Fire Model Development and Experimental Validation at NIST

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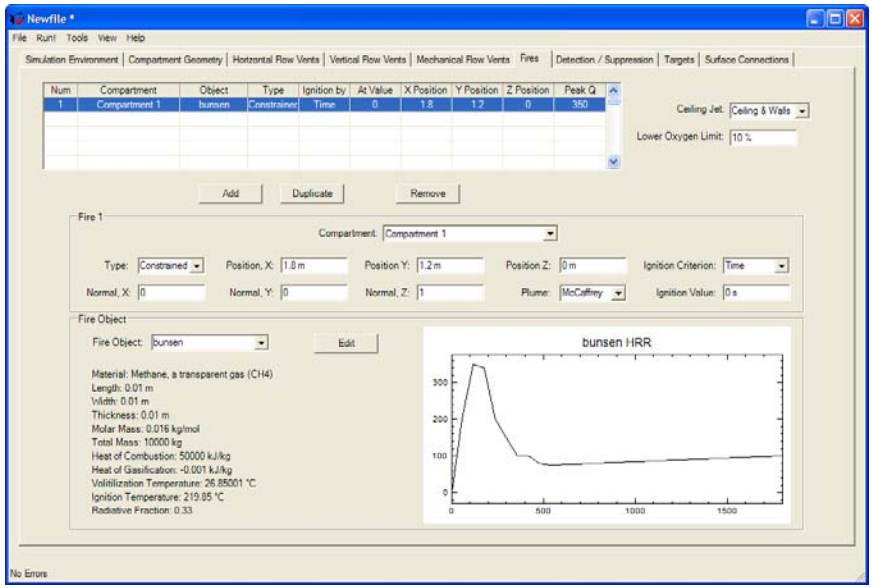
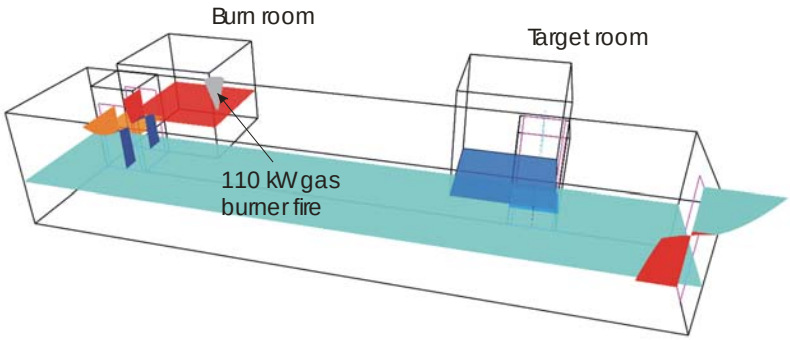
NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

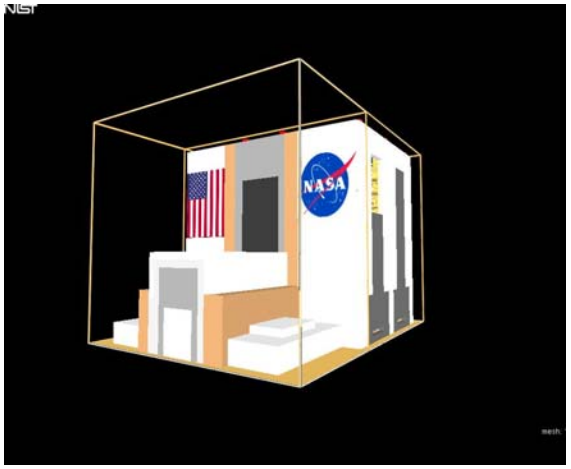
CFAST
Consolidated Fire And Smoke Transport

- Zone fire model where each compartment divided into two “zones”
- Conservation of mass and energy is applied to each zone through set of Ordinary Differential Equations
- Multiple compartments (≤100)
- Appropriate flow of heat and gases between compartments

