Tennessee Valley Authority, Post Office Box 2000, Spring City, Tennessee 37381

JUN 30 1993

William J. Museler
Site Vice President
Watts Bar Nuclear Plant

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D.C. 20555

Gentlemen:

In the Matter of the Application of	)	Docket Nos. 50-390
Tennessee Valley Authority	)	50-391

WATTS BAR NUCLEAR PLANT (WBN) - RESPONSE TO NRC REQUEST FOR ADDITIONAL INFORMATION - THERMO-LAG RELATED AMPACITY DERATING ISSUES (TAC M63648)

The purpose of this letter is to reply to NRC's letter dated May 5, 1993, that requested additional information pertaining to the WBN Thermo-Lag conduit fire test plans which were submitted February 10, 1993. The Enclosure provides a restatement of the comments and questions in NRC's letter dated May 5, 1993, and the associated TVA response. There are no new commitments contained in this submittal.

Should there be any questions regarding this information, please contact Paul Pace at (615) 365-1824.

Very truly yours,

J E Moody

for

William J. Museler

Enclosure
cc: See page 2

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cc (Enclosure):

NRC Resident Inspector
Watts Bar Nuclear Plant
P.O. Box 700
Spring City, Tennessee 37381

Mr. P. S. Tam, Senior Project Manager
U.S. Nuclear Regulatory Commission
One White Flint North
11555 Rockville Pike
Rockville, Maryland 20852

U.S. Nuclear Regulatory Commission
Region II
101 Marietta Street, NW, Suite 2900
Atlanta, Georgia 30323

ENCLOSURE

WATTS BAR NUCLEAR PLANT
THERMO-LAG AMPACITY DERATING ISSUES
REQUEST FOR ADDITIONAL INFORMATION

The following is in response to questions and comments in NRC's letter dated May 5, 1993.

NRC ITEM NUMBER 1

The proposed IEEE Standard P848 Draft 12 has been issued by the IEEE Task Group 12-45, correcting the previous Draft (11) version. Given TVA's participation on the subject Task Group, please identify what changes, if any, will be made to meet the current draft of the IEEE Standard in the final test report. Please identify what empirical evidence (test data) has been developed to validate the assumptions inherent in the IEEE procedure.

TVA RESPONSE

The exceptions taken to Draft 11 as a result of the issuance of Draft 12, as well as exceptions taken by TVA as a result of lessons learned during the tests are described in Attachment C to TVA lab test procedure, "Watts Bar Nuclear Plant, Testing to Determine Ampacity Derating Factors for Fire Protected Cables", Job Number 93-0501, Revision 3, dated April 22, 1993. The exceptions taken by TVA and the basis for each are:

a. Exception: The tested conduits are 20 feet long and supported 5 feet from each end.

   Basis: Draft 11 states that the conduit shall be 12 feet long and supported 18 inches from each end. Draft 12 states that the conduit length shall be a minimum of 12 feet. This option was added at the request of TVA and would ensure reduction of any end effects.

b. Exception: Three single conductor 750 MCM copper cables are being used in lieu of one three conductor cable.

   Basis: Draft 11 states that one three-conductor 750 MCM copper cable will be used in the 4-inch conduit. At the request of TVA and TU, the standard was changed to permit the use of three single conductor 750 MCM cables. Utilities typically use individually jacketed single conductors rather than three-conductor construction for cables this size. As a result, cable vendors do not stock such a three-conductor cable and a special production run (minimum 5,000-10,000 feet) would be required to satisfy the test lab's need for less than 100 feet.

The single-conductor material can be drawn directly from utility or manufacturer stock and has the advantage of being more representative of the installed material.

c. Exception: Type T thermocouples with an accuracy of +/- 0.5 degrees C are being used.

Basis: Draft 11 states that type K special grade thermocouples will be used. Draft 12 was changed to ensure greater accuracy by requiring type T special grade thermocouples or equivalent. The draft 12 language will permit the use of any grade thermocouple as long as it can be demonstrated by test to meet the accuracy requirements for the type T special grade.

d. Exception: Three thermocouples are being used on each conductor (e.g., a total of nine thermocouples for three conductors).

