Fire Tests and Analyses of a Rail Cask-Sized Calorimeter

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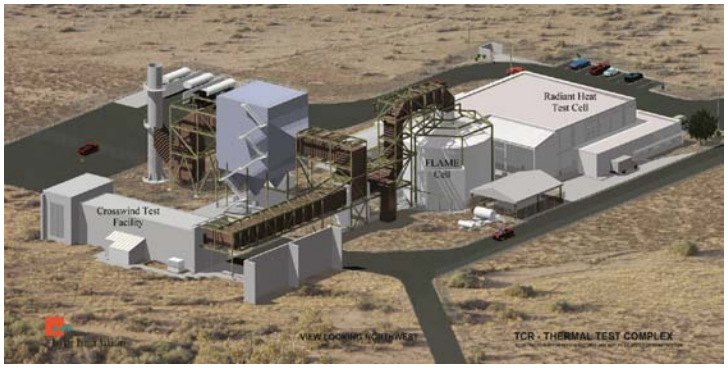
Why Large Calorimeter Benchmark Testing?

- **Understand effects of large fully-engulfed objects**
  - Large objects such as spent fuel packages ***have a marked impact*** on the surrounding fire environment
- **Predict temperatures outside the cask**
  - Increase confidence in CFD fire models (*i.e.,* CAFE)
  - Accurately account for fire/object interactions
- **Predict large object (internal) response to fires**
  - Models must be benchmark against experimental data (Nicolette and Larson, 1989)
  - Ideally, data should be obtained from tests involving similar size objects
    - Difficult to scale thermal effects

Package Certification Facilities at Sandia

- **Some of the fire testing facilities available:**
  - *Large open pool fire facility*
    - Lurance Canyon Burn Site
      - 10CFR71 regulatory fire
  - *Smaller scale thermal tests facility*
    - Thermal Test Complex (TTC)
      - Small pool fire testing simulating natural wind conditions
      - Radiant heat
      - Cross wind facility
- **Experiments designed to collect data for:**
  - Package certification / evaluation
  - *Support validation & benchmark of analysis codes such as CAFE*



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Large Calorimeter Test Series: Calorimeter and Pool Layout

- **Calorimeter**
  - Cylindrical carbon steel pipe
  - 4.57m (15ft) in length, 2.44m (8ft) in diameter, 2.54cm (1in) thick wall
- **Pool**
  - 7.93m (26ft) in diameter
  - 7.58m^3 (2,000 gallons) of JP-8
  - Enough to burn for about 30min minutes
- **Calorimeter/pool configuration**
  - Calorimeter on two stands, 1m (3.28ft) above the fuel pool
  - Calorimeter centered with the pool

