UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

MEMORANDUM FOR: Robert B. Minogue, Director
Office of Standards Development

Harold R. Denton, Director
Office of Nuclear Reactor Regulation

FROM: Saul Levine, Director
Office of Nuclear Regulatory Research

SUBJECT: RESEARCH INFORMATION LETTER # 46, "EFFECTIVENESS OF CABLE TRAY COATING MATERIALS AND BARRIERS IN RETARDING THE COMBUSTION OF CABLE TRAYS SUBJECTED TO EXPOSURE FIRES AND IN PREVENTING PROPAGATION BETWEEN CABLE TRAYS (HORIZONTAL OPEN SPACE CONFIGURATION)"

References:

1. SAND78-0518, "Preliminary Report on Fire Protection Research Program Fire Retardant Coatings Tests," March, 1978.
2. SAND78-1456 (NUREG/CR-0381), "Preliminary Report on Fire Protection Research Program Fire Barriers and Fire Retardant Coatings Tests," September 1978.
3. Memorandum from Saul Levine to E. G. Case and R. B. Minogue, Subject: Research Information Letter #14 - "Physical S[illegible]aration Criteria for Electrical Cable Trays (Horizontal Open Space Configuration)," dated November 9, 1977.
4. NUREG/CR0376, "Models of Horizontal Electric Cables and Cable Trays Exposed to a Fire Plume," September 7, 1978.

1.0 INTRODUCTION

This memorandum transmits the results of a completed portion of the NRC Fire Protection Research program relating to the effectiveness of cable tray fire retardant coating materials and barriers in retarding the combustion within and propagation between horizontal cable trays. The research results include a test method that can be used to evaluate the relative performance of these protective measures. Data were obtained on the effectiveness of candidate fire retardant coating materials and barrier designs that are in use or are being considered for nuclear power plants.

2.0 SUMMARY

The research results support the following conclusions:

- An acceptable test methodology was developed for use in evaluating fire retardant coating materials and barrier designs with horizontal cable trays.
- There was a significant decrease in fire damage to the cable in both the fire retardant coating and barrier tests with cable qualified to the IEEE-383 flame test standard.
- Moreover, with cable qualified to the IEEE-383 flame test all fire coatings tested prevented propagation between trays without the use of additional barriers.
- However, fire did propagate between cable trays with one fire retardant coating using cable not qualified to the IEEE-383 flame test standard.
- Fire propagation between cable trays was prevented with all barrier designs tested with cable not qualified to the IEEE-383 flame test standard.
- All fire retardant coating materials and barriers studied offered some additional protection for the cables in a tray subjected to the test fires.

3.0 BACKGROUND

3.1 Support for Staff Positions

The specific research upon which this RIL is based is outlined in the Research Support Branch Plan (Enclosure 1) for Fire Protection Research. The overall Fire Protection program is based on the research need identified in the research request SD 77-10 (August 19, 1977), the NRR program support letter from B. Rusche to H. Kouts dated June 25, 1976, the review of the Browns Ferry fire, as well as through consultation and formal review with the NRC user groups. The Fire Protection Research Review Group has been and continues to be the focal point for both the formulation of the research program and evaluation of program results that form the basis of this RIL. (Related to this is the NRR/RES task force to evaluate the impact on the fire protection research program of including full-scale replication tests.)

The specific user requirement for the research conducted to date with cable tray fire retardant coatings and barriers is based on the need to provide test data to confirm the guidance given in Appendix A to the Branch Technical Position APCSB 9.5.1, "Guidelines for Fire Protection for Nuclear Power Plants," and in the draft Regulatory Guide 1.120, "Fire Protection Guidelines for Nuclear Power Plants." Regulatory Guide 1.75 ("Physical Independence of Electrical Systems") requires only consideration of electrically initiated fires without consideration of any fuel source other than the cable insulation itself. The staff position for evaluation of the fire protection capability is that exposure fires must be considered. The type and size of the exposure fire are to be based on a fire hazards analysis and will vary from plant to plant and will also be different for different locations within the plant. The tests conducted to date and the conclusions presented in this RIL comprise an assessment of the effectiveness of cable tray fire retardant coatings and barriers in preventing the propagation of exposure fires in horizontally oriented cable trays.

3.2 Testing Rationale

Previous exposure fire testing showed that even with cable qualified to the IEEE-383 flame test additional protection beyond the 5-ft (1.5-m) vertical and 3-ft (0.9-m) horizontal separation distance defined in R.G. 1.75 may be required between redundant safety divisions. Work was undertaken to study the effectiveness of cable tray fire retardant coating materials and barriers in preventing the spread of fire between redundant safety divisions.

