TU ELECTRIC

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C. Lance Terry
Group Vice President

February 28, 1997

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 SAFETY EVALUATION OPEN ITEMS ON CPSES
UNIT 1 REGARDING THERMO-LAG CABLE FUNCTIONALITY ISSUES
(TAC NO. M85536)

REF:

1) NRC letter from Mr. Timothy J. Polich to Mr. C. Lance Terry dated May 22, 1996

2) TU Electric letter logged TXX-96414, from Mr. C. Lance Terry, to NRC dated October 24, 1996

3) TU Electric letter logged TXX-97024, Mr. C. Lance Terry, to NRC dated February 4, 1997

In response to NRC letter from Mr. Timothy J. Polich to Mr. C. Lance Terry dated May 22, 1996 (Reference 1) which contained seven open items, TU Electric provided a response via Reference 2.

On December 5, 1996, TU Electric held a meeting with the NRC to discuss responses to open items logged via reference 1 and 2. During this meeting, TU Electric determined that additional information with respect to the subject open items was warranted. TU Electric verbally informed the NRC that the aforementioned information would be submitted to the NRC on January 15, 1997. However, on or about December 22, 1996, after reviewing the scope of work, TU Electric verbally contacted the NRC to explain that, based on the extensive efforts required (e.g., walkdown of the plant configurations, review of documents, and additional evaluations), the information could not be provided per the original schedule. Mr. Timothy J. Polich of your Staff requested that TU Electric submit a letter with a revised schedule which was provided to the NRC via Reference 3.

Per the schedule submitted in reference 3 and in order to close the Thermo-Lag issues at CPSES Unit 1, TU is providing revised responses to the open items identified via Reference 1. Enclosed CPSES Engineering Report ER-ME-067 Revision 4 is being provided for your staff's review. The engineering report documents a summary of the results of extensive documentation reviews, walkdowns and engineering evaluations performed by TU Electric Engineering and Nuclear Overview organizations at CPSES.

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P. O. Box 1002 Glen Rose Texas 76043

As a result of TU Electric's evaluation of the concerns/issues raised during the December 5, 1996 meeting, TU Electric reviewed the response made to the NRC in that meeting and referenced letters and has amended its response via the enclosed Engineering Report ER-ME-067 Rev. 4. It should be noted that TU Electric has opted to perform upgrades to Thermo-Lag installations at CPSES Unit 1, based on accepted Unit 2 specific tests, documented via NUREG 0797 Supplement 26 and 27. These upgrades involve 1-1/2" conduits, 1-1/2" and 2" airdrops and cable tray firestops installed at CPSES Unit 1. These upgrades will be performed under Design Modification 97-014. However, the finalization of the schedule for upgrading the Unit 1 installations will be predicated on NRC's acceptance of TU Electric's revisions to ER-ME-067. The NRC open items and a brief description of the responses are provided herein.

Open Item 1:

Raceway at CPSES Unit 1 where the total enclosed thermal mass is less than the total enclosed thermal mass of the tested configurations.

Response:

TU Electric has performed an evaluation which demonstrates that reductions in percentage fill (cable mass) below the values utilized in the fire tests will not adversely impact the functionality of the cables. Please refer to enclosed CPSES Engineering Report ER-ME-067, Rev. 4, Appendix F.

Open Item 2:

The hose stream performance of the Thermo-Lag "Box Assembly" tested in Scheme 11-4.

Response:

Based on the December 5, 1996 meeting, TU Electric has a better understanding of the NRC staff's specific concern with this issue. TU Electric has performed an evaluation of the hose stream performance of The Thermo-Lag "Box Assembly" tested in Scheme 11-4, and has concluded that the "box design" enclosures installed in Unit 1 are acceptable based on the following:

- The thermal performance of the "box design" enclosure in Test 11-4, constructed using a single layer of Thermo-Lag panels, was well within acceptance levels; and

- The box assembly joints were upgraded (i.e., staples and tie wires over an external stress skin layer with or without tie wire "stitches"). These upgraded joint configurations were previously qualified via Test Schemes 15-1 , 14-1 and 12-1, for which post hose stream barrier integrity was maintained; and

- The physical size of the Unit 1 configurations, in terms of Thermo-Lag panel spans, are bounded by those tested. Specifically, the unsupported span for the bottom panel installed on the 30" cable tray tee section in Test Scheme 14-1 envelopes the corresponding panel spans for all Unit 1 configurations.

For details of the evaluation please refer to ER-ME-067, Rev. 4, Appendix F.

Open Item 3:

Thermo-Lag fire stops installed in cable trays at CPSES Unit 1.

Response:

After the December 5, 1996, meeting with the NRC, TU Electric consulted with its Fire Protection Contractor and performed several walkdowns and documentation reviews of the installed raceways. The purpose of this review was to determine the types and location of the fire stops. This effort yielded results different than expected. Three different types of fire stop material were found in Unit 1 installed raceways. These are; a) Thermo-Lag 330-1, b) Silicone Foam, and c) Silicone Elastomer. As stated in ER-ME-067, Rev. 4 Attachment 2 to Appendix F, Silicone Elastomer and Thermo-Lag fire stop material were considered acceptable by evaluation. However, Silicone Foam material will be removed or augmented with acceptable firestop material via Design Modification 97-014.

Open Item 4:

Silicone foam fire stops installed in cable trays at CPSES Unit 1, where the qualification is based on fire tests that used silicone elastomer.

Response:

Refer to response for open item 3 above.

Open Item 5:

The use of Test Scheme 9-3 (1 1/2-inch and 2-inch conduits) at CPSES Unit 1.

Response:

TU Electric has opted to upgrade the 1-1/2-inch conduit installations to comply with previously accepted CPSES Unit 2 Test Scheme 9-2 (accepted via NUREG 0797, Supplement 26). The 2 inch conduits were found to be acceptable (with cable functionality), as stated in Reference 1.

Open Item 6:

The use of Test Scheme 11-2 (2-inch air drop) at CPSES Unit 1.

Response:

TU Electric has opted to upgrade the 1 1/2-inch and 2 inch air drops to comply with previously accepted CPSES Unit 2 Test Scheme 9-2.

Open Item 7:

The use of Test Scheme 15-2 for cables smaller than 750 KcMil [MCM]

Response:

TU Electric Test Scheme 15-2 was performed to bound a "unique" configuration. TU Electric does not use this test to certify configurations that are less than 750 MCM cable. This response was previously accepted via Reference 1, and was deemed closed during the December 5, 1996 meeting.

TU Electric believes that the plant modification/rework can be completed within 12 months or the following refueling outage for Unit 1 (whichever is later), after NRC acceptance of this response. It should be noted that some rework necessitates de-energizing essential cables to effectively perform upgrades. Such work can only be performed during outage conditions. Should you have any questions or need additional information, please contact Obaid Bhatty at (817) 897-5839.

Sincerely,

C. L. Terry

C. L. Terry

By: Roger D. Walker
Roger D. Walker
Regulatory Affairs Manager

OB:ob
Enclosure

cc: Mr. J. E. Dyer, Region IV
Mr. J. I. Tapia, Region IV
Mr. T. J. Polich, NRR
Resident Inspectors, CPSES

Reason for Revision 1

This report is being revised to eliminate the use of Test Reports produced by Industrial Testing Laboratories Inc. (ITL) and to incorporate the result of the Texas Utilities Test Program conducted at Omega Point Laboratories. The report is also being revised to provide a basis for the approach used in the Texas Utilities Test Program.

Due to the extensive changes to this report, no revision bars are used. Confirmation is Required since the Omega Test Reports were not finalized at the time of issue of this report. In addition further tests are currently planned.

Reason for Revision 2

This report is being revised to incorporate the results of the Texas Utilities Test Program conducted at Omega Point Laboratories between November 4 and December 3, 1992, and to incorporate the revisions to the acceptance criteria.

Due to the extensive changes to this report no revision bars are used. confirmation is Required since the Omega Test Reports were not finalized at the time of issue of this report. In addition further tests (ampacity tests) are currently planned. See section 8.0 for open items.

Reason for Revision 3

This report is being revised in response to TXX-93061 dated January 28, 1993 (Reference 10.22.7). Changes made via this revision include incorporation of final results of the Texas Utilities Test Program. Specifically, results from a confirmatory 1-hour fire endurance test of a 36" wide cable tray barrier and completion of ampacity derating testing described in TXX-93101 dated February 26, 1993 (Reference 10.22.9) have been included. These testing activities were performed between March 2 and 12, 1993 at Omega Point Laboratories (OPL). Additionally, results from a separate series of 1-hour fire endurance tests, conducted for qualification of various CPSES Unit 1 raceway barriers as described via TXX-93353 dated October 28, 1993 (Reference 10.22.15) have been included. These testing activities, also conducted at OPL, were performed between August 11 and 17, 1993. Accordingly, this revision also removes the "Interim" designation of the report as all testing activities relative to qualification of CPSES Unit 1 and Unit 2 Thermo-Lag fire barriers have been completed.

Due to the extent of changes to the report, no revision bars are used.

Reason for Revision 4 : This report is being revised to incorporate responses to the seven open items in the NRC letter dated May 22, 1996, from Mr. Timothy J. Polich to Mr. C. Lance Terry regarding Thermo-Lag installations and fire endurance testing implemented to certify Unit 1 fire barriers. Please refer to Appendix F of this report for details.

Due to the extent of changes to the report, no revision bars are used.

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FOREWORD

This report documents the basis for the acceptance and continued use of Thermo-Lag as a fire barrier material at Comanche Peak Steam Electric Station (CPSES). The report defines and summarizes the qualification of the Thermo-Lag fire barriers used in the protection of safe shutdown related components and fire barriers within the plant. Included in this report are descriptions of the CPSES Fire Protection System and Thermo-Lag qualification, including licensing basis, methodology and performance acceptance criteria associated with fire barrier qualification testing.

CPSES FIRE PROTECTION SYSTEM

The overall Fire Protection Program was developed utilizing the defense in depth concept. This concept is a combination of:

1. Preventing fires from starting

2. Quickly detecting and suppressing fires that do occur to limit the extent of damage

3. Designing plant safety systems so that if a design basis fire occurs, in spite of the fire protection systems provided, the fire will not prevent plant safe shutdown functions from being performed.

Measures have been taken to prevent fires from starting. The plant is constructed of either non-combustible or fire resistant materials and transient combustibles not identified in the Fire Protection Report are managed through administrative controls. The active Fire Protection System at CPSES detects, alarms, and extinguishes fires. It is comprised of two subsystems: Fire Detection and Fire Suppression. The Fire Detection System is a plant-wide system designed to detect fires in the plant, alert the Control Room operators, and alert the plant fire brigade of the fire and its location. The Fire Suppression System is designed to extinguish any design basis fire. It is comprised of a water supply system, fixed water sprinkler and spray systems, halon systems, fire hose stations, and portable extinguishers. Where redundant fire safe shutdown equipment cabling outside containment is located in the same fire area and is not separated by a horizontal distance of 20 feet with negligible intervening combustibles or fire hazard, one train of this cabling, if not one hour rated cable, is enclosed by a one hour fire barrier with fire detection and fire suppression (or radiant energy shield inside containment) unless an alternate shutdown path is utilized or justifications for deviations are provided.

BACKGROUND

During the process of selecting one hour raceway barrier systems, ampacity derating, material weight and thickness along with barriers used by other utilities were determining factors. Thermo-Lag (Manufactured by Thermal Science, Inc. (TSI) of St. Louis, Mo.) was selected to provide a one-hour barrier for cable raceway systems. Thermo-Lag 330 Fire Resistant Material is a sacrificial barrier that operates on the principle of sublimation with partial intumescence.

TU Electric conducted a full scale fire endurance test at Southwest Research Institute (SWRI) in 1981 (Reference 10.12.10) in order to obtain a one hour fire rating for Thermo-Lag in accordance with American Nuclear Insurers (ANI) Bulletin dated July, 1979 (Reference 10.3.2) and ASTM E119-80 Time/Temperature requirements (Reference 10.1.1). The results of the test indicated that the protective Thermo-Lag envelope system successfully withstood the fire exposure and hose stream tests without allowing the passage of flames as well as protecting the circuit integrity of the cables within the electrical raceway system. An ASTM E84 (Reference 10.1.4) test determined that Thermo-Lag had a flame spread rating of 5, fuel contribution rating of 0 and smoke developed rating of 15. This is consistent with licensing commitments which require less than 25 for each of these variables. The SWRI report was submitted to the NRC for evaluation of Thermo-Lag as an acceptable fire barrier material for use at CPSES (Reference 10.22.2). In a letter dated December 1, 1981, the NRC replied that they had evaluated the fire test report and concluded that it demonstrated that TSI Thermo-Lag material/system exhibits characteristics equivalent or better than other approved materials, and therefore can provide an acceptable fire barrier for electrical raceway system. The NRC concluded that the use of the TSI material/system met the requirements of Appendix R to 10 CFR Part 50 and is therefore acceptable. Additionally, refer to Section 7.0 for additional information with respect to combustability of Thermo-Lag.

Comanche Peak has consistently utilized the ANI acceptance criteria as our licensing basis for fire barriers for electrical raceways. As discussed below, TU Electric also agreed to use additional acceptance criteria in the tests conducted in November/December 1992. Based on concurrence from the NRC via SSER 27 (Reference 10.24.5) and to simplify the fire endurance test methodology, for testing performed subsequent to November/December 1992, TU Electric opted to use the revised acceptance criteria only, in lieu of the ANI acceptance criteria.

In June, 1991, the NRC established a Special Review Team to review the safety significance and generic applicability of certain technical issues regarding the use of Thermo-Lag at nuclear power plants. Prior to the issuance of the report by the Special Review Team, the NRC released to the industry a draft generic letter (92-XXX) on Thermo-Lag in February, 1992. (Reference 10.7.3) The draft generic letter identified several concerns related to the acceptability of Thermo-Lag.

In light of the concerns raised in the draft generic letter and the status of CPSES Unit 2 construction activities (Thermo-Lag installation was to begin in the very near future), TU Electric performed an extensive review to assess its position with respect to the continued use of Thermo-Lag for CPSES Unit 2. Based on an NRC concern about the acceptance of

previous Thermo-Lag tests, TU Electric performed independent full scale fire endurance testing of Thermo-Lag raceway assemblies that were representative of plant configurations and enveloped the range of installed commodity sizes. Applicable TU Electric specifications and installation and inspection procedures, site craft and QC personnel as well as CPSES stock material, as specified by the TU Electric Quality Assurance Program for procurement and installation were utilized for the testing. This testing was observed by NRC staff personnel. The testing program demonstrated that Thermo-Lag provides a qualified one hour fire barrier system.

TU ELECTRIC TESTING PROGRAM

The independent testing program for TU Electric Thermo-Lag was intended to accomplish the following objectives:

1. Demonstrate that Thermo-Lag is an effective fire barrier when properly configured.

2. Demonstrate that cables are able to perform their safe shutdown functions when protected by Thermo-Lag.

The test program was conducted in five separate sessions.

Test Sessions 1 and 2 were performed in June and August of 1992. These tests were conducted using test assemblies constructed in accordance with CPSES installation procedures in effect at the time and/or upgrades of structural joints and upgrades of small conduit barriers (additional thickness). Results of these tests are provided in section 4.0 and Appendix A of this report. During these tests, TU Electric learned that joints for Thermo-Lag board material must be reinforced for cable trays and box enclosures, small conduits must have additional Thermo-Lag material thickness, and raceway supports perform adequately without complete fireproofing.

Based on the results of these tests and discussions with the NRC Staff, TU Electric elected to conduct a series of confirmatory tests utilizing updated acceptance criteria for fire barrier integrity and cable functionality. The proposed acceptance criteria was transmitted to the NRC for review on September 24, 1992. TU Electric met with the NRC staff on October 27, 1992, to discuss the proposed acceptance criteria. Further revisions to the acceptance criteria were agreed to during this meeting. On October 29, 1992, the NRC transmitted to TU Electric "Thermo-Lag Acceptance Methodology for Comanche Peak Steam Electric Station-Unit 2" (Reference 10.22.1). This acceptance criteria was utilized in the confirmatory testing and is discussed in more detail in Section 3 of the report.

The third series of tests was planned with the following objectives:

1. Confirm the adequacy of the small conduit upgrade configuration;

2. Confirm the adequacy of junction box and lateral bend condulet (LBD) enclosure upgrade techniques;

3. Confirm the adequacy of design configurations with Thermo-Lag 330-660 "Flexi-Blanket" on Air Drops;

4. Confirm the adequacy of the cable tray upgrade techniques;

5. Confirm the adequacy of conduit radial bend upgrade techniques.

Session 3

Independent testing was performed at Omega Point Laboratories on November 4, through December 3, 1992.

In summary, satisfactory tests were conducted on the following test assemblies:

1. Conduit Assemblies (3/4" with 1/4" overlay, 3" and 5" conduits without overlays, with LBD's and radial bends, and 3" conduits with LBDs and connected to junction boxes);

2. Junction Boxes (with both 1 and 2 layers of Thermo-Lag 330-1 panels. When two layers were used the first layer was flat panels and the second layer was "ribbed" panels. Flat panels were used for the single layer configuration);

3. Air Drops (2 and 3 layers of Flexi-Blanket);

4. Cables Trays without Tees (12", 24", and 30");

5. Cable Trays with Tees (24" with stitching (method used to join prefabricated sections of Thermo-Lag using stainless steel wire), and 30" without stitching);

6. A test for 1-1/2" and 2" conduit without overlay (test results required cable functionality evaluation)

This test session confirmed the upgrade requirements which had been incorporated into the Unit 2 design and installation for Thermo-Lag raceway barriers.

Observations and results of the third series of tests were as follows:

Conduit Tests

Acceptable cable temperatures with no fire barrier burn through and no cable degradation (including acceptable Insulation Resistance (IR) test results) were observed for all Unit 2 conduit tests. These tests also confirmed the acceptability of the upgrade (reinforcement) details for the LBD enclosures and radial bends.

A Unit 1 test for 1-1/2" and 2" conduit without overlay which resulted in minor burn through, high cable temperatures and some outer jacket damage, but no inner jacket damage, no loss of continuity, acceptable IR test results and a cable functionality evaluation that

verified that high temperatures would not impair the cables installed in Unit 1 1-1/2" and 2" conduits. The results of this test were incorporated into the unit 1 design only.[1]

Junction Box Tests

Acceptable cable and junction box temperatures with no fire barrier burn through and no cable degradation (including acceptable IR test results) were observed for the junction boxes with a double layer of 1/2" Thermo-Lag panels as well as for single layer configuration. These tests confirmed the joint reinforcement details for junction boxes.

Air Drop Tests

Acceptable cable temperatures with no fire barrier burn through and only three cables with minor cable jacket swelling (with no other cable degradation and acceptable IR test results) were observed for the air drops using Thermo-Lag 330-660 Flexi-Blanket. The smaller (2" and less) diameter air drops were covered with 3 layers of 1/2" Flexi-Blanket while the larger air drops were covered with only 2 layers of Flexi-Blanket.[1]

12" Wide Tray Test

Acceptable cable and tray rail temperatures with no fire barrier burn through and no cable degradation (including acceptable IR test results) were observed. These tests confirmed the upgrade details were acceptable.

24" Wide Tray Tests

Acceptable cable and tray rail temperatures with no fire barrier burn through and no cable degradation (including acceptable IR test results) were observed. These tests included one tray with a horizontal 24" Tee. The bottom panel of the Tee section under the fire stop sagged during the hose stream test which resulted in opening of the fire barrier envelope. The attachment detail of the bottom panel to the fire stop was revised and tested satisfactorily in Scheme 14-1 (30" tray).

30" Wide Tray Tests

Acceptable cable and tray rail temperature with no fire barrier burn through and no cable degradation (including acceptable IR test results) were observed. These tests included one with a tee, and were conducted with and without "stitching" of the butt joints.

The fourth series of tests was planned with the following objectives:

1. Confirm the adequacy of cable tray upgrade techniques (without stitching of the butt joints) for a 36" wide cable tray.

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[1]see Appendix F for additional details

2. Confirm that Thermo-Lag barriers can adequately perform their function without imposing a 30 day cure time.

3. Confirm the adequacy of cable ampacity derating values used in the CPSES cable sizing design basis. A separate test method as described in Section 6 was utilized for determination of cable ampacity derating values.

Session 4

Independent testing was performed at Omega Point Laboratories between March 2 and 12, 1993.

In summary, a satisfactory test was conducted for a 36" wide cable tray upgraded with application of external stress skin and trowel grade material only, i.e., no stitching of butt joints was utilized. Acceptable cable and tray rail temperatures with no fire barrier burn through and no cable degradation (including acceptable IR test results) were observed. The test was performed following a 7 day cure of the Thermo-Lag barrier. This test confirmed the applicability of the previously established upgrade methods for 36" cable tray barriers and that a 30 day cure time is not required for a functional barrier.

Additionally, cable ampacity derating testing was conducted for the following 1-hour Thermo-Lag barrier configurations:

1. 3/4" conduit with 1/2" thick preshaped sections and 1/4" thick overlay containing a single three conductor cable (3/C #10 AWG);

2. 2" conduit with 1/2" thick preshaped sections and 1/4" thick overlay containing a single three conductor cable (3C/#6 AWG);

3. 5" conduit with 1/2" thick preshaped sections containing four separate single conductor cables (1/C 750 kMCil);

4. 24" cable tray with 1/2" thick panels upgraded with stitched butt joints and external stress skin with trowel grade material buildup applied over longitudinal and butt joints. The cable tray contained 126 passes of single three conductor cable (3C/#6 AWG)

5. Air drop configuration with 3 separate single conductor cables (1/C 750kMCil) covered with 3 layers of 330-660 Flexi-Blanket;

6. Air drop configuration with a single three conductor cable (3C/#6 AWG) covered with 3 layers of 330-660 Flexi-Blanket.

Refer to Section 6 for details of the cable ampacity derating testing.

The fifth series of tests was planned with the following objectives:

1. Evaluate the performance of less extensive upgrades for 12" - 24" wide cable trays than those qualified during Test Session 3;

2. Evaluate the performance of less extensive upgrades for 330-660 Flexi-Blanket coverage on air drop cables than those qualified during Test Session 3;

3. Evaluate the performance of flexible stainless steel mesh with trowel grade material buildup to reinforce radial bend areas on protected conduits and regions where 330-660 Flexi-Blanket on air drops interfaces with cable tray coverage;

4. Evaluate the performance of Thermo-Lag "box design" enclosures constructed with a single layer of panels to envelope air drop cables extending from cable trays;

5. Evaluate the performance of 2 layers of 330-660 Flexi-Blanket installed to protect large power cables in exposed cable trays;

Session 5

Independent testing was performed at Omega Point Laboratories between August 11 and 17, 1993.

In summary, satisfactory tests were conducted on the following test assemblies:

1. Cable Trays without Tees (12" tray without upgrade and 24" tray with stress skin and trowel grade buildup applied along longitudinal joints only);

2. Air Drops (2 layers of Flexi-Blanket on 1-1/2" and 2" diameter cable bundles);

3. Conduit Radial Bends (stainless steel mesh with trowel grade buildup);

4. Air Drop/Cable Tray Interfaces (stainless steel mesh with trowel grade buildup);

5. "Box Design" Enclosures for Air Drops (single panel layer with joints reinforced using stress skin and trowel grade buildup);

6. Large Power Cables in Exposed Tray (2 layers of Flexi-Blanket).

This test session confirmed that less extensive upgrade methods could, in some instances, be incorporated into the Unit 1 Thermo-Lag barrier backfit effort.

Observations and results of the fifth series of tests were as follows:

12" Wide Tray Test

Acceptable cable temperatures and no cable degradation (including acceptable IR test results) were observed. The cable tray barrier was tested without upgrade and demonstrated that such nonreinforced envelopes installed on straight horizontal and vertical tray runs including radial bends (except tees), can maintain electrical cables free from fire damage.

24" Wide Tray Test

Acceptable cable and tray rail temperatures with no fire barrier burn through and no cable degradation (including acceptable IR test results) were observed. The cable tray barrier tested was upgraded with a layer of external stress skin and trowel grade material buildup to reinforce longitudinal joints only (no stitching of butt joints). Additionally, at horizontal support locations Thermo-Lag panel strips were secured to the underlying panels on the support member. These panel strips effectively reinforced the region where panels installed on the underside of horizontal tray portion abuts the panels used to cover the horizontal support members. This test demonstrated that less extensive upgrades than those previously qualified can be successfully applied to straight horizontal and vertical tray runs including radial bends (except tees) for envelopes installed on 18" - 24" wide cable trays.

Air Drop Tests

Acceptable cable temperatures (with one exception) with no fire barrier burn through and no cable degradation (including acceptable IR test results) were observed for air drop cables protected with 2 layers of 330-660 Flexi-Blanket. The air drop cable bundles transitioned between 1-1/2" and 2" conduits and a 24" wide cable tray protected with Thermo-Lag panels. Additionally, the interface region where air drops entered the top surface of the cable tray envelope was reinforced using stainless steel mesh and trowel grade material buildup. One thermocouple on a cable within the bundle emanating from the 2" conduit exceeded single maximum temperature criterion at 59 minutes, however no visual degradation of the cable was observed and IR test results were acceptable. This test demonstrated that less extensive upgrades than those previously qualified can be successfully applied to air drops with a nominal cable bundle diameter of 1-1/2" and 2", including the interface regions with protected cable trays.[1]

Conduit Test

Acceptable conduit surface and cable temperatures with no fire barrier burn through and no cable degradation (including acceptable IR test results) were observed for radial bend coverage upgraded with stainless steel mesh and trowel grade material buildup. This test demonstrated that less extensive upgrades than those previously qualified can be successfully applied to conduit radial bend areas.

Cable "Box Design" Enclosure Test

Acceptable cable temperatures and no cable degradation (including acceptable IR test results) were observed. This test demonstrated that air drop cables which transition between protected cable trays and embedded "through wall" sleeves can be satisfactorily protected when enclosed in "box" enclosures constru cted using a single layer of Thermo-Lag panels.[1]

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[1] see Appendix F for additional details

Large Power Cables in Exposed Tray Test

Acceptable cable temperatures with no fire barrier burn through and only minor cable jacket deterioration (including acceptable IR test results) were observed. Excessive temperatures were however recorded by thermocouples installed on bare #8 AWG copper conductors installed within the individual protected cable bundles. See Appendix A for further discussion of the test acceptance basis. This test demonstrated that acceptable cable temperatures for 1/C 750kMCil cables protected with 330-660 Flexi-Blanket can be maintained when such protective cable bundles are routed in exposed cable trays.

CONCLUSIONS

As a result of tests conducted during the 5 test sessions summarized above, TU Electric has concluded:

1. Thermo-Lag performs its design function if properly configured.

2. Thermo-lag installations for 3/4" through 1-1/2" diameter conduits perform their design function when upgraded by addition of 1/4" thick overlays.

3. Thermo-Lag installations for 2" diameter conduits perform their design function without addition of overlays as demonstrated by cable functionality evaluation.

4. Thermo-Lag installations for 3" diameter and larger conduits perform their design function without addition of overlays.

5. Thermo-Lag installations for lateral bend condulets (LBDs), junction boxes, pullboxes, etc. perform their design function when joints and conduit interfaces are reinforced with external stress skin and trowel grade material buildup.

6. Thermo-Lag installations for conduit radial bends perform their design function when configured as follows:

   a. 3/4" through 1-1/2" -addition of 1/4" thick overlay and external stress skin or stainless steel mesh in conjunction with trowel grade material buildup.

   b. Larger than 1-1/2" - addition of either external stress skin or stainless steel mesh in conjunction with trowel grade material buildup.

7. Thermo-Lag installations for 12" wide cable trays perform their design functions when configured as follows:

   a. Straight horizontal and vertical runs including radial bends - no upgrade or reinforcement of joints is required.

   b. Tee sections - unsupported bottom butt joints require reinforcement with either external stress skin and trowel grade material buildup or stitching.

and longitudinal joints require reinforcement with external stress skin and trowel grade material buildup.

8. Thermo-Lag installations for 18" through 24" wide cable trays perform their design function when configured as follows:

   a. Straight horizontal and vertical runs including radial bends - longitudinal joints require reinforcement with external stress skin and trowel grade material buildup. Unsupported bottom butt joints at support locations only, require reinforcement with external stress skin and trowel grade material buildup or additional Thermo-Lag panel strips attached to the horizontal support member coverage.

   b. Tee sections - unsupported bottom butt joints require reinforcement with either external stress skin and trowel grade buildup or stitching, and longitudinal joints require reinforcement with external stress skin and trowel grade material buildup.

9. Thermo-Lag installations for cable trays wider than 24" perform their design function when configured as follows:

   a. Straight horizontal and vertical runs including radial bends - unsupported bottom butt joints on horizontal portions and top and bottom butt joints on vertical portions require reinforcement with either external stress skin and trowel grade material buildup or stitching, and longitudinal joints require reinforcement with external stress skin and trowel grade material buildup.

   b. Tee sections - unsupported bottom butt joints require reinforcement with either external stress skin and trowel grade buildup or stitching, and longitudinal joints require reinforcement with external stress skin and trowel grade material buildup.

10. Thermo-Lag installations for air drop cables perform their design function when configured as follows:

   a. Cable bundle diameters 2" and less - three (3) layers of 330-660 Flexi-Blanket are required.

   b. Cable bundle diameters greater than 2" - two (2) layers of 330-660 Flexi-Blanket are required.

11. Thermo-Lag "box design" installations for air drop cables perform their design function with a single layer of Thermo-Lag panels.[1]

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[1] see Appendix F for additional details with respect to barrier opening

12. Thermo-Lag installations for single large power cables (i.e., 1/C 750kMCil) wrapped with 2 layers of 330-660 Flexi-Blanket and routed in exposed cable tray perform their design function, however addition of a third layer is necessary to ensure complete thermal protection of the cables

13. Cable ampacity derating factors applied at CPSES are sufficient to assure cables will perform their design function

14. Where Thermo-Lag coverage on a cable tray terminates away from the walls, floors, etc., installed Fire stops constructed of Thermo-Lag or Silicone Elastomer materials are adequate to ensure protected cables perform their design function. Refer to Appendix F for details regarding fire stops.

In addition, these tests demonstrated that plant installation of supports with structural members protected for a nominal 9" distance from the raceway envelope is acceptable and that a fog nozzle hose stream test is an effective hose stream test.

1.0 PURPOSE

The purpose of this report is to evaluate the acceptability of Thermo-Lag for use as a fire barrier for CPSES.

Section 2.0 provides background information related to Thermo-Lag and its role in providing defense-in-depth for fire protection at CPSES.

Section 3.0 provides the licensing basis for fire barriers for CPSES.

Section 4.0 describes the qualification tests and their results for Thermo-Lag for CPSES, and compares those results against the CPSES licensing basis.

Section 5.0 describes the overall programs utilized for installation of upgraded Thermo-Lag barriers in Unit 2 and upgrade of existing Thermo-Lag barriers in Unit 1.

Section 6.0 evaluates the CPSES ampacity derating testing and calculations for cables installed in electrical raceways that have a Thermo-Lag fire barrier.

Section 7.0 discusses the combustibility effects of Thermo-Lag.

Section 8.0 identifies the additional actions that TU Electric is planning to ensure the adequacy of Thermo-Lag for CPSES.

Section 9.0 provides TU Electric's conclusions regarding the acceptability of Thermo-Lag for use as a fire barrier for CPSES.

2.0 BACKGROUND

The purpose of the Fire Protection Program at CPSES is to ensure the ability to safely shut down the plant in the event of a fire.

The overall Fire Protection Program was developed utilizing the defense in depth concept. This concept is a combination of:

1. Preventing fires from starting

2. Quickly detecting and suppressing fires that do occur to limit the extent of damage

3. Designing plant safety systems so that if a design basis fire occurs, in spite of the fire protection systems provided, the fire will not prevent plant safe shutdown functions from being performed.

Measures have been taken to prevent fires from starting. The plant is constructed of either non-combustible or fire resistant materials, and transient combustibles are managed through administrative controls.

The active Fire Protection System at CPSES detects, alarms, and extinguishes fires. It is comprised of two subsystems: Fire Detection and Fire Suppression. The Fire Detection System is a plant-wide system designed to detect fires in the plant, alert the Control Room operators, and alert the plant fire brigade of the fire and its location. The Fire Suppression System is designed to extinguish any design basis fire. It is comprised of a water supply system, fixed water sprinkler and spray systems, halon systems, fire hose stations, and portable extinguishers.

The passive Fire Protection System at CPSES protects safe shutdown systems from the effects of fires. In particular, the plant is divided into fire areas which are separated by three-hour structural fire barriers to limit the impact of a postulated fire to a local area. Additionally, where redundant fire safe shutdown equipment cabling outside of containment is located in the same fire area and is not separated by a three hour fire barrier or a horizontal distance of 20 feet with negligible intervening combustibles or fire hazard, one train of this cabling, if not one hour rated cable, is enclosed by a one hour fire barrier with fire detection and fire suppression unless an alternate shutdown path is utilized or justifications for alternate protection schemes are provided.

At CPSES, Thermo-Lag is utilized to provide this one-hour fire barrier. Thermo-Lag Fire Resistant Materials operate on the principle of sublimation with partial intumescence. The performance of the product is based on the integrated effect of sublimation, heat blockage derived from endothermic reaction and decomposition and increased thermal resistance of the char layer developed through the process of intumescence and the effect of reradiation. In short, Thermo-Lag is a sacrificial barrier and during the course of a fire, Thermo-Lag is designed to be consumed through the sublimation and decomposition process.

Thermo-Lag is used at CPSES to provide a one-hour fire barrier between redundant trains of fire safe shutdown equipment. In this use, the material is installed as a protective

envelope around essential commodities, such as a raceway, junction box, or pull box which contain safe shutdown cables. In these applications, the Thermo-Lag material is used to preclude fire-induced damage to the cables thereby protecting safe shutdown function.

Thermo-Lag is also used as a fireproofing material for the protection of structural steel. This use is evaluated in Appendix D of this report.

3.0 LICENSING BASIS FOR FIRE BARRIERS FOR CPSES ELECTRICAL RACEWAYS

3.1 NRC Regulations

The applicable NRC regulations are contained in 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 3, which states in its relevant part:

> Structures, systems, and components important to safety shall be designed and located to minimize, consistent with other safety requirements, the probability and effect of fire and explosions.

Specific direction to implement GDC 3 is provided in 10 CFR 50.48 (e).

Appendix R to Part 50 (Reference 10.4.2) also contains provisions related to fire protection. However, Appendix R only applies to plants that were licensed to operate prior to 1979. Since CPSES was not licensed to operate prior to 1979, Appendix R does not constitute a requirement for CPSES. However, as discussed below, Appendix R does provide guidance for CPSES.

3.2 NRC Guidance

As stated in NRC Supplemental Safety Evaluation Report (SSER) 21 for CPSES (Reference 10.24.2), Appendix R to Part 50, Appendix A to BTP APCSB 9.5-1 (Reference 10.4.1) and Generic Letters (GL) 81-12 and 86-10 (References 10.7.1 and 10.7.2) provide guidance for the CPSES Fire Protection Program.

Section III.G of Appendix R to Part 50 states that, when redundant trains of systems necessary to achieve and maintain hot shutdown are located in the same fire area outside containment, means shall be provided to ensure that one of the redundant trains is "free of fire damage". This section also states that one acceptable means consists of the following:

> Enclosure of cable and equipment and associated non-safety circuits of one redundant train in a fire barrier having a one-hour rating. In addition, fire detectors and an automatic fire suppression system shall be installed in the fire area.

The statement of Considerations for Appendix R also states that the standard test fire for rating barriers is defined by ASTM E-119 (which is similar to NFPA 251) (References 10.1.1 and 10.2.1).

Section D.1(a) of Appendix A to BTP APCSB 9.5-1 states that redundant safety systems should be separated from each other so that both are not subject to fire damage. With respect to cables and cable tray penetrations, Section D.3 (d) stated as follows:

> Cable and cable tray penetration of fire barriers (vertical and horizontal) should be sealed to give protection at least equivalent to that fire barrier. The design of fire barriers for horizontal and vertical cable trays should, as a minimum, meet the requirements of ASTM E-119, "Fire Test of Building Construction and Materials," including the hose stream test.

Section 3.1 of Enclosure 2 to GL 86-10 contains provisions related to qualification tests for fire barriers. This Section states that, in accordance with NFPA 251, the temperatures of the unexposed side of conduit and cable tray fire barrier wrap should not exceed 325°F during qualification tests. However, it also allows temperatures to exceed 325°F if justification is provided, which "may be based on an analysis demonstrating that the maximum recorded temperature is sufficiently below the cable insulation ignition temperature." This section also identifies criteria that should be met if the field configuration cannot exactly replicate the tested configuration.

Applicable NRC guidance for fireproofing is discussed in GL 86-10 and states that compliance with the NRC guidance is not required, and a licensee may deviate from this guidance if the deviation is identified and justified.

3.3 TU ELECTRIC COMMITMENTS

The Final Safety Analysis Report (FSAR) (Reference 10.6.1) and the Fire Protection Report (FPR) (Reference 10.6.2) for CPSES are the primary sources of TU Electric's commitments related to fire protection.

Section 9.5.1 of the CPSES FSAR states:

> Where redundant fire safe shutdown systems, required to bring the plant to a hot standby condition, are located within the same fire area and are subject to damage from a single fire hazard a Fire Hazards Analysis Evaluation demonstrates and documents compliance to that recommended in the guideline by protecting the function with one of the following:
>
> For systems located outside the Containment Building the following is provided:
>
> 1) A one-hour fire barrier or one hour fire rated cable for one set of required fire safe shutdown cabling and, based on the fire hazards of the area, automatic fire suppression and fire detection are provided.
>
> 2) Alternate shutdown capability
>
> 3) Fire detection and suppression, adequate for the hazards of the area, accompanied by 20 feet of horizonal separation with negligible intervening combustibles or fire hazards, unless justified as described in the Fire Protection Report.
>
> 4) Separation of redundant required sets of fire safe shutdown systems and components by a fire barrier having a 3 hour rating, unless justified as described in the Fire Protection report.

The FSAR and the FPR do not contain any provisions governing the procedures or acceptance criteria for qualification tests for fire barriers for electrical raceways. In particular, neither contain a commitment to qualify fire barriers for electrical raceways in accordance with ASTM E-119 (although such commitments are contained for fire barriers for other

components, such as penetrations). The NRC reviewed and accepted the CPSES Fire Protection Program in SSERs 12, 21, and 23 (References 10.24.1 through 10.24.3), which similarly address the criteria to be used for fire barriers for electrical raceway.

However, other licensing correspondence between the NRC and TU Electric did discuss qualification testing of Thermo-Lag for CPSES electrical raceways. In particular, in a letter dated November 18, 1981 (Reference 10.22.2), TU Electric requested the NRC to evaluate a qualification test report for Thermo-Lag to determine its acceptability to meet the requirements for fire barrier material. As stated in the test report, the qualification tests were run using the following procedures and acceptance criteria:

- Use of the ASTM E-119 time/temperature curve for the fire test.
- Use of the ANI Standard #5 (July 1979) for instrumentation, hose stream test, and acceptance criteria for circuit integrity and continuity.

With the exception of the time/temperature curve, ASTM E-119 was not used in this qualification test, because it is not applicable to raceway fire barriers. ASTM E-119 was intended to demonstrate in terms of fire endurance (time) the ability of a wall or floor assembly to contain a fire or to retain the structural integrity (including beams and columns) or both during the test conditions imposed by this standard. The standard was not specifically developed for testing of cable raceway barriers and as such does not contain provisions which address the integrity of the circuit. This was recognized in later ANI guidelines (Reference 10.3.1 and 10.3.2).

By letter dated December 1, 1981, from Robert L. Tedesco to R.J. Gary (Reference 10.22.3), the NRC concluded that, based upon its review of the test report, Thermo-Lag provides an acceptable fire barrier for cable trays and cables, meets the requirements of Appendix R, and therefore is acceptable.

The ANI standard identifies a number of requirements for conducting a test, including the following:

- Materials and components in the system, with the exception of the cable, shall be rated as non-combustible, i.e. flame spread, fuel contribution and smoke developed of 25 or less.
- The test exposure fire shall be the standard temperature-time curve in ASTM-E-119 for a minimum of one hour.
- After completion of the test exposure fire, the assembly shall be subjected to a hose stream.
- Cables shall be energized during the test.
- Thermocouples shall be located on the surface of the cables, and temperatures shall be recorded throughout the test.

The ANI standard states that the tests are acceptable if circuit integrity is maintained during the fire test and the hose stream test.

Applicable NRC guidance for fire proofing is discussed in GL 86-10 and states that compliance with NRC guidance is not required, and a licensee may deviate from this guidance if the deviation is identified and justified. This is the basis for the usage of Thermo-Lag as a Fireproofing material which is discussed in Appendix D to this report.

3.4 APPLICATION OF ANI CRITERIA BY TU ELECTRIC

As discussed above, the TU Electric acceptance criteria (used for the first and second series of tests in June and August 1992, respectively) was based upon ANI Bulletin No. 5, "ANI/MAERP Standard Fire Endurance Test Method to Qualify a Protective Envelope for Class IE Electrical Circuits" (Reference 10.3.2). TU Electric has interpreted this bulletin to require that the cables be free of fire damage such that the electrical circuits remain functional during the test.

Functionality can be demonstrated by one or more of several means.

Circuit Integrity

The cables are monitored throughout the fire endurance test to ensure that circuit integrity is maintained. This low voltage monitoring assures that a closed circuit is available at all times.

Cable Temperature

The test configuration is monitored at various locations to determine cable temperature throughout the test. Cable temperature can indicate an onset of cable damage. Cable temperatures below 325°F are considered a clear indication of no cable damage. Higher temperatures may also be acceptable but they must be evaluated separately or supplemented with additional inspection or test results.

Cable Inspections

When other criteria do not clearly indicate a functional cable, the cable may be visually inspected following the fire test. A cable which shows no effects from the fire is considered a functional cable. Some visual damage may be acceptable but additional evaluation of test results need to be considered.

Insulation Resistance (Megger) Test

A megger test at the cable's rated voltage indicates the capability of the cable to function. For a cable which was not altered by the fire, this test demonstrates the capability of the cable to function. For cables which sustained slight alteration during the fire (i.e. hardening, blistering, cracking, etc.), consideration is given to the worst

conditions that could occur in the plant (e.g. the affected portion of the cable against the tray or conduit).

Based on the NRC letter dated October 29, 1992 (Ref 10.22.1), for the third series of tests (The November/December 1992 tests) cable functionality was demonstrated using Insulation Resistance tests. The test method tested individual conductor to individual conductor and individual conductors to ground for each cable using the criteria outlined in Reference 10.22.1.

The demonstration that a specific test configuration is acceptable is based upon demonstrating that the cable remains functional. Some or all of the testing results above are considered to conclude that the fire barrier configuration is acceptable.

3.5 OCTOBER 1992 ACCEPTANCE CRITERIA

Following TU Electric's tests in June and August 1992, the NRC expressed concerns about the use of the ANI acceptance criteria, in part because these acceptance criteria were not the same as the criteria the NRC was applying to the industry as a whole (i.e., ASTM E-119 and GL 86-10). In order to alleviate the NRC's concerns, TU Electric submitted a letter to the NRC on September 24, 1992 (Reference 10.22.17), detailing the company's position on the proposed acceptance criteria for qualification testing of Thermo-Lag. This letter was also discussed with the NRC during a meeting on October 27, 1992, and the proposed acceptance criteria was revised to resolve NRC concerns.

In a letter dated October 29, 1992 entitled "Thermo-Lag Acceptance Methodology for Comanche Peak Steam Electric Station - Unit 2" (Reference 10.22.1), the NRC approved the use of TU Electric's revised acceptance criteria. The approved acceptance criteria are summarized below:

1. Average external conduit and average cable tray rails temperatures (supplemented by cable temperatures) do not increase by more than 250°F (i.e. temperatures do not exceed 250°F plus ambient), provided a similar series of thermocouples (e.g. cable tray side rails) are averaged together. In addition, no single thermocouple reading shall exceed 30 percent above the maximum allowable average temperature rise (i.e. 250°F + 75°F = 325°F, above ambient) during the fire test. If either, the 250°F average rise or the single 325°F point rise is exceeded, then visual cable inspections are required.

2. There shall be no burn through of the fire barrier (i.e the raceway is not visible through the fire barrier). If burn through occurs, cable functionality testing is required.

3. If the temperature criteria are not satisfied, cables shall be visually inspected. The cables are acceptable if none of the following attributes are identified during the inspections: Jacket swelling, splitting, or discoloration; shield exposed; jacket hardening; jacket blistering, cracking or melting; conductor exposed, degraded or

discolored; or bare conductor exposed. If these cable visual criteria are not satisfied, cable functionality tests are required.

4. If there are signs of thermal damage to the cables, or if barrier burn through occurs, Insulation Resistance (IR) tests are used to demonstrate functional performance of cables.

The minimum acceptable insulation resistance value (using the test voltage values for various voltages listed below) is determined using the following expression.

$$IR\ (\text{mega-ohms}) \geq \frac{\{[1\ \text{mega-ohm per kv}) + 1] * 1000\ \text{ft}\}}{\text{length of cable (ft)}}$$

Cable Type	Operating Voltage	Megger Test Voltage
Power	≥ 1000 volts	2500 VDC
	< 1000 volts	1500 VDC
Instrument	≤ 250 VDC	500 VDC
Instrument and	≤ 250 VDC	500 VDC
Control	≤ 120 VAC	500 VDC

5. An IR (megger) test should be performed for instrumentation cables (at least once during a one hour fire test), in order to assure that the cables will maintain sufficient insulation resistance levels necessary for proper operation of the instruments or if the IR test is not performed during the fire endurance test, LOCA temperature profiles may be used to evaluate cable functionality.

These acceptance criteria were used in TU Electric's subsequent series of tests, conducted in November and December of 1992 (Session 3), March of 1993 (Session 4) and August of 1993 (Session 5).

3.6 SUMMARY

NRC regulations do not specify any acceptance criteria for qualification tests for fire barriers for electrical raceway. Similarly, neither the FSAR (Reference 10.6.1), Fire Protection Report (Reference 10.6.2), nor SSERs for CPSES issued through SSER 23 identified any particular acceptance criteria for qualification tests for fire barriers for electrical raceways. However, NRC did approve a qualification test report for Thermo-Lag for CPSES electrical raceways, that utilized the ANI acceptance criteria and the ASTM E-119 time/temperature curve (Reference 10.22.3).

The June and August 1992 tests were evaluated under the ANI criteria using ASTM E-119 as guidance.

In a letter dated October 29, 1992 (Reference 10.22.1), NRC approved additional acceptance criteria for Thermo-Lag at CPSES. The guidance provided in GL-86-10 required that cables be maintained free of fire damage. The additional acceptance criteria provided in the above letter does not reduce that requirement, but does clarify what is required to meet that requirement. The results of subsequent TU Electric testing were evaluated using this acceptance criteria.

For testing conducted in March of 1993 (Session 4) and August of 1993 (Session 5), TU Electric opted to eliminate the ANI criteria for circuit integrity and continuity from the test acceptance basis. The NRC provided concurrence with this change in fire endurance test methodology via SSER 27 (Reference 10.24.5).

4.0 THERMO-LAG FIRE ENDURANCE TEST

4.1 Test Methodology

When possible, all materials used (Thermo-Lag, cable tray, cables, conduits, and penetration seal materials) were taken from the CPSES warehouse. No effort was made to select the "best" materials. In fact, the issuance of materials for the test articles was the same as for the materials in the plant using work package and picking tickets.

4.1.1 June 1992 and August 1992 Tests

In the June 1992 and August 1992 tests, circuit integrity was used as the acceptance criteria based on the NRC approval (Reference 10.22.3) of the SWRI Test (Reference 10.12.10). The intent of protecting the cables is to ensure that they will perform their function during and after a fire until the plant is in a safe shutdown condition and the cables can be inspected and replaced, if required.

As part of the test program at Omega Point, the cables were also visually inspected to determine degradation and megger tested to ensure the cables would remain functional.

Cable temperatures along with other temperatures such as tray rail temperatures were monitored to provide an indication of the performance of the Fire Barrier System and to provide a basis for engineering evaluation of non-tested configurations.

The conduit itself is an integral part of the Fire Barrier System and provides not only mechanical protection of the cables but also a thermal barrier for the cables.

During the evaluation of the test data for cable trays, it was noted that the cable and tray rail temperature, away from where the Thermo-Lag joints opened met the acceptance criteria for nonload bearing walls of NFPA 251.

4.1.2 November and December 1992 Tests, March 1993 Test and August 1993 Tests

In the November 1992 and subsequent tests, raceway temperatures were used as the baseline acceptance criteria in accordance with the NRC letter, dated October 29, 1992 (Reference 10.22.1). These acceptance criteria limit the average temperature rise to 250°F and individual thermocouple temperature rise to 325°F. If this criterion was exceeded, then visual cable inspections are required.

In addition to temperature rise, visual inspection of the fire barrier was also required to ensure that there was no burn through of the barrier. If this criterion was not met, cable functionality testing was required.

The hose stream was applied with a 30 degree fog nozzle, five feet from the barrier, with 75 psi at the nozzle for a 5 minute duration. The acceptance criteria was no raceway visible through the barrier after the hose stream.

As part of the testing program, the cables were visually inspected and insulation resistance (IR) tests were conducted on the cables, immediately following the hose stream tests.

4.2 Test Results

Based upon the review of plant raceway geometries documented in Appendix C of this report, the following commodities were identified for inclusion in the CPSES fire test program:

- Conduits (3/4", 1", 1-1/2", 2", 3" & 5")
- Cable Trays (12", 24" 30" & 36")
- Junction boxes
- Air drops
- Thermo-Lag "box design" enclosure for air drops
- Protected cables contained in exposed cable tray

Testing has been conducted at Omega Point Testing Laboratory, San Antonio, Texas, including twenty three fire tests and six ampacity tests in five testing sessions.

- Test Session 1, June, 1992 Schemes 1 to 5
- Test Session 2, August, 1992 Schemes 6 to 8
- Test Session 3, November, December 1992 Schemes 9-1 to 11-1, 12-1 to 13-1 and 14-1
- Test Session 4, March 1993, Scheme 15-1 and Ampacity Derating Tests
- Test Session 5, August 1993, Schemes 11-2, 11-4, 11-5, 13-2 and 15-2

The individual test schemes are described in detail in Appendix A.

The acceptance criterion for Test Sessions 1 and 2 tests was ANI Bulletin No. 5, "ANI/MAERP Standard Fire Endurance Test Method to Qualify a Protective Envelope for Class 1E Electrical Circuits" (Reference 10.3.2). Its intent is to demonstrate in terms of fire endurance (time), the ability of an electrical cable to remain functional inside a protective envelope during a fire test condition. The ANI acceptance criteria is "All Circuits Are To Be Monitored To Detect Failure, Circuit-To-Circuit, Circuit-To-System and Circuit-To-Ground" and maintain circuit integrity after a fire endurance test using the ASTM E-119 time vs temperature curve and a hose stream test.

The acceptance criterion for subsequent Test Sessions 3, 4 and 5 tests was the NRC letter dated October 29, 1992 (Reference 10.22.1). Its intent is to demonstrate in terms of fire endurance (time), the ability of an electrical cable to remain functional inside a fire

barrier during a fire test condition. The acceptance criterion ensures cable functionality after a fire endurance test using the ASTM E-119 time vs temperature and a fog nozzle hose stream test.

4.2.1 CONDUITS

Together the five testing sessions have tested the full range of conduits (3/4" through 5") installed at CPSES. The Scheme 2 (session 1) conduit tests showed high temperature responses in the small conduits. Specifically, although circuit integrity was maintained, the 3/4" conduit reached a cable temperature of 609°F and resulted in cable degradation. The 1" conduit maintained circuit integrity throughout the test, however blistering of the jacket was observed and the cable was considered to have suffered "fire damage". The 5" conduit of Scheme 2 (session 1) passed both the fire endurance and hose steam tests, circuit integrity was maintained and the cables were free of fire damage.

Due to the results of the 3/4" and 1" conduits tested in Scheme 2 (session 1), a subsequent test (Scheme 7(session 2)) was conducted to test upgraded Thermo-Lag application techniques and to bound the range of conduits requiring an upgrade. Scheme 7 included 3/4", 1-1/2", 2", and 3" conduit sizes. The upgrades for the 3/4" conduits in scheme 7 (session 2) are discussed below.

The 3" conduit in Scheme 7 (session 2) passed the fire endurance test in that circuit integrity was maintained. The hose stream test was not conducted on Scheme 7 (session 2) per agreement with NRC request to allow for a more effective barrier inspection. Instead the test article was cooled with a garden hose. The conduit lateral bend (LBDs) enclosures shifted, opening up the top joints of the LBD enclosure and some slight blistering of the outer jacket of one cable was observed. Because the LBD joint opened, it was decided to reinforce the LBD enclosure.

The 2" and 1-1/2" conduits in Scheme 7 (session 2) passed the fire endurance test since circuit integrity was maintained. However, there was blistering of the cable jackets and the LBD enclosures opened similar to the 3" conduit. Pending further testing and analysis of results, to support completion of the Unit 2 Thermo-Lag installation, it was decided to reinforce the LBD and to upgrade the fire barrier on the 1-1/2" and 2" conduits using a total thickness of 3/4" of Thermo-Lag material.

The test of 3/4" conduits in Scheme 7 (session 2) was designed to evaluate four Thermo-Lag application upgrade techniques.

- 3/4" Preshaped Sections (PSS)
- 1/2" (PSS) with an overlay of 1/4" (PSS)
- 1/2" (PSS) with 1/4" buildup of trowel grade material
- 1/2" (PSS) with 1/4" spiral wound 330-660 Flexi-Blanket

All four designs passed the fire endurance test. Based on the visual inspections of cables, only the cable inside the 1/4" thick pre-shaped overlay article had no blistering of the cable. These LBD enclosures opened similar to the other applications in Scheme 7 (session 2). It was decided to use the 1/4" pre-shaped overlay with reinforced LBD enclosures in Unit 2's design. Additionally, this same upgrade method for 3/4" through 1-1/2" conduits and lateral bend enclosures was later deemed necessary for Unit 1.[1]

Due to the results of the 3/4" through 2" conduits tested in Scheme 7 (session 2), subsequent tests (Schemes 9-1, 9-3, 10-1, and 10-2 (session 3)) were conducted to test upgraded Thermo-Lag application techniques.

A 3/4" conduit with the 1/4" overlay along with 3" and 5" conduits, all with upgraded LBD enclosures and radial bends, were tested in Scheme 9-1 (session 3) and passed the fire endurance test. The cable temperatures were all below the maximum and average allowable. There was no burn through of the fire barrier after the hose stream test, no visible cable degradation, circuit integrity was maintained and all cables passed the insulation resistance (IR) tests. The exposed conduit thermocouple leads became saturated with Thermo-Lag decomposition residue and the readings were determined to be incorrect and thus were not used (see Section 4.4.1 for further discussion).

Additional 3" conduits which were upgraded with reinforced joints on the LBD's were included as part of test schemes 10-1 and 10-2 (session 3) and passed the fire endurance test. The cable temperatures were all below maximum and average allowable for Scheme 10-1 (session 3) and Test Scheme 10-2 (session 3). There was no burn through of the fire barrier after the hose stream test, no visible cable degradation, circuit integrity was maintained and all cables passed the IR tests. The exposed conduit thermocouples again became saturated and the readings were determined to be incorrect and thus were not used (see Section 4.4.1 for further discussion).

A 3/4" conduit with 3/4" thickness prefabricated half sections was tested in Scheme 9-3 (session 3). This test was conducted to determine if this method could be qualified for backfit on Unit 1. As described above, this method of upgrade was not used.

Additionally, 1-1/2" and 2" conduits with only 1/2" thick prefabricated half sections and LBD upgrades were tested in Scheme 9-3 (Session 3). This test was conducted to determine if the 1/4" overlay was required for backfit on Unit 1, if the LBD enclosures were reinforced. The results of this test were that the maximum and average temperature criteria on the cables was exceeded. However, visual examination showed only outer jacket damage and no damage on the inner jacket. No loss of circuit integrity occurred and the IR test results were within allowable limits. A subsequent cable functionality evaluation (Reference 10.23.2) indicated that the elevated temperatures reached in the test would not impair the function of the cables installed in 1-1/2" and 2" conduits in Unit 1. The surface conduit thermocouples became saturated and were not used (See Section 4.4.1 for further discussion). Therefore, the design for upgrade of Unit 1 barriers did not specify 1/4" thick overlays for installation of 1-1/2" and 2" conduits. However, based on the December 5, 1996, meeting

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[1] see Appendix F for details

with the NRC, TU Electric Management chose to upgrade the 1-1/2" conduits similar to configurations tested in Unit 2 test scheme 9-1.[1]

A 2" conduit with upgrade only at the radial bends was tested in Scheme 13-2. This test was conducted to determine if stainless steel mesh with trowel grade material buildup was an acceptable method of upgrading radial bends on conduits in Unit 1. The test results demonstrated that this method was acceptable for upgrade of conduit radial bends.

4.2.2 **CABLE TRAY**

Cable trays (12", 24", 30" and 36") were tested in Schemes 1-2, 3, 5, 6, 8, 11-1, 11-2, 11-4, 11-5, 12-1, 12-2, 13-1, 13-2, 14-1 and 15-1. The test articles in Schemes 3, 5, 6, and 8 (sessions 1+2) were assembled in accordance with CPSES procedures at the time of testing. The Scheme 1 assembly 2 (session 1) test was done to an upgraded design, to test upgrade techniques of butt joint stitching and external stress skin reinforcement at joints. Schemes 11-1, 12-1, 12-2, 13-1 and 14-1 (session 3) were assembled in accordance with the revised CPSES procedures.

Scheme 3 (session 1) tested a 12" tray which passed the fire endurance test and hose stream test. Circuit integrity was maintained and the cables were "free of fire damage."

Scheme 5 (session 1) tested a 30" tray with a tee section. The bottom joint on the Thermo-Lag under the tee opened at approximately 15 minutes into the test and circuit integrity was lost at 42 minutes and the test was stopped. The article was cooled down with a garden hose. A review of the test article showed that fire damage was localized to the area around the joint and the rest of the article was in good condition.

Based on the results of testing Scheme 5 (session 1), Scheme 1 assembly 2 (session 1) (upgraded design) was tested (Scheme 1 assembly 1 was a non-upgraded design which was not tested). Scheme 1 assembly 2 (session 1) tested a 36" tray with a tee, upgraded by reinforcing the joints with stitching or stress skin overlay. Scheme 1 (session 1) passed the fire endurance and hose stream test in that circuit integrity was maintained and the cables were "free from fire damage." This test demonstrated the acceptability of the upgrade design.

In order to determine which trays needed to incorporate or backfit the upgrade, a 24" tray with a tee (Scheme 6 (session 2)) and a 30" tray without a tee (Scheme 8) were tested. In both cases, it was observed that butt joints opened to some degree. Based on this performance, it was decided that trays would be upgraded with stitching and stress skin overlay.

Based on the test results of Schemes 6 and 8 (session 2), confirmatory testing was performed in Schemes 11-1, 12-1, 12-2, 13-1, 14-1 (session 3), Scheme 15-1 (session 4) and Unit 1 test schemes 11-2, 11-4, 11-5 and 13-2 (session 5). These tests were conducted to validate joint reinforcement details.

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[1] see Appendix F for additional details

Scheme 11-1 (session 3) tested a 24" tray with middle and end air drops. This scheme passed the fire endurance test. The tray rail and cable temperatures were all below the maximum and average allowable. There was no burn through of the fire barrier after the hose stream test. In addition, there was no visible cable degradation in the tray area, circuit integrity was maintained and all cables passed the IR tests.

Scheme 12-1 (session 3) tested a 30" tray without a tee. This scheme passed the fire endurance test. The tray rail and cable temperatures were all below the maximum and average allowable. There was no burn through of the fire barrier after the hose stream test. In addition, there was no visible cable degradation, circuit integrity was maintained and all cables passed the IR tests.

Scheme 12-2 (session 3) tested a 24" tray with a tee section. This Scheme passed the fire endurance test. The tray rail and cable temperatures were all below the maximum and average allowable. There was no burn through of the fire barrier; however, during the hose stream test, the Thermo-Lag panel below the fire stop (seal) in the tee sagged which provided an opening between the panel and fire stop. There was no visible cable degradation, circuit integr ty was maintained and all cables passed the IR tests. Due to the opening of the fire barrier, the cable temperatures were evaluated against CPSES LOCA temperature qualifications profiles and found to be acceptable. The CPSES design requirements were revised to provide mechanical attachment of the bottom Thermo-Lag panel to the fire stop.

