Understanding the Fire Hazards of Grouped Electrical Cables

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INTRODUCTION

Nuclear power plants typically contain hundreds of kilometers of electrical cables. The *in situ* fire fuel load is dominated by cable insulating materials in most areas of a plant. The cables are found in both routing raceways and electrical cabinets. In a postulated fire scenario, they can be an ignition source, an intervening combustible, and/or a device that can potentially lose functionality. The cables are made up of a variety of thermoplastic (TP) and thermoset (TS) materials. Thermoplastic materials tend to melt and drip when burned, whereas thermosets tend to form a char layer.

Electrical cables have been responsible for, or contributed to, a number of fires in commercial nuclear plants over the years. In 1975, a serious fire involving electrical cables occurred at the Browns Ferry Nuclear Power Plant operated by the Tennessee Valley Authority [1]. The fire caused damage to more than 1,600 cables resulting in loss of all Unit 1 emergency core cooling system equipment. The damage was extensive because of the flammability of the cables, including ease of ignition, and flame spreading.

TEST PROGRAM

CHRISTIFIRE (Cable Heat Release, Ignition, and Spread in Tray Installations during FIRE) is an Office of Nuclear Regulatory Research (RES, US NRC) program to quantify the mass and energy released from burning electrical cables [2]. The experimental program has two main thrusts—bench-scale measurements of small samples of burning cables and full-scale measurements of the heat release and fire-spread rates of cables burning within typical ladder-type trays. The bench-scale measurements include micro-calorimetry of cable components, effluent characterization using absorption spectroscopy, and measurements of the heat release rate using a cone calorimeter. The full-scale measurements include the burning of a variety of cables within a typical tray under radiant panel heating, and full-scale, multiple tray fires. Table 1 summarizes the experiments. The experiments can be roughly divided into two types – one to measure heat release and spread rates, the other to assess the composition of the cable materials and combustion products. From the point of view of a fire model, these experiments quantify the production rates of mass and energy for a tray of burning cables.

Table 1. Outline of Experimental Program

Scale	Description	Related Standard
Full	Horizontal Trays	None
Intermediate	Radiant Panel	None
Small	Cone Calorimeter	ASTM D 6113
Small	Tube Furnace	ISO/TS 19700
Micro	Micro-Calorimetry	ASTM D 7309

RESULTS

Figure 1 presents results of the Radiant Panel experiments for all of the cables tested. The data indicates that thermoset cables burn in a range from 100 kW/m^2 to 200 kW/m^2, whereas thermoplastics burn from 200 kW/m^2 to 350 kW/m^2. These ranges are fairly broad due to differences in the specific cable materials and construction, and also differences in the exposing heat flux. Note that in most cases, the measured heat release rate increased with increasing imposed heat flux. However, in some cases, the value did not exhibit this trend. The reason for this has more to do with the method of extracting the average value from a time-dependent burning history than with anything physical. Also, the way the cables were positioned in the tray did sometimes impact the burning pattern.

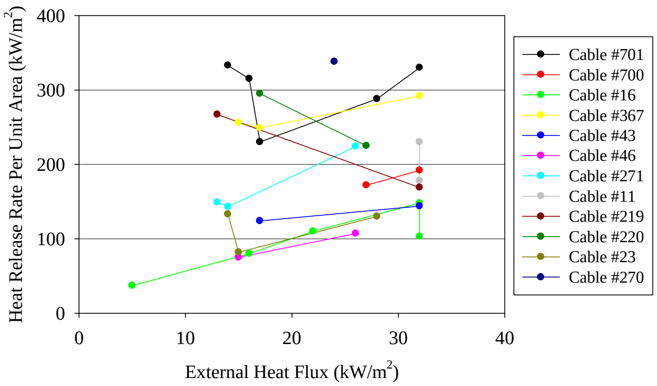

Fig. 1. Summary of the radiant panel heat release rates. Cables 219, 220, 367 and 701 have properties typical of thermosets. The rest behave like thermoplastics.

Figure 2 shows a multiple tray experiment consisting of four trays, one above the other with a spacing of 30 cm (1 ft). Each tray was 3.6 m (12 ft) long and contained 40 thermoplastic (PE insulated, PVC jacketed) cables. The cables were packed loosely. The burner under the bottom tray was maintained at about 40 kW and turned off following the observation of sustained burning in Tray 2. The fire spread to the ends of each tray, following a V-pattern by which the cables in front of the flames were pre-heated by the fire in the tray above. There was virtually no solid residue left after the experiment, only the copper conductors remained. The results of similar experiments performed with thermoset cables were significantly different, mainly in the peak heat release rate. The measured burning rates of the thermoplastic cables in the radiant panel apparatus and the cone calorimeter were greater than the thermoset cables by approximately 30 %, but the peak heat release rates of the thermoplastic cables in the multiple tray experiments were greater by factors ranging from 3 to 8. The reason for this is the fact that the thermoplastic cables have a significantly lower burning temperature, as measured in the micro-calorimeter, allowing a fire to grow and spread more rapidly.

CONCLUSION

The CHRISTIFIRE test program is a multiple year project to assess the burning behavior of grouped electrical cables. The first phase of the program has focused on open, horizontal configurations of ladder-back cable trays. The experimental results indicate a clear distinction in the burning behavior of thermoplastic and thermoset cables, in particular the heat release rate per unit area (100 to 200 kW/m^2 for TS and 200 to 350 kW/m^2 for TP). This can lead to a roughly ten-fold increase in the heat release rate of an array of burning cable trays.

The next phase of the CHRISTIFIRE program will address vertical tray configurations, as well as horizontal configurations within enclosures. The importance of enclosures is that the spread rate of the fire is more likely to be enhanced by trapped heat within the compartment.

Fig. 2. Photograph of a multiple tray test involving a thermoplastic cable.

REFERENCES

1. U.S. NRC. “Cable Fire at Browns Ferry Nuclear Power Station,” NRC Bulletin BL-75-04, U.S. Nuclear Regulatory Commission, Washington, DC, March (1975)
2. McGrattan, K.B. *et al*. *Cable Heat Release, Ignition and Spread in Tray Installations during Fire (CHRISTIFIRE), Volume 1: Horizontal Trays*, NUREG/CR-7010, US Nuclear Regulatory Commission, Washington, DC (2010).