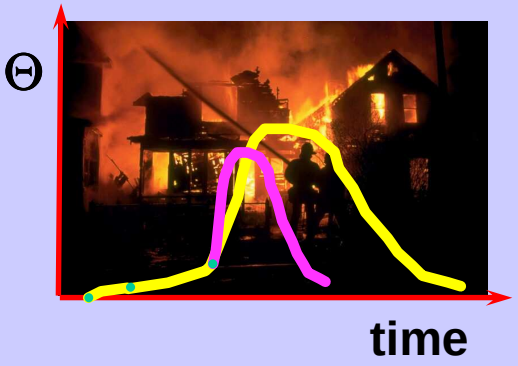
ArcelorMittal

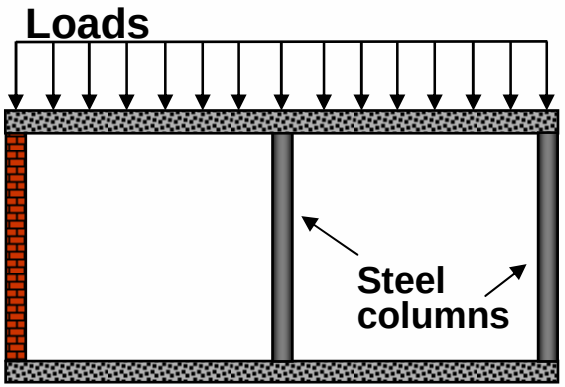
Secure With Steel Training
19th and 20th March 2009

Resistance to Fire - Chain of Events

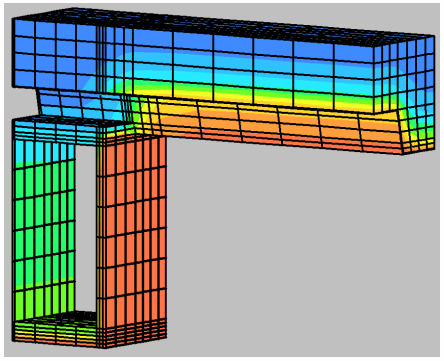
1: Ignition



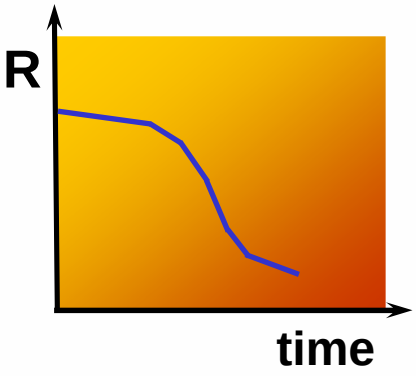
2: Thermal action



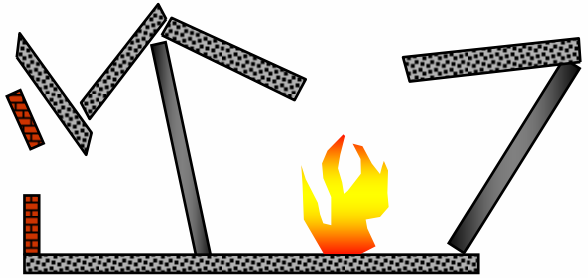
3: Mechanical actions



4: Thermal response



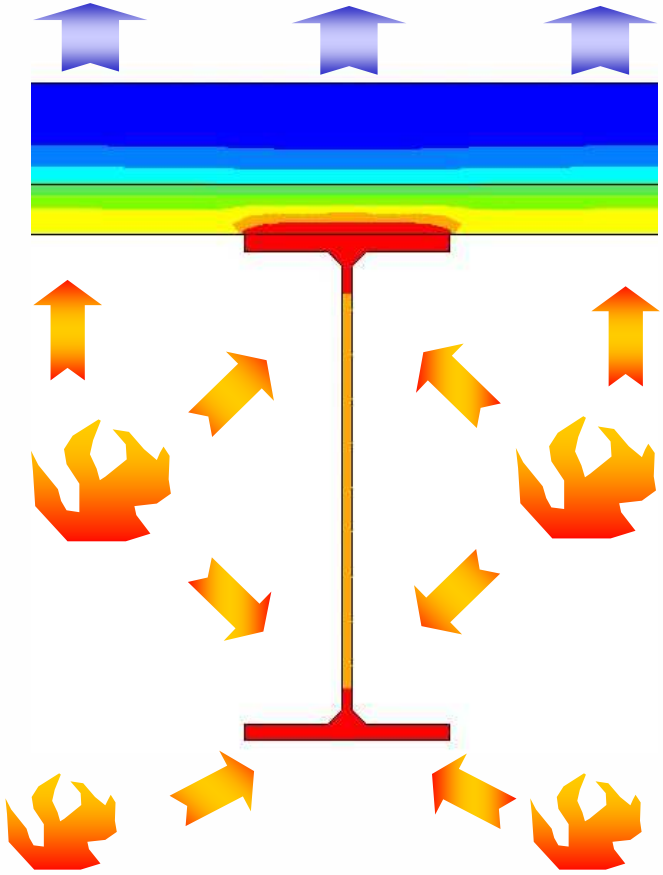
5: Mechanical response



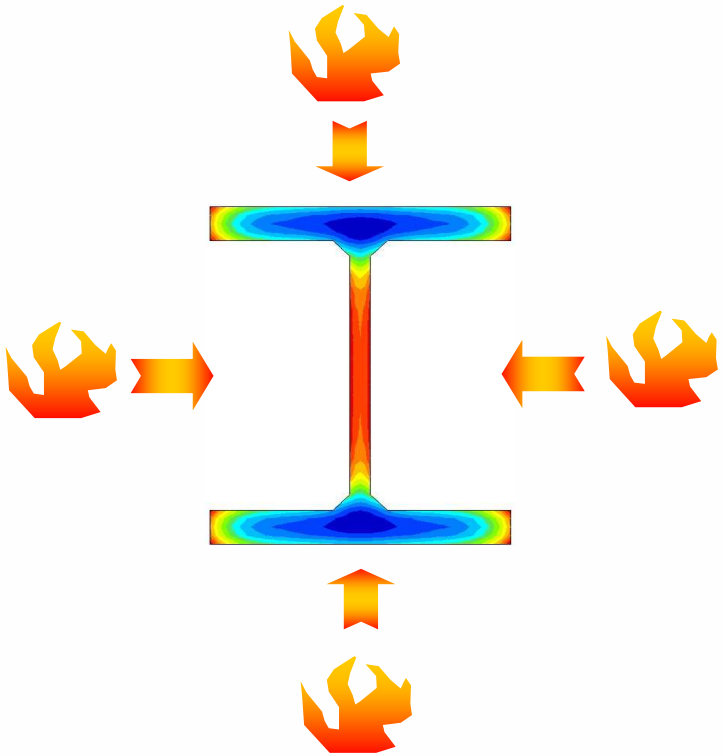
6: Possible collapse

Thermal action on structure

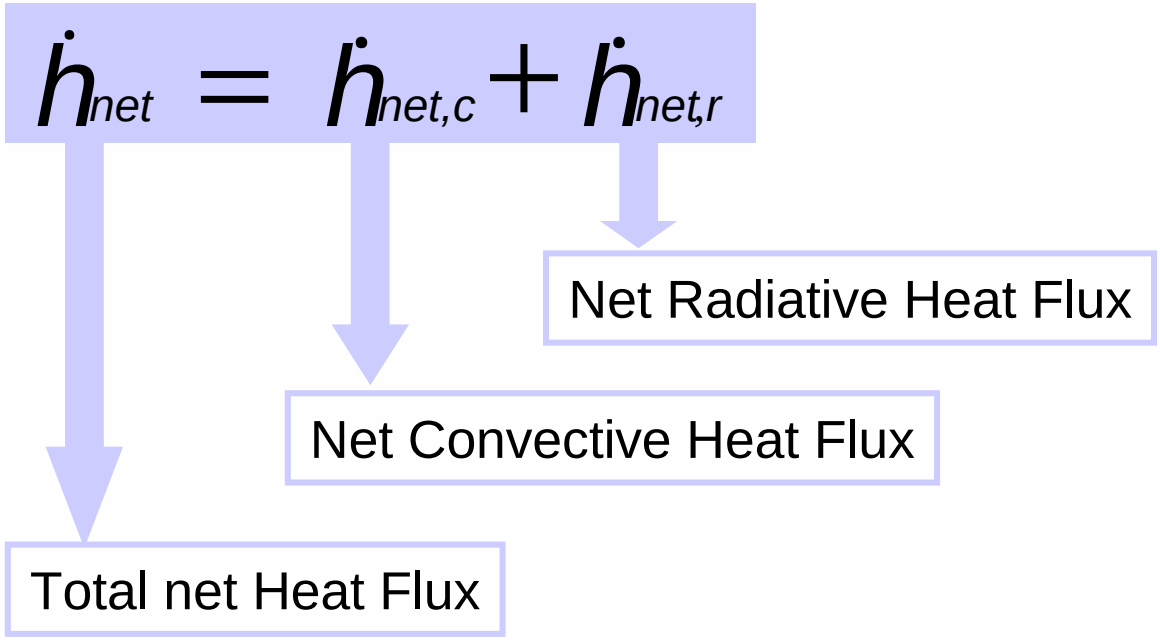
Composite Slab
1 side exposed



Column
4 sides exposed

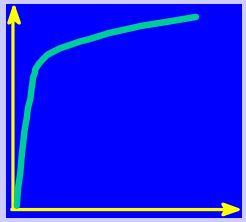
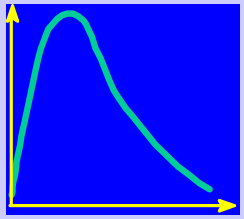
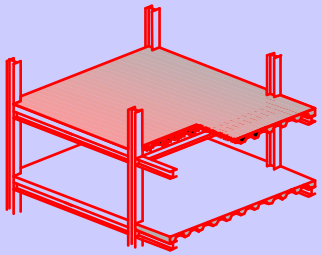


Heat transfer at surface of building elements

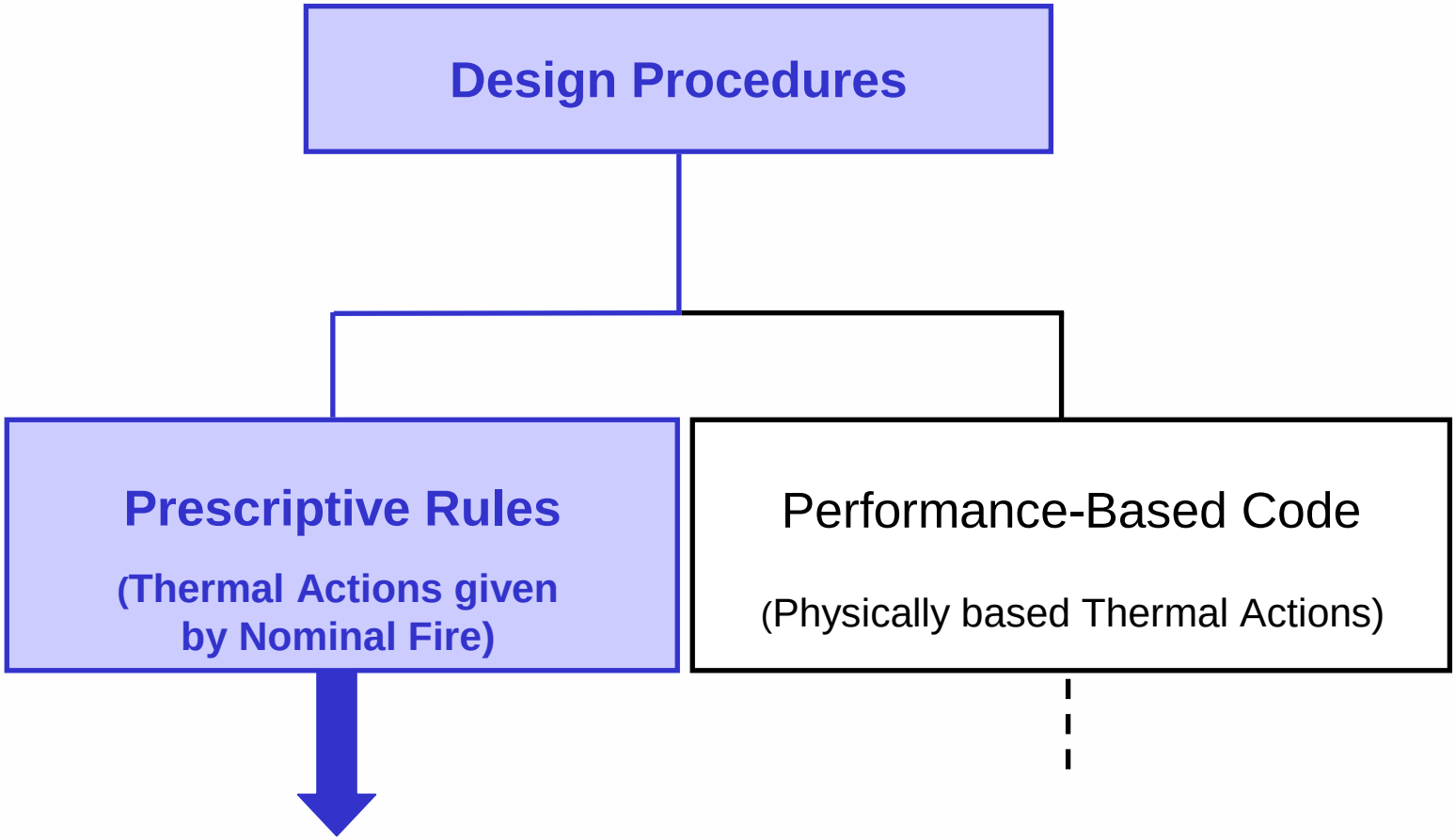


- Exposed side
- Non-exposed side

Structural Fire Safety Engineering vs. Classification

	Prescriptive	Performance based
	standard fire 	natural fire 
	classification	fire safety eng.
	fire safety eng.	fire safety eng.