Specifically, the scope of this RIL covers evaluation of the effectiveness of certain cable tray fire retardant coating materials and cable tray barriers in retarding combustion and preventing propagation of closely spaced cable trays subject to exposure fires.

4.0 TESTS

4.1 Test Configurations

The test configuration simulates cables placed in the horizontal open space of a plant where the effects of reflected heat from the walls and ceiling are minimized. One and two tray tests were conducted each using 18-inch-wide (0.45-m) open-ladder steel cable trays 12-ft (3.7m) long. As with previous horizontal open space cable tray tests the separation between trays was 10.5 inches (26.7 cm).

Fires were started using both propane burners and diesel fuel. The propane burner test fire had previously been shown to be of sufficient intensity and size to consistently result in a fully developed fire in the ignition tray (SAND71-1424). Measurements made of the test diesel fuel fire show that it is comparable to the propane burner test fire in terms of heat flux produced if the fire surface area and burn times are similar. Both ignition sources exposed a 3-ft. (0.9-m) section of the cable tray to the flame. Air flow was maintained to simulate normal ambient plant air flow in plant open space areas. All tests used cable trays that had a random fill pattern with the cable loaded to the top of the side rails. This resulted in a cable loading less than the maximum volumetric loading of 40% permitted by the Insulated Power Cable Engineering Association. Previous tests showed that the random fill patterns (with minimum fuel density and maximum air space in a fully loaded cable tray) represented the worst allowable case with regard to combustion and propagation and was used on all cable tray coating and barrier tests.

Tests were conducted with cable that was qualified to the flame test standard of IEEE-383-74 and also with cable that could not qualify to this standard.

In an effort to obtain a more basic understanding of the combustibility of candidate fire retardant coating materials, small-scale furnace tests were conducted on all coating materials used in the full tray tests. The tests were conducted using a 6-inch-square (15-cm-square) sample of coated cable. The test furnace provided controlled air flow and radiant heat flux. The specimens were heated in a controlled temperature environment in the presence of a pilot ignition source and basic combustibility measurements made to establish the time to ignition, time to maximum heat release, and cumulative heat release. Radiant heat fluxes similar to those encountered in the full tray ignition testing were used (approximately 4 watts/cm^2).

The full-scale test used six different fire retardant coating materials; five of the six coatings were sprayed on to the manufacturers' recommended wet thicknesses. The sixth fire retardant coating was applied with a trowel in accordance with the manufacturer's specification. In addition to the cable tray fire retardant coatings, tests were conducted using solid bottom cable trays without covers, solid bottom cable trays with vented covers, cable trays with solid covers (open ladder bottom), ladder cable trays covered with a ceramic fiber blanket, and two open ladder cable trays with a solid fire barrier between trays. The full-scale testing covered both one- and two-tray tests. The single tray tests were conducted to study the degree to which combustion was retarded and the two-tray tests were conducted to study the degree to which propagation between trays was prevented. (Note: In the two-tray tests, a barrier above the upper tray simulated the boundary of a third tray.) Propane burners and diesel fuel exposure fires were utilized. The propane burners were arranged to provide an exposure fire identical to that utilized in prior unprotected cable tray tests, and as in previous testing the propane burners were used in 5-minute burn cycles with a thermal barrier above the ignition tray during the burn period. The diesel fuel exposure fires were contained in an enclosure 36 inches by 18 inches (0.9-m x 0.4-m) the same distance below the tray as the propane burners. Two gallons of fuel were ignited to create a fire which burned for about 13 minutes. (There was no thermal barrier above the ignition tray for the diesel fuel fires.)

4.2 Test Specimen Standards

The significance of the research covered by this RIL should be viewed primarily as the development of a test methodology by which passive fire protective measures can be evaluated. The tests developed can be performed by suppliers and plant operators to justify alternate fire retardant coatings and barriers not tested by NRC or to demonstrate the effectiveness of those measures tested by the NRC in situations where the design basis fire is significantly different than the test case fires used in this research. Furthermore, suppliers of fire retardant coating and barrier materials may change their products or recommended practices which may require further verification of their effectiveness. In conducting this research, currently accepted design practices and materials were used when available. In the absence of accepted design practice, supplier recommendations were used. With the exception of the solid barrier between trays, no NRC test guidance is currently available for any of the passive fire protective measures evaluated.

4.3 Test Limitations

In evaluating these or other tests results for the fire retardant coatings and barriers, particular care should be exercised with regard to (1) the thickness of the fire retardant coating materials used, and (2) the method of installation of the ceramic fiber blanket. No attempt was made to determine the amount of uncovered blanket or degraded fire retardant coating that would alter the test results with regard to the propagation of a fire between cable trays, nor was there any attempt to evaluate in a quantitative way the significance of the vent area in the test of solid bottom trays with vented covers.