Basis: Draft 11 states that a total of three thermocouples will be used to determine the conductor temperatures. Draft 12 states that three thermocouples will be used in each of the three vertical planes. By requiring the placement of a thermocouple on each conductor in a three-conductor test, the standard ensures that the test results are not sensitive to the specific orientation of the cable set. In performing both three and four-conductor testing, TVA placed thermocouples on every conductor in each of the three required vertical planes. When tests were performed using 8-3/c #6 AWG cables, TVA placed a thermocouple on one conductor in each cable in each vertical plane. Since every cable was instrumented, the concern for orientation of the cable set was eliminated.

e. Exception: A qualitative measurement of moisture content is being taken rather than a direct reading in percent moisture.

Basis: Draft 11 states that moisture content, in percent moisture, will be determined for the fire barrier material. Draft 12 states that the test specimen's dry state shall be established by the manufacturer and achieved prior to the test through natural or artificial aging. TSI has established that the cure time for Thermo-Lag is 30 days. Testing did not begin until the thirty day cure period was complete.

Although not required by draft 12, TVA measured the moisture content using procedures and equipment as specified by TSI. That process provided a qualitative assessment of the moisture content rather than a direct reading in percent.

f. Exception: The accuracy of the current measurement devices being used is +/-1 percent of reading.

Basis: Draft 11 states that the current value will be reported to 0.1 ampere, but no accuracy is stated. Draft 12 requires an accuracy of +/-0.5 percent instead of an absolute current value. The change was made to reflect the magnitude of current which needs to be measured when 750 MCM conductors are used (ICEA standard value is 598 amps) and the impossibility of measuring that current to 0.1 amps (0.017 percent) with standard laboratory instrumentation. Upon further review, the 0.5 percent requirement has been shown to be too restrictive. TVA understands that the next draft of the standard will therefore raise this accuracy requirement to 1.0 percent. A 1.0 percent criteria has been utilized in the TVA testing and has been found to be satisfactory.

g. Exception: A temperature rate of change of +/-0.2 degrees C per hour is being used to determining equilibrium conditions.

Basis: Draft 11 states that the rate of change will not exceed +/-0.55 degrees C per hour. Draft 12 states that the rate of change will be +/-0.2 degrees C per hour. The tighter specification will ensure that equilibrium has been achieved.

The primary assumption inherent in drafts 11 and 12 of IEEE P-848 is that tests using three conductors, fed single-phase, will provide the same results as those performed with the same conductors powered with three-phase current. However during single-phase testing, TVA determined that significant inductive heating in the conduit resulted from current "imbalance" (conduit surface temperature was noted to be between 75 degrees C and 80 degrees C). The heating may have influenced the test results; therefore, TVA undertook further testing to determine the effects of current imbalance on test results and ensure appropriate ampacity derate factors were established. The impact on test results varies as a function of two parameters.

First, a review of applicable literature shows that conduit losses are inversely proportional to the square root of the product of the conduit electrical resistivity and magnetic permeability. The literature also indicates that under certain conditions of current imbalance, the losses in the conduit could be as much as 25 times those in the conductor. Where the conduit losses predominate, the specific conduits utilized for baseline and wrapped specimens may significantly effect equilibrium current.

Secondly, the elevated conduit temperature impacts the effective thermal resistance from the conduit to the surrounding air. As can be demonstrated by using Equation 42 of the Neher-McGrath paper (see below), effective thermal resistance (and hence the equilibrium current for the baseline conduit) varies inversely with a power function of the difference in temperature between the surface and the surrounding air. A change in

conduit temperature from 60 degrees C to 80 degrees C will decrease the effective thermal resistance of a 4-inch conduit to the surrounding air by approximately 15 percent.

$$Re = \frac{15.6n}{Ds\left(\frac{dT}{Ds}\right)^{1/4} + 1.6\epsilon(1 + 0.0167Tm)}$$

where: Re is the effective thermal resistance from the conduit (or Thermo-Lag, if installed) to the surrounding air.
n is the number of conductors within the conduit.
Ds is the diameter of the conduit (or Thermo-Lag if installed).
dT is the temperature difference between the surface of the conduit (or Thermo-Lag) and ambient air. The dT selected for the above evaluation was based on the approximately 80°C readings taken during the single-phase three conductor tests and the 60°C readings taken during testing with balanced "currents."
ϵ is the emissivity of the conduit (or Thermo-Lag).
Tm is the average of the surface temperature of the conduit (or Thermo-Lag) and the ambient air.

