

# **3D Interpolation method for intumescent coatings**

**By**

Mr. Hans van de Weijgert MSc MIFireE MBEng  
Senior Consultant

**International Fire Consultants Ltd**



# Presentation Outline

- The Problem
- Performance time as a function of  $H_p/A$  and DFT
- Discretizing the ( $H_p/A$ , DFT) plane into triangular domains
- Forming a plane and its equation
- Calculating performance times
- Test evidence with various data points
- Output from the 3D Interpolation method
- Visualisation of previously unrevealed information
- Adding the fourth dimension
- An assessment method based upon factual measurements
- Criteria for acceptability



# The problem

- The problem is four dimensional:
  - Section factor ( $H_p/A$ )
  - Dry film thickness (DFT)
  - Performance time ( $t$ )
  - Design steel temperature ( $T$ )

- The problem can be reduced to 3 dimensions in which:

x-axis represents  $H_p/A$

y-axis represents DFT

z-axis represents  $t$

- The w-axis would represent design temperature
- w-axis can be accounted for by considering the 3-dimensional space repeatedly in increments of design temperature

i.e. 3-D plot for 350 °C, another 3-D plot for 400 °C etc



## Performance time as a function of Hp/A and DFT

- Each test specimen can be represented by a Hp/A and a DFT value

So, a section with a Hp/A value of  $230\text{m}^{-1}$  and a DFT of  $1.23\text{mm}$  would be represented as  $(x, y) = (230, 1.23)$

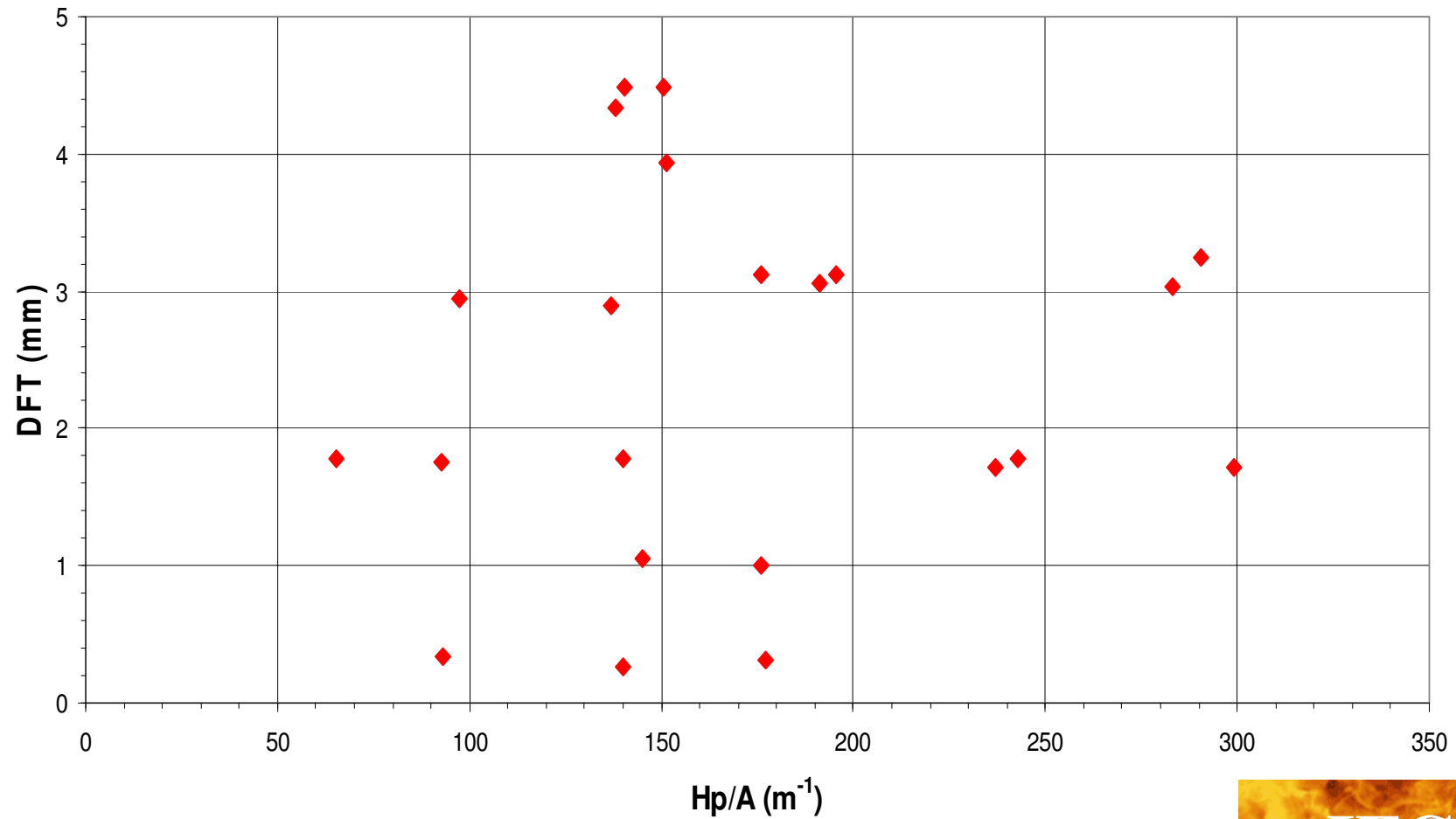
- Following a standard fire test each specimen will have an associated time to reach a design temperature (performance time)

So, if the section above had a performance time of 35 minutes it would be represented as  $(x, y, z) = (230, 1.23, 35)$

