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Fire Protection Research Program at Sandia Laboratories

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

ABSTRACT

Sandia 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 December 1979. 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. A facility has been completed which will be used to assess the effectiveness of various suppression systems in extinguishing large-scale cable tray 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 Laboratories are to:

(1) provide data either to confirm the suitability of current design standards and regulatory guides for

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fire protection and control in light water reactor power plants, or to indicate areas where they should be updated;

(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.

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 20 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 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 all 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 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.

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 (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 sec and the photoelectric detector activating at 14 sec. Two of the fusible links at the closest sprinkler location activated (one at 52 sec, the other at 54 sec) but the third did not activate at all, consequently, no water was supplied. At 3 min 13 sec, a short circuit between conductors was indicated. At 3 min 55 sec, 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 inches) above the fire pan].

Effectiveness of Fire Shields

Sandia 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 and using single and double tray configurations as well as electrical cable which passed the IEEE Std 383-1974 flame retardancy test and cable which did not pass this test.

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 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.

Figure 1. Cable Trays and Conduit loaded with Qualified Cable for Full Scale Exposure Fire Test.

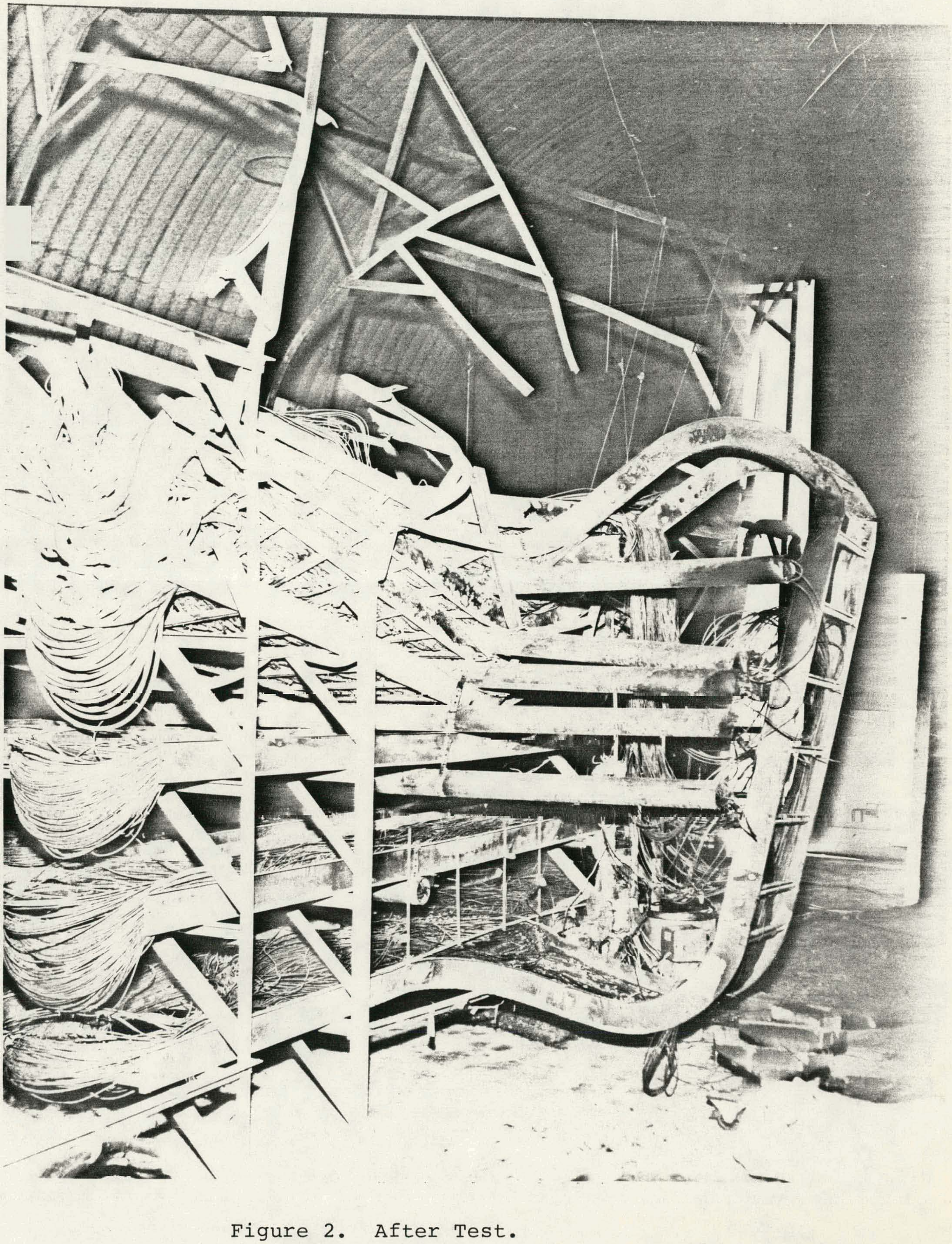

Figure 2. After Test.