Scheme 13-1 (session 3) tested a 12 in tray which was upgraded with reinforced longitudinal and butt joints. This scheme passed the fire endurance test. The tray rail and cable temperatures were all below the maximum and average allowable. There was no burn through of the fire barrier. In addition, there was no visible cable degradation, circuit integrity was maintained an all the cables passed the IR tests.

Scheme 14-1 (session 3) tested a 30" tray with a tee. All joints were reinforced with stress skin overlay only. The tee had the bottom panel fastened to the fire stop. This scheme passed the fire endurance test. The tray rail and cable temperatures were below the maximum and average allowable except a single tray rail temperature was 401°F which exceeded the 395°F limit. However, the 395°F limit was exceeded in the last minutes of the test. There was no burn through of the fire barrier after the hose stream test and no visible cable degradation. Circuit integrity was maintained and all cables passed the IR tests.

Scheme 15-1 (session 4) tested a 36" tray without a tee. All joints were reinforced with stress skin and trowel grade buildup only, with no stitching of joints. This scheme passed the fire endurance test. The maximum and average temperatures for both cable and tray were well below the allowable. There was no burn through, visible cable inspection revealed no thermal damage and the IR tests were well within allowable limits. Based on concurrence with the NRC (Reference 10.24.5) and to simplify conduct of the test, circuit integrity was not monitored.

Scheme 11-2 (session 5) tested a 24" tray with middle and end air drops. This was a Unit 1 test which tested 1-1/2" and 2" air drops with 2 layers of Flexi-Blanket, a tray with all joints upgraded with stress skin and trowel grade only and a modified upgrade of the air drop and tray interface with stainless steel mesh and trowel grade. Additionally, at

horizontal support locations, Thermo-Lag panel strips were secured to the underlying panels on the support member to reinforce the region where panels installed on the underside of the horizontal tray portion abuts the panels used to cover the horizontal support members. This was a satisfactory test. However, based on the December 5, 1996, meeting with the NRC, TU Electric Management chose to upgrade the 1-1/2" and 2" air drops similar to configurations tested in Unit 2 test scheme 11-1 (refer to Appendix F for additional details). One thermocouple on the 2" air drop exceeded the single maximum temperature criterion at 59 minute but all other maximum and average temperatures were well below the allowable. There was no burn through, visual cable inspection revealed no significant thermal damage a d the results of the IR tests were well within the allowable limits.[1]

Scheme 11-4 (session 5) tested two (2) stacked 24" cable trays with air drops transitioning from the trays to 8 embedded wall sleeves. This was a Unit 1 test which tested "box" design enclosure coverage for air drops consisting of a single layer of Thermo-Lag panels and the interface with the concrete structure. All joints on the box and the longitudinal and butt joints on the tray were reinforced with stress skin and trowel grade only and the wall interface was upgraded with stress skin and trowel grade plus additional panel material flared out onto the concrete and secured with Hilti bolts. Additionally, at horizontal support locations, Thermo-Lag panel strips were secured to the underlying panels on the support member to reinforce the region where panels installed on the underside of horizontal tray portions abut the panels used to cover the horizontal support members. This was a satisfactory test. All raceway and cable temperature readings were well below the maximum and average allowable, visual cable inspection revealed no apparent thermal damage to the cables, the barrier opened during the hose stream test but there was no burn through and the IR tests were well within allowable limits. There was some minor jacket swelling on power cables which is discussed further in Section 4.5.5. However, based on the fire barrier opening, additional reinforcement of these enclosures was implemented for Unit 1 configurations.[1]

Scheme 11-5 (session 5) tested three (3) 24" trays arranged side by side with various upgrades on the joints. This was a Unit 1 test in which one tray had longitudinal joint upgrade only with stress skin and trowel grade, one tray had circumferentially wrapped stress skin and trowel grade only and one tray was upgraded with ceramic banding material wrapped circumferentially around the tray. Additionally, for the tray reinforced along longitudinal joints, at the horizontal support location, Thermo-Lag panel strips were secured to the underlying panels on the support member to reinforce the region where panels installed on the underside of the horizontal tray portion abuts the panels used to cover the horizontal support member. The tray with the circumferentially wrapped stress skin had the barrier breached and was not considered satisfactory. This upgrade method was not used for upgrade of Unit 1 tray coverage. The other two upgrade methods were satisfactory. The average and maximum raceway and cable temperatures on the longitudinal stress skin upgrade were well below the allowable. The raceway temperatures for the tray with ceramic banding reinforcement exceeded allowable but the cable temperatures were below allowable and the visual examination revealed no apparent thermal damage to the cables, there was no burn through and the IR tests were well within allowable limits. There was some jacket swelling

[1] see Appendix F for additional details

on power cables, which is discussed further in Section 4.5.5. Based on the results of this test, the method selected for upgrade of 18"-24" cable trays in Unit 1 was reinforcement of longitudinal joints with stress skin and additional panel strips to reinforce bottom butt joints at horizontal support members. Use of the ceramic banding upgrade was controlled by design and utilized on a limits basis only, where stress skin could not be installed along longitudinal joints.

Scheme 13-2 (session 5) tested a 12" cable tray without a tee and a 2" conduit with radial bends. This was a Unit 1 test which tested a 12" cable tray envelope with no joint upgrade (as currently installed in Unit 1) and conduit radial bend upgrade with stainless steel mesh and trowel grade. The test was satisfactory even though raceway temperatures exceeded average and maximum temperature allowances and there was some minor burn through on the tray coverage. The cable condition in the radial bend area on the conduit and in the tray indicated no cable damage with only minor jacket discoloration in the tray. All cable temperature measurements were within allowable limits. The IR tests were well within allowable limits.

Scheme 15-2 (session 5) tested large power cables (1/C 750 kMCil) wrapped with Thermo-Lag "Flexi-Blanket" in an exposed tray. This was a Unit 1 test which tested wrapping 2 power cables individually with 2 layers of "Flexi-Blanket" and laying them in a 36" cable tray which was not protected with Thermo-Lag. Although single point and average temperature increase parameters were exceeded on bare #8 AWG copper wires within the protective wraps, the assembly, as tested, met the acceptance criteria contained in the NRC letter dated October 29, 1992 (Reference 10.22.1), for the following parameters, 1) barrier inspection revealed no barrier openings or burn through, 2) visual cable inspection revealed no appreciable, penetrating thermal damage to the conductor insulation, and 3) the results of the insulation resistance tests were well within allowable limits. However, based on the temperatures recorded on the bare #8 AWG copper conductor, TU Electric has opted to add a third layer of 330-660 Flexi-Blanket to ensure complete thermal protection of the cables. Additionally, during this test, steam and fluid were observed being driven from the "Flexi-Blanket" material. This phenomena is further discussed in Section 4.5.6.

4.2.3 Thermo-Lag Fire Stops

A Thermo-Lag fire stop installed per CPSES procedures in place at the time was tested in Scheme 4 (session 1) to evaluate sealing of cable tray envelopes where coverage terminates away from the walls, floors, etc. This test was performed prior to receipt of the October 29, 1992 test criteria on a vertically oriented 36" wide tray with a 5" deep Thermo-Lag 330 fire stop. The fire stop passed the IEEE-634 acceptance criteria (reference 10.19.1) in that the back side temperature (380°F average) was significantly below the ignition temperature of the cable (700°) and did not allow the passage of the hose stream past the fire stop. However, this test is not directly credited in the acceptance basis for Thermo-Lag cable tray fire stops installed at CPSES.[1]

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[1]see Appendix F for additional details

4.2.4 Junction Boxes

A junction box with Thermo-Lag installed per CPSES procedures in place at the time was tested in Scheme 2. The installation passed the fire endurance and hose stream test in that circuit integrity was maintained and the cables were free from fire damage.

Due to results of the Scheme 7 test (session 2), where LBD "box" enclosures shifted during the test, confirmatory testing of upgraded junction box designs were successfully performed in Schemes 10-1 and 10-2 (session 3).

Scheme 10-1 (session 3) tested one vertical and one horizontal junction box. The Thermo-Lag design used two layers of 1/2" nominal prefabricated panels with the first being flat panels and the second being ribbed panels. The junction boxes passed the fire endurance test. The cable and junction box temperatures were all well below maximum and average allowable. There was no burn through of the fire barrier. In addition, there was no visible cable degradation, circuit integrity was maintained and all cables passed the IR tests.

Scheme 10-2 (session 3) tested one vertical and one horizontal junction box. The Thermo-Lag design used one layer of 1/2" nominal flat panels. The junction boxes passed the fire endurance test. The cable and junction box temperatures were all below maximum and average allowable. There was no burn through of the fire barrier. In addition, there was no visible cable degradation, circuit integrity was maintained and all cables passed the IR tests.

4.2.5 Air Drops

Scheme 11-1 (session 3) tested several cable air drops protected with Thermo-Lag 330-660 Flexi-Blanket. These air drops ranged from the approximate size of a 1" conduit to that of a 5" conduit. Flexi-Blanket used for heat path protection on nonessential air drops (protruding cables) was also tested. The air drops with 1" to 2" diameter cable bundles were protected with three layers of 1/4" Flexi-Blanket, while the 3" and larger were protected with two layers of 1/4" Flexi-blanket. All cable temperatures, inside conduit temperatures, and cable tray rail temperatures were below maximum and average allowable. There was no burn through of the fire barrier. In addition, there was no visible degradation of the cable except on the 5" air drop bundle where three cables showed signs of jacket blistering. The insulation on the individual conductors showed no signs of degradation, circuit integrity was maintained and all the cables passed the IR tests.

Scheme 11-2 (session 5) tested air drops with the approximate size of a 1-1/2" and a 2" conduit. This was a Unit 1 test in which the air drops were protected with 2 layers of "Flexi-Blanket". Flexi-Blanket used for heat path protection on a nonessential air drop (protruding cable) was also tested. This was a satisfactory test. One thermocouple on the 2" air drop exceeded maximum temperature, but all other maximum and average temperatures were well below the allowable, there was no burn through, visual cable inspection revealed no thermal damage and the results of the IR tests were well within allowable limits. However, based on the December 5, 1996 meeting with the NRC, TU Electric Management chose to upgrade the 1-1/2" and 2" airdrops similar to configurations tested in Unit 2 test scheme 11-1 (refer to Appendix F for additional details).

Scheme 11-4 (session 5) tested air drops transitioning from cable trays to embedded wall sleeves. This was a Unit 1 test which tested a "box" design enclosure consisting of a single layer of Thermo-Lag panels extending from the tray coverage and butting to the concrete wall at the wall sleeves. All joints were upgraded with stress skin and trowel grade and the wall interface was reinforced with stress skin and trowel grade and panels flared out and HiTti bolted to the concrete. This was a satisfactory test. All cable and raceway temperature readings were well below maximum and average limits and visual cable inspection revealed no thermal damage to the cables. The barrier opened during the hose stream test but there was no burn through and the IR tests were well within allowable limits. There was some jacket swelling on power cables which is discussed further in Section 4.5.5. However, based on the fire barrier opening, additional reinforcement of these enclosures was implemented for Unit 1 configurations (refer to Appendix F for additional details).

4.2.6 **Summary of Test Results**

Thermo-Lag 330-1 materials generally soften early in the test (material temperature around 250°F). For cable trays wider than 12", this can allow prebuttered joints under stress to open unless reinforced either by stitching the joints or providing an overlay of Thermo-Lag 330-69 Stress Skin and Thermo-Lag 330-1 trowel grade material. This effect was more pronounced on trays than on conduits because the conduit circular shape provides structural stability.

The design originally called for the use of stainless steel banding to support the Thermo-Lag panels. On large tray (24" and over), internal bands are provided. The external banding slackened almost immediately in the fire tests. The slackened bands along with the softened Thermo-Lag allowed the bottom panels on trays to sag, pulling open the joints. The internal banding, which was protected, did not sag and supported the top panel.

The overall performance of Thermo-Lag was acceptable on wide cable trays when the joints were properly reinforced with either application of stress skin and trowel grade material or stitching with stainless steel tie wire.

The banding on conduits did not exhibit the same slouching as banding on cable trays and the banding provides support for the preshaped Thermo-Lag sections.

On 3/4" through 1-1/2" conduits, the 1/2 in. (nominal) preshaped Thermo-Lag 330 sections did not pass the test unless a 1/4" overlay was installed over the 1/2" thick Thermo-Lag. Also radial bends for all conduit sizes required additional protection with either stress skin or stainless steel mesh in conjunction with trowel grade material buildup. For all conduit sizes the preshaped conduit sections provide enough rigidity to prevent the butt and longitudinal joints from opening. However, butt joints at box enclosures (e.g., LBDs) required reinforcement with additional trowel grade material and stress skin to prevent opening of the joints.

4.3 ISSUES RAISED BY THE NRC

4.3.1 Hose Stream Test

The first series of tests conducted at Omega Point Laboratory used a 2 1/2 in. playpipe with a 1-1/8 in. smooth bore nozzle at 30 psi positioned at a distance of 20 ft from the test article (ANI criteria) to induce an impact, erosion, and cooling effect.

This approach did not damage the cable and cable tray, or penetrate the conduits/junction box. However, it dislodged large amounts of the Thermo-Lag material. This resulted in the hose stream test destroying evidence of any Thermo-Lag failures such as small burn through areas or cracked joints. Based on this, an alternate hose stream test using a 30 degree 1-1/2 in. fog nozzle held 5 ft from the article at 75 psi was used during the Omega Point testing conducted on August 20 and 21, 1992. This fog nozzle hose stream provided the impact, erosion, and cooling effect, but did not dislodge large sections of Thermo-Lag, allowing for a better inspection of the fire barrier. The use of the fog nozzle is described in IEEE 634 and BTP CMEB 9.5.1 as an alternate to the playpipe for penetration seals (fire barrier seals). The only difference between IEEE 634 and BTP CMEB 9.5.1 is that the former states a distance of 10 ft from the centerline of the test article while BTP CMEB 9.5.1 says 5 ft from the article and IEEE 634 states a minimum duration of 2 1/2 minutes, while BTP CMEB 9.5.1 does not specify a duration.

In order to ensure sufficient cooling impact, CPSES testing used a 5 minute duration with a 1-1/2 in. diameter fog nozzle set at a discharge angle of 30 degrees with a nozzle pressure of 75 psi maintained at a distance of 5 ft perpendicular from the outside face of the test article.

Both IEEE 634 and BTP CMEB 9.5.1 specify a minimum flow of 75 gpm. The Elkhart nozzle used in the CPSES tests had a rated flow of 88 gpm at 75 psi which ensured that the 75 gpm minimum was maintained. The 5 ft perpendicular distance from the outside face of the test article was used because this maintained a distance of less than 10 ft from the centerline of the article which satisfies IEEE 634.

The basis for using the alternate hose stream test method was to preserve the Thermo-Lag envelope geometry while providing an impact, erosion, and cooling test. Since, the Branch Technical Position accepts the alternate method for fire seals and since the impact, erosion, and cooling effect would be the same on either the penetration seal or fire barrier, an adequate level of assurance that the barrier would function was maintained.

The NRC letter dated October 29, 1992 (Reference 10.22.1) approved the use of the fog nozzle and this method was used in the November and December 1992 tests (third test session), the March 1993 tests (fourth session) and the August 1993 tests (fifth session).

Although it is not the intent of the hose stream test to replicate fire fighting methods, the fog nozzle used during testing is consistent with the type nozzles installed in the plant (30°fog). Additionally the nozzle pressures used during testing envelop the nozzle pressures of the plant standpipe and hose system.

4.3.2 Nine (9) inch Rule

CPSES specifications require that items protruding from a raceway be covered with Thermo-Lag to a distance of 9 in. from the raceway. In most of the test articles, the 9 in. rule was tested to reflect the various configurations in the plant. The results of these tests indicate that the exposed steel protected in this manner did not provide a heat path into the enclosure. In fact, in many cases, the cable temperatures were lower in the areas where the 9 in. rule was being tested. Therefore, covering a protruding item for at least 9 in. away from the cables being protected with either Thermo-Lag 330 or 660 (Flexi-Blanket) provides adequate protection to prevent significant heat intrusion. In SSER 26 (Reference 10.24.4), the NRC accepted TU Electric's position of 9 in coverage of items protruding from protective raceway envelopes for Unit 2 configurations. No differences exist between Unit 1 and Unit 2 Thermo-Lag barriers for protection of protruding items.

4.3.3 Test Article Supports

CPSES does not fireproof the structural steel cable raceway supports in the plant. CPSES has provided the NRC with documentation in accordance with Generic Letter 86-10 to justify not installing structural fireproofing on cable raceway supports. However, cable raceway supports are considered protruding items and are covered with Thermo-Lag 330 in accordance with the 9 in. rule to prevent their being a heat path through the protective envelope.

Predicated upon CPSES analysis, raceway supports are not protected in the plant, eliminating the need to perform structural fireproofing tests on the supports. Therefore, to eliminate a variable from the test program, the raceway supports were covered with Thermo-Lag 330 in Schemes 1 to 5 (session 1). In these Schemes, the raceway supports were covered by a single layer of 1/2 in. prefabricated section of Thermo-Lag 330 until at least 9 in. away from raceway. The rest of the distance to the test deck was covered with two layers of 1/2 in. prefabricated panels. (Note: the 9 in. rule was tested elsewhere in the test program.) When the NRC expressed a concern that the covering of the supports did not represent the plant condition and that the support could provide a significant heat path into the envelope or a heat sink, it was decided not to cover the supports in subsequent test sessions.

Instead, in these subsequent tests (Sessions 2-5), the supports were covered out to approximately 9 in. with Thermo-Lag [for protruding items in accordance with plant design] (References 10.14.1 and 10.14.2). The test results from Schemes 6 through 14-1 (sessions 2 and 3) showed that the exposed supports did not provide a significant heat path into the envelope. In fact, the cable thermocouple reading closest the supports tended to be lower than the surrounding readings.

The exposed supports also did not cause any visible distortion of the test articles. Therefore, whether supports are entirely covered or covered for only a 9 in. distance had no impact on the test results.

4.3.4 Topcoat

Thermo-Lag 350 Topcoat was applied on the Thermo-Lag 330 prefabricated panels at TSI in accordance with Reference 10.14.1 and reapplied where required (Reference 10.4.1 and 10.14.2) on all test articles. Therefore, Thermo-Lag 330-1 with topcoat is a tested configuration. Test Scheme 13-2 resulted in a satisfactory test of 350-5000-10 Topcoat formulation which was installed on one half of the 12" tray over a layer of 350 Topcoat. The 2" conduit assembly in Test Scheme 13-2 utilized 350 Topcoat on one [illegible] the configuration and 350-5000-10 formulation on the remaining portion. [illegible]nces or adverse affects of Thermo-Lag materials were observed with either type [illegible] topcoat applied.

4.3.5 Using Density as Receipt Acceptance Criteria

CPSES uses density (weight per square foot of board) as the key attribute when inspecting shipments of Thermo-Lag prefabricated/preshaped panels and sections. The other attributes are:

- No holes or cracks wider than 0.05 in.
- No holes or cracks extending through the material to the stress side.
- No visible mechanical damage (i.e., gouges, breaks, tears, etc)

CPSES also has source (at the Vendor's facilities) inspection and surveillance of TSI, including verification of the TSI thickness checks and weight of the materials. CPSES requires TSI to implement a quality assurance program, and CPSES maintains inspection reports verifying the thickness and weight checks.

CPSES use of density as an attribute is supported by the test data which shows that even where the envelope did open, as long as there was enough material off gassing to provide a thermal barrier (cooling), the temperature in the effected area did not rise drastically (see Appendix A).

The intumescent property of Thermo-Lag forms a char layer which is approximately four times the original thickness which would offset any minor thickness anomalies.

The weight (density) check is sufficient to detect any large internal voids in the prefabricated panels which would not be picked up by measuring the thickness of the panel. Also, a uniformly thin board would not pass the density (weight) inspection. Therefore, as demonstrated in numerous fire tests, the density inspection along with the visual inspection and source inspections provided adequate quality control of the Thermo-Lag 330 prefabricated panels.

With regards to Request for Additional Information, requested by the NRC, TU Electric provided additional information on voids and delaminations of Thermo-Lag conduit prefabricated sections in a letter logged, TXX-92589, dated December 15, 1992 (Reference 10.22.18).

In SSER 26 (Reference 10.24.4), the NRC accepted TU Electric's overall procurement and quality control processes for installing Thermo-Lag on test assemblies during Session 3 and for Unit 2 in-plant configurations. Additionally, the NRC accepted the resolution of issues associated with voids and delaminations as described by Reference 10.22.18.

4.3.6 **Thermo-Lag Functionality (Cure Time) (Sessions 1, 2 and 3)**

During the independent fire endurance qualification testing which TU Electric performed at Omega Point Laboratories in San Antonio, Texas, test assemblies were cured for 30 days prior to testing. The 30 day cure period was included into the test program after discussions with the NRC Staff. During these discussions NRC staff was concerned that the additional moisture in the Thermo-Lag before the 30 day curing period would give non-conservative results. To address this concern TU Electric took this measure to assure that test assemblies had cured (dried out) prior to fire tests. This measure assured that no moisture present in the material prior to drying out would aid in the performance of the material during a fire endurance test. Having material installed in the plant that has not received a 30 day cure or drying out period would only enhance the performance of the material in the event of a fire during the first 30 days after installation of the Thermo-Lag.

Notwithstanding the above, TU Electric procures prefabricated panels and shapes of Thermo-Lag. The Thermo-Lag vendor applies topcoat to the prefabricated panels and shapes. Additionally, conversations with the vendor confirms that there is no requirement for 30 day cure time, and that upon receipt by the customer the prefabricated material is capable of performing its design function. There are also no vendor guidelines which require that the trowel grade Thermo-Lag 330-1 material to be cured for 30 days. TU Electric applies topcoat only at joints, seams and other areas where trowel grade material is applied. TU Electric specifications require that top coat should be applied over Thermo-Lag material after allowing a minimum of 72 hours cure time, or obtaining a reading less than 100 using a Delmhorst Model DP moisture meter with a scale of 0-100. The cure times stated in the specifications (References 10.14.1 and 10.14.2) are to allow the material (trowel grade 330-1) to dry before applying topcoat to ensure that the topcoat adheres properly.

Topcoat is a paint used to provide an environmental (e.g., water, dirt) protective finish for the Thermo-Lag. The topcoat is not required for fire barrier functionality.

To address functionality of Thermo-Lag prior to 30 day cure, Test Scheme 15-1 (session 4) utilized a Thermo-Lag configuration (36" cable tray) that was tested satisfactorily after a 7 day cure.

Based on the above discussion TU Electric concludes that Thermo-Lag is functional, capable of performing its design function, immediately after completion of the installation and inspection. A Thermo-Lag installation consists of prefabricated board or conduit sections that are supplied by the manufacturer in a ready for service condition and trowel grade

material that is used to pre-butter joints, stainless steel wire and banding material, staples, and stress skin. The tie wires, staples, and stress skin provide a mechanical reinforcement of the joints. After these materials are assembled and inspected the installation is functional. The topcoat is not required for the Thermo-Lag to be functional and is applied to prevent degradation from environmental effects of moisture and dirt over the life of the plant.

4.4 Test Observation

4.4.1 Exposed Conduit Thermocouples

While conducting the November 4, 1992 fire test (Scheme 9-1 (session 3)), extremely high thermocouple readings were observed. These readings (as high as 1480°F) were all from the exposed conduit thermocouples. The corresponding cable thermocouples all read less than 200°F. This occurred at about 30 minutes into the test. By the end of the test (60 minutes), the thermocouple which had read 1480°F had dropped 516°F. It was also noted that the thermocouple with the longest run of thermocouple wire in between the conduits and Thermo-Lag had the highest readings.

During the post-hose stream inspection, it was noted that the thermocouple leads were saturated in various locations with a sticky (molasses type) residue. Also, the conduits showed no signs of having reached temperatures over 500°F since the galvanizing still looked like new and Magic Marker marks were still visible on the galvanizing. There was no visible cable degradation in the areas of these high readings and all the cables passed the IR tests.

The worst reading thermocouple was checked and appeared to be working correctly. However, when a portion of the thermocouple with this residue was placed in a beaker of warm water (with the end still exposed to the air), the thermocouple jumped approximately 10°F. The thermocouple reading should not have changed.

This phenomena was also observed on subsequent conduit tests. It was also observed that the highest readings occurred just as the cable temperatures were reaching 200°F. Subsequently, the thermocouple readings on the exposed conduit would drop.

During a re-examination of Scheme 7 (session 2), it appears that the same phenomenon happened, only it was not observed because of the higher cable temperatures and the higher temperatures where the joints opened.

These higher recorded temperatures were caused by the water driven out of the Thermo-Lag condensing on the cold conduit steel. This water and the Thermo-Lag off-gas residue saturates the thermocouple. The water and residue set up an ionic potential which the thermocouple reads. The longer the thermocouple wire, the greater the potential and the higher the reading.

As the conduit reaches 212°F, the water is evaporated, drying out the thermocouple and reducing the potential, thereby lowering the thermocouple reading.

Due to the unreliability of the thermocouple readings on the exposed conduit, these readings were not used to evaluate Schemes 9-1, 9-3, 10-1, and 10-2 for conduits. The NRC staff accepted TU Electric's technical position relative to the unreliability of conduit surface thermocouple readings via SSER 26 (Reference 10.24.4).

4.4.2 Cable Stiffening

After several of the fire tests, during the cable visual inspections, slight cable/jacket stiffening was noted. Upon closer inspection, it was found that the jacket and conductor insulation had not stiffened, but the cellophane-type material wrapped around the conductors had actually shrunk. The shrinking of this wrap bound the conductors such that the conductors could not slide by one another and thus caused the stiffening. If the cable was bent/worked back and forth several times, the stiffening disappeared. Visual examination of the cables after working out the stiffness showed no signs of degradation of the jacket or conductors.

The shrinking of this wrap appears to happen at lower temperatures. It is estimated to occur around 250°F based on cable temperature peaks during the fire test. This cable/jacket stiffening has no effect on the effect on the cable performance but was something noted during the inspections. The NRC staff accepted TU Electric's technical position regarding the slight stiffening of cables subjected to fire tests via SSER 26 (Reference 10.24.4).

4.5 **Other Issues**

4.5.1 Toxicity

The issue of toxicity has been raised based on the statement that Thermo-Lag releases Hydrogen Cyanide (HCN) when it volatizes.

Thermo-Lag is not unique in this respect, HCN may be present when nitrogen containing materials such as ordinary commercial products like acrylics, polyurethane foams or wool are burned. Many fire retardant materials also release HCN when burned.

Hydrogen Cyanide is one of several toxic elements that are released during a fire. The major toxin is carbon monoxide.

In the incipient (early) stages of a fire, the HCN concentrations are too low to have an effect on personnel. The fire alarms will detect a fire and provide ample warning to ensure evacuation of personnel before lethal levels of HCN are reached.

The fire brigade is trained and wears Self Contained Breathing Apparatus (SCBA) when fighting a fire. Should operator actions be required in the respective area, suitable protective means would also be utilized. Therefore, fire brigade and operations personnel are protected from the effects of smoke (products of combustion). This is consistent with standard fire department practices when fighting a commercial fire.

Smoke removal equipment is also on site, and would be used to quickly purge the spaces after a fire.

Therefore, Thermo-Lag off gassing HCN in a fire is no different then many other products of combustion in the plant and has been addressed programmatically.

4.5.2 Thermo-Lag Seismic II/I Considerations

Thermo-Lag used for cable and raceway fire barrier and structural steel fireproofing is classified in DBD-ME-028 (Reference 10.17.2) as non-seismic (Seismic Category None). However, since the fire barrier and fireproofing materials is installed in areas containing safety-related equipment it must meet the requirements of Regulatory Guide 1.29. Specifically, the failure of the Thermo-Lag and other fireproofing materials during or after the design basis earthquake cannot reduce the functional capability of structures, systems, or components required to safely shut the plant down.

The CPSES Seismic II/I Program has addressed the requirements of Regulatory Guide 1.29 for the design and operation of both Unit 1 and Unit 2. In this program Thermo-Lag is not considered to be a potentially damaging source. Gross failure/falling of the material under CPSES design basis seismic inertial loading would not occur. This position is supported by the following:

- Thermo-Lag panels and sections are secured in place with extensive use of mechanical fasteners; staples, wire ties, additional stress skin, and steel bands. The fasteners assure that the material is positively attached to the electrical raceway which has been seismically qualified for the added weight;
- Earthquake experience does not indicate gross failure and falling of fire barrier materials due to seismic inertia when the materials is adequately attached to the supporting structure; and
- Local cracking/chipping of the Thermo-Lag and structural steel fireproofing materials may occur but the resulting "debris" is non-damaging.

In SSER 26 (Reference 10.24.4), the NRC accepted TU Electric's program for addressing seismic concerns for Thermo-Lag materials installed at CPSES such that Thermo-Lag will not have damaging effects on Seismic Category I plant features.

4.5.3 Consideration of Thermo-Lag Weight in Electrical Raceway Design Validation

All CPSES electrical raceway and supports which require the use of the Thermo-Lag fire barrier material have been qualified for the resulting additional dead weight loads and seismic inertia in accordance with the applicable DBD's and procedures. The deadweight and inertia loads have conservatively considered all significant weight components including the upgraded design configurations.

The additional weight used in the qualifications is based on the following:

- The extent of Thermo-Lag coverage on raceway has been based on the applicable installation documents as confirmed by field walkdown;

- The weight of the Thermo-Lag installations on conduits is based on the maximum weights allowed by the specification (Reference 10.14.1) for the prefabricated conduit sections. These weights are verified by QC on receipt. Where installed, 1/4" additional thickness (i.e., overlay sections) of Thermo-Lag has been considered to evaluate the resultant weight from the Thermo-Lag upgrade.

- The weight of the Thermo-Lag installations on cable trays is based on the maximum weights allowed by the specification (Reference 10.14.1) for the prefabricated panels. These weights are verified by QC on receipt. The 1/4" additional thickness of Thermo-Lag has been considered to evaluate the resultant weight from the Thermo-Lag upgrade (i.e. additional stress skin and trowel grade on the seams between the prefabricated panels); and

- The weight of the Thermo-Lag installation on the electrical junction boxes is based on the upper bound weights identified during the QC receipt inspection (Reference 10.14.1) of the prefabricated Thermo-Lag panels.

In SSER 26 (Reference 10.24.4), the NRC accepted TU Electric's methodology for addressing Thermo-Lag weight considerations in the design of Unit 2 electrical raceway and supports.

4.5.4 Cables in Contact with Thermo-Lag

For cables installed in cable trays, administrative controls effectively preclude Thermo-Lag panels from being installed if the cable fill results in cables extending above the tray side rails (except where cables enter or exit the tray). The applicable electrical installation specifications (References 10.14.4 and 10.14.5) and QC inspection procedure (Reference 10.18.3) explicitly require that cables do not extend above tray side rails. Additionally, prior to Thermo-Lag installation on trays, the applicable cable tray run must be inspected and released by QC (electrical). Finally, the applicable Thermo-Lag installation specifications (References 10.14.1 and 10.14.2) require resolution by Engineering where a cable overfill condition exists. Where a specific overfill condition has been evaluated and approved by Engineering, the resolution typically results in increasing the height of the Thermo-Lag panel pieces installed over the tray side rails thus effectively increasing the size of the protective envelope to preclude cables contacting the stress skin side of the Thermo-Lag. In SSER 26 (Reference 10.24.4), the NRC accepted TU Electric's programmatic controls for ensuring cables routed within trays do not contact the stress skin side of Thermo-Lag panels installed on the trays.

4.5.5 Cable Jacket Swelling

During performance of fire tests during Session 5 (Test Schemes 11-4 and 11-5), some of the cables in the tests experienced jacket ballooning. The cables in question were Okonite with three double jacketed conductors. The cable consisted of three jacketed conductors and fillers which were bound together with a binder tape, and an overall jacket was then applied.

Moisture trapped within the region between the binder tape and the outer jacket induced sufficient pressure during the test to cause ballooning of the outer jacket. The

thermocouples which were applied with a glass reinforced tape trapped the moisture in the untaped region. The moisture converting to steam when temperatures reached 212°F resulted in substantial pressure being applied to the outer jacket.

The amount of water required to cause ballooning of the cable would in no way impact the cables performance under normal conditions. The water vapor that was trapped under the jacket due to the tape used to secure the thermocouples would not exist in the plant. The steam would be allowed to move away from the area exposed to the fire where it would then condense back to water. In this situation the water would have no adverse affect on the plant. See Reference 10.22.14 for an evaluation of this phenomena.

4.5.6 Steam and Moisture Discharging from "Flexi-Blanket" Wrapped Cables

During the Scheme 15-2 test, it was observed by the NRC and documented in NRC Inspection Report 50-445/93-34; 50-446/93-34 (Reference 10.22.19) that steam and fluid were emitted from the "Flexi-Blanket" material wrapped around the 1/C 750kMCil power cables. There were 2 protective wrap bundles, each containing a single power cable wrapped with 2 layers of 330-660 "Flexi-Blanket". Each bundle also had a #8 bare copper conductor secured to the power cable. Each power cable and bare copper conductor was instrumented with thermocouples. (See Appendix A for a more detailed discussion of this test.)

The observed phenomena occurred at about 30 minutes into the test for the front bundle and at 40 minutes on the rear bundle. The steam and fluid were being driven out from the open ends of the two wrap bundles where they protruded from the side walls of the test furnace. A review of the thermocouple readings on the bare #8 copper conductors in each bundle indicated that some readings were around 212°F at that time. It would be expected that the readings on the copper conductors would be representative of the temperatures on the backside of the Thermo-Lag.

As Thermo-Lag is heated, moisture is driven out of the material. Once the temperature reaches 212°F, the moisture changes to steam. This is a normal occurrence and was specifically observed in test schemes 7, 9-1, 9-3, 10-1 and 10-2 as discussed in section 4.4.1. As the steam exited the furnace it would rapidly cool and condense back into water. This would have occurred, to some extent, on all of the tests but was evident in schemes 15-2 because the Thermo-Lag entered and exited the furnace at a more visible location (through the side walls) instead of the top of the furnace as was the case for most of the other tests and all other tests involving "Flexi-Blanket" (schemes 11-1 and 11-2). The other 2 tests which exited the wall (schemes 11-4 and 11-5) had fire stops poured around the cables where they exited the furnace instead of against the Thermo-Lag as was the case in scheme 15-2. This resulted in a tighter seal plus the other end of these 2 assemblies exited through the top of the furnace.

As discussed in section 4.5.5, in a plant configuration the steam would freely propagate away from the area exposed to the fire where it would then condense back to water. The small amount of water involved would not adversely affect the cables performance since it is external to the cable. Also, this phenomena would have been present to some extent on all of the test assemblies and there were no adverse affects (observed or measured) which could be attributed to moisture release from the Thermo-Lag identified on any of these tests.

5.0 COMPARISON OF DESIGN/INSTALLATION REQUIREMENTS AGAINST THE TEST RESULTS

The applicable CPSES Thermo-Lag installation specifications (Refs. 10.14.1 and 10.14.2) and typical design drawings (Refs. 10.15.2 and 10.15.4) provide the technical requirements for installing Thermo-Lag material on required commodities. For cable and raceway barrier configurations, these technical requirements such as material thickness, sealing and reinforcements of joints, etc., are based on methods used to construct test assemblies during TU Electric's 1-hour Thermo-Lag fire endurance qualification test program conducted at Omega Point Laboratories (Reference 10.12). For structural steel configurations, technical requirements are based on References contained in Section 10.21.

The installation requirements and construction details for applying Thermo-Lag to most plant commodities and configurations thereof such as cable trays, conduits, junction boxes, etc., are enveloped by the typical detail design drawings and installation specifications. Accordingly, most of these commodity configurations and techniques for Thermo-Lag installation are qualified directly by specific tests. However, it is recognized that due to specific field conditions and limitations such as interferences, clearances between commodities, etc., creation of unique design configurations and acceptance of minor deviations from specified technical requirements (where appropriately justified) are inevitable. It is also recognized that due to the number and variation of these special instances it is not feasible to qualify all aspects of each unique configuration or minor deviations through specific fire endurance testing. In fact, in some instances limitations of industry test apparatus may preclude such testing.

Instead, the goal of a qualification test program is to qualify the critical attributes of the fire barrier system, such as material thickness, joint reinforcement techniques, interfaces between different materials, etc., for the range of commodity sizes anticipated in plant configurations. Based on the qualification of these critical attributes, specific plant conditions requiring unique configuration designs and minor deviations can be reasonably resolved. The NRC staff has recognized this concept through the provisions of Generic Letter 86-10 (Reference 10.7.2) which enables licensees to evaluate field installations which vary from configurations qualified via fire endurance tests using criteria provided therein.

In accordance with the CPSES design control program, where due to field conditions, the techniques or configurations for installing Thermo-Lag on required commodities are not bounded by the installation specification or typical details, installation personnel are required to identify the condition for resolution by Engineering via initiation of a design change document. For field work implemented prior to fuel load, the applicable design document was a Design Change Authorization (DCA). For field work implemented subsequent to fuel load, the applicable design change document is a Design Change Notice (DCN), controlled via the CPSES Design Modification (DM) program. Additionally, DCAs/DCNs are initiated to identify specific instances where obstructing commodities (piping, ductwork, raceway, etc.) serve to interfere with the protective envelope such that specified requirements cannot readily be achieved. Resolution of these specific field conditions is provided by Engineering in

accordance with the governing design change process procedure. Resolution of these issues is based on methods and techniques qualified through test, experience and familiarity with the proper uses and limitations of Thermo-Lag materials gained through the qualification test program and conservative engineering practices.

Accordingly, CPSES Engineering Report ER-ME-082 (Reference 10.23.1) serves to correlate Unit 1 and Unit 2 Thermo-Lag configurations to the applicable qualification test ("scheme"), or portions thereof and hence provide a basis for acceptance in accordance with the provisions of NRC Generic Letter 86-10. This process was utilized for all typical details approved for generic use via the design drawings (Reference 10.15.4), the requirements contained in the Unit 2 Installation Specification CPES-M-2032 (Reference 10.14.2) and such unique configurations and minor deviations described above as bounded by applicable DCAs/DCNs.

Specification 2323-MS-38H (Reference 10.14.1) and the M1-1701 typical detail drawings (Reference 10.15.2) are now the design documents governing Thermo-Lag installation for both Units. Revision 4 of Reference 10.14.1 and DCN 6943 (Reference 10.15.5) have incorporated the requirements of the Unit 2 Specification CPES-M-2032 and the M2-1701 drawings into the Specification (Reference 10.14.1) and the M1-1701 drawings. These design documents are consistent with the reconciliation of the specification and typical details provided in ER-ME-082.

6.0 AMPACITY DERATING FACTORS

6.1 TU Electric conducted a series of ampacity derating tests for Thermo-Lag fire barrier configurations at Omega Point Laboratories (OPL) in San Antonio, Texas from March 3, through March 13, 1993 and preliminary results were provided to the NRC in TXX-93136 (Reference 10.22.11) and the test report was provided by TXX-93214 (Reference 10.22.12). The NRC staff observed test preparation and testing from March 2 to 7, 1993. The first test group, conducted from March 2, 1993 to March 3, 1993, consisted of a 3/4" diameter conduit with a single 3/C #10 AWG 600-volt copper cable and a 2" - diameter conduit with a single 3/C #6 AWG 600-volt copper cable. The second test group, conducted from March 5 to March 8, 1993, consisted of a 24" x 4" cable tray filled to a 2.95" depth with 3/C #6 AWG 600-volt copper cables and a free air drop (small)made of a single 3/C #6 AWG 600-volt copper cable. The final test group, conducted from March 10 to 14, 1993, consisted of a 5" diameter conduit with four 1/C 750MCM 600-volt copper cable and a free air drop (large) made of three 1/C 750MCM 600-volt copper cable. The ampacity derating factor test results are summarized below.

The TU Electric ampacity derating test methodology followed the guidance detailed in the proposed standard IEEE P848 (Reference 10.11.5), except for the following changes described further in TU Electric's ampacity test plan, revision 4, (Reference 10.12.28).

1) Conduit/air drop test articles were selected to be consistent with CPSES installation including the enhanced Thermo-Lag configurations.

2) Test articles were supported by wood blocks during the performance of the tests.

3) Type T special accuracy thermocouples were used for the conduit/air drop test articles and for all ambient temperature measurements. Type K thermocouples were used for tray configurations, with directions to make adjustments, if necessary, for the difference in accuracy.

4) Baseline tests may be run before or after the ampacity derating test.

5) Three thermocouples were installed at each location for the conduit/air drop test articles.

6) Both the baseline and ampacity derating test shall utilize measured current normalized as outlined in ICEA P-46-426 (Reference 10.11.6) for final conductor and ambient temperatures (that were not 90°C and 40°C, respectively).

In addition, the subject test plan supplemented elements of the Draft IEEE-P848 document in the following manner:

- Use a clamp-on ammeter with an accuracy of ± 1 percent to take the final current measurements.

- Base the data interpretation of the ampacity derating factor on the measured values irrespective of the published ICEA values in accordance with the TU Electric letter to the NRC of February 26, 1993 (Reference 10.22.9).

The ampacity derating test procedure used for the test articles was performed in two steps, as follows:

1) An ampacity product (or derating) test was conducted with the Thermo-Lag material configured around the test article.

2) Then the baseline test was conducted on the instrumented article without the Thermo-Lag product.

Each ampacity test was performed by raising the conductor temperature from ambient (i.e., 40°C) to its rated temperature limit (i.e., 90°C), allowing the test article to reach thermal equilibrium, and then measuring the final current or ampacity value for the test article. The ampacity derating factor was calculated as follows:

Ampacity derating factor = $1 - I_f / I_o$

where:

I_f = ampacity value for product test
I_o = ampacity value for baseline test

6.2 TU Electric has completed the testing to establish ampacity derate factors for cables/raceways protected by the upgraded Thermo-Lag fire barrier configurations qualified during TU Electric's fire endurance test program (Reference 10.12.28). The derate factors determined by testing are as follows:

Raceway Type & Size	Cable Type & Size and Section	Thermo-Lag Type and Thickness	Percent Derate Test Value Document	Minimum Design Margin available (Note 1)
3/4" Conduit	3/c# 10 AWG	1/2" 330 w/ 1/4" overlay	9.1	35-9.1 = 25.9
2" Conduit	3/c# 6 AWG	1/2" 330 w/ 1/4" overlay	6.5	35-6.5 = 28.5
5" Conduit	4-1/c# 750 MCM	1/2" 330	10.7	23-10.7 = 12.3
24" Tray	126-3/C#6 AWG 1/2"	303 panels	31.4	38-31.4 = 6.6
Air Drop	3/c#6 AWG	3 layers 1/4" 330-660 wrap	23	35-23 = 12
Air Drop	3-1/c# 750 MCM	3 layers 1/4" 330-660 wrap	31.7	35-31.7 = 3.3

NOTE 1: Minimum design margin is obtained by subtracting the percent derate value obtained by the most limiting cable derate equivalent percent obtained by the calculation performed, which are listed below. This minimum design margin is for the effects of Thermo-Lag only, and is in addition to the 25% design margin provided in the sizing of all power cables.

TU Electric had previously utilized derate factors which are described in Design Basis Document (DBD)-EE-052 (Reference 10.17.1).

- 7.5% for cables in conduit
- 31% for cables in trays
- TU Electric had evaluated the adequacy of air drops protected with Thermo-Lag by assuring that the cable ampacity for air drops under Thermo-Lag is equal to or greater than the cable ampacity for a tray or conduit protected with Thermo-Lag. This evaluation was done by developing a mathematical model for air drop cables covered by Thermo-Lag per Calculation 16345-EE(B)-140 (Reference 10.16.4).

Based on the results of testing described in the table above TU Electric has revised its DBD-EE-052 to reflect the following derate factors:

- 18% for cables in conduits
- 32% for cables in trays and air drops

Based on the test results and the evaluations discussed below, TU Electric has concluded that the CPSES cable design envelopes the derate factors obtained by testing, and the CPSES cable design is acceptable. This conclusion is based on the following calculations:

- Calculation 2-EE-053 was reviewed for all cables covered by the upgraded Thermo-Lag (except for 6.9kV and 480V Switchgear cables as discussed below) and it was concluded that the cable design at CPSES has ampacity margin available for cable derate equivalent to 40% for cables in tray, and a cable derate equivalent to 35% (Note 2) for cables in conduits. This information has since been incorporated into Calculations EE-0008, EE-0009 and EE-0010 (References 10.16.10 through 10.16.12) and Calculation 2-EE-053 has been superseded.

- Calculation 2-EE-CA-0008-3038 (Reference 10.16.9), was reviewed for cables fed from 480V switchgear and it was concluded that the cable design at CPSES has ampacity margin available for a cable derate equivalent to 38% ((Note 2) for cables in tray and a cable derate equivalent to 23% (Note 2) for cables in conduit. The calculation has since been revised to incorporate the test results.

- Calculation EE-CA-0008-3097 (Reference 10.16.11) was reviewed for cables which are fed from 6.9kV switchgear and it was concluded that the cable design of CPSES has ampacity margin available for a cable derate equivalent to 40% (Note 2) for cables in both tray and conduit. The calculation has since been revised to incorporate the test results.

The acceptability of cable design adequacy for cable air drops protected by Thermo-Lag was evaluated by establishing that the allowable ampacity for cable in air drops covered in Thermo-Lag is equal to or greater than the allowable ampacity for the same cable within either conduit or tray covered by Thermo-Lag, therefore the limiting condition is the allowable ampacity with cable tray or conduit. TU Electric's evaluation has established that for cable air drops from conduit, CPSES cable design has ampacity margin available to accept a derate of 35% (Note 2). For cable drops from trays, the CPSES cable design can accept a derate of 39% (see Section 6.12) based on the aforementioned calculations.

As delineated above, a review of CPSES calculations has established the design margin for cable ampacity derating. These margins have been compared to the derate factors for Thermo-Lag established by our confirmatory testing program; and are in addition to the cable design requirements, which utilizes 1.25 times the devices current requirements when sizing power cables. TU Electric concludes that CPSES cable design has sufficient margin to accommodate the derating obtained by testing. TU Electric has updated the Design Basis Document (DBD)-EE-052, and associated documents to incorporate the tested cable derate factors.

NOTE 2: These values represent most limiting conditions for the described cables with respect to plant configuration.

6.3 Evaluation for Thermo-Lagged Cable Air Drops Derate Factor

All cables are routed in trays and conduits except for small transition points, which are generally limited to 3'-6" in length, where cables are in air. The cable sizing calculations evaluate the acceptability of cable sizing for cables with Thermo-Lagged raceways as required. If the cable allowable ampacity for Thermo-Lagged air drops is larger than the cable ampacity with Thermo-Lagged trays or conduit, then Thermo-Lagged air drop cables are acceptable.

Tables 1 and 2 below evaluate cable allowable derate factors for Thermo-Lagged air drops which will provide cable ampacities in Thermo-Lagged air drops at least equal to the cable ampacities in Thermo-Lagged trays or conduits.

Table 1 shows a minimum allowable derate factor of 35% which is greater than than tested derate factor of 31.7%. Therefore Thermo-Lagged air drops from conduits will have adequate cable ampacities.

Table 2 shows a minimum allowable derate factor of 39% which is greater than tested derate factor of 31.7%. Therefore Thermo-Lagged air drops from trays will have adequate cable ampacities.

TABLE 1
AIR DROP THERMO-LAG DERATE FACTORS FOR CABLE DROPS FROM CONDUITS

CABLE TYPE & SIZE	AMPACITY IN AIR ICEA P46-426	AMPACITY IN AIR FOR 3/C OR 3-1/C	AMPACITY IN CONDUIT 3/C OR 3-1/C ICEA P46-426	REDUCTION FACTOR AIR TO CONDUIT	ALLOWABLE MARGIN IN CONDUIT CABLE DESIGN NOTE 2&3	ALLOWABLE CABLE DROP TL DERATE
3/C-#10	55	55	40	.727	35%/.65	53%/.473
3/C-#8	59	59	52	.881	35%/.65	43%/.573
3/C-#6	79	79	69	.873	35%/.65	43%/.567
3/C-#4	104	104	91	.875	35%/.65	43%/.569
3/C-#2	138	138	123	.891	35%/.65	42%/.579
3/C-#2/0	215	215	190	.884	35%/.65	43%/.575
3/C-#4/0	287	287	255	.889	35%/.65	42%/.578
1/C-#2	192	163 (NOTE 1)	123	.755	14%/.86	35%/.649
1/C-#2/0	298	253 (NOTE 1)	190	.751	14%/.86	35%/.646
1/C-#4/0	400	340 (NOTE 1)	255	.750	14%/.86	35%/.645
1/C-250 MCM	445	378 (NOTE 1)	282	.746	14%/.86	35%/.624
1/C-350 MCM	552	469 (NOTE 1)	348	.742	14%/.86	36%/.638
1/C-500 MCM	695	590 (NOTE 1)	425	.720	14%/.86	38%/.619
1/C-756 MCM	898	763 (NOTE 1)	524	.687	14%/.86	40%/.599

NOTES:

1. ICEA P46-426 does not define a cable derate factor for 3-1/C in air. However for conservatism a derate factor of 15% is used to arrive at amapcity values for 3-1/C in air. This assumption is supported by test data for a 750 MCM air drop, where the base line current was greater than 763 Amps.

2. The Switchgear cable sizing calculation, which utilizes only 1/C cables, has established a minimum allowable derate factor of 14% for Thermo-Lagged conduit.

3. The Calculation for evaluation of Ampacity of Thermo-Lagged raceways for cables from MCC's and panels has established an acceptable Thermo-Lagged conduit derate factor of 35%.

TABLE 2
AIR DROP THERMO-LAG DERATE FACTORS FOR AIR DROPS FROM TRAYS

CABLE TYPE & SIZE	AMPACITY IN AIR ICEA P46-426	AMPACITY IN RANDOM FILLED TRAY	REDUCTION FACTOR AIR TO TRAY	CABLE TRAY DERATE FACTOR (NOTE 2)	ALLOWABLE CABLE DROP TL DERATE
3/C-#10	55	20	.36	31.4/.686	75%/.27
3/C-#8	59	32	.54	31.4/.686	62%/.37
3/C-#6	79	51	.65	31.4/.686	55%/.44
3/C-#4	104	71	.68	31.4/.686	53%/.46
3/C-#2	138	120 2/C	.67	31.4/.686	40%/.60
3/C-#2/0	215	161 TR	.75	31.4/.686	48%/.51
3/C-#4/0	287	253 TR	.88	31.4/.686	39%/.6
1/C-#2	192	NOT USED	N/A	N/A	N/A
1/C-#2/0	298	141	.47	31.4/.686	67%/.32
1/C-#4/0	400	209	.52	31.4/.686	64%/.35
1/C-250 MCM	445	NOT USED	N/A	N/A	N/A
1/C-350 MCM	552	345	.625	31.4/.686	57%/.42
1/C-500 MCM	695	468	.67	31.4/.686	54%/.45
1/C-756 MCM	896	675	.75	31.4/.686	48%/.51

NOTES:

1. Ampacity in random filled trays are from calculation EE-78 (600V power cable ampacities for various tray fills) for different cables highest cable ampacities are used for this evaluation.

2. Thermo-Lagged tray cable derate factor of 31.4% is per CPSES test data. Adequacy of this derate factor is evaluated for all cables in Thermo-Lag trays.

7.0 COMBUSTIBILITY OF THERMO-LAG

Information Notice (IN) 92-82, "Results of Thermo-Lag 330-1 Combustibility Testing" was issued on December 15, 1992 (Reference 10.8.5) to inform licensees of the results of small scale testing performed for the staff by the National Institute of Standards and Technology (NIST). These tests subjected 1/2" and 1" thick Thermo-Lag 330 panel samples to two separate tests to investigate the combustibility properties of the material. The subject tests were 1) ASTM E136, "Standard Test Method for Behavior of Material in a Vertical Tube Furnace at 750°C" (Reference 10.1.2), and 2) ASTM E1354, "Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products using an Oxygen Consumption Calorimeter" (Reference 10.1.3). The results of the ASTM E136 tests were that Thermo-Lag 330 material failed criteria invoked by the standard to qualify it as noncombustible. Since this test is a pure pass/fail determination, the material is defined by ASTM E136 criteria as combustible. The results of the ASTM E1354 tests compared peak and total heat release rates (HRR) to values established for gypsum wallboard. As such, the values obtained for peak HRR were determined to be equivalent to those for gypsum, while values obtained for total HRR were determined to be more than 8 times higher than those for gypsum. The Information Notice conveyed these results to licensees for consideration of impact where Thermo-Lag is used for enclosure of intervening combustibles to achieve a horizontal distance of 20 feet between redundant safe shutdown trains. Additionally, the results conveyed by IN 92-82 were provided for consideration of impact where Thermo-Lag is utilized inside noninerted containment structures as a noncombustible radiant energy shield to achieve protection of safe shutdown circuits.

As stated in the NUMARC Thermo-Lag Combustibility Guidelines (Reference 10.26), ASTM E136 is a severe test protocol and not fully representative of fire conditions in most areas of a nuclear power plant. Thermo-Lag requires a relatively high temperature (>540°C (1000°F)) to ignite. This flash ignition temperature was determined for Texas Utilities using ASTM D1929 "Standard Method of Tests of Ignition Properties of Plastics" (Reference 10.16). Thermo-Lag also requires a high radiant flux for ignition (> 25 kW/m^2 (2.2 $Btus/ft^2$)) to ignite and will absorb a large amount of energy before ignition (thermal inertia ($k\rho C$ of > 3.0 $kW^2/m^4{}^\circ K^2$ s (.0072 Btu^2/ft^4R^2s)). Thermo-Lag's minimum temperature for lateral flame spread is the same as its minimum temperature for ignition, therefore Thermo-Lag on its own will not spread a flame laterally.

In response to conversations between TU Electric and the NRC on January 21 and 22, 1993 relative to Unit 2 Thermo-Lag configurations, TXX-93060 (Reference 10.22.6) was issued on January 25, 1993. The information provided by TU Electric is summarized below.

- Thermo-Lag is not utilized to eliminate intervening combustibles in order to obtain a horizontal distance of 20 feet with negligible intervening combustibles between redundant [Unit 2] safe shutdown trains. This is documented by the "Unit 2 Fire Safe Shutdown Analysis" (Reference 10.16.7) and the "Unit 2 Physical Separation Analysis and Unit 2 Cables and Components in Common Areas" (Reference 10.16.8).

- Thermo-Lag is not utilized as a radiant energy shield inside Unit 1 or Unit 2 containment structures.

- There is no Thermo-Lag installed in non-raceway applications for Unit 2 (i.e., as used for protection of structural steel supporting 2 hour rated gypsum wall assemblies around stairways) which could act as an intervening combustible between redundant safe shutdown trains.

- CPSES plant areas where Thermo-Lag installed at CPSES safe shutdown raceways could potentially constitute an intervening combustible between redundant equipment or components were assessed. Based on fire protection features provided in these areas, the properties of Thermo-Lag and overall low quantities of in-situ combustibles to fuel a postulated fire, significant fire propagation between redundant CPSES safe shutdown equipment or components along raceways protected with Thermo-Lag is considered not credible.

8.0 OPEN ITEMS

1. incorporation of Combustibliity of Thermo-Lag into Fire Hazards Analysis.

2. Implementation of final upgrades of Unit 1 Thermo-Lag configurations identified in Appendix F (i.e., DM 97-14).

9.0 CONCLUSIONS

As a result of tests conducted during the 5 test sessions summarized herein, TU Electric has concluded:

1. Thermo-Lag performs its design function if properly configured

2. Thermo-Lag installations for 3/4" through 1-1/2" diameter conduits perform their design function when upgraded by addition of 1/4" thick overlays

3. Thermo-Lag insta 'ations for 2" diameter conduits perform their design function without addition of overlays as demonstrated by cable functionality evaluation

4. Thermo-lag installations for 3" diameter and larger conduits perform their design function without addition of overlays

5. Thermo-Lag installations for lateral bend condulets (LBDs), junction boxes, pull boxes, etc. perform their design function when joints and conduit interfaces are reinforced with external stress skin and trowel grade material buildup.

6. Thermo-Lag installations for conduit radial bends perform their design function when configured as follows:

   a. 3/4" through 1-1/2" - addition of 1/4" thick overlay with external stress skin or stainless steel mesh and trowel grade material buildup.[1]

   b. Larger than 1-1/2" - addition of either external stress skin or stainless steel mesh in conjunction with trowel grade material buildup.[1]

7. Thermo-Lag installations for 12" wide cable trays perform their design functions when configured as follows:

   a. Straight horizontal and vertical runs including radial bends - no upgrade or reinforcement of joints is required

   b. Tee sections - unsupported bottom butt joints require reinforcement with either external stress skin and trowel grade material buildup or stitching, and longitudinal joints require reinforcement with external stress skin and trowel grade material buildup

8. Thermo-Lag installations for 18" through 24" wide cable trays perform their design function when configured as follows:

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[1] see Appendix F for additional details

a. Straight horizontal and vertical runs including radial bends - longitudinal joints require reinforcement with external stress skin and trowel grade material buildup. Unsupported bottom butt joints at support locations only, require reinforcement with external stress skin and trowel grade material buildup or additional Thermo-Lag panel strips attached to the horizontal support member coverage

b. Tee sections - unsupported bottom butt joints require reinforcement with either external stress skin and trowel grade buildup or stitching, and longitudinal joints require reinforcement with external stress skin and trowel grade material buildup

9. Thermo-Lag installations for cable trays wider than 24" perform their design function when configured as follows:

a. Straight horizontal and vertical runs including radial bends - unsupported bottom butt joints on horizontal portions and top and bottom butt joints on vertical portions require reinforcement with either external stress skin and trowel grade material buildup or stitching, and longitudinal joints require reinforcement with external stress skin and trowel grade material buildup.

b. Tee sections - unsupported bottom butt joints require reinforcement with either external stress skin and trowel grade buildup or stitching, and longitudinal joints require reinforcement with external stress skin and trowel grade material buildup.

10. Thermo-Lag installations for air drop cables perform their design function when configured as follows:

a. Cable bundle diameter 2" and less - three (3) layers of 330-660 Flexi-Blanket are required.[1]

b. Cable bundle diameters greater than 2" - two (2) layers of 330-660 Flexi-Blanket are used.[1]

11. Thermo-Lag "box design" installations for air drop cables perform their design function with a single layer of Thermo-Lag panels.

12. Thermo-Lag installations for large power cables (i.e., 1/C 750kMCil) wrapped with 2 layers of 330-660 Flexi-Blanket and routed in exposed cable tray perform their design function, however addition of a third layer is necessary to ensure complete thermal protection of the cables.

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[1]see Appendix F for additional details

13. Cable ampacity derating factors applied at CPSES are sufficient to assure cables will perform their design function.

In addition, these tests demonstrated that plant installation of supports with structural members protected for a nominal 9" distance from the raceway envelope is acceptable and that a fog nozzle hose stream test is an effective hose stream test.

10.0 REFERENCES

10.1 American Society for Testing and Standards (ASTM) Publications

10.1.1 ASTM E-119 (88), "Standard Methods of Fire Tests of Building Construction and Materials"

10.1.2 ASTM E-136, "Test Method for Behavior of Materials in a Vertical Tube Fur ace at 750°C", ASTM

10.1.3 ASTM E-1354 (92), "Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter"

10.1.4 ASTM E-84 (76), "Test Method for Surface Burning Characteristics of Building Materials"

10.1.5 ASTM E-162 (90), "Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source"

10.1.6 ASTM D1929, "Standard Method of Tests of Ignition Properties of Plastics"

10.2 National Fire Protection Association (NFPA) Publications

10.2.1 NFPA 251 (1985), "Standard Methods of Fire Tests of Building Construction and Materials"

10.3 American Nuclear Insurers (ANI)

10.3.1 ANI Bulletin B.7.2, 11/87, Attachment B, entitled "ANI/MAERP RA Standard Fire Endurance Test Method to Qualify A Protective Envelope for Class 1E Electrical Circuits," Revision 1

10.3.2 ANI Bulletin No. 5, "ANI/MAERP Standard Fire Endurance Test Method to Qualify a Protective Envelope for Class 1E Electrical Circuits," dated July 1979.

