PRE-FLASHOVER FIRE PATTERN REPEATABILITY ON GYPSUM WALLBOARD

Daniel Madrzykowski
National Institute of Standards and Technology
Gaithersburg, MD., USA

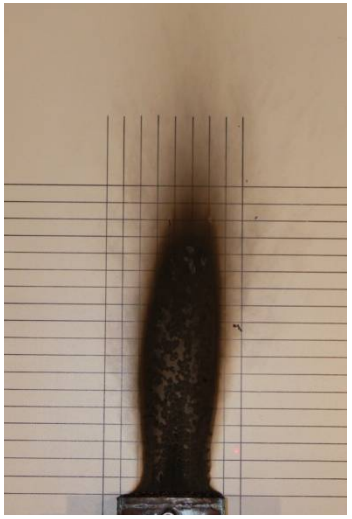
Charles Fleischmann, PhD
Department of Civil and Natural Resources Engineering
University of Canterbury
Christchurch, NZ

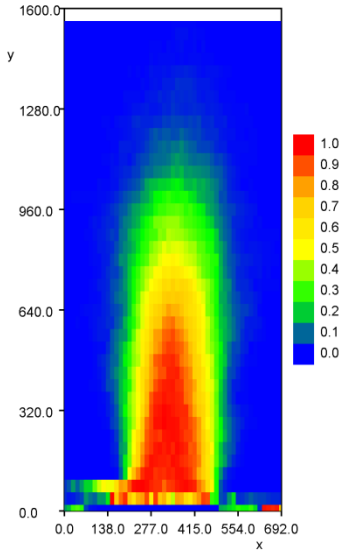
UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

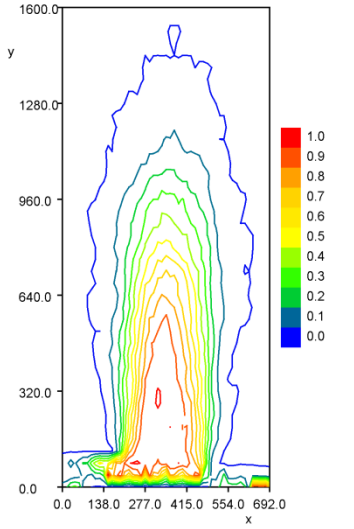
NIST National Institute of Standards and Technology U.S. Department of Commerce

Overview

- Introduction
- Technical Approach
  - Fuel Choice
  - Fire Source Characterization
    - Repeatability
      - HRR
      - Flame Height
  - Fire Pattern Experiments
    - Wall Construction
- Summary







Introduction

- Fire Patterns

  "The visible or measureable physical changes, or identifiable shapes, formed by a fire effect or group of fire effects." **NFPA 921, Guide for Fire & Explosion Investigations, 2014 ed.**

- The analysis of fire patterns is performed in an attempt to trace fire spread, identify areas and points of origin, and identify the fuels involved.

  "…much more research is needed on the natural variability of burn patterns…"

  Strengthening Forensic Science in the United States: A Path Forward, Committee on Identifying the Needs of the Forensic Sciences Community ; Committee on Applied Theoretical Statistics, National Research Council, National Academy of Sciences, 2009.

Pre-Flashover vs Post-Flashover

Literature Review

- Significant areas of research have been completed on
  - Flame heights and fire plumes
  - The thermal transfer to a wall or corner from a fire
  - Thermal degradation of gypsum wallboard

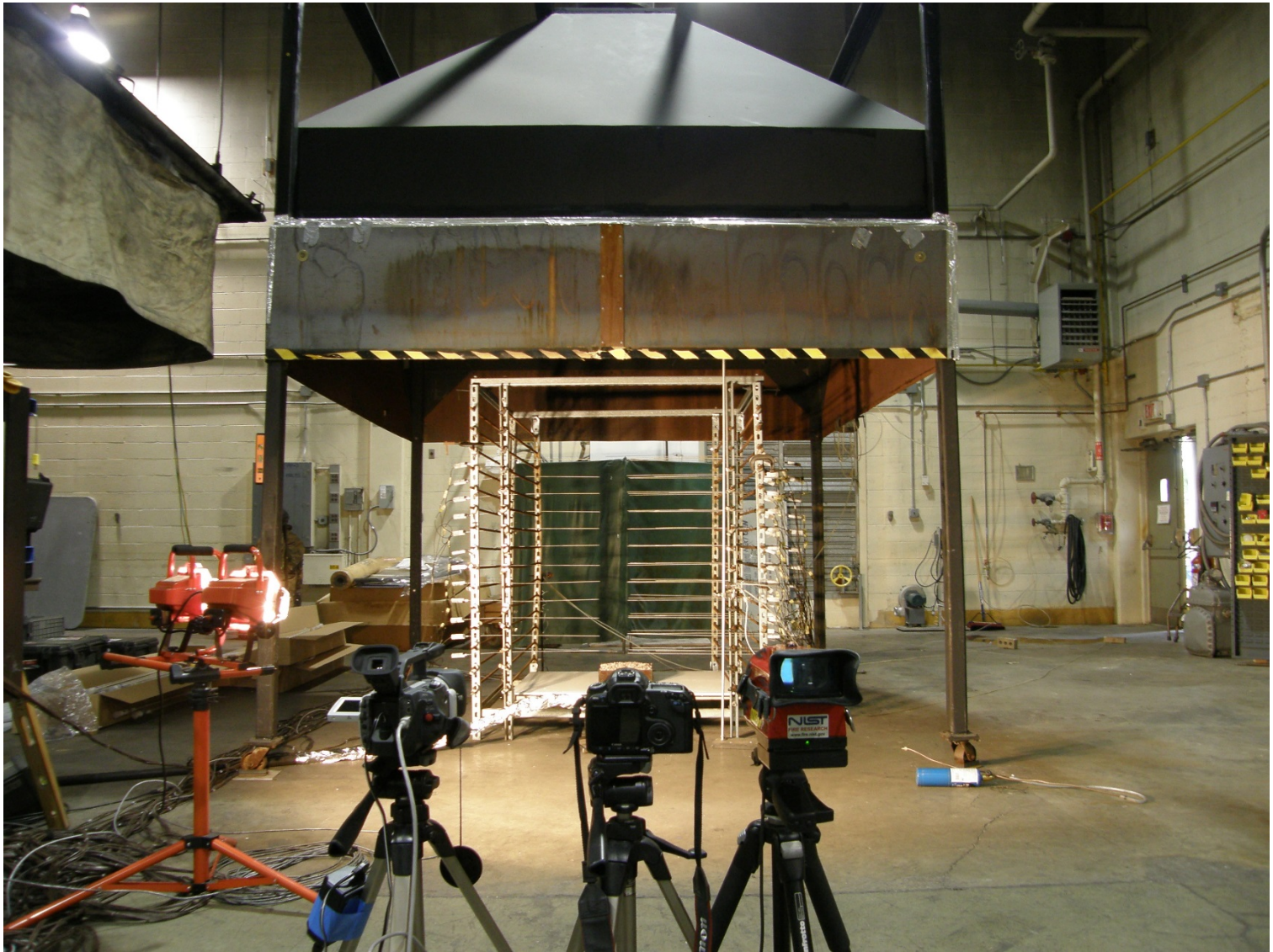
Gaps

- Most of the heat transfer research has been done with laboratory fuels and non-combustible walls
- No correlations between the thermal degradation from a fire and the resulting fire pattern.
- No measure of repeatability for fire patterns under a given set of conditions.
- No validation of the use of computational tools' to reasonably simulate a fire pattern

