Fire Spread on Walls and Ceiling to Flashover

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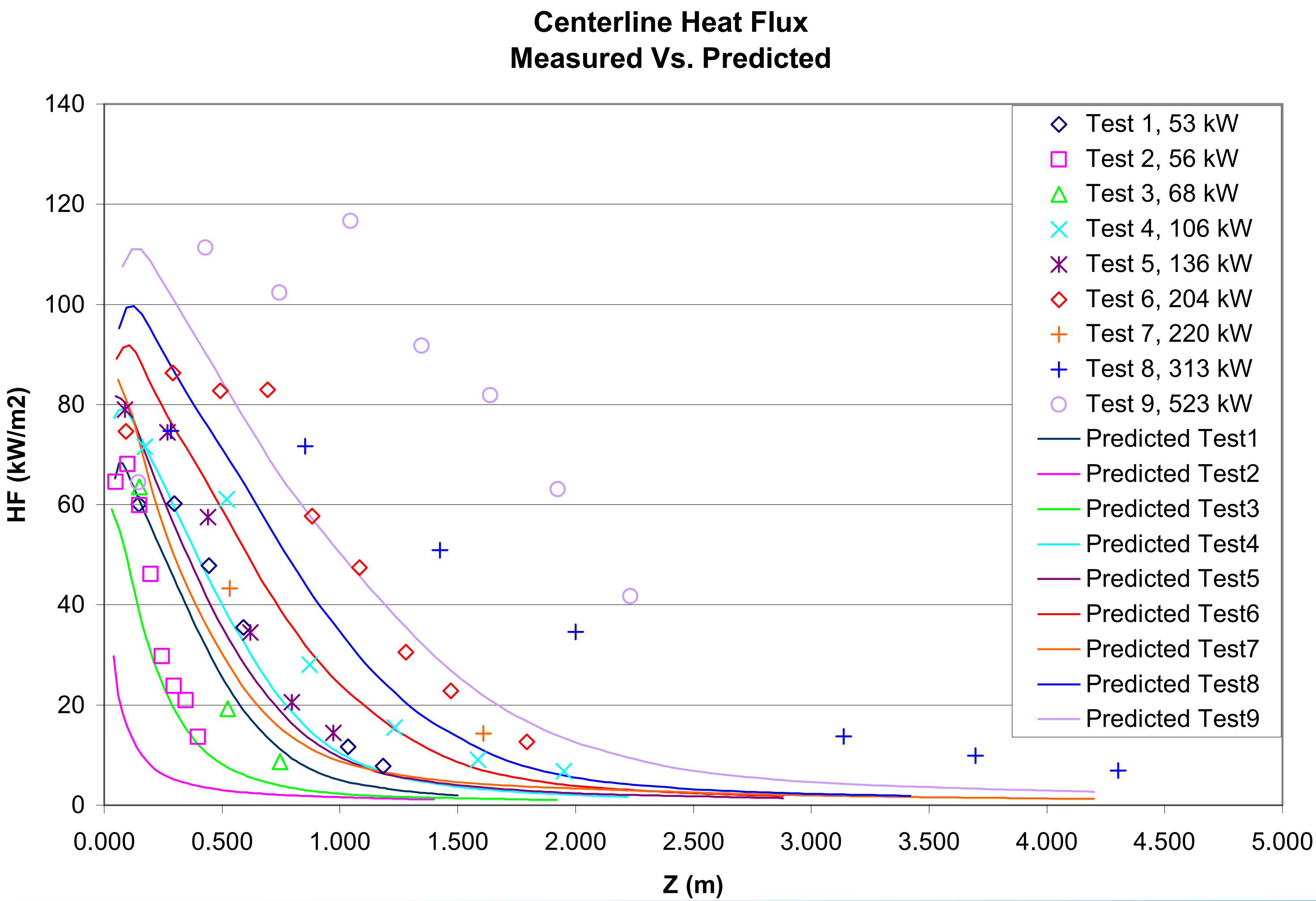
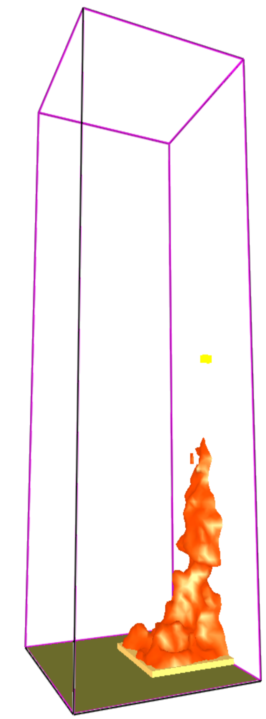
Engineering Model: Combustion

- Flame heat flux
- Flame extension
  - from measurements or correlations
- Difficulties with prediction
  - various modes of spread
  - reaction region, radiation, turbulence

FDS & DATA of Back et al



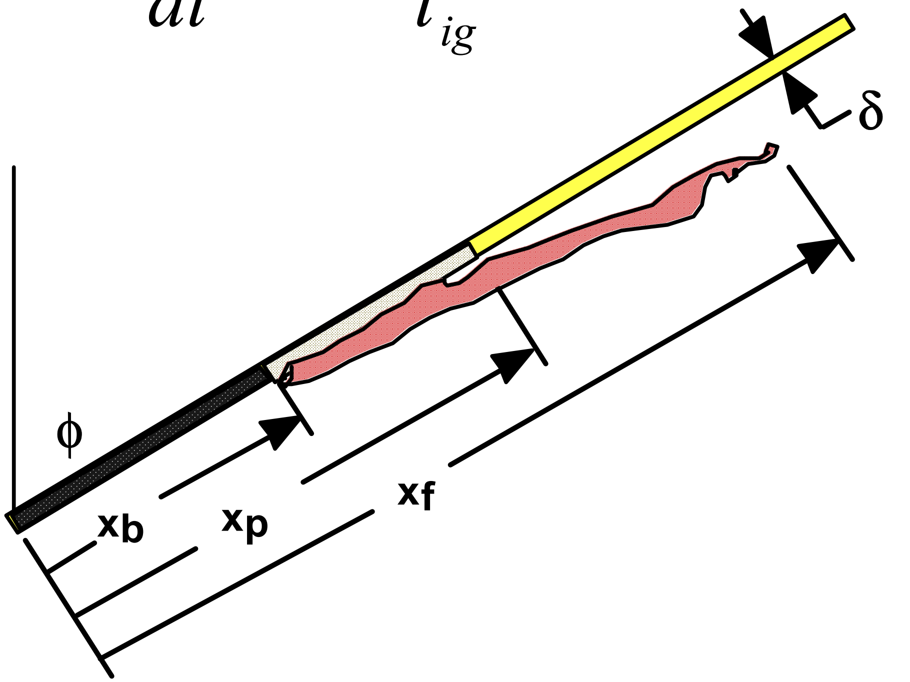


Engineering Model: Material

- Properties from tests and analysis
- Consistent with model
- Measurable and consistent
- Time-averaged

