cable}}$$

Given this formula, it can now be seen that the relationship between "heat intensity" and ampacity is quite direct. In a sense, the "heat intensity" can be viewed as the cable ampacity normalized against the cable size.

The utility analysis considers four cases for which "heat intensity" is calculated:

Case 1: The USNRC/SNL ampacity test set; baseline and clad measured ampacity values.

Case 2: The ICEA P-54-440 cable tray ampacity limits for a 1.5" depth of fill; baseline ampacity and derated by 32%.

Case 3: CPS design approach for in-plant cables; the original design ampacity and that value derated by 32%. This case should correspond to the ICEA tables with a depth of fill of 2" as discussed further below.

Case 4: Individual in-plant cables with a margin of less than 50%; nominal ICEA baseline ampacity and actual in-plant ampacity load.

The utility typically concludes that "since the heat intensity of the cables with the smallest margin is lower than the heat intensity of the derated cables of IEIN 94-22, all of the cables within the Thermo-Lag are acceptable." There are several points of concern regarding this analysis.

First, the use of the USNRC/SNL manufacturer replication test for the assessment of in-plant ampacity factors is considered inappropriate. The following quotations are taken directly from the test report, SAND94-0146 (a document cited by the utility):

> "It must be recognized that the configuration used in the original manufacturer's tests, and hence by SNL, is quite poor from an experimental control standpoint." ... "Achieving a stable and representative final ampacity conditions is unnecessarily complicated ..." (pg. 60)

tests were never intended to reproduce the conditions of Stolpe's test, and hence, the ICEA tables. Because each case is related to a different depth of fill, the values cannot be "directly compared" as is stated by the utility. The utility is comparing "apples and oranges" in this analysis. A direct comparison would, at the least, require that all of the values be placed on a common basis for depth of fill. The ICEA tables provide for a correction for depth of fill variations and, at the least, this correction should be applied to all cases before any comparisons are attempted. These values simply cannot be compared until they are presented on a consistent depth of fill basis.

The second point of technical concern regarding this aspect of the utility analysis is that, in effect, CPS is comparing the actual ampacity limits measured in a particular ampacity derating test to the ampacity tables, the original CPS design practice, and in-plant cable ampacity loads. This is generally contrary to the intent of the ampacity derating test approach. The ampacity derating test measures the relative change in current carrying capacity due to the fire barrier system for a relatively "generic" cable configuration. It is assumed that the relative impact on ampacity limits would not be significantly affected by the various physical parameters of the cable system, so long as nominal similarity is maintained (e.g., don't attempt to apply tray results to conduits). It is then intended that the derating values which characterize this relative impact be applied to the nominal tabulated ampacities to ensure that cables are operating within acceptable limits.

Derating tests are not intended to measure absolute ampacity limits, either in a clad or baseline condition. The utility is, in effect, comparing the absolute measured ampacities to in-plant cable loads. Hence, the clad ampacity test becomes a test of the absolute ampacity limits of the cables rather than a test of the relative impact of the fire barrier. This represents a fundamental violation of the intent of the ampacity derating test approach. This practice also raises several points which must be addressed:

- The CPS assessment practice of comparing measured clad test "heat intensity" values to those of in-plant cables will remove any potential conservatism which derives from the ampacity tables. The original ampacity tables are generally assumed to contain some degree of conservatism. However, the extent of this conservatism has not been fully demonstrated, nor has it been demonstrated that conservatism exists for all cable sizes and fill conditions. Hence, for some configurations this practice could result in the removal of conservatism which does not, in fact, exist. While the removal of conservatism may be acceptable, it must be clearly recognized that this is what is taking place, and the basis for removing this conservatism must be very well documented and established. Use of the results of any one ampacity derating test, and in particular the USNRC/SNL manufacturer replication test, is not an appropriate basis for such an assessment. The practice of removing conservatism which derives from the ampacity tables should, at the least, be given much more thorough consideration before being accepted as a design practice.

