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JAN 06 1998

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SUSQUEHANNA STEAM ELECTRIC STATION
NRC GENERIC LETTER 92-08 - THERMO-LAG 330-1
DESTRUCTIVE EXAMINATIONS & AMPACITY DERATING
PLA-4819 FILE R41-2

Docket Nos. 50-387
and 50-388

The purpose of this letter is to provide the results of the destructive examinations performed by PP&L for confirming the details of construction of Thermo-Lag raceway fire barriers used at SSES. The destructive examinations verified the important characteristics of construction for the SSES Thermo-Lag raceway fire barrier from the perspective of fire performance and ampacity derating. In addition, this letter also addresses new information discovered during the destructive examinations relative to the use of Thermo-Lag 330-1 as a barrier to achieve physical independence of electrical systems (Regulatory Guide 1.75) and provides a revision to our commitment for ampacity derating factors for power raceway covered with Thermo-Lag 330-1.

I. Background:

I.1 Destructive Examinations:

PLA-4089 was provided by PP&L in response to a Request for Additional Information regarding Generic Letter 92-08 pursuant to 10 CFR 50.54 dated December 22, 1993. In PLA-4089 dated February 3, 1994, PP&L initially committed to perform destructive examinations under item No. 3 of the request for additional information (Request No. II.B.2).in response to NRC Request II.B.2. PP&L's commitment was to perform destructive examinations on a justifiable sample.

PLA-4236 dated December 22, 1994, was written in response to a follow-up NRC Request for Additional Information regarding Generic Letter 92-08 dated September 23, 1994. This response was a supplement to the information provided in PLA-4089. In PLA-4236, under the response to NRC Request II.B.1, PP&L stated that some destructive examinations had already been completed and that additional examinations would be conducted after our safe shutdown work

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was completed and the total population of required fire barriers was known. PP&L further stated that "*The examinations will consist of a determination of those parameters required to use the NEI Industry Applications Guide and any supporting engineering analysis in justifying the acceptability of the barriers.*" PP&L's approach to destructive exams was further clarified in our response to NRC Request II.B.2. In this response, PP&L stated that "*To the extent possible, the destructive examination sample will be selected from the population of barriers that the revised safe shutdown analysis has determined to be no longer required.*"

PLA-4286 dated March 27, 1995 was written in response to a follow-up NRC Request for Additional Information regarding Generic Letter 92-08 dated December 29, 1994. In PLA-4286, PP&L provided additional information related to destructive examinations, chemical and density testing and ampacity derating. PP&L committed to perform chemical and density testing on samples of Thermo-Lag material representative of that installed in the plant. This work was completed as a part of the NEI Industry Chemical Testing Program. PLA-4484 dated July 29, 1996 provided PP&L's final response to the NRC on this issue. Additionally, PLA-4286 further elaborated on the approach to be used for destructive examinations at SSES. This letter stated that the thickness of the Thermo-Lag installations would be verified and that the installed material would be checked for the presence of voids, cracks and delaminations during the destructive examinations. PP&L further stated that "*Raceway fire barriers found to be required by the revision to our Appendix R analysis will be destructively examined on a sampling basis. Destructive examinations will be used to verify the correctness of the important barrier parameters assigned to each installation type.*" Additionally, PP&L stated that "*A random sample of barriers representative of required barriers will be selected. The sample will include conduit, cable tray and boxes for both 1-hour and 3-hour applications from each construction vintage. The sample size will be sufficient to provide reasonable assurance that the materials and details of construction are representative of those used in the generic testing used to qualify the barriers.*" Finally, PP&L stated that "*Upon completion of the work described above, a report will be provided to the NRC confirming that the effort has been completed and providing the results of the examinations and inspections and any changes from the previously submitted plans.*"

PLA-4349 was written in response to a follow-up NRC Request for Additional Information regarding Generic Letter 92-08 dated June 13, 1995. In PLA-4349 dated August 2, 1995, PP&L stated that "*...destructive examinations and field walkdowns are required to finalize the ampacity issue for Susquehanna. These will be performed in conjunction with the destructive examinations and detailed field walkdowns performed for the Thermo-Lag fire endurance issue.*"

This letter provides PP&L's final response to the NRC on the results of the destructive examination program.