Spread Model

$$v_p = \frac{dx_p}{dt} = \frac{x_f - x_p}{t_{ig}}$$

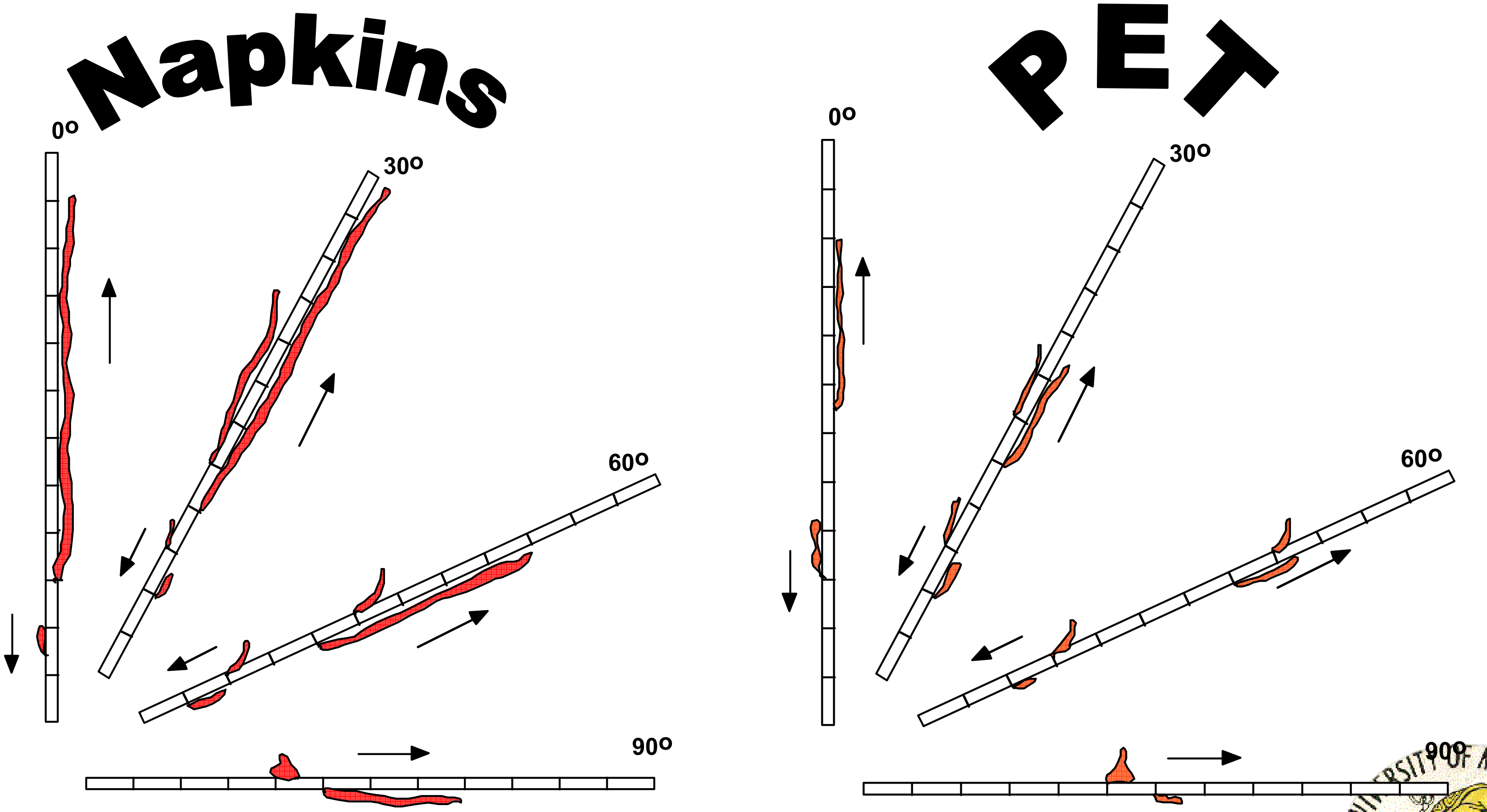


Ignition Theory

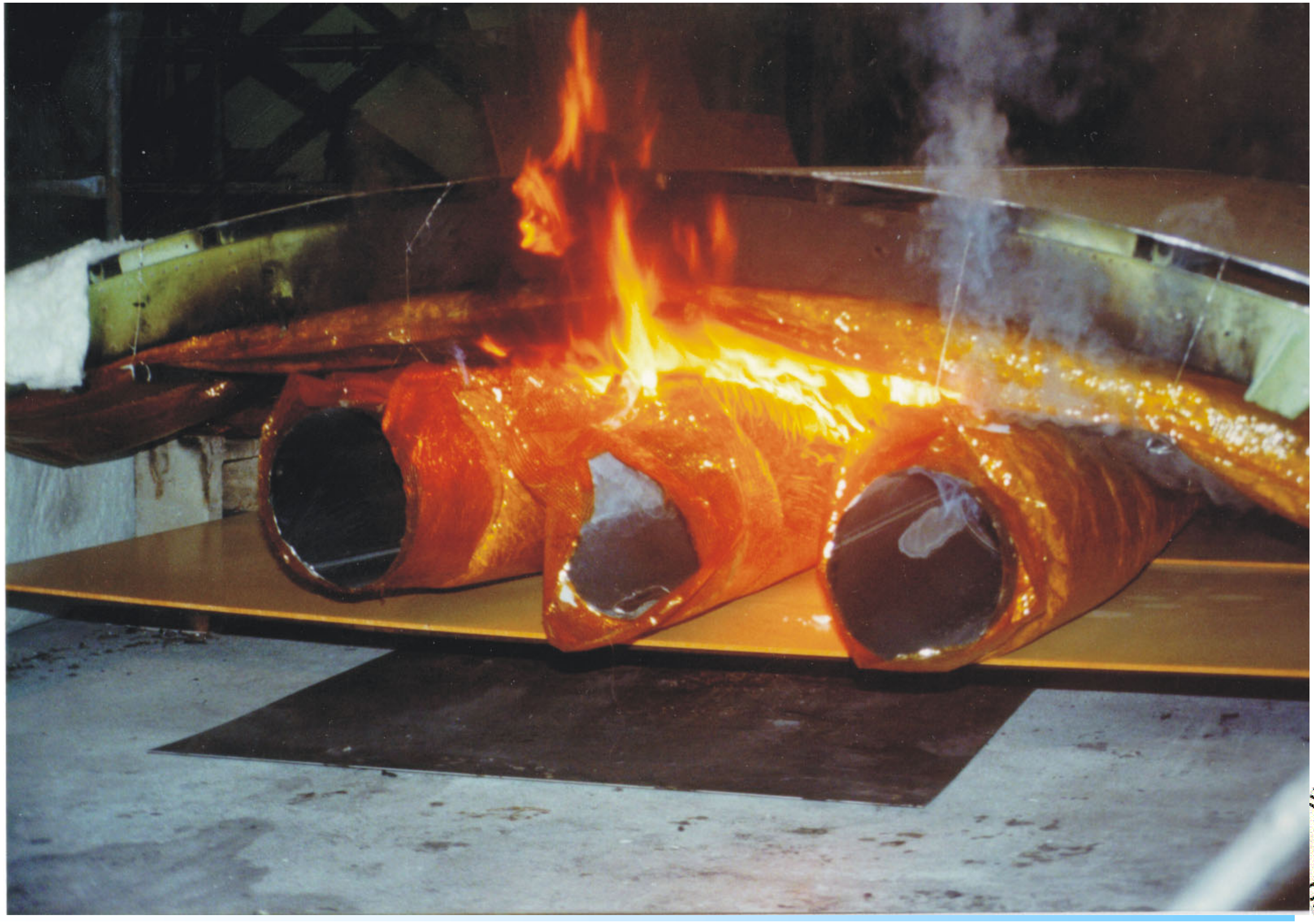
$$\text{Thin}: t_{ig} = \rho c d (T_{ig} - T_o) / \dot{q}''$$

$$\text{Thick}: t_{ig} = (\pi / 4) k \rho c \left[(T_{ig} - T_o) / \dot{q}'' \right]^2$$

