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Workshop On Fire Testing Measurement Needs: Proceedings

William Grosshandler
(Editor)

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IMPROVED REAL-SCALE FIRE MEASUREMENTS HAVING MEANINGFUL UNCERTAINTY LIMITS

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Workshop on Fire Testing Measurement Needs

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REAL-SCALE FIRE MEASUREMENTS AND UNCERTAINTY ANALYSIS

- Real-scale testing is widely employed in fire research and testing both at NIST and elsewhere
- Experimental designs seldom consider uncertainties associated with experiments or attempt to minimize uncertainties (e g , statistical designs), minimum uncertainties required are not specified
- Experimental uncertainties are usually not estimated and propagation of error analyses are not performed
- Results are often reported with improper number of significant figures and without uncertainty limits

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"A measurement result is only complete when accompanied by a quantitative statement of uncertainty."

"This policy requires that NIST measurement results be accompanied by such statements and that a uniform approach to expressing measurement uncertainty be followed."

---NIST Technical Note 1297

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WHY **MEASURE 'TEMPERATURE IN FIRES?**

- High temperatures are a characteristic of combustion.
- High temperatures can generate large radiative fluxes which support fires (e.g., pyrolysis or vaporization of fuels, flame spread, flashover)
- Temperature is an indicator of the potential for damage.
- Temperature is an indirect indicator of heat release rate.

Rates of chemical reactions are highly dependent on temperature.
- e.g., reactions of solids, i.e., pyrolysis
  gas-phase combustion
  water-gas shift reaction

Temperature is viewed as one of the easier to measure fire characteristics.

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WHY DOES A THERMOCOUPLE JUNCTION TEMPERATIIRE DIFFER FROM THE LOCAL GAS TEMPERATURE?

Heating or cooling effects due to:
- Radiation
- Conduction Along Thermocouple Wires
- Catalytic Heating Due to Surface Reaction
- Aerodynamic Heating at High Velocities

Time Response Limitations

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WHAT ACCURACY IS "REQUIRED" FOR TEMPERATURE MEASUREMENTS IN FIRES?

Very little guidance avmlable in the literature

- Little discussion of effects of uncertainty on models and/or correlations.
- It is clear that required accuracy depends on how the data will be used
  - Estimate flashover time for compartment fire
  - Determine air flow rate through doorway to ± 10% by measuring velocity and density (ideal gas law) of incoming gas.

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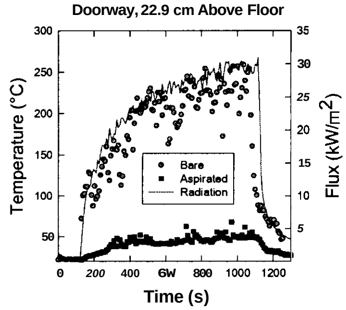
400 kW Natural-Gas Fires
Doorway, 22.9 cm Above Floor



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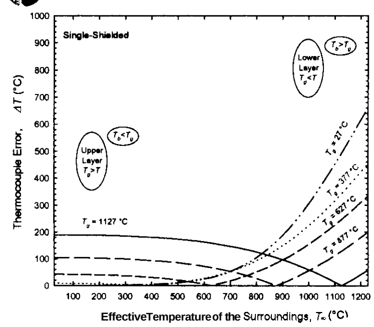

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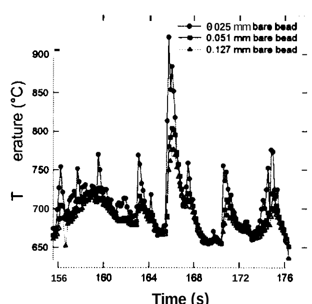
400 kW Natural-Gas Fire
Rear, 80 cm above floor



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MEASUREMENT OF SMOKE MASS CONCENTRATION, GENERATION RATE, AND YIELD

- Imuortance: thermal radiation (e.g., flashover), visibility, smoke damage.
- Historically difficult to measure, required collection on filter of smoke from known volume of fire gases followed by weighting.
- Smoke extinction measurements often recorded, but treated as qualitative comparison of smoke obscuration.
- Specific extinction coefficient required for quantitative extinction measurements of smoke mass concentration not well characterized.

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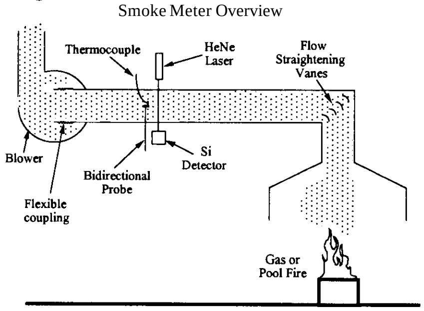
Smoke Meter Overview



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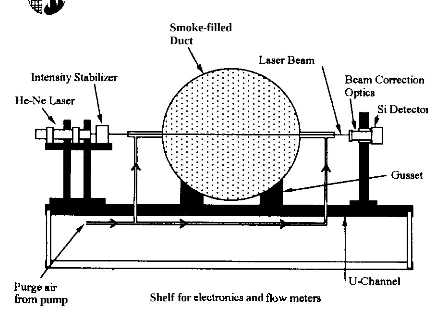

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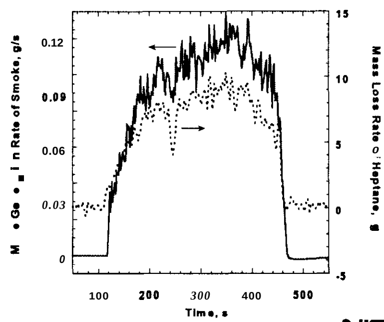

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Heptane Smoke Yield

- Measured value using optical smoke meter: 0.0129
- Measured value using sampling and wighting: '0.012 with 20% estimated uncertainty

Values are equal within experimental uncertainty.

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SMOKE YIELD UNCERTAINTY ANALYSIS (continued)

$$Yield = \frac{K\dot{V}C}{\sigma_s \dot{m}_f}$$

Total Type B Uncertainty	**13.9%**
Total Type A Uncertainty	**3.0%**
Combined Standard Uncertainty	**14.2%**
Expanded Uncertainty (k=2, 95% confidence interval)	**28.4%**

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CURRENT AND FUTURE BFRL FIRE MEAUREMENT UNCERTAINTY ASSESSMENT

Heat Flux Gages

- Coordinating Fire FORUM Heat Flux Measurement Working Group (first task, calibration round robin)
- In-house effort on uncertainty (analysis of effect of convection on Schmidt-Boelter gage)

Rate of Heat Release

- Develop new technique for volume flow rate based on conservation of mass (helium leak detector)
- Characterize uncertainties for various hoods in Large-Scale Fire Research Facility

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