I.2 Ampacity Derating:

In PLA-4349 dated August 2, 1995, PP&L committed to use the ampacity derating values approved for TUEC for 1-hour installations at Susquehanna for both 1 and 3-hour installations. These values were as follows:

Raceway Type	NRC Approved Ampacity Derating Value
Small Free Air Cable	21.3%
Large Free Air Cable	31.7%
Conduit	21.0%
Cable Tray	31.5%

PLA-4560 was written in response to a follow-up NRC Request for Additional Information regarding Generic Letter 92-08 dated December 18, 1996. In PLA-4560 dated February 4, 1997, PP&L provided additional information related to ampacity derating factors for raceway at SSES protected with Thermo-Lag 330-1 for both 1 and 3-hour conduit applications. PP&L concluded based on the FPC 3-hour test results that the use of 21% ampacity derating factor for 3-hour Thermo-Lag installations was "*....conservative and provided a significant margin of safety.*" Similarly, PP&L stated that *"Based on the non-standard testing performed by TVA, it can be concluded that an appropriate adjustment factor for the common enclosure situation where a single row of power conduits are wrapped in a common enclosure is on the order of 8%. Since the values that we have selected for ampacity derating for 1-hour and 3-hour conduit have margin over the actual tested value, this margin will be used to bound the situation where a single row of power conduit is wrapped in a common enclosure."*

Based on the results of our destructive examinations and a detailed review of all ampacity derating testing conducted to date, PP&L has concluded that the ampacity derating factors applicable to 1 and 3-hour conduit wrapped with Thermo-Lag 330-1 can be reduced. Conversely, PP&L has concluded that the ampacity derating values for cable tray using cable tray covers and wrapped with Thermo-Lag 330-1 must be increased. This letter provides the revised ampacity derating values and the justification for the values selected.

I.3 Thermo-Lag 330-1 used for Regulatory Guide 1.75:

In PLA-4089 dated February 3, 1994, PP&L stated that "*Thermo-Lag 330-1 is not used at SSES to achieve physical independence of electrical systems (Regulatory Guide 1.75).*" This letter provides a revised response from PP&L to the NRC on the use of Thermo-Lag 330-1 as a barrier to achieve physical independence of electrical systems based on the results of our destructive examinations.

II. Discussion:

II.1 Destructive Examinations:

The destructive examination of the installed Thermo-Lag raceway fire barriers was completed during the first and second quarter of 1997. As stated in PLA-4236 dated December 22, 1994, a sample of our installed raceway fire barriers was destructively examined. This sample was determined to be representative of the population of raceway fire barriers determined to be required at the completion of our Appendix R Safe Shutdown revision. As stated in section II.B.2 of PLA-4236, the raceway fire barriers selected for destructive examinations were, to the greatest extent possible, taken from the population of raceway fire barriers that were determined to be no longer required based on our revision to the Appendix R Safe Shutdown Analysis. The sample included conduit, cable tray and boxes for both 1-hour and 3-hour applications. Samples from each of the four construction vintages identified in the visual walkdowns were examined during these destructive examinations. There are four basic vintage fire wrap style groups which envelope all thermo-lag fire wrap installations at SSES. Each of these styles is based on the Thermal Science Inc. (TSI) material supplied to SSES and the installation requirements in place during a particular time frame. These groups are as follows:

TL - Vintage Fire Wrap

Identified by the designation TL, this thermo-lag incorporates TSI manufactured Thermo-Lag subliming material 330-1 sprayed-on in place over stress skin in a monolithic/continuous coating. The stress skin was Thermo-Lag 330-69 which was pre-primed with Thermo-Lag 351 primer.

PFTL - Vintage Fire Wrap

Identified by the designation PFTL, this thermo-lag incorporates panels fabricated in a shop environment on site (SSES) using TSI manufactured Thermo-Lag 330-1 subliming material sprayed-on over stress skin in a monolithic/continuous coating. The stress skin used was Thermo Lag 330-69 and the primer was Thermo-Lag 351.

TSL - Vintage Fire Wrap

Identified by the designation TSL, this thermo-lag incorporated pre-fabricated thermo-lag panels and pre-shaped conduit sections supplied by TSI and installed by PP&L/Bechtel (contractors other than Transco). The materials used in the fabrication of this fire wrap were Thermo-Lag 330-1 subliming material with Thermo-Lag 330-69 stress skin monolithically adhered to the pre-fabricated panels and sections.

