Fire Dynamics
Compartment fire phenomena I

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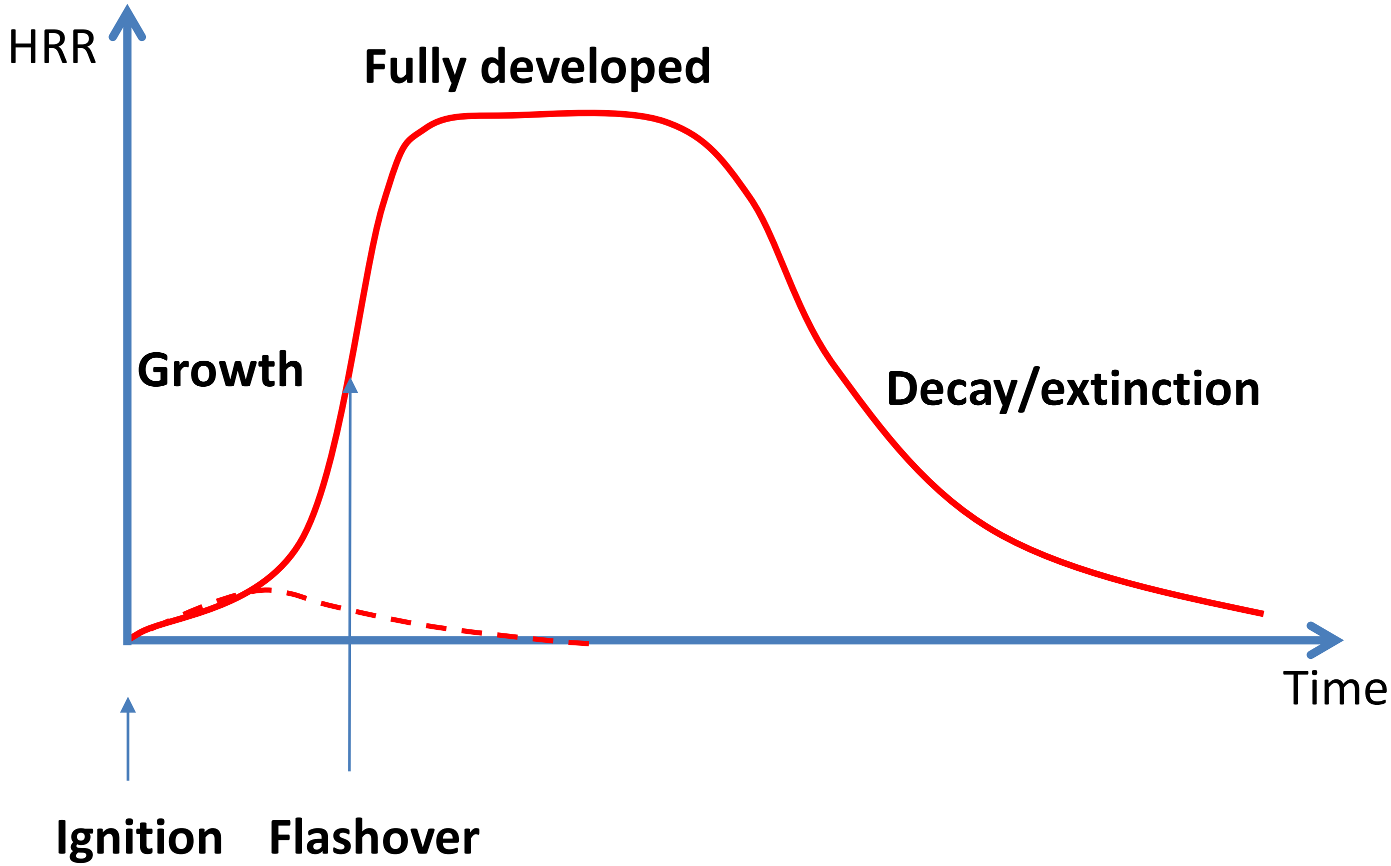
Objectives

