Assessment of Intumescent Coatings Using the Differential Equation Analysis for the Steel in Fire Forum (StiFF)

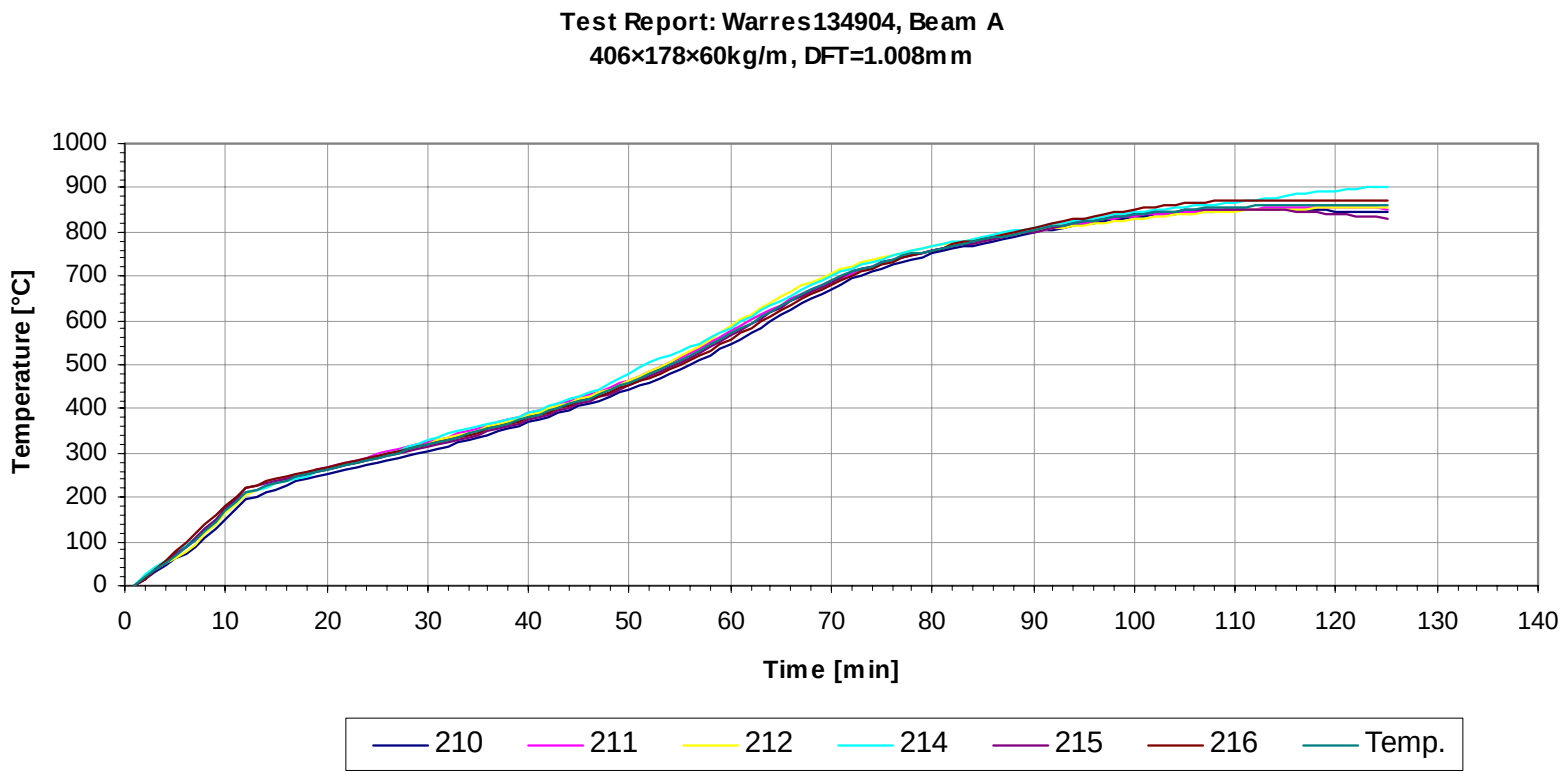
BY

Hans van de Weijgert MSc MIFireE MBEng
Senior Consultant

INTERNATIONAL FIRE CONSULTANTS LTD
20 Park Street
Princes Risborough
Buckinghamshire
HP27 9AH - UK
Tel: + 44 (0)1844 275500
Fax: + 44(0)1844 274002

Overview Test Results

Specimen with good performance



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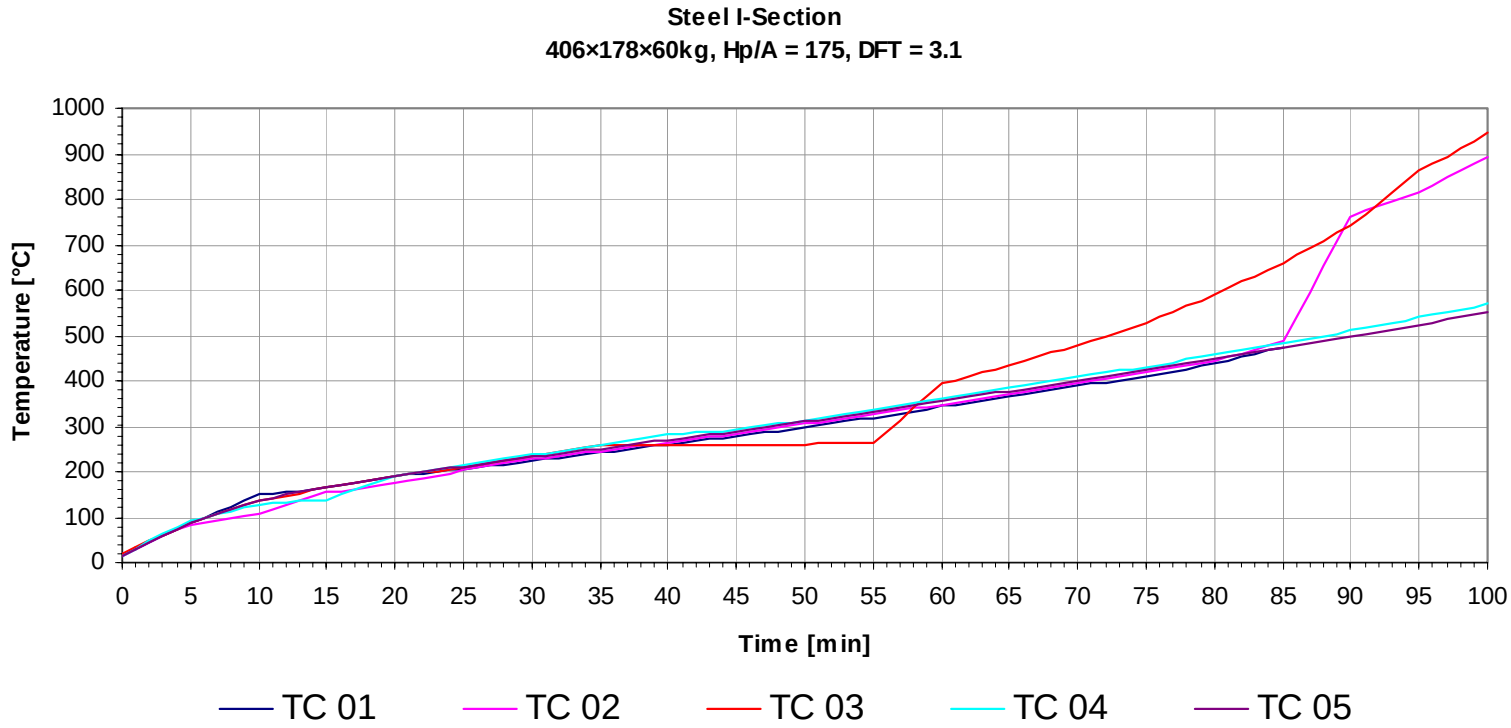
Overview Test Results