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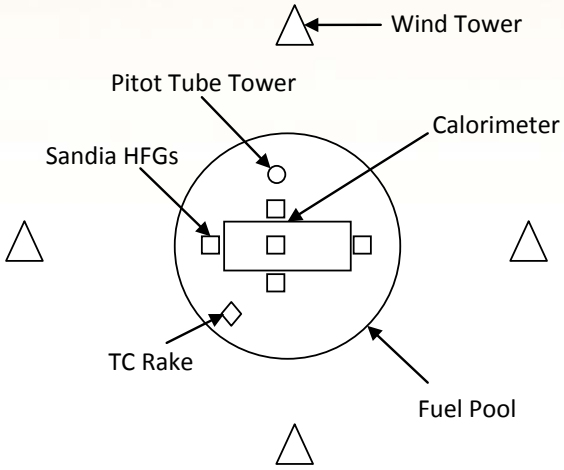
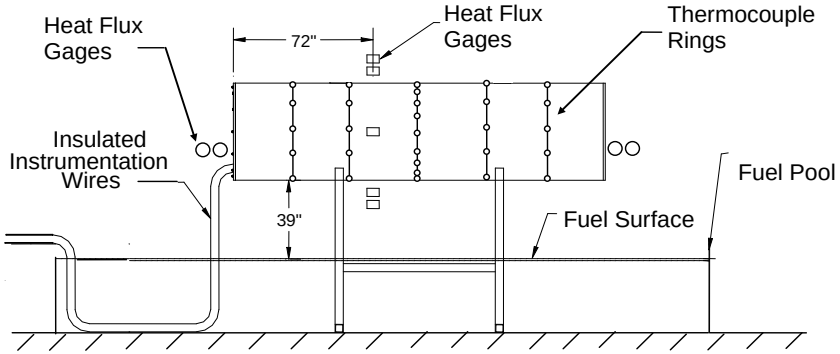
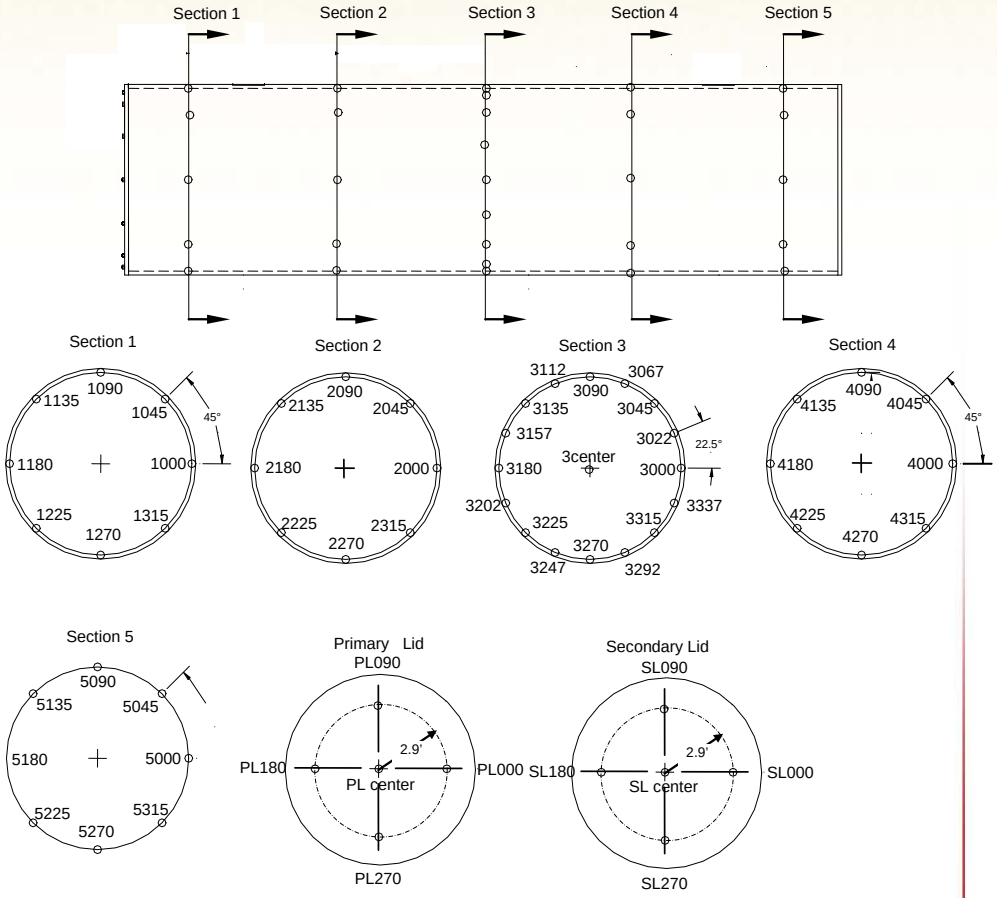
Large Calorimeter Test Series: Instrumentation







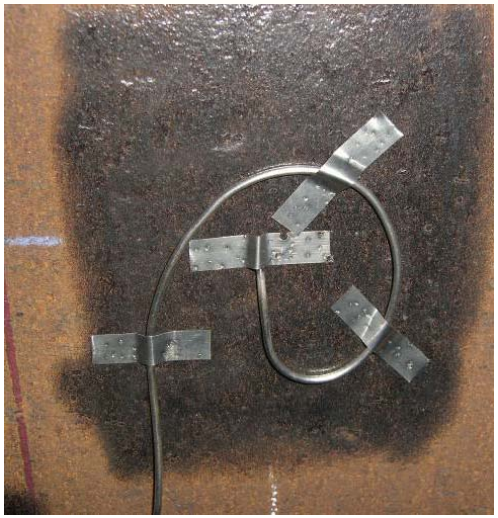
Note: "PL" stands for primary lid and "SL" stands for secondary lid

