UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555

March 16, 1994

NRC INFORMATION NOTICE 94-22: FIRE ENDURANCE AND AMPACITY DERATING TEST RESULTS FOR 3-HOUR FIRE-RATED THERMO-LAG 330-1 FIRE BARRIERS

Addressees

All holders of operating licenses or construction permits for nuclear power reactors.

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice to inform licensees of the preliminary results of fire endurance and ampacity derating tests of Thermo-Lag 330-1 (Thermo-Lag) fire barriers conducted by the NRC at Underwriters Laboratories, Incorporated (UL). It is expected that recipients will review the information for applicability to their facilities and consider actions as appropriate to avoid similar problems. However, suggestions contained in this information notice are not NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances

As part of its continuing evaluation of Thermo-Lag fire barrier performance, the NRC Office of Nuclear Reactor Regulation (NRR) conducted three full-scale fire endurance tests and one full-scale ampacity derating test of 3-hour fire-rated Thermo-Lag fire barriers. The principal objective of the tests was to evaluate the performance of the barriers against the results of tests previously reported by Thermal Science, Incorporated (TSI, the vendor).

Sandia National Laboratories (SNL), Albuquerque, New Mexico, provided technical assistance by designing and executing the test program and preparing the test report. The base test specimens were constructed and instrumented at SNL. The test specimen fire barriers were constructed at UL by trained Thermo-Lag installers under the direction of SNL during October and November 1993. The tests were conducted at UL under the direction of the NRC and SNL during December 1993. The NRC staff informed the Nuclear Management and Resources Council (NUMARC) of the test results during a public meeting at NRC Headquarters on February 9, 1994. The final test results will be documented in SNL Report SAND94-0146, "An Evaluation of the Fire Barrier System Thermo-Lag 330-1." The staff will place this report in the NRC Public Document Room after it is completed. The staff expects the report to be completed during April 1994.

Discussion

Each of the four base test articles was a U-shaped configuration laying sideways which duplicated configurations, material specifications, dimensions, orientations, cable types and fills, and instrumentation, previously tested and reported by the vendor. A single layer of cables was installed in each of the fire test articles in accordance with the types and placements reported in the vendor's test reports. The cable fill for the ampacity derating test article is discussed under the "Ampacity Derating Test" section of this information notice.

Each of the base test articles was protected by a 3-hour fire barrier formed from two layers of nominal ½-inch-thick Thermo-Lag 330-1 preformed panel. SNL purchased the Thermo-Lag preformed panels and trowel-grade material used to construct the test article fire barriers from Texas Utilities Electric Company (TU Electric). TU Electric performed a source inspection of the materials at TSI and the NRR Vendor Inspection Branch conducted a receipt inspection of the materials at the Comanche Peak Steam Electric Station when TU Electric delivered the materials to SNL.

The fire barriers for Test Articles 1, 2, and 4, were constructed in accordance with TSI Technical Note 20684, Revision V, "Thermo-Lag 330 Fire Barrier System Installation Procedures Manual Power Generating Plant Application," November 1985. The fire barrier for Test Article 3 was constructed in accordance with the methods used by the vendor for Test Article 4 of TSI 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. Table 1 summarizes the test article characteristics.

The stress skin (an embedded wire mesh) for the inner barrier layer faced toward the cable tray. The stress skin for the outer layer faced away from the cable tray. All joints and seams were offset. The edges of the individual panel sections were buttered with trowel-grade Thermo-Lag 330-1 material before they were joined and secured. This assembly technique, as opposed to the dry-fit method, ensured that each joint and seam was filled to its full thickness with Thermo-Lag material. The individual barrier pieces for Test Articles 1, 2, and 4 were banded with stainless steel tie wire. The individual pieces for Test Article 3 were not banded. Instead, each seam and joint was reinforced with stainless steel wire stitches and laces. In addition, flanges were formed along the edges and butt joints of the outer layer. The flanges were bolted together with nominal ¼-inch-20 by 2-inch machine bolts and hex-nuts. After the barriers were installed, the test articles were cured for at least 30 days in a secure temperature-controlled environment before the tests were conducted.

The instrumentation used to record test data, including the SNL data logging equipment and the UL furnace-monitoring and control systems, was calibrated using equipment traceable to National Institute of Standards and Technology standards. NRC, SNL, and UL participated in and observed all four tests.