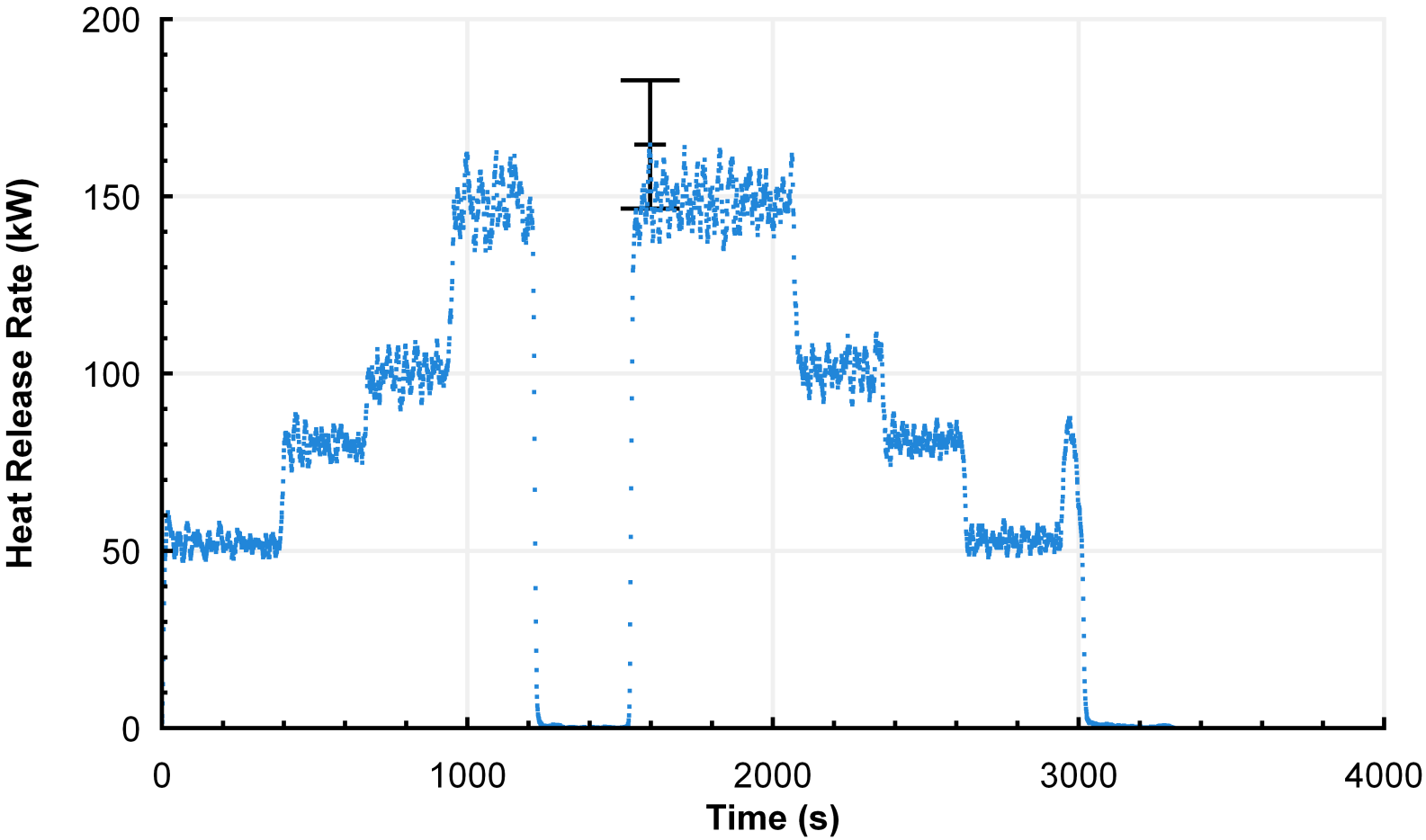
Technical Approach

- Repeatability of the Fire Patterns –Full Scale
  - Source Fire Characterization, 3 different fuels
    - Repeatability of Heat Release Rate, Flame Height,
    - Free Burn, Non-combustible Target Wall, Instrumented Gypsum Board Wall
  - Fire Pattern Repeatability
    - Painted 12.7 mm thick gypsum wallboard will serve as the target fuel/surface for exposure to the fires
    - Variations in wall construction (insulation) will be examined
    - Several fuel positions relative to wall and corner examined
    - Conduct replicates.
    - Patterns recorded manually, photographically and with video. Analyze height, width, shape and area of each pattern

Source Term Characterization Experimental Arrangement



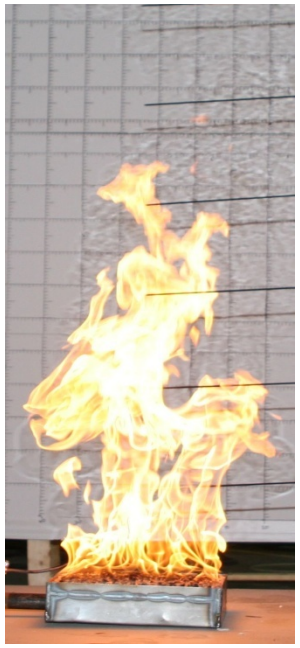
HRR System Calibration

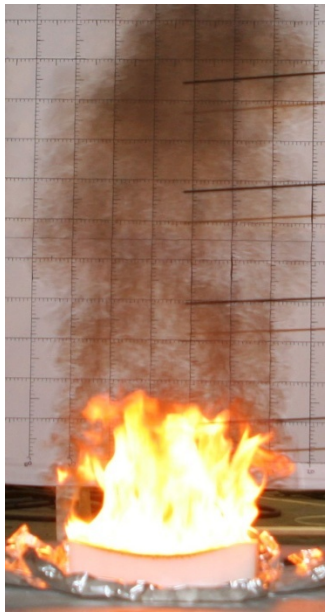


Source Fire Characterization

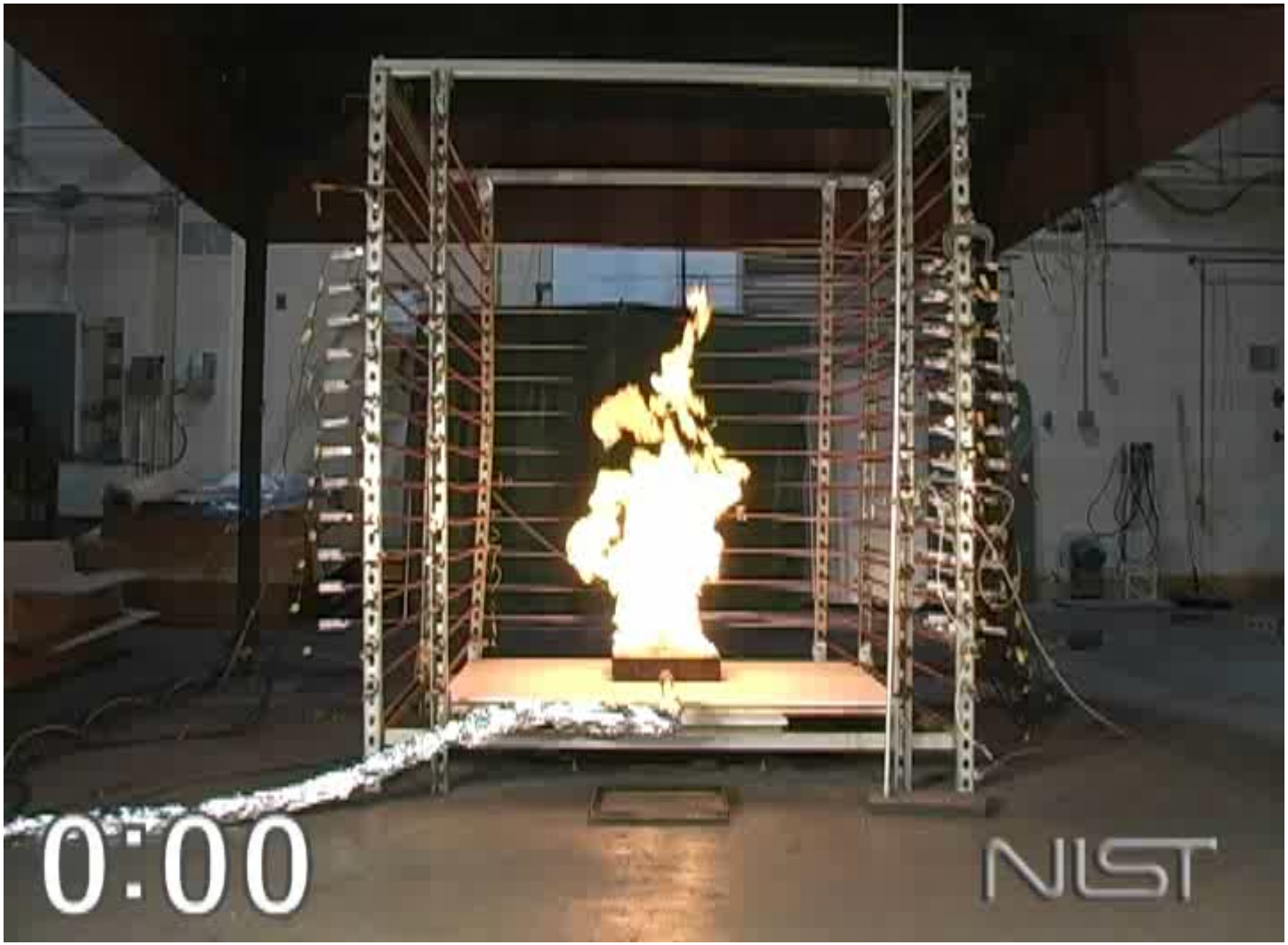
- Heat Release Rate
- Flame/Plume Temperatures
- Total Heat Flux and temperature at target wall surface

•Burner/pan/fuel size
0.305 m x 0.305 m x 0.076m
•Natural gas
•Gasoline
•Polyurethane foam

