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FINAL REPORT

of the

SPECIAL REVIEW TEAM FOR THE REVIEW OF THERMO-LAG FIRE BARRIER PERFORMANCE

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U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation

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EXECUTIVE SUMMARY

Many U.S. Nuclear Regulatory Commission (NRC) licensees use the Thermo-Lag 330-1 (Thermo-Lag) fire barrier system to meet the NRC's requirements for the protection of safe shutdown equipment. In response to industry operating experience and allegations regarding the use of Thermo-Lag, the Director of the Office of Nuclear Reactor Regulation (NRR) established a special review team to determine whether or not the operating experience and allegations had generic applicability and to assess the safety significance of any identified concerns. The purpose of this report is to document the results of the review completed by the special review team.

The special review team reviewed the NRC's requirements and guidance regarding fire barriers; reviewed docket information for six operating reactors and information provided voluntarily by three licensees; reviewed vendor supplied documentation and fire endurance and ampacity derating test reports; and visited five operating reactors.

Findings

Based on its review, the special review team concluded that:

- The fire resistance ratings and the ampacity derating factors for the Thermo-Lag 330-1 fire barrier system are indeterminate.
- Some licensees have not adequately reviewed and evaluated the fire endurance test results and the ampacity derating test results used a the licensing basis for their Thermo-Lag barriers to determine the validity of the tests and the applicability of the test results to their plant designs.
- Some licensees have not adequately reviewed the Thermo-Lag fire barriers installed in their plants to ensure that they meet NRC requirements and guidance, such as that provided in Generic Letter 86 10, "Implementation of Fire Protection Requirements," April 24, 1986.
- Some licensees used inadequate or incomplete installation procedures during the construction of their Thermo-Lag barriers.

Safety Significance

Although the special review team considers the fire resistance ratings of the Thermo-Lag fire barriers indeterminate, there is evidence that the barriers will provide some level of fire protection. In addition, most fire areas have low fuel loads, controlled ignition sources, and are equipped with other passive and active fire protection features to alert and assist plant operators in the event of a fire. Therefore, the review team considers the relative safety significance of the fire barrier concerns to be low.

Ampacity derating calculations based on nonconservative derating factors could result in the installation of undersized cables and raceway overfilling. This could cause higher than

design operating temperatures within the raceways thereby reducing the design life of the cables. Design changes may be required to extend cable life and to restore safety margins. The special review team did not identify any immediate public health and safety concerns regarding the ampacity derating issues, but recommends that the licensees and the NRC staff assess the safety significance of any plant-specific ampacity derating issues that are identified during follow up reviews of the generic concerns.

Recommendations

Based on its findings regarding the use of Thermo-Lag fire barriers by the commercial nuclear power industry and the relative safety significance of the findings, the special review team recommended to the Director, NRR, that the NRC:

- Advise industry of the staff's concerns regarding Thermo-Lag fire barriers through the Nuclear Utilities Management and Resources Council (NUMARC),
- Provide the industry with the results of the team's plant site visits and the specific concerns and technical issues regarding Thermo-Lag that were identified by the review team,
- Issue a generic letter that discusses the concerns and requires the licensees to provide information needed by the staff to verify compliance with the NRC's requirements, and
- Review the licensees' corrective action plans for resolving any plant-specific Thermo-Lag fire barrier design, evaluation, and installation issues.

Review Status

The special review team met with NUMARC on February 12, 1992, to discuss the results of its review. The team discussed the technical and safety concerns it identified while performing its special review assignment. The team provided a draft generic letter to attendees of the meeting. The draft generic letter was placed in the NRC public document room with the team's meeting minutes.[1]

The review team's trip reports were placed in the NRC public document room on March 18, 1992.[2] This report documents additional technical issues and concerns identified by the review team while performing its review assignment

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[1] Memorandum from F.J. Miraglia, NRR, to T.E. Murley, NRR, "Minutes - Meeting Between the Special Review Team for the Review of Thermo-Lag Fire Barrier Performance and NUMARC," February 13, 1992.

[2] Letter from A. Thadani, NRR, to A. Marion, NUMARC, March 18, 1992.

The special review team has satisfied its charter and has transferred the remaining activities to the NRR line organization. These activities include, for example, finalizing the generic letter proposed by the special review team, working with NUMARC and industry to resolve generic technical and safety issues, and reviewing corrective action plans for resolving any plant-specific issues.

BACKGROUND

The Thermo-Lag 330-1 (Thermo-Lag) fire barrier system is available from its manufacturer and supplier, Thermal Science, Incorporated (TSI, the vendor), St. Louis, Missouri, with fire resistance ratings of 1 hour and 3 hours. The NRC licensees use Thermo-Lag fire barriers to satisfy the NRC's requirements and guidance for protecting safe shutdown equipment from fire and to achieve physical independence of electric systems.

Establishment of Special Review Team

Gulf States Utilities (GSU), the licensee for River Bend Station (RBS), informed the NRC of Thermo-Lag fire barrier installation problems[3] and of the failure of an "as-designed" Thermo-Lag fire barrier during a 3-hour fire endurance test conducted by the Southwest Research Institute (SwRI).[4] Later, GSU reported additional discrepancies in the installation of Thermo-Lag fire barriers at RBS.[5] In addition, in February 1991, the NRC received allegations that Thermo-Lag fire barriers may not provide an adequate fire barrier. During May 1991, the staff visited RBS to review with GSU the circumstances surrounding the failed fire test and the installation discrepancies. The staff found that the results of the SwRI fire endurance test raised concerns regarding the ability of Thermo-Lag to provide a fire rated barrier.

In response to the RBS operating experience and the allegations, T. E. Murley, Director, NRR, directed that a review of the safety significance and generic applicability of the technical issues regarding the use of Thermo-Lag be conducted. He established a special review team in June 1991. The purpose of this report is to document the results of the team's review.

The vendor provided to the review team a list of commercial nuclear power plants that use Thermo-Lag fire barriers.[6] These plants are identified in Attachment 1. During its review, the team found that the amount of Thermo-Lag installed by these licensees varies widely. For example, a Northern States Power engineer informed the special review team that only

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[3] GSU Licensee Event Report (LER) 89-009, "Inadequate Thermo-Lag Coverings as Fire Barrier Per T.S. 7.7.7.a," April 17, 1989.

[4] Letters from J.E. Booker, GSU, to U.S. NRC, December 20, 1989 and January 9, 1990.

[5] GSU LER 90-003, "Inadequate Thermo-Lag Fire Barrier Envelopes Surrounding Safe Shutdown Circuits Per T.S. 3/4.7.7," March 8, 1990 and Rev. 1, July 12, 1990, Rev. 2, February 4, 1991, and Rev. 3, June 28, 1991; and GSU LER 91-008, "Lack of Fire Wrap - Inadequate Fire Barrier Caused by Inconsistency in Design Bases Documentation," May 15, 1991.

[6] Appendix VII to letter from R. Feldman, TSI, to F.J. Miraglia, NRR, October 5, 1991.

two conduits are protected with Thermo-Lag fire barriers at Monticello. Conversely, Texas Utilities Electric Company (TU) has installed more than 20,000 square feet of Thermo-Lag in Comanche Peak Steam Electric Station (CPSES), Unit 1.

NRC Licensing Reviews of Thermo-Lag Fire Barriers

While conducting its special review assignment, the team identified 49 test reports that document the results of fire endurance tests conducted to determine or evaluate the fire resistance of Thermo-Lag fire barriers installed on electrical raceways. These tests, which were performed by various sponsors between February 1981, and December 1990, are identified in Attachment 2. Of these 49 fire tests, the team found that the NRC staff reviewed four fire endurance test reports for Thermo-Lag fire barriers during plant licensing activities. These licensing reviews are discussed below.

The first fire endurance test of a Thermo-Lag fire barrier that the staff reviewed was a 1-hour fire endurance test conducted by SwRI for CPSES in September 1981.[7] Based on its evaluation of the SwRI test report, the staff concluded that the TSI material/system could be used to meet the requirements of Appendix R to 10 CFR Part 50 and was, therefore, acceptable for use at CPSES.[8]

The second and third tests reviewed by the staff were submitted by Pennsylvania Power & Light Company (PP&L) in 1982. After the staff accepted the use of Thermo-Lag barriers at CPSES, PP&L informed the staff of its intention to use the CPSES test as its technical basis for installing Thermo-Lag fire barriers at Susquehanna Steam Electric Station (SSES), Unit 1.[9] However, PP&L changed the barrier design that the staff accepted for CPSES by not using fiberglass armoring. The staff found the use of the Thermo-Lag barrier acceptable, but did not accept the design change and requested that PP&L submit test data to demonstrate that the modified Thermo-Lag fire barrier design would provide a 1-hour fire rating. Later, PP&L submitted a TSI test report to support the design change for staff review.[10] The fire test was described in the report as a "simulated" ASTM E119 test. The staff found that the simulated test differed from the ASTM E119 test method in several areas, such as the accuracy of the furnace temperature control and the type and the number of thermocouples used for measuring test specimen temperatures. The staff also found that the

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[7] SwRI Report 03-6491, "Fire Qualification Test of a Protective Envelope System," October 27, 1981.

[8] Letter from R.L. Tedesco, NRR, to R.J. Gray, Texas Utilities Generating Company, December 1, 1981.

[9] Letter from N.W. Curtis, PP&L, to A. Schwencer, NRR, February 9, 1982.

[10] Letter from N.W. Curtis, PP&L, to A. Schwencer, NRR, May, 12, 1982, and TSI Technical Note 8232-1, "Engineering Test Report - One Hour ASTM E-119 Fire Simulation Facility Fire Test Followed by a Short Term Water Hose Stream Impact Test on a Class 1E Cable Tray and Air Drop Assembly," June 1981.

application procedure used for the test specimen was not clearly specified and that the test results did not provide adequate assurance that the proposed cable wrap was tested in the as-installed configuration. Finally, the staff was concerned that adequate quality assurance procedures were not followed in the preparation of the test assembly, during the conduct of the test, and during the preparation of the test report. On these bases, the staff concluded that the test was not performed in accordance with American Society for Testing and Materials (ASTM) Standard E119, "Standard for Fire Resistance of Building Materials," and, therefore, was not acceptable.[11] Later, PP&L submitted a report for a 1-hour fire endurance test conducted at SwRI for PP&L to justify the proposed design change.[12] This SwRI test showed that conduits protected by the proposed method provided a 1-hour fire rating. However, the cable tray and air drop barriers failed to meet the temperature rise acceptance criteria. The staff accepted this test for conduit fire barriers at SSES, but not for cable trays or air drops.[13]

The fourth report involving Thermo-Lag fire barriers that was reviewed by the staff was a 3-hour fire endurance test submitted by Washington Public Power Supply System (WPPSS) for Washington Nuclear Project, Unit 2 (WNP2).[14] The staff found this test, which was conducted by TSI at its test facility, an acceptable basis for installing Thermo-Lag fire barriers at WNP2.[15]

The review team found that the three fire test reports that were accepted by the staff documented tests of specimens assembled using the vendor's direct spray application method. However, with the exception of SSES, Unit 1 and limited applications at WNP2, the review team did not find any field installations that were constructed using the direct spray method. Most of the Thermo-Lag fire barriers installed in the field are constructed of prefabricated Thermo-Lag 330-1 panels and preshaped conduit sections that have been cut to size and shape and fastened together with either stainless steel wires or bands. The joints where the individual panel sections meet are sealed with trowel grade Thermo-Lag material. Most of the 49 test reports identified by the review team document the results of tests involving these types of installations. However, these reports do not appear to have been reviewed by the staff.

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[11] U.S. NRC, "Safety Evaluation Report Related to the Operation of Susquehanna Steam Electric Station, Units 1 and 2," NUREG-0776, Supplement 3, July 1982, pg 9-1.

[12] Letter from N.W. Curtis, PP&L, to A. Schwencer, NRR, August 25, 1982 and SwRI Report 01-7163, "Qualification Fire Test of a Protective Envelope System," August 1982.

[13] U.S. NRC, "Safety Evaluation Report Related to the Operation of Susquehanna Steam Electric Station, Units 1 and 2," NUREG-0776, Supplement 4, November 1982, pg 9-2.

[14] ITL Report 82-5-355B, "Three-Hour Fire Endurance Tests on Thermo-Lag 330-1 Subliming Coating Envelope System for WPPSS Nuclear Projects," July 1982.

[15] U.S. NRC, "Safety Evaluation Report Related to the Operation of WPPSS Nuclear Project No. 2," NUREG-0892, Supplement 3, May 1983, pg 9-3.

Previously Identified Fire Barrier Concerns

While conducting its review, the special review team found that both the NRC and industry have addressed prior concerns regarding fire barrier testing and installation. Examples of these concerns are discussed below.

In SECY 83-269, "Fire Protection Rule for Future Plants," July 5, 1983, the staff informed the Commission of generic issues arising from its review of almost 600 requests for exemptions from the requirements of Appendix R to 10 CFR Part 50. These issues included problems encountered with the testing and installation of fire rated cable wraps. The staff reported that although the materials performed adequately in laboratory test furnaces, field installations introduced uncertainties due to variations in the training and abilities of installation personnel. The staff considered these uncertainties to be of marginal safety significance. The staff also reported that some facilities had installed fire barriers without a basis for their fire rating such as an Underwriters Laboratories, Incorporated (UL) listing or testing conducted by a nationally recognized testing laboratory for the configurations installed in the plant. The NRC informed the industry of these problems in Office of Inspection and Enforcement (OIE) Information Notice (IN) 84-09, "Lessons Learned From NRC Inspections of Fire Protection Safe Shutdown Systems (10 CFR 50, Appendix R)," February 13, 1984. The IN stated: "At some of the facilities inspected, fire barriers were installed without basis for their fire rating (such as UL listing or testing conducted by a nationally recognized testing laboratory for the configurations installed in the plant). Fire barriers installed to meet the requirements of Section III.G.2 of Appendix R must have such a rating."

During a 1986 Appendix R inspection of WNP2,[16] the staff found that the supports for electrical raceways protected with Thermo-Lag were not protected in accordance with the tested configuration. The licensee resolved this finding by conducting additional fire endurance testing to verify that the installed support fire protection was adequate. Later, during a 1987 WNP2 inspection,[17] the staff found that although redundant safe shutdown circuits were protected with Thermo-Lag material, "the protection provided did not qualify as a 1 or 3-hour fire barrier because the licensee applied the material improperly and in untested configurations. Preliminary results of tests conducted by the licensee indicate that the 1-hour application may provide a 32 to 50-minute fire rating. The 3-hour application may provide 150 to 160-minute fire rating." The licensee resolved this issue by removing and replacing some of the fire barriers and by qualifying others by fire endurance tests conducted at TSI. Finally, in March 1991, as part of a scheduled annual inspection, the licensee for WNP2 found two deficiencies with a Thermo-Lag fire barrier protecting a safety-related cable tray.[18] The licensee attributed the defects--inadequate Thermo-Lag thickness on the side rail

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[16] Inspection Report 50-397/86-05, April 2, 1986.

