

ADVANCED FIRE SAFETY ENGINEERING

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Aluejohtaja

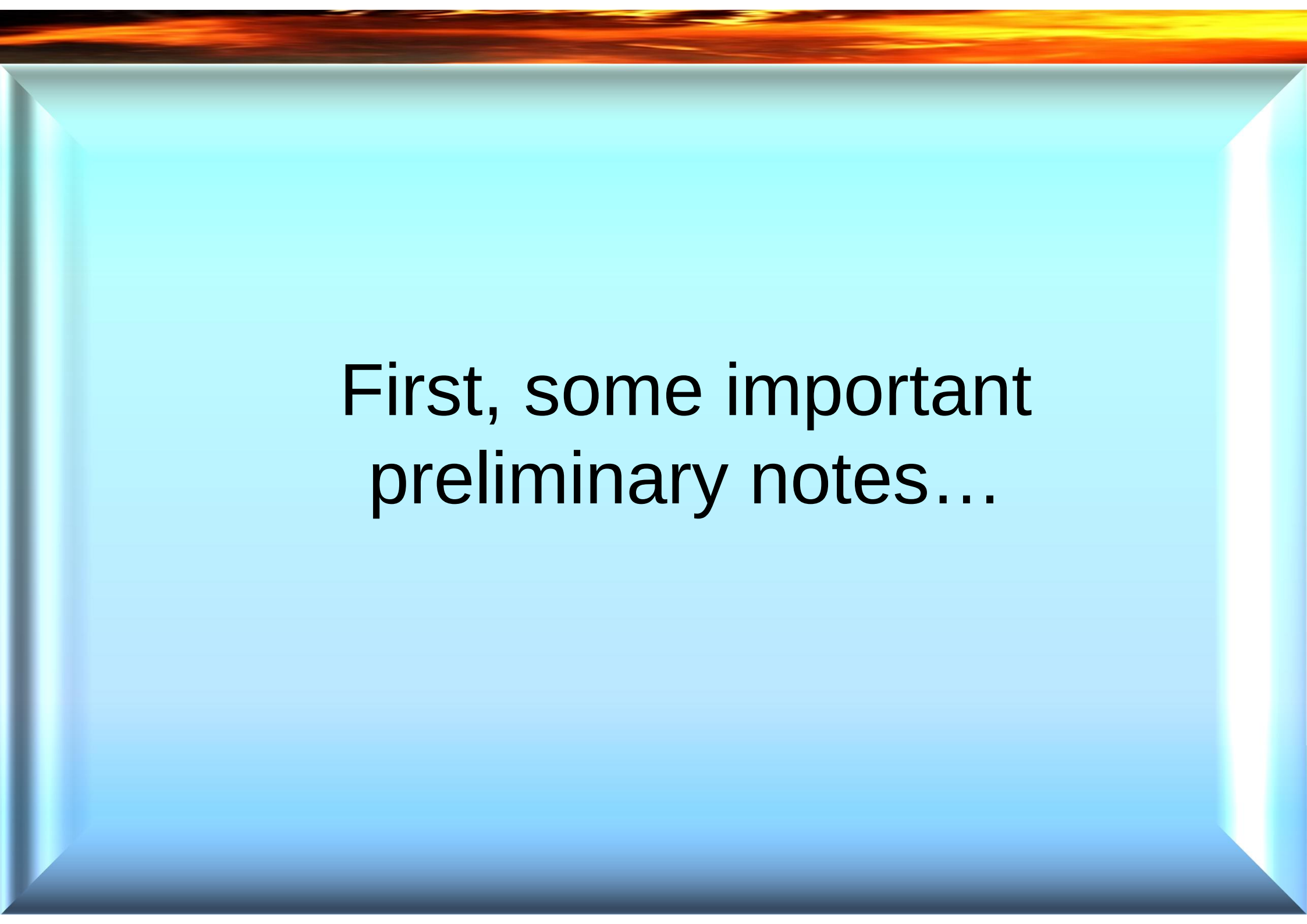
PALOTEKNINEN INSINÖÖRITOIMISTO MARKKU KAURIALA Oy

and the same in English....





ABOUT ROOM FIRE TEMPERATURES ...



First, some important
preliminary notes...

