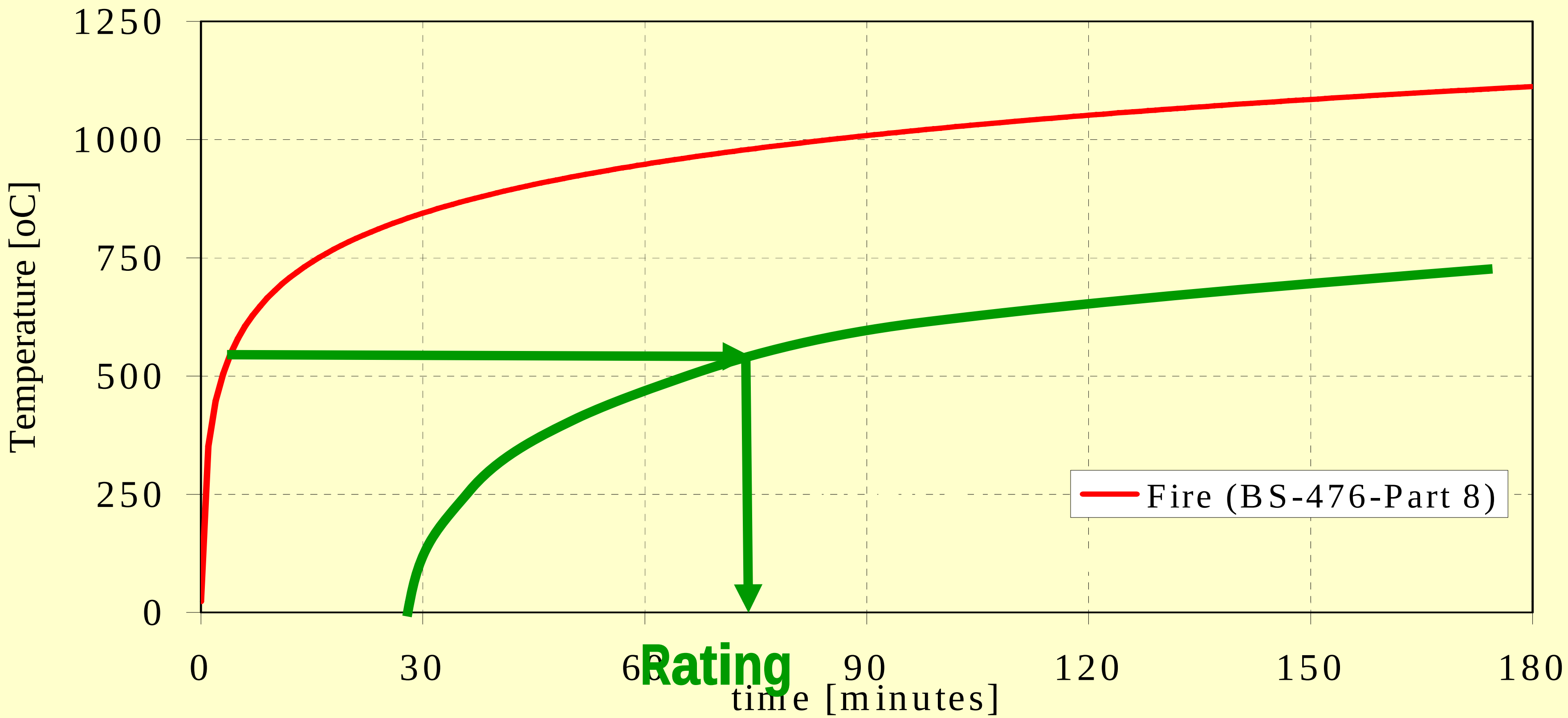
Fire Modelling –
A Structural Engineering Perspective