[17] Inspection Report 50-397/87-02, April 17, 1987.

[18] WPPSS LER 91-004, "Inadequate Fire Protection (Thermo-Lag) of Division II Safe Shutdown Cables Due to Inadequate Installation and Inspection," April 28, 1991.

of the cable tray and an incomplete transition between a prefabricated Thermo-Lag panel and a Thermo-Lag spray application--to installation errors and inadequate inspection practices.

In another example of a plant specific problem, CPSES originally built its Thermo-Lag fire barriers using panels that had been site-fabricated by the CPSES constructor. Subsequently, the licensee identified deficiencies in the thicknesses of these panels during inspections of the installed fire barriers.[19] The licensee removed about 12,000 square feet of the site-fabricated Thermo-Lag panels and replaced them with panels manufactured by the vendor.

Although not directly related to the Thermo-Lag fire barrier issues, the special review team noted that the NRC recently addressed similar concerns regarding penetration seal design, qualification testing, and documentation. The team found that the operating experience discussed in the information notices issued regarding these concerns[20] provided insights into the implementation of the NRC's requirements and guidance for the protection of safe shutdown capability and qualification fire testing.

Ampacity Derating

While conducting its review assignment, the special review team reviewed nine test reports that document the results of tests conducted to determine the ampacity derating factors for various Thermo-Lag fire barriers. These test reports are identified in Attachment 3.

The review team found that the vendor has documented a wide range of ampacity derating factors that were determined by testing. For example, the vendor provided test reports to licensees that document ampacity derating factors for cable trays that range from 7 percent to 28 percent for 1-hour barriers and from 16 percent to 31 percent for 3-hour barriers. By Mailgram of October 2, 1986, the vendor informed the NRC and its customers of the results of ampacity derating tests performed at UL. The ampacity derating factors derived from these UL tests[21] exceeded those previously reported by the vendor (for example, ITL Reports 82-355-C, 82-355-F, and 82-355-F1). The review team also found that an ampacity derating test conducted at SwRI yielded ampacity derating factor of 37 percent for a 1-hour barrier.

The special review team also found that the staff and the licensees have previously addressed concerns regarding ampacity derating. For example, in 1986, NRC inspected the Minnesota

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[19] Letter from W.J. Cahill, TU Electric, to U.S. NRC, October 12, 1989.

[20] IN 88-04, "Inadequate Qualification and Documentation of Fire Barrier Penetration Seals," February 5, 1988; IN 88-04, Supplement 1, "Inadequate Qualification and Documentation of Fire Barrier Penetration Seals," August 9, 1988; and IN 88-56, "Potential Problems with Silicone Foam Fire Barrier Penetration Seals," August 5, 1988.

[21] UL Project 86NK23826, File R6802, "Special Services Investigation of Ampacity Deratings for Power Cables in Steel Conduits and in Open Ladder Cable Trays with Field-Applied Enclosures," January 27, 1987.

Mining and Manufacturing Company (3M), Saint Paul, Minnesota,[22] to review the circumstances surrounding concerns identified during an NRC inspection at Fort Calhoun Station.[23] The NRC concerns were: (1) Omaha Public Power District (OPPD), the licensee for Fort Calhoun Station, did not verify the validity of the ampacity derating values supplied to them by 3M, and (2) OPPD or other NRC licensees could misinterpret the derating values because of the way they were presented by 3M. After the vendor inspection, 3M informed its nuclear customers that its ampacity derating information should be used only to assess the general impact of 3M's fire protective envelope systems with respect to ampacity derating and that ampacity critical situations must be evaluated by performing actual tests.

[22] Inspection Report 99901038/85-01, March 11, 1986.

[23] Inspection Report 50-285/85-22, December 13, 1985.

NRC REQUIREMENTS AND GUIDANCE

While conducting its review, the special review team reviewed the NRC's requirements and guidance regarding fire barriers and ampacity derating, and the documents that provide the bases for the requirements and guidance. The following discussions provide an overview of the current requirements and guidance regarding fire barriers. They do not contain any new requirements or staff positions.

Fire Protection

Federal Register, Volume 45, Number 105, "Fire Protection Program for Nuclear Power Plants Operating Prior to January 1, 1979," May 29, 1980, and Generic Letter (GL) 86-10, "Implementation of Fire Protection Requirements," April 24, 1986, contain detailed discussions of the NRC's fire protection requirements and guidance. (The NRC's requirements and guidelines for fire barriers are contained in a variety of NRC documents. The extent to which these requirements and guidelines apply to a specific plant depends on plant age, licensee commitments, the NRC safety evaluation reports and supplements for the plant, and the fire protection license conditions.)

General Design Criterion (GDC) 3, "Fire protection," of Appendix A, "General Design Criteria for Nuclear Power Plants," to Title 10 of the *U.S. Code of Federal Regulations*, Part 50 (10 CFR Part 50) states that structures, systems, and components important to safety shall be designed and located to minimize, consistent with other safety requirements, the probability and effect of fires and explosions. The licensees rely on their fire protection programs to satisfy GDC 3. Following a major fire at the Browns Ferry Nuclear Station on March 22, 1975, the NRC evaluated the need for improving the fire protection programs at all nuclear power plants.[24] Following this evaluation, the NRC issued guidance for implementing GDC 3 in Branch Technical Position (BTP) Auxiliary and Power Conversion Systems Branch (APCSB) 9.5-1, "Guidelines for Fire Protection for Nuclear Power Plants." This guidance did not apply to plants docketed at that time. The NRC later provided guidance for operating reactors in Appendix A to BTP APCSB 9.5-1, "Guidelines for Fire Protection for Nuclear Power Plants Docketed Prior to July 1976." These BTPs include guidance for fire barriers and protection of electric cable constructions.

By early 1980, most operating plants had implemented most of the guidelines in BTP APCSB 9.5-1 or Appendix A to BTP APCSB 9.5-1. However, several licensees refused to adopt staff guidance related to several specific generic issues. On May 29, 1980, the NRC published a proposed rule for nuclear power plant fire protection, Section 50.48, "Fire protection," (10 CFR 50.48) and Appendix R to 10 CFR Part 50, "Fire Protection Program for Nuclear Power Facilities Operating Prior to January 1, 1979," which proposed minimum

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[24] U.S. NRC, "Recommendations Related to Browns Ferry Fire," NUREG-0500, February 1976

requirements for the unresolved issues.[25] On February 17, 1981, 10 CFR 50.48 and Appendix R to 10 CFR Part 50 became effective.[26]

Section 50.48 requires that each nuclear power plant licensed to operate before January 1, 1979, meet the requirements of Section III.G, "Fire protection of safe shutdown capability," of Appendix R to 10 CFR Part 50 even if the NRC had previously approved alternative fire protection features in these areas. In a separate action the Commission required that all plants to receive their operating license after January 1, 1979, also satisfy specific requirements of Appendix R to 10 CFR Part 50, including Section III.G.

The objective of Section III.G of Appendix R is to ensure that at least one means of achieving and maintaining safe shutdown conditions will remain available during and after any postulated fire in the plant. Licensees can satisfy Section III.G by separating one safe shutdown train from its redundant train with fire-rated barriers. The fire resistance rating required of the barrier, either 1 hour or 3 hours, depends on the other fire protection features provided in the fire area. Many NRC licensees use raceway protective envelopes, such as Thermo-Lag fire barriers, to satisfy the separation requirements of Section III.G of Appendix R to 10 CFR Part 50.

The NRC has provided guidance for implementing its fire protection requirements through regulatory guides, standard review plans, branch technical positions, and generic letters. BTP Chemical Engineering Branch (CMEB) 9.5-1, "Guidelines for Fire Protection For Nuclear Power Plants," July 1981, included the acceptance criteria identified in a number of these documents, including Appendix R to 10 CFR Part 50. BTP CMEB 9.5-1 states: "This document supplements Regulatory Guide 1.75 in determining the fire protection for redundant cable systems."

Between March and May of 1984, the staff held a series of regional workshops with the applicants and licensees on the implementation of the NRC's fire protection requirements. At those workshops, the staff distributed some 59 pages of NRC staff responses to industry questions, including those regarding fire barriers, that were compiled by the Nuclear Utility Fire Protection Group[27] (NUFPG) following a February 1984, industry seminar at which over 90 percent of the nuclear utilities were represented.

Following a Commission meeting on the status of Appendix R implementation of May 30, 1984, the Executive Director for Operations (EDO) directed NRR to establish a fire protection policy steering committee (FPPSC) to review fire protection issues to assure

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[25] U. S. NRC, "Fire Protection Program for Nuclear Power Plants Operating Prior to January 1, 1979," *Federal Register*, Vol. 45, No. 105, May 29, 1980, pp. 36082-36090.

[26] U. S. NRC, "Fire Protection Program for Operating Nuclear Power Plants," *Federal Register*, Vol. 45, No. 225, November 19, 1980, pp. 76602-76616.

[27] A group formed in 1980 to participate in fire protection matters and composed of 27 nuclear utilities.

consistent levels of fire protection safety at all plants.[28] One of the issues reviewed by the FPPSC was the adequacy of the NRC guidance to the industry. In its final report,[29] the FPPSC concluded that the NRC had provided adequate technical guidance to the industry, but that there were areas where confusion could arise. The FPPSC concluded that new guidance was not needed and recommended that the existing guidance be brought together in one generic letter and that the Standard Review Plan, technical specifications, and licenses be made consistent. Following comment by the program offices and the regions, the EDO directed in December 1984, that the FPPSC report be issued to the utilities and to the public for comment.[30] Comments were received from individual utilities, NUFPG, and consultants. The FPPSC updated its recommendations to reflect resolution of the comments,[31] the recommendations were reviewed and approved by the Committee for the Review of Generic Requirements (CRGR),[32] and the EDO recommended to the Commission that the generic letter proposed by the FPPSC be issued.[33] The Commission accepted the EDO's recommendation on March 7, 1986.[34] The generic letter proposed by the FPPSC was issued as Generic Letter 86-10, "Implementation of Fire Protection Requirements," on April 24, 1986. The detailed guidance provided to the utilities by the staff during the regional workshops was appended to GL 86-10.

The special review team found the outcome of this review of the NRC's fire protection requirements and guidance significant to its own review effort for a number of reasons. First, the staff had completed a thorough review of the NRC's fire protection requirements and guidance with Commission involvement and approval; second, the review concluded that the NRC had provided adequate technical guidance to the industry; third, the staff uniformly disseminated its interpretations of the requirements and guidance to the industry; fourth, the

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[28] Memorandum from W.J. Dircks, EDO, to H.R. Denton, NRR, *et al*, September 13, 1984.

[29] Memorandum from Fire Protection Policy Steering Committee to W.J. Dircks, EDO, October 26, 1984.

[30] GL 85-01, "Fire Protection Steering Committee Report," January 9, 1985; and U.S. NRC, "Availability of NRC Fire Protection Policy Steering Committee Report for Comment," *Federal Register*, Vol. 50, No. 10, January 15, 1985, pp. 2056-2057.

[31] Memorandum from R.H. Vollmer, FPPSC, to H.R. Denton, NRR, May 3, 1985.

[32] August 20, 1985 memorandum from V. Stello to W.J. Dircks forwarding Minutes of CRGR Meeting 78 of July 8, 1985 and August 21, 1985 memorandum from V. Stello to W.J. Dircks forwarding Minutes of CRGR Meeting 79 of July 24, 1985.

[33] Memorandum from W.J. Dircks to the Commissioners (SECY-85-306), "Staff Recommendations Regarding the Implementation of Appendix R to 10 CFR 50," September 15, 1985.

[34] Memorandum from S.J. Chilk, Secretary, to V. Stello, Jr., Acting EDO, March 7, 1986.

staff solicited comments from the public and the industry; and lastly, the staff received only one editorial comment on its acceptance criteria for fire barriers,[35] which it incorporated into GL 86-10.[36]

Fire Barrier Qualification

The NRC provided its technical basis for requiring 3-hour fire barriers in the *Federal Register* notice that issued 10 CFR 50.48 and Appendix R to 10 CFR Part 50. The NRC stated that although nuclear power plants have low fire loads, the potential consequences of fire are serious. Therefore, 3 hours was selected as the minimum fire resistance rating for fire barriers used to separate redundant safe shutdown systems. Where plant conditions preclude the installation of a 3-hour fire barrier, the NRC considers a 1-hour fire barrier with automatic fire detection and suppression systems to be equivalent to a 3-hour fire barrier. Therefore, fire barriers relied upon to protect shutdown systems need to have a fire resistance rating of either 1 hour or 3 hours. The NRC also noted that fire barriers are rated for fire resistance by being exposed to the standard test fire defined by ASTM E119, "Standard for Fire Resistance of Building Materials." BTP APCSB 9.5-1 and Appendix A to BTP APCSB 9.5-1 reference NFPA Standard 251[37] and define fire rating as: "the endurance period of a fire barrier or structure; it defines the period of resistance to a standard fire exposure before the first critical point in behavior is observed."

In GL 86-10, the NRC provided guidance on its fire barrier acceptance criteria, the documentation needed to verify the fire barrier ratings, and the evaluation of deviations between tested configurations and field installations. GL 86-10 stated that the fire resistance rating of each fire barrier used to satisfy the NRC's requirements should be determined by a standard fire endurance test. This standard, ASTM E119 or NFPA 251, specifies that a test specimen representative of the construction for which a fire rating is desired, as to materials, method of assembly, dimensions, and configuration, be exposed to a standard test fire.

The NRC applies the NFPA 251 acceptance criteria for non-bearing fire barriers to electrical raceway fire barriers. These criteria specify that the transmission of heat through the barrier "shall not have been such as to raise the temperature on its unexposed surface more than 250 °F above its initial temperature." It is generally recognized that the ambient air temperature is 75 °F at the beginning of a fire test. The resulting 325 °F cold side temperature criterion is used because the raceway fire barriers function to preserve the

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[35] SECY-85-306, Enclosure 9, "Steering Committee Resolution of Comments on the Recommendations of the Fire Protection Policy Steering Committee (50FR2056, Jan. 15, 1985; GL 85-01)."

[36] Section 3.2, "Fire Barrier Qualification," of Enclosure 2 to GL 86-10, April 24, 1986.