Actions on Structures Exposed to Fire
EN 1991-1-2 - Prescriptive Rules



Nominal Temperature-Time Curve

*) Nominal temperature-time curve

Standard temperature-, External fire - & Hydrocarbon fire curve

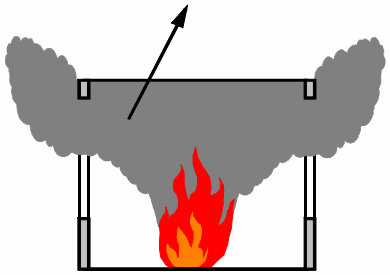
No data needed

*) Simplified Fire Models

Localised Fire

- HESKESTADT
- HASEMI

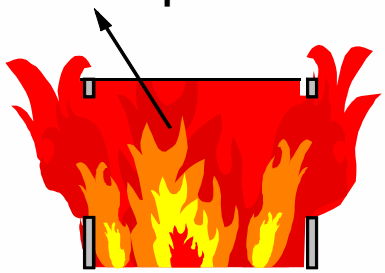
θ (x, y, z, t)



Fully Engulfed Compartment

- Parametric Fire

θ (t) uniform in the compartment



Rate of heat release
Fire surface
Boundary properties
Opening area
Ceiling height

*) Advanced Fire Models

- Two-Zone Model
- One-Zone Model
- Combined Two-Zones and One-Zone fire
- CFD

+

Exact geometry

Prescriptive Fire Regulations Defining ISO Curve Requirements

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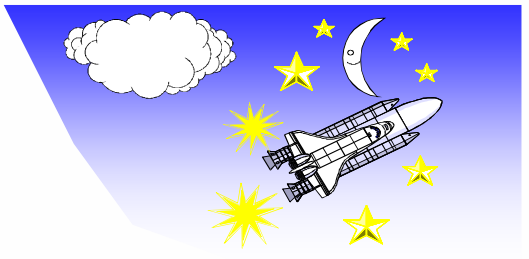
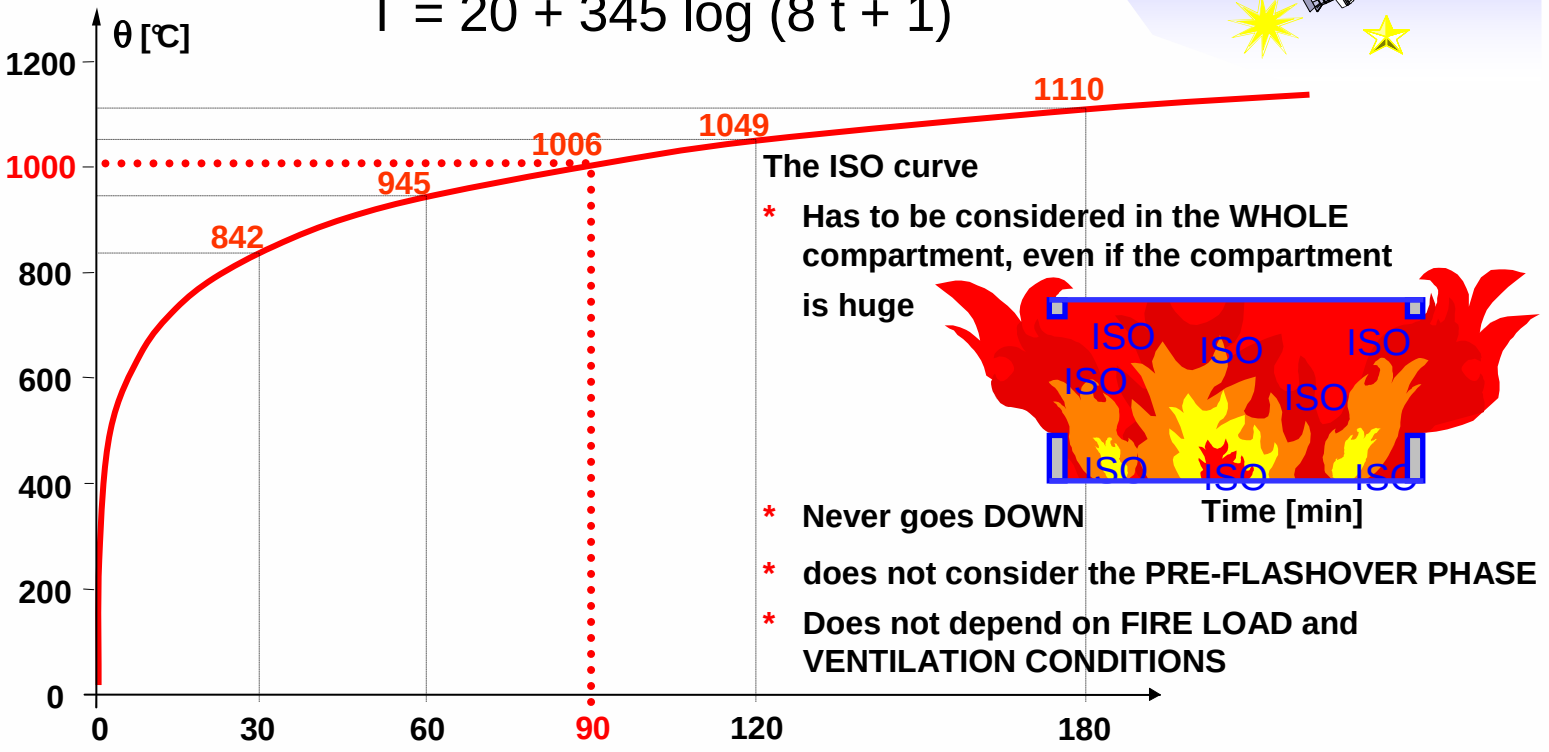


ISO-834 Curve (EN1364 -1)

$$T = 20 + 345 \log (8 t + 1)$$

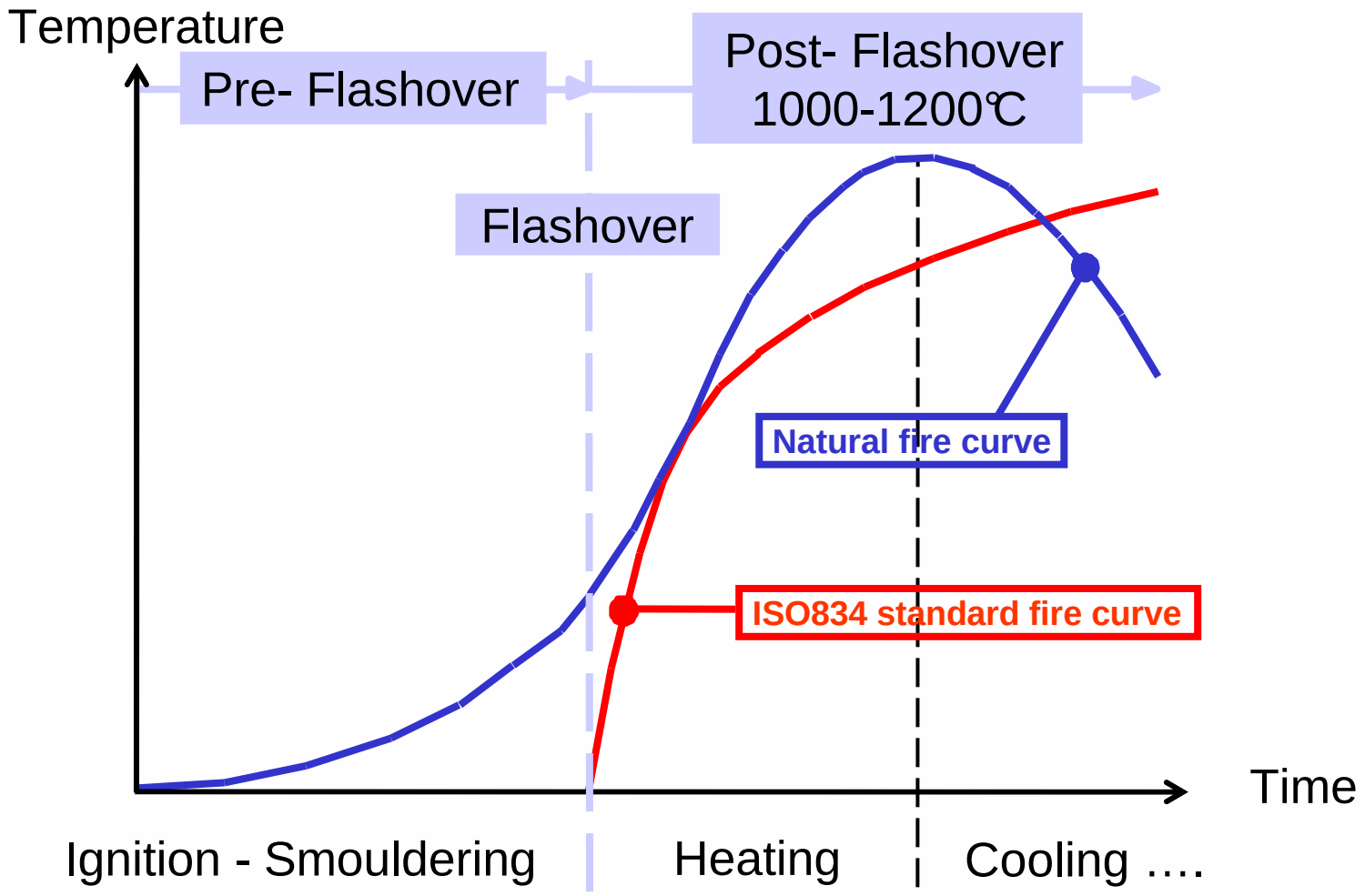


The ISO curve

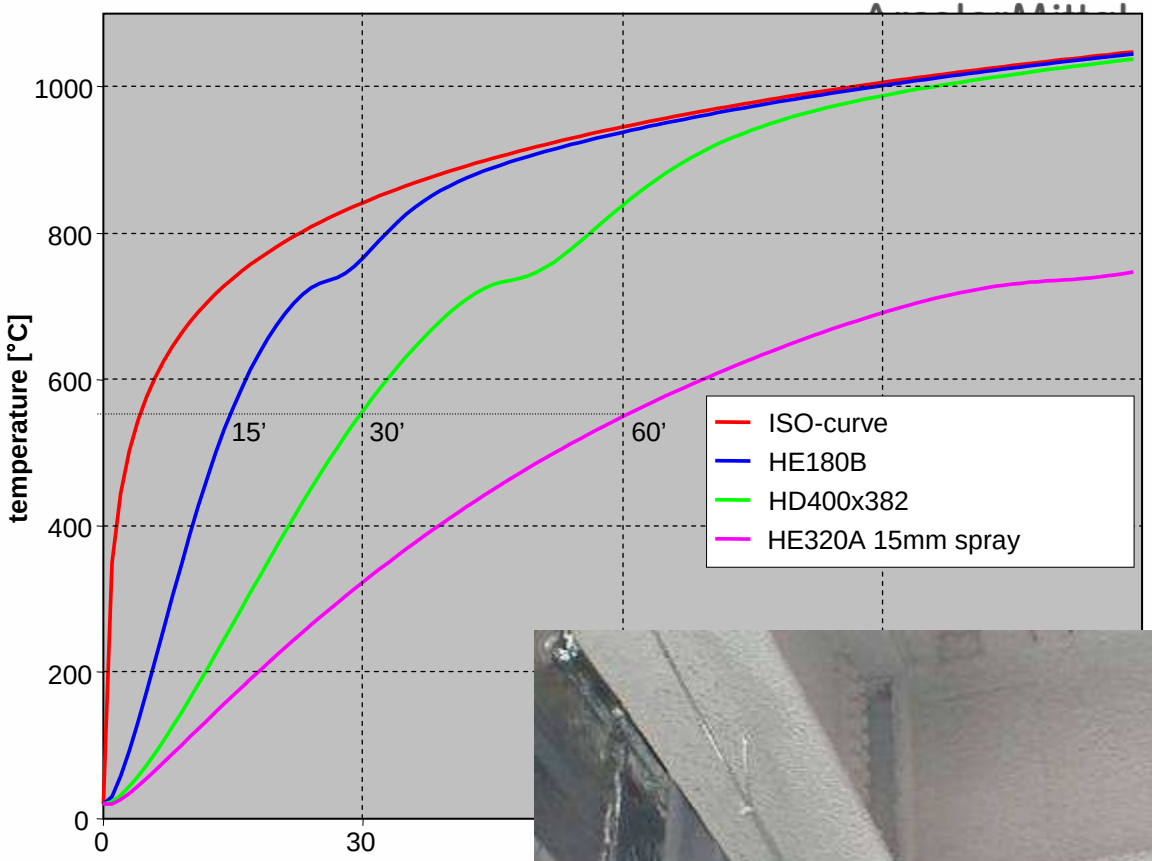
* **Has to be considered in the WHOLE compartment, even if the compartment is huge**

* **Never goes DOWN**
* **does not consider the PRE-FLASHOVER PHASE**
* **Does not depend on FIRE LOAD and VENTILATION CONDITIONS**

Stages of a Natural Fire and the Standard Fire Curve



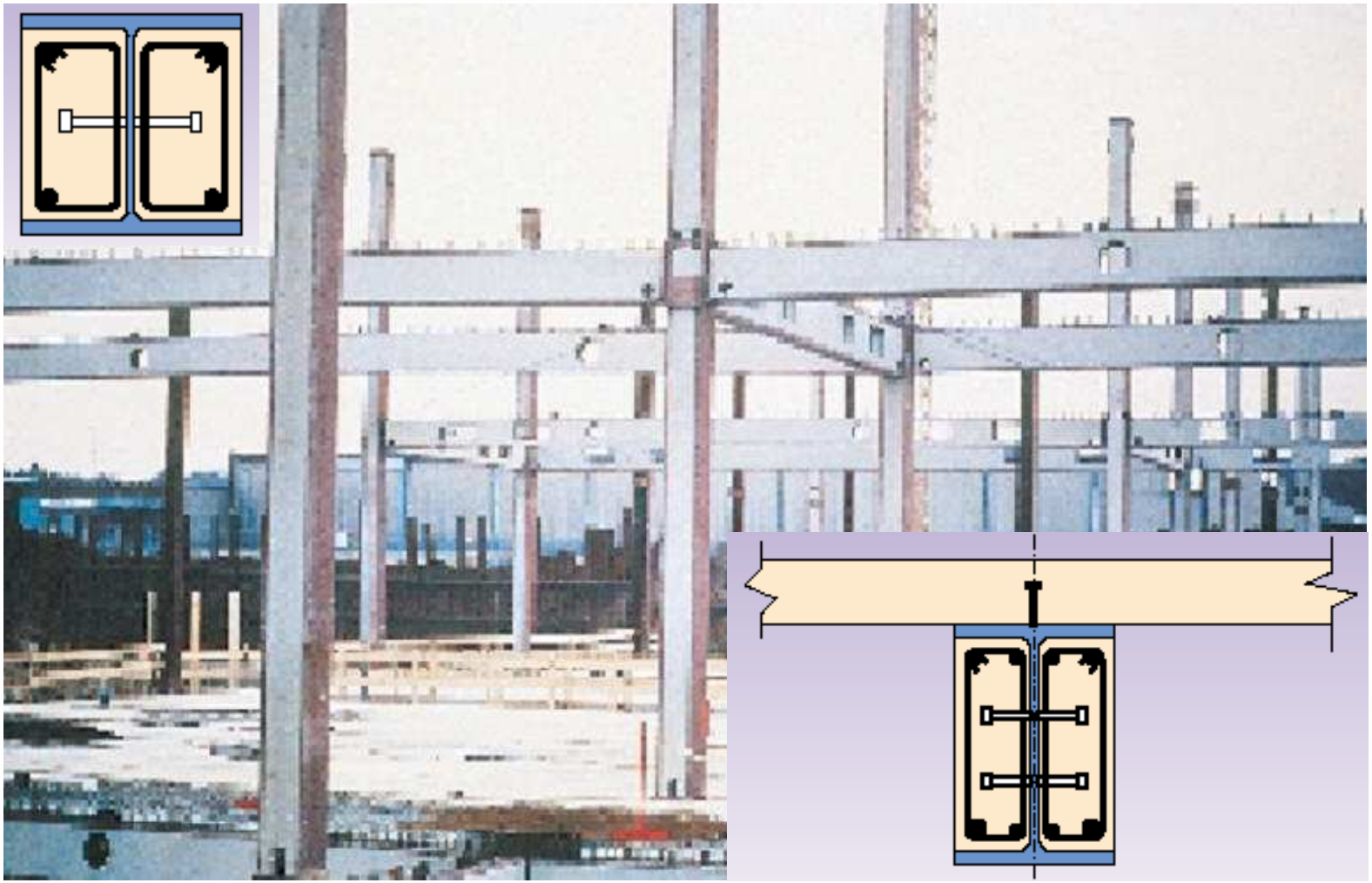
- Passive Protection of steel for fire resistance > 30minutes