ADVANCED FIRE SAFETY ENGINEERING

- **FULFILS THE INTENT OF THE FIRE REGULATIONS – AND VERIFIES THAT THIS INDEED IS THE CASE**
 - protect people in the building and the fire fighters
 - prevent excessive spread of flames and smoke
 - eliminate fire spread to neighboring buildings
 - make sure that the structures maintain their load-bearing capacity and compartmentation ability (insulation & integrity)
 - safeguard property and environment

PERFORMANCE BASED APPROACH

- Drivers of performance-based design (acc. to Bisby, 2012)
 - Economic
 - Money savings from reduced fire protection or larger compartments
 - Architecture
 - Enables different architecture than prescriptive methods
 - Innovation
 - Ensures that new methods, materials or innovative designs are safe
 - Sustainability
 - Structural optimization
 - Safety
 - Provides at least “equivalent” safety compared to prescriptive methods

NIST in PALOLABORATORION ENTISEN JOHTAJAN, JACK SNELL in VISIO (2000)

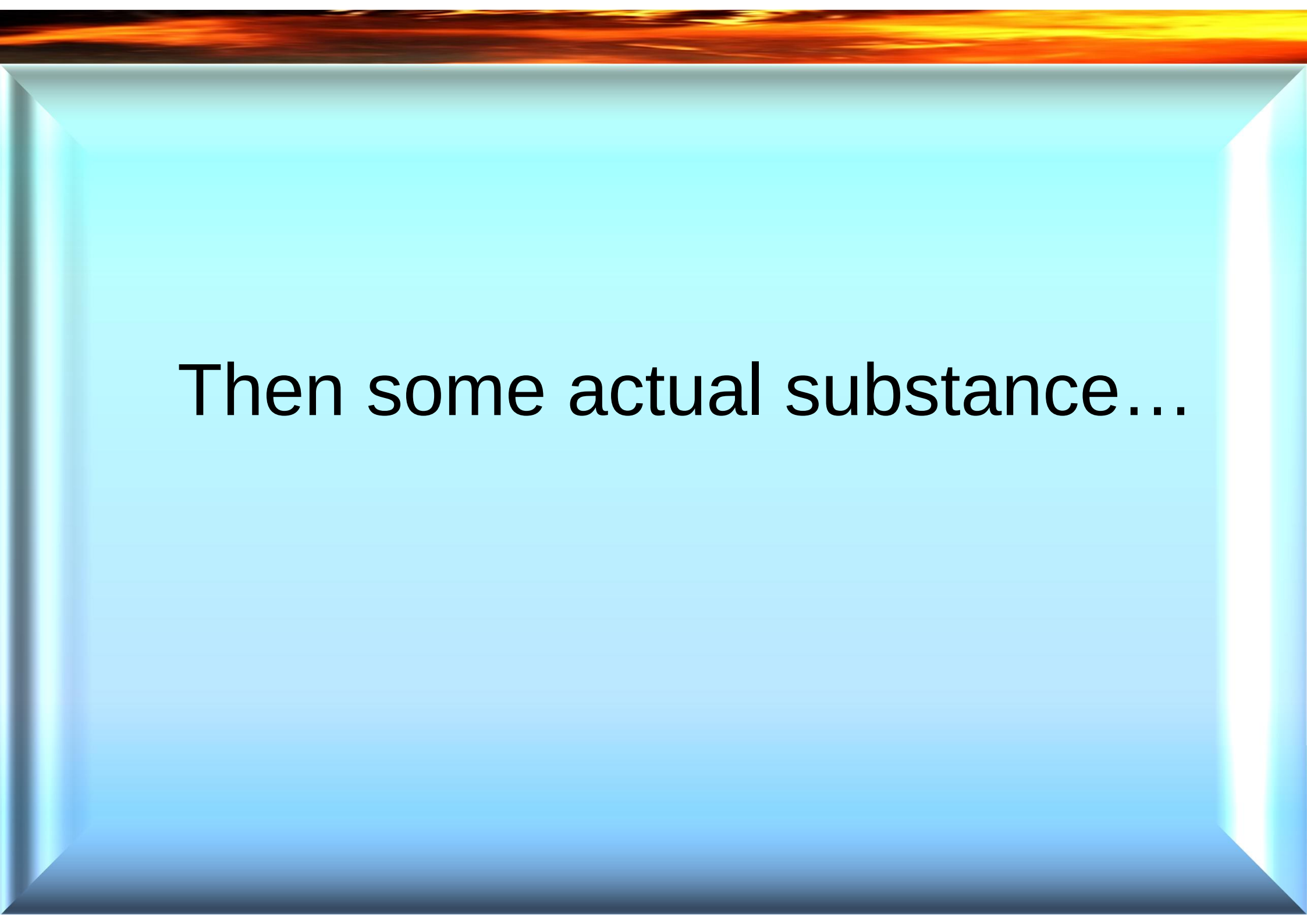
Vision

Ideally, one would like to apply human knowledge and ingenuity to minimize the hazard and risk of fire, so that dangerous fires are no more likely than, say, being struck by lightning.

History suggests two complementary and highly interrelated strategies. One is public knowledge and understanding of fire risk and what to do about it. The other, an enabler of the first, is to develop scientific knowledge and engineering disciplines of fire and fire safety.

Our vision for fire safety engineering builds on this point to include also the following:

Fire safety engineering becomes a science-based, academic discipline and engineering profession resulting in a proactive rather than reactive mindset regarding fire safety; so that cost-effective fire safety technologies become commercially available, and FSE is accepted globally as the basis for assured fire safety with the consequence that fire risk is understood and cost-effectively managed.