Specimen with bad performance



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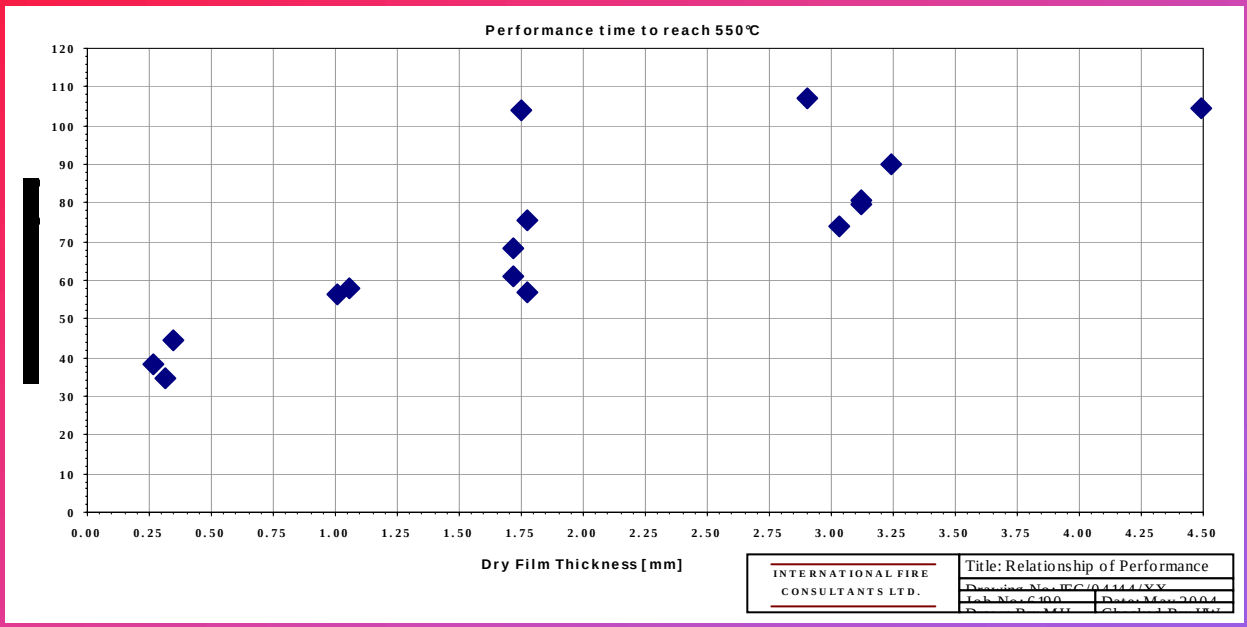
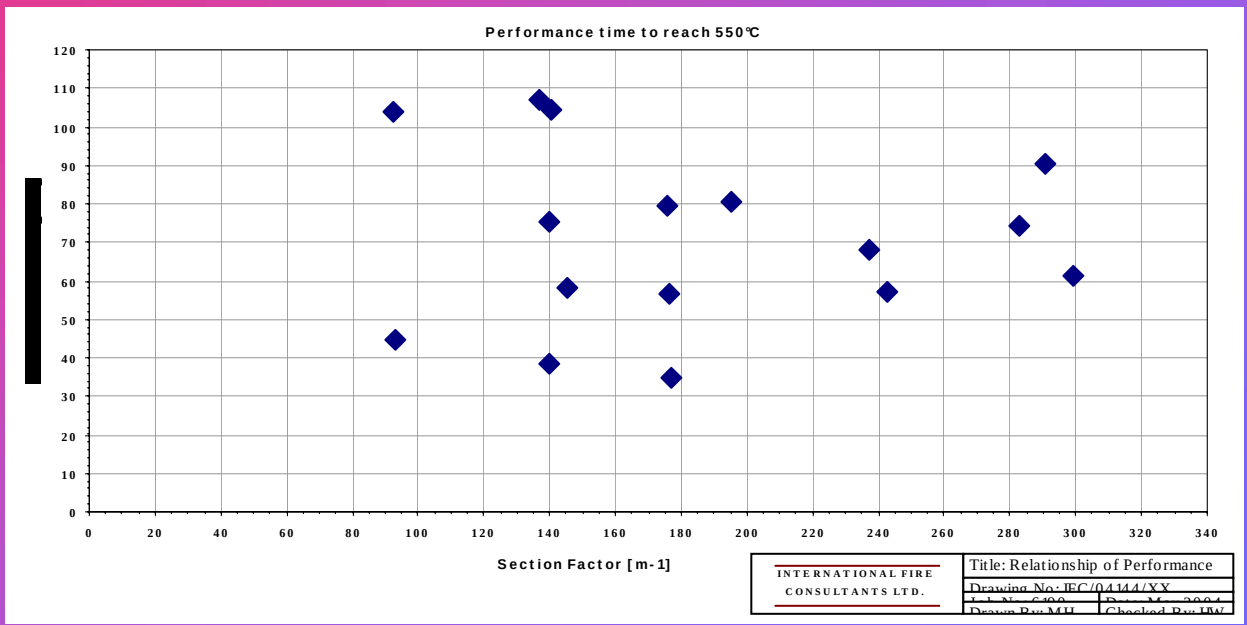
Test Results