- In conjunction with the comment immediately above, the CPS practice can be viewed as analogous to a practice which was once proposed as a part of the IEEE P848 ampacity derating test standard. In an early draft of that standard the ampacity derating factor was to be calculated by comparing the clad test ampacity to the ampacity obtained from the ICEA tables (rather than to that obtained in the baseline experiment). This practice removed the conservatism from the ICEA tables, and in effect, meant that the clad ampacity test was, in fact, a test of actual ampacity limits for a protected cable. This practice was considered contrary to the intent of ampacity derating. Based largely on USNRC objections to this practice, it was removed from later versions of the standard. Ampacity derating factors must now be based on comparison of clad and baseline test results. In much the same way, because the utility is comparing the "heat intensity" from a clad ampacity test to its in-plant "heat intensity" it is effectively turning the clad ampacity test into a test of actual ampacity limits under protected conditions.

- The utility practice assumes that the "heat intensity" factor is the correct way to extrapolate the results of the ampacity derating test to actual in-plant applications, and for the extrapolation from one cable size to another. The technical basis for this assumption must be established beyond the original reasoning of Stolpe because the method goes well beyond Stolpe's intended objectives. For Stolpe, the "heat intensity" was simply a convenient way to describe his methodology for extrapolating his test results to other untested configurations. Stolpe's original work recognized that conservatisms had been incorporated into both his tests and thermal analysis. While the "heat intensity" assumptions were clearly imperfect (see discussion above), they were assumed to introduce errors which remained within the bounds of his other conservatisms. Because CPS is now, in effect, using the "heat intensity" from a clad ampacity test as the ultimate measure of <u>absolute</u> cable ampacity limits, the "heat intensity" extrapolation should be thoroughly validated for the full range of cables and loading conditions being considered in the analysis. While this approach may well have potential merit, its validation would be a non-trivial undertaking. The utility submittal has provided an inadequate technical basis for its application at CPS.

One final point of concern is that the utility analyses of both the ICEA tables and the original CPS design is based on a assumed derating impact of 32% for all barrier systems, including both 1-hour and 3-hour cable tray fire barriers and conduits. The basis for this value is apparently CPS Calculation 19-AI-8. This calculation is not provided in the utility submittal, and should be reviewed to assess the appropriateness of this assumption. Alternatively, the utility should provide a reassessment based on the use of ampacity derating factors derived from experiments. This value may not bound the barriers at CPS, particularly including the nominal 3-hour cable tray fire barriers.

Overall, the utility comparisons of the in-plant "heat intensities" to the USNRC/SNL manufacturer replication test is considered an inappropriate basis for the final evaluation of cable ampacity limits at CPS. In addition to the overall limitations to

the USNRC/SNL test, which are clearly identified in the test report, there are a number of points of technical concern which must also be addressed even if the method were to be applied to an alternate source of ampacity data. It is recommended that this aspect of the utility analysis not be credited. An alternate basis for the assessment of the acceptability of in-plant cable loads is needed.

While the utility may, of course, attempt to address the concerns identified in this review, it should be recognized that this approach to analysis represents a fundamental departure from currently accepted ampacity design approaches. As such, the overall methodology, once the identified concerns are addressed, should be subjected to a very rigorous technical review, and the methodology should be validated by comparison to actual test results for a full range of application conditions. With sufficient development and validation, the methodology may provide a new means for assessing ampacity limits. However, because it is a fundamental departure from currently accepted methods, it is recommended that a very high burden of review and validation be placed on the method before it is accepted as a design practice.

3.0 REVIEW OF UTILITY ANALYSES

3.1 Overview

The utility has provided analyses for the cable installations in five specific fire zones or areas (A-1a, C-2, CB-1e, CB-1f, and D-8). These calculations will be reviewed individually in the following sections. Given the concerns cited above regarding the utility analysis of the USNRC/SNL ampacity test reported in IEIN 94-22, SNL has not given significant additional attention to the individual fire area calculations based on this approach. Rather, the SNL review has focussed instead on the utility margins analyses.

One factor which affects all of these individual area reviews is the fact that SNL has not been able to verify the utility calculation of the baseline ampacity values assumed by the utility. This is because the utility has not provided any information on how these values were obtained beyond citing the ICEA ampacity tables and a 2" depth of fill for design purposes. However, in applying these tables, one must know a number of factors related to the cables (outside diameter, conductor size, voltage rating, number of conductors, insulation and jacketing configuration, etc) and to the ambient environment temperature assumed in the assessment. While some of this information, in particular conductor size and number, can be obtained for many of the cables from the tables provided in the submittal, it is not possible to fully assess the appropriateness of the utility baseline ampacity values without either access to the utility supporting calculations (including any corrections made by the utility for cable diameter, ambient temperature, and cable fill) or specific and detailed example calculations representative of each of the various utility applications (e.g., trays and conduits).