TVA undertook a series of 4 conductor (750 MCM) single-phase tests (for both the 1 and 4-inch conduits) to minimize the conduit heating effect. Conduit temperatures dropped substantially (from 75 - 80 degrees C to 60 degrees C). However, the test results still appeared to be somewhat dependent upon some characteristic of the individual conduits. A literature search showed that when the NEC derating factors for multiple conductors in conduit were being developed, the same three-phase versus single-phase questions arose. Tests conducted to satisfy those concerns utilized 12 conductors per conduit and found no significant difference due to the power supply. TVA performed a 24 conductor (8-3/c #6 AWG) single-phase test and has performed a three-phase test using the same 8-3/c cable set. The conductor size was selected to remain consistent with that utilized in the 1-inch conduit and the number of cables was chosen to achieve an approximate 40 percent fill. The results of the three-phase tests in the 4-inch conduit are consistent with those obtained for the 24 conductor single-phase test. Further testing is planned for 1-inch conduit using 3/c #6 AWG supplied with three-phase power.

In the process of investigating and testing, emissivity was identified as a parameter which may be dependent upon the individual conduit utilized. Conduit emissivities may vary according to the manufacturer, date of

manufacture, and general condition. As can be demonstrated by using Equation 42 of the Neher-McGrath paper, emissivity influences the effective thermal resistance from the conduit to the surrounding air and hence the equilibrium current established during the baseline test. If the conduit used to establish the baseline has a low emissivity, the baseline current will be suppressed (compared to the standards). The effect of emissivity could potentially be as great as the effect of the Thermo-Lag in establishing the final correction factor.

Initial results indicate that the new derating factor for Thermo-Lag wrapped conduits will be bounded by the factors previously used for WBN; however, the TVA ampacity testing is on-going and these results should be regarded as preliminary. The test data will be made available for NRC review following completion of testing as described in the Watts Bar Nuclear Plant response to Generic Letter 92-08, dated April 16, 1993 (TVA Letter No. T04930416884). TVA is represented on the working group for IEEE P-848 and has advised the Chairman of the findings to date.

NRC ITEM NUMBER 2

TVA states that tests conducted by other organizations, such as Texas Utilities, that are evaluated as appropriate for TVA installations may be utilized in the WBN test program. Please provide the quality assurance and engineering evaluations which establish the suitability of application for the construction, quality control and test program of the test article(s) to WBN plant installation, and quality assurance program requirements. Describe and disposition any differences between the test articles and WBN installed configurations.

TVA RESPONSE

Ampacity derating factors for cable trays and free air-drops protected with Thermo-Lag are being developed from results of tests performed for Texas Utilities at Omega Point Laboratories in San Antonio, TX. Test plans prepared by Texas Utilities for these tests were reviewed by TVA.

Tests at Omega Point were conducted in accordance with a 10CFR50 Appendix B quality assurance program which included control of material, construction of test samples, performance of tests, and documentation of test results. Omega Point Laboratory has been approved by TVA to provide 10CFR50 Appendix B testing services.

TVA is preparing the following documents to ensure that the installation of Thermo-Lag at WBN is consistent with tested installations or deviations appropriately evaluated:

a. Design Standard DS-M-17.2.2, revision 0, "Electrical Raceway Fire Barrier Systems"

b. General Engineering Specification G-97, revision 0, "Installation, Modification, and Maintenance of Electrical Raceway Fire Barrier Systems"

DS-M-17.2.2 addresses the design of fire barrier systems. Specification G-97 addresses the installation requirements. Any differences between the tested configurations and the installed configuration will be appropriately evaluated to ensure that the installations are bounded by the qualification test assembly configurations as described in the Watts Bar Nuclear Plant response to Generic Letter 92-08, dated April 16, 1993 (TVA Letter No. T04930416884).