Then some actual substance...

ORIGINS OF ROOM-FIRE MODELLING

- The Standard Fire acc. to Leonard Y. Cooper & Kenneth D. Steckler, NISTIR 5842, 1996:
 - Historical evidence indicates that the standard temperature-time curve was prescribed in 1917 with very little knowledge of the levels and the temporal development of temperatures in actual room fires.
 - The standard curve was basically an idealization of temperature-time curves measured in furnaces at various laboratories; was deemed to represent a severe fire,
 - and was intended only to provide a basis for comparing the fire endurance of building assemblies using a simple test.
 - Full-scale room burnout tests conducted at the National Bureau of Standards in the 1920s established that the actual temperature histories of room fires differed significantly from the standard curve.
- Summary:
 - A simple practical solution to tackle the fire-related problems of the rapidly growing mega-cities in the USA

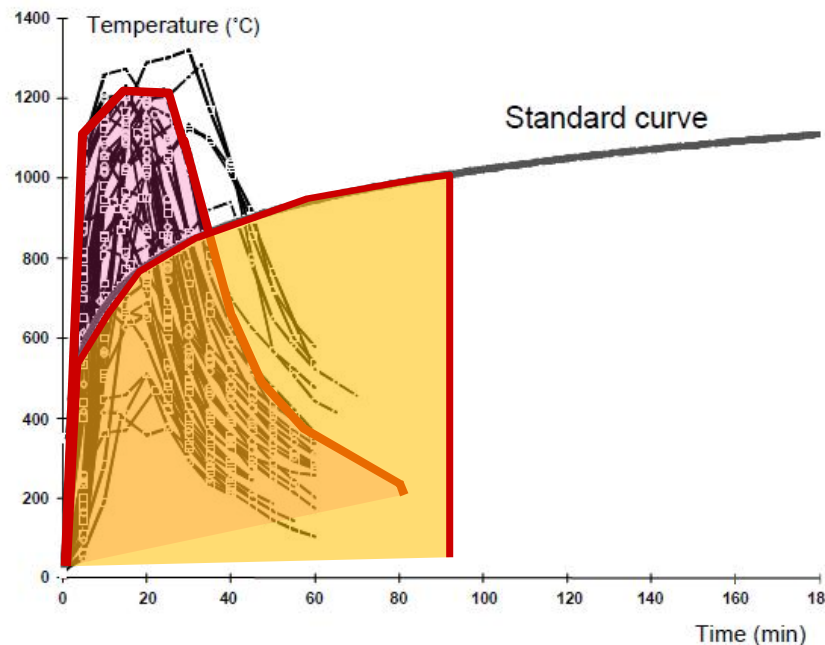
STANDARD FIRE, OOP-S... AND CLOSE SAVE...

- 5 years after its introduction, in 1922, Ingberg et al. noticed that the standard fire failed to describe most burning test data
- But Ingberg “saved” the standard fire by introducing the concept of equivalent areas

**THIS IS BAD, PITIFUL
ACTUALLY!!**

**THEY “FORGOT”
RADIATION $\sim T^4$**

**YET, THERE IS ALSO
SOMETHING FUNNY:
THIS GIMMICK CAN
ACTUALLY BE FOUND
IN THE EUROCODE
EN1991-1-2**



DATA SHOWN: Daniel Joyeux. 2002.
Experimental investigation of fire door
behavior during a natural fire. Fire
Safety Journal 37 (2002) 605–614

Fig. 1. Temperature-time curves from experimental tests.

- **OUTCOME:**
 - Publication “Ingberg, S.H., *Tests of the Severity of Building Fires, NFPA Quarterly, Vol 22, pp. 43-61, July 1928*” fixed the standard fire as the room fire model

ORIGINS OF ROOM-FIRE MODELLING, cnt'd

- Kuno Kawagoe, Japan, 1950's:
 - or: Prof. Ptchelintsev of the Moscow Academy of Sciences, 1952
 - Beyond the standard-fire approximation
 - The Classical Burning Rate Expression:

$$R = (5.5 - 6.0) A \sqrt{H} \text{ (Kg/min)}$$

- And Acknowledging that There can be Only a Limited Amount of Stuff that can Burn – i.e., Fire Load – in a Room

