TU ELECTRIC

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U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

SUBJECT: COMANCHE PEAK STEAM ELECTRIC STATION (CPSES) - UNIT 1
DOCKET NO. 50-445
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION REGARDING
THERMO-LAG CABLE FUNCTIONALITY ISSUES (TAC NO. M85536)

REF:
1) NRC letter dated June 15, 1994, from Mr. Thomas A. Bergman to Mr. William J. Cahill, Jr.
2) NRC letter dated October 29, 1992, from Ms. Suzanne C. Black to Mr. William J. Cahill, Jr.
3) Safety Evaluation Report, NUREG-0797, Supplement No. 27 dated April 1993
4) TU Electric letter logged TXX-93331 from Mr. William J. Cahill, Jr., to NRC dated September 16, 1993
5) TU Electric letter logged TXX-94157 from Mr. William J. Cahill, Jr., to NRC dated June 16, 1994
6) Safety Evaluation Report, NUREG-0797, Supplement No. 26 dated February 1993

Gentlemen:

This is in response to a request for additional information submitted by Reference 1. We have reviewed your documents and the requested information is provided below. Additionally, during a re-review of the Ampacity Derating Test Report, it was noted that the one hour average of maximum position 2 temperature was used to calculate the percent derate. Utilizing one hour average of maximum position was an error. The maximum temperature at position 2 should have been utilized. TU Electric has previously stated that the equilibrium time for the 2" clad conduit was 1002 minutes. The equilibrium time was actually 994 minutes. TU Electric has recalculated the percent derate using the correct temperatures, the recalculated percent derate values as well as the originally submitted values are provided in attachment 2 to this letter. The revised percent derate values are negligible, and do not impact TU Electric's calculations for as installed cables enveloped with Thermo-Lag.

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GENERAL RESPONSES

Question 1:

The licensee should state in accordance with the acceptance methodology described in the NRC letter to William J. Cahill Jr. dated October 29, 1992, (hereinafter the October 29, 1992, letter or acceptance criteria) that the minimum insulation resistance values will be maintained for any special application instrumentation (i.e., nuclear instrumentation) cables that will be utilizing the subject Thermo-Lag fire barrier configurations. If there are no special application cables that will be utilizing the subject Thermo-Lag fire barrier configurations please confirm that fact. Any potential impact on the functionality of these special application cables should be assessed by the licensee.

Response 1:

The statement in item 4 of the October 29, 1992 letter refers to the acceptability of 1 meg ohm insulation resistance for nuclear instrumentation cables. Nuclear instrumentation at CPSES consists of the Nuclear Instrumentation System (NIS) and the neutron flux monitoring (N16) system. CPSES does not utilize the NIS for fire safe shutdown capability and has no NIS installations which are Thermo-Lagged. Therefore, an assessment of 1 meg ohm on functionality is not required for NIS cables. The neutron flux monitoring system is used to assess reactor power in a fire scenario. Neutron flux signals are carried over mineral-insulated cables which are qualified to perform their intended function during a LOCA. One of two redundant neutron flux monitoring channels is routed in 3" conduit and Thermo-Lagged. The worst fire endurance test temperature for this configuration is less than the minimum LOCA test qualification temperature for these mineral-insulated cables and therefore the 1 ohm insulation resistance assessment for this cable is not necessary. Furthermore, the LOCA test was conducted over a longer period than the fire endurance test.

Based on the above, TU Electric has concluded that the neutron flux monitoring cables will retain their insulating properties and perform their intended function during a fire.

Question 2:

In general, the swelling and splitting of the cable jacket observed during the subject tests will not be significant in and of itself in terms of impacting cable functionality. One exception to this observation is that cables that are manufactured with a bonded jacket configuration may be subject to insulation failure due to jacket degradation. That is, certain single conductor cables are manufactured with the jacketing material physically bonded to the inner insulation. In this configuration, industry testing has shown that cracking of the bonded jacket can create stress concentrations and initiate cracks in the insulation that leads to catastrophic cable failure. The likelihood of such failures is particularly important for aged cables for which the jacket and insulation material have become embrittled.

The licensee should address this issue by 1) identifying any cases in which bonded jacket cables, including power and control cables, are housed within Thermo-Lag fire barrier envelopes, and 2) assessing the potential for failure of such cables including the end of life cable conditions.

Response 2:

At CPSES cables with bonded jacket are housed within the Thermo-Lag fire barrier envelope. TU Electric tested these cables in several tests. In fact, the cables that experienced jacket swelling were of a bonded jacket construction. The jacket swelling was attributed to moisture being trapped between the inner and outer jackets of the cable. There was no heat damage associated with the jacket swelling, and the inner insulation would not be susceptible to the swelling because moisture would not be present under the insulation. See reference 4 for TU Electric's evaluation regarding jacket swelling.

