3D Interpolation method for intumescent coatings

By

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Presentation Outline

- The Problem
- Performance time as a function of Hp/A and DFT
- Discretizing the (Hp/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 (Hp/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 Hp/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℃, another 3-D plot for 400℃ 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

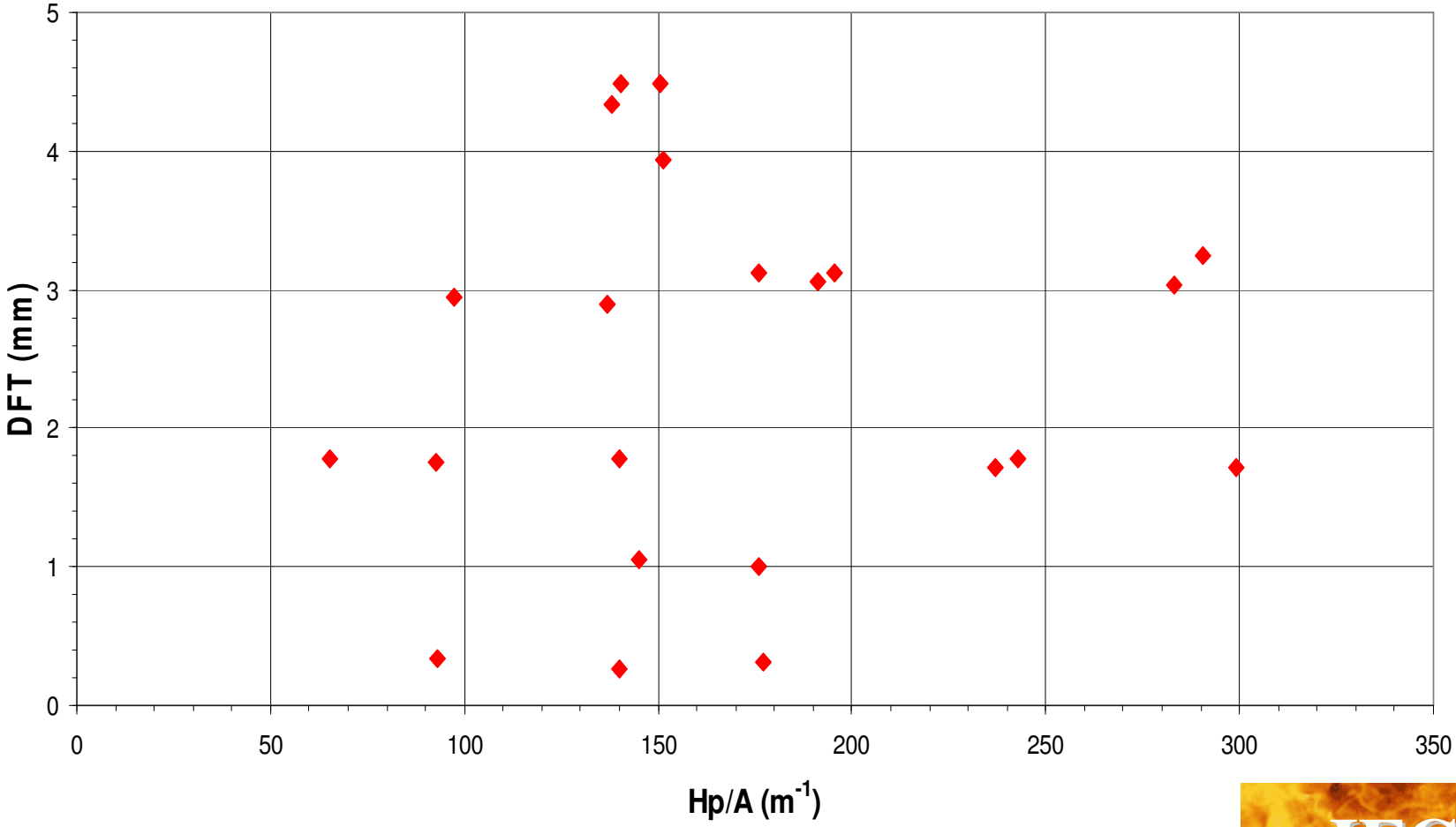
  So, a section with a Hp/A value of 230m^{-1} and a DFT of 1.23mm would be represented as (x, y) = (230, 1.23)