when the Fire Load is consumed,
the temperature starts to fall

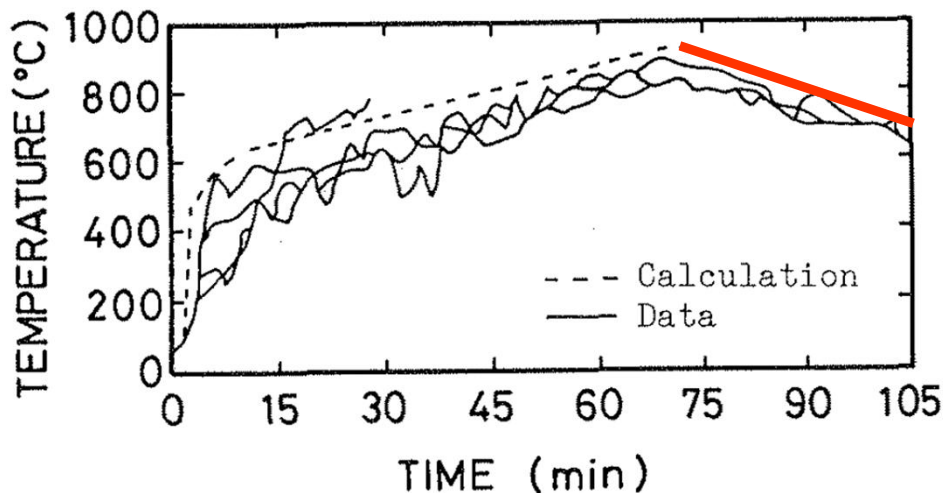
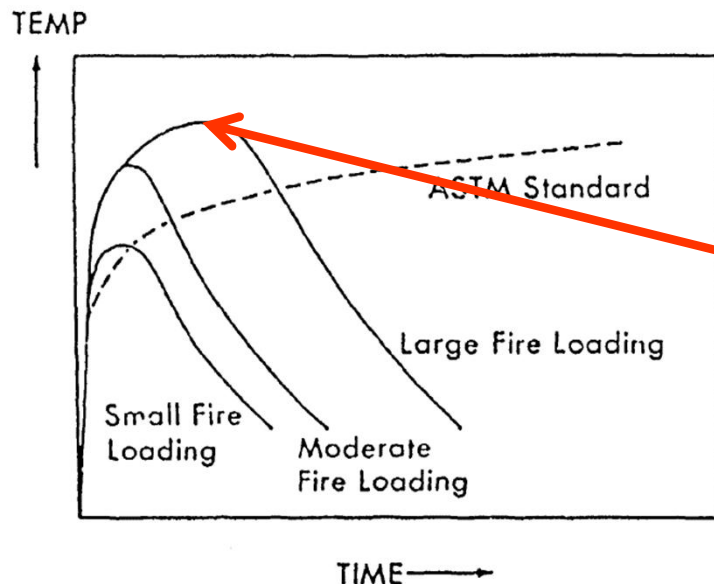


Figure 1

Estimation of time
temperature curve.

ORIGINS OF ROOM-FIRE MODELLING, cnt'd

- OK, but what is the temperature?
 - Determined from empirical curves, for example



Seigel, L.G., The Severity of Fires in Steel Framed Buildings, Behavior of Structural Steel in Fire Symposium No. 2, Proceedings of a Symposium held at the Fire Research Station, Boreham Wood, Herts, January 24, 1967, Her Majesty's Stationery Office, pp. 57-63, 1968.

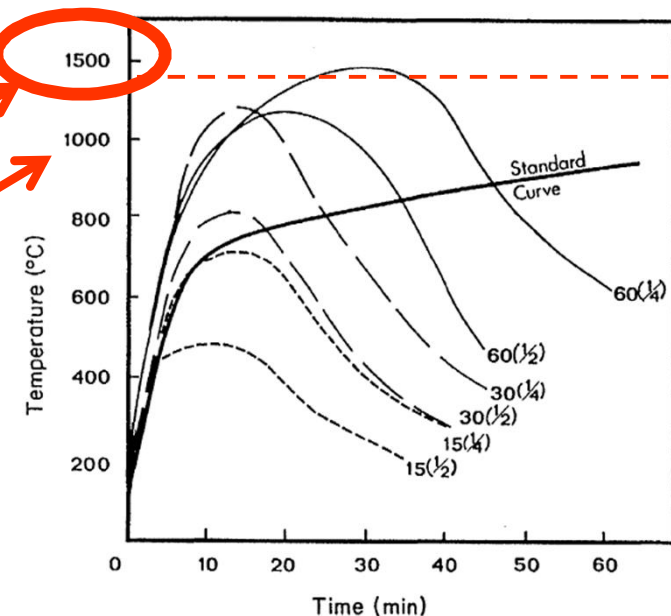
How high will T rise?

How high can T rise?

Butcher, E.G, Chitty, T.B., and Ashton, L.A., The Temperature Attained by Steel in Building Fires, Fire Research Technical Paper No. 15, H.M. Stationery Office, London, 1966..

Some data show 1500 °C, OK?