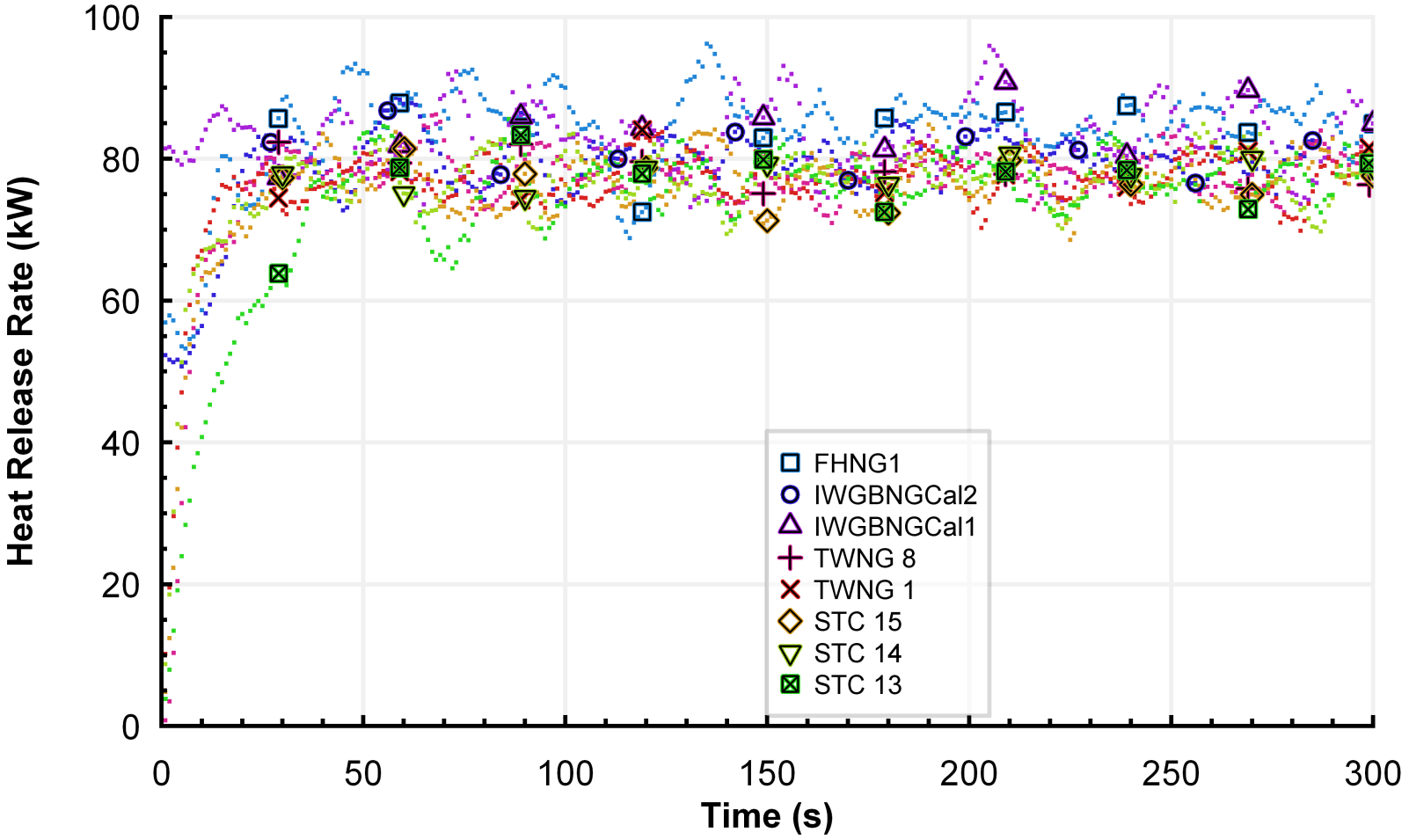




Natural Gas

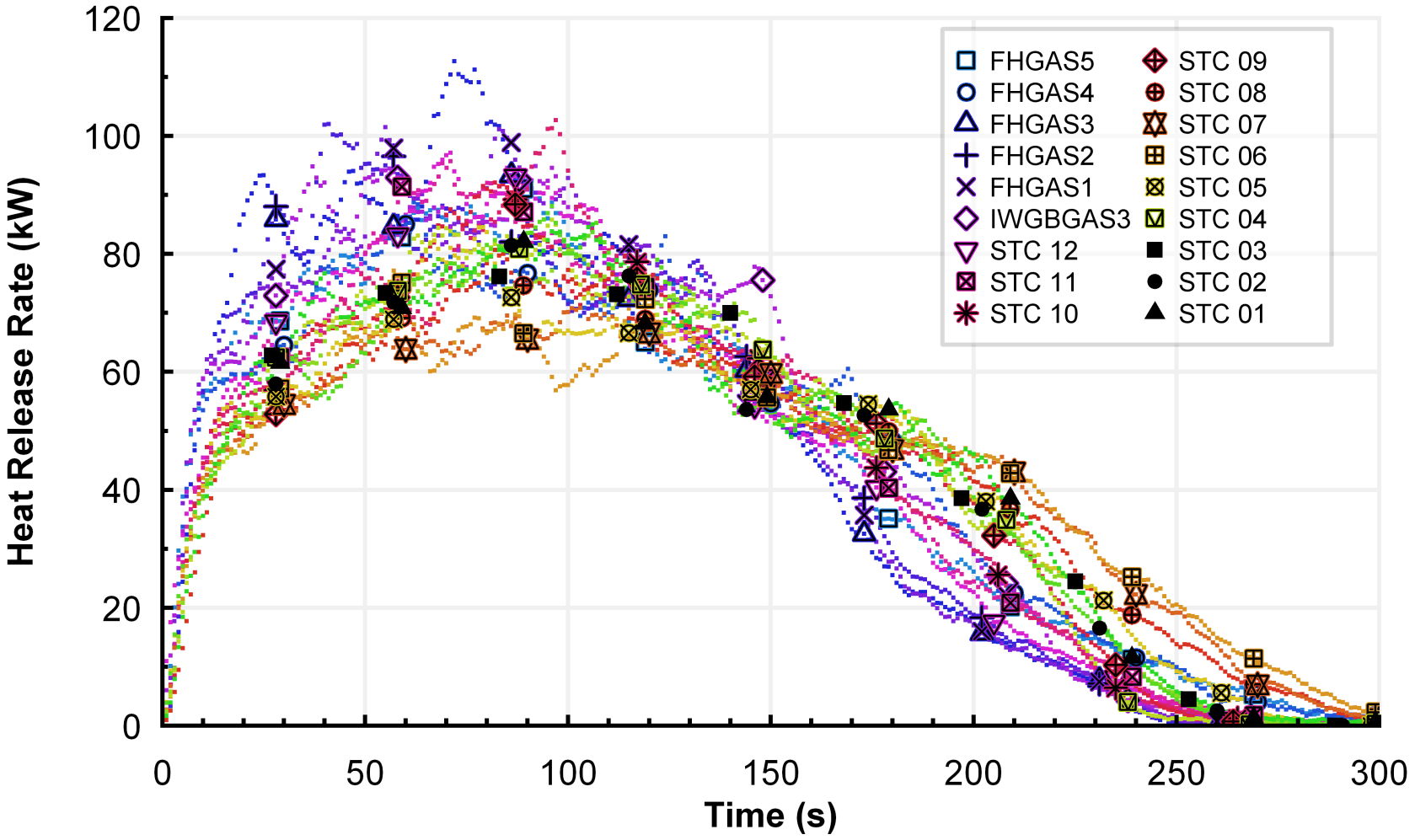


Heat Release Rate – Natural Gas

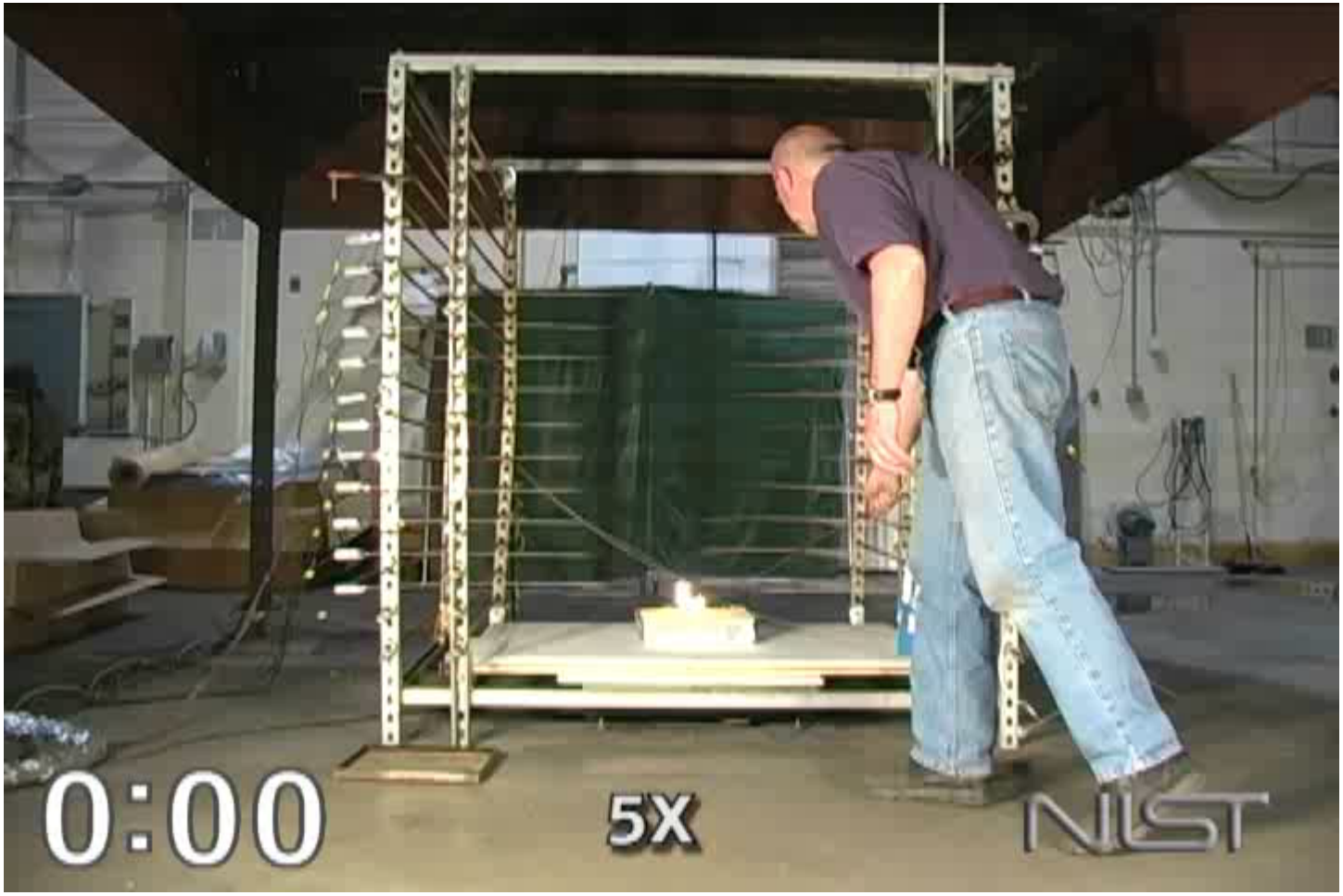


Gasoline

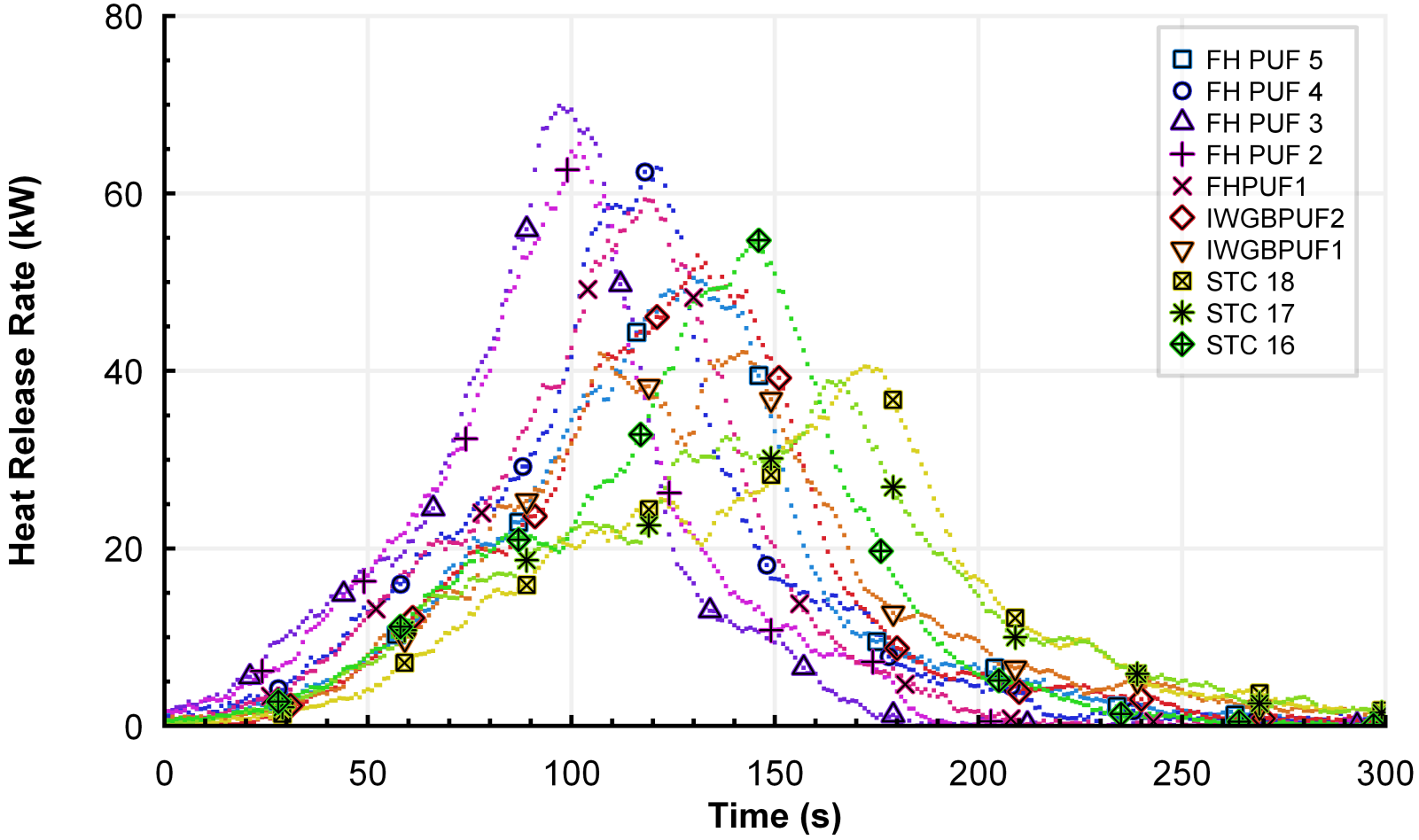
Heat Release Rate - Gasoline



Polyurethane Foam

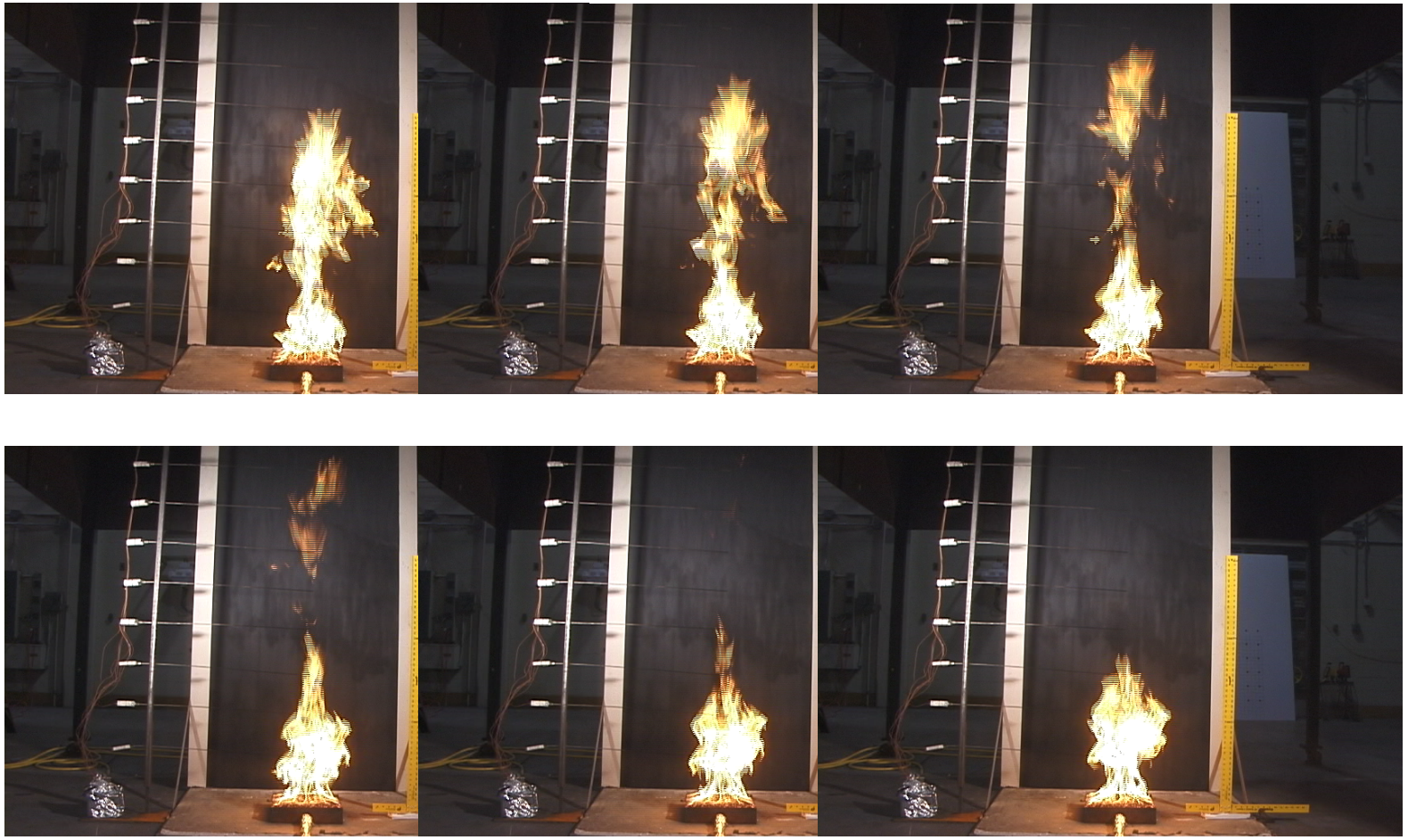


