An Initial Review of the Florida Power Crystal River Ampacity Derating Test Report 95NK17030NC1973

A Letter Report to the USNRC

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Revision 0

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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 licensee submittals associated with fire protection and electrical engineering. This letter report represents the first report in an anticipated series of review reports associated with ampacity derating submittals from the Florida Power Corporation (FPC) for the Crystal River Energy Complex (CREC). The submittal reviewed by SNL documents the results of a series of test sponsored by the licensees to assess the derating impact of Thermo-Lag 330-1[1] and Mecatiss fire barriers when installed on cable trays and conduits. This report documents the results of an initial SNL review of the licensee submittal. The documents were submitted by the licensee in response to USNRC Generic Letter 92-08 and a subsequent USNRC Request for Additional Information (RAI) of June 22, 1995. This work was performed as Task Order 1 of USNRC JCN J2503.

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[1]Thermo-Lag 330-1 is a registered trademark of Thermal Sciences Inc.

1.0 INTRODUCTION

1.1 Objective

In response to USNRC Generic Letter 92-08 and a subsequent USNRC Request for Additional Information of June 22, 1995, the Florida Power Corporation (FPC) Crystal River Energy Complex (CREC) provided documentation of the licensee position regarding ampacity derating factors associated with its installed fire barrier systems. In particular, the licensee responded to two specific questions raised in the RAI and submitted to the USNRC a test report documenting the results of a series of test to assess the ampacity derating impact of certain Thermo-Lag 330-1 and Mecatiss fire barrier systems for the protection of cable trays and conduits.

SNL was asked to review these items under the terms of a general technical support task ordering agreement JCN J2503, Task Order 1. The documents reviewed by SNL are:

- Letter, P. M. Beard, Jr., FPC, to the USNRC Document Control Desk, Item 3F0795-05, July 27, 1995.

- Letter, G. L. Boldt, FPC, to the USNRC Document Control Desk, Item 3F0696-14, June 26, 1996, including an attached test report from Underwriters Laboratory, "Ampacity Test Investigation of Raceway Fire Barriers For Conduit and Cable Tray Systems," Report Number 95NK17030NC1973, May 7, 1996.

This letter report documents the initial results of SNL's review. It should be noted that the SNL review is limited to a review of the licensee RAI responses and an assessment of the acceptability of the licensee submitted test report and the ampacity derating factors derived therein. SNL has not reviewed any documentation related to the full process by which the licensee has assessed actual in-plant cable ampacity loads, and hence, this review does not include any assessment of these practices.

1.2 Overview of the Licensee Ampacity Derating Approach

The licensee approach is based on an experimental determination of ampacity derating factors for certain fire barrier installations, presumably typical of those used in the plant. The tests were performed consistent with the guidance provided in Draft 16 of the IEEE P848 test standard for ampacity derating. The tests performed included three different types of test items; namely, 1" conduits, 4" conduits, and a 4"x24" cable tray, all consistent with the IEEE standard. Six basic fire barrier systems were evaluated for each test item including a 1-hr TSI system Thermo-Lag 330-1 at nominal 5/8" thickness, a 3-hr TSI system Thermo-Lag 330-1 at nominal 1¼" thickness, a 1-hr Mecatiss upgrade system MPF-60 over the 1-hr TSI system, a 3-hr Mecatiss upgrade system MPF-180 over the 3-hr TSI system, a 1-hour Mecatiss stand-alone system MTS-1, and a 3-hr Mecatiss stand-alone system MTS-3.

1.3 Organization of Report

Section 2 of this report provides a brief review of the specific licensee RAI responses of July 27, 1995. This bulk of this review has focused on a technical review of the test report submitted by

the licensee. Section 3 provides a point by point review of the licensee test report including a discussion of potential areas of concern. Section 4 summarizes the SNL findings and recommendations.

2.0 LICENSEE RESPONSE OF JULY 27, 1995

2.1 Overview

In an RAI of June 22, 1995, the USNRC asked the licensee to respond to two concerns related to its then planned ampacity derating test program. The licensee response to these specific concerns was provided by FPC in a letter of July 27, 1995. The subsections that follow provide SNL's assessment of these responses.

