SAND2020-2165PE

HEAF Cable Fragility Testing

PRESENTED BY

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Purpose

- Fire PRA targets (typically electrical cable) have known thermal fragility characteristics for traditional thermal fires.

- Under high intensity, short duration exposures the failure and heat transfer mechanisms may change the fragility characteristics.

- The purpose of this initiative is to determine the fragility of fire PRA targets exposed to high intensity heat sources.

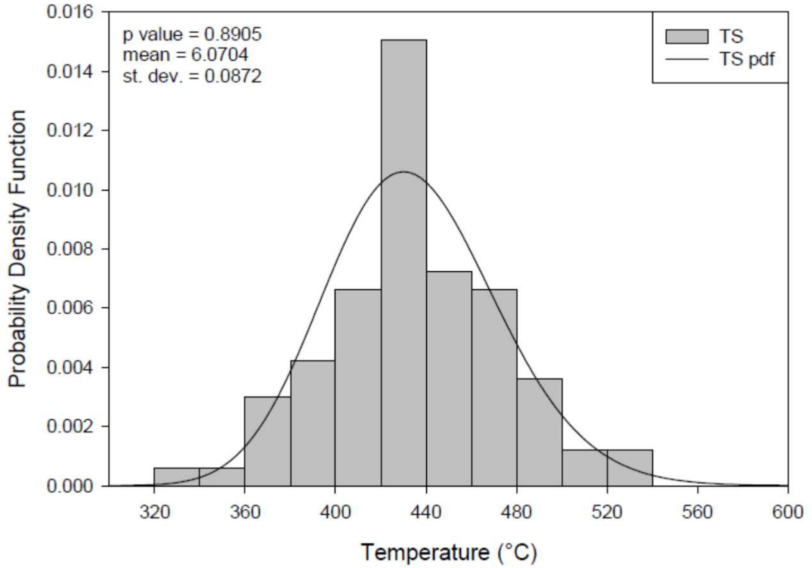
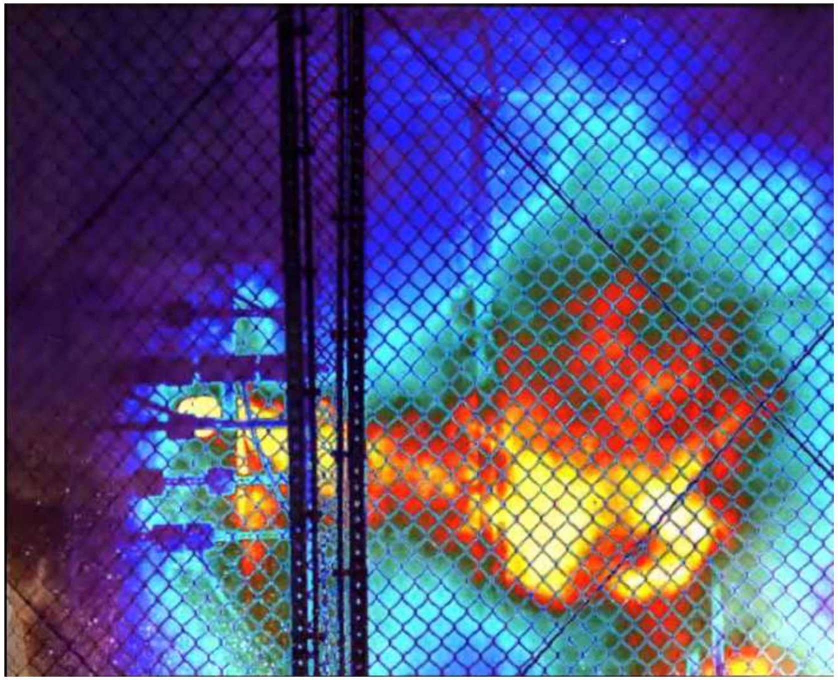


Figure 29. Overlay of thermoset log-normal distribution on SNL thermoset data histogram