Also, another aspect of the utility submittal which left considerable uncertainty was that many of the cables are identified as either "3/C, #19/22 AWG, 1KV" or as "2/C, #19/25 AWG, 600V." The use of the "#19/22 AWG" and "#19/25 AWG" is a rather unusual and unfamiliar cable sizing designation. SNL has interpreted this to imply that each conductor is comprised of 19 individual strands of either 22 or 25 AWG wire (the use of 19 individual strands to form an overall conductor is quite common in the manufacture of cables). In this case, the overall conductor for the "#19/22 AWG" would likely correspond to a 10 AWG wire, and the "#19/25 AWG" would likely correspond to a 12 AWG wire. This interpretation is generally consistent with the estimated ampacity limits for these cables (either 16 or 10 A respectively). However, the utility should clarify this point by identifying the actual overall gage of the cable conductors.

These fasts noted, SNL was able to verify that the cable ampacity values cited are in nominal agreement with the ICEA tables. That is, that the cited ampacity values are in the same nominal range of ampacity cited in the ICEA table for cables of this size. Hence, it is not expected that gross errors in the calculation of baseline ampacities have been made by the utility.

3.2 Fire Zone A-1a

Fire Zone A-1a is described as a "relatively large and open fire zone with a floor area of 2964 square feet and a height of 28.33 feet." Thermo-Lag is apparently installed on three horizontal cable trays in this area. Two of the three tray installations were intended to serve as 1-hour rated fire barriers, while the third was installed as a "fire break" to establish a 20 foot combustible free zone. It is unclear whether or not the installations are nominally similar, but it would reasonable to expect that all of the barriers were installed in a similar manner. The utility should be asked to verify this observation.

The utility ampacity assessment includes the consideration of 20 specific power cables routed in such barrier systems. The calculated ampacity margins for 17 of the 20 cables are specifically cited as "over 50%." For the remaining three cables the following results are obtained:

- Cable 1RP02C: This is a DC inverter power feed cable which has its "conductors paralleled" so that the total load per conductor is limited to 40A. The calculated allowable ampacity is 117 amps. Hence, the cable appears to also have margin in excess of 50%, although this is not specifically cited by the utility. The utility also notes that this is based on the nominal rated load of the inverter rather than on the lower existing load.

- Cable 1RD31B: This is a 3/C 6AWG cable which is identified as having a nominal base margin of 22%. However, the utility cites that this value is based on an assumed tray fill depth of 2" when in reality the tray fill is less than 1". Using a 1" depth of fill to calculate the baseline ampacity, the utility calculates an available margin 49%. This is considered an acceptable relaxation of one source of initial conservatism in the utility analysis.

- Cable 1VD02A: This is a 3/C 4/0AWG cable. The nominal margin initially calculated for this cable was 31.4%. However, similar to the arguments for Cable 1RD31B, the utility reduces the conservatism in the initial calculation by using the actual cable tray depth of fill. As a result, a modified margin of 37.7% is calculated.

Based on these estimates, the minimum available margin for the CPS cables in this area is 37.7%. Since all of the cable trays are protected by nominal 1-hour fire barriers, it is likely that a comparison of the utility margin to test results now available from TVA and TU would reveal this to be an acceptable margin. However, the utility has not included such a comparison in its assessment. As noted above, the utility comparisons to the values in IEIN 94-22 is considered inappropriate.

3.3 Fire Area C-2

Fire Area C-2 is identified as an area in the containment building but outside of the drywell. The submittal states that the "Thermo-Lag installations in fire zone C2 consists of a one hour fire wrap on tray and conduits." There are apparently three

protected cable trays, and the utility analysis includes assessments for 30 cables in these cable trays. The utility identifies five specific clad conduits, each of which contains from one to 12 individual cables, each cable having two or three conductors each.