Fire Endurance Tests

The following performance capabilities were evaluated: (1) the ability of the Thermo-Lag barrier to keep the average temperature of the unexposed side of the barrier (as measured on the exterior surface of the cable trays) from rising more than 139 °C [250 °F] above the ambient temperature at the start of the test, (2) the ability to keep the temperature of any single thermocouple from rising more than 30 percent above the allowable average temperature rise (181 °C [325 °F]), (3) the ability to maintain circuit integrity during the fire exposure and hose stream test, (4) the ability to maintain the cables free of visible fire damage, and (5) the ability to remain intact during the fire and hose stream tests.

Temperatures were measured by Teflon-insulated Type K thermocouples installed on certain cables (as documented in the vendor test reports). In addition, thermocouples were installed on the cable tray side rails, on the unexposed side of the Thermo-Lag panels, and in the air space between the cables and the unexposed side of the Thermo-Lag panels. In keeping with the objective of evaluating thermal performance against test results previously reported by the vendor, the temperature results reported below were those measured by the thermocouples installed on the cables and the cable tray side rails. Four cables in each of the fire tests were connected to a separate low-voltage power supply (28-VDC, 1 Amp) which was configured to conduct circuit-to-circuit (conductor-to-conductor), circuit-to-ground (conductor-to-ground), and circuit-to-system (conductor continuity) integrity tests as documented in the vendor test reports.

The three fire endurance tests were performed in the UL column furnace. To facilitate duplication of the original TSI test configurations, UL modified the nominal 10-foot by 10-foot by 10-foot furnace to allow the test to be inserted into the furnace through one of the furnace walls. The standard time-temperature fire from American Society for Testing of Materials (ASTM) Standard E-119-75, "Standard Methods of Fire Tests of Building Construction and Materials," was followed. UL technicians operated the test furnace and recorded the furnace temperature data. SNL provided the instrumentation and data acquisition system for obtaining and recording the test temperature and circuit integrity data. During the fire exposure, visual observations were made through viewing ports located in three of the furnace walls. The following test results are summarized in Table 2.

Article 1 was tested on December 8, 1993. The ambient temperature at the start of the test was 19 °C [66 °F]. Therefore, the average temperature rise criterion for this test was 158 °C [316 °F] and the single-point temperature rise criterion was 200 °C [392 °F]. The single-point temperature criterion was exceeded about 1 hour and 5 minutes after the start of the test (1:05). A conductor-to-ground fault was detected at about 1:16 and the average temperature rise criterion was exceeded at about 1:20. The test was terminated at 2:30.

Article 2 was tested on December 7, 1993. The ambient temperature at the start of the test was 19 °C [66 °F]. Therefore, the average temperature rise criterion for this test was 158 °C [316 °F] and the single-point temperature rise criterion was 200 °C [392 °F]. The single-point temperature criterion was exceeded at about 0:55, a conductor-to-ground fault was detected at about 0:59, and the average temperature criterion was exceeded at about 1:03. The test was terminated at 2:00.

Article 3 was tested on December 6, 1993. The ambient temperature at the start of the test was 20 °C [68 °F]. Therefore, the average temperature rise criterion for this test was 159 °C [318 °F] and the single-point temperature rise criterion was 201 °C [394 °F]. The single-point temperature criterion was exceeded at about 1:50, the average temperature rise criterion was exceeded at about 1:58, and a conductor-to-ground fault was detected at about 1:59. The test was terminated at 3:00.

For all three fire tests, when the tests were terminated, most of the individual thermocouples exceeded the single point temperature criterion. In addition, Thermo-Lag panels had fallen off the test articles exposing the cable trays and cables to the fire. Most of the remaining Thermo-Lag had been reduced to char. Post-test inspections revealed that all of the cable jacket and conductor insulation had been consumed during the fire exposures. Only bare copper conductors remained in the cable trays. Detailed test results, including temperature data, observations and photographs will be provided in SNL Report SAND94-0146.

The test plan specified that a standard ASTM solid hose stream test would be performed at the end of the fire test. However, because of the early termination of two of the three tests and the poor condition of all three articles when the tests were terminated, the hose stream tests were not conducted. Less severe hose streams were used, however, to extinguish the burning Thermo-Lag material and to cool the test articles. These hose streams washed away most of the Thermo-Lag that had not fallen from the articles during the fire exposure.