- Data points are factual, i.e. measured values



## An example data set in the (x, y) plane



## 3-D representation of an example data set

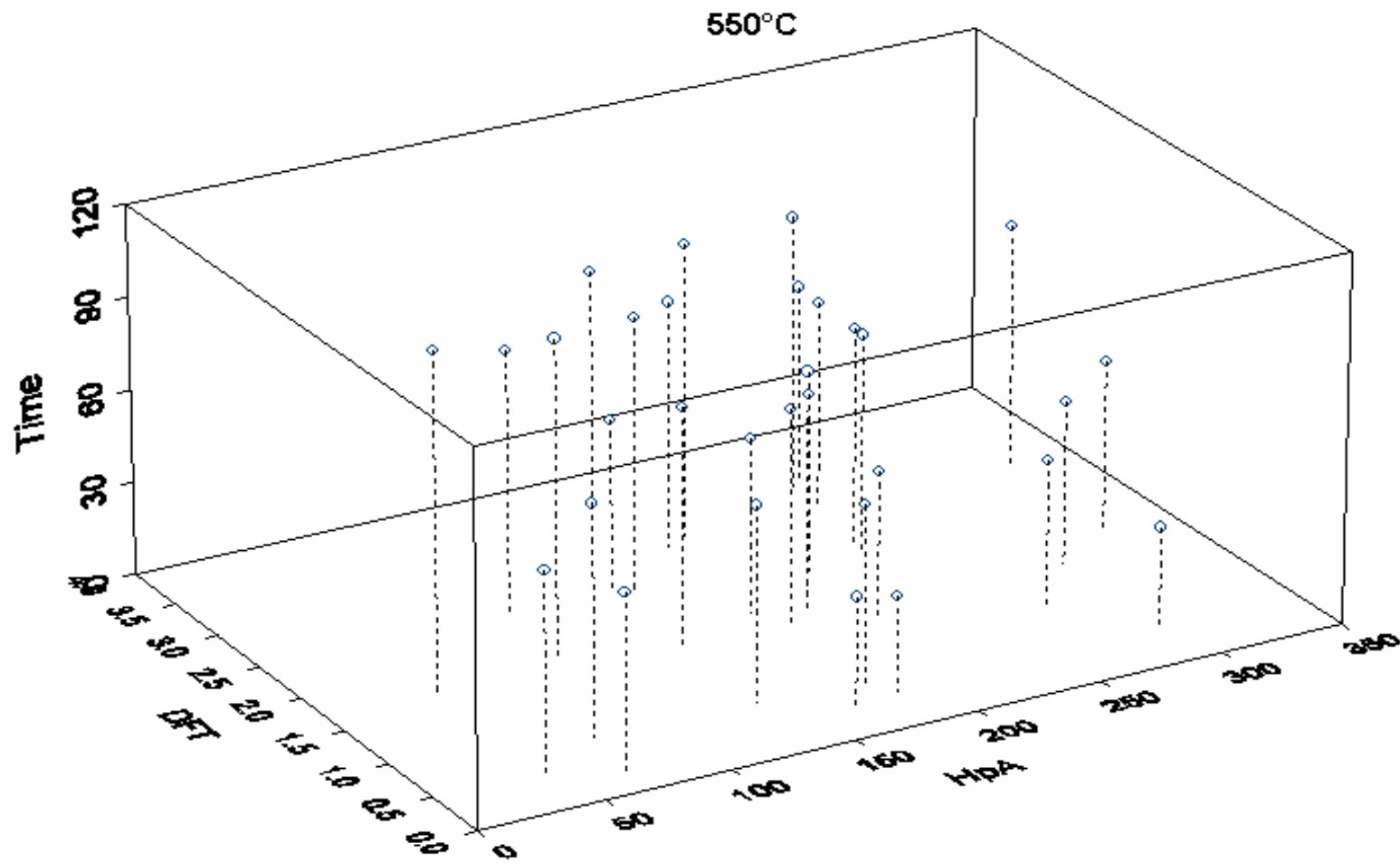


Fig. 1: 3D - Representation of data set for 550°C

## Discretizing the (Hp/A, DFT) plane into triangular domains

- Three dots can be identified  $(x_1, y_1)$ ,  $(x_2, y_2)$  and  $(x_3, y_3)$  representing corners of a triangle
- Joining the dots creates the triangle (in the  $z=0$  plane)
- Line equations will have the form  $y = ax + b$