[37] National Fire Protection Association (NFPA) Standard 251, "Standard Methods of Fire Tests of Building Construction and Materials," is identical to ASTM E119 and is referenced in some NRC guidance documents.

integrity of the cables and keep them free of fire damage. GL 86-10 stated that cables that begin to degrade at 450 °F will be free of fire damage at 325 °F.

GL 86-10 also stated that to verify the fire resistance rating of the fire barrier, the licensees should have the design description of the barrier and the report that documented that a test assembly passed a standard fire endurance test. According to the test standard, the test assembly should represent materials, method of assembly, dimensions, and configuration for which a fire resistance rating is desired. Construction variations may substantially change the performance characteristics of the assembly. Therefore, to ensure that the fire barriers can provide the level of fire protection required, the licensees should either install barriers that replicate the configurations that were tested or justify that fire barriers that deviate from the tested configurations provide an equivalent level of protection. In Section 3.2.2, "Deviations from Tested Configurations," of Enclosure 2 to GL 86-10, the staff identified five criteria that should be met by the licensees where exact replication of *tested* configurations for cable tray and conduit barriers cannot be achieved in the field. The criteria addressed the continuity of the barrier material, the thickness of the barrier, the nature of the support assembly, the end use of the fire barrier, and the review of the configurations by a qualified fire protection engineer. Section C, "Documentation Required to Demonstrate Compliance," of GL 86-10 discussed the evaluations, and the supporting calculations, needed to demonstrate compliance with Appendix R.

Ampacity Derating

GDC 17, "Electric power systems," of Appendix A to 10 CFR Part 50, states: "The safety function for each [electric power] system shall be to provide sufficient capacity and capability to assure that [design conditions are not exceeded]." To meet this GDC, the licensees derate power cables enclosed in electrical raceways using the ampacity derating factors for the materials surrounding the cables, such as, cable trays, conduits, or duct banks. Cables enclosed in raceways protected by fire barrier materials require additional derating because of the insulating effect of the fire barrier materials. In addition, 10 CFR 50.55a(h), "Protection systems," requires that protection systems meet the requirements set forth in the Institute of Electrical and Electronics Engineers (IEEE) Standard: "Criteria for Protection Systems for Nuclear Power Generating Stations," (IEEE-279). Section 4.3 of IEEE-279 identifies the requirement for derating of components.

BTP APCSB 9.5-1 and Appendix A to BTP APCSB 9.5-1 state: "Possible cable derating owing to use of [fire retardant coatings] must be considered during design." In addition, Section 8.3.1, "A-C Power Systems (Onsite)," of NUREG-0800, "Standard Review Plan," Revision 2, July 1981, states: "PSB (Power Systems Branch) will review cable derating and raceway fill to ensure compliance with accepted industry practices."

Conclusion

In the review team's judgement, the staff provided adequate technical guidance regarding fire barriers to the industry and took appropriate actions, such as holding meetings and issuing information notices and generic letters, where confusion could arise. The team found,

however, that the guidance may not have been implemented by the licensees in a way that the staff intended, as evidenced by the continuing history of fire barrier problems.

SPECIAL REVIEW TEAM ACTIVITIES, CONCERNS, AND TECHNICAL ISSUES

Scope of Review

The special review team focused on the following generic safety issues regarding the use of Thermo-Lag barriers by the industry:

- Will Thermo-Lag fire barriers provide a rated fire barrier when installed in accordance with the tested configurations and the vendor's installation procedures?
- Have the licensees evaluated the fire endurance and ampacity derating test results used as the licensing basis for Thermo-Lag barriers to determine the validity of the tests and the applicability of the test results to the plant designs?
- Have the licensees evaluated the Thermo-Lag barrier configurations installed in their plants to ensure that they meet the applicable NRC requirements and guidance?
- Have the licensees installed their Thermo-Lag fire barriers properly?
- Have the licensees reviewed the revised ampacity derating factors for Thermo-Lag that were provided by the vendor[38] to determine whether or not they were applicable to their specific plant designs?

Plant Reviews

The special review team reviewed docket information for RBS (Attachment 4), CPSES (Attachment 5), WNP2 (Attachment 6), the Perry Nuclear Power Plant (PNPP), and SSES (Attachment 7); reviewed information provided voluntarily by the licensees for the Palo Verde Nuclear Generating Station, the Callaway Plant, and the Donald C. Cook Plant; and reviewed vendor documentation and fire endurance and ampacity derating test reports. Members of the special review team also visited RBS,[39] CPSES,[40] WNP2,[41] PNPP,[42]

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[38] Mailgram from R. Feldman, TSI, to U. S. NRC, October 2, 1986.

[39] Memorandum from L.R. Plisco and K.S. West, NRR to F.J. Miraglia, NRR, October 31, 1991.

[40] Memorandum from L.R. Plisco and K.W. West, NRR to F.J. Miraglia, NRR, December 24, 1991.

[41] Memorandum from L.R. Plisco and K.S. West, NRR, to F.J. Miraglia, NRR, December 11, 1991.

[42] Memorandum from L.R. Plisco and K.S. West, NRR, to F.J. Miraglia, NRR, December 18, 1991.

and the Callaway Plant[43] to review licensee fire barrier procurement and installation specifications and procedures, and to observe designs and field installations of Thermo-Lag fire barriers. (The review team's trip reports were placed in the NRC's public document room on March 18, 1992.[44])

NRC Meeting with TSI

During its review, the special review team developed questions regarding Thermo-Lag fire barrier components and materials, barrier installation methods, and fire endurance and ampacity derating test procedures and results which it submitted to the vendor.[45] The vendor answered the questions,[46] and, on October 17, 1991, met with the staff to discuss its response and other technical issues arising during the review.[47] Following the meeting, the review team issued follow-up questions,[48] which the vendor also answered.[49]

Vendor Inspection of TSI

The special review team requested a vendor inspection of TSI and assisted the vendor inspectors prepare for the inspection and develop the inspection plan. The vendor inspection, which was conducted December 16 through 20, 1991, consisted of an examination of procedures and records, interviews with personnel, and observations by the inspectors. The inspectors found that the vendor's QA program (1) did not specify a requirement for measuring the minimum thickness and maximum weight of prefabricated panels and conduit sections and (2) did not specify adequate controls over fire endurance tests. The inspectors found that fire endurance test reports issued by Industrial Testing Laboratories, Incorporated (ITL) were actually written by the vendor and reported the results of tests performed by the

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[43] Memorandum from L.R. Plisco and K.S. West, NRR, to F.J. Miraglia, NRR, January 7, 1992.

[44] Letter from A. Thadani, NRR, to A. Marion, NUMARC, March 18, 1992.

[45] Letters from F.J. Miraglia, NRR, to R. Feldman, TSI, September 10, 1991 (Accession Number 9203180415) and September 18, 1991 (Accession Number 9203180424).

[46] Letters from R. Feldman, TSI, to F.J. Miraglia, NRR, September 12, 1991 and October 5, 1991.

[47] Official Transcript of Proceedings, "Meeting with Thermal Science, Inc., to Discuss Issues Involving Thermo-Lag 330," October 17, 1991. (Accession Number 9202050305.)

[48] Letters from F.J. Miraglia, NRR to R. Feldman, TSI, October 31, 1991 (Accession Numbers 9203180429 and 9203190253).

[49] Letters from R. Feldman, TSI, to F.J. Miraglia, NRR, November 8, 1991, November 12, 1991, and December 3, 1991.

vendor of specimens constructed by the vendor. The inspection report was issued March 26, 1992[50] with two Notices of Nonconformance.

Installation Problems

The special review team reviewed the RBS operating experience and SwRI Draft Report 01-2702, "Three-Hour Qualification Test on Two Protective Envelope Systems for Class 1E Electrical Circuits and Five Penetration Seals," May 1991. The team then prepared IN 91-47, "Failure of Thermo-Lag Fire Barrier Material To Pass Fire Endurance Test," which was issued by the NRC on August 6, 1991. This information notice alerted NRC licensees to a number of Thermo-Lag fire barrier design and installation deficiencies identified by GSU at RBS.

While reviewing IN 91-47, the Cleveland Electric Illuminating Company (CEI), the licensee for PNPP, found discrepancies in the installation of Thermo-Lag fire barriers that could adversely affect the safe shutdown capability at PNPP. Specifically, CEI found that the distances between mechanical fasteners exceeded the vendor's recommendations.[51] On November 19, 1991, members of the special review team visited PNPP to review the issue with CEI and observe the as-built Thermo-Lag fire barriers.[52]

During the visit to PNPP and the four other plants, the team identified a number of Thermo-Lag fire barrier installation problems and concerns. In addition, during the meeting of October 17, 1991, the vendor informed the NRC that its installation procedures did not include several installation steps and precautions because the information was presented during the certification training.[53] On December 6, 1991, NRR issued IN 91-79, "Deficiencies in the Procedures for Installing Thermo-Lag Fire Barrier Materials," to inform the NRC licensees of the observed installation problems. (These installation issues are detailed in IN 91-79, in the transcript of the October 17, 1991 meeting, and in the team's trip reports, and, therefore, are not repeated in this report.)

Review of Fire Endurance Test Reports

The special review team reviewed 34 of the 49 fire endurance test reports identified in Attachment 2 (those shown in bold typeface were reviewed). The team's technical assistance

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[50] Inspection Report 99901226/91-01, issued March 26, 1992.

[51] CEI LER 91-020, "Cable Tray Raceways Found to be Impaired as a Fire Barrier Adversely Affecting Safe Shutdown Requirements," November 19, 1991.

[52] Memorandum from L.R. Plisco and K.S. West, NRR, to F.J. Miraglia, NRR, December 18, 1991.

[53] Official Transcript of Proceedings, "Meeting with Thermal Science, Inc., to Discuss Issues Involving Thermo-Lag 330," October 17, 1991, pp. 155-159.

contractor, National Institute of Standards and Technology (NIST), provided technical input to the team's review of seven of the test reports.

The review team identified concerns regarding compliance with NRC requirements and guidance, compliance with ASTM E119, and adherence to good engineering practice. The team's specific concerns involved test procedures, test facilities, test equipment and personnel, methods of assembly, quality assurance, and acceptance criteria. Based on its reviews of the test reports, the team concluded that many of the tests did not meet NRC requirements and guidance and, therefore, may not provide adequate technical bases for establishing the fire resistance ratings of Thermo-Lag fire barriers.

In addition, the team is concerned that for the test reports it reviewed, the process used to determine the fire resistance ratings of the Thermo-Lag fire barriers deviated from good engineering practices. ASTM E119 fire endurance tests conducted to determine the fire resistance rating of an assembly differ from other types of qualification tests. For example, the fire barrier assembly does not come manufactured from the vendor (such as a fire door assembly), nor is it a matter of assembling component parts together in the field. Instead, skilled crafts personnel have to be instructed and trained how to construct a rated assembly using a variety of component parts for a range of configurations. The fire resistance of the assembly can be affected by changing material thickness, joining and sealing methods, fastener spacing, fastener location, and a myriad of other construction details. Therefore, for assemblies requiring a "rated design," testing laboratories clearly document the design to be qualified.[54] This documentation shows the geometry (configuration) and the component parts, specifies construction details such as minimum measurements, locations of components, and methods of assembly. In the team's judgement, the lack of a well documented rated design makes the fire barrier applications tested uncertain.

Examples of specific fire endurance testing concerns identified by the review team follow. (Additional testing issues are detailed in IN 91-47, in the transcript of the October 17, 1991 meeting, and in the team's trip reports, and, therefore, are not repeated in this report.)

October 1989 GSU Fire Test Failure

On October 26, 1989, SwRI performed a 3-hour fire endurance test of a cable tray and support protected by a Thermo-Lag fire barrier for GSU.[55] The test report shows that the tray failed on temperature rise within 60 minutes and collapsed in less than 90 minutes. The failure of this test raised concerns regarding the adequacy of Thermo-Lag cable tray enclosures and led to the issuance of IN 91-47. (The staff is currently working with GSU to have this SwRI fire test report placed in the NRC public document room.)

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[54] The most widely-used compilation of rated designs in the United States is the *Fire Resistance Directory*, UL, Northbrook, Illinois. This document contains numerous examples of rated design sheets.

[55] SwRI Draft Report 01-2702, "Three-Hour Qualification Test on Two Protective Envelope Systems for Class 1E Electrical Circuits and Five Penetration Seals," May 1991.

After IN 91-47 was issued, the vendor, in letters to licensee fire protection engineers[56] and the NRC,[57] stated that the October 1989, SwRI fire endurance test was not a valid test because of installation deficiencies. The vendor believes that the Thermo-Lag-protected test assembly failed and collapsed because the seam at the interface of the Thermo-Lag and Promat interface, which covered the cable tray support, separated under fire exposure and allowed fire gases to enter the interior of the cable tray.

The test assembly consisted of two 30-inch-wide aluminum ladder back cable trays spaced about 4 1/2-feet apart and supported by a U-shaped tube steel support. Each tray began 12 inches above the surface of a concrete test slab, extended downward through the slab to a 90° bend, continued horizontally for 44 inches to another 90° bend, and extended upward through the slab for 12 inches. The bottom of the horizontal section of each tray was 36 inches below the inside surface of the slab. A common support was anchored to the underside of the test slab and supported both trays at the bottoms of the trays. Each cable tray was filled with about 12 percent cable fill, with a single No. 8 AWG bare copper wire installed in the center of the tray.

One of the cable trays was protected by Thermo-Lag 330-1 prefabricated panels. The other tray was protected by Promat-L board. The horizontal segment and 18 inches of the vertical segments of the tray support were protected with the appropriate fire barrier material. (The remaining portions of the vertical runs were unprotected and were exposed to the furnace fire.) The two dissimilar fire barrier materials met near the center of the horizontal portion of the support. The details of the interface design were not reported.

On October 7, 1991, the review team travelled to RBS and interviewed the GSU employees that built and inspected the test specimen and that witnessed the test. These employees informed the team that the test assembly was constructed in accordance with TSI's and GSU's installation procedures using TSI certified installers and that the test was conducted in accordance with ASTM E119 by a recognized testing laboratory. The GSU representatives informed the review team that GSU had provided some test data to the vendor, had asked the vendor to evaluate the test results, and had met with the vendor to discuss the test results. GSU considered the SwRI test valid.

The review team also discussed the test failure with the vendor during the October 17, 1991 meeting. The vendor informed the review team that it had received test data and photographs of the test specimen from GSU, but that it had not observed the test specimen, did not witness the test, and had not reviewed the test report. During the meeting, the vendor informed the staff that the test failed within a matter of minutes because the dissimilar

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[56] Letter from R.A. Lohman, TSI, to F. Garrett, Arizona Public Power, *et al*, August 23, 1991.

