Enhancements to the FIVE Methodology

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Background on FIVE

- Developed by EPRI in early 1990s for nuclear utilities to use in IPEEEs
- Included two parts
  - Overall methodology developed by PLC
  - Methods of quantitative fire hazard analysis developed by Mowrer
- Fire hazard analysis methods intended for screening purposes
  - Widely used for qualification purposes

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The FIVE methodology

- Developed as series of lookup tables for one-zone one-room analysis
  - Average gas temperature
    - Unventilated enclosure (base case)
    - Naturally ventilated enclosure
    - Mechanically ventilated enclosure
  - Fire plume sublayer
  - Ceiling jet sublayer
  - Thermal radiation

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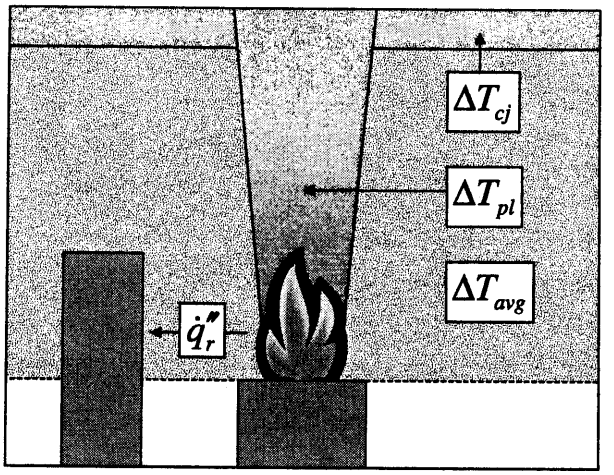
The FIVE methodology



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The FIVE methodology

- Average hot gas layer temperature

$$\Delta T_{avg} = T_o\left[exp(Q_{net}/Q_o)-1\right]$$

- Plume temperature

$$\Delta T_{pl} = \Delta T_{avg} + 25\frac{\dot{Q}_c^{2/3}}{z^{5/3}}$$

- Ceiling jet temperature

$$\frac{\Delta T_{cj}}{\Delta T_{pl}} = \frac{0.32}{(r/H)^{2/3}}$$

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FireMD features

- A one-room two-zone fire model with the following features:
  - Implemented in Access and Excel (97 / 2000)
  - Natural and mechanical ventilation
    - Floor / wall / ceiling vents
    - Specified injection / extraction rates
  - Plume / ceiling jet sublayers
  - Detection algorithm with RTI / conduction
  - Target / boundary heating

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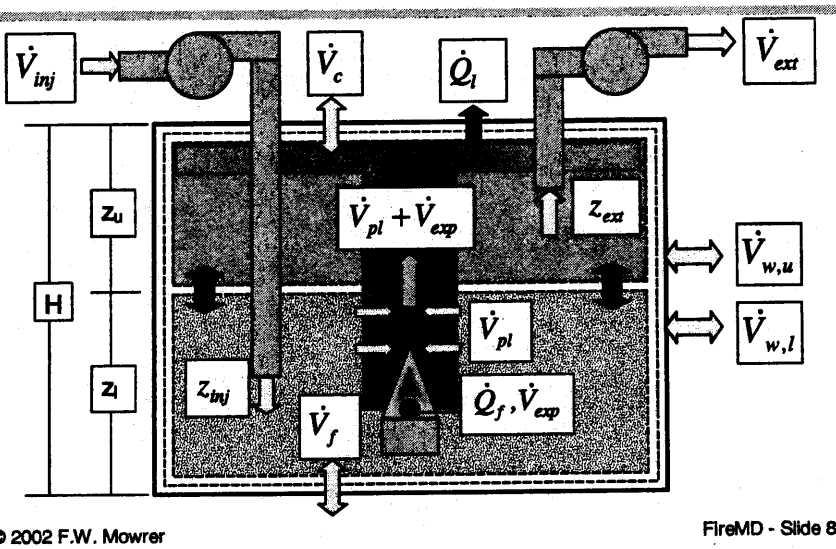
FireMD diagram