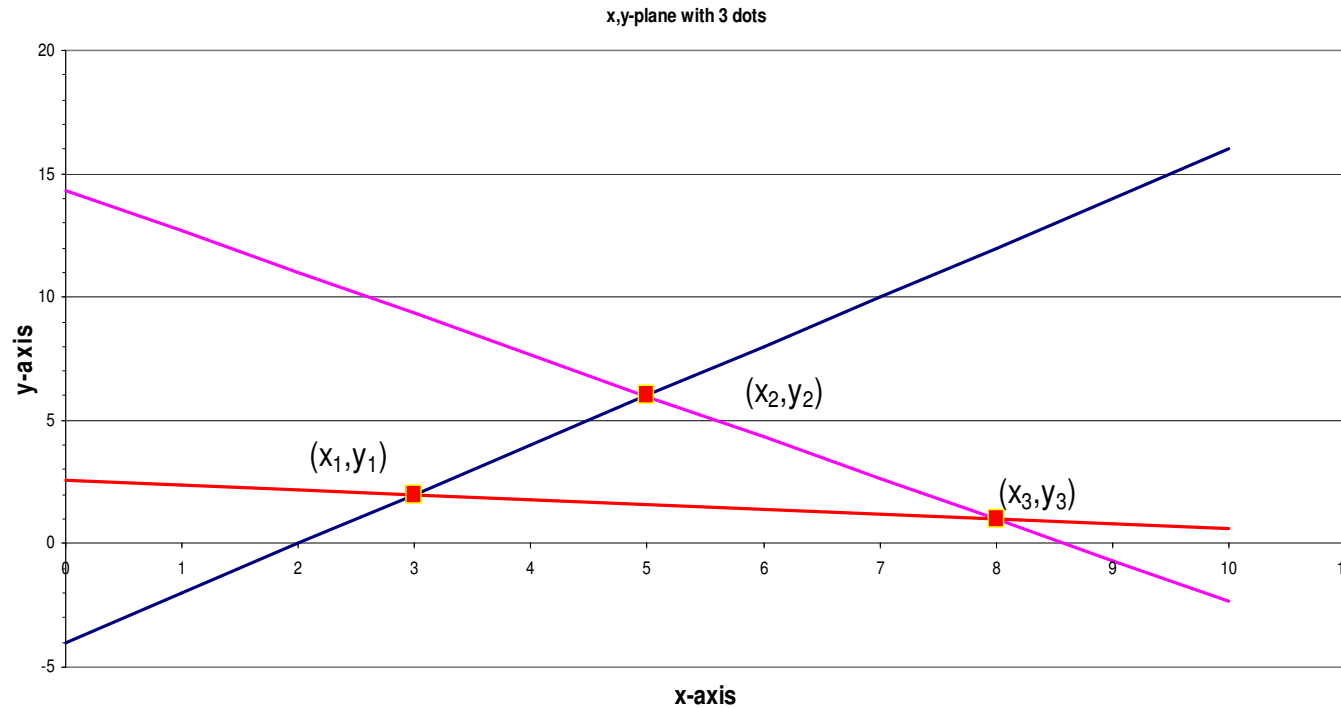


Figure 2

# Discretizing the (Hp/A, DFT) plane into triangular domains

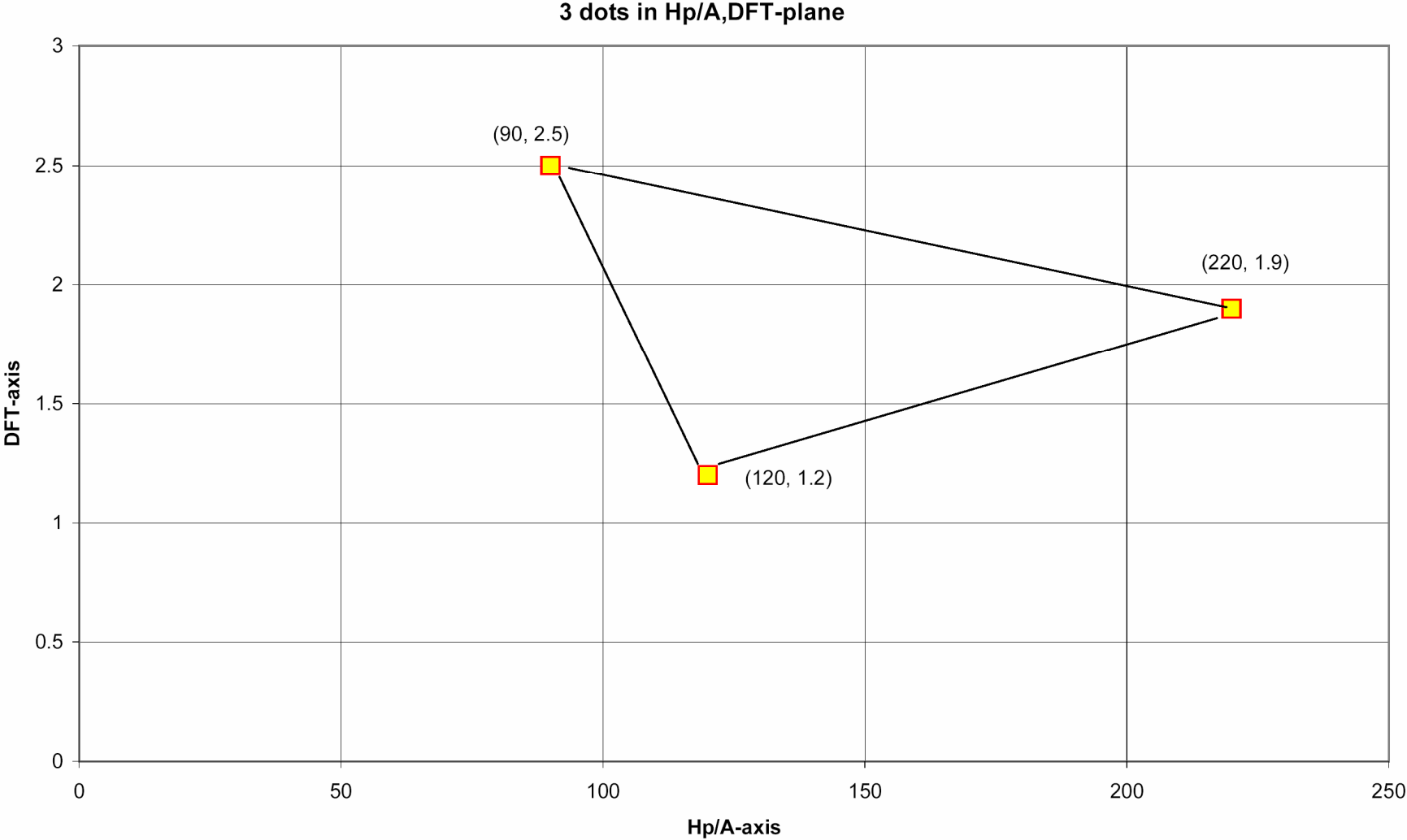


Figure 3

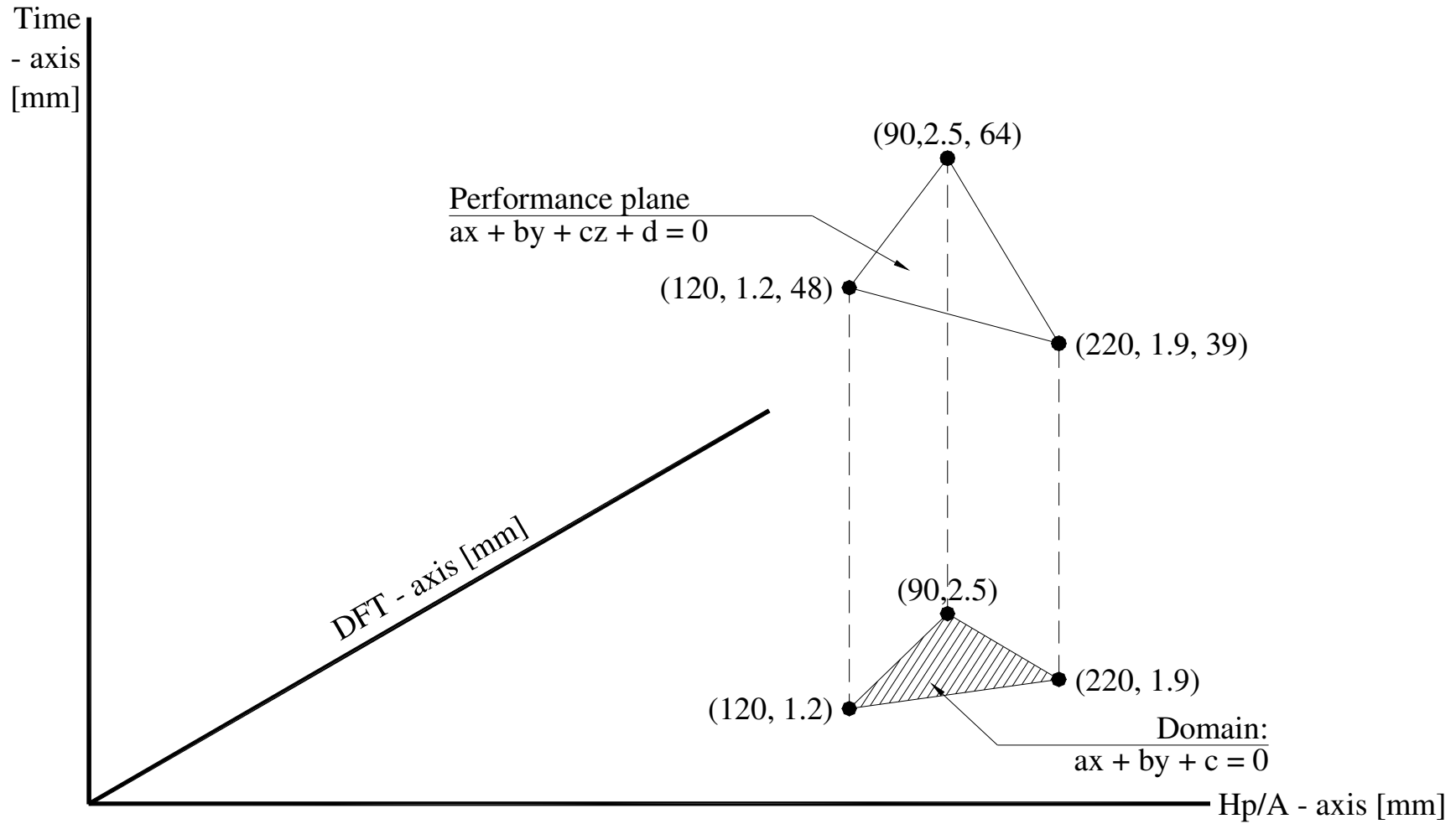
# Forming a plane and its equation

- The triangle encloses an area called the domain
- In 3-dimensional space the three dots  $(x_1, y_1, z_1)$ ,  $(x_2, y_2, z_2)$  and  $(x_3, y_3, z_3)$  can be imagined to lay in one plane
- The equation has the form:

$$ax + by + cz + d = 0$$



# Forming planes



# Calculating performance times

- Having obtained the plane equation, the z-value can be obtained for any x and y combination within the domain

i.e. the performance time can be calculated for all combinations of Hp/A And DFT values within the triangle in the z=0 plane

- A more understandable form of the plane equation is:

$$a \cdot H_p/A + b \cdot DFT + c \cdot \text{time} + d = 0$$