[57] Letter from R. Feldman, TSI, to F.J. Miraglia, NRR, October 5, 1991.

fire barrier materials protecting the cable tray support separated under fire exposure thereby allowing flames to enter the cable tray.[58]

The review team performed an independent evaluation of SwRI Draft Report 01-2702. NIST provided technical input to the team. The review team reviewed the temperatures recorded at locations on the bare copper wire adjacent to thermocouple (TC) 82 (located inside the Thermo-Lag-protected tray on the bare copper conductor in the horizontal portion of the tray), as well as temperatures along the horizontal support between the insulation interface and the center of the cable tray.

Temperatures recorded at points along the copper wire adjacent to TC 82 (TC 81 and TC 83) do not show evidence of impinging furnace gases before or at the time of excess temperature at TC 82. Although it is possible that a narrow jet of furnace gases entered the cable tray and struck TC 82 but not TC 83, which was closer to the interface of the Thermo-Lag and Promat fire barrier materials, the more plausible explanation of the temperature recorded during the test is that the Thermo-Lag material enclosing the tray failed in the area of TC 82 independent of any failure at the interface of the materials.

The review team concluded that the vendor's explanation of the test failure is possible. However, based on its interviews with GSU and the vendor, and its independent review of the test report and the thermocouple temperature data, the team concluded that the SwRI test specimen failed due to a failure of the Thermo-Lag material enclosing the cable tray, independent of any failure of the material protecting the tray support. This finding contributed to the review team's conclusion that the fire resistance ratings for Thermo-Lag are indeterminate. Additional qualification testing issues and concerns that reinforced this conclusion are discussed below.

Industrial Testing Laboratories, Incorporated Tests

Of the 49 fire endurance test found by the review team, 28 were performed at the vendor's facility and involved Industrial Testing Laboratories, Incorporated, St. Louis, Missouri. The team reviewed 16 of the ITL tests and identified general and test-specific concerns, which are discussed below. NIST provided technical input to the team's review of four of the ITL tests.

ITL Tests - Common Concerns

The review team is concerned that ITL may not have the skills or technical expertise needed to perform ASTM E119 fire endurance tests. The team found, for example, that although ITL is listed in the ASTM-published directory of U.S. testing laboratories,[59] ITL does not identify expertise in fire endurance testing in its listing.

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[58] Official Transcript of Proceedings, "Meeting with Thermal Science, Inc., to Discuss Issues Involving Thermo-Lag 330," October 17, 1991, pp. 159-167.

[59] *Directory of Testing Laboratories*, 1991 edition, ASTM, Philadelphia, PA.

The ITL test reports indicate that the tests were controlled and supervised by ITL, but the team found that ITL may not have participated in the preparation or approval of the test plans, the design or construction (including inspection) of the test specimens, the installation of the thermocouples, or the operation of the test equipment, which is located at the vendor's facility. ITL's role appears to have been limited to witnessing data acquisition. During the December 1991 vendor inspection of TSI, an ITL representative that was involved with several of the fire endurance tests informed the vendor inspectors that he did not compare the test specimens' dimensions against the test plans or the daily work sheets, and did not review calibration records for the test instrumentation. The ITL representative stated that his role in the tests ended when the raw test data (thermocouple temperature strip charts) were collected. The inspectors found that the vendor drafted and prepared the test reports, including the raw data, for ITL's signature. The ITL representative informed the vendor inspectors that his review of the test reports prepared by the vendor was minimal and did not include comparisons of the reported data against the acquired raw data. (Detailed discussion of ITL's role in the TSI fire endurance tests that were presented as ITL tests are included in Section 3.7, "Qualification Type Testing," and Section 3.8, "Industrial Testing Laboratory Role," of NRC Inspection Report 99901226/91-01, which was issued on March 26, 1992.)

ITL did not specify whether or not the thermocouple assemblies or the placement of the furnace thermocouples met the requirements of ASTM E119. Section 4, "Furnace Thermocouples," of ASTM E119 specifies that furnace thermocouples use No. 18 gage Chromel-Alumel wires and that they be enclosed in standard weight iron, steel, or Inconel pipe, or that they be verified to have the same time constant as do these standard thermocouples. Section 4 also specifies the guidelines for the locations of furnace thermocouples. ITL referred to using shielded Chromel/Alumel thermocouples for monitoring furnace temperatures. The review team is concerned that the use of incorrect thermocouple assemblies or improper placement of the thermocouples could affect the control of the fire test and the ability to maintain the standard time-temperature curve specified by ASTM E119.

The ITL reports do not provide the level of detail required to verify that the test specimen thermocouples met the requirements of ASTM E119. Section 5, "Temperature of Unexposed Surfaces of Floors, Roofs, Walls, and Partitions," of ASTM E119 provides requirements for the construction and location of the thermocouples used to monitor the test specimen temperatures. Errors could arise if the thermocouples were shielded or too thick.

In addition, the ITL test reports typically state that "thermocouples were used to measure the *cable surface* temperatures." GL 86-10 (Enclosure 2, page 8) states that "transmission of heat through the barrier shall not have been such as to raise the temperature on its *unexposed surface* more that 250 °F above its initial temperature." The review team is concerned that the method used by ITL to measure test specimen temperatures does not appear to meet either ASTM E119 or the guidance in GL 86-10.

It appears that ITL has misinterpreted the ASTM E119 standard-time temperature curve. In addition, the requirements of Section 5.3 of ASTM E119 are incorrectly summarized in the ITL test reports. This section requires not that the temperature be between the standard curve and 10 percent below as stated in the ITL reports but, rather, that the area under the

time-temperature curve be as close as possible to the standard, within prescribed *symmetric* plus-or-minus limits.

The ITL reports reviewed by the review team do not make the test data corrections specified in ASTM E119. Section 6, "Report of Results," of ASTM E119 describes a mandatory correction for fire endurance tests of 30 minutes or over and Section 6.4 gives an equation that is used to adjust the time to failure positively or negatively, depending on whether the furnace temperatures were excessive or insufficient.

The ITL reports document fire endurance tests of fire barrier test specimens that are atypical of the installed configurations observed by the review team. The configuration of each cable tray test specimen reviewed by the team was a tight U-shaped assembly laid on its side. The assemblies were cantilevered from the front face of the furnace and inclined downward. The far end of each assembly, near the bend of the "U," was supported by a knife-edge type of support that appeared to be resting on the furnace floor. (Reference, for example, Figure 5, "General Arrangement of a Test Article in the Test Furnace," of ITL Report 87-5-77, Revision 1, June 29, 1987.) This test assembly configuration is atypical of the configurations observed by the special review team during its plant site visits in terms of both the layout of the tray and the method of support. In the team's opinion, the ITL test specimens did not meet Section 7.1 of ASTM E119, which states that "the test specimen shall be truly representative of the construction for which classification is desired."

The construction of the ITL test specimens may not have been truly representative of the range of configurations for which fire resistance ratings were needed. The ability of a fire barrier to limit heat transfer into the barrier enclosure during exposure to the standard test fire and the ability of the test specimen to maintain its structural integrity throughout the fire exposure and the hose stream test are the test acceptance criteria. The cable trays observed by the review team in the field ranged in width from 6 inches to 36 inches. The cable trays tested by ITL were 6 inches and 12 inches wide. From the perspective of heat transfer through a barrier and into the raceway, the review team believes that small enclosures are the worst case configurations. From the standpoint of structural integrity, the review team believes that larger configurations are probably the worst case configurations. Section 7.1 of ASTM E119 states that "the test specimen shall be truly representative of the construction for which classification is desired as to materials, workmanship, and details such as dimensions of parts." Therefore, in the review team's judgement, tests of representative cable tray sizes and configurations should have been conducted to determine the fire resistance ratings for the range of possible field configurations.

The ITL reports do not include dimensioned drawings of the test specimens. Section X3.3, "Description of Test Assembly," of ASTM E119 provides guidance on the reporting of the description of the test assemblies. The sole test assembly descriptions provided by ITL are thermocouple location drawings and, in some cases, photographs.

ITL Tests - Test-Specific Concerns

In addition to the aforementioned common concerns, which the review team found with all of the ITL reports it reviewed, the team found test specific concerns. Examples of these concerns are presented below.

ITL Report 82-3-2.[60] This report presented the results obtained from a 3-hour fire endurance test of the Thermo-Lag fire wall system. The test assembly consisted of a 3 foot by 3 foot section of expanded metal protected on both sides by Thermo-Lag material and stress skin. Section 14, "Size of Sample," of ASTM E119 specifies that for walls, the area exposed to fire shall be not less than 100 square feet with neither dimension less than 9 feet. The specimen tested by the vendor does not meet the ASTM criteria for walls and, therefore, does not meet NRC guidance.

ITL Report 82-11-80[61] and ITL Report 82-11-81.[62] The vendor informed the review team during the October 17, 1991, meeting that the cure time for the Thermo-Lag 330-1 material is 30 days.[63] The team found that some of the specimens tested under these two tests did not cure for 30 days prior to the tests. For example, the On-Site Applied Chronological Log Sheets for Report 82-11-80 indicated that a finish coating of Thermo-Lag 330-1 was applied to Test Specimen 2G on August 24, 1982. The test was conducted 16 days later on September 9, 1982. Finish coatings applied to Test Specimens 4 and 6 also cured for only 24 and 25 days, respectively, before their tests.

Several of the specimens tested in these two ITL tests also used a cure accelerator. ITL reported that this optional material, which is intended to accelerate the set up time of the Thermo-Lag subliming coating, will not adversely affect the fire resistive properties of the material. However, a technical basis for this statement is not provided in either of the test reports.

A Daily Work Sheet (page 10 of 13, August 20, 1982) for Test Specimen 1G of Report 82-11-81 states that: "All first layer pieces were attached by lacing with tie wires." A

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[60] ITL Report 82-3-2, "Three Hour ASTM E119 Fire Endurance Test to Qualify the Thermo-Lag 330 Conformable Three Hour Stress Skin Fire Wall System as a Nuclear Fire Wall," Revision 1, March 1982.

[61] ITL Report 82-11-80, "One Hour Fire Endurance Tes s Conducted on Test Articles Containing 'Generic' Cables Protected with the Thermo-Lag 330-1 Subliming Coating Envelope System," November 1982.

[62] ITL Report 82-11-81, "Three Hour Fire Endurance Tests Conducted on Test Articles Containing 'Generic' Cables Protected with the Thermo-Lag 330-1 Subliming Coating Envelope System," November 1982.

[63] Official Transcript of Proceedings, "Meeting with Thermal Science, Inc., to Discuss Issues Involving Thermo-Lag 330," October 17, 1991, pg 51.

photograph on page 58 of this report (Figure 16B) shows what appears to show this lacing technique. Appendix 9 of this test report states that the materials were installed in accordance with TSI's Nuclear QA Manual and QC Operating Procedures Manual. However, these documents (Appendix I, Section 4, of the test report) do not specify this assembly method.

ITL Report 84-12-181.[64] One of the objectives of this test (page 4) was to demonstrate that the use of 12 inch spacing of mechanical ties comprised of *either* stainless steel tie wires *or* stainless banding will perform satisfactorily. Page 1 of the report stated that the tie wires and banding were installed alternately at 12 inch intervals. It is the review team's judgement that a successful test of this configuration would demonstrate that the alternating configuration performs satisfactorily, but would not prove that either wires or bands could be used to fasten the panel sections.

In the team's view, to meet the stated test objective, either two complete tests should have been conducted or, as a minimum, one entire half of the test assembly should have been equipped with wires ties and the other half with bands. In addition, the team did not find this fastening method (alternating bands and tie wires) used at any of the five plants it visited.

Another objective of ITL Test 84-12-181 was to demonstrate that a P1000 unistrut that penetrates a Thermo-Lag fire barrier will not degrade the barrier if the unistrut is protected with Thermo-Lag material for a distance of 18 inches from the point of penetration into the enclosure. A 24 inch length of unistrut was welded to one side of the cable tray. With the exception of a four inch stub, the unistrut was protected within the Thermo-Lag cable tray fire barrier. It is the review team's judgement that this arrangement was nonconservative in that it reduced the surface area available for heat transfer into the barrier. In the opinion of the review team, the design of the test specimen configuration was not representative of a fire barrier penetration and was not suitable for achieving the stated test objective.

Construction Technology Laboratories, Incorporated Tests

In its August 23, 1991, letter to licensee fire protection engineers, the vendor stated that Construction Technology Laboratories, Incorporated (CTL) Reports 240056 824-63, Revision 1,[65] and 240056-824 824-59, Revision 1,[66] documented successful full scale fire

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[64] ITL Report 84-12-181, "Three Hour Fire Endurance Test Conducted on a Ladder Cable Tray with a P1000 Unistrut Attachment and Transition Section Protected with the Thermo-Lag 330 Fire Barrier System," Revision 2, June 1985.

[65] CTL Report 240056 824-63, Revision 1, "Fire Test on Aluminum Ladder Back Tray Protected by Thermo-Lag Prefabricated Panels in a Steel Bulkhead," October 1989.

[66] CTL Report 240056-824 824-59, Revision 1, "Fire Test on Aluminum Ladder Back Cable Tray Protected by Thermo-Lag Prefabricated Panels for Gulf States Utilities," October 1989.

endurance tests of 30-inch wide aluminum cable trays. The vendor provided these two CTL test reports and CTL Report 240056-824 824-77,[67] which documents a third test of a 30-inch wide cable tray fire barrier, to the special review team during the October 17, 1991 meeting.[68] The review team reviewed these three tests and identified the concerns discussed below. (NIST provided input to the team's review of CTL Reports 240056-824 824-63, Revision 1, and 240056-824 824-59, Revision 1.)

The method for determining the thicknesses of the barrier materials is not reported. The hand-written log sheets in the report appendices indicate that the vendor made the measurements. It does not appear that CTL verified the barrier thicknesses. It also appears that the discussions of thicknesses of the Thermo-Lag materials were revised. For example, CTL Report 240056 824-63 (page 6) states: "The electrical protective envelope system consisted of 1-in. minimum thickness (measured thickness 1-1/2 in.) THERMO-LAG Prefabricated Panels." Revision 1 to the report (page 6) states: "Their thickness was 1 in. and 1-1/2 in. maximum." Neither description is consistent with the measured thicknesses listed in the log sheets.

The reports do not provide the level of detail required to verify that the test specimen thermocouples were located in accordance with Section 5 of ASTM E119 and the NRC guidance provided in GL 86-10.