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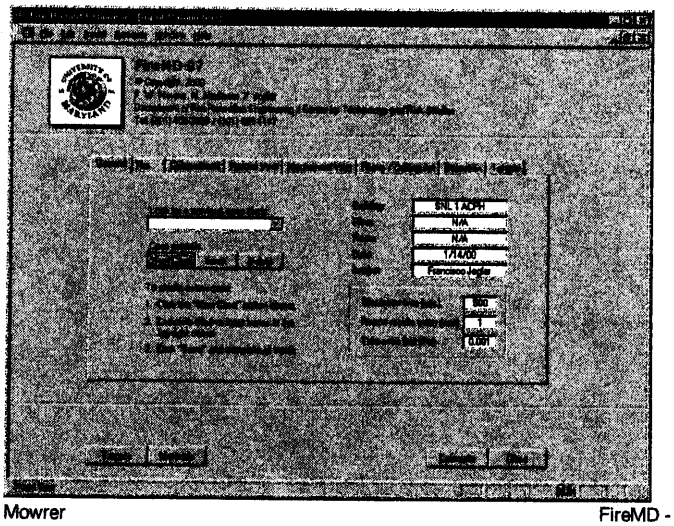
FireMD - General



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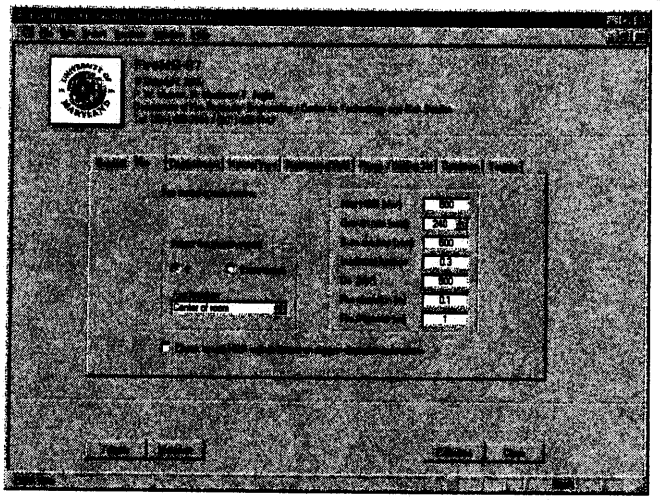
FireMD - Fire



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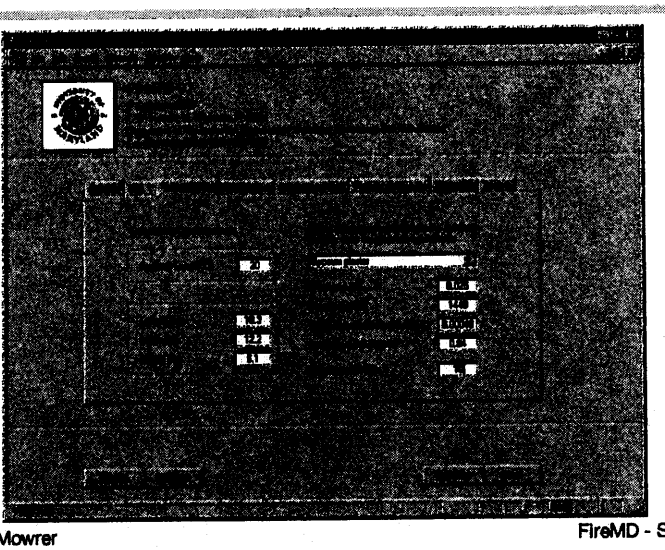
FireMD - Compartment