Unrestricted use of the cable tray fire retardant coating test results also requires caution since there are many untested variables which can influence the selection of a cable tray coating. The following items were not covered in the research completed thus far:

1 - No evaluation has been made of the aging characteristics of the fire retardant coating materials. This topic has a number of different aspects. There is the possibility of a long term reaction of the fire retardant coating material with the cable jacket. There is also the question of chemical and mechanical stability of the fire retardant coating material itself as it ages. The fire retardant coatings all have different trace materials and exhibit different mechanical properties when cured. The significance of these differences was not evaluated, although work is planned on the aging of fire retardant coating materials.

2 - The method of installation of the fire retardant coating requires specific consideration and depends upon the supplier's recommended thickness for cable tray application and the method of application (i.e., sprayed or troweled). The wet consistency (which may be affected by shelf life) may have a significant effect on the ability to apply the material evenly. If the material is sprayed, the spraying equipment may also play an important role in obtaining a uniform layer of coating. The current practice is to measure the thickness of the wet coating material on the top cables. However, depending on the spraying equipment used (or trowling technique) and the wet consistency of the material, the degree to which the coating material is forced down into the tray between cables will vary. The degree to which the coating material can fill the voids in the cable tray was shown to be an important variable affecting the ability of the coated cable trays to resist damage from exposure fires.

3 - No attempt was made in this research to evaluate coatings with equal thickness applications. The research was intended to be confirmatory of the products being sold and with the specifications recommended by the supplier.

4 - The question of intumescence was not evaluated except as it affected the effectiveness of the fire retardant coatings with the fully developed test fires. It is possible that the properties of a coating could change because of intumescent behavior before it is exposed to the intense portion of the fire. The fire retardant coatings were not evaluated with regard to their effectiveness in slowly developing fires. Also the slowly developing fire might also be important for a fire redardant coating that depends primarily on the release of water and or gas to retard the combustion of the cable.

5.0 RESULTS

Prior test data and the RES evaluation in RIL #14 (Ref. #3) showed that the most important factor in determining if a cable tray fire will develop is the spacing between cables within a given tray since this spacing establishes the air-fuel mixture at the burning surface. It was established by measurement and observation of the prior test films that the fire propagation from one tray to a tray above it depended on the collection of hot gaseous fuel released from the cable exposed to fire. Fire propagation occurred by ignition of the gaseous fuel above the cable tray to which the fire is spreading, with a subsequent spread of the flame down into the tray itself.

Subsequent to the writing of RIL #14 this conclusion has been verified by additional tests without fire retardant coatings and barriers and also during the fire retardant coating and barrier tests at Sandia Laboratories. Furthermore an analytical report NUREG/CR-0376 (Ref. #4) "Models of Horizontal Electric Cables and Cable Trays Exposed to a Fire Plume" completed by the Applied Physics Laboratory (APL) verifies these conclusions. The APL research provides mathematical correlation of the experimental determined favorable conditions for the development and propagation of fires in horizontally oriented cable trays. Specifically the equation governing mass flux of the flammable gas indicates that it is roughly proportional to the mass flux of fire plume gas from the tray whose bottom side is being heated by the ignition tray. It is the spacing between cables that enables the fire plume gas to pass through the tray and collect above it.

These experimental and analytical conclusions verify that the Sandia fire retardant coating and barrier tests covered worst case conditions for horizontally oriented cable trays insofar as the cable spacing and loading are concerned.

The following specific conclusions can be drawn from the tests and analysis conducted Ref. (1) and (2):

1 - All coating materials studied offer some protection against the test fires; however, there was a wide range of effectiveness among the coatings in both their ability to retard combustion when exposed to a fire and in their ability to prevent fire propagation from one tray to another. Two of the coatings tested (type D and type E) prevented ignition for six five-minute burn cycles.

2 - With cable qualified to the IEEE-383 flame test standard, all coatings tested prevented propagation between trays; however with one coating tested (type C), relatively high cable temperatures (in excess of 1000°F) were measured in the upper tray. With another coating tested (type A), cable temperatures in the upper tray in excess of 800°F were measured.

3 - With cable not qualified to the IEEE-383 flame test standard, one of the coatings tested (type C) did not prevent fire propagation between trays.

4 - There was good correlation of data between (1) the small-scale, (2) single-tray, (3) two-tray propane burner, and (4) two-tray diesel fuel fire tests indicating that any of the test procedures developed as part of this research can be utilized for further evaluation. However, verification of the ability of a cable tray fire retardant coating or barrier to prevent tray-to-tray propagation can only be accomplished with one of the two tray tests developed. A comparison of the diesel fuel fire and the propane burner fire showed that if the surface area and burn times of the fires are the same the two are very similar with regard to the heat flux produced.