Moisture conditioning time and procedures are not specified or reported in these CTL reports. Section 11, "Protection and Conditioning of Test Specimens," of ASTM E119 specifies that test specimens be conditioned until they attain moisture equilibrium. As discussed in the previous section, the vendor informed the review team during the October 17, 1991, meeting that the cure time for Thermo-Lag 330-1 materials is 30 days. The test specimen for CTL Report 240056 824-63 was constructed on April 5, 1989, and the fire endurance test was conducted nine days later on April 14, 1989. Clearly the trowel grade Thermo-Lag 330-1 used to seal the joints between individual panel sections was not cured to the vendor's specifications prior to the conduct of the test. Finally, the daily work sheets for the tests indicate that an additional layer of Thermo-Lag trowel grade material was applied to the surfaces of the test specimens after they were installed in the furnace two days prior to the conduct of the tests. The cure time for the Thermo-Lag prefabricated panels used to construct the test specimens was also not reported.

The reports lack a "visual observation" section as required by Section 46.4 of ASTM E119. It is standard practice when conducting ASTM E119 fire endurance tests for a technician to continuously monitor the visual condition of the test specimen. Anything that happens to the specimen is indicated on the observations sheet. Such observations can include, for example: the time when the specimen started to smoke, sections of specimen falling into the furnace,

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[67] CTL Report 240056-824 824-77, "Fire Test on Aluminum Ladder Back Cable Tray Protected by Thermo-Lag Prefabricated Panels," November 1989.

[68] Official Transcript of Proceedings, "Meeting with Thermal Science, Inc., to Discuss Issues Involving Thermo-Lag 330," October 17, 1991, Attachments 3, 4, and 5.

and similar events. This information provides insights regarding the nature of the specimen's performance.

The reports indicate that the test specimen fire barriers were constructed in accordance with TSI Technical Note 20684, "Thermo-Lag 330 Fire Barrier System Installation Procedures Manual Power Generating Plant Applications," (Tech Note 20684). However, construction of the specimens appears to have deviated from the methods specified in Tech Note 20684 in a direction that would enhance the fire performance of the test assemblies. For example, the Daily Work Sheets included with the reports indicate that "stainless steel bands... made use of corner L angles." These pieces are not specified in Tech Note 20684. In addition, Tech Note 20684, Section II, Paragraph 1.1.4 specifies a maximum spacing of 12 inches. The distances between the bands is not explicitly reported in the bodies of the test reports. However, photographs included with the reports indicate that band spacing may have been less than 12 inches. The Daily Work Sheets state that "stainless steel banding was used within two inches on both sides of all seams," and that spacing is 12 inches maximum and a minimum of 6 inches. The Daily Work Sheets also indicate that "stress skin was used across the seams." These installation details are not specified in Tech Note 20684, and are not typical of the field installations observed by the review team during its plant site visits.

Moreover, the test reports do not include any discussions of these deviations from the vendor's installation procedures, including their probable effect on the fire performance the test assemblies. The review team believes that these construction deviations are actually design improvements that may have enhanced the fire performance of the test assemblies.

Application of Fire Endurance Test Results

Fire Walls

The review team is concerned that licensees may have used ITL Report 82-3-2, "Three Hour ASTM E119 Fire Endurance Test To Qualify the Thermo-Lag 330 Conformable Three Hour Stress Skin Fire Wall System as a Nuclear Fire Wall,"[69] as the technical bases for installing Thermo-Lag walls, large enclosures, and other vertical and horizontal barriers to achieve Appendix R separation. As previously discussed, the review team found that the test documented in this test report was not conducted in accordance with ASTM E119 and, therefore, does not meet NRC guidance for fire barriers. The review team did not find any ASTM E119 fire endurance test that were conducted on walls or large enclosures. However, a number of sites visited by the review team have walls and large enclosures constructed of Thermo-Lag panels.

Methods of Assembly

During its site visits, the review team learned that several licensees, for example, GSU and Union Electric Company, used ITL Reports 82-11-80 and 82-11-81 as the technical bases for

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[69] Official Transcript of Proceedings, "Meeting with Thermal Science, Inc., to Discuss Issues Involving Thermo-Lag 330," October 17, 1991, Attachment 6.

installing Thermo-Lag fire barriers in its plants to meet NRC requirements. The application methods reported for the test specimens tested in these two tests included direct application techniques such as brushing and spraying trowel grade Thermo-Lag material directly onto stress skin that had been formed around the raceway. However, these licensees have installed Thermo-Lag fire barriers constructed of prefabricated panels and preshaped conduit sections. The direct application of trowel grade material differs from the prefabricated panel application most notably in that the barriers applied using direct application methods do not have joints. The barriers constructed of panel and conduit sections do have joints. In the review team's judgement, the use of direct application test results to support prefabricated panel configurations does not meet ASTM E119 criteria that the test specimen be representative of the construction for which a fire rating is desired, and, therefore, does not meet NRC guidelines.

The test specimens tested in ITL Reports 82-11-80 and 82-11-81 used a cure accelerator. However, the licensees did not use this material during the construction of their Thermo-Lag fire barriers, and did not evaluate the differences between the as-built and the tested configurations.

The review team is concerned that other licensees have used these ITL tests as its technical bases for installing Thermo-Lag fire barriers. The review team believes that this shows that some licensees may not have adequately reviewed the fire endurance test results to determine their applicability to the plant designs.

Extrapolation of Test Results

During its plant site visits, the review team observed cable trays up to 36 inches wide protected with Thermo-Lag fire barriers. However, of the 49 fire tests identified by the review team, only four involved cable trays wider than 14 inches. These were the October 1989 test performed at SwRI and the three CTL tests discussed previously. Although the test specimen for the SwRI test was constructed by certified installers in accordance with the vendor's procedures, it failed catastrophically. CTL reported that its tests passed, but the review team found that the CTL test specimens included components and installation detail's that were not specified in the vendor's installation procedures (Tech Note 20684). As discussed in the previous section, the review team believes that these additional details may have improved the fire performance of the CTL test specimens.

Following the CTL tests, the vendor issued new procedures for installing Thermo-Lag fire barriers on *aluminum* cable trays. These procedures[70] include some of the assembly details employed for the CTL test specimens that are not specified in Tech Note 20684, including the installation of stainless steel bands within 2 inches of all joints (tie wires do not appear to be an option) and the wrapping of butt joints with stress skin and trowel grade Thermo-Lag material.

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[70] TSI Technical Note 20684 A1., "Thermo-Lag 330 Fire Barrier System Installation Procedures for Aluminum Cable Trays - Power Generating Applications," October 1989.

The review team is concerned that these details specified in Tech Note 20684-AL may be needed to ensure the integrity of the fire barrier because of the width of the cable tray, not because the tray is made of aluminum. If, if fact, the fire barrier construction details specified in Tech Note 20684-AL are needed to ensure the integrity of fire barriers on wider trays, regardless of tray material, then the fire barriers installed by the licensees without these construction features may not provide the level of fire resistance intended by the licensees.

18-Inch Rule

To prevent heat transfer into the fire barrier that could damage protected components, the vendor's generic installation procedure recommends that all penetrations into the fire barrier system be fire protected to the same level of fire resistance as the raceway for a distance of 18 inches, minimum, as measured from the outer surface of the fire barrier, covering all continuous paths.[71] This is commonly referred to this as "the 18-inch rule."

The review team is concerned that ITL Report 84-12-181, "Three Hour Fire Endurance Test Conducted on a Ladder Cable Tray with a P1000 unistrut Attachment and Transition Section Protected with the Thermo-Lag 330 fire Barrier System," Revision 2, June 1985, is being used by licensees as the technical basis for the 18-inch rule. As previously discussed, the team believes that the design of the test specimen configuration was not representative of typical fire barrier penetrations and, therefore, was not suitable for demonstrating that heat would not be transferred into typical barrier envelopes through penetrations protected for only 18 inches.

Review of Ampacity Derating Test Reports

The special review team reviewed nine ampacity derating tests (Attachment 3) and found conflicting test results. For example, the vendor has reported derating factors for cable trays that range from 7 percent[72] to 28 percent[73] for 1-hour fire barriers and from 16 percent[74]

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[71] TSI, "Thermo-Lag 330 Fire Barrier System Installation Procedures Manual, Power Generating Plant Applications," TSI Technical Note 20684, Revision V, November 1985, pg. I-9.

[72] TSI Technical Note 11171, "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," November 1981.

[73] UL Test 86NK23826, "Special Services Investigation of Ampacity Ratings for Power Cables in Steel Conduits and in Open Ladder Cable Trays with Field Applied Enclosures," January 21, 1987.

[74] ITL Report 82-5-355F, "Ampacity Derating Test for 1000 Volt Power Cables in a Ladder Cable Tray Protected With a Three Hour Rated Design of Thermo-Lag 330-1 Subliming Coating Envelope System," July 1982.

to 31 percent[75] for 3-hour barriers. In addition, ampacity derating tests of Thermo-Lag materials conducted for 3M[75] found the ampacity derating to be 37 percent for a 1-hour Thermo-Lag fire barrier. The review team noted similar inconsistencies in the ampacity derating factors for Thermo-Lag conduit fire barriers.

By Mailgram of October 2, 1986, the vendor informed the NRC of the results of ampacity derating tests performed at the UL. The ampacity derating factors obtained from the UL tests (UL Project 86NK23826, File R6802, January 1987) exceeded those previously reported by the vendor (for example, ITL Reports 82-355-C, 82-355-F, and 82-355-F1). The vendor informed the NRC that the UL test results were sent to its customers,

During its plant site visits, the licensees for CPSES and PNPP informed the review team that it had received the vendor's Mailgram and had considered the new ampacity derating information into the plant designs. However, several licensees, for example, GSU and WPPSS, informed the review team that it had no record of having received the Mailgram. Therefore, some licensees that use Thermo-Lag fire barriers (for fire protection and for electrical separation) have not determined if the derating factors derived from the UL test apply to their plant designs.

Some of the factors that affect ampacity include: cable temperature rating, cable jacket material, conductor material and size, cable loading, the number of cables in a group, raceway components, fire barrier materials, and the ambient temperature. ITL performed the 82-355 series tests using WNP2-specific components such as cables, raceways, and fire barrier materials. During a visit to WNP2, WPPSS representatives informed the review team that they believed the ITL 82-355 series tests were more conservative than the UL test because of the tray configuration, the type of cable conductor used, and other factors. The licensee also stated that the baseline ampacity deratings derived from the 82-355 series tests were close to those reported by National Electrical Manufacturers Association[76] (NEMA), whereas those derived from the UL tests were almost two times greater than the NEMA baseline data. The licensee concluded that (1) the NEMA data validated the 82-355 series tests, (2) the derating factors derived from the 82-355 series tests were valid for WNP2 and (3) the factors derived from UL Project 86NK23826 do not apply to WNP2. WPPSS also informed the task force that the WNP2 design does not include sufficient margin to accept additional cable derating without adversely effecting cable performance.

The review team identified ampacity derating as a generic concern. The review team is concerned about the inconsistencies in the derating test results and that some licensees have not adequately reviewed the ampacity derating test results to determine the validity of the tests and the applicability of the test results to their plant designs.

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[75] SwRI Project 01-8818-208/209-a, "Ampacity Derating of Fire Protected Cables in Cable Trays Using a One-Hour Subliming, Rigid Board Provided by 3M, Incorporated," August 11, 1986.

[76] IPCEA-NEMA Standard Publication entitled "Ampacities - Cables in Open-top Cable Trays," (IPCEA Publication P-54-440, Second Edition; NEMA Publication WC 51-1975).

SAFETY SIGNIFICANCE

Fire Protection

The licensees use the defense-in-depth concept of echelons of safety systems to achieve the high degree of safety required for nuclear power plants. This concept is also applicable to nuclear power plant fire safety. The defense-in-depth principle applied to the fire protection program is aimed at achieving an adequate balance in preventing fires from starting, detecting and suppressing fires quickly to limit damage, and designing plant safety systems so that a fire that starts in spite of the fire prevention program will not prevent essential plant safety functions from being performed. No one of these echelons can be perfect or complete by itself, but each echelon should meet certain minimum requirements. However, strengthening any one echelon can compensate in some measure for weaknesses, known or unknown, in the others.

In the *Federal Register* notice that issued the proposed Appendix R to 10 CFR Part 50,[77] the NRC stated: "The phenomenon of fire is believed to be sufficiently well understood to permit evaluation of existing and potential fire hazards and probable extent of damage should a fire occur. Such evaluations are useful in assessing the possible consequences of fire in a given area. However, the phenomenon of fire is so unpredictable in occurrence and development that measures to prevent unacceptable consequences may not be omitted on the basis of low probability of occurrence. The minimum fire protection requirements for nuclear power plants must be established not only to identify fire hazards but also to protect against unacceptable consequences of fire."

The primary objective of the fire protection program is to minimize both the probability and consequences of postulated fires. In spite of steps taken to reduce the probability of fire, fires are expected to occur. Therefore, means are needed to detect and suppress fires with emphasis on providing passive and active fire protection of appropriate capability and adequate capacity for the systems necessary to achieve and maintain safe plant shutdown with or without offsite power. Generally, in plant areas where the potential fire damage may jeopardize safe plant shutdown, the primary means of fire protection should consist of fire barriers and fixed automatic fire detection and suppression systems. Also, a backup manual fire fighting capability should be provided throughout the plant to limit the extent of fire damage. The licensees determine the adequacy of fire protection for plant safety systems and areas by analysis of the effects of the postulated fire relative to maintaining the ability to safely shut down the plant and minimize radioactive releases to the environment in the event of a fire.

The variables used to evaluate the level of fire protection needed in a given fire area include:

- Fire loading and fire hazards.

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[77] U. S. NRC, "Fire Protection Program for Nuclear Power Plants Operating Prior to January 1, 1979," *Federal Register*, Vol. 45, No. 105, May 29, 1980, pp. 36082-36090.

- Automatic fire detection and suppression capability.
- Layout and configurations of safety trains.
- Reliance on fire barriers including, the quality of the materials and system, and the quality of the installation.
- Fire area construction (walls, floor, ceiling, dimensions, volume, ventilation, and congestion).
- Location and type of manual fire fighting equipment and accessibility for manual fire fighting.
- Potential disabling effects of fire suppression systems on shutdown capability.
- Availability of oxygen (for example, inerted containment).
- Amount of cable insulation and other combustible materials.
- Alternative or dedicated shutdown capability.

During the NRC reviews of the licensees' fire protection programs, the staff evaluated these variables to ensure that each licensee provided an adequate level of protection. In addition, the NRC has granted licensees requests for exemptions from specific Appendix R requirements and has approved deviations from staff guidance. The staff performed safety evaluations and granted the exemptions and deviations based on fire hazards analyses performed by the licensees that demonstrated that an alternative provided an equivalent level of protection. The NRC provided criteria for evaluating exemptions in GL 81-12, "Fire Protection Rule," February 20, 1981.