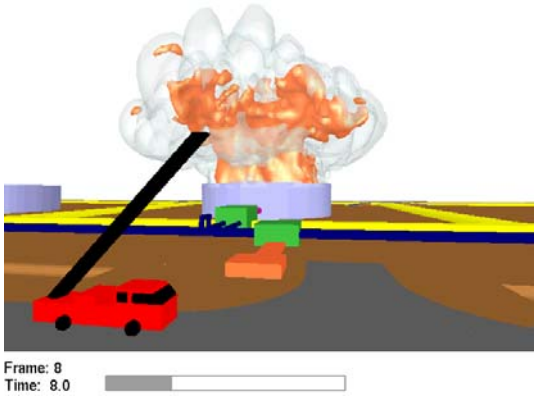


CFAST Interface, funded by US NRC

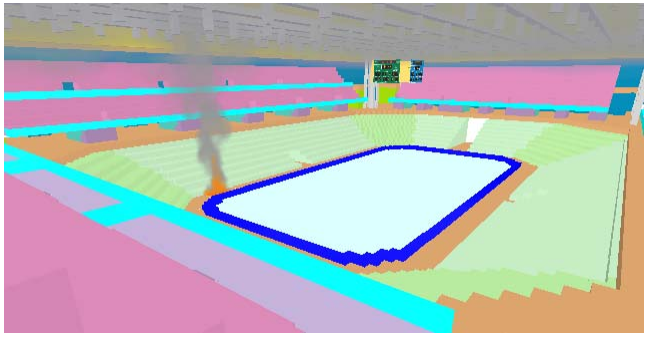




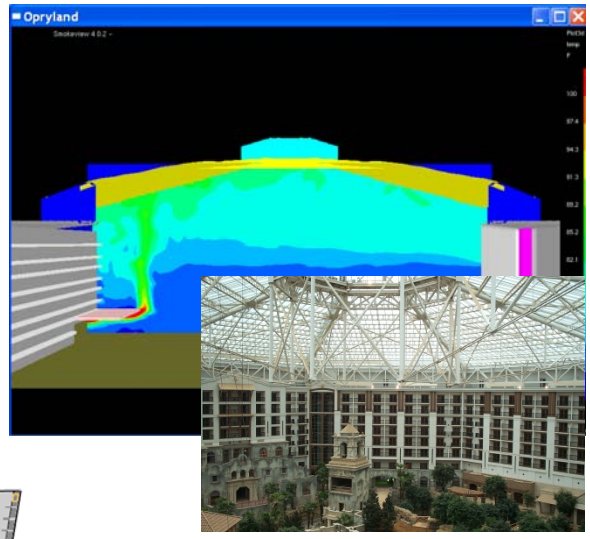
NASA Vehicle Assembly Building
Kennedy Space Center
courtesy Rolf Jensen



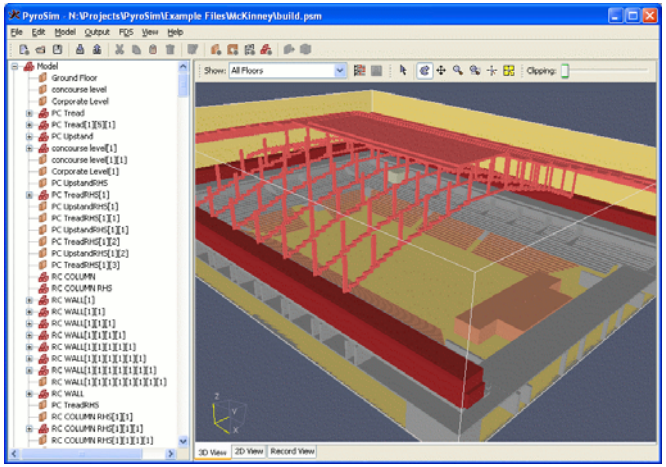
Tank Fire Analysis, courtesy
Combustion Science and Engineering



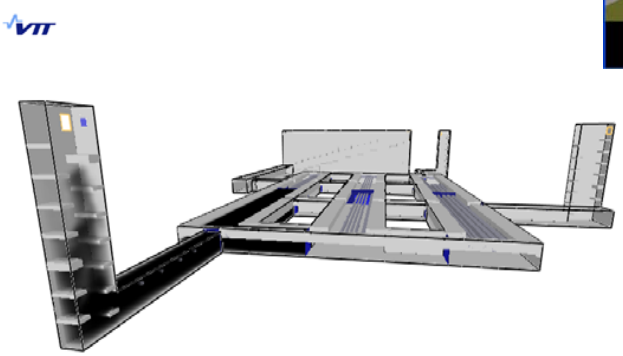
2006 Olympic Ice Hockey Stadium,
Turin, Italy, courtesy Arup



Courtesy, Schirmer Engineering



PyroSim, courtesy Thunderhead
Engineering Consultants, Manhattan, Kansas



Parking Garage, courtesy VTT, Finland

Time: 1705.0

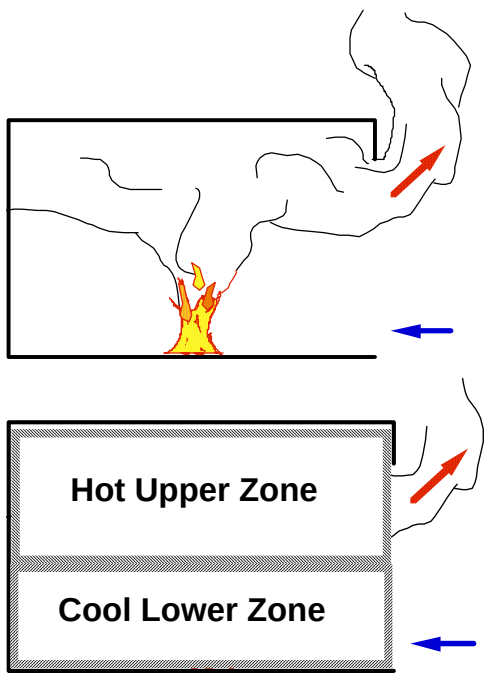
Models Selected for NRC/EPRI V&V

Fire Dynamics Tools (FDTs)	NRC Spreadsheets
FIVE-Rev1	EPRI Spreadsheets
Cons. Fire & Smoke Transport (CFAST)	NIST zone model
MAGIC	Electricite de France zone
Fire Dynamics Simulator (FDS)	NIST CFD Model

