TU ELECTRIC

ENGINEERING REPORT

EVALUATION OF THERMO-LAG FIRE BARRIER SYSTEMS

ER-ME-067

REVISION 2

Interim Report
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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.

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FORWARD

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 qualifications, 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 Resistent 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 in order to obtain a one hour fire rating for Thermo-Lag in accordance with American Nuclear Insurers (ANI) Bulletin dated July, 1979 and ASTM E119-80 Time/Temperature requirements. 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 cable trays and conduit. An ASTM E84 test determined that Thermo-Lag had a flame spread of 5, fuel contribution of 0 and smoke developed 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. 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 cable trays and cables. 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.

Comanche Peak has consistently utilized the ANI acceptance criteria as our licensing basis, and has utilized these acceptance criteria for fire barriers for electrical raceways for our current testing program. As discussed below, TU Electric also agreed to use additional acceptance criteria in the tests conducted in November/December 1992.

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. 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 are representative of plant configurations and envelope the 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 three 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 (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 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 meet 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. 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 LBD upgrade technique

3. Confirm the adequacy of design configurations 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.

<u>Session 3</u>

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, all with LBD's and radial bends, and 3" conduits 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)

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, and 30" without stitching)

Observations and results of these 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 conduits. These tests also confirmed the acceptability of the upgrade (reinforcement) details for the LBD's and radial bends.

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 as well as for the single layer configuration. These tests confirm 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 degration 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 1/4" flexi-blanket while the larger air drops were covered with only 2 layers of flexi-blanket.

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 are 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 temperatures 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.

CONCLUSIONS

As a result of tests conducted in June, August and November/December 1992, TU Electric has concluded:

1. Thermo-Lag performs its design function if properly c .figured

2. Thermo-Lag installations for conduit 2 inches diameter and smaller performs its design function when upgraded by addition of 1/4 inch thick overlay

3. Thermo-Lag installations for cable trays perform their design function when unsupported bottom butt joints and vertical joints are reinforced with stitching and/or additional stress skin.

4. Thermo-Lag configurations for LBD boxes, junction boxes, etc. perform their design function when reinforced with additional stress skin.

5. Thermo-Lag 330-660 "flexi-blanket" installations on air drops perform their design function when properly configured.

These upgrades are now being used in the Unit 2 installation and are being evaluated for backfit into Unit 1 at the first opportunity. In addition, these tests demonstrated that plant installation of supports without structural fire proofing is acceptable and that the 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 evaluates the CPSES installation specifications and configurations for Thermo-Lag and evaluates their adequacy based upon the test results and configurations.

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

Section 7.0 is reserved for a combustibility evaluation 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 protect the ability to safely shutdown 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 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 deviations 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 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, Appendix R to Part 50, Appendix A to BTP APCSB 9.5-1; and Generic Letters (GL) 87-12 and 86-10 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).

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 fire criteria that should be met if the field configuration cannot exactly replicate the test 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) and the Fire Protection Report for CPSES are the primary sources of TU Electric's commitments related to fire protection.

Section 9.5.1 of the CPSES FSAR states that where both trains of a system required for hot standby are located in the same fire area outside containment and are not separated by more than 20 feet, one train of cabling will be protected by at least a one-hour fire barrier, fire detection, and automatic sprinklers.

The FSAR and the Fire Protection Report 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, 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, 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, the NRC concluded that, based upon its review of the test report, the 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.

<u>Circuit Integrity</u>

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.

<u>Cable Temperature</u>

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.

<u>Cable Inspections</u>

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.

<u>Insulation Resistance (Megger) Test</u>

A megger t[illegible] 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), for the Third series of tests (The November/December tests) cable functionality was demonstrated using Insulation Resistance tests. The test method tested individual conductor to individual conductor and individual conductors to shield and to ground for each cable using the criteria outlined in Reference 10.22.

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, 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", 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 (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 thermocouple (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, cable 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 Control	≤ 250 VDC	500 VDC
	≤ 120 VAC	500 VDC

5. An IR (megger) test should 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 third series of tests, which were conducted in November and December of 1992.

3.6 SUMMARY

NRC regulations do not specify any acceptance criteria for qualification tests for fire barriers for electrical raceway. Similarly, neither the FSAR, Fire Protection Report, nor applicable SSERs for CPSES identify 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.

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, 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 the November and December 1992 tests were evaluated using this acceptance criteria.

4.0 THERMO-LAG FIRE ENDURANCE TESTS

4.1 Test Methodology

When possible, all materials used (Thermo-Lag, cable tray, cables, conduits, and seals) 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 pick 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 10.20) 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 meggerred to ensure the cable 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 1992 and December 1992 Tests

In the November 1992 and December 1992 tests, raceway temperatures were used as the baseline acceptance criteria in accordance with the NRC letter, dated October 29, 1992 (Ref. 10.22). 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. The acceptance criteria was no raceway visible through the barrier after the hose stream.

As part of the program, the cables were visually inspected and 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 test program:

- Conduits (3/4", 1", 1 1/2", 2", 3" & 5")
- Cable Trays (12", 24", 30" & 36")
- Thermo-Lag penetration fire stops

- Junction boxes
- Air drops

Testing has been conducted at Omega Point Testing Laboratory, San Antonio, Texas, including seventeen test schemes in three 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 14-1

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" (Ref. 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 Test Session 3 tests was the NRC letter dated October 29, 1992 (Ref. 10.22). 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 hose stream test.

4.2.1 CONDUITS

Together the three 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 the NRC request to allow for a more effective barrier inspection. Instead the test article was cooled with a garden hose. The Lateral Bends (LBDs) shifted, opening up the top joints of the LBD and some slight blistering of the outer jacket of one cable was observed. Because the LBD joint opened, it was decided to reinforce the LBDs.

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 LBDs opened similar to the 3" corduit. It has been decided to reinforce the LBD and to upgrade 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/stress skin
- 1/2" (PSS) with 1/4" spiral wound 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 LBDs opened similar to the other applications in Scheme 7 (session 2). It has been decided to use the 1/4" pre-shaped overlay with reinforced LBDs in Unit 2's design.

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

The 3/4" with the 1/4" overlay along with the 3" and 5" conduits, all with upgraded LBDs and radial bends, were tested in Scheme 9-1 (session 3) and passed the fire endurance test. The cable temperatures were all below 321°F (250°F + 71°F (ambient)). 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 became saturated and the readings were determined to be incorrect and thus were not used (see Section 4.4.1 for further discussion).

The 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 313°F (250°F + 63°F (ambient)) for Scheme 10-1 (session 3) and 318°F (250°F + 68°F (ambient)) for Test Scheme 10-2 (session 3) except of one reading which was 324 °F which is well below the 393 °F limit. 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 thermocouple became saturated and the readings were determined to be incorrect and thus were not used (see Section 4.4.1 for further discussion).

The 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. The results of the test are still under evaluation.

The 1 1/2" and 2" conduits with only 1/2" thick prefabricated half section 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, and radial bends were reinforced. The results of this test are still under evaluation.

4.2.2 CABLE TRAY

Cable tray (12", 24", 30" and 36") were tested in Schemes 1, 3, 5, 6, 8, 11-1, 12-1, 12-2, 13-1, and 14-1. 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 the upgraded technique of butt joint stitching or stress skin overlay. Schemes 11-1, 12-1, 12-2, and 13-1 (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 2) 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, and 14-1 (session 3). These tests were conducted to validate joint reinforcement 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 321°F (250°F + 71°F ambient). 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 cable temperatures were all below 321°F (250°F + 71°F ambient). The tray rail average temperatures were below 321°F and the maximum single temperature was below 396°F (325°F + 71°F). 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 cable temperatures were all below 317°F (250°F + 67°F ambient). The tray rail average temperatures were below 317°F and the maximum single temperature was below 392°F (325°F + 67°F ambient). 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 integrity 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. This detail was satisfactorily tested in Scheme 14-1.