The fire areas at higher risk, if raceway fire barriers do not provide the level of fire resistance intended by the licensees, are the areas where NRC granted exemptions from the requirements of Section III.G.2 of Appendix R to 10 CFR Part 50 (or deviations from equivalent NRC guidance), because reduced defense-in-depth may have been approved based on the assumption that the installed fire barriers would perform as intended. The following configurations are ranked from the most safety significant to least safety significant. (These are general rankings. The true safety significance of any particular configuration is also dependant on the nature of the protected equipment and its relative importance to safety. Factoring in this aspect would require licensee input and a case-by-case analysis.)

- Exemption from Section II.G.2.c of Appendix R. When one train of a system required to achieve safe shutdown is separated from its redundant train by a 1-hour fire rated barrier and automatic fire detection and suppression capabilities are installed, Section III.G.2.c of Appendix R is met. If the licensee has been granted an exemption from the requirement to provide automatic detection and suppression systems, the ability to achieve safe shutdown is largely dependent on the ability of the 1-hour fire barrier to maintain the protected train free of fire damage. If the fire

barrier cannot provide this level of protection, safe shutdown capability may be adversely affected.

- Exemption from Section III.G.2.a of Appendix R. When one train of a system required to achieve safe shutdown is separated from its redundant train by a 3-hour fire rated barrier, Section III.G.2.a of Appendix R is satisfied. Automatic fire detection and suppression capabilities are not required. Therefore, the ability to achieve safe shutdown is dependent on the 3-hour fire barrier to maintain one train free of fire damage.

  The technical bases for approving this type of exemption may have included fire test results that, in combination with a fire hazards analysis, demonstrated reasonable assurance that safe shutdown could be chieved if a fire barrier of less than 3-hours fire resistance is installed. If the fire test results are not valid, then the fire hazards analysis would not be valid and the level of fire protection needed to protect safe shutdown capability may not be provided.

- Exemption from Section II.G.2.c of Appendix R. When one train of a system required to achieve safe shutdown is separated from its redundant train by a 1-hour fire rated barrier and automatic fire detection and suppression systems are installed, Section III.G.2.c of Appendix R is met. If the licensee has been granted an exemption from the requirement to provide either automatic fire detection *or* suppression systems, the ability to achieve safe shutdown is dependent on actuation of the installed system and the 1-hour fire barrier to maintain one train free of fire damage. If the fire test results are not valid, the level of protection needed to protect safe shutdown capability may not be provided.

- Compliance with Section III.G.2 of Appendix R to 10 CFR Part 50 based on invalid fire test results or improper fire barrier installation.

The review team considers the relative safety significance of the subject fire protection concerns to be low for the following reasons. Fire resistive barriers are evaluated in a testing furnace by exposing a test specimen to a fire whose severity follows a time varying temperature curve--the standard time-temperature curve--for the duration of the fire rating required. The NRC has conservatively selected 3-hours as the minimum fire resistance rating for fire barriers used to separate redundant safe shutdown systems. (1-hour barriers with automatic fire detection and suppression systems are considered equivalent to 3-hour barriers.) The fire test standard maximizes fire severity by subjecting the barrier to a fire of rapid temperature rise in a confined space that totally engulfs the test specimen. In an actual fire situation, the fire resistance required of a barrier depends on the expected severity of the fire to which it may be exposed. Typical nuclear plant fire loads are not great enough to produce a fire approaching the severity of a test fire. In addition, an actual nuclear power plant fire would have a much slower temperature rise than the test fire. In large open volumes, such as most nuclear plant fire areas, a fully developed fire may occur in one part of the area, but it is not probable that the entire volume (fire area) would flashover. Unless a fire reaches this stage, it is not likely to present a credible challenge to any nuclear power plant fire barrier. Although the fire resistance ratings of the Thermo-Lag fire barriers are

considered indeterminate, the special review team believes the barriers will provide some level of fire protection. In addition, most plant areas have controlled ignition sources, which helps reduce the occurrences of fires and are equipped with other passive and active fire protection features, and are continuously occupied by plant operators, security, and other personnel, which contributes to early fire detection and suppression activities.

Ampacity Derating

Cables enclosed in electrical raceways are derated using the ampacity derating factors for the materials surrounding the cables, for example, cable trays, conduits, or duct banks, to ensure that systems provide sufficient capacity and capability to perform their intended safety functions. Cables enclosed in raceways protected by fire barrier materials require additional derating because of the insulating effect of the fire barrier materials. Cable derating calculations that are based on inaccurate or nonconservative derating factors could result in the installation of undersized cables and raceway overfilling. This could cause higher than design operating temperatures within the raceways thereby reducing the expected design life of the cables. In extreme cases, cable jacket insulation failures could occur. Therefore, undersized safety-related cables reduce plant safety margins. If inaccurate or nonconservative derating factors are used by the licensees for the electrical system design basis, design changes could be required to extend cable life and to restore safety margins. The special review team did not identify any immediate public health and safety concerns regarding the ampacity derating issues during its review. The review team recommends that the licensees and the NRC staff assess the safety significance of any plant-specific issues that arise following issuance of the generic letter.

CONCLUSIONS

The special review team found the following regarding the use of Thermo-Lag by the licensees:

- The fire resistance ratings and the ampacity derating factors for the Thermo-Lag 330-1 fire barrier system are indeterminate.

- Some licensees have not adequately reviewed and evaluated the fire endurance test results and the ampacity derating test results used as the licensing basis for their Thermo-Lag fire barriers to determine the validity of the tests and the applicability of the test results to their plant designs.

- Some licensees have not adequately reviewed the Thermo-Lag fire barriers installed in their plants to ensure that they meet NRC requirements and guidance, such as that provided in Generic Letter 86-10, "Implementation of Fire Protection Requirements," April 24, 1986.

- Some licensees used inadequate or incomplete installation procedures during the construction of their Thermo-Lag barriers.

RECOMMENDATIONS

Based on its findings regarding the use of Thermo-Lag fire barriers by the commercial nuclear power industry and the relative safety significance of the findings, the special review team recommended to the Director, NRR, that the NRC:

- Advise industry of the staff's concerns regarding Thermo-Lag fire barriers through the Nuclear Utilities Management and Resources Council,

- Provide the industry with the results of the team's plant site visits and the specific concerns and technical issues regarding Thermo-Lag barriers that were identified by the review team,

- Issue a generic letter that discusses the concerns and requires the licensees to provide information needed by the staff to verify compliance with the NRC's requirements, and

- Review the licensees' corrective action plans for resolving any plant-specific Thermo-Lag fire barrier design, evaluation, and installation issues.

APPENDIX A

LIST OF ATTACHMENTS

1. Nuclear Power Plants Identified by TSI as Using Thermo-Lag 330-1 Fire Barriers.
2. Fire Endurance Test Reports Involving Thermo-Lag 330-1 Fire Barrier Systems.
3. Ampacity Derating Test Reports Involving Thermo-Lag 330-1 Fire Barrier Systems.
4. River Bend History and Documentation Reviewed by Special Review Team.
5. Comanche Peak History and Documentation Reviewed by Special Review Team.
6. WNP2 History and Documentation Reviewed by Special Review Team.
7. Susquehanna History and Documentation Reviewed by Special Review Team.

APPENDIX B

ACRONYMS AND INITIALISMS

3M	Minnesota Mining and Manufacturing Company
ANI	American Nuclear Insurers
APCSB	Auxiliary and Power Conversion Systems Branch
APS	Arizona Public Service
ASTM	American Society for Testing and Materials
BTP	Branch Technical Position
CEI	Cleveland Electric Illuminating Company
CFR	U.S. Code of Federal Regulations
CMEB	Chemical Engineering Branch
CPSES	Comanche Peak Steam Electric Station
CR	Condition Report
CRGR	Committee for the Review of Generic Requirements
CTL	Construction Technology Laboratories, Incorporated
EDO	Executive Director for Operations
F	Fahrenheit
FPPSC	Fire Protection Policy Steering Committee
FSAR	Final Safety Analysis Report
FR	*Federal Register*
GDC	General Design Criterion
GL	Generic Letter
GSU	Gulf States Utilities
HVAC	Heating, ventilation, and air conditioning
IEEE	Institute of Electrical and Electronics Engineers
IN	Information Notice
IPCEA	Insulated Power Cable Engineers Association
IR	Inspection Report
ITL	Industrial Testing Laboratory, Incorporated
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Technology
NRC	U. S. Nuclear Regulatory Commission
NRR	Office of Nuclear Reactor Regulation

NUFPG	Nuclear Utility Fire Protection Group
NUMARC	Nuclear Utilities Management and Resources Council
OIE	Office of Inspection and Enforcement
OPPD	Omaha Public Power District
PNPP	Perry Nuclear Power Plant
PP&L	Pennsylvania Power & Light Company
PSB	Power Systems Branch
QA	Quality Assurance
QC	Quality Control
RBS	River Bend Station
SAIC	Science Applications International Corporation
SER	Safety Evaluation Report
SSER	Supplemental Safety Evaluation Report
SSES	Susquehanna Steam Electric Station
SwRI	Southwest Research Institute
TC	Thermocouple
TER	Technical Evaluation Report
TSI	Thermal Science, Incorporated
TU	Texas Utilities Electric Company
UL	Underwriters Laboratories, Incorporated
VIB	Vendor Inspection Branch
WNP2	Washington Nuclear Project, Unit 2
WPPSS	Washington Public Power Supply System

ATTACHMENT 1

NUCLEAR POWER PLANTS IDENTIFIED BY TSI AS USING THERMO-LAG 330-1 FIRE BARRIERS[1]

Arkansas Nuclear One	Hatch	San Onofre
Beaver Valley	Indian Point	Sequoyah
Braidwood	LaSalle	Shearon Harris
Browns Ferry	Limerick	Shoreham
Brunswick	Maine Yankee	South Texas
Byron	Millstone	Summer
Callaway	Nine Mile Point	Surry
Clinton	North Anna	Susquehanna
Comanche Peak	Oyster Creek	Three Mile Island
D.C. Cook	Palisades	Trojan
Cooper	Palo Verde	Turkey Point
Crystal River	Peach Bottom	Vermont Yankee
Davis-Besse	Perry	Vogtle
Diablo Canyon	Prairie Island	WNP2
Duane Arnold	Rancho Seco	Watts Bar
Fermi	River Bend	Wolf Creek
Grand Gulf	St. Lucie	Zion

[1] Appendix VIII to letter from R. Feldman, TSI, to F.J. Miraglia, NRR, October 5, 1991.

ATTACHMENT 2

FIRE ENDURANCE TEST REPORTS INVOLVING THERMO-LAG 330-1 FIRE BARRIER SYSTEMS

This attachment lists the fire endurance test reports involving Thermo-Lag 330-1 fire barrier systems that were identified by the special review team. The reports shown in bold typeface were reviewed by the review team.

TEST DATE	REPORT
February 13, 1981, June 6, 1981, and June 7, 1981	These tests were included with TSI Technical Note 90181, August 1981 (1-hr cable trays and conduits)
April 27, 1981	**TSI Technical Note 8275-1, June 1981** (1-hr conduit for SSES)
April 28, 1981	**TSI Technical Note 8232-1, June 1981 and Rev. 1, June 1982** (1-hr cable tray for SSES)
September 17, 1981	**SwRI Report 03-6491, October 27, 1981** (1-hr cable tray and conduits for CPSES)
March 1982	**ITL Report 82-3-2, March 1982** (Fire wall)
May 17-28, 1982	**ITL Report 82-5-355A, June 1982** (1-hr cable trays and conduits for WNP2)
June 18-25, 1982	**ITL Report 82-5-355B, July 1982** (3-hr cable trays for WNP2)
August 10, 1982	**SwRI Report 01-7163, August 1982** (1-hr cable tray and conduit submitted to NRC by PP&L)
September 9-28, 1982	ITL Report 82-11-80, November 1982 (5 "generic" tests, 1-hr cable trays and conduits)
September 10 - October 12, 1982	ITL Report 82-11-81, November 1982 (5 "generic" tests, 3-hr cable trays and conduits)

November 1982	ITL Report 82-11-240 (1-hr conduit for WNP2)
October 22, 1982	ITL Report 82-11-241, November 1982 (1-hr conduit)
June 1, 1983	ITL Report 83-5-472A, July 1983 (1-hr cable tray)
June 7, 1983	ITL Report 83-5-472, Rev. 1, September 1983 (1-hr cable tray)
July 1984	ITL Report 84-6-109
December 13, 1984	ITL Report 84-12-181, Rev. 2, June 1985 (3-hr cable tray w/unistrut attachment protected for 18 inches from barrier penetration)
April 1985	ITL Report 85-4-235 (3-hr fire wall)
June 18, 1985	SwRI Project 01-8305-040b (CTP 1092A), October 31, 1985 (penetration seal test involving Thermo-Lag on conduit)
June 1985	ITL Report 84-12-294 (3-hr conduits)
June 1985	ITL Report 85-2-382, Rev. 1 (3-hr cable tray w/air drop and unistrut)
June 1985	ITL Report 85-1-106, Rev. 1 (Flex-conduit and cable tray)
June 1985	ITL Report 85-4-377, Rev. 1 (1-hr conduit)
June 1985	ITL Report 85-3-314 (1-hr conduit with Flexi-blanket)
June 1985	ITL Report 85-6-283 (3-hr conduit with Flexi-blanket)
January 1986	ITL Report 86-1-143 (1-hr conduit)

March 10-17, 1986	**3M Test 86-42 and 86-43, March 21, 1986** (1-hr side-by-side baseline test w/3m Interam)
June 13, 1986	**3M Test 86-73 (PJ-10), undated** (1-hr combined Interam/Thermo-Lag side-by-side and interface tests)
August 19, 1986	**3M Test 86-92 (PJ-16) (Twin Cities Testing #414186-1119), October 1986** (3-hr Interam/Thermo-Lag interface test for WPPSS)
August 1986	**ITL Report 86-8-207** (1 hr conduit)
September 17, 1986	**3M Test 86-102 (PJ-21), undated** (1-hr Interam/Thermo-Lag side-by-side and interface tests)
September 28, 1986	**Bisco Report 748-218, September 28, 1986** (1-hr small-scale)
October 21, 1986	**3M Test 86-112 (PJ-24), October 1986** (1-hr Interam/Thermo-Lag interface test)
November 21, 1986	**CTL Report CRE134/4324, January 1987** (1-hr Interam/Thermo-Lag interface)
January 1987	**ITL Report 86-11-155, Rev. 1** (1-hr air duct)
February 1987	**ITL Report 86-10-49, Rev. 1** (1-hr conduit)
March 31, 1987	**ITL Report 87-3-606, April 1987** (3-hr conduits, WNP2 in-situ low pressure extrusion application technique)
April 1, 1987	**ITL Report 87-4-3, April 1987** (1-hr conduits, WNP2 in-situ low pressure extrusion application technique)
April 13, 1987	**Warnock-Hersey International Report WHI-495-PSV-0543, undated** (1-hr boxed conduit penetrated by pipe for APS)

May 7, 1987	**ITL Report 87-5-76, June 1987** (Repeat of 3M Test 86-92, 3-hr Interam/Thermo-Lag interface test)
May 7, 1987ITL Report 87-5-77, Rev. 1, June 1987	(1-hr cable tray w/unistrut protected for 9 inches from barrier penetration)
March 9, 1988	**Raw data from ITL test, no test report prepared** (3-hr cable tray, RBS "as-installed")
July 30, 1988	**ITL Report 88-07-5982, September 29, 1988** (3-hr cable tray, RBS "as-installed")
April 14, 1989	**CTL Report 240056-824/824-63, September 1989 and Rev. 1, October 1989** (3-hr Al cable tray)
May 5, 1989	**CTL Report 240056-824/824-59, August 1989 and Rev. 1, October 1989** (3-hr Al cable tray)
May 5, 1989	**CTL Report 240056-824/824-75, November 1989** (3-hr cable tray)
May 5, 1989	**CTL Report 240056-824/824-77, November 1989** (3-hr Al cable tray)
October 26, 1989	**SwRI Report 01-2702, May 1991 (Final Draft)** (3-hr Al cable tray for GSU)
November 20 - December 18, 1990	**ITL, Preliminary Draft Test Report, January 1991** (1-hr and 3-hr in-situ and upgrade tests for RBS)

ATTACHMENT 3

AMPACITY DERATING TEST REPORTS INVOLVING THERMO-LAG 330-1 FIRE BARRIER SYSTEMS

This attachment lists the ampacity derating test reports involving Thermo-Lag 330-1 fire barrier systems that were reviewed by the special review team.