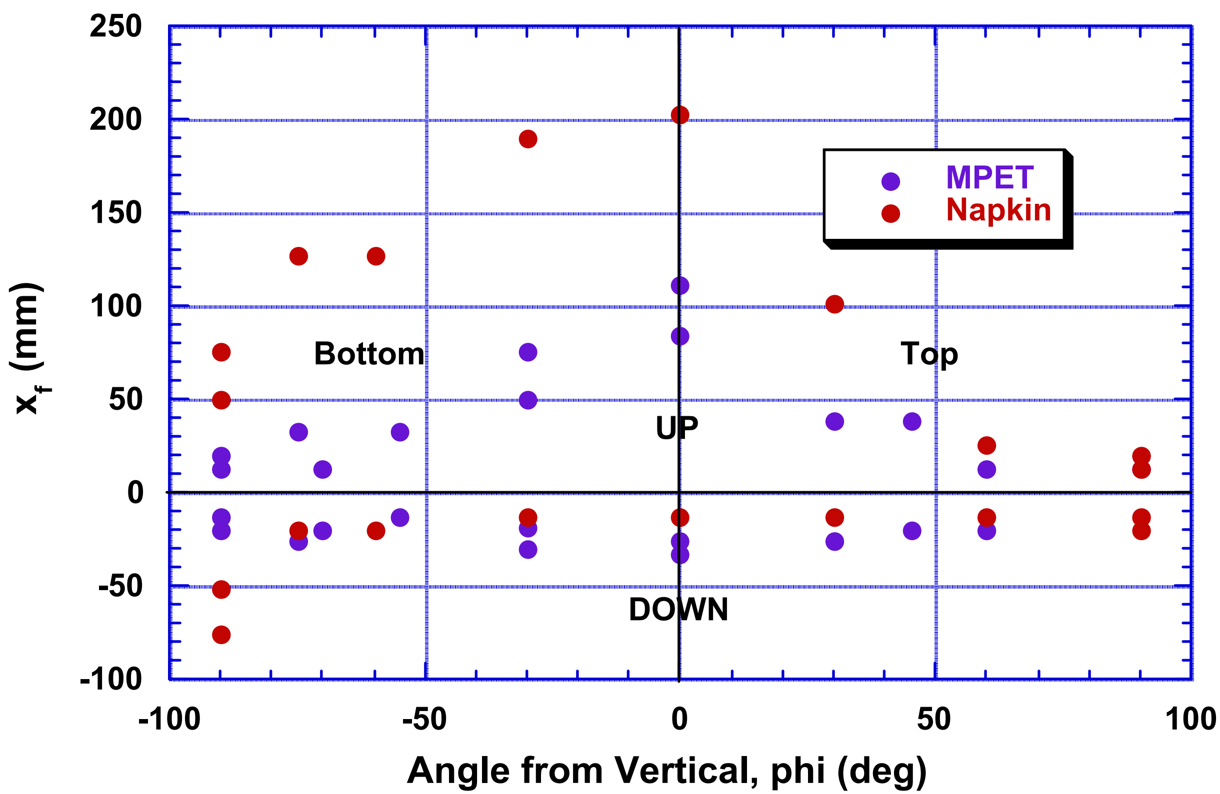
Example for a Thin Material



Aircraft Acoustic Insulation

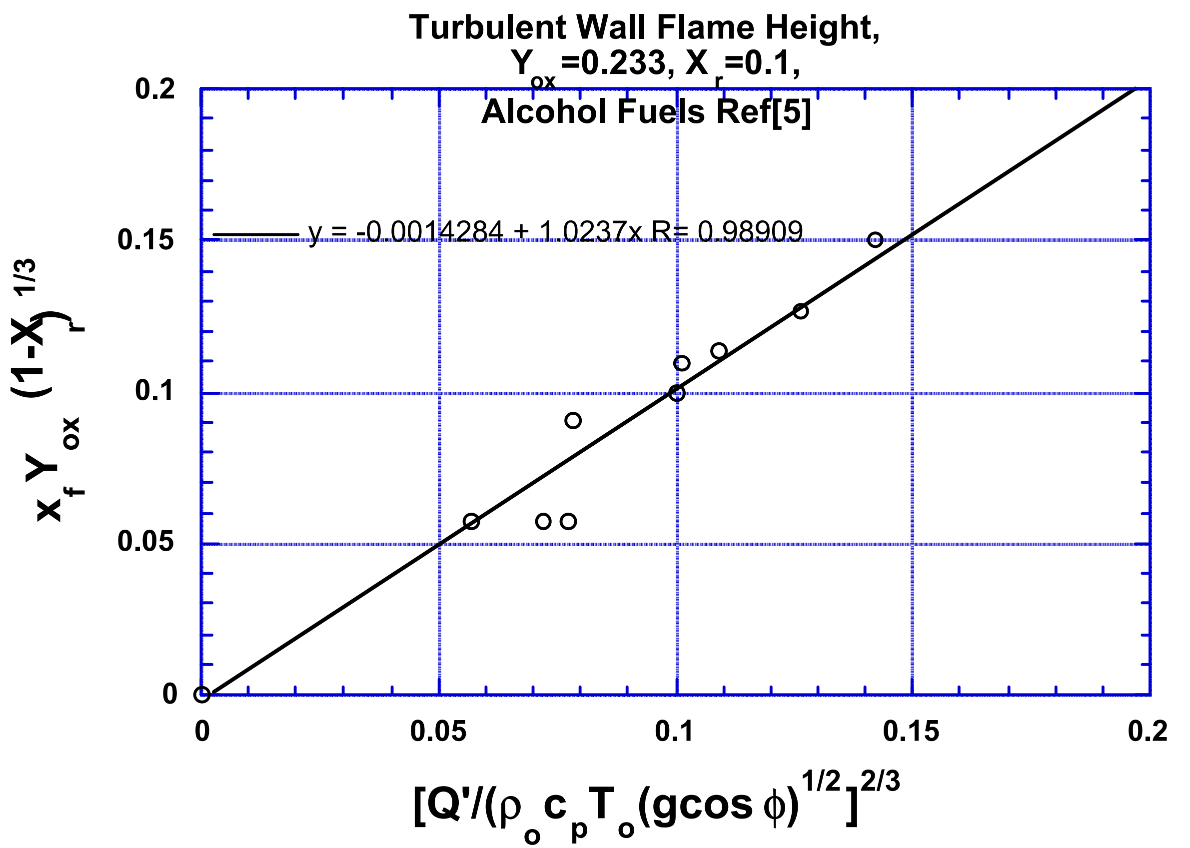