TTL - Vintage Fire Wrap

Identified by the designation TTL, this thermo-lag incorporated pre-fabricated thermo-lag panels and pre-shaped conduit sections supplied by TSI and installed by Transco during the SSES Appendix 'R' Closeout Project (1988 through 1989). From 1990 to the present time, additions and modifications to thermo-lag have been installed by PP&L, or subcontractors working under PP&L's direct supervision. The materials used in the fabrication of this fire wrap were Thermo-Lag 330-1 subliming material with Thermo-Lag stress skin monolithically adhered to the pre-fabricated panels and sections.

The following table provides a list of the raceway examined and their raceway type and construction vintage:

Item	Raceway #	Raceway Type	# of Cuts	Remarks
1	E1K1W6	1½" conduit	3	TTL-1
2	E1P197/247/397	3" conduit	1	TTL-1
3	JB1570	24×24×8 box	1	TTL-1
4	E2K1R3	1" conduit	2	TTL-1, includes 8×8×18 pullbox
5	F2K484	1½" conduit	2	TTL-1, includes 12×12×6 pullbox
6	A2P017	2" conduit	1	TL-1
7	A2P014	2" conduit	1	TL-1
8	B1K044	4" conduit	1	TL-1
9	D1M031	4" conduit	1	TL-1
10	D2P044	3" conduit	1	TSL-1
11	D1K196	1" conduit	1	TSL-1
12	JB1910	24×24×8 box	1	TL/TSL/PFTL-1
13	1MT510	?" conduit	1	TTL-1, includes 12×12×4 pullbox
14	E2M303	1" conduit	1	TTL-3, includes 4×4×12 pullbox
15	E1K990	2" conduit	1	TSL-1, includes 4×4×16 pullbox
16	JB0094	36×16×12 box	1	TTL-1
17	F1P463	2" conduit	1	TSL-1, includes 10×10×4 pullbox
18	JB3695	16×14×12 box	1	TL/PFTL-1
19	F2KU99	6×6 wireway	1	TTL-1
20	E1KU79-91	24×6 tray	4	TTL-1
21	E1KK17	24×6 tray	1	TSL-1/3
22	E2KJ86	30×6 tray	2	TSL-1

The following observations were recorded for each of the construction vintages examined:

Spray-on Thermo-Lag (TL vintage).

a) TL vintage is chemically the same material as the PFTL, TSL and TTL vintage Thermo-Lag materials, and all of these materials were supplied by TSI.
b) The stress skin steel mesh was entirely wrapped around each conduit with an overlap of 1¼" to 1½" at the longitudinal and vertical joints. The stress skin was securely fastened to each conduit utilizing stainless steel tie wires spaced at approximately 3" centers.
c) The Thermo-Lag subliming material was sprayed-on in-place over the stress skin in a monolithic coating. Due to the continuous application of the thermo-lag over the stress skin, there are no seams or joints. There was also no indication of transverse butt joints. The material appeared to be a homogeneous installation.
d) The Thermo-Lag coating was applied in three layers (passes). Slight indications of a 'Cold Joint' (delaminations) were found where the spray-on layers were applied and, subsequently, allowed to dry prior to the application of the next layer.
e) A comparison was made between the 'Cold Joint' in the TL vintage Thermo-Lag, and the separations found between the TTL/TSL vintage Thermo-Lag base material and the external layer of trowel grade material. It was concluded that the 'Cold Joint' looked the same as the separations, and, as a result, will behave the same in a fire situation.
f) NEI testing showed that the use of external trowel grade material is an enhancement of the fire performance. Therefore the 'Cold Joint' is not a detriment to fire performance from either a thermal or structural integrity perspective. The lack of a seam, as is found in the spray-on in-place TL vintage, is an enhancement from a structural integrity perspective over those designs where a seam is actually used, e.g. TSL and TTL. Therefore, TL will have better fire performance capability than the equivalent thickness of pre-fabricated Thermo-Lag material.