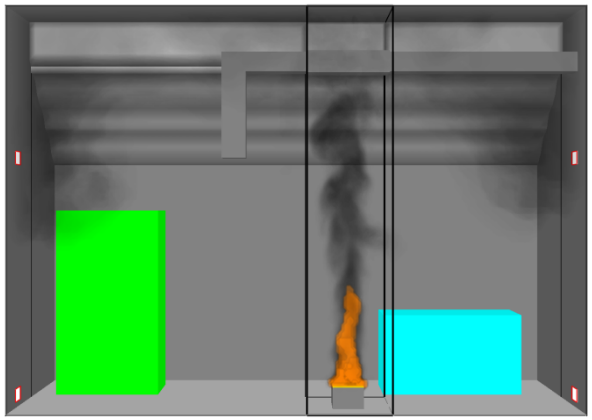
Hand Calculations

$$L_f = 0.23\dot{Q}^{2/5} - 1.02D$$

Zone Models



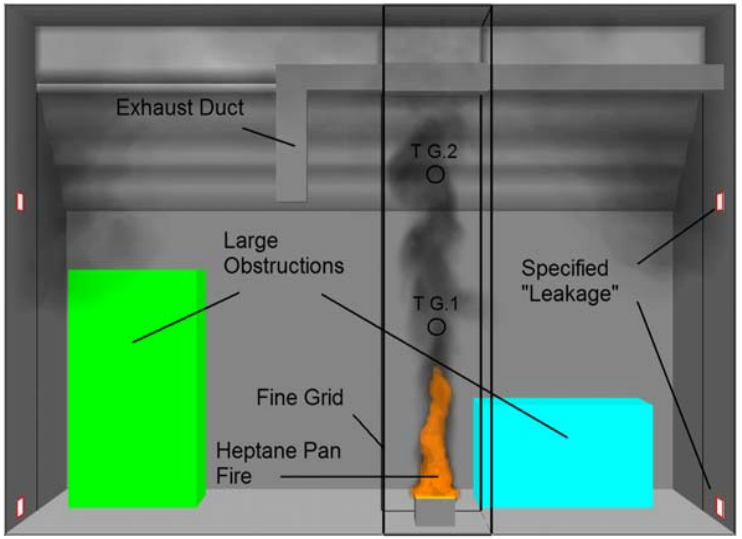
Field (CFD) Models



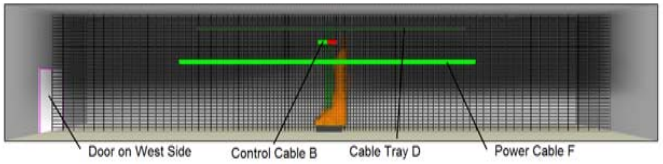
ASTM E 1355
Standard Guide for Evaluating the Predictive Capability of Deterministic Fire Models

- ***Verification:*** the process of determining that the implementation of a calculation method accurately represents the developer's conceptual description of the calculation method and the solution to the calculation method. Is the Math right?

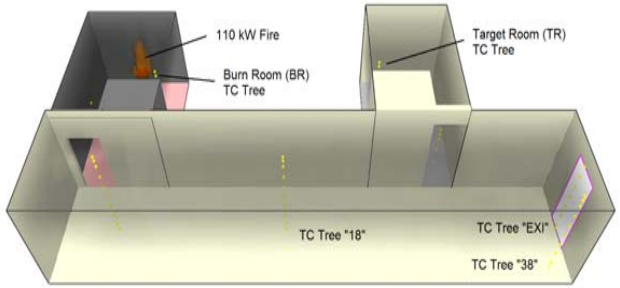
- ***Validation:*** the process of determining the degree to which a calculation method is an accurate representation of the real world from the perspective of the intended uses of the calculation method**.**
  Is the Physics right?