2.2 Item 1: Appendix B

The first of the USNRC RAI items questions the adequacy of the licensee's intent to treat its ampacity derating tests as an "Appendix B QA program for fire protection." The licensee response appears to acknowledge that the tests will be performed consistent with the USNRC request, although the SNL reviewer is unqualified to assess the compliance of the licensee's test program with the Appendix B requirements. This is an area of expertise outside the scope of the SNL/USNRC task ordering agreement under which these efforts are being conducted. SNL makes no recommendations as to the acceptability of this response.

2.3 Item 2: Aluminum Versus Steel Trays

The second RAI item raised by the USNRC in its letter of 6/22/95 questioned the applicability of tests conducted using steel raceways to applications at the plant involving aluminum raceways. The licensee response cites several points as justifying this approach:

- The IEEE P848 standard calls for the use of steel raceways in testing.
- The issue was discussed with IEEE P848 committee members, and the basis for this decision was cited.
- The licensee and the P848 committee conclude that use of steel would conservatively bound the results for aluminum. A technical argument to this effect is provided.

SNL finds the last of these three points to be the most telling. That is, SNL agrees with the licensee assessment that the use of steel test samples would conservatively bound aluminum raceway applications. The supporting technical arguments provided are reasonable. The reduced emissivity of an aluminum raceway as compared to a steel raceway will primarily impact the base line ampacity measured in a test. With an aluminum raceway the base line ampacity should be reduced. The clad ampacity would likely be impacted to a much lesser degree due to the fact that cladding decreases the importance of radiation heat transfer from the raceway surfaces in the overall heat balance. Hence, the derating impact derived from a steel raceway test should be more conservative than an equivalent aluminum raceway test.

In summary, SNL agrees with the licensee assessment that the steel raceway test results will conservatively bound the applications involving aluminum raceways. No further actions on this item are recommended.

3.0 A REVIEW OF THE CRYSTAL RIVER TEST PROGRAM

3.1 Overview

3.1.1 Test Organization and Protocol

The tests submitted by FPL/CREC were actually performed by Underwriters Laboratory as a "Special Services Investigation." The implications of this distinction are simply that the licensee was not seeking a "UL listing" of its barrier systems nor has it established the follow-up program normally associated with such a listing. However, it should also be noted that the tests were performed under the direct supervision and control of UL personnel. For example, while the fire barrier systems were installed by either licensee employees (in the case of the TSI products) or by manufacturer employees (in the case of the Mecatiss products), all installations were monitored and assessed by UL personnel to ensure compliance with the cited installations procedures.

These factors are important in that they establishes a significant level of independence from both FPL and the barrier manufacturers. In general, UL is eminently qualified to perform ampacity derating tests in an appropriate manner.

The test protocol utilized in the test program was based on Draft 16 of the IEEE P848 standard. This included the guidelines on the size, composition, and construction of the actual test items. All of the provisions of the standard were followed in testing. All of the test acceptance criteria were achieved with, in the end, only one notable exception (see discussion in Section 3.2.2 below). In particular, data gathering and analysis all appear to have been accomplished consistent with the standard protocol. Also, the licensee tests did establish that steady state test conditions were achieved consistent with the standard in all regards (linear regression, slope, and running average calculations were performed and achieved the standard objectives for steady state).

3.1.2 Test Articles Evaluated

The licensee test program involved four Test Articles. Each of these test articles was, in turn, comprised of three items; namely, a 1" conduit, a 4" conduit, and a 4"x24" ladder back cable tray. Each of the items in each test article was evaluated in a base line condition, and separately in the clad condition. Hence, there were a total of four 1" conduits, four 4" conduits, and four 4"x24" cable trays evaluated. Each of the 1" conduits had a single, 4/C, 10AWG, 600V light power or control cable installed. For each of the 4" conduits, a tightly wrapped bundle of 12, 3/C, 6AWG, 600V cables (a total of 36 individual conductors) was installed. The 4"x24" cable trays each had three layers of the 3/C 6AWG cable installed. All of these provisions are fully consistent with the test standard specifications.