Scheme 13-1 (session 3) tested a 12" tray which was upgraded with reinforced longitudinal and butt joints. This Scheme passed the fire endurance test. The cable temperatures were all below 318°F (250°F + 68°F ambient). The tray rail average temperatures were below 318°F and the maximum single temperature was below 393°F (325°F + 68°F). There was no burn through of the fire barrier. In addition, there was no visible cable degradation, circuit integrity was maintained and 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 average cable temperatures were below the 320°F (250°F + 70°F ambient). The maximum single cable temperatures were 336°F which was well below 395°F (325°F + 70°F ambient). [illegible] tray rail average temperatures were below 320°F. The maximum single tray [illegible]l temperature was 401°F which exceeds the 395°F limit. However, the [illegible]5°F [illegible]it was exceeded in the last minute of the test. There was no burn throu[illegible] of [illegible] fire barrier after the hose stream test and no visible cable degradation. Circuit integrity was maintained and all cables passed the IR tests.

4.2.3 **Thermo-Lag Fire Stops**

A Thermo-Lag penetration fire stop installed in accordance with CPSES procedures was tested in Scheme 4 (session 1) in accordance with IEEE-634. This test was done 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 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.

4.2.4 **Junction Boxes**

A junction box with Thermo-Lag installed in accordance with the 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 the results of Schemes 7 (session 2), where LDB "box" enclosures shifted during the test, confirmatory testing of an upgraded junction box designs were 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 313°F (250°F + 63°F ambient). 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 l[illegible] 1/2" nominal flat panels. The junction boxes passed the fire endurance [illegible]. The cable temperatures were all below 319°F (250°F + 69°F ambient). The [illegible] box inside average surface temperatures were below 319°F and the single maximum temperatures were below 394°F (325°F + 69°F ambient). 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 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 tray rail temperatures were below 321°F (250°F + 71°F ambient). 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.

4.2.6 Summary of Test Results

The Thermo-Lag 330-1 material showed signs of softening early in the test (material temperature around 250°F). This allowed prebuttered joint under stress to open unless the joint had been reinforced either by stitching the joints or by providing an overlay of Thermo-Lag Stress-Skin Type 330-69 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 into 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 the Thermo-Lag 330-1 was acceptable on cable trays when the joints were reinforced by stitching and/or the application of stress-skin and trowel grade material.

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

On small conduits (≤ 2"), the 1/2 in. (nominal) pre-shaped Thermo-Lag 330 sections did not pass the test unless a 1/4" overlay was installed over the 1/2" thick Thermo-Lag. For all conduit sizes the pre-shaped conduit section provides enough rigidity to prevent the butt and longitudinal joints from opening. However, butt joints at box enclosures (e.g., LBDs) had to be reinforced 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 and 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 or cracked joints. Based on this, an alternate hose stream test using a 30 deg 1-1/2 in. fog nozzle 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, CP&ES testing used a 5 minute duration with a 1-1/2 in. dia. fog nozzle set at a discharge angle of 30 percent 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 test has a rated flow of 88 gpm at 75 psi which ensures 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 (Ref. 10.22) approved the use of the fog nozzle and this method was used in the November and December test (third test 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 (30^0fog). Additionally the nozzle pressures used during testing envelop the nozzle pressures of the plant standpipe and hose system.

4.3.2 9 in. Rule

CPSES specifications require that items protruding from a raceway be covered with Thermo-Lag to a distance of 9" 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 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.

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 envelop.

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 Schemes 6, 7, 8, 9-1, 9-3, 10-1, 10-2, 11-1, 12-1, 12-2, 13-1, and 14-1 (sessions 2+3).

In Schemes 6 through 14-1 (sessions 2+3), the supports were covered out to approximately 9 in. with Thermo-Lag [for protruding items in accordance with plant design] (Reference 10.14.1).The test results from Schemes 6 through 14-1 (sessions 2+3) showed that the exposed supports did not provide a significant heat path into the envelop. In fact, the cable thermocouple reading closest to 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 left exposed had no impact on the test results.

4.3.4 Top Coat

Top coat was applied on the Thermo-Lag 330 prefabricated panels at TSI in accordance with Reference 10.14.1 and reapplied where required by Reference 10.4.1 on all test articles. Therefore, Thermo-Lag 330-1 with top coat is a tested configuration.

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 an 10 CFR 50 Appendix B 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 the fire test, the density inspection along with the visual inspection and source inspections provided adequate quality control of the Thermo-Lag 330-1 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.

4.4 Test Observation

4.4.1 Exposed Conduit Thermocouple

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 thermocouple. The corresponding cable thermocouple all read less than 200°F. This occurred at about 30 minutes into the test. By the end of the test (60 minutes), the same thermocouple 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 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 next day, 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 thing 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 setup 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.

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 cable performance but was something noted during the inspections.

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 narcotic is carbon monoxide, HCN is defined as a narcotic when discussing toxicity in a fire which is given every product during the combustion process.

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 as non-seismic (Seismic Category None). However, since the fire barrier and fireproofing material 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 Unit 2 Seismic II/I program has addressed the requirements of Regulatory Guide 1.29 for the design and operation of Unit 2. In this program Thermo-Lag is not considered to be a potentially damaging sources. Gross failure/falling of the material under CPSES design basis seismic inertia 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 indicated gross failure and falling of fire barrier materials due to seismic inertia when the material 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.

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

All CPSES Unit 2 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 Unit 2 Thermo-Lag scheduled and is confirmed by field walkdown;
- The weight of the Thermo-Lag installations on conduits is based on the maximum weights allowed by the specification (2323-MS-38H) for the prefabricated conduit sections and LBD's. These weights are verified by QC on receipt;
- The weight of the Thermo-Lag installations on cable trays is based on the maximum weights allowed by the specification (2323-MS-38H) for the

prefabricated panels. These weights are verified by QC on receipt. 1/4" additional thickness of Thermo-Lag has been considered to evaluate the resultant weight from the Thermo-Lag upgrade (ie, 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 (2323-MS-38H) of the prefabricated Thermo-Lag panels.

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) explicity require that cables do not extend above tray side rails. Additionallly, 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 fo 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.

5.0 COMPARISON OF DESIGN/INSTALLATION REQUIREMENTS AGAINST THE TEST RESULTS

The design and installation requirements for Thermo-Lag for CPSES were reviewed to determine whether those requirements are consistent with the Thermo-Lag test results.

5.1 Specification Review

5.1.1 Specification CPSES-M-2032, Rev. 0, including DCA 95794, Rev. 7, (Reference 10.14.2), "Procurement and Installation of Fire Barrier and Fireproofing Material"

This specification is applicable to installation in Unit 2 and common areas with respect to Unit 2 work only.

This specification was reviewed against CPSES test results from the fire endurance tests performed at Omega Point Laboratories (References 10.12.1 to 10.12.19, excluding 10.12.9,10). This review is documented in Appendix B.

This review was limited to Thermo-Lag installation on cable raceway. Radiant Energy Shield (RES) installation which is part of the specification, is outside of the scope of this review. The review of this specification for structural steel fireproofing is provided in Appendix D of this report.

This review determined that the Thermo-Lag installation attributes and requirements are consistent with the test fire results and are adequately documented in the specification.

5.1.2 Specification 2323-MS-38H, Rev. 2, including DCA 77269, Rev. 3 (Reference 10.14.1), "Cable Raceway Fire Barrier Materials"

The specification is applicable to installation for Unit 1, and Unit 2 after completion.

This specification is in the process of being revised to incorporate the required upgrades to the installations based on CPSES testing of Thermo-Lag at Omega Point Laboratories and was not ready for review in time for issuance of revision 2 of this report.

5.1.3 Specification 2323-AS-47, Rev. 3 (Reference 10.14.3), "Fireproofing of Structural Steel"

This specification is applicable to installation for Unit 1, and Unit 2 after completion.

The specification was reviewed against Underwriters' Laboratories, Inc. (UL) Fire Resistance Directory, specifically detail X-611.

This review was limited to Thermo-Lag installation. Other fireproofing materials are outside the scope of this review.

This specification incorporates the requirements of the UL directory. In fact, this specification provides additional requirements which will ensure an adequate Thermo-Lag installation.

Section 4.1 allows the use of prefabricated panels to be inserted in the trowel-grade material. An Engineering Evaluation of this design is provided in Appendix D of this report.

5.2 Installation Schedule Review

The installation schedules M1-1700 (Unit 1) and M2-1700 (Unit 2) were reviewed to determine if the commodities protected (size and configurations) are enveloped by the fire test data.