- Understanding flashover compartment fire phenomena

Compartment fire HRR curve



Growth period

- Growth rate: t^2 fire or t^3 fire

$$\dot{Q} = \alpha t^2, \ \dot{\mathrm{Q}}[\mathrm{kW}], \ \mathrm{t[s]}$$

where,

$$\alpha = 0.00293 \text{ for slow growth } [\mathrm{kW/s^2}]$$

$$\alpha = 0.01172 \text{ for medium growth } [\mathrm{kW/s^2}]$$

$$\alpha = 0.0469 \text{ for fast growth } [\mathrm{kW/s^2}]$$

$$\alpha = 0.1876 \text{ for ultrafast growth } [\mathrm{kW/s^2}]$$

$$\dot{Q} = 1055\left(\frac{t}{t_1}\right)^2, \ \dot{\mathrm{Q}}[\mathrm{kW}], \ \mathrm{t[s]}$$

where,

$$t_1 = 600\ s \text{ for slow}$$

$$t_1 = 300\ s \text{ for medium}$$

$$t_1 = 150\ s \text{ for fast}$$

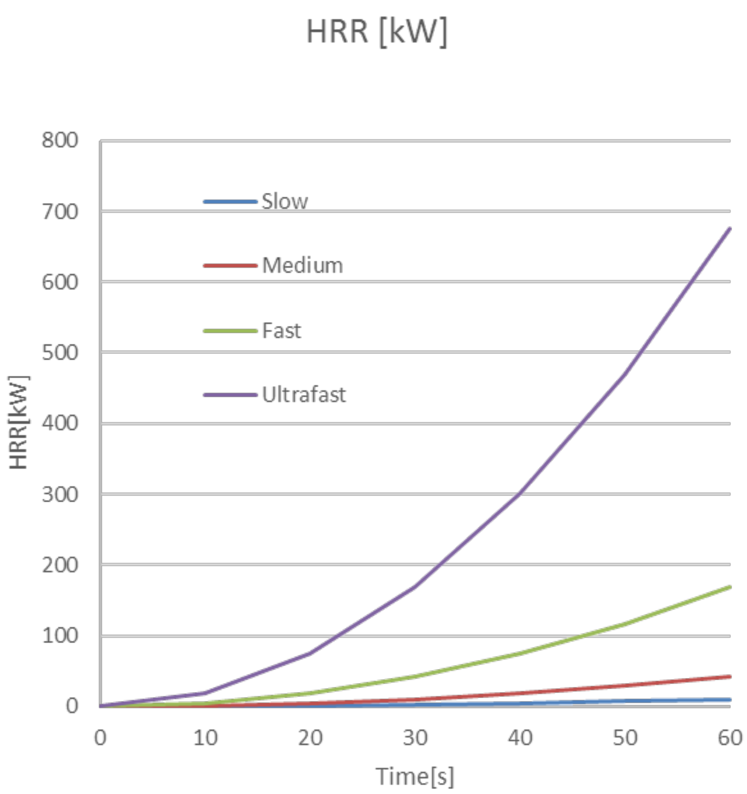
$$t_1 = 75\ s \text{ for ultrafast}$$

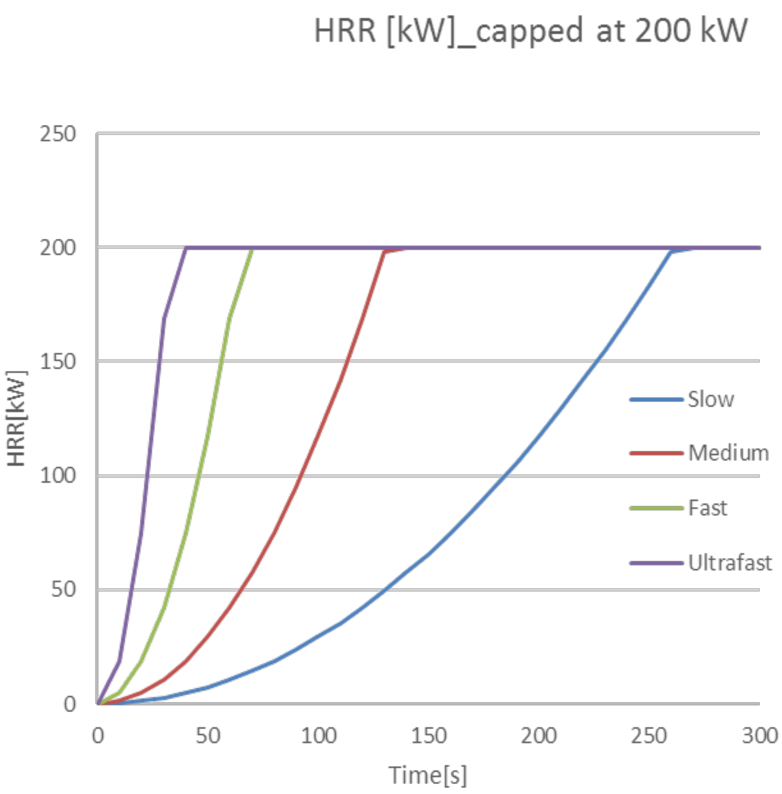
$$\dot{Q} = 0.00068 t^3 H, \ \dot{\mathrm{Q}}[\mathrm{kW}], \ \mathrm{t[s]}$$

where,

$$H = \text{height to which storage is capable of [m]} > 5 \text{ m}$$

HRR of t-squared fire





Flashover phenomena (00:44 sec)