10.3.3 ANI Bulletin No. 7, "ANI/MAERP Standard Method of Fire Tests of Cable and Pipe Penetration Fire Stops

10.4 NRC Fire Protection Guidelines and Regulations

10.4.1 Appendix A to BPT APCSB 9.5-1, NRC Supplemental Guidance Nuclear Plant Fire Protection Functional Responsibilities Administrative Controls and Quality Assurance"

10.4.2 Federal Register/Volume 45 No. 225/Wednesday, November 19, 1980 Fire Protection Program for Operating Nuclear Power Plants 10 CFR, Part 50, Appendix R

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10.6 CPSES Licensing Basis Documents

10.6.1 Final Safety Analysis Report, Section 9.5.1

10.6.2 Fire Protection Report

10.7 NRC Generic Letters

10.7.1 NRC Generic Letter 81-12, "Fire Protection Rule" (45 FR 76602) dated November 19, 1980.

10.7.2 NRC Generic Letter 86-10 "Implementation of Fire Protection Requirements," 4/24/86

10.7.3 NRC (Draft) Generic Letter 92-XX "Thermo-Lag Fire Barriers," dated February 11, 1992.

10.7.4 NRC Generic Letter 92-08, "Thermo-Lag 330-1 Fire Barriers," dated December 17, 1992.

10.7.5 NRC (Final Draft) Supplement 1 to GL 86-10, "Fire Endurance Test Acceptance Criteria for Fire Barrier Systems Used to Separate Redundant Safe Shutdown Trains Within the Same Fire Area"

10.8 NRC Information Notices

10.8.1 NRC Information Notice No. 92-55 "Current Fire Endurance Test Results for Thermo-Lag Fire Barrier Material," dated July 27, 1992.

10.8.2 NRC Information Notice No. 92-46 "Thermo-Lag Fire Barrier Material Special Review Team Final Report Findings, Current Fire Endurance Tests, and Ampacity Calculation Errors," dated June 23, 1992.

10.8.3 NRC Information Notice No. 92-79 "Deficiencies in the Procedures for Installing Thermo-Lag Fire Barrier Materials," dated December 6, 1991.

10.8.4 NRC Information Notice No. 91-47 "Failure of Thermo-Lag Fire Barrier Materials to Pass Fire Endurance Test," dated August 6, 1991.

10.8.5 NRC Information Notice No. 92-82, "Results of Thermo-Lag 330-1 Combustibility Testing," dated December 15, 1992.

10.9 NRC Bulletins

10.9.1 NRC Bulletin No. 92-01 "Failure of Thermo-Lag 330 Fire Barrier System to Maintain Cabling in Wide Cable Trays and Small Conduits Free From Fire Damage," dated June 24, 1992.

10.9.2 NRC Bulletin No. 92-01, Supplement 1 "Failure of Thermo-Lag 330 Fire Barrier to Perform its Specified Fire Endurance Function," dated August 28, 1992.

10.10 NRC Office of Inspector General Case No. 91-4N, "Adequacy of NRC Staff's Acceptance and Review of Thermo-Lag 330-1 Fire Barrier Material," dated August 12, 1992.

10.11 Cable Ampacity Tests References

10.11.1 TSI Technical Note 111781, dated November 1981, "Engineering Report on Ampacity Test for 600 Volt Power Cables Installed in a Five Foot Length of Two Inch Conduit Protected with Thermo-Lag 330-1 Subliming coating Envelope System"

10.11.2 Industrial Testing Laboratories, Inc. (ITL) Report No. 82-355-F-1, Revision 1, dated January 1985, "Ampacity Test for 600 Volt Power Cables in an Open Top Cable Tray Protected by the Thermo-Lag 330-1 Subliming Coating Envelope System"

10.11.3 ITL Report No. 83-8-183, dated August 1983, "Ampacity Derating Test at 70°C, 80°C, and 90°C, for 1000 Volt Power Cables in a Ladder Cable Tray Assembly Protected with a One-Hour Fire Rated Design of the Thermo-Lag 330 Fire Barrier System

10.11.4 Underwriters Laboratories, Inc. (UL) Letter to TSI, dated January 21, 1987, for Project 86NK23826, File R6802, "Special Service Investigation of Ampacity Ratings for Power Cables in Steel Conduits and in Open-Ladder Cable trays with Field-Applied Enclosures"

10.11.5 IEEE-P848, Procedure for the Determination of the Ampacity Derating of Fire Protected Cables", Draft 11, dated April 16, 1992

10.11.6 ICEA P-46-426 (62), "Power Cable Ampacities for Copper Cables, Maintained Spacing in Trays"

10.12 Thermo-Lag 330 Test Reports

10.12.1 Omega Point Laboratories Final Report 12340-93543b dated 9-9-92, Scheme No. 1-2

10.12.2 Omega Point Laboratories Final Report 12340-93543c dated 2-19-93, Scheme No. 2-1

10.12.3 Omega Point Laboratories Final Report 12340-93543e dated 3-3-93, Scheme No. 3

10.12.4 Omega Point Laboratories Final Report 12340-93543f dated 3-30-93, Scheme No. 4

10.12.5 Omega Point Laboratories Final Report 12340-93543g dated 7-11-93, Scheme No. 5

10.12.6 Omega Point Laboratories Final Report 12340-93543h dated 6-11-93, Scheme No. 6

10.12.7 Omega Point Laboratories Final Report 12340-93543i dated 6-11-93, Scheme No. 7

10.12.8 Omega Point Laboratories Final Report 12340-93543j dated 6-11-93, Scheme No. 8

10.12.9 Southwest Research Institute (SWRI) Project No. 01-6763-302 Final Report, dated 12-2-81, "Fire Resistance of Irradiated Thermo-Lag 330-1"

10.12.10 SWRI Project No. 03-6491 Final Report, dated 10-27-81, "Fire Qualification Test of a Protective Envelope System".

10.12.11 Omega Point Laboratories Final Report 12340-94367a dated 11-23-92, Scheme No. 9-1

10.12.12 Omega Point Laboratories Final Report 12340-94367j, dated 12-28-92, Scheme 9-3

10.12.13 Omega Point Laboratories Final Report 12340-94367c dated 12-2-92, Scheme No. 10-1

10.12.14 Omega Point Laboratories Final Report 12340-94367d dated 12-16-92, Scheme No. 10-2

10.12.15 Omega Point Laboratories Final Report 12340-94367f dated 1-14-93, Scheme No. 11-1

10.12.16 Omega Point Laboratories Final Report 12340-95766, dated 8-27-93, Scheme 11-2

10.12.17 Omega Point Laboratories Final Report 12340-95767, dated 10-4-93, Scheme 11-4

10.12.18 Omega Point Laboratories Final Report 12340-95768, dated 8-27-93, Scheme 11-5

10.12.19 Omega Point Laboratories Final Report 12340-94367i dated 12-16-92, Scheme No. 12-1

10.12.20 Omega Point Laboratories Final Report 12340-94367h dated 12-16-92, Scheme No. 12-2

10.12.21 Omega Point Laboratories Final Report 12340-94367l dated 12-9-92, Scheme No. 13-1

10.12.22 Omega Point Laboratories Final Report 12340-95769, dated 8-23-93, Scheme 13-2

10.12.23 Omega Point Laboratories Final Report 12340-94367m dated 12-16-92, Scheme No. 14-1

10.12.24 Omega Point Laboratories Final Report 12340-951009, dated 3-19-93, Scheme 15-1

10.12.25 Omega Point Laboratories Final Report 12340-95770, dated 10-4-93, Scheme 15-2

10.12.26 Omega Point Laboratories Final Report 12340-93953, dated 7-10-92

10.12.27 Omega Point Laboratories Final Report on OPL Project No. 94105, "Evaluation of Heat Release Parameters of Thermo-Lag 330 (Draft)", dated July 21, 1992

10.12.28 Omega Point Laboratories Final Report 12340-94583, 96165-95168, 95246, dated 3-19-93, Schemes AC-1, AC-4, AC-5, AA 1-1, AA 4-2, and AT-1

10.12.29 Omega Point Labortories Final Report 1380-96148, dated April 11, 1994, NEI Test 2-8

10.13 <u>Thermal Science, Inc. (TSI) Installation Procedures</u>

10.13.1 TSI Technical Note 20684, Revision V, dated November 1985, "Thermo-Lag Fire Barrier System Installation Procedures Manual Power Generating Plant Applications"

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10.13.3 TSI Technical Note 80181, Revision II, "Thermo-Lag 330-1 Subliming Coating Envelope System Application Procedures," dated December 1981.

10.13.4 TSI Technical Note 80181, Revision IV, "Thermo-Lag 33-01 Subliming Coating Fire Barrier System Application Procedures," dated June 1983.

10.13.5 TSI Technical Note 99777 "Material Application Guides Thermo-Lag 330-1 Subliming Coating System".

10.13.6 TSI Technical Note 11601 "Thermo-Lag 330-1 Coating Thickness For One and Three Hour Fire Rating For Structural Steel Members" by Wesson and Associates Inc.

10.14 <u>CPSES Specifications</u>

10.14.1 2323-MS-38H, "Cable Raceway Fire Barriers", Rev. 4

10.14.2 CPES-M-2032, "Procurement and Installation of Fire Barrier and Fireproofing Materials", Rev. 0

10.14.3 2323-AS-47, "Fireproofing of Structural Steel", Rev. 2

10.14.4 2323-ES-100 "Electrical Installation" Rev. 9

10.14.5 CPES-E-2004 "Electrical Installation" Rev. 1

10.15 <u>CPSES Drawings</u>

10.15.1 CPSES Unit 1 Drawing no. M1-1700, "Thermo-Lag and RES Schedule"

10.15.2 CPSES Unit 1 Drawing No. M1-1701, Sheets 1-7, "Thermo-Lag Typical Details"

10.15.3 CPSES Unit 2 Drawing No. M2-1700, "Unit 2 Thermo-Lag Report"

10.15.4 CPSES Unit 2 Drawing No. M2-1701, Sheets 1-15, "Thermo-Lag typical Details"

10.15.5 CPSES Design Change Notice 6943, Rev. 1

10.16 <u>CPSES Calculations</u>

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10.16.3 CPSES Unit 1 and 2 Calculation 16345/6-EE(B)-004 Rev. 0, "Cable Ampacity Derating Factors for Conduits Boxed in with Thermo-Lag (TSI Product)"

10.16.4 CPSES Unit 1 and 2 Calculation No. 16345-EE(B)-140 Rev. 1, "Ampacity of Power Cable Wrapped with Thermo-Lag 330-660 Installed as Free Air Drop"

10.16.5 CPSES Unit 1 and 2 Calculation No. 16343/G-EE(B)-142, Rev. 2, "Thermo-Lag Tray Interface Analysis"

10.16.6 CPSES Unit 1 Calculation No. 0210-063-0043, Rev. 7, "Maximum Permissible Fire Loading/Non-Rated Features Analysis"

10.16.7 CPSES Unit 2 Calculation No. 2-ME-0282, Rev. 0, "Unit 2 Fire Safe Shutdown Analysis"

10.16.8 CPSES Unit 2 Calculation No. 2-ME-0279, Rev. 0, "Unit 2 Physical Separation Analysis and Unit 2 Cables and Components in Common Areas"

10.16.9 CPSES Calculation No. #2-EE-CA-0008-3038, Rev. 6, "Unit 2 Class 1E 480 Volt Switchgear Feeder Cable Sizing Calculation"

10.16.10 CPSES Calculation No. #2-EE-CA-0008-3097, Rev. 1, "6.9KV Unit 2 Class 1E Switchgear Cable Sizing Calculation"

10.16.11 CPSES Calculation No. EE-0008, Rev. 4, "Cable Breaker and Thermal Overload Sizing of Class 1E 480V MCC Branch Feeder Circuits"

10.16.12 CPSES Calculation No. EE-0009, Rev. 3, "Cable and Breaker Sizing for Class 1E, 118, 120 Volt and 120/208 Volt Branch Feeder Circuits and Size Verification of Non-Automatic Circuit Breakers"

10.16.13 CPSES Calculation No. EE-0010, Rev. 4, "125 Volt DC Class 1E Cable Sizing Switchboard and Panel Board Breaker/Fuse Size Verification"

10.17 CPSES Design Basis Documents

10.17.1 DBD-EE-052 "Cable Philosophy and Sizing Criteria"

10.17.2 DBD-ME-028 "Classification of Structures, Systems and Components"

10.18 CPSES Procedures

10.18.1 NEO Quality Assurance Department Procedure No. NQA 3.09-1.07, "Inspection of Fire Protection to Cable Raceway and Structural Steel" (CPSES Unit 1)

10.18.2 CPSES Construction/Quality Procedure No. CQP-CV-107, "Application of Fire Barrier and Fireproofing Materials" (CPSES Unit 2 and Common)

10.18.3 CPSES Construction/Quality Procedure No. CQP-EL-205 "Cable Inspection" Rev. 2

10.18.4 CPSES Construction/Quality Procedure No. CMP-CV-1005 "Application of Fire Protection Materials"

10.19 Penetration Seal Test Standards

10.19.1 IEEE Standard 634-1978, "IEEE Standard Cable Penetration Fire Stop Qualification Test"

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10.21 Structural Steel Fire Tests

10.21.1 UL Test Results File No. R10515-3,-4 on Steel Columns Protected with Building Units

10.21.2 ITL Report No. 89-07-5334 "Three Hour Fire Endurance Test Conducted on an Unrestrained Structural Steel Beam"

10.21.3 ITL Report No. 89-07-5335 "Three Hour Fire Endurance Test Conducted on an Iterface Design of Thermo-Lag Prefabrecated Panel/Mandoval P-50 and a Unistrut"

10.21.4 Underwriter Laboratories "Fire Resistance Directory", Designs X-003 and X-611

10.22 NRC/TU Electric Correspondence

10.22.1 NRC Letter to W. J. Cahill, Jr., dated October 29, 1992, "Thermo-Lag Acceptance Methodology for Comanche Peak Steam Electric Station - Unit 2", Docket No. 50-446.

10.22.2 TXX-3437, dated November 15, 1981, Comanche Peak Steam Electric Station Fire Barrier Material Test Report

10.22.3 NRC Letter to R.J. Gray, dated December 1, 1981, "Comanche Peak Tray Fire Barrier Evaluation", Docket Nos. 50-445 and 50-446.

10.22.4 TXX-93034, dated January 15, 1993, "Comanche Peak Steam Electric Station (CPSES) Docket Nos. 50-445 and 50-446 Fire Protection Inspection"

10.22.5 TXX-93038, dated January 19, 1993, "Comanche Peak Steam Electric Station (CPSES) - Unit 2 Docket No. 50-446 Response to Generic Letter 92-08 Thermo-Lag 330-1 Fire Barriers"

10.22.6 TXX-93060, dated January 25, 1993, "Comanche Peak Steam Electric Station (CPSES) Docket No. 50-446 Responses to Request for Additional Information for CPSES Unit 2"

10.22.7 TXX-93061, dated January 28, 1993, "Comanche Peak Steam Electric Station (CPSES) Docket No. 50-446 Responses to Request for Additional Information for CPSES Unit 2"

10.22.8 TXX-93076, dated February 1, 1993, "Comanche Peak Steam Electric Station (CPSES) - Unit 2 Docket No. 50-446 36 " Wide Cable Tray"

10.22.9 TXX-93101, dated February 26, 1993, "Comanche Peak Steam Electric Station (CPSES) - Clarifications on Ampacity Derating Test and Thermo-Lag Fire Endurance Test "

10.22.10 TXX-93125, dated March 10, 1993, "Comanche Peak Steam Electric Station (CPSES) - Docket Nos. 50-445 and 50-446, Preliminary Fire Endurance and Ampacity Test Results"

10.22.11 TXX-93136, dated March 23, 1993, "Comanche Peak Steam Electric Station (CPSES) - Docket Nos. 50-445 and 50-446, Ampacity Test Results and Thermo-Lag Box Design Configurations"

10.22.12 TXX-93214, dated May 26, 1993, "Comanche Peak Steam Electric Station (CPSES) - Docket Nos. 50-445 and 50-446, NRC TAC Nos. M85988, M85999, Thermo-Lag Laboratory Test Result Reports for 6" Cable Tray and Ampacity Derating of Cable Protected by Thermo-Lag, and TAC No. M86000 for Motor Operated Valves"

10.22.13 TXX-93023, dated January 19, 1993, "Comanche Peak Steam Electric Station (CPSES) - Docket No. 50-446, Thermo-Lag Laboratory Test Results Reports and Responses to Request for Additional Information for CPSES Unit 2"

10.22.14 TXX-93331, dated September 16, 1993, "Comanche Peak Steam Electric Station (CPSES) - Docket No. 50-445, Draft Cable Functionality Evaluation Report and Evaluation of Jacket Swelling"

10.22.15 TXX-93353, dated October 28, 1993, "Comanche Peak Steam Electric Station (CPSES) - Docket No. 50-445, Thermo-Lag Laboratory Test Results and Responses to Request for Additional Information for CPSES Unit 1"

10.22.16 NRC Letter to W.J. Cahill, Jr., dated February 14, 1994, "Request for Additional Information Comanche Peak Steam Electric Station (CPSES), Unit 2 Thermo-Lag Related Ampacity Derating Issues"

10.22.17 TXX-92466, dated September 24, 1992, "Comanche Peak Steam Electric Station (CPSES) - Docket Nos. 50-445 and 50-446, Confirmatory Testing of Thermo-Lag Fire Barrier System at CPSES"

10.22.18 TXX-92589, dated December 15, 1993, "Comanche Peak Steam Electric Station (CPSES) - Docket Nos. 50-445 and 50-446, Response to Request for Additional Information"

10.22.19 NRC Letter to W.J. Cahill, Jr., dated August 30, 1993, "NRC Inspection Report 50-445/93-34; 50-446/93-34"

10.23 <u>CPSES Engineering Reports</u>

10.23.1 Engineering Report ER-ME-082, Rev. 1, "Evaluation of Unit 2 Thermo-Lag Configurations"

10.23.2 Engineering report ER-EE-006, Rev. 0, "Evaluation of Fire Endurance Test Results Related to Cable Functionality in 1-1/2" and 2" Conduits"

10.24 <u>Supplemental Safety Evaluation Reports (SSER) NUREG 0797</u>

10.24.1 SSER 12, Date issued October, 1985

10.24.2 SSER 21, Date issued April, 1989

10.24.3 SSER 23, Date issued February, 1990

10.24.4 SSER 26, Date issued February, 1993

10.24.5 SSER 27, Date issued April, 1993

10.25 <u>Underwriter's Laboratories ASTM E84 Tests</u>

10.25.1 Thermo-Lag 330-1 Subliming Compound without Topcoat, UL File No. R6076, dated June 16, 1981.

10.25.2 Thermo-Lag 350 Topcoat, UL File No. R6076B, dated June 16, 1981.

10.26 NUMARC Thermo-Lag Combustibility Guidelines issued on October 12, 1993

APPENDIX A

TEST SUMMARIES

APPENDIX A
TEST SUMMARIES

A1 Omega Point Test No. 12340-9354 · Scheme 1, Assembly 2

The fire endurance test documented in Reference 10.12.1 was conducted at Omega Point Laboratories on June 22, 1992, and the test report was issued on November 4, 1992. The fire endurance test, hose stream test, and electrical circuit monitoring test were performed to the criteria of American Nuclear Insurers (ANI) Bulletin No. 5 (Reference 10.3.2). This is the original acceptance criteria used by CPSES as documented in Southwest Research Institute (SWRI) Project No. 03-6491 (Reference 10.12.9) dated October 27, 1981, that was reviewed and accepted by the NRC by letter dated December 1, 19[illegible] (Reference 10.22.3).

A1.1 Test Article

Scheme No. 1 Assembly 2 (upgraded version) consisted of a T.J. Cope brand 36 in. wide x 4 in. deep 12 gage ladder back tray tee section, catalog No. GG-36ft-12-06-CP, connecting two Burndy-Husky 12 gage ladder back verticals, catalog No. S6YA-36-144, that transitioned into a U-shaped configuration have a 8 ft-6in horizontal run dimension and a vertical dimension of 6 ft-0in at each leg. One leg transitioned into the tee section via a 36 in. x 4 in. ladder back 90 deg vertical with a 24 in. inside radius bend fitting. The opposite leg transitioned into the tee section via an 1/4 in. thick x 7-3/4 in. x 7-3/4 in. ASTM A36 carbon steel L-shaped splice plate (CPSES site fabricated) forming a "squared" 90 deg angle. The 90 deg angle is not used at CPSES but was required in the test to fit the test article into the test oven. A 1/3 mix of power, instrumentation, and control cables, totaling 52 cables, were pulled into the tray maintaining a single layer, except in the tee section wherein cables were looped towards the mouth of the tee thereby ensuring circuit continuity. The mouth of the tee was filled with a 5 in. wide mixture of Thermo-Lag 330-1 tray stop.

This assembly was supported by three (3) trapeze type hangers using 3 in. channels bolted together with 5/8 in. diameter x 1-1/2 in. ASTM A307 carbon steel bolts. The channels were attached to 4 x 4 x 1/2 in. clip angles fillet welded to the 3 in. channel on each vertical side. The 4 x 4 clip angles were then attached to a 1/4 in. thick reinforced steel deck using 1/2 in. diameter threaded rods. From the bottom of the tray to the top support the clip angles measured 3 ft-0 in. in length. Above the vertical tray leg connected to the "sweeping" 90 deg bend, an 8 in. wide x 12 in. high (all-around) rectangular concrete collar [illegible]ded a 44 in. x 12 in. block out that was filled with Dow Corning 3-6548 silicone RTV foam. An internal seal (silicone elastomer-Promatec 45B) was poured into each cable tray vertical at the 1/4 in. reinforced deck level. A single protruding item (Unistrut P1001) was installed onto the outside face of the "square" 90 deg vertical approximately 12 in. down from the underside of the 1/4 in. decking and extending approximately 20 in. beyond the face of the tray.

A1.2 TSI Thermo-Lag Protective Envelope Materials and Enclosures

1/2 in. thick (nominal) Thermo-Lag 330-1 flat board and 1/2 in. thick Thermo-Lag 330-1 prefabricated v-rib panels with stress skin on only one side was installed in accordance with References 10.14.1, 10.15.4, and 10.18.2, except where upgraded for testing of design changes as described below.

Thermo-Lag 330-1 flat boards were applied to hanger supports then Thermo-Lag 330-1 prefabricated panels with V-ribs were installed to the inside face of the sweeping 90 deg bend and on top of the horizontal run; V-ribs were extended perpendicular to tray side rails.

Thermo-Lag 330-1 prefabricated panels were installed onto the bottom and top of the tray; V-ribs were extended parallel to the tray rail.

Thermo-Lag 330-1 prefabricated panels were installed onto the side rails. V-rib were extended vertically.

Thermo-Lag 330-1 prefabricated panels were installed onto the vertical riser and outside face of the sweeping 90 deg angle; V-ribs were extended vertically.

Upgrade - At the side panels, opposite the mouth of the tee section, a thin layer of 330-1 trowel grade approximately 3/16 in. thick was applied from the joint, extending approximately 5 in. towards the middle of the tray, on the top, bottom, and side exterior panel surfaces. Then Thermo-Lag stress skin Type 330-69 was cut and formed into a squared U-shaped configuration (5 in. overlay on top and bottom), which was placed over top, bottom, side panels, and 3/16 in. thick trowel grade, then the stress skin was stapled using 1/2 in. long Arrow or Bostitch T-50 staples at a distance 1 in. minimum, 2 in. maximum from the edge of the stress skin and 3 in. c/c spacings. The two stress skin legs were tie wired in place at 5 in. to 6 in. max on centers and a skim coat of 330-1 trowel grade material approximately 1/16 in. thick was applied over the stress skin and tie wires. Finally, Thermo-Lag 350 topcoat was applied over areas where Thermo-Lag 330-1 trowel grade had been applied after the required 72 hours cure period.

Upgrade - Stitching was applied (denoted as a tie wire connecting two adjoining Thermo-Lag 330-1 boards through one or more field drilled holes) at the inside and outside joint of the 90 deg angle, 7 stitches were placed 6 in. apart.

Upgrade - Stitching was applied 3-3/4 in. away from squared 90 deg angle on the top board, 8 stitches were placed 5 in. apart.

Upgrade - Stitching was applied on the top and bottom 330-1 boards along the mouth edge of tee into the 330-1 tray stop, 8 stitches were placed 5 in. apart.

Upgrade - Approximately 5 in. from mouth of the tee towards the center of the tray extending parallel to previous stitches, 8 stitches at 5 in. apart were added.

Upgrade - Stitching was applied approximately 8 in. away from the center of support hanger (closest to the top sweeping 90 deg bend) toward the center of the tray, extending across the width of tray, 8 stitches were placed 5 in. apart.

Upgrade - Stitching was applied to the top and bottom Thermo-Lag boards with the side panels at the beginning of the sweeping 90 deg bend transition from horizontal to the bottom of the 1/4 in. decking, stitching was 5 in. apart.

Upgrade - Horizontal boards were scored and folded at 9 places at 5 in. apart (top) and 10 places at 6 in. apart (bottom) and applied to the sweeping 90 deg bend.

In accordance with the 9 in. rule for protruding items, the P1001 unistrut was wrapped with Thermo-Lag flat panels over the total width of the 36 in tray plus 9 in. from the tray along unistrut. Where the Thermo-Lag application terminated the remaining unistrut was left unprotected.

Note: All joints were "prebuttered" and banding (including internal banding) was installed in accordance with Reference 10.14.1. All Thermo-Lag prefabricated panels were inspected prior to shipment from TSI (source inspection) and their weight was checked (density checked) upon receipt in accordance with Refernce 10.14.1 and Purchase Order.

A1.3 ASTM E-119 Standard Time Temperature

The Thermo-Lagged test article was exposed to the standard time-temperature curve of ASTM E-119 for 1 hour.

A1.4 Temperature Review

ASTM E-119 and NFPA 251 specify that the transmission of heat through the wall or partition during the fire endurance test shall not have been such as to raise the temperature on its unexposed surface more than 250°F (139°C) above its initial temperature. ASTM E-119 and NFPA 251 further state that where the conditions of acceptance place a limitation on the rise of temperature of the unexposed side, the temperature end point of the fire endurance test shall be determined by the average of the measurements taken at individual points; except that if a temperature rise 30 percent in excess of the specified limit occurs at any one of these points, the remainder shall be ignored and the fire endurance period judged as ended.

The ambient air temperature at the start of the test was 84°F.

The maximum average temperature would be equal to 250°F plus ambient. For this test, the maximum average temperature rise would equal 334°F.

The maximum individual temperature would be equal to 325°F plus ambient. For this test, the maximum individual temperature rise would equal 409°F.

During the test the maximum recorded individual outside cable tray rail temperature was 377°F and the maximum recorded average cable rail temperature was 294°F.

During the test the maximum recorded individual cable surface temperature was 314°F and the maximum recorded average cable surface temperature was 248°F.

The temperature criteria in ASTM E-119 were not applicable to this test, never the less, the test temperature satisfied the temperature criteria in ASTM E-119.

Visual inspection of the cables after the test showed that all the cables were "free from fire damage." A small nick was found on one cable. This nick was determined to have been caused during the pulling of the cables.

The cable temperatures in the area of the Unistrut support that was incorporated into the test article to validate the 9 in. rule (heat path into envelope) were all below 325°F.

A1.5 Hose Stream Test

Following the exposure fire, the test article was subjected to a 2-1/2 minute hose stream test utilizing a 2-1/2 in. diameter national standard playpipe equipped with a 1-1/8 in. nozzle. The nozzle pressure was maintained at 30 psi. The nozzle distance was maintained at 20 ft from the test article.

Circuit continually was maintained during the hose stream test. Some of the Thermo-Lag was dislodged during the hose stream test but the cables remained "free from fire damage."

A1.6 Electrical Circuit Monitoring Test

At no time during the fire endurance test or the hose stream test did the electrical circuit monitoring system identify any shorts, shorts to ground, or open circuits (loss of continuity) on any of the monitored circuits.

All cables were meggered after the hose stream test (next morning) and only one cable showed any degradation. This cable was identified as having a small nick in the cable jacket. This nick was caused during the installation of the cable and did not occur during the test.

A1.7 Comments

The test article meets the acceptance criteria established by CPSES (based on ANI Bulletin No. 5) in that circuit integrity was maintained throughout the fire endurance and hose stream tests.

The Thermo-Lag fire stop installed in the open end (mouth) of the tee section performed satisfactorily, as did the penetration seals at the test deck. These seals confirm the design used at CPSES for penetration seal/Thermo-Lag 330 interfaces in the plants.

A2 Omega Point Test No. 12340-93543c - Scheme 2, Assembly 1

The fire endurance test documented in Reference 10.12.2 was conducted at Omega Point Laboratories on June 17, 1992, and the test report was issued on February 19, 1993. The fire endurance test, hose stream test, and electrical circuit monitoring test were performed to the criteria of American Nuclear Insurers (ANI) Bulletin No. 5 (Reference 10.3.2). This is the original acceptance criteria used by CPSES as documented in Southwest Research Institute (SWRI) Project No. 03-6491 (Reference 10.12.9) dated October 27, 1981, that was reviewed and accepted by the NRC by letter dated December 1, 1981 (Reference 10.22.3).

A2.1 Test Article

Scheme 2, Assembly 1, consisted of one junction box (24 in. x 18 in. x 8 in.) and three conduits (5 in. 1 in., 3/4 in. diameter). The junction box was in the center of test article approximately 3 ft below the test desk. The junction box (JB) was supported by a 3 x 3 x 1/4 tube steel support, and had a 1 in. conduit with a 90 deg elbow attached to the front of the JB to simulate a nonprotected entry into a JB. The three conduits extended out both sides of the JB (3/4 in., 1 in., 5 in. conduit on each side) to lateral bends (90 deg bends) and rose vertically through the test deck.

The 1 in. conduit representing a nonprotected entry was sealed with a silicone elastomer seal (Promatec 45B). All conduits penetrating the test deck were sealed with Promatec 45B in accordance with CPSES procedures.

The 3/4 in, 1 in., and 5 in. conduits were supported by 3 in. x 3 in. x 1/4 in. tube steel on either side of the JB. The tube steel was attached to the conduits by a 1 in. x 6 in. flat plate.

The vertical conduit risers (3/4 in., 1 in., and 5 in.) were attached to a 1/2 in. plate which was attached to a 3 in. x 3 in. x 1/4 in. tube steel commodity. These commodities were for testing the 9 in. heat path rule.

A2.2 TSI Thermo-Lag Protective Envelope Materials and Enclosure

One-half inch thick Thermo-Lag 330-1 flat board were used on supports and lateral bends.

One-half inch thick Thermo-Lag 330-1 preshaped conduit sections were used on 3/4 in., 1 in., and 5 in. diameter conduits.

The two protruding tube steel items were protected as protruding items in accordance with Reference 10.14.1. One was protected with flat 1/2 in. 330-1 Thermo-Lag panels; the other was protected with two layers of 1/4 in. thick Thermo-Lag 330-660 Flexi-blanket.

The 1 in. diameter conduit protruding item from the junction box was protected in accordance with Reference 10.14.1 using 1/2 in. thick Thermo-Lag 330-1 preshaped conduit sections.

All joints were "Pre-buttered" and Banding (wires) was installed in accordance with Reference 10.14.1. All Thermo-Lag prefabricated panels were inspected prior to shipment, and weight was inspected upon receipt in accordance with Reference 10.14.1.

A2.3 ASTM E119 Standard Time-Temperature

The Thermo-Lagged test article was exposed to the standard time-temperature curve of ASTM E-119 for 1 hour.

A2.4 Temperatures

ASTM E-119 and NFPA 251 specifies that the transmission of heat through the wall or partition during the fire endurance test shall not have been such as to raise the temperature on its unexposed surface more than 250°F (139°C) above its initial temperature. ASTM E-119 and NFPA 251 further state that where the conditions of acceptance place a limitation on the rise of temperature of the unexposed side, the temperature end point of the fire endurance test shall be determined by the average of the measurements taken at individual points; except that if a temperature rise 30 percent in excess of the specified limit occurs at any one of these points, the remainder shall be ignored and the fire endurance period judged as ended.

The ambient air temperature at the start of the test was 87°F.

The maximum average temperature would be equal to 250° plus ambient. For this test, the maximum average temperature would equal 337°F.

The maximum individual temperature would be equal to 325°F plus ambient. For this test, the maximum individual temperature would equal 412°F.

- 5-inch Conduit

  The maximum average instrument cable surface temperature was 191°F, the maximum average control cable surface temperature was 142°F, and the maximum average control

cable surface temperature was 158°F for an overall average cable surface temperature of 164°F.

The conduit had a maximum recorded average outside steel temperature of 299°F, even though the inside of the conduit is considered the inside of the fire barrier assembly.

The maximum recorded individual cable surface temperature was 233°F and the maximum recorded overall average cable surface temperature was 164°F.

The temperature criteria in ASTM E-119 was not applicable to this test, never the less, the test temperature satisfied the temperature criteria in ASTM E-119.

An inspection of the cables after the hose stream test revealed that the cables were "free from fire damage."

- 1-inch Conduit

  The maximum cable (inside of conduit) temperature was 466°F. The temperature profile within the conduit varied from a low of 243°F to a high of 463°F. The horizontal mid-span sections had the highest temperatures, and the thermocouples closest to the supports had the lowest temperatures. This demonstrates that the thermal mass (ratio of weight to heated area) play an important role in the thermal response of the barrier.

  The conduit outside steel average temperature was 412°F.

  An inspection of the cable after the hose stream test showed blistering of the cable jacket where the cable temperature was 463°F, but only discolorization of the conductor insulation.

- 3/4-inch Conduit

  The maximum recorded cable surface (inside of conduit) temperature was 609°G. The temperature profile within the conduit varied from a low of 249°F to a high of 609°F. The horizontal mid-span sections had the highest temperatures and the thermocouples closest to the supports had the lowest temperatures. This demonstrates that the thermal mass (ratio of weight to heat perimeter) plays an important role in the thermal response of the barrier. An inspection of the cable after the hose stream test showed blistering of the jack, and, in at least one location, damage to the insulation on the conductors.

- Junction Box

  The maximum recorded cable surface (inside of box) temperature was 311°F. The temperature profile showed that a temperature variation was caused by the conduits connected to the box since the highest temperature was on the cable run in the 3/4 in. conduit and the lowest was on one of the cables run in the 5 in conduit.

  The junction box steel average temperature was 483°F.

  An inspection of the cables inside the junction box after the hose stream test showed that the cables were "free from fire damage."

  The conduit cable temperature near the exposed protruding items exhibited lower temperature than in the horizontal sections of the conduits. This demonstrates that the 9 in. rule for heat path on protruding items if acceptable.

A2.5 Hose Stream Test

Following the exposure fire, the test article was subjected to a 2-1/2 minute hose stream test utilizing a 2-1/2 in. diameter National Standard playpipe equipped with a 1-1/8 in. nozzle. The nozzle pressure was maintained at 30 psi. The nozzle distance was maintained at 20 ft from the test article.

Circuit continuity was maintained during the hose stream test. Most of the Thermo-Lag was dislodged during the hose stream test but the hose stream did not penetrate the conduits or junction box which are part of the test assembly.

A2.6 Electrical Circuit Monitoring Test

At no time during the fire endurance test or hose stream test did the electrical circuit monitoring system identify any shorts, shorts to ground, or open circuits (loss of continuity) on any of the monitored circuits.

The cables were meggered after the hose stream test (next morning) and only the cable in the 3/4 in. conduit showed degradation. The cable in the 1 in. conduit was "wet" meggered and found to be acceptable.

A2.7 Comments

The cables in the 5 in. conduit and junction box were free of fire damage. The cable in the 1 in. conduit although blistered would perform its intended function after the fire test. It was questionable whether the 3/4 in. instrument cable would function properly.

The hose stream removed most of the Thermo-Lag from the test article, with the banding supporting most of the remaining material.

The use of the 9 in. rule using either Thermo-Lag 330-660 Flexi-blanket, Thermo-Lag 330-1 flat panels or Thermo-Lag 330-1 preshaped conduit sections to prevent heat intrusion into the envelope was demonstrated to be acceptable.

The penetration seal inside the conduit at the junction box also performed satisfactorily.

<u>A3 Omega Point Test No. 12340-93543e - Scheme 3</u>

The fire endurance test documented in Reference 10.12.3 was conducted at Omega Point Laboratories on June 18, 1992, and the test report was issued on March 3, 1993. The fire endurance test, hose stream test and electrical circuit monitoring test was performed to the criteria of American Nuclear Insurers (ANI) Bulletin No. 5 (Reference 10.3.2). This is the original acceptance criteria used by CPSES as documented in Southwest Research Institute (SWRI) Project No. 03-6491 (Reference 10.12.9) dated October 27, 1981 that was reviewed and accepted by the NRC by letter dated December 1, 1981 (Reference 10.22.3).

A3.1 Test Article

Scheme 3 consisted of a 12" wide x 4" deep ladder back cable tray constructed in a U-shaped configuration having a 5 ft horizontal run through to radial 90 degree bends to two 6 ft vertical risers. The distance from the bottom of tray to the underside of the test deck was 3 ft. A 1/3 fill mix of 18 instrumentation, power and control cables were installed in a single layer into the tray.

The assembly was internally supported by two trapeze type hangers 3 in. channel for the bottom and 4 in. channel for the vertical support.

An internal tray seal (silicone elastomer) was installed in the vertical section of the tray at the test deck.

A3.2 TSI Thermo-Lag Protective Envelope Materials and Enclosure

1/2" thick (nominal) Thermo-Lag 330-1 prefabricated flat boards were used on the entire hanger supports.

1/2" thick (nominal) Thermo-Lag 330-1 prefabricated V-ribbed panels were installed on the tray with the ribs running perpendicular to tray side rails on the top of the tray and parallel to tray rails on the bottom and sides.

1/2" thick Thermo-Lag 330-1 prefabricated V-ribbed panels were installed on the top (inside) 90 degree radial bends with the ribs perpendicular to the tray side rails. These panels were scored approximately 1/4" deep the entire width of the panel on the outside surface at 2" intervals. Each scored groove was then filled with Thermo-Lag 330-1 trowel grade material.

1/2" thick Thermo-Lag 330-1 prefabricated V-ribbed panel was installed on the bottom (outside) 90 degree radial bends with the ribs parallel to the side rails. These panels were scored and folded similar to the inside of the bend panels above, except the scores were approximately 2 1/2 in. apart.

All joints were "pre-buttered" and banding (wires) was installed in accordance with Reference 10.14.1. All Thermo-Lag 330-1 prefabricated panels were inspected prior to shipment from the vendor, and weight was inspected upon receipt per Reference 10.14.1.

A3.3 ASTM E-119 Standard Time-Temperature

The Thermo-Lagged test article was exposed to the standard time-temperature curve of ASTM E-119 for 1 hour.

A3.4 Temperatures

ASTM E-119 and NFPA 251 specifies that the transmission of heat through the wall or partition during the fire endurance test shall not have been such as to raise the temperature on its unexposed surface more than 250°F (139°C) above its initial temperature. ASTM E-119 and NFPA 251 further states that where the conditions of acceptance place a limitation of the rise of temperature of the unexposed side, the temperature end point of the fire endurance test shall be determined by the average of the measurements taken at individual points; except that if a temperature rise 30 percent in excess of the specified limit occurs at any of these points, the remainder shall be ignored and the fire endurance period judged as ended.

The ambient air temperature at the start of the test was 95°F.

The maximum average temperature would be equal to 250°F plus ambient. For this test the maximum average temperature would equal to 345°F.

The maximum individual temperature would be equal to 325°F plus ambient. For this test the maximum individual temperature would equal 420°F.

The maximum recorded individual outside cable tray rail temperature was 381°F and the maximum recorded average outside cable tray rail temperature was 337°F.

The maximum recorded individual cable surface temperature was 292°F and the maximum recorded average cable surface temperature was 257°F.

The temperature criteria in ASTM E-119 was not applicable to this test, never the less, the test temperature satisfied the temperature criteria in ASTM E-119.

Visual inspection of the cables after the test revealed that the cables were "free of fire damage."

A3.5 Hose Stream Test

Following the exposure fire, the test article was subjected to a 2-1/2 minute hose stream test utilizing a 2-1/2 in. diameter national standard play pipe equipped with a 1-1/8 in. nozzle. The nozzle pressure was maintained at 30 psi. The nozzle distance was maintained at 20 feet from the test article.

Circuit integrity was maintained during the hose stream test. Some of the Thermo-Lag was dislodged during the hose stream test but the cable remained "free from fire damage."

A3.6 Electrical Circuit Monitoring Test

At no time during the fire endurance test or hose stream test did the electrical circuit monitoring system identify any shorts, shorts-to-ground or open circuits (loss of continuity) on any of the monitored circuits.

The cables were meggered in place after the hose stream test (next morning) and the test did not indicate any degradation of the cable.

A3.7 Comments

The test article met the acceptance criteria established by CPSES (based on ANI Bulletin No. 5), in that circuit integrity was maintained.

Furthermore, the temperature criteria of ASTM E-119 and NFPA 251 was also met.

A4 Omega Point No. 12340-93543F - Scheme 4

The test documented in Reference 10.12.4 was conducted at Omega Point Laboratories on June 23, 1992 and the test report was issued on March 30, 1993. This test was conducted to evaluate sealing of cable tray envelopes where coverage terminates away from walls, floors, etc. The fire endurance and hose stream tests were performed in accordance with American Nuclear Insurers (ANI) Bulletin No. 5 (Reference 10.3.2).

A4.1 Test Article

Scheme No. 4 consisted of a single vertical 35" wide x 4" deep x 7'-6" long (T.J. Cope brand) ladderback cable tray with a 1/3 mix of instrumentation, power and control cabling. A total of 156 cables were installed in the tray to achieve a 40% fill. 12" up from the bottom of the tray, a 5" wide 330-1 Thermo-Lag tray stop was poured in place extending over the entire inside width of the tray. The 330-1 Thermo-Lag tray stop was placed in such a manner that cables toward the back of the tray were also within the protective 330-1 tray stop envelope.

Omega Point Laboratories furnished and installed two 1-1/2" x 1-1/2" x 2'-9" long strut type mechanical clamping devices to prevent cables from sagging during the test. With three 3/8" diameter through bolts equally spaced from one another, the mechanical clamping device was positioned on the front and back face of the cables within the tray. In addition to the mechanical clamping device, the cables were also secured in place using plastic tie wraps tied to tray rungs, or in some instances stainless steel tie wire was used due to the proximity of the cables.

Omega Point Laboratories furnished a 1'-0" thick concrete slab having a 1'-0" wide x 4'-0" long block out. The 36" vertical tray was inserted into the blockout wherein 3'-6" of the tray hung below the underside of the concrete slab and a 2" gap remained all around the tray. The blockout opening was sealed using silicone elastomer (Promatec 45B).

Thermo-Lag 330-1 prefabricated panels were installed onto the 36" vertical tray beginning 12" above the bottom of tray extending 4'-6" upward leaving 12" of cables exposed unprotected to the fire source. The side panels were installed in compression wherein the front and rear panels sandwiched the side panels and metal banding applied.

There were no supports required internally, therefore, a unistrut dead weight type support was installed on top of the test decking.

A4.2 TSI Thermo-Lag Protective Envelope Material

The 5" deep fire stop consisted of Thermo-Lag 330-1 trowel-grade material pored into and worked around the cables in the tray in accordance with Reference 10.14.1.

The tray was enclosed using 1/2 in. (nominal) Thermo-Lag 330-1 prefabricated V-ribbed panels. The top and bottom panel (front and back panels) were installed with the "V" ribs perpendicular to the tray rails and the side panels parallel to the tray rails.

All joints were "pre-buttered" and banding (wires) was installed in accordance with Reference 10.14.1. Thermo-Lag 330-1 prefabricated panels were inspected prior to shipment from the vendor and weight was inspected upon receipt per Reference 10.14.1.

A4.3 ASTM E-119 Standard Time-Temperature

The Thermo-Lagged test article was exposed in accordance with Reference 10.19 to the standard time-temperature curve of ASTM E-119 for 1 hour.

A4.4 Temperature Review

A 89°F initial temperature allowed for a maximum average temperature of 339°F, and a single maximum temperature on 414°F. Temperatures on cables within the confines of the cable tray protective envelope met the temperature acceptance criteria. However, the average temperature increase criterion was exceeded on the right cable tray side rail at 55 minutes and on the left rail at 59 minutes. The maximum average temerature was 380°F, recorded on the right tray side rail. The maximum single point side rail temperature was 391°F.

A4.5 Hose Stream Test

Following the fire exposure, the test assembly was subjected to a hose stream test, using a solid stream delivered at 30 psi nozzle pressure, from a standard plypipe, for 2-1/2 minutes. As had occurred with other initial TU Electric Thermo-Lag fire endurance tests, the force of the solid hose stream resulted in dislodgment of panels used to cover the cable tray, but the fire stop assembly was not adversely affected by the hose stream, and remained fixed in place. Post-test examination revealed that the Thermo-Lag trowel grade material used to construct the fire stops had been charred to a depth of approximately 1-1/2". Only minor stiffening of the cables above the fire stop had occurred with no observable signs of thermal degradation.

A4.6 Comments

This test is not directly credited in the acceptance basis for Thermo-Lag cable tray fire stops installed at CPSES.[1]

<u>A5 Omega Point Test No. 12340-93543g - Scheme 5</u>

The fire endurance test documented in Reference 10.12.5 was conducted at Omega Point Laboratories on June 19, 1992, and the test report was issued on July 11, 1993. The fire endurance test, hose stream test and electrical circuit monitoring test were performed to the criteria of American Nuclear Insurers (ANI) Bulletin No. 5 (Reference 10.3.2). This is the original acceptance criteria used by CPSES as documented in Southwest Research Institute (SWRI) Project No. 03-6491 (Reference 10.12.9) dated October 27, 1981 that was reviewed and accepted by the NRC by letter dated December 1, 1981 (Reference 10.22.3).

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[1] see appendix F for additional details

A5.1 Test Article

Scheme No. 5 consisted of a 30" wide x 4 deep ladder back (T. J. Cope brand) cable tray with a 30" x 4" tee section catalog No. GI-30FT-12-06-CP and two 30" ladderback verticals catalog No. GG-30SL-12-06 forming into a U-shaped configuration having a 8'-9" horizontal run dimension and a vertical riser of 7'-0" at each leg. From each end of the horizontal run a 30" x 4" 60 degree and 30 degree fitting, but having 12" inside radius bends were installed to transition the tray from horizontal into the vertical riser. These fittings were connected using vendor supplied splice plates and 3/8" diameter bolting hardware. The bottom of the tray was set at three feet below the test deck.

A 1/3 mix of instrumentation, control and power cables (totaling 44 cables) were pulled into the 30" tray. These cables were looped into the tee section of the tray.

A silicone elastomer (Promatec 45B) 6-in. deep stop was installed in the open end of the tee section. After the elastomer cured, a 0.10 thick stainless steel piece of sheet metal was wrapped around the stop and banded in place, in accordance with CPSES procedures.

The tray was supported internally by three trapeze type hangers using 3" channels bolted together with 5/8" x 1-1/2" A307 bolting material. The vertical channels are attached to 4" x 4" x 1/2" clip angles fillet welded to a 3" channel on each vertical side. The 4 x 4 angles were then attached to a 1/4" thick reinforced decking using a 1/2" diameter threaded rods. Mounted on the outside face of the vertical tray run was an 8'-0" long P1001 unistrut positioned horizontally such that unistrut extended beyond the side rail. This was done to simulate a protruding item to test the 9" rule for heat path.

The vertical tray risers were sealed at the test deck with silicone elastomer (Promatec 45B) in accordance with CPSES procedures.

A5.2 TSI Thermo-Lag Protective Envelope Materials and Enclosure

1/2" (nominal) thick Thermo-Lag 330-1 flat boards with an inner layer of stress skin was applied to the supports. 1/2" (nominal) thick Thermo-Lag 330-1 prefabricated V-ribbed panels were installed on the cable tray in accordance with Reference 10.14.1 (non-upgrade design). The V ribs were installed perpendicular to the tray rails on the top (inside) of the tray and parallel to the side rails on the side and bottom (outside) of the tray. 1/2" (nominal) thick Thermo-Lag 330-1 prefabricated V-ribbed panels were installed on the radial bends (top and bottom pieces) using the score and fold technique with scores approximately at 5 in. intervals with the ribs perpendicular to the tray rails on both the top and bottom.

The P1001 unistrut protruding item was protected using 1/2" Thermo-Lag 330-1 flat boards covering the entire width of the tray plus an additional 9 in. This left 47 in. of unistrut unprotected.

All joints were "pre-buttered" and banding (wires) was installed in accordance with Reference 10.14.1 (non-upgraded design). Thermo-Lag 330-1 prefabricated panels were inspected prior to shipment from the vendor, and weight was inspected upon receipt per Reference 10.14.1.

A5.3 ASTM E-119 Standard Time-Temperature

The Thermo-Lagged test article was exposed to the standard time temperature curve of ASTM E-119 for approximately 44 min. at which time the test was terminated due to loss of circuit integrity.

A5.4 Temperature Review

The Thermo-Lag protective envelope opened up at the butt joint on the left side bottom piece of the tee section and at the corner between the horizontal butt joint and corner (longitudinal) joint with the side rail at approximately 20 min. into the test.

The peak temperature at 44 min. was 723°F on the side rail where the joint opened and the closets cable thermocouple to the opening reached 578°F.

The temperatures on the vertical cable tray cables were less than 230°F and the tray rails were less than 245°F. In fact, temperature dropped drastically as the thermocouples location got away from the breech in the Thermo-Lag envelope.

The temperatures on the cables and tray rails in the vicinity of the unistrut protruding item was below 245°F.

A5.5 Hose Stream Test

In order to preserve the condition of the test article, the hose stream test was not conducted. The test article was cooled off using a garden hose, to prevent further deterioration of the enclosure.

A5.6 Electrical Circuit Monitoring Test

Circuit integrity was lost at 42 minutes into the test.

A5.7 Comments

During visual inspection of the test article, it was evident that the fire damage was limited to the area where the joint opened up. Also of note is the fact that the joint opened with 20 minutes of the start of the test but circuit integrity was not lost until 42 minutes into the test. Thermocouple in the area of the opening also rose more slowly than was expected demonstrating that the Thermo-Lag provides a cooling effect evens in the area around the breech of the enclosure.

The vertical section of the envelope remained intact and there was no significant heat intrusion from the protruding item (unistrut).

A6 Omega Point Test No. 12340-93543h - Scheme 6

The fire endurance test documented in Reference 10.12.6 was conducted at Omega Point Laboratories on August 20, 1992, and the test report was issued on June 11, 1993. The fire endurance test and electrical circuit monitoring test were performed to the criteria of American Nuclear Insurers (ANI) Bulletin No. 5 (Reference 10.3.2). This is the original acceptance criteria used by CPSES as documented in Southwest Research Institute (SWRI) Project NO. 03-6491 (Reference 10.12.9) dated October 27, 1981, that was reviewed and accepted by the NRC by letter dated December 1, 1981 (Reference 10.22.3).

The hose stream test was conducted using the guidance provided in BTP CMEB 9.5.1 and in IEEE STD 634 (Reference 10.19.1) for penetration seals.

A6.1 Test Article

Scheme 6 consisted of 24" wide x 4" deep ladder back tray with a horizontal tee section at mid-span. There was two vertical 24" sections connected to the horizontal section by a 90° radial bend on one end and a 90° site fabricated angle on the other end (the 90° angle is not used at CPSES but was required for the Test Article to fit in the Test Oven). A 1/3 fill mix of power, control and instrumentation cables were installed in the tray maintaining a single layer, except in the tee section where cables were looped toward the open end of the tee to represent cable entering and leaving the tee.

The open end of the tee was sealed using a 5 in. deep Thermo-Lag 330-1 tray stop consisting of both prefabricated panel section and trowel grade material.

The assembly was supported internally by two trapeze type hangers using 3" channels bolted together. The distance from the bottom of the tray to the underside of the test deck was approximately 3 ft.

The vertical tray sections were sealed at the test deck using a silicone elastomer.

A6.2 TSI Thermo-Lag Protective Envelope, Materials and Enclosure

1/2" (nominal) thick Thermo-Lag 330-1 prefabricated V ribbed panels with stress skin on the inside were installed on the cable tray in accordance with Reference 10.14.1 (non-upgraded design).

1/2" (nominal) thick Thermo-Lag 330-1 flat boards with stress skin on the inside were installed on the supports to a distance of approximately 9 in. from the tray in accordance with Reference 10.14.1 for protruding items.

The V ribs were installed perpendicular to the rails on the top (inside) panels on the tray and parallel to the rails on the sides and bottom (outside).

The 90° radial bend top and bottom panels were installed using the scored and groove method. The top and bottom panels had scores spaced about 2" apart.

The bottom joint on the 90° angle between the bottom piece and outside section was stitched at five places evenly across the joint.

All joints were "pre-buttered" and banding (wires) was installed in accordance with Reference 10.14.1 (non upgraded design). Thermo-Lag 330-1 prefabricated panels were inspected prior to shipment from the vendor and weight was inspected upon receipt per Reference 10.14.1.

A6.3 ASTM E-119 Standard Time-Temperature

The Thermo-Lagged test article was exposed to the standard time-temperature curve of ASTM E-119 for 1 hour.

A6.4 Temperature Review

During the test 3 joints opened in the enclosure. They were; the vertical riser butt joint on the left hand side, outside section, the vertical riser butt joint on the right hand side, outside section and the bottom longitudinal joint along the tee section left bend into the tee.

The peak temperature was 484°F on the front tray rail and 484°F on the left vertical riser.

The high temperatures were localized to the locations where the joints opened. The physical inspection of the assembly after the hose stream test also only indicates degradation of the outer cable jacket in areas where the joints opened up. The average cable temperature was only 317°F and the average rail temperature was 401°F. These numbers include the thermocouple reading around the openings in the enclosure.

A6.5 Hose Stream Test

Following the exposure fire, the test article was subjected to a 5 minute hose stream test utilizing a 1-1/2 in. dia fog nozzle set at a discharge angle of 30% with a nozzle pressure of 75 psi (this Elkhart nozzle is rated 88 gpm at 75 psi). The nozzle distance was maintained at 5 ft perpendicular from the outside edge of the test article.

This hose stream criteria was agreed to by T.U. Electric personnel and NRC staff personnel (see hose stream discussion later in this section).

Circuit continuity was maintained during the hose stream test. A small amount of Thermo-Lag was dislodged during the hose stream test, but no joints which had not already opened in the exposure fire were opened during the hose stream test.

A6.6 Electrical Circuit Monitoring Test

At no time during the fire endurance test or the hose stream test did the electrical circuit monitoring system identify any shorts, shorts to ground, or open circuits (loss of continuity) on any of the monitored circuits.

The cables were meggered after the hose stream test and only one instrument cable showed signs of degradation.

A6.7 Comments

During the visual inspection of the test article, it was determined that the fire damage was limited to those areas where the joints opened.

The non-protected vertical supports had no impact on the results of test and provided justification for the use of the 9" rule on tray supports and other protruding items.

<u>A7 Omega Point Test No. 12340-93543i - Scheme 7</u>

The Fire endurance test documented in Reference 10.12.7 was conducted at Omega Point Laboratories on August 19, 1992, and the test report was issued on June 11, 1993. The fire endurance test, and electrical circuit monitoring test were performed to the criteria of American Nuclear Insurers (ANI) Bulletin No. 5 (Reference 10.3.2). This is the original acceptance criteria used by CPSES as documented in Southwest Research Institute (SWRI) Project NO. 03-6491 (Reference 10.12.9) dated October 27, 1981 that was reviewed and accepted by the NRC by letter dated December 1, 1981 (Reference 10.22.3).

NOTE: Per NRC staff's request, a hose stream test was not conducted.

A7.1 Test Article

Scheme 7 consisted of one 3" conduit, one 2" conduit, one 1-1/2" conduit and two 3/4" conduits. The conduits were installed in a "U" shaped configuration with Lateral Bends at the turns.

The conduits were supported mid-span by a Unistrut P1001 trapeze hanger.

The conduits were sealed with silicone elastomer (Promatec 45B) external to the conduits at the test deck and internally at the tops of the conduits in accordance with site procedures.

A7.2 TSI Thermo-Lag Protective Envelope, Materials and Enclosure

The 3", 2" and 1-1/2" conduits were covered with 1/2" (nominal) thick Thermo-Lag 330-1 preshaped conduit sections.

The Lateral Bends (LBD's) were covered with 1/2" (nominal) thick Thermo-Lag 330-1 prefabricated panels. The two 3/4" conduit was subdivided into four separate installation configurations using the mid-span support as the break point.

3/4" (nominal) thick Thermo-Lag 330-1 preshaped conduit sections were installed on one side of a 3/4" conduit and the other side was covered by 1/2" (nominal) thick Thermo-Lag 330-1 preshaped conduit section with an additional layer of Thermo-Lag 330-1 trowel-grade, followed by a layer of Thermo-Lag Stress Skin Type 330-69 and finally a layer of Thermo-Lag

330-1 trowel-grade to provide a 1/4 build up on top of the 1/2" Thermo-Lag 330-1 preshaped conduit sections. The LBD's were covered with 1/2" Thermo-Lag pre-fabricated panels.

The other conduit was covered with 1/2" (nominal) thick Thermo-Lag 330-1 preshaped conduit sections with half of the conduit receiving a 1/4" layer of spiral wrapped Thermo-Lag 330-660 Flexi-blanket and the other half of the conduit receiving an additional 1/4" (nominal) thick Thermo-Lag 330-1 preshaped conduit section overlayed on to the 1/2" section. The LBD's were covered with 1/2" Thermo-Lag 330-1 pre-fabricated panels.

The Unistrut support was protected to a distance of approximately 9 in. away from the conduits with 1/2" thick Thermo-Lag 330-1 flat board.

All joints were "pre-buttered" and banding (wires) was installed in accordance with Reference 10.14.1 Thermo-Lag 330-1 Prefabricated panels were inspected prior to shipment from the vendor and weight was inspected upon receipt per Reference 10.14.1.

A7.3 ASTM E-119 Standard Time Temperature

The Thermo-Lagged test article was exposed to the standard time-temperature curve of ASTM E-119 for 1 hour.

A7.4 Temperature Review

Data was taken using two computer data acquisition systems. After 13 minutes of data acquisition, it was noticed that Computer No. 1 was not accepting data from channels 85 through 100. The computer was stopped, reprogrammed to accept all 100 channels and restarted. Consequently, the first 15 minutes of data for the affected channels was lost.

A very rapid temperature rise on several thermocouples was noticed around 31 minutes, and a ground loop from the circuit integrity systems was suspected. To verify that a ground loop was not occurring, the circuit integrity voltage was disconnected for two data scans (32 and 33 minutes). No change was observed, and the circuit integrity system was vindicated and reconnected.

At 8 minutes, Thermocouple (TC) No. 10 failed and was disconnected.

At 17 minutes, TC NO. 31 failed (indicated a negative temperature) and was disconnected after a determination was made that it could not be repaired.

ASTM E-119 and NFPA 251 specifies that the transmission of heat through the wall or partition during the fire endurance test shall not have been such as to raise the temperature on its unexposed surface more than 250°F (139°C) above its initial temperature. ASTM E-119 and NFPA 251 further states that where the conditions of acceptance place a limitation on the rise of temperature of the unexposed side, the temperature end point of the fire endurance test shall be determined by the average of the measurements taken at individual points; except that if a temperature rise 30 percent in excess of the specified limit occurs at any one these points, the remainder shall be ignored and the fire endurance period judged as ended.

The ambient air temperature at the start of the test was 83°F.

The maximum average temperature would be equal to 250°F plus ambient. For this test the maximum average temperature would equal 333°F.

The maximum individual temperature would be equal to 325°F plus ambient. For this test the maximum individual temperature would equal 408°F.

The temperature criteria in ASTM E-119 was not applicable to the test.

- 3" conduit

  The maximum individual cable (inside of conduit) temperature was 399°F and the maximum average cable temperature was 200°F. The inside edge of the right LBD fitting (metal temperature) reached 623°F. As the test article was removed from the oven it was noted that the joint between the top of the LBD and the conduit had opened. During the visual inspection (next morning), it was noted that the outer jacket of one of the cables in the 3" conduit right at the LBD had blistered.