For CPSES, in the configuration's used to support the Unit 1 design, no jacket swelling was identified which would create stress concentration's or initiate cracks in the insulation which could challenge the functionality of the cable. Imposing an assessment of end-of-life conditions is considered a new or different staff position from the previously applicable staff position although, in this case, it is TU Electric's position that the cable damage seen in the applicable CPSES tests would not result in cable failure at any time during cable life.

Question 3:

Stone and Webster Calculation SWEC IC(B)-071 Revision 2 was cited by the licensee as the basis for the transmitter circuit model presented in TU ER-EE-006. Please provide a copy of the subject document for staff review.

Response 3:

The Stone and Webster calculation is attached as enclosure 1.

Question 4:

The October 29, 1992, letter stated that, "the cable tray side rail and the external conduit temperatures would be used to determine the temperature acceptance of the fire barrier system. In addition, your staff agreed, for cable trays, to also use the cable thermocouple temperature readings to <u>supplement</u> [emphasis added] the raceways thermocouples in assessing the thermal performance of the fire barrier system."

In addition, the staff reiterated through Supplement 1 to Generic Letter 86-10 which was issued for public comment on July 23, 1993, that measuring cable temperatures is not a reliable means for determining excessive temperature conditions that may occur at any point along the length of the cable during the fire test and that temperatures measured on the surface of the raceway (e.g., exterior of the conduit, side rails of the cable trays) provide an indication of the actual temperature rise within the fire barrier system.

Although the licensee completed fire endurance testing for CPSES Unit 1 in August of 1993, the licensee did not perform the periodic insulation resistance level measurements during the fire exposure test as stipulated by the October 29, 1992, acceptance criteria to demonstrate functionality. As of this date the licensee has performed its engineering analysis on the basis of supplementary information provided by cable temperature measurements.

While an analysis may justify the functionality of a specifically tested specimen on the basis of cable temperatures alone, unless that analysis incorporates the higher temperatures associated with the raceway surfaces it would not be expected to bound other configurations. The presence of barrier burnthrough conditions at the end of the fire test for several test schemes further complicates the applicability of the test results to other plant configurations. For example, for a given tested configuration if instrumentation cables were added (i.e., greater cable fill) the individual cables that were added would experience a higher temperature profile due to the greater metal to cable contact although the average cable temperature would be expected to be lower due to the larger mass.

In the cases where the barrier burnthrough occurs during the fire exposure the greater metal to cable contact could create localized hot spots. Therefore, for accurate cable IR prediction, the worst case temperature exposure should be determined using the side rail or external conduit temperatures and the cable temperature as upper and lower temperature bounds respectively. Given the various cable fills to be bounded by the tested configuration the licensee analysis should select the appropriate worst case temperature value (hereafter referred to as the worst case peak temperature) that would be experienced by the installed raceway configuration. This temperature value could then be used to develop a cable IR to demonstrate the functionality of the cables.

The licensee should utilize the individual peak side rail or external conduit temperature measurements in the determination of the worst case temperature exposure for the applicable installed raceways or provide a technical justification for the approach taken that addresses the above concern.

Response 4:

The fire endurance test acceptance criteria was provided by the NRC via reference 2. This acceptance criteria was used by TU Electric. Generic Letter (GL) 86-10 Supplement 1 was issued on July 23, 1993 and was issued for public comment only, and was not issued as a final version until March 25, 1994. The criteria via GL 89-10 Supplement 1 is not considered to be applicable for the TU Electric testing program, which was completed in August 1993 because of the existence of the acceptance criteria provided in reference 2. (Please refer to response to question 1 in reference 4, TU Electric's response to questions from the Auxiliary Systems Branch) Additionally, your staff stated that; "TU Electric did not perform the periodic insulation resistance level measurements during the fire exposure test as stipulated by the October 29, 1992, acceptance criteria to demonstrate functionality." During CPSES Unit 2 fire endurance testing

program, TU Electric informed the staff that for test scheme 15-1, the circuit integrity measurements were not taken. The NRC staff acknowledged this, and stated the following via reference 3 (SSER-27) in April of 1993:

> "The staff does not consider circuit integrity measurements an adequate test of cable functionality, and has determined that post-fire megger testing (described in the acceptance criteria as appropriate cable functionality testing) should be conducted as soon as possible following the test. Therefore, TU Electric's minor change to their test methodology (not performing circuit integrity measurements) is acceptable."

All tests performed for Unit 1 did include post-fire megger testing (Insulation Resistance Test) and the results for this test attribute was acceptable.

Barrier burnthrough conditions at the end of the fire tests do not further complicate the applicability of the test results to other plant configurations because of the following:

A) On test scheme 11-5 the barrier was breached for a specific upgrade, TU Electric did not use this specific upgrade to certify Unit 1 installations.

B) On test scheme 13-2 there was minor burnthrough at the seam of the 12"X4" cable tray barrier and minor jacket discoloration was noted. The test was deemed acceptable based on the cable visual inspection and the insulation resistance measurements, as provided via reference 2.

C) On scheme 11-4, the barrier opened due to the hose stream tests, but no burnthrough occurred. (See reference 4, response to question 3 for additional information.)