Heat Release Rate – Polyurethane Foam



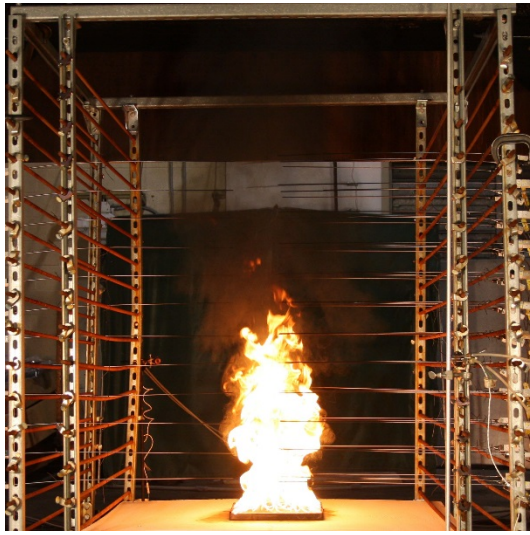
Video Frame Analysis

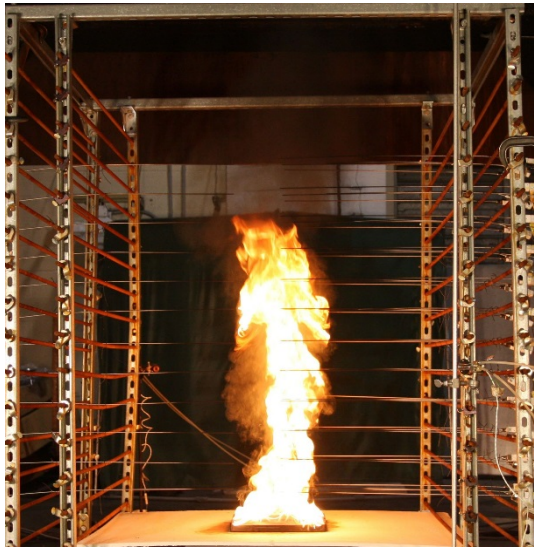
Video Frame Analysis



Flame Heights

Fuel	Mean H_f (m)	Range H_f (m)
Natural Gas	0.71	0.40 to 0.98
Gasoline	0.83	0.52 to 1.1
Polyurethane Foam	0.47	0.30 to 0.78