- 3/4" conduit with additional 1/4" Thermo-Lag 330-1 preshaped conduit section (overlay) build-up

  The maximum individual cable (inside of conduit) temperature was 346°F at the interface with Thermo-Lag 330-660 Flexi-blanket overlay and the maximum average cable temperature was 289°F. The inside edge of the LBD (metal temperature) reached 368°F. During the visual inspection, it was noted that the LBD had moved as the upper joint had opened. The visual inspection also revealed that cables installed in that portion in the 3/4" conduit that was protected with the 1/4" Thermo-Lag 330-660 Flexi-blanket overlay was "Free from Fire Damage".

- 3/4" conduit with 3/4" thick Thermo-Lag preshaped conduit sections

  The maximum individual cable (inside of conduit) temperature was 490°F and the maximum average cable temperature was 380°F. During the visual inspection, it was noted that the top joint of the LBD had opened up. During the physical inspection (next morning), the cable showed blistering of the outer cable jacket.

- 3/4" conduit with 1/4" Thermo-Lag 330-1 trowel-grade addition

  The maximum individual cable (inside of conduit) temperature was 380°F and the maximum average cable temperature was 352°F. The inside edge of the LBD (metal temperature) reached 477°F. During the visual inspection, it was observed that the top joint of the LBD had opened. During the physical inspection, (next morning) the cable showed blistering of the outer cable jacket.

- 3/4" conduit with Thermo-Lag 330-660 Flexi-blanket build-up

The maximum individual cable (inside of conduit) temperature was 409°F and the maximum average cable temperature was 378°F. The inside edge of the LBD (metal temperature) reached 493°F. During the visual inspection, it was observed that the top joint of the LBD had opened. During the physical inspection (next morning), the cable showed blistering of the outer cable jacket.

- 1-1/2" conduit

  The maximum individual cable (inside of conduit) temperature was 388°F and the maximum average cable temperature was 318°F. The inside edge of the left LBD was 429°F and the right LBD was 409°F.

  During the visual inspection, it was observed that the top joints of the LBD's had opened. During the physical inspection (next morning), the cable showed deterioration of the cable jacket.

- 2" conduit

  The maximum individual cable (inside of conduit) temperature was 445°F and the maximum average cable temperature was 303°F. The inside edge of the right LBD reached 400°F.

  During the visual inspection; it was observed that the top joints of the LBD's had opened. During the physical inspection (next morning), the cable showed deterioration of the cable jacket.

The unprotected Trapeze Unistrut support had no impact on the test. The temperature on the top of the 3" and 2" conduits (closest to the vertical supports) at the center of the conduits were only 399°F and 375°F respectively. The temperatures just outboard of the centerline in the 3" conduit were 429°F and 301°F and on the 2" conduit was 405°F. Therefore, the support provided no significant thermal input to the cables. Centerline temperature of all cables were less than 346°F with the highest temperature on the 2" and 3" conduits being 270°F.

A7.5 Hose Stream Test

At the request of the NRC staff, a hose stream test was not conducted. Instead, a garden hose was used to cooldown the test article so that a visual inspection could be conducted.

A7.6 Electrical Circuit Monitoring Test

At no time during the fire endurance test did the electrical circuit monitoring system identify any shorts, shorts to ground or open circuits (loss of continuity) on any of the monitored circuits.

At 60 minutes, the circuit integrity systems were disconnected and the computers stopped. A hot megger test was attempted, with inconclusive results. The circuit integrity systems

were reconnected at 68 minutes, the data acquisition was restarted, and the specimen was removed from the test furnace and cooled with the spray from a small hose.

A7.7 Comments

For the 3" conduit, the opening of the LBD caused the blistering of the cable jacket.

For the 2" and 1-1/2" conduits, the LBD's opened at both ends of each conduit.

For the 3/4" conduit with a 1/2" thick Thermo-Lag 330-1 preshaped conduit section and an added 1/4" thick Thermo-Lag 330-1 preshaped conduit section, the LBD appeared to be opening at the joint.

For the 3/4" conduit with the 3/4" thick Thermo-Lag 330-1 preshaped conduit sections, the LBD joint opened. There was also blistering of the outer cable jacket.

For the 3/4" conduit with 1/4" thick Thermo-Lag 330-660 Flexi-blanket on top of the 1/2" thick Thermo-Lag 330-1 preshaped conduit sections, the LBD joints opened. There was also blistering of the outer cable jacket.

For the 3/4" conduit with 1/4" thick Thermo-Lag 330-1 trowel-grade buildup over the 1/2" Thermo-Lag 330-1 preshaped conduit section, the LBD joint opened. There was also blistering of the outer cable jacket.

The temperature criteria in ASTM E-119/NFPA 251 are not applicable to this test; Never the less, the temperature of the following components satisfied the temperature criteria in ASTM E-119/NFPA 251 (i.e. maximum average Temperature of 330°F and maximum temperature of 408°F): the maximum and average cable temperature in the 3" conduit, the average cable temperature in the 2 and 1-1/2" conduit, and the maximum and average temperatures in the 3/4" conduit with the 1/4" preshaped overlay.

The unprotected support had no adverse impact on the test, demonstrating the effectiveness of the 9" rule to prevent heat infusion into the envelope. There was no deformation of the conduit caused by movement of the supports or deformation of the supports.

A8 Omega Point Test No. 12340-93543j - Scheme 8

The fire endurance test documented in Reference 10.12.8 was conducted at Omega Point Laboratories on August 21, 1992, and the test report was issued on June 11, 1993. The fire endurance test and electrical circuit monitoring test was performed to the criteria of American Nuclear Insurers (ANI) Bulletin No. 5 (Reference 10.3.2). This is the original acceptance criteria used by CPSES as documented in Southwest Research Institute (SWRI) Project No. 03-6491 (Reference 10.12.9) dated October 28, 1981, that was reviewed and accepted by the NRC by letter dated December 1, 1981 (Reference 10.22.3).

The hose stream test was conducted using the guidance provided by BTP CMEB 9.5.1 (see Section 6.10) and IEEE Std. 634 (Reference 10.19) for penetration seals.

A8.1 Test Article

Scheme 8 consisted of a 30" wide x 4" deep ladderback tray installed in a U shape. The article was installed so that the bottom of the tray was approximately 3 ft below the test deck. A 1/3 fill mix of power, control and instrumentation cables were installed in the tray, maintaining a single layer.

The assembly was supported internally by two trapeze type hangers using 3" channels bolted together.

The vertical tray sections were sealed at the test deck using a silicone elastomer (Promatec 45B).

A8.2 TSI Thermo-Lag Protective Envelope Materials and Enclosure

1/2" (nominal) thick Thermo-Lag 330-1 V-ribbed prefabricated panels with stress skin on the inside were installed on the cable tray in accordance with Reference 10.14.1 (non-upgraded design).

1/2" (nominal) thick Thermo-Lag 330-1 prefabricated flat panels with stress skin on the inside were installed on the supports to a distance of approximately 9 in. from the tray in accordance with Reference 10.14.1 for protruding items.

The V-ribs were installed perpendicular to the rails on the top (inside) panels on the tray and parallel to the rails on the sides and bottom (outside).

The 90° radial bend top and bottom panels were installed using the scored and grooved method. The top and bottom panels had scores spaced about 2 in. apart.

All joints were "pre-buttered" and banding (wires) was installed in accordance with Reference 10.14.1 (non upgraded design). Thermo-Lag 330-1 prefabricated panels were inspected prior to shipment from the vendor and weight was inspected upon receipt per Reference 10.14.1.

A8.3 ASTM E-119 Standard Time-Temperature

The Thermo-Lagged test article was exposed to the standard time-temperature curve of ASTM E-119 for 1 hour.

A8.4 Temperature Review

The bottom butt joint, mid-span on the horizontal section, opened at about 30 min. into the test. It was decided to continue the test until circuitry integrity was lost. Circuitry integrity was maintained for the full one hour. During the visual inspection, it was observed that the butt joints on the outside of the vertical sections had also opened.

The peak temperature on an individual cable reached 703°F. The maximum temperature on the cable tray rails were 764°F. Both of these temperatures were in the vicinity of the bottom joint that opened.

There was a wide variation in temperatures from a high of 764°F to a low of 231°F. The lower temperatures were in the areas furthest from the opening in the enclosure. In fact, the average maximum cable temperature in the vertical sections was only 280°F.

This wide variation in temperatures demonstrates that the Thermo-Lag material functioned properly and that the weakness at the joints, which allowed the joints to open was the failure mode.

A8.5 Hose Stream Test

Following the exposure fire, the test article was subjected to a 5 minute hose stream test utilizing a 1-1/2 in. diameter fog nozzle set at a discharge angle of 30% with a nozzle pressure of 75 psi (this Elkhart nozzle is rated at 88 gpm at 75 psi). The nozzle distance was maintained at 5 ft perpendicular for the outside surface of the test article.

This hose stream criteria was agreed to by T.U. Electric personnel and NRC staff personnel (see hose stream discussion later in this section).

Circuit continuity was maintained during the hose stream test. A small amount of Thermo-Lag was dislodged during the hose stream test, but no joints which had not already opened during the exposure fire were opened during the hose stream test.

A8.6 Electrical Circuit Monitoring Test

At no time during the fire endurance test or hose stream test did the electrical circuit monitoring system identify any shorts, shorts-to-ground, or open circuits (loss of continuity) on any of the monitored circuits.

The cables were meggered after the hose stream test (next morning). Many of the cables showed degradation of the cable jacket.

A8.7 Comments

The bottom joint on the horizontal section of the tray opened at approximately 30 min. into the test. Except in the area of the joint failure, the temperatures on the cables were below the 30% in excess of 250°F plus ambient in NFPA 251 and the average cable temperatures below 250°F plus ambient (which is not applicable to this test).

The Thermo-Lag material, except for the joint failure, performed adequately.

The fog hose stream allowed for a more informative inspection of the test article then the solid stream specified by ANI.

A9 SWRI Project NO. 01-6763-302

A fire test of irradiated samples of Thermo-Lag 330-1 was conducted by SWRI (Reference 10.12.9). The total exposure dose to the samples was 2.12×10^8 rads. A fire test was performed on one irradiated sample and one nonirradiated sample.

The purpose of the fire test of irradiated samples of Thermo-Lag 330-1 was to demonstrate that the fire resistive properties of the Thermo-Lag panels would not be degraded after exposure to radiation. The test results indicate the fire resistive properties actually increased following radiation exposure. Although this fire test did not represent a typical installation detail (flat panel section in a small oven), the results are considered applicable to all installation details that incorporate Thermo-Lag 330-1 into the design that may be subjected to a radiation exposure.

A9A Omega Point Test No. 12340-94367a - Scheme 9-1

The fire endurance test documented in Reference 10.12.11 was conducted at Omega Point Laboratories on November 4, 1992, and the test report was issued on November 23, 1992. The fire endurance test, hose stream test and cable functionality (Insulation Resistance) tests were performed to the requirements of the NRC letter dated October 29, 1992 (Reference 10.22.1). Due to the time required (approx. 30 minutes) to conduct the insulation resistance (IR) tests on multi-conductor instrument cable, IR tests were not conducted during the fire endurance tests.

A9A.1 Test Article

Scheme 9-1 consisted of one 5" conduit, one 3 conduit and one 3/4" conduit. The conduits were installed in a "U" shaped configuration with Lateral Bends (LBD's) at the turns on the right and Radial Bends on the left side.

The conduits were supported by two unistrut P1001 trapeze hangers: one 10" to the left of the 5" conduit LBD and the other 3' to the left of the first.

A 1/3 fill mix of power, control and instrumentation cables were installed in the 3" and 5" conduits. The 3/4" conduit contained a single instrument cable.

The conduits were sealed externally at the test deck using silicone foam and internally at the tops of the conduits with silicone elastomer (Promatec 45B).

A9A.2 TSI Thermo-Lag Protective Envelope Materials and Enclosure

The 3" and 5" conduits were covered with 1/2" (nominal) thick Thermo-Lag 330-1 preshaped conduit sections. The 3/4" conduit received an additional 1/4" (nominal) thick Thermo-Lag 330-1 preshaped conduit section overlayed on top of the 1/2" Thermo-lag preshaped section.

The LBD's were covered with 1/2" (nominal) thick Thermo-Lag 330-1 prefabricated panels. The panels were reinforced at the joints with a layer of trowel grade and stress skin.

The radial bends covered with 1/2" (nominal) thick Thermo-Lag 330-1 preshaped sections. The sections were reinforced with a layer of trowel grade and stress skin along the length of the bend.

The unistrut supports were protected to a distance of approximately 9 in. away from the conduits with 1/2" thick Thermo-Lag 330-1 flat board.

All joints were "pre-buttered" and banding (wires) was installed in accordance with Reference 10.14.1. The Thermo-Lag 330-1 prefabricated panels were inspected prior to shipment from the vendor and weights were verified upon receipt per Reference 10.14.1.

A9A.3 ASTM E-119 Standard Time-Temperature

The Thermo-Lagged test article was exposed to the standard time-temperature curve of ASTM E-119 for 1 hour.

A9A.4 Temperature Review

Reference 10.22.1 specifies that the transmission of heat through the fire barrier during the fire endurance test shall not have been such as to raise the average temperature on the exposed conduit surface more than 250°F above its initial temperature. Reference 10.22.1 further states that no single temperature rise shall exceed 30% of the average specified limit or 325°F. If either of these temperatures are exceeded then visual cable inspection and IR cable tests is required to demonstrate the cables are free of fire damage.

The ambient air temperature at the start of the test was 71°F.

The maximum average temperature would be equal to 250°F plus ambient. For this test the maximum average temperature would equal to 321°F.

The maximum individual temperature would be equal to 325°F plus ambient. For this test the maximum individual temperature would equal 396°F.

As discussed in Section 4.4 of this report, the accuracy of the exposed conduit thermocouples was in question and the their readings were not used. Instead the cable thermocouples along with the cable criteria stated above were used.

The peak temperature on an individual cable in the 5" conduit reached 191°F and the average reached 134°F.

The peak temperature on an individual cable in the 3" conduit reached 309°F and the average reached 180°F.

The peak temperature on an individual cable in the 3/4" conduit reached 299°F and the average reached 244°F.

A9A.5 Hose Stream Test

Following the exposure fire, the test article was subjected to a 5 minute hose stream test utilizing a 1-1/2 in. diameter fog nozzle set at a discharge angle of 30% with a nozzle pressure of 75 psi (this Elkhart nozzle is rated at 88 gpm at 75 psi). The nozzle distance was maintained at 5 ft perpendicular from the outside surface of the test article.

After the hose stream test a visual inspection of the fire barrier was conducted. There was no burn through of the fire barrier and the conduit's galvanizing looked like it was new.

A9A.6 Electrical Circuit Monitoring Test

At no time during the fire endurance test or hose stream test did the electrical circuit monitoring system identify any shorts, shorts-to-ground, or open circuits (loss of continuity) on any of the monitored circuits.

The cables were visually inspected after the hose stream test. There was no sign of cable degradation. There was some cable stiffening which is acceptable and is discussed in section 4.4 of this report.

The cables were meggered after the hose stream test and all the cables passed the IR testing. In fact, the majority of the cables showed no reduction of the insulation resistance from the readings taken before the test.

A9A.7 Comments

Thermo-Lag material performed adequately.

The reinforced LBD and Radial bend design and the 1/4" overlay provide adequate upgrades to the Thermo-Lag design and the test confirms those designs.

Cable temperatures were enveloped by the CPSES LOCA temperature qualifications.

A9B Omega Point Test No. 12340-94367j - Scheme 9-3

The fire endurance test documented in Reference 10.12.12 was conducted at Omega Point Laboratories on December 3, 1992, and the test report was issued on December 28, 1992. The fire endurance test, hose stream test and cable functionality (Insulation Resistance) tests were performed to the requirements of the NRC letter dated October 29, 1992 (Reference 10.22.1). Due to the time required (approximately 30 minutes) to conduct the insulation resistance (IR) tests on multi-conductor instrument cable, IR tests were not conducted during the fire endurance tests.

A9B.1 Test Article

Scheme 9-3 consisted of one 2 in. conduit, one 1-1/2 in. conduit and a 3/4 in. conduit, each installed in a "U-shaped" configuration extending up through the test deck. The conduits each had lateral bend (LBDs) on each side where the vertical section transitions to the horizontal section.

A single trapeze type unistrut hanger supports all three conduits at the midpoint of the horizontal section. Unistrut clamps attach the conduits to the hanger.

Except for the 3/4 in. conduit, a 1/3 mix of Power, Instrumentation and Control cables (1 of each) were pulled into the conduits. The 3/4 in. conduit had a single instrument cable.

Conduits were sealed externally at the test deck using silicone foam and internally with silicone elastomer.

A9B.2 TSI Thermo-Lag Protective Envelope Materials and Enclosure

Each rigid conduit raceway was covered first prior to installing a material on the support members using 1/2 in. nominal thickness Thermo-Lag 330-1 Pre-Shaped Conduit Material except the 3/4 in. conduit system which used 3/4 in. nominal thickness pre-shaped material as described below. All joint, seams and built-up areas were pre-caulked with 330-1 Trowel Grade Material and secured in place with stainless steel tie wire and metal banding material.

The UniStrut trapeze type support member was covered with Thermo-Lag Flat Panel material for a 9 in. distance extending from the closest Thermo-Lag Pre-Shaped section leaving the remaining Unistrut support steel surface unprotected from the fire source.

Each raceway LBD fitting was covered with a flat panel material in a manner similar to an L-shaped box configuration. All joints were pre-caulked with 330-1 Trowel Grade Material and secured in place with stainless steel banding material. The LBD "box" configurations were then upgraded as described below.

All joints were "pre-buttered", and banding (wires) was installed in accordance with Reference 10.14.1. The Thermo-Lag 330-1 prefabricated panels were inspected prior to shipment from the vendor and weights were verified upon receipt per Reference 10.14.1.

The 3/4 in. dia. raceway was clad with 3/4 in. nominal thickness Thermo-Lag 330-1 Conduit Sections, secured using stainless steel tie wire. All joints were pre-caulked with Thermo-Lag 330-1 Trowel Grade Material.

All LBD flat panel box design joints were pre-caulked with 3/16 in. of Thermo-Lag 330-1 Trowel Grade and upgraded using Thermo-Lag 330-69 Stress Skin with a 2 in. min. overlap on adjoining panels. Where the raceway enters and exits the LBD, stress skin was cut such that when folded, 2 in. of stress skin material lapped over the adjoining Thermo-Lag 330-1 panel and raceway. The Thermo-Lag 330-1 Trowel Grade was allowed to set and become tacky prior to applying the stress skin. The stress skin was secured to the LBD box with 1/2 in. long

staples. Where the stress skin is attached to the entering and exiting raceway, a 2 in. high stress skin collar was circumferentially wrapped around the raceway and stapled in place. After the stress skin had been applied to all the LBD box joints, a skim coat of Thermo-Lag 330-1 Trowel Grade was applied over the stress skin.

A9B.3 ASTM E-119 Standard Time Temperature

The Thermo-Lagged test article was exposed to the standard time-temperature curve of ASTM E-119 for 1 hour.

A9B.4 Temperature Review

Reference 10.22.1 specifies that the transmission of heat through the fire barrier during the fire endurance test shall not have been such as to raise the average temperature on the exposed conduit surface more than 250°F above its initial temperature. Reference 10.22.1 further states that no single temperature rise shall exceed 30% of the average specified limit or 325°F. If either of these temperatures is exceeded then visual cable inspections and IR cable tests are required to demonstrate the cables are free of fire damage.

The ambient air temperature at the start of the test was 65°.

The maximum average temperature would be equal to 250°F plus ambient. For this test the maximum average temperature would equal 315°F.

The maximum individual temperature would be equal to 325°F plus ambient. For this test the maximum individual temperature would equal 390°F.

As discussed in Section 4.4 of this report, the accuracy of the exposed conduit thermocouples was in question and their readings were not used. Instead, the cable thermocouples along with the cable criteria stated above were used.

On the 3/4 in. conduit

Peak temperature on the cable reached 522°F and the average temperature reached 279°F.

On the 1-1/2 in. conduit

Peak temperature on an individual cable reached 478°F and the average temperature reached 313°F.

On the 2 in. conduit

Peak temper[illegible]re on an individual cable reached 423°F and the average temperature reached 3[illegible]

The maximum criteria were exceeded for cable on all three assemblies.

A9B.5 Hose Stream Test

Following the exposure fire, the test article was subjected to a 5 minute hose stream test utilizing 1-1/2 in. diameter fog nozzle set at a discharge angle of 30° with a nozzle pressure of 75 psi at a distance of 5 feet. The minimum flow rate from the nozzle was 75 gpm.

After the hose stream test a visual inspection of the fire barrier was conducted. There was burn through on the 1-1/2 in. and 2 in. conduit assemblies but none on the 3/4 in. conduit.

A9B.6 Electrical Circuit Monitoring Test

At no time during the fire endurance test or hose stream test did the electrical conduit monitoring system identify any shorts, shorts to ground, or open circuits (loss of continuity) on any of the monitored circuits.

On the 3/4 in. conduit, the cable suffered no apparent heat damage. The cable jacket was slightly stiffened in the condulet area. The remainder of the cable length was still flexible.

In the 1-1/2 in. conduit, the cable jackets of the power cable was blistered and cracked above the right LBD area (at the barrier burn through site) and 2 ft. to the left of the right LBD. The outer jacket was cut away to observe the inner conductor insulation. The inner conductor insulation appeared intact and undamaged. The remaining cables were still flexible and visibly undamaged. Slight greenish-white residue on some cables in condulet area (possibly from filler material between conductors inside the outer insulation sheath.)

In the 2 in. conduit, the cable jackets of the power cable was blistered and cracked in the area between the left LBD and the midspan support member (at the barrier burn through site). The outer jacket was cut away to observe the inner conductor insulation. The inner conductor insulation appeared intact and undamaged. The remaining cables were still flexible and visibly undamaged. Slight greenish-white residue on some cables in condulet area (possibly from filler material between conductors inside the outer insulation sheath.)

The cables were meggered after the hose stream test and the results of the IR tests were well within the allowable limits for all assemblies tested.

A9B.7 Comments

The 2 in., 1-1/2 in., and 3/4 in. Conduit assemblies, clad in a nominal 1/2 in. thickness Thermo-Lag 330-1 material with additional upgrades presented herein, met acceptance criteria contained in the NRC letter dated October 29, 1992 (Reference 10.22.1), for the following parameters: 1) visual cable inspection revealed no apparent thermal damage (on the inner conductor insulation, 2) no loss of circuit integrity occurred during the course of the fire and hose stream tests, and 3) the results of the insulation resistance tests were well within the allowable limits.

In addition, Engineering Report ER-EE-006 (Reference 10.23.2) evaluated the functionality of the cables contained in the 1-1/2 in. and 2 in. conduits at CPSES Unit 1 based on the temperatures reached in this test. The evaluation demonstrated that the elevated temperatures reached in test scheme 9-3 will not impair the function of the cables installed in 1-1/2 in. and 2 in. conduit.

A10A Omega Point Test No. 12340-94367c - Scheme 10-1

The fire endurance test documented in Reference 10.12.13 was conducted at Omega Point Laboratories on November 5, 1992, and the test report was issued on December 2, 1992. The fire endurance test, hose stream test and cable functionality (insulation Resistance) tests were performed to the requirements of the NRC letter dated October 29, 1992 (Reference 10.22.1). Due to the time required (approx. 30 minutes) to conduct the insulation resistance (IR) tests on multi-conductor instrument cable, IR tests were not conducted during the fire endurance tests.

A10A.1 Test Article

Scheme 10-1 consisted of two 3" conduits, one horizontally mounted junction box located at mid-span and one vertically mounted junction box located on the right side riser. The conduits and junction boxes were installed in a "U" shaped configuration with Lateral Bends (LBD's) at the turns.

The horizontal junction box was supported by a section of 3" tube steel mounted on the top of the box conduits.

A 1/3 by fill, mix or power, control and instrumentation cables were installed in the 3" conduit and were routed through the junction boxes.

The conduits were sealed externally at the test deck using silicone foam and internally at the tops of the conduits with silicone elastomer (Promatec 45B).

A10A.2 TSI Thermo-Lag Protective Envelope Materials and Enclosure

The 3" conduits were covered with 1/2" (nominal) thick Thermo-Lag 330-1 preshaped conduit sections. The junction boxes were covered with two layers of 1/2" thick prefabricated panels of Thermo-Lag. The first layer used flat panels while the second layer used "ribbed" panels. The junction box joints were reinforced with trowel grade Thermo-Lag and stress skin.

The LBD's were covered with 1/2" (nominal) thick Thermo-Lag 330-1 prefabricated panels. The panels were reinforced at the joints with a layer of trowel grade and stress skin.

The tube steel support was protected to a distance of approximately 9 in. away from the conduits with 1/2" thick Thermo-Lag 330-1 flat board.

All joints were "pre-buttered", and banding (wires) was installed in accordance with Reference 10.14.1. The Thermo-Lag 330-1 prefabricated panels were inspected prior to shipment from the vendor and weights were verified upon receipt per Reference 10.14.1.

A10A.3 ASTM E-119 Standard Time-Temperature

The Thermo-Lagged test article was exposed to the standard time-temperature curve of ASTM E-119 for 1 hour.

A10A.4 Temperature Review

Reference 10.22.1 specifies that the transmission of heat through the fire barrier during the fire endurance test shall not have been such as to raise the average temperature on the exposed conduit surface more than 250°F above its initial temperature. Reference 10.22.1 further states that no single temperature rise shall exceed 30% of the average specified limit or 325°F. If, either of these temperatures is exceeded then visual cab[illegible] tion and IR cable tests are required to demonstrate the cables are free of fire [illegible]

The ambient air temperature at the start of the test was 63°F.

The maximum average temperature would be equal to 250°F plus ambient. For this test the maximum average temperature would equal to 313°F.

The maximum individual temperature rise would be equal to 325°F plus ambient. For this test the maximum individual temperature would equal 388°F.

As discussed in Section 4.4 of this report, the accuracy of the exposed conduit thermocouples was in question and their readings were not used. Instead the cable thermocouples along with the cable criteria stated above were used.

The peak temperature on an individual cable in the front 3" conduit reached 232°F and the average reached 155°F.

The peak temperature on an individual cable in the rear 3" conduit reached 232°F and the average reached 146°F.

The peak temperature on the inside surface of the horizontal junction box reached 186°F and the average reach 172°F.

The peak temperature on the inside surface of the vertical junction box reached 198°F and the average reached 146°F.

A10A.5 Hose Stream Test

Following the exposure fire, the test article was subjected to a 5 minute hose stream test utilizing a 1-1/2 in. diameter fog nozzle set at a discharge angle of 30% with a nozzle pressure of 75 psi (this Elkhart nozzle is rated at 88 gpm at 75 psi). The nozzle distance was maintained at 5 ft perpendicular from the outside surface of the test article.

After the hose a visual inspection of the fire barrier was conducted. There was no burn through of the fire barrier and the conduit's galvanizing looked like it was new.

A10A.6 Electrical Circuit Monitoring Test

At no time during the fire endurance test or hose stream test did the electrical circuit monitoring system identify any shorts, shorts-to-ground, or open circuits (loss of continuity) on any of the monitored circuits.

The cables were visually inspected after the hose stream test. There was no sign of cable degradation. There was some cable stiffening which is acceptable and is discussed in section 4.4 of this report.

The cables were meggered after the hose stream test and all the cables passed the IR tests. In fact, the majority of the cables showed no reduction of the insulation resistance from the readings taken before the test.

A10A.7 Comments

Thermo-Lag material performed adequately.

The reinforced LBD design provides adequate upgrades to the Thermo-Lag design and the test confirms those designs.

The upgrades to the junction boxes provide an adequate design.

Cable temperatures were enveloped by the CPSES LOCA temperature qualifications.

A10B Omega Point Test No. 12340-94367a - Scheme 10-2

The fire endurance test documented in Reference 10.12.14 was conducted at Omega Point Laboratories on November 19, 1992, and the test report was issued on December 16, 1992. The fire endurance test, hose stream test and cable functionality (Insulation Resistance) tests were performed to the requirements of the NRC letter dated October 29, 1992 (Reference 10.22.1). Due to the time required (approx. 30 minutes) to conduct the insulation resistance (IR) tests on multi-conductor instrument cable, IR tests were not conducted during the fire endurance tests.

A10B.1 Test Article

Scheme 10-2 consisted of two 3" conduit, one horizontally mounted junction box located at mid span and one vertically mounted junction box located on the right side riser. The conduits and junction boxes were installed in a "U" shaped configuration with Lateral Bends (LBD'S) at the turns.

The horizontal junction box was support by a section of 5" tube steel mounted on the top of the box conduits.

A 1/3 fill mix of power, control and instrumentation cables were installed in the 3" conduit and were routed through the junction boxes.

The conduits were sealed externally at the test deck using silicone foam and internally at the tops of the conduits with silicone elastomer (Promatec 45B).

A10B.2 TSI Thermo-Lag Protective Envelope Materials and Enclosure

The 3" conduits were covered with 1/2" (nominal) thick Thermo-Lag 330-1 preshaped conduit sections. The junction boxes were covered with a single layers 1/2" thick prefabricated flat panels of Thermo-Lag.

The junction box joints were reinforced with trowel grade Thermo-Lag and stress skin.

The LBD's were covered with 1/2" (nominal) thick Thermo-Lag 330-1 prefabricated panels. The panels were reinforced at the joints with a layer of trowel grade and stress skin.

The tube steel support was protected to a distance of approximately 9 in. away from the conduits with 1/2" thick Thermo-Lag 330-1 flat board.

All joints were "pre-buttered", and banding (wires) was installed in accordance with Reference 10.14.1. The Thermo-Lag 330-1 prefabricated panels were inspected prior to shipment from the vendor and weights were verified upon receipt per Reference 10.14.1.

A10B.3 ASTM E-119 Standard Time-Temperature

The Thermo-Lagged test article was exposed to the standard time-temperature curve of ASTM E-119 for 1 hour.

A10B.4 Temperature Review

Reference 10.22.1 specifies that the transmission of heat through the fire barrier during the fire endurance test shall not have been such as to raise the average temperature on the exposed conduit surface more than 250°F above its initial temperature. Reference 10.22.1 further states that no single temperature rise shall exceed 30% of the average specified limit or 325°F. If either of these temperatures is exceeded then visual cable inspection and IR cable tests are required to demonstrate the cables are free of fire damage.

The ambient air temperature at the start of the test was 68°F.

The maximum average temperature would be equal to 250°F plus ambient. For this test the maximum average temperature would qual to 318°F.

The maximum individual temperature would be equal to 325°F plus ambient. For this test the maximum individual temperature would equal 393°F.

As discussed in Section 4.4 of this report, the accuracy of the exposed conduit thermocouples was in question and their readings were not used. Instead the cable thermocouples along with the cable criteria stated above were used.

The peak temperature on an individual cable in the front 3" conduit reached 324°F and the average reached 174°F.

The peak temperature on an individual cable in the rear 3" conduit reached 294°F and the average reached 177°F.

The peak temperature on the inside surface of the horizontal junction box reached 366°F and the average reached 280°F.

The peak temperature on the inside surface of the vertical junction box reached 334°F and the average reached 259°F.

A10B.5 Hose Stream Test

Following the exposure fire, the test article was subjected to a 5 minute hose stream test utilizing a 1-1/2 in. diameter fog nozzle set at a discharge angle of 30% with a nozzle pressure of 75 psi (this Elkhart nozzle is rated at 88 gpm at 75 psi). The nozzle distance was maintained at 5 ft perpendicular from the outside surface of the test article.

After the hose stream test, a visual inspection of the fire barrier was conducted. There was no burn through of the fire barrier and the conduit galvanizing looked like it was new.

A10B.6 Electrical Circuit Monitoring Test

At no time during the fire endurance test or hose stream test did the electrical circuit monitoring system identify any shorts, shorts-to-ground, or open circuits (loss of continuity) on any of the monitored circuits.

The cables were visually inspected after the hose stream test. There was no sign of cable degradation. There was some cable stiffening which is acceptable and is discussed in section 4.4 of this report.

The cables were meggered after the hose stream test and all the cables passed the IR tests. In fact, the majority of the cables showed no reduction of the insulation resistance from the readings taken before the test.

A10B.7 Comments

Thermo-Lag material performed adequately.

The reinforced LBD design provides an adequate upgrades to the Thermo-Lag design and the test confirms those designs.

The reinforced joint design to the junction boxes provides an adequate design.

This test demonstrates that only a single layer of 1/2" thick Thermo-Lag board is required on a junction box.

Cable temperatures were enveloped by the CPSES LOCA temperature qualifications.

A11A Omega Point Test No. 12340-94367f - Scheme 11-1

The fire endurance test documents in Reference 10.12.15 was conducted at Omega Point Laboratories on November 17, 1992, and the test report was issued on January 14, 1993. The fire endurance test, hose stream test and cable functionality (Insulation Resistance) tests were performed to the requirements of the NRC letter dated October 29, 1992 (Reference 10.22.1). Due to the time required (approx. 30 minutes) to conduct the insulation resistance (IR) tests on multi-conductor instrument cable, IR tests were not conducted during the fire endurance tests.

A11A.1 Test Article

Scheme 11-1 consisted of one 5" air drop, one 3" air drop, one 2" air drop, one 1" air drop and one 24" tray. The test article was installed in a "U" shaped configuration with the 3", 2" and 1" air drop coming down from the respective size conduits on the left side of the assembly. The conduits extended through the test deck with approximately 6" into the furnace and 3' above the furnace. The 3", 2" and 1" air drops entered the horizontal end of the 24" tray. The 5" air drop extended down from a 5" conduit which extended through the test deck in a similar manner as the other conduits and entered the tray mid span through the top of the tray.

The 24" tray has a horizontal section and a vertical section. The vertical section rises through the test deck on the right side. The two sections were connected together with a radial bend.

The assembly was supported internally by two trapeze type hangers using 3" channels bolted together.

Two single cable heat path cables were included in the test article. One penetrated the 5" air drop fire barrier and the other penetrated the tray vertical section fire barrier.

A 1/3 fill mix of power, control and instrumentation cables were installed in the 2", 3" and 5" air drops and the 1" air drop had a single control cable.

The conduit stubs were sealed externally at the test deck using silicone foam and internally at the tops of the conduits with silicone elastomer (Promatec 45B).

The vertical tray section was sealed at the test deck using a silicone foam.

A11A.2 TSI Thermo-Lag Protective Envelope Materials and Enclosure

The 3" and 5" air drops were covered with 2 layers of 1/4" thick Thermo-Lag 330-660 "flexi blanket". The 1" and 2" air drops were covered with 3 layers of Flexi-blanket.

The 3" and 5" conduits were covered with 1/2" (nominal) thick Thermo-Lag 330-1 preshaped conduit sections. The 1" and 2" conduits received an additional 1/4" (nominal) thick Thermo-Lag 330-1 preshaped conduit section overlayed on top of the 1/2" Thermo-Lag preshaped section.

1/2" (nominal) thick Thermo-Lag 330-1 V-ribbed prefabricated panels with stress skin on the inside were installed on the cable tray in accordance with Reference 10.14.1. The corner joints were reinforced with trowel grade Thermo-Lag and stress skin and the butt joints were reinforced with "stitching", trowel grade Thermo-Lag and stress skin.

1/2" (nominal) thick Thermo-Lag 330-1 prefabricated flat panels with stress skin on the inside were installed on the supports to a distance of approximately 9 in. from the tray in accordance with Reference 10.14.1 for protruding items.

The V-ribs were installed perpendicular to the rails on the top (inside) panels on the tray and parallel to the rails on the sides and bottom (outside).

The 90° radial bend top and bottom panels were installed using the scored and grooved method. The top and bottom panels had scores spaced about 2 in. apart.

All joints were "pre-buttered", and banding (wires) was installed in accordance with Reference 10.14.1. The Thermo-Lag 330-1 prefabricated panels were inspected prior to shipment from the vendor and weight was verified upon receipt per Reference 10.14.1.

A11A.3 ASTM E-119 Standard Time-Temperature

The Thermo-Lagged test article was exposed to the standard time-temperature curve of ASTM E-119 for 1 hour.

A11A.4 Temperature Review

Reference 10.22.1 specifies that the transmission of heat through the fire barrier during the fire endurance test shall not have been such as to raise the average temperature on the exposed conduit surface more than 250°F above its initial temperature. Reference 10.22.1 further states that no single temperature rise shall exceed 30% of the average specified limit of 325°F. If either of these temperatures is exceeded then visual cable inspection and IR cable tests are required to demonstrate the cables are free of fire damage.

The ambient air temperature at the start of the test was 71°F.

The maximum average temperature would be equal to 250°F plus ambient. For this test the maximum average temperature would equal to 321°F.

The maximum individual temperature would be equal to 325°F plus ambient. For this test the maximum individual temperature would equal 396°F.

As discussed in Section 4.4 of this report, the accuracy of the exposed conduit thermocouple was in question and their readings was not used. Instead the cable thermocouples along with the cable criteria stated above were used.

The peak temperature on an individual cable in the 5" air drop reached 291°F and the average reached 199°F.

The peak temperature on an individual cable in the 3" air drop reached 291°F and the average reached 195°F.

The peak temperature on an individual cable in the 2" air drop reached 253°F and the average reached 202°F.

The peak temperature on an individual cable in the 1" air drop reached 240°F and the average reached 201°F.

The peak temperature on the tray's front rail reached 274°F and the average reached 251°F.

The peak temperature on the tray's rear rail reached 301°F and the average reached 242°F.

A11A.5 Hose Stream Test

Following the exposure fire, the test article was subjected to a 5 minute hose stream test utilizing a 1-1/2 in. diameter fob nozzle set at a discharge angle of 30% with a nozzle pressure of 75 psi (this Elkhart nozzle is rated at 88 gpm at 75 psi). The nozzle distance was maintained at 5 ft perpendicular from the outside surface of the test article.

After the hose stream test a visual inspection of the fire barrier was conducted. There was no burn through of the fire barrier.

A11A.6 Electrical Circuit Monitoring Test

At no time during the fire endurance test or hose stream test did the electrical circuit monitoring system identify any shorts, short-to-ground, or open circuits (loss of continuity) on any of the monitored circuits.

The cables were visually inspected after the hose stream test. There was no sign of cable degradation on the cables with exception of two cables (leaving the 5" conduit and entering the 5" air drop) where there was minor blistering of the cable jacket. Inspection of the insulation on the conductor in the area of the blisters showed no sign of degradation. There was some cable stiffening which is acceptable and is discussed in section 4.4 of this report.

The cables were meggered after the hose stream test and all the cables passed the IR testing. In fact the majority of the cables showed no reduction of the insulation resistance from the readings taken before the test.

A11A.7 Comments

Thermo-Lag material performed adequately.

The Thermo-Lag 330-660 "flexi-blanket designs provide an acceptable fire barrier system. The 9" rule for heat path using flexi-blanket is acceptable.

Cable temperatures were enveloped by the CPSES LOCA temperature qualifications.

A11B Omega Point Test No. 12340-95766 - Scheme 11-2

The fire endurance test documented in Reference 10.12.16 was conducted at Omega Point Laboratories on August 12, 1993, and the test report was issued on August 27, 1993. The fire endurance test, hose stream test and cable functionality (Insulation Resistance) tests were performed to the requirements of the NRC letter dated October 29, 1992 (Reference 10.22.1). Due to the time required (approximately 30 minutes) to conduct the insulation resistance (IR) tests on multi-conductor instrument cable, IR tests were not conducted during the fire endurance tests.

A11B.1 Test Article

Scheme 11-2 consisted of one 1-1/2" air drop, one 2" air drop and one 24" tray. The test article was installed in a "U" shaped configuration with the 1-1/2" air drop coming down from a 1-1/2" conduit on the left side of the assembly. The conduit extended through the test deck with approximately 8" into the furnace and 3' above the furnace. The 1-1/2" air drop entered the horizontal end of the 24" tray. The 2" air drop extended down from a 2" conduit which extended through the test deck in a similar manner as the other conduit and entered the tray mid span through the top of the tray.

The 24" tray has a horizontal section and a vertical section. The vertical section rises through the test deck on the right side. The two sections were connected together with a radial bend.

The assembly was supported internally by a trapeze type hanger using 3" steel channels bolted together.

A single protruding cable to introduce a heat path was included in the test article. This cable penetrates the tray vertical section fire barrier.

An approximate 1/3 mix of Power, Instrumentation and Control cables were pulled into the tray, maintaining a single layer, and into the 1-1/2" and 2" air drops. In order to monitor temperatures in the interior of the air drops, a single bare #8 AWG stranded copper wire cable was instrumented with thermocouples and wrapped loosely around the cable in each air drop bundle.

The conduit stubs were sealed externally at the test deck using silicone foam and internally at the tops of the conduits with silicone elastomer (Promatec 45B).

The vertical tray section was sealed at the test deck using a silicone foam.

All joints were "pre-buttered", and banding (wires) was installed in accordance with Reference 10.14.1. The Thermo-Lag 330-1 prefabricated panels were inspected prior to shipment from the vendor and weights were verified upon receipt per Reference 10.14.1.

A11B.2 TSI Thermo-Lag Protective Envelope Materials and Enclosures

The 1-1/2" and 2" air drops were covered with 2 layers of 1/4" thick Thermo-Lag 330-660 "Flexi-Blanket".

The 1-1/2" and 2" conduits were covered with 1-1/2" (nominal) thick Thermo-Lag 330-1 preshaped conduit sections.

1/2" (nominal) thick Thermo-Lag 330-1 V-ribbed prefabricated panels with stress skin on the inside were installed on the cable tray in accordance with reference 10.14.1. The corner joints and the butt joints were reinforced with trowel grade Thermo-lag and stress skin.

1/2" (nominal) thick Thermo-Lag 330-1 prefabricated flat panels with stress skin on the inside were installed on the support to a distance of approximately 9" from the tray in accordance with Reference 10.14.1 for protruding items.

The V-ribs were installed perpendicular to the rails on the top and bottom of the horizontal tray run and on both the inside and the outside of the radial bend. Panels installed against tray side rails in the horizontal run were positioned with the V-ribs oriented vertically. Panels installed against the tray side rails in the radial bends and vertical tray section had V-ribs oriented horizontally.

The 90° radial bend top and bottom panels were installed using the scored and grooved method. The top and bottom panels had scores spaced 2" to 3" apart.

Additionally, at horizontal support locations Thermo-Lag panel strips were secured to the underlying panels on the support member. These panels strips effectively reinforced the region where panels installed on the underside of horizontal tray portion abuts the panels used to cover the horizontal members.

All joints were "pre-buttered" and banding was installed was installed in accordance with Reference 10.14.1. The Thermo-Lag 330-1 prefabricated panels were inspected prior to shipment from the vendor and weight was verified upon receipt per Reference 10.14.1.

A11B.3 ASTM E-119 Standard Time Temperature

The Thermo-Lagged test article was exposed to the standard time-temperature curve of ASTM E-119 for 1 hour.

A11B.4 Temperature Review

Reference 10.22.1 specifies that the transmission of heat through the fire barrier during the fire endurance test shall not have been such as to raise the average temperature on the exposed conduit surface more than 250°F above its initial temperature. Reference 10.22.1 further states that no single temperature rise shall exceed 30% of the average specified limit or 325°F. If either of these temperatures is exceeded then visual cable inspections and IR cable tests are required to demonstrate the cables are free of fire damage.

The ambient air temperature at the start of the test was 92°F.

The maximum average temperature would be equal to 250°F plus ambient. For this test the maximum average temperature would equal 342°F.

The maximum individual temperature would be equal to 325°F plus ambient. For this test the maximum test the maximum individual temperature would equal 417°F.

The peak temperature on the bare #8 AWG copper conductor (which extended between both air drops) reached 344°F and the average reached 249°F.

The peak temperature on the 2" conduit stub reached 225°F and the average reached 224°F.

The peak temperature on an individual cable in the 2" air drop reached 439°F and the average reached 228°F.

The peak temperature on the 1-1/2" conduit stub reached 249°F and the average reached 241°F.

The peak temperature on an individual cable in the 1-1/2" air drop reached 327°F and the average reached 226°F.

The peak temperature on the tray's front rail reached 295°F and the average reached 250°F.

The peak temperature on the tray's rear rail reached 309°F and the average reached 249°F.

All of the thermocouples in the 24" cable tray, all of the thermocouples in the 1-1/2" air drop and all but a single thermocouple location in the 2" air drop, met the maximum and average temperature criteria.

A11B.5 Hose Stream Test

Following the exposure fire, the test article was subjected to a 5 minute hose stream test utilizing a 1-1/2 in. diameter fog nozzle set at a discharge angle of 30° with a nozzle pressure of 75 psi at a distance of 5 feet. The minimum flow rate from the nozzle was 75 gpm.

After the hose stream test a visual inspection of the fire barrier was conducted. There was no burn through or openings in the fire barrier envelope.

A11B.6 Insulation Resistance Testing

As an additional check on the condition of the conductor insulation, insulation resistance testing was performed on each cable type before the fire and after the hose stream test. The insulation resistance tests were performed using TU Electric owned and calibrated adjustable megohm meter, set to the 500 volt DC level for insulation resistance testing on all instrumentation cables and the 1500 volt DC level for all power and control cables. To perform the insulation resistance test, the connection to ground was broken for each cable type and the test instrument leads connected from conductor to conductor and from each conductor to ground. Any leakage between the cable type's conductors and ground, or from conductor to conductor, is readily detected in this manner. Upon discovery of an ohmic reading which is lower than the criteria set in the October 29, 1992, NRC letter (Reference 10.22.1), the reading will be documented in the test report and the splices between cables will be broken and each cable tested separately to determine which cable conductor is bad or if there is a bad splice or test lead. Provided the low reading is on a cable, that cable will be removed from the raceway and visually examined to determine where and how the failure occurred.

No apparent thermal cable damage was noted in the cable tray section.

In the 2" air drop, surface char was noted on the W-020 power cable approximately 12 in. above the top of the cable tray horizontal section. Damage did not extend completely through the cable outer jacket. The localized surface char covered an area approximately 0.24 in^2 on the outer cable jacket. No other apparent thermal cable damage was noted.

In the 1-1/2" air drop a small blister (approximately 1/8" in diameter) was noted on the W-023 power cable approximately 12" above top of the cable tray horizontal section. Damage did not extend completely through the cable outer jacket. No other apparent thermal cable damage was noted.

The cables were meggered after the hose stream test and the results of the IR tests were well within the allowable limits for all assemblies tested.

A11B.7 Comments

The 24" cable tray assembly clad in 1/2" nominal V-rib with 2 in. and 1-1/2 in. air drop assemblies, clad in nominal 1/2 in. thickness Thermo-Lag 330-660 Flexi-Blanket material with upgrades provide an acceptable fire barrier system for a fire resistance rating of one hour.

Although a single point temperature increase parameter was exceeded in one cable in the 2 in. air drop bundle, the overall assembly met the acceptance criteria contained in Reference 10.22.1 for the following parameters: 1) no barrier opening occurred on the assembly following the fire endurance and hose stream tests, 2) visual cable inspection revealed no significant thermal damage in the assemblies, and 3) the results of the insulation resistance tests were well within the allowable limits for all assemblies tested.

A11C Omega Point Test No. 12340-95767, Scheme 11-4

The fire endurance test documented in Reference 10.12.17 was conducted at Omega Point Laboratories on August 16, 1993 and the test report was issued on October 4, 1993. The fire endurance test, hose stream test and cable functionality (Insulation Resistance) tests were performed to the requirements of the NRC letter dated October 29, 1992 (Reference 10.22.1). Due to the time required (approximately 30 minutes) to conduct the insulation resistance (IR) tests on multi-conductor instrument cable, IR tests were not conducted during the fire endurance tests.

A11C.1 Test Article

Scheme 11-4 consists of cables air dropping from a bank of cast-in-concrete conduit stubs into two stacked 24 in. ladder back cable trays. The two cable trays were fashioned into a pair of nested "U" shaped assemblies, one on top of the other and each extending up through the test deck. The block out containing the cast-in-concrete conduit stubs is located in the front deck wall and the distance from the inside surface of the concrete to the front tray side rail is 10-1/2 in. The bottom of tray to bottom of tray separation for the horizontal sections of the two trays is 12 in. and for the vertical sections is 15". The horizontal section tray bottom for the top tray is 36 in. down from the test deck and the bottom tray is 48 in. down from the deck. The concrete blockout is 24 in. high by 40 in. wide and contains 8 - 4 in. conduits.

The assembly is supported internally by two trapeze type hangers using 3" steel channels bolted together.

An approximate 1/3 mix of Power, Instrumentation and Control cables were pulled into each tray, maintaining a single layer except where cables exited the cable trays to enter the conduit stubs. Of the cables placed in each cable tray, a group consisting of one of each designated type (power, control and instrumentation) was installed such that the cables exited the cable tray, passed through one conduit stub, looped outside of the test enclosure into an adjacent conduit stub, and reentered the cable tray near the place of exit. The looped cables in the lower tray exited and entered the tray over the side rail and the looped cables in the upper tray exited and entered the tray between the rungs in the bottom of the tray. In order to monitor temperatures in the interior of the box design air drop, bare #8 AWG copper wires were instrumented with thermocouples and wrapped loosely around the cables in the air drop area. The layout of the bare copper wires followed the looped electrical cables.

The tray blockout at the deck was sealed with silicone foam as were the embedded conduits. The internal tray at the deck was sealed with elastomer.

All joints were "pre-buttered" and banding (wires) was installed in accordance with Reference 10.14.1. The Thermo-Lag 330-1 prefabricated panels were inspected prior to shipment from the vendor and weights were verified upon receipt per Reference 10.14.1.

A11C.2 TSI Thermo-Lag Protective Envelope Materials and Enclosure

The support members were covered first using 1/2" (nominal) thick Thermo-Lag 330-1 prefabricated flat panels with stress skin on the inside and covering the support to a distance of approximately 9 in. to 11 in. from the tray in accordance with Reference 10.14.1 for protruding items.

1/2" (nominal) thick Thermo-Lag 330-1 V-ribbed prefabricated panels with stress skin on the inside were installed on the cable tray in accordance with reference 10.14.1. The longitudinal and butt joints were reinforced with trowel grade Thermo-Lag and stress skin.

The V-ribbed panels were oriented identically on both cable trays.. Specifically, panels were installed on tray top and bottom surfaces, including radial bends, with the V-ribs oriented perpendicular to the tray side rails. In the horizontal tray sections, panels were installed on the side rails with the V-ribs oriented vertically. Through the radial bends, the rib orientation transitioned such that on the vertical tray riser sections the panels installed on the side rails had V-ribs oriented horizontally.

The box assembly was constructed by extending the V-rib panel installed on the horizontal portion of the top cable tray over to the concrete wall section above the embedded sleeves. The panel was pre-caulked and butted to the concrete wall. A Thermo-Lag 330-1 Flat Panel was installed on the underside of the horizontal portion of the bottom cable tray. This panel was scored and grooved creating two "hinged" portions to facilitate extension of the panel to the concrete wall section below the embedded sleeves. This panel was also pre-caulked and butted to the concrete wall. The side portions of the box assembly were constructed of V-rib panels installed between the top and bottom tray envelopes, extending to and similarly butted to the concrete wall section on either side of the embedded sleeves. The V-ribs of the side portions of the box assembly were oriented vertically. The front portion of the box assembly consisted of the individual V-rib panels installed on the side rails of the top and bottom cable tray horizontal runs and a single V-rib panel piece bridging the coverage of the top and bottom panel side rails.

The joints associated with the box assembly were reinforced with trowel grade and stress skin. Additionally, to reinforce the box assembly at the concrete wall interface, an approximate 2 1/4 in. wide stress skin piece was wrapped around the entire perimeter of the enclosure immediately adjacent to the wall secured in place with staples and covered with a Trowel Grade skim coat. To secure the box enclosure to the concrete wall surface, a separate stress skin wrap was installed around the perimeter extending approximately 3 in. onto all sides of the box assembly, stapled to the underlying Thermo-Lag panels and then flared out onto the concrete surface for an approximate 2 in. distance. Trowel Grade material was then applied over the stress skin and 2 in. wide 330-1 Flat panels strips installed in a "picture frame" fashion over the stress skin portion which flared onto the concrete surface using 1/4 in. dia. x 3 1/4 in. long "Hilti" bolts spaced at approximate 10 in. intervals.

To reinforce butt joints between panels installed on the undersides of the top and bottom cable trays and panels covering horizontal support members, 2 in wide Flat Panel strips were secured to the panels on the supports using #12 x 11/4 in. long screws. Thus, butt joints

between panels on the tray undersides and those installed on the horizontal support members were effectively covered by the 2 in. Flat Panel strips.

Finally, a layer of 350 Topcoat was applied to the completed barrier assembly over all exposed surfaces where 330-1 Trowel Grade material was used to cover stress skin areas.

All joints were "pre-buttered" and banding (wires) was installed in accordance with Reference 10.14.1 (non upgraded design). Thermo-Lag 330-1 prefabricated panels were inspected prior to shipment from the vendor and weight was verified upon receipt per Reference 10.14.1.

A11C.3 ASTM E-119 Standard Time Temperature

The Thermo-Lagged test article was exposed to the standard time-temperature curve of ASTM E-119 for 1 hour.

A11C.4 Temperature Review

Reference 10.22.1 specifies that the transmission of heat through the fire barrier during the fire endurance test shall not have been such as to raise the average temperature on the exposed conduit surface more than 250°F above its initial temperature. Reference 10.22.1 further states that no single temperature rise shall exceed 30% of the average specified limit or 325°F. If either of these temperatures is exceeded then visual cable inspections and IR cable tests are required to demonstrate the cables are free of fire damage.

The ambient air temperature at the start of the test was 91°F.

The maximum average temperature would be equal to 250°F plus ambient. For this test the maximum average temperature would equal 341°F.

The maximum individual temperature would be equal to 325°F plus ambient. For this test the maximum test the maximum individual temperature would equal 416°F.

The peak temperature on the bare #8 AWG copper conductor within the air drop box reached 287°F and the average reached 251°F.

The peak temperature on an individual cable in the air drop box reached 241°F and the average reached 231°F.

The peak temperature on an individual cable in the cable trays reached 311°F and the average reached 242°F.

The peak temperature on the tray front rail reached 322°F and the average reached 255°F.

The peak temperature on the tray rear rail reached 335°F and the average reached 257°F.

All of the thermocouples in the 24" cable trays, and the air drop box met the maximum and average temperature criteria.

A11C.5 Hose Stream Test

Following the exposure fire, the test article was subjected to a 5 minute hose stream test utilizing a 1-1/2 in. diameter fog nozzle set at a discharge angle of 30° with a nozzle pressure of 75 psi at a distance of 5 feet. The minimum flow rate from the nozzle was 75 gpm.

After the hose stream test a visual inspection of the fire barrier was conducted. There was no burn through or openings in the fire barrier envelope as a result of the thermal effects of the fire exposure. The stress skin upgrade applied to the lower rear tray rail was hanging loosely from the assembly. Following the hose stream test the Thermo-Lag pieces remained affixed and the stainless steel banding was sagging from the assemblies. The panel joint located behind the stress skin that was sagging prior to the hose stream test had opened allowing the tray within to be visible.

A11C.6 Insulation Resistance Testing

As an additional check on the condition of the conductor insulation, insulation resistance testing was performed on each cable type before the fire and after the hose stream test. The insulation resistance tests were performed using TU Electric owned and calibrated adjustable megohm meter, set to the 500 volt DC level for insulation resistance testing on all instrumentation cables and the 1500 volt DC level for all power and control cables. To perform the insulation resistance test, the connection to ground was broken for each cable type and the test instrument leads connected from conductor to conductor and from each conductor to ground. Any leakage between the cable type's conductors and ground, or from conductor to conductor, is readily detected in this manner. Upon discovery of an ohmic reading which is lower than the criteria set in the October 29, 1992, NRC letter (Reference 10.22.1), the reading will be documented in the test report and the splices between cables will be broken and each cable tested separately to determine which cable conductor is bad or if there is a bad splice or test lead. Provided the low reading is on a cable, that cable will be removed from the raceway and visually examined to determine where and how the failure occurred.

The cables were meggered after the hose stream test and the results of the IR tests were well within the allowable limits for all assemblies tested.

No apparent thermal cable damage was noted in the air drop box or the inner (top) cable tray. In the outer (lower) tray, most W-020 power cable jackets were swollen and "ballooned" considerably in the left vertical cable tray section and the cables were slightly discolored (cable jackets tinted gray) and slightly stiffened. The remainder of the cable length was still flexible and visibly undamaged. This jacket swelling is discussed further in Section 4.5.5. However, based on the barrier opening, additional reinforcement of these envelopes was implemented for Unit 1 configurations.[1]

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[1] see appendix F for additional details

A11C.7 Comments

The box design air drop assembly, as well as both of the 24 in. cable tray assemblies, clad in a nominal 1/2 in. thickness Thermo-Lag 330-1 material with upgrades presented herein, met the requirements for a fire resistance rating of one hour, as described below.

The assembly, as tested, met the acceptance criteria contained in the NRC letter dated October 29, 1992 (Reference 10.22.1), for the following parameters: 1) single point and average temperature increase parameters were not exceeded, 2) the barrier opened during the hose stream test, but a visual cable inspection revealed no apparent thermal damage to the conductor insulation (see Section 4.5.5 for a further discussion of the power cable jacket swelling), and 3) the results of the insulation resistance tests were well within the allowable limits.

A11D Omega Point Test No. 12340-95768, Scheme 11-5

The fire endurance test documented in Reference 10.12.18 was conducted at Omega Point Laboratories on August 11, 1993 and the test report was issued on August 27, 1993. The fire endurance test, hose stream test and cable functionality (Insulation Resistance) tests were performed to the requirements of the NRC letter dated October 29, 1992 (Reference 10.22.1). Due to the time required (approximately 30 minutes) to conduct the insulation resistance (IR) tests on multi-conductor instrument cable, IR tests were not conducted during the fire endurance tests.

A11D.1 Test Article

Scheme 11-5 consisted of three parallel 24 in. wide ladderback cable trays each assembled into an "L shaped" configuration which extended down through the horizontal upper deck then out through the front deck wall utilizing a ladderback 90° vertical fitting to transition from vertical to horizontal. The bottom of each tray was 36 in. down from the deck and the vertical tray was 72 in. from the front deck wall where the tray exited the furnace. The trays were approximately 12 in. apart in the furnace.

Each tray was independently supported internally by a trapeze type hanger utilizing 3" steel channels bolted together.

An approximate 1/3 mix of Power, Instrumentation and Control cables were pulled into each tray maintaining a single layer.

Each tray penetration through the deck was individually sealed with silicone foam and all three trays went through a single blockout in the front deck wall and it was also sealed with silicone foam. Internal silicone elastomer (Promatec 45B) seals were placed in each tray at the deck and the front wall.

A11D.2 TSI Thermo-Lag Protective Envelope Materials and Enclosure

The support members were covered first using flat Thermo-Lag 330-1 panel material for a distance of approximately 9 in. to 11 in. from the cable trays. All joints were pre-caulked

with Thermo-Lag 330-1 Trowel Grade material and secured in place with stainless steel tie wires. The remainder of all supports were left exposed.

Prior to installing panels on the trays, the horizontal run of each tray was pre-banded using stainless steel banding wrapped completely around the tray perimeters at 12 in. intervals.

All portions of the each cable tray were covered with Thermo-Lag 330-1 V-Ribbed panels except where trays penetrated through the silicone foam blockout, whereby flat panels were installed on tray top and bottom surfaces. The flat panel coverage extended onto the horizontal tray sections for a distance of approximately 3 in. from the blockout seal.

Panels were installed such that the side radial panels were effectively sandwiched between the top and bottom panels, and thereby placed into compression when the external banding was tightened. The panels installed on inside surfaces on the radial bends were scored to a depth of 1/4 in., perpendicular to the raceway, at 2 in. intervals to allow for curvature. The panels installed on the outside of the radial bends were similarly scored, at 3 in. intervals. All joints between panels and the seams in scored areas were pre-caulked with Thermo-Lag 330-1 Trowel Grade material and were secured in place with stainless steel banding. Banding was installed within 2 in. on either side of butt joints occurring on top or bottom panels. The maximum band spacing was 12 in. o.c., but to prevent this distance from being exceeded, in some instances bands were spaced closer. On radial bends, one band was installed around each scored section. A minimum of one band (2 bands maximum) was also installed around the tray envelopes where panel pieces were used to cover splice plates on the tray side rails.

A different technique for reinforcing joints between panels and/or providing additional thermal protection was installed on each cable tray assembly.