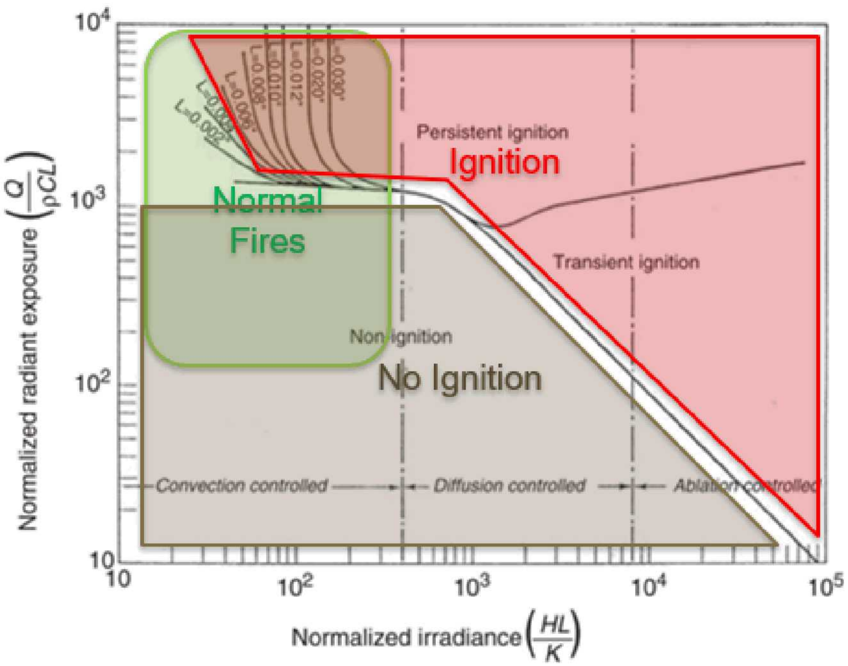
Background

- An electrical cable target exposed to a HEAF will fail when the conductor insulation reaches an temperature limit that results in an functional failure
- The failure characteristics for targets exposed to a HEAF may be different than those of traditional fire exposure curves.
  - A HEAF exposes targets to a much higher heat flux for a much shorter duration then when compared to a traditional fire curve
- The failure characteristics of cables exposed to traditional fire curves is the gradual thermal decomposition of a cable due to longer term exposure, which leads to electrical failure
- Due to the high heat flux and short exposure duration of a HEAF, material ablation and subsequent ignition of the cable insulation would result in different failure characteristics
  - During traditional fire exposure tests, ignition of the cable jacket and electrical failure were observed at nearly the same temperature
  - It is reasonable to solely evaluate ignition as the failure characteristic based on the HEAF exposure conditions and confirmation from traditional fire exposure tests