Spray-on Thermo-Lag Panels fabricated at SSES (PFTL vintage)

a) The composition of the PFTL vintage thermo-lag panels is the same as the TL vintage Thermo-Lag.
b) Ribbed stress skin steel mesh was utilized as a mechanical base for application of the spray-on, TSI manufactured, Thermo-Lag. As an additional reinforcing measure, the stress skin was attached to the inside of the panels with ½" staples spaced at approximately 2" to 4" centers after completing the spraying operation.
c) The Thermo-Lag subliming material was applied in three layers (passes) over the stress skin. The same 'Cold Joints' were found as those previously noted for the TL vintage construction. The joints between the panels were, generally, post-buttered.
d) The panels were coated with a min. of 1/16" layer of trowel grade material on the outside surface of the Thermo-Lag and with a larger buildup at the joints and corners. The panels were held together using stainless steel wires or bands spaced at approximately 9" centers.

e) The v-ribs were located on the inside faces of the panels and were spaced at approximately 6" centers. Orientation of the ribs varied from one raceway to another.
f) Results of destructive examinations performed on PFTL thermo-lag material has identified construction comparable to TSL and TTL installation details.

Pre-fabricated Thermo-lag Panels and Pre-Shaped Sections (TSL and TTL vintage)

a) The conduit fire wrap consisted of pre-shaped Thermo-Lag sections, with butt joints and seams pre-buttered with trowel grade material. Joints and seams were not reinforced. The sections were held together using stainless steel bands or tie wires spaced at approximately 9" centers.
b) The cable tray, box and wireway raceways were wrapped with v-rib pre-fabricated panels with butt joints pre-buttered with trowel grade material. Some boxes utilized Thermo-Lag flat panels. The panels were held in position utilizing stainless steel bands and / or wires spaced at a maximum of 9" centers. Bands and tie wires were located a maximum of 2" from butt joints. With the exception of a small portion of raceway E1KU80, pre-buttering of raceway corners was performed. Transverse butt joints were reinforced with 4" wide stress skin attached to the outside of the Thermo-Lag panels using ½" staples spaced at 2" to 4" centers.
c) The v-ribs were located on the inside faces of the panels and were spaced at approximately 6½" centers. Orientation of the ribs varied from one raceway to another.
d) Generally, Thermo-Lag panels associated with cable tray or wireway raceways, were installed such that the side panels were sandwiched between the top and bottom panels, and thereby, placed into compression when the external banding was tightened.
e) When cable tray raceways did not contain tray covers, the Thermo-Lag panels were held in position utilizing stainless steel bands at a maximum of 9" centers, however, every other band was utilized for pre-banding the top side of the cable tray Thermo-Lag, resulting in a maximum spacing of 18" for pre-banding.
f) The Thermo-Lag base sections were generally coated with a minimum of 1/16" layer of trowel grade material on the outside surface of the Thermo-Lag, with a larger buildup at the seams, butt joints and outside corners of the panels.

The overall conclusions of the SSES Phase II Destructive Examination Program are as follows:

a) From a chemical composition standpoint, all Thermo-Lag utilized at SSES has been demonstrated to be chemically consistent from one SSES Thermo-Lag construction vintage to another, as well as, with all of the industry Thermo-Lag samples included in the NEI Industry Chemical Testing Program.
b) The thickness of the base material of the 1 hour barrier used at SSES has been determined to be in the ½" to ¾" range. External trowel grade buildup of approximately 1/8" ± 1/16" was generally utilized on all Thermo-Lag except the TL vintage. Where the trowel grade buildup was used, the overall thickness of the 1 hour barriers was in the range of 9/16" to 7/8".
c) The overall thickness of the 3 hour barrier was determined to be in the 1 1/8" to 1 5/8" range.

d) The evaluation provided above has demonstrated that installations constructed in the TL, spray-on in-place, and the PFTL, site fabricated spray-on panel vintages are bounded from a thermal and structural integrity standpoint by fire testing conducted using pre-fabricated panels and pre-formed half round sections provided by TSI.

Observations noted during the examinations confirm that the physical condition of the wrap is very good and well constructed. The material consistency in terms of chemical composition and density between the TL/PFTL vintage Thermo-Lag and the TSL/TTL vintage Thermo-Lag has been proven and is documented in the NUCON test reports. The fifteen samples, tested by NUCON in the NEI Industry Chemical Testing Program, were taken from SSES plant locations and were chosen from within each fire wrap vintage group found at SSES, which included samples removed from spray-on in-place Thermo-Lag, SSES site fabricated spray-on Thermo-Lag panels and TSI supplied pre-fabricated panels and sections. The test results concluded that the Thermo-Lag samples were consistent with each other and also consistent to other Thermo-Lag sample results tested as part of the NEI Generic Testing Program.