- 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

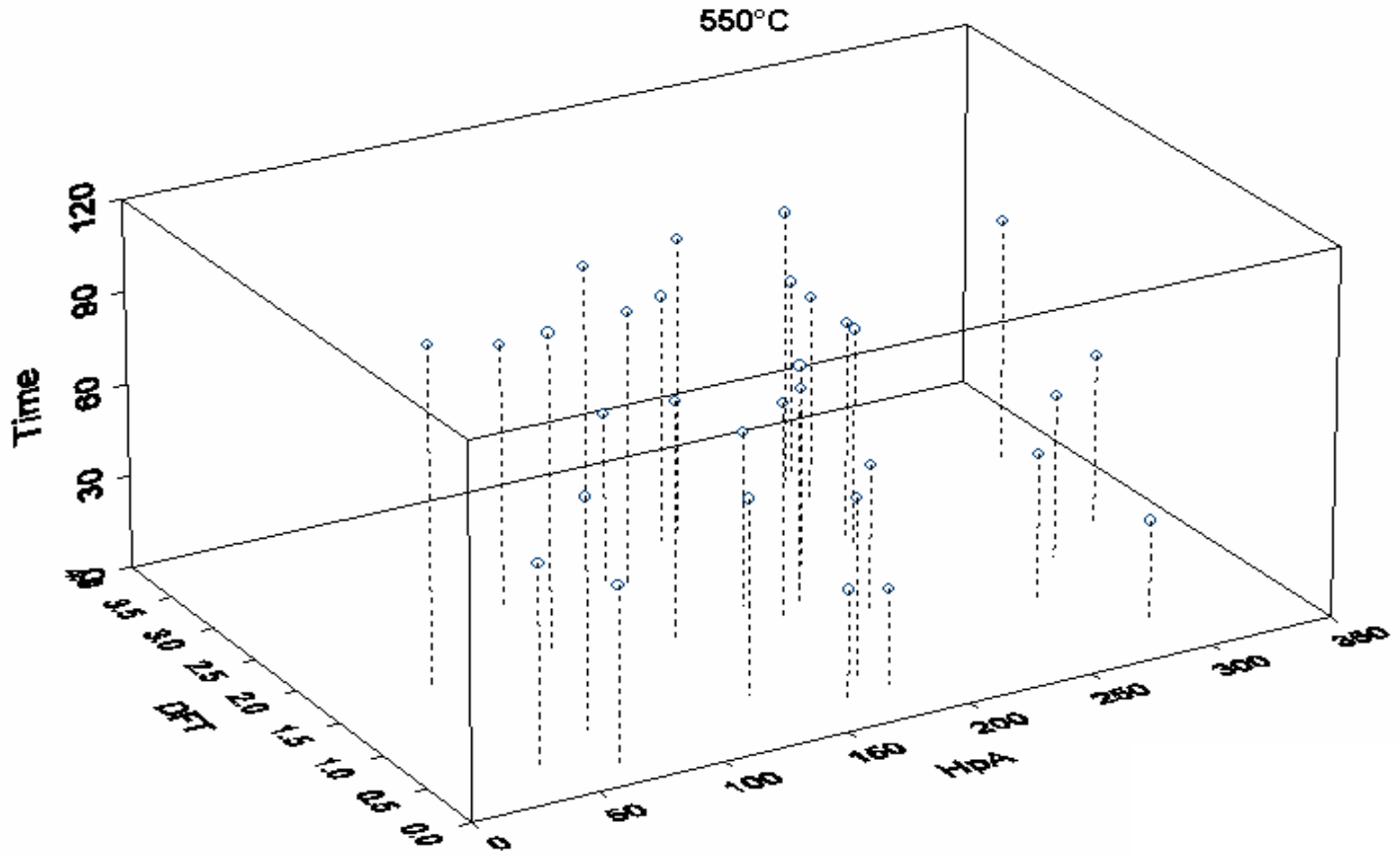


Fig. 1: 3D - Representation of data set for 550°C

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

