JENSEN HUGHES

Advancing the Science of Safety

THE MEASURED HEAT RELEASE RATES OF TRANSIENT FUEL ITEMS FOUND IN NUCLEAR POWER PLANTS

Jason Floyd and Matthew DiDomizio, Jensen Hughes, USA
Kevin McGrattan and Matthew Bundy, National Institute of Standards and Technology, USA
Marko Randelovic and Ashley Lindeman, Electric Power Research Institute, USA

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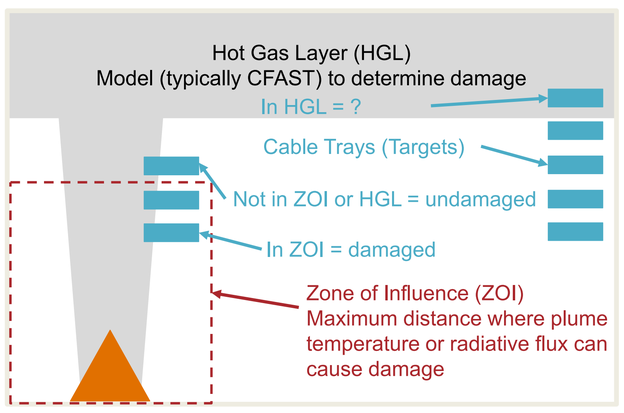
1 Fire Modeling for PRA* in a Nutshell



*PRA = probabilistic risk assessment

2 Transient Fires in PRA

A transient fire is a fire that results from combustible materials not fixed in place like a motor, transformer, or electrical cabinet. A transient fire could occur anywhere that there is a surface where transient materials could be placed.

The current recommended approach on treating transient fires is contained in NUREG/CR-6850 and NUREG/CR-6850 Supplement 1. The recommendation is that transient fires are represented by a gamma distribution with a 75th percentile HRR of 142 kW and a 98th percentile HRR of 317 kW with a growth rate of 2 minutes (unconfined) or 8 minutes (confined – e.g. trash can).

In a PRA, transient fires are typically the number two or three source of fire risk in a nuclear power plant.

3 PRA Realism

At first fire PRAs were used for NFPA 805, to demonstrate that a plant met an overall limit on core damage frequency. It was recognized that conservatisms in the PRAs existed, but they were tolerated since plants were still able to meet risk targets.

Now PRAs are being used for risk informed maintenance activities. All plants have technical specifications which define minimum amounts of safety equipment that must be operational. If a plant drops below this it must go offline. For some equipment a brief time period for repair is allowed. Being offline can mean $1,000,000 a day or more in lost revenue. Technical specification times originated long before PRAs and were largely based on expert judgement. A plant can get a longer time for repair if the PRA shows the risk is small. PRA conservatism makes this more difficult. This has resulted in a number of research efforts to improve realism in fire PRAs.

4 The Realism Issue

The 317 kW 98th percentile heat release rate is based on a set of 27 experiments from the literature at the time NUREG/CR-6850 was being written. Some of the experiments contain fuel items not typically found in risk significant areas of a plant. As a whole, the set of experiments appear to be more severe than operational experience (all plants report fire events to a centralized database maintained by EPRI).

A typical cable tray arrangement is for trays to run 0.3 to 0.6 m above electrical cabinets that are 1.8 to 2.1 m tall. This is within the ZOI of a 317 kW fire.

This suggests that not only does the guidance lack realism (not matching operational experience) but it is also likely resulting in significant conservatisms in fire PRAs.

5 Project Outline

Phase 1: Burn fuel packages representative of transient fire events in the Fire Events Database (FEDB).

- 290 tests of 99 fuel package were done using a 100 kW calorimeter at Jensen Hughes in Baltimore, MD USA (EPRI funded tests) and the 1 and 3 MW calorimeters at the National Institute of Standards and Technology in Gaithersburg, MD USA (US Nuclear Regulatory Commission [NRC] funded tests). Fires burned without intervention until there was no visible flame.
- Ignition sources were selected to be representative of the strength and duration of those in FEDB events.

Phase 2 (Future Work): Using the FEDB transient fire events, weight the test data and generate new gamma distributions for HRR and ZOI plus guidance on how to model the time-dependence of a transient fire.