Although TU Electric considers this new position by the NRC staff to be overly conservative and considers that the evaluations performed using cable temperature to be acceptable and conservative, the matter is of no consequence for CPSES Unit 1 since such evaluations were not needed to demonstrate cable functionality.

Question 5:

The transmitter circuit model utilized by the licensee may not accurately reflect an actual transmitter circuit for all degraded circuit conditions, and if used may lead to non-conservative estimates of the cable insulation resistance (IR) induced signal errors.

The licensee models a transmitter as a device that produces a variable resistance value based upon a desired input. While a transmitter can be modeled as a variable resistor, its behavior more closely represents a current source that produces the required current on the basis of the scaled input parameter (e.g., pressure, flow). That is, a transmitter operating within its specifications will produce a specific current regardless of the

circuit voltage. This design characteristic enables a transmitter to operate over a range of input voltages without calibration of the voltage source and without consideration of line voltage drops.

In the licensee's model, because the transmitter is treated as a resistor with a particular value associated with its reading, the current through the transmitter is also reduced (based upon the simple V-IR relationship). In reality, given no change in the measured transmitter input the voltage across the transmitter will degrade, but the internal transmitter circuitry will compensate and maintain its current output at the initial levels. Thus, in the licensee's model, a reduction in the transmitter current offsets, to some degree, the increase in the leakage path current. In reality, this offsetting of the leakage path current would not occur.

In the staff's model, the total circuit current is calculated as:

$$I_{total} = I_{trans.} + I_{leakage}$$

and the error in the signal is:

$$\text{Delta } I = I_{total} - I_{trans.} = I_{leakage}$$

This leakage current is:

$$I_{leakage} = \frac{V_{source} - R_{ext}(I_{trans.} + I_{leakage})}{R_{IR} + R_{ext}}$$

where the second term in the numerator accounts for the voltage drop across the external source resistor R_{ext} due to the total current flow. Solving for $I_{leakage}$ yields:

$$I_{leakage} = \frac{V_{source} - R_{ext}(I_{trans.})}{R_{IR} + R_{ext}}$$

If R_{ext} is considered in the denominator as small compared to R_{IR}, which was also assumed in the licensee's calculation, then the leakage current is given by:

$$I_{leakage} = \frac{V_{source} - R_{ext}(I_{trans.})}{R_{IR}}$$

The (R_{ext} X $I_{trans.}$) term in the numerator cannot be discounted since this value can be significant in comparison to the source voltage.

In the particular case examined by the licensee, and using the assumed values of IR obtained by the licensee, the differences between the two models were insignificant because the predicted leakage currents were low. However, the modeling results become more pronounced at higher levels of

circuit degradation, thereby leading to larger predicted leakage currents. The differences between the licensee model and the model described above are highlighted for informational purposes in Attachment 1.

The Instrumentation of America (ISA) has previously considered the modeling of instrumentation circuit degradation as described in ISA-dRP67.04, Part II, "Methodologies for the Determination of Setpoints for Nuclear Safety-Related Instrumentation" (See Appendix D). The licensee should provide justification for the approach taken or perform an analysis using the more accurate model of a transmitter circuit under the degraded circuit conditions.

Response 5:

TU Electric concurs with the staff's assessment of the model used to evaluate leakage current effects on transmitter accuracy. TU Electric has reevaluated the leakage current effects utilizing the constant current model provided by the staff. The analysis is provided in attachment 1 to this letter. It should also be noted that the insulation resistance levels associated with the cables involved in the fire tests were relatively high. Therefore, TU Electric also concurs with the staff that, "the difference between the two models were insignificant because the predicted leakage currents were low."

Question 6:

The licensee cites the insulation resistance (IR) measurements presented in Rockbestos Report QR-7804 as the basis of the subject analysis. However, the correlation used by the licensee as determined by our contractor, Sandia National Laboratories (SNL), is based on a equation that was presented by Rockbestos in a supplement to QR-7804 (Report QR-7804-S).

However, the purpose of that presentation was to show that the IR behavior at LOCA testing peak exposure temperatures are consistent between the past and present studies. In fact, the premise of QR-7804 is that the earlier works presented unrealistically conservative IR values at typical LOCA temperatures due to an instrumentation oversight. This supplement also clearly states in its opening remarks "the results of QR-7804 may be used to predict the Insulation Resistance of any .. under LOCA conditions," and this statement remains the fundamental premise of the QR-7804 work and its supplement.

In 1989, SNL personnel participated in a staff audit of CPSES Equipment Qualification (EQ) program. During that audit, TU Electric was presented with a letter from R. J. Gehm of the Rockbestos Corporation to Mr. Malhotra of Impell Corporation (who was acting on behalf of TU Electric and CPSES) dated August 10, 1989, concerning the IR behavior of Rockbestos cables at CPSES. This letter reiterated the manufacturer's position that the QR-7804 data was considered the most appropriate basis for estimating cable IRs.