<u>Ampacity Derating Test</u>

Test Article 4 was an ampacity derating test article constructed in accordance with TSI Report 82-5-355F, "Ampacity Derating Test for 1000V Power Cables in a Ladder Cable Tray Protected with a Three Hour Rated Design of the Thermo-Lag 330-1 Subliming Coating Envelope System," July 13, 1982. The cable tray was loaded to about 60 percent of the full tray depth with 20 lengths of 1/C, 2/0 AWG, 600-V cable; 58 lengths of 1/C, 4 AWG, 600-V cable; and 99 lengths of 1/C, 8 AWG, 600-V cable. One length represented one pass through the cable tray. All of the cables of a given cable size were joined together into a single electrical loop. Each loop was instrumented with six 24-gauge bare-bead Type K thermocouples with welded junctions. In each case, the insulation on the cable was slit so that the thermocouple junction could be installed below the insulation in contact with the conductor. Thermocouples were also installed on the cable tray side rails, on the inner surface of the fire barrier, and on the outer surface of the fire barrier. Three thermocouples were installed to measure the ambient temperature in the test chamber discussed below.

Cable ampacity and temperature data was obtained for Test Article 4 before the Thermo-Lag fire barrier was installed (baseline or unprotected cable tray data). On October 14, 1993, Article 4 was placed in a high-ambient temperature environmental test chamber set at 40 °C [104 °F] and allowed to soak for about four hours. A separate power supply was connected to each of the three cable loops and power was applied according to an initial estimate of the ampacity of each cable. The amperage was adjusted over a period of about six hours until it appeared that a steady state conductor temperature near 90 °C [194 °F] at the hot spot for each cable size would be reached. The test article was left to settle overnight (about 16 hours). The next day, final ampacity adjustments were made, and the test article was again allowed to settle (typically two to three hours after each adjustment). Stable conditions were achieved after the final adjustments when the cable temperatures did not fluctuate more than ±1 °C [1.8 °F] between repeated 10-minute interval data scans. After stable conditions were reached, the baseline temperatures were logged at 10-minute intervals for a final 1-hour period. Cable amperage readings were also taken at the beginning and end of the final hour to verify the presence of stable source currents. Following the baseline test, the 3-hour Thermo-Lag fire barrier described above was installed on Article 4 and allowed to cure. On December 9 and 10, 1993, the protected cable tray ampacity and temperature data were obtained in accordance with the process used to obtain the baseline data.

Baseline and protected cable ampacity adjustment factors (AF) were calculated for each cable size according to the following formula from Insulated Cable Engineers Association (ICEA) Standard P-46-426, "Power Cable Ampacities:"

$$I'_c = I_c(AF_c) = I_c\sqrt{\left(\frac{T'_c - T'_a}{T_c - T_a}\right)\left(\frac{234.5 + T_c}{234.5 + T'_c}\right)}$$

where the values with primes indicate the desired conditions and the values without primes indicate the experimental data. Temperature units are degrees Celsius. For both the baseline and the protected cases, the desired cable temperature (T'_c) was 90 °C [194 °F] and the desired ambient temperature (T'_a) was 40 °C [104 °F]. The measured baseline temperatures and ampacities and the calculated baseline ampacity adjustment factors are provided in Table 3. The measured temperatures and ampacities and the calculated ampacity adjustment factors for the protected cables are provided in Table 4. For both the baseline and protected cases, the average of the hot-spot cable temperatures recorded at 10-minute intervals during the final hour were used to calculate the ampacity adjustment factor for that cable.

The ampacity derating factor (ADF) for each cable type is the ratio of the reduction in current carrying capacity (protected ampacities) to the original

current carrying capacity (baseline ampacities). The ADF for each cable type was calculated using the following formula:

$$ADF = \frac{I'_{baseline} - I'_{protected}}{I'_{baseline}} (100)$$

In this format, the ADF is expressed as a percentage drop in current-carrying capacity. The calculated ampacity derating factors were 46.4 percent, 36.0 percent, and 35.3 percent for the 8 AWG, 4 AWG, and 2/0 cables, respectively. Table 5 provides a comparative summary of the ampacity data and ampacity derating factors from the SNL/UL test and the results reported by the vendor in TSI Report 82-5-355F. Table 5 also shows the results of recalculations performed by SNL of the test data reported in TSI Report 82-5-355F. Detailed explanations of the two-step recalculations, which were needed to allow comparisons of the SNL/UL test results with the reported vendor test results, will be documented in SNL Report SAND94-0146.