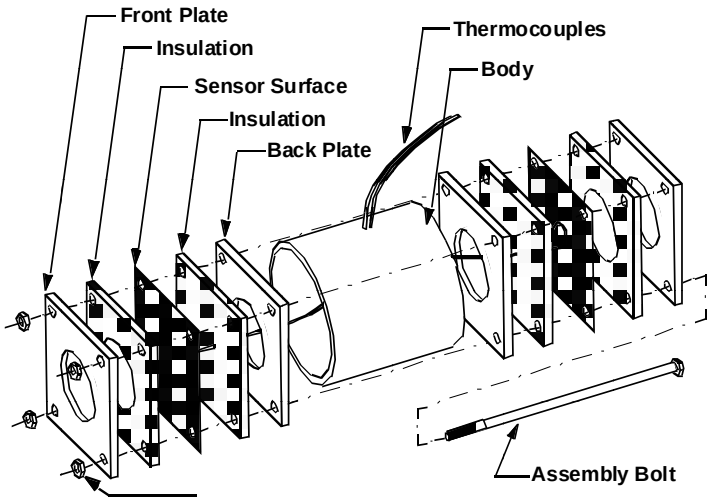
TC ocations

24 HFGs, 12 wind probes
TC rake, 3 flow probes

Over 60 TCs on Calorimeter body
Many other TCs on other locations

Large Calorimeter Test Series: Instrumentation (Cont'd)