The differences between the old and new data sets are significant, particularly when the results are extrapolated to higher temperatures. The QR-7804 study was initiated by Rockbestos specifically because the manufacturer noted that the test configuration used in earlier studies had allowed parallel leakage paths to exist, which resulted in an under-prediction of the cable IR performance at typical EQ temperatures. Hence, the QR-7804 study was carefully configured so as to avoid these problems.

The correlations used to predict IR versus temperature assume a linear relationship. The new data associated with QR-7804 predicts a much sharper decline in IR with increased temperature. This is illustrated in the attached figure from the draft SNL report of the IR "K" value versus temperature (note SNL has extended the manufacturer's original plots to illustrate the effects at higher temperatures).

In the example case presented by the licensee the revised correlation for the IR "K" factor should have been:

$$K = 4 \times 10^{21} \exp(-0.079\ T)$$

Thus, at a temperature of 478°F (248°C or 521°K) the "K" value is:

$$K = 4 \times 10^{21} \exp(-0.079 \times 521) = 5.32 \times 10^{3} \text{ ohm-1000 FT}$$

as compared to the licensee's calculated value of 7.3×10^{4} ohm-1000 FT. Under these conditions the IR over a 20' segment of cable exposed to this temperature (assuming no change in physical characteristics of the cable) would be 0.082 MΩ rather than 1.132 MΩ as calculated by the licensee.

The staff does not consider the use of a correlation from an older study without supporting justification to be an appropriate basis for assessing cable IR performance. The staff requests that the licensee provide justification of the methodology used or perform its analysis on the basis of the actual QR-7804 IR correlation as provided by the manufacturer.

Response 6:

TU Electric does not agree with the statement that the premise of QR-7804 is that the earlier works presented unrealistically conservative IR values at typical LOCA temperatures. Question 6 quotes only, in part, from the report. The entire statement from the report actually reads "[T]his supplement is intended to show that both radiation and chemically crosslinked Firewall III exhibit similar behavior and that the results of QR-7804 may be used to predict the Insulation Resistance of any Firewall III construction under LOCA conditions. TU Electric, however, agrees at the temperature levels associated with the functionality evaluation the analysis should have been performed utilizing the QR-7804 results. This analysis has been redone utilizing the methodology delineated in attachment 1 of reference 1 and has concluded that there is no significant impact.

Question 7:

Given Items 5 and 6 above the licensee is requested to review their example case analysis and address the impact of instrument circuit errors. The staff notes that the peak temperature of 478°F fails to envelope the performance of the 3/4" conduit test assembly with a peak temperature of 522°F (Scheme 9-3).

Response 7:

See response to items 5 and 6 above. Additionally, it should be noted that cable functionality analysis (ER-EE-006) does not address acceptability of 3/4" conduit. The 3/4" conduit configuration were upgraded based on Unit 2 test scheme 9-1, and was accepted as a satisfactory test via SSER-26 (reference 5).

Question 8:

The licensee utilized average cable temperatures and peak (i.e., highest single point) cable temperatures in two separate analyses (i.e., Engineering Report ER-EE-006, Attachment 2 to TXX-93353) to demonstrate cable functionality for the tested configurations. The use of a single point value for the determination of cable IR has the disadvantage that localized "hot" spots may not be appropriately represented in the analysis. For example, a single high thermocouple measurement may unfairly bias the total cable IR to be considered unacceptable.

Attachment 1 provides a calculational framework developed by the staff's contractor, Sandia National Laboratories, to derive an insulation resistance value using cable temperature measurements taken during the fire exposure. Attachment 1 also provides the preliminary results by SNL using the subject calculational framework and previous comments on the licensee's analysis.

However, as discussed above cable temperatures represent only a lower temperature bound for the cable functionality evaluation. The licensee should provide justification for whichever approach (average cable temperature or single peak temperature) is used in the determination of the worst case temperature exposure as discussed in Item 4.

Response 8:

TU Electric concurs with the staff's position, that an evaluation of the actual fire exposure temperature for the cable will provide a more accurate determination of a cable's ability to perform its intended function with regard to insulation resistance and instrument accuracy. This methodology is inherently conservative. The cable temperatures, for calculational purposes, are assumed to be uniform throughout the cable insulation. In fact this is not the case. The thermocouples are placed on the cable jacket and the thermal insulating properties of the jacket are not considered.

Additionally, the thermal time constant associated with the jacket/insulation will not allow uniform heating of the insulation in the time period that the cables are exposed to temperatures above the acceptance criteria.

In light of this however, the averaging of cable temperatures does have its place and is useful when the contribution of the conductor temperature is considered for the purposed of dielectric strength (as was the case in TXX-93353 attachment 2). The averaging of cable temperatures allows an evaluation to be performed in a manner that is more representative of the actual insulation temperature. Attachment 2 of TXX-93353 demonstrated that the dielectric strength would be sufficient to insure that the cable would perform its intended function. This position is supported by Generic Letter 86-10, supplement 1 which states "Thermosetting electrical conductor insulation materials usually retain their electrical properties under short-term exposures to temperatures as high as 260°C (500°F)."