# Test evidence with various data points

- Typically manufacturers have test evidence incorporating more than 3 specimens
- The principle of forming triangles can be extended to create more triangles in the (x, y) plane
- It is observed that:
  - 3 dots will form 1 triangle
  - 4 dots will form at least 2 triangles
  - 5 dots will form at least 3 triangles
  - 6 dots will form at least 4 triangles.....



# Test evidence with various data points

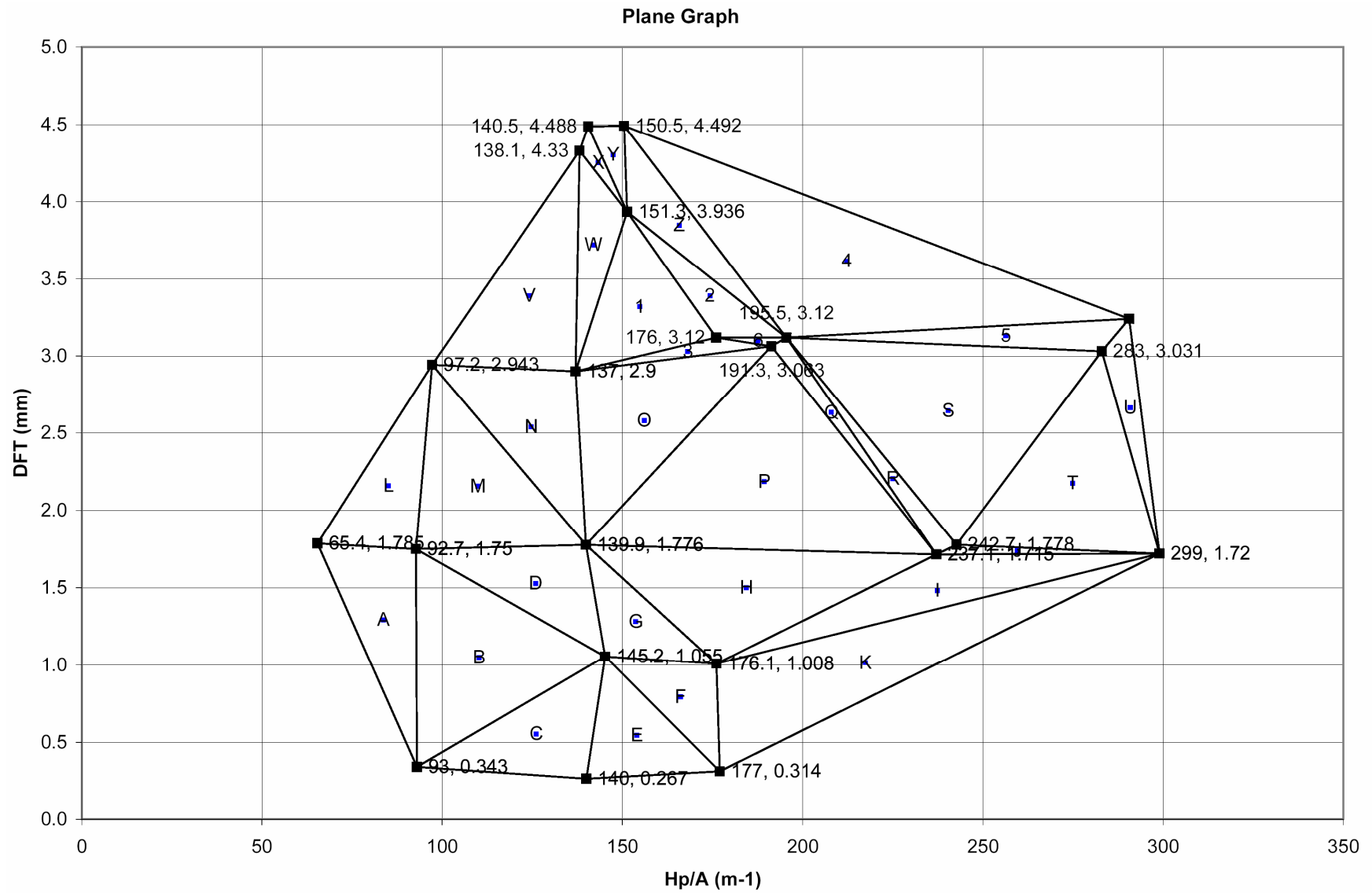


Figure 5

# Test evidence with various data points

- Each triangle forms the domain for which  $(x_i, y_i)$ -dots within that triangle deliver the  $z_i$ -value using the plane equation  
  
i.e. each triangle in the (Hp/A, DFT)-plane forms the domain for which a combination of Hp/A and DFT values provide a performance time using the plane equation
- The planes intersect at lines that connect the measured performance times in the 3-dimensional space.
- The planes combine to form a 3-dimensional “landscape”