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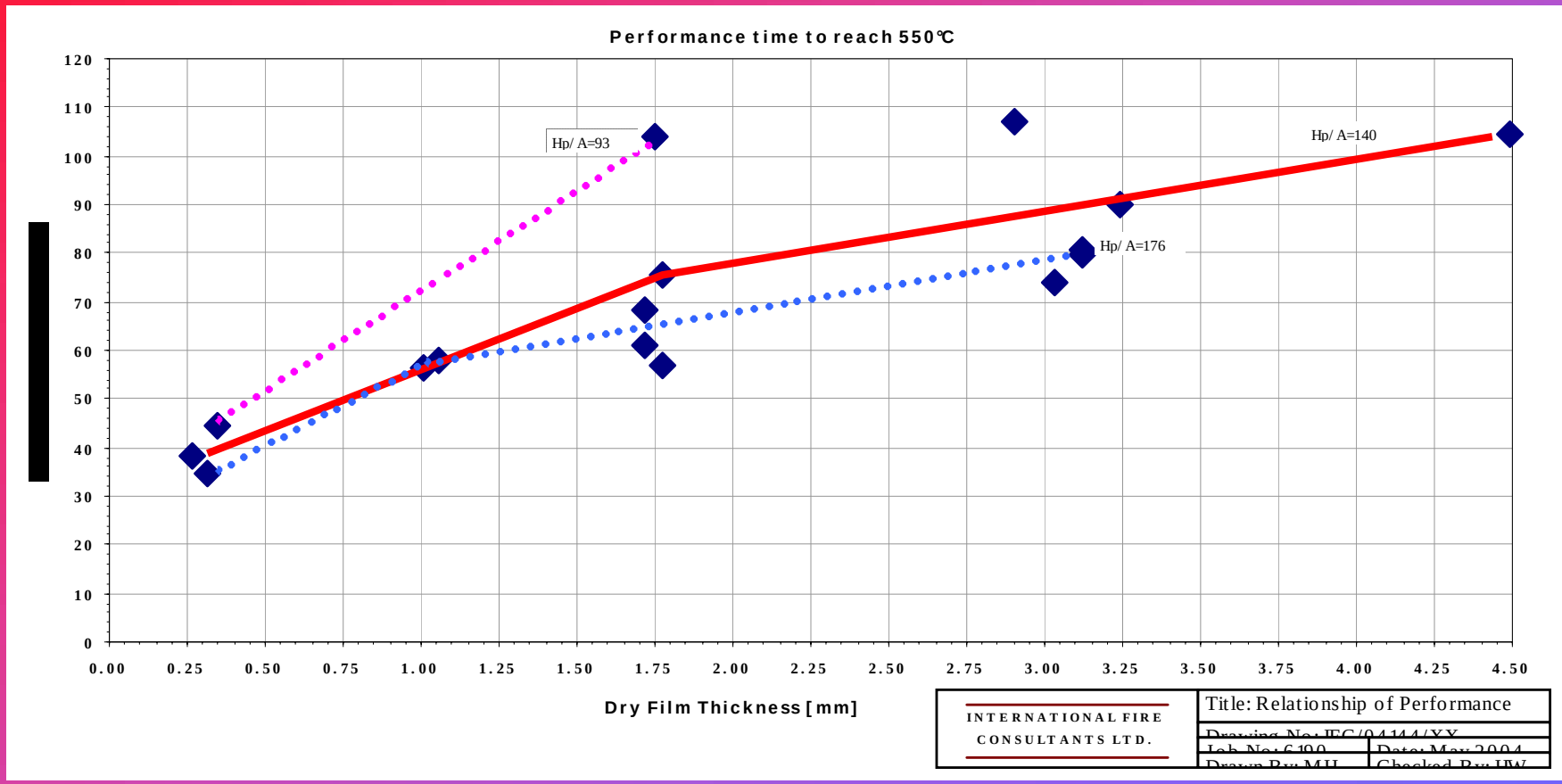
Test Data Analysis

Performance as Function of DFT



Characteristic Temperature

$$\frac{(T_{\bar{x}} + T_{\max})}{2} = T_{char}$$

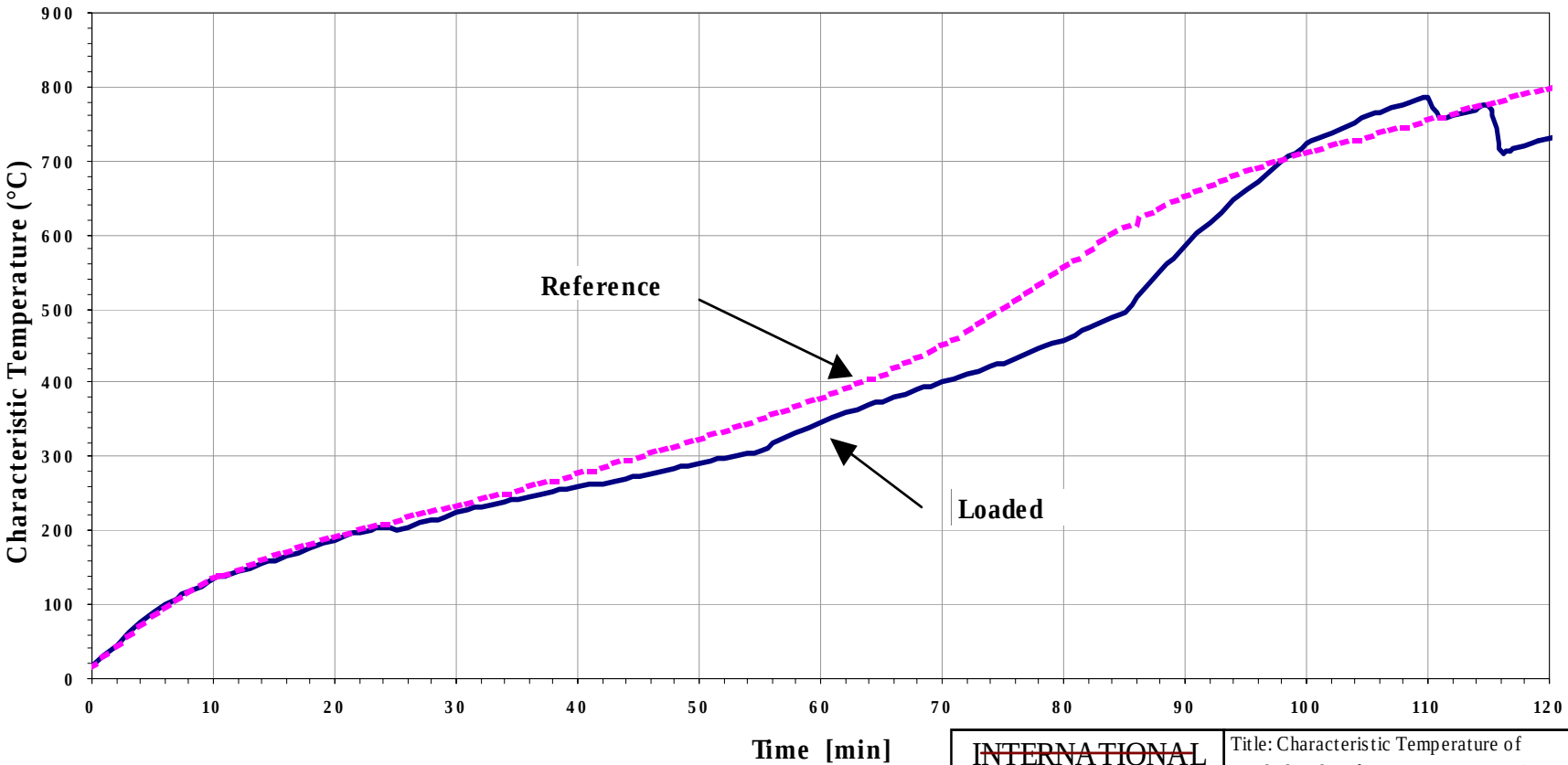
Stickability (k-factor)