The Thermo-Lag vintage styles, used at SSES, are constructed and installed as 'TSI fire barrier system' utilizing material supplied by TSI , and equal to the material used in the industry testing per NEI fire endurance test reports. Therefore the baseline configurations described above can be used as a basis for comparison with NEI and other industry testing to evaluate SSES installations for required upgrade configurations.

Based on the large quantity of existing 1-hour Thermo-Lag installations at SSES, the availability of a substantial amount of fire and ampacity derating testing that could be used to support the upgrading of these installations and the good performance of the Thermo-Lag material from both a fire and ampacity perspective when properly applied, PP&L has concluded that Thermo-Lag upgrades will be the primary means of correcting the current situation with our installed and required Thermo-Lag raceway fire barriers. Where required for situation unique reasons, however, alternate fire barrier materials may be used.

The destructive examinations described above provided information for the power raceway protected with Thermo-Lag for the ampacity derating issue. In addition to this information, however, walkdowns of power raceway protected with Thermo-Lag were required to identify those installations where bundled raceway configurations existed that might not be covered by existing ampacity derating testing. These walkdowns were performed and the conclusions from these walkdowns are described below:

The following conclusions have been drawn from the walkdown performed to determine as-built wrap and configuration conditions for power raceway protected with Thermo-Lag:

a) Conduits are typically wrapped individually in rounded configurations.
b) Cable tray, wireway and boxes are always wrapped individually in boxed configurations.
c) The worst case wrap configuration was a bundle of power conduit with 3 conduit wrapped in a common enclosure.

II.2 Ampacity Derating:

The following derating factors are the ampacity derating factors that PP&L has used when evaluating power cables in raceways wrapped with Thermo-Lag 330-1 material:

Recommended Ampacity Derating Values for SSES	
Raceway Type	Fire Barrier Derating Factor
Conduit	10.7%
Conduit- [non-std.]	15.7%[1]
Air Drops	10.7%
Boxes	10.7%
Cable Tray	31.5%
Cable Tray w/cov	41.0%
Wireway	41.0%

The following justification is provided in support of the values selected above.

Conduit, Boxes and Air Drops

To the best of our knowledge, the following is a summary of results of the Thermo-Lag Ampacity Derating testing performed within the industry to date on conduit:

[1] This value includes an additional 5.0% derate to cover non-standard configurations identified at SSES.

Conduit[2] Testing							
Tested By	Conduit Size	Fire Barrier Nominal Thickness	Cables Tested	Base Amps (Stds.)	Base Amps Test	Derated Amps Test	ACF
TSI	2"	1/2"	3-2/0[3]	190.0	153.41	141.72	0.924
UL*	4"	1/2"	7-3c/#6[4]	34.5	34.1	34.8	1.020[5]
UL*	4"	1"	7-3c/#6	34.5	34.1	30.9	0.906
TUEC*	3/4"	3/4"	3c/#10	40.0	39.6	35.9	0.906
TUEC*	2"	3/4"	3c/#6	69.0	64.5	60.2	0.933
TUEC	5"	1/2"	4c/750	419.0	571.0	510.0	0.893
TVA	1"	5/8"	3c/#6	69.0	54.3	52.4	0.965
TVA	1"	3/4"	3c/#6	69.0	54.3	52.6	0.969
TVA	1"	1"	3c/#6	69.0	54.3	51.9	0.956
TVA*	1"	5/8"	4c/#6	55.0	60.8	59.7	0.982
TVA*	1"	3/4"	4c/#6	55.0	60.8	60.2	0.990
TVA*	1"	1"	4c/#6	55.0	60.8	58.8	0.967
TVA*	1"	5/8"	3c/#6[6]	69.0	64.2	64.3	1.002
TVA*	1"	3/4"	3c/#6	69.0	64.2	63.6	0.991
TVA*	1"	1"	3c/#6	69.0	64.2	62.7	0.977
TVA*	1"	5/8"	3c/#6[7]	69.0	62.6	64.3	1.027
TVA*	1"	3/4"	3c/#6	69.0	62.6	63.6	1.016
TVA*	1"	1"	3c/#6	69.0	62.6	62.7	1.002
TVA	4"	5/8"	3c/750	524.0	234.1	246.3	1.052
TVA	4"	3/4"	3c/750	524.0	234.1	215.0	0.918
TVA	4"	1"	3c/750	524.0	234.1	228.2	0.975
TVA*	4"	5/8"	4c/750	419.0	420.3	450.8	1.072
TVA*	4"	3/4"	4c/750	419.0	420.3	424.5	1.010
TVA*	4"	1"	4c/750	419.0	420.3	433.5	1.031
TVA*	4"	5/8"	4c/750	419.0	434.5	450.8	1.038
TVA*	4"	3/4"	4c/750	419.0	434.5	424.5	0.997
TVA*	4"	1"	4c/750	419.0	434.5	433.5	0.998
TVA*	4"	5/8"	8-3c/#6	31.0	32.1	34.3	1.068
TVA*	4"	3/4"	8-3c/#6	31.0	32.1	33.1	1.031
TVA*	4"	1"	8-3c/#6	31.0	32.1	33.4	1.040
TVA*	4"	5/8"	8-3c/#6	31.0	33.2	34.3	1.033