A summary of the review on M2-1700 is provided in Appendix C. M1-1700 was only compared against M2-1700 for differences. The review of M1-1700 demonstrated no significant differences from M2-1700. The review of M2-1700 demonstrated that the installed commodities are enveloped by the test configurations, except for multiple raceways and other commodities in common fire barrier enclosures.

Multiple raceways in common enclosures will be evaluated as large trays (36" with tee was tested) with the joints reinforced. An engineering evaluation will be finalized to document acceptability of the installations on a case-by-case bases.

5.3 Design Change Document Review

5.3.1 The design change documents (e.g. Design Change Notices) for one time deviations from the specification for Unit 1 were reviewed against TSI installation guidelines. This was done prior to the start of the CPSES fire tests. Unit 1 is presently evaluating the Thermo-Lag installation against the new design requirements and will backfit these requirements into Unit 1. Therefore, the previous design change documents will be superseded and do not require a review.

5.3.2 Design Change Documents for Unit 2 are being reviewed. This is an on going process since Thermo-Lag is still being installed in Unit 2. The document review and if required engineering evaluations will be documented in the engineering report "Thermo-Lag Fire Barrier Non-standard Installation Review" (ref. 10.23.1)

6.0 Ampacity Derating Factors

The NRC in Draft Generic Letter 92-XX (Reference 10.10) raised a concern that ampacity derating factors may not be conservative. This concern was based on the fact that certain as-built configurations in some plants may not be representative of the tested configurations.

As stated in DBD-EE-052, "Cable Philosophy and Sizing Criteria," cable ampacity derating factors for Thermo-Lag raceways at CPSES Units 1 and 2 are as follows:

1. 31 percent for single trays enclosed with Thermo-Lag applied against ICEA P-54-440 "Cables in Random Filled Trays" (factors taken from UL Report R6802 (Reference 10.11.4)).

2. 20 percent for single conduits enclosed with box design Thermo-Lag, applied against ICEA P-46-426 "Power Cable Ampacities for Conduits in Air" (factors determined by calculation 16345/6-EE(B)-004 (Reference 10.16.3)).

3. 7.5 percent for single conduit enclosed with shell design Thermo-Lag (factor based on review of TSI Report No. 111781 for 1-in. conduit (Reference 10.11.1)).

4. Other specific cable ampacity derating factors for free air wrapped cables (factors determined by calculation 16345-EE(B)-140 (Reference 10.16.4)).

Variations in configuration in the field that differ from the approved guidelines are documented in the Design Change documents which allow the configurations. The engineering basis for each design change documents the fact that the derating factors are not impacted (example of this is DCA-87040, Rev. 1).

Concerns raised by the subject generic letter and from the other sources regarding the appropriate cable ampacity factor for Thermo-Lag 330-1 fire barrier systems on power cable are as follows:

6.1 ISSUE 1

CONCERN: TSI provided test results to licensees that documented ampacity derating factors for enclosed tray ranging from 12.5 percent for 1-hour barriers to 20.55 percent for three-hour barriers. On October 2, 1986, TSI informed its customers and the NRC that, while performing tests at Underwriter's Laboratory (UL) facility, TSI found that the ampacity derating factors for Thermo-Lag were greater than previous tests indicated.

The UL tested ampacity derating factor ranged from 28 percent for 1-hour barriers to 31 percent for 3-hour barriers. However, TSI stated that the test results may not be comparable to previous test results since the test procedure and configurations were different.

Testing conducted at Southwest Research Institute (SWRI) (by TSI competitors), as reported by the NRC, found the ampacity derating at 37 percent for a 1-hour barrier.

The NRC is concerned that licensees may be using nonconservative ampacity derating factors for cable in tray with Thermo-Lag.

DISCUSSION: The ampacity derating factors differ significantly between the Industrial Testing Laboratories (ITL) Report and the UL Report. The test philosophy and method differ considerably between the two tests. Since the test philosophy used by UL is consistent with the latest draft of a proposed IEEE standard on "Ampacity Derating of Fire Protected Cables," CPSES utilizes the cable derating factor for power tray consistent with the results of the UL report.

UL is a nationally recognized testing agency and has published the ampacity tables for the National Electric Code. The test results from SWRI have not been made available to CPSES.

The thickness of the 1-hour rated Thermo-Lag in the UL test was a minimum 0.5 in. and 0.6 in. maximum. However, the Unit 1 Brown & Root installation procedure indicates that a maximum thickness of 0.75 is permitted. To account for this, a 31 percent derating factor is used for CPSES. This 31 percent corresponds to the derating factor for 1.0 in. thick product (3 hour fire barrier) in the UL test and would be applied against the ICEA cable ampacity standard for single trays enclosed with Thermo-Lag.

6.2 ISSUE 2

<u>CONCERN</u>: The ampacity derating factors for enclosed conduit from the TSI report (7.5 percent) differ significantly from the UL Report (0 percent).

The NRC is concerned that licensees may be using nonconservative ampacity derating factors for cable in conduit with Thermo-Lag.

<u>DISCUSSION</u>: The significant differences for derating factors between the TSI report (7.5 percent) and UL report (0 percent) may be due to differences in conduit sizes used in the test. The tests utilized the pre-shaped form of Thermo-Lag on conduit. The Thermo-Lag is manufactured in two halves and fits over the conduit. On the 4-in. conduit, the Thermo-Lag fits tightly against the conduit, improving heat transfer. However, for the 1-in. conduit used in the TSI test, a small air gap can be expected between the Thermo-Lag and the conduit, resulting in reduced heat transfer and lower ampacities. Accordingly, the TSI results will be used for all conduit sizing using the pre-shaped shell shaped Thermo-Lag.

6.3 ISSUE 3

<u>CONCERN</u>: The thermal resistance of Thermo-Lag, as determined in an ambient test environment of 40°C, versus a normal plant ambient environment of 50°C, was used in calculating the ampacity of cables. The concern was that this may result in a less conservative ampacity rating.

<u>DISCUSSION</u>: An analysis for using the thermal resistance of Thermo-Lag, applicable for an ambient environment of 40°C was performed for calculating the ampacity of cables in an ambient environment of 50°C. The analysis showed that use of the 40°C thermal resistance factor results in a more conservative ampacity derating factor, and therefore is acceptable.

6.4 ISSUE 4

<u>CONCERN</u>: Thermo-Lag 1-hour installation procedures at CPSES require a thickness of 0.500 in. with a tolerance of 0.250 in. The concern was that this installation may require additional derating factors.

<u>DISCUSSION</u>: The results of the UL test for the 1" thick product were used.

6.5 ISSUE 5

CONCERN: No cable ampacity testing was submitted for box design Thermo-Lag on conduit. The concern was that cables installed in these configurations may not have proper ampacity ratings applied.

DISCUSSION: Unit 1 installation procedure CP-CPM-10.3 permitted the conduit to be boxed out with Thermo-Lag, which may produce an air gap between the Thermo-Lag and the conduit resulting in an expected higher derating factor. This condition was analyzed in calculation 16345/6-EE(B)-004 (Reference 10.16.3), and it was concluded that a 20 percent derating factor should be applied against the ICEA P-46-426 cable ampacity standard for single conduit enclosed with Thermo-Lag. The installation procedure was modified accordingly

6.6 ISSUE 6

CONCERN: No cable ampacity testing was submitted for Thermo-Lag on free air drop cable. The concern was that cables installed in this configuration may not have proper ampacity ratings applied.

DISCUSSION: Calculation 16345-EE(B)-140 calculates the ampacity of free air cables which are wrapped with the flexible version of Thermo-Lag (330-660). Instead of calculating a derating factor, a specific ampacity is developed.

Based on the discussion above and review of the existing documentation (Reference 10.11.1 through 10.11.4) adequate documentation and engineering basis is available to support the numbers used.

6.7 ISSUE 7

CONCERN:

An August 1992 NRC Office of Inspector General (OIG) report (Reference 10.10), alluded to the presence of a previously undisclosed cable tray Thermo-Lag ampacity test report conducted by Underwriters Laboratory (UL). This second report purportedly has a greater ampacity derating factor than the published UL Test Report R5802 (Reference 10.11.4). Additionally, Thermo-Lag enclosed conduits in sizes 2 inch and smaller are being modified to increase their performance in fire tests. The modification will increase the existing ampacity derating factors.

