UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

September 15, 1994

APPLICANT: Tennessee Valley Authority (TVA)

FACILITY: Watts Bar Nuclear Plant, Units 1 and 2

SUBJECT: MEETING SUMMARY - AUGUST 30, 1994 MEETING WITH THE TENNESSEE VALLEY AUTHORITY REGARDING PROPOSED USE OF THERMO-LAG FIRE RETARDANT MATERIAL (TAC M63648)

REFERENCE: Meeting notice by P. S. Tam, August 10, 1994

On August 30, 1994, NRC and TVA representatives met in Rockville, Maryland, to discuss TVA's proposed use of Thermo-Lag fire retardant material at Watts Bar, in particular, TVA's ampacity derating tests and associated test plan. Meeting participants and observers are listed in Enclosure 1.

The staff identified three issues with respect to ampacity derating testing that need further clarification. The handout provided as Enclosure 2 details the technical basis for the concerns of the staff in regards to the effects of variable conduit emissivities, wall temperature variations in test enclosures affecting test results, and the applicability of ongoing ampacity derating tests to future non-standard thermo-lag enclosed electrical raceway configurations.

TVA personnel stated that they are aware of the variations in emissivities due to surface finish and attributed it to the nonuniform manufacturing and storage of the conduits. TVA personnel asked the staff to review the material pertaining to emissivity variation in the requests for additional information (RAI) dated November 26, 1993 and June 30, 1993, then respond with further inquiries if necessary.

The staff expressed concern with regards to variations in wall temperatures in the test enclosure during the ampacity derating testing. TVA was asked to explain what provisions were taken during the tests to ensure that the wall temperature did not differ significantly from the ambient air temperature which was maintained at 40° ±2°C, or assess the impact of this effect upon overall ampacity derating factors. TVA agreed to do this in its next submittal.

270060

9409290328 940915
PDR ADOCK 05000390
F PDR

DF01

Finally, the staff requested a list of the nonstandard configurations which would involve ampacity derating considerations (i.e. power circuits) TVA expects to utilize during thermo-lag installation. TVA agreed to submit their best estimate of those non-standard configurations and the rationale behind the test selection.

Laura A. Dudes, Project Engineer
Project Directorate II-4
Division of Reactor Projects - I/II

Docket Nos: 50-390 and 50-391

Enclosures: 1. Participants and Observers List
2. NRC Handout

cc w/encl 1: See next page

Dist. w/encl 1:

W. Russell/F. Miraglia	0-12-G-18
R. Zimmerman	0-12-D-22
S. Varga	0-14-E-4
G. Lainas	0-14-E-4
OGC	0-15-B-18
E. Jordan	
C. Craig	0-12-E-4
D. Houston	
C. McCracken	0-8-D-1
N. Dudley	T-2-E-5
T. Berlinger	0-7-E-4
T. Blatchford	
ACRS(10)	
G. Tracy	0-17-G-21
W. Jensen	0-8-E-2
B. Boger	RII

Dist. w/encls 1&2:
Docket Files
PUBLIC
WBN Rdg. File
J. Jaudon
P. Tam

DOCUMENT NAME: G: 830MTG.SUM

To receive a copy of this document, indicate in the box: "C" = Copy without attachment/enclosure "E" = Copy with attachment/enclosure "N" = No copy

OFFICE	PDII-4/LA	PDII-4	PDII-4/PM	SELB	SELB
NAME	BClayton	LDudes	PTam	RJenkins	AGill
DATE	/ /94	/ /94	/ /94	/ /94	/ /94

OFFICE	SPLB	SPLB	PDII-4/D		
NAME	PMadden	SWest	FHebdon		
DATE	/ /94	/ /94	/ /94		

OFFICIAL RECORD COPY

Orig. page misplaced. — no signatures on this one

Finally, the staff requested a list of the nonstandard configurations which would involve ampacity derating considerations (i.e., power circuits) TVA expects to utilize during thermo-lag installation. TVA agreed to submit their best estimate of those nonstandard configurations and the rationale behind the test selection.