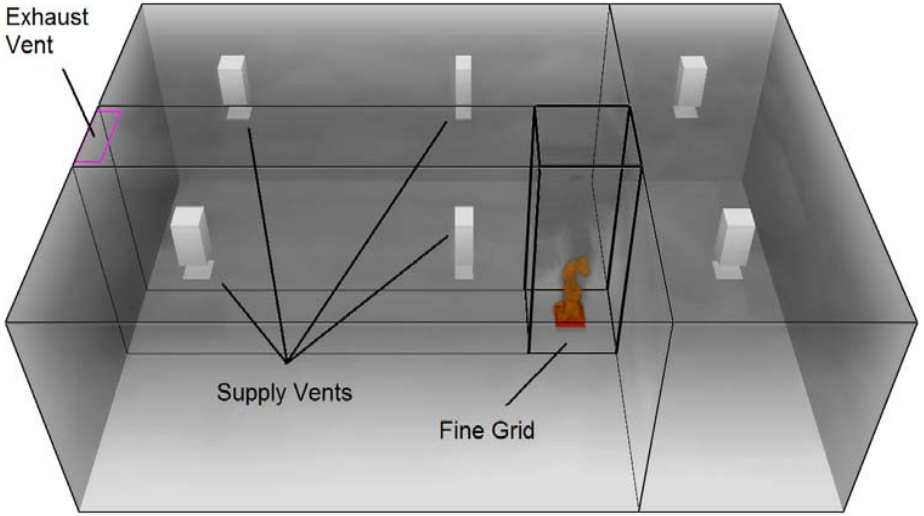
VTT, Finland



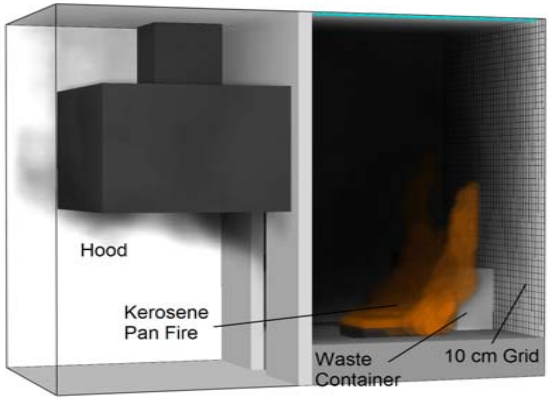
NIST, USA



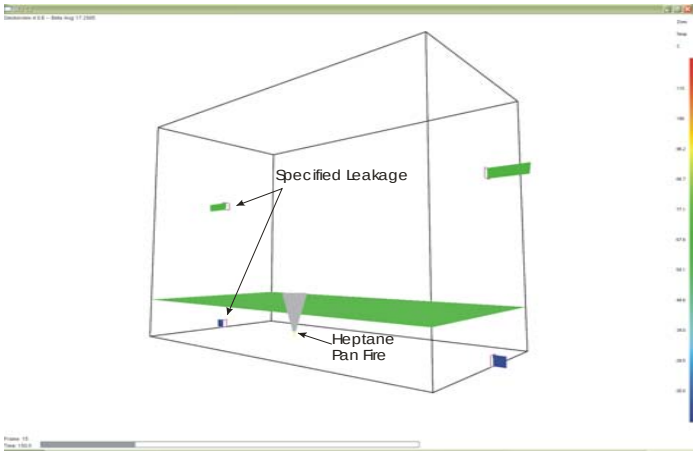
NBS, USA

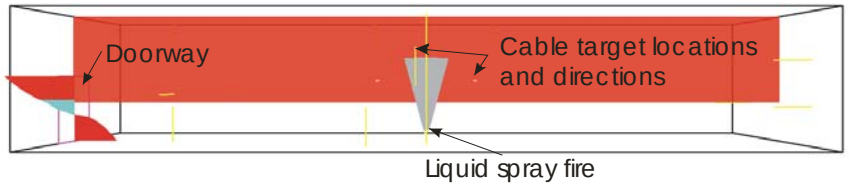


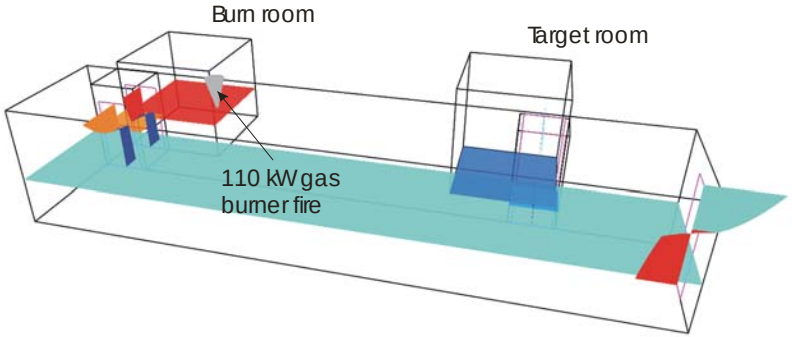
Sandia/FM (USA)