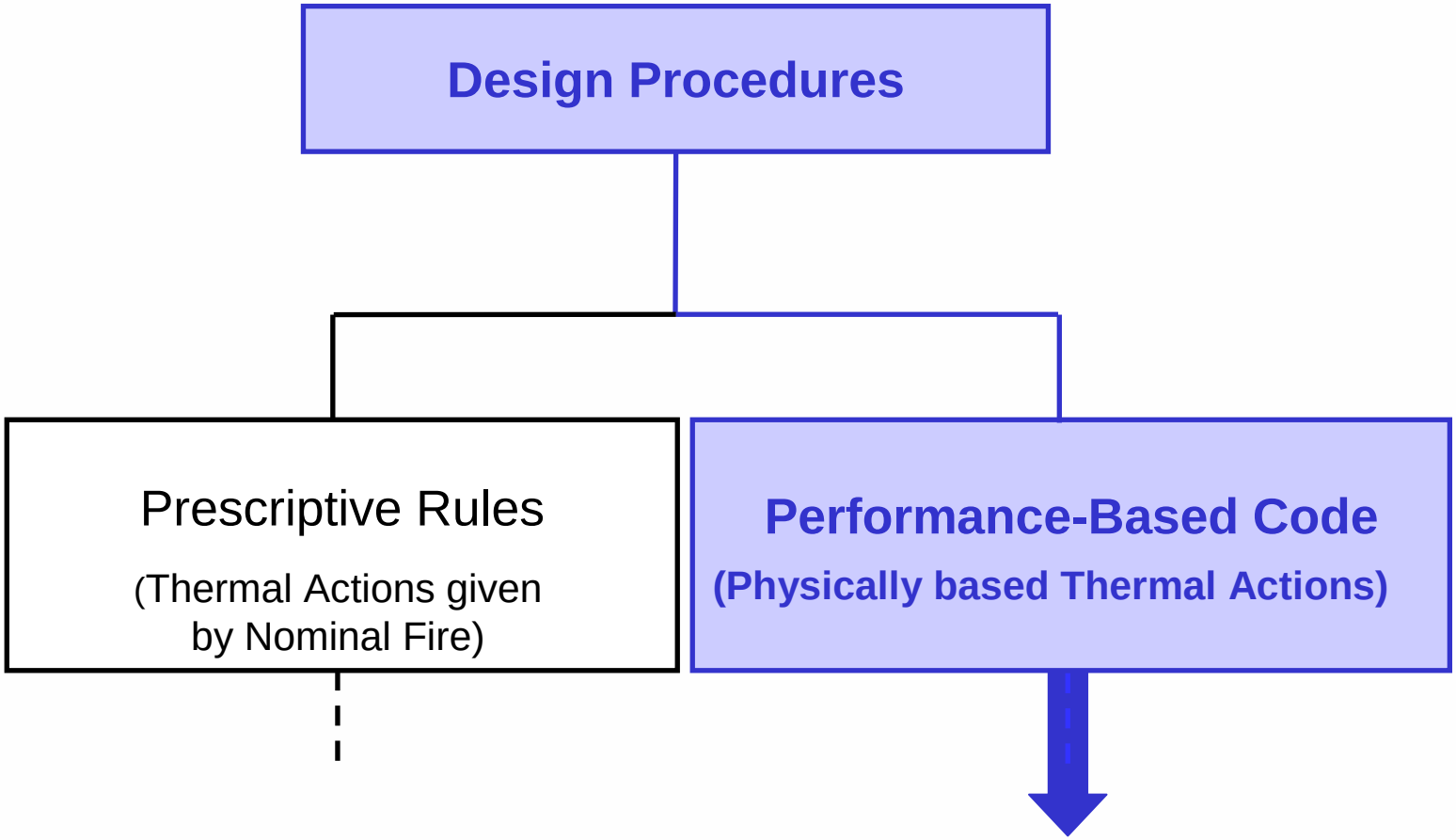
Solution
- not aesthetic
- not competitive

Additional cost of the protection > 40% of the finished steel structure

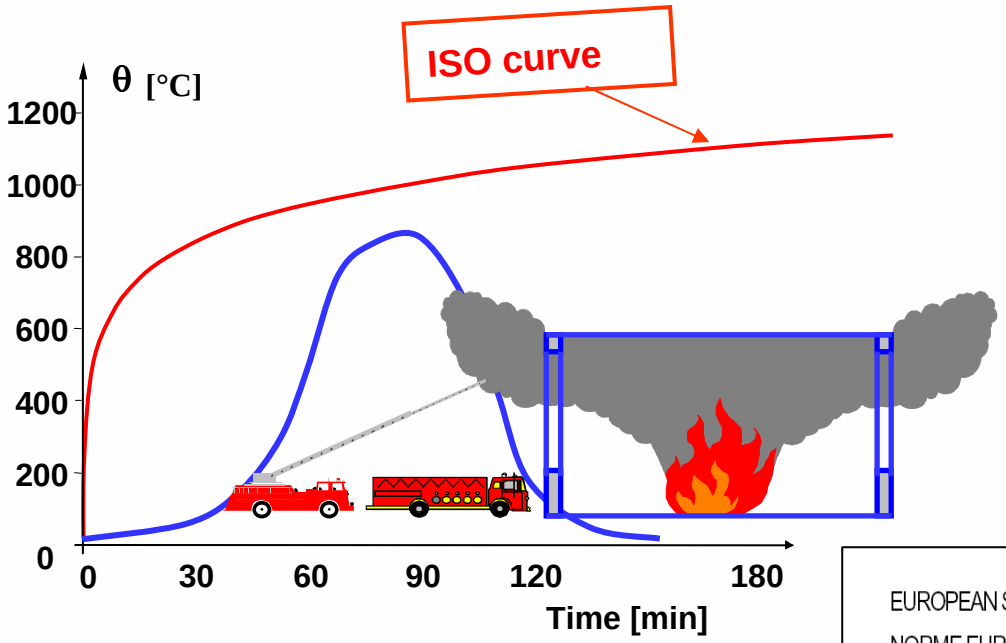
Partially Encased Beams & Columns



Actions on Structures Exposed to Fire
EN 1991-1-2 - Performance Based Code



Natural Fire Safety Concept



Implemented in:

- EN 1991-1-2
- Some National Fire Regulations include now alternative requirements based on Natural Fire

EUROPEAN STANDARD **EN 1991-1-2**
NORME EUROPÉENNE
EUROPÄISCHE NORM
November 2002

ICS 13.220.50; 91.010.30

English version

Eurocode 1: Actions on structures - Part 1-2: General actions - Actions on structures exposed to fire

Eurocode 1: Actions sur les structures au feu - Partie 1-2: Actions générales - Actions sur les structures exposées

Eurocode 1 - Einwirkungen auf Tragwerke - Teil 1-2: Allgemeine Einwirkungen - Brandeinwirkungen auf Tragwerke

Natural Fire Model

*) Nominal temperature-time curve

Standard temperature-, External fire - & Hydrocarbon fire curve

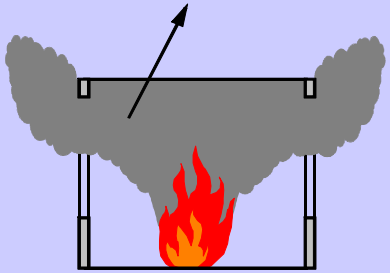
No data needed

*) Simplified Fire Models

Localised Fire

- HESKESTADT
- HASEMI

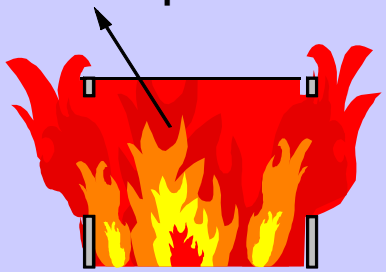
θ (x, y, z, t)



Fully Engulfed Compartment

- Parametric Fire

θ (t) uniform in the compartment



Rate of heat release
Fire surface
Boundary properties
Opening area
Ceiling height

*) Advanced Fire Models

- Two-Zone Model
- One-Zone Model
- Combined Two-Zones and One-Zone fire
- CFD

+

Exact geometry

List of needed Physical Parameters for Natural Fire Model

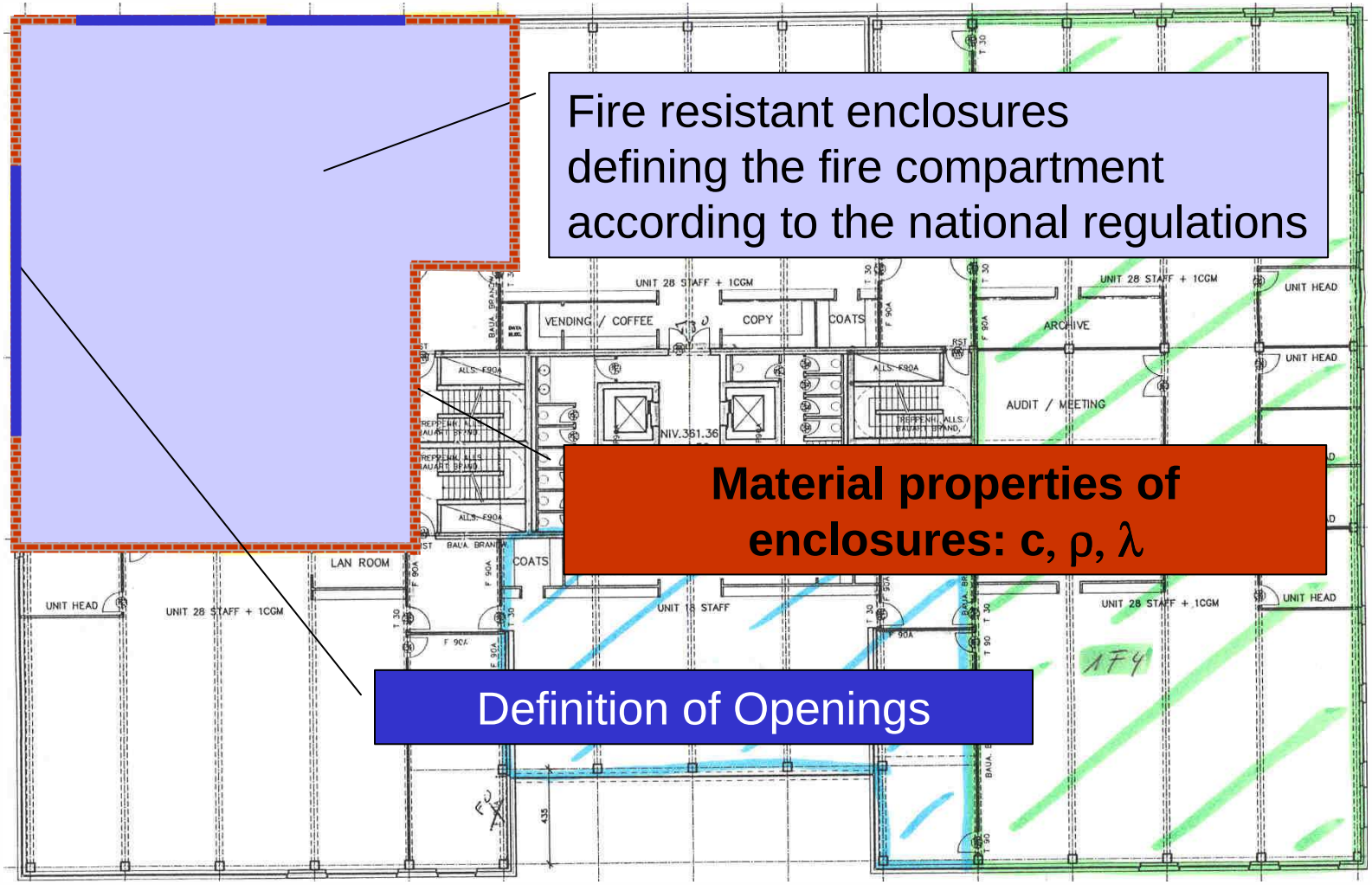
- Boundary properties
- Ceiling height
- Opening Area

} Geometry

- Fire surface
- Rate of heat release

} Fire

Characteristics of the Fire Compartment



Characteristic of the Fire for Different Buildings

Occupancy	Fire Growth Rate	RHR $[kW/m^2]$	Fire Load $q_{f,k}$ 80% fractile $[MJ/m^2]$
Dwelling	Medium	250	948
Hospital (room)	Medium	250	280
Hotel (room)	Medium	250	377
Library	Fast	500	1824
Office	Medium	250	511
School	Medium	250	347
Shopping Centre	Fast	250	730
Theatre (movie/cinema)	Fast	500	365
Transport (public space)	Slow	250	122

Fire Load Density

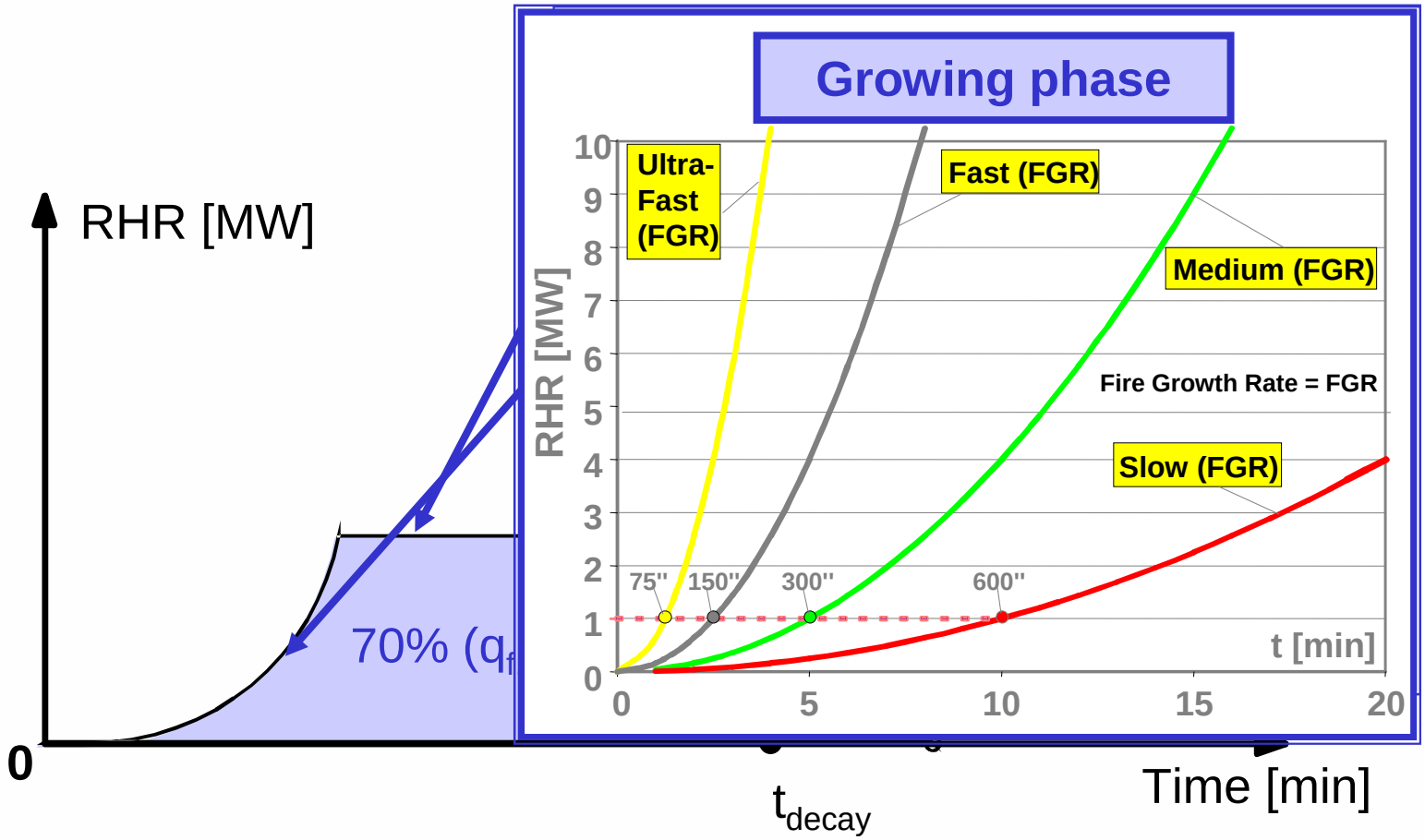
Compartment floor area A_f [m²]	Danger of Fire Activation δ_{q1}	Danger of Fire Activation δ_{q2}	Examples of Occupancies
25	1,10	0,78	Art gallery, museum, swimming pool
250	1,50	1,00	Residence, hotel, office
2500	1,90	1,22	Manufactory for machinery & engines
5000	2,00	1,44	Chemical laboratory, Painting workshop
10000	2,13	1,66	Manufactory of fireworks or paints

$$q_{f,d} = \delta_{q1} . \delta_{q2} . \prod \delta_{ni} . m . q_{f,k}$$

Automatic

Automatic Water Extinguishing System δ_{n1}	Independent Water Supplies δ_{n2}			Automatic fire Detection & Alarm		Automatic Alarm Transmission to Fire Brigade δ_{n5}	Work Fire Brigade δ_{n6}	Off Site Fire Brigade δ_{n7}	Safe Access Routes δ_{n8}	Fire Fighting Devices δ_{n9}	Smoke Exhaust System δ_{n10}
	0	1	2	by Heat δ_{n3}	by Smoke δ_{n4}						
0,61	1,0	0,87	0,7	0,87 or 0,73		0,87	0,61 or 0,78		0,9 or 1 / 1,5	1,0 / 1,5	1,0 / 1,5

