U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

RIC 2007

Fire Research-Integrating Research into Practical Applications

"Development of a Cable Response Model and Fire Model Verification and Validation"

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Topics

- Modeling Cable Failure
- Incorporating such a model into a practical fire model

Simple Response Models in Fire

$$\frac{dT_l}{dt} = \frac{\sqrt{|\mathbf{u}|}}{\mathrm{RTI}}(T_g - T_l)$$

Solve for link temperature using velocity **u** and gas temperature from Fire Model. The RTI (Response Time Index) is unique to each sprinkler.
Source: Gunnar Heskestad, Factory Mutual

$$\frac{dY_c}{dt} = \frac{Y_e(t) - Y_c(t)}{L/\mathbf{u}}$$

Solve for smoke chamber concentration using external smoke concentration and velocity **u** from Fire Model. L is a length scale unique to each detector.

Surely, you're joking…

There must be more to sprinklers and smoke detectors than just these simple equations!

<u>Absolutely</u>, but consider the fire models in which these sub-models are embedded…

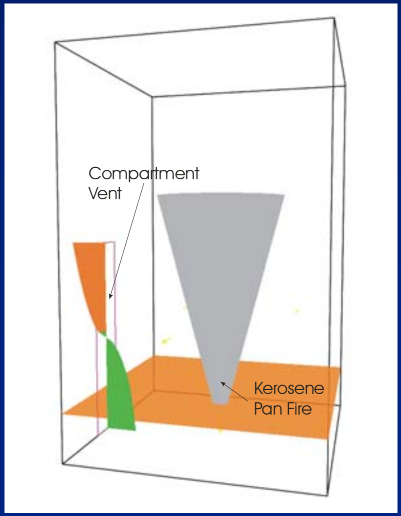
Three Classes of Fire Models

Hand Calculations

$$T_g - T_\infty = 6.85 \left(\frac{\dot{Q}^2}{A_0 \sqrt{H_0}\, h_k A_T} \right)^{1/3}$$

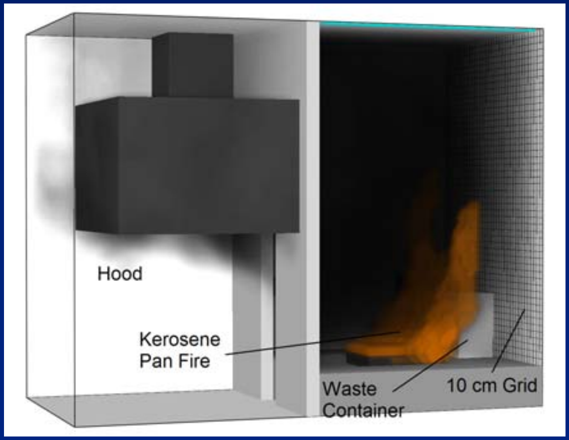
McCaffrey, Quintiere, Harkleroad (MQH)

Two-Zone Models



CFAST, NIST

CFD



FDS, NIST

Fire Model V&V

- NRC has produced a V&V Guide for 5 different fire models (NUREG 1824)
- 2 sets of hand calcs, 2 zone, 1 CFD
- Experimental Uncertainty and Model Error quantified in a novel way
- Defines current state of the art