DISCUSSION:

General CPSES Cable Design Criteria

Power cables are qualified for continuous operation at a conductor temperature of 90 degrees centigrade for the qualified life of the cable . Non Class 1E cables are derated for an ambient temperature of 40 degrees centigrade (50 degrees centigrade cor Class 1E cables. All cables are sized to carry at least 125% of the full load amperes for a conductor temperature of 90 degrees centigrade. All power cables have an emergency rating to withstand five operations lasting not more than 100 hours each, at a conductor temperature of 130 degrees centigrade. All power cables have a short circuit rating of 250 degrees centigrade. Therefore, cables operating at full load will maintain cable conductor temperatures well below 90 degrees centigrade.

The above criteria are implemented prior to derating of ampacity due to the addition of Thermo-Lag.

Not withstanding the above, TU Electric is in the process of determining the ampacity derating factors for the upgraded Thermo-Lag designs. There is no issued standard for determining the ampacity derating factors for fire wrapped raceways. TU Electric is testing to the draft IEEE Standard 848 Draft 11 with the following differences.

1. 3/C No. 6 AWG cable is used in the tray.

2. The largest cable size in conduit.

3. Raceways filled per CPSES requirements.

4. The smallest air drop bundle has 3/C No. 6 AWG cable installed in it and the largest air drop bundle has 3-1/C No. 750 MCM installed it in it.

TU Electric is testing the following configurations without Thermo-Lag to get a baseline and with Thermo-Lag to determine the derating factor.

1. Small air drop with 3 layers of Flexi-Blanket on a single 3 conductor No. 6.

2. Large air drop with 2 layers of Flexi-Bloanket on three single conductor 750 MCM cables.

3. 3/4" conduit with a 1/2" thick and then a 1/4" thick layers of Thermo-Lag with a single 3 conductor cable No. 8 in the conduit.

4. 2" conduit with a 1/2" thick and then a 1/4" thick layers of Thermo-Lag with the largest 3 conductor cable or three single conductors in the conduit.

5. 5" conduit with a 1/2" thick layer of Thermo-lag with three single conductor 750 MCM cables in the conduit.

6. 24" x 4" cable tray with three conductor No. 6 cables to a fill of 40% in the tray.

TU Electric will complete the ampacity derating testing and will identify corrective action, if required, by the completion of the first refueling outage.

7.0 COMBUSTIBILITY OF THERMO-LAG

TU Electric is evaluating the combustibility of Thermo-Lag, which was provided by NRC Information Notice 92-82 "Results of Thermo-Lag 330-1 Combustibility Testing." The results of this evaluation will be incorporated in the applicable documents.

8.0 OPEN ITEMS

1. EVALUATION OF UNIT 1
2. COMBUSTIBILITY OF THERMO-LAG
3. REVIEW OF FINALIZED OMEGA POINT LABORATORIES REPORTS
4. FINALIZE AMPACITY DERATING ANALYSIS

9.0 CONCLUSIONS

As a result of tests conducted in June, August and November/December 1992, TU Electric has concluded:

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

2. Thermo-Lag installations for conduit 2 inches diameter and smaller performs its design function when upgraded by addition of 1/4 inch thick overlay

3. Thermo-Lag installations for cable trays perform their design function when unsupported bottom butt joints and vertical joints are reinforced with stitching and/or additional stress skin.

4. Thermo-Lag Box configuration for LBD boxes, JB boxes, etc. perform their design function when reinforced with additional stress skin.

5. Thermo-Lag 330-660 "flexi-blanket" installations on air drops perform their des.gn function when properly configured.

These upgrades are now being used in the Unit 2 installation and are being evaluated for backfit into Unit 1. In addition, these tests demonstrated that plant installation of supports without structural fire proofing is acceptable and that the fog nozzle hose stream test is an effective hose stream test.

10.0 REFERENCES

10.1 ASTM E-119 (83) "Standard Methods of Fire Tests of Building Construction and Materials, American Society for Testing and Materials"

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

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

10.6 CPSES Final Safety Analysis Report, Section 9.5.1

10.7 NRC Generic Letters

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

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

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. 91-79 "Deficiencies in the Procedures for Installing Thermo-Lag Fire Barrier Materials," dated December 6, 1991.

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

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 Thermal Science, Inc. (TSI) Cable Ampacity Tests

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"

10.12 CPSES Protective Envelope Fire Endurance Tests

10.12.1 Omega Point Laboratories Final Report 12340-93543b dated 11-04-92 later, Scheme No. 1 Assembly No. 2,

10.12.2 Omega Point Laboratories Final Report 12340-93543c dated (later), Scheme No. 2 "not issued"

10.12.3 Omega Point Laboratories Final Report 12340-93543e dated (later), Scheme No. 3 "not issued"

10.12.4 Omega Point Laboratories Final Report 12340-93543f dated (later), Scheme No. 4 "not issued"

10.12.5 Omega Point Laboratories Final Report 12340-93543g dated (later), Scheme No. 5 "not issued"

10.12.6 Omega Point Laboratories Final Report 12340-93543h dated (later), Scheme No. 6 "not issued"

10.12.7 Omega Point Laboratories Final Report 12340-93543i dated (later), Scheme No. 7 "not issued"

10.12.8 Omega Point Laboratories Final Report 12340-93543j dated (later), Scheme No. 8 "not issued"

10.12.9 Southwest Research Institute (SWRI) Project No. 01-6763-302 Final Report, dated December 2, 1981, "Fire Resistance of Irradiated Thermo-Lag 330-1"

10.12.10 SWRI Project No. 03-6491 Final Report, dated October 27, 1981, "Fire Qualification Test of a Protective Envelope System".

10.12.11 Omega Point Laboratories Final Report 12340-94367a dated (later), Scheme No. 9-1 "not issued"

10.12.12 Omega Point Laboratories Final Report 12340-94367c dated (later), Scheme No. 10-1 "not issued"

10.12.13 Omega Point Laboratories Final Report 12340-94367d dated (later), Scheme No. 10-2 "not issued"

10.12.14 Omega Point Laboratories Final Report 12340-94367f dated (later), Scheme No. 11-1 "not issued"

10.12.15 Omega Point Laboratories Final Report 12340-94367i dated (later), Scheme No. 12-1 "not issued"

10.12.16 Omega Point Laboratories Final Report 12340-94367h dated (later), Scheme No. 12-2 "not issued"

10.12.17 Omega Point Laboratories Final Report 12340-94367l dated (later), Scheme No. 13-1 "not issued"

10.12.18 Omega Point Laboratories Final Report 12340-94367m dated (later), Scheme No. 14-1 "not issued"

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"

10.13.2 TSI Technical Structural Steel

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 330-1 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 CPSES Unit No. 1 Specification No. 2323-MS-38H, "Cable Raceway Fire Barriers"

10.14.2 CPSES Unit No. 2 Specification No. CPSES-M-2032, "Procurement and Installation of Fire Barrier and Fireproofing Materials"

10.14.3 CPSES Unit 1 and 2 Specification No. 2323-AS-47, "Fireproofing of Structural Steel"

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"

10.16 CPSES Calculations

10.16.1 CPSES Unit 1 and 2 Calculation No. ME-CA-0000-0965, "Thermo-Lag Primary Protruding Member Installation Requirements"

10.16.2 CPSES Unit 1 and 2 Calculation No. ME-CA-0000-2062, "Heat Transfer Analysis of Cable Tray Supports to Determine Thermo-Lag Requirements"

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. 0210-063-043 Rev. 0 "Maximum Permissible Fire Loading/ Non-Rated Features Analysis"

10.17 CPSES Design Basis Document

10.17.1 DBD-EE-052 "Cable Philosophy and Sizing Criteria," Rev. 3

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 CQP-EL-205 "Cable Inspection" Rev.2

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

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

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 Interface Design of Thermo-Lag Pre-fabricated Panel/Mandoval P-50 and a Unistrut Test"

10.22 NRC Letter to Mr Cahill dated October 2?, 1992 "Thermo-Lag Acceptance Methodology for Comanche Peak Steam Electric Station-Unit 2", Docket No. 50-446.