Test data will be published as a joint EPRI/NRC report (NUREG)

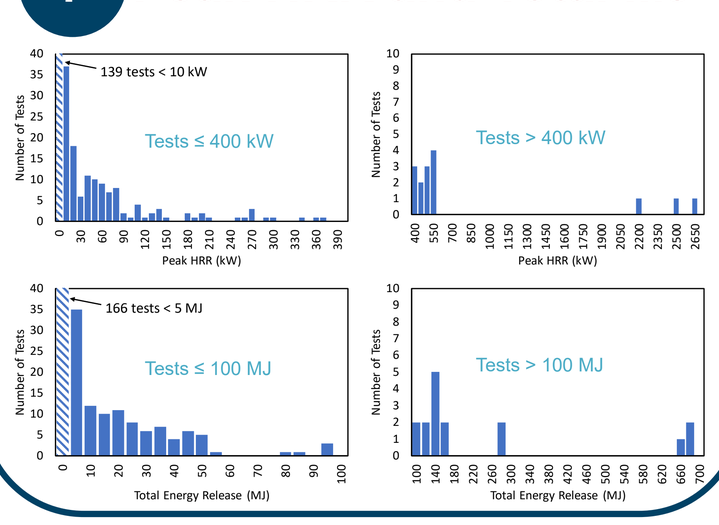
6 Ignition and Fuels

- Butane lighter – fast igniting fuels
- Nylon wick – 6 cm x 1 cm nylon rope with 5 mL of heptane
- Continuous flame – ~100 W propane flame from 0.5 cm tubing
- Radiant panel – 15 cm x 25 cm panel at 30+ kW/m^2 representing a halogen work light.

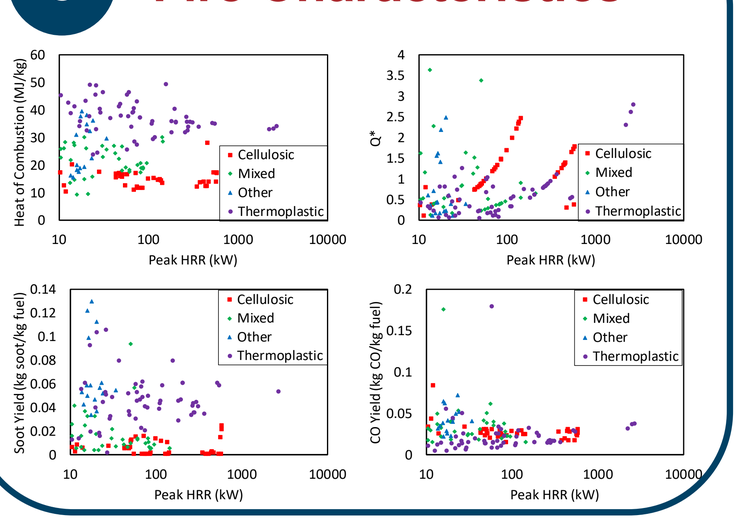
Cotton rags, paper, cardboard boxes, duct tape, tarps, debris piles, plastic buckets, vacuums, trash bags, mop+bucket, rope, plastic chain, power cords, safety cones and chain stanchions, plastic tubing, canvas tool bag with tools, wood scaffolding and pallets, laptop computer, tablet computer. Flammable liquids in plastic bottles, oil absorbing pads, tablet computer, temperature ventilation ducts

For each fuel type there were multiple configurations and repeat tests.