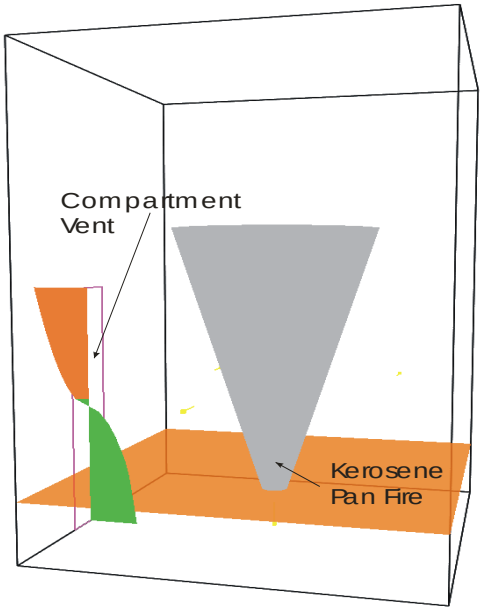


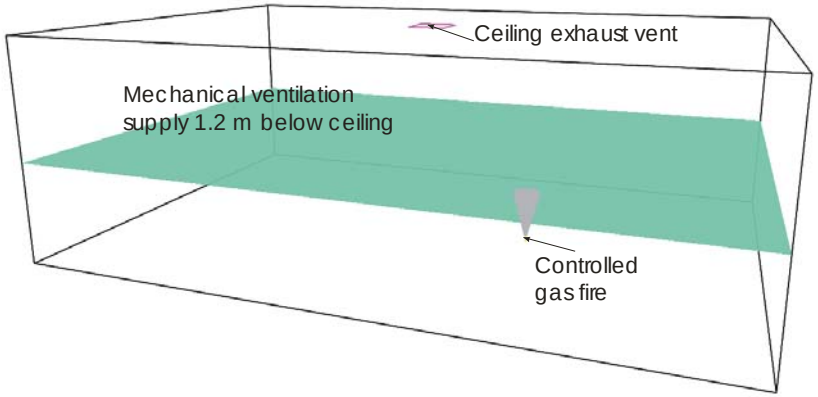
iBMB, Germany

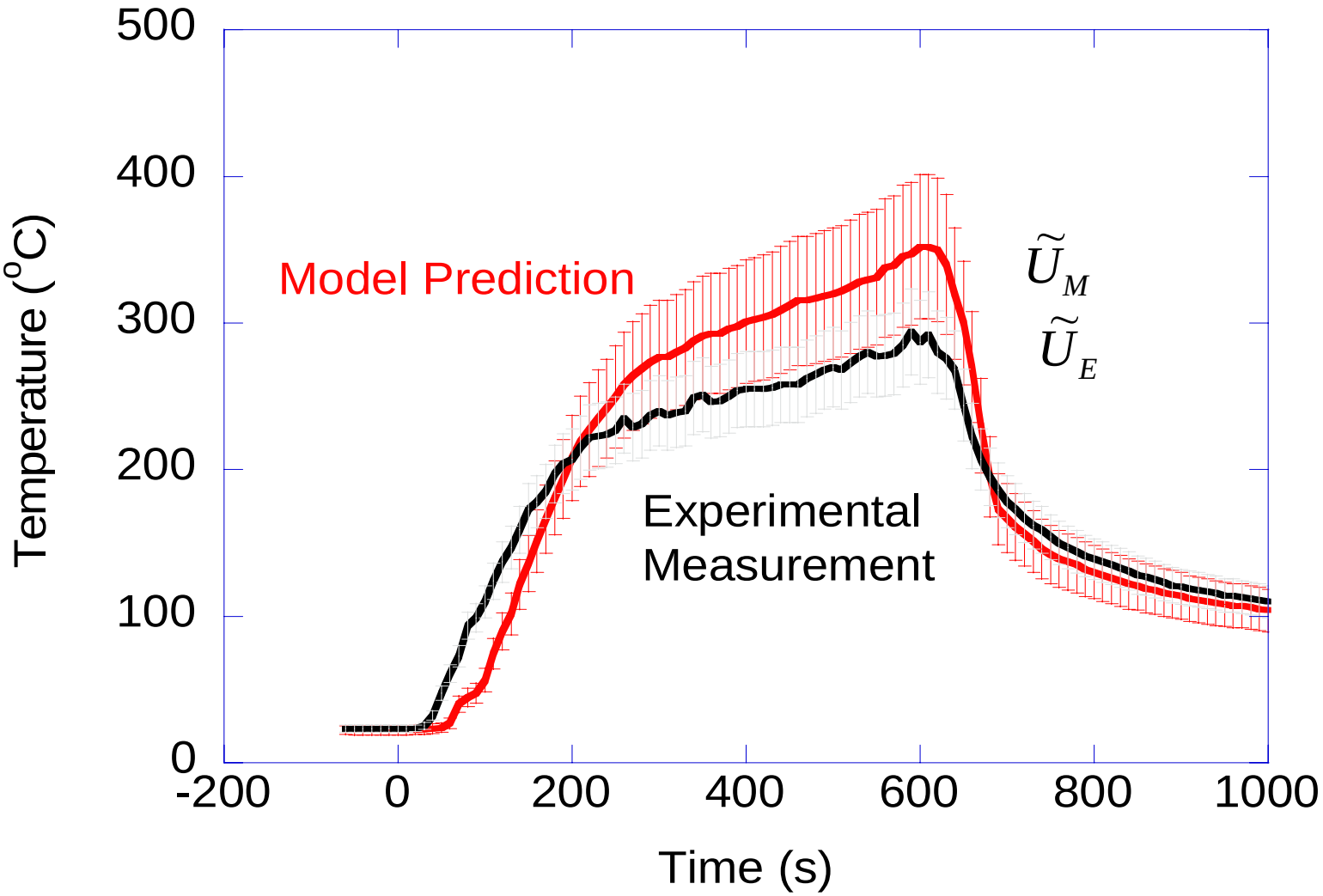

Specified Leakage
Heptane
Pan Fire


Doorway
Cable target locations
and directions
Liquid spray fire

