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MEMORANDUM FOR: Edson G. Case, Acting Director
Office of Nuclear Reactor Regulation

Robert B. Minogue, Director
Office of Standards Development

FROM: Saul Levine, Director
Office of Nuclear Regulatory Research

SUBJECT: RESEARCH INFORMATION LETTER #14 - "PHYSICAL SEPARATION CRITERIA FOR ELECTRICAL CABLE TRAYS (HORIZONTAL OPEN SPACE CONFIGURATION)"

Introduction

This memorandum transmits the results of a completed portion of the NRC Fire Protection Research Program relating to the adequacy of cable tray separation to prevent the spread of electrically initiated and exposure fires. It indicates that currently used criteria for cable tray separation appear to be adequate for electrically initiated fires but that changes may be required for fire due to external ignition sources.

Background

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 conjunction with the review of the Browns Ferry fire and through consultation and formal review with the NRC user groups. The Electrical Standards and Fire Protection Research Review Group was the focal point for both the formulation of the research program and evaluation of program results that form the basis of this RIL.

The specific user requirement for the research conducted to date with electrically initiated fires is based on the need to verify Regulatory Guide 1.75, "Physical Independence of Electric Systems." Exposure fire testing employing external fuel sources was conducted to provide data for the current NRC staff position as documented in the 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 requires only consideration of electrically initiated fires without consideration of any fuel source other than the cable insulation itself.

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However, the staff position for future plants is that exposure fires must be considered. The type and size of the exposure fire is 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 support an assessment of the effectiveness of separation distance in preventing the propagation of both electrically initiated fires and exposure fires.

A complete systems test including all cable tray configurations and cable tray components such as conduits, barriers, breaks and penetration fire stops was not possible because of the lack of uniformity in existing and proposed plants, the size of the test that would be required, and because there is no single design basis fire that can be utilized for design purposes. The total electrical cable system fire problem is covered by the first five program elements outlined in Enclosure 1. This RIL covers results from tests and analysis for the horizontal open space cable tray configurations portion of the first program element. Subsequent RIL's will cover data on vertical cable tray configurations and enclosed or tunnel areas.

Specifically, the scope of this RIL covers evaluation of the effectiveness of cable tray separation for typically loaded horizontal cable trays in a building approximately 60 ft. long, 19 ft. high and 24 ft. wide simulating an open plant configuration where the effects of reflected heat from the walls and ceiling are minimized. Eighteen-inch wide open-ladder steel cable trays, typical of those used in power plants, were used. Horizontal and vertical separation distances between single trays representing different safety divisions were varied from five ft. vertical and three ft. horizontal (which are required in Regulatory Guide 1.75 for separation between safety divisions) to a minimum of 10.5 inches vertical and 8 inches horizontal. Tests were also conducted with a single division comprising 14 closely packed trays. The fourteen cable trays simulating a closely packed single division were spaced 10.5 inches vertically and 8 inches horizontally (Figure 1). Allowable separation distances stated in Regulatory Guide 1.75 were used between redundant divisions.

Fires were started using both electrical intiation (simulating an electrical short between two conductors) and an exposure fire using propane burners. Air flow was maintained to simulate normal ambient plant air flow in plant open space areas. Some initial testing utilized cable trays that were uniformly loaded up to the top of the side rails, which resulted in a 60% volume fill. Later tests, including all of the tests with the packed 14 tray division, used a random fill pattern with a loading of approximately 40% volume fill recommended by the Insulated Power Cable Engineering Association (IPCEA). Rated electrical load on cables was utilized initially but was shown to have no significant effect on the propagation of fires in open ladder, uncovered trays.

The cable fill pattern was varied from a uniform fill pattern representing the maximum fuel density and minimum air space between cables to a random pattern with minimum fuel density and maximum air space. Fire retardant cable was utilized that is in compliance with IEEE-383, "IEEE Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations."

Results

The test data and analysis (Enclosure 2) in support of this RIL show that there are a number of key parameters that determine whether or not a cable tray fire will develop and propagate to an adjacent tray. Probably the most important factor in determining if a cable tray fire will develop is the spacing between cables in the tray which establish the air-fuel mixture at the burning surface. Since the cable pattern cannot be specified and maintained during power plant construction, a random pattern with maximum and uniform air space between cables was chosen after it was shown to be the most vulnerable to fire propagation. This pattern with a 40% volume fill was used for most of the tests.