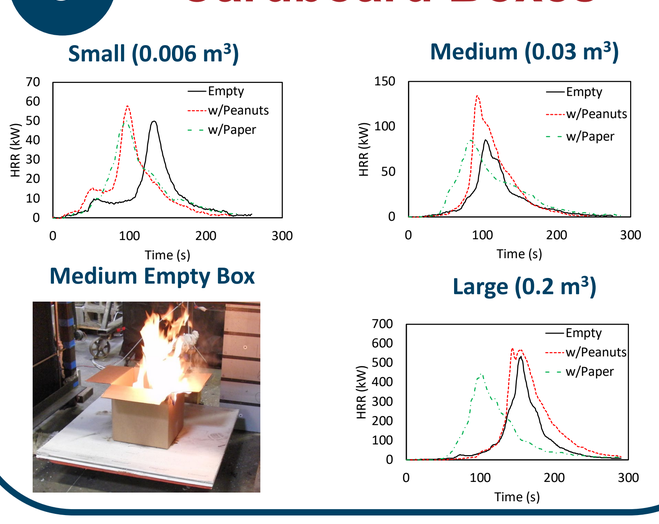
7 Peak HRR and Total MJ



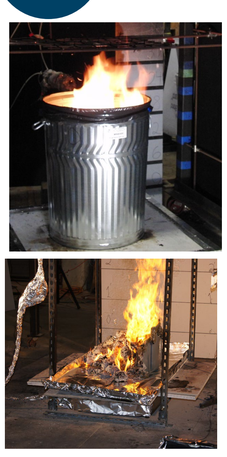
8 Fire Characteristics

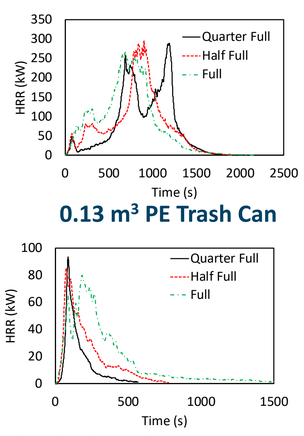


9 Cardboard Boxes



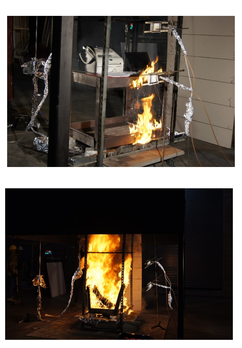
10 Trash Cans



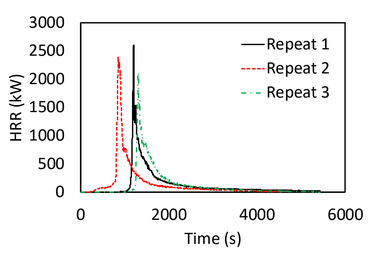


Cans have PE bag, plastic water bottles (empty), paper

11 Plastic Cart w/ Laptop



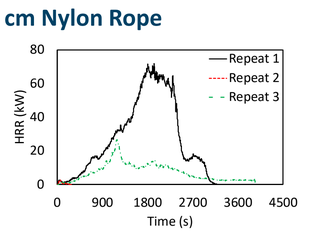
Laptop, 3-ring Binder w/paper, and printer on two-shelf plastic work cart



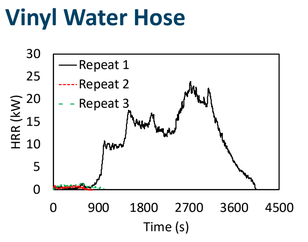
This test represents the worst transient fire event in the FEDB

12 Rope/Hose

15.2 m of 2.5 cm Nylon Rope

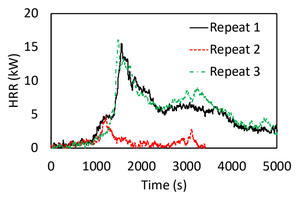


15.2 m of 1.9 cm Vinyl Water Hose

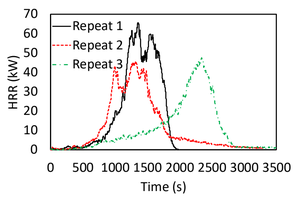


13 Safety Cone/Stanchion

Stack of Four 23 cm Tall Plastic Safety Cone

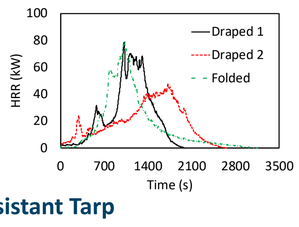


102 cm Tall Plastic Chain Stanchion

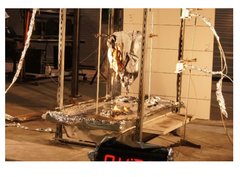


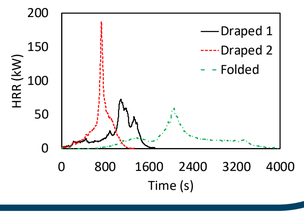
14 Plastic Tarps

Fire Resistant Tarp



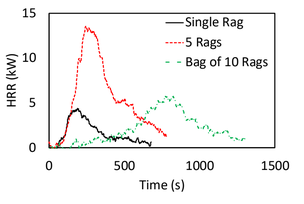
Non-Fire Resistant Tarp



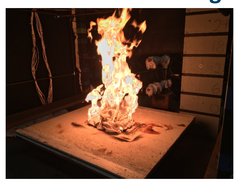


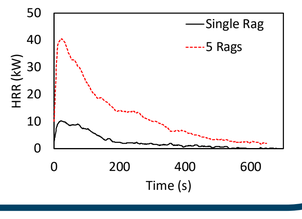
15 Cotton Rags

Dry Cotton Rags



Cotton Rags w/5 mL Heptane Per Rag





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