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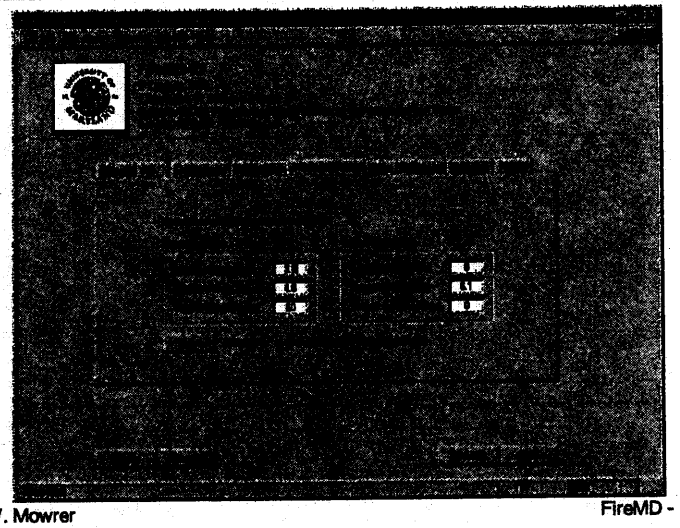
FireMD - Ventilation



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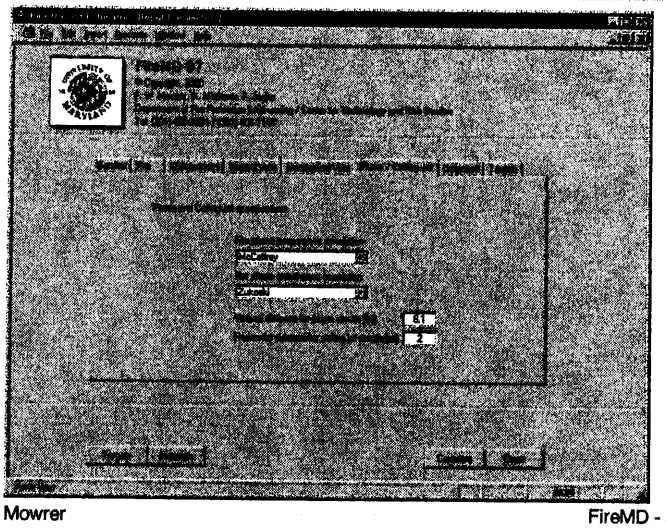
FireMD - Plume / CJ



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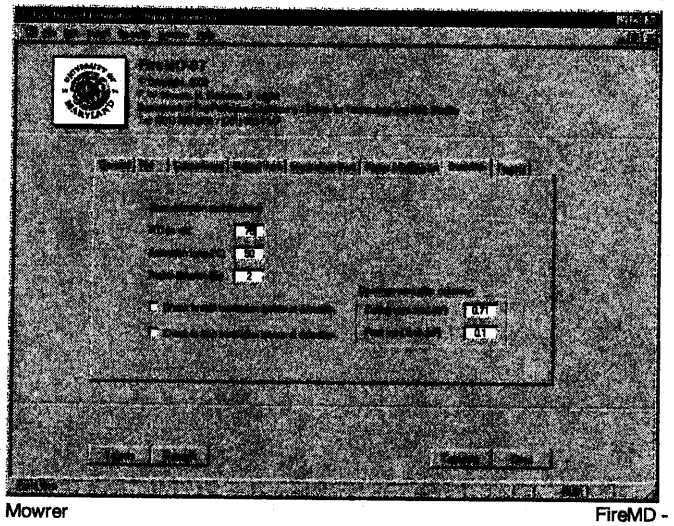
FireMD - Detection



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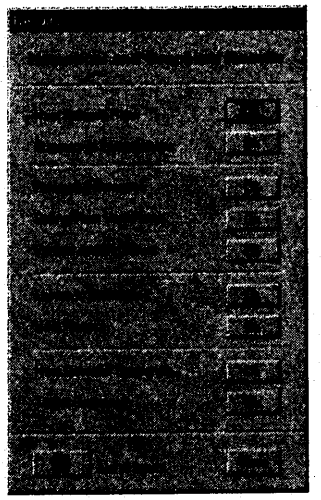
FireMD - Results