Peter S. Tam for
Laura A. Dudes, Project Engineer
Project Directorate II-4
Division of Reactor Projects - I/II

Docket Nos: 50-390 and 50-391

Enclosures: 1. Participants and Observers List
2. NRC Handout

cc w/encl 1: See next page

cc:
Mr. Craven Crowell, Chairman
Tennessee Valley Authority
ET 12A
400 West Summit Hill Drive
Knoxville, TN 37902

Mr. W. H. Kennoy, Director
Tennessee Valley Authority
ET 12A
400 West Summit Hill Drive
Knoxville, TN 37902

Mr. Johnny H. Hayes, Director
Tennessee Valley Authority
ET 12A
400 West Summit Hill Drive
Knoxville, TN 37902

Mr. Oliver D. Kingsley, Jr.
President, TVA Nuclear and
Chief Nuclear Officer
Tennessee Valley Authority
6A Lookout Place
1101 Market Street
Chattanooga, Tennessee 37402-2801

Dr. Mark O. Medford, Vice President
Engineering & Technical Services
Tennessee Valley Authority
3B Lookout Place
1101 Market Street
Chattanooga, TN 37402-2801

Mr. D. E. Nunn, Vice President
New Plant Completion
Tennessee Valley Authority
3B Lookout Place
1101 Market Street
Chattanooga, TN 37402-2801

Mr. J. A. Scalice, Site Vice President
Watts Bar Nuclear Plant
Tennessee Valley Authority
P.O. Box 2000
Spring City, TN 37381

General Counsel
Tennessee Valley Authority
ET 11H
400 West Summit Hill Drive
Knoxville, TN 37902

Mr. Roger W. Huston, Manager
Nuclear Licensing and Regulatory Affairs
Tennessee Valley Authority
4G Blue Ridge
1101 Market Street
Chattanooga, TN 37402-2801

Mr. B. S. Schofield
Site Licensing Manager
Watts Bar Nuclear Plant
Tennessee Valley Authority
P.O. Box 2000
Spring City, TN 37381

TVA Representative
Tennessee Valley Authority
11921 Rockville Pike
Suite 402
Rockville, MD 20852

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

Senior Resident Inspector
Watts Bar Nuclear Plant
U.S. Nuclear Regulatory Commission
Route 2, Box 700
Spring City, TN 37381

The Honorable Robert Aikman
County Executive
Rhea County Courthouse
Dayton, TN 37321

The Honorable Garland Lanksford
County Executive
Meigs County Courthouse
Decatur, TN 37322

Mr. Michael H. Mobley, Director
Division of Radiological Health
3rd Floor, L and C Annex
401 Church Street
Nashville, TN 37243-1532

Ms. Danielle Droitsch
Energy Project
The Foundation for
Global Sustainability
P.O. Box 1101
Knoxville, TN 37901

Mr. Bill Harris
Route 1, Box 26
Ten Mile, TN 37880

LIST OF PARTICIPANTS AND OBSERVERS

ROCKVILLE, MARYLAND

AUGUST 30, 1994

Name	Affiliation
Carl Berlinger	NRR/Electrical Engineering Branch
Thomas Blatchford	NRC/Inspector General
Bob Borsum	BWNT
Kent W. Brown	TVA/Corporate Electrical
Claudia Craig	NRC/Office of Executive Director
Laura Dudes	NRC/NRR/Project Directorate II-4
Noel Dudley	NRC/ACRS Staff
Amritpal (Paul) Gill	NRR/Electrical Engineering Branch
Paul Gunter	NIRS
Suheil Haddad	Sargent & Lundy
Frederick Hebdon	NRC/NRR/Project Directorate II-4
Dean Houston	NRC/ACRS Staff
Roger Huston	TVA/Corporate Licensing
Ronaldo Jenkins	NRR/Electrical Engineering Branch
Walton Jensen	NRR/Probabilistic Safety Assessment Branch
Patrick Madden	NRR/Plant Systems Branch
Conrad McCracken	NRR/Plant Systems Branch
Milad A. Milad	Sargent & Lundy
J.W. Muffett	Texas Utilities Electric Co.
Steve Nowlen	Sandia National Laboratory
James J. Raleigh	STS
Bruce Schofield	TVA/Watts Bar Site Licensing
Bert Spear	Florida Power Corporation
Theresa Sutter	Bechtel
Peter Tam	NRC/NRR/Project Directorate II-4
Roger D. Walker	Texas Utilities Electric Co.
Steven West	NRR/Plant Systems Branch
Scott Wingate	NUS
George Wu	NEI