$$k_{stickability} = \frac{T_{char} LB}{T_{char} UB}$$

$k = 1.0$ = *Ideal*

$k = 1.4$ = *High*

Characteristic Temperature



INTERNATIONAL FIRE CONSULTANTS	Title: Characteristic Temperature of Loaded and Reference Beam, WFRC
	Drawing No: IFCA/04144/XX
	Job No: 6190 — Date: May 2004
	Drawn By: MH — Checked By: HW

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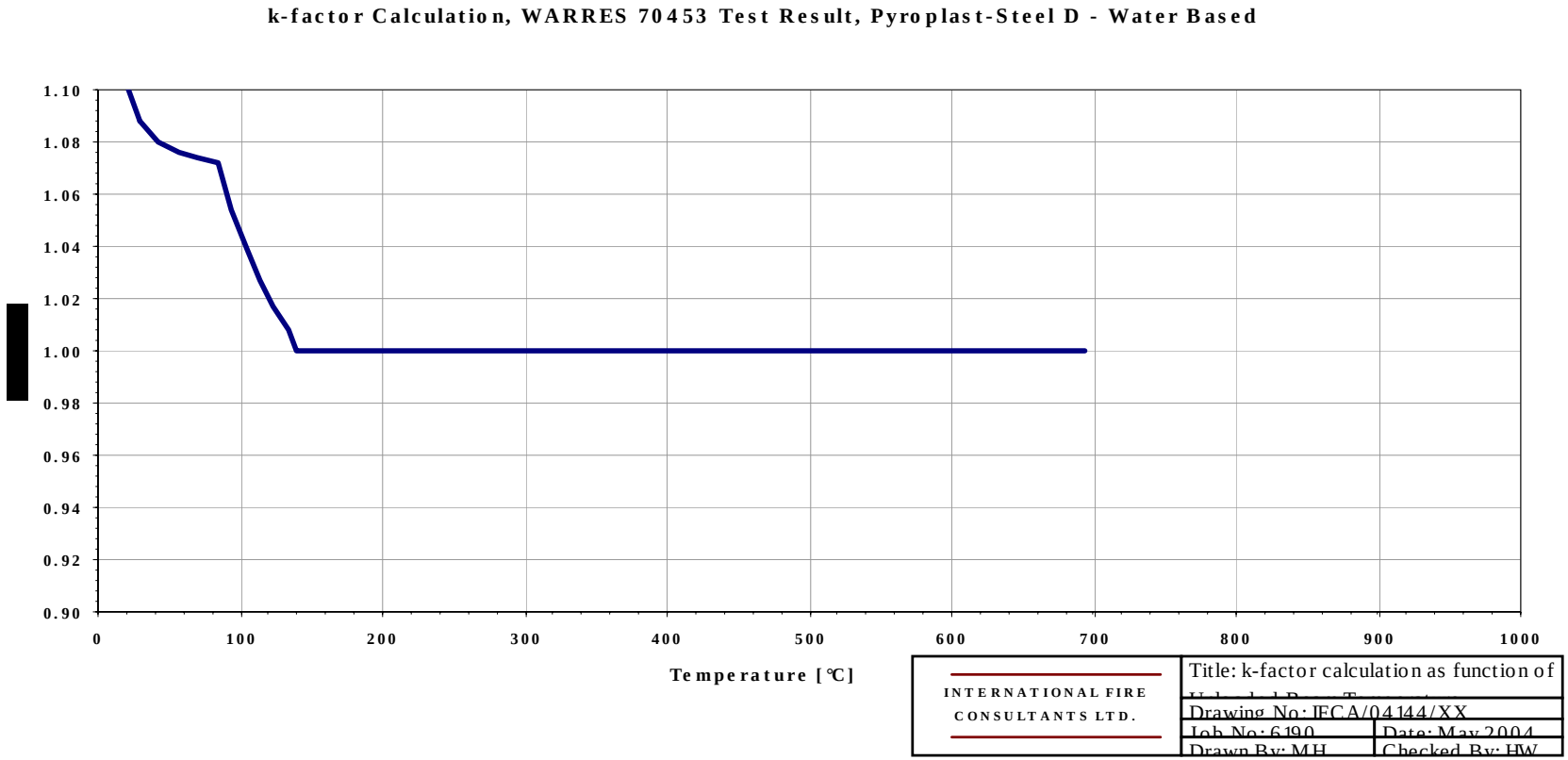
Stickability (k-factor) Water Based