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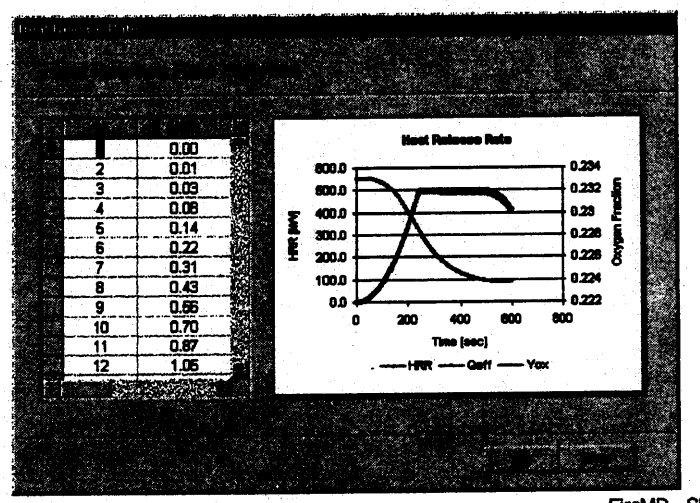
FireMD - HRR



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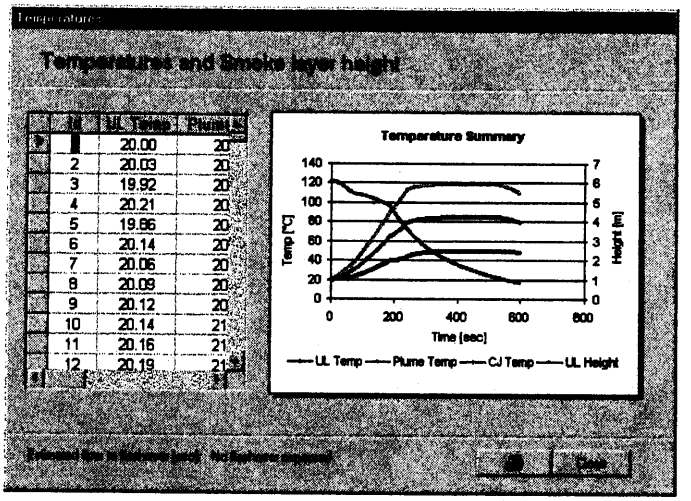
FireMD - Temperatures



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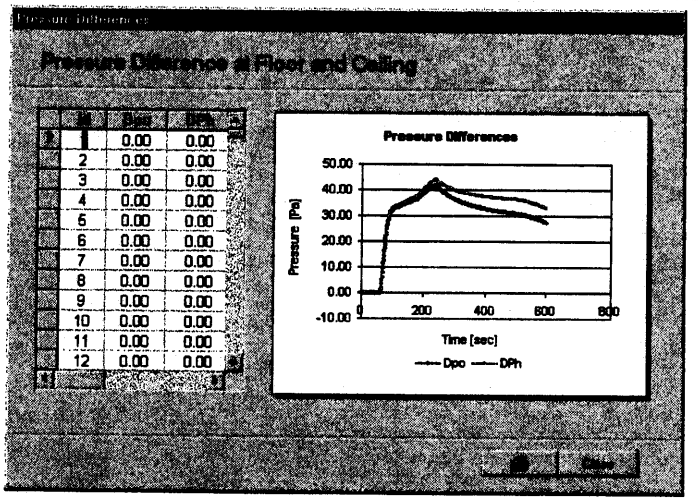
FireMD - Pressures



