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Fire Protection Research Program at Sandia National Laboratories*

Leo J. Klamerus
Systems Safety Technology Division 4442
Sandia National Laboratories
Albuquerque, New Mexico 87185

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ABSTRACT

Sandia National Laboratories is executing a program for the Nuclear Regulatory Commission to provide data needed for confirmation of the suitability of current design standards and regulatory guides for fire protection and control in water reactor power plants. This paper summarizes the activities of this ongoing program through October 1980. Characterization of electrically initiated fires revealed a margin of safety in the separation criteria of Regulatory Guide 1.75 for such fires in IEEE-383 qualified cable. However, tests confirmed that these guidelines and standards are not sufficient, in themselves, to protect against exposure fires. This paper describes both small and full scale tests to assess the adequacy of fire retardant coatings and full scale tests on fire shields to determine their effectiveness. It also describes full scale tests to determine the effects of walls and ceilings on fire propagation between cable trays. Some small-scale scoping tests have been conducted to investigate the effects of varying the furnace pressure on cable penetration performance in the ASTM-E-119 Fire Test. The Sandia Fire Research Facility has been completed and a series of tests have been run to assess the effectiveness of Halon-1301 as a suppression system in extinguishing deep-seated cable-tray fires. It was found that given sufficient soak times Halon systems are effective in extinguishing such fires.

INTRODUCTION

The Office of Nuclear Regulatory Research of the United States Nuclear Regulatory Commission is conducting confirmatory research in areas considered important to protecting the health and safety of the public. Fire protection, established by NUREG-0050, "Recommendations Related to Browns Ferry Fire," is one area of such research.

The objectives of the Fire Protection Research Project at Sandia National Laboratories are to:

(1) provide data either to confirm the suitability of current design standards and regulatory guides for fire protection and control in light water reactor power plants, or to indicate areas where they should be updated;

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(2) obtain data to facilitate either modification or generation of standards and guides (changes are to be made where appropriate to decrease the vulnerability of the plant to fire, provide for better control of fires, mitigate the effects of fires on plant safety systems, and remove unnecessary design restrictions);

(3) Obtain fire effects data and assess improved equipment, design concepts, and fire prevention methods that can be used to reduce vulnerability to fire.

PROGRAM RESULTS

Cable-Tray Separation

In support of some of the provisions of NRC Regulatory Guide 1.75 "Physical Independence of Electric Systems," tests were conducted at Sandia with varying separation distances to determine the minimum separation necessary for cables most susceptible to fire. Vertical separation distances from 152 cm (5 ft) down to 26.7 cm (10.5 in) and horizontal separation distances from 91 cm (3 ft) down to 23 cm (9 in) were tested. For electrically initiated fires in a horizontal open-space configuration, it was determined that a fire will not propagate from the ignited tray to adjacent trays. These tests were conducted with fire retardant IEEE-383 qualified cable, 12-gage single-conductor and 12-gage triplex wire, utilizing both uniform and random-pattern cable packing.

Tests were also conducted with an experimental exposure (fuel) fire. The objective was to determine whether cable-tray separation alone is sufficient to prevent fire propagation between trays and between redundant safety divisions if an exposure fire resulted in a fully developed cable-tray fire.

The type and size of the worst-case exposure fire that must be considered for licensing are based on a fire-hazard analysis and will vary from plant to plant. Accordingly, no attempt was made to define a design-basis fire for the exposure-fire tests. Single-tray tests were conducted to find a reasonable set of conditions that would result in a fully developed cable-tray fire. The experimental exposure fire was then used in full-scale cable-tray exposure-fire tests. Propane burners were used to start an exposure fire in one tray, with a barrier placed between it and the tray above. When a fully developed fire was obtained in the first tray, the burners were turned off and the barrier was removed. This method allows experimental study of fire propagation from tray to tray under specific conditions and without the exposure fire affecting the other cable trays.

As noted above, a series of tests were conducted on arrays of cable trays, with both electrical and exposure-fire initiation. An array of 14 closely spaced cable trays was used to simulate a single safety division. Simulated redundant safety divisions were separated by the required 152 cm (5 ft) vertical and 91 cm (3 ft) horizontal distance. The principal conclusion was that a fully developed fire in the bottom cable tray of a stacked array may propagate to a redundant safety division without fire suppression systems (as expected). On the other hand, electrically initiated fires (IEEE-383 qualified cable) do not propagate because they do not result in a fully developed cable tray fire.

In order to determine the characteristics of a cable-tray fire in cable tunnels or in areas where structural walls are close enough to the tray to influence the fire, some of the tests were repeated to include the effect of walls and ceilings. The preliminary indication is that there is a greater chance of fire propagation under these conditions than with a similar configuration in an open area. It was shown that both the weight loss and heat flux at the top tray follow an inverse square law relationship with the distance to the corner.

In typical plant installations, cable trays are oriented vertically at some locations and in others are oriented both vertically and horizontally. Vertical cable trays have been and will be tested in both the open-space configuration and with walls and ceilings close enough to affect the fire.