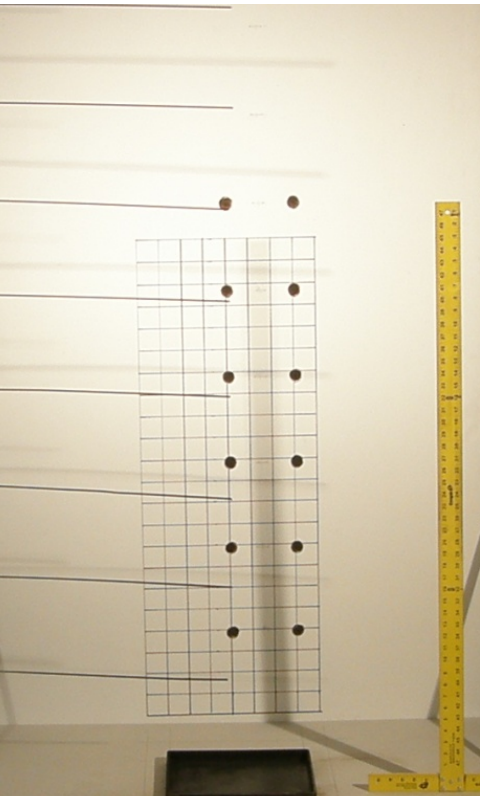




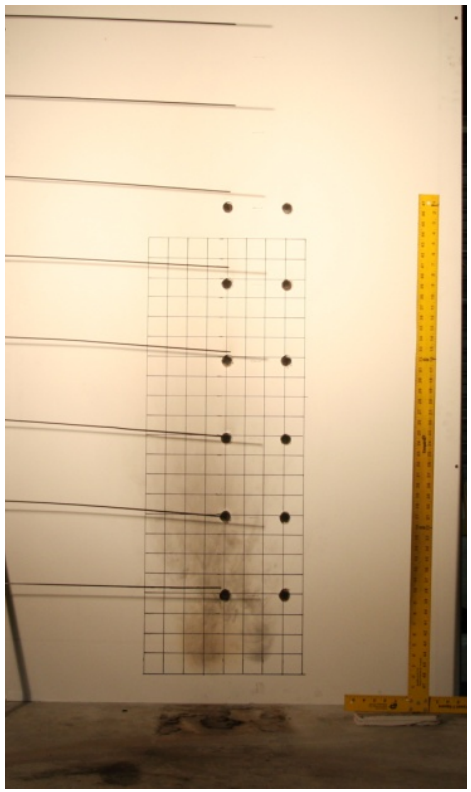
Instrumented Gypsum Board Wall

- Instrumented in a similar manner to the calibration wall.
- Limitations – intrusive measurements, water cooled heat flux gauges, thermocouples.
- Extremely labor intensive