# Test evidence with various data points

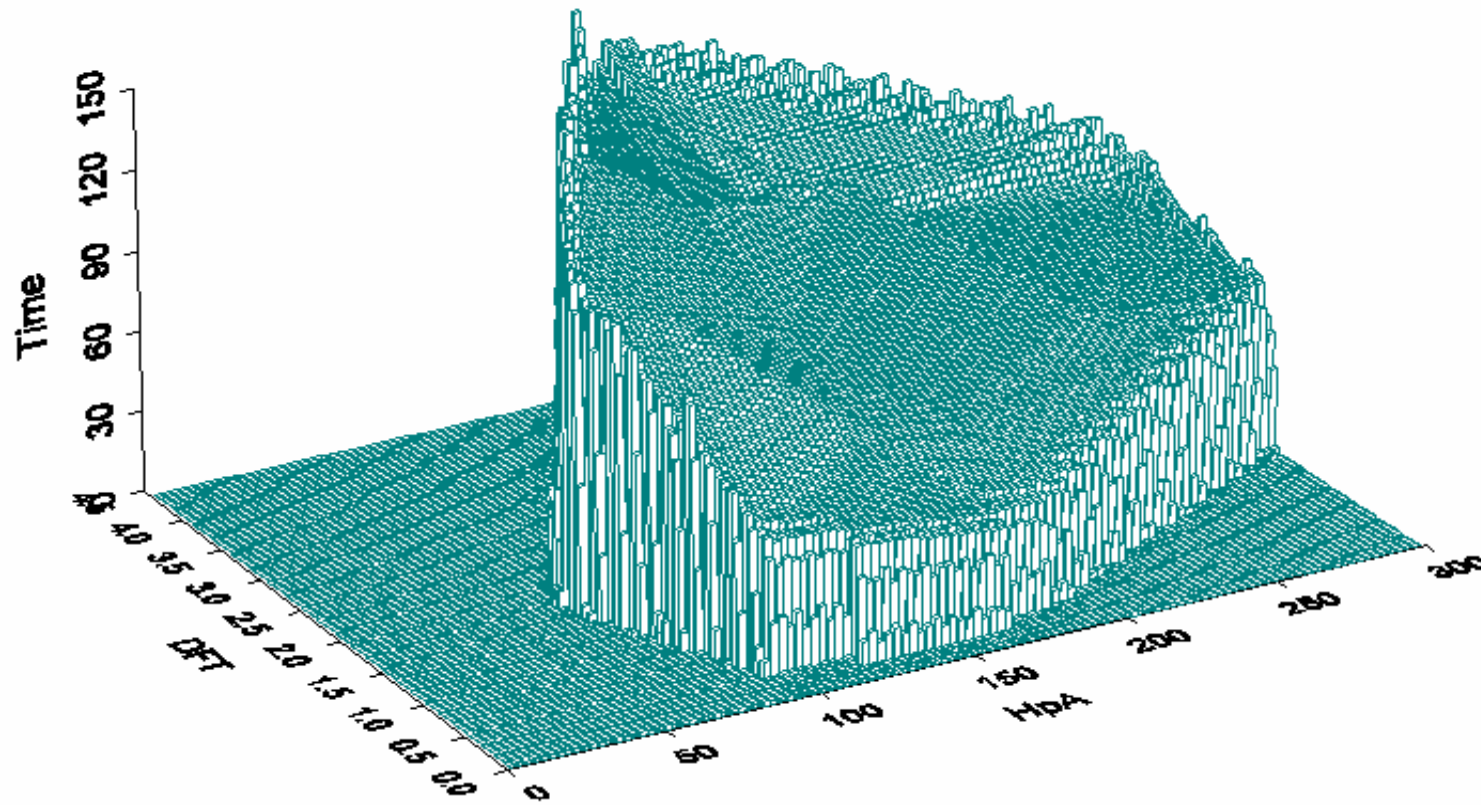


Figure 6

# Output from the 3D Interpolation method

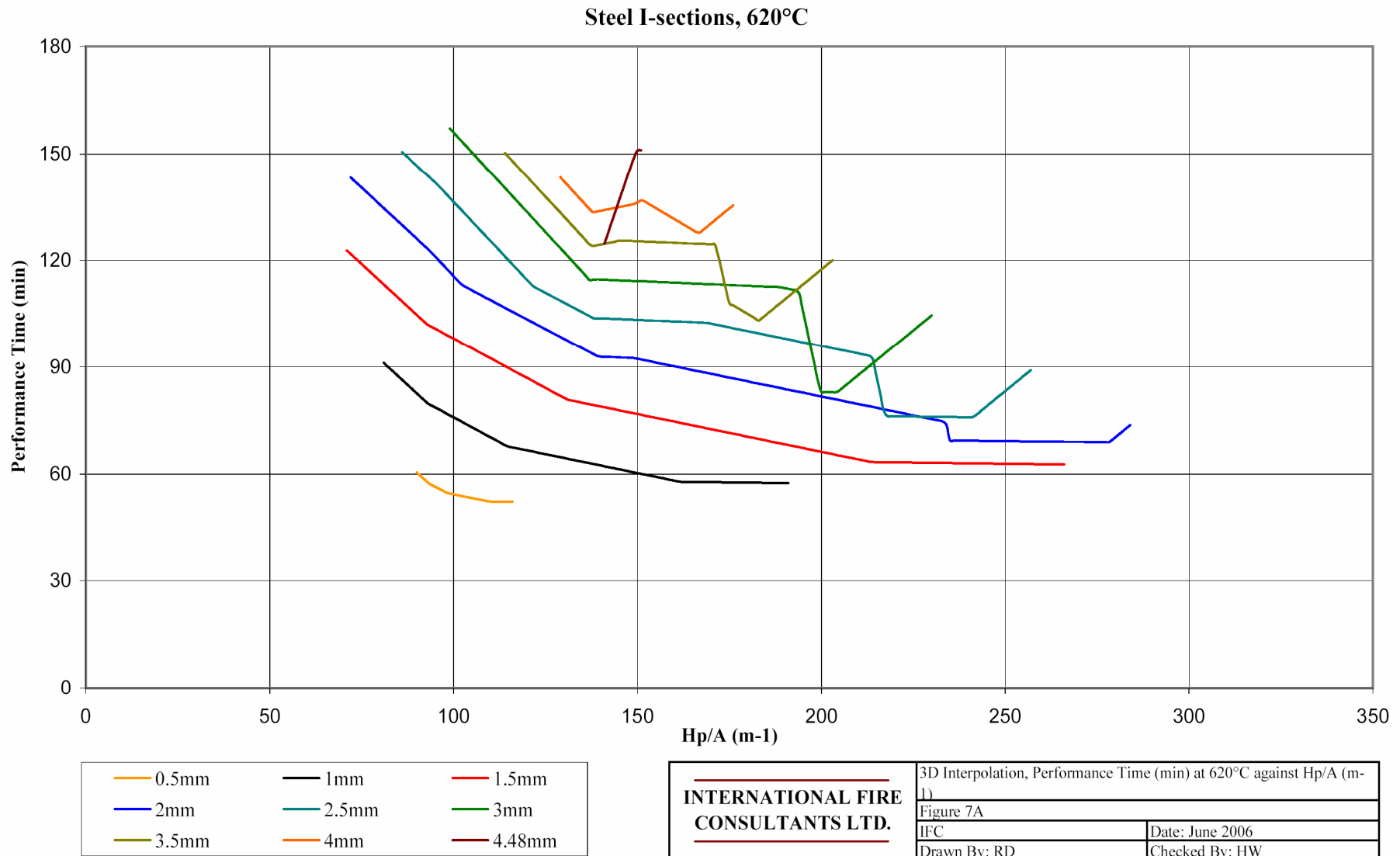
- An assessment of the performance of an intumescent coating will include:
  - performance time as a function of DFT (graphed for different values of  $H_p/A$ )
  - performance time as a function of  $H_p/A$  (graphed for different values of DFT)
- Performance time as a function of DFT is a vertical cross section through the “landscape” for a constant  $H_p/A$
- Performance time as a function of  $H_p/A$  is a vertical cross section through the “landscape” for a constant DFT
- Performance time of 0 is returned when there is no applicable test evidence