All of the cables analyzed by the utility were found to have nominal ampacity margins of greater than 50% with a single exception:

- Cable 1SC02B: This is a 3/C 2AWG cable in a cable tray installation. The nominal initial margin for this cable was found to be 23.75%. However, the utility notes that this cable "is only energized intermittently since it feeds the motor for the 1C41-P001B pump (Standby Liquid Control). During normal plant operations, this pump is only run for short periods to perform surveillance. In an accident scenario that required the pump to inject into the vessel, the maximum run time would be less than two hours. Therefore this cable is not impacted by derating."

  While SNL disagrees with the statement that "this cable is not impacted by derating" because all cables may be nominally impacted by derating, overall the utility arguments are considered an appropriate approach to cable ampacity assessment in this case. Of most significance is the fact that the utility has considered the maximum possible run time for this cable, less than two hours. The time required for a cable to reach its equilibrium temperature is much longer than the 2-hour maximum run time cited by the utility, and no credit has been taken by the utility for factors such as load diversity. Given that the cable does have significant margin available, the utility approach in this case is considered appropriate. However, the final assessment should include the consideration of appropriate experimental ampacity derating results.

For this fire area, all of the cables were demonstrated to have significant margin available. Hence, it appears that all of the cables within this fire area are operating within acceptable ampacity limits. The only real uncertainty for this fire area is the appropriateness of the baseline cable ampacity values which could not be verified as discussed above.

3.4 Fire Zone CB-1e

Fire Zone CB-1e is a "general access corridor ... and secondary floor." There are three cable trays protected by a nominal 1 hour Thermo-Lag fire barrier system. The utility ampacity analysis includes the assessment of ampacity limits for 69 individual cables. All of the cables were found to have an ampacity margin of "over 50%" with the following four exceptions:

- Cable 1CM09K: The base analysis for this 3-conductor power cable assumed that all three conductors were loaded, and found a nominal margin of 31%. In fact, this is a single phase circuit, and the ground conductor would not normally carry any current. Using this factor the utility determines a modified margin of 43.6%. This analysis is an appropriate basis for removal of one source of analysis conservatism.

- Cables 1DG29A and 1DG30A: These two cables are cited as power cables to a diesel generator air start compressor motor and the initial utility estimate of ampacity margin was 16%. The utility states that these cables are subject only to non-continuous loads, and hence, the utility concludes that "these cables are not impacted by derating." SNL disagrees with this statement for two reasons. First, all cables are nominally impacted by ampacity derating, and all power cables should be assessed to some degree. Second, the utility should consider the maximum operation time of the compressors (see the analysis of cable 1SC02B in fire area C-2 for example), and the power cycling times if the system is subject to periodic automatic cycling. The ampacity loads should then be assessed in light of these operating conditions. In particular, if the maximum operation time is short, and the cycling time is long, in comparison to the thermal settling time of the cables, then the utility argument that the intermittent loads are not of concern would be shown to have merit. Given that some ampacity margin is available, the utility may well be able to demonstrate the acceptability of the in-plant ampacity loads, but some additional consideration is required.

- 1VD02A: This cable is a large 3/C #4/0 AWG power cable with an initial ampacity margin estimate of 31%. The utility base ampacity analysis is based on an assumed depth of fill of 2", when in fact, the cable is located in trays with a depth of fill of 1.5" or less. Correcting for the maximum depth of fill experienced by the cable, the utility calculates a modified margin of 35%. This is considered an appropriate basis of analysis which removes one known source of conservatism in the initial utility analyses.

Based on these assessments, the utility has shown that, with the exception of the two compressor cables, all of the cables in this area have an available margin of 35% or greater. Given that the fire barriers in this area are nominal 1-hour cable tray fire barrier systems, the utility can likely demonstrate the adequacy of its ampacity margins through a comparison to the ITU cable tray test results. The utility assessment of the compressor cables as non-continuous loads does require some additional justification.