NRC ITEM NUMBER 3

The subject test plan specifies that 1-inch conduit and 4-inch conduit test articles are the only conduit sizes to be tested to determine the ampacity derating associated with the Thermo-Lag protective material. In Section 2.0, OBJECTIVE of the subject Test Plan, TVA states that "the results of the test will allow determination of a single derating factor for each configuration of fire barrier material, regardless of conduit size." However, IEEE P848, Draft 11 states in Section 5.3.2.2 that "the application of the fire protection system may result in differing derating for different conduit sizes." Please describe how the conduit sizes chosen provide ampacity derating results which bound the WBN plant configuration, given other conduit sizes (e.g., 3/4-inch and 5-inch conduit sizes) listed on Attachment 1 of TVA's submittal.

TVA RESPONSE

3. Section 5.3.2.2 of draft 11 of IEEE P-848 requires that tests be performed on both 1-inch and 4-inch conduits. Both derating factors determined by those tests are to be reported, with the worst derating to be used for the entire range.

Draft 12 of IEEE P-848 elaborates on the representative nature of the two specified sizes. Section 4.2.3 of the standard states, "Conduit ampacity tests shall utilize 1 and 4-inch rigid steel conduits. Tests conducted using these two sizes shall be considered representative of all sizes provided that the fire protective system installation methods and configurations are consistent across the entire size range. Where the installation methods, configurations, or fit differ according to conduit size the user shall test sizes to bound the specific application."

WBN's test plan adheres to the standard in these respects. Each of the three Thermo-Lag configurations which were evaluated for fire endurance is being ampacity tested using both 1 and 4-inch conduits. A consistent fit across the entire size range is ensured through WBN's practice of "pre-buttering" the interior and all seams of the preformed Thermo-Lag sections with trowelable Thermo-Lag material. While derating factors are being

established for both conduit sizes of the tested configurations, TVA's ampacity design standard is being based on the worst case factor for each configuration.

NRC ITEM NUMBER 4

The subject Test Plan does not specify that laboratory activities will be controlled under an Appendix B quality assurance program and that the test articles will be procured to Appendix B purchase requirements. Please identify quality assurance requirements applicable for ampacity derating tests.

TVA RESPONSE

TVA's test plan prepared by Nuclear Engineering, "Development of Ampacity Derating Factors for Fire Wrapped Raceways," Revision 0, dated January 7, 1993 (and subsequent revisions), stipulates in Section 5.0, "Responsibilities," that the laboratory shall "prepare test items in accordance with Appendix B Quality Assurance and Quality Control Programs and other applicable procedures." Section 6.0, "QA Requirements," further stipulates that "this test is required to be performed by a laboratory with an approved QA program and all documentation of the tests shall be produced as a QA document."

Additional details regarding the QA controls applied to the subject test program are discussed in Sections 2.5 and 3.0 of TVA's Central Laboratories Services Department Test Plan (which implements the Nuclear Engineering test plan), "Watts Bar Nuclear Plant, Testing to Determine Ampacity Derating Factors for Fire Protected Cables," Job Number 93-0501, Revision 3, dated April 22, 1993 (and subsequent revisions). This document references the following Central Laboratory Services Department (CLSD) and industry QA documents:

a. CLS-QAP-1.1, "Organization"
b. CLS-QAP-4.1, "M & TE Calibration Program"
c. CLS-QAP-4.7, "Engineering Services Program
d. ANSI N45.2-1971, "Test Control"
e. 10CFR50 Appendix B, "Quality Assurance Criteria for Nuclear Power Plants"

The CLSD test plan states in Section 3.0 that "all test equipment and instrumentation to be used in the performance of this test program shall be calibrated in accordance with applicable standards and QA procedures and will conform to applicable portions of ANSI N45.2 and 10CFR50 Appendix B (except the moisture meter described in steps 5.3.3 and 5.3.14)." It further states that "all personnel, procedures, and instructions used in the performance of this test program shall comply with the applicable requirements of the Central Laboratory Services Department (CLSD) Quality

Assurance Program." This program has been audited by TVA. As a result, CLSD has been approved to provide 10CFR50 Appendix B testing services.