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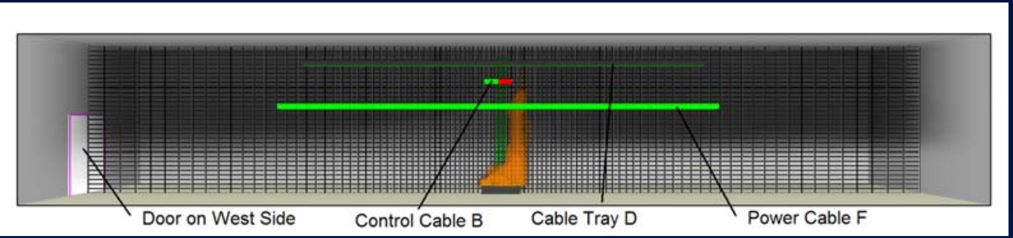
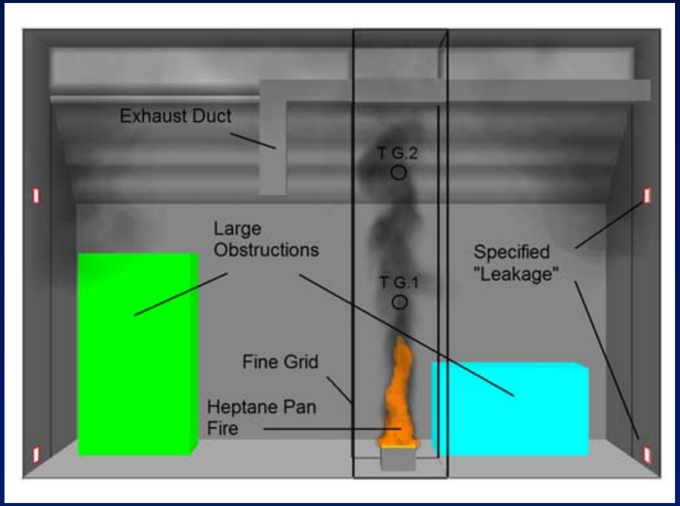
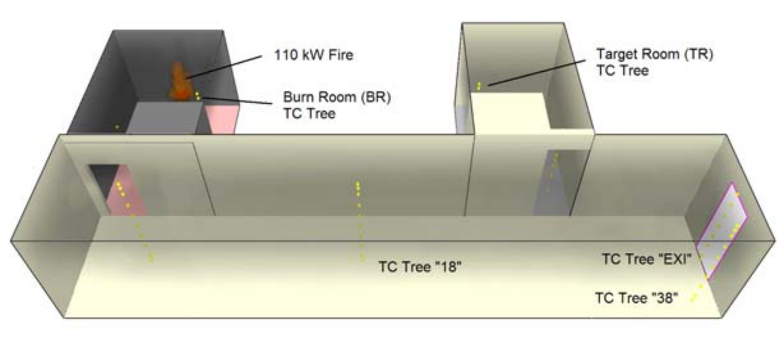