3.5 Fire Zone CB-1f

Fire Zone CB-1f is a "general access and equipment area ... in the control building." Within this area there is apparently one power cable tray protected by a nominal 3-hour Thermo-Lag fire barrier system (tray P2E). The utility evaluation includes consideration of 79 individual power cables. Of these cables, all but nine are shown to have margins of "over 50%." Of the remaining nine cables, the utility provides reassessments for two:

- 1CM09K: The base analysis for this 3-conductor power cable assumed that all three conductors were loaded, and found a nominal margin of 31%. In fact, this is a single phase circuit, and the ground conductor would not normally carry any current. Using this factor the utility determines a modified margin of 43.6%. This analysis is an appropriate basis for removal of one source of analysis conservatism.

- 1LV53D: The base analysis for this 3-conductor power cable assumed that all three conductors were loaded, and found a nominal margin of 25%. In fact, this is a single phase circuit, and the ground conductor would not normally carry any current. Using this factor the utility determines a modified margin of 38.4%. This analysis is an appropriate basis for removal of one source of analysis conservatism.

The remaining 7 cables with less than 50% margin are not reassessed by the utility. the available margin for these cables ranged from 37.57% to 49.85%. Given that the fire barrier in this case is a nominal 3-hour system, these margins may, or may not, be sufficient to account for the fire barrier impact. The utility assessment has not demonstrated that these margins are acceptable for this fire area and for the installed fire barriers. Additional analysis is needed to support the final assessment of this fire area.

3.6 Fire Area D-8

Fire Area D-8 is identified as the "Division 1 diesel generator ventilation fan room and breathing air filter train A, B, C and compressor room ... in the diesel generator building." The installations of interest in the fire area are two conduits, each of which houses a single 3/C, 750 MCM, 5 KV power cable, and each of which is protected by a nominal 1-hour Thermo-Lag fire barrier system.

The calculated ampacity margin for each of the two cables is 34.16%. While SNL was unable to find any specification of the conduit size, it is likely that this margin would adequately bound the ampacity derating impact of a Thermo-Lag conduit fire barrier if the tests from TU or TVA are considered. The utility assessment for this area, while considered incomplete, can be easily completed through a simple comparison to available test results.

4.0 SUMMARY OF REVIEW FINDINGS AND RECOMMENDATIONS

4.1 Summary of Findings on Utility Margins Methodology

One of the two underlying methodologies employed by the utility for the assessment of cable ampacity factors is based on an assessment of the available ampacity margin for the cables installed at CPS. The review findings with regard to this margins analysis methodology are as follows:

- In general, the utility margins analysis approach is considered an appropriate methodology for demonstrating the adequacy of in-plant cable loads. Provided that the available margins equal or exceed the anticipated fire barrier derating impact, the utility could appropriately conclude that the cable loading values at CPS are acceptable.

- The final assessments of cable ampacity acceptability should be based on either tests which have been accepted by the USNRC and/or on well-founded, and validated methods of thermal analysis. The utility has not provided assessments which meet this criteria (see related discussion in Section 4.2 below).

- Extrapolation of experimental results must include the consideration of the applicability of the experimental results to the fire barriers installed at CPS. In particular, the utility should discuss the configuration of its various fire barrier systems in comparison to the tested configurations.

4.2 Summary of Findings on Utility Analysis of IEIN 94-22/SAND94-0146

The final utility assessments of ampacity acceptability are based on a comparison of in-plant cable "heat intensities" to the "heat intensities" measured in a single USNRC/SNL manufacturer replication test as documented in IEIN 94-22 and in SAND94-0146. The findings of this review with respect to this analysis approach are as follows:

- SAND94-0146, which is cited by the utility includes the following statement:

  > "It should be noted that because of these experimental shortcoming, SNL does not consider the ampacity derating test results reported here to represent a reliable assessment of the ampacity derating factors which would be encountered in actual applications. It is recommended that ampacity derating assessments be based on alternative tests utilizing test articles which are geometrically more simplistic ..., and for which a less inter-dependent temperature control is possible ..."

  The use of this test by the utility as the basis for its final assessments of ampacity load acceptability is inappropriate.

- Beyond the issue of overall applicability of the USNRC/SNL test, the utility analysis methodology is also considered inappropriate based on technical

concerns as well. Points of concern identified in this review include (1) inadequate treatment of depth of fill as an important parameter in the "heat intensity" analysis, (2) removal of the conservatism assumed to exist in the ICEA tabulated ampacity values without adequate justification, (3) inadequate justification for the assumption that derating of the ICEA tables by 32% will bound the derating impact of all fire barrier systems installed at CPS, (4) fundamental violation of the intent of the ampacity derating test approach, and (5) inadequate justification for the use of "heat intensity" as the ultimate measure of cable ampacity limits.