[2] All conduits were rigid steel and all conductors were copper.

[3] Folded into two loops. 0.562" diameter; 0.25 in^2 cross-sectional area; 19 strands of 0.0827" copper wire.

[4] Each of the three stranded conductors consisted of seven 0.060" diameter tinned stranded copper strands. Each insulated and jacketed conductor had an outside diameter of 0.34". The cable outside diameter was 1.000". This footnote applies to the test listed next also.

[5] Calculation EC-AMPS-0003 states that this value is an anomaly, but provides no additional information. It is believed that the positive test value for a derating drove this determination. Based on the testing values tabulated within this table, this positive value should not be considered to be an anomaly.

[6] This test and the next two listed had the conductors powered by a 3 phase power source.

[7] This test and the next two listed had the conductors powered by a 3 phase power source.

Conduit[2] Testing							
Tested By	Conduit Size	Fire Barrier Nominal Thickness	Cables Tested	Base Amps (Stds.)	Base Amps Test	Derated Amps Test	ACF
TVA*	4"	3/4"	8-3c/#6	31.0	33.2	33.1	0.997
TVA*	4"	1"	8-3c/#6	31.0	33.2	33.4	1.006
TVA*	4"	5/8"	8-3c/#6[8]	31.0	32.4	34.0	1.049
TVA*	4"	3/4"	8-3c/#6	31.0	32.4	31.7	0.978
TVA*	4"	1"	8-3c/#6	31.0	32.4	33.7	1.040
TVA*	4"	5/8"	8-3c/#6[9]	31.0	33.4	34.0	1.018
TVA*	4"	3/4"	8-3c/#6	31.0	33.4	31.7	0.949
TVA*	4"	1"	8-3c/#6	31.0	33.4	33.7	1.009
TVA	1" [10]	1 1/4" [11]	4c/#10	32.0	32.65	29.66	0.908
TVA	4"	1 1/4"	12-3c/#6	27.6	29.21	25.56	0.875
FPC*	1"	5/8"	4c/#10	32.0	32.1	32.5	1.012[12]
FPC*	1"	1 1/4"	4c/#10	32.0	30.5	31.8	1.043
FPC*	4"	5/8"	12-3c/#6	27.6	27.2	28.1	1.033
FPC*	4"	1 1/4"	12-3c/#6	27.6	26.0	25.3	0.973

The following statistics can be developed from this test data:

ACF $Avg._{\text{with correlation to Stds.}}$ = 35.144/35 = 1.004 ⇒ **ADF = +0.4%**

This average represents the average of all test results where the base amps determined in the test program showed good correlation to the base amps that would have been developed for the same configuration using industry standards. The tests used in this average are marked with an '*' in the first column. The TVA 3-hour tests were not included since they had two additional layers of Thermo-Lag 770-1 material on top of the Thermo-Lag 330-1 material. In selecting the appropriate value from the industry standards, load diversity was not used since in the test set up, all circuits in the test assembly were energized simultaneously.

ACF $Avg._{\text{all}}$ = 44.579/45 = 0.991 ⇒ **ADF = 0.9%**

ACF $Avg._{\text{all, except 770-1}}$ = 42.796/43 = 0.995 ⇒ **ADF = 0.5%**

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[8] This test and the next two listed had the conductors powered by a 3 phase power source.
[9] This test and the next two listed had the conductors powered by a 3 phase power source.
[10] Two layers of Thermo-Lag 770 material were applied over top of the Thermo-Lag 330-1 in this test and in the test described on the line below.
[11] Two layers of Thermo-Lag 770 material were applied over top of the Thermo-Lag 330-1 in this test and in the test described on the line below.
[12] This test was discounted by FPC testing personnel because of a possible test anomaly. The 1-hour test was not re-run with a new cable.