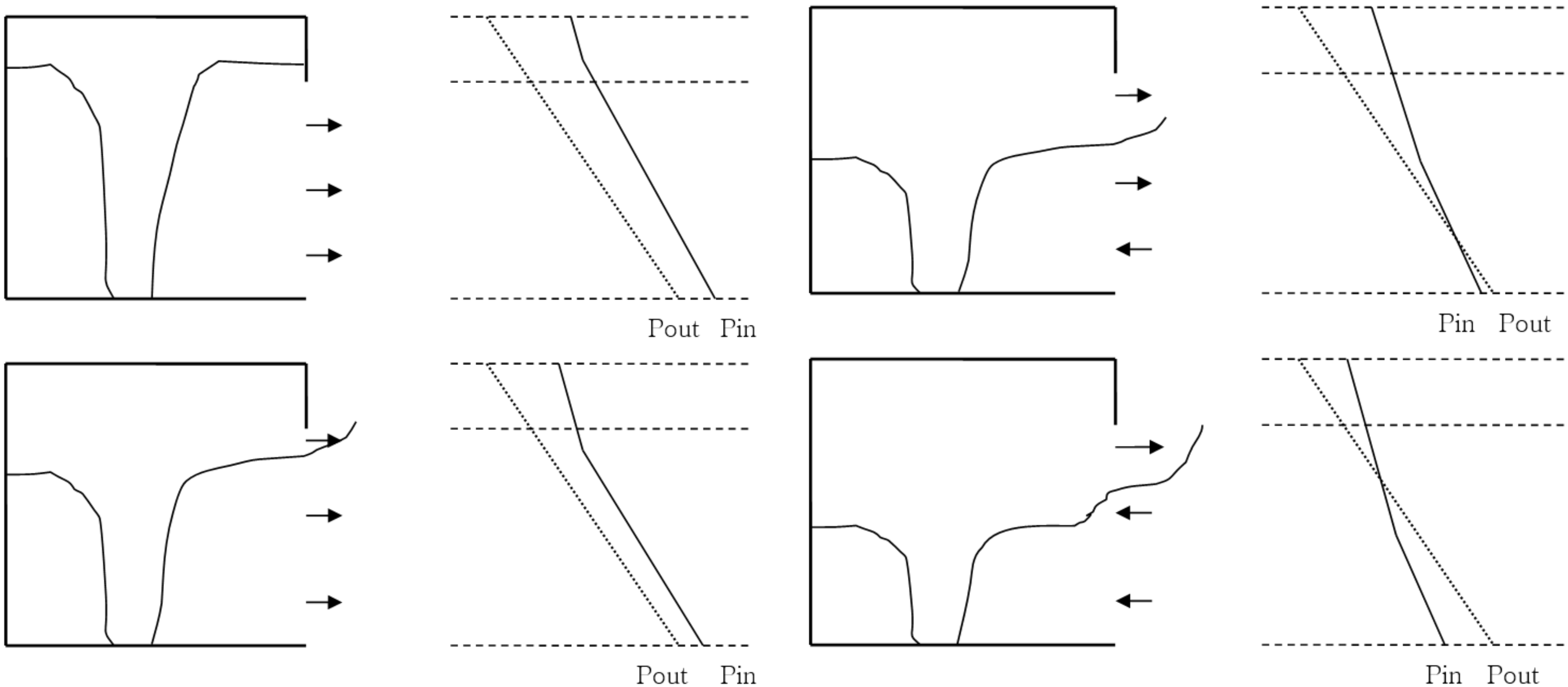
Flashover

- **600 ^{o}C in upper gas layer temperature (about 3 m high ceiling)**
- 450 ^{o}C in upper gas layer temperature (about 1 m high ceiling)
- **~20 kW/m^2 at the floor level**
- **Ignition of crumpled paper at the floor**
- Projected flame out of an opening in the standard ISO room

Fully developed and decay period

- Typically less focused than pre-flashover. Why?
- Important in terms of the performance of structural elements.

Pressure profile in pre-flashover



Pre-flashover compartment Temp.