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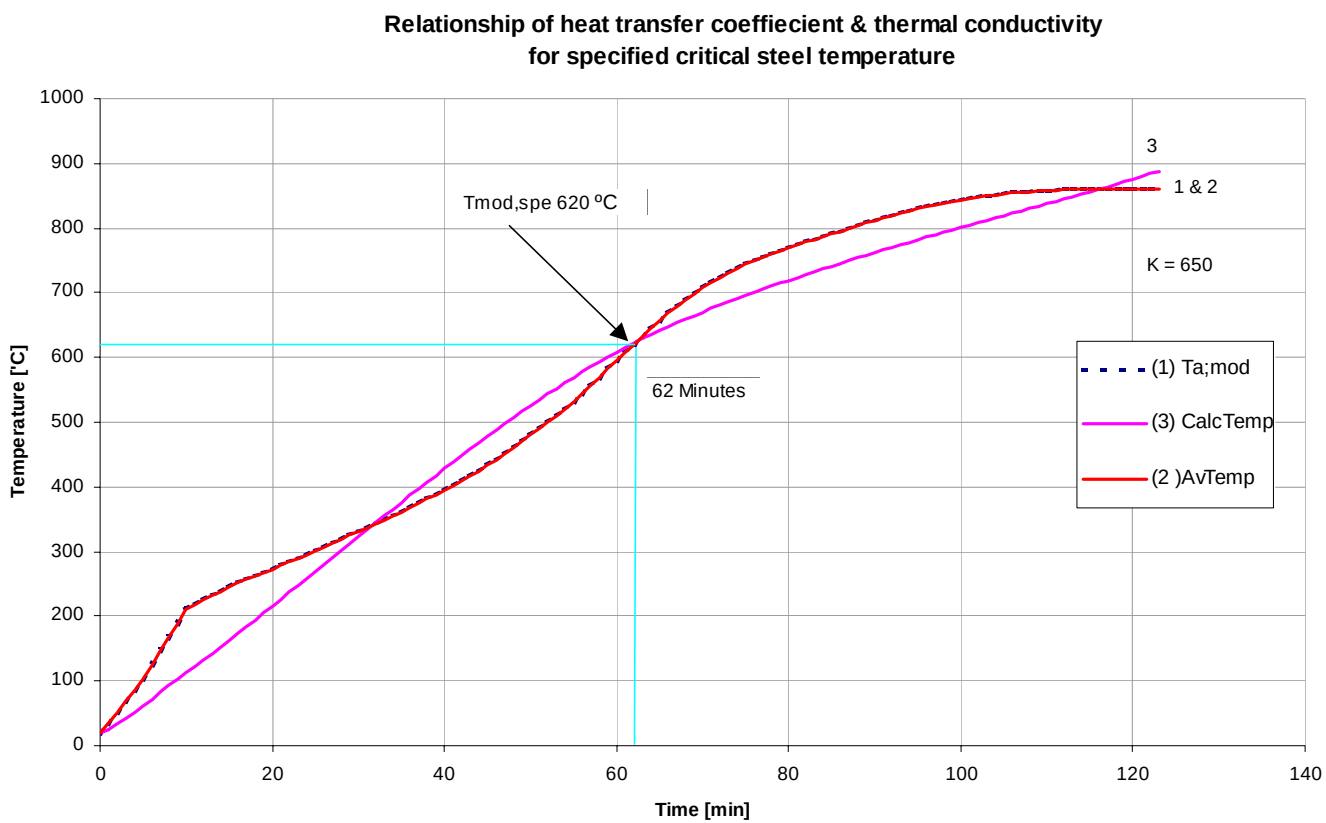
Input data

- Average Temperature of steel sections
  - Section factor Hp/A
  - Protection thickness
- Stickability correction
  - K-factor
- Thickness discrepancy
  - Loaded Beam
  - Unloaded Beam
- T_{mod}=Modified steel temperature

Relationship of heat transfer coefficient & thermal conductivity for specified critical steel temperature



Rate Temperature Rise

$$\Delta T = \frac{K}{\rho Ca}\left(Hp / A\right)\left(T_{furnace} - T_{steel}\right)\Delta t$$

Where :

K	$=$	*Heat transfer coefficient* $[W / m^2 K]$
ρ	$=$	*Density of steel* $[kg / m^3]$
Ca	$=$	*Specific Heat steel* $[J / kgK]$
Hp / A	$=$	*Section factor* $[m^{-1}]$
$T_{furnace}$	$=$	*Temperature of furnace* $[°C]$
T_{steel}	$=$	*Temperature of steel* $[°C]$
Δt	$=$	*time step* $[s]$