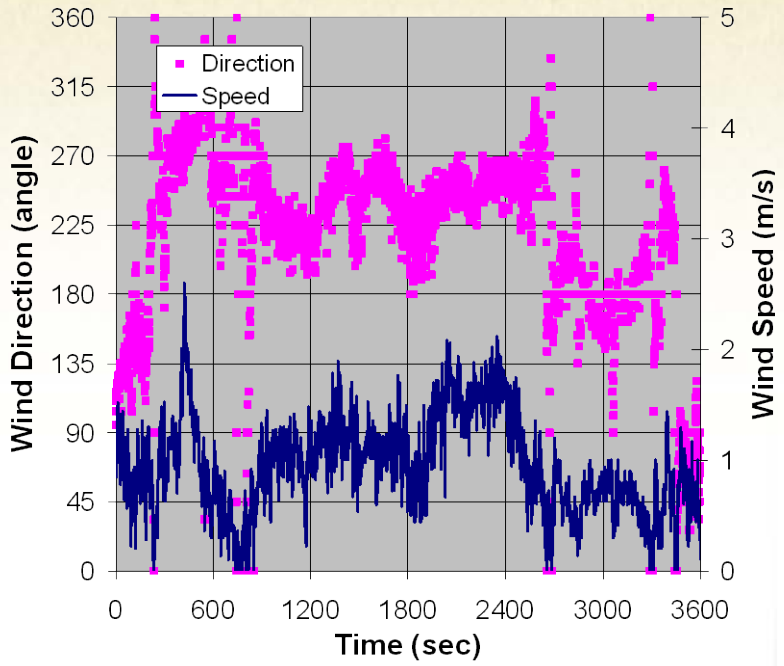


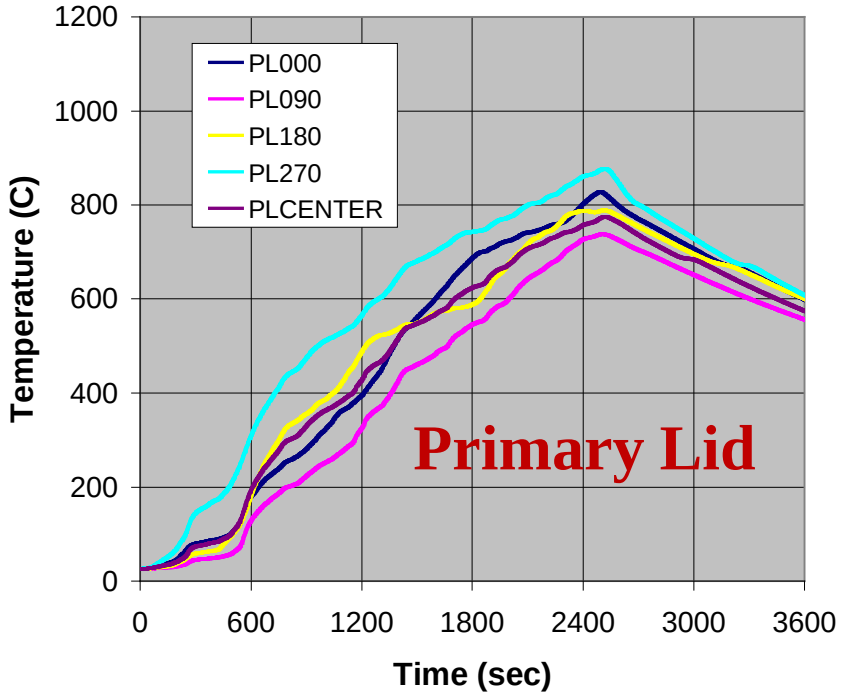
Fire Tests…

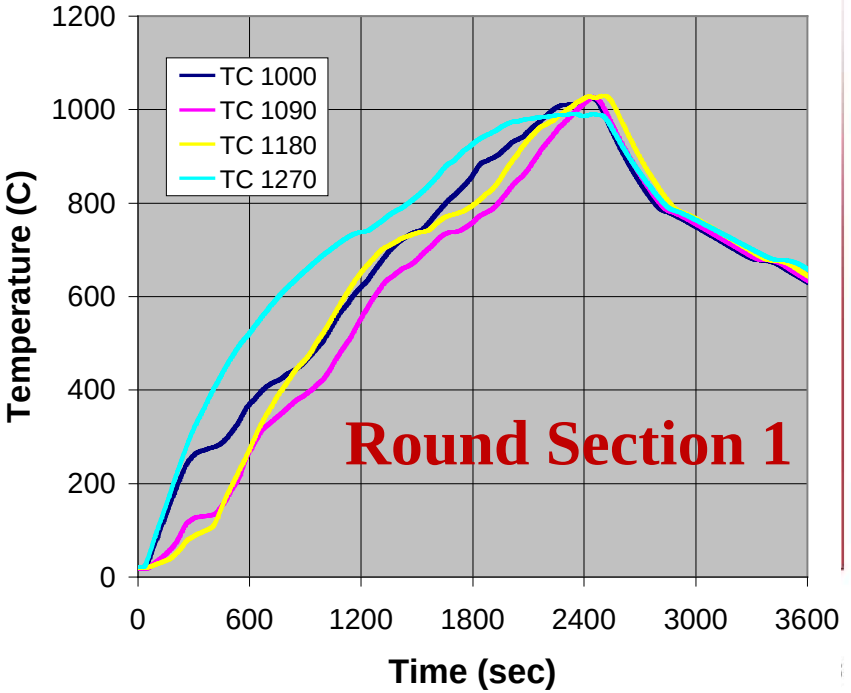
Test 3

Test 1

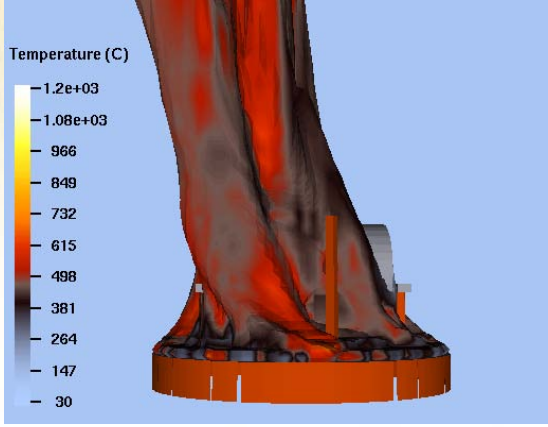
Large Calorimeter Test Series: Test 1 Results







Container Analysis Fire Environment (CAFE) Computer Code



- **Developed at Sandia National Laboratories to predict response of casks in large fires for risk studies**
- **Links a CFD fire simulator to finite element models of casks or other objects**
- **The fire simulator uses physics-based models for fuel evaporation, reaction chemistry, convection and radiation heat transfer**
- **CAFE can predict well the heat transfer within and outside a fires even when coarse (fast running) grids are employed**
- **Ongoing efforts to benchmark and fine-tune CAFE models**