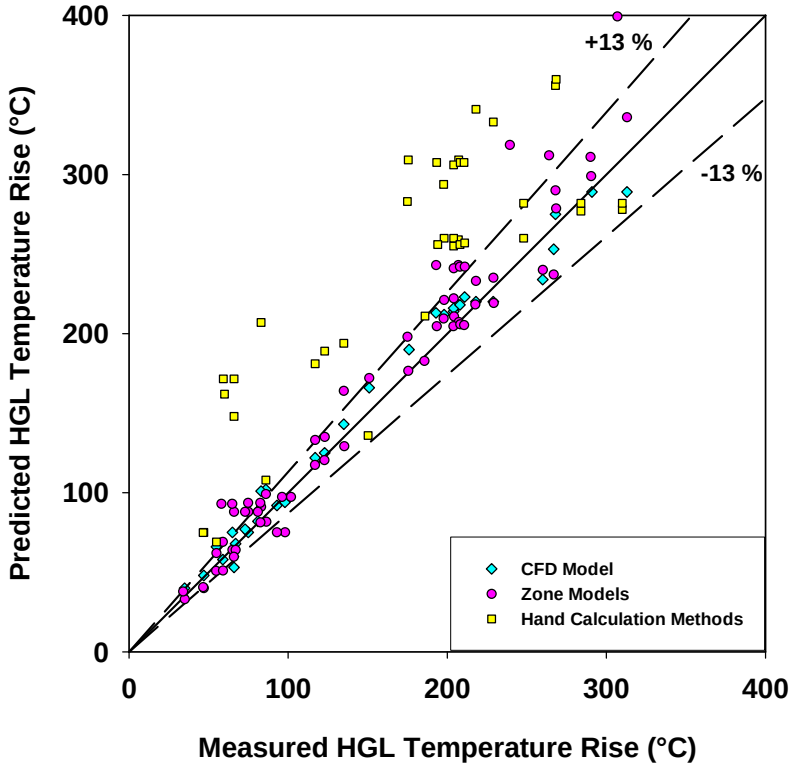

Burn room
Target room
110 kW gas
burner fire

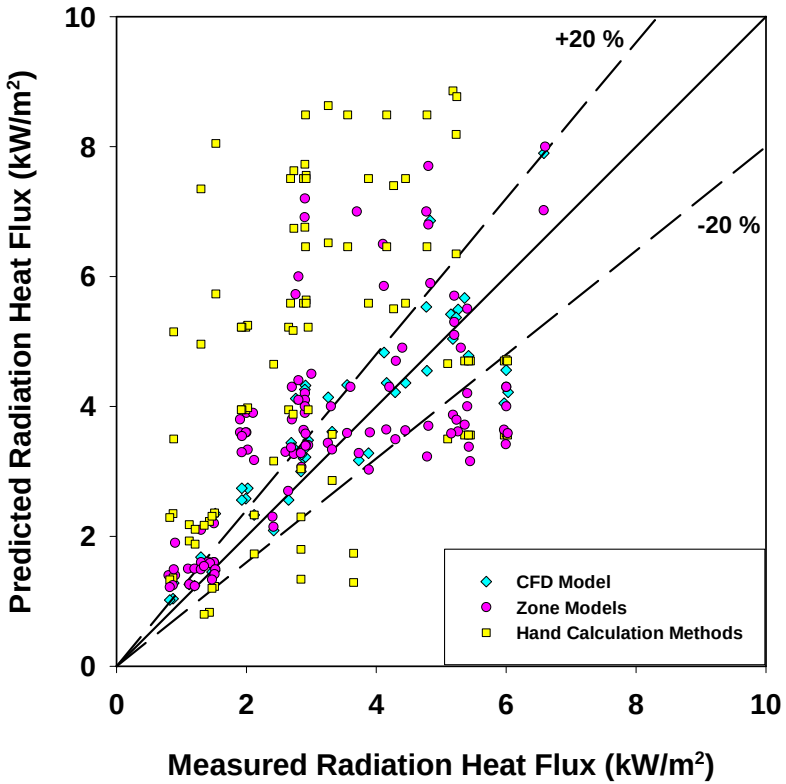

Compartment
Vent
Kerosene
Pan Fire


Ceiling exhaust vent
Mechanical ventilation
supply 1.2 m below ceiling
Controlled
gas fire