It was established by measurement and observation of the 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 fuel. Propagation in thestests conducted 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. A necessary condition for fire propagation is that the fire become fully developed in terms of the cable bundle temperature and the equilibrium heat fluxes reached. The burning surface area is probably the most important factor in establishing a fully developed fire. This fully developed condition must be sustained long enough to allow for the collection of the gaseous fuel. Also, sufficient fuel must be available to support the combustion long enough to allow for the collection of sufficient gaseous fuel. The air flow over the cable trays and the extent to which the gaseous fuel can be trapped by ceiling walls or other barriers also affect the degree to which the gaseous fuel collects around the cable tray. It was shown that a fully loaded cable tray is itself a sufficient barrier for the collection of the gaseous fuel.

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Two propane burners rated at 70,000 Btu/hr., burning for five minutes beneath a cable tray, provided sufficient conditions to yield a fully developed cable fire. However, it cannot be concluded from the tests that these are minimum conditions. Also, the test data show that for the configuration tested, a fully developed cable fire will propagate if the fire covers at least an 18 x 36 inch area and there is sufficient fuel to sustain the fire for about five to ten minutes. As is the case for conditions determined to obtain a fully developed fire, these conditions for propagation may not be a minimum set.

In summary, it is beneficial to consider the cable tray fire question in two parts. The first consideration is to establish the possibility of a fire developing in a cable tray. If a cable fire develops in a cable tray, the next consideration is the possibility of the fire propagating to an adjacent tray. In keeping with this problem definition, the following specific conclusions can be drawn from the tests and analysis conducted.

1. It is possible to initiate a fire electrically in a fully loaded open ladder cable tray by generating an overcurrent in two contiguous conductors. The rated cable current must be increased by about a factor of five to start the fire.

2. With an electrically initiated fire in a cable tray, propagation to adjacent cable trays is unlikely in horizontally oriented cable trays filled with electrical cable capable of passing the current version of the IEEE-383 standard. The apparent reason that cable tray fire propagation is unlikely is because there is less chance of an electrically initiated fire becoming fully developed.

   The tests showed that an electrically initiated fire started at a single location and was followed by other sporadic point source fires. For the tests conducted with electrical initiation, the fires did not spread over a large enough area to become fully developed. For the cable tray configuration tested, it isuunlikely that an electrically initiated fire could cause concurrent burning o over a large enough surface area to establish a fully developed fire which is a necessary condition for propagation. It is possible that further testing with electrical initiation under different conditions, such as sustained overload in covered trays may result in fully developed fires.

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3. Fully developed cable tray fires were obtained using two propane gas burners each having a nominal rating of 70,000 Btu/hr. with a burn time of five minutes. (IEEE-383 specifies a single 70,000 Btu/hr. with a 20 minute burn time). Such an exposure fire is not considered unreasonable and has been estimated to be equivalent to the fire that would result from a small oil spill (approximately one gallon) and subsequent ignition.

4. If a fully developed fire is obtained in a cable tray, propagation to adjacent trays located 10.5 inches or less above the fire is likely to occur in plant open space areas. Tests were not conducted to determine the minimum space required between trays to prevent a fully developed fire from propagating to the tray above it.

5. A fully developed fire initiated in a typically loaded safety division (consisting of two horizontal stacks of seven trays with a spacing of 10.5 inches between each tray and the tray above and a spacing of 8 inches between the two stacks), after tray-to-tray propagation within that division may propagate to a redundant safety division across the 5 ft. vertical separation distance specified in Regulatory Guide 1.75.

<u>Evaluation</u>

The data obtained confirm the original licensing position as taken in Regulatory Guide 1.75 requiring a vertical separation of 5 ft. between safety divisions if only electrically initiated fires are considered. Testing was limited to electrical cable capable of passing IEEE-383 installed in horizontally oriented cable trays in a test cell simulating a plant open space area.

Regulatory Guide 1.75 is based on consideration of internally electrically initiated fires, and the supposition is made that additional fuel or ignition sources need not be considered. Appendix A to the Branch Technical Position APCSB 9.5-1, "Guidelines for Fire Protection for Nuclear Power Plants," issued in May 1976, and the proposed Regulatory Guide 1.120, "Fire Protection Guidelines for Nuclear Power Plants" both require that fuel, in addition to the cable insulating material,

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including external ignition sources be considered for generation of exposure fires. The data from the exposure fire tests show that additional protection, beyond the 5 ft. vertical and 3 ft. horizontal separation distance may be required between redundant safety divisions. Work is scheduled to confirm generic barrier and coating designs and materials that will provide adequate protection for the redundant safety divisions when subjected to exposure fires.