Rate of Heat Release Curve
Stationary State and Decay Phase



Natural Simplified Fire Model

*) Nominal temperature-time curve

Standard temperature-, External fire - & Hydrocarbon fire curve

No data needed

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Localised Fire

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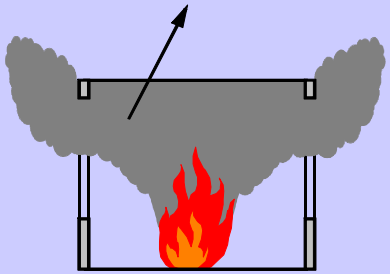
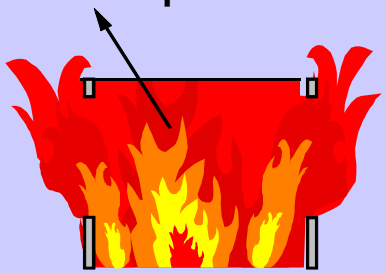
θ (x, y, z, t)



Fully Engulfed Compartment

- Parametric Fire

θ (t) uniform in the compartment



Rate of heat release
Fire surface
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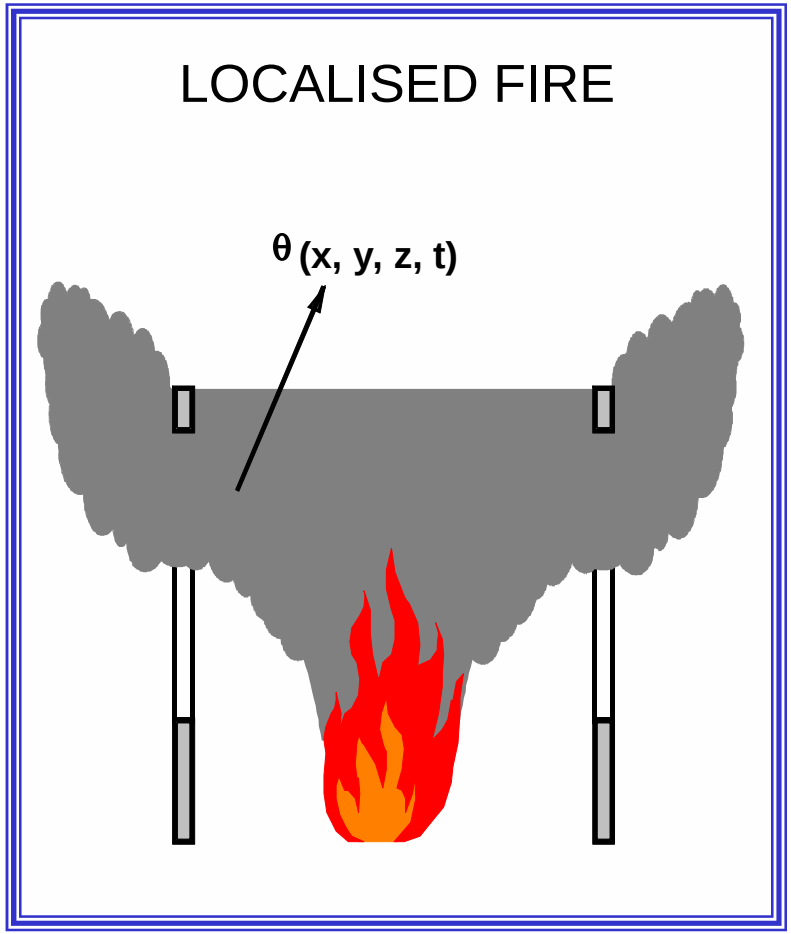
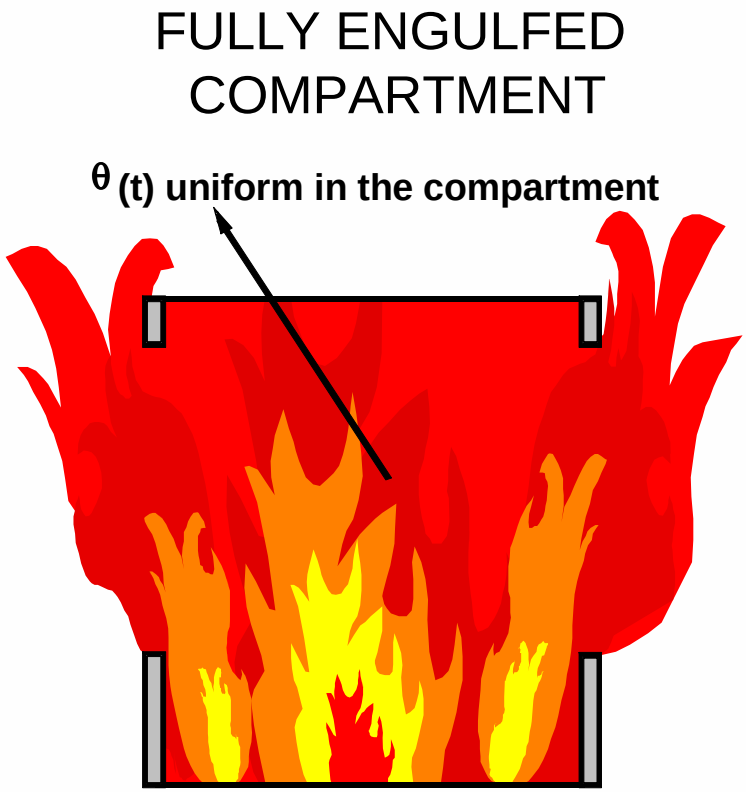
Exact geometry

Simplified Fire Models
Localised Fire





Simplified Fire Models
Fully Engulfed Compartment

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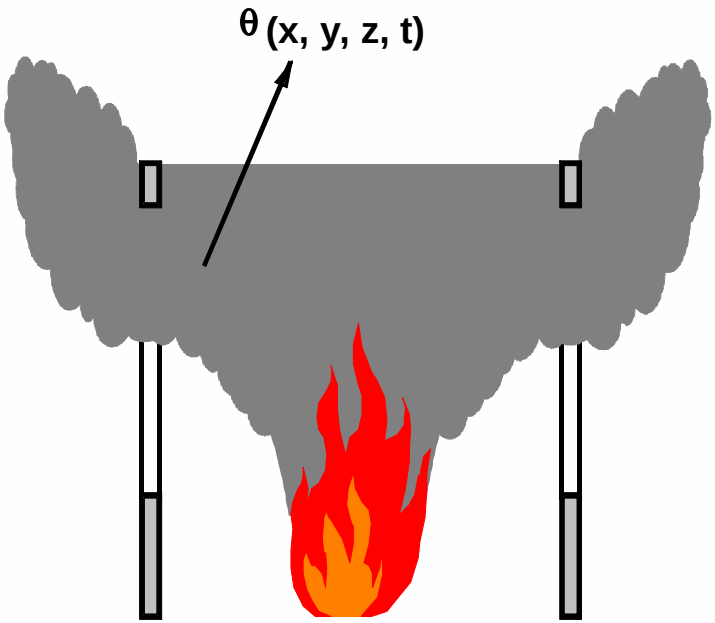
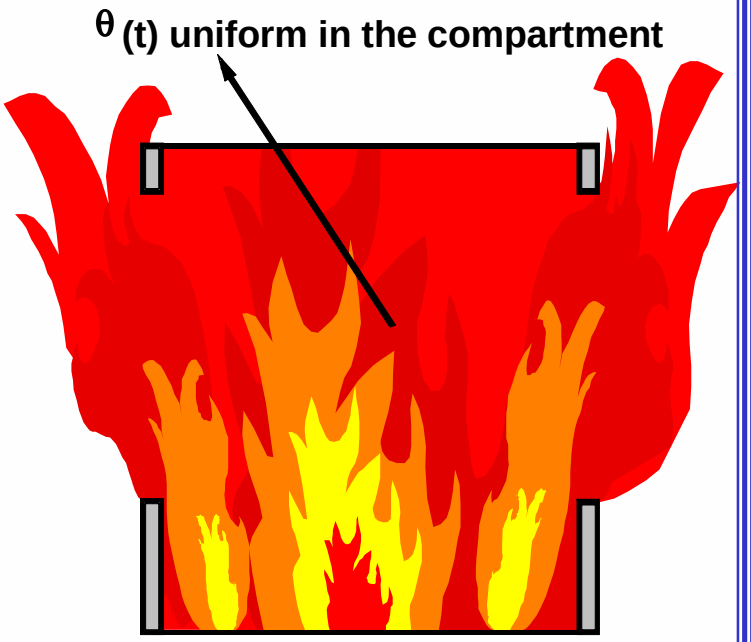
LOCALISED FIRE



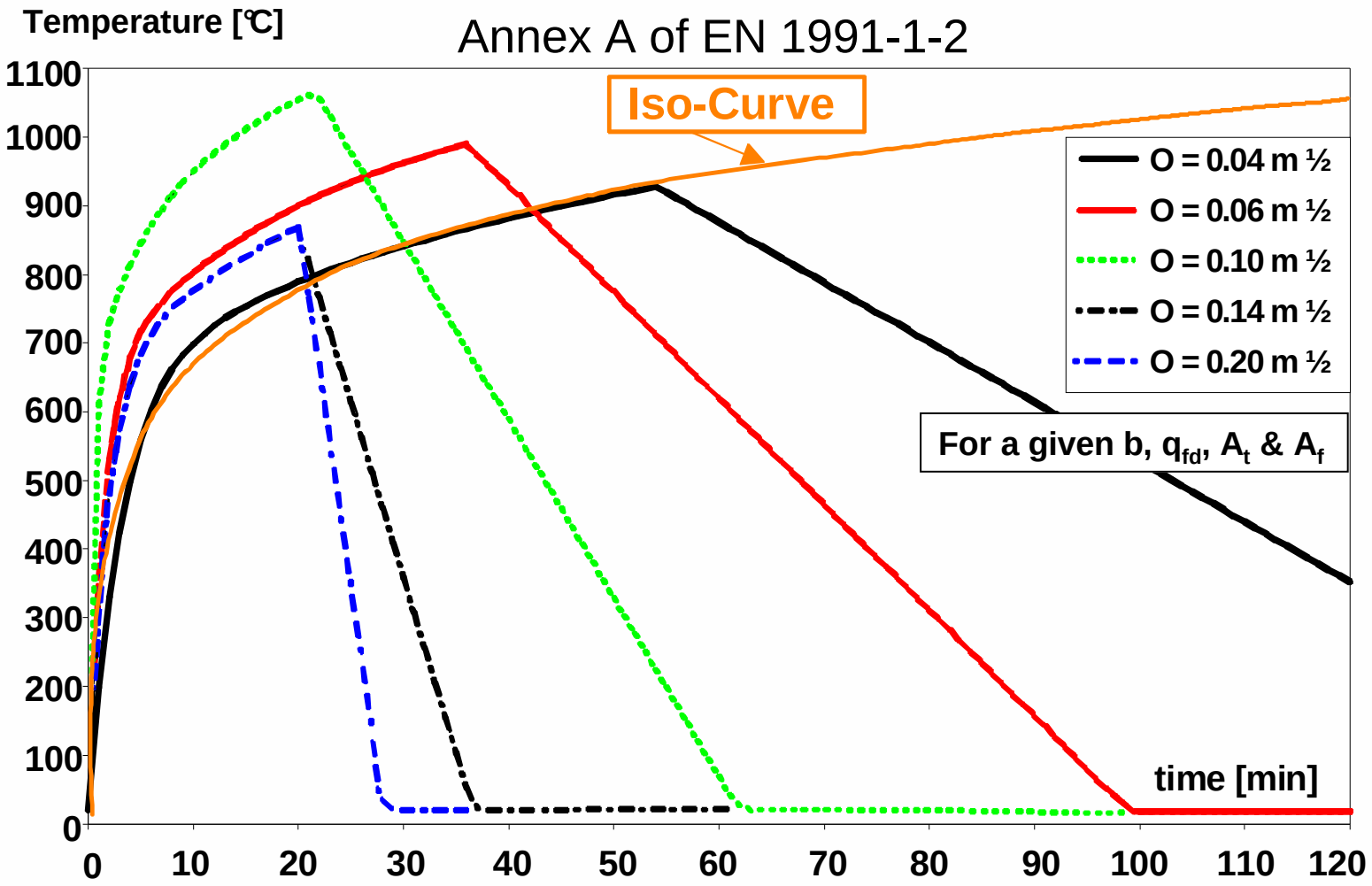
FULLY ENGULFED COMPARTMENT



Real Fire Test Simulating an Office Building

Fully engulfed fire

Fully Engulfed Compartment
Parametric Fire



Natural Advanced Fire Model

***) Nominal temperature-time curve**

Standard temperature-, External fire - & Hydrocarbon fire curve

No data needed

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Localised Fire

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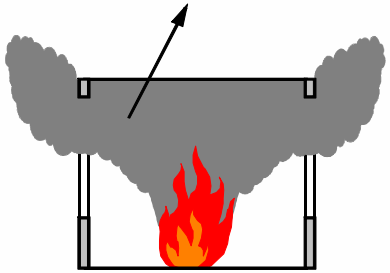
- **HASEMI**

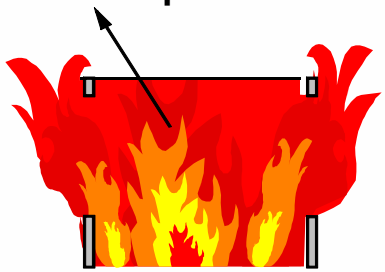
θ (x, y, z, t)



Fully Engulfed Compartment

- **Parametric Fire**

θ (t) uniform in the compartment



Rate of heat release
Fire surface
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Opening area
Ceiling height