It should also be noted that the licensee test procedures included the testing of a full test article simultaneously. That is, in any given ampacity test, a 1" conduit, a 4" conduit and a 4"x24" cable tray were tested simultaneously in a common test enclosure. The standard does specifically allow for such simultaneous testing provided that the test specimens are not located one above another, but rather, that a minimum clearance of 36" of horizontal space is provided between the test items. These requirements were achieved in the licensee tests as demonstrated by the dimensional drawings provided in the test report.

3.1.3 Instrumentation

All of the instrumentation specifically required in the IEEE standard was installed in the FPC tests. In addition, the licensee included a number of supplemental thermocouples to measure conduit and cable tray surface temperatures, and fire barrier material surface temperatures (outside for all layers and inside for some). All test data was monitored using calibrated devices and UL is known to have an excellent calibration process that is followed as routine practice. No anomalies in this regard were noted.

3.1.4 Fire Barrier Systems Evaluated

The licensee has investigated six basic fire barrier systems, each installed on the 1" conduit, the 4" conduit and the 4"x24" cable tray. These are:

- A 1-hour Thermo-Lag 330-1, single layer, fire barrier system alone
- A 3-hour Thermo-Lag 330-1, single layer, fire barrier system alone
- A 1-hour Thermo-Lag 330-1 fire barrier system with a Mecatiss MPF-60 upgrade system
- A 3-hour Thermo-Lag 330-1 fire barrier system with a Mecatiss MPF-180 upgrade system
- A 1-hour Mecatiss MTS-1 system
- A 3-hour Mecatiss MTS-3 system

One important factor to note is that the fire barrier system for the cable tray specimens included the installation of a solid tray cover on the ladder back cable tray. It is implied by the instrumentation drawings that the base line tests did not include this tray cover, as would be appropriate. However, it is recommended that the licensee be asked to confirm this observation.

3.1.5 Summary of Test Results

The test results obtained by FPC are summarized in Table 3.1. For each of the test items in each barrier configuration both the ampacity correction factor (ACF) and the ampacity derating factor (ADF) is given. Recall that the relationship between these two values is as follows:

$$ADF = (1 - ACF) * 100\%$$

3.2 Anomalies Addressed in the Test Report

3.2.1 Problems with Base Line Test Ampacities for 1" Conduits

The licensee report includes a discussion of an apparent discrepancy involving the base line tests for the 1" conduit specimens. In particular, the base line ampacity limits for the 1" conduits in Test Articles 1 and 2 differed significantly from those for the nominally identical 1" conduits in Test Articles 3 and 4. This anomaly was investigated at some lengths. Although no firm conclusion was reached as to the cause of the discrepancy, it was ultimately concluded that the original Test Article 1 and 2 results were in error and had recorded a false-high ampacity limit (the tests had overstated the actual base line current limits). These base line tests were repeated after removal of

the barrier system and the modified results were in agreement with the Test Article 3 and 4 results. The original base line results were discarded, and the newer values were used to calculated ACF/ADF values.

Table 3.1: Summary of FPC/CREC test results.			
Test Item	Barrier System	ACF	ADF (%)
1" Conduit Tests	1-hr Thermo-Lag	No Result*	No Result*
	3-hr Thermo-Lag	1.04	-4.26
	MPF-60 Upgrade	0.838	16.2
	MPF-180 Upgrade	0.843	15.7
	MTS-1	0.818	18.2
	MTS-3	0.775	22.5
4" Conduit Tests	1-hr Thermo-Lag	1.03	-3.31
	3-hr Thermo-Lag	0.973	2.69
	MPF-60 Upgrade	0.801	19.9
	MPF-180 Upgrade	0.765	23.5
	MTS-1	0.769**	23.1**
	MTS-3	0.665	33.5
Cable Tray Tests	1-hr Thermo-Lag	0.590	41.0
	3-hr Thermo-Lag	0.586	41.4
	MPF-60 Upgrade	0.444	55.6
	MPF-180 Upgrade	0.421	57.9
	MTS-1	0.397	60.3
	MTS-3	0.361	63.9
* No results reports due to problem with original base line test and inability to repeat clad test.			
** As discussed below, SNL will question these results.			