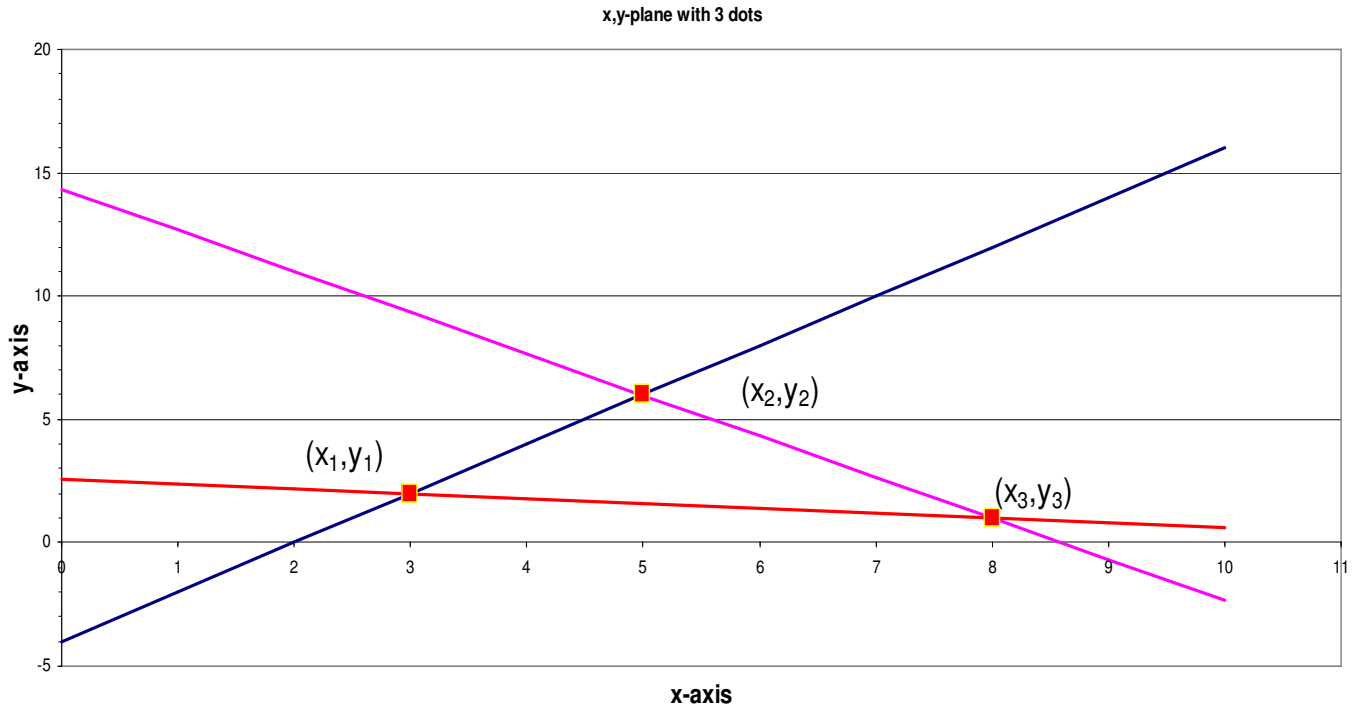


Figure 2

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

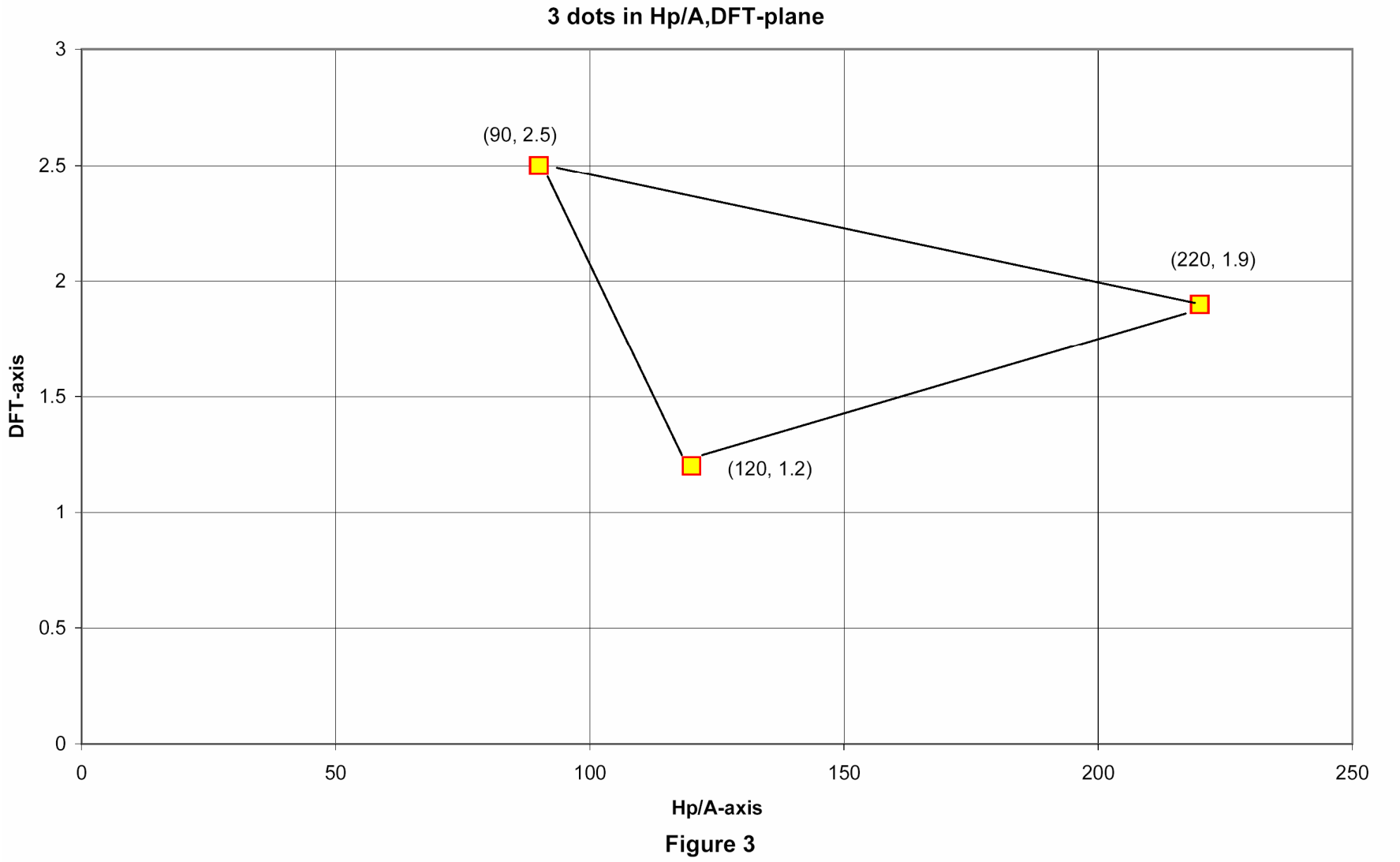


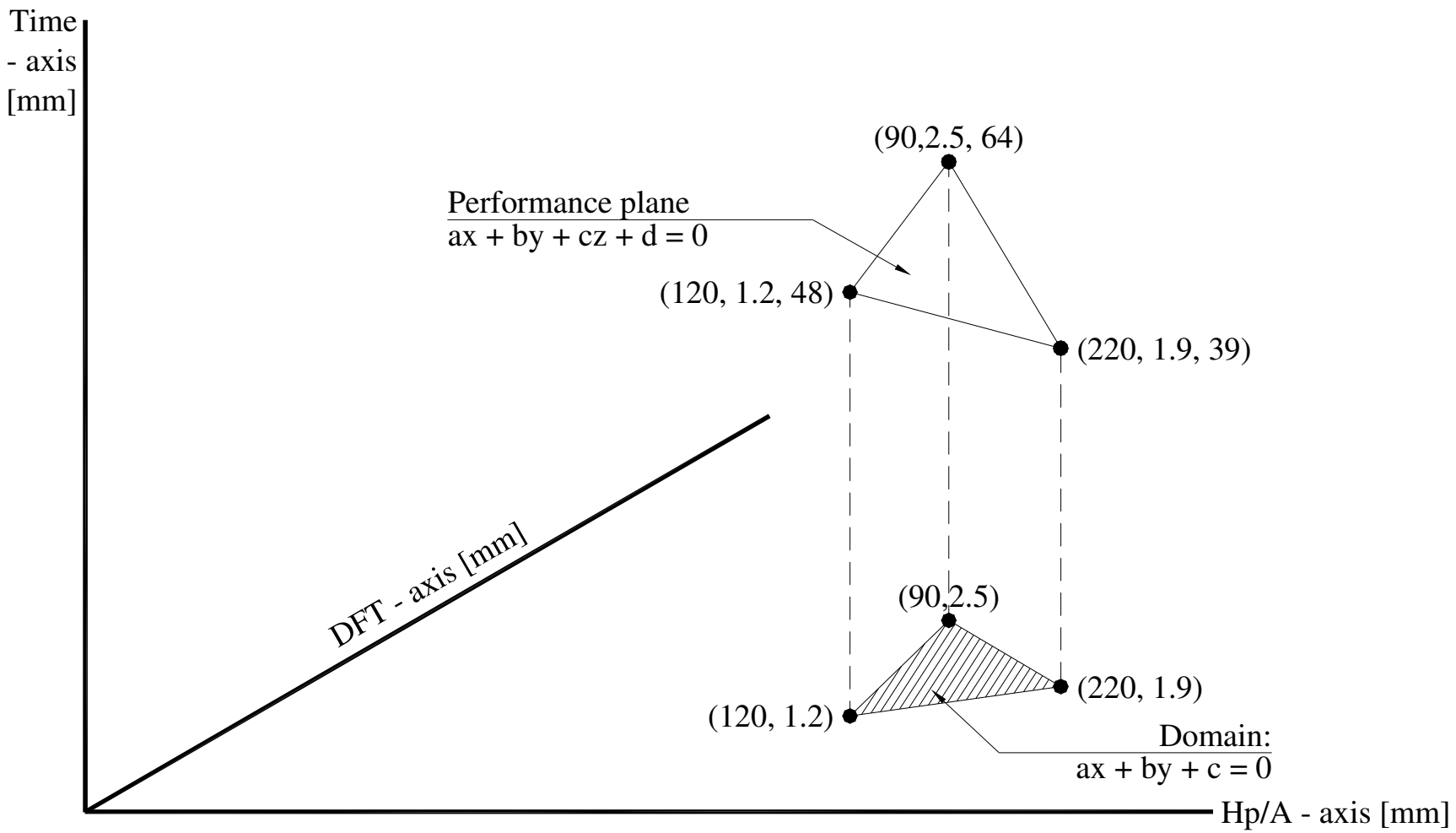
Figure 3

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:

$$a \cdot Hp/A + b \cdot DFT + c \cdot time + d = 0$$

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……..

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Test evidence with various data points

