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HEAF Target Fragility Progress

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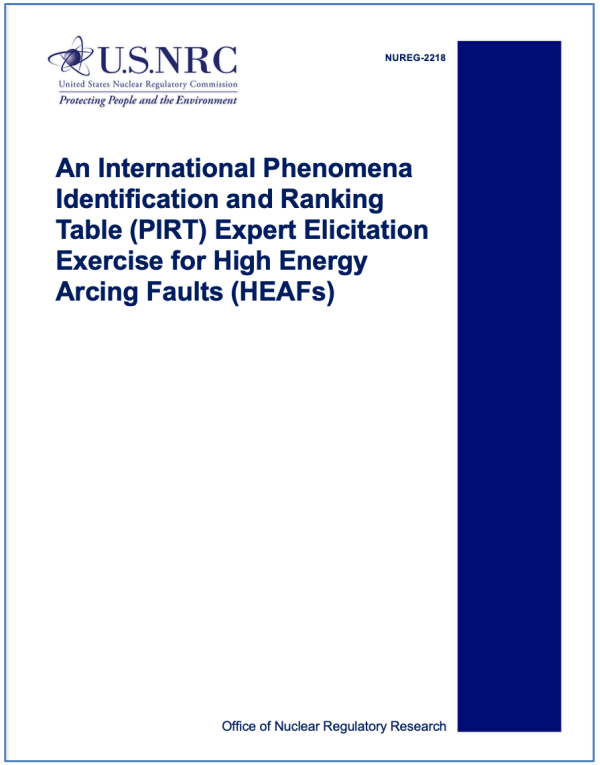
Background

- 2017 Phenomena Identification and Ranking Table (PIRT) identified the assessment of target fragility as a high research priority
  - ”Classical” fire failure metrics (e.g., internal jacket temperature of a cable exposed to a fire) are based on low heat flux, long duration exposures
  - HEAF exposures are high heat flux, short duration exposures, and target response is not well characterized



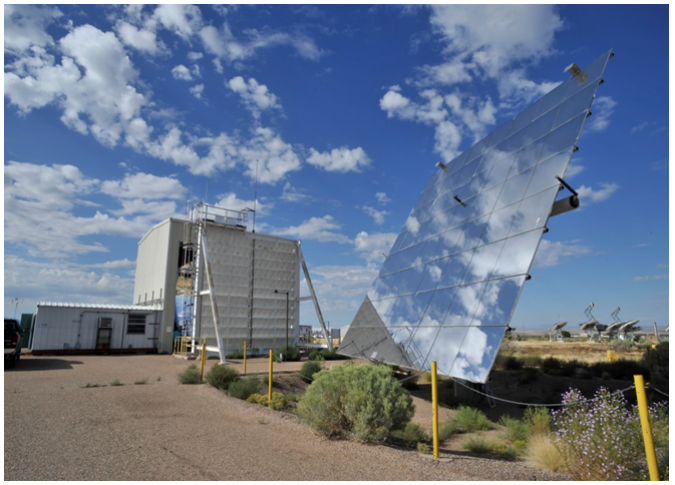
https://www.nrc.gov/docs/ML1803/ML18032A318.pdf

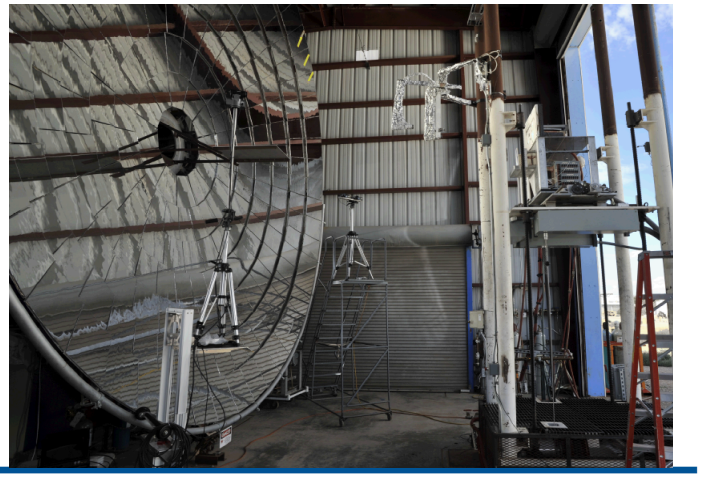
Objectives

- The goal of this effort is to evaluate the fragility of targets exposed to the environmental conditions after a HEAF
  - Tests at high heat flux/short duration exposures are needed to gain insight on relevant physics and failure modes
- After working group review of possible targets, the test effort was focused on cable targets
  - As in other areas of fire PRA, two categories of cable (thermoset and thermoplastic) were addressed