As a part of the problem diagnosis process, UL did change out the cable installed in the 1" conduits for Test Articles 1, 2, and 3. This was apparently to ensure that the cables were not the problem, a fact verified by the results. However, this problem did compromise one of the specific item fire barrier system tests. That is, the Mecatiss MPF-60 upgrade to the 1" conduit in Test Article 1 had already been installed at the time the error was detected. This made it impossible to fully reproduce the test for the 1-hour Thermo-Lag only fire barrier system without resorting to construction of a whole new test article. This is because the original base line test had been determined to be invalid, but the clad test with only the Thermo-Lag fire barrier system could not be reproduced with the newly installed cable. It was considered inappropriate to compare the new base line test to a clad test that used a different set of cable and thermocouples, and hence, no results for this test item are reported with only the 1-hr Thermo-Lag fire barrier system.

The licensee treatment is considered adequate to res[illegible] the observed anomaly in the context of all of the base line tests. That is, the licensee document[illegible] onsistency between four separate base line tests for each of its 3 test items (1" conduit[illegible]uits, and cable trays) is considered adequate to ensure that the base line test results are [illegible]ble. Hence, in the context of the base

line test results, SNL finds that this anomaly was adequately resolved by the testing laboratory, and no actions in this regard are recommended.

However, SNL has concerns that because the exact source of the anomaly was never conclusively identified, there is no clear assurance that the a similar anomaly did not impact other licensee tests, and in particular, the clad test results. This issue will be taken up in Section 3.3.1 below.

3.2.2 Failure to Achieve Temperature Balance

The IEEE test standard specifies that as a part of the test protocol the average conductor temperature measured at the center of the test item should be compared to that measured 3 feet to each side of the center. The center and side location values should agree to within ±4°C. In certain of the licensee tests, this condition was not achieved. Most of these anomalies were resolved through retesting of the test items. However, for one case the anomaly was not resolved; namely, the Test Article 2, 1" conduit, base line test. This has the potential to impact the Test Article 2 results for both the 3-hour Thermo-Lag barrier only, and the MPF-180 upgrade system.

The test report cites that "Short of installing a new instrumented cable, reinstalling the MPF-180 and TSI-3 hr systems and repeating the ampacity test series a third time, no remedy for the anomaly was available. A third series of ampacity tests to resolve the anomaly was not conducted." Hence, the reported results include crediting of the test results impacted by this anomaly. No final resolution is provided, and no discussion justifying the use of these test results is provided in the report.

The unresolved anomaly involves a temperature difference in one base line test between Sections 1 and 2 of 4.8°C as compared to the limit in the standard of 4°C. Hence, SNL notes that the differences is not grossly out of compliance with the standard. Further, SNL notes that the base line current measured for this conduit was very consistent with the other 1" test articles that are nominally identical to this item (30.2 versus a range of values from 29.8 to 32.0A).

Given these observations, SNL finds that this anomaly, while not fully resolved in the licensee documentation, is quite minor, and should not be considered to have significantly compromised the test results. It is recommended that these test results should be accepted despite this minor anomaly. No further actions on this anomaly are recommended.

3.3 Anomalies Noted by SNL

3.3.1 Apparent Discrepancy in Clad Case for 4" Conduit with MTS-1 System

As was noted in Section 3.2.1 above, the FPC/UL tests did experience some anomalous current readings. In particular, false-high current values for two of its base line test specimens were obtained. No clear and definitive source for this error was identified, although it was speculated that a loose shunt connection had caused the problems. The failure to concisely identify a cause for this problem leaves open the possibility that other tests may have been affected by a similar problem.