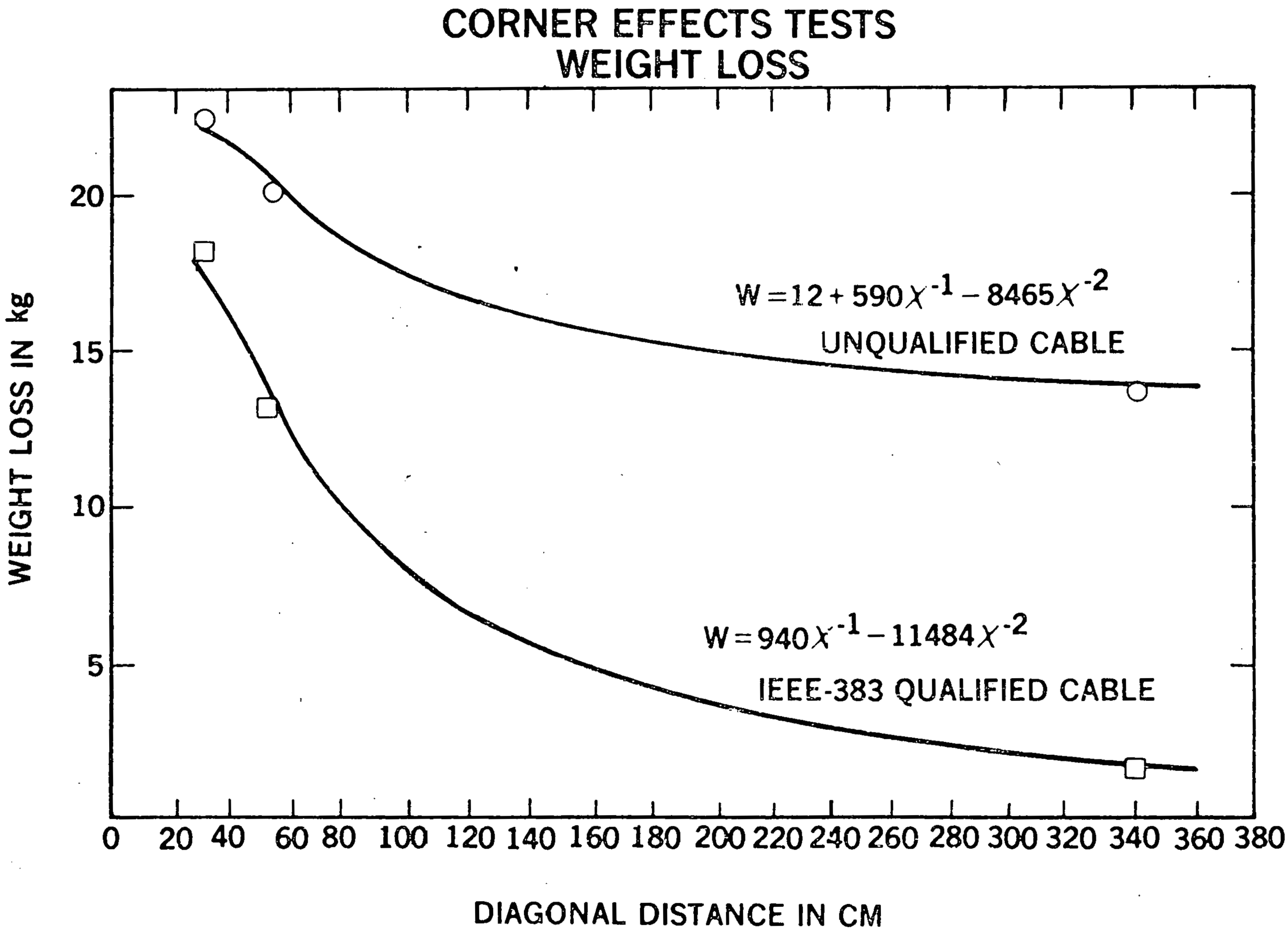

Figure 3. Weight Loss of Cables in Corner Effects Fire Test.