5 - All barrier designs studied offered some protection against the test fires. For the tests of propagation through barriers, the experiments were conducted only with cable that is not qualified to the IEEE-383 flame test standard, and in all cases propagation was prevented.

6 - With all barrier designs tested with cable that is not qualified to the IEEE-383 flame test, fire did develop in the ignition tray in either one or two-burn cycles.

7 - The barrier designs ("solid bottom no cover" and "solid bottom vented cover") and the fire retardant coatings (type D and E) tested in single tray tests with cable qualified to the IEEE-383 flame test offered protection against the ignition and electrical failure in the cable tray exposed to the test fire.

8 - There was a distinct improvement in performance in both the coating and barrier tests with cable qualified to the IEEE-383 flame test standard.

6.0 EVALUATION AND RECOMMENDATIONS

The data presented in this RIL, and an advance draft copy of the RIL, have been reviewed with members of the Fire Protection Research Review Group. There is general agreement with the contents of this RIL with the exception of the RES recommended minimum thickness and inspection to guarantee total blockage of all space between cables.

The data discussed in this RIL are of primary concern in those cases where a permanent rated barrier has not and cannot be utilized between safety divisions. Previous testing as discussed in RIL #14 (Reference 3) showed that use of cable qualified to the IEEE-383 flame test standard is not in itself a sufficient defense against the propagation of fire across a 5-ft (1.5-m) vertical and 3-ft (0.9-m) horizontal separation distance if exposure fires are considered credible.

The data discussed in this RIL showed that protection against the propagation of fire between cable trays can be obtained with both cable tray coating materials and various cable tray barrier designs. However, there is a distinct improvement in the degree of protection offered when cable qualified to the IEEE-383 flame test standard is used.

For those cases where the cable is not qualified to the IEEE-383 flame test standard, all of the coating materials and barrier designs tested exhibited poorer performance with regard to their ability to retard combustion. However, with the exception of coating Type C all coatings and barriers prevented fire propagation between cable trays.

If fire retardant coatings are utilized the quality control of the application is important. Based on the experience gained in conducting the fire retardant coating tests at Sandia and observations of actual cable tray applications it is concluded that a minimum thickness should be established for use of fire retardant coatings in nuclear power plants.

Therefore, if cable tray coatings are used it is recommended that a 1/8-in (0.3-cm) dry thickness be required. The thickness recommended by the suppliers of coatings A, B, C, and G is 1/8-in (0.3-cm) wet. The suppliers of coatings D and E recommended a coating which is 1/4-inch (0.6-cm) thick when wet. The supplier of coating E changed this thickness specification to 5/32-inch (0.4-cm) wet before the last portion of the test program without any noticable change in the relative performance of the coatings tested. However, if all coatings are required to be applied to the same thickness it may be that the differences in their effectiveness will be reduced. Because of application and the amount of water in the wet condition (30 to 40%) it is unrealistic to expect thickness tolerances better than ± 25% after drying.

Based on the experience gained in conducting the cable tray fire test and fire retardant coating tests at Sandia, it is concluded that whatever protective measure is utilized it should present a solid barrier to the fire and not allow the passage of combustible gas through the cable bundle within the tray. If fire retardant cable tray coatings are used consideration should be given to surrounding the cable with the fire retardant material, and a suitable check should be required to ensure that all air passages through the cable bundle have been blocked by the fire retardant coating material. A visual check above the cable tray with a high intensity lamp placed below the tray may be useful.

Fire retardant coatings and barriers can be utilized to prevent tray-to-tray fire propagation with cable capable of passing the IEEE-383 flame test standard with cable tray configurations and fires similar to those on which the fire retardant coating tests were conducted. For coating type C which exhibited only marginal performance with cable qualified to the IEEE-383 flame test standard at the nominal recommended thickness of 1/8-inch (0.3-cm) wet, verification from applicants using the Sandia two-tray configuration should be requested with the 1/8-inch (0.3-cm) dry thickness to ensure an adequate margin in preventing propagation.

Fire retardant coating types A, B, D and E can be utilized to prevent tray-to-tray fire propagation with cable not qualified to the IEEE-383 flame test standard with cable tray configurations and fires similar to those on which the fire retardant coating tests were conducted.

The barrier designs tested can be utilized to prevent tray-to-tray fire propagation with cable not qualified to the IEEE-383 flame test standard with cable tray configurations similar to those on which the barriers were tested at Sandia.

7.0 COORDINATION CONTACT

For coordination of any further evaluation of these results and for discussion and future experiments the reader is advised to contact Mr. Ronald Feit, Fire Protection Research Program Manager, RES, Telephone 427-4272.

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Enclosures: As stated