As will be demonstrated in the following discussion, SNL does consider that one test in particular did, in all likelihood, experience a similar problem that impacted the test results. The particular concern is associated with the clad test for the MTS-1 system installed on the 4" conduit (the 4" conduit of Test Article 3). Based on SNL calculations, it is suspected that this test also suffered from a false-high current reading. Given that this is a clad test, a false-high current reading in this test would yield an overly optimistic ampacity derating impact.

In order to illustrate why SNL has reached this conclusion, one must look at the available data in a somewhat unique way. One way to view the cable/conduit/barrier thermal system is using the electrical network analogy. That is, one can think of heat flow as analogous to electrical current, temperature as analogous to voltage, and thermal resistance as analogous to electrical resistance. Using these analogies, the system can be viewed as a thermal resistance network characterized by certain temperatures, heat flows, and thermal resistance elements. Under this approach, heat flow between two elements or nodes of the thermal system (Q) can be expressed as follows:

$$Q = \frac{\Delta T}{R_{thermal}}$$

where (ΔT) is the temperature difference between the thermal elements or nodes, and ($R_{thermal}$) is the thermal resistance between the elements or nodes. Given this expression, if the heat load and temperature difference are known, then one can easily calculate the effective thermal resistance between the two elements. In the case of the ampacity derating tests, the heat load is easily determined based on the cable current setting as follows:

$$Q = I^2 R_{elec} \; n_{conductor}$$

where (R_{elec}) is the electrical resistance of the conductors, and ($n_{conductor}$) is the number of conductors within the conduit.

Of most critical importance to the current discussion will be the thermal resistance that exists between the cables and the conduit. This thermal resistance has been the focus of considerable investigation. The most concise treatment was that of Buller/Neher[2] and Neher/McGrath[3]. In these works this value was found to be a function of the conduit size and cable fill characteristics only. It is especially important to recognize that this value will not be influenced in any way by external factors such as the ambient temperature, or the presence of a fire barrier system.

In fact, one of the fundamental precepts of a conduit ampacity derating test set is that the thermal behavior between the cables and the conduit should remain constant in the clad and the base line tests. That is one of the primary reasons why the IEEE standard requires that the same physical

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[2]F. H. Buller and J. H. Neher, "The Thermal Resistance Between Cables and a Surrounding Pipe or Duct Wall," AIEE Transactions V69, 1950 pgs 342-349.

[3]J. H. Neher, and M. H. McGrath, "The Calculation of the Temperature Rise and Load Capacity of Cable Systems," AIEE Transactions, Oct. 1957, pgs 752-772.

test specimen (conduit and cables) be used to perform both the clad and base line tests. Otherwise, unintended changes in the internal thermal behavior might easily bias the test results which are intended to reflect only changes in the external thermal behavior.

Given this concept, one simple check that can be performed to assess the consistency between a base line and a clad conduit ampacity test is to check the value of the internal cable to conduit thermal resistance in each test. This value should remain essentially constant, and significant deviations would be indicative of potential problems. The only supplemental data, beyond that required by the IEEE P848 standard, needed to perform this calculation is the temperature of the conduit itself. Fortunately, the FPC/UL tests report these conduit temperature values for most of the tests performed.

Using the FPC/UL data, and the two equations above, SNL has calculated the effective thermal resistance between the cables and the conduits for all those tests which report conduit temperatures. A variety of temperature bases were tried (i.e., cable hot spot to individual conduit temperatures, cable hot spot to average conduit temperature, and cable average temperature to conduit average temperature). The results for each of these calculations were quite consistent. For illustrative purposes, the discussions which follow will utilize the thermal resistance values based on the difference between the average temperature of the cable bundle at the center location as reported by UL and the average temperature of the conduit surface[4]. Table 3.2 illustrates the results obtained by SNL for the 1" conduit test items.