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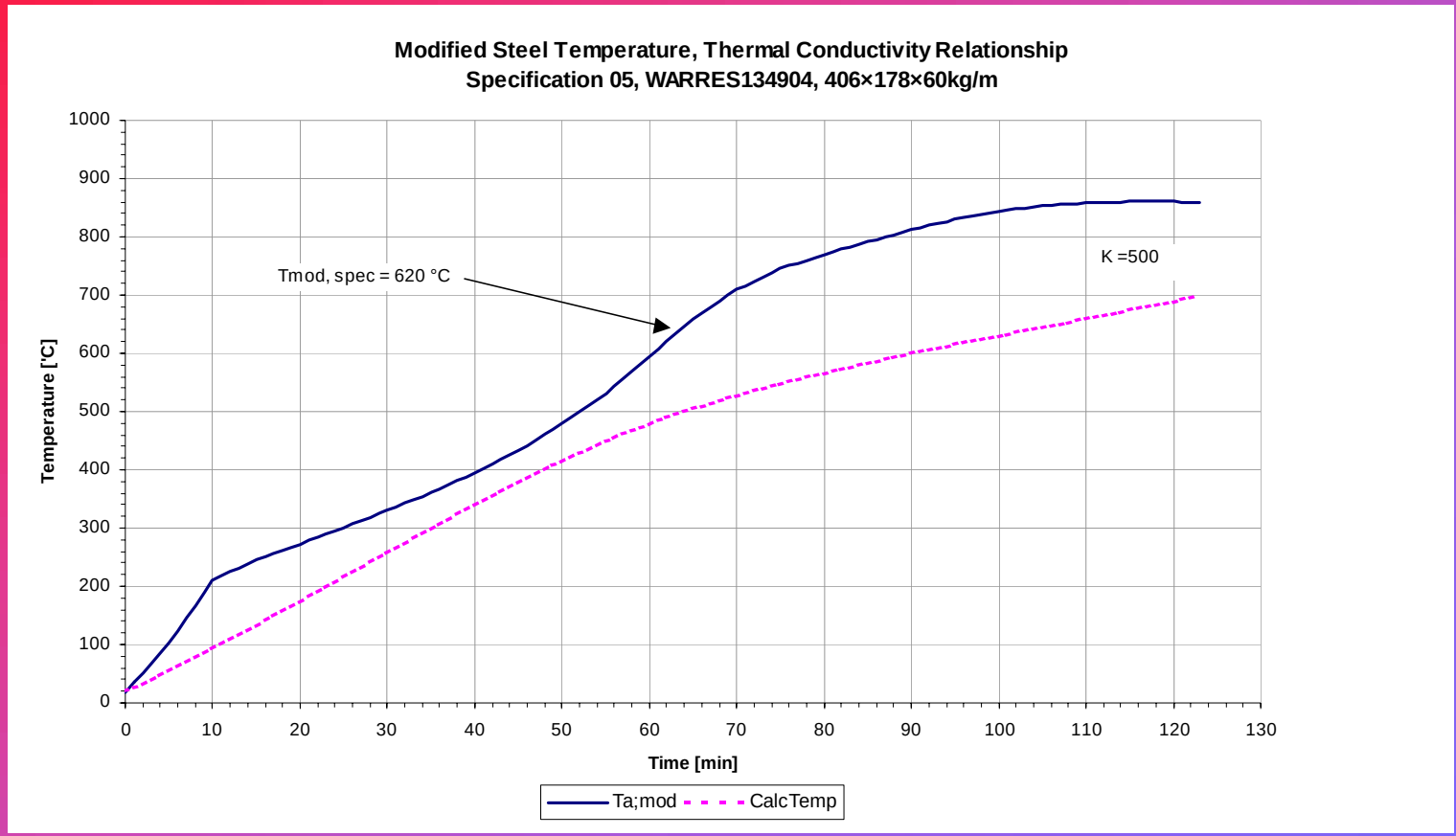
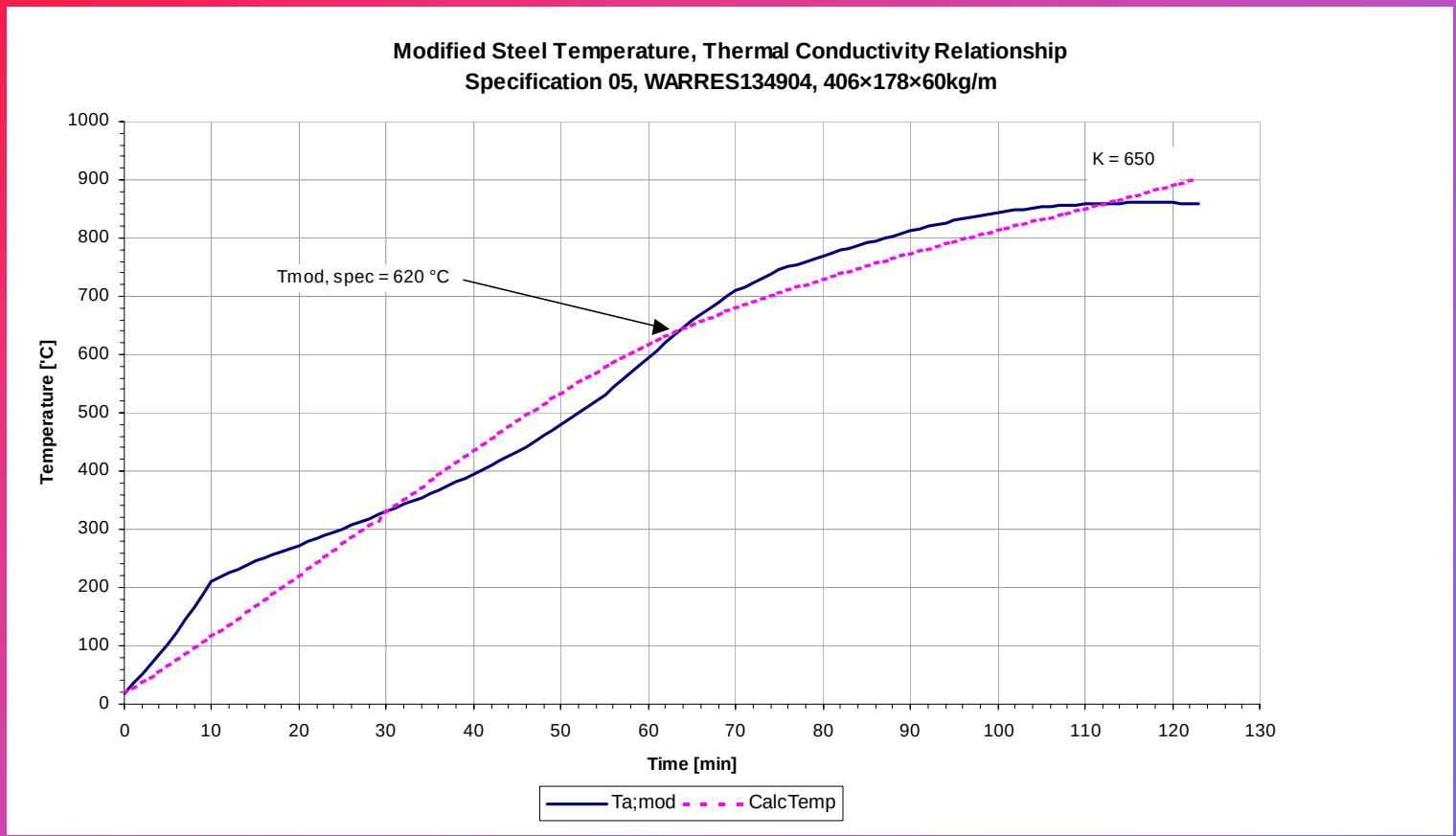
Heat Transfer Analysis