Test Facility

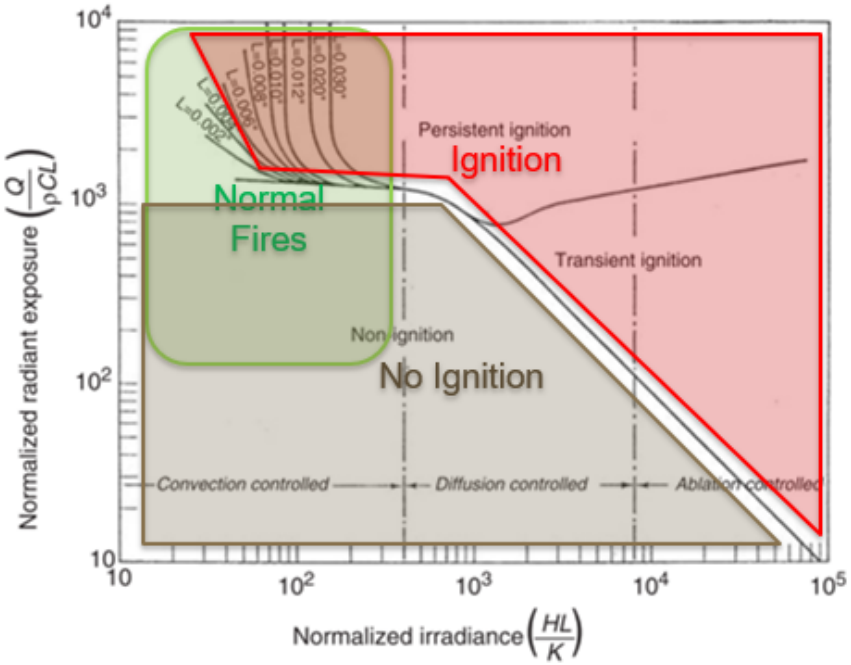
- Tests were conducted at the Solar Furnace at the National Solar Thermal Test Facility at Sandia National Laboratories in Albuquerque, NM.
  - Concentrates sunlight to generate thermal environments reaching 6 MW/m^2 on a spot ~5 cm in diameter
- The heliostat (top) reflects sunlight through an attenuator onto a large reflective parabolic dish (bottom) to concentrate heat flux onto a target





Hypothesis

- A literature review was conducted to evaluate relevant phenomena
- The ignition threshold of blackened cellulose as a function of heat flux and total energy was evaluated in the 1960s by Stan Martin
  - This includes bifurcation of the ignition region into two subregions: transient and persistent ignition.
- This work has been extended to several different materials through test data collected at the Solar Furnace and/or Solar Tower
- A preliminary lumped-material model of a cable was derived for the high heat flux exposure conditions resulting from a HEAF
- This model was compared to full-scale test data as a proof-of-concept, which yielded encouraging results
- The tests at the Solar Furnace would be used to gather data on the material properties of different cables with respect to the ignition model



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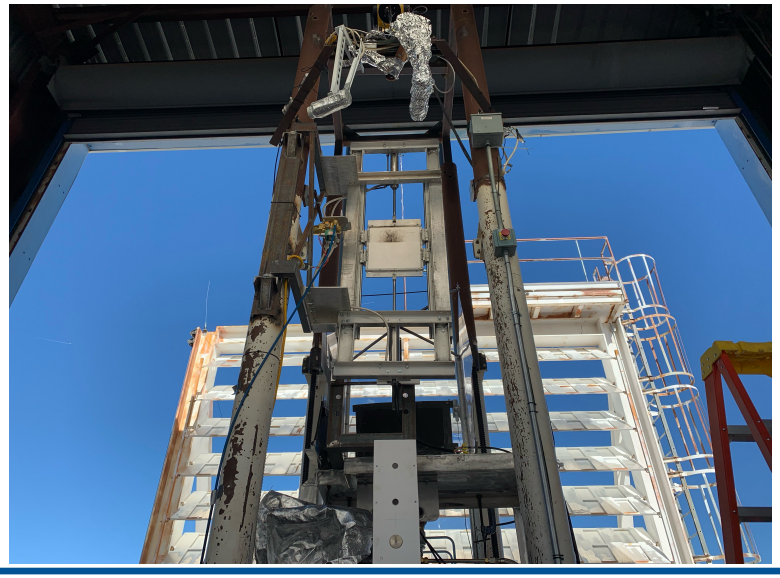
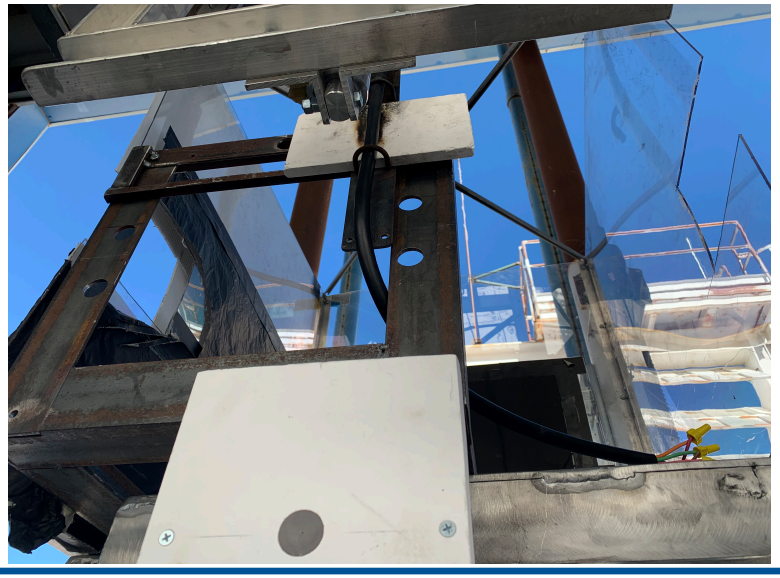
Test Plan