As can be seen, the values derived are quite consistent with one notable exception. Within any given test article, the derived values are extremely consistent, varying in all cases by less than ±4%, and for most cases by less than by less than ±2.5%. Even comparing one test article to another, the variation is no more than ±10%. The one clear exception is the original base line test for Test Article 1. In this one case, a value is derived that is far lower than any of the other cited values. In fact, the estimated base line thermal resistance is nearly 30% lower than the values obtained for the two corresponding clad cases.

This calculation is fully consistent with the UL observation that the initial base line test for Test Article 1 suffered a false-high current reading. This false-high current would overstate the heating rate, and hence understate the thermal resistance factor given that the temperatures were measured correctly. As can be seen the thermal resistance calculation can provide a clear and accurate indication of potential problems in the test data. (It is fully expected that a similar treatment for the Test article 2 initial base line run would reveal a similar effect, and that the same treatment for the repeated base line tests would reveal thermal resistance values far more consistent with the other cited values. Unfortunately, the report does not provide the necessary conduit temperature data for these cases.)

Now consider the same process as applied to the 4" conduit tests. The results for these test items are summarized in Table 3.3. The values are again calculated on the same basis; namely, average cable temperature at the center location as reported by UL and the average conduit temperature.

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[4]The average conduit temperature was calculated by SNL using the simple average of the temperatures for all conduit thermocouples installed on a given test item as reported by UL.

Table 3.2: Summary of thermal resistance calculation results generated by SNL for the FPC/UL 1" conduit ampacity tests. All values are calculated based on the difference between the average temperature of the cable bundle and the average conduit temperature.

Test Article	Barrier Configuration*	Cable to Conduit Thermal Resistance (°C*ft/W)
Test Article 1	Base Line	4.15
	Clad: 1hr TSI	5.91
	Clad: MPF-60	5.84
Test Article 2**	Clad: 3-hr TSI barrier	6.16
	Clad: MPF-180	6.43
Test Article 3	Base Line	6.85
	Clad: MTS-1	6.80
Test Article 4	Base Line	6.96
	Clad: MTS-3	6.48
Range of derived values:***		5.84-6.96

*Note that values can only be calculated for the initial licensee runs. The repeated tests do not report conduit temperature data. Hence, all references here are to the first test of each identified configuration only.

**The initial run of the base line case for Test Article 2 is unavailable due to an apparent oversight in preparation of the UL report. See Section 3.3.2 for further discussion.

***Range excludes Test Article 1 base line test.

Table 3.3: Summary of Thermal Resistance calculation results generated by SNL for the FPC/UL 4" conduit ampacity results. All values are calculated based on the difference between the average temperature of the cable bundle and the average conduit temperature.

Test Article	Barrier Configuration	Cable to Conduit Thermal Resistance (°C*ft/W)
Test Article 1	Base Line	1.84
	Clad: 1hr TSI	1.73
	Clad: MPF-60	1.74
Test Article 2	Base Line	1.86
	Clad: 3-hr TSI barrier	1.87
	Clad: MPF-180	1.93
Test Article 3	Base Line	1.86
	Clad: MTS-1	1.43
Test Article 4	Base Line	1.79
	Clad: MTS-3	1.77
Range of Results:*		1.73-1.93

*The range of results excludes the Test Article 3 clad test.

In this case the overall values are much lower indicating a better overall thermal contact between the cables and the conduit. More importantly, as with the 1" case the results are, again, very self-consistent with one notable exception. Within any given test article, the variations are all within a ±4% band. Even comparing between test articles, the variations are all within a ±8% band. The one notable exception is the clad test for Test Article 3. In this one case, the thermal resistance value is approximately 23% lower than the corresponding base line test value. This deviation is much larger than one should anticipate, rivals that of the Test Article 1 base line test known to have been a problem, and is certainly an indication that a similar problem may have occurred in this test.