Too low K value



Heat Transfer Analysis

Correct K value



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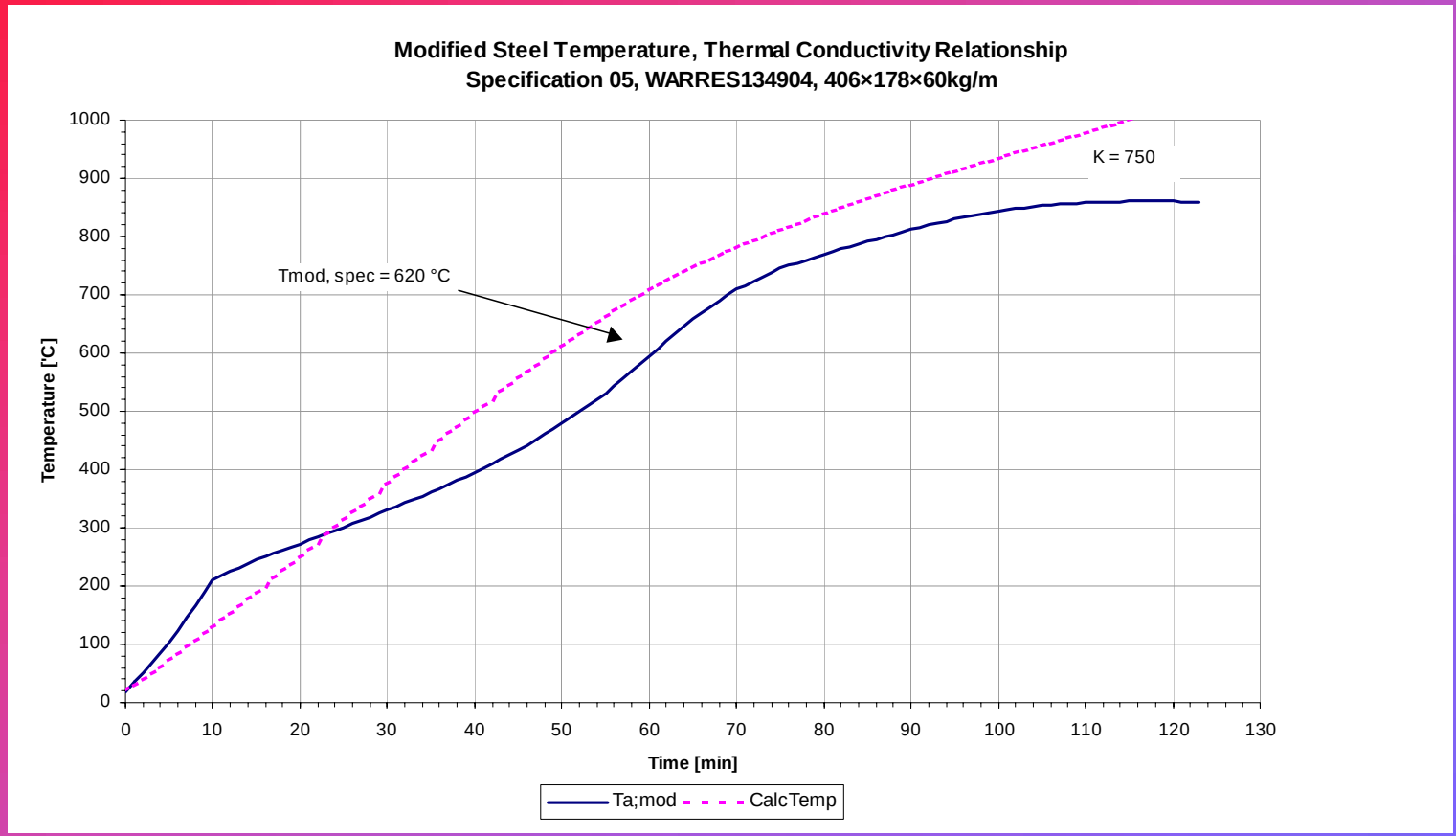
Heat Transfer Analysis
Too high K value



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Heat Transfer Coefficient & Thermal Conductivity

$$K = \frac{1}{DFT}\left(C_0 + C_1 T + C_2 DFT + C_3 Hp/A\right)$$

Where :	DFT	$=$ Dry film thickness $[m]$
	T	$=$ Temperature of interest $[^{o}C]$
	Hp/A	$=$ Section factor $[m^{-1}]$
	$C_{1,2,3}$	$=$ Constants (results from linear regression)
	K	$=$ Heat Transfer Coefficient $[W/m^2K]$

$$\lambda = K \times DFT$$

Where :	λ	$=$ Thermal conductivity $[W/mK]$
	DFT	$=$ Dry Film Thickness $[m]$
	K	$=$ Heat Transfer Coefficient $[W/m^2K]$

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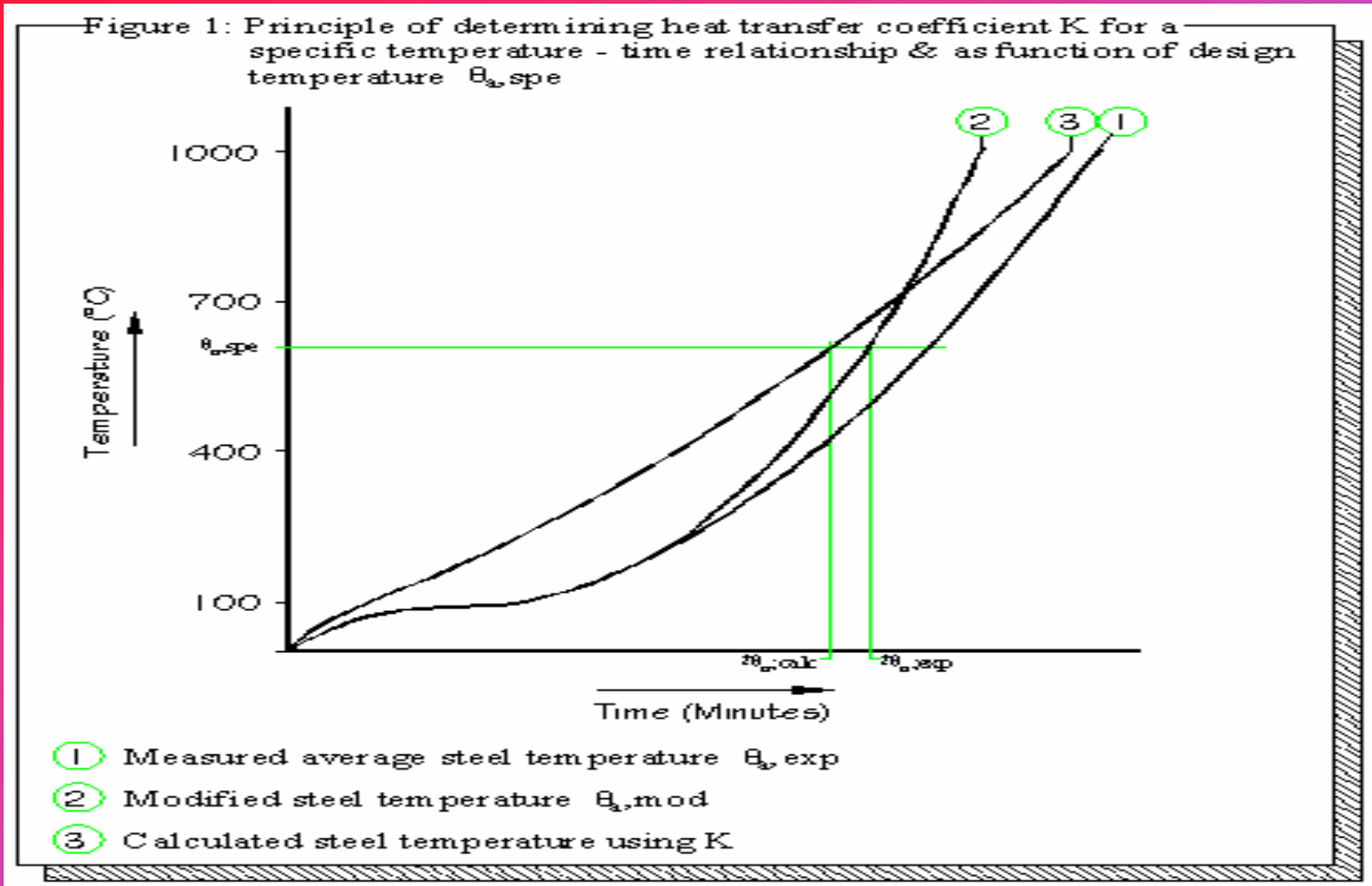
Verification of criteria for acceptability