Cable self heating will only be a concern in power cables where insulation resistance, and the resulting leaking current, is not the primary concern. In order to ensure the effects of leakage currents are adequately addressed the "hot spot" methodology will be utilized for the purpose of evaluating instrumentation cables. The analysis performed in attachment 1 has utilized the methodology recommended by the staff and delineated in attachment 1 of reference 1.

Responses to Attachment 2 to TXX-93353

Question 9:

As in the ER-EE-006 analysis, the transmitter circuit model used may not accurately reflect the behavior of the circuit under all degraded conditions. The model used by the licensee may result in non-conservative estimates of transmitter errors under degraded conditions. The same comments apply as stated for Item 5.

Response 9:

See response to question 5 above. Attachment 1 to this letter contains TU Electric's revised functionality evaluation.

Question 10:

As in the ER-EE-006 analysis, the correlation used for estimation of cable IR versus temperature behavior is not that associated with the QR-7804 IR correlation. This choice could result in non-conservative predictions of cable IR at elevated temperatures. The same comments apply as stated for Item 6.

Response 10:

See response to question 6 above. Attachment 1 to this letter contains TU Electric's revised functionality evaluation.

Question 11:

Attachment 2 does not provide a direct comparison of cable IR performance during the fire exposure to the acceptance criteria described in the October 29, 1992, letter for instrumentation cables. The licensee did not perform the periodic insulation resistance level measurements during the fire exposure test. The licensee should provide further justification for this approach or analytically determine the insulation resistance level during the fire test as described in the above calculational framework based upon the worst case peak temperatures.

Response 11:

See response to question 4 and 8 above. Attachment 1 to this letter contains TU Electric's revised functionality evaluation.

Question 12:

Unlike the ER-EE-006 analysis, which considered the impact of the single point high temperature measured during the fire exposure tests. Attachment 2 considers only the peak temperature as averaged over the full length of a given cable. The analysis in Attachment 2 does not consider the potential breakdown of the cables at the hot spot. This assumption may be non-conservative, and not reflective of the wide variations in temperature shown in the test data.

The licensee's basis that the analysis method is conservative is that copper is an excellent thermal conductor and will average temperatures and thus prevent localized insulation hot spots. The test data, however, question the validity of this assumption. While copper does act to average out temperatures to some extent, the rate of heat input to the cables experienced during the test exceeded the ability of the copper to distribute this heat evenly. While the average temperature over the length of the subject cable reached a maximum value of 296°F, the peak single point temperature reached 478°F (based on the power cable in the 1-1/2" conduit).

This variation in temperature data demonstrates that the licensee's assumption of uniform cable temperature may not be conservative. The analysis should consider the breakdown of a cable at a single point that is reflective of actual anticipated cable behavior. That is, the cable would be expected to break down initially at a very localized location rather than along its entire exposed length.

The licensee's analysis does not envelope the average cable temperature measurements made during all of the TUE tests under review. On the basis of the rationale stated above the licensee should provide additional justification for its approach or utilize the single high peak temperature values in the calculational framework as described above to demonstrate compliance with NRC cable IR performance acceptance criteria.

Response 12:

See response to question 8 above. Attachment 1 to this letter contains TU Electric's revised functionality evaluation.

Question 13:

The analysis in Attachment 2 considers a cable conductor temperature of 90°C and an ambient temperature of 50°C for a net temperature rise in the cable of 40°C. However, basic cable ampacity factors are based on an assumed conductor temperature of 90°C and an ambient temperature of 40°C. The licensee should confirm that the subject cables have been rated for an ambient temperature of 50°C.

Response 13:

TU Electric has confirmed that the cables are sized (rated) for an ambient temperature of 50°C.

Question 14:

The licensee incorrectly converted temperature differences from °C to °F using conversion formulas for changing actual temperatures from °C to °F. That is, the licensee used in the subject calculation a temperature rise of 104°F rather than a temperature rise of 72°F to represent the change from ambient temperature (122°F) to rated operating temperature (194°F). The licensee analysis should be corrected with respect to this error.

Response 14:

The staff is correct. However, TU Electric's calculation contained in the Attachment 2 to TXX-93353 was superseded by the Engineering Report ER-EE-006. The subject attachment was for information only and only evaluated the peak temperature of 400°F, and the Engineering Report (ER-EE-006) evaluated the peak temperatures of 478°F.

Question 15:

The analysis provided by the licensee only involves instrumentation circuits. The acceptance criteria specify pre- and post-test IR measurements as simple checks for those fire barriers that marginally exceeded the temperature and barrier condition acceptance criteria. However, given the high temperature deviations that are being considered and the presence of barrier burnthroughs, the breakdown of a power or control cable should be analyzed.