500
400
300
200
100
0
-200
0
200
400
600
800
1000
Temperature (°C)
Time (s)
Model Prediction
Experimental
Measurement
$\tilde{U}_M$
$\tilde{U}_E$

Results of NRC V&V (NUREG 1824)





From *Fire Protection Engineering*, Spring 2007

Simple Response Models in Fire

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

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

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

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

THIEF Model

1.5 kJ/kg/K

0.2 W/m/K

$$\rho c \frac{\partial T}{\partial t} = \frac{1}{r}\frac{\partial}{\partial r} k r \frac{\partial T}{\partial r}$$

Mass per unit length/Area

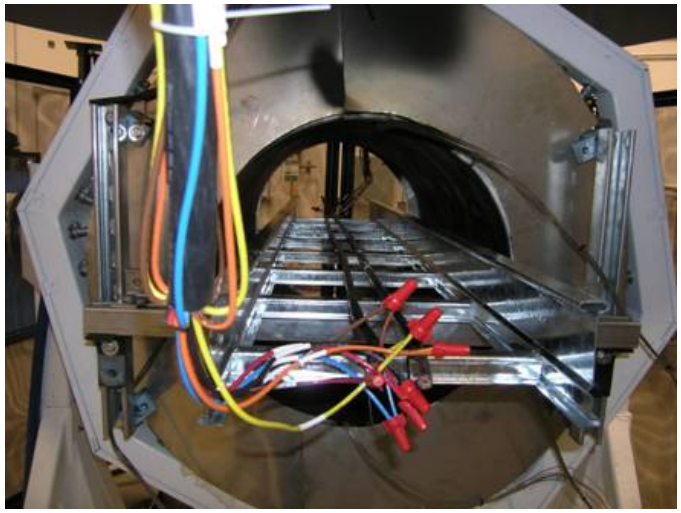
$$k \frac{\partial T}{\partial r}(R,t) = \dot{q}''$$

Predicted by Fire Model

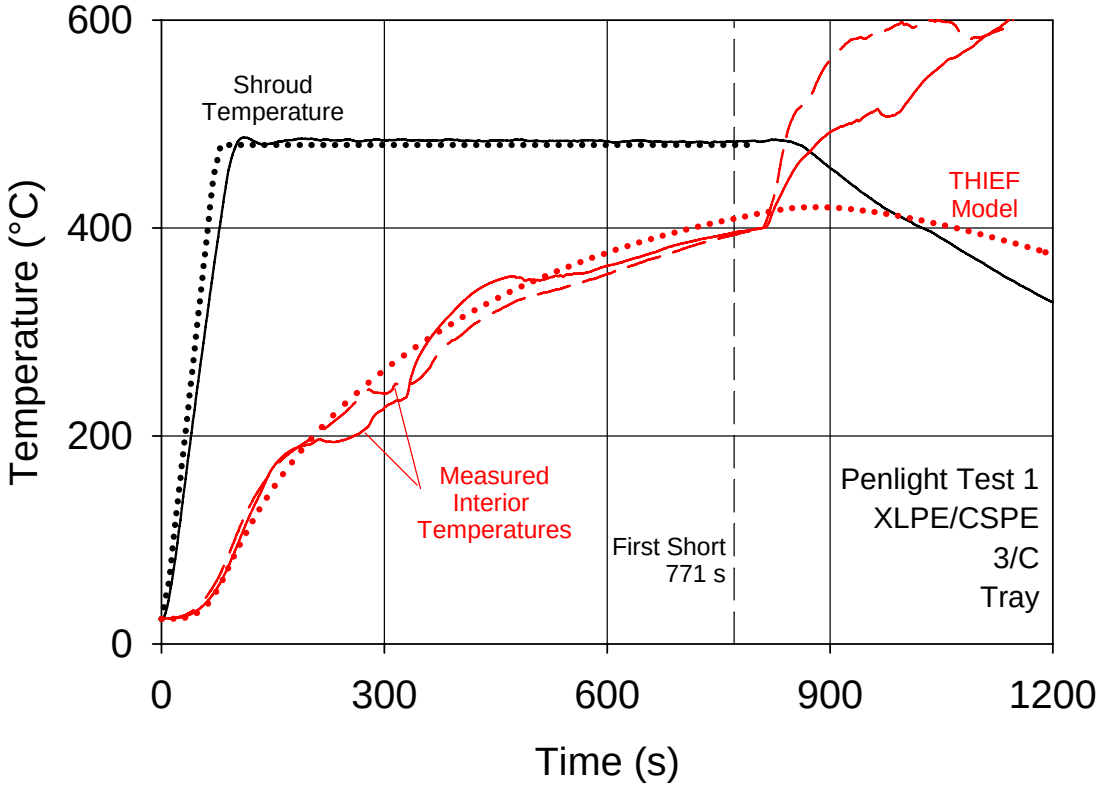
- 1-D heat conduction for cable *T*(r,t)
- Homogenous cylinder, i.e. no layers
- Constant thermal conductivity (k)
- Constant specific heat (c)
- Bulk density (ρ) determined from mass and diam.
- Failure temperature obtained experimentally

