January 9, 2015

MEMORANDUM TO: Joseph G. Giitter, Director
Division of Risk Assessment
Office of Nuclear Reactor Regulation

FROM: Richard P. Correia, Director ***/RA/***
Division of Risk Analysis
Office of Nuclear Regulatory Research

SUBJECT: INSIGHTS FROM RECENTLY COMPLETED FIRE RETARDANT CABLE COATING TESTING AND FUTURE RESEARCH PLANS

In September 2014, an advanced copy of the draft report entitled, "Response Bias of Electrical Cable Coatings at Fire Conditions (REBECCA-Fire), Volume 1" was transmitted to your staff for review and comment. That report documents the results from a recent testing program, completed at Sandia National Laboratories, which explored the effect fire retardant cable coatings have on delaying the "time to damage," i.e., loss of cable functionality, when exposed to severe thermal exposures; additionally, insights on time to ignition were also documented in the (REBECCA-FIRE) report. That report, along with the literature search provided in 2012, serves as partial fulfillment of your user need request to provide confirmatory data to support enhancements to the guidance provided in Appendix Q "Appendix for Chapter 11, Passive Fire Protection Features," of EPRI 1011989 (NUREG/CR-6850), "EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities." The second phase of this work is being performed in parallel at the National Institute of Standards and Technology (NIST), and will involve conducting larger scale testing to collect flame spread, time to damage, and time to ignition data on cable coating and cable tray covers.

On November 25, 2014, our respective staff members and the principle investigator from the national laboratory met to discuss the report. During this meeting it was decided that final publication of the report as a NUREG/CR would be delayed until the second phase of testing is complete. The purpose of holding the release of the results is to ensure that the two experimental programs being performed at different laboratories provide complete, comprehensive characterization of the fire retardant cable coatings' performance, when published. However, our staff also believes it to be beneficial at this time to provide you (at a high level) the insights from this testing that could aid in clarifying Appendix Q guidance for your staff and stakeholders who may use it in performance-based applications. This memorandum documents an overview of the testing completed to date, and provides these high-level insights.

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Current Appendix Q Guidance

The guidance currently provided in Appendix Q of EPRI 1011989 (NUREG/CR-6850) is based on large- scale fire tests conducted by Sandia National Laboratories in the late 1970s. These tests measured the effects of five different fire retardant intumescent coatings on time to ignition and time to damage. The tests, which were conducted with a diesel fuel pool fire, were deemed most indicative of the conditions resulting from the most likely ignition sources and were used to provide the following guidance:

- Time to Ignition
  - Coated, nonqualified cables can be assumed to not ignite for at least 12 minutes
- Time to Damage
  - Large Exposure Fires
    - Coated, nonqualified cables can be assumed to not be damaged for at least 3 minutes
  - Cable Tray Fires
    - Coated, nonqualified cables can be assumed to not be damaged for at least 10 minutes

This guidance is limited and does not appear to be applied consistently in PRA analyses. Therefore, a user need was developed that requests clarification, as well as comparisons between cable coating performance as it relates to “time to damage” and “time to ignition”.

Summary of Small-Scale Testing

Fire retardant intumescent coatings from three different manufactures were applied to cables in several configurations to be evaluated. The coatings selected ranged in thermal performance, and represented a minimal, mid-range, and best performing coatings; based on the literature search and previous testing performed in the late 1970s and early 1980s. Single cables, seven- and ten-cable bundles were assembled with thermocouples located underneath the jacket of several electrical cables in the bundle and fire retardant cable coating was applied to the assembly. Other electrical cables in the bundles were similarly protected and monitored for electrical circuit functionality. The single cables and cable bundles were placed in a ladder back cable tray and then coated and allowed to cure per vendor recommendations. Once cured, the entire assembly was placed in the radiant thermal exposure chamber and connected to thermal monitoring and electrical circuit functionality equipment. The assembly was exposed to a realistic thermal radiant exposure until cable electrical functionality damage was observed. Uncoated cables and cable bundles were also exposed in separate tests at the same thermal conditions, and used as a control to evaluate the performance differences. This approach was similar to the test procedure used in previous circuit functionality testing, including NUREG/CR-6931, “Cable Response to Live Fire (CAROLFIRE);” NUREG/CR-7100, ”Direct Current Electrical Shorting in Response to Exposure Fire (DESIREE-Fire);” and NUREG/CR-7102, “Kerite Analysis in Thermal Environment of Fire (KATE-Fire).”