- The cable tray installed on the right side of the test deck utilized a stress skin overlap of the longitudinal joints along the tray sides. Specifically, following completion of the "baseline" protective envelope described above, an approximately 3/16 in. thick layer of Thermo-Lag 330-1 Trowel Grade material was applied along the side rail panels overlapping onto the top and bottom panels by approximately 5 in. Next, "U" shaped 330-60 stress skin pieces were installed over the areas where trowel grade material was applied. The stress skin pieces were secured in place with 9/16 in. long staples and then an approximate 1/16 in. skim coat layer of trowel grade material was applied over the stress skin. To reinforce butt joints between bottom panels and Thermo-Lag panels covering the horizontal support member, a 2 in. wide flat panel was secured to the "baseline" panels on the member using either #12 x 1-1/4 in. screws or 1 in. long staples. Such panel strips were installed on either wide of the support coverage and they extended the full width of the tray protective envelope. Thus, the butt joint between the baseline panels on the tray bottom and those installed on the bottom support member was effectively covered by the 2 in. wide flat panel strip. Finally, a layer of 350 Topcoat was applied to the completed envelope over all areas where 330-1 Trowel Grade material was used.

- The cable tray installed in the center of the test deck utilized 1 in. wide Nextel ceramic fiber bands wrapped circumferentially around the exterior of the "baseline" panels to structurally reinforce the protective envelope. The ceramic bands were installed in the immediate vicinity of the bottom panel butt joint and the panels on the bottom support member on both sides of the support. Ceramic bands were also installed on approximate 24 in. centers as measured along the bottom surface of the protective envelope. The ceramic banding was held in place by passing the two ends of the wrap through a double "D" ring assembly and tightening the wrap securely by hand. The ceramic banding was installed after 350 Topcoat had been applied in areas where 330-1 Trowel Grade material was used.

- The cable tray installed on the left side of the test deck utilized a 6 in. wide circumferential stress skin wrap around the exterior of the baseline panels such that butt joints on the top and bottom panels were overlapped by 3 in. on each side. Similar 6 in. wide stress skin wraps were also installed on both sides of the butt joints between bottom panels and the panels covering the bottom support member. An approximate 3/16 in. thick layer of Thermo-Lag 330-1 Trowel-Grade was applied over the "baseline" panels prior to installing the circumferential stress skin wrap. The stress skin was secured in place with 9/16 in. long staples and then an approximate 1/16 in. thick skim coat of trowel grade was applied over the stress skin. Finally, a layer of 350 Topcoat was applied to the completed envelope over all areas where 330-1 Trowel Grade was used.

The V-ribbed panels were oriented identically on all cable trays. Specifically, panels were installed on tray top and bottom surfaces, including radial bends, with the V-ribs oriented perpendicular to the tray side rails. In the horizontal tray sections, panels were installed on the side rails with the V-ribs oriented vertically. Through the radial bends, the rib orientation transitioned such that on the vertical tray riser sections the panels installed on the side rails had V-ribs oriented horizontally.

All joints were "pre-buttered", and banding (wires) was installed in accordance with Reference 10.14.1. The Thermo-Lag 330-1 prefabricated panels were inspected prior to shipment from the vendor and weights were verified upon receipt per Reference 10.14.1.

A11D.3 ASTM E-119 Standard Time Temperature

The Thermo-Lagged test article was exposed to the standard time-temperature curve of ASTM E-119 for 1 hour.

A11D.4 Temperature Review

Reference 10.22.1 specifies that the transmission of heat through the fire barrier during the fire endurance test shall not have been such as to raise the average temperature on the exposed conduit surface more than 250°F above its initial temperature. Reference 10.22.1 further states that no single temperature rise shall exceed 30% of the average specified limit or 325°F. If either of these temperatures is exceeded then visual cable inspections and IR cable tests are required to demonstrate the cables are free of fire damage.

The ambient air temperature at the start of the test was 92°F.

The maximum average temperature would be equal to 250°F plus ambient. For this test the maximum average temperature would equal 342°F.

The maximum individual temperature would be equal to 325°F plus ambient. For this test the maximum test the maximum individual temperature would equal 417°F.

On the right cable tray

Peak temperature on the cables reached 336°F and the average reached 302°F.

Peak temperature on the right tray rail reached 311°F and the average reached 270°F.

Peak temperature on the left tray rail reached 362°F and the average reached 293°F.

On the center cable tray

Peak temperature on the cables reached 414°F and the average reached 339°F.

Peak temperature on the right tray rail reached 468°F and the average reached 358°F.

Peak temperature on the left tray rail reached 467°F and the average reached 371°F.

On the left cable tray

Peak temperature on the cables reached 385°F and the average reached 284°F.

Peak temperature on the right tray rail reached 549°F and the average reached 340°F.

Peak temperature on the left tray rail reached 425°F and the average reached 323°F.

All thermocouples on the right 24" cable tray and all but the cable tray side rails of the center and left cable trays met the maximum and average temperature criteria.

A11D.5 Hose Stream Test

Following the exposure fire, the test article was subjected to a 5 minute hose stream test utilizing a 1-1/2 in. diameter fog nozzle set at a discharge angle of 30° with a nozzle pressure of 75 psi at a distance of 5 feet. The minimum flow rate from the nozzle was 75 gpm.

After the hose stream test a visual inspection of the fire barrier was conducted. There was no burn through or openings in the fire barrier envelope for the right and center trays. The left tray had a barrier opening along with subsequent damage to the outer cable jacket.

A11D.6 Insulation Resistance Testing

As an additional check on the condition of the conductor insulation, insulation resistance testing was performed on each cable type before the fire and after the hose stream test. The insulation resistance tests were performed using TU Electric owned and calibrated adjustable megohm meter, set to the 500 volt DC level for insulation resistance testing on all instrumentation cables and the 1500 volt DC level for all power and control cables. To perform the insulation resistance test, the connection to ground was broken for each cable type and the test instrument leads connected from conductor to conductor and from each conductor to ground. Any leakage between the cable type's conductors and ground, or from conductor to conductor, is readily detected in this manner. Upon discovery of an ohmic reading which is lower than the criteria set in the October 29, 1992, NRC letter (Reference 10.22.1), the reading will be documented in the test report and the splices between cables will be broken and each cable tested separately to determine which cable conductor is bad or if there is a bad splice or test lead. Provided the low reading is on a cable, that cable will be removed from the raceway and visually examined to determine where and how the failure occurred.

Most W-020 power cable jackets were swollen and "ballooned" considerably in the horizontal cable tray sections, due to softening of the outer jacket material and pressure build-up within the cable. The thermocoupled power cables suffered more severe swelling due to the multiple constrictions placed on the jacket by the glass-fiber electrical tape spaced 6 in. o.c. Most swollen cables lost pressure after cooling, with the jackets remaining stretched and oversized. No apparent thermal cable damage was noted on the right and center trays. On the left cable tray, thermal cable damage was noted across the underside of the cable tray approximately 12 in. from the front deck wall. All nylon tie wraps were melted on the second rung from the wall. Many of the outer cable jackets were charred and split. A greenish-blue residue was noted on some of the control cables (melted fiber filler material). The cable's inner conductor insulation had no visible thermal damage. No thermal damage extended to the top of the tray cables.

The cables were meggered after the hose stream test and the results of the IR test were within the allowable limits for all assemblies tested.

A11D.7 Comments

All three of the 24 in. cable tray assemblies, clad in a nominal 1/2 in. thickness Thermo-Lag 330-1 material with upgrades presented herein, met the requirements for a fire resistance rating of one hour, as described below.

Although single point and average temperature increase parameters were exceeded on the left cable tray assembly and a barrier opening was present (along with subsequent damage to the outer cable jackets), the assembly met the acceptance criteria contained in the NRC letter dated October 29, 1992 (Reference 10.22.1), for the following parameters: 1) visual cable inspection revealed no apparent thermal damage to the conductor insulation (see Section 4.5.5 for a further discussion of the power cable jacket swelling), and 2) the results of the insulation resistance tests were well within the allowable limits.

The right cable tray experienced no deviations from the acceptance criteria contained in Reference 10.22.1, specifically 1) single point and average temperature increase parameters were not exceeded, 2) no barrier openings or burn through occurred, 3) visual cable inspection revealed no apparent thermal damage (see Section 4.5.5 for a further discussion of the power cable jacket swelling), and 4) insulation resistance test results were well within allowable limits.

The center cable tray exceeded single point and average temperature increase parameters for the tray side rails, however the assembly met acceptance criteria for the following parameters: 1) visual inspection revealed no barrier opening or burn through, 2) visual cable inspection revealed no apparent thermal damage, and 3) the insulation resistance tests were all within allowable limits (see Section 4.5.5 for a further discussion of the power cable jacket swelling).

<u>A12A Omega Point Test No. 12340-94367i - Scheme 12-1</u>

The fire endurance test documented in Reference 10.12.19 was conducted at Omega Point Laboratories on November 12, 1992, and the test report was issued on December 16, 1992. The fire endurance test, hose stream test and cable functionality (Insulation Resistance) tests were performed to the requirements of the NRC letter dated October 29, 1992 (Reference 10.22.1). Due to the time required (approx. 30 minutes) to conduct the insulation resistance (IR) tests on multi-conductor instrument cable, IR tests were not conducted during the fire endurance tests.

A12A.1 Test Article

Scheme 12-1 consisted of a 30" wide x 4" deep ladderback tray installed in a U shape. The article was installed so that the bottom of the tray was approximately 3 ft below the test deck. A 1/3 by fill mix of power, control and instrumentation cables were installed in the tray, maintaining a single layer.

The assembly was supported internally by two trapeze type hangers using 3" channels bolted together.

The vertical tray sections were sealed at the test deck using a silicone foam.

A12A.2 TSI Thermo-Lag Protective envelope Materials and Enclosure

1/2" (nominal) thick Thermo-Lag 330-1 V-ribbed prefabricated panels with stress skin on the inside were installed on the cable tray in accordance with Reference 10.14.2. The corner joints were reinforced with trowel grade and stress skin and the butt joints were reinforced with "stitching" trowel grade and stress skin.

1/2" (nominal) thick Thermo-Lag 330-1 prefabricated flat panels with stress skin on the inside were installed on the supports to a distance of approximately 9 in. from the tray in accordance with Reference 10.14.2 for protruding items.

The V-ribs were installed perpendicular to the rails on the top (inside) panels on the tray and parallel to the rails on the sides and bottom (outside).

The 90° radial bend top and bottom panels were installed using the scored and grooved method. The top and bottom panels have scores spaced about 2 in. apart.

A12A.3 ASTM E-119 Standard Time-Temperature

The Thermo-Lagged test article was exposed to the standard time-temperature curve of ASTM E-119 for 1 hour.

A12A.4 Temperature Review

Reference 10.22.1 specifies that the transmission of heat through the fire barrier during the fire endurance test shall not have been such as to raise the average temperature on the exposed conduit surface more than 250°F above its initial temperature. Reference 10.22.1 further states that no single temperature rise shall exceed 30% of the average specified limit or 325°F. If either of these temperatures is exceeded then visual cable inspection and IR cable tests are required to demonstrate the cables are free of fire damage.

The ambient air temperature at the start of the test was 71°F.

The maximum average temperature would be equal to 250°F plus ambient. for this test the maximum average temperature would equal to 321°F.

The maximum individual temperature would be equal to 325°F plus ambient. For this test the maximum individual temperature would equal 396°F.

The peak temperature on an individual cable reached 311°F and the average reached 238°F.

The peak temperature on the front rail reached 363°F and the average reached 270°F.

The peak temperature on the rear rail reached 343°F and the average reached 273°F

A12A.5 Hose Stream Test

Following the exposure fire, the test article was subjected to a 5 minute hose stream test utilizing a 1-1/2 in. diameter fog nozzle set at a discharge angle of 30% with a nozzle pressure of 75 psi (this Elkhart nozzle is rated at 88 gpm at 75 psi). The nozzle distance was maintained at 5 ft perpendicular from the outside surface of the test article.

After the hose stream test a visual inspection of the fire barrier was conducted. There was no burn through of the fire barrier.

A12A.6 Electrical Circuit Monitoring Test

At no time during the fire endurance test or hose stream test did the electrical circuit monitoring system identify any shorts, shorts-to-ground, or open circuits (loss of continuity) on any of the monitored circuits.

Although not required, the cables were visually inspected after the hose stream test. There was no sign of cable degradation. There was some cable stiffening which is acceptable and is discussed in section 4.4 of this report.

The cables were meggered after the hose stream test and all the cables passed the IR tests. In fact, the majority of the cables showed no reduction of the insulation resistance from the readings taken before the test.

A12A.7 Comments

Thermo-Lag material performed adequately.

The reinforced joint designs provide an adequate upgrades to the Thermo-Lag design and this test confirms those designs.

Cable temperatures were enveloped by the CPSES LOCA temperature qualifications.

A12B Omega Point Test No. 12340-94367h - Scheme 12-2

The fire endurance test documented in Reference 10.12.20 was conducted at Omega Point Laboratories on November 11, 1992, and the test report was issued on December 16, 1992. The fire endurance test, hose stream test and cable functionality (Insulation Resistance) tests were performed to the requirements of the NRC letter dated October 29, 1992 (Reference 10.22.1). Due to the time required (approx 30 minutes) to conduct the insulation resistance (IR) tests on multi-conductor instrument cable, IR tests were not conducted during the fire endurance tests.

A12B.1 Test Article

Scheme 12-2 consisted of a 24" wide x 4" deep ladderback tray with a horizontal tee section mid span installed in a U shape. The article was installed so that the bottom of the tray was approximately 3 ft below the test deck. A 1/3 fill mix of power, control and instrumentation cables were installed in the tray, maintaining a single layer.

The assembly was supported internally by two trapeze type hangers using 3" channels bolted together.

The vertical tray sections were sealed at the test deck using a silicone foam.

A12B.2 TSI Thermo-Lag Protective Envelope Materials and Enclosure

1/2" (nominal) thick Thermo-Lag 330-1 V-ribbed prefabricated panels with stress skin on the inside were installed on the cable tray in accordance with Reference 10.14.2. The corner

joints were reinforced with trowel grade Thermo-Lag and stress skin and the butt joints were reinforced with "stitching", trowel grade Thermo-Lag and stress skin.

1/2" (nominal) thick Thermo-Lag 330-1 prefabricated flat panels with stress skin on the inside were installed on the supports to a distance of approximately 9 in. from the tray in accordance with Reference 10.14.2 for protruding items.

The V-ribs were installed perpendicular to the rails on the top (inside) panels on the tray and parallel to the rails on the sides and bottom (outside).

The 90° radial bend top and bottom panels were installed using the scored and grooved method. The top and bottom panels had scores space about 2 in. apart.

All joints were "pre-buttered", and banding (wires) was installed in accordance with Reference 10.14.1 (non-upgraded design). Thermo-Lab 330-1 prefabricated panels were inspected prior to shipment from the vendor and weight was verified upon receipt per Reference 10.14.1.

A12B.3 ASTM E-119 Standard Time-Temperature

The Thermo-Lagged test article was exposed to the standard time-temperature curve of ASTM E-119 for 1 hour.

A12B.4 Temperature Review

Reference 10.22.1 specifies that the transmission of heat through the fire barrier during the fire endurance test shall not have been such as to raise the average temperature on the exposed conduit surface more than 250°F above its initial temperature. Reference 10.22.1 further states that no single temperature rise shall exceed 30% of the average specified limit or 325°F. If either of these temperatures is exceeded then visual cable inspection and IR cable tests are required to demonstrate the cables are free of fire damage.

The ambient air temperature at the start of the test was 67°F.

The maximum average temperature would be equal to 250°F plus ambient. For this test the maximum average temperature would equal to 317°F.

The maximum individual temperature would be equal to 325°F plus ambient. For this test the maximum individual temperature would equal 392°F.

The peak temperature on an individual cable reached 280°F and the average reached 244°F.

The peak temperature on the front rail reached 353°F and the average reached 287°F.

The peak temperature on the rear rail reached 332°F and the average reached 277°F.

A12B.5 Hose Stream Test

Following the exposure fire, the test article was subjected to a 5 minute hose stream test utilizing a 1-1/2 in. diameter fog nozzle set at a discharge angle of 30% with a nozzle pressure of 75 psi (this Elkhart nozzle is rated at 88 gpm at 75 psi). The nozzle distance was maintained at 5 ft perpendicular from the outside surface of the test article.

After the hose stream test a visual inspection of the fire barrier was conducted. There was no burn through of the fire barrier, however during the hose stream test the Thermo-Lag panel, below the fire stop (seal) in the tee, sagged down providing an opening between the panel and the fire stop.

A12B.6 Electrical Circuit Monitoring Test

At no time during the fire endurance test or hose stream test did the electrical circuit monitoring system identify any shorts, shorts-to-ground, or open circuits (loss of continuity) on any of the monitored circuits.

The cables were visually inspected after the hose stream test. There was no sign of cable degradation.

The cables were meggered after the hose stream test and all the cables passed the IR tests. In fact the majority of the cables showed no reduction of the insulation resistance from the readings taken before the test.

A12B.7 Comments

Thermo-Lag material performed adequately.

The reinforced joint designs provide an adequate upgrade to the Thermo-Lag design and this test confirms those designs.

The fire stop detail was changed and was tested satisfactorily in scheme 14-1.

Cable temperatures were enveloped by the CPSES LOCA temperature qualifications.

<u>A13A Omega Point Test No. 12340-943671 - Scheme 13-1</u>

The fire endurance test documented in Reference 10.12.21 was conducted at Omega Point Laboratories on November 12, 1992, and the test report was issued on December 9, 1992. The fire endurance test, hose stream test and cable functionality (Insulation Resistance) tests were performed to the requirements of the NRC letter dated October 29, 1992 (Reference 10.22.1). Due to the time required (approx. 30 minutes) to conduct the insulation resistance (IR) tests on multi-conductor instrument cable, IR tests were not conducted during the fire endurance tests.

A13A.1 Test Article

Scheme 13-1 consisted of a 12" wide x 4" deep ladderback tray installed in a U shape. The article was installed so that the bottom of the tray was approximately 3 ft below the test deck. A 1/3 fill mix of power, control and instrumentation cables were installed in the tray, maintaining a single layer.

The assembly was supported internally by two trapeze type hangers using 3" channels bolted together.

The vertical tray sections were sealed at the test deck using a silicone foam.

A13A.2 TSI Thermo-Lag Protective Envelope Materials and Enclosure

1/2" (nominal) thick Thermo-Lag 330-1 V-ribbed prefabricated panels with stress skin on the inside were installed on the cable tray in accordance with Reference 10.14.2. The corner joints were reinforced with trowel grade Thermo-Lag and stress skin.

1/2" (nominal) thick Thermo-Lag 330-1 prefabricated flat panels with stress skin on the inside were installed on the supports to a distance of approximately 9 in. from the tray in accordance with Reference 10.14.2 for protruding items.

The V-ribs were installed perpendicular to the rails on the top (inside) panels on the tray and parallel to the rails on the sides and bottom (outside).

The 90° radial bend top and bottom panels were installed using the scored and grooved method. The top and bottom panels had scores spaced about 2 in. apart.

All joints were "pre-butters", and banding (wires) was installed in accordance with Reference 10.14.1 (non-upgraded design). Thermo-Lab 330-1 prefabricated panels were inspected prior to shipment from the vendor and weight was verified upon receipt per Reference 10.14.1.

A13A.3 ASTM E-119 Standard Time-Temperature

The Thermo-Lagged test article was exposed to the standard time-temperature curve of ASTM E-119 for 1 hour.

A13A.4 Temperature Review

Reference 10.22.1 specifies that the transmission of heat through the fire barrier during the fire endurance test shall not have been such as to raise the average temperature on the exposed conduit surface more than 250°F above its initial temperature. Reference 10.22.1 further states that no single temperature rise shall exceed 30% of the average specified limit or 325°F. If either of these temperatures is exceeded then visual cable inspection and IR cable tests are required to demonstrate the cables are free of fire damage.

The ambient air temperature at the start of the test was 68°F.

The maximum average temperature would be equal to 250°F plus ambient. For this test the maximum average temperature would equal to 318°F.

The maximum individual temperature would be equal to 325°F plus ambient. For this test the maximum individual temperature would equal 393°F.

The peak temperature on an individual cable reached 265°F and the average reached 220°F.

The peak temperature on the front rail reached 330°F and the average reached 285°F.

The peak temperature on the rear rail reached 324°F and the average reached 271°F.

A13A.5 Hose Stream Test

Following the exposure fire, the test article was subjected to a 5 minute hose stream test utilizing a 1-1/2 in. diameter fog nozzle set at a discharge angle of 30% with a nozzle pressure of 75 psi (this Elkhart nozzle is rated at 88 gpm at 75 psi). The nozzle distance was maintained at 5 ft perpendicular from the outside surface of the test article.

After the hose stream test a visual inspection of the fire barrier was conducted. There was no burn through of the fire barrier.

A13A.6 Electrical Circuit Monitoring Test

At no time during the fire endurance test or hose stream test did the electrical circuit monitoring system identify any shorts, shorts-to-ground, or open circuits (loss of continuity) on any of the monitored circuits.

Although not required, the cables were visually inspected after the hose stream test. There was no sign of cable degradation.

The cables were meggered after the hose stream test and all the cables passed the IR tests. In fact the majority of the cables showed no reduction of the insulation resistance from the readings taken before the test.

A13A.7 Comments

Thermo-Lag material performed adequately.

The reinforced joint designs provide an adequate upgrades to the Thermo-Lag design and this test confirms those designs.

Cable temperatures were enveloped by the CPSES LOCA temperature qualifications.

A13B Omega Point Test No. 12340-95769 - Scheme 13-2

The fire endurance test documented in Reference 10.12.22 was conducted at Omega Point Laboratories on August 12, 1993, and the test report was issued on August 23, 1993. The

fire endurance test, hose stream test and cable functionality (Insulation Resistance) tests were performed to the requirements of the NRC letter dated October 29, 1992 (Reference 10.22.1). Due to the time required (approximately 30 minutes) to conduct the insulation resistance (IR) tests on multi-conductor instrument cable, IR tests were not conducted during the fire endurance tests.

A13B.1 Test Article

Scheme 13-2 consisted of one 12" wide ladderback cable tray and a 2" conduit each installed in a "U" shaped configuration side by side 20 in. apart. The conduit extended down through the test deck with each vertical leg transitioning to the horizontal with a radial bend. The cable tray extended down through the test deck with each vertical leg transitioning to the horizontal with a ladderback 90° vertical fitting. The bottom of the horizontal sections of both tray and conduit was 36" down from the test deck.

The cable tray was supported internally by two trapeze type hangers using 3" steel channels bolted together. The conduit was supported internally by two unistrut hangers consisting of a vertical piece which was attached with a conduit clamp.

An approximate 1/3 mix of Power, Instrumentation and Control cables were pulled into tray and conduit. The cables in the tray maintained a single layer and occupied about 15% of the total tray area. The cables in the conduit occupied about 44% of the total conduit area.

The blockout in the test deck for the tray and conduit was sealed with silicone foam and the internal trays and conduits was sealed with a silicone elastomer.

A13B.2 TSI Thermo-Lag Protective Envelope Materials and Enclosures

The entire tray was covered with Thermo-Lag 330-1 V-Ribbed panels on the top, bottom and sides of the tray. In each case, the side panels were placed into compression whereby once the banding is applied and tightened, the side panels were sandwiched by the top and bottom panels. The V-ribbed panels applied to the inside surfaces of the radial bends were scored to a depth of 1/4 in., perpendicular to the raceway, at 3 to 4 in. intervals to allow for curvature. The V-ribbed panels installed on the outside of the radial bends were scored to a depth of 1/4 in., perpendicular to the raceway, at 4 in. intervals to allow for curvature. All joints, seams and scored grooves were pre-caulked with Thermo-Lag 330-1 Trowel Grade material and all panels were secured in place using the stainless steel bands spaced at 12 in. maximum intervals.

After the entire tray assembly was clad, the support members were covered with flat Thermo-Lag 330-1 panel material for a distance of approximately 9 in. as measured from the tray protective envelope. All joints and seams were pre-caulked with Thermo-Lag 330-1 Trowel-Grade material, then secured in place using 16 stainless steel tie wire (on the inside layer of panels), and 1/2 in. wide x 0.020 in. thick Type 304 stainless steel banding straps.

The rigid conduit was covered prior to installing material on the support members using 1/2 in. nominal thickness Thermo-Lag 330-1 Pre-Shaped Conduit Material. All joint, seams and built-up areas were pre-caulked with 330-1 Trowel Grade Material and secured in place with

stainless steel tie wire and metal banding material. The Thermo-Lag 330-1 Pre-Shaped Conduit Material applied to the radial conduit bends was miter cut and fit to the conduit as individual segments. The seams between these segments were pre-caulked prior to installation.

The Unistrut support members were covered with Thermo-Lag Flat Panel material for a 9 in. distance extending from the closest Thermo-Lag Pre-Shaped section leaving the remaining UniStrut support steel surface unprotected from the fire source.

Finally, after allowing the Thermo-Lag material to cure, all areas on the cable tray and 1/2 of the area on the conduit where 330-1 Trowel Grade material was applied, were coated with a layer of 350 Topcoat.

No upgrade techniques were applied to the cable tray protective envelope. However, to qualify the 350-5000-10 Topcoat Formulation in fire endurance tests, 1/2 of the cable tray protective enve'oped was coated with this Topcoat over the existing layer of 350 Topcoat which had been previously applied over areas where 330-1 Trowel Grade material was installed.

In the conduit radial bend areas, an approximate 3/16 in. thick layer of 330-1 Trowel Grade material was applied over the mitered pre-shaped conduit section pieces. A single layer of type 304 stainless steel mesh was then wrapped around the radial bends and secured in place with stainless steel tie wire. Next, an approximate 1/16 in. thick layer of 330-1 Trowel Grade material was applied over the stainless steel to fill in any void areas within the mesh network.

Finally, following cure of the Thermo-Lag materials, the remaining portion of the conduit protective envelope was coated with a layer of Thermo-Lag 350-5000-10 Topcoat in areas where Thermo-Lag 330-1 Trowel-Grade material had been applied.

The V-ribs were installed perpendicular to the rails on the top and bottom of the horizontal tray run and on both the inside and the outside of the radial bend. Panels installed against tray side rails in the horizontal run were positioned with the V-ribs oriented vertically. Panels installed against the tray side rials in the radial bends and vertical tray section had V-ribs oriented horizontally.

All joints were "pre-buttered" and banding was installed was installed in accordance with Reference 10.14.1. The Thermo-Lag 330-1 prefabricated panels were inspected prior to shipment from the vendor and weight was verified upon receipt per Reference 10.14.1.

A13B.3 ASTM E-119 Standard Time Temperature

The Thermo-Lagged test article was exposed to the standard time-temperature curve of ASTM E-119 for 1 hour.

A13B.4 Temperature Review

Reference 10.22.1 specifies that the transmission of heat through the fire barrier during the fire endurance test shall not have been such as to raise the average temperature on the exposed conduit surface more than 250°F above its initial temperature. Reference 10.22.1 further states that no single temperature rise shall exceed 30% of the average specified limit or 325°F. If either of these temperatures is exceeded then visual cable inspections and IR cable tests are required to demonstrate the cables are free of fire damage.

The ambient air temperature at the start of the test was 92°F.

The maximum average temperature would be equal to 250°F plus ambient. For this test the maximum average temperature would equal 342°F.

The maximum individual temperature would be equal to 325°F plus ambient. For this test the maximum test the maximum individual temperature would equal 417°F.

On the cable tray:

Peak temperature on an individual cable reached 396°F and the average reached 328°F.

Peak temperature on the front tray rail reached 447°F and the average reached 380°F.

Peak temperature on the rear tray rail reached 442°F and the average reached 376°F.

On the conduit:

Peak temperature on an individual cable reached 351°F and the average reached 254°F.

Peak temperature on the conduit surface reached 546°F and the average reached 366°F.

Of the thermocouples in the 12 in. cable tray and the 2 in. conduit, all but the cable tray side rails and conduit surface thermocouples met the maximum and average temperature criteria.

A13B.5 Hose Stream Test

Following the exposure fire, the test article was subjected to a 5 minute hose stream test utilizing a 1-1/2 in. diameter fog nozzle set at a discharge angle of 30° with a nozzle pressure of 75 psi at a distance of 5 feet. The minimum flow rate from the nozzle was 75 gpm.

After the hose stream test a visual inspection of the fire barrier was conducted. Internal barrier stress skin was visible in a small patch on the bottom panel of the cable tray adjacent to the rear tray rail and just left of center and in two small patches along the pre-shaped conduit material seam on the rear of the conduit assembly, at the approximate outer quarter points of the overall assembly length.

A13B.6 Insulation Resistance Testing

As an additional check on the condition of the conductor insulation, insulation resistance testing was performed on each cable type before the fire and after the hose stream test. The insulation resistance tests were performed using TU Electric owned and calibrated adjustable megohmmeter, set to the 500 volt DC level for insulation resistance testing on all instrumentation cables and the 1500 volt DC level for all power and control cables. To perform the insulation resistance test, the connection to ground was broken for each cable type and the test instrument leads connected from conductor to conductor and from each conductor to ground. Any leakage between the cable type's conductors and ground, or from conductor to conductor, is readily detected in this manner. Upon discovery of an ohmic reading which is lower than the criteria set in the October 29, 1992, NRC letter (Reference 10.22.1), the reading will be documented in the test report and the splices between cables will be broken and each cable tested separately to determine which cable conductor is bad or if there is a bad splice or test lead. Provided the low reading is on a cable, that cable will be removed from the raceway and visually examined to determine where and how the failure occurred.

The cables were slightly discolored in the central, horizontal portion of the cable tray assembly (cable jackets tinted gray). The cable jackets were slightly stiffened in this area. The remainder of the cable length was still flexible and visibly undamaged. On the conduit, the cables were slightly stiffened in the area around the radial bends. The remainder of the cable length was still flexible and visibly undamaged. Refer to Section 4.4 for cable stifffening evaluation.

A13B.7 Comments

The 12 in. cable tray and the 2 in. diameter conduit assembly, clad in a nominal 1/2 in. thickness Thermo-Lag 330-1 material with upgrades at the conduit radial bends as presented herein, met the requirements, for a fire resistance rating of one hour.

Although the single point temperature increase parameter was exceeded and internal barrier stress skin was visible after the fire and water hose stream exposures (in a small patch on the bottom panel of the cable tray assembly, adjacent to the rear tray rail and just left of center and in two small patches along the pre-shaped conduit material seam on the rear of the conduit assembly, at the approximate outer quarter-points of the overall assembly length), the assembly met the acceptance criteria contained in NRC letter dated October 29, 1992 (Reference 10.22.1), for the following parameters: 1) visual cable inspection revealed no indication of thermal damage, and 2) the results of the insulation resistance tests were well within the allowable limits.

<u>A14 Omega Point Test No. 12340-94367m - Scheme 14-1</u>

The fire endurance test documented in Reference 10.12.23 was conducted at Omega Point Laboratories on December 1, 1992, and the test report was issued on December 16, 1992. The fire endurance test, hose stream test and cable functionality (Insulation Resistance) tests were performed to the requirements of the NRC letter dated October 29, 1992 (Reference 10.22.1). Due to the time required (approx. 30 minutes) to conduct the insulation resistance (IR) tests on multi-conductor instrument cable, IR tests were not conducted during the fire endurance tests.

A14.1 Test Article

Scheme 14-1 consisted of a 30" wide x 4" deep ladderback tray with a horizontal tee section mid span installed in a U shape. The article was installed so that the bottom of the tray was approximately 3 ft below the test deck. A 1/3 fill mix of power, control and instrumentation cables were installed in the tray, maintaining a single layer.

The assembly was supported internally by two trapeze type hangers using 3" channels bolted together.

The vertical tray sections were sealed at the test deck using a silicone foam.

A14.2 TSI Thermo-Lag Protective Envelope Materials and Enclosure

1/2" (nominal) thick Thermo-Lag 330-1 V-ribbed prefabricated panels with stress skin on the inside were installed on the cable tray in accordance with Reference 10.14.2. The corner joints were reinforced with trowel grade Thermo-Lag and stress skin and the butt joints were reinforced with trowel grade Thermo-Lag and stress skin. The butt joints were not "stitched".

1/2" (nominal) thick Thermo-Lag 330-1 prefabricated flat panels with stress skin on the inside were installed on the supports to a distance of approximately 9 in. from the tray in accordance with Reference 10.14.2 for protruding items.

The V-ribs were installed perpendicular to the rails on the top (inside) panels on the tray and parallel to the rails on the sides and bottom (outside).

The 90° radial bend top and bottom panels were installed using the scored and grooved method. The top and bottom panels had scores space about 2 in. apart.

The Thermo-Lag panel under the fire stop in the tee section was screwed into the seal (Promatec 45B) using 14 gage self-tapping screws.

All joints were "pre-buttered", and banding (wires) was installed in accordance with Reference 10.14.1 (non-upgraded design). Thermo-Lag 330-1 prefabricated panels were inspected prior to shipment from the vendor and weight was verified upon receipt per Reference 10.14.1.

A14.3 ASTM E-119 Standard Time-Temperature

The Thermo-Lagged test article was exposed to the standard time-temperature curve of ASTM E-119 for 1 hour.

A14.4 Temperature Review

Reference 10.22.1 specifies that the transmission of heat through the fire barrier during the fire endurance test shall not have been such as to raise the average temperature on the

exposed conduit surface more than 250°F above its initial temperature. Reference 10.22.1 further states that no single temperature rise shall exceed 30% of the average specified limit or 325°F. If either of these temperatures is exceeded then visual cable inspection and IR cable tests are required to demonstrate the cables are free of fire damage.

The ambient air temperature at the start of the test was 70°F.

The maximum average temperature would be equal to 250°F plus ambient. For this test the maximum average temperature would equal to 320°F.

The maximum individual temperature would be equal to 325°F plus ambient. For this test the maximum individual temperature would equal 395°F.

The peak temperature on an individual cable reached 336°F and the average reached 233°F.

The peak temperature on the front rail reached 401°F and the average reached 283°F.

The peak temperature on the rear rail reached 315°F and the average reached 270°F.

A14.5 Hose Stream Test

Following the exposure fire, the test article was subjected to a 5 minute hose stream test utilizing a 1-1/2 in. diameter fog nozzle set at a discharge angle of 30% with a nozzle pressure of 75 psi (this Elkhart nozzle is rated at 88 gpm at 75 psi). The nozzle distance was maintained at 5 ft perpendicular from the outside surface of the test article.

After the hose stream test a visual inspection of the fire barrier was conducted. There was no burn through of the fire barrier.

A14.6 Electrical Circuit Monitoring Test

At no time during the fire endurance test or hose stream test did the electrical circuit monitoring system identify any shorts, shorts-to-ground, or open circuits (loss of continuity) on any of the monitored circuits.

The cables were visually inspected after the hose stream test. There was no sign of cable degradation. There was some cable stiffening which is acceptable and is discussed in section 4.4 of this report.

The cables were meggered after the hose stream test and all the cables passed the IR tests. In fact the majority of the cables showed no reduction of the insulation resistance from the readings taken before the test.

A14B.7 Comments

Thermo-Lag material performed adequately.

The reinforced joint designs provide an adequate upgrades to the Thermo-Lag design and this test confirms those designs.

The revised design attaching the bottom panel to the fire stop performed adequately.

Cable temperatures were enveloped by the CPSES LOCA temperature qualifications.

A15A Omega Point Test No. 12340-951000 - Scheme 15-1

The fire endurance test documented in Reference 10.12.24 was conducted at Omega Point Laboratories on March 4, 1993, and the test report was issued on March 19, 1993. The fire endurance test, hose stream test and cable functionality (Insulation Resistance) tests were performed to the requirements of the NRC letter dated October 29, 1992 (Reference 10.22.1). Due to the time required (approx. 30 minutes) to conduct the insulation resistance (IR) tests on multi-conductor instrument cable, IR tests were not conducted during the fire endurance tests.

A15A.1 Test Article

Scheme 15-1 consisted of a 36 in. wide ladderback tray assembled into a "U-shaped" configuration. The cable tray extended down through the test deck with each vertical leg transitioning to the horizontal with a ladderback 90° to vertical fitting. The distance from the bottom of the horizontal tray section to the deck was 36 in.

The assembly was supported internally by two trapeze type hangers using 3" channels bolted together.

An approximate 1/3 mix of Power, Instrumentation and Control cables were pulled into the tray, maintaining a single layer.

The vertical tray sections were sealed at the test deck using silicone foam and internally using a silicone elastomer.

A15A.2 TSI Thermo-Lag Protective Envelope Materials and Enclosure

To preclude excessive sagging of the material installed across the horizontal run to the tray, the cable tray was "pre-banded" using stainless steel banding material wrapped completely around the body of the tray in the horizontal run. These bands were spaced at 24 in. maximum intervals. The entire tray was covered with Thermo-Lag 330-1 V-Ribbed panels on the top, bottom and sides of the tray. In each case, the side panels were placed into compression whereby once the banding is applied and tightened, the side panels were sandwiched by the top and bottom panels. The V-ribbed panels applied to the inside surfaces of the radial bends were scored to a depth of 1/4 in., perpendicular to the raceway, at 3-7/16 in. intervals to allow for curvature. The V-ribbed panels installed on the outside of the radial bends were scored to a depth of 1/4 in., perpendicular to the raceway, at 4 in. intervals to allow for curvature. All joints, seams and scored grooves were pre-caulked

with Thermo-Lag 330-1 Trowel Grade material and all panels were secured in place using the stainless steel bands spaced at 12 in. maximum intervals.

After the entire tray assembly was clad, the support members were covered with flat Thermo-Lag 330-1 panel material for a distance of approximately 9 in. as measured from the tray protective envelope. All joints and seams were pre-caulked with Thermo-Lag 330-1 Trowel-Grade material, then secured in place using 16 - 18 GA stainless steel tie wire (on the inside layer of panels) and 1/2 in. wide x 0.020 in. thick Type 304 stainless steel banding straps.

At side panels, a thin layer of Thermo-Lag 330-1 Trowel-Grade material (approximately 3/16 in. thick) was applied extending 5 in. towards the middle of the tray on the top, bottom and side exterior panel surfaces. Then Thermo-Lag 330-69 stress skin was cut and formed into a squared U-shaped configuration, which was placed over the exterior Thermo-Lag 330-1 top, bottom, side panels and the 3/16 in. Thermo-Lag 330-1 Trowel-Grade such that when installed, each stress skin "leg" overlaid the top and bottom Thermo-Lag panels by 5 in.. Along sweeping 90° bends, the 330-69 stress skin "legs" were wedge cut to allow the material to conform to the bend radius and a 5 in. wide strip of stress skin was placed over the top and bottom legs of the stress skin. The stress skin was then stapled using 1/2 in. long Arrow or Bostitch T-50 staples at a distance of 2 in. maximum and 1 in. minimum from the edge of the two stress skin and 3 in. on centers. Stainless steel tie wire was then used to tie the two stress skin legs in place at 5 in minimum to 6 in. maximum centers. The stress skin was installed such that the top and bottom Thermo-Lag 330-1 panels were overlapped by 5 in. A skim coat of Thermo-Lag 330-1 Trowel-Grade material, approximately 1/16 in. thick was applied over the stress skin and tie wires.

A circumferential wrap of 330-69 stress skin was also applied to all butt joints in a similar manner, thus allowing for a 5 in. overlap on each side of the butt joint. A skim coat of trowel grade material (1/16 in. thick) was applied over all stress skin and tie wires.

A thin layer of Thermo-Lag 330-1 Trowel-Grade material approximately 3/16 in. thick was applied to the Thermo-Lag panel pieces covering the side rail splice plates. Pieces of 330-69 stress skin were cut into squares and folded so that, when placed over the splice plate, a "tab" of stress skin would extend from both the top and the bottom, toward the center of the tray. The folded stress skin was stapled in place using 1/2 in. long Arrow or Bostitch T-50 staples at a distance of 2 in. maximum and 1 in. minimum from the edge of the stress skin and 3 in. on centers. A skim coat of Thermo-Lag 330-1 Trowel-Grade material, approximately 1/16 in. thick was then applied over the stress skin and staples.

Where V-ribbed panels were installed on the top and bottom of the horizontal tray run and on both the inside and the outside of the radial bends, the V-ribs were positioned perpendicular to the tray side rails. Panels installed against tray side rails were positioned with the V-ribs positioned vertically.

Finally, Thermo-Lag 350 Topcoat was applied over areas where the Thermo-Lag 330-1 Trowel-Grade material had been applied, following the required 72 hours of cure time.

This test was conducted after a 7 day cure of the Thermo-Lag barrier in order to confirm that Thermo-Lag barriers can adequately perform their function without imposing a 30 day cure time.

A15A.3 ASTM E-119 Standard Time-Temperature

The Thermo-Lagged test article was exposed to the standard time-temperature curve of ASTM E-119 for 1 hour.

A15A.4 Temperature Review

Reference 10.22.1 specifies that the transmission of heat through the fire barrier during the fire endurance test shall not have been such as to raise the average temperature on the exposed conduit surface more than 25 °F above its initial temperature. Reference 10.22.1 further states that no single temperature rise shall exceed 30% of the average specified limit or 325°F. If either of these temperatures is exceeded then visual cable inspection and IR cable tests are required to demonstrate the cables are free of fire damage.

The ambient air temperature at the start of the test was 68°F.

The maximum average temperature would be equal to 250°F plus ambient. For this test the maximum average temperature would equal to 318°F.

The maximum individual temperature would be equal to 325°F plus ambient. For this test the maximum individual temperature would equal 393°F.

The peak temperature on the tray rails reached 292°F and the average reached 246°F.

The peak temperature on an individual cable reached 277°F and the average reached 241°F.

All thermocouples in the 36 in. tray system met the maximum and average temperature criteria.

A15A.5 Hose Stream Test

Following the exposure fire, the test article was subjected to a 5 minute hose stream test utilizing a 1-1/2 in. diameter fog nozzle set at a discharge angle of 30% with a nozzle pressure of 75 psi (this Elkhart nozzle is rated at 88 gpm at 75 psi). The nozzle distance was maintained at 5 ft perpendicular from the outside surface of the test article.

After the hose stream test a visual inspection of the fire barrier was conducted. There was no burn through or openings in the fire barrier envelope.

A15A.6 Insulation Resistance Testing

As an additional check on the condition of the conductor insulation, insulation resistance testing was performed on each cable type before the fire and after the hose stream test. The insulation resistance tests were performed using TU Electric owned and calibrated

adjustable megohmmeter, set to the 500 volt DC level for insulation resistance testing on all instrumentation cables and the 1500 volt DC level for all power and control cables. To perform the insulation resistance test, the connection to ground was broken for each cable type and the test instrument leads connected from conductor to conductor and from each conductor to ground. Any leakage between the cable type's conductors and ground, or from conductor to conductor, is readily detected in this manner. Upon discovery of an ohmic reading which is lower than the criteria set in the October 29, 1992, NRC letter (Reference 10.22.1), the reading will be documented in the test report and the splices between cables will be broken and each cable tested separately to determine which cable conductor is bad or if there is a bad splice or test lead. Provided the low reading is on a cable, that cable will be removed from the raceway and visually examined to determine where and how the failure occurred.

The cables were visibly undamaged. The cable jackets were slightly stiffened in the radial bend areas (Refer to Section 4.4 for cable evaluation). The remainder of the cable length was still flexible.

The cables were meggered after the hose stream test and the results of the IR tests were well within the allowable limits for all assemblies tested.

A15A.7 Comments

The 36 in. cable tray, clad in a nominal 1/2 in. thickness Thermo-Lag 330-1 material with upgrades presented herein, met the requirements for a fire resistance rating of one hour.

The assembly met the acceptance criteria contained in the NRC letter dated October 29, 1992 (Reference 10.22.1) for the following parameters: 1) single point temperature increase remained below 325°F, 2) no burn through was evident on the assembly following the fire endurance and hose stream tests, 3) visual cable inspection revealed no apparent thermal damage, and 4) the results of the insulation resistance tests were well within the allowable limits.

A15B Omega Point Test No. 12340-95770 - Scheme 15-2

The fire endurance test documented in Reference 10.12.25 was conducted at Omega Point Laboratories on August 17, 1993, and the test report was issued on October 4, 1993. The fire endurance test, hose stream test and cable functionality (Insulation Resistance) tests were performed to the requirements of the NRC letter dated October 29, 1992 (Reference 10.22.1).

A15B.1 Test Article

Scheme 15-2 consisted of wrapped cable bundles laid in a 36 in. wide ladderback cable tray which is assembled into a single, horizontal straight run and entering/exiting the furnace at the left and right side wall deck. The distance from the bottom of the tray to the test deck is 36 in.

The assembly was supported internally by two trapeze type hangers using 3" channels bolted together.

A total of 5 power cables were bundled into 3 bundles and placed in the cable tray. Two bundles, each containing a single 1/C 750kCMil 600V power cable, were wrapped in 330-660 "Flexi-Blanket" and a third bundle containing 3 3/C #6 AWG 600V power cables was wrapped in Siltemp material and placed in between Thermo-Lag bundles for cable loading purposes to simulate the CPSES conditions.

The blockout for the tray entering and leaving the furnaces was sealed with silicone foam.

In order to monitor temperatures in the interior of the 330-660 Flexi-Blanket bundles, a #8 bare copper conductor was instrumented with thermocouples and secured to the power cables in the Thermo-Lag bundles.

A15B.2 TSI Thermo-Lag Protective Envelope Materials and Enclosure

Each individual power cable was separately wrapped with a layer of Thermo-Lag 330-660 "Flexi-Blanket". A 2 in. overlap of the material was maintained and no 330-660 Trowel Grade material was used to pre-caulk the overlap area. The first layer was secured using stainless steel banding at approximate 6 in. intervals. A second layer of "Flexi-Blanket" was similarly applied, maintaining a 2 in. overlap. The overlap area of the second layer was pre-caulked with a layer of 330-660 Trowel Grade material. The second layer was also secured with stainless steel banding at approximately 6 in. intervals. The protected cables were then laid in the exposed cable tray. The bundle of three power cables were wrapped with Siltemp material and Scotch 3M type 69 Glass Cloth tape. This bundle was then laid in the tray and secured as described above.

The two Thermo-Lag wrapped bundles were placed in the tray midway between center and siderail and the 3 cable bundle was placed in between. One of the Thermo-Lag bundles was secured to the tray rungs with plastic tie wraps and the other with steel banding.

A15B.3 ASTM E-119 Standard Time-Temperature

The Thermo-Lagged test article was exposed to the standard time-temperature curve of ASTM E-119 for 1 hour.

A15B.4 Temperature Review

Reference 10.22.1 specifies that the transmission of heat through the fire barrier during the fire endurance test shall not have been such as to raise the average temperature on the surface more than 250°F above its initial temperature. Reference 10.22.1 further states that no single temperature rise shall exceed 30% of the average specified limit of 325°F. If either of these temperatures is exceeded then visual cable inspection and IR cable tests are required to demonstrate the cables are free of fire damage.

The ambient air temperature at the start of the test was 92°F.

The maximum average temperature would be equal to 250°F plus ambient. For this test the maximum average temperature would equal to 342°F.

The maximum individual temperature would be equal to 325°F plus ambient. For this test the maximum individual temperature would equal 417°F.

Front Thermo-Lag Bundle

The peak temperature on bare copper wire reached 717°F and the average reached 465°F.

The peak temperature on the cable reached 238°F and the average reached 215°F.

Rear Thermo-Lag Bundle

The peak temperature on bare copper wire reached 586°F and the average reached 310°F.

The peak temperature on the cable reached 377°F and the average reached 231°F.

There were no t ermocouples on the three cable, non-Thermo-Lag wrapped bundle.

The maximum temperature criteria on both bare copper wires and the average criteria on the front bundle bare copper conductor were exceeded, but the cables met the maximum and average temperature criteria.

A15B.5 Hose Stream Test

Following the exposure fire, the test article was subjected to a 5 minute hose stream test utilizing a 1-1/2 in. diameter fog nozzle set at a discharge angle of 30% with a nozzle pressure of 75 psi (this Elkhart nozzle is rated at 88 gpm at 75 psi). The nozzle distance was maintained at 5 ft perpendicular from the outside surface of the test article.

After the hose stream test a visual inspection of the fire barrier was conducted. There was no burn through or openings in the fire barrier envelope.

A15B.6 Insulation Resistance Testing

As an additional check on the condition of the conductor insulation, insulation resistance testing was performed on each cable type before the fire and after the hose stream test. The insulation resistance tests were performed using TU Electric owned and calibrated adjustable megohmmeter, set to the 1500 volt DC level for both power cables. To perform the insulation resistance test, the connection to ground was broken for each cable and the test instrument leads connected from conductor to ground. Any leakage between the cable type's conductors and ground, is readily detected in this manner. Upon discovery of an ohmic reading which is lower than the criteria set in the October 29, 1992, NRC letter (Reference 10.22.1), the reading will be documented in the test report and that cable will be removed from the raceway and visually examined to determine where and how the failure occurred.

For the front cable bundle, the outer cable jacket charred in several places (corresponding to lack of uncharred Thermo-Lag material). Dissection of cable revealed that damage was contained only in the outer mechanical sheath. No thermal damage reached the inner dielectric insulation.

For the rear cable bundle, the outer cable jacket charred in several places (corresponding to lack of uncharred Thermo-Lag material). Dissection of cable revealed that damage was contained only in the outer mechanical sheath. No thermal damage reached the inner dielectric insulation.

The cables were meggered after the hose stream test and the results of the IR tests were well within the allowable limits for both assemblies tested.

A15B.7 Comments

The wrapped cable assemblies, each containing a single 1/C 750kCMil 600V power cable, clad in a nominal 1/2 in. thickness Thermo-Lag 330-660 material and routed in exposed tray as presented herein, met the requirements for a fire resistance rating of one hour, as described below.

Although the single point and average temperature increases parameters were exceeded on the bare #8 AWG copper wires within the protective 330-660 Flexi-Blanket bundles, the assembly, as tested, met the acceptance criteria contained in the NRC letter dated October 29, 1992 (Reference 10.22.1), for the following parameters, 1) barrier inspection revealed no opening into the protective bundles, 2) visual cable inspection revealed no appreciable, penetrating thermal damage to the conductor insulation, and 3) the results of the insulation resistance tests were well within the allowable limits.

The significant difference in temperatures recorded by thermocouples installed on the cables and those installed on the bare copper wires within the protective wrap is attributed to the large thermal mass of the power cable in comparison to the bare copper wires. It is this difference in thermal mass which enables the cables evaluated within the scope of this test to meet the acceptance criteria.

Additionally, as discussed in Section 4.5.6, steam and fluid were visually observed being driven from the ends of the two protective "Flexi-Blanket" bundles containing the 1/C 750kCMil power cable as they exited the test furnace. This release of moisture from the "Flexi-Blanket" material was determined to have no adverse impact on functionality of the protected cables.

Thermo-Lag installations for large power cables (i.e., 1/C 750kMCil) wrapped with 2 layers of 330-660 Flexi-Blanket and routed in exposed cable tray perform their design function, however addition of a third layer is necessary to ensure complete thermal protection of the cables.

APPENDIX B

RESULTS OF THE ACCEPTANCE TESTS

SESSION 1 - JUNE 1992
RESULTS OF ACCEPTANCE TESTS
TEST CRITERIA - ANI STANDARD

TEST SCHEME CONFIGURATION DESCRIPTION	RESULTS	REMARKS
SCHEME 2-1 3/4", 1" AND 5" CONDUITS W/JB - NO UPGRADES	SEE REMARKS	-5" CONDUIT - PASSED-NO CABLE DAMAGE. MAINTAINED CIRCUIT INTEGRITY. -1" CONDUIT - INDETERMINATE OUTER CABLE JACKET DAMAGE, INSULATION RESISTANCE - SATISFACTORILY MAINTAINED CIRCUIT INTEGRITY -3/4" CONDUIT - FAILURE OCCURRED DUE TO SIGNIFICANT DEGRADATION OF CABLE JACKET - BARRIER DISLODGED DUE TO HOSE STREAM.
SCHEME 3 12" WIDE CABLE TRAY - NO UPGRADES	SATISFACTORY	SATISFACTORY TEST. CIRCUIT INTEGRITY MAINTAINED. NO CABLE DAMAGE - BARRIER DISLODGED DUE TO HOSE STREAM.
SCHEME 4 36" WIDE VERTICAL CABLE TRAY WITH THERMO-LAG FIRE STOP - NO UPGRADES	SATISFACTORY	SATISFACTORY TEST. NO CABLE DAMAGE, INSIDE THE ENVELOPE - BARRIER ON TRAY DISLODGED DUE TO HOSE STREAM. HOSE STREAM DID NOT PENETRATE FIRE STOP.
SCHEME 5 30" WIDE CABLE TRAY WITH TEE SECTION - NO UPGRADES.	FAILED	TEST FAILURE. CIRCUIT INTEGRITY FAILED AT 42 MINUTES. SIGNIFICANT DEGRADATION OF CABLING WHERE THERMO-LAG FAILED.
SCHEME 1-2 36" WIDE CABLE TRAY W/TEE - UPGRADED BARRIER DESIGN	SATISFACTORY	SATISFACTORY TEST. CIRCUIT INTEGRITY MAINTAINED. NO CABLE DAMAGE - BARRIER DISLODGED DUE TO HOSE STREAM.

SESSION 2 - AUGUST 1992
RESULTS OF ACCEPTANCE TESTS
TEST CRITERIA - ANI STANDARD

TEST SCHEME CONFIGURATION DESCRIPTION	RESULTS	REMARKS
SCHEME 7 ONE 3" CONDUIT. ONE 2" CONDUIT ONE 1-1/2" CONDUIT AND TWO - 3/4" CONDUITS WITH LBDs 3", 2" AND 1-1/2" CONDUITS NOT UPGRADED. 3/4" CONDUITS UPGRADED WITH 3/4" PRESHAPED THERMO-LAG, 1/4" OVERLAY ON TOP OF 1/2" PRESHAPED THERMO-LAG, FLEXIBLANKET WRAP, AND 1/4" TROWEL GRADE BUILDUP OVER 1/2" PRESHAPED THERMO-LAG.	SEE REMARKS	THE TEMPERATURES FOR 1/4" OVERLAYS WERE SATISFACTORY. A POST FIRE HOSE STREAM WAS NOT PERFORMED FOR THIS TEST, AND THE TEST SPECIMEN WAS DISASSEMBLED FOR ANALYSIS. SOME BLISTERING OF CABLE JACKET WAS NOTED. THE TEST WAS PERFORMED TO EVALUATE DIFFERENT UPGRADE TECHNIQUES. 3" CONDUIT - CABLING WAS SATISFACTORY 1-1/2" & 2" CONDUIT - INDETERMINATE. LBD BOX ENCLOSURES SHIFTED DURING THE TEST.
SCHEME 6 24" WIDE TRAY WITH TEE SECTION -NO UPGRADES.	SEE REMARKS	TEST FAILURE. THERMO-LAG JOINTS OPENED. CIRCUIT INTEGRITY WAS MAINTAINED CABLE JACKET DEGRADATION WAS NOTED). A FOG HOSE STREAM ALLOWED FOR A MORE INFORMATIVE POST TEST, FIRE BARRIER INSPECTION.
SCHEME 8 30" WIDE CABLE TRAY NO - UPGRADES.	SEE REMARKS	THE BUTT JOINTS ON THE THERMO-LAG OPENED AT ABOUT 30 MINUTES. EXCEPT FOR THE JOINT FAILURE, THERMO-LAG PERFORMED ADEQUATELY. A FOG HOSE STREAM ALLOWED FOR A MORE INFORMATIVE POST TEST, FIRE BARRIER INSPECTION.

SESSION 3 - NOVEMBER thru DECEMBER 1992
RESULTS OF ACCEPTANCE TESTS
TEST CRITERIA - NRC LETTER DATED OCTOBER 29, 1992

TEST SCHEME CONFIGURATION DESCRIPTION	RESULTS	REMARKS
SCHEME 9-1 5", 3", & 3/4" DIA. CONDUITS - UPGRADED BARRIER DESIGN	SATISFACTORY	SATISFACTORY TEST. INDETERMINATE CONDUIT SURFACE TEMPERATURE EVALUATION PROVIDED TO NRC STAFF.
SCHEME 10-1 TWO 3" DIA. CONDUITS W/JBs - UPGRADED BARRIER DESIGN	SATISFACTORY	SATISFACTORY TEST. INDETERMINATE CONDUIT SURFACE TEMPERATURE EVALUATION PROVIDED TO NRC STAFF.
SCHEME 10-2 TWO 3" DIA. CONDUITS W/JBs - UPGRADED BARRIER DESIGN	SATISFACTORY	SATISFACTORY TEST. INDETERMINATE CONDUIT SURFACE TEMPERATURE EVALUATION PROVIDED TO NRC STAFF.
SCHEME 11-1 24" WIDE CABLE TRAY W/AIR DROPS - UPGRADED BARRIER DESIGN	SATISFACTORY	SATISFACTORY TEST.
SCHEME 12-1 30" WIDE CABLE TRAY - UPGRADED BARRIER DESIGN	SATISFACTORY	SATISFACTORY TEST.
SCHEME 12-2 24" WIDE CABLE TRAY W/TEE - UPGRADED BARRIER DESIGN	SATISFACTORY	SATISFACTORY TEST. HOSE STREAM DISLODGED THERMO-LAG AT MOUTH OF TEE. EVALUATION ACCEPTED BY NRC STAFF.

SESSION 3 - NOVEMBER thru DECEMBER 1992
RESULTS OF ACCEPTANCE TESTS
TEST CRITERIA - NRC LETTER DATED OCTOBER 29, 1992
(cont'd)

TEST SCHEME CONFIGURATION DESCRIPTION	RESULTS	REMARKS
SCHEME 13-1 12" WIDE CABLE TRAY-UPGRADED BARRIER DESIGN	SATISFACTORY	SATISFACTORY TEST.
SCHEME 14-1 30" WIDE CABLE TRAY W/TEE-UPGRADED BARRIER DESIGN	SATISFACTORY	SATISFACTORY TEST. EVALUATION OF MAXIMUM INDIVIDUAL RACEWAY TEMPERATURE AT ONE LOCATION ACCEPTED BY NRC STAFF.
SCHEME 9-3 3/4" UPGRADED, 1-1/2" AND 2" CONDUITS UPGRADED AT LBD ENCLOSURES ONLY	SATISFACTORY WITH CABLE FUNCTIONALITY EVALUATION	SATISFACTORY VIA EVALUATION OF CABLE FUNCTIONALITY FOR 1-1/2" AND 2"

SESSION 4 - NOVEMBER thru DECEMBER 1992
RESULTS OF ACCEPTANCE TESTS
TEST CRITERIA - NRC LETTER DATED OCTOBER 29, 1992
(cont'd)

TEST SCHEME CONFIGURATION DESCRIPTION	RESULTS	REMARKS
SCHEME 15-1 36" WIDE CABLE TRAY UPGRADED-BARRIER DESIGN	SATISFACTORY	SATISFACTORY TEST. CIRCUIT INTEGRITY NOT MEASURED BASED ON NRC STAFF CONCURRENCE.