10.23 CPSES Engineering Reports

10.23.1 Engineering Report ER-ME-(later) "Thermo-Lag Fire Barrier Non-Standard Installation Review Rev. 0 (Not Issued)

10.24 Supplement Safe Evaluation Reports (SSER) NUREG 0797

10.24.1 SSER 12, Date issued October, 1985

10.24.2 SSER 21, Date issued April, 1989

10.24.3 SSER 22, Date issued January, 1990

A1 Omega Point Test No.12340-93543a - 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, 1981 (Reference 10.20).

Note: Assembly 1 of this test scheme was not tested.

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 having a 8 ft-6 in. horizontal run dimension and a vertical dimension of 6 ft-0 in. 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 surrounded 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 "squared" 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-ribs 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 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 tray 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 continuity 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 use of Thermo-Lag 330-660 Flexi blanket to satisfy the 9-in. rule of preventing heat intrusion into the protective envelope was demonstrated to be acceptable.

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/Therm-Lag 330 interfaces in the plants.

A2.2 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 (later). 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 10.20).

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 deck. 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 out 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 Flexiblanket.

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°F 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 are 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°F. 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 jacket, 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 is 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 preform 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 Flexiblanket, 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.

A3 Omega Point Test No. 12340-93543e - Scheme 3

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 (later). 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 10.20).

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 are 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 Penetration Seal Test documented in Reference 10.12.4 was conducted at Omega Point Laboratories on June 23, 1992 and the test report was issued (later). The Penetration Seal Test was conducted in accordance with IEEE 634 "Standard Cable Penetration Fire Stop Qualification Test" (Reference 10.19). This is the test standard reference in CPSES's FSAR (Section 9.5.1, see Section 6.7 of this document).

A4.1 Test Article

Scheme No. 4 consisted of a single vertical 36" 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.

An 8" wide silicone elastomer[(Promatec 45B) fire stop] was poured 2'-5" up from the centerline of the 330-1 tray stop material. The stop was allowed to cure, then a 0.10" thick stainless steel sheet metal plate was wrapped around the Promatec 45B tray stop, and metal banded in place. The stop was aligned with the test deck during installation.

Omega Point Laborator'ss furnished a 1'-0" thick concrete slab having a 1'-0" wide x 4 -0" long blockout. The 36" vertical tray was inserted into the blockout wherein 3'-6" of the tray hangs below the underside of the concrete slab and a 2" gap remains all around the tray. Around the blockout opening was sealed using a 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 Penetration Stop consisted of Thermo-Lag 330-1 trowel-grade material poured 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

The maximum temperature was 466°F with an average temperature of 380°F. These temperatures are significantly below the ignition temperatures of IEEE 383 cable (at least 700°F) which is the only ignition source inside the enclosure. These temperatures meet the requirements IEEE 634.

A4.5 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.

The Thermo-Lag envelope surrounding the penetration stop opened up (joints opened) during the hose stream test. However, the hose stream did not penetrate or dislodge the Thermo-Lag fire stop.

A4.6 Comments

The penetration Thermo-Lag stop installed in accordance with Reference 10.14.1 meets the acceptance criteria of IEEE 634.

A5 Omega Point Test No. 12340-93543g - Scheme 5

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 (later). 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 10.20).

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, both 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 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 were 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 events 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 10.12.3 was conducted at Omega Point Laboratories on August 1992, and the test report was issued on (later). 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 10.20).

The hose stream test was conducted using the guidance provided in BTP CMEB 9.5.1 and in IEEE STD 634 (Reference 10.19) for penetration seals.

A6.1 Test Article

Scheme 6 consisted of a 24" wide x 4" deep ladder back tray with a horizontal tee section at mid-span. There were 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 travel 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 for 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 [illegible]termined that the fire damage was limited to those areas where [illegible].

The non-protected vertical supports had no [illegible] on the results of test and provided justification for the use of the 9[illegible] 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 (later). 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 10.20).

> NOTE: In accordance with the 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 were 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 flexiblanket 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 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 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 are 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 flexiblanket 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 flexiblanket 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 flexiblanket 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 Steam 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 flexiblanket on top of the 1/2" thick Thermo-Lag 330-. 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 a 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. 12340-935435 - 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 (later). 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 10.20).

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 sect ., 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 was 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. The total exposure dose to the samples was 2.12 x 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 (later). 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 (Ref. 10.22). 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 wupported 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 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 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 envoloped by the CPSES LOCA temperature qualifications.

10A 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 (later). 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 (Ref. 10.22). 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 4" tube steel mounted on the top of the box conduits.

A 1/3 by 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).

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 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 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 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 reached 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 (later). 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 (Ref. 10.22). 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 4" tube steel mounted on the top of the box conduits.

A 1/3 by 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 gradc 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 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 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.

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's 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.

A11 Omega Point Test No.12340 94367f - Scheme 11-1

The fire endurance test documented in Reference 10.12.15 was conducted at Omega Point Laboratories on November 17, 1992, and the test report was issued on (later). 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 (Ref. 10.22). 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.

A11.1 Test Article

Scheme 11-1 consisted of one 5 . drop, one 3" air drop, one 2" air drop, one 1" air drop and one 24" tray. e 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 by 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.

A11.2 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.

A11.3 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.

A11.4 Temperature Review

Reference 10.22 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 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.

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.

A11.5 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.

A11.6 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 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.

A11.7 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 envoloped by the CPSES LOCA temperature qualifications.

A12A Omega Point Test No.12340-94367i - Scheme 12-1

The fire endurance test documented in Reference 10.12.16 was conducted at Omega Point Laboratories on November 12, 1992, and the test report was issued on (later). 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 (Ref. 10.22). 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 10.14.1. 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 10.14.1 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 have 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 verified upon receipt per Reference 10.14.1.

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 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 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 t[illegible] hose stream test a visual inspection of the fire barrier was conducted. There [illegible] 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 10.12.17 was conducted at Omega Point Laboratories on November 11, 1992, and the test report was issued on (later). 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 (Ref. 10.22). 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 10.14.1. 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 (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.

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 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 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 incpection 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 upgrades 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>A13 Omega Point Test No.12340-943671 - Scheme 13-1</u>

The fire endurance test documented in Reference 10.12.18 was conducted at Omega Point Laboratories on November 12, 1992, and the test report was issued on (later). The fire endurance test, nose stream test and cable functionality (Insulation Resistance) tests were performed to the requirements of the NRC letter dated October 29,1992 (Ref. 10.22). 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.

A13.1 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.

A13.2 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. 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 10.14.1 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 verified upon receipt per Reference 10.14.1.

A13.3 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.

A13.4 Temperature Review

Reference 10.22 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 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.

A13.5 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.

A13.6 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 signs 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.

A13.7 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.

A14 Omega Point Test No.12340-94367m - Scheme 14-1

The fire endurance test documented in Reference 10.12.19 was conducted at Omega Point Laboratories on December 1, 1992, and the test report was issued on (later). 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 (Ref. 10.22). 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 by percent 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 10.14.1. The corner joints were reinforced with trowel grade Thewrmo-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 10.14.1 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.

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 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 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 reachwd 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 signs 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.

A14.7 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 envoloped by the CPS&S LOCA temperature qualifications.

<u>Spec. CPSES-M-2032 Rev. 0</u>
<u>Including Rev. 7 to DCA 95794</u>
<u>Reviewed to CPSES Thermo-Lag Tests</u>

Spec. Section	Subject	Covered by Scheme	Comments
1.0	Scope	N/A	
1.1	Applicability	N/A	
1.2	Definitions	N/A	
1.3	Changes and Notification	N/A	
1.4	Scope of Work	N/A	
1.5	Work Coordination	N/A	
2.0	Applicable Documents	N/A	
2.1	General	N/A	
2.2	Codes and Standards	N/A	
3.0	Material and Installation Requirements	N/A	
3.1	Thermo-Lag Fire Barrier Material	N/A	Title
3.1.1	Material Acquisition	All Schemes	Same materials were used in all tests except fiberglass gauze which is not used in raceway application.
3.1.2	Performance Goals	N/A	Vendor requirements not applicable to test data.
3.1.3	Design Performance Goals	N/A	Title
3.1.3.1	Environmental Requirements	N/A	
3.1.3.2	Water Sprays on No Burned Material	N/A	
3.1.3.3	Raceway Barrier Required at One Hour Rates	Schemes 1,3,4,9-1,10-1,10-2,11-1,12-1,12-2,13-1,14-1	These tests demonstrate that Thermo-Lag barriers can withstand a one hour fire using the E-119 time temperature curve.
3.1.3.4	Structural Steel Fireproofing	UL designs X-611,X-003	Tested to UL criteria, documented by Engineering Analysis in Appendix D of this Report.
3.1.3.5	Seismic Requirements	N/A	