For power and control applications the higher voltage potential gives rise to heating effects as leakage currents are introduced during a fire. The cable breakdown, as the cable IR degrades, leads to higher leakage currents that creates a secondary heating effect on the basis of simple resistance heating. This heating effect acts to supplement the normal cable self

heating caused by the normal current flowing through the cable and further increases the localized insulation temperature. This localized heating further reduces the cable IR and further increases the leakage currents in a self-feeding process.

In one example, if the cable had a 480V potential through a leakage path resistance R= 539 ohms the leakage current can be estimated as:

$$I = \frac{V}{R} = \frac{480}{539} = 0.89 \text{ A}$$

and the resistance heating effect associated with this leakage current would be approximated as:

$$P = I^2 R = (0.89)^2 \text{ X } 539 = 427 \text{ W}$$

While normal circuit protection devices would not detect a fault of less than 1 ampere on a 480 V power circuit, a 427 Watt heating effect localized over a 20 foot segment of cable could lead to cable failure within a short period of time.

This level of additional self heating can be compared to the normal self heating effect due to current flow in the cable. If we consider for illustration purposes a cable tray with a 2" depth fill and a 30% ampacity derating factor due to the fire barrier, then the current carrying capacity of the 6 AWG wire would be approximately 16.1 amperes. Given a wire resistivity of .5 ohm per 1000 foot, the heating effect per unit foot of cable would be approximately:

$$P = I^2 R = (16.1)^2 \text{ X } 0.5 \text{ X } 10^{-3} = 0.13 \text{ W/ft}$$

This result compared to the previous example of approximately 21 W/ft indicates a high level of localized heating. The staff requests that the licensee provide further justification for its approach or include consideration of power and control cable performance and damage potential in its analysis.

Response 15:

An instrumentation cable was utilized for evaluation purposes because it has the thinnest insulation wall. If leakage currents were within an acceptable range, dielectric strength would not be an issue. TU Electric does take issue with the initial conditions as stated by the staff. An insulation resistance of 539 ohms is unrealistically low. The worst case analysis performed in attachment 1 revealed an IR of 3.2 Meg ohms. Also, the current carrying capacity of a 6 AWG wire was established as 16.1 amps. While this appears to be reasonable for a "cable tray with a 2 inch depth of fill and a 30 percent ampacity derate" it is inappropriate for evaluating the dielectric strength of the insulation. The current carrying capacity of a cable in free air or in conduit is more appropriate. If 500,00 ohms would have been selected as the insulation resistance the leakage current would have been:

$$I = V/R = 480/500{,}000 = .00008 \text{ A}$$

and the resistance heating effect associated with this leakage current would be approximated as:

$$P = I^2R = (.00008)^2 \times 500{,}000 = .0032 \text{ W}$$

This amount of additional heating will have no adverse effect on cable performance.

Response to Specific Test Reports

Test Report for Scheme 9-3

Question 16:

The test report does not provide a direct comparison of the cable IR performance during the fire exposure to the October 29, 1992, acceptance criteria for instrumentation cables. The licensee did not perform periodic insulation resistance level measurements during the fire exposure test. The licensee should provide further justification for the approach taken or analytically determine the insulation resistance level during the fire test as described in the above calculational framework on the basis of worst case peak temperatures.

Response 16:

See response to question 4 and attachment 1 to this letter.

Test Report for Scheme 11-2

Question 17:

The test report does not provide a direct comparison of the cable IR performance during the fire exposure to the October 29, 1992, acceptance criteria for the 2 inch air drop configuration where maximum temperature acceptance criteria was exceeded and damaged power cable was observed during the visual inspection. The licensee should provide further justification or analytically determine the insulation resistance level during the fire test as described in the above calculational framework. In addition, the licensee should provide further justification or evaluate for the power cable case the impact of self heating effects on cable functionality as discussed in Item 15.

Response 17:

See response to question 4 please note that the power cables in question did not suffer any significant thermal damage (minor surface ablation of jacket only), also see response to 12.

Test Report for Scheme 11-5

Question 18:

The test report does not provide a direct comparison of the cable IR performance during the fire exposure to the October 29, 1992, acceptance criteria for instrumentation cables. The licensee did not perform the periodic insulation resistance level measurements during the fire exposure test. The licensee should provide additional justification or analytically determine the insulation resistance level during the fire test as described in the above calculational framework on the basis of worst case peak temperatures.

Response 18:

The periodic insulation resistance level measurements were not required to be performed, see response to question 4. However, for the cable tray upgrade that was implemented (i.e., longitudinal stress skin overlay), the test met the acceptance criteria based on the NRC October 29, 1992 letter (reference 2), independent of cable functionality, based on satisfactory raceway temperatures and barrier condition.

For the tray upgrades that were only used in localized areas of congested trays (i.e., ceramic bandings), the test met the acceptance criteria without cable functionality demonstration based on satisfactory barrier condition and cable visual inspection.

Question 19:

The left cable tray assembly of Scheme 11-5 experienced a barrier opening and cable damage. The staff is concerned about the results of the post test examination that indicates that the outer cable jackets were charred. This charring of the cable jacketing material indicates a higher level of damage than that observed in other tests. Charring indicates that combustion of the cable jacket was taking place during the fire exposure. Charring is outside the expected scope for thermal degradation described in the October 29, 1992, letter.