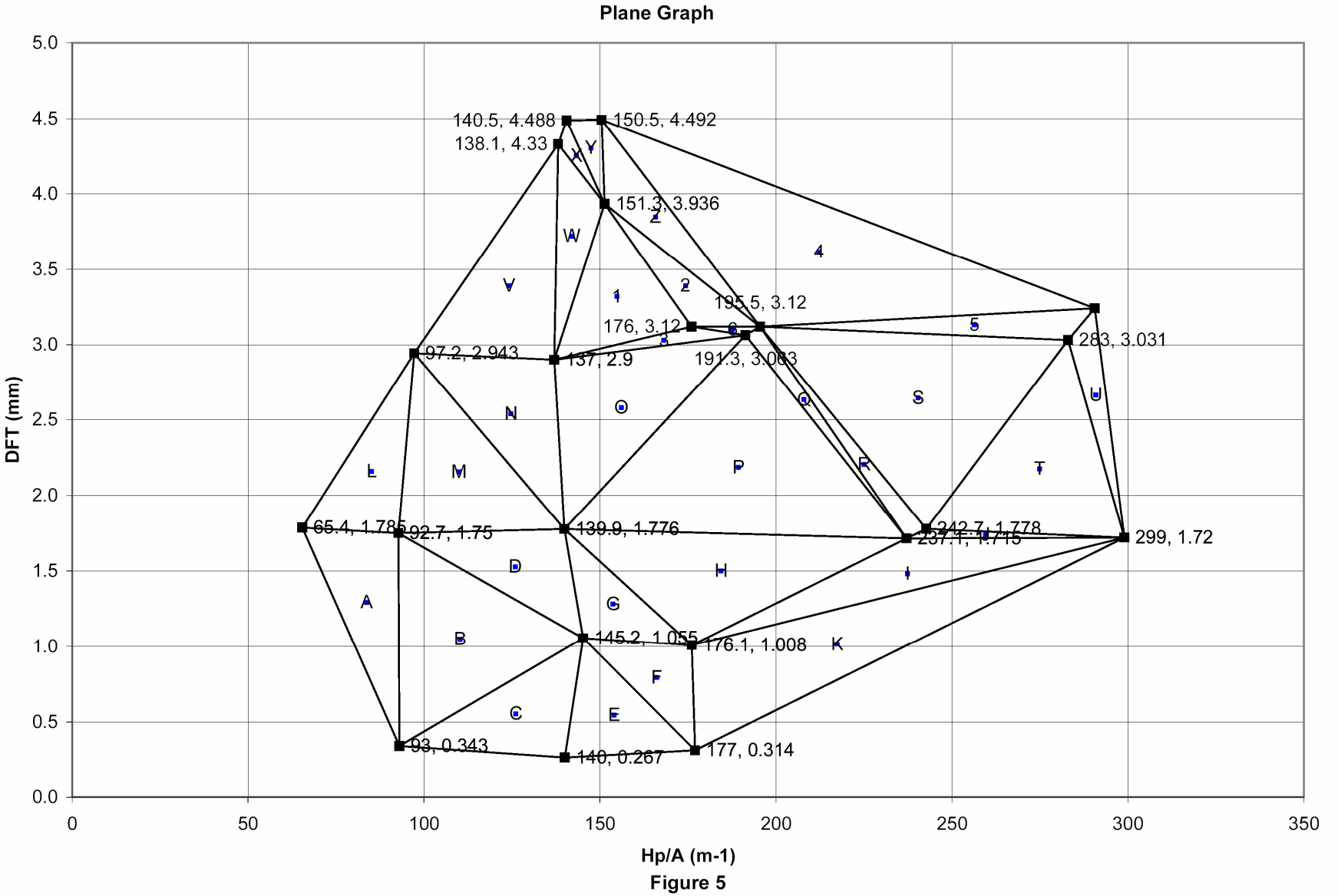

Figure 5

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

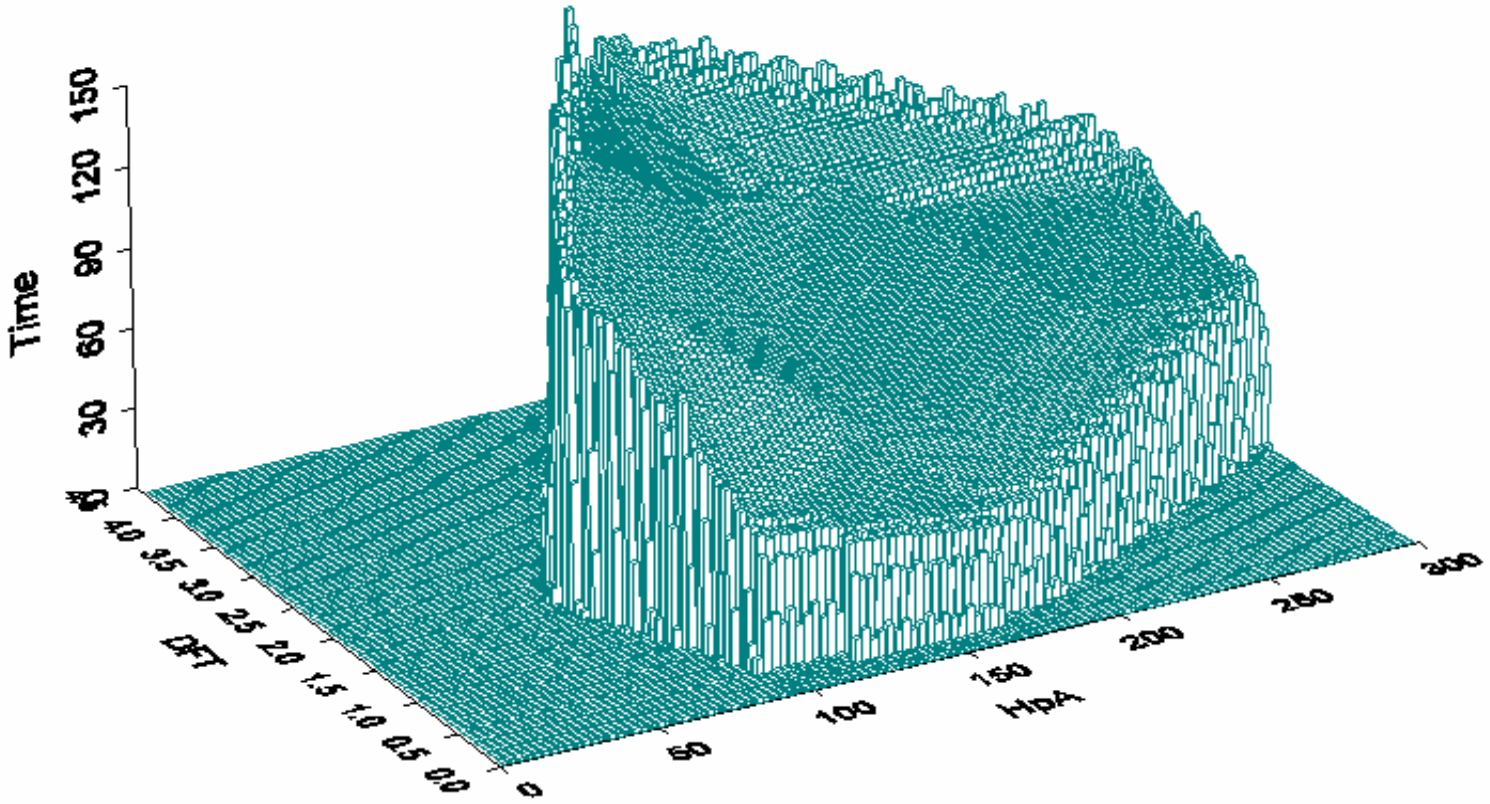

Figure 6

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 Hp/A)
  - performance time as a function of Hp/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 Hp/A
- Performance time as a function of Hp/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 Hp/A shows that lines for DFTs intersect
- The method allows identification of areas where improvement of the intumescent formulation