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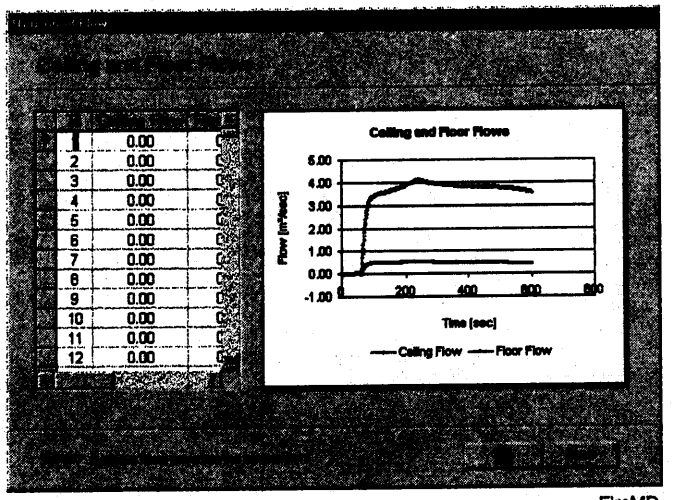
FireMD - Ceiling/floor



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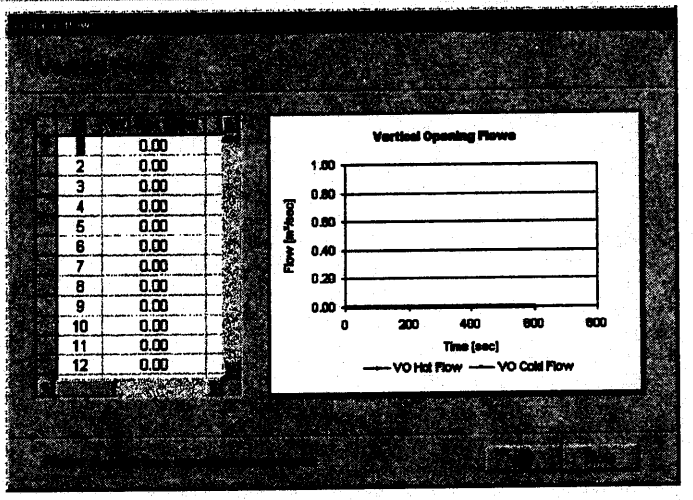
FireMD - Vertical flows



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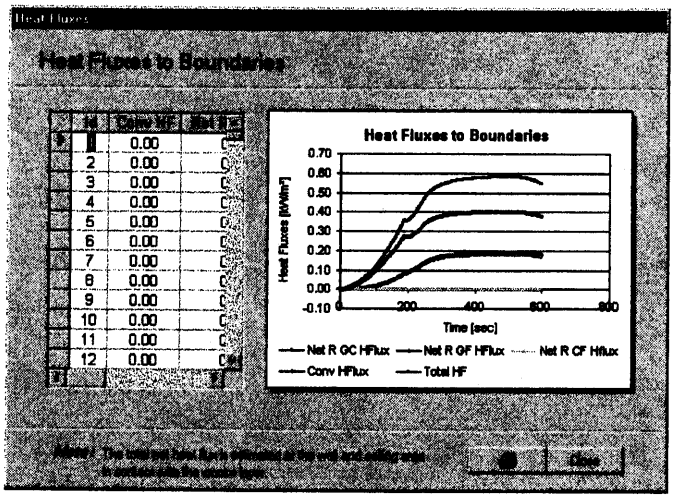
FireMD - Heat fluxes



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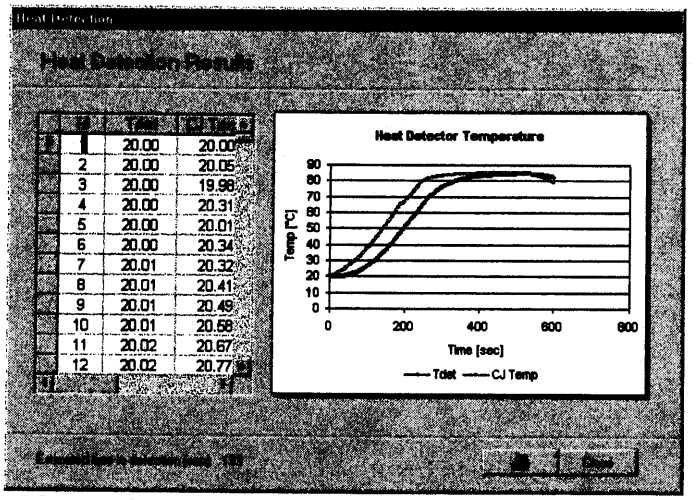
FireMD - Detection