RESULTS OF AMPACITY DERATING TESTS

RACEWAY/CABLE CONFIGURATION	THERMO-LAG CONFIGURATION	PERCENT DERATING
3/4" DIA. CONDUIT W/SINGLE 3/C 10 AWG 600V CABLE	½" THICK (NOMINAL) THERMO-LAG PRESHAPED CONDUIT SECTIONS W/1/4" THICK (NOMINAL) OVERLAY SECTIONS	9.1
2" DIA. CONDUIT W/SINGLE 3/C 6 AWG 600V CABLE	1/2" THICK (NOMINAL) THERMO-LAG PRESHAPED CONDUIT SECTIONS W/1/4" THICK (NOMINAL) OVERLAY SECTIONS	6.5
5" DIA. CONDUIT W/FOUR 1/C 750 KCMIL 600V CABLES	1/2" THICK (NOMINAL) THERMO-LAG PRESHAPED CONDUIT SECTIONS	10.7
24" WIDE LADDER BACK CABLE TRAY W/126 PASSES OF A SINGLE 3/C 6 AWG 600V CABLE	1/2" THICK (NOMINAL) V-RIB PANELS WITH ALL JOINTS AND SEAMS REINFORCED USING STRESS SKIN AND TROWEL GRADE BUILDUP	31.4
SINGLE 3/C 6 AWG 600V AIR DROP CABLE	3 COMPLETE WRAPPED LAYERS OF 1/4" THICK (NOMINAL) THERMO-LAG 330-660 FLEXI-BLANKET MATERIAL	23
THREE 1/C 750 KCMIL 600V AIR DROP CABLES	3 COMPLETE WRAPPED LAYERS OF 1/4" THICK (NOMINAL) THERMO-LAG 330-660 FLEXI-BLANKET MATERIAL	31.7

SESSION 5 - AUGUST 1993
RESULTS OF ACCEPTANCE TESTS
TEST CRITERIA - NRC LETTER DATED OCTOBER 29, 1992

TEST SCHEME CONFIGURATION DESCRIPTION	RESULTS	REMARKS
SCHEME 11-5 (3) 24"x4" CABLE TRAYS WITH DIFFERENT JOINT UPGRADE TECHNIQUES	SATISFACTORY FOR LONGITUDINAL JOINT UPGRADES SEE APPENDIX A FOR RESULTS FOR OTHER 2 CABLE TRAYS	RACEWAY TEMPERATURE - SATISFACTORY CABLE TEMPERATURE - SATISFACTORY BARRIER CONDITION - SATISFACTORY CABLE VISUAL/MEGGER - SATISFACTORY (TEST ACCEPTABLE PER NRC LETTER MAY 22, 1996)
SCHEME 13-2 12"x4" CABLE TRAY (NO UPGRADES) 2" DIA. CONDUIT (UPGRADE AT RADIAL BENDS ONLY)	SATISFACTORY	RACEWAY TEMPERATURE - UNSATISFACTORY CABLE TEMPERATURE - SATISFACTORY BARRIER CONDITION - UNSATISFACTORY CABLE VISUAL/MEGGER - SATISFACTORY (TEST ACCEPTABLE PER NRC LETTER MAY 22, 1996 WITH FUNCTIONALITY EVALUATION)
SCHEME 11-2 24"x4" CABLE TRAY WITH 1-1/2" AND 2" DIA. CABLE AIR DROP BUNDLES	SATISFACTORY	RACEWAY TEMPERATURE - SATISFACTORY CABLE TEMPERATURE - SATISFACTORY (1-1/2" DIA.) CABLE TEMPERATURE - UNSATISFACTORY (2" DIA.) BARE #8 TEMPERATURE - SATISFACTORY BARRIER CONDITION - SATISFACTORY CABLE VISUAL/MEGGER - SATISFACTORY (TEST ACCEPTABLE PER NRC LETTER MAY 22, 1996 FOR CABLE AND 1-1/2" AIR DROP)
SCHEME 11-4 (2) 24"x4" TRAYS (STACKED) WITH CABLE AIR DROPS THROUGH EMBEDDED SLEEVES COVERED BY A "BOX" CONFIGURATION	SATISFACTORY	RACEWAY TEMPERATURE - SATISFACTORY CABLE TEMPERATURE - SATISFACTORY BARE #8 TEMPERATURE - SATISFACTORY BARRIER CONDITION - UNSATISFACTORY (HOSE STREAM DAMAGE-SEE APPENDIX F FOR EVALUATION) CABLE VISUAL/MEGGER - SATISFACTORY (TEST ACCEPTABLE PER NRC LETTER MAY 22,1996)

SESSION 5 - AUGUST 1993
RESULTS OF ACCEPTANCE TESTS
TEST CRITERIA - NRC LETTER DATED OCTOBER 29, 1992
(cont'd)

TEST SCHEME CONFIGURATION DESCRIPTION	RESULTS	REMARKS
SCHEME 15-2 36"x4" EXPOSED CABLE TRAY WITH (2) INDIVIDUALLY WRAPPED 1/C 750KMCIL CABLES	SATISFACTORY BUT OPTED FOR THIRD LAYER OF 330-660 FLEXI-BLANKET TO ENSURE THERMAL PROTECTION OF THE CABLES.	RACEWAY TEMPERATURE - N/A CABLE TEMPERATURE - SATISFACTORY BARE #8 TEMPERATURE - UNSATISFACTORY BARRIER CONDITION - SATISFACTORY CABLE VISUAL/MEGGER - SATISFACTORY (TEST ACCEPTABLE PER NRC LETTER MAY 22,1996 WITH THE THIRD LAYER OF FLEXI-BLANKET)

APPENDIX C

THERMO-LAG REVIEW MATRIX

UNIT 1
THERMO-LAG INSTALLATION REVIEW MATRIX

COMMODITY	CONDUIT 3/4" CONTROL	CONDUIT 3/4" INSTRUMENT	CONDUIT 1" POWER	CONDUIT 1" CONTROL	CONDUIT 1" INSTRUMENT	CONDUIT 1-1/2" POWER
FIRE ENDURANCE						
TESTED CONFIGURATION	NO	YES	NO	NO	NO	NO
QUALIFYING TEST	SCHEME 9-1	SCHEME 9-1	SCHEME 9-1 BASED ON 3/4" CONDUIT	SCHEME 9-1 BASED ON 3/4" CONDUIT	SCHEME 9-1 BASED ON 3/4" CONDUIT	SCHEME 9-1. BASED ON 3/4" CONDUIT
PERCENT FILL AS TESTED	NOT TESTED	39.82	NOT TESTED	NOT TESTED	NOT TESTED	NOT TESTED
PERCENT FILL AS INSTALLED *	30.2	28.3	36	51.2	34.9 - 69.8	15.2 - 45.1
TEST ACCEPTABLE	YES USING OVERLAY	YES USING OVERLAY	YES USING OVERLAY	YES USING OVERLAY	YES USING OVERLAY	YES USING OVERLAY
ACCEPTED ENGINEERING EVALUATION	N/A	N/A	N/A	N/A	N/A	N/A
AMPACITY DERATING						
DERATING FACTOR AND METHOD	N/A	N/A	11% BY TUE TEST RESULTS	N/A	N/A	11% BY TUE TEST RESULTS
QUALIFYING TEST	N/A	N/A	BOUNDED BY 5" CONDUIT	N/A	N/A	BOUNDED BY 5" CONDUIT

* SEE APPENDIX F FOR DETAILS (TYPICAL)

UNIT 1 (CONTD.)
THERMO-LAG INSTALLATION REVIEW MATRIX

COMMODITY	CONDUIT 1-1/2" CONTROL	CONDUIT 1-1/2" INSTRUMENT	CONDUIT 2" POWER	CONDUIT 2" CONTROL	CONDUIT 2" INSTRUMENT	CONDUIT 3" POWER
FIRE ENDURANCE						
TESTED CONFIGURATION	NO	NO	YES	YES	YES	YES
QUALIFYING TEST	SCHEME 9-1 BASED ON 3/4" CONDUIT	SCHEME 9-1 BASED ON 3/4" CONDUIT	SCHEME 13-2 WITH CABLE FUNCTIONALITY	SCHEME 13-2 WITH CABLE FUNCTIONALITY	SCHEME 13-2 WITH CABLE FUNCTIONALITY	SCHEME 9-1, 10-1,10-2 & SCHEME 13-2 FOR RADIAL BENDS
PERCENT FILL AS TESTED	NOT TESTED	NOT TESTED	39.82	39.82	39.82	9-1 = 39.82 10-1 = 43.4 10-2 = 43.4 13-2 = 43.4
PERCENT F[illegible] AS INSTALLED *	23.5 - 47.1	14.7 - 44.1	9.2 - 61.3	8.3 - 46.4	1.5 - 38.1	16.5 - 40.7
TEST ACCEPTABLE	YES USING OVERLAYS	YES USING OVERLAYS	YES	YES	YES	YES
ACCEPTED ENGINEERING EVALUATION	N/A	N/A	YES	YES	YES	N/A
AMPACITY DERATING						
DERATING FACTOR AND METHOD	N/A	N/A	11% BY TUE TEST RESULTS	N/A	N/A	11% BY TUE TEST RESULTS
QUALIFYING TEST	N/A	N/A	BOUNDED BY 5"CONDUIT	N/A	N/A	BOUNDED BY 5"CONDUIT

UNIT 1 (CONTD.)
THERMO-LAG INSTALLATION REVIEW MATRIX

COMMODITY	CONDUIT 3" CONTROL	CONDUIT 3" INSTRUMENT	CONDUIT 4" POWER	CONDUIT 4" CONTROL	CONDUIT 4" INSTRUMENT	CONDUIT 5" POWER
			FIRE ENDURANCE			
TESTED CONFIGURATION	YES	YES	NO	NO	NO	YES
QUALIFYING TEST	SCHEME 9-1, 10-1,10-2 & SCHEME 13-2 FOR RADIAL BENDS	SCHEME 9-1, 10-1,10-2 & SCHEME 13-2 FOR RADIAL BENDS	SCHEME 9-1, 10-1,10-2 BASED ON 3", 5" CONDUITS & SCHEME 13-2 FOR RADIAL BENDS	SCHEME 9-1,10-1,10-2 BASED ON 3",5" CONDUIT & SCHEME 13-2 FOR RADIAL BENDS	SCHEME 9-1, 10-1-10-2 BASED ON 3",5" CONDUIT & SCHEME 13-2 FOR RADIAL BENDS	SCHEME 9-1 & SCHEME 13-2 FOR RADIAL BENDS
PERCENT FILL AS TESTED	9-1 = 39.82 10-1 = 43.4 10-2 = 43.4 13-2 = 43.4	9-1 = 39.82 10-1 = 43.4 10-2 = 43.4 13-2 = 43.4	NOT TESTED	NOT TESTED	NOT TESTED	9-1 = 39.82
PERCENT FILL AS INSTALLED*	26.8 - 40.7	4.6 - 27.1	23.6 - 33.7	9.1 - 44.8	11.8 - 59.9	30.6
TEST ACCEPTABLE	YES	YES	YES	YES	YES	YES
ACCEPTED ENGINEERING EVALUATION	N/A	N/A	N/A	N/A	N/A	N/A
			AMPACITY DERATING			
DERATING FACTOR AND METHOD	N/A	N/A	11% BY TUE TEST RESULTS	N/A	N/A	11% BY TUE TEST RESULTS
QUALIFYING TEST	N/A	N/A	BOUNDED BY 5"CONDUIT	N/A	N/A	BOUNDED BY 5"CONDUIT

UNIT 1 (CONTD.)
THERMO-LAG INSTALLATION REVIEW MATRIX

COMMODITY	CONDUIT 5" CONTROL	CONDUIT 5" INSTRUMENT	TRAY 12" X 4" POWER	TRAY 12" X 4" CONTROL	TRAY 12" X 4" INSTRUMENT	TRAY 18" X 4" POWER
FIRE ENDURANCE						
TESTED CONFIGURATION	YES	YES	YES	YES	YES	NO
QUALIFYING TEST	SCHEME 9-1 & SCHEME 13-2 FOR RADIAL BENDS	SCHEME 9-1 & SCHEME 13-2 FOR RADIAL BENDS	SCHEME 13-2 WITH CABLE FUNCTIONALITY	SCHEME 13-2 WITH CABLE FUNCTIONALITY	SCHEME 13-2 WITH CABLE FUNCTIONALITY	SCHEME 11-5, 13-2 BASED ON 24" X 4" AND 12" X 4" TRAYS
PERCENT FILL AS TESTED	9-1 = 39.82	9-1 = 39.82	14.68	14.68	14.68	NOT TESTED
PERCENT FILL AS INSTALLED *	23.1 - 47.7	0.3	13 - 115.2	15.4 - 69.9	2.1 - 11.5	24 - 89.5
TEST ACCEPTABLE	YES	YES	YES	YES	YES	YES
ACCEPTED ENGINEERING EVALUATION	N/A	N/A	YES	YES	YES	N/A
AMPACITY DERATING						
DERATING FACTOR AND METHOD	N/A	N/A	32% BY TUE TEST RESULTS	N/A	N/A	32% BY TUE TEST RESULTS
QUALIFYING TEST	N/A	N/A	BOUNDED BY 24" X 4" TRAY	N/A	N/A	BOUNDED BY 24" X 4" TRAY

UNIT 1 (CONTD.)
THERMO-LAG INSTALLATION REVIEW MATRIX

COMMODITY	TRAY 18"X 4" CONTROL	TRAY 18"X 4" INSTRUMENT	TRAY 18"X6" CONTROL	TRAY 24"X 4" POWER	TRAY 24"X 4" CONTROL
FIRE ENDURANCE					
TESTED CONFIGURATION	NO	NO	NO	YES	YES
QUALIFYING TEST	SCHEME 11-5, 13-2 BASED ON 24" X 4"/ 12" X 4" TRAYS	SCHEME 11-5, 13-2 BASED ON 24" X 4"/ 12" X 4" TRAYS	SCHEME 11-5, 13-2 BASED ON 24" X 4"/ 12" X 4" TRAYS	SCHEME 11-5	SCHEME 11-5
PERCENT FILL AS TESTED	NOT TESTED	NOT TESTED	NOT TESTED	16.49	16.49
PERCENT FILL AS INSTALLED *	12.8 - 46.2	3.8 - 69.2	47.9	3.1 - 109.5	0.2 - 56.4
TEST ACCEPTABLE	YES	YES	YES	YES	YES
ACCEPTED ENGINEERING EVALUATION	N/A	N/A	N/A	N/A	N/A
AMPACITY DERATING					
DERATING FACTOR AND METHOD	N/A	N/A	N/A	32% BY TUE TEST RESULTS	N/A
QUALIFYING TEST	N/A	N/A	N/A	N/A	BOUNDED BY 24" X 4" TRAY

UNIT 1 (CONTD.)
THERMO-LAG INSTALLATION REVIEW MATRIX

COMMODITY	TRAY 24"X 4" INSTRUMENT	TRAY 24"X 6" CONTROL	TRAY 30"X 4" POWER	TRAY 30"X 6" CONTROL	TRAY 30"X 6" INSTRUMENT
FIRE ENDURANCE					
TESTED CONFIGURATION	YES	NO	YES	NO	NO
QUALIFYING TEST	SCHEME 11-5	SCHEME 11-5 BASED ON 24"X4" TRAY	SCHEME 14-1	SCHEME 14-1 BASED ON 30"X4" TRAY	SCHEME 14-1 BASED ON 30"X4" TRAY
PERCENT FILL AS TESTED	16.49	NOT TESTED	17.32	NOT TESTED	NOT TESTED
PERCENT FILL AS INSTALLED *	2.6 - 61.?	6.6 - 56.2	16.1 - 89.9	25.7 - 44.3	1
TEST ACCEPTABLE	YES	YES	YES	YES	YES
ACCEPTED ENGINEERING EVALUATION	N/A	N/A	N/A	N/A	N/A
AMPACITY DERATING					
DERATING FACTOR AND METHOD	N/A	N/A	32% BY TUE TEST RESULTS	N/A	N/A
QUALIFYING TEST	N/A	N/A	BOUNDED BY 24" X 4" TRAY	N/A	N/A

UNIT 1 (CONTD.)
THERMO-LAG INSTALLATION REVIEW MATRIX

COMMODITY	AIR DROP VARIOUS	PULL/JUNCTION BOXES VARIOUS	MULTIPLE TRAYS IN COMMON ENCLOSURE	TWO CONDUITS IN COMMON ENCLOSURE	ELEC BOXES IN COMMON ENCLOSURE
FIRE ENDURANCE					
TESTED CONFIGURATION	YES	YES	NO	NO	NO
QUALIFYING TEST	SCHEME 11-1	SCHEME 10-2	NOT TESTED	NOT TESTED	NOT TESTED
PERCENT FILL AS TESTED	N/A	N/A	N/A	N/A	N/A
PERCENT FILL AS INSTALLED	N/A	N/A	N/A	N/A	N/A
TEST ACCEPTABLE	YES	YES	N/A	N/A	N/A
ACCEPTED ENGINEERING EVALUATION	N/A	N/A	ER-ME-082	ER-ME-082	ER-ME-082
AMPACITY DERATING					
DERATING FACTOR METHOD	VARIOUS BY CALCULATION 16345-EE(B)-140	BOUNDED BY ATTACHED RACEWAYS	VARIOUS JUSTIFICATION IN DCA/DCN ENGINEERING BASIS	VARIOUS JUSTIFICATION IN DCA/DCN ENGINEERING BASIS	VARIOUS JUSTIFICATION IN DCA/DCN ENGINEERING BASIS
QUALIFYING TEST	BY TUE TESTS	N/A	N/A	N/A	N/A

UNIT 1 (CONTD.)
THERMO-LAG INSTALLATION REVIEW MATRIX

COMMODITY	STRUCTURAL STEEL VARIOUS	HATCH COVERS
FIRE ENDURANCE		
TESTED CONFIGURATION	NO	NO
QUALIFYING TEST	UL X-611 AND X-003 WITH ENGINEERING EVALUATIONS	N/A
TEST ACCEPTABLE	YES	N/A
ACCEPTED ENGINEERING EVALUATION	SEE APPENDIX D FOR ENGINEERING EVALUATION	CALCULATION 0210-063-0043
AMPACITY DERATING		
DERATING FACTOR METHOD	N/A	N/A
QUALIFYING TEST	N/A	N/A

UNIT 2
THERMO-LAG INSTALLATION REVIEW MATRIX

COMMODITY	CONDUIT 3/4" CONTROL	CONDUIT 3/4" INSTRUMENT	CONDUIT 1" POWER	CONDUIT 1" CONTROL	CONDUIT 1" INSTRUMENT	CONDUIT 1-1/2" POWER
FIRE ENDURANCE						
TESTED CONFIGURATION	YES	YES	NO	NO	NO	YES
QUALIFYING TEST	SCHEME 9-1	SCHEME 9-1	SCHEME 9-1 BASED ON 3/4" CONDUIT	SCHEME 9-1 BASED ON 3/4" CONDUIT	SCHEME 9-1 BASED ON 3/4" CONDUIT	SCHEME 9-1 BASED ON 3/4" CONDUIT
PERCENT FILL AS TESTED	39.82	39.82	NOT TESTED	NOT TESTED	NOT TESTED	39.82
PERCENT FILL AS INSTALLED*	30	28	36	30 - 40	35	9
TEST ACCEPTABLE	YES USING OVERLAY	YES USING OVERLAY	YES USING OVERLAY	YES USING OVERLAY	YES USING OVERLAY	YES USING OVERLAY
ACCEPTED ENGINEERING EVALUATION	N/A	N/A	N/A	N/A	N/A	N/A
AMPACITY DERATING						
DERATING FACTOR AND METHOD	N/A	N/A	11% BY TUE TEST RESULTS	N/A	N/A	11% BY TUE TEST RESULTS
QUALIFYING TEST	N/A	N/A	BOUNDED BY 5" CONDUIT	N/A	N/A	BOUNDED BY 5" CONDUIT

* SUBMITTED TO THE NRC VIA REV. 2 OF ER-ME-067 (TYPICAL)

UNIT 2 (CONTD.)
THERMO-LAG INSTALLATION REVIEW MATRIX

COMMODITY	CONDUIT 1-1/2" CONTROL	CONDUIT 1-1/2" INSTRUMENT	CONDUIT 2" POWER	CONDUIT 2" CONTROL	CONDUIT 2" INSTRUMENT	CONDUIT 3" POWER
FIRE ENDURANCE						
TESTED CONFIGURATION	NO	NO	NO	NO	NO	YES
QUALIFYING TEST	SCHEME 9-1 BASED ON 3/4" CONDUIT	SCHEME 9-1 BASED ON 3/4" CONDUIT	SCHEME 9-1 BASED ON 3/4" CONDUIT	SCHEME 9-1 BASED ON 3/4" CONDUIT	SCHEME 9-1 BASED ON 3/4" CONDUIT	SCHEME 9-1, 10-1,10-2
PERCENT FILL AS TESTED	NOT TESTED	NOT TESTED	NOT TESTED	NOT TESTED	NOT TESTED	9-1 = 39.82 10-1 = 43.4 10-2 = 43.4
PERCENT FILL AS INSTALLED*	29 - 46	26 - 35	9 - 28	13 - 32	4 - 54	8 - 35
TEST ACCEPTABLE	YES	YES	YES	YES	YES	YES
ACCEPTED ENGINEERING EVALUATION	N/A	N/A	N/A	N/A	N/A	N/A
AMPACITY DERATING						
DERATING FACTOR AND METHOD	N/A	N/A	11% BY TUE TEST RESULTS	N/A	N/A	11% BY TUE TEST RESULTS
QUALIFYING TEST	N/A	N/A	BOUNDED BY 5" CONDUIT	N/A	N/A	BOUNDED BY 5" CONDUIT

UNIT 2 (CONTD.)
THERMO-LAG INSTALLATION REVIEW MATRIX

COMMODITY	CONDUIT 3" CONTROL	CONDUIT 3" INSTRUMENT	CONDUIT 4" POWER	CONDUIT 4" CONTROL	CONDUIT 4" INSTRUMENT	CONDUIT 5" POWER
FIRE ENDURANCE						
TESTED CONFIGURATION	YES	YES	NO	NO	NO	YES
QUALIFYING TEST	SCHEME 9-1, 10-1 & 10-2	SCHEME 9-1, 10-1 & 10-2	SCHEME 9-1, 10-1 & 10-2 BASED ON 3", 5" CONDUIT	SCHEME 9-1,10-1 & 10-2 BASED ON 3",5" CONDUIT	SCHEME 9-1, 10-1 & 10-2 BASED ON 3",5" CONDUIT	SCHEME 9-1
PERCENT FILL AS TESTED	9-1 = 39.82 10-1 = 43.4 10-2 = 43.4	9-1 = 39.82 10-1 = 43.4 10-2 = 43.4	NOT TESTED	NOT TESTED	NOT TESTED	9-1 = 39.82
PERCENT FILL AS INSTALLED*	40	12 - 54	9 - 40	34 - 51	22 - 51	13 - 26
TEST ACCEPTABLE	YES	YES	YES	YES	YES	YES
ACCEPTED ENGINEERING EVALUATION	N/A	N/A	N/A	N/A	N/A	N/A
AMPACITY DERATING						
DERATING FACTOR AND METHOD	N/A	N/A	11% BY TUE TEST RESULTS	N/A	N/A	11% BY TUE TEST RESULTS
TESTING CATEGORIES	N/A	N/A	BOUNDED BY 5" CONDUIT	N/A	N/A	BOUNDED BY 5" CONDUIT

UNIT 2 (CONTD.)
THERMO-LAG INSTALLATION REVIEW MATRIX

COMMODITY	CONDUIT 5" CONTROL	CONDUIT 5" INSTRUMENT	TRAY 12" X 4" POWER	TRAY 12" X 4" CONTROL	TRAY 12" X 4" INSTRUMENT	TRAY 18" X 4" POWER
FIRE ENDURANCE						
TESTED CONFIGURATION	YES	YES	YES	YES	YES	NO
QUALIFYING TEST	SCHEME 9-1	SCHEME 9-1	SCHEME 13-1	SCHEME 13-1	SCHEME 13-1	SCHEME 13-1, 12-2 BASED ON 12" X 4" / 24" X 4" TRAYS
PERCENT FILL AS TESTED	39.82	39.82	14.69	14.69	14.69	NOT TESTED
PERCENT FILL AS INSTALLED*	33 - 41	32 - 51	45 - 107	22 - 30	3 - 48	42 - 135
TEST ACCEPTABLE	YES	YES	YES	YES	YES	YES
ACCEPTED ENGINEERING EVALUATION	N/A	N/A	N/A	N/A	N/A	N/A
AMPACITY DERATING						
DERATING FACTOR AND METHOD	N/A	N/A	32% BY TUE TEST RESULTS	N/A	N/A	32% BY TUE TEST RESULTS
TESTING CATEGORIES	N/A	N/A	BOUNDED BY 24" X 4" TRAY	N/A	N/A	BOUNDED BY 24" X 4" TRAY

UNIT 2 (CONTD.)
THERMO-LAG INSTALLATION REVIEW MATRIX

COMMODITY	TRAY 18" X 4" CONTROL	TRAY 18" X 4" INSTRUMENT	TRAY 18" X 6" POWER	TRAY 18" X 6" CONTROL	TRAY 24" X 4" POWER	TRAY 24" X 4" CONTROL
FIRE ENDURANCE						
TESTED CONFIGURATION	NO	NO	NO	NO	YES	YES
QUALIFYING TEST	SCHEME 13-1 & 12-2 BASED ON 12"X4" / 24"X4" TRAY	SCHEME 13-1 & 12-2 BASED ON 12"X4" / 24"X4" TRAY	SCHEME 13-1 & 12-2 BASED ON 12"X4" / 24"X4" TRAY	SCHEME 13-1 & 12-2 BASED ON 12"X4" / 24"X4" TRAY	SCHEME 12-2 & 11-1	SCHEME 12-2 & 11-1
PERCENT FILL AS TESTED	NOT TESTED	NOT TESTED	NOT TESTED	NOT TESTED	12-2 = 16.63 11-1 = 8.32	12-2 = 16.63 11-1 = 8.32
PERCENT FILL AS INSTALLED*	39	5 - 65	9	9	11 - 52	11 - 53
TEST ACCEPTABLE	YES	YES	YES	YES	YES	YES
ACCEPTED ENGINEERING EVALUATION	N/A	N/A	N/A	N/A	N/A	N/A
AMPACITY DERATING						
DERATING FACTOR AND METHOD	N/A	N/A	32% BY TUE TEST RESULTS	N/A	32% BY TUE TEST RESULTS	N/A
TESTING CATEGORIES	N/A	N/A	BOUNDED BY 24" X 4" TRAY	N/A	N/A	N/A

UNIT 2 (CONTD.)
THERMO-LAG INSTALLATION REVIEW MATRIX

COMMODITY	TRAY 24" X 4" INSTRUMENT	TRAY 24" X 6" CONTROL	TRAY 30" X 4" POWER	TRAY 30" X 6" CONTROL	TRAY 30" X 6" INSTRUMENT	TRAY 36" X 6" CONTROL
FIRE ENDURANCE						
TESTED CONFIGURATION	YES	NO	YES	NO	NO	NO
QUALIFYING TEST	SCHEME 12-2 & 11-1	SCHEME 12-2 & 11-1 BASED ON 24"X4" TRAY	SCHEME 12-1 & 14-1	SCHEME 12-1 & 14-1 BASED ON 30"X4" TRAY	SCHEME 12-1 & 14-1 BASED ON 30"X4" TRAY	SCHEME 15-1
PERCENT FILL AS TESTED	12-2 = 16.63 11-1 = 8.32	NOT TESTED	12-1 = 17.09 14-1 = 17.32	NOT TESTED	NOT TESTED	NOT TESTED
PERCENT FILL AS INSTALLED*	1 - 43	15 - 55	20 - 120	21 -44	21	6
TEST ACCEPTABLE	YES	YES	YES	YES	YES	YES
ACCEPTED ENGINEERING EVALUATION	N/A	N/A	N/A	N/A	N/A	N/A
AMPACITY DERATING						
DERATING FACTOR AND METHOD	N/A	N/A	32% BY TUE TEST RESULTS	N/A	N/A	N/A
TESTING CATEGORIES	N/A	N/A	3	N/A	N/A	N/A

UNIT 2 (CONTD.)
THERMO-LAG INSTALLATION REVIEW MATRIX

COMMODITY	TRAY 36" X 4" INSTRUMENT	AIR DROP VARIOUS	PULL/JUNCTION BOXES VARIOUS	TWO TRAYS IN COMMON ENCLOSURE	TWO CONDUITS IN COMMON ENCLOSURE	ELEC BOXES IN COMMON ENCLOSURE
FIRE ENDURANCE						
TESTED CONFIGURATION	YES	YES	YES	NO	NO	NO
QUALIFYING TEST	SCHEME 15-1	SCHEME 11-1	SCHEME 10-1 & 10-2	NO	NO	NO
PERCENT FILL AS TESTED	17.43	N/A	N/A	N/A	N/A	N/A
PERCENT FILL AS INSTALLED*	6	N/A	N/A	N/A	N/A	N/A
TEST ACCEPTABLE	YES	YES	YES	N/A	N/A	N/A
ACCEPTED ENGINEERING EVALUATION	N/A	N/A	N/A	ER-ME-082	ER-ME-082	ER-ME-082
AMPACITY DERATING						
DERATING FACTOR METHOD	N/A	32% BY TUE TEST RESULTS	BOUNDED BY ATTACHED RACEWAYS	VARIOUS JUSTIFICATION IN DCA ENGINEERING BASIS	VARIOUS JUSTIFICATION IN DCA ENGINEERING BASIS	VARIOUS JUSTIFICATION IN DCA ENGINEERING BASIS
TESTING CATEGORIES	N/A	TUE TESTS	N/A	N/A	N/A	N/A

UNIT 2 (CONTD.)
THERMO-LAG INSTALLATION REVIEW MATRIX

COMMODITY	STRUCTURAL STEEL VARIOUS	HATCH COVERS
FIRE ENDURANCE		
TESTED CONFIGURATION	NO	NO
QUALIFYING TEST	UL X-611 AND X-003 WITH ENGINEERING EVALUATIONS	N/A
TEST ACCEPTABLE	YES	N/A
ACCEPTED ENGINEERING EVALUATION	SEE APPENDIX D FOR ENGINEERING EVALUATION	CALCULATION 2-FP-0080
AMPACITY DERATING		
DERATING FACTOR METHOD	N/A	N/A
TESTING CATEGORIES	N/A	N/A

APPENDIX D

STRUCTURAL STEEL FIRE PROOFING EVALUATION

STRUCTURAL STEEL FIRE PROOFING EVALUATION

The evaluation of structural steel fireproofing is based in the guidance provide in G.L. 86-10 which allows the use of untested configurations as long as an evaluation against a tested configuration is used and the protection is of an equal thickness, is continuous, and is installed in a similar manner. This evaluation demonstrates that fireproofing designs used at CPSES meet those requirements.

FOR UNIT 1 AND COMMON

The Thermo-Lag Fireproofing was installed in accordance with Specification 2323-AS-47 (Reference 10.14.3). The Thermo-Lag 330-1 material was trowel applied to the structural steel using the basic techniques outlined in U.L. design no. X-611 (Reference 10.21.4) and TSI Technical Note 99777 (Reference 10.13.5).

The minimum dry film thicknesses for Thermo-Lag 330-1 as specified in Appendix E to 2323-AS-47 were reviewed and are at least 10% greater than the thickness specified in TSI Technical Report 11601 (Reference 10.13.6).

The specification allows the use of Prefabricated Thermo-Lag 330-1 panels to be inserted in the trowel grade material to help build up to the required material thicknesses specified in Appendix E. The prefabricated panels are the exact same material as the trowel grade material, only preformed and cured. The panels are cleaned and abraded before insertion into the trowel grade material to ensure bonding between the panels and the trowel grade material. When the trowel grade material cures, the fireproofing becomes monolithic. When the prefabricated panels are used, the fiberglass cloth required by U.L. X-611 is installed in a layer of trowel grade material applied over the panels to ensure that the last 1/4 in. of the assembly contains the fiberglass reinforcement.

The specification requires that all protruding heat paths be protected for at least 12 in. (12" rule) to prevent the intrusion of a significant amount of heat into the envelope. The basis for the 12 in rule, is the U.L. requirement to protect steel decking for a minimum of 12 in. away from a fireproofed steel beam to prevent heat intrusion into the beam. The steel deck presents more of a challenge than a small protruding item, because the steel deck is continuous along the top for the beam and is a heat path from both sides of the beam. Therefore, the 12" rule provides more than adequate heat path protection.

Therefore, the installation design requirements specified in 2323-AS-47 are more than adequate to ensure the structural steel will meet the required fire endurance requirements.

FOR UNIT 2 AREAS ONLY

Thermo-Lag Fireproofing was installed in accordance with specification CPES-M-2032 (Reference 10.14.2) using the design outlined in U.L. design X-003 (Reference 10.21.4). The Thermo-Lag was used for the fireproofing of the structural tube steel used to support the 2 hour fire rated stairwell (gypsum) walls in the Safeguards Building to protect the frames of the fire dampers/tornado dampers installed in these walls. The frames are protected by the Thermo-Lag attached to the tube steel.

Thermo-Lag 330-1 prefabricated panels are applied to the tube steel by screwing on two layers of ½" nominal thick panels to the steel. The screws (fasteners) are ANSI B16.6.4 self tapping No. 14, 1" long (first layer) and 1 3/4" long (second layer) screws, spaced 12 in. on center (O.C.) with the second layer screws offset from the first layer with the screws along the centerline of the tube steel. The tube steel ranges in size from 4 in. to 8 in. The horizontal butt joints are staggered by at least one inch and all joints are pre-buttered.

U.L. design X-003 was used as guidance for the installation. However, the geometry of the installation with the use of tube steel and the relationship of the steel to the gypsum walls required variation from the U.L. design.

The fasteners are the same gage and type, and are spaced 12" O.C. as specified in X-003. However, since two layers are used instead of the one layer required, the second layer screws provided an additional reinforcement for the first layer. Also, the screws installed to attach the first layer are protected by the second layer which is not the case in the U.L. design. The U.L. design requires that the screws be installed at the corners to affix the ends of the corners together. The installation does not allow this technique to be used. Therefore, the screws are installed at the centerline for the steel. The U.L. design is for a wide flange steel column which has an open span across the web, so that only the corners can be used. Using the centerline of the steel, reduces the unsupported distance to only four inches and is more conservative than the U.L. design.

The U.L. design requires that stress skin be installed at the horizontal butt joints. The horizontal butt joints are staggered between the first and second layer of Thermo-Lag and therefore, the first layer joints are protected by the second layer. Based on this configuration the stress skin is not needed and was not specified.

The U.L. X-003 design requires a minimum thickness of 9/16" of material for a 10WF49. A 10WF49 has a W/D ratio (weight to heated perimeter) of 9.9. The smallest tube steel used (4") has a W/D ratio of 9.02. Based on the difference in ratios the tube steel would require a thickness of 5/8" of material. This thickness is in agreement with the data provided in Reference 10.13.6. The specification requires two layers of ½" board be used which provides a minimum thickness of 1 full inch. By using 2 layers of board, an additional layer of stress skin is provided. Recent fire testing done by CPSES for electrical raceways has shown the intermediate stress skin layer greatly enhances the performance of the Thermo-Lag in a fire.

Specification CPES-M-2023 requires that protruding heat path items be protected a minimum of 4" from the structural steel (4" rule) to prevent heat intrusion into the structural steel. The 4" rule is supported by I.T.L. Report No. 89-07-5335 (Reference 10.21.3) for a unistrut assembly and I.T.L. Report No. 89-07-5334 (Reference 10.21.2) for a Structural Steel Beam. Both tests support the 4" rule for a 3 hour endurance while the stairwell walls only require a two hour rating.

The structural steel in the walls is embedded in such a way that only 2 sides (for a corner) would be exposed to a fire while the U.L. test exposes all four fires in the furnace. Exposing all four sides is a much more severe condition than only 2 sides in that the heat is introduced in all four directions, where as with only two sides exposed, the other two side can release some of the heat for the steel.

Based on the above, the design specified in CPES-M-2032 provides an adequate design to protect the structural steel and ensures the fire barrier will meet the required fire endurance requirements.

APPENDIX E

METHODOLOGY FOR CERTIFYING CPSES UNIT 1 THERMO-LAG

APPENDIX E

METHODOLOGY FOR CERTIFYING CPSES UNIT 1 THERMO-LAG CONDUITS ♦

COMMODITY	ACCEPTANCE TEST	UPGRADE	SUPPORT EVAL.	AMPACITY
3/4"	UNIT 2 (Scheme 9-1)	YES/UPGRADE COMPLETED	YES	UNIT 2 TEST
1"	UNIT 2 (Scheme 9-1)	YES/UPGRADE COMPLETED	YES	UNIT 2 TEST
1-1/2"	UNIT 2 (Scheme 9-1)	YES/UPGRADE	YES	UNIT 2 TEST
2"	UNIT 1 W/CABLE FUNCTION EVAL. (Scheme 13-2)	YES/UPGRADE	YES	UNIT 2 TEST
3" & LARGER	UNIT 2 (Schemes 9-1, 10-1 & 10-2)	YES/UPGRADE	YES	UNIT 2 TEST

♦ All radial bends upgraded based on Unit 1 Test Scheme 13-2 for stainless steel mesh

All conduit interfaces at LBD, junction boxes, etc., upgraded based on Unit 2 Test Schemes 9-1, 10-1 and 10-2

APPENDIX E

METHODOLOGY FOR CERTIFYING CPSES UNIT 1 THERMO-LAG (CONT'D)
CABLE TRAYS

COMMODITY	ACCEPTANCE TEST	UPGRADE	SUPPORT EVAL.	AMPACITY
12"	UNIT 1 (SCHEME 13-2)	NO	NO	UNIT 2 TEST
18"	UNIT 1 (SCHEME 11-5)	YES	YES	UNIT 2 TEST
24"	UNIT 1 (SCHEME 11-5)	YES	YES	UNIT 2 TEST
30"	UNIT 2 (SCHEME 14-1)	YES	YES	UNIT 2 TEST
36"[4]	UNIT 2 (SCHEME 15-1)	YES	YES	UNIT 2 TEST
TEES	UNIT 2 (SCHEME 14-1)	YES	YES	UNIT 2 TEST
FIRE STOPS	UNIT 2 (SCHEME 14-1) (SCHEME 11-2) NEI TEST 2-8 ♦	YES	YES	UNIT 2 TEST
CABLES WRAPPED IN EXPOSED TRAY	UNIT 1 (SCHEME 15-2)	YES[5]	YES	UNIT 2 TEST

♦ For additional details refwer to Appendix F

4 Re-routed FSSA cable in smaller tray or conduits

5 3 layers of Flexi-Blanket (330-660)

APPENDIX E

METHODOLOGY FOR CERTIFYING CPSES UNIT 1 THERMO-LAG (CONT'D)
FLEXIBLE CONDUITS & AIRDROPS

COMMODITY	ACCEPTANCE TEST	UPGRADE	SUPPORT EVAL.	AMPACITY
LESS THAN 1-1/2"	UNIT 2 (SCHEME 11-1)	YES	NO	UNIT 2 TEST
1-1/2"	UNIT 1 (SCHEME 11-2)	NO	NO	UNIT 2 TEST
2"	UNIT 2 (SCHEME 11-1)	NO	NO	UNIT 2 TEST
3" & LARGER	UNIT 2 (SCHEME 11-1)	NO	NO	UNIT 2 TEST

APPENDIX E

METHODOLOGY FOR CERTIFYING CPSES UNIT 1 THERMO-LAG (CONT'D)
MISCELLANEOUS

COMMODITY	ACCEPTANCE TEST	UPGRADE	SUPPORT EVAL.	AMPACITY
AIRDROPS AT CABLE TRAYS	UNIT 2 (SCHEME 11-1)	YES	YES	UNIT 2 TEST
CONDUIT LATERAL BENDS & PULLBOXES	UNIT 2 (SCHEME 10-2)	YES	YES	UNIT 2 TEST
CONDUIT RADIAL BENDS	UNIT 1 (SCHEME 13-2)	YES	YES	UNIT 2 TEST
JUNCTION BOXES	UNIT 2 (SCHEME 10-2)	YES	YES	UNIT 2 TEST
"BOX" CONFIGURATION	UNIT 1 (SCHEME 11-4)	YES	YES	UNIT 2 TEST

APPENDIX F
REVISED RESPONSES TO NRC OPEN ITEMS

APPENDIX F
REVISED RESPONSES TO NRC OPEN ITEMS

BACKGROUND

NRC letter dated May 22, 1996, from Mr. Timothy J. Polich to Mr. C. Lance Terry requested responses to seven items regarding Thermo-Lag installations and fire endurance testing implemented to certify CPSES Unit 1 fire barriers. TU Electric responded to these items via letter TXX-96414 dated October 24, 1996. Prior to issuing the responses to the seven open items TU Electric had requested a meeting with the NRC to gain a better understanding of these open items. During a meeting on December 5, 1996, held at NRC Region IV offices in Arlington, Texas, it became evident that TU Electric did not fully understand NRC staff's questions. Therefore, some of the responses submitted via TXX-96414 were not fully responsive to the issues. During this December 5, 1996, meeting TU Electric Management informed the NRC staff that due to new information received during this meeting TU Electric will revise CPSES Engineering Report ER-ME-067 to document the responses to the seven open discussed in NRC's May 22, 1996 letter.

RESPONSES TO NRC OPEN ITEMS

NRC open items (May 22, 1996 letter) and TU Electric's response to the open items are provided below:

OPEN ITEM 1

For raceways at CPSES Unit 1, where the total enclosed thermal mass is less than the total enclosed thermal mass of the tested configurations, the test results do not provide an adequate basis for evaluating fire barrier performance. The rating of these barriers (if any) is therefore indeterminate, and these configurations may deviate from the licensee's commitment, in section 9.5.1 of the CPSES Final Safety Analysis Report (FSAR), to provide barriers having a fire resistance rating of 1 hour at CPSES Unit 1.

RESPONSE TO OPEN ITEM 1

The Staff expressed a concern regarding that changes, primarily reductions, in cable mass would affect the performance of the enclosed cables. The specific area of concern was that the fire tests would only bound raceways configurations which had percentage fills equal to or greater than those tested. As the cable fill decreased the expected temperature profile would correspondingly increase. The increased cable temperatures would cause cables which would be functional at a higher percentage to no longer be able to perform their intended functions. The raceways of primary concern were the 2 inch conduit (which differed from Unit 2) and the 12 inch cable tray (it has the lowest mass).

TU Electric has performed the following evaluation which demonstrates that reductions in percentage fill (cable mass) below the values utilized in the fire tests will not adversely impact the functionality of the cables.

TU EVALUATION

PURPOSE

The purpose of this evaluation is to describe the methodology used to determine how electrical cable temperatures recorded inside a Thermo-Lag 330-1 fire barrier system, can be correlated to reasonably predict cable temperatures for equivalent systems containing other cable fill volumes. a 2 inch diameter conduit and a 12 inch cable tray are considered to represent CPSES Unit 1 bounding configurations because they are the smallest raceways (lowest raceway mass) not directly qualified as part of the Unit 2 test program.

BACKGROUND

Conduit

TU Electric Test Scheme 13-2 (Omega Point Laboratories Project No. 12340-95769) was conducted to evaluate the performance of a ½ inch thick (nominal) Thermo-Lag 330-1 fire barrier system installed on a 2 inch diameter steel conduit. This barrier system was subjected to a standard ASTM E119 fire test exposure for a 60 minute duration. The U-shaped conduit configuration consisted of horizontal and vertical segments joined by two 90° radial bend fittings. The barrier system was upgraded in the radial bend regions with a layer of external stainless steel mesh and Thermo-Lag 330-1 trowel grade material. The horizontal and vertical segments were not upgraded. Therefore, the barrier system tested is representative of that installed on 2 inch diameter conduits in Unit 1 applications. The cable fill for the tested conduit was approximately 43% and consisted of 1 (W-020) power cable, 1 (W-048) control cable, and 2 (W-071) instrumentation cables. Thermocouples were installed at 6 inch intervals on the power and control cables, and on one of the instrumentation cables. Thermocouples were also installed at 12 inch intervals on the outside surface of the conduit. The maximum single temperature recorded on the conduit surface was 546°F (454°F above the starting ambient temperature of 92°F). The maximum temperature attained by averaging all conduit surface thermocouples was 366°F (274°F above initial temperature). The maximum single temperature attained on the surface of the cables was 351°F (259°F above the starting temperature), which was recorded on the power cable. The maximum temperature attained by averaging all power cable thermocouples (worse case) was 256°F (162°F above initial temperature).

Cable tray

TU Electric Test Scheme 13-2 (Omega Point Laboratories Project No. 12340-95769) was conducted to evaluate the performance of a ½ inch thick (nominal) Thermo-Lag 330-1 fire barrier system installed on a 12 x 4 inch steel cable tray. No upgrades such as joint reinforcement were utilized to construct the barrier system. This barrier system was subjected to a standard ASTM E119 fire test exposure for a 60 minute duration. The U-shaped tray configuration consisted of horizontal and vertical segments. The cable fill for the tested conduit was 14.68% and consisted of 4 (W-023) power cables, 3 (W-046) control cables, 4 (W-063) instrumentation cables and 4 (W-071) instrumentation cables. Thermocouples were installed at 6 inch intervals on one of the power, control and instrumentation cables. Thermocouples were also installed at 12 inch intervals on the surface of the cable tray side rails. The maximum single temperature recorded on the cable tray surface was 447°F (355°F

above the starting ambient temperature of 92°F). The maximum temperature attained by averaging all cable tray surface thermocouples was 380°F (288°F above initial temperature). The maximum single temperature attained on the surface of the cables was 396°F (304°F above the starting temperature), which was recorded on the instrument cable. The maximum temperature attained by averaging all instrument cable thermocouples (worse case) was 328°F (236°F above initial temperature).

METHODOLOGY

The following methodology was used to arrive at the temperatures listed in Table 1 in the conclusions section below:

Determining Effect of Percent Cable Fill on Thermal Performance

Conduit

TVA Test Assembly 6.1.14 (Omega Point Laboratories Project No. 11210-98892) was chosen as a baseline for determining maximum cable temperature variances based on percent cable fill in a given conduit. This test assembly was chosen because it contained three nearly identical conduit runs. The three conduit runs were of a common size (3" diameter), material (aluminum), orientation and utilized the same Thermo-Lag fire barrier construction methods.

> Note: The Thermo-Lag 330-1 barrier material used to protect the three TVA conduits is the same as that used in the TU Electric installations (½" thick nominal half round conduit sections with pre-buttered joints). Any differences in construction techniques and raceway attributes between the three TVA test articles and the TU Electric installations are immaterial since the purpose of this step of the analysis is to compare the test results of the three TVA test articles to determine the influence that cable fill has on thermal performance of the protected raceway. Once these effects are established, they will be applied to TU Electric construction techniques and raceway attributes.

The only significant difference when comparing the three TVA conduit runs is the percent cable fill in each as indicated below:

- The first 3" conduit, designated as Conduit B in the test assembly, contained a single bare #8 AWG copper conductor resulting in an effective cable fill of 0%.
- The second 3" conduit, designated as Conduit C in the test assembly, contained a single bare #8 AWG copper conductor and five DEKORAN® WVE TYPE MS 7/C 16AWG electrical cables resulting in an effective cable fill of 12.33%.
- The third 3" conduit, designated as Conduit D in the test assembly, contained a single bare #8 AWG copper conductor and 16 DEKORAN® WVE TYPE MS 7/C 16AWG electrical cables resulting in an effective cable fill of 39.45%.

Each of the conduit test articles were fitted with thermocouples installed along the (internal) #8 AWG bare copper conductor at 6 inch intervals. Temperatures recorded by these thermocouples were recorded throughout the test duration, in accordance with ASTM E119 requirements.

Utilizing the temperature values attained at the conclusion of the fire test for each of the reported categories, a comparison was made between the maximum internal (i.e. cable) temperature and the cable/conduit mass associated with each of the conduits. This comparison resulted in three temperature, with respect to mass, data points for one raceway type. a Least-Squares curve fit analysis was then performed on the data points. The results of the curve fit process was excellent, with the correlation between the data and the curve being approximately 99%.

The following data was utilized in the analysis:

Conduit B
Maximum Internal Temperature at 0% fill, 2.41 lbs./ft. = 323°F

Conduit C
Maximum Internal Temperature at 12.33% fill, 3.26 lbs./ft. = 304°F

Conduit D
Maximum Internal Temperature at 40% fill, 5.11 lbs./ft. = 231°F

<u>Applying Effect of Percent Cable Fill to TU Electric Specific Conduits</u>

Since the TU Electric conduit and barrier parameters are not identical to the TVA tested parameters, actual results of TU Electric Test Scheme 13-2 (Omega Point Laboratories Project No. 12340-95769) were used in conjunction with the performance curve derived from the TVA test. This allowed TU Electric to determine the anticipated temperature increase which could be expected with changes in enclosed conduit/cable mass. Once this equation was established, the curve obtained from the TVA data was shifted to correspond to TU Electric's maximum cable temperature. The effect that various changes in conduit/cable mass have on maximum cable temperature can now be calculated.

Specifically, TU Electric Test Scheme 13-2 tested a 2 inch diameter steel conduit clad with ½" thick (nominal) Thermo-Lag 330-1 half round conduit sections. This conduit utilized site-specific cables supplied from CPSES inventory to achieve a 43.47% cable fill (cable/conduit weight of 4.69 lbs./ft.). These consisted of one W-020 Power cable, one W-048 Control cable and two W-071 Instrumentation cables. The conduit test article was fitted with thermocouples along the (internal) Power, Control and Instrumentation cables at 6 inch intervals. The cable conductor temperatures were recorded throughout the test duration. Based on the average initial temperature for all thermocouples at the start of the test being 92°F, the temperature increase over the duration of the test is presented as follows:

Maximum Cable* Conductor Temperature = 259°F
*worse case cable temperature

These temperature values were then incorporated into the equation previously derived to calculate the affects of a change in cable/conduit mass. This analysis is included in Attachment 1 to Appendix F.

Cable Tray

This analysis utilized two sets of cable tray data, one set from TVA and another from TU Electric, in order to determine the most conservative manner in which to analyze reductions in raceway percentage fill (cable/tray mass). TVA conducted Test 6.1.7, (Omega Point project number 11960-97185), in which three identical 18 x 4 inch cable trays were tested in order to determine the affects of reduced cable mass on temperatures of contained cables. In these tests TVA only varied the percentage fill/ cable mass. Attachment 1 to appendix F provides an analysis of this data in which the maximum temperature of the enclosed cables with respect to the enclosed cable/tray mass is plotted. a Least-Squares linear regression was then applied to the data points. There was an 86% correlation between the data and the established curve.

TU Electric then applied the equation in an attempt to determine if it would approximate actual tested values. Specifically, the 12 x 4 inch cable tray barrier system evaluated during TU Electric in Test Scheme 13-2. The combined cable tray/cable weight in this test was 15.75 lbs./ft. The maximum cable temperature for this configuration was 328 °F. The equation established based on the TVA data predicted a maximum temperature of 324 °F. This resulted in a 98% correlation between the predicted and actual test values.

Notwithstanding the excellent correlation associated with the equation developed with the TVA data, TU Electric conducted three fire tests on cable trays which could also be evaluated, Test schemes 13-2, 11-5 and 12-2. In each of these tests, the maximum cable temperature was plotted verses the inclosed cable/tray mass. a Least-Squares regression analysis was then performed on the data. There was 99.6% correlation between the data and the established curve. The calculated temperature rise based on this equation is 398 °F compared to the tested value of 396 °F. The TU Electric equation provides the best correlation with tested values and provides the most conservative results. Therefore, this methodology will be employed within the analysis contained in Attachment 1 to Appendix F.

CONCLUSIONS

It is reasonable to conclude that raceway runs of various cable fills have the same parameters as those tested in TU Electric Test Scheme 13-2, with respect to material (steel), Thermo-Lag fire barrier material and construction methods. These configurations are expected to attain the temperature increase presented in Tables 1 and 2.

The temperature increase values presented in Tables 1 and 2 are based on the actual maximum (final) cable temperatures attained at the conclusion of TU Electric Test Scheme 13-2, and have been adjusted for a zero percent cable fill using correction factors delineated above and shown in Attachment 1 to appendix F.

The calculated increases in the cable temperature will have no adverse affect on the functionality of the cables.

Table 1

CONDUIT

Percent Fill	Cable/Conduit Mass (lbs./ft.)	Cable Max. Temp (°F.)	Cable Max. Temp. Increase
0%	3.5	392	41
43%	4.69	351	

Table 2

CABLE TRAY

Percent Fill	Cable/Tray Mass (lbs./ft.)	Cable Max. Temp (°F.)	Cable Max. Temp. Increase
0%	11	425	29
14.68%	15.75	396	

Open Item 2:

Test Scheme 11-4 did not meet the acceptance criteria for a hose stream test as specified in the NRC letter dated October 29, 1992. An engineering analysis has not been submitted by TU Electric for NRC staff review to address this unsatisfactory condition. As this configuration has been declared acceptable by the licensee without NRC review and concurrence, the licensee may have deviated from the commitment specified in its September 24, 1992, letter.

RESPONSE TO OPEN ITEM 2

Based on the December 5, 1996 meeting, TU Electric has a better understanding of the NRC staff's specific concern with this issue.

The purpose of this test was to evaluate the performance of a "box design" enclosure constructed using a single layer of 1/2" (nominal thickness) Thermo-Lag panels to protect cables which air drop from cable trays to adjacent embedded wall sleeves. Qualification of this design was seen as beneficial to preclude installation of a two layer panel system as implemented for similar Unit 2 configurations. Actual construction of this test enclosure resulted in an unsupported span of approximately 38" for panels forming the top and bottom portions of the "box". To reinforce joint areas between panels, a layer of Thermo-Lag 330-1 trowel grade material was applied, followed by an external layer of Thermo-Lag 330-69 stress skin to effectively overlap each joint by a minimum of 5". The stress skin was secured in place with 9/16" long staples and a skim coat of Thermo-Lag 330-1 trowel grade material was applied to cover the stress skin. This method of joint reinforcement was similar to that qualified during previous (Unit 2) tests of protective envelopes on wide cable trays (i.e., those installed on a 36" wide cable tray, and a tee section for a 30" wide cable tray in Test Schemes 15-1 and 14-1 respectively). However, in an attempt to qualify a less extensive upgrade techniques for Unit 1, the box design enclosure in Test Scheme 11-4 did not include use of 16 GA stainless steel tie wire fasteners installed over the external layer of stress skin that had been utilized to construct the cable tray envelopes for Test Schemes 15-1 and 14-1. Specifically, in lieu of securing the stress skin layer with both 9/16" long staples and tie wire fasteners (which were positioned at approximate 6 inch intervals), the Scheme 11-4 configuration utilized staples only. This method proved effective in that all raceway and cable temperatures remained well within acceptance limits for the entire 1-hour fire exposure portion of the test. However, when the test article was removed from the furnace and positioned for the hose stream test, it was observed that a portion of the external stress skin layer used to reinforce the large span of the bottom panel had started to dislodge. Subsequent application of the hose stream resulted in a barrier opening along the joint area. Although a barrier opening occurred during the hose stream test, the thermal performance of the enclosure during the fire exposure portion of the test resulted in considerable margin between the recorded temperatures and those allowed by the test acceptance criteria. Specifically, the highest temperatures developed within the enclosure were recorded on cable tray side rail surfaces, which experienced an average temperature increase of 166°F and a maximum temperature increase of 244°F, compared to the allowable average and maximum temperature increase parameters of 250°F and 325°F respectively. On this basis, the integrity of the enclosure was maintained throughout the fire test. It should be noted that in Test Scheme 11-5, the external stress skin layer used to reinforce the joints of a 24" wide cable tray envelope was also secured using staples only (i.e., no tie wires). This barrier system maintained satisfactory raceway and cable temperatures and no openings occurred during the hose stream test.

During the December 5, 1996 meeting TU Electric indicated that during subsequent implementation of the Unit 1 Thermo-Lag barrier modifications, all of the existing "box design" enclosures installed to protect cable air drops between trays and adjacent embedded wall sleeves were rebuilt. In actuality, depending on their specific configuration, location, accessibility, etc., only some of these enclosures were rebuilt. For those that were rebuilt, many incorporated the use of stainless steel tie wire "stitching" techniques to mechanically attach adjacent Thermo-Lag panels. The remaining enclosures were upgraded beyond the tested configuration. However, in each case, the designs implemented were based on those qualified by test. Specifically, the M1-1701 "Thermo-Lag Typical Details" were revised to require installation of 16 GA stainless steel tie wire fasteners, spaced at 6 inch (maximum) intervals, for the bottom panels of all such box design enclosures. This method of upgrade is consistent with that qualified via Test Schemes 15-1 and 14-1 for panel spans that envelope the Unit 1 field configurations. The use of stainless steel tie wire "stitching" method was also qualified by previous Unit 2 testing (e.g., Test Scheme 12-1).

In conclusion, the "box design" enclosures installed in Unit 1 are acceptable based on the following:

- The thermal performance of the "box design" enclosure in Test 11-4, constructed using a single layer of Thermo-Lag panels, was well within acceptance levels.
- The methods utilized to reinforce joint areas of such configurations in Unit 1 (i.e., staples and tie wires over an external stress skin layer with or without tie wire "stitches") were previously qualified via Test Schemes 15-1 , 14-1 and 12-1, for which post hose stream barrier integrity was maintained.
- The physical size of the Unit 1 configurations, in terms of Thermo-Lag panel spans, are bounded by those tested. Specifically, the unsupported span for the bottom panel installed on the 30" cable tray tee section in Test Scheme 14-1 was approximately 42", which envelopes the corresponding panel spans for all Unit 1 configurations.

OPEN ITEM 3

The licensee references Test Scheme 4 as the basis for qualifying Thermo-Lag cable tray fire stops at CPSES Unit 1, however this test report was not provided for NRC staff review. Summary data regarding Test Scheme 4, provided by the licensee in ER-ME-067, Revision 3, states that the maximum single point temperature recorded was 466°F with a maximum average temperature of 380°F. These temperatures exceed the maximum allowable temperatures specified in the NRC letter dated October 29, 1992 (maximum single point 325°F above ambient, maximum average 250°F above ambient). The staff concluded that raceway barriers that have Thermo-Lag 330-1 fire stops installed similar to that configuration tested in Scheme 4 may not meet the acceptance criteria for a rating of 1 hour. Therefore, these configurations may deviate from the licensee's commitment in Section 9.5.1 of the CPSES FSAR, to provide barriers having a fire resistance rating of 1 hour at CPSES Unit 1.

RESPONSE TO OPEN ITEM 3

TU Electric has performed an evaluation of the three different type of materials used to construct fire stops at CPSES. This evaluation is provided in Attachment 2 to Appendix F. The aforementioned evaluation concluded that; based on the results of the fire endurance tests listed in Section 3 of Attachment 2 of Appendix F, as augmented by the technical evaluations presented in Section 4 of Attachment 2 of Appendix F, fire stops installed at CPSES constructed of Thermo-Lag 330-1, Promatec 45B silicone elastomer and BISCO SF-60 silicone elastomer materials are acceptable designs to seal termination's of Thermo-Lag protective envelopes on cable trays. These fire stop designs are qualified for the entire range of installed cable tray sizes and associated electrical cable fill densities at CPSES. As stated earlier in this document, firestops constructed using Silicone Foam material will be removed or augmented with acceptable firestop material via Design Modification 97-014. Please refer to attachment 2 to appendix F.

OPEN ITEM 4

With regard to the silicone foam fire stops installed at CPSES Unit 1, where the qualification is based on CPSES Unit 2 fire tests, that utilized silicone elastomer, the staff concludes that as the material properties of silicone foam and silicone elastomer are significantly different (i.e., the density of silicone elastomer is 3 to 4 times that of silicone foam), no correlation of fire performance can be assumed. Therefore, the fire rating of raceway fire barriers that have fire stops constructed of silicone foam is indeterminate. These configurations may deviate from the licensee's commitment, in Section 9.5.1 of the CPSES FSAR, to provide barriers having a fire resistance rating of 1 hour at CPSES Unit 1.

RESPONSE TO OPEN ITEM 4

With respect to silicone foam, after December 5, 1996, TU Electric performed an extensive review of construction work packages (including design documents) and performed field walkdowns. These walkdowns resulted in discovery of 6 silicone foam fire stops. TU Electric will rework these silicone foam fire stops to bring them in compliance with tested configuration i.e., silicone elastomer via Design Modification No. 97-014. Additionally please refer to response to open item 3 above.

OPEN ITEM 5

Based on information submitted to the NRC staff, the staff found that (1) there is insufficient evidence to demonstrate that Test Scheme 9-3 (1 ½" and 2" conduit) would ensure that the subject cables would function during and after exposure and (2) several factors (i.e., calculated composite and hot-spot cable IR values and apparent burn through on the 2" conduit specimen) also indicate unacceptable performance.

RESPONSE TO OPEN ITEM 5

For 1-1/2" conduits, TU Electric has elected to upgrade the 1-1/2" conduit assemblies with 1/4" overlays, similar to tested and installed for CPSES Unit 2. TU electric will certify

the 1-1/2' conduits under the auspices of Test Scheme 9-2, previously accepted by the NRC staff via NUREG 0797, Supplement 26. The upgrades will be performed via Design Modification No. 97-014.

with respect to 2" conduits, these installations are acceptable under the auspices of Test Scheme 13-2. This test was deemed acceptable by the NRC staff in its May 22, 1996 letter. Additionally, please refer to attachment 3 to appendix F for response on effects of self heating on power cables as requested via the open item 5.