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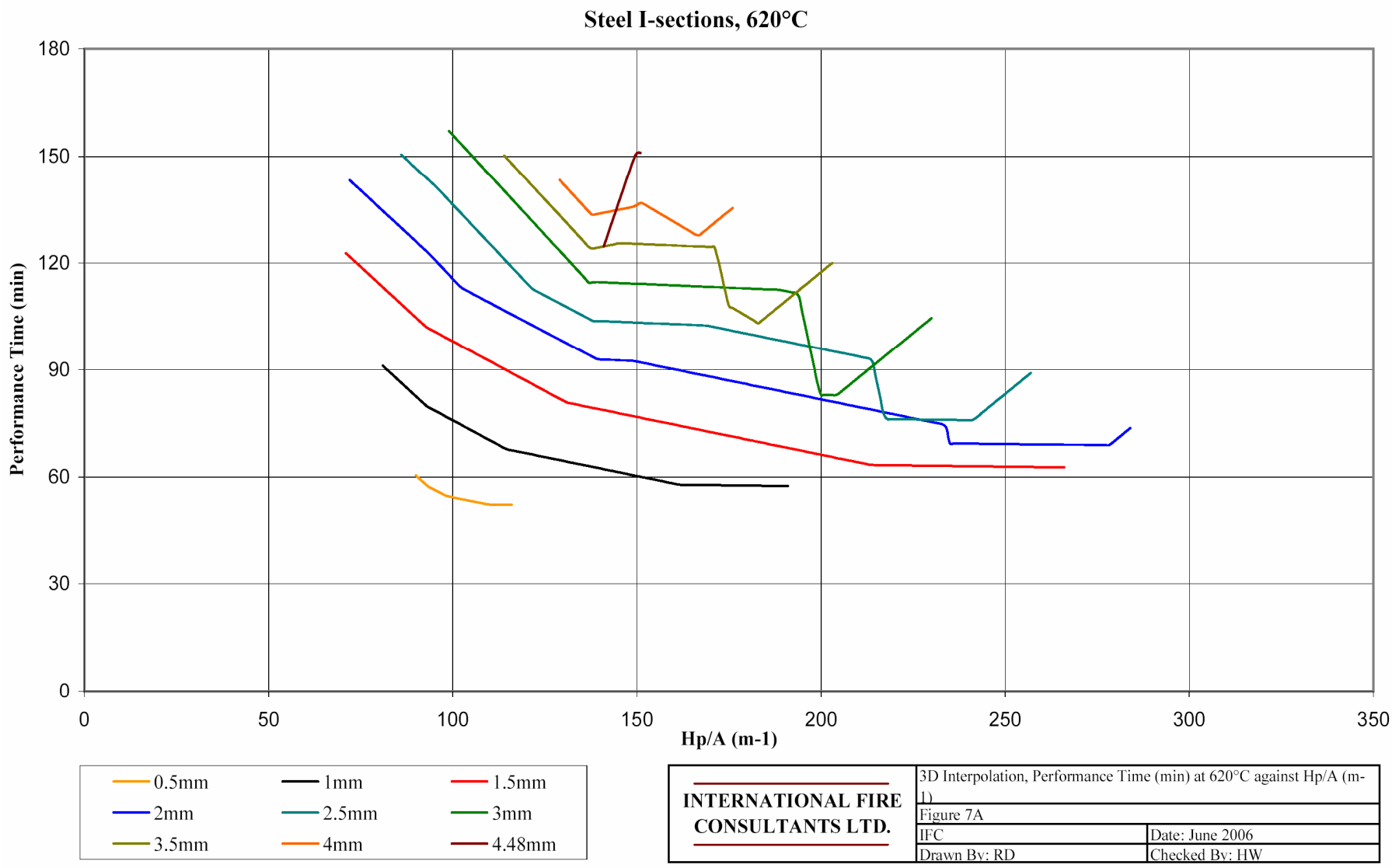
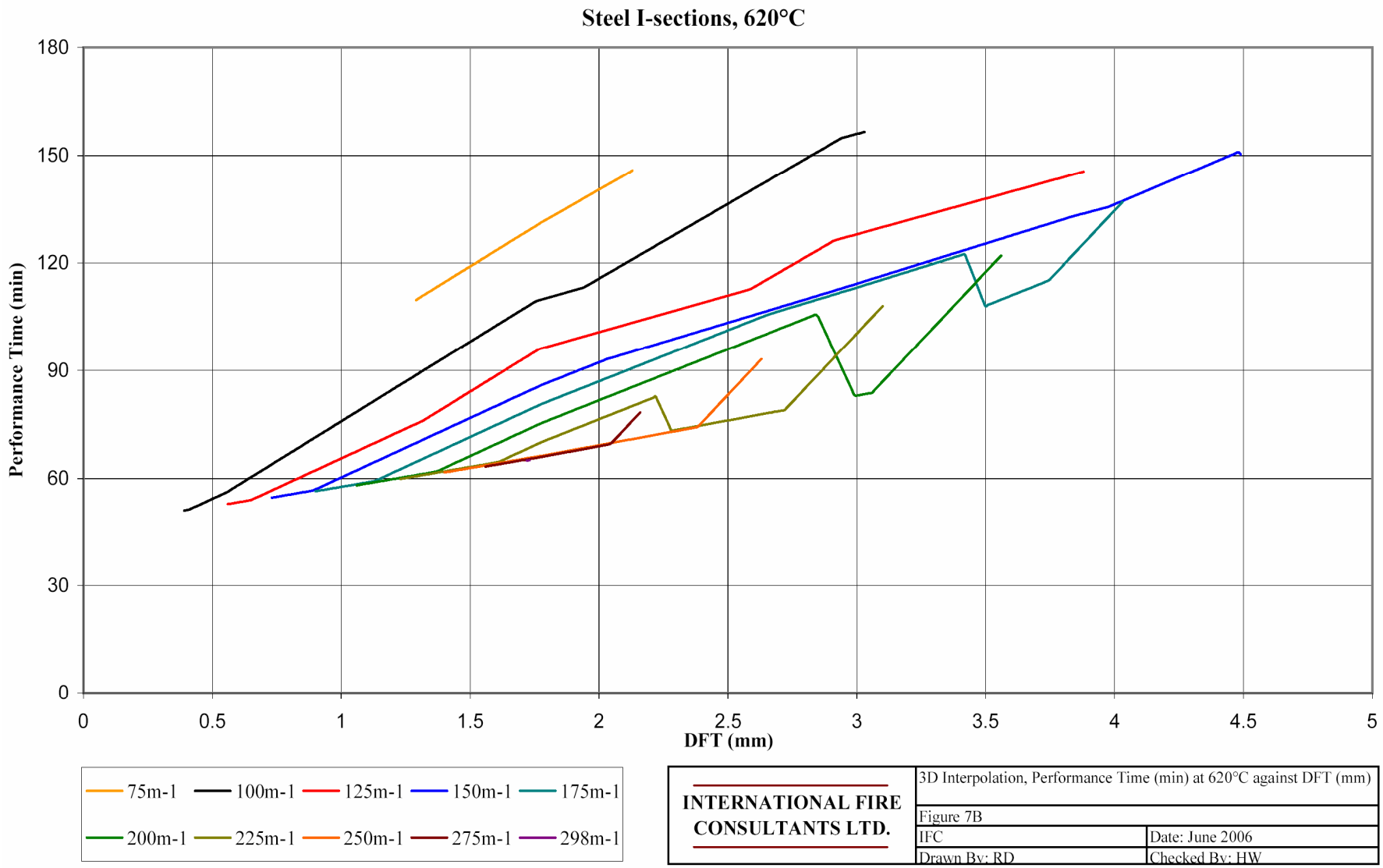
Visualisation of previously unrevealed information