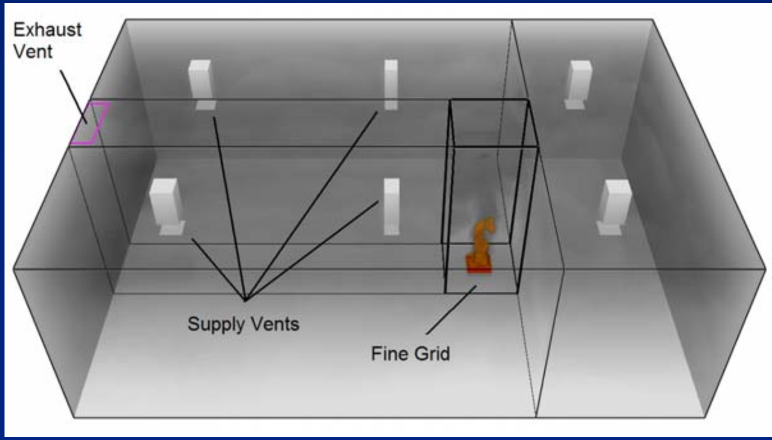
NIST, USA



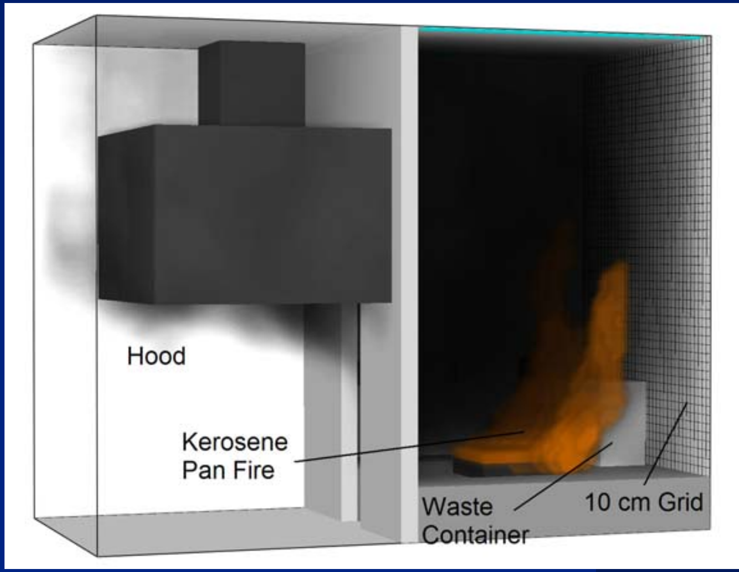
VTT, Finland



NBS, USA

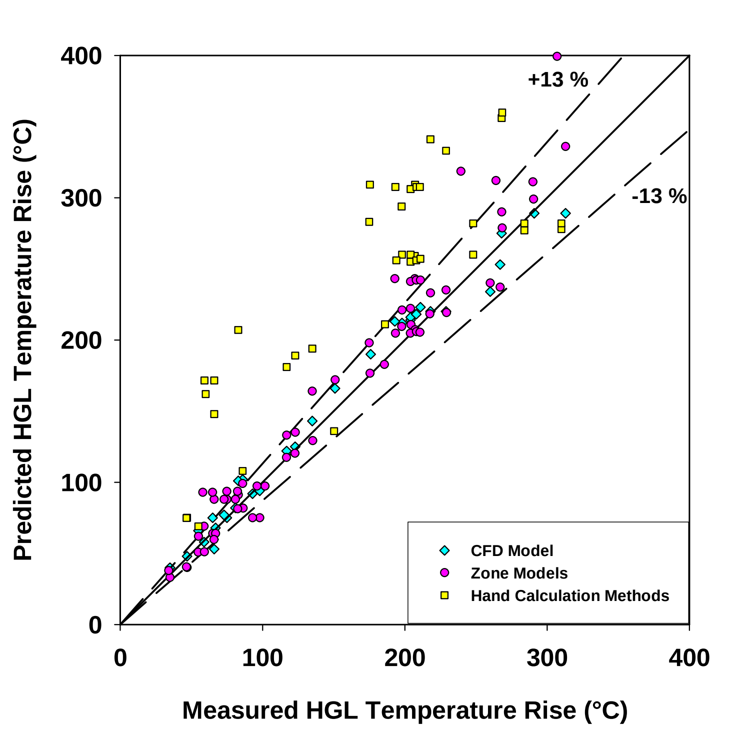


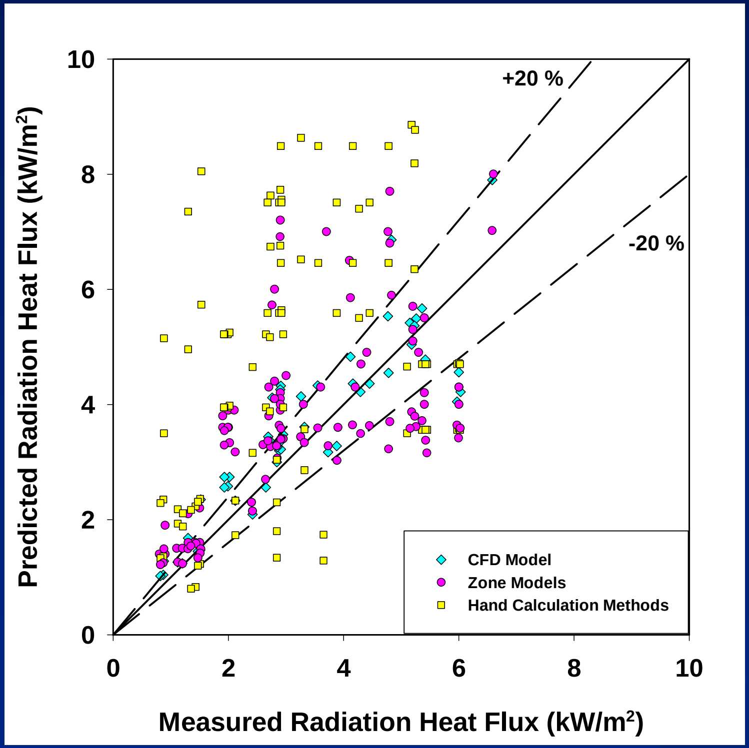
Sandia/FM (USA)



iBMB, Germany

Results of NRC V&V (NUREG 1824)





Cable Failure Model

$$\rho_s c_s \frac{\partial T_s}{\partial t} = \frac{k_s}{r} \frac{\partial}{\partial r}\left(r \frac{\partial T_s}{\partial r} \right)$$