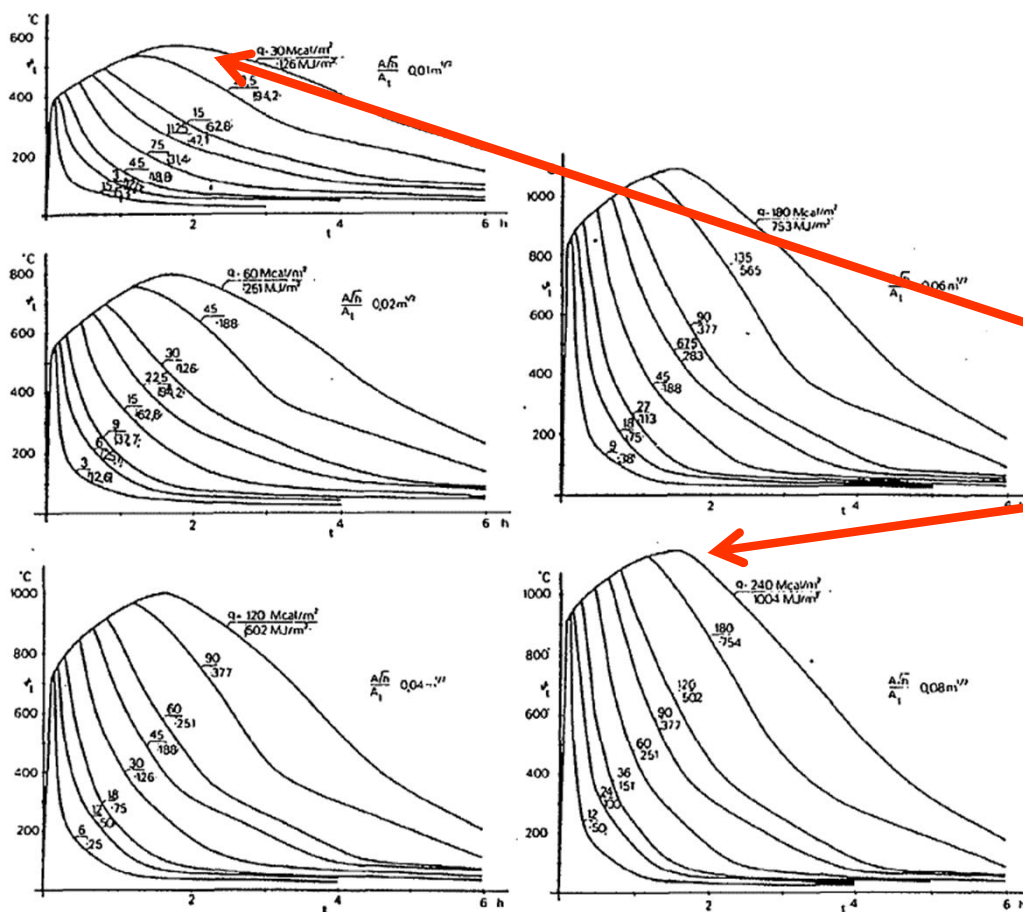
NOPE... for a psychic reasons, not physical one...



ORIGINS OF ROOM-FIRE MODELLING, cnt'd

- OK, still waiting for the temperature...
 - ǒ And the answer still is empirical curves, or semi-empirical curves such the Swedish Curves from 1960' re-incarnated as Eurocode parametric fire

ǒ There are actually Finnish Curves – much better ones, of course J - It is easy since all it takes is to write down the room energy budget and solve it for the temperature



From 600 $^{\circ}\text{C}$ to ...

1200 $^{\circ}\text{C}$

Pettersson, O. , Magnusson, S. , and Thor, J. , Fire Engineering Design of Steel Structures, Publication 50, Swedish Institute of Steel Construction, Stockholm, Sweden, 1976.

Magnusson, S.E. and Thelandersson, S., Temperature-Time Curves of Complete Process of Fire Development -- Theoretical Study of Wood Fires in Enclosed Spaces, Acta Polytechnica Scandinavica, Civil Engineering and Construction Series, No. 65, Stockholm, 1970.

COMPLETED UNDERSTANDING OF ROOM-FIRES?