Summary of Test Results

As a result of testing, the (high–level) observation was made that the fire retardant intumescent cable coatings, although difficult to ignite, eventually ignited and contributed exothermically to the net heat release of the system. The key finding is the relationship of cable assembly mass to thermal performance. The following results were identified:

- The single-cable coated samples, representing low thermal mass systems, showed no consistent time delays that could be credited based on this testing. This configuration would be representative of low mass cable air drops, individual cables in cable trays, or cables in trays with maintained spacing.

- Bundle configurations that were not well-secured showed signs of physical separation in several of the tests, resulting in the formation of gaps along the coating. When this occurred, the coated cable typically failed with minimal delay in time to damage from the control case. Both combustible (plastic zip strips) and noncombustible (wire ties) cable ties were found to be compromised during the tests. Cable tie spacing greater than 24 inches apart did not provide assurance that the bundle would not separate when heated.

- Bundle configurations with a cable mass of less than 1.9 lbs/ft, which included the single and seven-cable bundles, yielded inconclusive results for electrical failure delays for all three coating materials tested compared to the uncoated bundles. That is, some cables monitored for electrical functionality were delayed while other cables were not. Additional research may be needed to provide a better understanding and characterization of the cause of these variances.

- The ten-cable, well-secured, coated bundle configurations, with a cable mass of 2.7 lbs/ft, showed a net benefit of at least 10 minutes in time to damage,, compared to uncoated configurations in all tests. This net benefit was in agreement with, or suggested better performance than those time delays currently cited in Appendix Q of EPRI 1011989 (NUREG/CR-6850).

Impact on Appendix Q Guidance

These results indicate that, lightly loaded cable trays (single layer, maintained spacing or single cable) and low mass air drop configurations less than 1.9 lbs/ft of cable mass, have not been shown to benefit from the application of cable coating material with respect to providing additional time to damage, beyond that of an uncoated cable. For heavier loaded cable trays, which are coated and well-secured, the ten-cable coated bundle configurations, greater than 2.7 lbs/ft of cable mass, provide reasonable indications that the current guidance in Appendix Q of EPRI 1011989 (NUREG/CR-6850) is slightly conservative, with a large variance between the different coating materials tested.

Based on the information currently available, and until further testing is completed, the guidance herein can be followed when applying Appendix Q approaches.

No time delay for either ignition or damage should be credited for the following conditions:

- When applied to individual lengths of cable, including cable air drops, individual cables in a cable tray, or cables in trays with maintained spacing, unless the coated cable exceeds a mass of 2.7 lb/ft.

- When applied to cables in a cable tray where there is only a single row (e.g., a single layer of cables spanning all or part of a tray and coated as a group) unless each of the individual cables exceeds a mass of 2.7 lb/ft.

- When applied to a bundle configuration that (1) is not known to be well secured with cable ties spaced no more than 24 inches apart or (2) has a mass less than 2.7 lbs/ft based on total coated cable mass per unit length. This would include both air drops and cables coated as a group within a cable tray.

A time delay for both ignition and damage of 10 minutes can be credited for the following conditions:

- Application of intumescent coatings to random-fill cable trays with less than three times the recommended application thickness, with at least three layers of cables, and a minimum 16-inch width of cables coated as a group, with a mass of at least 2.7 lb/ft. Three layers of cables represent the number of layers tested in the bundled cable tests.

- Cable bundles, including air drops, that are well-bound with ties at least every 24 inches and have a minimum mass per unit length of 2.7 lb/ft.

Additional Testing Required

Although single cable, bundle and lightly-loaded cable tray configurations are found in NPP applications with fire retardant cable coatings, many configurations found in the plants use cable coatings on randomly filled cable trays with higher cable tray loading configurations. Fully loaded cable tray configurations were not evaluated under this small-scale testing program due to resource limitations, limits on the amount of combustible material within the radiant compartment, and plans to include such testing in other programs' follow-on work.

Additional research is currently being planned to examine the effectiveness of fire retardant cable coatings in larger scale fire tests. These experiments would expose fully-coated trays with instrumented cables to representative exposure fire scenarios. In addition, small-scale tests would be conducted using standard test methods, such as the Cone Calorimeter (ASTM E1354) and the Lateral Ignition Flame Spread Test (LIFT) (ASTM E1321), to develop engineering data that can be used to assess and model the performance of these coating materials. If feasible, the test data obtained from this research will be used to incorporate modeling of cable coating into a model for predicting the electrical failure of cables.

This model was developed by NIST as part of the CAROLFIRE program (Volume 3 of NUREG/CR-6931, “Thermally-Induced Electrical Failure (THIEF) Model”), and provides estimates of potential electrical failure of cables when exposed to fire-induced environmental conditions.

Given its medium priority and resource commitments on high-priority projects, results from this second phase are expected to be completed sometime in calendar year 2016.

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