It is the overall finding of this review that this aspect of the utility analyses should not be credited. While the utility may choose to address the identified concerns, the overall methodology represents a fundamental departure from accepted approaches to ampacity derating assessments. As such, it is recommended that a very high burden of review and validation be placed on this method before acceptance by the USNRC be allowed.

4.3 Summary of Finding on Specific Utility Analyses

The review of the individual utility analyses has focused on the utility margins analysis only. The utility use of the USNRC/SNL manufacturer replication test is considered inappropriate as discussed in 2.3 and 4.2 above. The findings of this part of the review can be summarized as follows:

- SNL was unable to verify the appropriateness of the baseline cable ampacity values cited in the utility analysis because insufficient information has been provided by the utility. In general terms, the values cited appear nominally consistent with the ICEA ampacity tables. However, a clarification of how the base ampacity values were determined is needed to complete the review. Providing copies the referenced utility design calculations or providing specific and detailed example calculations illustrating all aspects of each application (trays and conduits) would fulfill this need, see Section 4.4 below.

- The utility has used an unusual and unfamiliar notation to identify many of the cables considered in the analysis ("#19/22 AWG" and "#19/25 AWG"). The SNL interpretation indicates that these may be 10AWG and 12 AWG wires respectively. The ampacity limits cited are also nominally consistent with these cable sizes. However, clarification of this notation is needed.

- In general the utility has demonstrated that the cables at CPS have significant margin available. For most cases it is likely that the utility can successfully demonstrate that the cable margins are adequate. However, this assessment should be based on an alternative approach to that presented in this submittal. That is, the utility has based its final acceptability assessments on the single USNRC/SNL manufacturer replication test as documented in IEIN 94-22. This test is considered an inappropriate basis for the assessment of in-plant ampacity derating effects, and further, the utility analysis process is considered fundamentally flawed (as noted in 2.3 above). The final utility

assessments should be based on either test results from USNRC accepted tests, and/or on appropriate and validated thermal modeling results.

- For two cables, Cables 1DG29A and 1DG30A in fire area CB-1e, the utility has argued that these cables "are not impacted by derating" based on the observation that the cables are not continuously energized. While such an assessment might be justified, the utility must consider the maximum possible duration of cable operation under worst case conditions (as was done in the analysis of cable 1SC02B in fire area C-2 for example) and power cable cycling behavior (if applicable). If the maximum run time is short and the cycling time is long in comparison to the temperature rise time of the cable mass, then the utility argument would have merit. The utility has failed to demonstrate this in its assessment. Given that some ampacity margin is available, the utility may well be able to demonstrate the acceptability of the in-plant ampacity loads, but some additional documentation is required to support the utility assessment.

4.4 Recommendations

It is recommended that the USNRC prepare an RAI to the utility. It is recommended that the following issues should be raised in that RAI:

- The utility has not specified the ambient temperatures assumed in the application of the ICEA tables for cable ampacity. The utility should identify the ambient temperature assumed for each of the fire areas evaluated in the submittal. These values should be justified as either conservative or representative of the worst case in-plant service conditions.

- This review was unable to verify the utility calculated baseline ampacity values because insufficient information on the cable types and characteristics has been provided. In addition, the utility has not identified any corrections to the tabulated ampacities which were made to account for issues such as cable diameter, ambient temperature, and cable tray or conduit fill. It is assumed that these factors are discussed in the supporting documents cited in the submittal. In particular, the utility submittal cites four supporting documents as the basis for its cable ampacity design:
    - Calculation 19-AI-8
    - Calculation 19-G-01
    - Calculation 19-G-02
    - Calculation 19-G-31, Rev. 0

  Providing a copy of each of these documents for review would resolve the uncertainty. Alternatively, the utility should provide specific detailed example calculations to illustrate how each of these calculations impacted the utility ampacity assessment for each of its in-plant configurations (e.g., one specific cable tray example and one specific conduit example). These examples should illustrate how the base ampacity values were determined, including identification of the source documents and illustration of any corrections

applied to the tabulated ampacity values, and illustrate how the fire barrier ampacity derating factors were determined and applied.