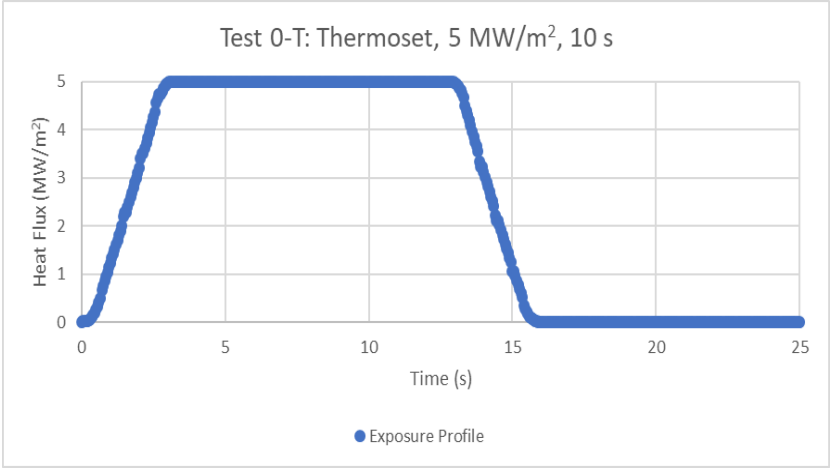
- The objective of testing was to establish, in conjunction with theory, an ignition model that robustly accounts for the variation of cable material properties found in nuclear power plants.
- A three-phase approach was taken to test planning
  - Phase 0 – Exploratory tests to evaluate the validity of the approach
  - Phase 0B – Exploratory tests to evaluate the feasibility of achieving persistent ignition at the Solar Furnace scale
  - Phase 1 – Tests to support data collection for development of persistent ignition model
- For each test phase, electrical and thermal instrumentation was used to monitor the cable response to the exposure
- Additionally, high-speed video was taken to evaluate transient and persistent ignition

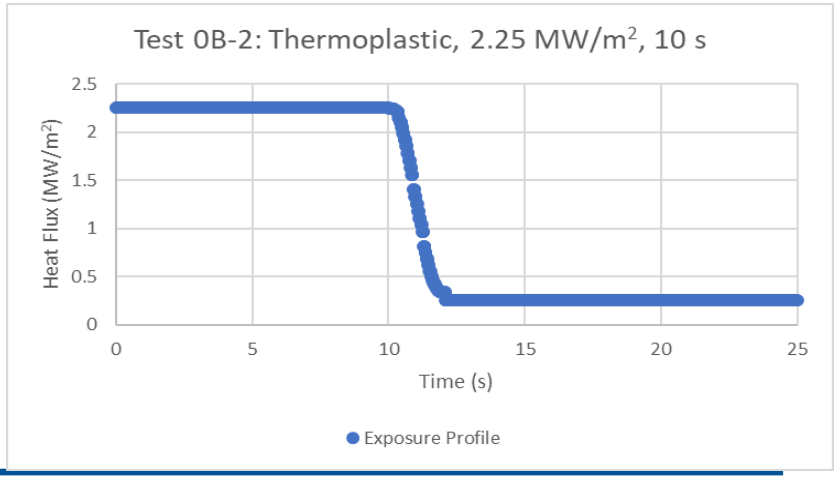




Results

- Phase 0
  - A single cable sample was used as the target
  - Exploratory tests yielded positive results on spontaneous ignition
  - However, sustained ignition was not observed during this test phase
    - The exposure profile did not account for heat feedback from heat sinks or surrounding cables after the initial exposure.
- Phase 0B
  - A three-cable bundle was used to evaluate if sustained ignition is possible.
  - Also, the heat flux profile was modified so that a secondary heat flux was provided after the initial exposure to simulate heat feedback
  - Additional tests were run with a single cable and the secondary heat flux
  - All tests yielded persistent ignition