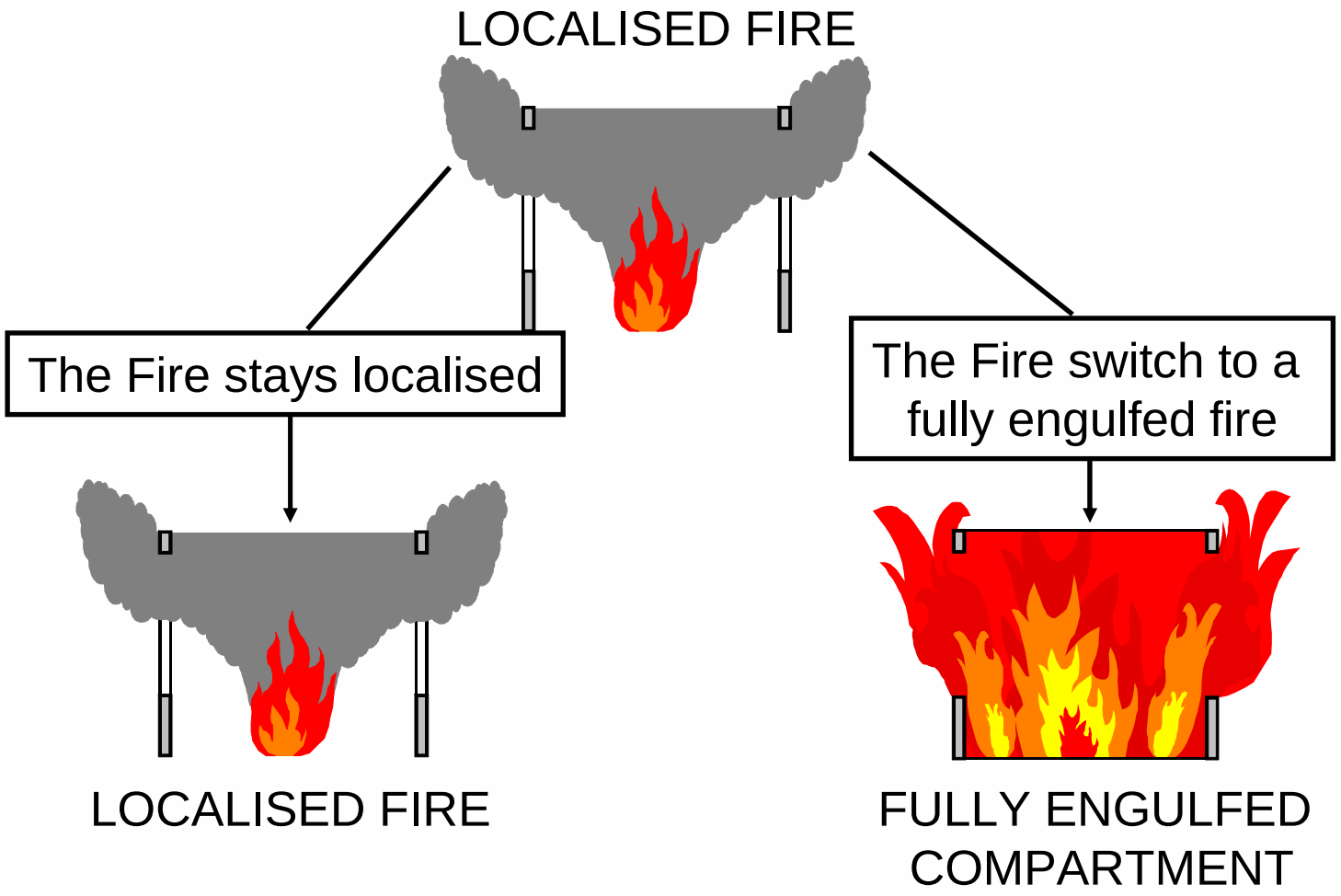
***) Advanced Fire Models**

- **Two-Zone Model**
- **One-Zone Model**
- **Combined Two-Zones and One-Zone fire**
- **CFD**