# Visualisation of previously unrevealed information

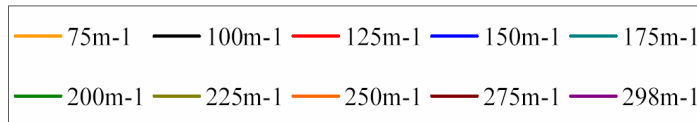
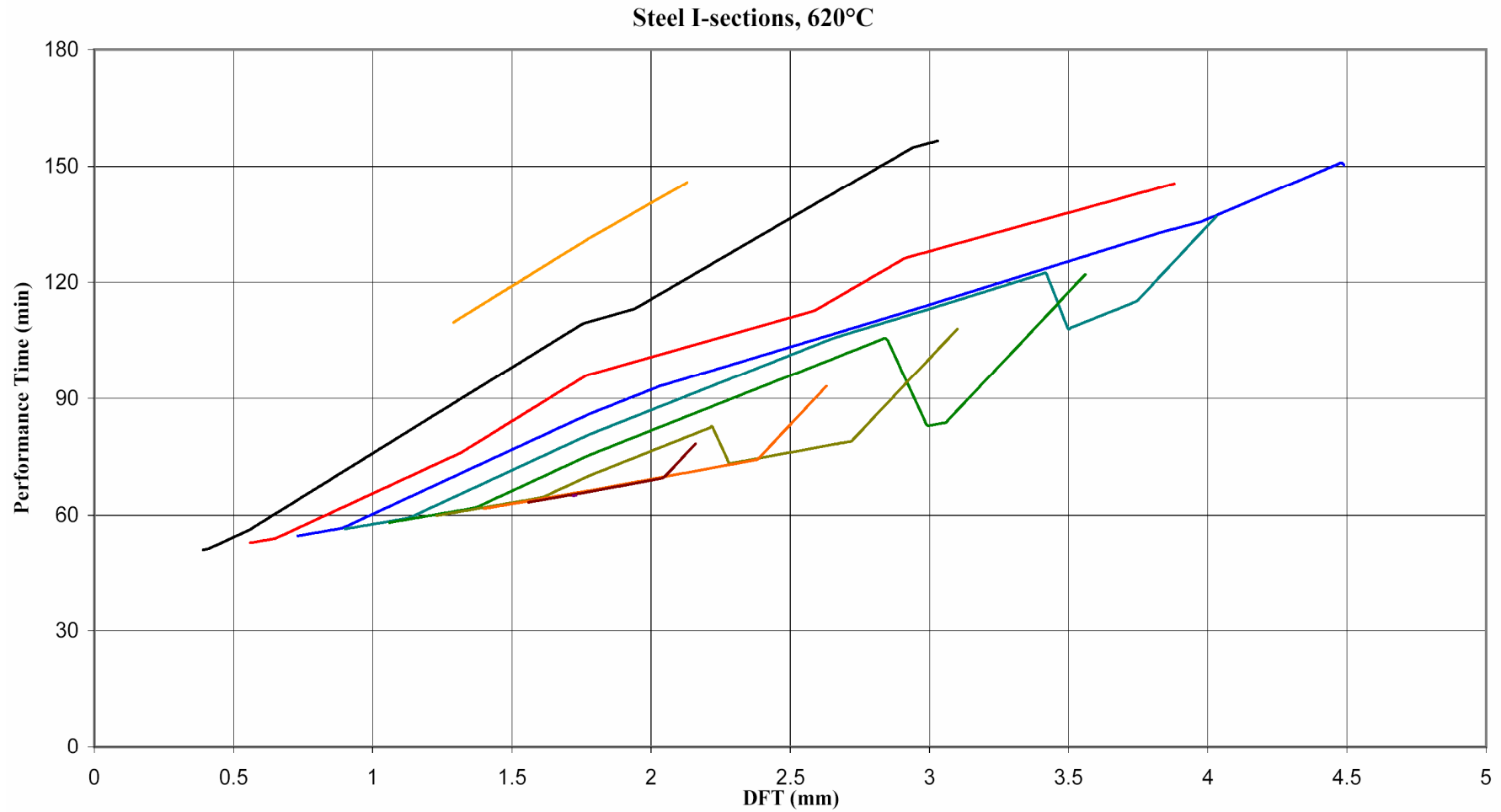
- Previously unrevealed information about behaviour of intumescent coatings can now be visualised
  - A higher DFT does not necessarily provide a longer performance time
    - Shown by local dips in the 3D landscape
  - Charts of performance time as a function of  $H_p/A$  shows that lines for DFTs intersect
- The method allows identification of areas where improvement of the intumescent formulation