Measured Flame Lengths used to compute gravity-assisted spread

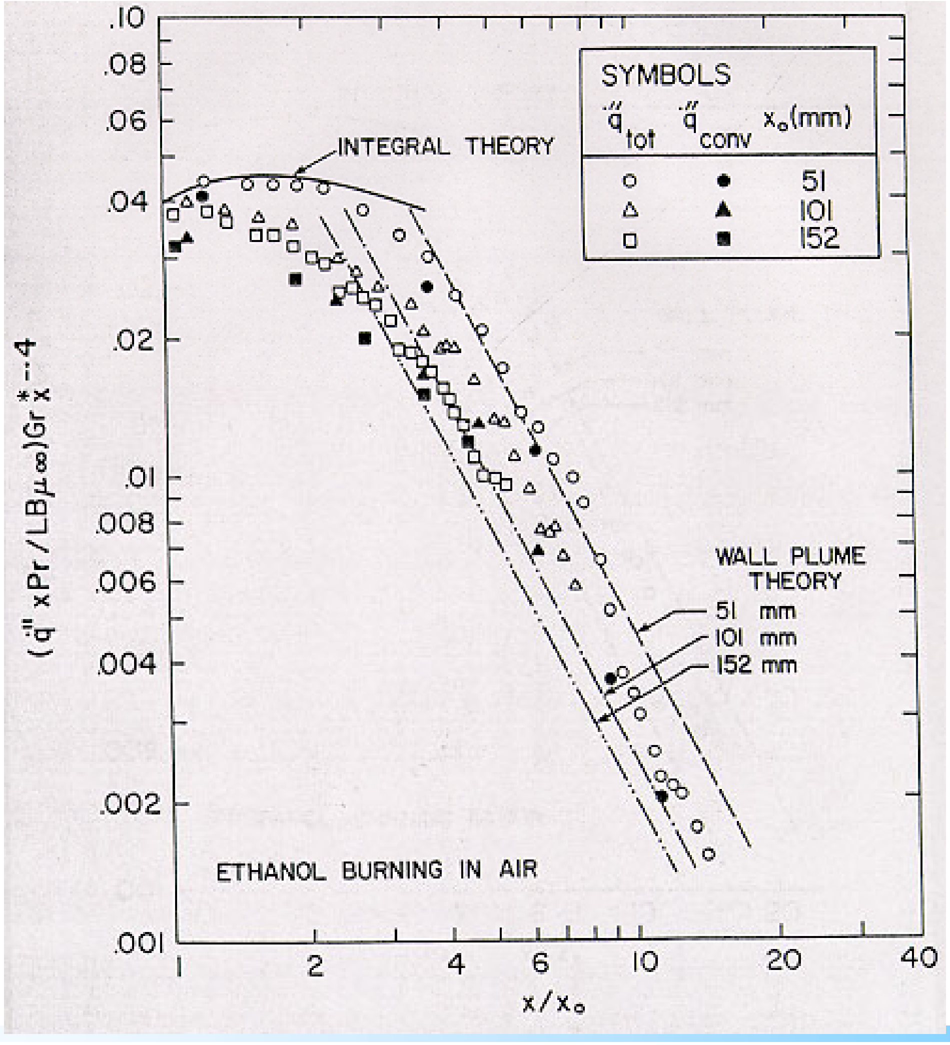


Flame Length Correlation (Ahmad & Faeth)