The next logical question to ask is how significant the impact might have been. This question can be answered by "working backwards" through this same process. We can assume that the measured temperatures are correct, and that the thermal resistance between the cable and the conduit during the clad test was in reality approximately the same as the value derived for the corresponding base line test. The question then is to estimate the actual current that should have yielded these test conditions. The first step is to calculate the heat flow rate based on the temperature difference and the base line case thermal resistance as follows:

$$Q = \frac{\Delta T}{R_{thermal}} = \frac{86.7 - 75.7}{1.86} = 5.914\ W/ft$$

Based on this heat flow rate we can now estimate the corresponding current based on the number of conductors and the electrical resistance values as follows:

$$I = \sqrt{\frac{Q}{R_{elec} * n_{conductor}}} = \sqrt{\frac{(5.914)}{(5.15E\text{-}4)\,(36)}} = 17.9\ A$$

This then is the "raw" current value we should have anticipated for this test. In order to perform the ampacity derating calculation we must normalize this value to the standard temperature conditions:

$$I' = I\sqrt{\frac{(90-40)\,(\alpha+T_c)}{(T_c-T_a)\,(\alpha+90)}} = 17.9\sqrt{\frac{(90-40)\,(234.5+90.5)}{(90.5-39.0)\,(234.5+90)}} = 17.6A$$

Finally, the ACF and ADF factors can be estimated using this modified estimate of the clad ampacity in comparison to the measured value of the base line ampacity as follows:

$$ACF = \frac{I_{clad}}{I_{baseline}} = \frac{17.6}{26.4} = 0.667$$

$$ADF = (1.0 - ACF) * 100\% = 33.3\%$$

Hence, this exercise has illustrated that the anticipated derating impact should have been on the order of 33.3% versus the value of 23.1% cited in the test report.

One might question the accuracy of this approach. This can be demonstrated by once again returning to the 1" conduit case known to have been compromised by a false-high ampacity measurement. If the same procedure is repeated for the first run of the base line test, the predicted normalized cable ampacity is found as follows[5]:

$$Q = \frac{\Delta T}{R_{thermal}} = \frac{88.2 - 57.1}{5.87} = 5.298\ W/ft$$

$$I = \sqrt{\frac{Q}{R_{elec} * n_{conductor}}} = \sqrt{\frac{(5.298)}{(1.31E-3)(4)}} = 31.8\ A$$

$$I' = I\sqrt{\frac{(90-40)(\alpha+T_c)}{(T_c-T_a)(\alpha+90)}} = 31.8\sqrt{\frac{(90-40)(234.5+90)}{(90.0-39.9)(234.5+90)}} = 31.8A$$

Hence, a "corrected" normalized base line ampacity of 31.8A is predicted as compared to the original value measured for this test of 37.8A. More importantly, the normalized base line current for the repeat test was found to be 32.1A, a value very close to the predicted value 31.8A. The minor differences can easily be attributed to the fact that the cables were replaced between tests which would cause a minor change in the thermal conditions. This predicted value certainly falls well within the range of values cited in the test report for the normalized 1" conduit base line ampacity values; namely, 30.2A to 32.1A.

Given these observations, SNL finds that the clad test ampacity for the 4" conduit protected by the MTS-1 fire barrier system is suspect. The test was likely compromised by a false-high ampacity limit similar to the false-high values obtained in the Test Article 1 and 2, 1" conduit, original base line tests. No other tests appear to have been impacted by a similar problem. This would have resulted in the calculation of a overly optimistic ADF value for this one barrier configuration, the MTS-1 system on a 4" conduit. SNL recommends that this particular test result should not be accepted by the USNRC as representative of the ampacity derating impact of this fire barrier system.

3.3.2 Discrepancy in Reporting of 1" Conduit Base Line Data for Test Article 2

In the actual data sets presented in Appendix B of the FPC/UL report, it appears that the data for the initial Test Article 1, 1" conduit has been inadvertently substituted for the intended Test Article

[5]Thermal resistance was taken as the average of the other two "first run" cases for the Test Article 1, 1" conduit as shown in Table 3.2; namely, the clad test for the 1-hr TSI barrier and the MFP-60 systems.