Dr M Gillie

Standard Fire Test

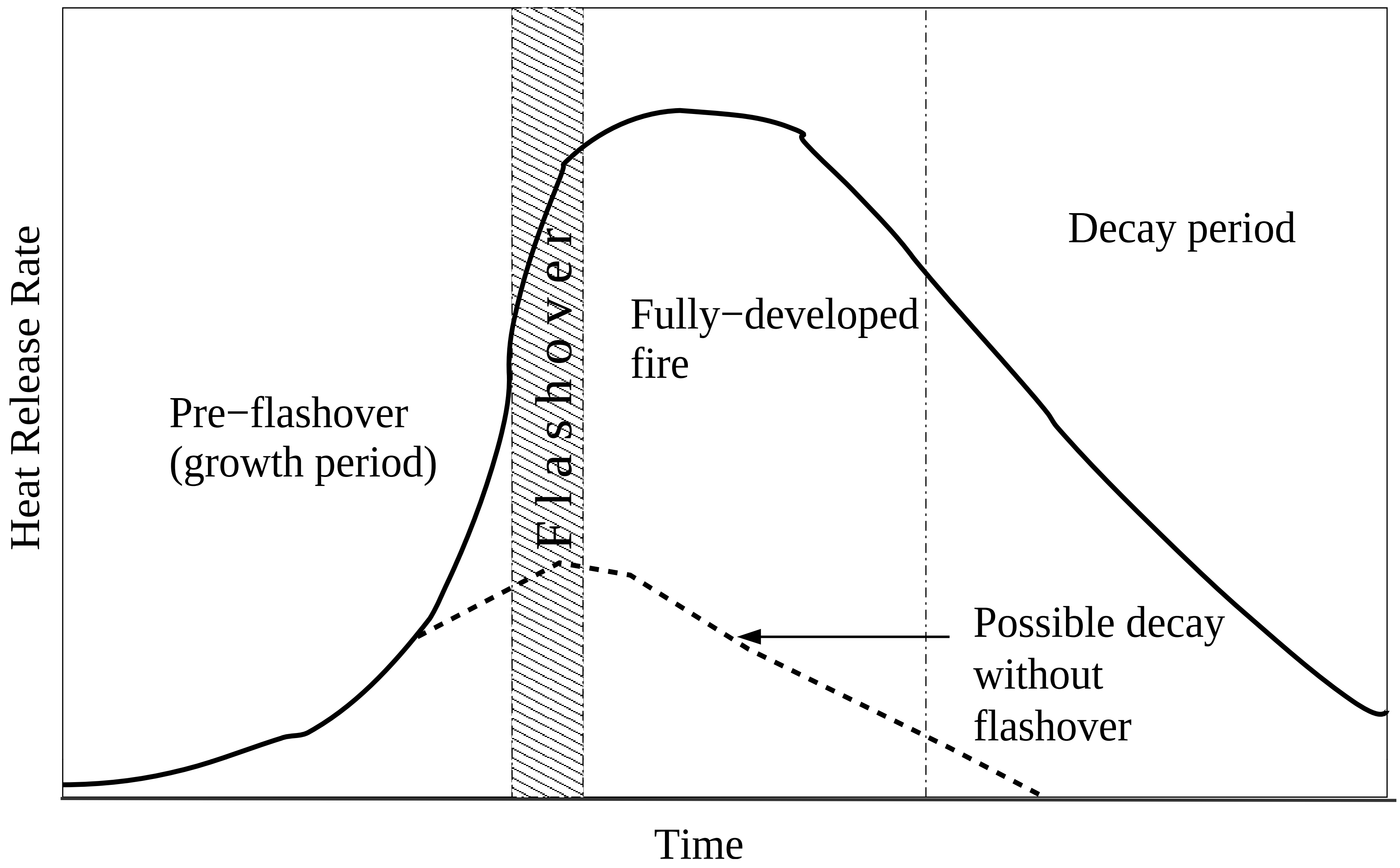
- Defined using a furnace Test (ASTM-E-119, ISO-834, BS-476 Part 8)



Pros and Cons

- Has limitations
  - – Not based on real fire data
  - – Test repeatability difficult
  - – No cooling phase
  - – Uniform heating
  - – Uses gas temperature “not fair”
- But
  - – Widely used
  - – Can be useful for crudely comparing products