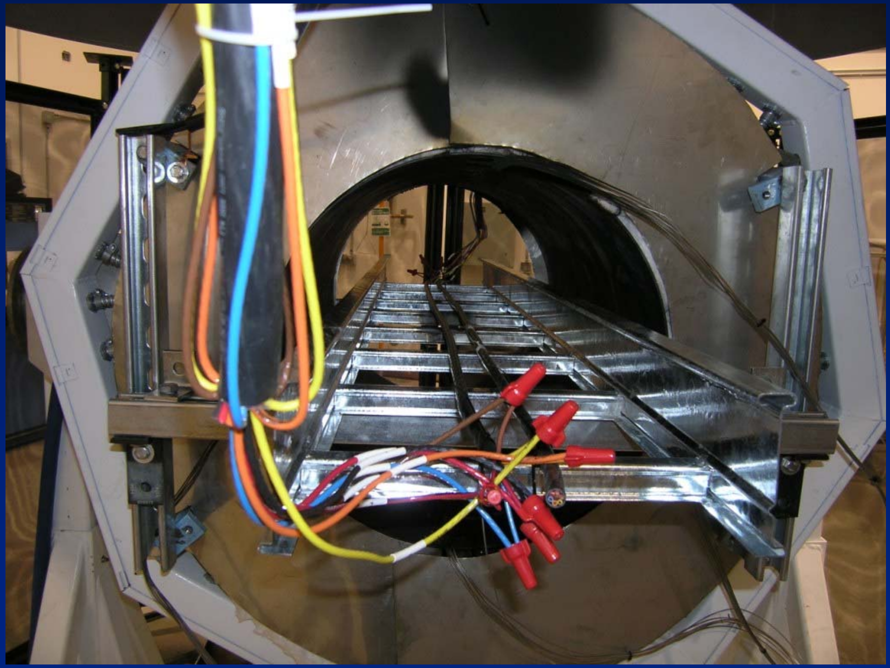
$$-k_s \frac{\partial T_s}{\partial r} = \dot{q}_c'' + \dot{q}_r''$$

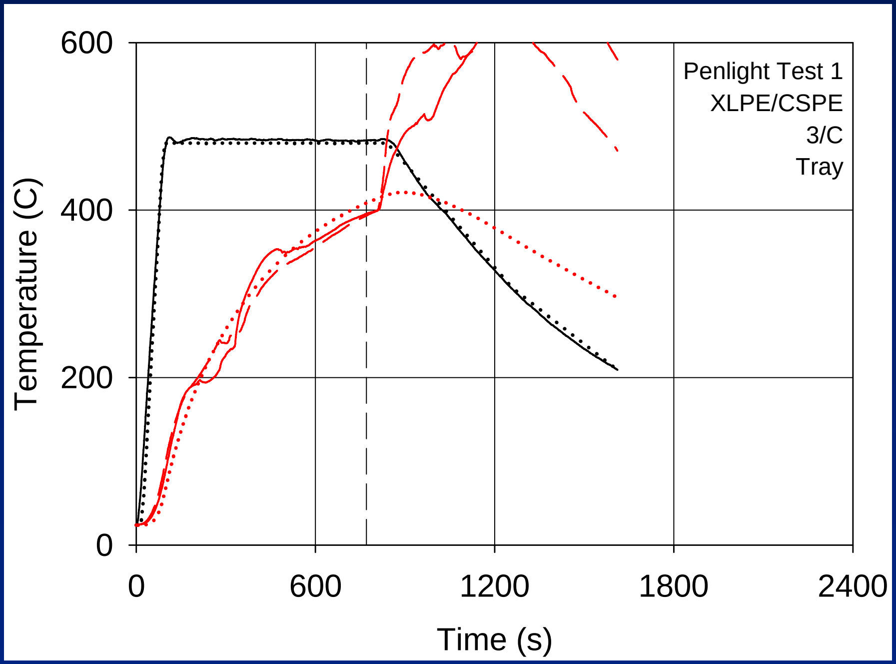
1-D heat conduction into homogenous cylinder. Thermal conductivity (k) and specific heat (c) assumed constant for all cables. Density (ρ) obtained from cable diameter and mass per unit length. Failure temperature obtained experimentally.

The Fire Model provides the convective and radiative heat flux at the cable surface.

