Attachment

NRC Comments on EPRI Technical Report 1022993
Evaluation of Peak Heat Release Rates in Electrical Cabinet Fires
Re-analysis of Table G-1 of NUREG/CR-6850 and Table G-1 of EPRI 1011989, February 2012

1. The report has calculated a severity partitioning factor (low intensity versus greater than low intensity) from the fire test data that is then applied in the analysis of HRR potential for those fires to be postulated in fire probabilistic risk assessment (PRA). This approach is fatally flawed because the fires postulated in fire PRA derive from a completely separate and uncorrelated basis; namely, the fire frequency analysis and the screening of events in the fire event database. These two items, the tests and the events retained in the fire frequency analysis, are completely disconnected and the partitioning factors calculated from the tests are without merit in the PRA fire scenario context.

2. The fire tests are **not** a statistical representation of either in-plant cabinets or, more specifically, actual fire ignition events in actual cabinets. It is wrong to correlate the tests directly to what will happen given an ignition event in any particular nuclear power plant.

3. It is not possible to correlate fires that did not spread during the various tests to what will happen given the fires that make up the fire frequency set. In particular, the fire frequency set has already screened out those reported "fires" that had no potential for fire spread or for a self-sustained fire. In contrast, the tests include many cases where, for whatever reason, the fire was not self-sustaining and self-extinguished with little or no fire spread. One simply cannot draw a direct correlation between these two completely separate observations.

4. In Chapter 4 of the report, it is assumed that the peak HRR of an open cabinet fire is linearly proportional to the total energy released in the experiment (Fig. 4-3). However, this relationship is, in general, not true. Cable experiments conducted as part of the CHRISTIFIRE test program (NUREG/CR-7010, Volume 1, "Cable Heat Release, Ignition, and Spread in Tray Installations During Fire") demonstrated that the peak HRR of a multiple tray cable fire could be doubled simply by spreading the equivalent mass of cable over a wider tray. The conclusion regarding the peak HRR of an open cabinet fire is based on approximately 16 experiments, of which only 7 produced peak HRRs exceeding 100 kW. The total energy released was roughly half of the theoretical value, but with an appreciable scatter ranging from about 0.1 to 0.8 (Fig. 4-2). From this information, a statistical model is applied to produce a probability distribution for the peak HRR. This model is fairly crude and its results (Figs. 4-6 and 4-7) are not substantiated by fire science and physics, or the relatively small sample size and large scatter in the measurements.

5. The concept of "combustion efficiency" is not well developed in the report. On page 4-4, it is stated that "the combustion in the cabinet will rarely, if ever, lead to the release of all the theoretical energy content of the combustible. This is because the actual oxidation reaction is not complete, as typically evidenced by the formation of soot byproducts during the fire." However, the authors use an effective heat of combustion of 31 MJ/kg

(NUREG/CR-4527), which already accounts for less than ideal combustion. The so-called "combustion efficiency" of the cables has more to do with the fact that electrical cables typically have residue yields of between 0 and 50% (NUREG/CR-7010, Volume 1); that is, there is a considerable amount of char and ash left over after a cable fire. In addition, it is almost certainly true that the fire does not spread to all of the cables within the cabinet in a typical experiment. Thus, in any given cable fire experiment, it is not unusual to consume about 50% of the combustible mass, but this should not be characterized as an inefficiency due to less than ideal combustion conditions. Regardless of what it's called, it just adds to the overall uncertainty of the analysis and lessens the need for a sophisticated statistical treatment of the data.

6. Potentially oxygen-limited or ventilated-limited electrical cabinet fires that have occurred at nuclear power plants might not have been reflected in the fire test data.

7. In Chapter 5 of the report, the methodology to predict the peak HRR of an electrical cabinet with limited ventilation is unnecessarily complicated and of questionable validity. The basic idea is that the HRR of the fire is limited by the ventilation rate. A widely accepted concept in fire science states that the natural ventilation rate into an under-ventilated compartment is proportional to the opening area multiplied by the square root of the opening height, the so-called $A\sqrt{h}$ rule. The proportionality constant is typically taken to be 0.5 kg/s/m$^{2.5}$, even though the value has been calculated to be anywhere between 0.4 and 0.61 kg/s/m$^{2.5}$ (Walton and Thomas, *4th Edition of Society of Fire Protection Engineers (SFPE) Handbook of Fire Protection Engineering*). Given the wide variety of applications, a more precise derivation of this proportionality factor is unwarranted. However, there is a considerable amount of effort in the cabinet fire analysis to refine this simple correlation well beyond its limits. Equation 5-1 involves a number of parameters that the authors roughly approximate, like the pressure drop coefficients, and a number of parameters that the authors spend a considerable amount of effort to quantify, like the inlet areas and gas temperature inside the cabinet. It is this inconsistent treatment of the general theory that casts doubt on everything to follow. Had the authors simply applied a simple $A\sqrt{h}$ rule and simple guidance on how to determine A and h, the resulting methodology would have been credible and practical. As it is now, it is too complicated, and in some instances unsubstantiated.

8. In Chapter 5 of the report, an important assumption in the ventilation-limited cabinet fire analysis is that the combustion does not take place outside of the cabinet. This is not a particularly good assumption because a fully-involved cabinet fire is capable of producing fuel gases at a rate that exceeds the air supply. In that case, these excess fuel gases will vent out of the cabinet and potentially burn. On page 5-9, the authors cite experiments at IRSN where significant flaming outside of the compartment occurred. However, the authors claim that this would not occur if the plastic cable material were Polyethylene (PE) or Polyvinylchloride (PVC) instead of Polymethylmethacrylate (PMMA) because of their "comparatively lower combustion efficiency, 0.88 and 0.35." They cite the 3rd Edition of the *SFPE Handbook* for these values. However, a reference for these values was not found in Table 3-4.14. Furthermore, as discussed in a prior comment, the term "combustion efficiency" is being used inappropriately throughout the report. The fact that in some of the experiments the cable is not completely consumed does not constitute a "combustion inefficiency" in the sense that is understood by the fire

science community. Finally, even if the authors' claim is taken at face value; there is no reason why a fire involving PMMA with a "combustion efficiency" of 0.96 would significantly differ from one involving PE with a "combustion efficiency" of 0.88. The apparatus used at Factory Mutual Research to make the measurements listed in Table 3-4.14 of the *SFPE Handbook* uses only a few grams of sample, has considerable uncertainty, and its results do not necessarily scale to that of a cabinet.