These tests were conducted by ITL, TSI, UL, and SwRI. The table includes the test report number, date of test report, description of the test, and the ampacity derating factors reported in the report. A consensus ampacity derating test standard does not exist. Therefore, the results of the individual tests should not be compared without a detailed review of the test article configuration.

REPORT NO.	DATE	TEST DESCRIPTION	DERATING FACTOR (%)
TSI Technical Note 92981	09/81	14" steel cable tray 600 volt power cable 210' #00 AWG 0.562" D 2820' #10 AWG 0.215" D	 7 10
TSI Technical Note 111781	02/85 (Rev 5) 11/81 (Orig)	1-hr 2" steel conduit 600 volt power cable 21' #00 AWG 0.562" D	 7.47
ITL 82-355-F1	01/85 (Rev 1) 07/82 (Orig)	1-hr solid bottom tray 600 volt power cables 210' #00 AWG 0.562" D 2820' #10 AWG 0.215" D	 12.48 12.39
ITL 82-5-355C	07/82	3-hr ladder back tray 1000 volt power cable 1485' #08 AWG 0.286" D 870' #04 AWG 0.377" D 300' #2/0 AWG 0.617" D	 16.15 16.86 17.68
ITL 82-5-355F	07/82	3-hr ladder back tray 1000 volt power cable 1485' #8 AWG 0.286" D 870' #4 AWG 0.377" D 300' #2/0 AWG 0.617" D	 16.15 16.86 17.68

REPORT NO.	DATE	TEST DESCRIPTION	DERATING FACTOR (%)
ITL 84-3-275A	03/84	3-hr ladder back tray 1000 volt power cables 1485' #8 AWG 0.286" D 870' #4 AWG 0.377" D 300' #2/0 AWG 0.617" D	 20.55 19.24 20.07
ITL 84-10-5	10/84	3-hr 2" steel conduit 600 volt power cable 21' #00 AWG 0.562" D	 9.72
SwRI Project 01-8818-208/209a (3M PJ-19)	08/86	1-hr 24" steel ladder back tray #6 AWG 0.75" D	 37.4
SwRI Project 01-8818-208/209c (3M PJ-19)	10/86	1-hr 4" steel conduit #6 AWG 0.75" D	 1.27
UL 86NK23826 File R6802 (South Texas)	01/87	1-hr 24" ladder back tray 3-hr 24" ladder back tray 2000 volt power cable 2980' #6 AWG 1" D	28.04 31.15
UL 86NK23826 File R6802 (South Texas)	01/87	1-hr 4" steel conduit 3-hr 4" steel conduit 2000 volt power cable 294' #6 AWG 1" D	0 9.4

ATTACHMENT 4

RIVER BEND HISTORY AND DOCUMENTATION REVIEWED BY SPECIAL REVIEW TEAM (Docket No. 50-458)

June 30, 1982	GSU submitted comparison of fire protection program to Appendix R with FSAR amendment.
April 6, 1983	Draft SER on fire protection. Safe shutdown and fire barriers remained open items.
May 1984	Safety Evaluation Report (NUREG-0989) issued. Safe shutdown still under review. Page 9-42 stated that all cable trays are steel construction.
August 9, 1984	TSI letter to Stone and Webster provided 1-hour, 3-hour, ampacity derating, and seismic qualification information .
September 24, 1984	First purchase order for TSI from GSU.
April 4, 1985	Onsite audit of fire protection by NRR. Fire barrier wrap installation not completed.
May 10, 1985	3-hour qualification tests of "as-installed" internal and external aluminum conduit seals conducted at SwRI by B&B/Promatec and GSU. (Thermo-Lag does not appear to have been used on test articles.) Reference SwRI Project Report 01-8305-040a.
June 18, 1985	3-hour fire test of flex conduit penetration seals conducted at SwRI by B&B/Promatec and GSU. Thermo-Lag on conduit disintegrated during the test. Reference SwRI Project Report 01-8305-040b, July 1985 and Promatec Report CTP-1092a, October 31, 1985. (According to Promatec Report CTP-1092b, GSU concluded that this test provided conclusive evidence that Thermo-Lag protection is not required to maintain flex conduit integrity.)
June 20, 1985	June 18, 1985 test rerun without Thermo-lag. Reference SwRI Project Report 01-8305-040c, August 1985 and Promatec Report CTP-1092b, November 1, 1985.
July 26, 1985	GSU submitted SwRI Report 01-8305-040a, June 1985 to NRC to justify Appendix R deviation for aluminum conduit seals.

August 1985	SSER 3 issued. Deviation granted for sealing inside aluminum conduits based on SwRI test report submitted to NRC on July 26, 1985. Also granted deviation on delay of installation of fire wrap on spent fuel cooling system and service water.
February 23, 1987	Condition Report 87-0236 initiated following review of February 3 1987, surveillance test results. Sixty percent of the barriers failed the acceptance criteria. This CR superseded by CR 87-0236A.
March 12, 1987	Condition Report 87-0236A initiated. Identified specific examples of deficient fire barriers. Cracks, wear conditions, unsealed joints, unprotected supports, and 18 inch criteria not met. Breakdown of vendor QC inspection program identified as root cause.
March 25, 1987	LER 87-005 submitted by GSU. Described fire barrier deficiencies, including incomplete construction, found during surveillance test procedure. Hourly fire watch patrols established in accordance with Tech Spec 3/4.7.7. GSU committed to make 100 percent visual inspection.
April 30, 1987	Internal RBS memo summarized the results of 100 percent fire barrier inspections committed to in LER 87-005.
May 20, 1987	Internal RBS memo from D. Beauchamp (GSU QC) on insufficient training given by TSI on May 18-19, 1987.
June 30, 1987	Condition Report 87-0698 initiated. Inspections required by CR 87-0236A and LER 87-005 found Thermo-Lag installations that did not conform to GSU requirements.
July 1, 1987	Condition Report 87-0705 initiated. Inspections required by CR 87-0236A and LER 87-005 found removal of ribs from Thermo-Lag panels during installation. This resulted in gaps in stress skin where ribs were cut.
July 13, 1987	Condition Report 87-0745 initiated. Inspections required by CR 87-0236A and LER 87-005 found stress skin and ribs removed from fire barriers. During discussions with GSU, TSI stated that removal would have little or no effect.
July 24, 1987	GSU issued purchase order (7-ON-72055) to TSI to conduct 3-hour fire endurance tests with stress skin removed.
August 20, 1987	TSI prepared engineering test plan for 3-hour fire endurance test for GSU.

January 6, 1988	Condition Report 88-0012 initiated. During installation of additional cables, control building cable tray found to have stress skin and ribs removed.
January 19, 1988	GSU letter to TSI asked for confirmation that use of 1-hour Thermo-Lag panel is acceptable with ribs and stress skin removed. (GSU referenced CR 88-0012.)
January 22, 1988	TSI letter to GSU submitted ITL Report 82-11-241 (direct spray application on conduit) and ITL Report 83-5-472A (direct spray, etc. to cable tray) to justify installation of 1-hour barriers without stress skin.
February 1, 1988	GSU provided comments on test plan to TSI. GSU stated that acceptance criteria should be 325 °F above ambient. (NRC criteria is 250 °F above ambient.)
February 4, 1988	Interim disposition prepared by GSU for CR 88-0012. Stated that "as-installed" 1-hour barriers were "qualified for use as is" based on TSI's January 22, 1988 letter. See August 29, 1990.
February 8, 1988	Revision I to TSI test plan for 3-hour test.
February 23, 1988	TSI letter to GSU provided Revision I to TSI test plan for comment.
March 9, 1988	3-hour fire test conducted on "as-installed" configuration (12 inch wide steel tray, stress skin and ribs removed) at TSI for GSU. Test terminated due to loss of control of the furnace. Circuit integrity lost at 2 hours and 15 minutes. No test report drafted. However, thermocouple records provided to NRC by TSI attorney. (July 29, 1988 test was intended as repeat of this test.)
March 15, 1988	GSU initiated audit of RBS fire protection program.
April 21, 1988	Internal GSU memo addressed results of March 1988 fire protection program audit. The effectiveness of fire barrier inspection surveillance test procedure (STP) was questioned (pg 8). LER 88-009 is referenced.
June 22, 1988	Revision II to TSI test plan for 3-hour test.
July 22, 1988	CR 88-0594 initiated.
July 29, 1988	3-hour fire test conducted on "as-installed" configuration (12-inch wide steel tray, stress skin and ribs removed) at TSI for GSU. Test specimen failed on temperature, circuit integrity, and structurally. Reference ITL Report 88-07-5982, September 29, 1988.

July 29, 1988	Condition Reports 88-0607 and 88-0608 initiated. Addressed 3-hour test failure at TSI.
October 11, 1988	TSI letter to GSU transmitted final test report ITL 88-07-5982, September 29, 1988. 325 °F exceeded at 90 minutes, circuit integrity failed at 115 minutes.
December 12, 1988	SwRI letter to GSU transmitted Addendum 1 to proposal for 3-hour fire endurance tests of "as-installed" and proposed "repaired" configurations.
January 1989	GSU initiated test program with SwRI to qualify "as-installed" Thermo-Lag fire barriers.
February 3, 1989	GSU letter informed TSI of plans to conduct fire tests at SwRI during March 1989 and provided copy of SwRI test plan.
March 3, 1989	TSI letter to GSU discussed developmental tests of proposed design modifications conducted at TSI and tests scheduled for April 1989 at CTL. TSI offered to exchange new 3-hour panels for used RBS materials and stated that tests at SwRI would not be cost effective. Letter acknowledged "prerequisites of government regulatory agencies," but stated that temperature measurements are not required and are for information purposes only.
Spring 1989	GSU put testing at SwRI on hold in favor of testing with TSI.
March 16, 1989	Condition Report 89-0204 initiated. Stress skin and ribs found removed from Thermo-Lag fire barriers.
March 31, 1989	GSU letter to TSI discussed upcoming testing at CTL. GSU asked to observe construction of test specimen and to witness the test. LER 88-009 referenced.
April 7, 1989	TSI letter to GSU provided details of upcoming (May 5, 1989) tests at CTL.
April 14, 1989	3-hour fire test conducted at CTL on 30-inch wide aluminum cable tray. Test passed. Rig constructed by TSI. CTL witnessed installation. Reference CTL Report 824-63 and Revision 1.
April 17, 1989	LER 89-009 submitted to NRC describing removal of ribs and stress skin from 1-hour Thermo-Lag fire barriers during construction. Fire watches established. 100 percent inspection planned.

May 5, 1989	3-hour fire endurance tests conducted at CTL on "as-designed" 30-inch wide aluminum cable trays. GSU witnessed initial construction of article at TSI. Test passed. However, GSU questioned application of extra coating on test article by TSI, which GSU could not reproduce. Reference CTL Reports 824-59 and 824-77.
Summer 1989	Additional questions raised by GSU on original qualification of Thermo-Lag.
August 1989	GSU re-established test program with SwRI.
October 12, 1989	RBS QC issued memo describing construction of 1-hour and 3-hour fire barrier test assemblies for October 1989 tests at SwRI. 1-hour barrier had ribs and stress skin removed, 3-hour barrier was "as-designed."
October 13, 1989	GSU letter invited TSI to inspect cable tray test assemblies prior to October 26, 1989 fire endurance tests at SwRI.
October 23, 1989	TSI letter informed GSU that they could not inspect test articles at SwRI.
October 26, 1989	3-hour fire test of 30-inch wide "as-designed" aluminum cable tray conducted at SwRI. Promat and Thermo-Lag tested. GSU constructed test articles. Thermo-lag failed at steel support and tray radius in less than one hour. (Final report not issued as of April 1992.)
October 26, 1989	1-hour fire test at SwRI. Documentation not available to NRC staff as of March 1992.
October 26, 1989	Condition Report 89-1144 initiated. "Qualification testing of 3-hour fire rated material fails to meet requirements of 10CFR50 Appendix R." All 1-hour and 3-hour Thermo-Lag barriers considered inadequate.
October 31, 1989	TSI letter to GSU transmitted CTL Report 824-59 (05/05/89 test) and CTL Report 824-63 (04/14/89 test). Stated thickness of panels was 1.250 inch +/- 0.250. Enclosed Tech Note 20684, Revision V with addendum (Tech Note 20684-AL) for aluminum cable trays.
November 8, 1989	TSI met with GSU to review SwRI test results.
November 9, 1989	GSU letter informed TSI of October 26, 1989 test results at SwRI and asked for evaluation. Letter states that thermocouple data for 1-hour and 3-hour SwRI tests were previously submitted to TSI.