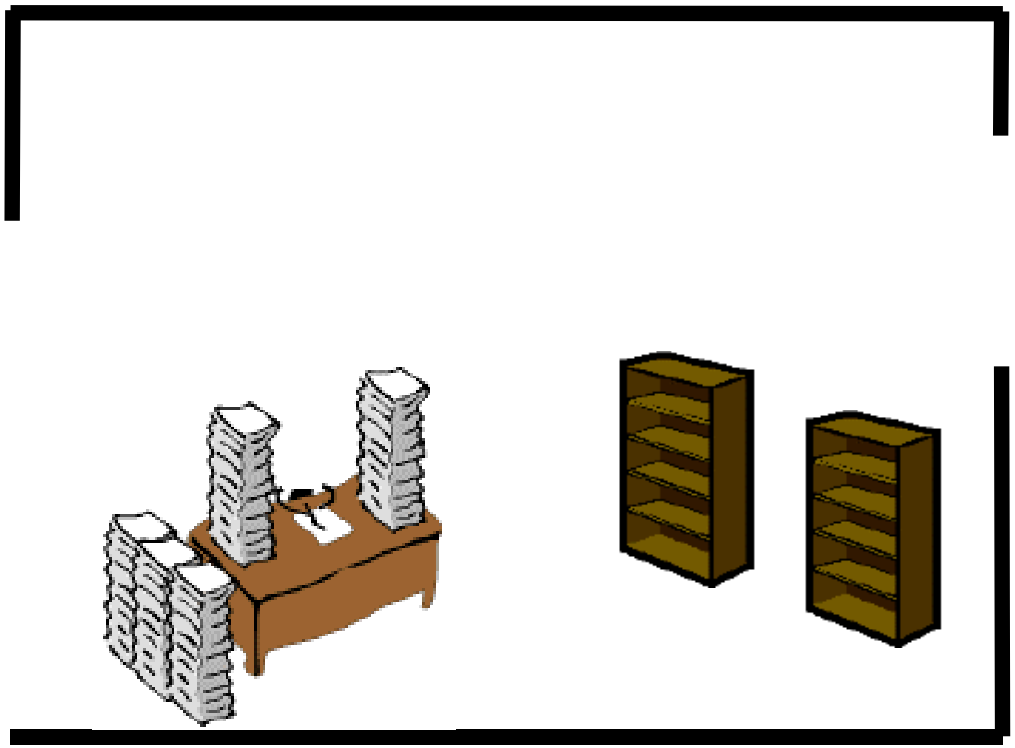
+

Exact geometry

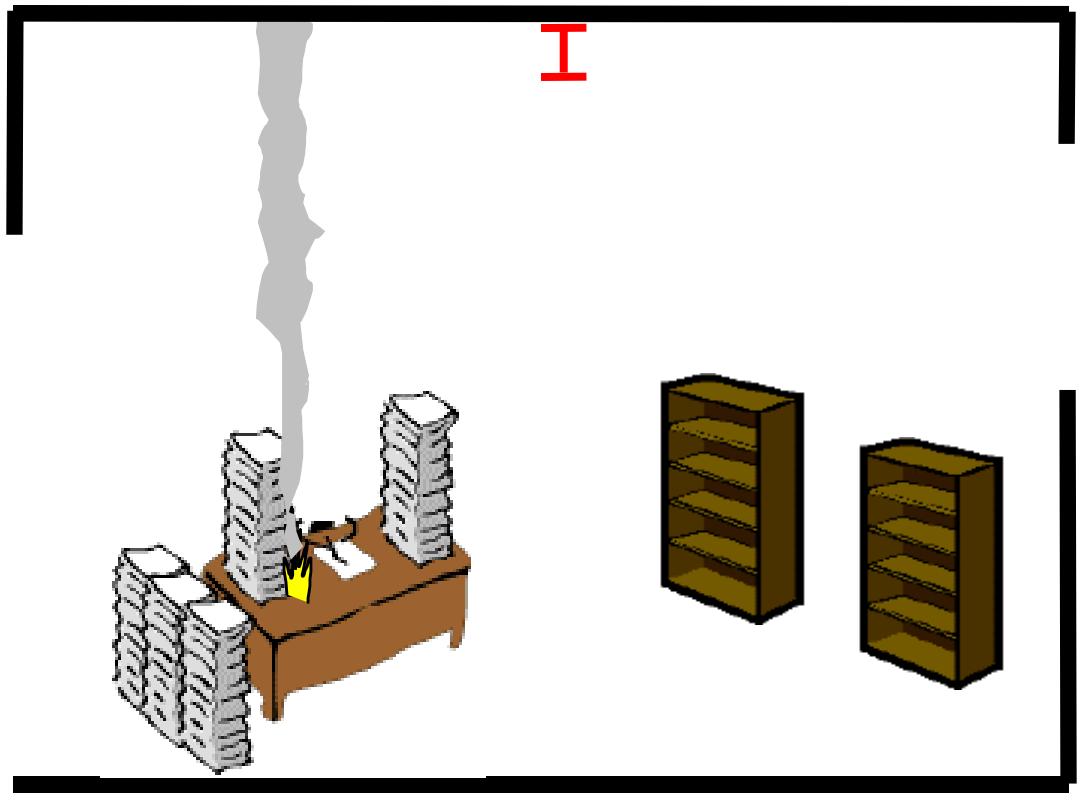
Advanced fire Models



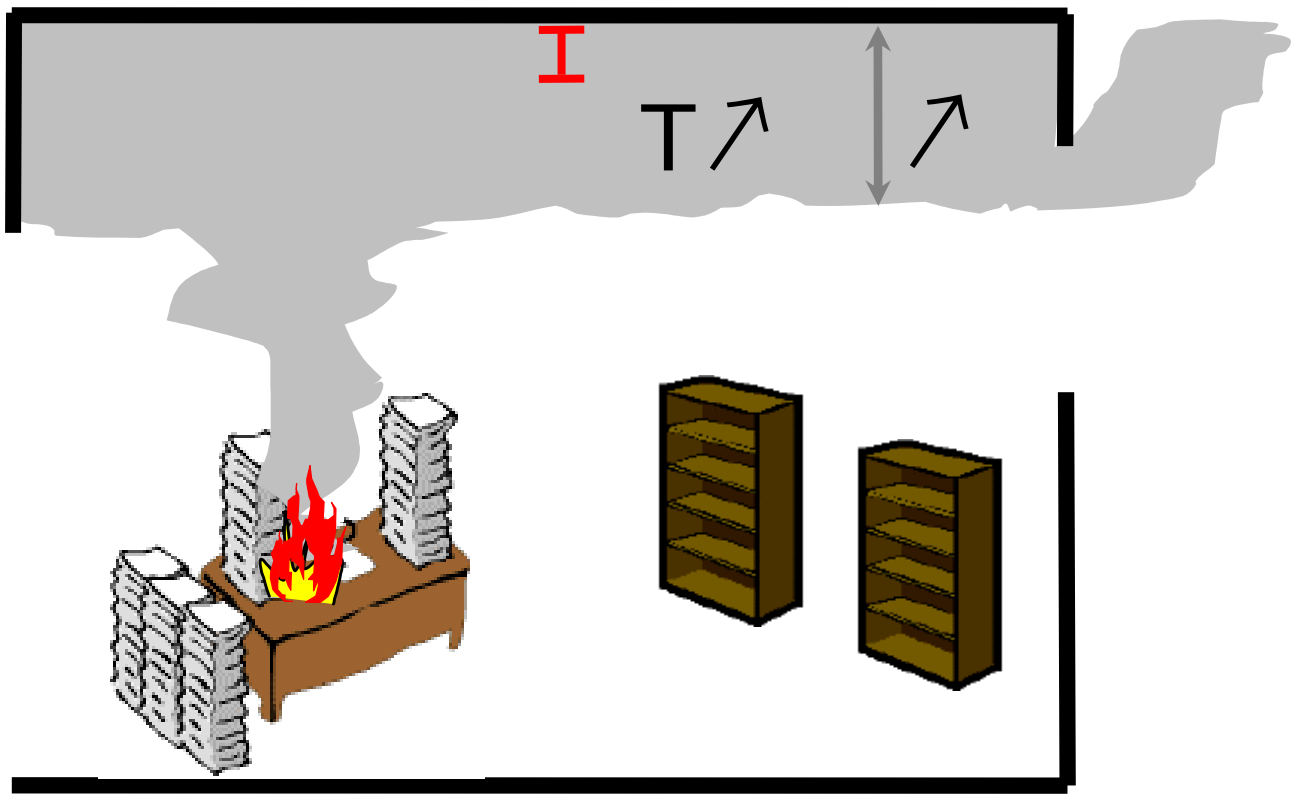
Fire compartment



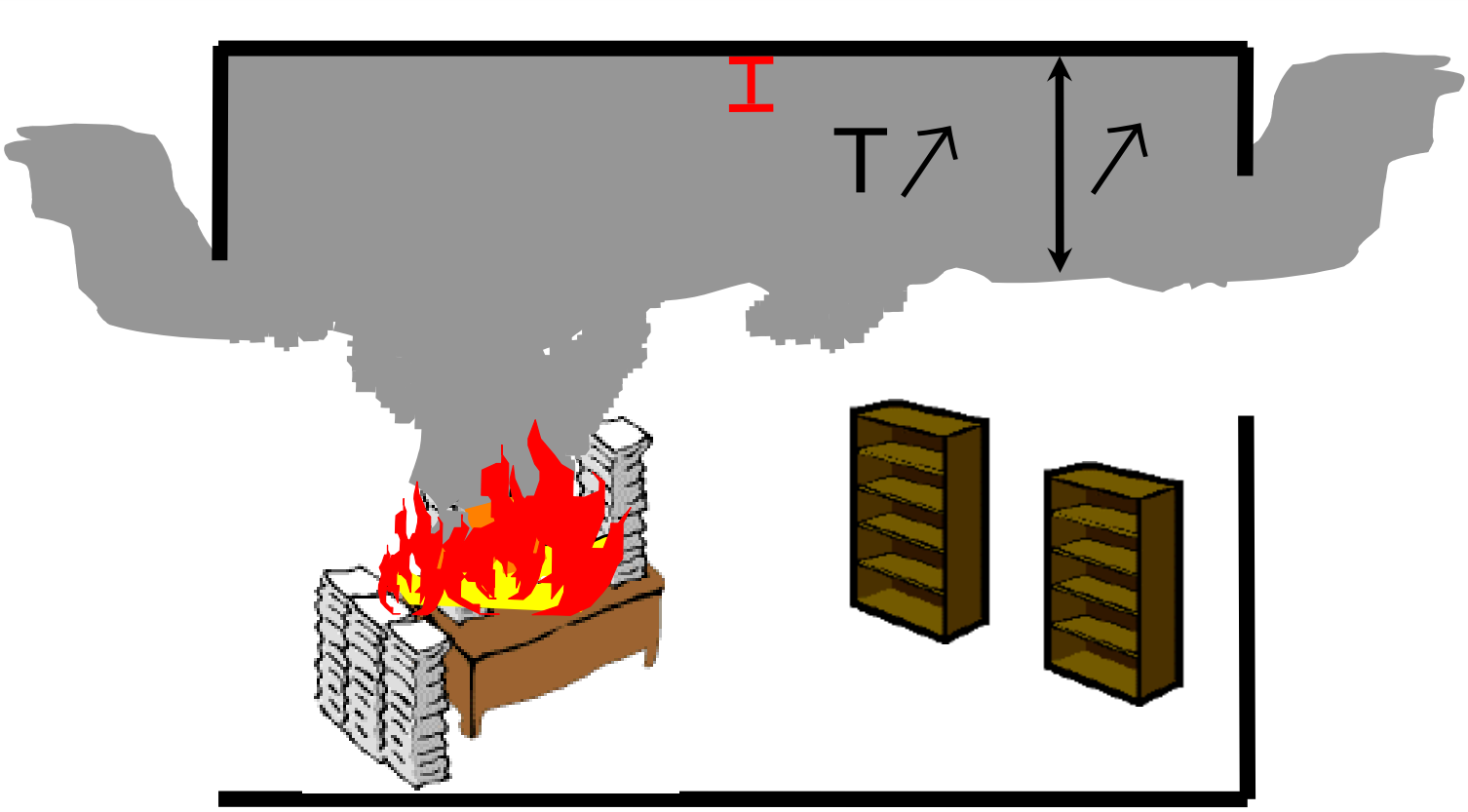
Ignition



Localised fire



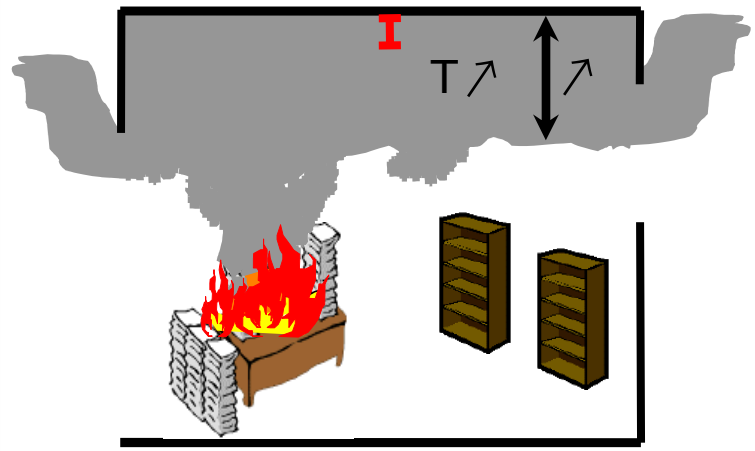
Growing of the localised fire

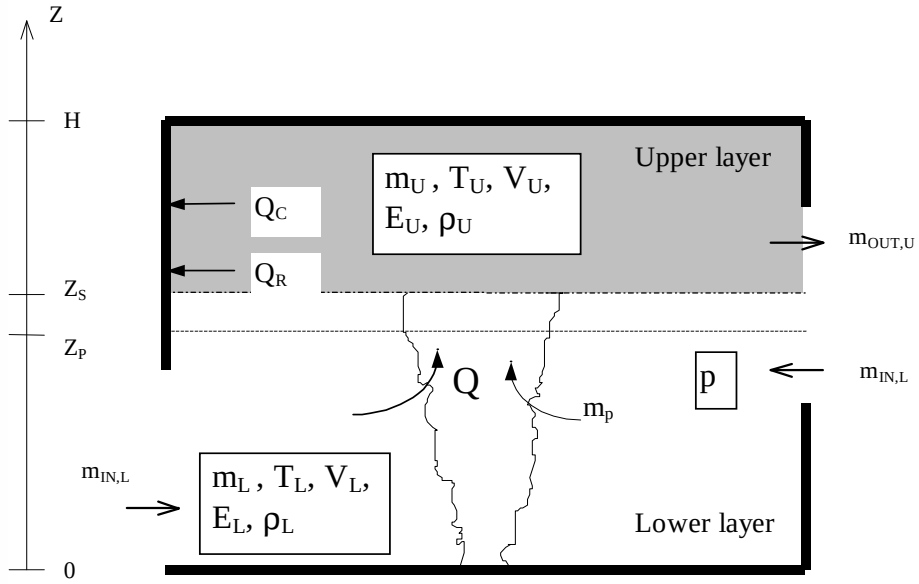


Ozone Theory: localised fire

→ Ozone Model

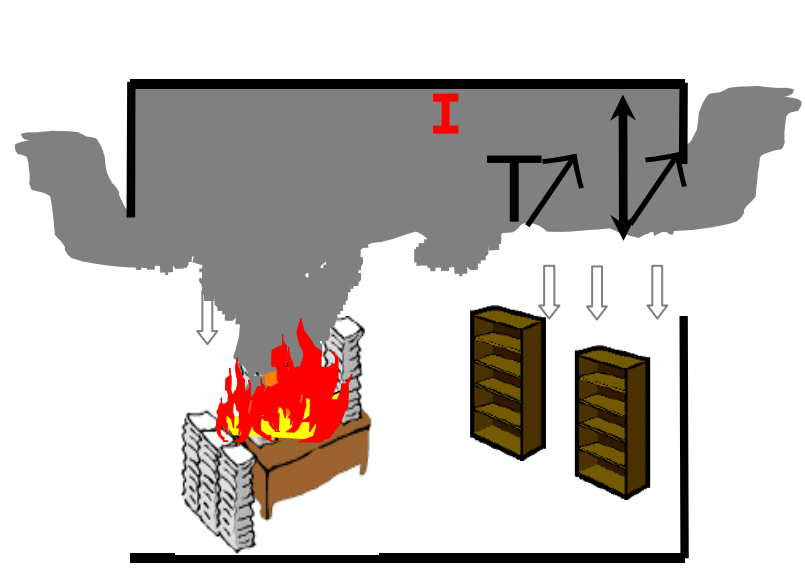
- Localised fire





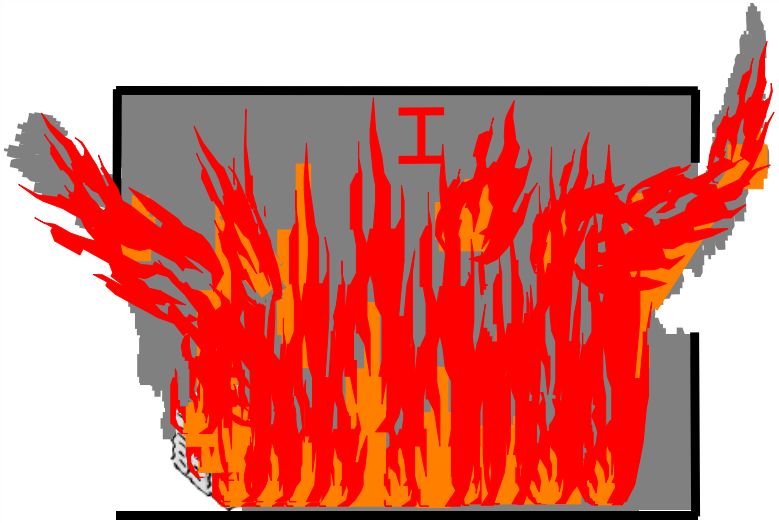
Ozone Theory:
Switch from 2 zones to 1 zone

- 2 ➔ 1 zone: if one of the following criteria is reached
  - T_{smoke} > 500 °C
  - Combustible material inside the smoke and T_{smoke} > 300 °C
  - Localised fire > 25 % of the total compartment surface
  - Smoke layer > 80 % of the compartment height

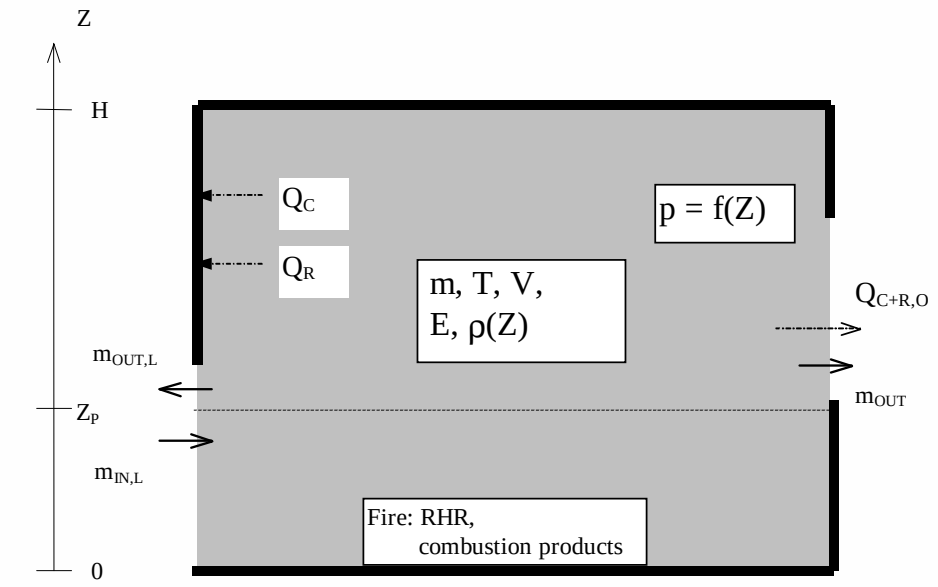


Ozone Theory:
Switch from 2 zones to 1 zone

- Fully engulfed fire



- Ozone Model



Large Compartment Test
Fire Load

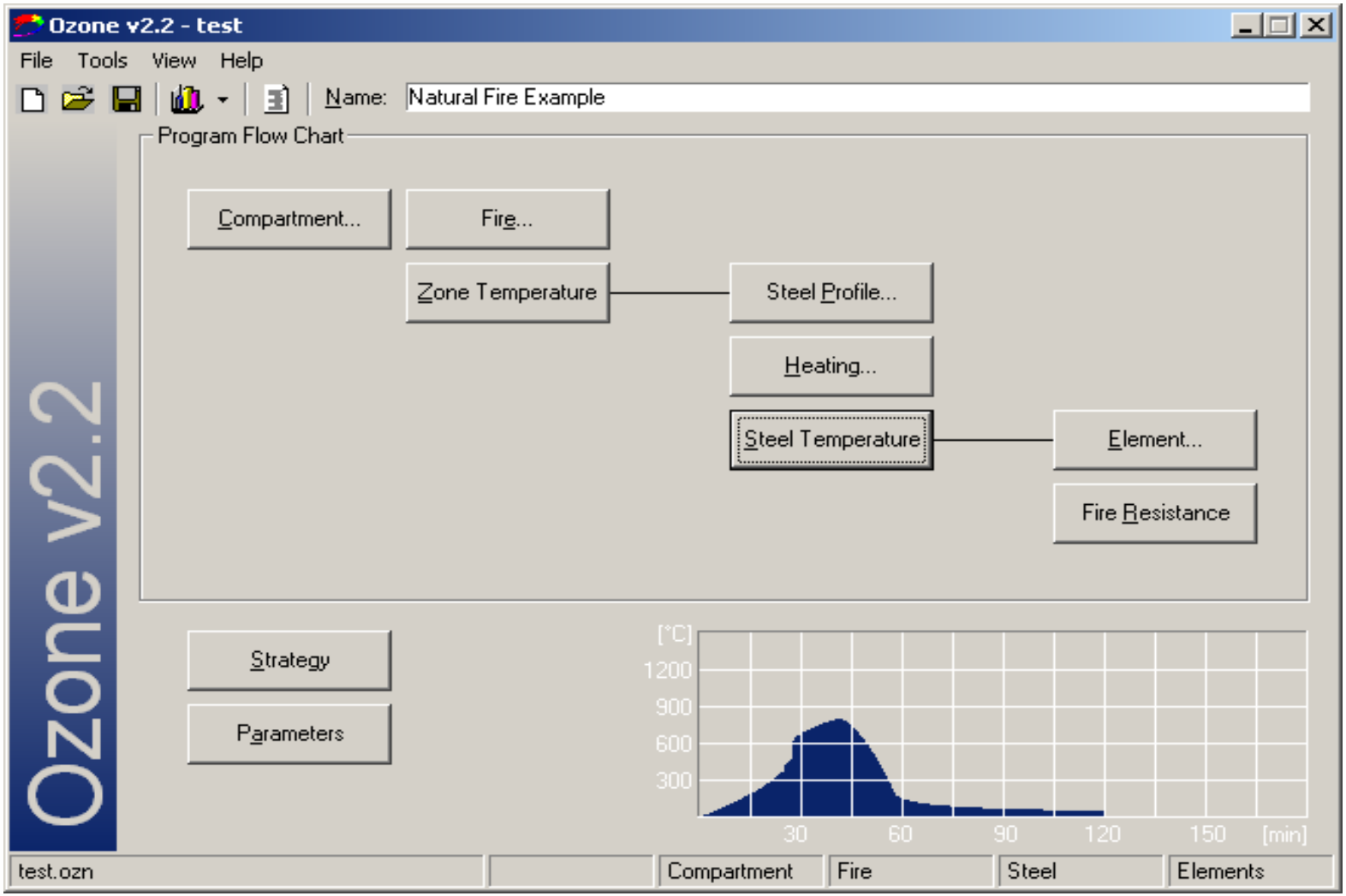
Large Compartment Test
External Flaming During the Test

Large Compartment Test
After the Test

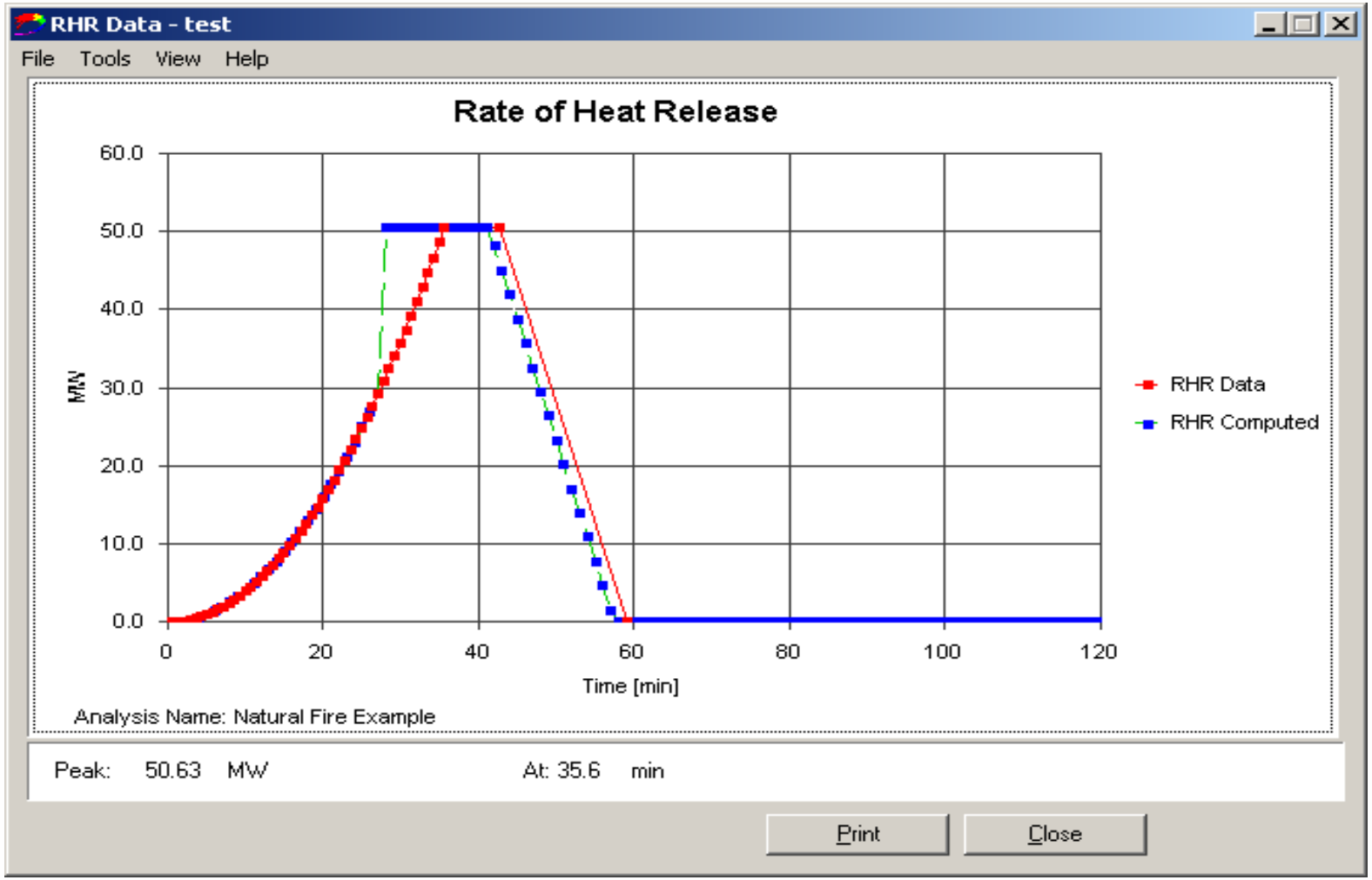

0


2
0

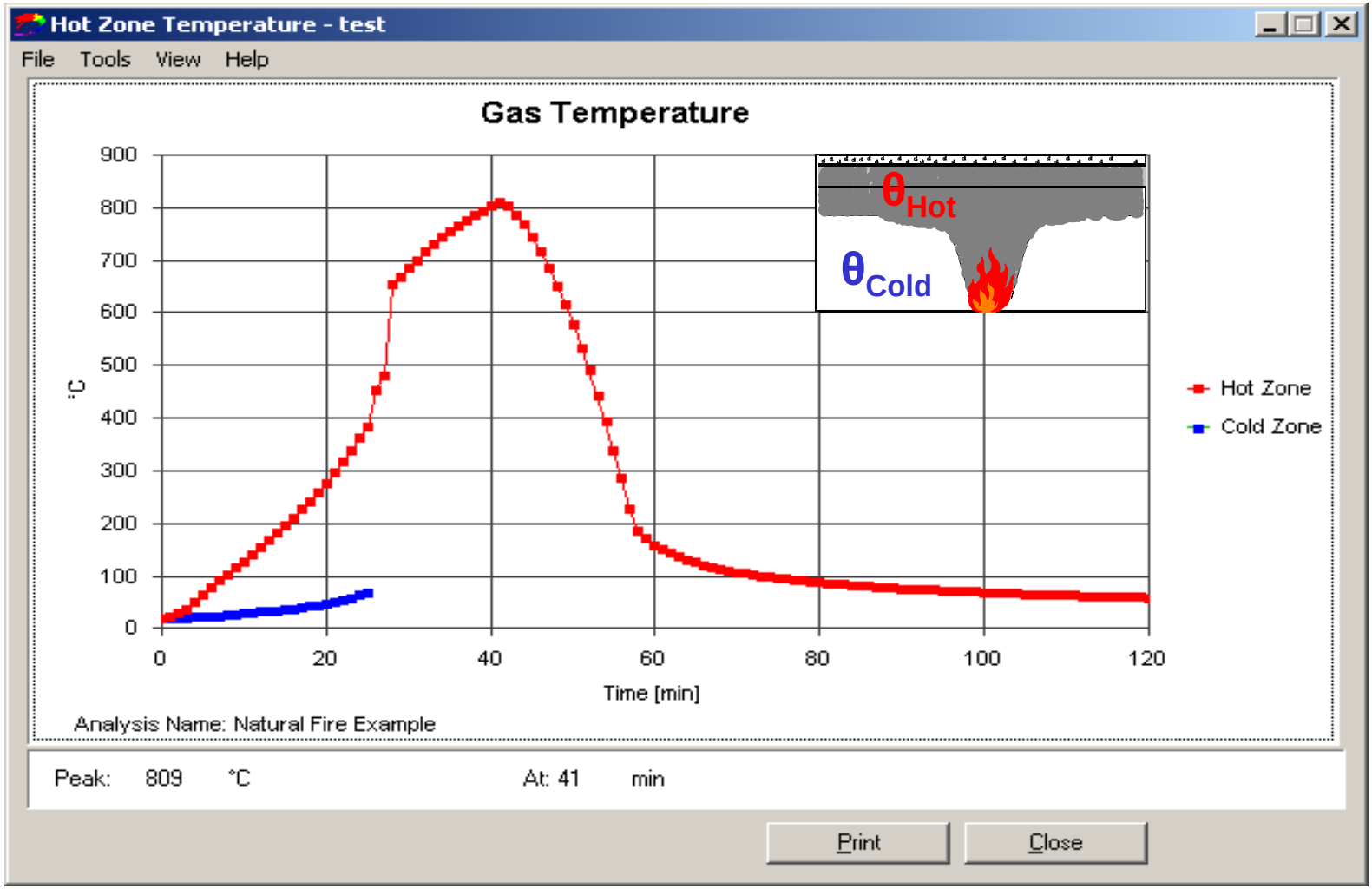
Two Zone Calculation Software “OZone V2.2”