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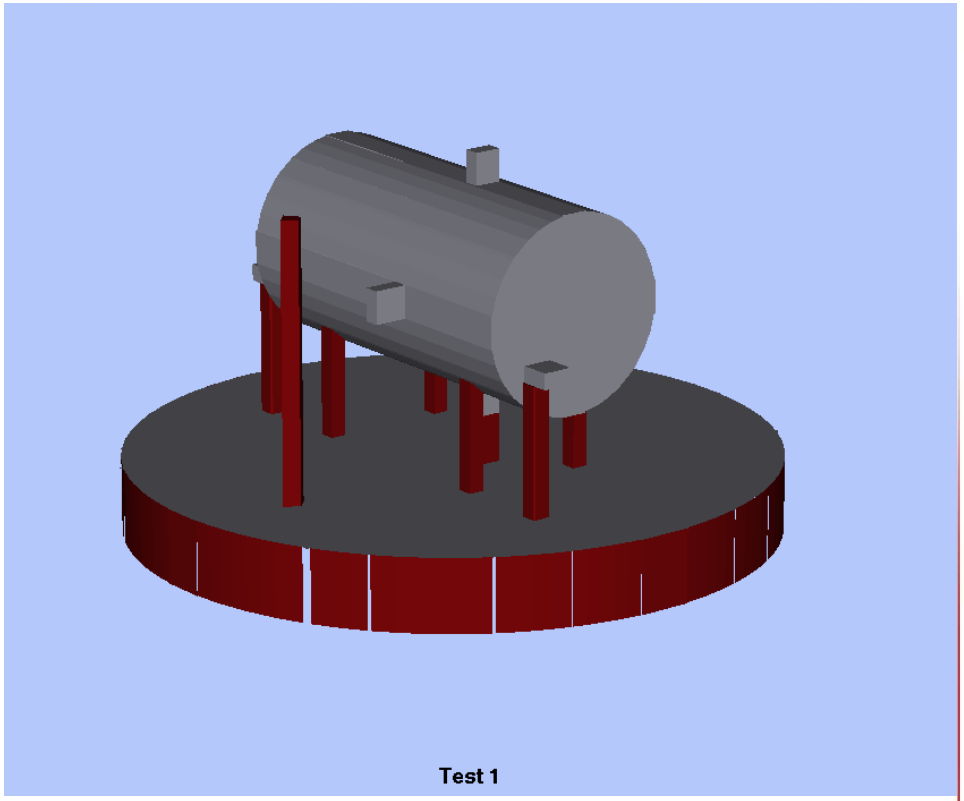
CAFE Model : Geometric Configuration and Boundary Conditions

- **Model included**
  - Stands
  - Instrumentation fixtures
- **Wind conditions**
  - From Test 1 data applied on all four lateral sides of the computational domain
- **Pressure**
  - Hydrostatic pressure used
- **Fuel pool**
  - Constant and uniform evaporation rate