OPEN ITEM 6

Based on information submitted to the NRC staff, the staff found that (1) there is insufficient evidence demonstrating that Test Scheme 11-2 (2" air drop) would ensure the subject cables would function during and after a fire exposure and (2) several factors (e.g., calculated composite and hot-spot cable IR values, charring) indicate also unacceptable barrier performance.

RESPONSE TO OPEN ITEM 6

After the December 5, 1996, meeting with the NRC staff, TU Electric Management elected to upgrade both 1-1/2" and 2" airdrops installed at CPSES Unit 1 raceways. TU Electric will upgrade these airdrops (1-1/2" and 2") to be in compliance with Unit 2 tested configuration 11-1, this test was previously deemed acceptable by the NRC staff via NUREG 0797 Supplement 26.

OPEN ITEM 7

The use of Test Scheme 15-2 for cables smaller than 750 KcMil [MCM] is an open item.

RESPONSE TO OPEN ITEM 7

TU Electric Test 15-2 was performed to bound a "unique" configuration. TU Electric does not use this test to certify configurations that are less than 750 MCM cable. TU Electric believes that this response was deemed to be acceptable, and was indicated as such during the December 5, 1996 meeting.

<u>ATTACHMENT 1 TO APPENDIX F</u>

"EVALUATION OF THE RELATIONSHIP BETWEEN ENCLOSED MASS AND CABLE TEMPERATURES FOR THE ELECTRICAL RACEWAYS AT CPSES"

Open Item 1
Evaluation of the relationship between enclosed mass and cable ter iperature for cables in tray.

This evaluation will establish a relationship between the mass enclosed by the Thermo-Lag barrier system and the average temperature associated with the enclosed cable mass. This data will then be utilized to predict the maximum temperature which would be experienced by the cables. Test data available from TU Electric and TVA will be utilized in this analysis.

TVA test data - TVA test 6.1.7, Omega Point Lab. Project Number 11960-97185

$i := 0..2$

Data points

$x_i :=$	$y_i :=$
4	286
10.24	205
73.36	147

x is the combined weight of the cable and tray, in lbs/ft

y is the avg. maximum temperature of the enclosed cable, in °F

A Least-Squares linear regression will be applied to the data points

$a := \mathrm{slope}(x, y)$

$a = -1.563$

Slope of the Least-Squares regression

$b := \mathrm{intercept}(x, y)$

$b = 258.307$

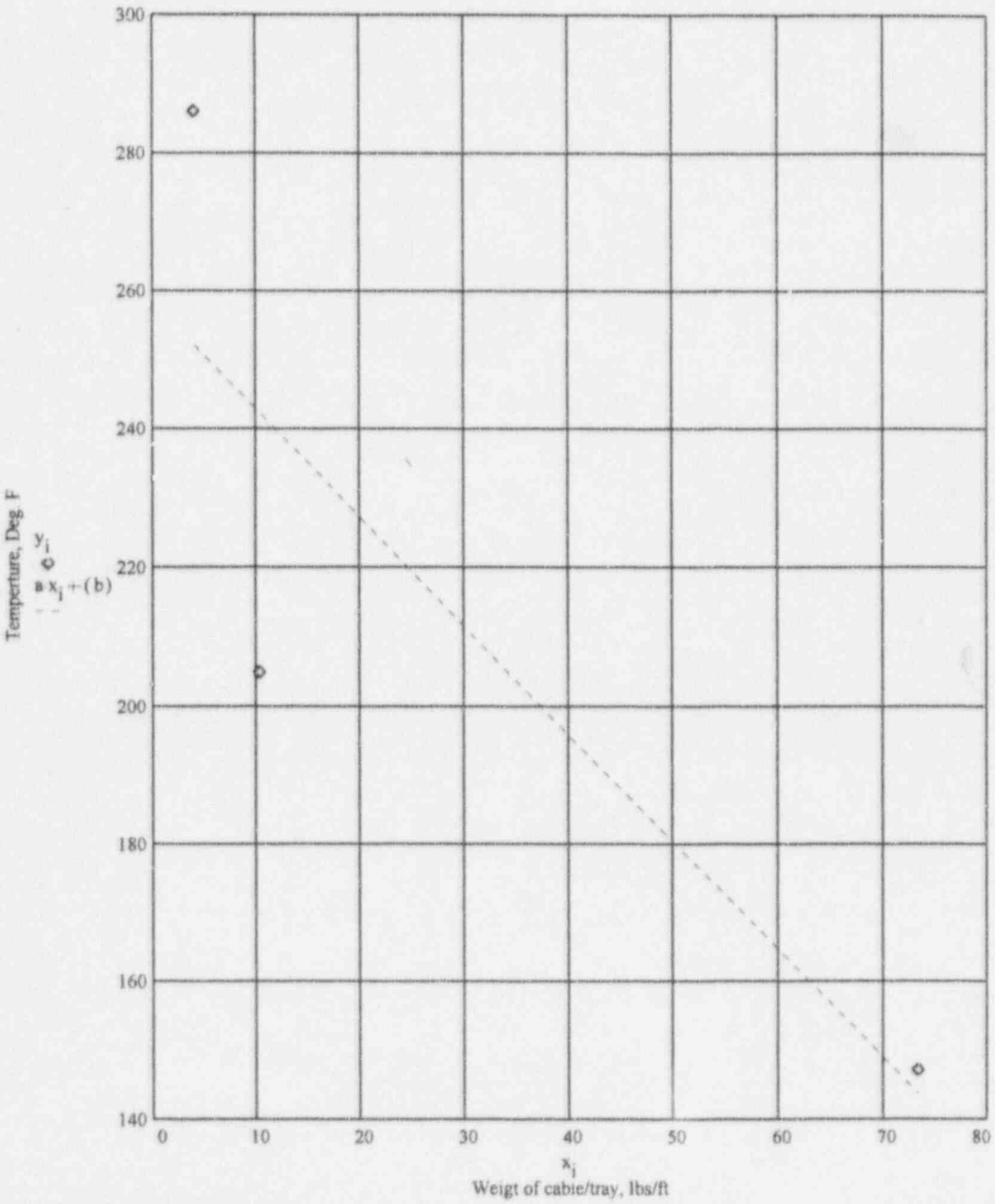
Y-intercept of the Least-Squares regression

$c := \mathrm{corr}(x, y)$

$c = -0.859$

Correlation coefficient - Pearson's r

Graph of Least-Squares regression for TVA Test 6.1.7 data



Comparison of Linear regression performed on the TVA data to TU Electric tested values.

$x := 15.75$	Weight of cable tray and contained cables in the 12 x 4 inch tray tested in Scheme 13-2, in lbs/ft
$y := a \cdot x + b$	Equation derived from the Linear regression analysis
$y = 233.689$	Temperature rise above 90 °F ambient, °F
$y + 90 = 324$	Predicted average cable temperature, in °F

The actual measured average temperature was 328°. The regression analysis provides a 98 percent approximation to the actual tested configuration.

Calculation of predicted temperature rise due to the removal of the cable mass

$x := 11$	Weight of empty 12" x 4" cable tray, in lbs per foot
$y := a \cdot x + b$	Equation derived from the Linear regression analysis
$y = 241.113$	Temperature rise above 90° F ambient, °F
$y + 90 = 331$	Predicted average cable temperature, °F
$\frac{331}{324} = 1.022$	Temperature increase due to reduced thermal mass
$396 \cdot 1.022 = 405$	Predicted maximum cable temperature associated with reduced cable mass, in °F.

TU Electric test data - Schemes 13-2, 11-5 and 12-2

$i := 0..2$

Data points (respectively)

$x_i :=$	$y_i :=$
15.75	396
28.07	336
36.58	280

x is the combined weight of the cable and tray, in lbs per foot

y is the maximum temperature of the enclosed cable, in °F

Note: the cable mass for Scheme 12-2 has been adjusted to include cable which was coiled in the "Tee" section. This adjustment is based on cable tray length exposed to the fire (13') and a cable cut length of (30'). An additional 75% has been added to the cable mass.

A Least-Squares linear regression will be applied to the data points

$a := \text{slope}(x, y)$

$a = -5.519$

Slope of the Least-Squares regression

$b := \text{intercept}(x, y)$

$b = 485.244$

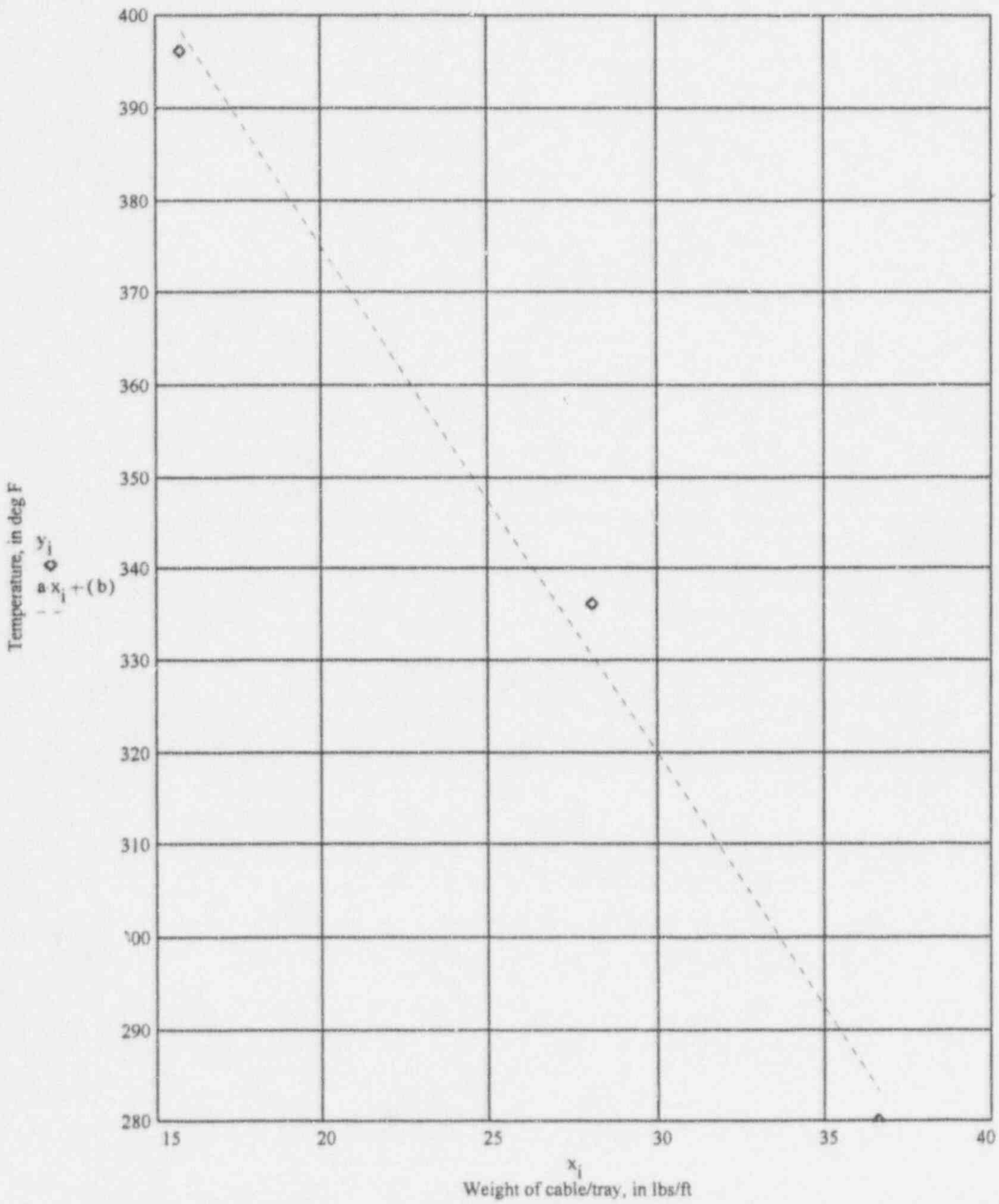
Y-intercept of the Least-Squares regression

$c := \text{corr}(x, y)$

$c = -0.996$

Correlation coefficient - Pearson's r

Graph of Least-Squares regression for TU Electric Test scheme 13-2, 11-5, and 11-2 data



Calculation of predicted temperature rise due to the removal of the cable mass

$x = 11$	Weight of empty 12" x 4" cable tray, in lbs per foot
$y = a \cdot x + b$	Equation derived from the Linear regression analysis
$y = 425$	Predicted maximum cable temperature due to reduced cable mass, °F

There is a 95 percent correlation between the results of the TU Electric and the TVA models. However, since the TU Electric model yielded the most conservative results (and results in a correlation coefficient of 99%) it will be utilized for the cable functionality evaluation.

The maximum cable temperature recorded on the 12 inch cable tray in test scheme 13-2 was 396° F. The cable tray in this test had a percentage fill of 14.68 percent. Based on the preceding models we would expect that there would be a 29° F rise in the temperature if the tray had been empty. The following functionality evaluation will include an additional 29° F to bound the worst case configurations at CPSES.

Scheme 13-2
12" cable tray

Worst case temperature profile

This profile utilizes the maximum cable temperature from each thermocouple group, regardless of which cable the thermocouple was attached to. This temperature profile also has 29° F added to it in order to account for the temperature increase associated with a theorized zero percent filled tray.

$i := 0..24$

$$T := \begin{bmatrix} 349 \\ 350 \\ 351 \\ 333 \\ 296 \\ 293 \\ 306 \\ 314 \\ 309 \\ 321 \\ 295 \\ 307 \\ 314 \\ 366 \\ 396 \\ 376 \\ 337 \\ 305 \\ 314 \\ 309 \\ 332 \\ 328 \\ 332 \\ 338 \\ 338 \end{bmatrix} + 29$$

Cable Type: **Power**

$D := .236$ — Diameter of insulation in inches.

$d := .146$ — Diameter of conductor in inches.

$K_i := \left[4\cdot 10^{21}\cdot e^{\left[-.079\cdot\left[\left[\frac{5}{9}\cdot(T_i-32)\right]+273\right]\right]}\right]$ — Insulation Resistance Constant.

$IR_i := \left(K_i\cdot\log\left(\frac{D}{d}\right)\right)$ — Insulation Resistance in Ω - 1000 ft.

$IR'_i := IR_i\cdot 1000$ — Insulation Resistance for a cable length, in Ω and ft.

$S := .5$ — Thermocouple Spacing.

$R := \frac{IR'}{S}$ — Insulation Resistance of each cable length, in Ω.

$$R_1 := \frac{1}{\left(\frac{1}{R_0}+\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4}+\frac{1}{R_5}+\frac{1}{R_6}+\frac{1}{R_7}+\frac{1}{R_8}+\frac{1}{R_9}+\frac{1}{R_{10}}+\frac{1}{R_{11}}+\frac{1}{R_{12}}+\frac{1}{R_{13}}+\frac{1}{R_{14}}+\frac{1}{R_{15}}+\frac{1}{R_{16}}+\frac{1}{R_{17}}\right)}$$

$$R_2 := \frac{1}{\left(\frac{1}{R_{18}}+\frac{1}{R_{19}}+\frac{1}{R_{20}}+\frac{1}{R_{21}}+\frac{1}{R_{22}}+\frac{1}{R_{23}}+\frac{1}{R_{24}}\right)}$$

$Rt := \frac{1}{\frac{1}{R_1}+\frac{1}{R_2}}$ $\quad Rt = 8.264\cdot 10^{6}$ — Insulation Resistance of entire cable, in Ω.

Insulation Resistance in Ω - 1000 ft. - Power Cable

IR_i
$9.117 \cdot 10^4$
$8.726 \cdot 10^4$
$8.351 \cdot 10^4$
$1.84 \cdot 10^5$
$9.334 \cdot 10^5$
$1.065 \cdot 10^6$
$6.018 \cdot 10^5$
$4.236 \cdot 10^5$
$5.276 \cdot 10^5$
$3.116 \cdot 10^5$
$9.753 \cdot 10^5$
$5.76 \cdot 10^5$
$4.236 \cdot 10^5$
$4.323 \cdot 10^4$
$1.159 \cdot 10^4$
$2.788 \cdot 10^4$
$1.544 \cdot 10^5$
$6.288 \cdot 10^5$
$4.236 \cdot 10^5$
$5.276 \cdot 10^5$
$1.923 \cdot 10^5$
$2.292 \cdot 10^5$
$1.923 \cdot 10^5$
$1.477 \cdot 10^5$
$1.477 \cdot 10^5$

Cable Type: **Control**

$D = .152$ Diameter of insulation in inches.

$d = .092$ Diameter of conductor in inches.

$K_i = \left[4 \cdot 10^{21} \cdot e^{\left[-.079 \cdot \left[\left[\frac{5}{9} \cdot (T_i - 32) \right] + 273 \right] \right]} \right]$ Insulation Resistance Constant.

$IR_i = \left(K_i \cdot \log\left(\frac{D}{d} \right) \right)$ Insulation Resistance in Ω - 1000 ft.

$IR'_i = IR_i \cdot 1000$ Insulation Resistance for a cable length, in Ω and ft.

$S = .5$ Thermocouple Spacing.

$R = \frac{IR'}{S}$ Insulation Resistance of each cable length, in Ω.

$$R_1 = \frac{1}{\left(\frac{1}{R_0} + \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} + \frac{1}{R_6} + \frac{1}{R_7} + \frac{1}{R_8} + \frac{1}{R_9} + \frac{1}{R_{10}} + \frac{1}{R_{11}} + \frac{1}{R_{12}} + \frac{1}{R_{13}} + \frac{1}{R_{14}} + \frac{1}{R_{15}} + \frac{1}{R_{16}} + \frac{1}{R_{17}} \right)}$$

$$R_2 = \left(\frac{1}{\frac{1}{R_{18}} + \frac{1}{R_{19}} + \frac{1}{R_{20}} + \frac{1}{R_{21}} + \frac{1}{R_{22}} + \frac{1}{R_{23}} + \frac{1}{R_{24}}} \right)$$

$Rt = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}$ $Rt = 8.64 \cdot 10^6$ Insulation Resistance of entire cable, in Ω.

Insulation Resistance in Ω - 1000 ft. - Control Cable

IR_i
$9.532 \cdot 10^4$
$9.123 \cdot 10^4$
$8.731 \cdot 10^4$
$1.924 \cdot 10^5$
$9.759 \cdot 10^5$
$1.113 \cdot 10^6$
$6.292 \cdot 10^5$
$4.429 \cdot 10^5$
$5.516 \cdot 10^5$
$3.258 \cdot 10^5$
$1.02 \cdot 10^6$
$6.022 \cdot 10^5$
$4.429 \cdot 10^5$
$4.52 \cdot 10^4$
$1.212 \cdot 10^4$
$2.914 \cdot 10^4$
$1.614 \cdot 10^5$
$6.575 \cdot 10^5$
$4.429 \cdot 10^5$
$5.516 \cdot 10^5$
$2.01 \cdot 10^5$
$2.396 \cdot 10^5$
$2.01 \cdot 10^5$
$1.545 \cdot 10^5$
$1.545 \cdot 10^5$

Cable Type: **Instrument**

$D = .120$ Diameter of insulation in inches.

$d = .060$ Diameter of conductor in inches.

$K_i = \left[4 \cdot 10^{21} \cdot e^{\left[-.079 \cdot \left[\left[\frac{5}{9} \cdot (T_i - 32)\right] + 273\right]\right]}\right]$ Insulation Resistance Constant.

$IR_i = \left(K_i \cdot \log\left(\frac{D}{d}\right)\right)$ Insulation Resistance in Ω - 1000 ft.

$IR'_i = IR_i \cdot 1000$ Insulation Resistance for a cable length, in Ω and ft.

$S = .5$ Thermocouple Spacing.

$R = \frac{IR'}{S}$ Insulation Resistance of each cable length, in Ω.

$$R_1 = \frac{1}{\left(\frac{1}{R_0} + \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} + \frac{1}{R_6} + \frac{1}{R_7} + \frac{1}{R_8} + \frac{1}{R_9} + \frac{1}{R_{10}} + \frac{1}{R_{11}} + \frac{1}{R_{12}} + \frac{1}{R_{13}} + \frac{1}{R_{14}} + \frac{1}{R_{15}} + \frac{1}{R_{16}} + \frac{1}{R_{17}}\right)}$$

$$R_2 = \frac{1}{\left(\frac{1}{R_{18}} + \frac{1}{R_{19}} + \frac{1}{R_{20}} + \frac{1}{R_{21}} + \frac{1}{R_{22}} + \frac{1}{R_{23}} + \frac{1}{R_{24}}\right)}$$

$Rt = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}$ $Rt = 1.193 \cdot 10^7$ Insulation Resistance of entire cable, in Ω.

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

$IS_{max} = .020$ Maximum Transmitter Current.

$IS_{min} = .004$ Minimum Transmitter Current.

$VS = 40$ Loop Power Supply Voltage.

$RL = 250$ External Source Resistor.

$$IE = \frac{VS - IS_{min} \cdot (RL)}{Rt}$$ Leakage Current.

$IE = 3.27 \cdot 10^{-6}$

$$IE(\%) = \frac{IE}{IS_{max} - IS_{min}} \cdot 100$$ Leakage Current as a Percent of Instrument Span.

$IE(\%) = 0.02$

Insulation Resistance in Ω - 1000 ft. - Instrument Cable

IR_i
$1.316 \cdot 10^5$
$1.259 \cdot 10^5$
$1.205 \cdot 10^5$
$2.656 \cdot 10^5$
$1.347 \cdot 10^6$
$1.537 \cdot 10^6$
$8.687 \cdot 10^5$
$6.115 \cdot 10^5$
$7.615 \cdot 10^5$
$4.497 \cdot 10^5$
$1.408 \cdot 10^6$
$8.314 \cdot 10^5$
$6.115 \cdot 10^5$
$6.24 \cdot 10^4$
$1.673 \cdot 10^4$
$4.023 \cdot 10^4$
$2.228 \cdot 10^5$
$9.076 \cdot 10^5$
$6.115 \cdot 10^5$
$7.615 \cdot 10^5$
$2.775 \cdot 10^5$
$3.308 \cdot 10^5$
$2.775 \cdot 10^5$
$2.133 \cdot 10^5$
$2.133 \cdot 10^5$

Open Item 1 (cont.)
Evaluation of the relationship between enclosed mass and cable temperature for cables in conduit.

This evaluation will establish a relationship between the mass enclosed by the Thermo-Lag barrier system and the average temperature associated with the enclosed cable mass. This data will then be utilized to predict the maximum temperature which would be experienced by the cables. Test data available from TU Electric and TVA will be utilized in this analysis.

$i := 0..2$

Data Points

$x_i :=$	$y_i :=$
2.41	323
3.255	304
5.114	231

Data points taken form TVA test Assembly 6.1.14 (Omega Point Project No. 11210-98892).

x = Enclosed weight of conduit and cables, lbs/ft.
y = Maximum cable temperature, °F

$a := \text{slope}(x, y)$

Slope of the Least-Squares regression

$a = -34.885$

$b := \text{intercept}(x, y)$

Y-intercept of the Least-Squares regression

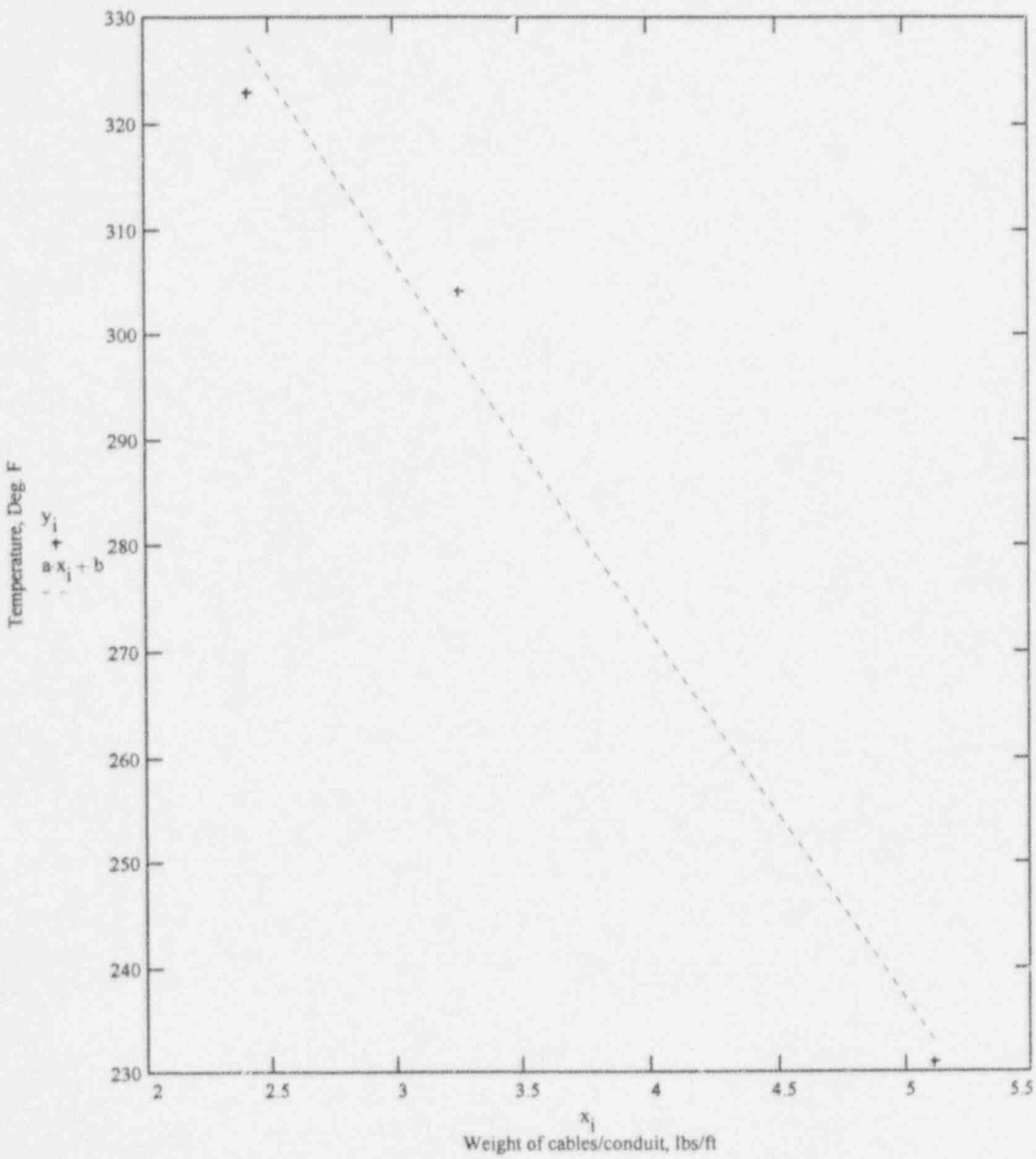
$b = 411.341$

$c := \text{corr}(x, y)$

Correlation coefficient - Pearson's r

$c = -0.994$

Graph of Least-Squares regression for TVA Test 6.1.14 data



In TU Electric Test Scheme 13-2 a single 2 in conduit was tested. This conduit had a percentage fill of 43.8 % and a weight per foot of 4.69 lbs. The correlation between the TVA data was 99 % indicating its close linear approximation. The TVA data provides an excellent comparison between cable temperature increase and reduction in cable mass. This data curve, shown above, will be shifted to pass through the lbs./ft. - temperature point experienced in Scheme 13-2.

$a = -34.885$ — Slope of the Least-Squares regression, established from TVA data points.

$b = 411.341$ — Y-intercept of the Least-Squares regression, established from TVA data points.

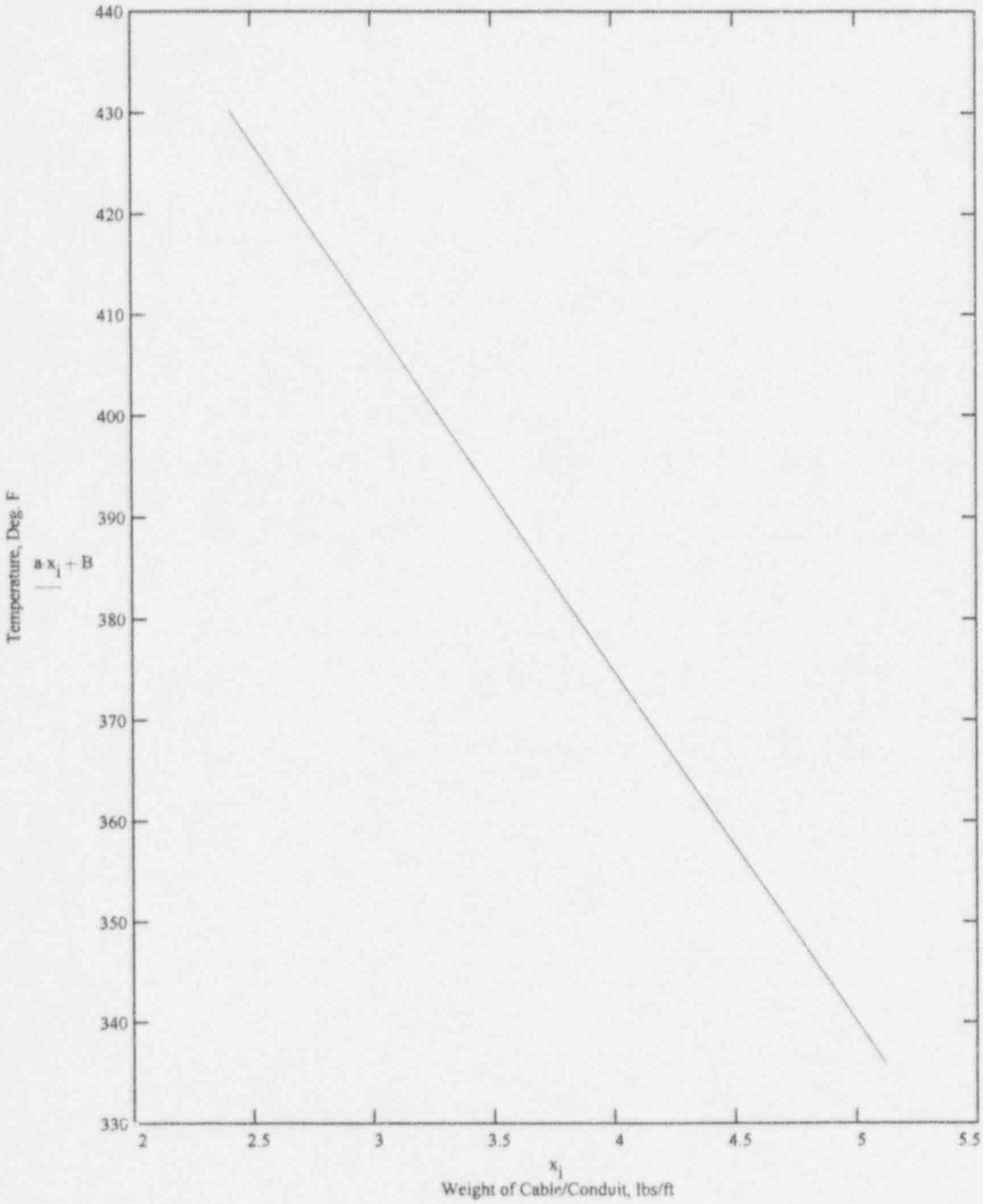
$c = 103$ — Value added to b to shift the curve through the scheme 13-2 data point.

$X_1 = 4.69$ — Cable and conduit weight associated with a percentage fill of 43.8 % in Scheme 13-2

$B = b + c$ $\quad B = 514.341$ — Y-intercept of the Least-Squares regression, established from TVA data points, and shifted through the Scheme 13-2 data point

$a \cdot X_1 + B = 351$ — Confirmation of equation with respect to scheme 13-2 data. The maximum cable temperature for Test Scheme 13-2 was 351° F.

Graph of Least-Squares regression for TU Electric Test Scheme 13-2 data



$j := 0..7$

Comparison between percentage fill ($TUpfill_j$) and enclosed mass (x_j)

$x_j :=$	$TUpfill_j :=$
3.5	0
3.67	6.3
3.84	12.5
4.01	18.8
4.18	25
4.35	31.3
4.52	37.5
4.69	43.8

$y_j := a \cdot x_j + B$

Projected change in the maximum cable temperature as the amount of contained cables is decreased.

y_j	$TUpfill_j$
392	0
386	6.3
380	12.5
374	18.8
369	25
363	31.3
357	37.5
351	43.8

Projected increase in cable temperature as the amount of contained cables is reduced.

$y_j - 351$	$TUpfill_j$
41	0
35	6.3
29	12.5
23	18.8
18	25
12	31.3
6	37.5
-0	43.8

Conclusion:

While cable mass will have an affect on the overall temperature profile, the increase in temperature will have no adverse affect on cable functionality. The TU Electric data shows excellent correlation between enclosed mass and maximum cable temperature. All of the cables maintain IR values in access of 8 meg. ohms and the predicted instrument error is negligible.

ATTACHMENT 2 TO APPENDIX F

"ELECTRICAL RACEWAY FIRESTOP EVALUATION"

1.0 PURPOSE

As described in Section 2.0 of the CPSES Fire Protection Report (Ref. 6.1), TU Electric may utilize provisions outlined in Generic Letter 86-10 (Ref. 6.2) to evaluate the acceptability of fire protection features installed for protection of safe shutdown capability. On this basis, the purpose of this evaluation is to demonstrate the acceptability of fire stop materials installed within cable trays protected with 1 hour rated Thermo-Lag 330-1 fire barrier systems, where such cable tray protective envelopes terminate away from structural concrete surfaces such as walls, floors, etc.

2.0 BACKGROUND

Three (3) basic materials have been utilized at CPSES to serve as fire stops where the Thermo-Lag fire barrier system coverage on protected cable trays terminates away from walls, floors, etc. These materials include Dow Corning 3-6548 Silicone RTV Foam, Silicone Elastomer (either BISCO SF-60 Silicone Elastomer or Promatec 45B Formulated Silicone Elastomer) and Thermo-Lag 330-1 materials consisting of both trowel grade and 1/2" thick (nominal) prefabricated panel consistencies.

2.1 Unit 2 Cable Tray Fire Stop Configurations

Based on the more favorable cable ampacity derating characteristics of silicone elastomer material over silicone foam, silicone elastomer material (Promatec 45B Formulated Silicone Elastomer) was used exclusively for Unit 2 configurations where Thermo-Lag fire barrier coverage on cable trays does not extend to the room boundaries within applicable plant areas. The Unit 2 Penetration Seal Database (Ref. 6.3) lists fifty (50) configurations where silicone elastomer fire stops were installed at termination points of Thermo-Lag fire barrier coverage on cable trays.

The use of Promatec 45B silicone elastomer fire stops to seal terminations of Thermo-Lag protective envelopes on cable trays was qualified during the TU Electric Fire Endurance Test Program. However, these tested configurations did not include electrical cable penetrations through the fire stop, as do many fire stop configurations installed at CPSES. Therefore, configurations where (nonessential) electrical cables extend through silicone elastomer cable tray fire stops will be addressed by this evaluation.

2.2 Unit 1 Cable Tray Fire Stop Configurations

Unlike Unit 2, no specific material requirements or limitations were applicable to similar terminations of Thermo-Lag fire barriers installed on Unit 1 cable trays. Therefore, at the discretion of responsible engineering and construction personnel, based on factors such as location, orientation, accessibility, etc., installation of fire stops constructed using any one of the three (3) materials described above was acceptable. Review of construction work documents applicable to Unit 1 configurations indicates 5 applications where silicone foam cable tray fire stops are installed, 10 applications where

silicone elastomer fire stops are installed, and 32 applications which utilize Thermo-Lag 330-1 materials for cable tray fire stops.

Fire stops constructed using silicone foam material to seal terminations of Thermo-Lag protective envelopes on cable trays were not specifically evaluated as part of the TU Electric or Nuclear Energy Institute (NEI) Fire Endurance Test Programs. Therefore, as a conservative measure, the 5 instances in Unit 1 where silicone foam fire stops were installed at cable tray fire barrier terminations will be modified by Design Modification (DM) No. 97-14 (Ref. 6.4), to result in tested configurations.

Fire Stop Design	Qualifying (Q) and Supporting (S) Fire Tests
Thermo-Lag 330-1	(Q) NEI Test 2-8 (S) TU Electric Test Scheme 4 (S) TU Electric Test Scheme 13-2 (S) TU Electric Test Scheme 1-2
Silicone Elastomer (Promatec 45B)	(Q) TU Electric Test Scheme 14-1 (S) Tech-Sil Test #TS-TP-0075-C (Q) Tech-Sil Test #TS-TP-0018 (S) Tech-Sil Test F-106 (S) NEI Test 2-8
Silicone Elastomer (BISCO SF-60)	(Q) BISCO Test 748-105 (S) NEI Test 2-8

3.0 FIRE ENDURANCE TESTS OF FIRE STOP MATERIALS

The qualification of the two remaining different types of fire stop designs are supported by various fire tested configurations as supplemented by this engineering evaluation. Specifically, the fire tests used to support qualification of each of the fire stop designs is as follows:

Specific details associated with these tests, such as test configuration, instrumentation, thermal performance and hose stream test methods are described in detail below.

3.1 <u>TU Electric Test Scheme 4</u> (Ref. 6.5)

This test was performed in June of 1992, prior to receipt of the October 29, 1992 letter (Ref. 6.6) which provided the NRC staff's acceptance methodology for TU

Electric testing of Thermo-Lag raceway fire barrier systems. As such, in and of itself, this test is not credited as the basis for qualification of Thermo-Lag fire stops at CPSES. However, as described in Section 4.0 below, some portions of this test are useful in support of other tests that more directly bound these types of installed cable tray fire stop designs.

Test Scheme 4 evaluated a Thermo-Lag 330-1 fire stop installed in a vertically oriented 36" x 4" steel ladder back cable tray section. The bottom of the cable tray extended approximately 48" below a horizontal concrete slab. The cable tray test assembly contained an assortment of power, control, and instrumentation cables taken from CPSES stock inventory. The cable fill used for this test was 49.32% for the full length of the cable tray. All but the lower 12" of the cable tray was covered with a 1 hour "baseline" Thermo-Lag barrier system (i.e., no upgrades such as joint reinforcement mechanisms, were applied). Specifically, 1/2" thick (nominal) prefabricated Thermo-Lag 330-1 v-ribbed panels were used to enclose the upper 36" of the tray segment. Panel joints and seams were pre-buttered with Thermo-Lag 330-1 Trowel Grade material and secured with 1/2" x 0.020" stainless steel bands. A Thermo-Lag 330-1 Trowel Grade fire stop, having a 4"-5" depth, was installed where the cables exited the Thermo-Lag cable tray envelope. All cables contained within the tray passed through the fire stop assembly and extended downward for approximately 12" toward the bottom of the test furnace. As such, the cables were fully exposed to the test fire environment before entering the fire stop and cable tray protective envelope.

The cable tray barrier and fire stop assembly was subjected to a 60 minute fire exposure, following the ASTM E119 standard time-temperature curve. Thermocouples placed along the cable tray side rails and on power, control and instrumentation cables within the cable tray enclosure were used to measure the thermal performance of the enclosure. An 89°F initial temperature allowed for a maximum average temperature of 339°F, and a single maximum temperature of 414°F. Temperatures on cables within the confines of the cable tray protective envelope met temperature acceptance criteria. However, the average temperature increase criterion was exceeded on the right cable tray side rail at 55 minutes and on the left rail at 59 minutes. The maximum average temperature was 380°F, recorded on the right tray side rail. The maximum single point side rail temperature was 391°F. Following the fire exposure, the test assembly was subjected to a hose stream test, using a solid stream delivered at 30 psi nozzle pressure, from a standard playpipe, for 2-1/2 minutes. As had occurred with other initial TU Electric Thermo-Lag fire endurance tests, the force of the solid hose stream resulted in dislodgment of panels used to cover the cable tray, but the fire stop assembly was not adversely affected by the hose stream, and remained fixed in place. Post-test examination revealed that the Thermo-Lag trowel grade material used to construct the fire stop had been charred to a depth of approximately 1-1/2". Only minor stiffening of the cables above the fire stop had occurred with no observable signs of thermal degradation.

3.2 <u>TU Electric Test Scheme 13-2</u> (Ref. 6.7)

This test was performed in August of 1993, and as such, was performed in accordance with the NRC staff acceptance methodology (Ref. 6.6). The purpose of this test was to evaluate the performance of a "baseline" Thermo-Lag 330-1 protective envelope consisting of 1/2" thick (nominal) prefabricated v-rib panels installed on a U-shaped 12" x 4" steel ladder back cable tray assembly. No upgrades, such as joint reinforcement mechanisms, were applied. The cable tray test assembly contained an assortment of power, control, and instrumentation cables taken from CPSES stock inventory. Consistent with other TU Electric tests of cable tray fire barrier systems, a single layer of cables was used, resulting in a fill of 14.68%. The Thermo-Lag fire barrier system was continuous for the length of the "U" shaped cable tray, there were no fire stops installed in this assembly.

The cable tray barrier assembly was subjected to a 60 minute fire exposure, following the ASTM E119 standard time-temperature curve. " 92°F initial temperature allowed for a maximum average temperature of 342°F, and a maximum single [illegible] temperature of 417°F. Thermal acceptance criteria (on the cable tray side rails) was exceeded at 53 minutes. The maximum average temperature after the 60 minute fire exposure was 380°F (on the front side rail), or 38°F above the allowable average temperature criterion. The maximum single point temperature of 447°F (or 30°F above the allowable maximum temperature criterion), also occurred on the front side rail. Temperatures on the cables remained within allowable limits. The maximum average temperature recorded on the cables was 328°F, and the maximum single point temperature was 396°F. The cable tray enclosure was then subjected to a hose stream test, using a 30° fog nozzle at a minimum nozzle pressure of 75 psi, for a duration of 5 minutes. Following the hose stream test, an approximate 15 sq. in. area on the underside of the envelope was visible where burn through of the barrier had occurred late in the test. Based on acceptable cable temperatures and visual inspection results, as supported by acceptable cable insulation resistance measurements, this test satisfied the acceptance criteria specified by the NRC staff (Ref. 6.6). Results of subsequent cable functionality analyses further substantiated the acceptability of the test (Ref. 6.8 and 6.9). NRC staff acceptance of the results of this test was provided via Ref. 6.10.

Even though there was no cable tray fire stop installed in the raceway test article, Test Scheme 13-2 has been included in this evaluation for the purpose of demonstrating that even if temperatures recorded on cable tray side rail surfaces exceed those allowable by the test protocol by as much as 38°F, the cables utilized at CPSES will remain functional.

3.3 <u>TU Electric Test Scheme 14-1</u> (Ref. 6.11)

This test was performed in December of 1992, and as such, was performed in accordance with the NRC staff acceptance methodology (Ref. 6.6). The purpose of this test was to evaluate the performance of an upgraded Thermo-Lag 330-1 protective envelope consisting of 1/2" thick (nominal) prefabricated v-ribbed panels installed on a 30" x 4" steel ladder back cable tray which included a "Tee" section. The cable tray assembly was configured in a U-shape, th the portion containing the Tee section

being horizontally oriented. A fire stop, consisting of Promatec 45B formulated silicone elastomer material, approximately 6" in depth, was installed to seal the opening in the side outlet of the Tee, perpendicular to the cable tray run. The cable tray test assembly contained an assortment of power, control, and instrumentation cables taken from CPSES stock inventory. Consistent with other TU Electric tests of cable tray fire barrier systems, a single layer of cables was used, resulting in a fill of 17.32%. No cables exited the raceway through the portion of the Tee sealed with the silicone elastomer fire stop, but cables were "looped" immediately behind the unexposed side of the fire stop. The upgrades applied to the "base" Thermo-Lag barrier system consisted of joint reinforcement with an external layer of stress skin and Thermo-Lag 330-1 trowel grade material. Steel screws, approximately 1-1/4" long were used to secure the Thermo-Lag panel on the underside of the Tee into the silicone elastomer fire stop. This upgrade was utilized to preclude excess sagging of the Thermo-Lag panel in this location, which, during a previous test of a 24" x 4" cable tray Tee section (TU Test Scheme 12-2, Ref. 6.12), had separated during the hose stream test, resulting in a minor barrier opening.

The cable tray barrier and fire stop assembly was subjected to a 60 minute fire exposure, following the ASTM E119 standard time-temperature curve. " 70°F, initial temperature allowed for a maximum average temperature of 320°F and a maximum single point temperature of 395°F. Temperatures on the cables remained within allowable limits as did the average temperature increase measured along the cable tray side rails. However, the maximum single point temperature criterion was exceeded by 6°F at one side rail location. The high temperature was recorded on the "back" side of the Tee section, i.e., the side opposing the fire stop location. Cable tray side rail temperatures immediately adjacent to the fire stop met acceptance criteria for average and single maximum temperature increase. The cable tray enclosure was then subjected to a hose stream test using a 30° fog nozzle at a minimum nozzle pressure of 75 psi, for a duration of 5 minutes. The cable tray enclosure and fire stop assembly remained fully intact throughout hose stream test. Post-test inspection revealed no thermal degradation of the cables, which was also confirmed via insulation resistance measurements. Therefore, this test satisfied the acceptance criteria specified by the NRC (Ref. 6.6). Reference 6.13 provided the NRC staff's acceptance of this test.

3.4 <u>TU Test Scheme 1-2</u> (Ref. 6.14)

This test was performed in June of 1992, prior to receipt of the October 29, 1992 letter (Ref. 6.6) providing the NRC staff's acceptance methodology for further TU Electric testing of Thermo-Lag raceway fire barrier systems. As such, in and of itself, this test is not credited as the basis for qualification of Thermo-Lag fire stops at CPSES. However, as described in Section 4.0 below, some portions of this test are useful in support of other tests that more directly bound these types of installed cable tray fire stop designs.

Test Scheme 1-2 evaluated the performance of an upgraded Thermo-Lag 330-1 protective envelope consisting of 1/2" thick (nominal) prefabricated v-ribbed panels installed on a 36" x 4" steel ladder back cable tray which included a Tee section. The cable

tray assembly was configured in a U-shape, with the portion containing the Tee section being horizontally oriented. A fire stop, consisting of Thermo-Lag 330-1 panels and trowel grade materials, 4"-5" in depth, was installed to seal the opening in the side outlet of the Tee, perpendicular to the cable tray run. The cable tray test assembly contained an assortment of power, control, and instrumentation cables taken from CPSES stock inventory. Consistent with other TU Electric tests of cable tray fire barrier systems, a single layer of cables was used, resulting in a fill of 16.95%. No cables exited the raceway through the portion of the Tee sealed with the Thermo-Lag fire stop, but cables were "looped" immediately behind the unexposed side of the fire stop. The upgrades applied to the "base" Thermo-Lag barrier system consisted of joint reinforcement with either an external layer of stress skin and Thermo-Lag 330-1 trowel grade material or stainless steel tie wires to "stitch" adjacent panels together. The interfaces between the fire stop and Thermo-Lag 330-1 panels forming the top and bottom of the cable tray envelope were "stitched" in this manner.

The cable tray barrier and fire stop assembly was subjected to a 60 minute fire exposure, following the ASTM E119 standard time-temperature curve. " 87°F, initial temperature allowed for a maximum average temperature of 337°F and a maximum single point temperature of 412°F. Temperatures on the cables remained within allowable limits as did temperatures measured along the cable tray side rails. The cable tray enclosure was then subjected to a hose stream test using a using a solid stream delivered at 30 psi nozzle pressure, from a standard playpipe, for 2-1/2 minutes. As had occurred with other initial TU Electric Thermo-Lag fire endurance tests, the force of the solid hose stream resulted in dislodgment of panels used to cover the cable tray, but the fire stop assembly was not adversely affected by the hose stream, and remained fixed in place. Post-test inspection revealed no thermal degradation of the cables.

3.5 NEI Test 2-8 (Ref. 6.15)

This test was performed in February of 1994 by the Nuclear Energy Institute (NEI), to evaluate the performance of 1 hour upgraded Thermo-Lag protective envelopes installed on two (2) each 24" x 4" (Trays "A" and "D") and 6" x 4" (Trays "B" and "C") aluminum ladder back cable trays. The barrier system installed on each cable tray was constructed with 1/2" thick Thermo-Lag 330-1 v-ribbed panels. The raceway article of interest for this test is Tray "A," which was a 24" x 4" cable tray. As with all cable trays evaluated during the NEI Thermo-Lag Test Program, this tray contained a single layer of "generic" electrical cables which were representative of those at CPSES. Specifically, an approximate 1/3 mix of power, instrumentation and control cables were utilized, which resulted in a 15.41% cable fill. The cable tray was configured such that the vertical tray segment passed through the top of the test furnace, and the horizontal segment passed through the front wall bulkhead of the furnace. The Thermo-Lag barrier system on Tray "A" terminated prior to the tray passing through the front wall assembly of the test furnace. This resulted in approximately 12" of the tray and the cables contained within, being fully exposed to the test furnace environment. To seal the barrier system protecting the cable tray from the exposed portion, a fire stop constructed using 1/2" prefabricated

Thermo-Lag 330-1 v-rib panels and trowel grade material was installed in the horizontal segment, at the termination of the cable tray envelope. The depth of the fire stop was 4" - 5". To reinforce areas where the Thermo-Lag panels constituting the tray envelope interfaced with the fire stop region, a steel clamp bar ("bracket") assembly was us . The bracket was constructed using 3/8" diameter all thread rod and 1/4" thick ste plate, and was attached on the outside of the cable tray protective envelope over the region where the fire stop was located. The upgrades applied to the cable tray envelope were similar to those used during TU Electric tests of Thermo-Lag cable tray barrier systems. Specifically, an external layer of stress skin and Thermo-Lag 330-1 trowel grade material was applied at all joints between panels.

The cable tray assembly was subjected to a 60 minute fire exposure, following the ASTM E119 standard time-temperature curve. A 54°F initial temperature allowed for a maximum average temperature of 304°F and a maximum single point temperature of 379°F. All temperatures remained within acceptance limits, except one thermocouple positioned on the right tray rail, immediately adjacent to the fire stop, recorded a temperature of 395°F, or 16°F above the allowable maximum single point temperature criterion. Exceedance of the maximum single point temperature criterion at this location occurred at 58 minutes into the test. The cable tray enclosure was then subjected to a hose stream test using a 30°fog nozzle at a minimum nozzle pressure of 75 psi, for a duration of 5 minutes. The cable tray enclosure and fire stop assembly remained fully intact throughout the hose stream test. Post-test inspection revealed no thermal degradation of the cables, including the area where the cables entered the unexposed side of the fire stop assembly.

3.6 <u>Tech-Sil Test #TS-TP-0075-C</u> (Ref. 6.16)

The purpose of this test was to qualify a 3 hour fire rated penetration seal design. The penetration seal material consisted of a 6" depth of Promatec 45B Formulated Silicone Elastomer with no permanent damming. The concrete test slab was 12" thick and contained a single opening. The opening was a 12" x 12" blockout with two sides of the opening lined with 1/4" thick plate steel. Penetrating items included an 11-3/4" x 8" pipe-tray with 49.66% cable fill, a 2-5/8" diameter insulated pipe, and a 4" diameter rigid steel conduit with cabling. The cabling tested was manufactured by Okonite and Rockbestos, and cables jacket materials included EPR (Ethylene Propylene Rubber) and CLP (Cross Linked Polyethylene). Since this 3 hour fire endurance test is being used to support silicone elastomer fire stops used in 1 hour raceway barrier systems, the remainder of this discussion will focus on seal performance at 1 hour into the 3 hour fire endurance test.

Temperatures on the unexposed side of the fire stop were monitored at several points throughout the fire test. Thermocouple readings were taken at the following locations:

- 3 points on the unexposed surface of the seal material (TC's 19, 20 & 21)
- 1 point at the pipe-tray to seal interface (TC 22)
- 1 point at the conduit to seal interface (TC 23)
- 6 points on various cables at the seal interface (TC's 24-30)

(Note: TC 30 malfunctioned during the test and was not considered to have recorded valid temperature readings.)

At 1 hour into the fire test, the average unexposed surface temperature was approximately 150°F. The interface temperature at the pipe-tray was 297°F. The interface temperature at the conduit was 167°F. The temperature recorded on the various cables at the seal surface ranged from 156°F-378°F. While three of the six cable temperatures exceeded the 250°F above ambient temperature criteria, none of the temperatures exceeded the single point temperature limit of 325°F above ambient. Furthermore, the average unexposed surface temperature was below acceptance limits. Therefore, temperature acceptance criteria was satisfied.

Upon completion of the 3 hour fire endurance test, the test assembly was subjected to three separate hose stream tests. The first test was performed in accordance with the hose stream requirements of IEEE-634 (Ref. 6.17). The second hose stream test was performed in accordance with Option 2.B.2 of the ANI/MAERP Standard Method of Fire Tests of Cable and Pipe Penetration Fire Stops (Ref. 6.18). The third hose stream test was performed in accordance with the requirements of ASTM E-119 (Ref. 6.19). Each of the hose stream tests was performed for a 12 second duration, and the test report states that the hose stream was applied to the exposed surface of the test slab. The test slab itself was 48" x 48", however, once the test slab was placed on top of the test furnace, the exposed area of the test slab was approximately 34" x 34" or roughly 8 ft2. Using an 8 ft2 exposure area, a 12 second hose stream duration satisfies typical testing standard requirements for fire stops. The test specimen successfully withstood all three hose stream tests.

3.7 Tech-Sil Test #TS-TP-0018 (Ref. 6.20)

The purpose of this test was to qualify a 3 hour fire rated penetration seal design. The penetration seal material consisted of a 6" depth of Promatec 45B Formulated Silicone Elastomer with no permanent damming. The concrete test slab was 12" thick and contained a single opening. The opening was a 32" x 32" blockout with two sides of the opening lined with 1/4" thick plate steel. Penetrating items included a 4" x 24" solid bottom cable tray with 57.93% fill of power cabling, a 6" x 24" solid bottom cable tray with 40.21% fill of control cabling, a single ground cable, a 2" diameter PVC coated flexible conduit with cabling and three, 4" diameter rigid steel conduit sleeves with cabling. The cabling tested was manufactured by Okonite, Anaconda and Samuel Morris, and cables jacket materials included EPR (Ethylene Propylene Rubber). Since this 3 hour fire endurance test is being used to support silicone elastomer fire stops used in 1 hour raceway barrier systems, the remainder of this discussion will focus on seal performance at 1 hour into the 3 hour fire endurance test.

Temperatures on the unexposed side of the fire stop were monitored at several points throughout the fire tests. Thermocouple readings were taken at the following locations:

- 7 points on the unexposed surface of the seal material

- 14 points on various control cables in the 6" x 24" tray, both on the jacket and on the cable conductor at the seal interface
- 18 points on various power cables in the 4" x 24" tray, both on the jacket and on the cable conductor at the seal interface

(Note: 9 other TC's recorded temperatures for the three internall conduit seals, however, these seals and associated temperatures are not considered relevant to this evaluation.

At 1 hour into the fire test, the average unexposed surface temperature was approximately 89°F. The average interface temperature on the cable jacket for the tray containing control cables was approximately 172°F. The average interface temperature on the conductor for the tray containing control cables was approximately 197°F. The average interface temperature on the cable jacket for the tray containing power cables was approximately 178°F. The average interface temperature on the conductor for the tray containing power cables was approximately 273°F. None of the thermocouple readings for the seal surface or either tray including cable jacket and conductor temperatures exceeded the single point temperature limit of 325°F above ambient, and as discussed above, the average unexposed side surface temperature was also below the 250°F above ambient limit. Therefore, temperature acceptance criteria was satisfied.

Upon completion of the 3 hour fire endurance test the test assembly was subjected to two separate hose stream tests. The first test was performed in accordance with the hose stream requirements of ASTM E-119 (Ref. 6.19). The second hose stream test was performed in accordance with the requirements of IEEE-634 (Ref. 6.17). Both of the hose stream tests were performed for a 24 second duration, and the test report states that the hose stream was applied to the seal specimen. The test slab itself was 48" x 48", yielding an exposed area of 16 ft2. Using a 16 ft2 exposure area, a 24 second hose stream duration satisfies typical testing standard requirements for fire stops. The test specimen successfully withstood both hose stream tests.

3.8 Tech-Sil Test F-106 (Ref. 6.21)

The purpose of this test was to qualify a 3 hour fire rated penetration seal design. The penetration seal material consisted of a 6" depth of Promatec 45B Formulated Silicone Elastomer with no permanent damming. The concrete test slab was 12" thick and contained a single opening. The opening was a 30" x 30" blockout with two sides of the opening coated with epoxy primer. Penetrating items included a 4" x 18" solid bottom cable tray with PVC jacketed cabling, a 4" x 24" ladder back cable tray with PVC jacketed cabling and a 6" diameter rigid steel conduit with PVC jacketed cabling. Approximately one half of the cables in each tray were lightly coated with Flamemastic prior to seal installation to simulate Flamemastic residue as a result of replacing previously installed Flamemastic seals. Since this 3 hour fire endurance test is being used to support silicone elastomer fire stops used in 1 hour raceway barrier systems, the remainder of this discussion will focus on seal performance at 1 hour into the 3 hour fire endurance test.

Temperatures on the unexposed side of the fire stop were monitored at several points throughout the fire tests. Thermocouple readings were taken at the following locations:

- 3 points on the unexposed surface of the fire stop (TC's 4, 5 & 6)
- 3 points on the unexposed surface of the fire stop 1" away from cables (TC's 1, 2 & 11)
- 1 point on the unexposed surface of the fire stop 1" away from the conduit (TC 13)
- 1 point at the blockout seal to opening edge interface (TC 3)
- 1 point on the 4" x 18" cable tray 1" above the fire stop surface (TC 9)
- 1 point on the conduit 1" above the surface of the fire stop (TC 14)
- 2 points on cabling 1" above the surface of the fire stop (TC's 10 & 12)

At 1 hour into the fire test, the average unexposed surface temperature based on the three surface thermocouples was 91°F. The average surface temperature at a point 1" from through penetrating items was approximately 144°F. The interface temperature at the cable tray (1" up) was 347°F. The interface temperature at the conduit (1" up) was 252°F. The temperatures recorded on the two cables at the cable to seal interface (1" up) were 148°F and 410°F. (Note: TC 12 which recorded the 410°F reading appears to have been functioning erratically during the test. All TC readings at the beginning of the test were between 80°F and 82°F except for TC 12 which recorded a temperature of 70°F. At 11 minutes and 33 seconds into the test, TC jumped from 71°F to 114°F and continued to climb for the duration of the test.)

With the exception of the temperature reading recorded by TC 12, all temperatures on the unexposed side of the fire stop were within the single point temperature limit of 325°F above ambient. Additionally, the average temperature recorded on the unexposed side of the fire stop was within the 250°F above ambient temperature limit. Therefore, temperature acceptance criteria was satisfied.

Upon completion of the 3 hour fire endurance test, the test assembly was subjected to two separate hose stream tests. The first test was performed in accordance with the hose stream requirements of ASTM E-814 (Ref. 6.22) and Option 2.B.3 of the ANI/MAERP Standard Method of Fire Tests of Cable and Pipe Penetration Fire Stops (Ref. 6.18). The second hose stream test was performed in accordance with the requirements of IEEE-634 (Ref. 6.17). Both of the hose stream tests were performed for a 45 second duration, and the test report states that the hose stream was applied to the exposed surface of the test slab The test slab itself was 66" x 66", yielding an exposed area of approximately 30 ft2. Using a 30 ft2 exposure area, a 45 second hose stream duration satisfies typical testing standard requirements for fire stops. The test specimen successfully withstood both hose stream tests.

3.9 <u>BISCO Test 748-105</u> (Ref. 6.23)

The purpose of this test was to qualify a 3 hour fire rated penetration seal design. The penetration seal material consisted of a 5" depth of BISCO SF-60 Silicone Elastomer with no permanent damming. The concrete test slab was 12" thick and

contained a single opening. The opening was a 30" x 30" blockout. Penetrating items included a 4" x 24" solid bottom cable tray and a 4" x 24" ladder back cable tray. Each cable tray contained a 50% cable fill which was comprised of instrument, power and control type cabling. The cable insulation was PE (Polyethylene) and the jacketing material was PVC. Since this 3 hour fire endurance test is being used to support silicone elastomer fire stops used in 1 hour raceway barrier systems, the remainder of this discussion will focus on seal performance at 1 hour into the three hour fire endurance test.