The licensee should provide additional justification or reconsider its position that the installed cables would be free from fire damage for the subject test configuration. In addition, due to the presence of the barrier opening, the licensee is requested to assess in the methodology stated above whether control or power cables would have been impacted by local hot spot temperatures.

Response 19:

Refer to response to question 2. The method upgrade used on the left cable tray of scheme 11-5 (circumferential stress skin wrap), which experienced a barrier opening and cable damage was not used to certify Unit 1 installations.

Test Report for Scheme 13-2

Question 20:

The test report does not provide a direct comparison of the cable IR performance during the fire exposure to the October 29, 1992, acceptance criteria for instrumentation cables. The licensee did not perform the periodic insulation resistance level measurements during the fire exposure test. The staff requests that the licensee provide further justification or analytically determine the insulation resistance level during the fire test as described in the above calculational framework on the basis of worst case (peak) temperatures. In addition, the licensee should provide additional justification or evaluate for the power cable case the impact of self heating effects on cable functionality as described in Item 15.

Response 20:

Refer to response to question 4 and question 15.

Test Report for Scheme 15-2

Question 21:

On the basis of visual observations of the Flexi-Blanket protected cable air drop, the staff questions the conclusion that the test passed on the basis of cable temperatures. The staff has two areas of concern.
The descriptions provided of the post-test visual inspection included a statement that "thermocouple lead insulation melted in several places (wire exposed in some)." This statement is repeated for each of the two Therm-Lag Flexi-Blanket protected assemblies. In addition, for the front cable bundle it is stated that "nearly all thermocouple wires on bare #8 melted into a cluster left of center of deck." These statements provide an indication that the thermocouple data gathered during the test may be unreliable and invalid. That is, the melting of the thermocouple insulation could result in the creation of false junctions and could severely distort the temperature readings. It may not be possible to determine where thermocouple measurements were made because a false junction could have formed at any point along the wire. In this case the reading themselves would be questionable since the quality of these false junctions would be unknown including the potential for shorts between thermocouple pairs.

The description of the post test inspection observations for the cables specimens (both Flexi-Blanket protected test articles) themselves included the statement that, "outer cable jacket charred in several places (corresponding to lack of uncharred material mentioned above)." As discussed in Item 19 for the Scheme 11-5 test, the presence of cable jacket charring is indicative of combustion and the licensee should reconsider its position that cables would be free from fire damage for the subject test configuration.

During November and December of 1992 the licensee did not use suspect and unreliable thermocouple readings to evaluate test Schemes 9-1, 9-3 10-1 and 10-2 for conduits. On the basis of the post-test condition of the thermocouple lead wire described in the test report the staff considers the temperature data unreliable and invalid. Given that cable functionality can not be demonstrated "pre-fire, during the fire..., and after the fire test conditions" as stated in the October 29, 1992, acceptance criteria, the licensee should provide additional technical data and an evaluation to demonstrate cable functionality, or the licensee should withdraw the subject test scheme for fire protection application.

Response 21:

The thermocouple leads which suffered thermal degradation during scheme 15-2 were located on the #8AWG bare copper conductor which were routed inside both protective envelopes. The thermocouples installed on the single conductor 750 KcMIL cables suffered no thermal deterioration and accurately measured temperatures experienced on the surface of the cables. The maximum cable temperature was 377°F and was taken from the thermocouples which did not suffer any thermal deterioration. Additionally, TU Electric opted to upgrade this particular configuration with a third layer of 330-660 flexi-blanket in the installed configuration. For additional information please refer to response to question 2 in reference 4.

If you need further information, please call Obaid Bhatty at extension (817) 897-5839.

Sincerely,

William J. Cahill, Jr.

William J. Cahill, Jr.

By: Roger D. Walker

Roger D. Walker
Regulatory Affairs Manager

OB:tg

ATTACHMENTS
ENCLOSURE

cc: Mr. L. J. Callan, Region IV
Mr. K. S. West, NRR
Ms. M. A. Miller, Region IV
Mr. T. A. Bergman, NRR
Resident Inspectors, CPSES

ATTACHMENTS TO TXX-94173

Calculation of the worst case theoritical IR for a Ther molagged cable. The temperature measurements are from the 1 1/2 inch conduit in sch me 9-3.