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

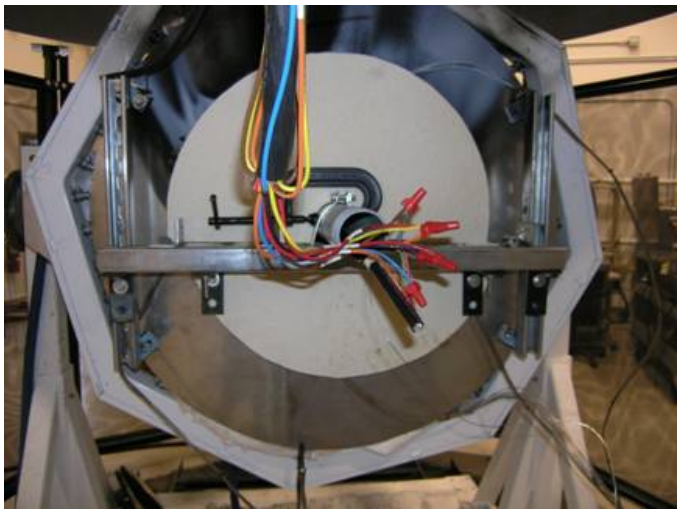
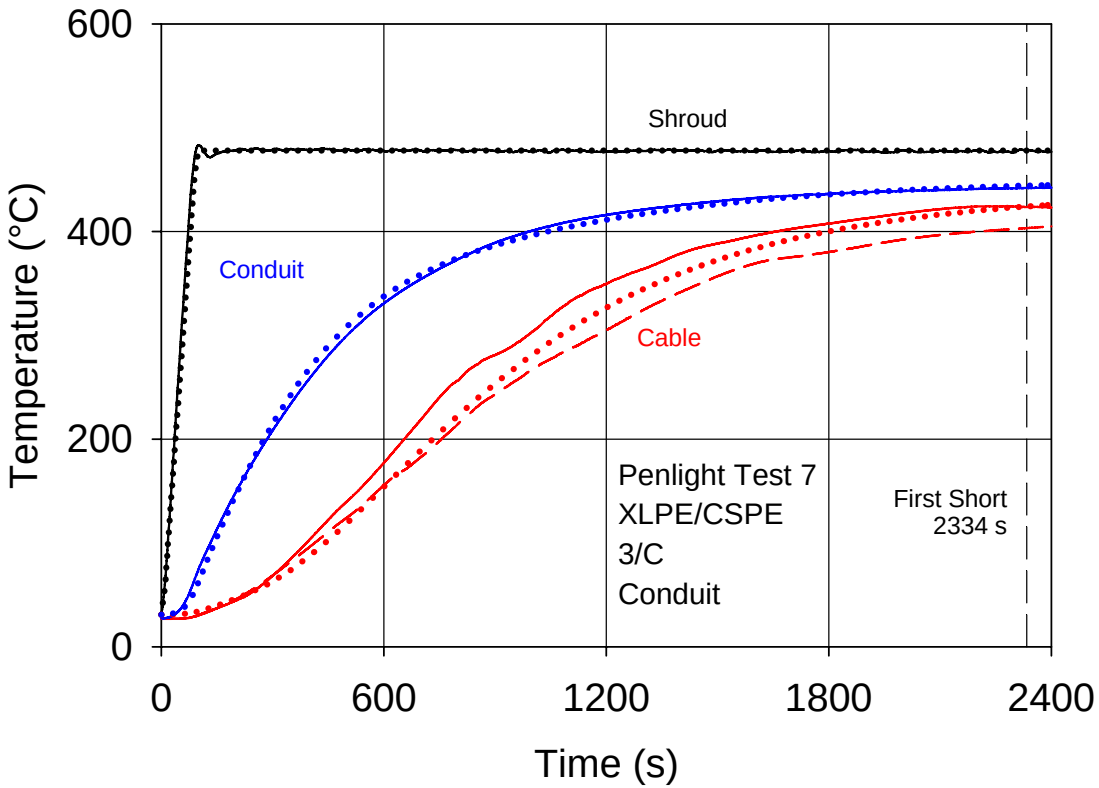
Penlight Results



Courtesy S Nowlen and F Wyant
Sandia National Laboratory



Conduit in Penlight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