ACF $Avg._{all\ "good"\ tests}$ = 30.022/30 = 1.001 ⇒ **ADF = +0.1%**
["Good" test are defined as all test except for the TSI testing, the TVA odd conductor testing and the TVA testing using Thermo-Lag 770-1.]

ACF $Avg._{1\ hour}$ = 28.873/29 = 0.996 ⇒ **ADF = 0.4%**
[Tests with Thermo-Lag thickness less than 1".]

ACF $Avg._{3\ hour,\ except\ 770\text{-}1}$ = 13.923/14 = 0.995 ⇒ **ADF = 0.5%**
[Tests with Thermo-Lag thickness 1" and greater.]

ACF $Avg._{3\ hour}$ = 15.706/16 = 0.982 ⇒ **ADF = 1.8%**

The average Ampacity Correction Factor (ACF) for all tests with good correlation to the base ampacity value that would be derived from Industry Standards (e.g. IPCEA, NEC) suggests that ampacity derating resulting from the use of a Thermo-Lag 330-1 fire barrier material applied to the external surface of a conduit is negligible (ADF = +0.4%). Conceptually, this makes sense because the higher emissivity and increased surface area between a wrapped and an unwrapped conduit gives the wrapped conduit assembly an increased radiative heat transfer capability ranging from approximately 2 to 4 times better than the unwrapped conduit. Similarly, the increased surface area provided by the wrap would also increase the convective heat transfer capability of the system.

TVA in a paper entitled, "Thermo-Lag Electrical Raceway Fire Barrier Systems Testing and Qualification", indicates that changes in the finishing process for conduits started in the 1950's resulted in emissivity values being on the order of 0.5. This same paper suggests that the emissivity for Thermo-Lag 330-1 is approximately 0.9. The following table illustrates how this difference when coupled with the larger surface area for a conduit protected with 5/8" of Thermo-Lag 330-1 increases the radiative heat transfer capability of the assembly.

Cond. Size	$\varepsilon_{wrapped\ conduit}$	$\varepsilon_{bare\ conduit}$	$\Phi_{wrapped\ conduit}$	$\Phi_{bare\ conduit}$	Inc. Factor[13]
3/4"	0.9	0.5	2.300"	1.050"	3.94
1"	0.9	0.5	2.565"	1.315"	3.51
1 1/2"	0.9	0.5	3.150"	1.900"	2.98
2"	0.9	0.5	3.625"	2.375"	2.74
3"	0.9	0.5	4.750"	3.625"	2.36
4"	0.9	0.5	5.750"	4.500"	2.30
5"	0.9	0.5	6.813"	5.563"	2.20

[13] Increase Factor = $(\varepsilon_{wrapped\ conduit}/\varepsilon_{bare\ conduit})\ (\Phi_{wrapped\ conduit}/\Phi_{bare\ conduit})$, where
ε - emissivity
Φ - diameter

The average ampacity derating factor for the conduit tested is in the +0.4 to 1.8% range. If the 3 hour testing by TVA which included the two additional layers of Thermo-Lag 770-1 material is excluded, then the average is less than 1% regardless of the thickness of the material. Based on a review of the averages tabulated above, the effects of inductive heating appear to affect the correlation of base amp values between the test results and the values that would be predicted by Industry Standards, but this phenomenon does not appear to significantly skew the average in a direction different than all other calculated averages.

Similarly, the effect of air gaps in the assembly does not appear to significantly skew the averages. Although the TVA evaluation used this attribute to explain the difference between their testing and the TUEC testing, a review of the FPC testing, which did not use pre-buttering of the conduit, showed ACF values comparable to the TVA test results.

Finally, the difference in thickness, between 1 hour, 3 hour and various upgrade thicknesses did not skew the average.

The largest 1 hour ADF found was 10.7% from the TUEC testing. The largest 3 hour ADF was 12.5% from the TVA testing. This test, however, included 2 additional layers of Thermo-Lag 770-1. Excluding this test, the largest 3 hour result was 9.4% from the original UL testing.