All material used to construct the test samples was procured by Watts Bar Procurement Engineering Group under the limited QA program for fire protection. Receipt inspection was performed at the Watts Bar site.

NRC ITEM NUMBER 5

TVA's submittal states, in response to NRC Question No. 2, that ampacity tests will be conducted for all intended Thermo-Lag applications regardless of temperatures recorded during fire endurance tests. Please provide ampacity derating test results or engineering justification for the presence of coiled cables in Pull/Junction Boxes, air drops and other electrical enclosures.

TVA RESPONSE

The scope of TVA's in-house ampacity test program includes both 1 and 4-inch conduits. For each conduit size, tests are conducted on unwrapped specimens to establish a baseline ampacity and on specimens with a nominal 5/8 inch base layer of Thermo-Lag, a nominal 5/8 inch base layer plus a nominal 3/8 inch upgrade layer, and a nominal 3/8 inch base layer plus a nominal 3/8 inch upgrade layer.

Ampacity tests will not be conducted for electrical enclosures such as junction boxes or pull boxes. Draft 12 of IEEE P-848 specifically addresses this issue. Section 4.2.3 states, "In addition to the conduit, the junction boxes and pull boxes may also be enclosed with a protective material. Since the surface area of the boxes is significantly greater than the conduit, heat transfer is improved proportionally. Therefore, junction boxes and pull boxes do not need to be included in the ampacity test."

Instrumentation or control cables could be coiled in pull boxes. Given the number of such cables which may be routed in a single conduit, congestion could occur in a box where multiple conduits intersect. Due to the negligible heat loading associated with instrumentation or control cables, TVA considers that such coiling does not present an ampacity concern.

In power cable applications, coiling to the extent that thermal heat buildup would occur is not feasible due to the size and stiffness of the cables. In addition, the number of such circuits which typically intersect at pull boxes is substantially less than in the case of instrumentation and control raceways and the longitudinal thermal conductivity of power cables is much higher due to their larger conductors. Both considerations ensure the absence of hotspots.

WBN's approach with respect to enclosures is consistent with industry practice in not establishing distinct ampacities for discontinuities in raceways due to their limited dimensions (e.g., tray crosses and tees, condulets, manholes). Ampacity derating factors for cable trays and free air-drops protected with Thermo-Lag are being developed based on the results of tests conducted for Texas Utilities at Omega Point Laboratories in San Antonio, TX.

NRC ITEM NUMBER 6

In Attachment 3 (Test Plan - Circuit Functionality Testing) of the TVA submittal, Section 8.0, PROCEDURE of the test, does not provide for a parametric assessment of insulation resistance changes during the elevated temperature exposure to establish functionality of instrumentation cables. It is not clear how "the measurement of leakage current for margin assessment only" will be used to provide information to TVA in the context of demonstrating functionality.

TVA RESPONSE

Circuit functionality testing would only be required if the cold side temperature rise exceeded the acceptance criteria. The Thermo-Lag wrapped tray and conduit configurations to be installed at WBN met the acceptance criteria for cold side temperature rise during their respective fire endurance tests. Therefore, no circuit functionality tests will be performed and the referenced part of the Test Plan will not be used for the Thermo-Lag installed at Watts Bar.

NRC ITEM NUMBER 7

How is the issue of the minimum insulation levels required for nuclear instrumentation cables, as applicable to WBN, assessed given the insulation resistance values shown in Section 8.4 of the subject Test Plan? Please also state whether the Test Plan criteria is acceptable for demonstrating the functionality of these cables.

TVA RESPONSE

See response to question 6.

NRC ITEM NUMBER 8

Although TVA has described in previous meetings (e.g., October 7, 1992 Meeting at NRC Headquarters) likely failure modes (i.e., creep and crack phenomena) during the cable functionality test, the subject Test Plan procedure does not include a visual inspection or examination to assess the condition of the cable samples following the elevated temperature exposure

portion of the test. The evidence of visible cable degradation would provide a subjective assessment verifying the information obtained through the megger and leakage current measurements. Please provide an assessment of the visible cable degradation in future circuit/cable functionality tests.

TVA RESPONSE

See response to question 6.