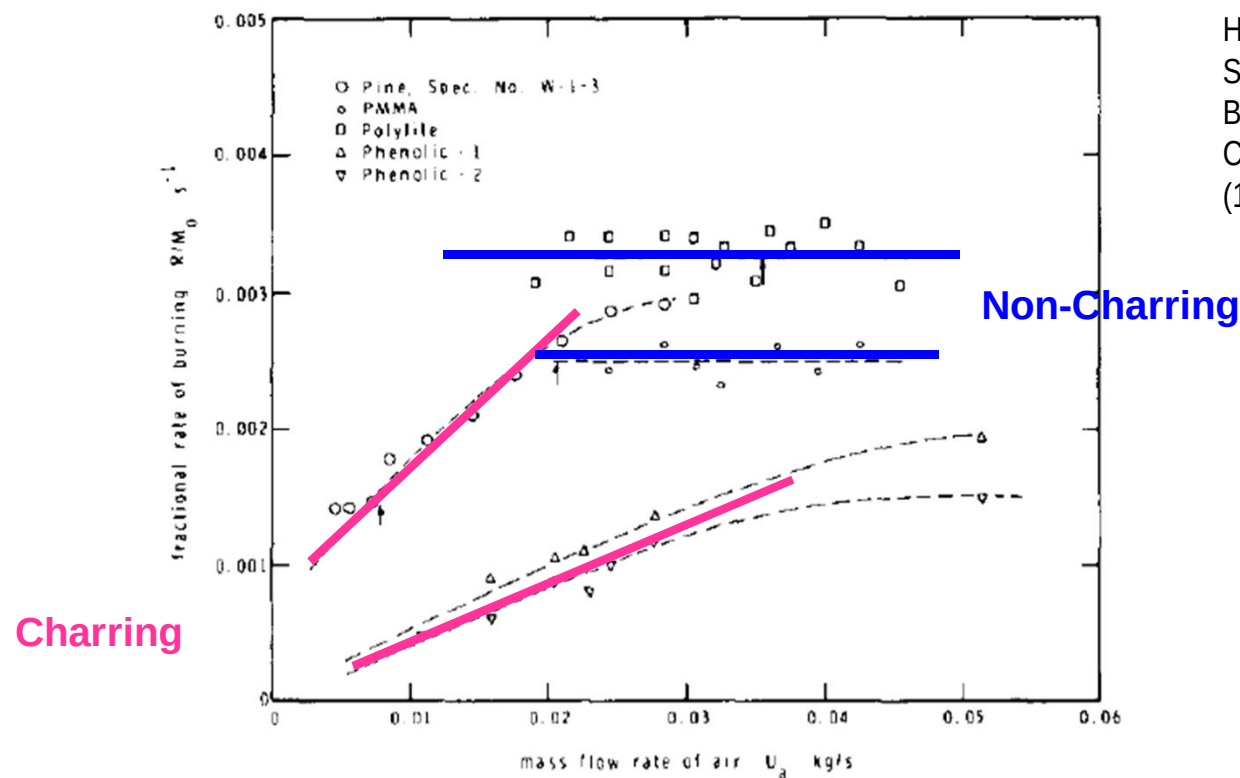
- The receipt seems complete:
 - We have a room with certain Fire Load Density (FLD) q'' [MJ/m²]
 - With the known FLD-normalization area A_{FLD} [m²] we have the total Fire Load [MJ]
 $Q = A_{FLD} \times q''$
 - The Fire Load is consumed at a rate $\dot{Q} = R \times DH_{c,eff}$ [MW]
 - ... and the burnout of the Fire Load takes time $Dt = Q/\dot{Q}$ [s]
 - ... and the max. temperature is a given function of the FLD q''
 and the ventilation described by $A_v H_v^{1/2}$ [m^{5/2}] – or more appropriately as a
 flow rate $A_v (g \check{z} H_v)^{1/2}$ [m³/s]

PERHAPS NOT...

- The basic assumption is in fact quite questionable:
 - why the burning rate should depend solely on the flow of oxygen into the room, i.e., $R \sim A_v(gH_v)^{1/2}$
 - as we know that the rate of thermal composition and, hence, the rate of burning depends on the heat exposure of the fire load, i.e., $R \sim \exp(-E/RT)$
 where T is the temperature of the decomposing fire load, which in a fully developed room fire depends mainly on the radiative heating
 $\dot{q}''_{\text{tot}} = \dot{q}''_c + \dot{q}''_r \gg \dot{q}''_{\text{rad}}$
 where
 $\dot{q}''_{\text{rad}} = \epsilon \sigma (T_r^4 - T^4)$
- So, why $\exp(-E/RT) \sim A_v(gH_v)^{1/2}$?
- The answer is that it depends on the burning material

PERHAPS NOT...

- For charring fuels $R \sim A_v(gH_v)^{1/2}$ while for non-charring fuels R is quite independent of ventilation



HARMATHY, T. Z. 1978. Experimental Study on the Effect of Ventilation on the Burning of Piles of Solid Fuels. COMBUSTION AND FLAME 31,259-264 (1978)

Fig. 4. Effect of ventilation on rate of burning (change of mass) of cribs.

EXPLANATION

- Actually the correct relation is $R \propto A_v(gH_v)^{1/2}$
with the meaning that burning rate R generates a flow $A_v(gH_v)^{1/2}$
- This is due to fact that in the presence of fire-generated gas-density difference **gravity** will inevitably generate a buoyancy-driven flow in the room openings
 δ and this flow rate will increase as the burning rate increases

DAS ENDLÖSUNG...