- The utility has used an unusual notation to identify many of the cables considered in the ampacity analyses. Specifically, many cables are identified as either "#19/22 AWG" or "#19/25 AWG". These descriptions should be clarified, and the overall size of the cable conductors provided as a single gage value consistent with the ICEA tables. If these cables sizes cannot be related to single gage values, then the utility should explain how the baseline ampacity of a non-listed cable size was determined.

- The utility has cited the results of a single USNRC-sponsored test as the basis for its final assessment of the acceptability of in-plant ampacity loads. As stated in the test report, this test was performed as a replication of an early manufacturer test, is known to have suffered from inherent and insurmountable experimental problems and limitations, and should not be used as the basis for the assessment of in-plant cable ampacity effects. The utility analysis of this test is considered inappropriate and this aspect of the analysis is not credited. The utility should provide an alternative basis for the final assessment of in-plant cable ampacity loads.

- A number of additional concerns were identified in the utility "heat intensity" analysis method. These include (1) inadequate treatment of depth of fill as an important parameter in the "heat intensity" analysis, (2) removal of the conservatism assumed to exist in the ICEA tabulated ampacity values without adequate justification, (3) inadequate justification for the assumption that 32% derating of the ICEA tables will bound the derating impact of all fire barrier systems installed at CPS, (4) fundamental violation of the intent of the ampacity derating test approach without adequate validation or justification, and (5) inadequate justification for the use of "heat intensity" as the ultimate measure of cable ampacity limits. This methodology is viewed as a fundamental departure from accepted ampacity derating approaches. Generally accepted practices are based on a derating of the tabulated ampacity values based on the results of either experiments or analyses. If the utility "heat intensity" analysis is to be credited, the utility should provide a detailed technical justification for this approach to analysis, document appropriate validation results, and compare and contrast the results of this method to other accepted ampacity derating assessment methods.

- The utility margins analysis approach is generally considered an appropriate approach to the resolution of ampacity loading issues at CPS. While the utility has demonstrated significant margin in its cable ampacity values, the utility should provide a final assessment of the acceptability of those margins in comparison to estimates of the fire barrier derating impact. This aspect of the analysis is considered lacking in the utility submittal. These estimates may derive from well founded and validated thermal calculations, or from appropriate experiments. Resolution of the cited concerns related to the utility "heat intensity" analysis methodology may resolve this aspect of the

review findings. Alternate methods of analysis could also be applied to resolve this concern.

- The utility notes in its submittal that "derating values are viewed as suspect by the USNRC, but no new values have been endorsed by them." This is no longer correct. Both TVA and TU have submitted a range of ampacity derating tests which have been reviewed by the USNRC. The utility should reconsider its final assessments of cable ampacity margin in light of the now available ampacity derating test results. Note that in applying such values, the utility must also demonstrate that the values are appropriate (or conservative) to the CPS barrier systems, or must provide for appropriate methods of extrapolating those results to the CPS installations.

- The utility analysis of Cables 1DG29A and 1DG30A in fire area CB-1e is considered insufficient. CPS has argued that these cables "are not impacted by derating" based on the observation that the cables are not continuously energized. This statement is considered inappropriate as all power cables are impacted to some extent by derating. The utility assessment of non-continuous loads must consider the maximum possible duration of cable operation under worst case conditions (as was done in the analysis of cable 1SC02B in fire area C-2 for example) and should consider power cycling (if appropriate). If the maximum run time is short and the power cycling time is long in comparison to the temperature rise time of the cable mass, then the utility argument would have merit. The utility has failed to demonstrate this in its assessment for these two cables. Additional documentation is required to support the utility assessment for these two cables.

- The utility has cited several cable tray barrier installations which are designed only to provide a "fire break" (to establish a 20 foot combustible free zone) and are not specifically intended to protect the cables in the clad tray. The utility should describe any differences in the construction or configuration of barriers installed as fire breaks as compared to those installed to protect installed cables from fire damage. If there are differences in construction, the utility should assess how these differences would impact the cable ampacity derating results.