$$T = \begin{bmatrix} 295 \\ 286 \\ 290 \\ 331 \\ 358 \\ 358 \\ 328 \\ 338 \\ 274 \\ 213 \\ 222 \\ 269 \\ 393 \\ 478 \\ 320 \\ 322 \\ 324 \\ 313 \\ 312 \\ 264 \\ 213 \\ 217 \\ 258 \\ 289 \\ 306 \\ 271 \\ 211 \end{bmatrix}$$

$$D = .118 \qquad d = .058 \qquad K = \overrightarrow{\left[4 \cdot 10^{21} \cdot e^{\left[-.079 \cdot \left[\left[\frac{5}{9} \cdot (T - 32)\right] + 273\right]\right]}\right]} \qquad IR = \overrightarrow{\left(K \cdot \log\left(\frac{D}{d}\right)\right)}$$

$$IR' = IR \cdot 1000 \qquad S = .5 \qquad R = \frac{IR'}{S}$$

$$R_1 = \frac{1}{\left(\frac{1}{R_0} + \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} + \frac{1}{R_6} + \frac{1}{R_7} + \frac{1}{R_8} + \frac{1}{R_9} + \frac{1}{R_{10}} + \frac{1}{R_{11}} + \frac{1}{R_{12}} + \frac{1}{R_{13}}\right)}$$

$$R_2 = \frac{1}{\left(\frac{1}{R_{14}} + \frac{1}{R_{15}} + \frac{1}{R_{16}} + \frac{1}{R_{17}} + \frac{1}{R_{18}} + \frac{1}{R_{19}} + \frac{1}{R_{20}} + \frac{1}{R_{21}} + \frac{1}{R_{22}} + \frac{1}{R_{23}} + \frac{1}{R_{24}} + \frac{1}{R_{25}} + \frac{1}{R_{26}}\right)}$$

$$Rt = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}} \qquad Rt = 3.2 \cdot 10^{6}$$

Where:

T = Temperature of insulation in degrees F.
D = Diameter over the insulation in inches.
d = Diameter over the conductor in inches.
K = Insulation Resistance constant.
IR = InsulationResistance in Meg ohms - 1000 ft.
IR' = Insulation Resistance for a cable length, in Meg ohms and ft.
S = Thermocouple spacing.
R = Insulation Resistance of each cable segment, in Meg ohms.
Rt = Insulation Resistance of entire cable, in Meg ohms.

The instrument error can then be calculated in the following manner:

$IS = .012$ $IS_{max} = .020$ $IS_{min} = .004$ $VS = 40$ $RL = 250$

$$IE = \frac{VS - IS_{min} \cdot (RL)}{Rt}$$ $IE = 1.219 \cdot 10^{-5}$

$$IE(\%) = \frac{IE}{IS_{max} - IS_{min}} \cdot 100$$ $IE(\%) = 0.076$

Where:

ISmax = Maximum transmitter current.
ISmin = Minimum transmitter current.
VS = Loop power supply.
RL = External source resistor.
IE = Leakage current.
IE(%) = Leakage current as a percent of instrument span.

The leakage current associated associated with this temperature profile would be insignificant for this worst case ambient temperature configuration.

PERCENT DERATES (Original)

TEST ITEM	EQU. VOLTAGE (VOLTS)	EQU. CURRENT (AMPS)	EQU. TEMP (°C)	ROOM TEMP (°C)	CORRECTED CURRENT (AMPS)	PERCENT DERATING
3C/#10 in 3/4" Conduit (base)	11.9	39.4	89.8	40.3	39.6	9.34
3C/#10 in 3/4" Conduit (clad)	11.0	36.0	89.4	39.3	35.9	9.34
3C/#6 in 2" Conduit (base)	9.96	64.6	90.5	40.3	64.5	6.67
3C/#6 in 2" Conduit (clad)	9.15	60.2	89.1	39.3	60.2	6.67
3C/#6 in Air Drop (base)	10.9	94.0	89.9	39.5	93.6	21.2
3C/#6 in Air Drop (clad)	8.12	74.0	90.9	40.5	73.8	21.2
3C/#6 in 24" Cable Tray (base)	46.5	23.2	89.8	39.5	23.1	31.6
3C/#6 in 24" Cable Tray (clad)	27.2	15.9	90.3	39.9	15.8	31.6

PERCENT DERATES (Revised)

TEST ITEM	EQU. VOLTAGE (VOLTS)	EQU. CURRENT (AMPS)	EQU. TEMP (°C)	ROOM TEMP (°C)	CORRECTED CURRENT (AMPS)	PERCENT DERATING
3C/#10 in 3/4" Conduit (base)	11.9	39.4	90.4	40.3	39.6	9.4
3C/#10 in 3/4" Conduit (clad)	11.0	36.0	90.2	39.3	35.9	9.4
3C/#6 in 2" Conduit (base)	9.96	64.6	90.4	40.3	64.5	6.6
3C/#6 in 2" Conduit (clad)	9.15	60.2	89.1	39.3	60.2	6.6
3C/#6 in Air Drop (base)	10.9	94.0	89.7	39.5	93.6	21.3
3C/#6 in Air Drop (clad)	8.12	74.0	90.9	40.5	73.8	21.3
3C/#6 in 24" Cable Tray (base)	46.5	23.2	89.7	39.5	23.1	31.5
3C/#6 in 24" Cable Tray (clad)	27.2	15.9	90.2	39.9	15.8	31.5

ENCLOSURE 1 TO TXX-94173

SWEC IC(B)-071
Revision 2