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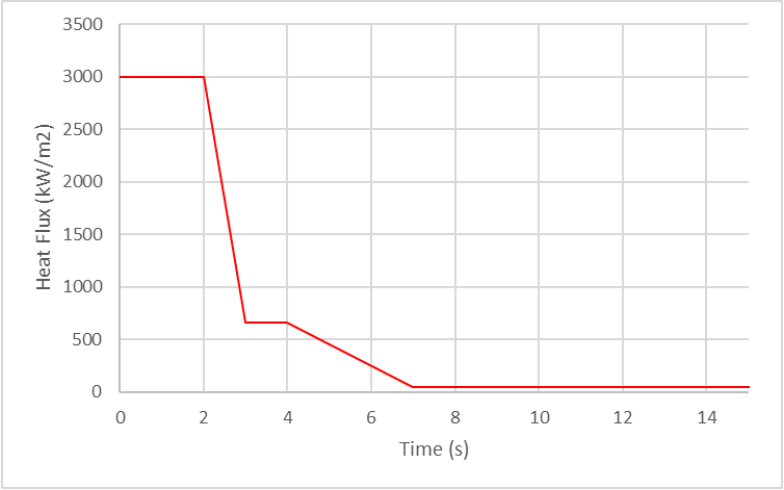
Results (cont'd)

- Phase 1
  - Test plan originally developed to support persistent ignition model for both thermoset and thermoplastic cables
    - Based on results from Phase 0B, it was decided that a single cable would be sufficient since it yielded persistent ignition with secondary heat flux
    - A modified profile was used, which captured insight from thermal monitoring instrumentation from the full-scale tests at KEMA
  - Daily meetings were held with the working group to discuss the results from the previous day and any modifications needed to the test plan based on results
    - Initial test results did not yield sustained ignition results, so working group decided to probe other failure modes
      - Electrical Failure
      - Sub-jacket temperature
      - Jacket Damage
      - Sustained ignition events were also observed in the later tests
    - Additionally, a three-cable bundle was introduced with shorter samples for the later tests



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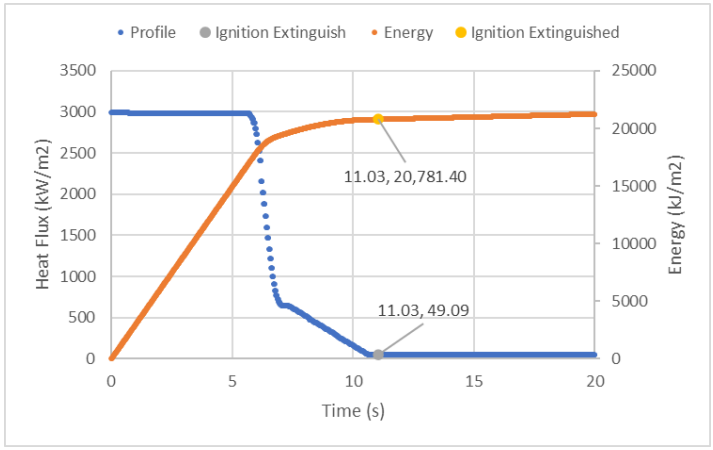
Results (cont'd)

- Phase 1 (cont'd)
  - Gathered data for both thermoset and thermoplastic cables
  - Sustained ignition data (bottom)
  - Damage as a function of total energy
  - Electrical failure of cables
  - Sub-jacket temperature



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Path Forward

- The working group is utilizing the test data to define a method to determine the fragility of cables exposed to a HEAF
- Use of data/insights from multiple sources
  - Full Scale Tests
  - Operating Experience
  - Phase 0, Phase 0B, and Phase 1 Tests at the Solar Furnace
  - International Data
- Evaluation of all phenomena to determine fragility
  - Jacket Damage
  - Persistent Ignition
  - Electrical Failure
  - Sub-jacket temperature
  - Etc.
- The group is currently working on determining the fragility of targets so that it may be combined with the source term to determine the ZOI