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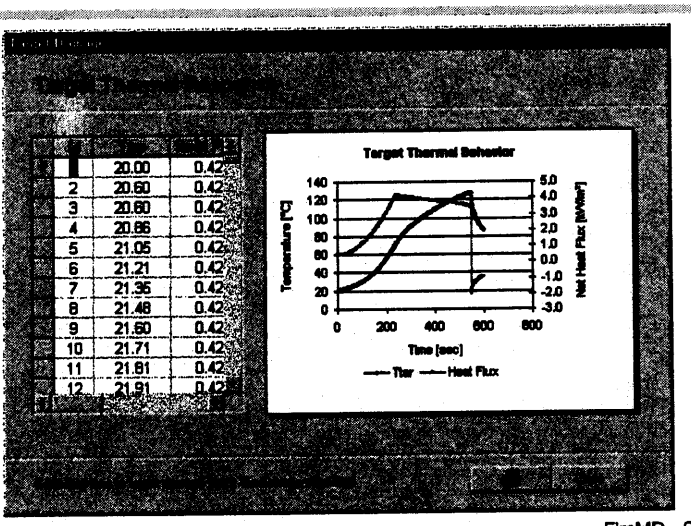
FireMD - Target



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FireMD validation studies

- FMSNL baseline validation enclosure fire tests
- LLNL mechanically ventilated enclosure fire tests

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FMSNL series

- Enclosure
  - 18.3 m (60') x 12.2 m (40') x 6.1 m (20') high
- Fire sizes / durations
  - 500 - 2000 kW / 10 - 20 minutes
- Ventilation
  - Mechanical injection through 6 vents located 1.2 m (4') below ceiling
  - 0.4 - 3.8 m^3/s (1 - 10 changes/hour)

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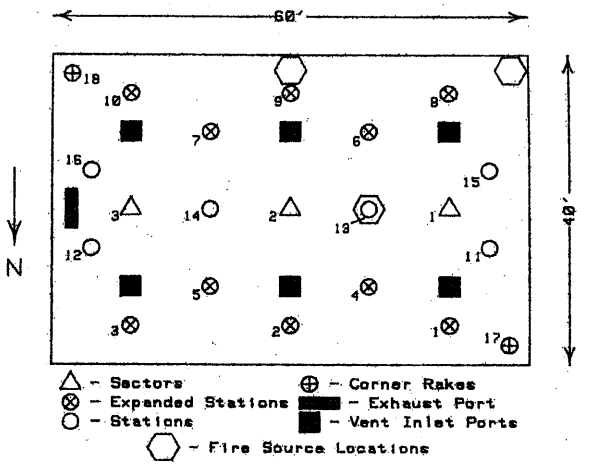
FMSNL instrumentation



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FMSNL series

- Test 4:
  - 1 air change per hour (0.38 m^3/sec)
  - Peak HRR = 500 kW, Growth time = 240 sec.
- Test 5:
  - 10 air changes per hour (3.8 m^3/sec)
  - Peak HRR = 500 kW, Growth time = 240 sec.
- Test 9:
  - 8 air changes per hour (3.3 m^3/sec)
  - Peak HRR = 1000 kW, Growth = 480 sec.