Compartment Fires



Assumptions in Swedish method

- No heat built-up in pre-flashover phase of fire
- Temperature uniform in the compartment
- Uniform heat transfer coefficient in compartment boundaries
- All combustion takes place in the compartment

Energy balance for a compartment – Swedish Method

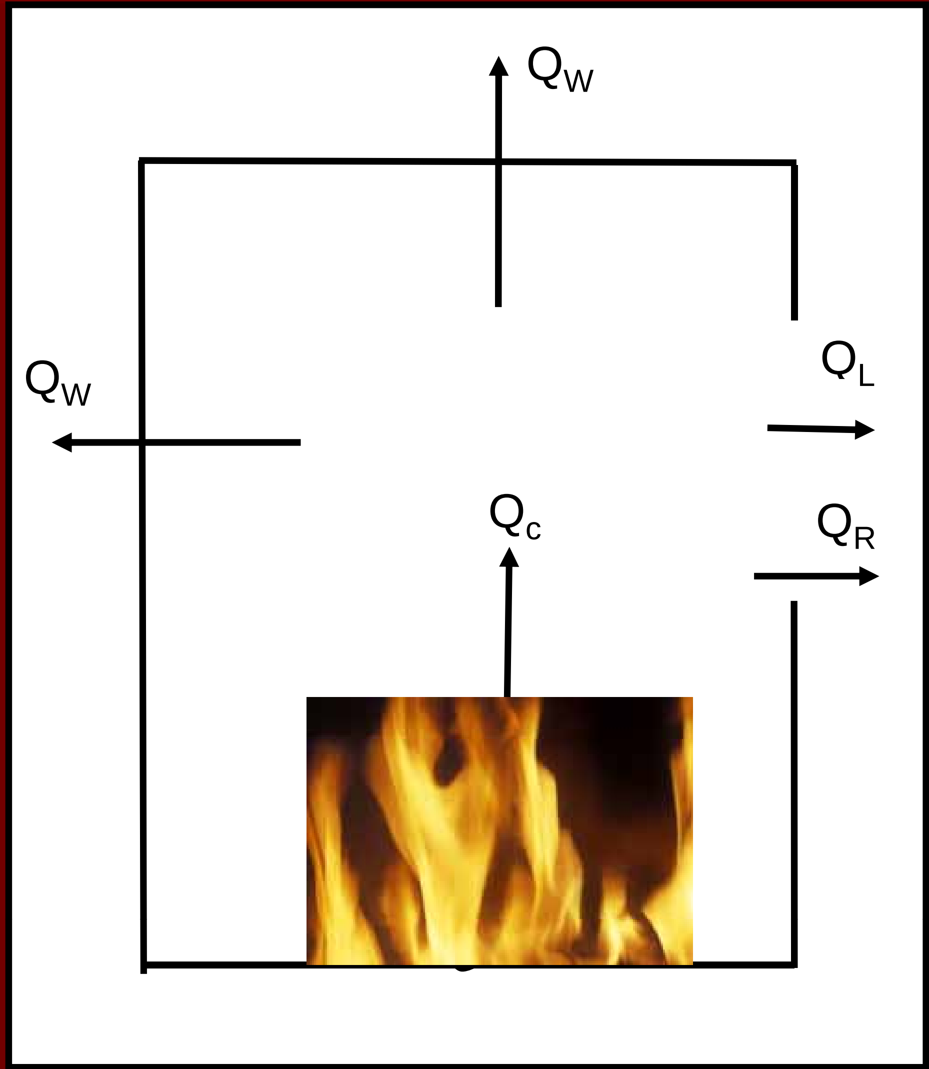
$$Q_C = Q_L + Q_W + Q_R$$

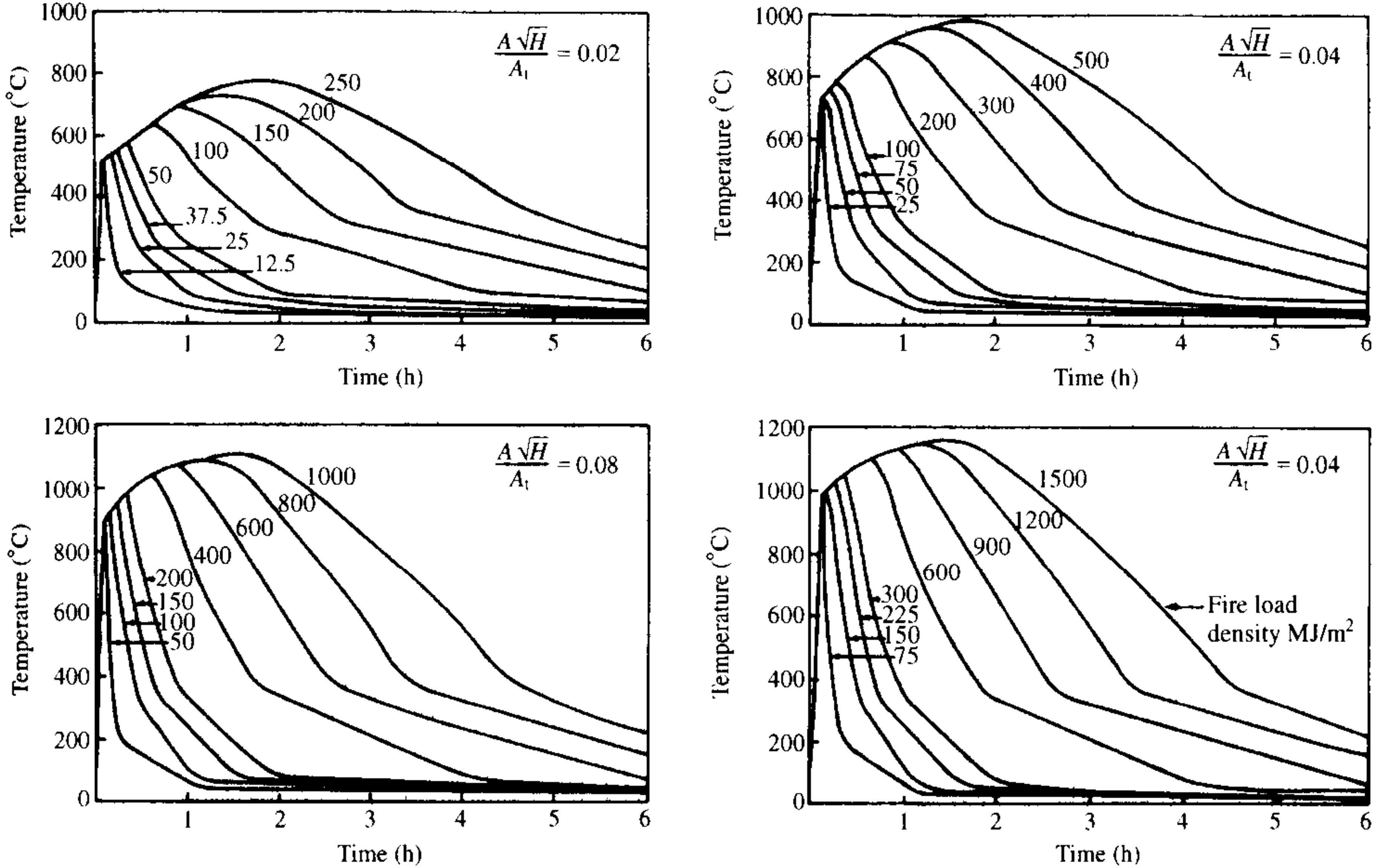
Q_c = Energy released by combustion

Q_l = Energy lost by exchange of gases

Q_w = Energy lost through compartment walls

Q_R = Energy radiated through opening





$\frac{A\sqrt{H}}{A_t} = 0.02$
250
200
150
100
50
37.5
25
12.5
Temperature (°C)
Time (h)
$\frac{A\sqrt{H}}{A_t} = 0.04$
500
400
300
200
100
75
50
25
Temperature (°C)
Time (h)
$\frac{A\sqrt{H}}{A_t} = 0.08$
1000
800
600
400
200
150
100
50
Temperature (°C)
Time (h)
$\frac{A\sqrt{H}}{A_t} = 0.04$
1500
1200
900
600
300
225
150
75
Fire load density MJ/m^2
Temperature (°C)
Time (h)