# Visualisation of previously unrevealed information



# Visualisation of previously unrevealed information



<b>INTERNATIONAL FIRE CONSULTANTS LTD.</b>	3D Interpolation, Performance Time (min) at 620°C against DFT (mm)	
	Figure 7B	
	IFC	Date: June 2006
	Drawn By: RD	Checked By: HW

# Advantages of 3-D interpolation method

- The 3-D interpolation method is based upon facts
- Assessments include no error
- Criteria for acceptability are complied with by default
- Lower and upper limits of DFT are identified for any particular Hp/A
- Predictive knowledge of the performance is provided
- Performance can be visualised in 3-D



# Adding the fourth dimension

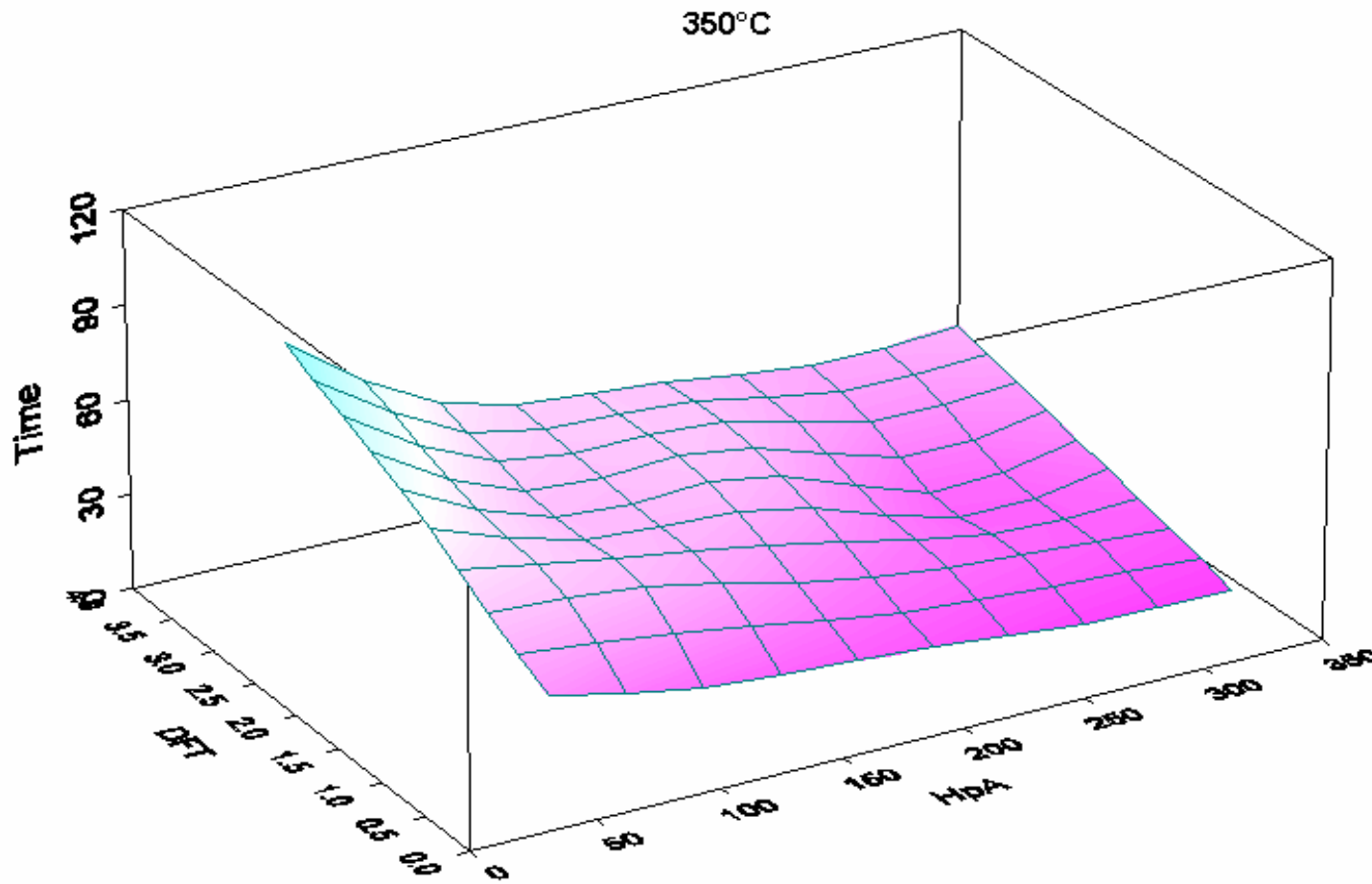


Figure 8