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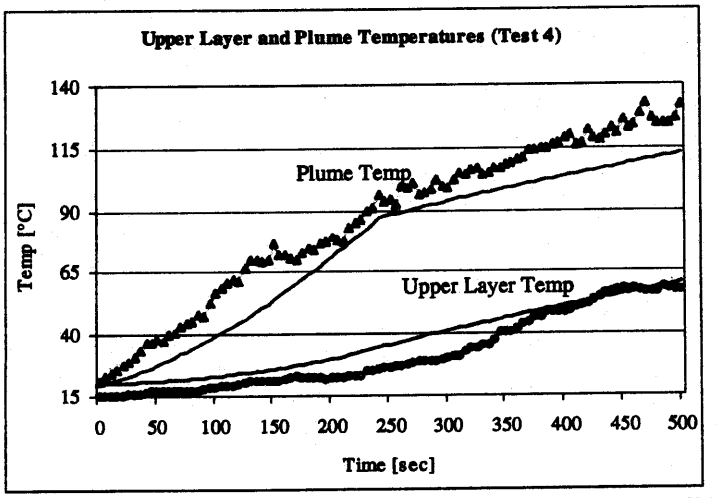
FMSNL Test 4



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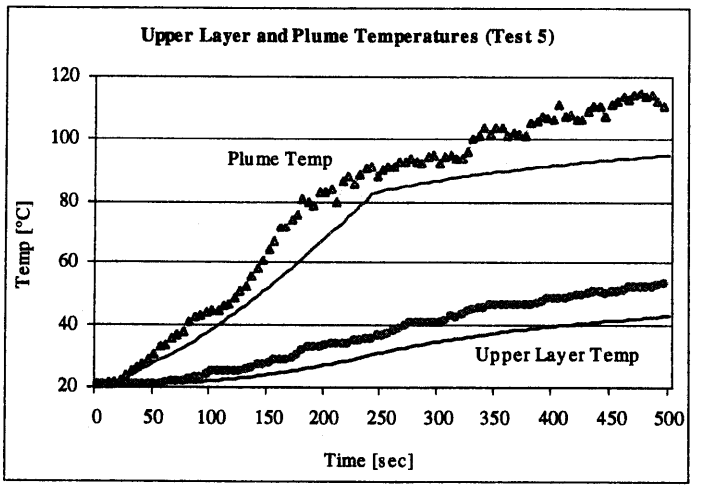
FMSNL Test 5



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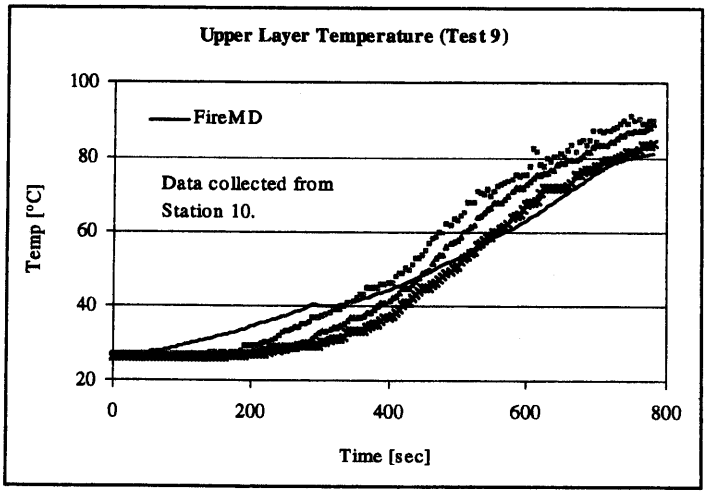
FMSNL Test 9



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LLNL series (Mod27B)

- Enclosure
  - 6.0 m (20') x 4.0 m (13') x 4.5 m (15') high
- Fire size
  - Steady 400 kW fire
- Ventilation
  - Mechanical extraction at 0.25 m^3/s through vent located 0.36 m (1.1') above floor
  - Makeup air through 0.24 m^2 inlet 0.1 m above floor