Pros and Cons

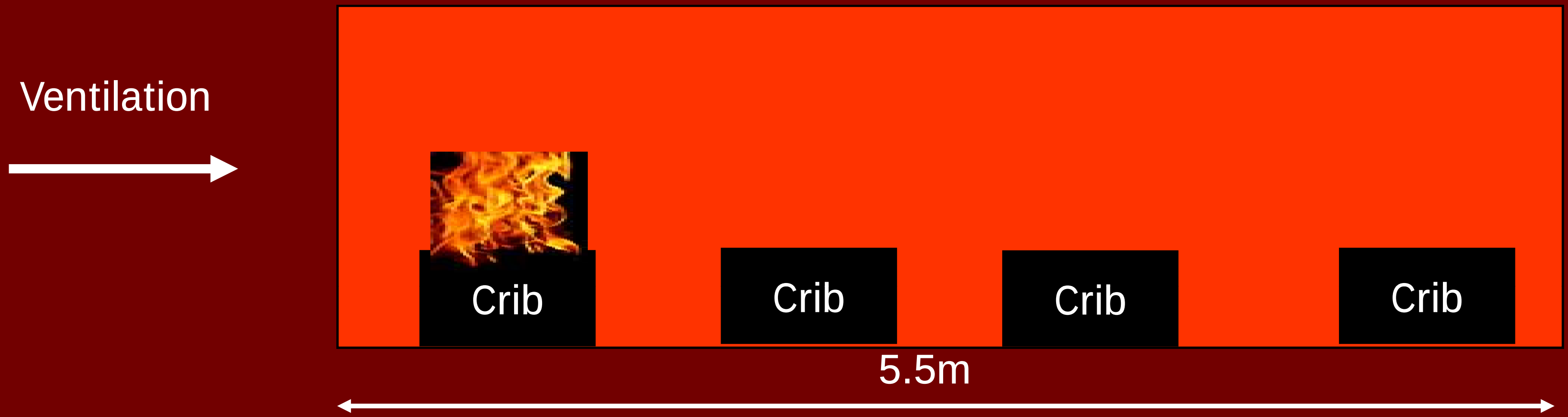
- Limitations
  - Crude
  - Rather severe
  - Implicit expressions (Eurocode parametric curves solve this)
  - Uniform fire
  - Hence maximum size of compartment
- But
  - “Not bad”
  - Can be used in performance-based design