Source: Andersson and Van Hees, SP Fire, Sweden.

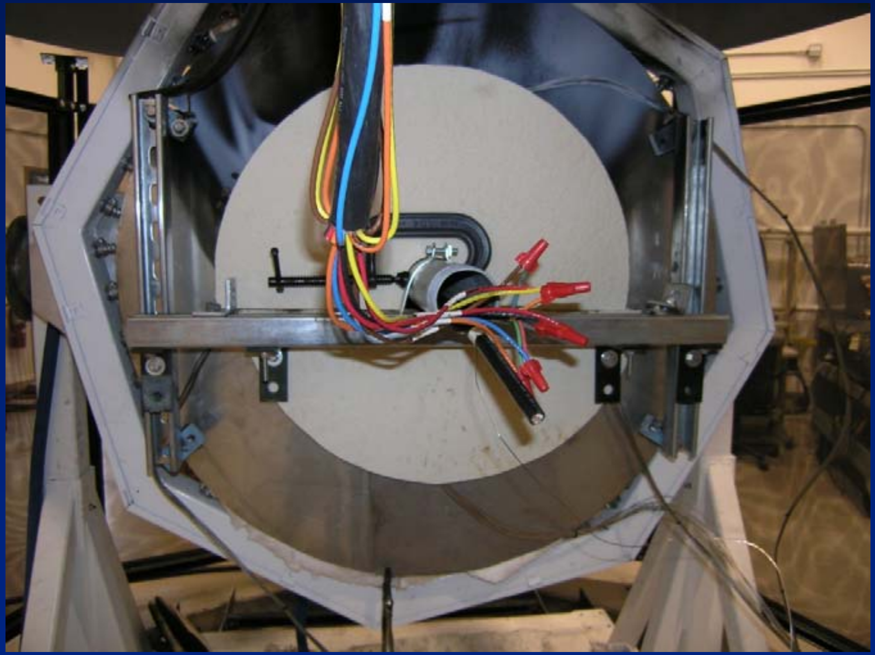
Results

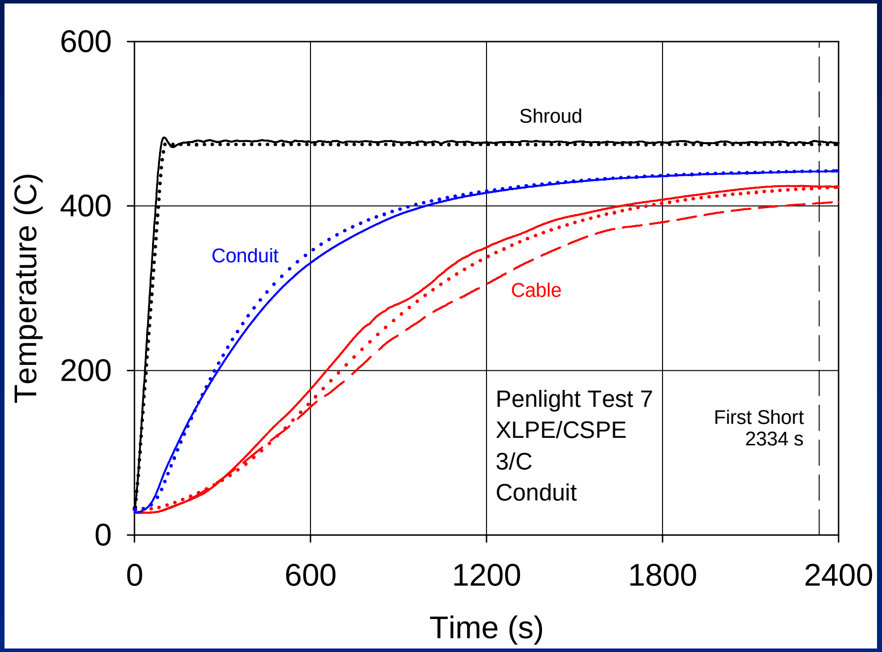




Courtesy Steve Nowlen and Frank Wyant
Sandia National Laboratory

More Results





Courtesy Steve Nowlen and Frank Wyant
Sandia National Laboratory

Summary

- Cable model developed in conjunction with CAROLFIRE test program
- Simplicity and accuracy of the model consistent with current generation large-scale fire models