2, 1" conduit initial base line test. That is, the tabulated data given in Appendix B is identical in every regard to that presented in Appendix A. This is a highly unlikely situation to occur by random. Further, the values reported in the data summary tables for the initial base line test for the Test Article 2, 1" conduit, do not match those given in Appendix B.

It appears that in preparing the test report, the data from the Test Article 1 test was inadvertently presented in Appendix B as well. This oversight is considered a minor discrepancy given that the Test Article 2 initial base line test was not used in the final data analysis by the licensee. While it would have been very interesting to supplement the discussions presented in Section 3.3.1 above with the additional Test Article 2 data, the data is clearly of no significant consequence to the final results of the licensee tests. This discrepancy in the documentation should be noted simply "for the record."

4.0 SUMMARY OF FINDINGS AND RECOMMENDATIONS

With respect to the Licensee's specific responses to the two items raised in the USNRC RAI of June 22, 1995, SNL makes the following findings and recommendations:

- Appendix B QA treatment: SNL make no recommendations regarding the acceptability of the licensee response to this RAI item. The nature of the RAI lies outside the scope of expertise of the SNL reviewer and the scope of work established for the general task ordering agreement under which these activities have been performed.

- Aluminum versus steel trays: SNL finds the licensee arguments in this regard to be acceptable. SNL finds that the use of steel raceways in the licensee tests will conservatively bound the results when applied to aluminum cable raceways installed at the plant. No further actions on this item are recommended.

With respect to the licensee submitted FPC/UL ampacity derating test report, SNL finds that the licensee tests have been performed and reported in a manner fully consistent with the IEEE P848 Draft 16 test standard. Any anomalies observed by the testing laboratory have been resolved in the test report with the following exception:

- The base line test for the 1" conduit in Test Article 2 did not achieve the IEEE objective of uniform temperature in that the average cable temperature at the center location deviated from the average temperature at one of the two side locations by 4.8°C, as compared to the test standard which calls for deviations of no more than 4°C. This anomaly is clearly noted in the test report, but no resolution is provided. SNL finds that this is a minor anomaly that will not significantly impact the reliability and validity of the test results. SNL recommends that the test results for this test item should be accepted by the USNRC, and that no further actions to resolve this anomaly are warranted.

SNL did, however, note one apparent anomaly not observed by the testing laboratory, and hence not discussed in the test report. This anomaly is considered to have compromised the results of one of the licensee tests:

- SNL finds that the clad test ampacity for the 4" conduit protected by the MTS-1 fire barrier system is suspect. The test was likely compromised by a false-high ampacity limit indication similar to the false-high indications identified by the testing laboratory in the Test Article 1 and 2, 1" conduit, original base line tests. No other tests appear to have been impacted by a similar problem. This apparent anomaly would have resulted in the calculation of a overly optimistic ADF value for this one barrier configuration, the MTS-1 system on a 4" conduit. SNL recommends that this particular test result should not be accepted by the USNRC as representative of the ampacity derating impact of this fire barrier system. The basis for this finding has been discussed in detail in Section 3.3.1 above.

Based on these findings, SNL recommends that the USNRC accept the ampacity derating test results derived in the FPC/UL test report as representative of the derating impact for the tested fire barrier systems with the exception of the MTS-1 system as installed on the 4" conduit section. As noted above, it is recommended that this one test result not be accepted.

In addition, SNL cites the following item as a point for which clarification is recommended:

- It is recommended that the licensee be asked to confirm that the cable tray base line ampacity tests were all performed in the absence of any solid tray covers having been installed on the test items. This appears to have been the case based on the drawings provided, but is not explicitly stated in the report. A simple statement confirming this observation would be sufficient to resolve any uncertainty in this regard.

Finally, SNL makes the following observation:

- SNL notes that the data provided in Appendix B of the report for the original base line test of the Test Article 2, 1" conduit test item, is an apparent duplication of the data set presented in Appendix A for the Test Article 1, 1" conduit test item. Given that the original base line test data for both test articles was not used in the final data analysis, this apparent reporting oversight is considered of no significant consequence. It is recommended that this observation be noted "for the record" only.