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CAFE Fire Simulation

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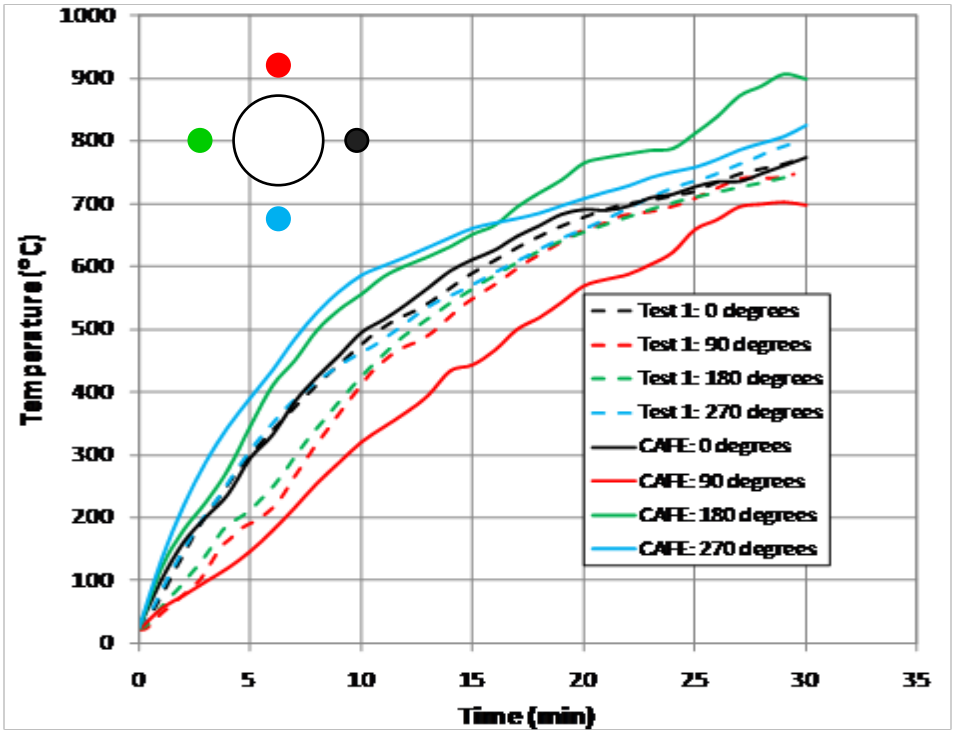
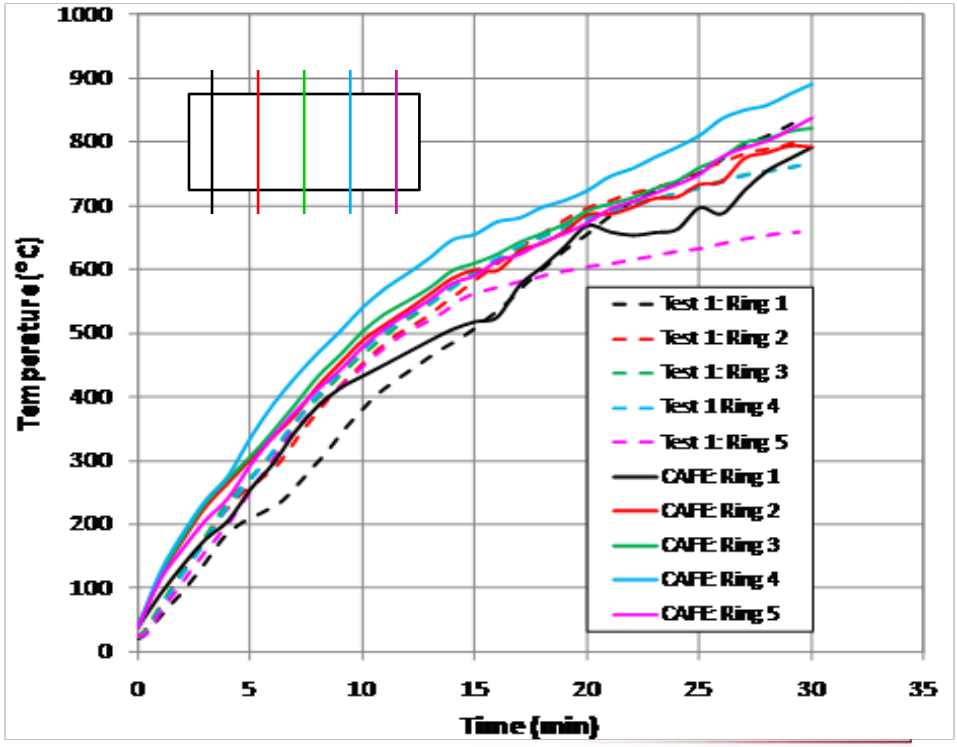
CAFE/P-Thermal Benchmark Results

- Used calorimeter surface temperatures for comparison

Averaged along the four circumferential sides



Averaged along the five calorimeter rings



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Summary

- **Three large-scale tests were performed with a rail-cask-size pipe calorimeter in JP-8 pool fires to benchmark CAFE**
- **Winds were light in Tests 1 and 2 and shifted directions**
  - **Winds were much stronger in Test 3, which lead to a higher fuel consumption rate on that test**
- **CAFE properly captured the effects of wind conditions on the average temperature response of the calorimeter**
- **CAFE generally bounded the experimentally measured calorimeter temperatures**

These results suggest that CAFE is capable of predicting cask response to large fires in a realistic manner

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