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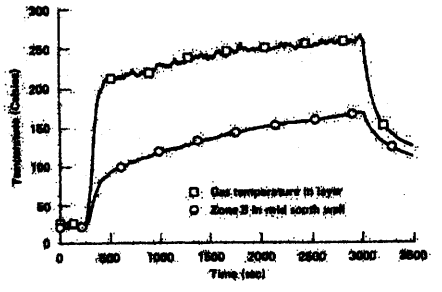
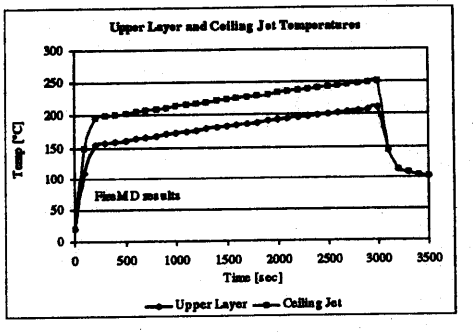
LLNL Mod27B

- Upper layer temperature





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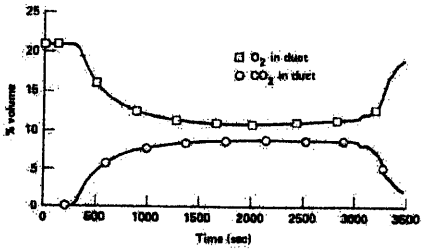
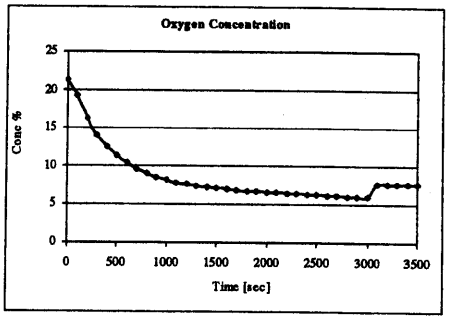
LLNL Mod27B

- Oxygen concentration





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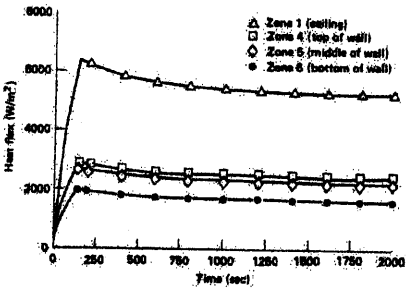
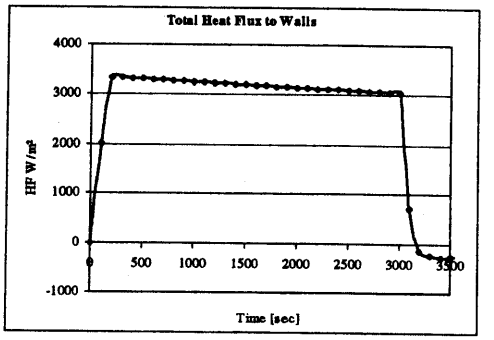
LLNL Mod27B

- Wall heat flux





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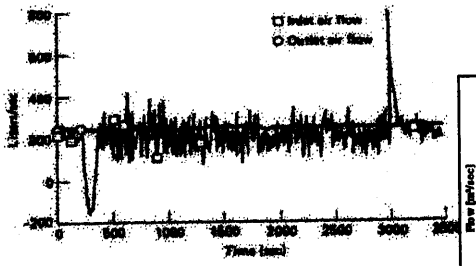
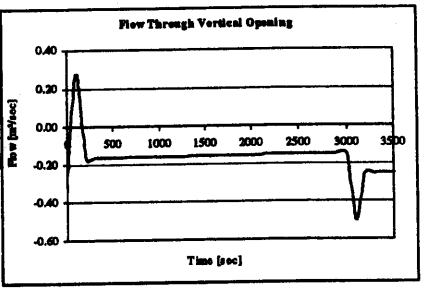
LLNL Mod27B

- Inlet / outlet air flow





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Summary

- FireMD provides useful enhancements to FIVE
- FireMD predictions compared with experimental measurements for a range of enclosure sizes, fire intensities and ventilation conditions
- FireMD predictions are generally within ~20% of measurements for temperatures and flow rates
- Further work needed on O2 concentration and higher temperature fire conditions
  - No work currently being done on the model

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