Spec. Section	Subject	Covered by Scheme	Comments
3.1.3.6	Forty Year Life Requirement	SWRI Test No. 01-6763-302	Irradiation test.
3.1.3.7	Repair of Materials	Scheme 1,9-1,10-1,12-1,12-2,14-1	Upgrades were a repair.
3.1.3.8	Irradiation	SWRI Test No. 01-6763-002	
3.1.3.9	Chemical reaction to plant materials	N/A	
3.2	Installation of Thermo-Lag on Raceway	N/A	Title
3.2.1	General	N/A	Title
3.2.1.1	Identifies M2-1700 as Installation Schedule	N/A	
3.2.1.2	Identifies Nominal Thickness of Thermo-Lag Prefabricated and Preshaped Panels and Sections	All Schemes	This is the material criteria used in all tests
3.2.1.3	Interfacing Item	N/A	
3.2.1.4	Multiple Commodity Enclosure	N/A	To be documented by Engineering Evaluation per G.L. 86-10.
3.2.1.5	Release Forms For Work	N/A	
3.2.1.6	Foreign Materials in Raceways	N/A	
3.2.1.7	Thermo-Lag Prime 351	All schemes	Used on support only.
3.2.1.8	Cable (Air) Drop to be Protected	Scheme 11-1	Only requires air drops to be protected.
3.2.1.9	Electrical Release Requirement	N/A	
3.2.1.10	Do Not Bevel Edge	N/A	Edge not beveled in test.
3.2.1.11	Requires all seams and joints to be filled with trowel grade and required 25% excess to allow for shrinkage	All schemes	This is prebuttering the joints which was done on all joints in every Omega Point Test.
3.2.1.12	Protection of Small Protruding Items	All schemes	This protects bolts and nuts etc. done on all tests.
3.2.1.13	Use of Flexi-Blanket on Non-rigid Raceways	Scheme 11-1	Cover by Air Drop Test

Spec. Section	Subject	Covered by Scheme	Comments
3.2.1.14	Spacing of fasteners not in spec. covered by (M2-1701)	All schemes	All Omega Point test articles used M2-1701 for details except for upgrades which are covered by this spec.
3.2.1.15	Requirements to maintain minimum thickness	All schemes	All tests articles met minimum thickness requirements.
3.2.1.16	Cleanliness Verification on resumption of work	N/A	Cleanliness on electrical items.
3.2.1.17	Identification if Raceway (Tag No.)	N/A	
3.2.1.18	Allows use of caulking guns to apply trowel grade materials	N/A	Trowel grade not affected by using caulking guns used at Omega Point.
3.2.1.19	Cleanliness of pump to fill caulking gun	N/A	Cleanliness ensures trowel-grade material not contaminated.
3.2.1.20	Allow pump to provide towel grade, but required trowel grade to be worked by hand	N/A	
3.2.2	Mixing Requirements	All schemes	Same methods used on test articles.
3.2.3	Prefabricated Section	N/A	Title
3.2.3.1	Use of V-ribbed and Flat Panel	All schemes	Same method used in all tests.
3.2.3.2	Alternate configuration requires Engineering approval	N/A	Installations other than tested configuration will be documented and evaluated by a Fire Protection Engineer in accordance with G.L. 86-10.
3.2.3.3	Attaching prefabricated panels to concrete with Hiltis	N/A	Concrete flairouts are not attached directly to the raceways and only provide additional protection where needed in accordance with M2-1701.
3.2.3.4	Requires tight fit at all joints and prebuttering	All schemes	All tests use this method.
3.2.3.5	Provide instruction on installation on JB and other non raceway items	All schemes	Same method used where required in test articles.

Spec. Section	Subject	Covered by Scheme	Comments
3.2.3.6	Fastener spacing requirement	All schemes	Same method used on all test articles.
3.2.3.7	Provides instruction on how to deal with bends and prefabricated panels	All schemes	Same method used on all test articles.
3.2.3.8	Allows score and fold method for bends	All schemes	Same method used on all test articles.
3.2.3.9	Does not allow breaking or forcing of prefabricated panels	N/A	Does not allow usage.
3.2.3.10	Requires installing Thermo-Lag on the commodity first	All schemes	Same method used on all test articles.
3.2.4	Special Requirement for Cable Trays	N/A	Title
3.2.4.1	Requirement to fill corners on score and fold method with trowel grade	All schemes	Same method used on all test articles where score and fold was used.
3.2.4.2	Requirement for internal banding on horizontal tray 24 and larger	Schemes 1, 12-1,12-2,14-1	Provides support of top panel.
3.2.4.3	Provides design requirement of V-rib orientation on cable tray	Schemes 1, 3,12-1,12-2,13-1,14-1	
3.2.4.4	Allows flattening of V-ribs at corner joints	Schemes 1, 12-1,12-2,13-1,14-1	
3.2.4.5	Tee sections require a single panel where possible	Schemes 1, 12-2,14-1	Provides the strongest configuration at the widest spans.
3.2.4.6a	Backfit design requirements on longitudinal joints	Scheme 1,12-1,12-2,14-1	Upgrade of joint by reinforcing with trowel-grade and stress-skin.
3.2.4.6b	New work, butt joints on trays reinforced by stitching with tie-wire	Scheme 1,12-1,12-2	Reinforcing of butt joints.
3.2.4.6c	New work, butt joints on trays to be reinforced with stress-skin and trowel-grade	Scheme 1,12-1,12-2,13-1	
3.2.4.6d	Backfit design requirements for butt joints on trays using stress-skin and trowel-grade buildup. Tee will require stitching of butt joints	Scheme 12-1,12-2,13-1	

Spec. Section	Subject	Covered by Scheme	Comments
3.2.4.6e	Install tie-wire on tee section bottom panels to rungs to support panel	Scheme 14-1	
3.2.4.7	Where the upgrades can not be installed, Engineer shall be notified.	N/A	Engineering to resolve and provide design and documentation if untested configuration in accordance with G.L. 86-10.
3.2.4.8	Traceability of butts reinforced with tie wires	N/A	Documentation only
3.2.5	Special Requirements for Conduits, Fittings, and Joints	N/A	Title
3.2.5.1	Requirement to install Thermo-Lag section on conduit first	Schemes 9-1,10-1,10-2	
3.2.5.2	Requirement for 1/4" preshaped overlay on top of 1/2" preshaped sections	Scheme 9-1	
3.2.5.3	Installation requirements on coupling	Scheme 9-1	
3.2.5.4	Installation of Thermo-Lag radial conduit bends	Scheme 9-1	
3.2.5.5	Where spec. design requirements cannot be met, Engineering to resolve	N/A	Engineering to resolve and provide design basis. If untested configuration, provide documentation as required by G.L. 86-10.
3.2.5.6	Thermo-Lag preshaped installation requirement	Schemes 9-1,10-1,10-2	1/2" nominal preshaped section installed.
3.2.5.7	Thermo-Lag installation requirements for LBDs, JB, etc.	Scheme 9-1,10-1,10-2	
3.2.5.7a	Installation on LBDs	Schemes 9-1,10-1,10-2	Reinforced joint on the LBDs.
3.2.5.7b	Installation on JB pull boxes, etc	Schemes 10-1,10-2	Reinforced joints.
3.2.6	Application of Trowel-Grade Thermo-Lag	N/A	Title
3.2.6.1	Surface Preparation	All schemes	Method used in all tests.
3.2.6.2	Application Technique	All schemes	Method used in all tests.