Zone Models

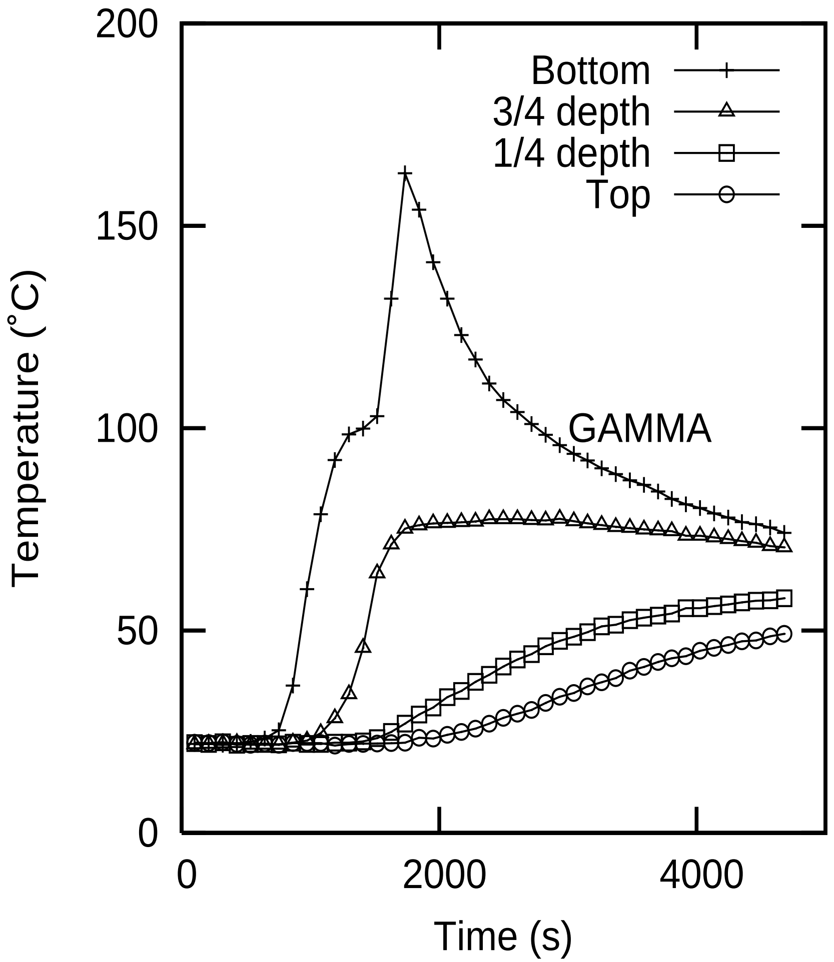
- More sophisticated energy balance models
- Assume uniform temperatures in each zone
- Normally computer based
- Several commercial codes available eg. Ozone, CFast
- Similar drawbacks and benefits to parametric curves

Real Fires

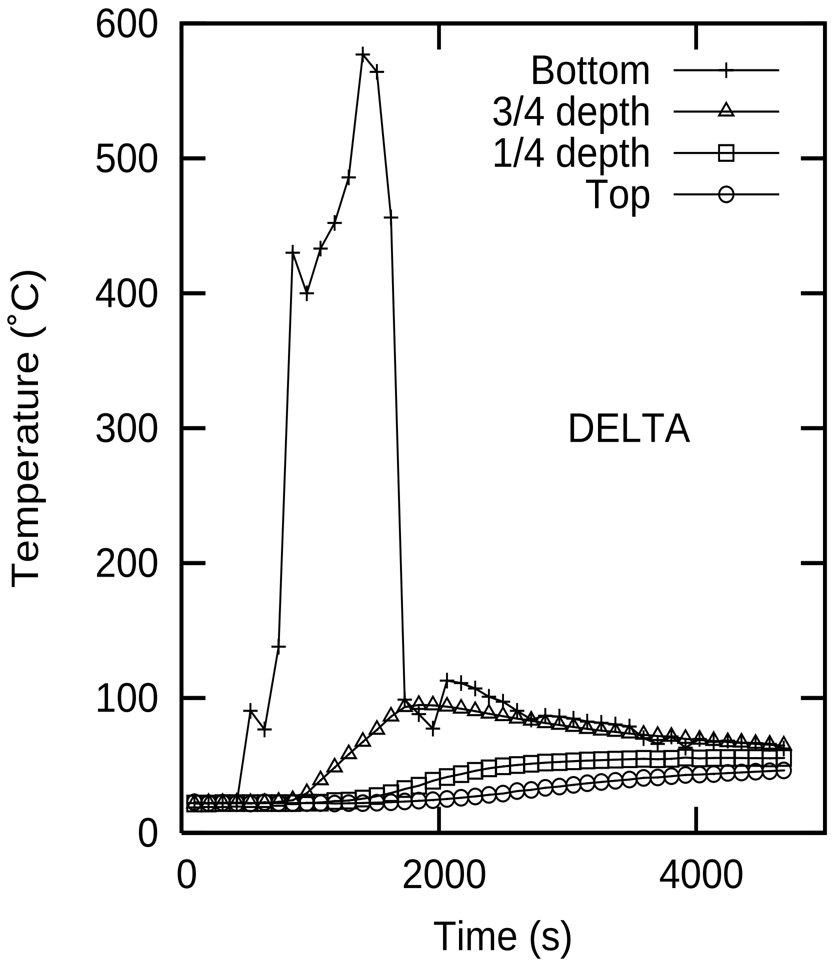
- Large compartment test at BRE showed travelling fire behaviour
- Travel times of the order of 45 minutes within compartment 5m deep