Fire Pattern from Gasoline Fire at Different Distances from Wall



0.305 m from wall



0.152 m from wall

0.076 m from wall

0.00 m from wall

Fire Pattern Experimental Arrangement

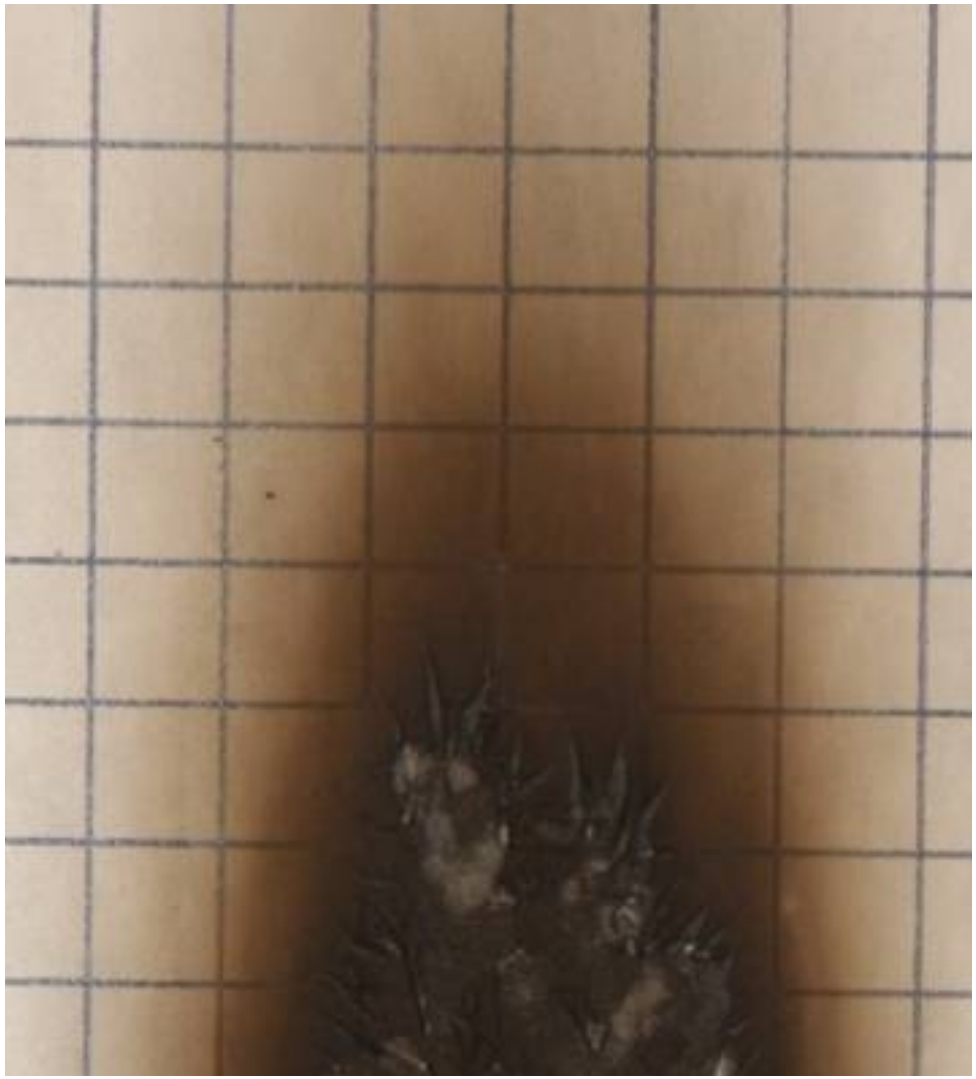
Line of Demarcation Definition

Fire effects that form patterns from DeHaan

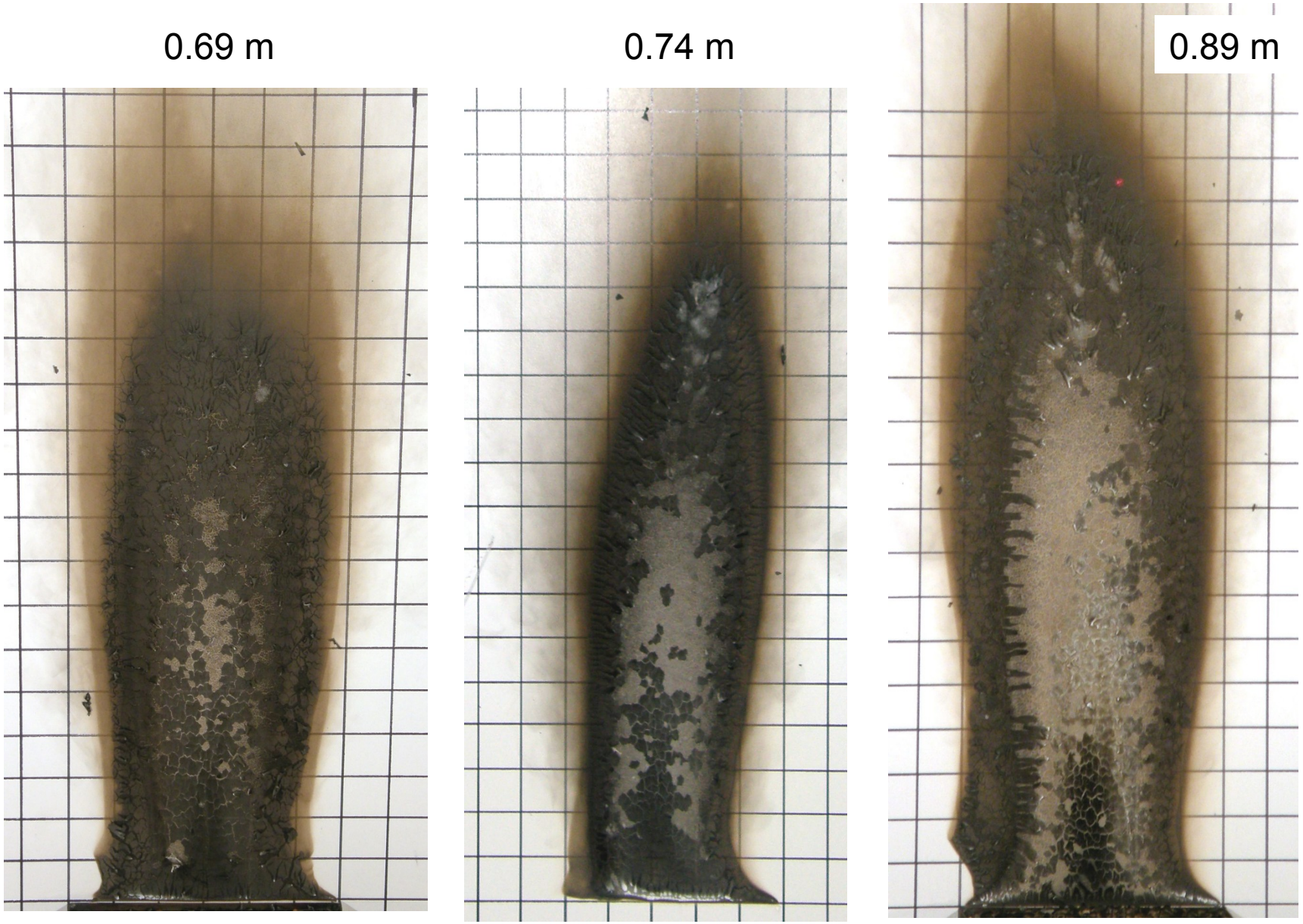
- Surface deposits
- Surface thermal effects
- Charring
- Penetration
- Consumption

DeHaan, John D., Kirk's Fire Investigation, Sixth Edition, Pearson Prentice Hall, Upper Saddle River, NJ., 2007.