# Adding the fourth dimension

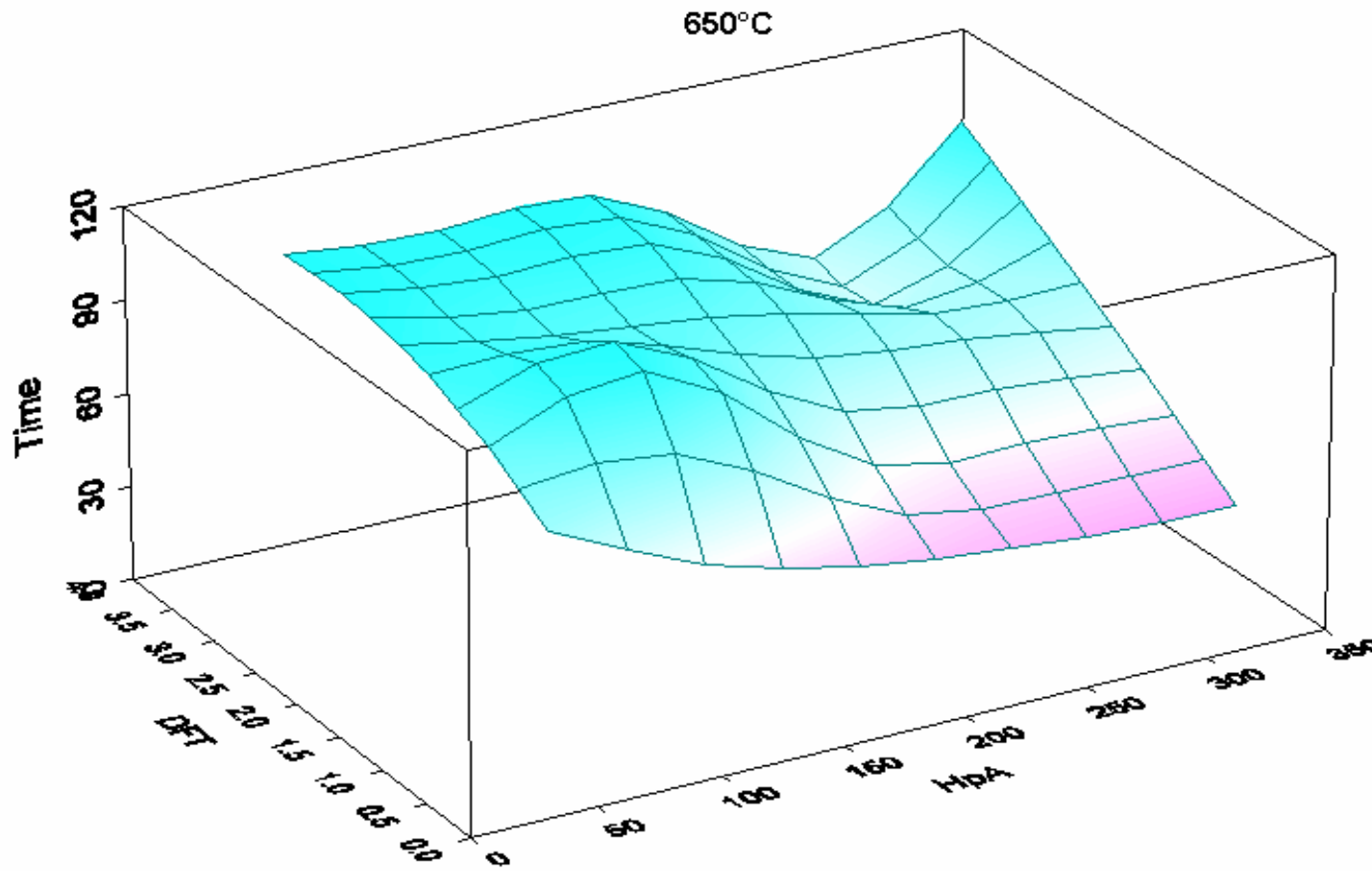


Figure 9

# Adding the fourth dimension

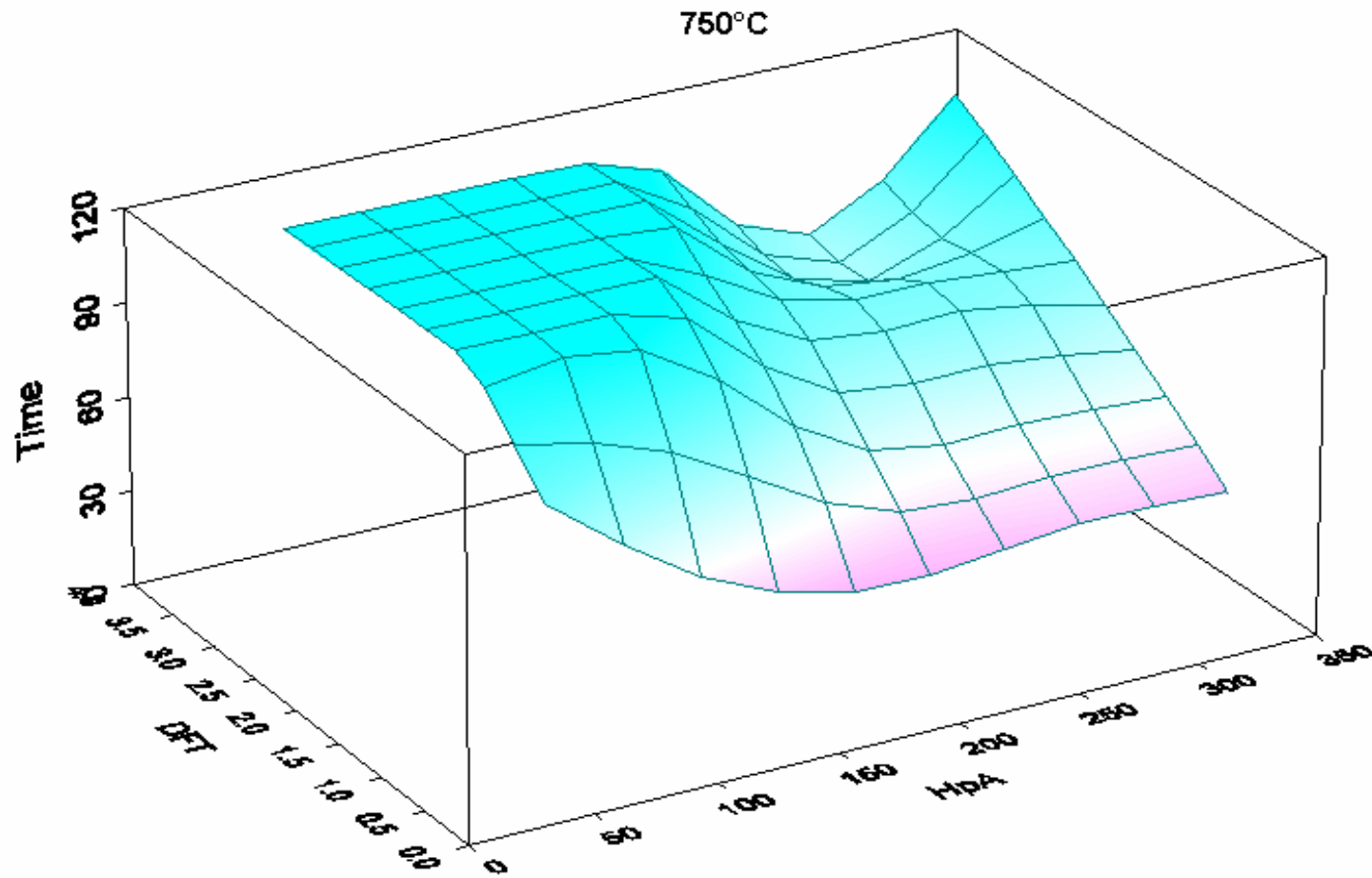


Figure 10

## An assessment method based upon factual measurements

- The 3-D interpolation method is based upon factual measurements and 3-D arithmetic
- No blurring due to statistical analysis
- No need for linear regression techniques
- No need for elaborate heat transfer calculations



# Criteria for acceptability

- The 3-D interpolation method is based upon facts, so the error is zero
- Criteria for acceptability are automatically complied with
- The difference between measured and calculated times is zero
- Calculated / Measured times = 1



**THE END**

**THANK YOU FOR YOUR TIME**

**ANY QUESTIONS?**