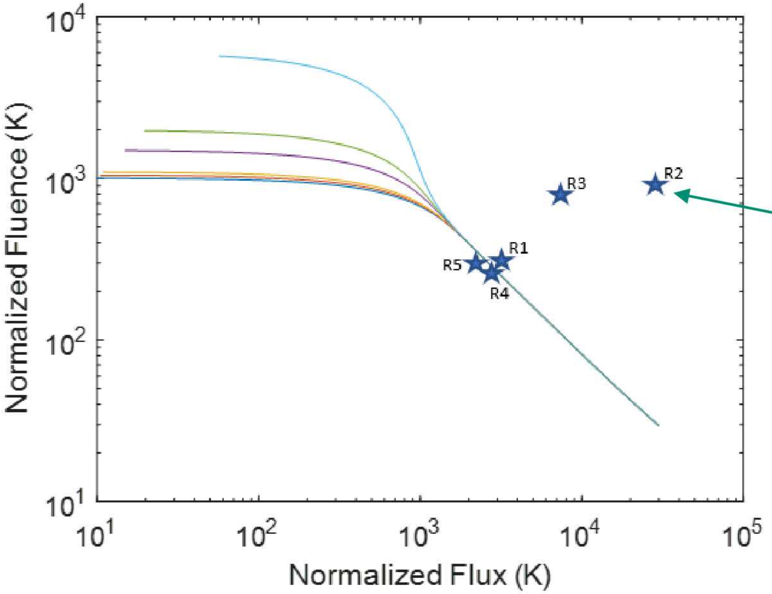
Approach

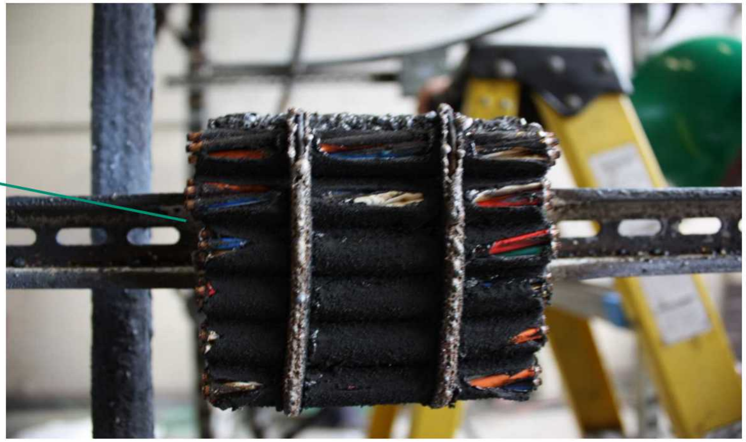
- Materials ignite as a function of both the heat flux and fluence exposure conditions
- Work performed by Stan Martin in the 1960s showed that the ignition threshold of blackened cellulose is a function of the rate of energy application and total energy applied
- Sandia National Laboratories has used the solar furnace at the National Solar Test Facility to extend this work to several different materials



Approach (cont'd)

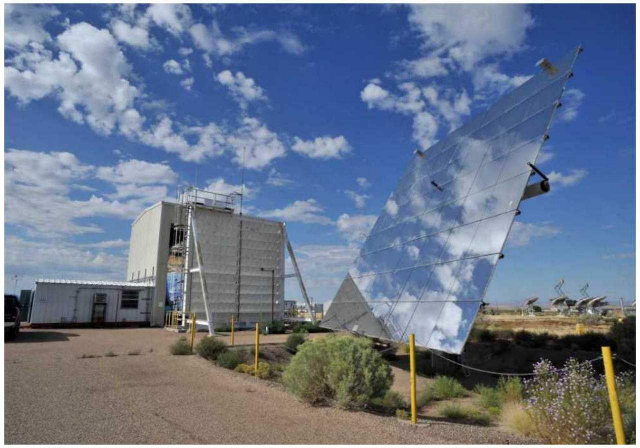
- As part of the HEAF fragility evaluation, a lumped-material model was derived for an insulated conductor to determine if this approach would be reasonable for a cable subject to a HEAF exposure
- Comparison of the model to previous test data showed that application of the ignition model is appropriate as the fragility failure criterion





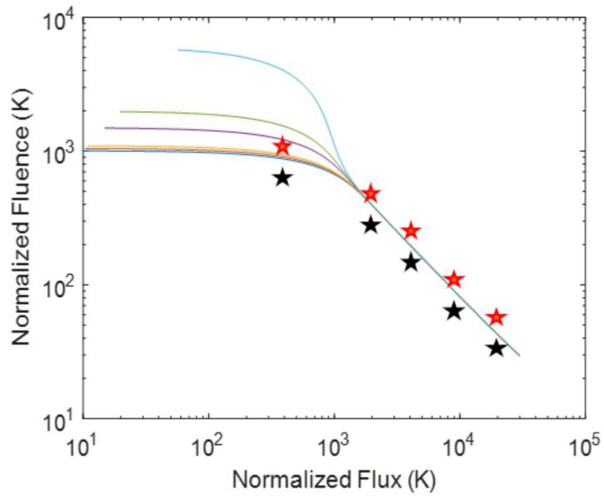
Confirmatory Testing

- The cable ignition model is the basis of the fragility evaluation plan, so validation of the model through confirmatory testing is essential.
- The main source of uncertainty in the fragility model is the variation of material properties of cables
- Experiments will be performed at the Solar Furnace at the National Solar Thermal Test Facility
- The Solar Furnace concentrates sunlight to generate intense thermal environments reaching 6 MW/m^2 on a spot roughly ~5 cm in diameter
- A heliostat uses flat mirrors to reflect the sunlight through an attenuator onto a large reflective parabolic dish