Penetration and Consumption of Paint and Paper

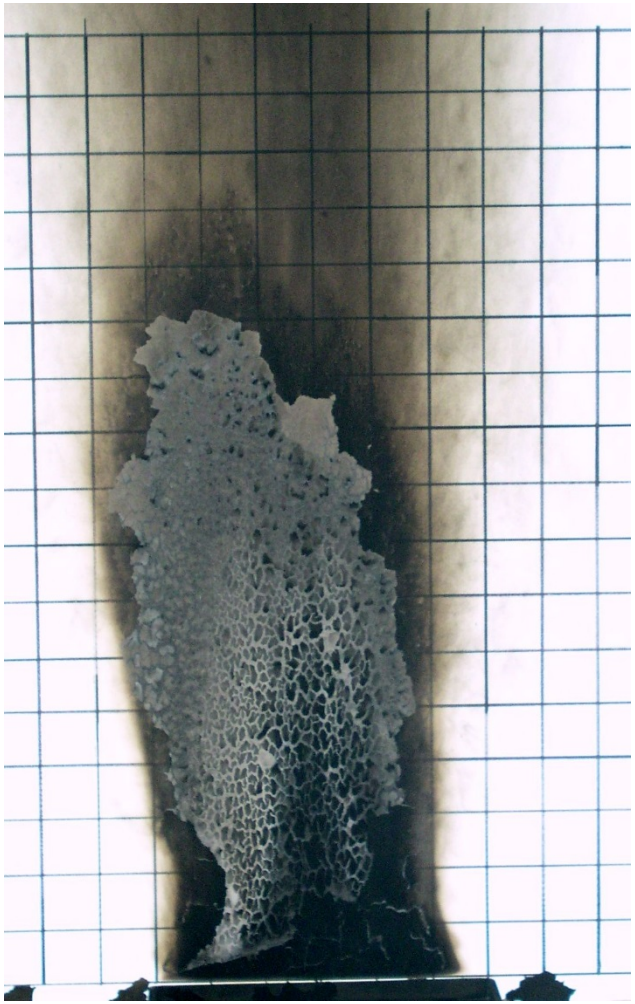


Patterns from Natural Gas Fire

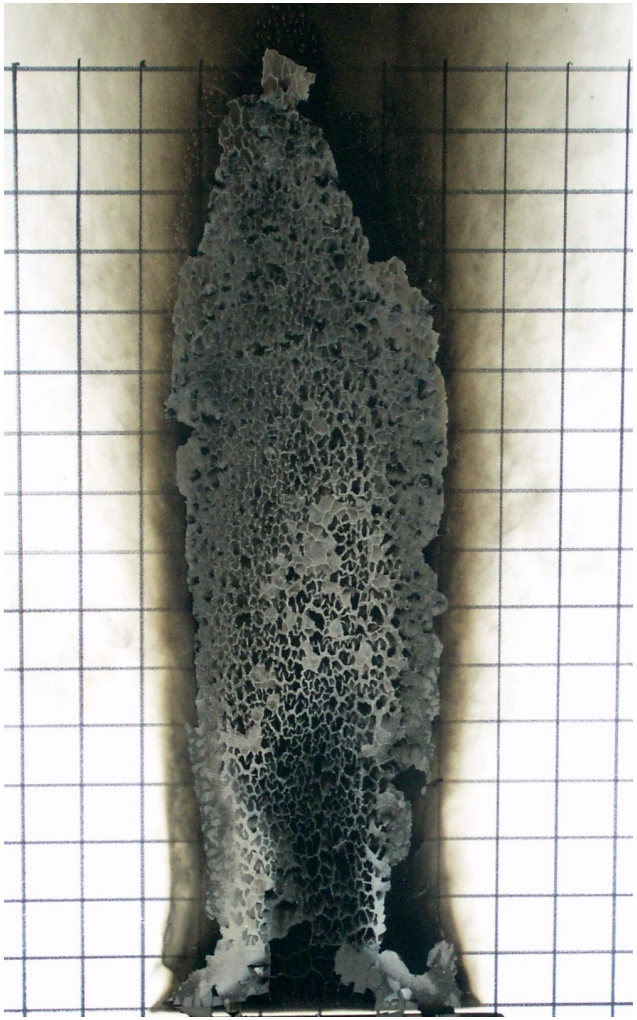


Patterns from Gasoline Fires

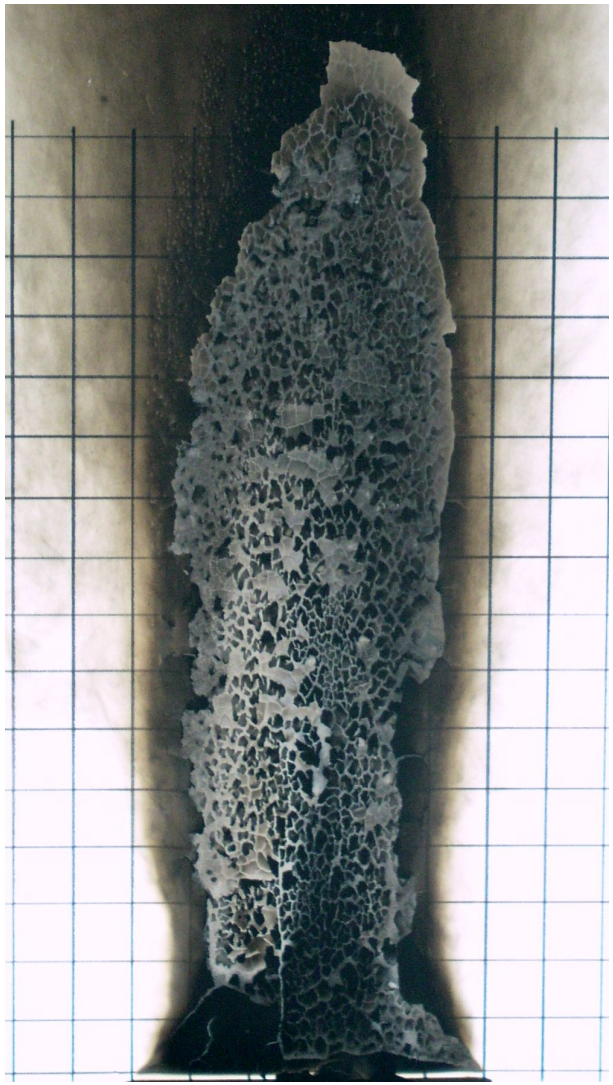
0.61 m



0.83 m

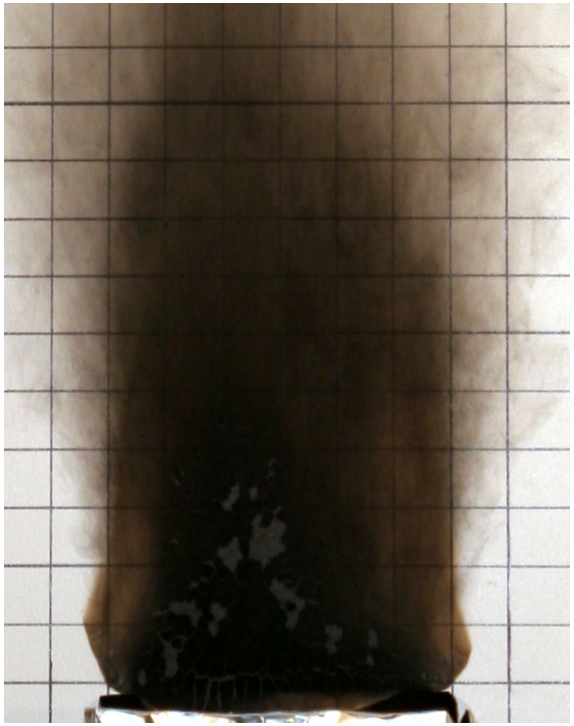


0.89 m

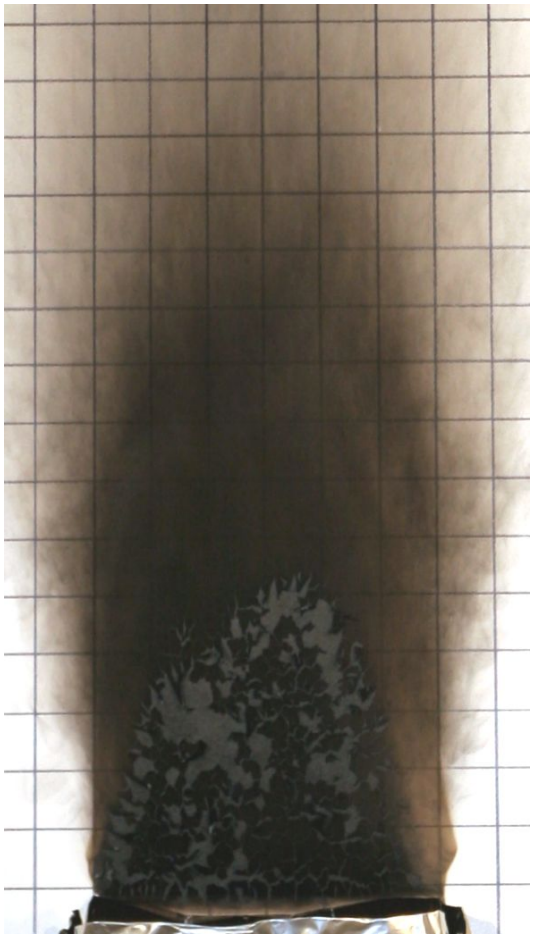


Patterns from PUF Fires

0.20 m

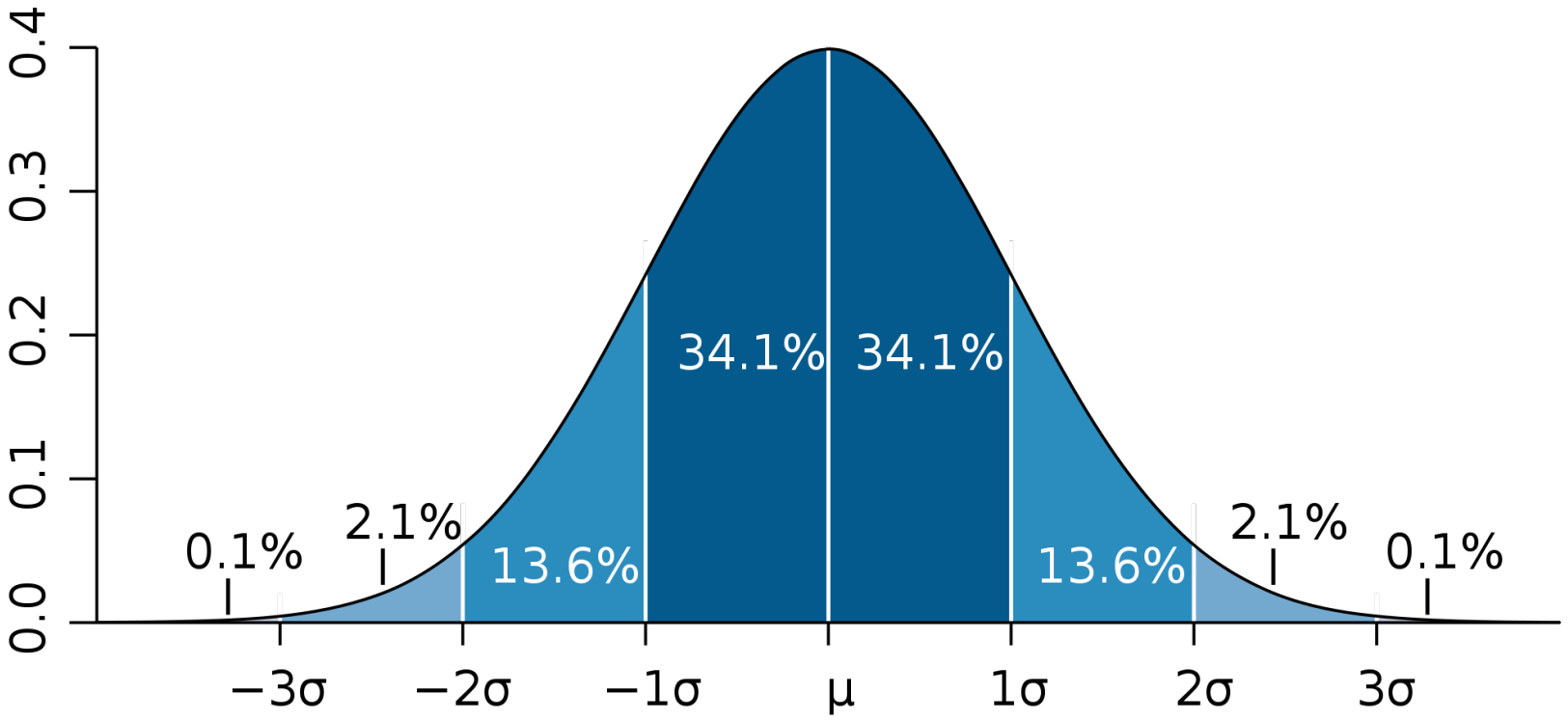


0.25 m



0.30 m

Normal Distribution
Standard Deviation Diagram



based on original graph by Jeremy Kemp

Fuel Comparison Fire Pattern Dimensions

Values presented with 95% confidence limits

Fuel (number of experiments)	**Height (m)**	**Width (m)**	**Height @ Max Width (m)**	**Area (m^2)**
Natural Gas (10)	0.74 ± 16%	0.24 ± 25%	0.41 ± 17%	0.15 ± 33%
Gasoline (12)	0.83 ± 18%	0.28 ± 32%	0.44 ± 41%	0.17 ± 25%
Polyurethane Foam (10)	0.24 ± 50%	0.28 ± 29%	0.04 ± 60%	0.05 ± 57%