Temperatures on the unexposed side of the fire stop were monitored at several points throughout the fire tests. Thermocouple readings were taken at the following locations:

- 3 points on the unexposed surface of the fire stop (TC's 1, 7 & 12)
- 2 points on the unexposed surface of the fire stop at the tray side rail interface (TC's 3 & 8)
- 1 point at the blockout seal to opening edge interface (TC 2)
- 6 points at cable to seal interfaces (2 power, 2 instrument, 2 control) on the unexposed surface of the fire stop (TC's 4, 5, 6, 9, 10 & 11)

At 1 hour into the fire test, the average unexposed surface temperature based on the three surface thermocouples was approximately 82°F. The average tray side rail temperature was approximately 241°F. The average cable interface temperature was approximately 231°F. None of the thermocouple readings for the seal surface or either tray including cable interface temperatures exceeded the single point temperature limit of 325°F above ambient, and as discussed above the average unexposed side surface temperature at various locations were all below the 250°F above ambient limit. Therefore, temperature acceptance criteria was satisfied.

Upon completion of the 3 hour fire endurance test the test assembly was subjected to a hose stream test. The hose stream test was performed in accordance with the hose stream requirements of ASTM E-119 (Ref. 6.19) for a 12 second duration. The test report states that the hose stream was applied to the exposed portion of the test slab. The test slab itself was 48" x 48", however, once the test slab was placed on top of the test furnace, the exposed area of the test slab was approximately 34" x 34" or roughly 8 ft2. Using an 8 ft2 exposure area, a 12 second hose stream duration satisfies typical testing standard requirements for fire stops. The test specimen successfully withstood the hose stream test.

4.0 QUALIFICATION BASIS FOR CPSES FIRE STOP DESIGNS

Evaluation of the qualification basis for fire stop designs at CPSES has been divided into two sections; Section 4.1 addresses Thermo-Lag 330-1 fire stops and Section 4.2 addresses silicone elastomer fire stops. Additionally, Section 4.2 is further structured into separate sections pertaining to Promatec 45B silicone elastomer (Section 4.2.1) and BISCO SF-60 silicone elastomer (Section 4.2.2).

4.1 Thermo-Lag 330-1 Fire Stops

Both the TU Electric and NEI Test Programs have included Thermo-Lag 330-1 cable tray fire stops in full scale fire endurance tests of Thermo-Lag cable tray protective envelopes. Under each program, the barrier systems were subjected to a 1 hour fire exposure, followed by hose stream tests, thereby challenging the thermal and structural performance capability of these fire stops as integral portions of the respective cable tray fire barrier systems.

As described in the "NEI Application Guide for Evaluation of Thermo-Lag Fire Barrier Systems" (Ref. 6.28), there are two basic failure mechanisms for Thermo-Lag raceway fire barriers. These mechanisms have been characterized as thermal failures and structural failures. Reference 6.28 states further that...

"Thermal failures can be generally attributed to insufficient Thermo-Lag material quantity or discontinuity of the protective envelope installed on the protected commodity. Structural failures can be generally attributed to stresses imposed on vulnerable areas of protective envelopes as the Thermo-Lag material softens during fire exposure. Areas susceptible to structural failures include joints along large unsupported panel spans and transitions between dissimilar barrier materials or between differing construction techniques."

For evaluation purposes, each of these failure mechanisms will be assessed below.

4.1.1 Thermal Failure Modes

The predominant methods of thermal failures for cable tray fire stops used where protective envelope coverage terminates, are excessive heat conduction along exposed side rail surfaces, and excessive transmission of heat through the fire stop via electrical cables that may penetrate through the fire stop. In each case, the potential exists for sufficient heat to be transmitted into the cable tray protective envelope, resulting in thermal failure of the overall barrier system. For heat conduction along exposed cable tray side rail surfaces, the contributing factors are essentially the type of material construction , i.e., steel or aluminum, and the corresponding mass of the side rails. Both of these attributes relate to how quickly the side rail surfaces will absorb and conduct heat into the cable tray protective envelope. For example, based on the heat capacity and mass per foot of aluminum compared to steel, for the same heat energy exposure, the temperature of an aluminum commodity will increase beyond that of an equivalent steel commodity (Ref. 6.29). For transmission of heat through the fire stop, either directly or along penetrating electrical cables, the contributing factors are essentially the material type and installed depth of the fire stop, and the overall type and quantity of penetrating cables. Of these two basic methods for thermal failure of fire stops, assessment of the results of NEI Test 2-8, augmented by

data from TU Electric Test Schemes 1-2 and 4, demonstrate that conduction of heat along exposed side rail surfaces represents the worse (i.e., bounding) case.

Results of NEI Test 2-8 (Ref. 6.15)

As shown in the table provided in Section 3.0, the primary qualifying fire test for CPSES Thermo-Lag 330-1 cable tray fire stops is NEI Test 2-8. This test was performed to evaluate the performance of "upgraded" 1 hour Thermo-Lag protective envelopes installed on cable trays. The specimen of interest in this test is Tray "A," which was a 24" x 4" ladder back design. A fire stop constructed of Thermo-Lag 330-1 prefabricated panel stock and trowel grade material was installed in the horizontal run of the cable tray, at the point where coverage of the Thermo-Lag envelope on the tray was terminated. Consistent with the methodology employed in both the TU Electric and NEI Test Programs, a single layer of electrical cables were contained with the tray. An approximate 1/3 mix of power, instrumentation and control cables were used, resulting in a 15.41% cable fill. The insulation and jacket materials for the tested cables were all thermo-set type (i.e., EPR-CPSE, XLP-CSPE and XLP-CPSE), and therefore equivalent to those installed at CPSES.

For test instrumentation purposes, thermocouples positioned at 6" intervals along the cable tray side rails, and on bare #8 AWG copper conductors placed on top of the cables, on top of the tray rungs (under the cables) and under the tray rungs, provided barrier performance data. At 58 minutes into the 1 hour test, one thermocouple (TC 226), located on the right side rail, recorded a temperature which exceeded the single maximum temperature increase criteria. At the 1 hour mark, the temperature recorded at this location reached 395°F, which was 16°F above the acceptance limit (i.e., an increase of 341°F above the initial 54°F was recorded, compared to the allowable 325°F increase). The location of this thermocouple was approximately 6" away from the unexposed side of the fire stop. It should be noted that the temperature recorded by the corresponding thermocouple positioned on the left side rail (TC 210), also located 6" back from the unexposed side of the fire stop, only reached 368°F. Therefore, side rail temperatures 6" away from the unexposed side of the fire stop reached a maximum of 395°F. However, thermocouples on the bare #8 AWG conductors positioned on top of the cables, on top of the tray rungs and below the tray rungs were located directly at the unexposed side of the fire stop. The highest temperature recorded by these thermocouples was 363°F (under the rungs). This is significant in that temperatures recorded inside the protective envelope, where cables actually penetrated the fire stop were lower than side rail temperatures 6" farther away.

Data from TU Electric Test Schemes 1-2 and 4 (Ref. 6.14, 6.5)

As discussed in Section 3.4, Test Scheme 1-2 test was performed to evaluate the effectiveness of conceptual joint reinforcement methods for a Thermo-Lag envelope installed on a 36" x 4" cable tray with "Tee" section. A fire stop

constructed of Thermo-Lag 330-1 panels and trowel grade material was used to seal the side outlet of the horizontally oriented tee section. The installed depth of the fire stop was 4"-5". No electrical cables extended through the fire stop. However, one each of the power, control and instrumentation cables equipped with thermocouples, were instead looped immediately behind the unexposed side of the stop. As such, three thermocouples (one on each of the three cables) were positioned to record temperatures at the unexposed side of the fire stop. Additionally, thermocouples were installed along the outside surfaces of the cable tray side rails at 12" intervals. This resulted in one thermocouple being positioned on each side rail near the unexposed side of the fire stop. All temperatures recorded during the test were within allowable limits, however, the maximum single point temperatures recorded on the tray side rails exceeded those recorded on the cables.

As discussed in Section 3.1, Test Scheme 4 was performed on a non-upgraded Thermo-Lag envelope installed on a vertically oriented 36" x 4" cable tray. The purpose of this test was to evaluate the performance of a fire stop constructed of Thermo-Lag 330-1 trowel grade material which was installed where the protective envelope coverage was terminated. The installed depth of this fire stop also was 4"-5". The cable tray was fully loaded with 164 cables (resulting in a fill of 49.32%) all of which penetrated through the fire stop. Thermocouples were installed on power, control and instrumentation cables and on the outside surfaces of the tray side rails near the unexposed side of the fire stop. The average temperatures recorded on the right and left side rail exceeded allowable limits at 55 and 59 minutes into the test (respectively). The single maximum temperature increase parameter was not exceeded. Consistent with Test Scheme 1-2 and NEI Test 2-8, the temperatures recorded on the tray side rails were significantly higher than those recorded on the cables, within the internal area of the tray.

Therefore, based on the results of NEI Test 2-8, as augmented with data from TU Electric Test Schemes 1-2 and 4, the following can be concluded:

- Temperatures recorded on outside surfaces of cable tray side rails in the vicinity of fire stops bound those on the unexposed side of fire stops, and are therefore the most conservative measure of fire stop thermal performance.

- Temperatures on side rail surfaces bound those within the internal areas of cable tray protective envelopes regardless if no cables (Test Scheme 1-2), a single layer of cables (NEI Test 2-8), or a full depth of cables (Test Scheme 4) extend through the fire stop.

Comparison Of NEI Test 2-8 To Installed CPSES Configurations

As with all cable trays utilized during the NEI Test Program, Tray "A" in NEI Test 2-8 was constructed of lightweight aluminum, weighing 2.12 lbs/lf, excluding the weight of electrical cables contained in the tray. The side rail

thickness was 0.060". Cable trays at CPSES that are clad with Thermo-Lag barriers (and therefore may contain Thermo-Lag 330-1 fire stops), are all of steel ladder back design. The installed cable trays range from 12" x 4" to 30" x 6" in size, and from 11.00 to 18.00 lbs/lf in weight, exclusive of the weight of electrical cabling. The side rail thickness of the installed cable trays is 0.105". Therefore, the cable tray material and mass tested via NEI test 2-8, bounds the material and mass for the range of cable trays installed at CPSES.

Accordingly, although the single maximum temperature increase criteria was exceeded on one cable tray side rail during NEI Test 2-8, given the more massive CPSES cable tray construction, lower side rail temperatures would be expected. Moreover, TU Electric has demonstrated that electrical cables installed at CPSES will remain functional at temperatures that bound those recorded during the NEI test. Specifically, the response to Open Item 1 in this Appendix provides the basis for cable functionality for limiting-case 12" x 4" cable trays with a zero percent theorized cable fill, based on the results of TU Electric Test Scheme 13-2.

Additionally, since the exposed side rails are essentially "outside" the perimeter of the cable tray fire stop, abatement of excessive heat being transmitted into the tray envelope is primarily dependent on methods used to install the Thermo-Lag panels along side rail surfaces and at interface regions with fire stops. As described above, the Thermo-Lag protective envelope installed on Tray "A" for NEI Test 2-8 was an "upgraded" design. The barrier system on the cable tray consisted of Thermo-Lag 330-1 v-rib panels, which were specially fabricated by the manufacturer to result in an average panel thickness of 2". These panels were then installed on the cable tray using a four piece design, in which the panel pieces installed along the side rails were effectively "sandwiched" between those installed on the top and bottom surfaces of the tray. The top and bottom panels were positioned such that the integral v-rib stiffeners were oriented parallel to the run of the tray. This is the limiting case panel orientation because, as the Thermo-Lag panels soften during fire exposure, v-ribs oriented in this manner do not provide as much support across the top and bottom spans, as when the v-ribs are oriented perpendicular to the tray run. Following installation of the panels, Thermo-Lag 330-1 trowel grade material was applied to seal joints and seams between panels in a "post-buttered" fashion. This method of applying trowel grade material is not as effective in sealing joints as "pre-buttering" of panel joint surfaces prior to installation. To provide reinforcement to the joint areas, an external layer of Thermo-Lag 330-69 stress skin and trowel grade material was applied. The stress skin was installed along the side rail portions of the enclosure and overlapped onto the top and bottom panels for a 3" distance. The stress skin was secured in place with 2" long staples and 16 GA stainless steel tie wires. As stated above, the fire stop, consisting of prefabricated Thermo-Lag panels and trowel grade material was installed in the horizontal run of the tray, where the barrier envelope coverage was terminated approximately 12" from the front wall of the test furnace. The depth of the

fire stop varied from 4" to 5". To reinforce areas where the Thermo-Lag panels forming the cable tray enclosure interfaced with the fire stop region, a steel clamp bar ("bracket") assembly was installed. This bracket was constructed using 3/8" diameter all thread rod and 3" thick steel plate, and was secured to the outside of the tray envelope over the region where the fire stop was located.

In comparison, the Thermo-Lag cable tray barrier systems installed at CPSES are constructed using prefabricated panels that have an average thickness of approximately 5/8". Moreover, all joints and seams between panels are "pre-buttered" with Thermo-Lag 330-1 trowel grade material prior to installation. To preclude sagging of top panels on horizontal runs, cable trays 24" and wider utilize stainless steel bands installed at 24" (max.) intervals, prior to installation of the panels. At CPSES, the method for reinforcing joint areas (on cable trays wider than 12") also utilizes external stress skin and trowel grade material, except that a 5" (min.) overlap distance is required, in lieu of the 3" distance employed for Tray "A" in NEI Test 2-8. Consistent with the tested configuration, where Thermo-330-1 fire stops are utilized at terminations of cable tray coverage at CPSES, a 4" (min.) to 5" (max.) depth of seal is required. To reinforce interface regions between cable tray envelopes and fire stops, a steel bracket assembly, similar to the tested configuration, is utilized at CPSES, except that 3/8" thick steel plate stock is required, compared to the tested 3" thick plate in NEI Test 2-8. On this basis, the Thermo-Lag cable tray barrier and fire stop system materials and construction techniques used in NEI Test 2-8 bound all aspects of those installed at CPSES.

In summary, the following attributes demonstrate why thermal failure of Thermo-Lag 330-1 cable tray fire stops installed at CPSES will not occur:

- The more massive steel cable trays installed at CPSES would result in lower side rail temperatures than those recorded during NEI Test 2-8.

- Functionality of electrical cables installed at CPSES has been demonstrated for temperatures which bound those recorded on limiting-case side rail locations of the fire stop configuration evaluated via NEI Test 2-8.

- The construction of Thermo-Lag fire stop configurations at CPSES, in terms of material type, installed depth and steel reinforcing bracket assembly is equivalent to, or "better than," the NEI Test 2-8 configuration.

- The methods used to construct actual Thermo-Lag 330-1 cable tray protective envelopes at CPSES are superior to those utilized for NEI Test 2-8.

4.1.2 Structural Failure Modes

Previous fire endurance testing has demonstrated that fire stops used at terminations of Thermo-Lag cable tray envelopes are prone to structural

failure. The first (and primarily) potential for structural failures involves locations where Thermo-Lag panels forming the bottom surfaces of tray envelopes extend out to cover the bottom area of fire stops. Since Thermo-Lag panels soften and tend to sag following fire exposure, barrier openings can, and have occurred at these interface regions following the fire exposure portion of tests, when the subsequent hose stream test was applied. Specifically, impact forces induced by the hose stream, when applied to vulnerable bottom panel/fire stop interface regions have, in some cases, been sufficient to result in barrier openings in these areas. This was the failure mode that occurred during TU Electric Test Scheme 12-2 (Ref. 6.12). In this test, a silicone elastomer fire stop was installed to seal the branch outlet in the horizontally oriented "Tee" section of a 24" x 4" cable tray assembly clad with an otherwise upgraded Thermo-Lag barrier system.

The second potential for structural failures involves the overall width and orientation of the cable tray run containing the fire stop assembly. Specifically, a fire stop installed in wider cable trays (e.g. 30") may be more prone to structural failure than an equivalent fire stop installed in a 12" wide tray. Moreover, a vertically oriented cable tray barrier and fire stop may be more challenged to maintain structural integrity, due to gravity effects, than a horizontal fire stop, particularly during performance of the hose stream test. As described below, each of these potential methods for structural failure of Thermo-Lag 330-1 cable tray fire stops has been addressed by testing that bounds fire stop configurations installed at CPSES.

<u>Barrier Openings At Bottom Panel/Fire Stop Interfaces</u>

Due to the barrier opening that occurred during Test Scheme 12-2 at the interface between the bottom panel of the cable tray envelope and the fire stop, an upgraded configuration was evaluated via Test Scheme 14-1 (Ref. 6.11). As described in Section 3.3, this test was performed to qualify an upgraded Thermo-Lag barrier system installed on a 30" x 4" cable tray which included a horizontally oriented Tee section. As with Test Scheme 12-2, a silicone elastomer fire stop was installed to seal the branch outlet portion of the Tee. To address the vulnerability of the bottom panel/fire stop interface, steel screws, approximately 1-1/4" long, were installed through the bottom Thermo-Lag panel and embedded in the underlying silicone elastomer fire stop material. Approximately five such screws were installed at equally spaced intervals across the span of the bottom panel. This method proved effective in that no barrier openings occurred during the fire endurance or subsequent hose stream tests.

However, due to concerns regarding the potential for screws to contact energized electrical cables penetrating through the fire stop, this method for reinforcing bottom panel/fire stop interfaces was not implemented for configurations installed at CPSES. Instead, the steel clamp bar ("bracket") assembly described in the previous section was devised and installed. Although not specifically evaluated during the TU Electric Test Program, a

nearly identical bracket assembly was qualified via NEI Test 2-8 as a viable method to reinforce bottom panel/fire stop interfaces. The NEI test utilized a fire stop constructed of Thermo-Lag 330-1 materials installed in a 24" wide cable tray. Since the tray was horizontally oriented, this configuration represented the worse case potential for sagging of the tray envelope bottom panel. The widest cable tray size in which Thermo-Lag 330-1 fire stops are installed at CPSES is 30", or approximately 6" wider than the tested NEI configuration. However, as described in Section 4.1.1 above, the method for stress skin reinforcement of longitudinal joints at CPSES requires a 5" (min.) overlap onto the top and bottom surfaces of cable tray envelopes wider than 12". The longitudinal joint reinforcement method for the tested NEI configuration only utilized a 3" stress skin overlap. On this basis, the minor difference between the 24" cable tray span for the tested NEI configuration, and the 30" (max.) cable tray span at CPSES is not significant. Therefore, there is sufficient assurance that the steel clamp bar bracket assemblies utilized for fire stops installed at CPSES, in conjunction with superior longitudinal joint reinforcement methods, are adequate to ensure that the structural integrity of bottom panel/fire stop interface regions of cable tray envelopes will be maintained.

Installed Fire Stop Width And Orientation

As described above, based on equivalent clamp bar bracket assemblies and superior joint reinforcement methods, Thermo-Lag 330-1 fire stops installed in 30" wide trays at CPSES are bounded from a structural performance standpoint by the configuration qualified via NEI Test 2-8 for 24" wide cable trays. Further, the horizontal orientation of the tested configuration represented the worse case for the challenging the integrity of the bottom panel/fire stop interface, since gravity effects would not contribute to sagging of top or bottom panels in vertical tray orientations.

However, unlike horizontally oriented fire stops, those installed in vertical orientations may be more prone to gravity effects causing overall displacement of the fire stop material (as opposed to limited separation at panel/fire stop interfaces). To address this potential, the results of Test Scheme 4 will be assessed.

As described in Section 3.1 for this test, a fire stop constructed using a 4"-5" depth of Thermo-Lag 330-1 trowel grade material was installed in a vertically oriented 36= x 4" cable tray. No upgrades were applied to the cable tray protective envelope, such as reinforced joints or panel/fire stop interfaces. Following the fire exposure portion of the test, the cable tray and fire stop barrier system were subjected to hose stream test in accordance with ASTM E119 criteria. This hose stream test consisted of delivering a solid stream to the test assembly from a distance of 20 feet, through a standard 1-1/8" diameter playpipe with a nozzle pressure of 30 psi, for a 2-1/2 minute duration. Since the smooth playpipe does not atomize the stream upon discharge, the solid stream method imparts substantially more impact force to

the test assembly than did the fog nozzle method employed for conduct of Test Scheme 14-1 and NEI Test 2-8. Despite subjecting the fire stop assembly to the more stringent hose stream test method, the Thermo-Lag 330-1 fire stop remained firmly embedded within the internal area of the cable tray.

In summary, the following attributes demonstrate why structural failure of Thermo-Lag 330-1 fire stops installed at CPSES will not occur:

- The limiting-case 30" wide cable tray configurations at CPSES are bounded by tested 24" wide horizontal tray orientations (NEI Test 2-8) and 36" wide vertical tray orientations (TU Electric test Scheme 4).

- Despite the fact that no upgrades were applied to the vertical cable tray and fire stop barrier system for Test Scheme 4, the fire stop remained in place during the more stringent straight stream method of applying the hose stream test.

- Equivalent clamp bar bracket assemblies and superior joint reinforcement methods are utilized for fire stops installed at CPSES compared to those for the tested NEI configuration.

4.2 Silicone Elastomer Fire Stops

Because limited testing exists for silicone elastomer fire stops installed to seal terminations of cable tray fire barriers with penetrating electrical cables, this evaluation relies in part on tests performed for silicone elastomer materials to seal penetrations through fire-rated walls, floors, etc. In all cases referenced within this evaluation, the silicone elastomer penetration seal tests were conducted for the purpose of obtaining a three (3) hour fire rating. Therefore, differences between these three (3) hour tests and the end use of the test data for supporting the qualification of one (1) hour fire barrier raceway systems will be addressed. Additionally, differences between the conventional penetration seal systems tested and the application of silicone elastomer fire stops in the end of Thermo-Lag fire barrier raceway enclosures will also be addressed. Accordingly, the guidance provided in Section 3.2.2, "Deviations from Tested Configurations," of Enclosure 2, "Appendix R Questions and Answers" to Generic Letter 86-10 will be used.

The guidance provided by G.L. 86-10 outlines five (5) criteria which must be considered when addressing differences between tested and installed fire barrier configurations. These criteria are as follows:

1. The continuity of the fire barrier material is maintained.

2. The thickness of the barrier is maintained.

3. The nature of the support assembly is unchanged from the tested configuration.

4. The application or "end use" of the fire barrier is unchanged from the tested configuration.

5. The configuration has been reviewed by a qualified fire protection engineer and found to provide an equivalent level of protection.

Because the differences for each of the fire tests conducted on penetration seal configurations are essentially the same in comparison to the end use of silicone elastomer fire stops in raceway fire barrier enclosures, the five (5) criteria listed above will be addressed generically as they relate to the use of penetration seal test data to evaluate fire barrier raceway enclosure fire stops.

1. The continuity of the fire barrier material is maintained.

   In both penetration seal and raceway fire barrier system end use applications, the continuity of the silicone elastomer seal material (i.e., "barrier material") is maintained. In the case of the tested penetration seal configurations, the silicone elastomer material was the sole means by which the openings were sealed. The silicone elastomer material was installed both in the blockout opening, as well as inside the cable trays forming a continuous seal or fire barrier across the entire opening. In raceway barrier fire stop applications, the silicone elastomer material is the sole material used to enclose the opening in the Thermo-Lag protective envelope. The silicone elastomer material is installed inside the cable tray forming a continuous seal across the entire opening. Therefore, since the continuity of the seal material (i.e., "barrier material") is maintained for both tested and installed configurations, the use of penetration seal test data to support raceway enclosure fire stop designs is acceptable.

2. The thickness of the barrier is maintained.

   In both penetration seal and raceway fire barrier system end use applications, the thickness of the silicone elastomer seal material (i.e., "barrier material") is maintained. In the case of Promatec 45B Formulated Silicone Elastomer fire stops, both tested and installed configurations use a minimum 6" depth of seal material. In the case of BISCO SF-60 Silicone Elastomer fire stops, both tested and installed configurations use a minimum 5" depth of seal material. Since the thickness of the barrier is maintained for both Promatec 45B Formulated Silicone Elastomer fire stops and BISCO SF-60 Silicone Elastomer fire stops, the use of penetration seal test data to support raceway enclosure fire stop designs is acceptable.

3. The nature of the support assembly is unchanged from the tested configuration.

   Although the nature of the support assembly is changed from tested configurations, the change results in additional support. In the tested configurations for penetration seal applications, the silicone elastomer seal material was installed in an opening in a horizontal test slab. No special damming materials or support mechanisms were present, and the seal material was held in place solely by the bond made between the seal material/opening edge and seal material/penetrating items (e.g., cable trays, conduits and cabling). These bonding areas were for the entire depth of the seal material (i.e., 6" depth for Promatec 45B Formulated Silicone Elastomer and 5" depth for BISCO SF-60 Silicone Elastomer). Both of these materials were tested at their respective depths for three (3) hours in the floor/ceiling orientation, which is considered the "worse case" orientation due to the effects of gravity on the unsupported seal. Upon completion of the three (3) hour fire endurance tests, each assembly successfully withstood one or more hose streams tests, and at least one of the hose stream tests for each test assembly was in accordance ASTM E-119 (e.g., solid stream type test).

   In raceway barrier enclosure fire stop applications, the silicone elastomer material is installed within the opening and held in place by the bond made between the seal material/opening edge (i.e., the cable tray on 3 sides and the Thermo-Lag panel on the top side) and seal material/penetrating items (i.e., cabling). These bonding areas are for the entire depth of the seal material (i.e., 6" depth for Promatec 45B Formulated Silicone Elastomer and 5" depth for BISCO SF-60 Silicone Elastomer). As part of the installed configurations, an additional support mechanism exists. This support mechanism is in the form of a "bracket" assembly comprised of 2" wide by 1/4" thick flat stock steel and 3/8" diameter all thread rod. This type of bracket assembly was developed and tested as part of the NEI Test Program to reinforce areas where the Thermo-Lag panels constituting the tray envelope interfaced with the fire stop region. The bracket assembly essentially clamps down on the top and bottom Thermo-Lag panels holding the fire stop in between the panels in compression (refer to the description of NEI Test 2-8; Section 3.5 of this document for further details). During exposure to a fire scenario, both the Thermo-Lag panels and the silicone elastomer fire stop material expand. This results in the compressive forces of the bracket assembly providing additional assurance that the fire stop will not fail structurally during a fire. Therefore, even though the nature of the support assembly is changed from tested configurations, the additional structural support added by the change (i.e., the addition of the bracket) enhances the performance of the fire stop design and is acceptable.

4. The application or "end use" of the fire barrier is unchanged from the tested configuration.

Although the application or "end use" of the fire barrier is changed from the tested configuration, the differences between as-tested and as-installed configurations are acceptable. As discussed above the primary purpose of many of the tested configurations used to qualify raceway enclosure fire stops was to substantiate conventional penetration seal designs. As such, many of the tested designs were criginally intended for an "end use" application other than as a raceway enclosure fire stop. The primary difference between these designs is that penetration seal designs are installed and tested within the plane of a concrete barrier resulting in exposure to the effects of the furnace fire from one side only, while raceway enclosure fire stops are installed in the end of a protective envelope and may be subjected to the effects of a fire on one face of the seal, as well as on all four sides which abut the Thermo-Lag panels comprising the fire barrier system. Although these two configurations are different, the purpose of the silicone elastomer seal material is the same for both applications; to prevent the passage of flame, smoke and hot gas to the other side of the fire barrier (or wrap system), while limiting the transmission of heat through the seal material. The acceptance criteria for both of these applications is the same with respect to limiting the transmission of heat through the seal material. The limiting unexposed side temperature for both applications is 250°F above ambient for the average temperature with no single point exceeding 325°F above ambient. Specific differences between both applications with respect to configuration as it relates to thermocouple placement, unexposed side temperature limits and hose stream test application are addressed below.

- For raceway barrier fire stops, the raceway enclosure surrounding the fire stop is exposed to the furnace atmosphere on four (4) sides in addition to the face of the fire stop. For penetration seals, only the face of the seal assembly is exposed to the furnace atmosphere, since the seal assembly is installed within the plane of the concrete test slab. The concern here is that in a raceway enclosure test, the unexposed surface of the fire stop does not receive the benefit afforded by the concrete test slab acting as a heat sink adjacent to the seal, as is the case for penetration seal tests. Additionally, there is a concern that the exposure on all four sides of the fire stop abutting the Thermo-Lag panels which make up the raceway enclosure is not present in the penetration seal configuration, thereby creating a less severe exposure for penetration seal tests. However, for both of these concerns, the significant factor is that both the penetration seal and raceway fire barrier system test protocols impose the same unexposed side temperature criteria. Therefore, provided that the Thermo-Lag panel material encapsulating the raceway meets the temperature acceptance criteria, the thermal performance of the elastomer seal material (including penetrating trays and cables) need only be addressed by this evaluation. Thermocouple locations and thermal performance are discussed below.

- For Thermo-Lag fire stops, temperature measurements are taken on cable tray side rails as well as on penetrating cables (preferably on bare #8 AWG copper conductors located above and below cables within the tray). These thermocouples are generally located on 6" centers starting at the exposed face of the fire stop, which results in the first thermocouples being located approximately 6" away from the unexposed surface of the fire stop on the inside of the envelope. For penetration seals, temperature measurements are generally taken on the unexposed surface of the seal material, at the interface of the seal material/cable tray side rails, and at the interface of the seal material/cabling (anywhere from at the surface to 1" above the seal surface). Since there are generally more thermocouple readings taken near the seal surface for penetration seal tests and these thermocouple locations are typically closer to the seal surface for penetration seal configurations than for raceway fire barrier system tests, using temperature data from penetration seal tests to evaluate fire stop designs is acceptable.

- For raceway barrier fire stops, hose stream test options are outlined in G.L. 86-10, Supplement 1 (Ref. 6.24) which allows three (3) options (one solid stream and two fog nozzles). The specified duration is dependent upon two conditions; 1) the fire test duration (i.e., one or three hours) and 2) the type of hose stream (i.e., solid stream or fog nozzle). One hour configurations which receive the solid stream type test require a hose stream duration of 1 minute, while one hour configuration tested using either of the fog nozzle type tests require a 5 minute hose stream duration. For penetration seals, the hose stream test options are essentially the same as those outlined in G.L. 86-10, Supplement 1, however, the duration requirements are different. Hose stream tests conducted on penetration seal configurations are typically performed for a duration of 2-1/2 minutes per 100 ft2 of exposed test area (or 1-1/2 seconds per 1 ft2 of exposed test area). The hose stream tests performed on the penetration seal tests referenced in this evaluation were in accordance with the typical penetration seal test hose stream duration requirements. Some of these tests had multiple hose stream tests performed , and all of these tests had at least one of the hose stream tests performed using the solid stream type application. Although the duration of the penetration seal hose stream tests were less than that required by G.L. 86-10, Supplement 1 the penetration seal tests had been subjected to 3 hour fire endurance tests prior to the hose stream application. Additionally, the silicone elastomer fire stop test in TU Electric Test 14-1 (Ref. 6.11) successfully withstood a hose stream test in accordance with one of the fog nozzle options outlined in G.L. 86-10, Supplement 1 for a 5 minute duration. Therefore, it can be concluded that silicone elastomer fire stops will adequately withstand the effects of a standard hose stream.

5. <u>The configuration has been reviewed by a qualified fire protection engineer and found to provide an equivalent level of protection.</u>

As documented by review and approval of this evaluation, the use of silicone elastomer fire stops as part of a raceway fire barrier enclosure has been reviewed and determined to provide an acceptable level of protection.

Based on the justifications provided above, it is acceptable to use penetration seal fire test data in conjunction with existing Thermo-Lag raceway barrier fire test data to support silicone elastomer fire stop designs. The following sections provide the detailed evaluation for silicone fire stop designs using both Promatec 45B Formulated Silicone Elastomer and BISCO SF-60 Silicone Elastomer.

4.2.1 Promatec 45B Formulated Silicone Elastomer

Promatec 45B Formulated Silicone Elastomer material (hereafter referred to as 45B elastomer) is an elastomer based product developed and marketed by Promatec. The exact composition of this material is considered proprietary by the manufacturer and the following information should be treated as such.

The primary material used in the formulation of 45B elastomer is straight silicone elastomer (68%). The remaining materials used in the formulation of 45B elastomer are silica flour (30%) and accelerator (2%). The manufacturer specifies that the minimum acceptable density of cured 45B elastomer is 70 lbs/ft3 (Ref. 6.25).

Fire stops comprised of 45B elastomer were used to seal the end of Thermo-Lag 330-1 fire barrier systems in certain installations for CPSES Unit 2. The use of 45B elastomer in this type of application is supported in limited applications by full scale fire endurance tests conducted by TU Electric and NEI. In addition, the use of 45B elastomer as a conventional penetration seal material has been extensively tested by the manufacturer of 45B elastomer (Promatec) and proven to be an acceptable method for sealing openings in barriers which must maintain up to a 3 hour fire rating. The combination of available testing performed on 45B elastomer for both penetration seal applications and for use in fire stopping the end of Thermo-Lag 330-1 fire barrier systems will be used to support CPSES installations of 45B elastomer fire stops.

In TU Electric Test Scheme 14-1, a 45B elastomer fire stop was installed in the opening of a Tee section in a 4" x 30" raceway covered with Thermo-Lag 330-1 material. The 45B elastomer fire stop was approximately 6" in depth, and the Tee section of the raceway containing the fire stop was in a horizontal position. While the

raceway contained an assortment of power, control and instrumentation cables representative of cables installed at CPSES (17.32% fill), none of the cabling passed through the 45B elastomer fire stop. Cable tray side rail temperatures immediately adjacent to the fire stop met acceptance criteria for both average temperature increase and maximum single point temperature increase, and the raceway enclosure, including fire stop, remained intact throughout the hose stream test. Therefore, TU Electric Test Scheme 14-1 supports 45B elastomer fire stop installations in horizontal applications for cable trays up to 4" x 30" in size when through penetrating cables are not present.

In Tech-Sil Tests #TS-TP-0075-C, #TS-TP-0018 and F-106, three different sized blockouts with various sized penetrating items were sealed with a 6" depth of 45B elastomer. All of the configurations were tested with the test slab in the horizontal position, resulting in a vertically exposed seal assembly. The penetrating items contained in these test assemblies included the following:

- (1) 4" x 24" solid bottom tray with 57.93% fill of power cabling
- (1) 6" x 24" ladder back tray with 40.21% fill of control cabling
- (1) 4" x 18" solid bottom tray filled with PVC jacketed cabling
- (1) 4" x 24" ladder back tray filled with PVC jacketed cabling
- (1) 8" x 11-3/4"x 1/4" thick tray with 49.66% fill of cabling
- (4) 4" diameter rigid steel conduits with cabling
- (1) 6" diameter rigid steel conduit with cabling
- (1) 2" diameter PVC coated flex conduit with cabling
- (1) 2-5/8" diameter insulated pipe
- (1) bare copper ground cable

Jacketing materials for the cabling used to fill the trays and conduits from these tests included PVC, EPR (Ethylene Propylene Rubber) and CLP (Cross-Linked Polyethylene).

All three of the Tech-Sil test assemblies were subjected to 3 hour fire endurance tests following the ASTM E-119 Standard Time-Temperature Curve, and as detailed in Section 3.0 of this evaluation, all three test assemblies satisfied temperature acceptance criteria at 1 hour into the 3 hour tests. Following completion of the 3 hour fire endurance tests, each of the test specimens was subjected to multiple hose stream tests. In all cases, two of the hose stream tests performed satisfied the standard ASTM E-119 solid stream type hose stream requirements and the IEEE-634 fog nozzle hose stream requirements. The duration for which each hose stream test was performed was in accordance with typical penetration seal testing standards (i.e., tests were performed for a duration equivalent to 2-1/2 minutes per 100 ft2 of exposed test specimen). Therefore, these

Tech-Sil tests substantiate that a 6" depth of 45B elastomer is capable of providing a fire stop rated in excess of 1 hour.

In NEI Test 2-8, a horizontally oriented aluminum cable tray Tee section clad with 1/2" thick Thermo-Lag 330-1 panels utilized a fire stop constructed from Thermo-Lag 330-1 materials to seal the end of the cable tray barrier enclosure. The enclosure/fire stop interface region was reinforced structurally with a clamp assembly comprised of 2" wide by 1/4" thick flat stock steel and all-thread rod. Two pieces of the flat stock material were cut such that they extended approximately 2" beyond the sides of the raceway enclosure. The flat stock material was placed on the top and bottom sides of the raceway enclosure and were connected with 3/8" diameter all-thread rod on both ends. This assembly clamped the enclosure material including the fire stop to prevent panel sagging and ensure the fire stop material remained in place. Similar type clamps are used at all raceway enclosure fire stops installed at CPSES regardless of the fire stop material used.

In conclusion, fire stops comprised of a 6" depth of 45B elastomer provide an acceptable method for sealing the end of 1 hour rated Thermo-Lag enclosures based on successful fire tests which demonstrated the following:

- A 45B elastomer fire stop without through penetrating cables successfully provided a 1 hour rated fire stop in a horizontal 4" x 30" cable tray Tee section per TU Test 14-1.
- 45B elastomer penetration seals with cabling successfully provided 3 hour rated fire stops in 4" x 18", 4" x 24", 6" x 24" and 8" x 11-3/4" cable trays with cabling in the vertical position per Tech-Sil Tests #TS-TP-75-C, #TS-TP-0018 and F-106.
- An enclosure clamp comprised of flat stock steel and all-thread rod provides additional structural integrity as demonstrated in NEI Test 2-8.

4.2.2 Dow Corning Sylgard 170 (BISCO SF-60)

BISCO SF-60 Silicone Elastomer (hereafter referred to as SF-60 elastomer) is an elastomer based product developed and marketed by BRAND fire Protection Services, Inc. (formerly BISCO). The exact composition of this material is considered proprietary by the manufacturer and the following information should be treated as such.

The sole material used in the formulation of SF-60 elastomer is straight silicone elastomer (100%). Minor amounts of an accelerator are added to the pure elastomer to achieve the fast cure version of this product. The base elastomer material used in SF-60 elastomer is

either Dow Corning Sylgard 170 A & B S icone Elastomer or General Electric RTV 6428 Silicone Elastomer. The minimum acceptable density of cured SF-60 elastomer installed at CPSES is 80 lbs/ft3 (Ref. 6.26). Since SF-60 elastomer is essentially straight elastomer which has a higher minimum density than the Promatec 45B Formulated Silicone Elastomer qualified previously, it is expected that SF-60 elastomer wil perform equal to or better than 45B elastomer in a similar configuration. This position is consistent with the fact that the performance of silicone based seal materials increases as the density of the material increases, such as in the case of high density silicone elastomer products which perform better (less thickness required) than straight silicone elastomer products, which in turn perform better than low density silicone elastomer products, which perform better than silicone foam products (Ref. 6.27).

Fire stops comprised of SF-60 elastomer were used to seal the end of Thermo-Lag 330-1 fire barrier systems in certain installations for CPSES Unit 1. The use of SF-60 elastomer in this type of application is supported in limited applications by full scale fire endurance tests conducted by TU Electric and NEI on a similar material (Promatec 45B Formulated Silicone Elastomer). In addition, the use of SF-60 elastomer as a conventional penetration seal material has been extensively tested by the manufacturer of SF-60 elastomer (BISCO) and proven to be an acceptable method for sealing openings in barriers which must maintain up to a 3 hour fire rating. The combination of available testing performed on SF-60 elastomer for penetration seal applications in conjunction with testing performed on Promatec 45B silicone elastomer for use in fire stopping the end of Thermo-Lag 330-1 fire barrier systems will be used to support CPSES installations of SF-60 elastomer fire stops.

In BISCO Test 748-105, a single 30" x 30" blockout with two (2) penetrating items was sealed with a 5" depth of SF-60 elastomer. This configuration was tested with the test slab in the horizontal position, resulting in a vertically exposed seal assembly. The penetrating items contained in this test assembly included the following:

- (1) 4" x 24" solid bottom tray with 50% fill of power, instrument and control cabling
- (1) 4" x 24" ladder back tray with 50% fill of power, instrument and control cabling

Insulation and jacketing materials for the cabling used to fill the trays in this test included PE (Polyethylene) insulation and PVC (Polyvinyl Chloride) jacketing.

The test assembly was subjected to 3 hour fire endurance test following the ASTM E-119 Standard Time-Temperature Curve, and as detailed in Section 3.0 of this evaluation, the test assembly satisfied temperature acceptance criteria at 1 hour into the 3 hour test. Following completion of the 3 hour fire endurance test, the test specimen was subjected to hose stream test which followed the standard ASTM E-119 solid stream type hose stream requirements. The duration for which the hose stream test was performed was also in accordance with ASTM E-119 (i.e., test was performed for a duration equivalent to 2-1/2 minutes per 100 ft2 of exposed test specimen). Therefore, this test substantiates that a 5" depth of SF-60 elastomer is capable of providing a fire stop rated in excess of 1 hour.

As previously qualified by this evaluation, raceway enclosure fire stops comprised of a 6" depth of Promatec 45B Formulated Silicone Elastomer provide at least 1 hour of protection (refer to Section 4.2.1 above). The following page contains Table 1 which provides a direct comparison of the temperature data for fire tests conducted on both 45B elastomer and SF-60 elastomer. Temperature data contained in Table 1 substantiates the conclusion that a 5" depth of SF-60 performs similarly to a 6" depth of 45B elastomer.

Therefore, fire stops comprised of a 5" depth of SF-60 elastomer provide an acceptable method for sealing the end of 1 hour rated Thermo-Lag enclosures based on the following:

- A 5" thick SF-60 silicone elastomer penetration seal successfully provided a 3 hour rated configuration in two (2) 4" x 24 cable trays with cabling in the vertical position per BISCO Test 748-105.
- One (1) hour Promatec 45B elastomer fire stop designs were previously review in Section 4.2.1 of this evaluation and determined to provide adequate protection.
- Per the test data summarized in Table 1, a 5" depth of SF-60 elastomer performs similarly to a 6" depth of Promatec 45B elastomer.

Therefore, BISCO SF-60 elastomer fire stops designs will also provide adequate protection.

Table 1.0 - Test Data Comparison

BISCO Test 748-105				Tech-Sil Test F-106				Tech-Sil Test TS-TP-0018			
(1) 30"x30" Blockout (1) 4"x24" CT (solid) 50% PE/PVC (1) 4"x24" CT (ladder) 50% PE/PVC Sealed with 5" depth SF-60 elastomer				(1) 30"x30" Blockout (1) 4"x18" CT (solid) ~50% PVC (1) 4"x24" CT (ladder) ~50% PVC (1) 6" Conduit with cabling Sealed with 6" depth 45B elastomer				(1) 32"x32" Blockout (2 sides steel lined) (1) 4"x24" CT (solid) 58% EPR (1) 6"x24" CT (solid) 40% EPR (3) 4" Conduits with cabling (1) 2" PVC Coated Flex Conduit (1) Ground Cable Sealed with 6" depth 45B elastomer			
TC	Location	T (1 hr)	ΔT	TC	Location	T (1 hr)	ΔT	TC	Location	T (1 hr)	ΔT
1	Surface	83°F	+6°	4	Surface	90°F	+9°	3	Surface	85°F	+5°
7	Surface	82°F	+6°	5	Surface	91°F	+10°	4	Surface	80°F	-
12	Surface	79°F	+3°	6	Surface	89°F	+7°	5	Surface	85°F	+5°
								6	Surface	80°F	-
								7	Surface	85°F	+5°
								8	Surface	80°F	-
								12	Surface	125°F	+45°
	Surface Average	82°F	+5°		Surface Average	90°F	+9°		Surface Average	89°F	+9°
TC	Location	T (1 hr)	ΔT	TC	Location	T (1 hr)	ΔT	TC	Location	T (1 hr)	ΔT
3	Tray Interface	239°F	+163°	9	Sm. Tray 1" Up	347°F	+267°		No Tray Data Available In This Test		
8	Tray Interface	242°F	+166°								
	Tray Average	241°F	+165°		Tray Average	347°F	+267°				
TC	Location	T (1 hr)	ΔT	TC	Location	T (1 hr)	ΔT	TC	Location	T (1 hr)	ΔT
4	Tray 1 Cable	384°F	+308°	1	Cable Int. 1" Out	128°F	+47°	-	Ave. of 16 TC's - Cable Jacket at Seal Surface	189°F	+103°
5	Tray 1 Cable	246°F	+169°	2	Cable Int. 1" Out	131°F	+50°				
6	Tray 1 Cable	179°F	+103°	11	Cable Int. 1" Out	177°F	+96°				
9	Tray 2 Cable	194°F	+118°	10	Cable Int. 1" Up	229°F	+148°	-	Ave. of 16 TC's - Cable Conductor at Seal Surface	239°F	+154°
10	Tray 2 Cable	223°F	+147°	12	Cable Int. 1" Up	410°F	+340°				
11	Tray 2 Cable	159°F	+83°								
	Cable Average	231°F	+155°		Cable Average	215°F	+136°		Cable Average	214°F	+129°

ΔT = Temperature above ambient

5.0 CONCLUSIONS

Based on the results of the fire endurance tests listed in Section 3, as augmented by the technical evaluations presented in Section 4, fire stops installed at CPSES constructed of Thermo-Lag 330-1, Promatec 45B silicone elastomer and BISCO SF-60 silicone elastomer materials are acceptable designs to seal termination's of Thermo-Lag protective envelopes on cable trays. These fire stop designs are qualified for the entire range of installed cable tray sizes and associated electrical cable fill densities at CPSES.

6.0 REFERENCES

6.1 CPSES "Fire Protection Report (FPR)," Revision 11.

6.2 NRC Generic Letter 86-10 "Implementation of Fire Protection Requirements, " dated April 24, 1986.

6.3 CPSES Integrated Nuclear Data Management System (INDMS) Unit 2 Penetration Seal Data Base.

6.4 CPSES Design Modification (DM) No. 97-14

6.5 Omega Point Laboratories Project No. 12340-93543f Scheme 4 "Fire Endurance Test of a Thermo-Lag 330-1 Fire Protective Envelope (36" Vertical Cable Tray Section with Fire Stop)," prepared for TU Electric, March 30, 1993.

6.6 Letter from S.C. Black, Director, Project Directorate IV-2, Division of Reactor Projects III/IV/V, Office of Nuclear Reactor Regulation to W.J. Cahill, Jr., Group Vice President, Nuclear, TU Electric, dated October 29, 1992.

6.7 Omega Point Laboratories Project No. 12340-95769, Scheme 13, Assembly 2 "Fire Endurance Test of a Thermo-Lag 330-1 Fire Protective Envelope (12 in. Cable Tray & 2 in. Conduit)," prepared for TU Electric, August 23, 1993.

6.8 CPSES Engineering Report (ER) No. ER-EE-006, "Evaluation of Fire Endurance Test Results Related to Cable Functionality in 1 2" & 2" Conduits," Rev. 0.

6.9 TU Electric letter logged, TXX-94267, from C.L. Terry to NRC dated November 9, 1994.

6.10 NRC, "Safety Evaluation OF Cable Functionality Issues Related To Thermo-Lag Fire Barriers At Comanche Peak Steam Electric Station, Unit 1," dated May 22, 1996.

6.11 Omega Point Laboratories Project No. 12340-94367m, Scheme 14, Assembly 1 "Fire Endurance Test of a Thermo-Lag 330-1 Fire Protective Envelope (30 in. Tray with Tee)," prepared for TU Electric, December 16, 1992.

6.12 Omega Point Laboratories Project No. 12340-94367h, Scheme 12, Assembly 2 "Fire Endurance Test of a Thermo-Lag 330-1 Envelope (24 in. Tray with Tee)," prepared for TU Electric, December 16, 1992.

6.13 NUREG-0797, Safety Evaluation Report Related to the Operation of Comanche Peak Steam Electric Station, Unit 2, Docket No. 50-446, Supplement No. 26, dated February 1993.

6.14 Omega Point Laboratories Project No. 12340-93543b, Scheme 1, Assembly 2 "Fire Endurance Test of a Thermo-Lag 330-1 Fire Protective Envelope (36" Tray with Tee)," prepared for TU Electric, September 9, 1992.

6.15 Omega Point Laboratories Project No. 13890-96148, "Fire Endurance Test of a Thermo-Lag 330-1 Fire Protective Envelope, Test 2-8 (Two 24 in. Aluminum Cable Tray and Two 6 in. Aluminum Cable Tray Assemblies)," prepared for Nuclear Utility Management and Resource Council, April 11, 1994.

6.16 Tech-Sil, Inc. Test Report #TS-TP-0075-C, "Fire & Hose-Stream Tests Of One Penetration ," revision 1, dated September 25, 1981.

6.17 IEEE Std 634-1978 "IEEE Standard Cable Penetration Fire Stop Qualification Test," Copyright 1978.

6.18 "ANI/MAERP Standard Method of Fire Tests of Cable and Pipe Penetration Fire Stops," transmitted ANI/MAERP Information Bulletin dated February, 1976.

6.19 ANSI/ASTM E119-76 "Standard Methods of Fire Tests of Building Construction and Materials," approved July 2, 1976.

6.20 Tech-Sil, Inc. Test Report #TS-TP-0018, "Fire & Hose Stream Test Of " Silicone Elastomer Seal In An Electrical Penetration," dated August 21, 1979.

6.21 Tech-Sil, Inc. Test F-106, "ASTM E814-81 Fire Test Of Through-Penetration Fire Stops: 3-Hour Fire Penetration Seal, 6 In. Of Silicone Elastomer," dated June 10, 1986.

6.22 ASTM E814-83 "Standard Method of Fire Tests of Through-Penetration Fire Stops," approved May 27, 1983.

6.23 BISCO Fire Test 748-105, "Fire Test Utilizing BISCO SF-60 Where Cable Trays Exist," dated June 10, 1983.

6.24 NRC Generic Letter 86-10, Supplement 1 "Fire Endurance Test Acceptance Criteria for Fire Barrier Systems Used to Separate Redundant Safe Shutdown Trains Within the Same Fire Area, " dated March 25, 1994.

6.25 Letter from Mr. Melvin S. Abrams (Construction Technology Laboratories) to Mr. Gregory J. Jarosz (Tech-Sil, Inc.), dated September 18, 1979.

6.26 CPSES Specification 2323-MS-38F "Fire Rated, Radiation Shielding, and Pressure Penetration Seals."

6.27 NRC Fire Protection Supplemental Safety Evaluation (SSER) 19, Appendix FF, for Watts Bar Nuclear Plant - Docket Nos. 50-390/391 (TAC M63648).

6.28 NEI Application Guide For Evaluation Of Thermo-Lag 330 fire Barrier Systems, VECTRA Technical Report 0784-00001-TR-02, Rev.2, dated February 23, 1996.

6.29 Omega Point Laboratories Project No. 11210-94943b, "Fire Endurance Test of a Thermo-Lag 330-1 Fire Protective Envelope (3 in. Steel, 3 in. Aluminum, & 1-1/2 in Steel Configurations & Generic 2 in. & 4 in. Tube Steel Support Members)," prepared for Tennessee Valley Authority, dated April 30, 1993.

ATTACHMENT 3 TO APPENDIX F

"CABLE SELF HEATING EVALUATION"

Open Item 5 - Cable Self Heating

In the May 22, 1996, letter from Mr. T. J. Polich to Mr. C. L. Terry, the NRC requested that TU Electric consider the effects of self heating on power cables. In this letter the NRC questioned the acceptability of the 1-1/2 and 2 inch air-drops and the 1-1/2 and 2 inch conduits based on the Scheme 9-3 testing (page 34). One of the primary concerns was the effect of cable self heating due to the I^2R losses which would normally be associated with power cables.

TU Electric will upgrade the 1-1/2 and 2 inch air drops and the 1-1/2 inch conduits. Theses configurations will be built in accordance with designs approved for Unit 2 and no further evaluation is required. The 2 inch conduits will be qualified in accordance with Scheme 13-2 and not Scheme 9-3. This test Scheme was found to be acceptable by the NRC Staff (page 39). Notwithstanding, an evaluation is provided which demonstrates functionality.

TU Electric has determined that cables protected within 2 inch conduit have a minimum ampacity margin of 100 percent. This calculation will determine the temperature increase associated with a specific decrease in actual cable loading. As agreed upon during the December 5, 1996 meeting this value will be subtracted form the 40° C to determine the temperature increase which is appropriate for CPSES (pages 86 - 87 of meeting transcripts).

$$I' = I \cdot \sqrt{\left(\frac{T_{c'} - T_{a'}}{T_c - T_a}\right) \cdot \left(\frac{234.5 + T_c}{234.5 + T_{c'}}\right)}$$

Equation for determining the cable ampacity, based on changes in conductor temperature or ambient temperature

Where:

I = equilibrium current, in amps
Tc = conductor temperature at current I, in °C
Ta = ambient temperature at current I, in °C
I\` = revised current based on Ta\` and Tc\`, in amps
Tc\` = revised conductor Temperature, in °C
Ta\` = revised ambient Temperature, in °C

In order to dete.mine the conductor temperature when the cable ampacity is varied the equation shown above will be solved for I. I' will then be varied to determine the corresponding temperature change.

$I := 60$ cable ampacity based on a 40° C ambient and a 90° C conductor temperature.

$T_c := 90$ conductor temperature, °C

$T_a := 40$ ambient temperature, °C

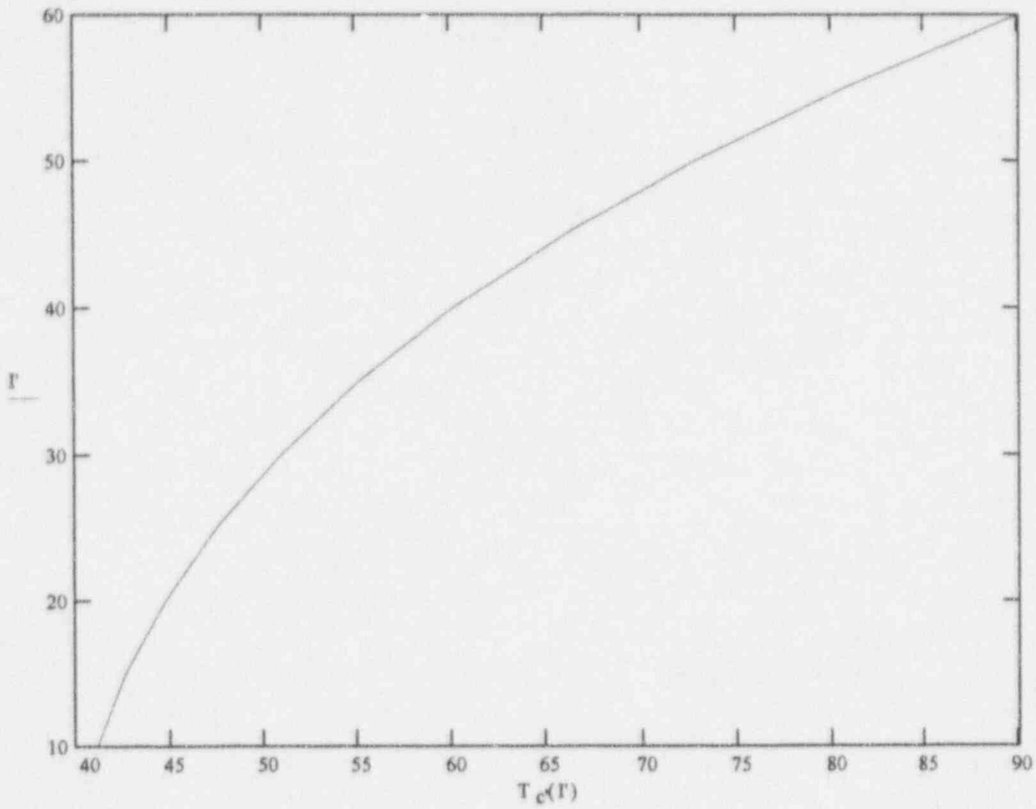
$T_{a'} := 40$ ambient temperature, °C

$I' := 60, 55 .. 10$ the current will be varied from 60 amps to 10 amps in 5 amp increments.

Solving the equation for Tc' yields:

$$T_{c'}(I') := -1. \cdot \frac{\left(-469. \cdot I'^2 \cdot T_c + 469. \cdot I'^2 \cdot T_a - 469. \cdot T_{a'} \cdot I^2 - 2. \cdot T_{a'} \cdot I^2 \cdot T_c\right)}{\left(469. \cdot I^2 + 2. \cdot I^2 \cdot T_c - 2. \cdot I'^2 \cdot T_c + 2. \cdot I'^2 \cdot T_a\right)}$$

Results



I'	$T_{c'}(I')$
60	90
55	81
50	73
45	66
40	60
35	55
30	51
25	48
20	45
15	43
10	41

The graphical and tabular results show that as the cable ampacity is decreased from 60 to 30 amps the corresponding conductor temperature falls by 39° C.

TU Electric has conservatively added 5° F to the following functionality evaluation in order to bound this condition.

Scheme 13-2
2" conduit

Worst case temperature profile

This profile utilized the maximum cable temperature from each thermocouple group, regardless of which cable the thermocouple was attached to. This temperature profile also has 5° F added to it in order to account for I^2R losses associated with the power cables.

$i := 0 .. 28$

$$T := \begin{bmatrix} 243 \\ 291 \\ 308 \\ 288 \\ 252 \\ 226 \\ 236 \\ 238 \\ 258 \\ 247 \\ 250 \\ 296 \\ 287 \\ 246 \\ 257 \\ 351 \\ 298 \\ 254 \\ 224 \\ 228 \\ 222 \\ 246 \\ 254 \\ 262 \\ 286 \\ 336 \\ 256 \\ 222 \\ 168 \end{bmatrix} + 5$$

Cable Type: **Power**

$D = .236$ Diameter of insulation in inches.

$d = .146$ Diameter of conductor in inches.

$K_i = \left[4 \cdot 10^{21} \cdot e^{\left[-.079 \cdot \left[\left[\frac{5}{9} \cdot (T_i - 32) \right] + 273 \right] \right]} \right]$ Insulation Resistance Constant.

$IR_i = \left(K_i \cdot \log\left(\frac{D}{d} \right) \right)$ Insulation Resistance in Ω - 1000 ft.

$IR'_i = IR_i \cdot 1000$ Insulation Resistance for a cable length, in Ω and ft.

$S = .5$ Thermocouple Spacing.

$R = \frac{IR'}{S}$ Insulation Resistance of each cable length, in Ω.

$$R_1 = \frac{1}{\left(\frac{1}{R_0} + \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} + \frac{1}{R_6} + \frac{1}{R_7} + \frac{1}{R_8} + \frac{1}{R_9} + \frac{1}{R_{10}} + \frac{1}{R_{11}} + \frac{1}{R_{12}} + \frac{1}{R_{13}} + \frac{1}{R_{14}} + \frac{1}{R_{15}} + \frac{1}{R_{16}} + \frac{1}{R_{17}} \right)}$$

$$R_2 = \frac{1}{\left(\frac{1}{R_{18}} + \frac{1}{R_{19}} + \frac{1}{R_{20}} + \frac{1}{R_{21}} + \frac{1}{R_{22}} + \frac{1}{R_{23}} + \frac{1}{R_{24}} + \frac{1}{R_{25}} + \frac{1}{R_{26}} + \frac{1}{R_{27}} + \frac{1}{R_{28}} \right)}$$

$Rt = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}$ $Rt = 2.079 \cdot 10^8$ Insulation Resistance of entire cable, in Ω.

Insulation Resistance in Ω - 1000 ft. - Power Cable

IR_i
$2.74\cdot10^7$
$3.333\cdot10^6$
$1.581\cdot10^6$
$3.802\cdot10^6$
$1.846\cdot10^7$
$5.778\cdot10^7$
$3.725\cdot10^7$
$3.412\cdot10^7$
$1.419\cdot10^7$
$2.299\cdot10^7$
$2.015\cdot10^7$
$2.676\cdot10^6$
$3.973\cdot10^6$
$2.402\cdot10^7$
$1.482\cdot10^7$
$2.394\cdot10^5$
$2.451\cdot10^6$
$1.691\cdot10^7$
$6.308\cdot10^7$
$5.292\cdot10^7$
$6.887\cdot10^7$
$2.402\cdot10^7$
$1.691\cdot10^7$
$1.19\cdot10^7$
$4.151\cdot10^6$
$4.625\cdot10^5$
$1.549\cdot10^7$
$6.887\cdot10^7$
$7.367\cdot10^8$

Conclusion:

The temperature increase associated with the 2 inch conduit has no adverse effect on the performance of the contianed power cables. The insulation resistance remains above 200 MΩ. This insulation resistance level will meet all TU Electric or NRC acceptance criteria.