- Determine the measured time, t (min) to reach 350°C…700°C
- Determine the Calculated time, t (min) to reach 350ºC … 700ºC
- Compare calculated time with measured time

Measured Vs. Calculated



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Tools to improve Assessment Results

- Bead thermocouple compared with plate thermometer
- Low k-factor for stickability, preferably k=1.0
- Criteria to be applied

Criteria for different Countries

- 20% NEN6072 – The Netherlands
- 30% BSXXXX – United Kingdom
- 30% EN13381-4 – Europe
- Mean value of % differences shall be < 0

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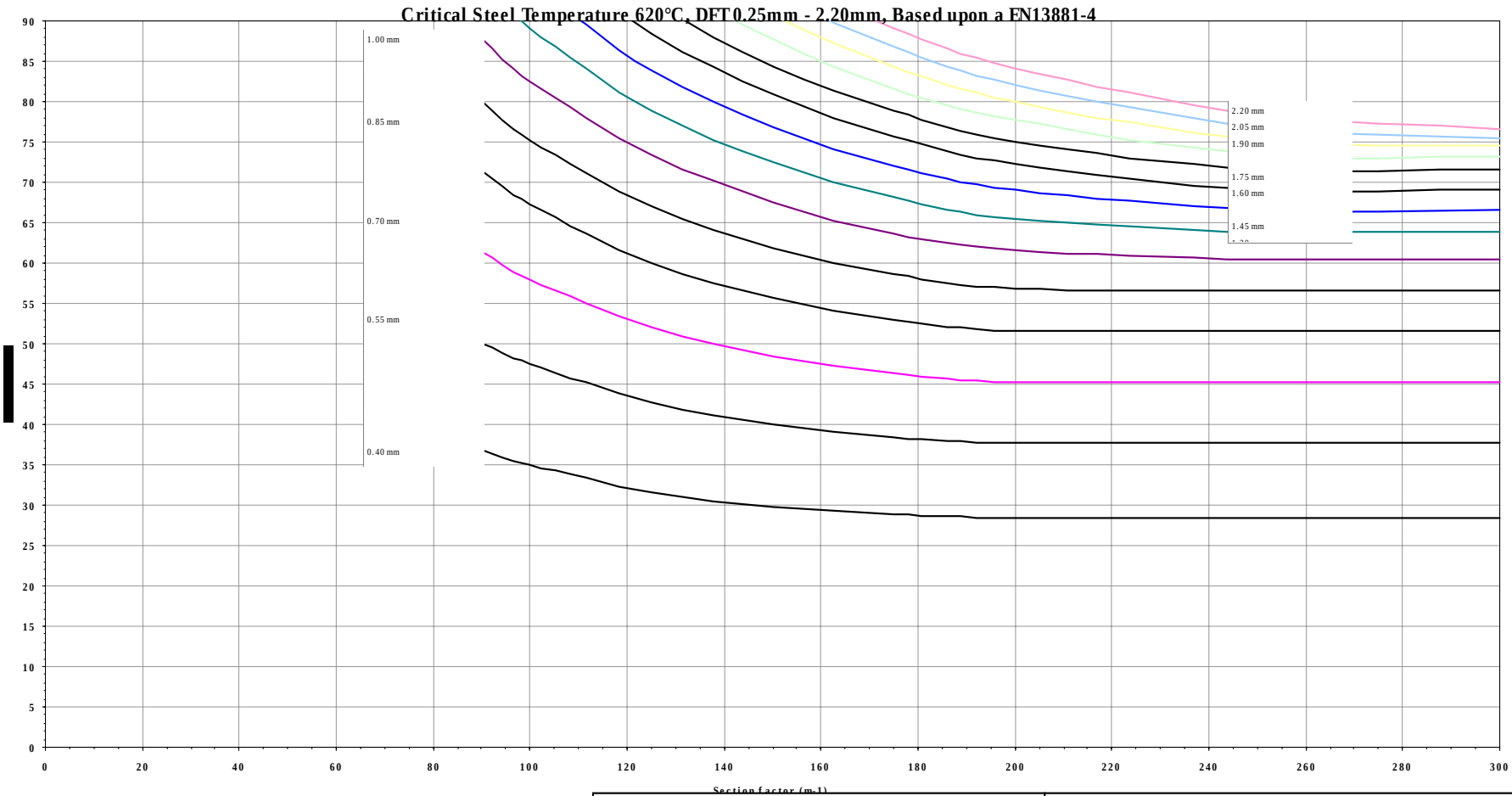
Preliminary Results

Water Based – Pyroplast-Steel D @ 620°C

No Criteria



INTERNATIONAL FIRE CONSULTANTS LTD.	Title: Critical steel temperature 620°C, Pyroplast-Steel D, Rütgers Organics GmbH
	Drawing No: IFCA/04144/B07
	Job No: 6190 — Date: May 2004
	Drawn By: MH — Checked By: HW

Conclusions

- Where are we now?
- Detailed Analysis
- Heat Transfer available
  - For Water based StiFF intumescent paint
- FOA report