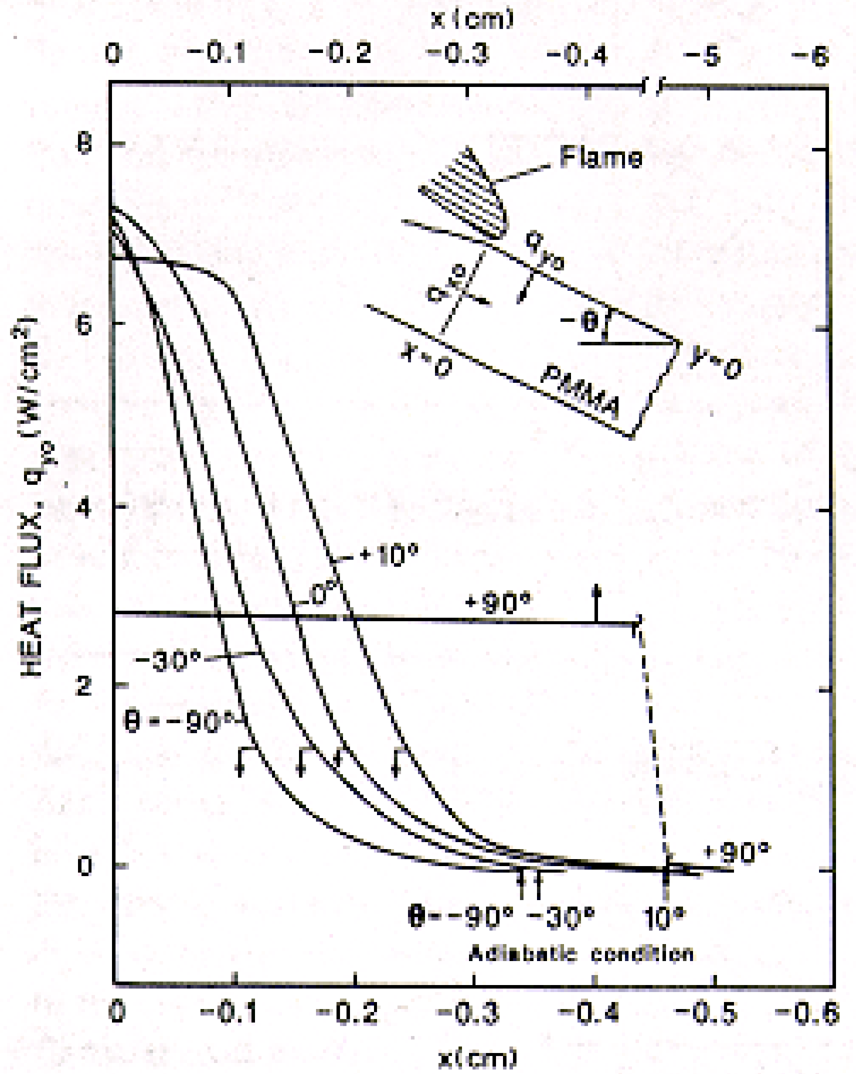
Gravity Assisted Spread



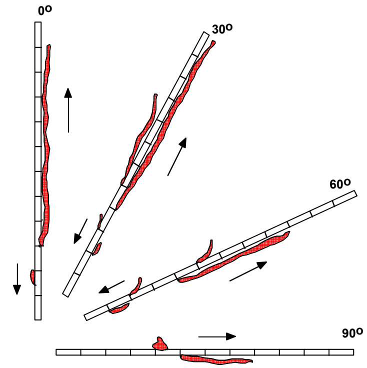
Heat Flux: Ahmad & Faeth



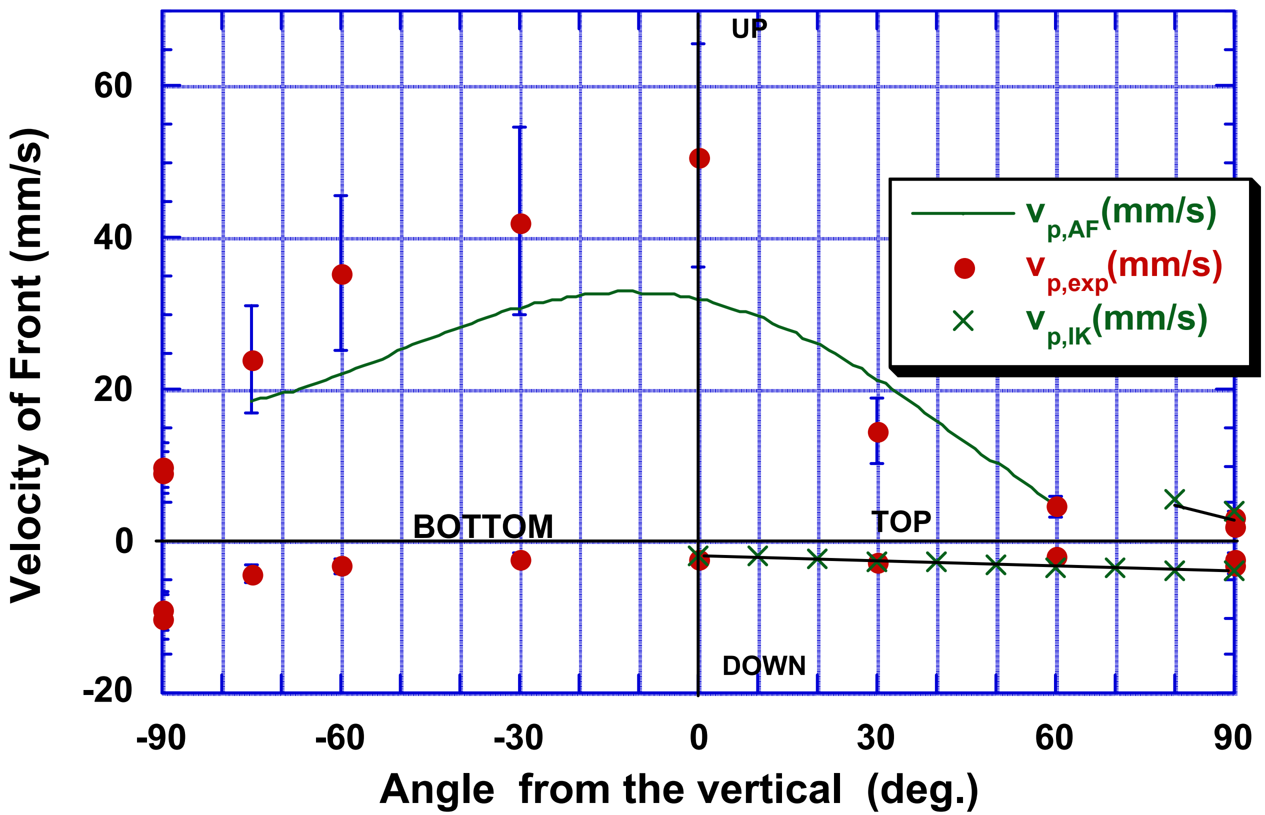
Opposed flow spread: (Ito & Kashiwagi, PMMA)