- Here's **Harmathy's** explanation for the difference between charring and non-charring fuels:

Harmathy, T. Z. 1979. EFFECT OF THE NATURE OF FUEL ON THE CHARACTERISTICS OF FULLY DEVELOPED COMPARTMENT FIRES. Fire and Materials. Vol. 3, No. 1, March 1979. Pp. 49-60

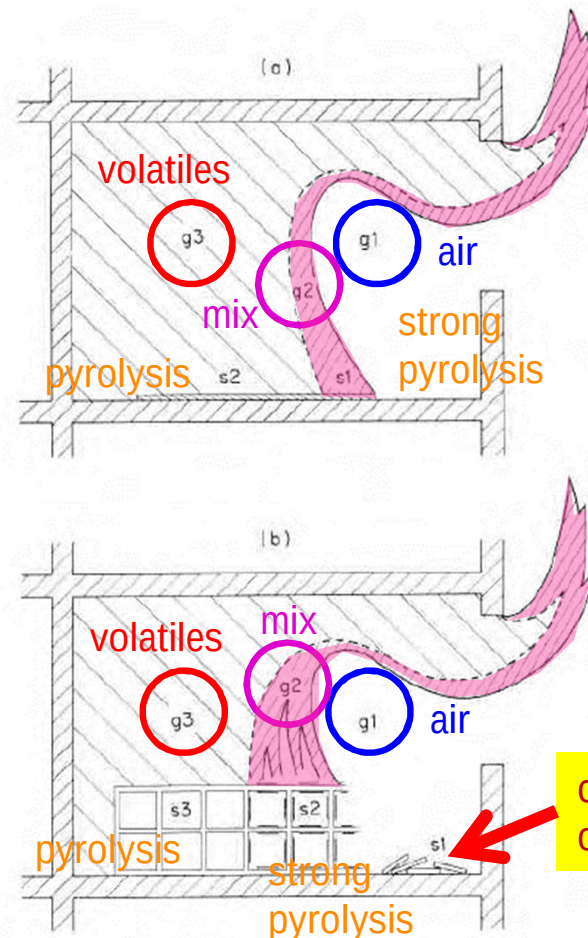


Figure 2. Modeling of fully developed compartment fires. (a) Pool fires of liquids and quasi-liquids; (b) pile fires of char-forming fuels.