The first full-scale vertical fire test was to demonstrate the effectiveness of a ceramic fiber blanket and automated fire suppression system to protect cables in a vertical cable tray configuration that is currently permitted by separation criteria guidelines. An open pool fire fueled by liquid hydrocarbon [~~0.008 m^3~~ 7.6 L (2 gal) of heptane] was used.

Three open-head sprinklers were located above the trays and connected to a separate manually operated water supply. Three dummy sprinkler heads without connection to the water supply were suspended near each open head. During the test the three dummy heads were monitored electrically to determine the times at which the fusible links were activated. In order to bracket the allowable response times, it was intended that only after activation of all three dummy heads in one location would the water system be manually operated. Two smoke detectors were also located in the test area.

The fire burned for about 40 minutes with the ionization detector activating at 11 s and the photoelectric detector activating at 14 s. Two of the fusible links at the closest sprinkler location activated (one at 52 s, the other at 54 s) but the third did not activate at all, consequently, no water was supplied. At 3 min 13 s, a short circuit between conductors was indicated. At 3 min 55 s, erratic measurements were recorded for the conductors in another tray indicating the existence of intermittent short circuits. In all cable trays except one, thermal damage of cables was observed near the base [8 to 15 cm (3 to 6 in) above the fire pan].

<u>Effectiveness of Fire Shields</u>

Sandia National Laboratories has completed a series of tests using different fire shields:

- ceramic wool blanket over ladder tray

- solid bottom tray with no cover
- solid cover on ladder tray with no vents
- vented cover on solid bottom tray
- 2.54 cm (1 in) fire barrier (thermal board) between trays.

The results of the tests showed that all fire shield designs offered some protection. None of the cable which passed the flame retardancy test in IEEE Std 383-1974 ignited. It is possible to ignite the cable which did not pass this flame retardancy test; however, no propagation was observed past the fire shields.

Experiments are planned to study the methodology for testing the fire retardancy of seals and penetrations. Some small-scale scoping tests have been conducted to investigate the effects of varying the furnace pressure on cable penetration performance in the ASTM-E-119 Fire Test.

Effectiveness of Fire-Retardant Coating Materials

The objective of this portion of the program is to provide information on the effectiveness of fire-retardant coating materials when used in typical cable-tray installations.

A survey of coating materials available for use in cable trays was initiated in August 1976. Generic types were chosen for testing and evaluation in small- and large-scale cable systems tests. Small-scale tests on basic coating properties have been conducted by using six coatings and two cable types. Full-scale tests were conducted using both single and double trays.

While the results showed that all coatings offer a measure of additional protection, there was a wide range in the relative effectiveness of the different coatings tested. No propagation to the second tray was observed in any of two-tray tests in which cable that passed the IEEE Std 383-1974 test was used. (Propagation was observed in three tests involving cable which did not pass the IEEE Std 383-1974 test.) Overall, a good correlation was obtained between small-scale and large-scale tests.

Halon-1301 Suppression Tests

Seven full scale cable tray fire tests have been conducted at Sandia's Fire Research Facility to provide confirmatory data on Halon 1301 as a suppression measure for such fires. Five of these tests used a 6% Halon-1301 concentration as a fire suppression agent while two of the tests used a lack of ventilation (oxygen deprivation) as a suppression technique. Results of three tests which used IEEE-383 qualified cable in a horizontal configuration were as follows: 1) A 45-minute Halon soak did not allow re-ignition; 2) a 10-minute Halon soak did not allow re-ignition; 3) a 4-minute Halon soak did allow re-ignition.

Results of two tests which used PE/PVC non-qualified cable were as follows: 1) a horizontal configuration with a 16-minute Halon soak did not allow re-ignition; 2) a vertical array test with a 5-minute Halon soak did not allow re-ignition. Results of two tests which used a horizontal configuration of IEEE-383 qualified cable and no Halon were as follows: 1) a 45-minute "buttoned up" period did not allow re-ignition when the ventilation system was turned on; 2) a 10-minute "buttoned up" period did allow re-ignition when the ventilation system was turned on.

These results indicate that at least a 10-minute soak period should be used for Halon suppression systems before the room is entered. The closing of fire dampers in a room is a valuable aid in suppressing the fire, and might be adequate by itself if given sufficient time before the fire brigade enters the room. The critical question is: "How long does it take for the exposed hot surfaces of the cable insulation to cool below its ignition temperature?" The tests described here attempted to answer this question by providing temperatures taken at the surface of several exposed cables. Cooling time will be influenced somewhat by the ambient temperature and to a large extent by internal cable bundle temperatures. These temperatures have also been recorded for the fire tests described. Deep seated fires were obtainable in cable trays using IEEE-383 qualified cable but were not seen in the tests using unqualified cable where flaming was more easily acquired.

Future Work

More full scale testing will be completed to assess the effectiveness of CO_2 and water as suppression systems in extinguishing deep-seated cable tray fires. These results will be compared with each other as well as the results obtained from the Halon-1301 suppression tests. Full-scale replication testing of actual plant configurations and fire protection systems will be implemented. Confirmatory data on both line and point fire detection systems will be obtained and an in-situ test method developed. The evaluation of penetration fire stop methodology will be continued.