TRANSIENT HEAT TRANSFER ANALYSIS OF THE FIRE / CONTAINER INTERFACE

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Objective:
Develop technical capability to simulate accidental fires and explosions (e.g.a missile involved in an intense jet-fuel fire after an airplane crash)

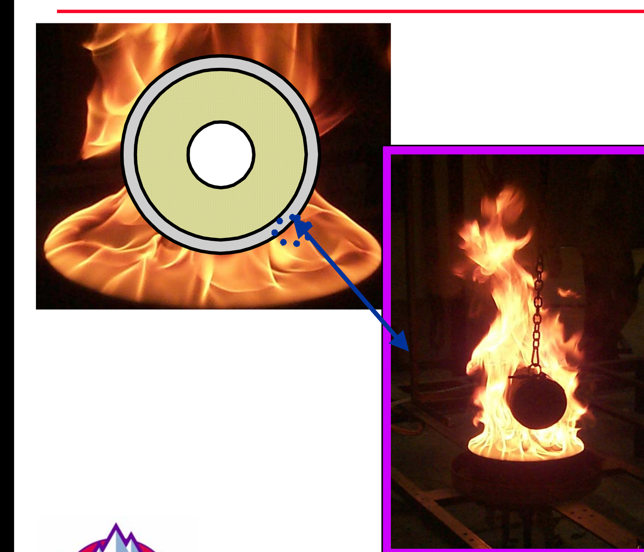
Dryden Flight Research Center ECN-31808 Photographed 1984
Controlled Impact Demonstration Crash (CID)

Validation: Modeling vs Experimental

Computer Simulation Courtesy of P. Smith

Jet A Pool Fire (C-SAFE PFTF)

Fire/Container Interface Study



-Pilot-Scale Pool Fire Experiments.

-Fire/Container Experiments

-Soot Deposition Measurements

C-SAFE Pool Fire Test Facility (PFTF)

- 0.30 m diameter pool (up to 1 m)
- Closed 4.5 x 4.5 m chamber with floor-mounted dampers for flow control
- Steady-state and batch pool fires

Spatial measurements of:

- Total and radiant heat flux
- Instantaneous soot concentration (Photoacoustic Analyzer)
- Temperature, species concentrations
- Real-time and high-speed video

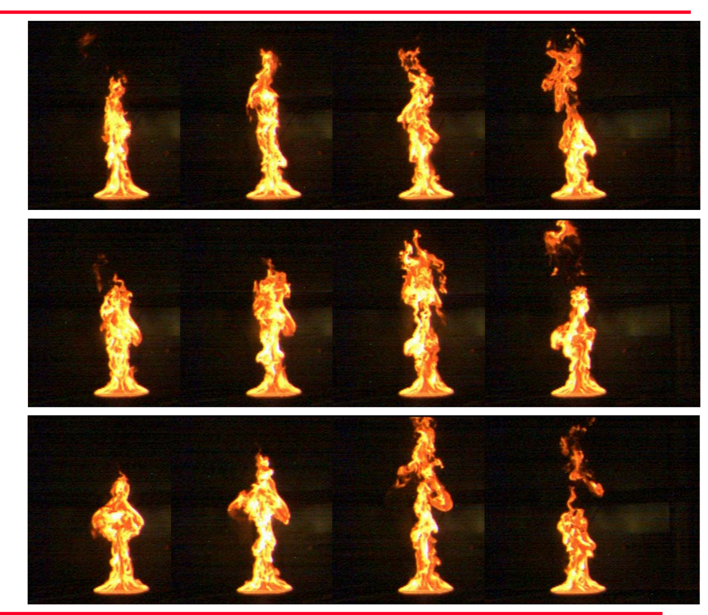
Puffing Frequency Analysis

Jet A Pool Fire

-Pictures from High-Speed Video (500fps)