Spec. Section	Subject	Covered by Scheme	Comments
3.2.6.3	Application Technique	All schemes	Method used in all tests.
3.2.6.4	Allowance requirement for trowel-grade shrinkage	All schemes	Method used in all tests.
3.2.7	Installation of Thermo-Lag 330-660 flexiblanket materials	Scheme 11-1	Flexiblanket use on Air Drops
3.2.8	Applying Topcoat	All schemes	Method used in all tests.
3.2.9	Safeguards Penetration Assemblies	None	Specific requirements for dealing with containment penetration on the safeguards side does not provide installation attribute guidance.
3.2.10	Raceway Supports Steel	Schemes 1,9-1,10-1,10-2,11-1,12-1,12-2,13-1,14-1	Provide requirement of 9" rule and guidance on priming supports. Same methods used in tests.
3.2.11	Fire Stops	All schemes	Fire stops tested in all tests, Thermo-Lag tray stop specifically in Scheme 4.
3.2.12	Repair Damaged Thermo-Lag Section	Schemes 1,9-1,10-1,10-2,12-1,12-2	Repairs are made using trowel-grade material. The test results show that trowel-grade material adheres to the prefabricated panels and it has no impact on the fire endurance if the material has a buildup of trowel-grade or a prefabricated section. Stress-skin is repaired in the same manner as used by TSI in their shop. As long as the stress-skin is mechanically bonded to itself (stapled or continuous) there is no impact.
3.2.13	Cable Replacement/Repair	Scheme 11-1,12-1,12-2,13-1,14-1	
3.2.14	Post Application	N/A	Work after installation is complete such as cleanup.

Spec. Section	Subject	Covered by Scheme	Comments
3.2.15	Deviations From Typical Details	N/A	Engineering to provide design basis and documentation as required by G.L. 86-10 if not a tested configuration.
3.3	Fire Proofing of Structural Steel	U.L. Design X-003	The engineering justification is provided in Appendix D
3.4	Radiant Energy Shield		Outside the scope of this document.
4.1	Quality Assurance Program Requirements	N/A	Title
4.1.1	General Requirements	N/A	General requirements for QA invoking Appendix A to the branch technical position and an augmented Quality Program.
4.1.2	Design Control and Procurement Document Control	N/A	General requirements.
4.1.3	Instructions Procedures and Drawings	N/A	General requirements.
4.1.4	Control of Purchased Material	N/A	General requirements.
4.1.5	Inspection, Test and Operations Status	N/A	General requirements.
4.1.6	Test and Test Control	All Schemes	Use on all tests at Omega Point.
4.1.7	Nonconforming Items	N/A	General requirements.
4.1.8	Corrective Actions	N/A	General requirements.
4.1.9	Records	N/A	General requirements.
4.1.10	Audits	N/A	General requirements.
4.2	General Verification for Thermo-Lag	N/A	Title.
4.2.1	Receipt and Storage Requirements	N/A	General requirements.

Spec. Section	Subject	Covered by Scheme	Comments
4.2.2	Receipt Inspection Instruction	All Schemes	This is the QA requirement used on all tests. Note: this section of the spec invokes 2323-MS-38H (the Unit 1 spec) which required that TSI perform Quality Control/Assurance in accordance with 10CFR50 Appendix B which by site requirements includes both thickness measurements and weight of prefabricated panels. Source inspection by TU at TSI is also required. On site receipt inspection only requires a visual inspection and a density check as discussed in Section 3.2.11.
4.2.3	Storage Inspection/Verification	All Schemes	These requirements used on all materials used in testing.
4.3	Thermo-Lag Installation Verification Requirements	N/A	Title
4.3.1	Cable and Raceway Application	All Schemes	The Quality Control requirements as applicable were used on the test article.
4.3.2	Structural Steel Application	N/A	Since the design review has not been completed this section was not reviewed.
4.4	Radiant Energy Shields (RES)	N/A	Not in the scope of this review.
4.5	RES Installation	N/A	Not in the scope of this review.
4.6	Thermo-Lag Fire Barrier/Fire Proofing Material Test Requirements	N/A	Title
4.6.1	General requirement	All Schemes	Met where applicable.
4.6.2	Fire Test	All Schemes	
4.6.3	Radiation Test	SWRI No. 01-6763-002	

Spec. Section	Subject	Covered by Scheme	Comments
4.6.4	Chemical Test	N/A	None reviewed.
4.6.5	Cable Ampacity Derating Test	N/A	See discussion in Section 6.0
4.6.6	Field Tests	N/A	Not used.
4.6.7	Seismic Qualifications	N/A	See Discussion in Section 4.5
4.7	RES	N/A	Out of scope of the review.
4.8	Document and Records	N/A	General requirements.
5.0	Preparation for Shipment	All Schemes	Same requirements used for all tests.
6.0	Supplemental Provision	N/A	General requirements.
App. A	Fireproofing	UL design X-003	Evaluation provide in Appendix D of this report.

APPENDIX C

THERMO-LAG INSTALLATION REVIEW MATRIX

COMMODITY	CONDUIT 3/4 CONTROL FILL 30%	CONDUIT 3/4 INSTRUMENT FILL 28%	CONDUIT 1 IN POWER FILL 36%	CONDUIT 1 IN CONTROL FILL 30-40%	CONDUIT 1 IN INSTRUMENT FILL 35%	CONDUIT 1 1/2 POWER FILL 9%
M2-1701 DETAIL NO.	4-1,2,3,4,5 4-6,7, 6-1,2	4-1,2,3,4,5 4-6,7, 6-1,2	4-1,2,3,4,5 4-6,7, 6-1,2	4-1,2,3,4,5 4-6,7, 6-1,2	4-1,2,3,4,5 4-6,7, 6-1,2	4-1,2,3,4,5 4-6,7, 6-1,2
TESTED CONFIGURATION	YES	YES	NO	NO	NO	NO
QUALIFYING TEST	SCHEME 9-1	SCHEME 9-1	SCHEME 9-1 BASED ON 3/4" COND.	SCHEME 9-1 BASED ON 3/4" CONDUIT.	SCHEME 9-1 BASED ON 3/4" CONDUIT.	SCHEME 9-1 BASED ON 3/4" CONDUIT
TEST ACCEPTABLE	YES USING OVERLAY	YES USING OVERLAY	YES	YES	YES	YES
ACCEPTED ENGINEERING EVALUATION	N/A	N/A	N/A	N/A	N/A	N/A
DERATING FACTOR METHOD	N/A	N/A	7.5 OR 20% BY CALCULATION/TEST UL. R6802	N/A	N/A	7.5 OR 20% BY CALCULATION/ TEST UL. R6802
TESTING CATEGORIES	N/A	N/A	1	1	1	1

KEY 1 = BOUNDED BY 3/4" - CONDUIT WITH OVERLAY

APPENDIX C

COMMODITY	CONDUIT 1 1/2 CONTROL FILL 29-46%	CONDUIT 1 1/2 INSTRUMENT FILL 26-35%	CONDUIT 2 IN POWER FILL 9-28%	CONDUIT 2 IN CONTROL FILL 13-32%	CONDUIT 2 IN INSTRUMENT FILL 4-54%	CONDUIT 3 IN POWER FILL 8-35%
M2-1701 DETAIL NO.	4-1,2,3,4,5 4-6,7, 6-1,2	4-1,2,3,4,5 4-6,7, 6-1,2	4-1,2,3,4,5 4-6,7, 6-1,2	4-1,2,3,4,5 4-6,7, 6-1,2	4-1,2,3,4,5 4-6,7, 6-1,2	4-1,2,3,4,5 4-6,7, 6-1,2
TESTED CONFIGURATION	NO	NO	NO	NO	NO	YES
QUALIFYING TEST	SCHEME 9-1 BASED ON 3/4 COND.	SCHEME 9-1 BASED ON 3/4 COND.	SCHEME 9-1 BASED ON 3/4 COND.	SCHEME 9-1 BASED ON 3/4 COND.	SCHEME 9-1 BASED ON 3/4 COND.	SCHEMES 9-1, 10-1,10-2
TEST ACCEPTABLE	YES	YES	YES	YES	YES	YES
ACCEPTED ENGINEERING EVALUATION	N/A	N/A	N/A	N/A	N/A	N/A
DERATING FACTOR METHOD	N/A	N/A	20% BY CALCULATION/TEST UL. R6802	N/A	N/A	20% BY CALCULATION/ TEST UL. R6802
TESTING CATEGORIES	1	1	1	1	1	N/A