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact the technical contact listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

Brian Grimes

Brian K. Grimes, Director
Division of Operating Reactor Support
Office of Nuclear Reactor Regulation

Technical contact: Steven West, NRR
(301) 504-1220

Attachments:
1. Table 1, "Summary of Test Article Characteristics," and Table 2, "Summary of Fire Endurance Test Results."
2. Table 3, "Baseline (Unprotected Cable Tray) Ampacity Test Data and Calculations," and Table 4, "Protected Cable Tray Ampacity Test Data and Calculations."
3. Table 5, "Comparative Summary of Ampacity Test Data and Derating Factors."
4. List of Generic Communications Concerning Fire Barriers
5. List of Recently Issued NRC Information Notices

Computer Printout: see Jacket

Table 1. Summary of Test Article Characteristics

Article	Test Type	Description	Barrier Design
1	3-Hour Fire Endurance	6-inch-wide by 6-inch-high, solid-bottom, steel cable tray based on Test Article 2 of TSI Report 82-5-355B, "Three-Hour Fire Endurance Test on Thermo-Lag 330-1 Subliming Coating Envelope System for Washington Public Power Supply System Nuclear Projects," July 1982.	Based on TSI Technical Note 20684, Revision V, November 1985.
2	3-Hour Fire Endurance	12-inch-wide by 4-inch-high, ladder-back, steel cable tray based on Test Article 4 of TSI Report 82-11-81, November 1982.	Same as Article 1.
3	3-Hour Fire Endurance	Same as Test Article 2.	Methods documented in TSI Report 82-11-81, November 1982.
4	Ampacity Derating	12-inch-wide by 4-inch-high, ladder-back, steel cable tray based on TSI Report 82-5-355F, July 13, 1982.	Same as Test Article 1.

Table 2. Summary of Fire Endurance Test Results
(All times in Hours:Minutes from the start of the test)

Article	Single Point Temperature Criterion and Time to Exceed	Average Temperature Criterion and Time to Exceed	Time to Circuit Fault	Test Duration
1	200 °C [392 °F]	158 °C [316 °F]		
	1:05	1:20	1:16	2:30
2	200 °C [392 °F]	158 °C [316 °F]		
	0:55	1:03	0:59	2:00
3	201 °C [394 °F]	159 °C [318 °F]		
	1:50	1:58	1:59	3:00

Table 3. Baseline (Unprotected Cable Tray)
Ampacity Test Data and Calculations

Cable Size	T_c (°C)	T_a (°C)	I_c (Amps)	AF_c	I'_c (Amps)
8 AWG	91.1	40.5	23.8	0.996	23.7
4 AWG	91.2	40.5	38.0	0.995	37.8
2/0	92.0	40.5	115.0	0.988	113.6

Table 4. Protected Cable Tray
Ampacity Test Data and Calculations

Cable Size	T_c (°C)	T_a (°C)	I_c (Amps)	AF_c	I'_c (Amps)
8 AWG	92.9	40.1	13.0	0.977	12.7
4 AWG	93.2	40.1	24.8	0.975	24.2
2/0	91.6	40.1	74.4	0.988	73.5

Key for Tables 3 and 4:

T_c = Average of cable temperatures recorded at 10-minute intervals during the final hour.
T_a = Average of ambient (test chamber) temperatures recorded at 10-minute intervals during the final hour after reaching desired stable conditions.
I_c = Measured cable ampacity at the end of the final hour.
AF_c = Cable ampacity adjustment factor.
I'_c = Adjusted cable ampacity.

Table 5. Comparative Summary of Ampacity Data and Derating Factors

Cable Size	Data Source	Baseline Ampacity (Amps)	Protected Ampacity (Amps)	Derating Factor (Percent)
8 AWG	SNL	23.7	12.7	46.4
	TSI[1]	17.46	14.64	16.15
	TSI[2]	20.38	13.89	31.84
	TSI[3]	23.96	14.83	38.11
4 AWG	SNL	37.8	24.2	36.0
	TSI[1]	35.77	29.74	16.86
	TSI[2]	41.75	28.21	32.43
	TSI[3]	41.75	28.21	32.43
2/0	SNL	113.6	73.5	35.3
	TSI[1]	105.91	87.18	17.68
	TSI[2]	123.60	82.69	33.10
	TSI[3]	131.60	84.82	35.55

1 Data reported in TSI Report 82-5-355F, July 13, 1982.
2 Inverted term in ampacity adjustment factor (AF) equation corrected.
3 Measured individual conductor temperatures used to calculate ampacity adjustment factors for each cable size.