November 9, 1989	TSI letter to GSU discussed test results. TSI claimed that Thermo-Lag/Promat interface and incorrect installation (gap widths, stress skin separation) caused the October 1989 SwRI test failure. TSI concluded that test was not valid.
November 10, 1989	GSU memorandum summarized November 10, 1989 meeting at RBS with TSI to discuss test failures. GSU memo stated that Part 21 reportability was being evaluated.
November 14, 1989	TSI letter to GSU confirmed plan for plant walkdowns by TSI.
November 17, 1989	GSU letter to TSI provided construction details of fire barriers installed at RBS for TSI review.
December 7, 1989	GSU met with TSI at RBS to discuss corrective actions for CR 89-1144.
December 7, 1989	TSI letter to GSU discussed upgrades and qualification testing.
December 18, 1989	TSI letter to GSU provided meeting summary from December 7, 1989 meeting. Provided TSI proposed upgrades and stated that ampacity reduction analysis had been performed.
December 18, 1989	GSU memorandum provided results of December 6/7, 1989 meeting with TSI at RBS.
December 20, 1989	GSU submitted Informational Report to NRC regarding testing of Thermo-lag fire barriers. Discussed questions concerning tray materials, joint sealing methods, and size of test configurations. CR 89-1144 referenced. GSU stated that their investigation revealed generic concerns and that the "test results are indeterminate."
January 9, 1990	Revision to December 20, 1989 Informational Report. Revised fire watch status. October 1989 SwRI test results still under evaluation by GSU. Committed to update report by March 31, 1990.
January 11, 1990	GSU letter to TSI stated that October 26, 1989 test failure would have occurred on tray without barrier interface problem. Also questioned gap widths and joint sealing.
January 26, 1990	NRC safe shutdown inspection (90-02) at RBS. Violation identified concerning FHA requirement not implemented by procedure.
February 7, 1990	Condition Report 90-0095 initiated. Thermo-Lag fire barriers in pipe tunnel found to have surface cracks on visual inspection. Fire watches established. Cracks to be patched.

February 8, 1990	Condition Reports 90-0101 and 90-0106 initiated. During surveillance inspection, deficiencies (small holes, cracks and unfilled seams) were found in Thermo-Lag fire barriers.
March 8, 1990	LER 90-003 submitted. Stated that surveillances conducted in February identified barrier deficiencies. References CRs 90-0094, 90-0095, 90-0101, and 90-0106. Committed to supplemental response to this LER and the January 9, 1990 Informational Report by July 15, 1990.
March 9, 1990	GSU met with TSI at RBS to discuss tests required to qualify "as-installed" barriers and potential repairs and upgrades.
March 19, 1990	TSI telecopied preliminary test procedure for November 1990 and December 1990 tests to GSU for comment. (No copy.)
April 1990	Test plan completed by TSI.
July 12, 1990	LER 90-003 Rev. 1 submitted to NRC. Stated that 1-hour and 3-hour fire tests are planned to (1) evaluate "as installed" barriers and (2) develop repair methods.
July 17, 1990	GSU issued purchase order (90-G-70456) to TSI to conduct 1-hour and 3-hour fire tests.
August 20, 1990	GSU and TSI agreed on schedule for construction and testing (for November 1990 and December 1990 tests at TSI).
August 27, 1990	TSI began assembly of test articles for November 1990 and December 1990 tests.
August 29, 1990	GSU memorandum stating that fire tests (October 1989 tests at SWRI?) failed to verify use of Thermo-Lag panels with ribs and stress skin removed for 1-hour fire rating. Reference TSI's January 22, 1988 letter.
September 10, 1990	GSU QC inspector arrived at TSI facilities to examine and monitor installation of test articles for 11/90 and 12/90 tests at TSI.
November 19, 1990	1-hour and 3-hour fire test program started at TSI facilities on "as-installed" and "upgraded" barrier configurations.
December 18, 1990	Testing completed at TSI. 1-hour and 3-hour "as-installed" conduits and cable trays failed. Some "upgrades" (addition of 1/4-inch thick panels) passed based on GSU acceptance criteria. However, the 3-hour cable tray upgrade failed.

December 22, 1990	ITL letter to GSU summarizing results of November 1990 and December 1990 tests performed by ITL at TSI lab.
February 4, 1991	LER 90-003 Rev. 2 submitted to NRC. Discussed ITL/TSI November and December 1990 fire tests. "As-installed" 1-hour and 3-hour tests failed. Additional 1-hour and 3-hour tests of "upgraded" configurations passed (according to GSU criteria) except for 3-hour cable tray.
April 26, 1991	Internal RBS memo provided information necessary to evaluate methods for installing fire barriers.
May 15, 1991	LER 91-008 submitted to NRC. Fire wrap was not installed on electrical cables per the FHA since plant startup. Found in response to review of FHA by contractor following up January 1990 NRC inspection. Corrective action not yet determined. References NRC Inspection Report 50-458/90-02.
May 24, 1991	SwRI letter to GSU transmitted draft final report 01-2702 for October 26, 1989 3-hour fire test to GSU for comment.
June 26, 1991	GSU letter to SwRI provided comments on SwRI Report 01-2702.
June 28, 1991	LER 90-003 Rev. 3 submitted to NRC. Acceptable upgrade for 3-hour cable tray protection has not been found. Several alternatives being explored by GSU. Fire watches remain in place. Committed to supplemental response by December 31, 1991.
August 6, 1991	Information Notice 91-47, "Failure of Thermo-Lag Fire Barrier Material to Pass Fire Endurance Test," issued.

(The special review team reviewed additional documents at the RBS site during its October 1991 site visit that are not listed here.)

ATTACHMENT 5

COMANCHE PEAK HISTORY AND DOCUMENTATION REVIEWED BY SPECIAL REVIEW TEAM (Docket No. 50-445)

September 17, 1981	One hour fire endurance test conducted at SwRI. Test assembly built by TSI. ANI standard used. 18" cable trays. Passed based on circuit integrity. Highest cable surface temperature 260 °F. Air drop reached 554 °F.
October 27, 1981	Test report SwRI Project 03-6491, "Fire Qualification Test of a Protective Envelope System."
October 29, 1981	Copy of SwRI test report hand delivered to NRC.
November 16, 1981	NRC memorandum from Johnston to Tedesco approving SwRI test report.
November 18, 1981	Letter from TU (Schmidt) to NRC (Tedesco) confirming that report was hand delivered on October 29, 1981, and requesting NRC to review the test report.
December 1, 1981	Letter from NRC (Tedesco) to TU (Gary) stating that on October 29, 1981, a copy of the test report was received by NRC. The test report was evaluated and approved.
December 7, 1981	Test report SwRI Project 03-6491 docketed in letter to NRC.
October 4, 1983	TU letter to NRC regarding need for protection of cable tray supports.
October 19-23, 1987	Fire protection program inspection conducted (87-22).
September 6, 1988	Technical Evaluation Report for CPSES fire protection program (SAIC).
September 15, 1989	TU verbally notified NRC concerning 50.55e on Thermo-Lag.
October 12, 1989	TU letter to NRC issuing 10CFR50.55e on site fabricated Thermo-Lag panels. Site fabricated Thermo-Lag panels were found with localized dry film thickness of less than 1/2 inch. Also seams and joints were found less than 1/2 inch.
October 26, 1989	TSI letter to TU stating that localized thickness variations to 3/8 inch are acceptable for less than 2% of the panel.

November 3, 1989	TSI letter to TU stating that localized thickness variations are acceptable for conduits.
December 1, 1989	NRC Inspection Report 89-71 which discusses Thermo-Lag thickness issue.
January 3-30, 1990	NRC Inspection 90-05 conducted. Reviewed Thermo-Lag allegations associated with receipt inspections.
May 17, 1990	Civil Penalty issued concerning Thermo-Lag.
June 1, 1990	TU response to Civil Penalty.
July 13, 1990	TU letter to Region IV discussing acceptance criteria for Thermo-Lag panels.
July 20, 1990	Region IV letter to TU acknowledging July 13, 1990, letter.

(The special review team reviewed additional documents at the CPSES site during its November 1991 site visit that are not listed here.)

ATTACHMENT 6

WNP2 HISTORY AND DOCUMENTATION REVIEWED BY SPECIAL REVIEW TEAM (Docket No. 50-397)

December 28, 1981	Letter from WPPSS to NRC summarizing telecon of December 11, 1981 between NRC, WNP2, Bechtel, and Burns & Roe on 3-hour barriers.
May 17-28, 1982	1-hour fire endurance test conducted at TSI. ITL Report 82-5-355A. Temperature reached 325F, however TSI indicated acceptance of barrier because no loss of circuit integrity occurred.
June 18-25, 1982	3-hour fire endurance test conducted at TSI. ITL Report 82-5-355B. According to report, all configurations passed circuit integrity and temperature.
August 2, 1982	WNP2 letter concerning fire endurance testing.
September 20, 1982	WNP2 submitted ITL Report 82-5-355A for NRC review. Results of the review were not formally transmitted to WNP2.
September 30, 1982	Telecon between WNP2 and NRC on test report data.
October 4, 1982	TSI letter to NRR responding to questions on tests conducted at TSI.
October 4, 1982	WNP2 response to NRC questions of September 30, 1982.
October 5, 1982	WNP2 submitted ITL Report 82-5-355B for NRC review.
November 15, 1982	Additional copies of 355B transmitted to NRC.
December 27, 1982	Draft SER on fire protection.
April 26, 1983	Revision II to TSI Engineering Test Plan for direct spray on cable tray.
May 1983	SSER #3 issued for WNP2. Page 9-3 approved the 3-hour TSI Thermo-Lag as fire rated barrier. States that material is capable of limiting temperature rise to not more than 250 °F above ambient.
June 7, 1983	ITL Test 83-5-472 conducted for 1-hour direct application method.
January 17, 1984	Draft SSER on fire protection.

March 3-7, 1986	Fire protection inspection (86-05). Unresolved items identified concerning protection of cable tray supports, intervening combustibles not covered, and unwrapped cable trays.
April 15, 1986	Enforcement Conference on fire protection.
May 9, 1986	Letter to RV from WNP2 responding to enforcement conference on Thermo-lag installation on supports. States problem was judgmental error.
July 29, 1986	WNP2 letter revising commitment to correct cable tray support protection to be completed in August 1986.
August 19, 1986	3-hour fire endurance test of 3M/TSI interface conducted at 3M. TSI failed 325 °F. Installed by certified installers.
September 23, 1986	Revision I to TSI Engineering Test Plan for 3-hour "In-situ" test of extrusion procedure.
October 8, 1986	WNP2 determined that cable derating calculations for service water did not consider routing in duct banks (LER 86-003). Further review identified Thermo-lag not taken into account. 31.5 percent derating used. No cables replaced.
October 20, 1986	3M letter to WPPSS enclosing test report for 3M/TSI interface test.
January 12-15, 1987	Fire Protection Inspection (87-02). Ampacity reviewed and closed. Violation concerning application method of Thermo-lag in untested configurations.
March 25, 1987	Revision II to TSI Engineering Test Plan for 3-hour "in-situ" test of extrusion procedure. Revision I to 1-hour test plan.
March 31, 1987	3-hour fire endurance test of 2" conduit with Thermo-Lag applied by extrusion. Conduit failed temperature and circuit continuity.
April 1, 1987	1-hour fire endurance test of 4" conduit with Thermo-Lag applied by extrusion.
April 13, 1987	WNP2 submittal of Fire Protection Re-evaluation. Discusses Thermo-lag fire barrier adequacy. States that fire tests to be conducted by April 1987 of untested configurations. Also states ampacity issued closed, but discusses 9.4 percent and 17.7 percent derating.
May 7, 1987	3M/TSI interface conducted by TSI for WNP2.

June 6-10, 1988	Fire protection inspection (88-16). Closes intervening combustible issue based on TSI letter.
February 14, 1990	SAIC technical evaluation report on WNP2 re-evaluation of fire protection program.
March 28, 1991	Application deficiencies noted on Thermo-lag barriers. Inadequate thickness and incomplete transition from spray to board.
August 23, 1991	Letter to J. Kittler from TSI responding to Information Notice 91-47.

(The special review team reviewed additional documents at the WNP2 site during its November 1991 site visit that are not listed here.)

ATTACHMENT 7

SUSQUEHANNA HISTORY AND DOCUMENTATION REVIEWED BY SPECIAL REVIEW TEAM (Docket No. 50-387)

March 25, 1981	Meeting between NRC staff and PP&L to discuss fire protection issues.
March 26, 1981	SER input, with several open items, including the battery room.
March 26, 1981	Licensee letter committing to install 2-hour fire rated ceiling and 2-hour enclosure in battery room.
April 15, 1981	SSER with only open item being alternate shutdown system.
June 19, 1981	Licensee informed NRC of testing of Quelcor cable wrap in July 1981.
October 26, 1981	Licensee letter submitted two test reports for cable wrap material. Included April 1981 and August 1981 TSI test reports.
February 9, 1982	Licensee letter with proposed modifications to the fire protection program including a 1-hour rated cable wrap for battery room and remote shutdown panel with only manual suppression and detection. Letter referenced previous NRC acceptance of Comanche Peak barrier in December 1981.
March 11, 1982	Meeting between the NRC staff and PP&L to discuss February 9, 1982 submittal. NRC requested a copy of the TSI test results, as installed, and installation procedure.
April 16, 1982	SSER accepted PP&L's February 9, 1982 proposal, but required an as installed test or automatic extinguishing system. "The proposed cable wrap was previously accepted based on independent laboratory test data . . . The applicant verbally stated that the manufacturer's recommended installation procedure had not been followed when the cable wrap was installed. We do not accept the material as a 1-hour fire barrier when installed differently."
May 12, 1982	Licensee provided TSI Technical Reports 8232-1 and 8275-1 (June 1981) and Bechtel installation procedures.
June 9, 1982	Licensee provided TSI letter, June 3, 1982, in response to NRC questions on tests submitted on May 12, 1982. TSI report "revised" to correct some noted errors.

June 28, 1982	SSER stating that TSI tests submitted by PP&L were not performed in accordance with adequate QA procedures and therefore not acceptable. The application procedure was also not clearly specified. Problems were noted with the accuracy of the furnace temperature control and thermocouples. The licensee should conduct an ASTM E-119 test at "an approved testing laboratory," or install automatic fire extinguishing system.
July 6, 1982	Licensee committed to perform a 1-hour test of TSI material using the Comanche Peak test procedure. Material to be installed per PP&L procedures submitted on May 12, 1982.
July 23, 1982	Licensee submitted copy of Test Specification.
August 25, 1982	Licensee submitted test report from SWRI. Test conducted on August 10, 1982.
August 31, 1982	Licensee committed to modify the installation of cable wrap on cable trays by adding fiberglass armoring in accordance with TSI Technical Note 80181, Revision I, August 1981.
September 15, 1982	SSER approved the 1-hour fire barrier installation. August 1982 test was only accepted for conduit. The cable trays exceeded 325F criteria, which was applied. The approved method of installation is based on CPSES submittal of October 27, 1981, and was referenced.