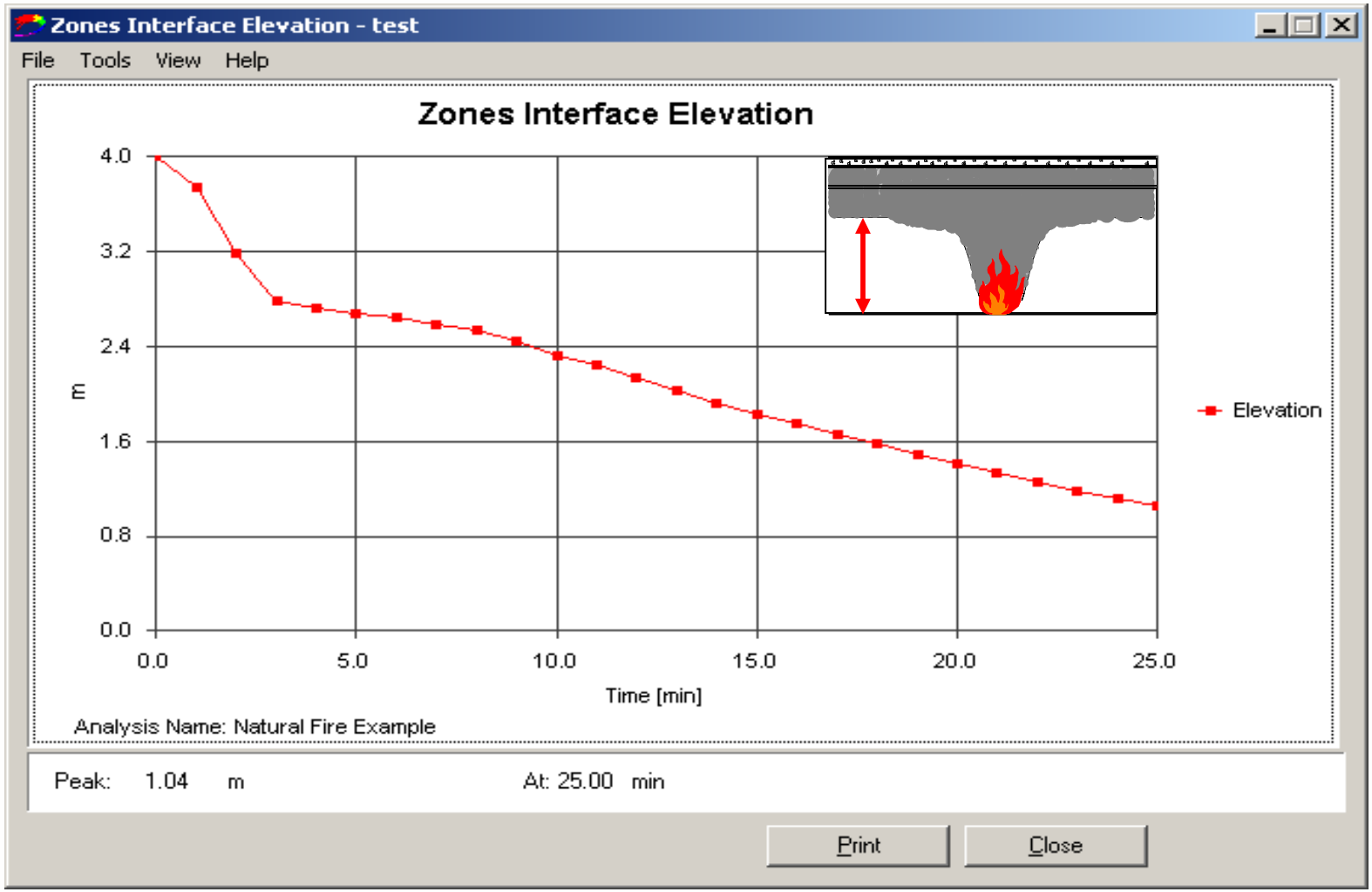
OZone results: Input and Computed RHR



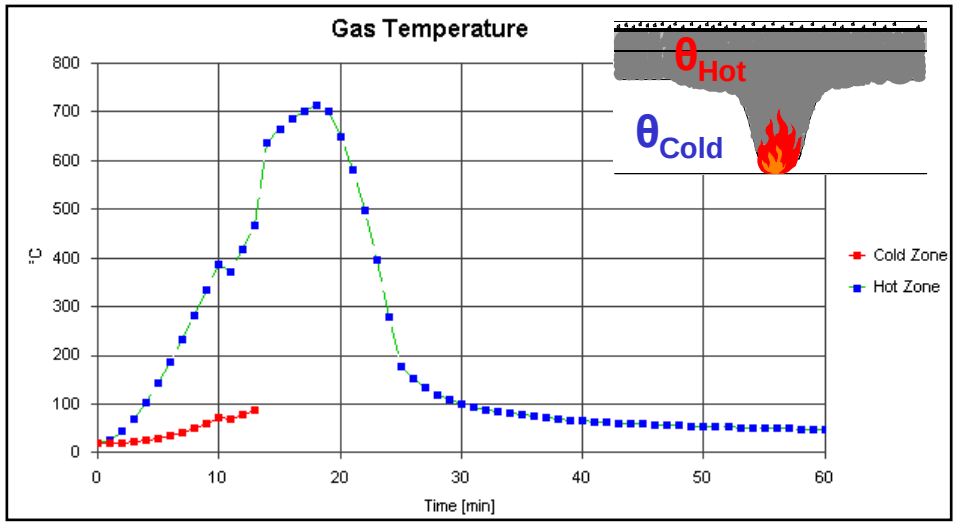
OZone results: Gas Temperatures

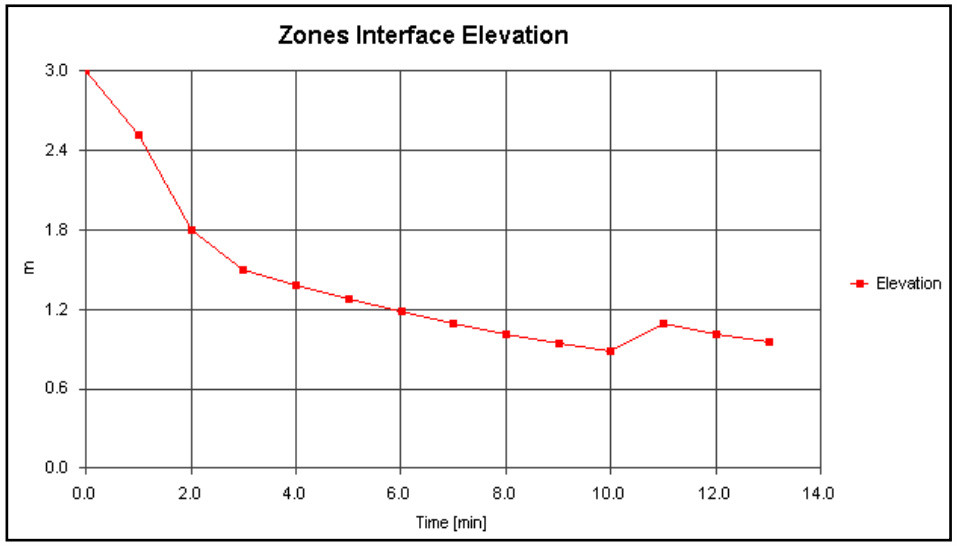


OZone results: Smoke Layer Thickness

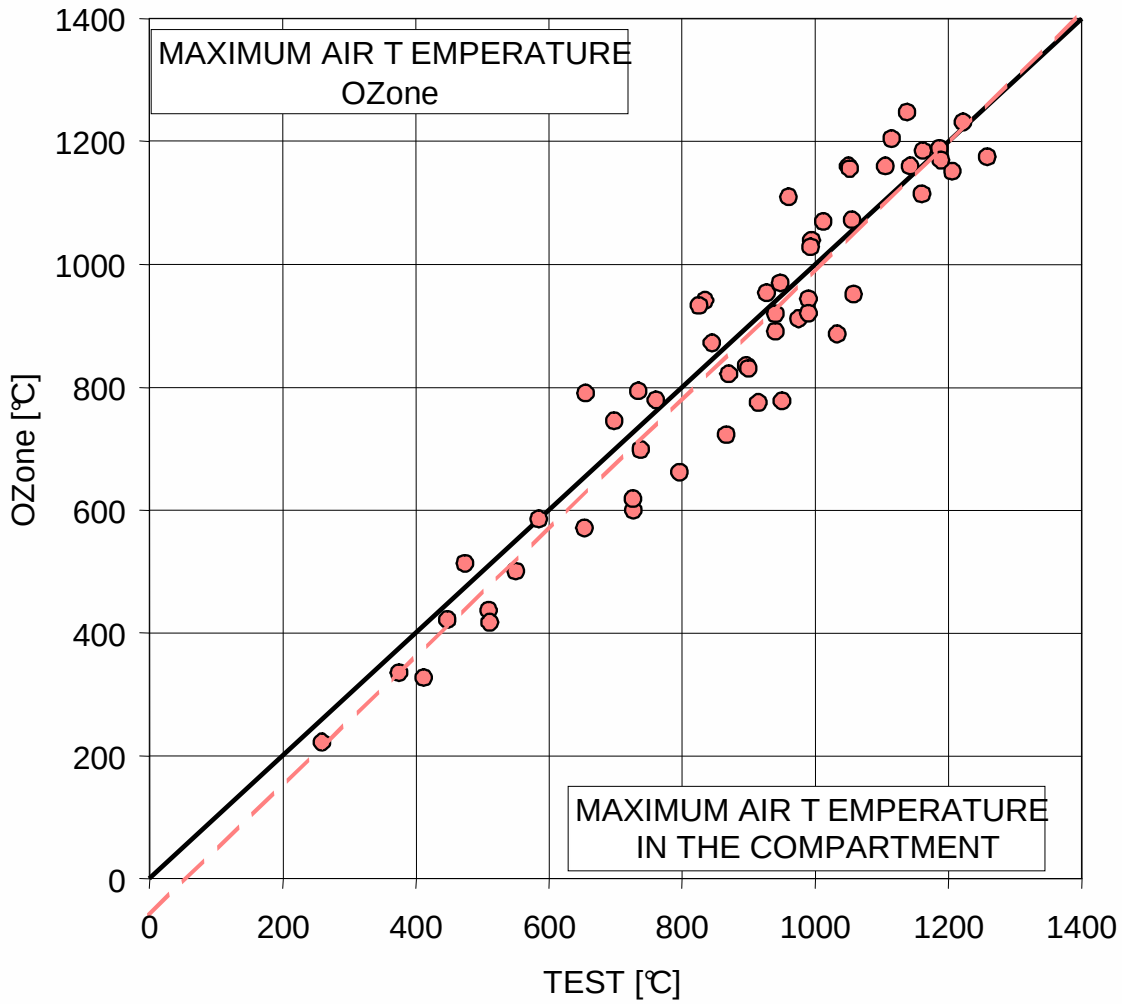


OZone results:

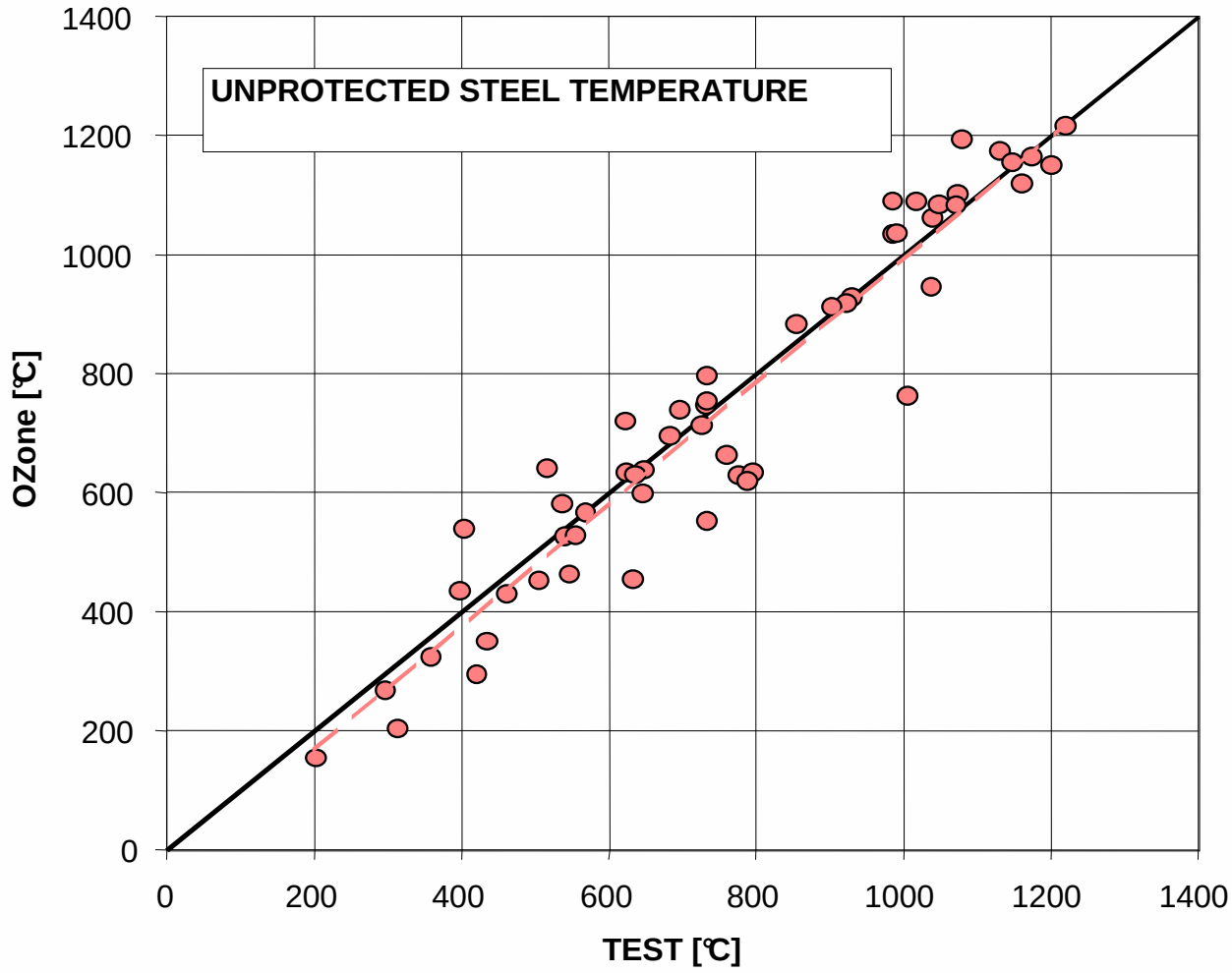




Calibration of Software OZone: Gas Temp

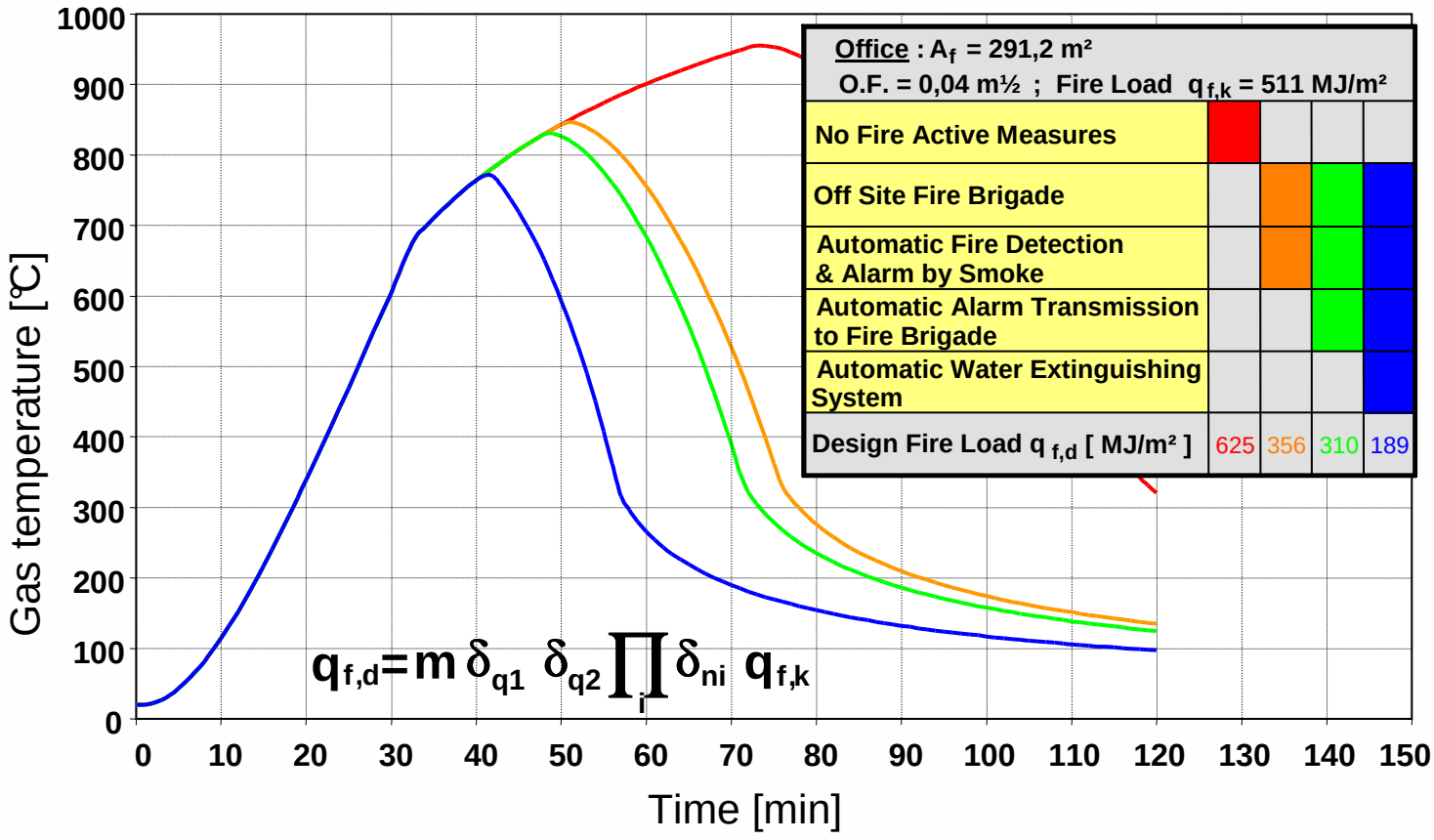


Calibration of Software OZone: Steel Temp

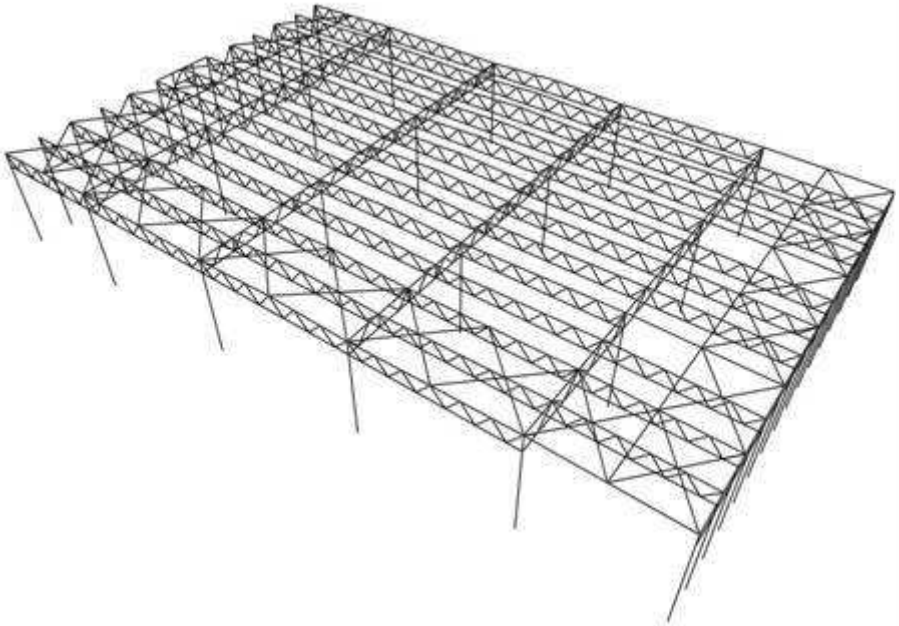


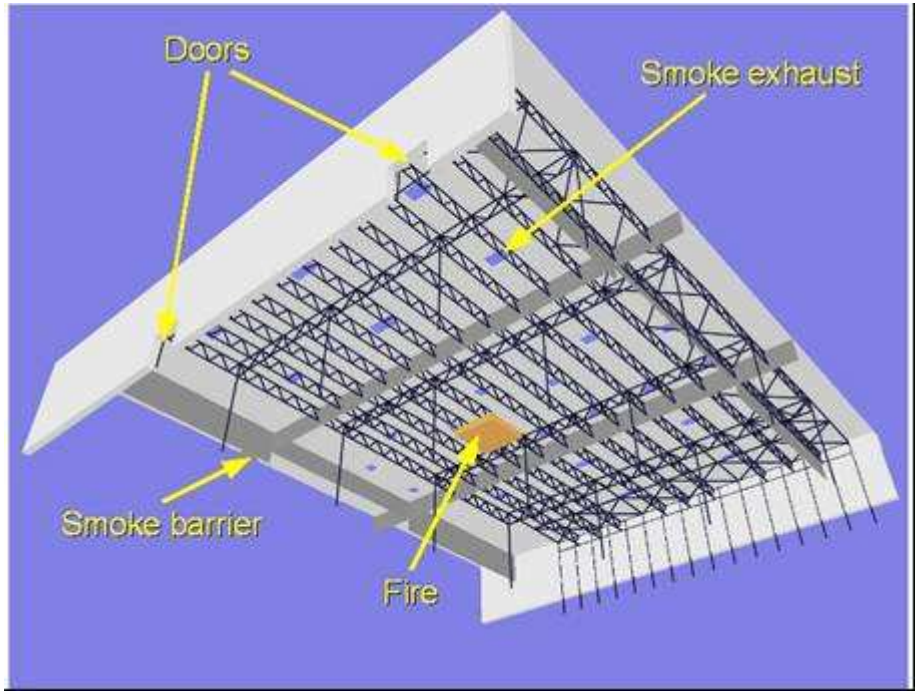
OZone: Case Study

Influence of the Actives Fire Safety Measures



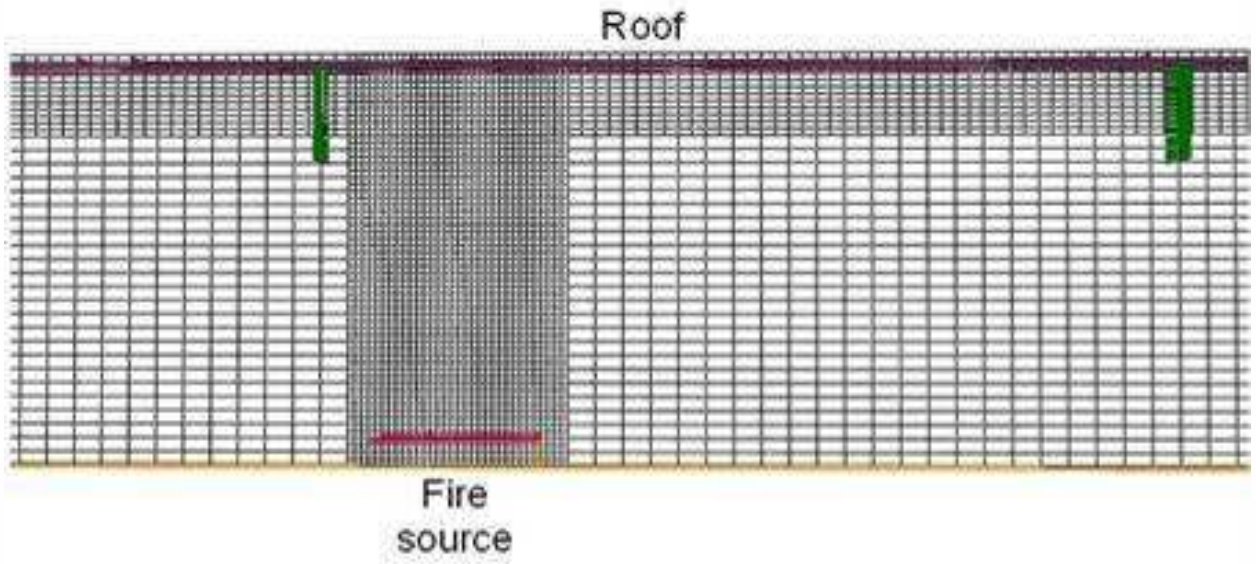
Computer Fluid Dynamics: Software FDS



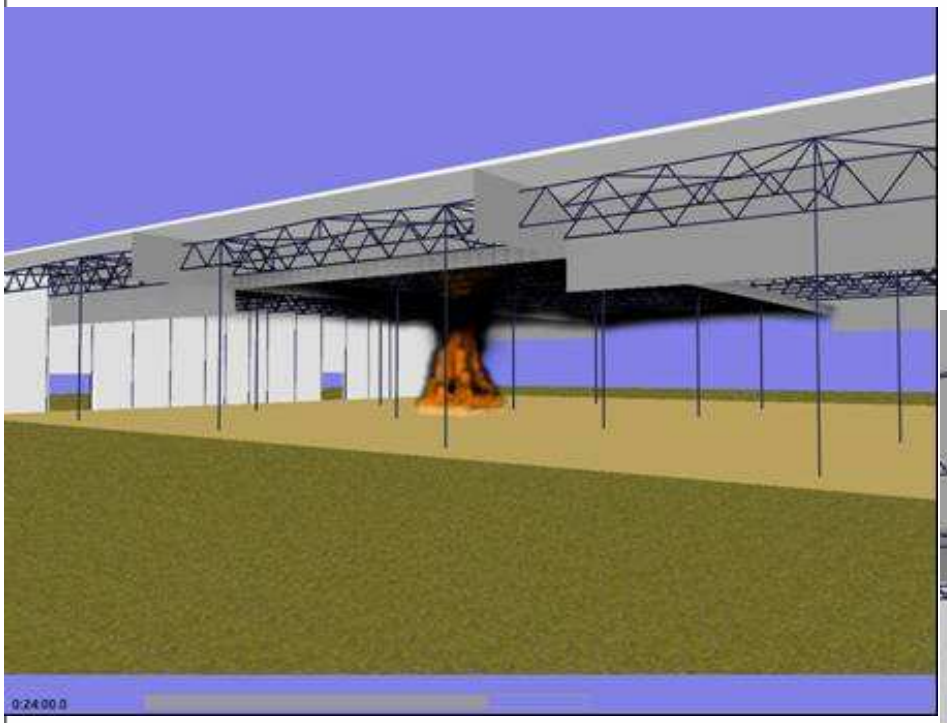


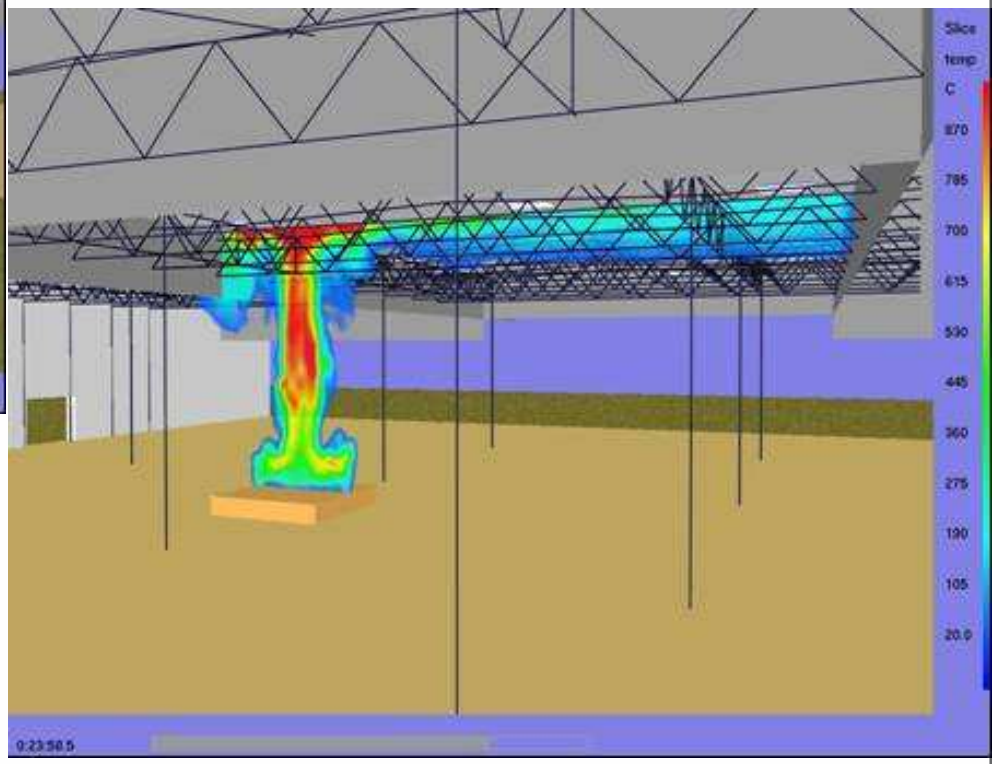
Computer Fluid Dynamics: Software FDS

Meshing de



FDS Resutls: Gas temperatures, smoke…





Thank you for your attention