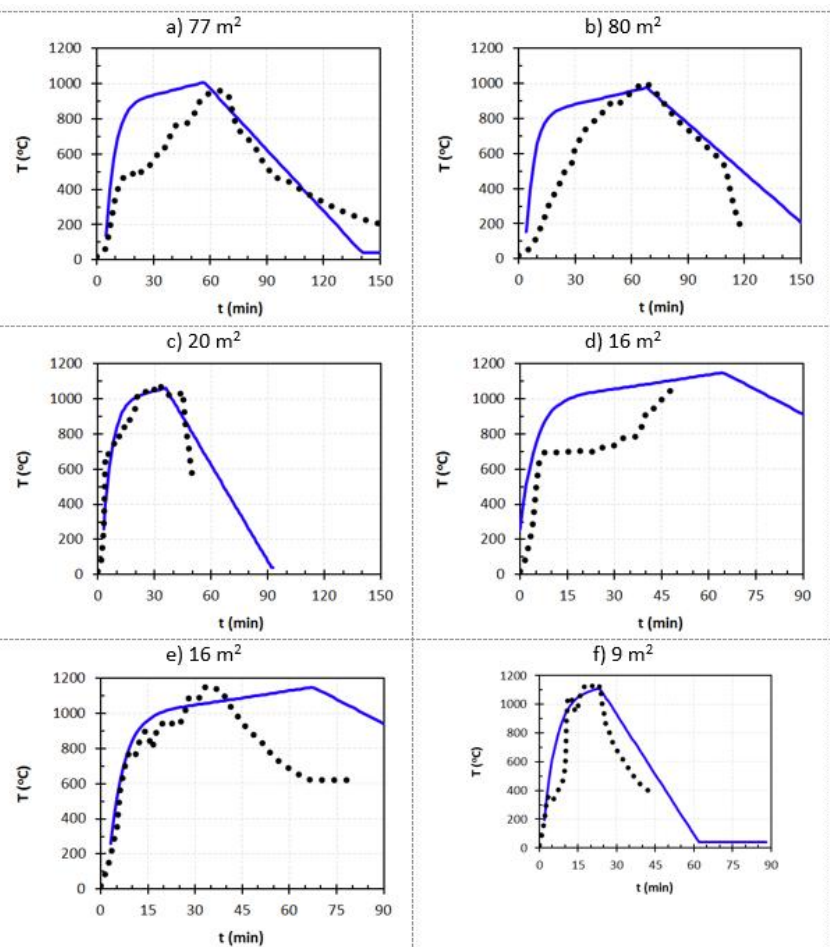


Implementation in design

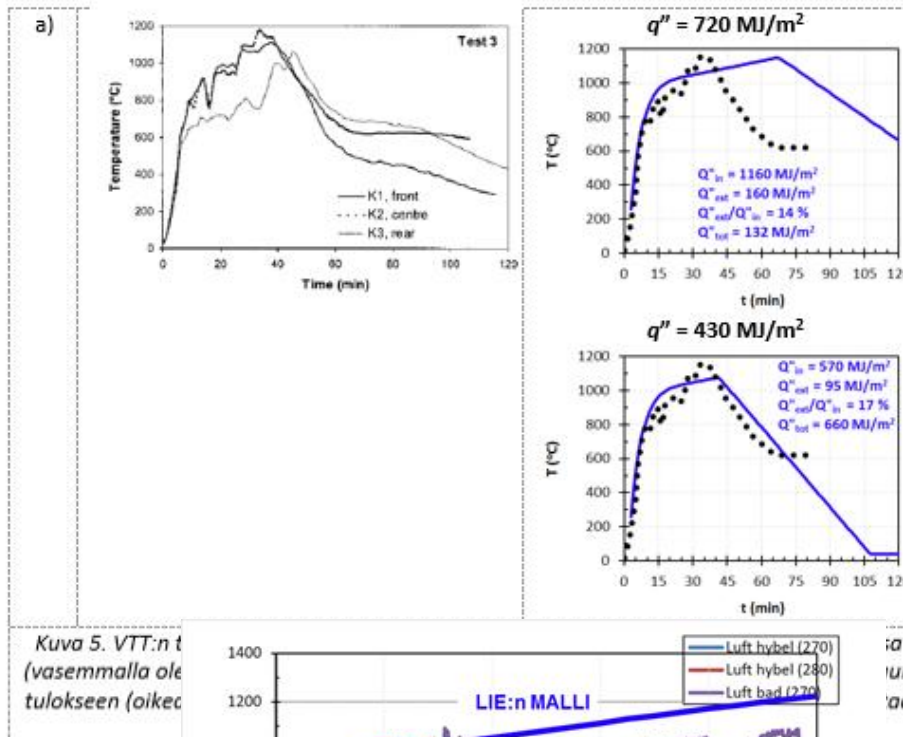
WE AT MK Ltd HAVE RE-VIVED THE ROOM-FIRE TEMPERATURE MODEL DEVELOPED IN CANADA IN THE 1960' & 1970's BY HARMATHY & LIE

- THIS MEANS THAT:
- **1) WE HAVE VALIDATED THIS MODEL**
 - VALIDATION = SUCCESFULL COMPARISON TO DATA
- **2) APPLIED IT TO DESIGN OF FIRE SAFE WOODEN BUILDINGS**

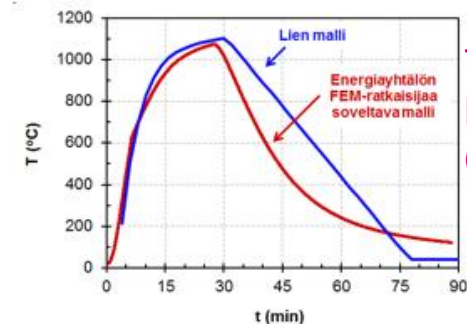
VALIDATION EXAMPLES



Kuva 2. Huonepalon laskentamallin validointi: a) Cardingtonin British Steel -koe, b) Euroconnection test, c) ETH Zürichin huonepalokoe, d) VTT:n huonepalokoe (Hakkarainen, testi 1), e) VTT:n huonepalokoe (Hakkarainen, testi 3) ja f) VTT:n julkisivukoelaitteella tehty koe.

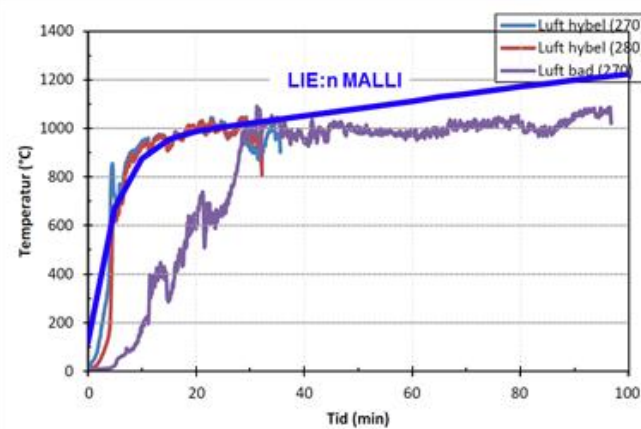


Kuva 5. VTT:n tulokseen (vasemmalla oleva tulokseen (oikea)



THE FINNISH CURVE

...ruostuvan huonepalomallin tulokseen.



CLT: SP Fire Research SA

APPLYING:

Dr. Salminen

KIITOKSET MINUN PUOLESTANI!