TVA in a paper entitled, "Fire Endurance and Ampacity Derating of One and Three Hour Thermo-Lag Electrical Raceway Fire Barrier Systems", recommended that an additional 5% derating be used to account for the effects due to variation in conduit surface emissivity.

In summary, the following ADF is recommended for use with conduit:

Base ADF	→ 1.8 %
Adjustment for Emissivity	→ <u>5.0 %</u>
Best Estimate	→ 6.8 %
Adjustment for highest test value	→ <u>3.9 %</u>
Single Conduit ADF	**→ 10.7 %**

This value can be used for all single conduits wrapped with 1 and 3 hour Thermo-Lag 330-1 fire barriers.

For non-standard configurations with up to three conduits wrapped in a common enclosure, an additional 5.0% derating will be included in the ADF. This increase is based on the non-standard configuration testing performed by TVA and documented in a paper entitled "Fire Endurance and Ampacity Derating of One and Three Hour Thermo-Lag Electrical Raceway Fire Barrier Systems". The test results reported by TVA in the above referenced paper indicate that the 1 x 3 direct mounted configuration had an ACF of 0.92 which equates to an

ADF of 8.0%. Since a single conduit in this TVA report is being derated by 3.0%, the 8.0% is 5.0% higher than is already accounted for in the derating value. **Therefore, the ADF for any non-standard configuration bounded by the configuration described above should be 15.7%.**

These values are also considered to be bounding for air drops that have the same fire barrier construction since in the air drop configuration the absence of the conduit makes the assembly less thermally challenging to the cables. The TUEC Air Drop tests showed higher ampacity derating values for the Air Drop configurations than for conduit. In these tests, however, the fire barrier material used three complete wraps of Thermo-Lag 330-660 Flexi-Blanket Material. Therefore, these test results for air drops are not directly comparable with the conduit testing where only Thermo-Lag 330-1 was used.

For a given wrap material, the derating factor for air drops will be lower than the derating factor for conduit or for cable tray. This is true since the air drop configuration is less thermally challenging due to the lack of an actual raceway and the thermal barrier provided by the raceway material. Therefore, each specific air drop does not need to be evaluated. Should the fire barrier configuration on air drops be changed to be more thermally challenging than the fire barrier on conduit, then specific ampacity testing will need to be performed on the air drop configuration.

For cable tray to cable tray air drops, the ADF value for the cable tray bounds both the conduit and air drop ADF values. Therefore, these configurations are also bounded. With respect to boxes protected with the same fire barrier construction as the conduits entering them, the conduit ADF values are bounding because of the increased surface area associated with either junction or pull boxes.

Cable Tray and Wireway

Cable tray without covers should be derated by 31.5% based on TUEC testing. Cable tray with covers and wireway should be derated by 41.0% based on FPC testing. No non-standard SSES configurations involving cable tray or wireway were identified as a part of the walkdowns performed in conjunction with the destructive examinations.

II.3 Thermo-Lag 330-1 used for Regulatory Guide 1.75:

During the pre-FPFI inspection walkdowns, it was discovered that certain raceway fire barriers had also been credited as barriers for Regulatory Guide 1.75 electrical separation. The raceway identified were exclusively cable tray. For those situations where the fire barrier had been credited for Regulatory Guide 1.75 electrical separation, it was determined that the cable trays were all raceway that were required to be protected based on the Appendix R Safe Shutdown Analysis performed in the latter half of the 1980's. The cable tray covers had been removed as a part of the Thermo-Lag 330-1 installation process to facilitate access to these cable trays for pulling additional cables in the future. This situation is currently being addressed as a Condition Report in our discrepancy management program.

The planned approach for resolving this discrepancy is to justify this condition for existing installations based on available industry testing, but to disallow the use of Thermo-Lag as a Regulatory Guide 1.75 electrical separation barrier on new installations in the future.

This response satisfies our commitment to provide a report providing the results of our destructive examinations. It also revises our previous commitment relative to ampacity derating factors for raceway fire barriers protected with Thermo-Lag. Finally, it clarifies our position relative to the use of Thermo-Lag as a Regulatory Guide 1.75 electrical separation barrier. If you have any questions on any of the issues addressed in this letter, please contact Mr. W.W. Williams at (610) 774-7742.

Sincerely,

R.G. Byram

copy: Regional Administrator - Region I
Mr. K. M. Jenison, NRC Sr. Resident Inspector
Mr. V. Nerses, NRC Sr. Project Manager