APPENDIX C

COMMODITY	CONDUIT 3 IN CONTROL FILL 40%	CONDUIT 3 IN INSTRUMENT FILL 12-54%	CONDUIT 4 IN POWER FILL 9-40%	CONDUIT 4 IN CONTROL FILL 34-38%	CONDUIT 4 IN INSTRUMENT FILL 22-51%	CONDUIT 5 IN POWER FILL 13-26%
M2-1701 DETAIL NO.	4-1,2,3,4,5 4-6,7, 6-1,2	4-1,2,3,4,5 4-6,7, 6-1,2	4-1,2,3,4,5 4-6,7, 6-1,2	4-1,2,3,4,5 4-6,7, 6-1,2	4-1,2,3,4,5 4-6,7, 6-1,2	4-1,2,3,4,5 4-6,7, 6-1,2
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
TEST ACCEPTABLE	YES	YES	YES	YES	YES	YES
ACCEPTED ENGINEERING EVALUATION	N/A	N/A	N/A	N/A	N/A	N/A
DERATING FACTOR METHOD	N/A	N/A	20% BY CALCULATION/TEST UL. R6802	N/A	N/A	20% BY CALCULATION/ TEST UL. R6802
TESTING CATEGORIES	N/A	N/A	N/A	N/A	N/A	N/A

APPENDIX C

COMMODITY	CONDUIT 5 IN CONTROL FILL 33-41%	CONDUIT 5 IN INSTRUMENT FILL 32-51%	TRAY 12 X 4 POWER FILL 45-107%	TRAY 12 X 4 CONTROL FILL 22-30%	TRAY 12 X 4 INSTRUMENT FILL 3-48%	TRAY 18 x 4 POWER FILL 42-135%
M2-1701 DETAIL NO.	4-1,2,3,4,5 4-6,7, 6-1,2	4-1,2,3,4,5 4-6,7, 6-1,2	5-1,2,3,3.1	5-1,2,3,3.1	5-1,2,3,3.1	5-1,2,3,3.1
TESTED CONFIGURATION	YES	YES	YES	YES	YES	NO
QUALIFYING TEST	SCHEME 9-1	SCHEME 9-1	SCHEME 3,13-1	SCHEME 3,13-1	SCHEME 3,13-1	SCHEME 13-1, 12-2,11-1 BASED ON 12"/24" TRAY
TEST ACCEPTABLE	YES	YES	YES	YES	YES	YES
ACCEPTED ENGINEERING EVALUATION	N/A	N/A	N/A	N/A	N/A	N/A
DERATING FACTOR METHOD	N/A	N/A	40% BY CALCULATION/ TESTING ITL.82-335-F-1	N/A	N/A	40% BY CALCULATION/ TESTING ITL.82-335-F-1
TESTING CATEGORIES	N/A	N/A	N/A	N/A	N/A	N/A

APPENDIX C

COMMODITY	TRAY 18 X 4 CONTROL FILL 39%	TRAY 18 X 4 INSTRUMENT FILL 5-65%	TRAY 18 X 6 POWER FILL 9%	TRAY 18 X 6 CONTROL FILL 9%	TRAY 24 X 4 POWER FILL 11-52%	TRAY 24 X 4 CONTROL FILL 11-53%
M2-1701 DETAIL NO.	5-1,2,3,3.1	5-1,2,3,3.1	5-1,2,3,3.1	5-1,2,3,3.1	5-1,2,3,3.1	5-1,2,3,3.1
TESTED CONFIGURATION	NO	NO	NO	NO	YES	YES
QUALIFYING TEST	SCHEME 13-1, 12-2,11-1 BASED ON 12"/24" TRAY	SCHEME 13-1, 12-2,11-1 BASED ON 12"/24" TRAY	SCHEME 13-1, 12-2,11-1 BASED ON 12"/24" TRAY	SCHEME 13-1,12-2,11-1 BASED ON 12"/24" TRAY	YES SCHEME 12-2,11-1	SCHEME 12-2, 11-1
TEST ACCEPTABLE	YES	YES	YES	YES	YES	YES
ACCEPTED ENGINEERING EVALUATION	N/A	N/A	N/A	N/A		
DERATING FACTOR METHOD	N/A	N/A	40% BY CALCULATION/ TESTING ITL 82-335-F-1	N/A	40% BY CALCULATION/ TESTING ITL 82-335-F-1	N/A
TESTING CATEGORIES	N/A	N/A	N/A	N/A	N/A	N/A

COMMODITY	TRAY 24 X 4 INSTRUMENT FILL 1-43%	TRAY 24 X 6 CONTROL FILL 15-55%	TRAY 30 X 4 POWER FILL 20-120%	TRAY 30 X 6 CONTROL FILL 21-44%	TRAY 30 X 6 INSTRUMENT FILL 21%	TRAY 36 X 6 CONTROL FILL 6%
M2-1701 DETAIL NO.	5-1,2,3,3.1	5-1,2,3,3.1	5-1,2,3,3.1	5-1,2,3,3.1	5-1,2,3,3.1	5-1,2,3,3.1
TESTED CONFIGURATION	YES	NO	YES	NO	NO	NO
QUALIFYING TEST	SCHEME 12-2,11-1	SCHEME 12-2,11-1 BASED ON 24"X 4" TRAY	SCHEME 12-1,14-1	SCHEME 12-1,14-1 BASED ON 30"X 4" TRAY	SCHEME 12-1,14-1 BASED ON 30"X 4" TRAY	SCHEME 1 BASED ON 36"X 4" TRAY CONFIRMED BY SCHEME 14-1
TEST ACCEPTABLE	YES	YES	YES	YES	YES	YES
ACCEPTED ENGINEERING EVALUATION	N/A	N/A	N/A	N/A	N/A	N/A
DERATING FACTOR METHOD	N/A	N/A	40% BY CALCULATION/ TESTING ITL 82-335-F-1	N/A	40% BY CALCULATION/ TESTING ITL 82-335-F-1	N/A
TESTING CATEGORIES	N/A	N/A	N/A	N/A	N/A	N/A

COMMODITY	TRAY 36 X 6 INSTRUMENT FILL .6%	AIR DROPS VARIOUS	PULL/JUNCTION BOXES VARIOUS	TWO TRAYS IN COMMON ENCLOSURE	TWO CONDUITS IN COMMON ENCLOSURE	ELEC BOXES IN COMMON ENCLOSURE
M2-1701 DETAIL NO.	5-1,2,3,3.1	3-1,1.1,1.2,2,2.1 3-3,4,5	2-2,3	N/A	N/A	N/A
TESTED CONFIGURATION	NO	YES	YES	NO	NO	NO
QUALIFYING TEST	SCHEME 1 BASED ON 36"X 4" TRAY CONFIRMED BY SCHEME 14-1	SCHEME 11-1	SCHEME 10-1,10-2	NO	NO	NO
TEST ACCEPTABLE	YES	YES	YES	N/A	N/A	N/A
ACCEPTED ENGINEERING EVALUATION	N/A	N/A	N/A	TEST DATA EVALUATED FOR CONFIGURATION ACCEPTABILITY	TEST DATA EVALUATED FOR CONFIGURATION ACCEPTABILITY	TEST DATA EVALUATED FOR CONFIGURATION ACCEPTABILITY
DERATING FACTOR METHOD	N/A	VARIOUS BY CALCULATION 16345-EE(B)-140	VARIOUS JUSTIFICATION IN DCA ENGINEERING BASIS	VARIOUS JUSTIFICATION IN DCA ENGINEERING BASIS	VARIOUS JUSTIFICATION IN DCA ENGINEERING BASIS	VARIOUS JUSTIFICATION IN DCA ENGINEERING BASIS
TESTING CATEGORIES	N/A	N/A	N/A	N/A	N/A	N/A

COMMODITY	STRUCTURAL STEEL VARIOUS	HATCH COVERS
M2-1701 DETAIL NO.	N/A	N/A
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	USED ON UNIT 1 ONLY, EVALUATIONS PROVIDED BY CALC REF. 10.16.6
DERATING FACTOR METHOD	N/A	N/A
TESTING CATEGORIES	N/A	N/A

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 (ref. 10.3.2). 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 and TSI Technical Note 99777 (ref. 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 (ref. 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 for 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 using the design outlined in U.L design X-003. 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 and 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 1/2" 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 the 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 provide 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.

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 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 1/2" 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 has shown the stress skin greatly enhances the performance of the Thermo-Lag in a fire.

Specification CPES-M-2032 requires that protruding heat path items be protected a minimum for 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 (ref. 10.21.3) for a unistrut assembly and I.T.L. Report No. 89-07-5334 (ref. 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.