List of Generic Communications Concerning Fire Barriers

Information Notice 91-47, "Failure of Thermo-Lag Fire Barrier Material to Pass Fire Endurance Test," August 6, 1991

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

Information Notice 92-46, "Thermo-Lag Fire Barrier Material Special Review Team Final Report Findings, Current Fire Endurance Tests, and Ampacity Calculation Errors," June 23, 1992

Bulletin 92-01, "Failure of Thermo-Lag 330 Fire Barrier System to Maintain Cabling in Wide Cable Trays and Small Conduits Free from Fire Damage," June 24, 1992

Information Notice 92-55, "Current Fire Endurance Test Results for Thermo-Lag Fire Barrier Material," July 27, 1992

Bulletin 92-01 Supplement 1, "Failure of Thermo-Lag 330 Fire Barrier System to Perform Its Specified Fire Endurance Function," August 28, 1992

Information Notice 92-82, "Results of Thermo-Lag 330-1 Combustibility Testing," December 15, 1992

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

Information Notice 93-40, "Fire Endurance Test Results for Thermal Ceramics FP-60 Fire Barrier Material," May 26, 1993

Information Notice 93-41, "One Hour Fire Endurance Test Results for Thermal Ceramics Kaowool, 3M Company FS-195 and 3M Company Interam E-50 Fire Barrier Systems," May 28, 1993

LIST OF RECENTLY ISSUED NRC INFORMATION NOTICES

Information Notice No.	Subject	Date of Issuance	Issued to
94-21	Regulatory Requirements when No Operations are being Performed	03/18/94	All fuel cycle and materials licensees.
94-20	Common-Cause Failures due to Inadequate Design Control and Dedication	03/17/94	All holders of OLs or CPs for nuclear power reactors.
94-19	Emergency Diesel Generator Vulnerability to Failure from Cold Fuel Oil	03/16/94	All holders of OLs or CPs for nuclear power reactors.
94-18	Accuracy of Motor-Operated Valve Diagnostic Equipment (Responses to Supplement 5 to Generic Letter 89-10)	03/16/94	All holders of OLs or CPs for nuclear power reactors.
94-17	Strontium-90 Eye Applicators: Submission of Quality Management Plan (QMP), Calibration, and Use	03/11/94	All U.S. Nuclear Regulatory Commission Medical Use Licensees.
94-16	Recent Incidents Resulting in Offsite Contamination	03/03/94	All U.S. Nuclear Regulatory Commission material and fuel cycle licensees.
94-15	Radiation Exposures during an Event Involving a Fixed Nuclear Gauge	03/02/94	All U.S. Nuclear Regulatory Commission licensees authorized to possess, use, manufacture, or distribute industrial nuclear gauges.

OL = Operating License
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current carrying capacity (baseline ampacities). The ADF for each cable type was calculated using the following formula:

$$ADF = \frac{I'_{baseline} - I'_{protected}}{I'_{baseline}} (100)$$

In this format, the ADF is expressed as a percentage drop in current-carrying capacity. The calculated ampacity derating factors were 46.4 percent, 36.0 percent, and 35.3 percent for the 8 AWG, 4 AWG, and 2/0 cables, respectively. Table 5 provides a comparative summary of the ampacity data and ampacity derating factors from the SNL/UL test and the results reported by the vendor in BI Report 82-5-355F. Table 5 also shows the results of recalculations performed by SNL of the test data reported in TSI Report 82-5-355F. Detailed explanations of the two-step recalculations, which were needed to allow comparisons of the SNL/UL test results with the reported vendor test results, will be documented in SNL Report SAND94-0146.

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Original signed by
Brian K. Grimes

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Division of Operating Reactor Support
Office of Nuclear Reactor Regulation

Technical contact: Steven West, NRR, (301) 504-1220

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In this format, the ADF is expressed as a percentage drop in current-carrying capacity. The calculated ampacity derating factors were 46.4 percent, 36.0 percent, and 35.3 percent for the 8 AWG, 4 AWG, and 2/0 cables, respectively. Table 5 provides a comparative summary of the ampacity data and ampacity derating factors from the SNL/UL test and the vendor's test. Table 5 also shows the results of recalculations performed by SNL of the test data reported in TSI Report 82-5-355F. Detailed explanations of the two-step recalculations, which were needed to allow comparisons of the SNL/UL test results with the vendor's test results, will be documented in SNL Report SAND94-0146.

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