Prediction



Calculated Flame Speed compared to Napkin Data



Electrical Cable Arrays: Borealis

Application: Room Corner Test ISO 9705

Gravity-assisted spread dominates

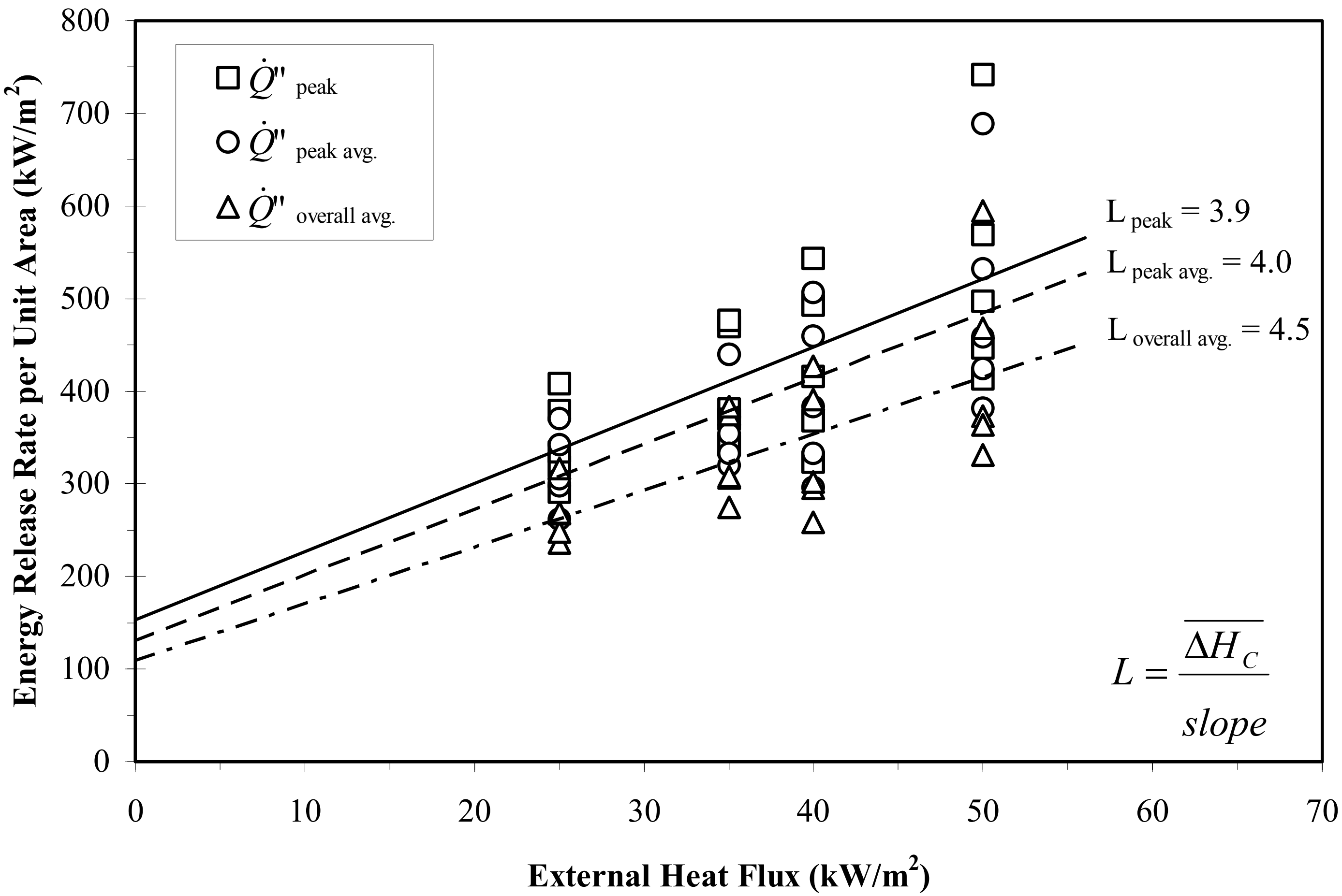
Simple flame length model:

$$x_f - x_b = k_f \dot{Q}''(x_p - x_b), \qquad k_f \approx 0.01\,\mathrm{m^2/kW}$$

From Cone:

$$\dot{Q}'' = \dot{q}''_{net} \frac{\overline{\Delta H_C}}{L} \qquad \Delta H_C(t) = \frac{\dot{Q}''(t)}{\dot{m}''(t)}$$