Real Fires



200
150
100
50
0
0
2000
4000
Time (s)
Temperature (°C)
Bottom
3/4 depth
1/4 depth
Top
GAMMA



600
500
400
300
200
100
0
0
2000
4000
Time (s)
Temperature (°C)
Bottom
3/4 depth
1/4 depth
Top
DELTA

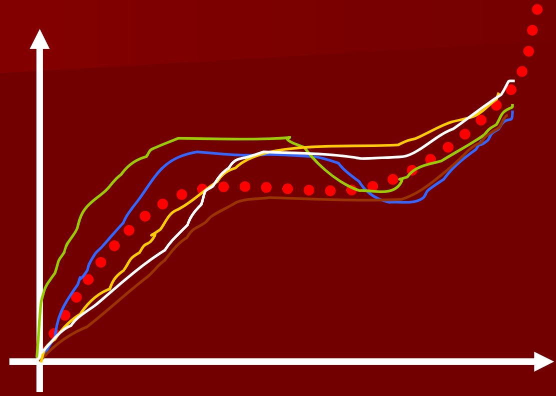
Modelling Real Fires

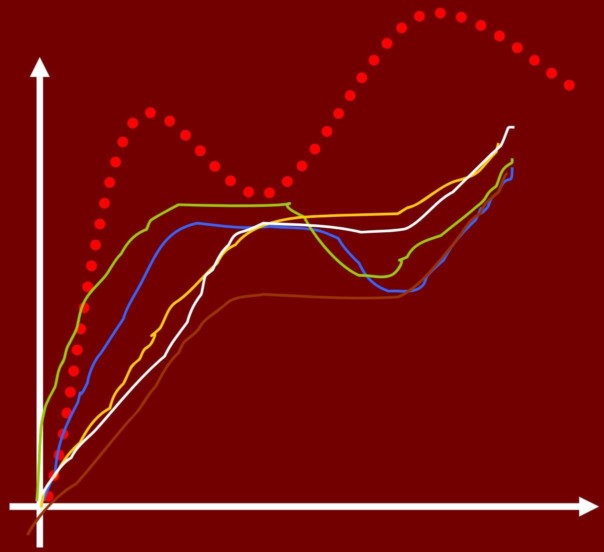
- Previous approaches fail to acknowledge that
  - Fires move
  - Temperatures in a compartment are not uniform
  - Large compartments need to be designed
- Two possible solutions
  - CFD models
  - Other methods of simply defining fires (e.g. Rein)

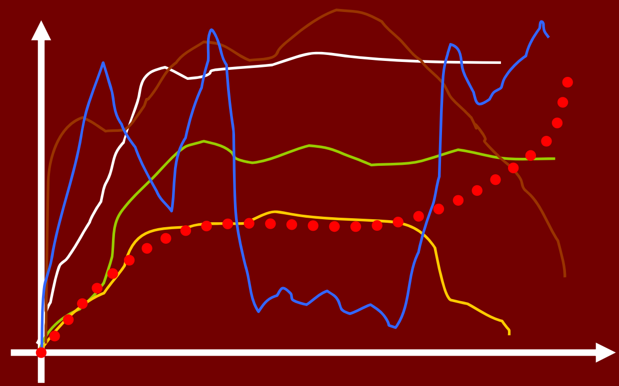
CFD Modelling

- Can predict huge range of phenomena
- Difficult to use due to many uncertainties in input variables
- Still a research method