Impact of Construction on Pattern

- Examine three types of wall construction
  - 12.7 mm thick gypsum on front of wood frame
  - 12.7 mm thick gypsum on front and rear of wood frame (typical interior wall arrangement)
  - 12.7 mm thick gypsum on front and rear of wood frame with “R-13” fiberglas insulation filling the wood frame void space (representing an exterior wall arrangement)
- Examine resulting patterns for changes in height, width, area, and shape.

Fire Pattern Comparison by Wall Type

OPEN

CLOSED

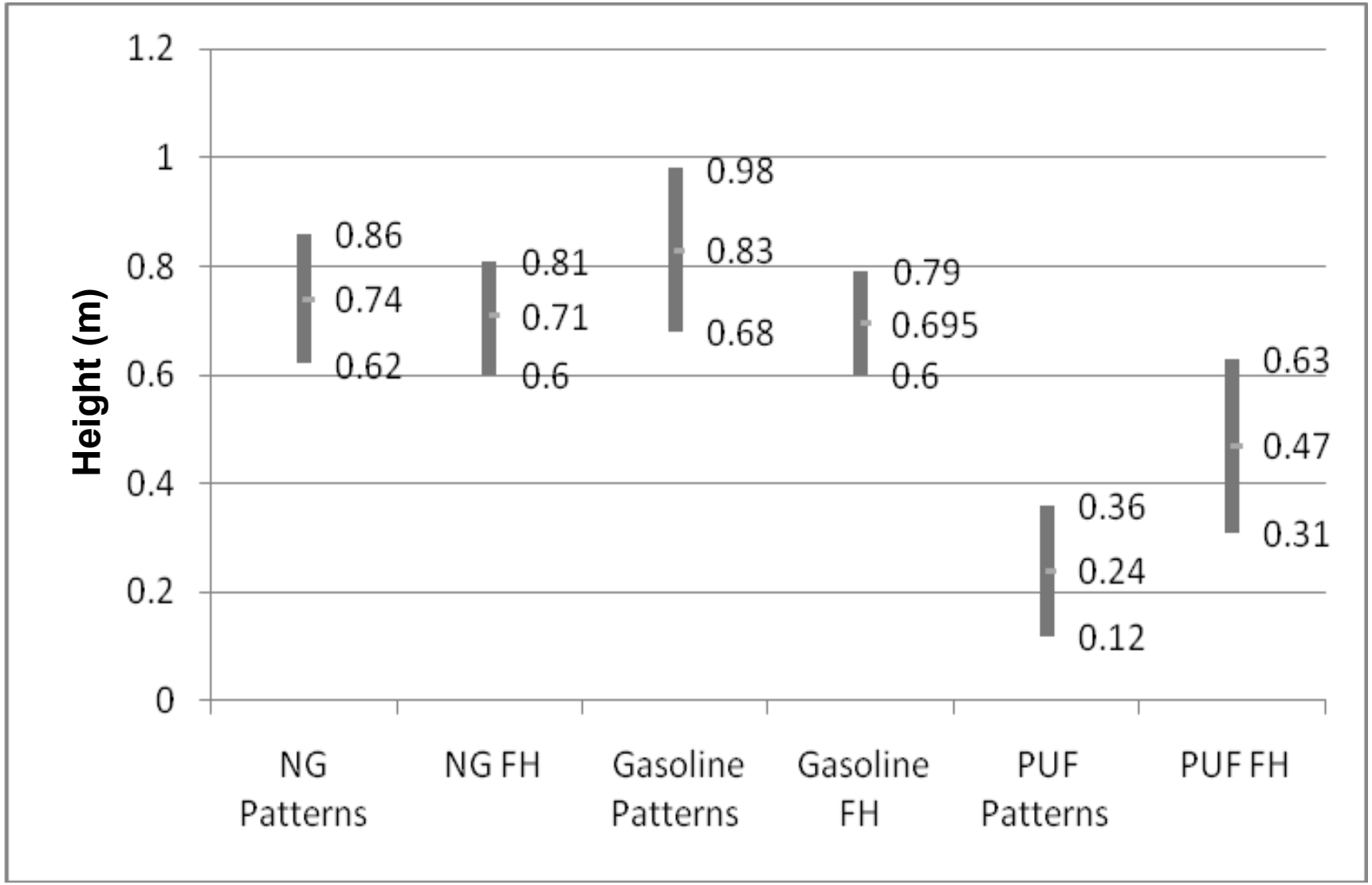
INSULATED

Comparison of Fire Pattern as a Function of Wall Construction Type.

Values presented with 95% confidence limits.

Fuel (# of Tests)	Wall Type	Max Height (m)	Max Width (m)	Height @Max Width (m)	Area (m^2)
Nat. Gas (10)	Open	0.74 ± 16%	0.24 ± 25%	0.41 ± 17%	0.15 ± 33%
Nat. Gas (10)	Closed	0.74 ± 8%	0.24 ± 7%	0.43 ± 7%	0.14 ± 6 %
Nat. Gas (10)	Insulated	0.71 ± 14%	0.23 ± 17%	0.42 ± 17%	0.15 ± 14%
Gasoline (12)	Open	0.83 ± 18%	0.28 ± 32%	0.44 ± 32%	0.17 ± 24%
Gasoline (10)	Closed	0.80 ± 13%	0.29 ± 14%	0.44 ± 14%	0.17 ± 24%
Gasoline (10)	Insulated	0.82 ± 11%	0.25 ± 32%	0.40 ± 32%	0.13 ± 30%

Mean Flame Heights vs Fire Pattern Heights

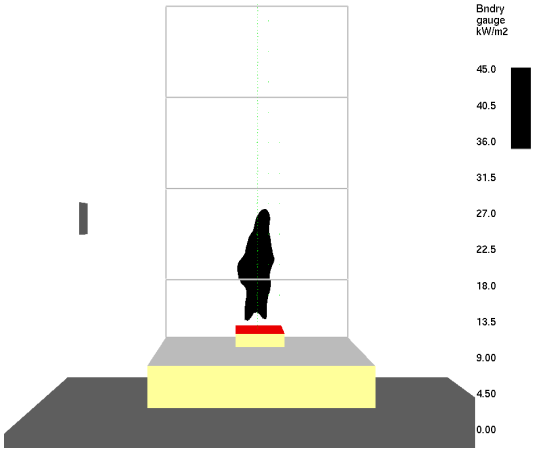


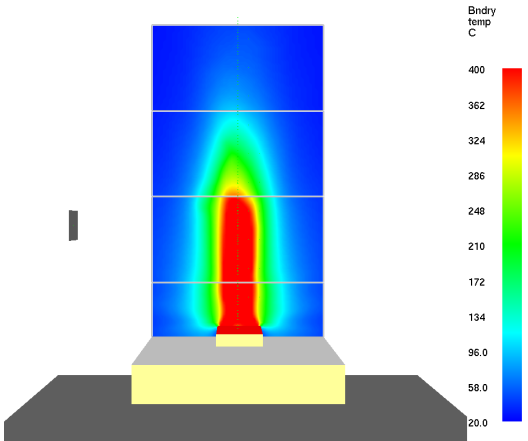
Summary

- Repeatability of HRRs of Natural Gas Fires similar to uncertainty of calorimeter
- HRRs of Gasoline and Polyurethane Foam were not as repeatable.
- Height of the fire patterns from the fires with the higher HRR (Natural Gas and Gasoline) were similar to the median flame height
- Uncertainties of < 18% on fire pattern height for Natural Gas and Gasoline
- Uncertainties of <33% for other pattern dimensions for Natural Gas and Gasoline

Future Comparisons/Validation

- Compare FDS simulation with field measures (photos) from pattern experiments.
- Compare FDS with point measures (temperature and heat flux) from instrumented wall experiments.





Questions ?

madrzy@nist.gov

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