ENCLOSURE 1

Table 3: THERMO-LAG conduit tests

Report	Conduit size	ACF	Barrier Thickness	Cable information
UL 86NK32826[21]	4"	1.02	1/2"	3/c 6AWG 7 lengths in series
UL 86NK32826[21]	4"	0.905	1"	3/c 6AWG 7 lengths in series
TSI 111781[14]	2"	0.924	1/2 "	#00 AWG 3 runs
ITL 84-10-5[19]	2"	0.906	1" min.	#00 AWG 600 volt three lengths
SwRI 01-8818-208/209C[20]	4"	0.994	3/4"	20 lengths 3/C 3AWG .75" dia.
TVA 93-0501[22]	4"	1.052	5/8"	3/c 6AWG Rockbestos 600V
TVA 93-0501[22]	4"	0.975	1"	3/c 6AWG Rockbestos 600V
TVA 93-0501[22]	4"	0.918	3/4"	3/c 6AWG Rockbestos 600V
TVA 93-0501[22]	4"	1.038	5/8"	4 conductor
TVA 93-0501[22]	4"	0.998	1"	4 conductor
TVA 93-0501[22]	4"	0.977	3/4"	4 conductor
TVA 93-0501[22]	4"	1.033	5/8"	24 conductor
TVA 93-0501[22]	4"	1.006	1"	24 conductor
TVA 93-0501[22]	4"	0.997	3/4"	24 conductor
TVA 93-0501[22]	4"	1.018	5/8"	3 phase
TVA 93-0501[22]	4"	1.009	1"	3 phase
TVA 93-0501[22]	4"	0.949	3/4"	3 phase
TVA 93-0501[22]	1"	0.965	5/8"	3/c 6AWG Rockbestos
TVA 93-0501[22]	1"	0.956	1"	3/c 6AWG Rockbestos
TVA 93-0501[22]	1"	0.969	1/2"	3/c 6AWG Rockbestos
TVA 93-0501[22]	1"	0.982	5/8"	4 conductor
TVA 93-0501[22]	1"	0.967	1"	4 conductor
TVA 93-0501[22]	1"	0.99	1/2"	4 conductor
TVA 93-0501[22]	1"	1.027	5/8"	3 phase
TVA 93-0501[22]	1"	1.002	1"	3 phase
TVA 93-0501[22]	1"	1.016	1/2"	3 phase

Minimum ACF = 0.905
Average ACF = 0.98
Maximum ACF = 1.05

The ACF for many of these measurements seems to indicate that adding some THERMO-LAG actually improves heat dissipation. Simple calculations of a model conduit were performed to understand the increase in ampacity for protected conduits that this implies. The formulas for these calculations are included in Appendix A. We assumed that the cable was in intimate contact with the conduit. As a result of these calculations, it is plausible that the protected conduit may have a higher rating than an unprotected conduit. Calculations show that the heat transfer with the thermally protection is similar, if not better, than a plain steel conduit for two reasons: heat transfer increases with the diameter of a cylinder (because the area for the transfer is larger), and THERMO-LAG 330, a white matte surface, has a higher radiative emissivity than a steel conduit (we have assumed that THERMO-LAG is similar to wallboard in emissivity.)

These calculations also show that the magnitude of radiative transfer of heat is comparable to that of the convective transfer for the protected conduit. If the temperatures of the test room walls are cooler than the air surrounding the conduit, the ACF is increased because of the high radiative heat transfer of THERMO-LAG. The radiative exchange is much more important to the protected conduit because of the higher outer surface emissivity. Radiative heat transfer is highly dependent on the temperature differences between the emitting and absorbing surfaces.* Hence, if the walls of the room are at 39°C instead of 40°C, an increase in the overall rate of heat transfer of about 7% results. Since the baseline conduit has a much lower emissivity, the impact of wall temperature on the overall rate of heat transfer is less significant, and can largely be ignored. Reduced wall temperature enhances the heat transfer capability of the protected conduit, and hence, enhances the ampacity. This results in an artificial increase in the value of the ACF of 4%. As shown in Appendix A, even relatively modest changes in the wall temperature could result in ACF values greater than unity. This is the most likely explanation for the scatter in the TVA results. That is, it is likely that in the TVA tests, variation in wall temperature could have resulted in the variation in values of ACF. Since we have no measurement of wall temperatures in these experiments, we have no way to know how much this affected the ACF during testing.

There are fewer differences in the methods employed for the conduit measurements than for the cable tray measurements. All of the conduit tests consisted of energizing one type of cable within a straight, horizontal conduit that was at least five feet in length. The TVA experiments varied the conductor wiring and cables between tests. TVA also varied the THERMO-LAG thicknesses. Wiring changes make significant changes to ampacity but had little affect on ACF. These changes in ampacity are further discussed in Appendix B.