- MQH correlation

$$\Delta T_g = 6.85\left(\frac{\dot{Q}^2}{A_o\sqrt{H_o}\,h_k A_T}\right)^{1/3}$$

where,

$$\Delta T_g = T_g - T_\infty$$

T_g = temperature of upper gas layer [K]

T_∞ = ambient temperature[K]

$\dot{Q}$ = heat release rate of fire in a compartment [kW]

A_o = opening area [m^2]

H_o = opening height [m]

h_k = effective heat trasnfer coefficient [kW/m-K], heat loss to walls and ceiling

A_T = total area of the compartment surface[m^2]

Pre-flashover compartment Temp.

- MQH correlation

$$\text{For t} > \text{t}_p,\ h_k = \frac{k}{\delta}$$

$$\text{For t} \leq \text{t}_p,\ h_k = \left(\frac{k\rho c}{t}\right)^{1/2}$$

where,

t = time of exposure [s]

t_p = thermal penetration time [s]= $\left(\frac{\rho c}{k}\right)\left(\frac{\delta}{2}\right)^2$

k = thermal conductivity [kW/m-K]

δ = thickness of compartment surface [m]

ρ = density of the compartment surface [kg/m^3]

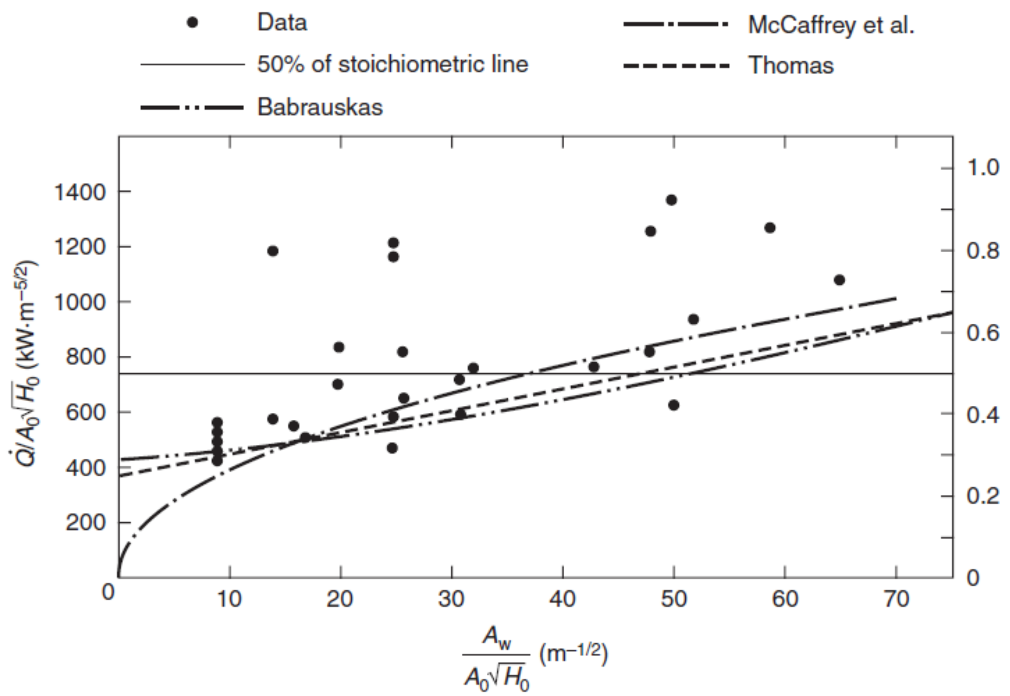
c = specific heat of the compartment surface [kJ/kg-K]

Prediction of flashover

$$\dot{Q}_{flashover} = 750 A_o \sqrt{H_o}, \text{ Babrauskas}$$

$$\dot{Q}_{flashover} = 610 \left(h_k A_T A_o \sqrt{H_o} \right)^{1/2}, \text{ MQH}$$

$$\dot{Q}_{flashover} = 7.8 A_T + 378 A_o \sqrt{H_o}, \text{ Thomas}$$



Example

- At 100 sec and 200 sec, Calculate ΔT_g of a room (3.6 m by 2.4 m by 2.4 m(H)) with and opening 2.1 m high and 0.9 m wide. HRR=750kW. The wall is 0.016 m gypsum boards on metal studs.

Gypsum board properties:

$$k = 0.48 \times 10^{-3} \text{ [kW/m-K]}$$

$$\delta = 0.016 \text{ [m]}$$

$$\rho = 1440 \text{ [kg/m}^3\text{]}$$

$$c = 0.84 \text{ [kJ/kg-K]}$$