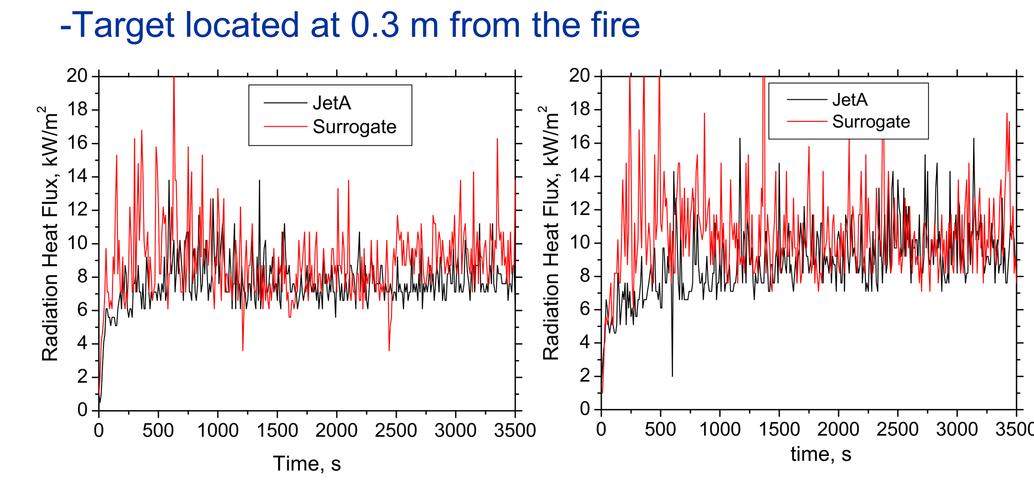
-The time between frames is 80 ms (Puffing Frequency of ~3.12 Hz).