Original Signed by
Saul Levine

Saul Levine, Director
Office of Nuclear Regulatory
Research

Enclosures:
1. Research Support Branch Plan
2. 8 Quick-Look Reports (Sandia Laboratories): July 76, August 76, October 76, November 76, December 76, February 77, March 77, July 77

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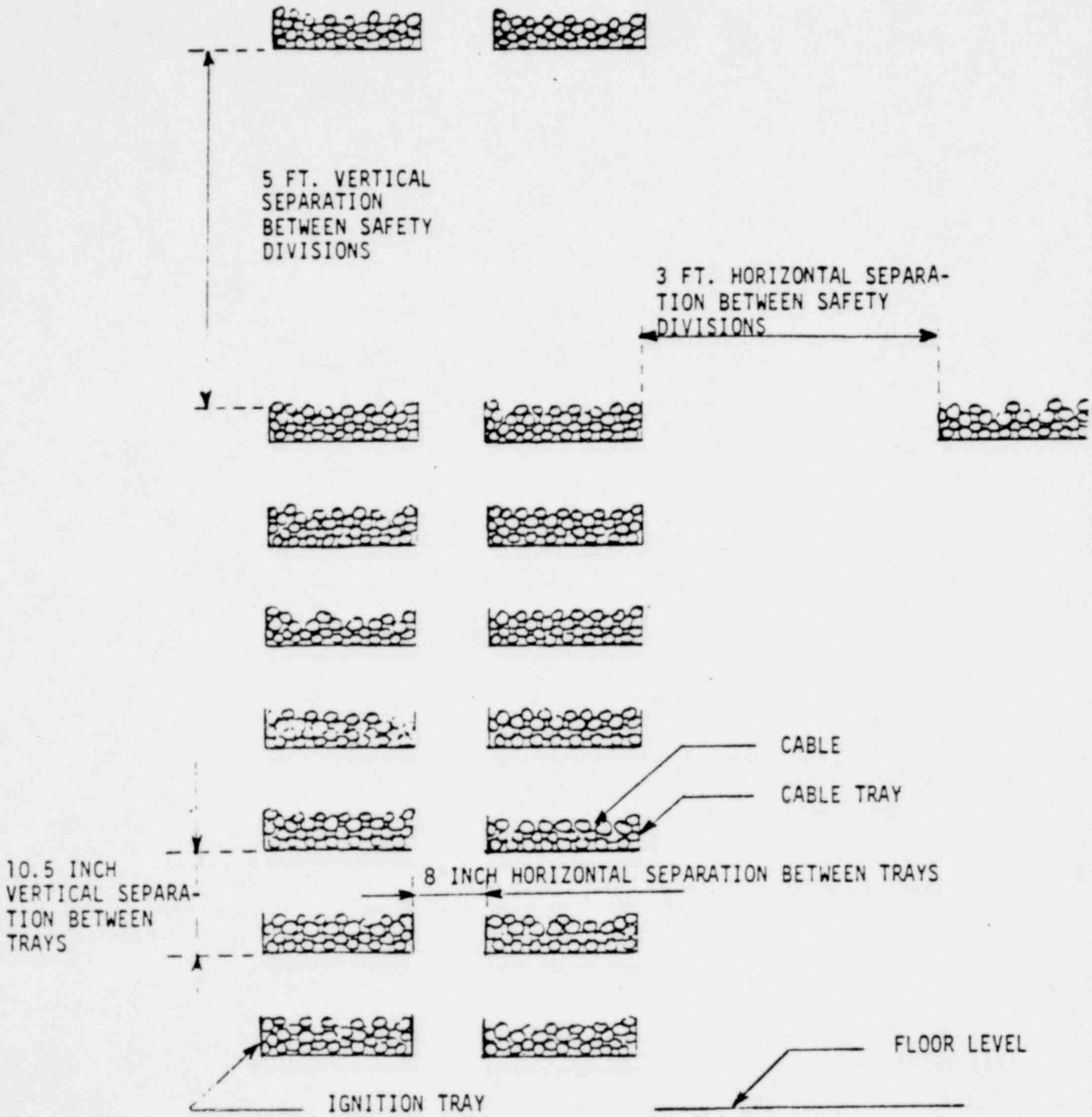

FIGURE I. HORIZONTAL OPEN SPACE CABLE TRAY ARRANGEMENT (STACKED TRAY TESTS)

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