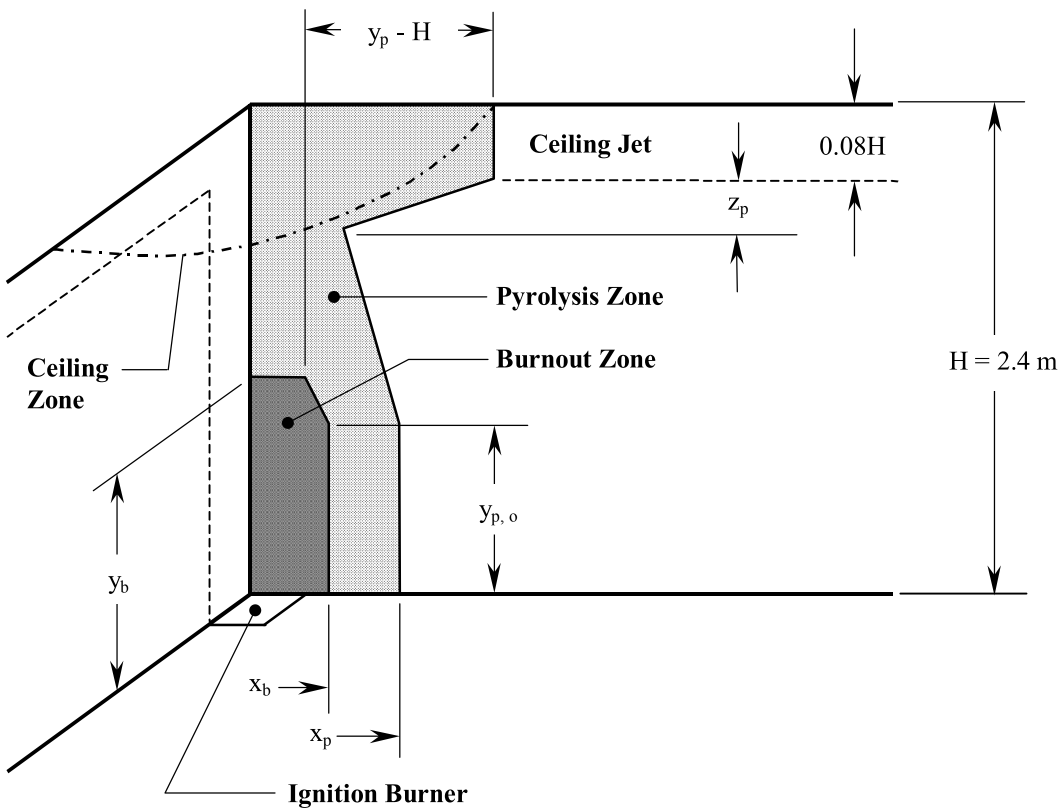
Heat of Gasification: art of measure



Material Properties

	Material Property	Symbol	Test Method
1.	Ignition Temperature	T_{ig}	Cone or LIFT
2.	Thermal Inertia	$k\rho c$	Cone or LIFT
3.	Minimum Surface Temperature for Lateral Flame Spread	$T_{s,min}$	LIFT
4.	Lateral Flame Spread Parameter	Φ	LIFT
5.	Effective Heat of Combustion	ΔH_C	Cone
6.	Effective Heat of Gasification	L	Cone
7.	Total Energy per Unit Area	$\dot{Q}''$	Cone

Room spread concept



Fire Growth

Spread

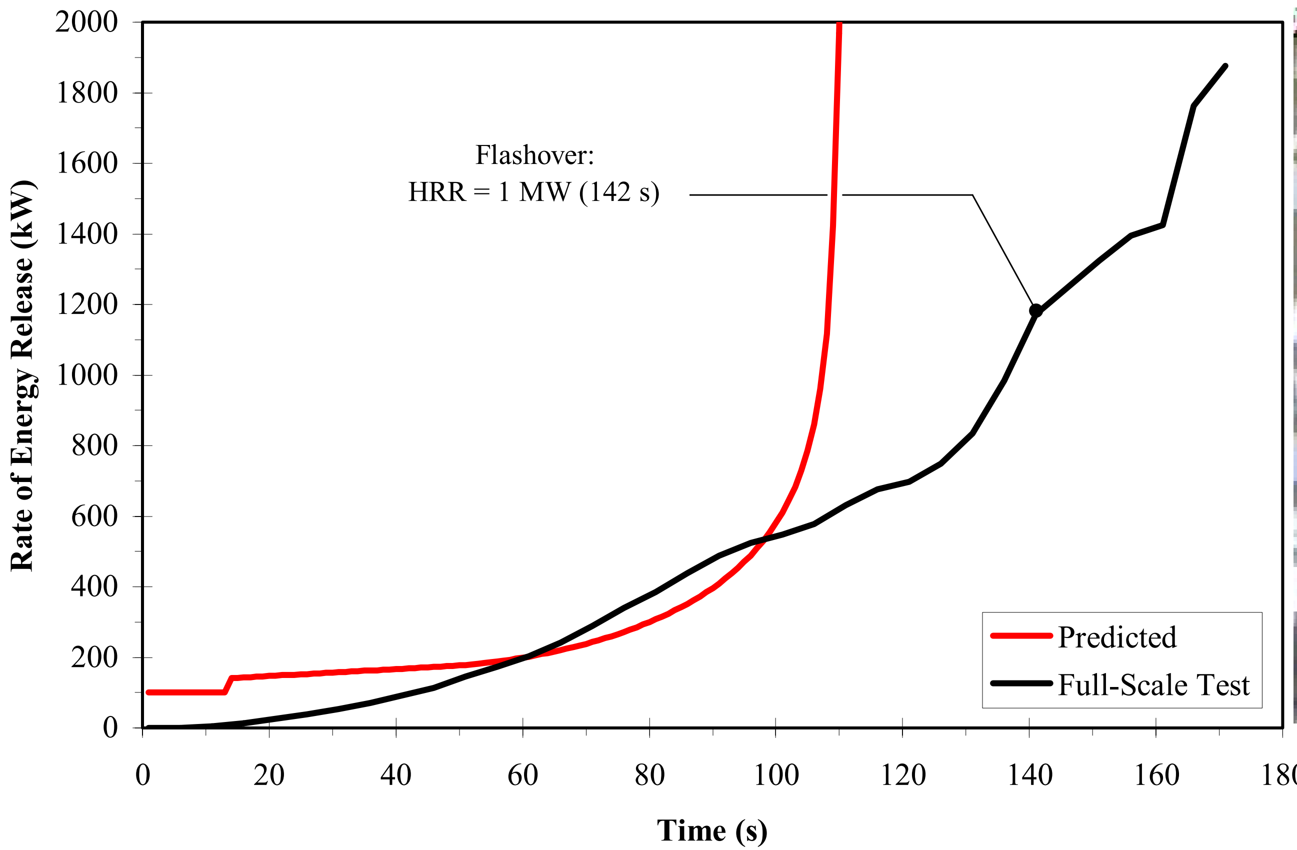
$$v = \frac{dx_p}{dt} = \frac{x_f - x_p}{t_{ig}}.$$