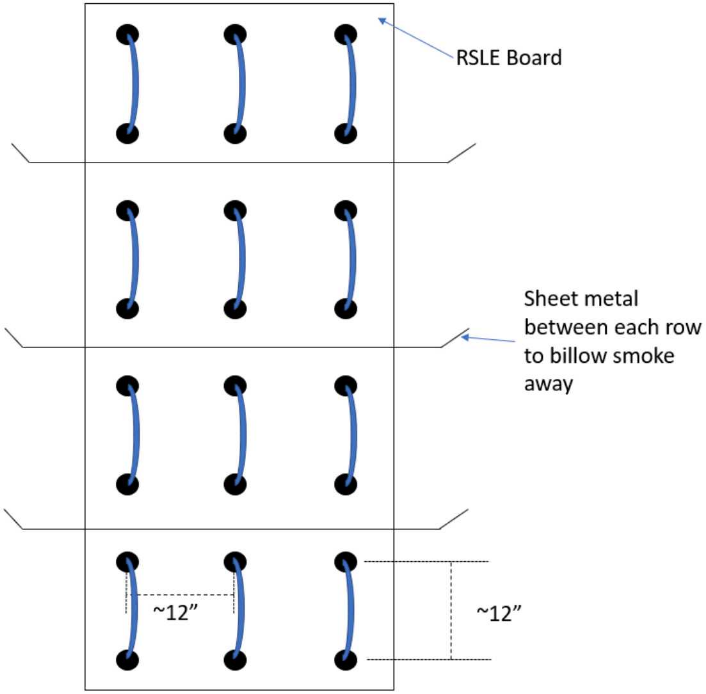
Confirmatory Testing (cont'd)

- There are several source and target variables that affect the ignition model
  - Cable Jacket Type/Material
  - Jacket Thickness
  - Heat Flux Magnitude
  - Exposure Duration
- The general test methodology consists of evaluating a given set of variables at a constant heat flux to find the ignition time
  - A constant heat flux will be applied to the target and the time of ignition is determined
  - This test is coupled with a subsequent test evaluated at the same heat flux, but for a duration below the ignition time (to confirm ignition did not occur)
  - Conducting these tests for the different variables will provide data to validate/modify the cable ignition model
- The cable samples will also be monitored for electrical failure and sub-jacket temperature to validate the use of ignition as the failure mechanism



Confirmatory Testing (cont'd)

- An experimental method test plan may be prohibitory because of the large number of tests necessary to fully test the variables of interest
- The design of experiments methodology will be utilized because a continuous response is expected across the range of variables based on the significant work done in this area on many different material types
- The testing will be broken into two test series:
  - **Phase 0** will be conducted initially to provide preliminary model data and verify that the ignition map methodology is valid. This test phase will consist of ~12 tests
  - **Phase 1** will follow and consist of ~50 tests, and will allow us to effectively model ignition across a wide range of cable jacket properties.



Application to Fire Model

Establishing and validating the cable fragility model directly informs the zone of influence calculation

- The cable ignition failure characteristic is a function of the heat flux and total energy exposure conditions, which are a function of the source term and location
- The source term modeling effort in SIERRA will produce flux and fluence at different distances from a given HEAF condition
- These flux and fluence values will be used as input to the cable fragility evaluation to determine whether failure occurs
- For a given HEAF condition (as a function of current, voltage, bus bar material, etc.), a zone of influence for cables can be calculated
- Discrete points across the full range of HEAF conditions will be modeled, and the results will be used to establish a representative zone of influence for a given range of HEAF conditions

Thank you!

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