For the TVA tests[22], the baseline measurement and the protected measurements were performed on the same cables but in different conduits (i.e. the cables were pulled into the "baseline" conduit, a measurement made, and then pulled into a protected conduit and another measurement made of the ampacity.) A problem with this method was evident almost immediately to the experimenters because the temperature on one end of the conduit was different from the other end. There was no obvious reason for this anomaly, but since the same conduit and cable were not used for the protected case, this caused a problem. It is likely that differences in the surface emissivity of the conduit sections may have caused this behavior. Presumably the same types of abnormalities in the conduit could also occur for the protected case, but since this was a different conduit, this effect

---

* The radiative heat transfer is $q = 2\pi r_o \sigma \varepsilon_o (T_o^4 - T_\infty^4)$. where T_o is the absolute temperature of the conduit surface and T_∞ is the absolute temperature of the walls of the test room.

Appendix A: Formulas For Calculating Conduit Heat Flow

In order to understand the mechanism by which THERMO-LAG-protected conduit can dissipate heat better than unprotected conduit, a few simple calculations will be made on ideal cylinders using information from the TVA report 93-0501[22]. Heat flow will be calculated per unit length because of the infinite length assumption. The heat conduction across a cylindrical shell with uniform temperatures inside and outside is:[26]

$$q_{cond} = 2\pi k \frac{T_i - T_o}{\ln\left(\frac{r_o}{r_i}\right)} \qquad \text{(A1)}$$

where k is the thermal conductivity of the cylinder material, r_i and r_o are the inside and outside radii, and T_i and T_o are the inner and outer surface temperatures in °K. The heat flows from the outer surface by two methods: convection and radiation. The heat flow per unit cylinder length due to radiation is:[26]

$$q_{rad} = 2\pi r_o \sigma \varepsilon_o (T_o^4 - T_\infty^4) \qquad \text{(A2)}$$

where ε_o is the emissivity of the cylinder surface, T_∞ is the temperature of the test enclosure walls and σ is the Stephan-Boltzman constant,(5.67×10^{-8} W/m^2-°K^4.) The emissivity is a value between 0 and 1 that describes how well light is absorbed by a surface. Emissivity is determined not only by color, but also by surface roughness. The emissivity of wallboard (white) is approximately 0.9; shiny metals have values of 0.1 or less.

Convection is dependent upon the shape of an object. Natural convection measurements are made in a still room. The convection coefficient for an infinite horizontal cylinder is[28] $h = (k_a Nu)/(2r_o)$ where Nu is the Nusselt number for a cylinder and k_a is the conductivity of air. The Nusselt number is found experimentally for a particular geometry; empirical fits have been found for several simple shapes. The Nusselt number for a horizontal cylinder has been given by Kreith[27]:

$$Nu = 0.53(Gr\,\mathrm{Pr})^{1/4} \qquad \text{(A3)}$$

where the Grashof number, Gr, is

$$Gr = \frac{g\beta(T_o - T_\infty)(2r_o)^3}{\nu^2} \qquad \text{(A4)}$$

and Pr, the Prandtl number, is 0.7 for the temperature range of interest here; g, the gravitational constant, is 9.8 m/s^2, while β is $1/T_O$ for gas. fitting the kinematic viscosity of air[26] in units of m^2/s, ν, with a cubic least-squares fit yields for T_o in ° Kelvin:

$$\nu = -1.637\times10^{-7} + 5.038\times10^{-9}(T_o) + 1.7\times10^{-10}(T_o)^2 + 5.973\times10^{-14}(T_o)^3 \qquad \text{(A5)}$$

The resulting heat transfer per unit length due to convection around a cylinder is :

$$q_{conv} = 2\pi r_o h(T_o - T_\infty) = \pi k_a Nu(T_o - T_\infty) \qquad \text{(A6)}$$

For the baseline case, the total heat loss due to the combination of radiation and convection must equal the conduction across the conduit wall.

The TVA report[22] includes information on the temperature of the outside of the conduit for the unprotected case. For a 1" conduit, the outer conduit temperature was 59.88°C when the conductor temperature was 90°C and the ambient temperature was 40.77°C. (Figure A1).