Burn-out

$$\frac{dx_b}{dt} = \frac{x_p - x_b}{t_b}$$

$$t_b = Q'' / \dot{Q}''.$$

Example of Prediction



Approximate Solution

$$\frac{\quad}{\quad} = \left(\frac{1}{a}\right)\left[(1 + a)\exp\left[a\left(\frac{t}{t_{ig}} - 1\right) - 1\right]\right]$$

where

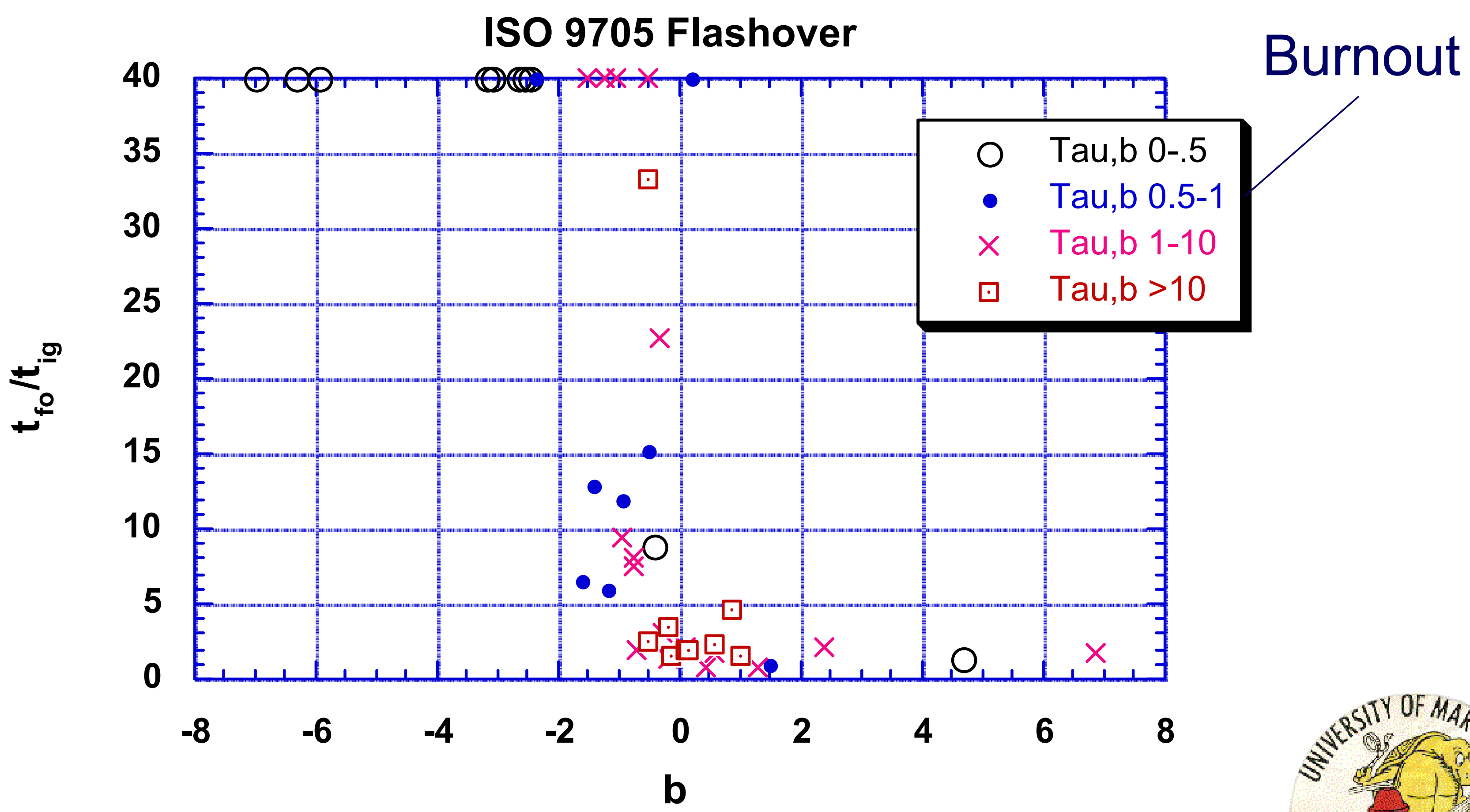
$$a = k_f \dot{Q}'' - 1$$

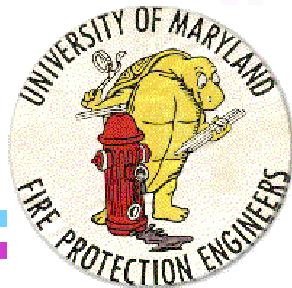
$$b = a - t_{ig} / t_b$$

After burnout:

$$\frac{x_p - x_b}{x_{f,ig}} = \left(\frac{1 + a}{a}\right)\left[(1 + a)\exp\left[a\left(\frac{t_b}{t_{ig}} - 1\right)\right]\right]\exp\left[b\left(\frac{t}{t_{ig}} - 1 - \frac{t_b}{t_{ig}}\right)\right]$$

Flashover time vs b (Energy factor)





Critical Flame Heat Flux for increasing spread rate and Flashover

$$\dot{q}''_{f,critical} = \sigma T_{ig}^4 + \left(\frac{L}{\Delta H_c}\right)\left(50 + 100\left(\frac{t_{ig}}{t_b}\right)\right), \text{kW/m}^2.$$

The heat flux from the ignition burner in the room corner test is about 60+/-20 kW/m^2.

CONCLUSIONS

- Flame spread can be computed
- Property data are needed
- Correlations are needed
  - Flame Heat Flux
  - Flame Length
- Igniter heat flux can be crucial