Possible Round Robin Predictions



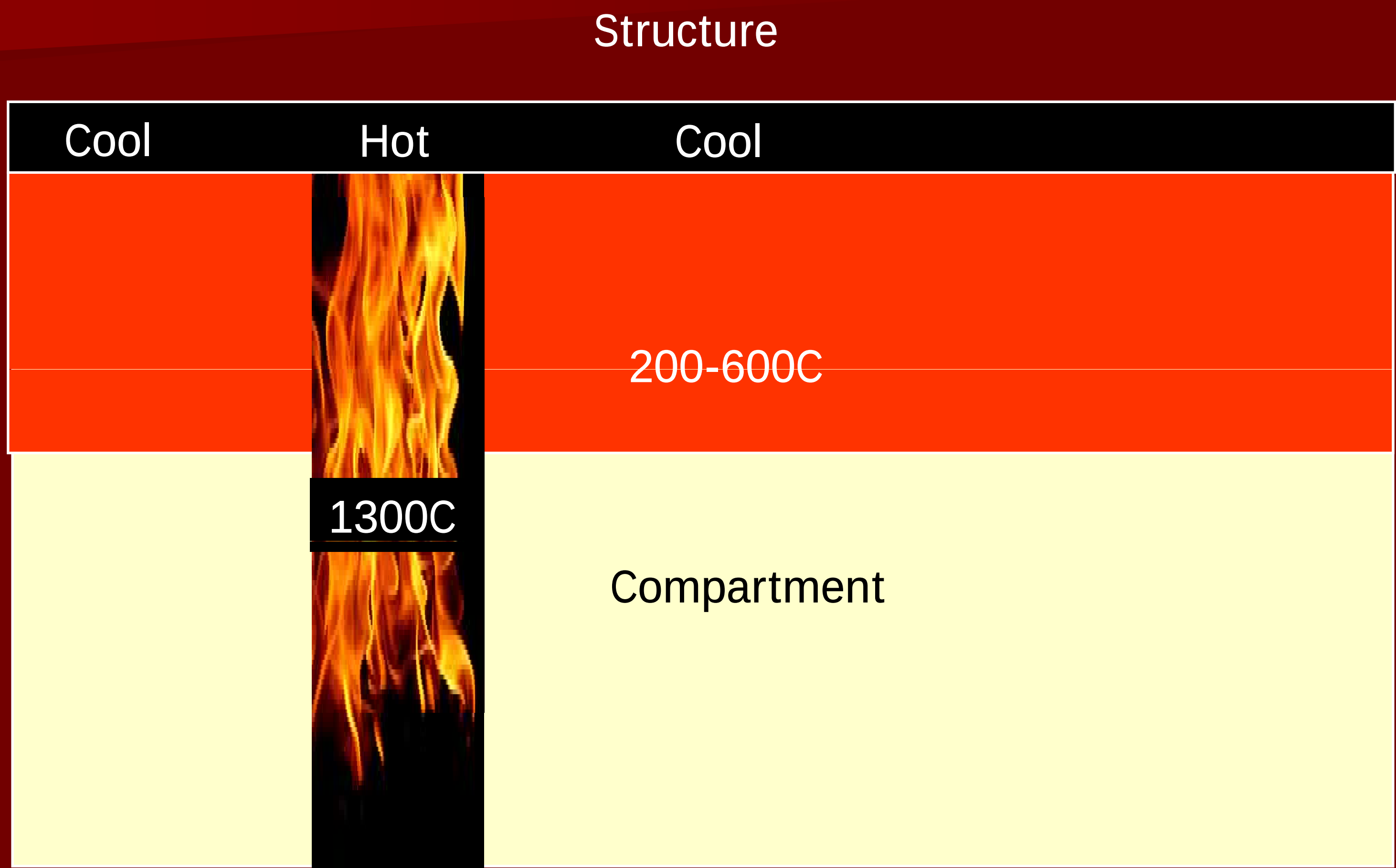




Simple Conceptual model

- Rein proposed a near field and far field model of temperature loading
  - – Near field from direct impingement of flames
  - – Far field as a result of hot gases in a compartment
  - – Speed of travel of near field governed by available fuel load and oxygen supply
  - – c15 minutes of near-field exposure for office loading

Defining Temperature Loading



Conclusions

- Parametric equations *probably* conservative
- Fires in large compartments will be significantly overestimated
  - Current assumptions very severe
- Better *useable* offer potential for
  - Better understanding of structural behaviour
  - Savings in fire protection
- Work to date of conceptual nature