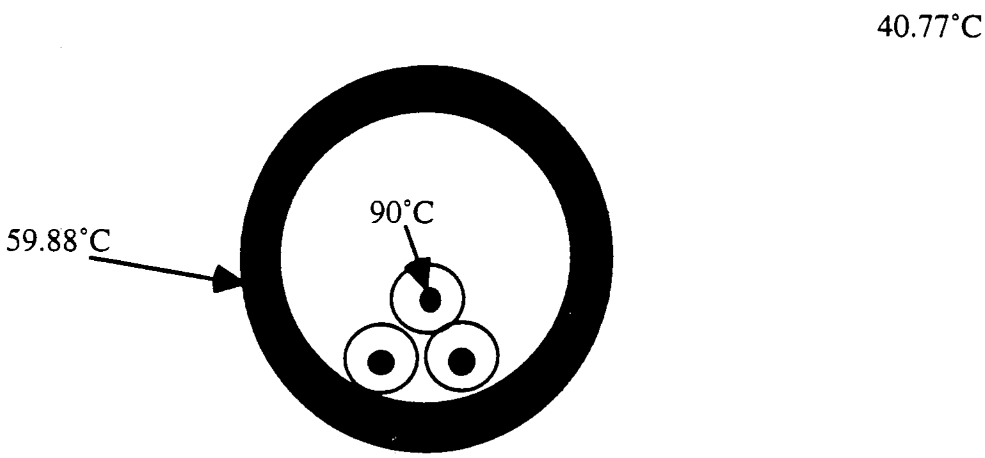

Figure A1 Schematic for calculation of conduit heat losses

We can calculate an effective thermal resistance (per unit length) from the conductor to the outside of the conduit by equating the heat flow from the conductor to the outside of the conduit to the heat flow from the conduit to the surrounding room.

$$\begin{aligned} q_{baseline} &= \frac{T_i - T_o}{R_{eff}} \\ &= 2\pi r_o h(T_o - T_\infty) + 2\pi r_o \varepsilon\sigma(T_o^4 - T_\infty^4) \qquad \text{(A7)} \\ &\approx 13.6 \ \mathrm{W/m} \end{aligned}$$

Here we have assumed that $\varepsilon = 0.22$, a typical value for steel. T_i is the temperature of the conductor (90°C), T_o is the temperature of the outside of the conduit (59.88°C), and T_∞ is the temperature of the surrounding enclosure (40.77°C). Here we have assumed that the surrounding air temperature used to calculate conduction is equal to the enclosure wall temperature used to calculate radiation.

For the protected case, the thermal resistance from the conductor to the outside surface of the THERMO-LAG is the effective resistance from the previous baseline case (R_{eff}), plus the resistance from the outer cylinder of THERMO-LAG, in this case a 0.5" thick layer. The combined thermal resistance is calculated as:

$$R = R_{eff} + \frac{\ln\left(r_{Tlag}/r_o\right)}{2\pi k_{Tlag}}$$

$$\approx 2.23\ \frac{^\circ\mathrm{C\text{-}m}}{\mathrm{W}} + \frac{\ln\left(\frac{0.0254}{0.0127}\right)}{2\pi\left(.211\frac{W}{^\circ C - m}\right)} \qquad \text{(A8)}$$

$$\approx 2.753\frac{^\circ C - m}{W}$$

where r_{Tlag} is the radius to the outside of the THERMO-LAG barrier (1" or .0254 m), r_o is the radius of the conduit (0.5" or .0127 m) and k_{Tlag} is the conductivity of THERMO-LAG (0.211 W/°C-m). The heat flow equation for the protected case is:

$$\frac{T_i - T_{Tlag}}{R} = h2\pi r_o\left(T_{Tlag} - T_\infty\right) + 2\pi r_o \sigma \varepsilon_{Tlag}\left(T_{Tlag}^4 - T_\infty^4\right) \qquad \text{(A9)}$$

Here we have assumed that $\varepsilon_{Tlag} = 0.9$, a value tabulated for wallboard. Equation A9 allows us to solve for T_{Tlag}, the THERMO-LAG surface temperature, by plotting the heat flow across the conduit and THERMO-LAG, and the heat flow due to convection and radiation. This equation is solved graphically (Figure A2) at the point of intersection between curves.

The resulting THERMO-LAG temperature was 48°C and the heat flow from the surface was 15 W/m, a larger number than for the baseline (i.e., unprotected) case. The radiative contribution to this calculation is 8 W/m while the convective contribution was only 7 W/m. For the unprotected conduit, however the radiative contribution is only 2.3 W/m compared to the convective contribution of 11.3 W/m (higher convection because the conduit was hotter). This simple calculation shows that the protected conduit can have higher heat dissipation than the unprotected one, provided the emissivity and increased surface area of the fire-barrier surface is high enough to offset its insulating properties.

Figure A2: Protected 1" Conduit Heat Flow Solution