-Published ~3Hz



Radiative Heat Flux: Jet A vs Surrogate

-Target located at 0.3 m from the fire



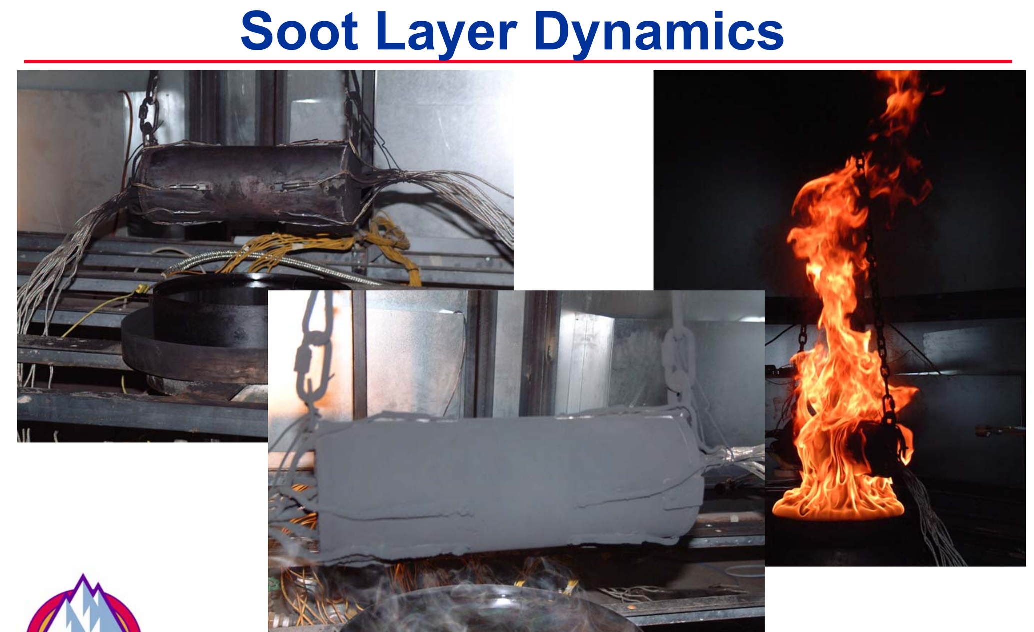
(a) Batch Pool Fires

(b) Steady State Pool Fires

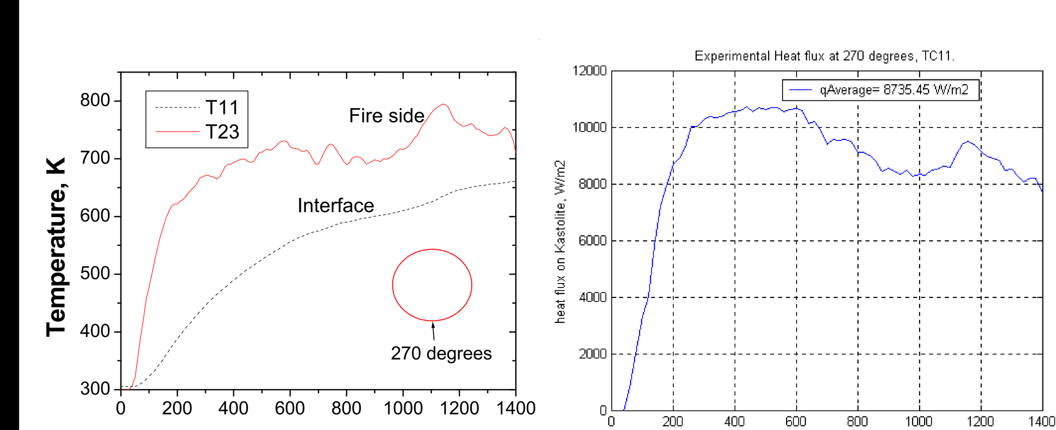
Fire/Container Experiments: Fluxes Measured for Different Scenarios

*Pictures for electrical fluxes in range encountered in fire experiments.

Fire/Container Experiments: Study Soot Layer Dynamics



Fire/Container Experiments: Study Thermal Behavior



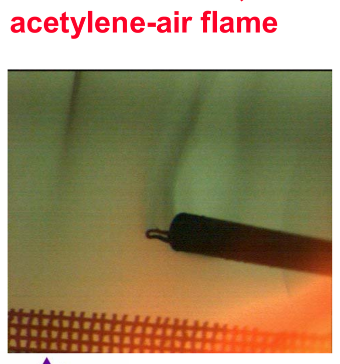
(a) Temperature

(b) Heat Flux

Soot Deposition Measurements

Thermocouple Particle Densitometry (TPD) (Rosner et al, 1995)

-Experiment: Thermocouple immersed in 2-d, laminar acetylene-air flame



-Mass, Energy and Thermophoretic Balance on the Thermocouple Junction

$$j = \frac{\rho d}{2} \cdot \frac{dd_j}{dt}$$

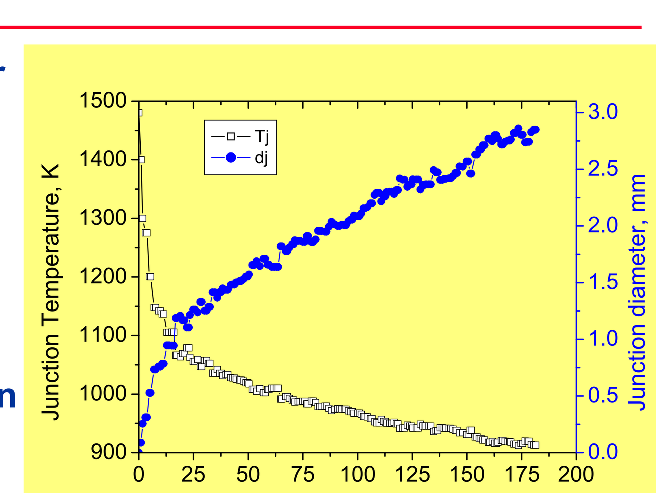
$$\varepsilon_j \cdot \sigma \cdot T_j^{\,4} = \frac{k_{g0} \cdot Nu_j}{2 \cdot d_j}\left(T_g^{\,2} - T_j^{\,2}\right)$$

$$j = D_T \cdot Nu_j \cdot f_v \cdot \frac{\rho_{soot}}{2 \cdot d_j} \cdot \left[1 - \left(\frac{T_j}{T_g}\right)^2\right]$$

Transient Soot Layer Thickness

-Transient Soot layer thickness (Thermophoretic analysis) is in good agreement with final measured value (3.1 mm)

-Soot volume fraction (4.1ppm) is also consistent with the laser measurement



Concluding Comments

-The C-SAFE Pool Fire Test Facility (PFTF) can be used to simulate a variety of accident scenarios.

-The heat fluxes in Thiokol experiments are in the range measured in pool fire experiments.

-Soot deposit on the container is an additional resistance to the conduction of heat transfer.

-Soot deposit also changes the radiative properties of the surface (i.e. absorb and radiate part of incident radiation)

-Thermophoresis is the dominant process governing deposition of particles on the container.

-A fast response thermocouple can be used to infer transient soot deposit thickness and soot volume fraction.