INTERNATIONAL FIRE CONSULTANTS LTD.	3D Interpolation, Performance Time (min) at 620°C against Hp/A (m-1)	
	Figure 7A	
	IFC	Date: June 2006
	Drawn By: RD	Checked By: HW

Visualisation of previously unrevealed information



INTERNATIONAL FIRE CONSULTANTS LTD.	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

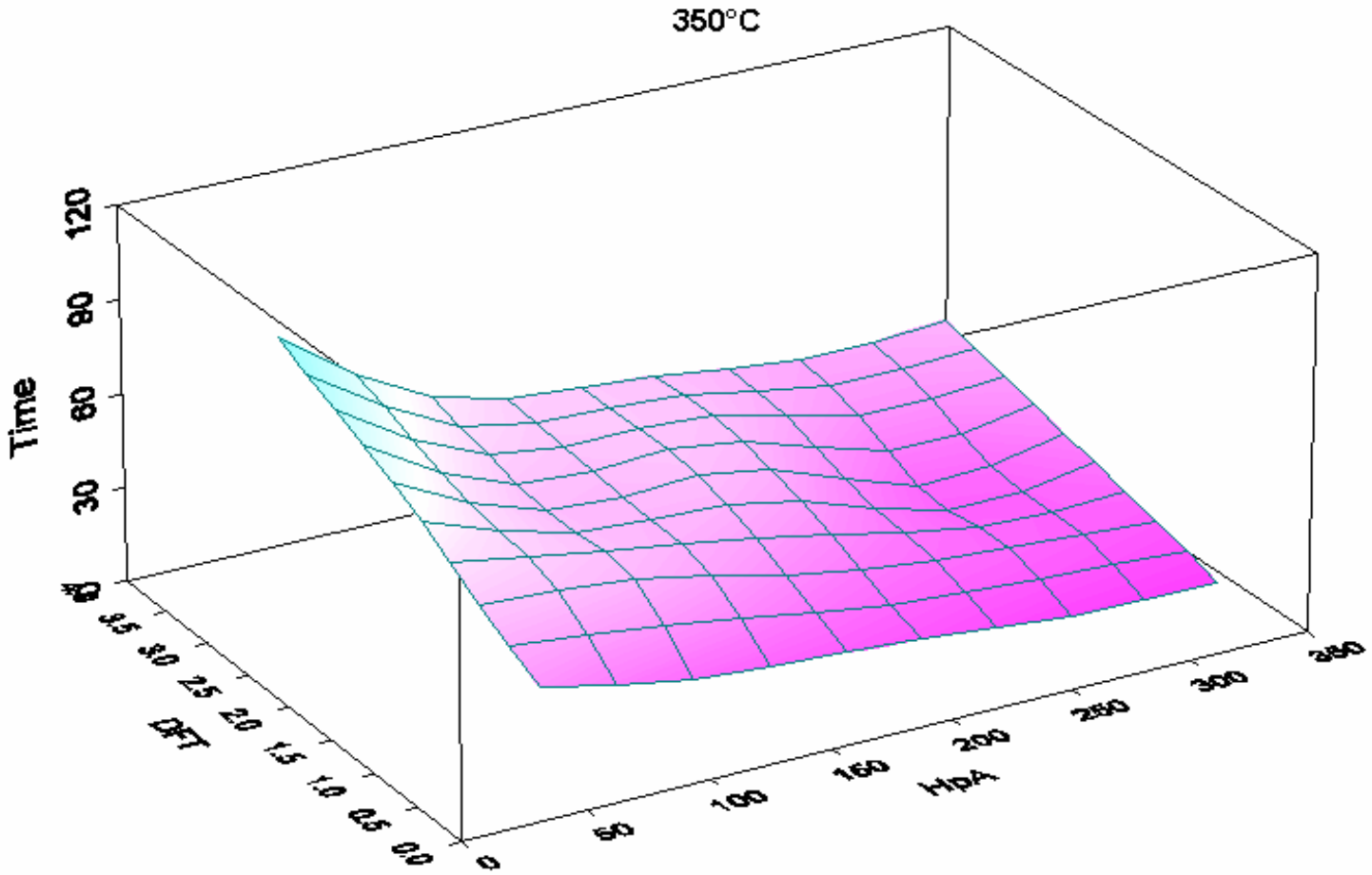


Figure 8

Adding the fourth dimension

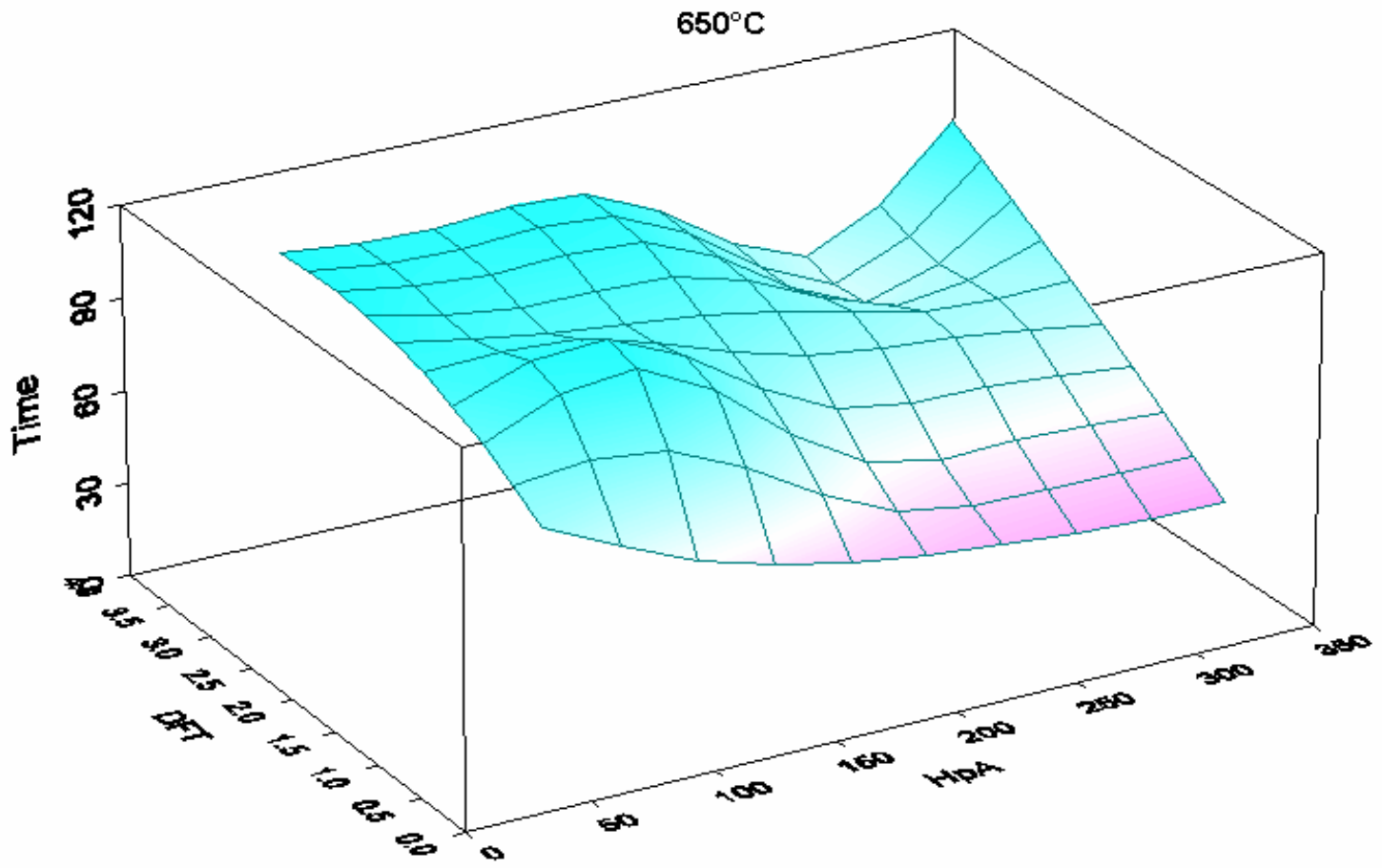


Figure 9

Adding the fourth dimension

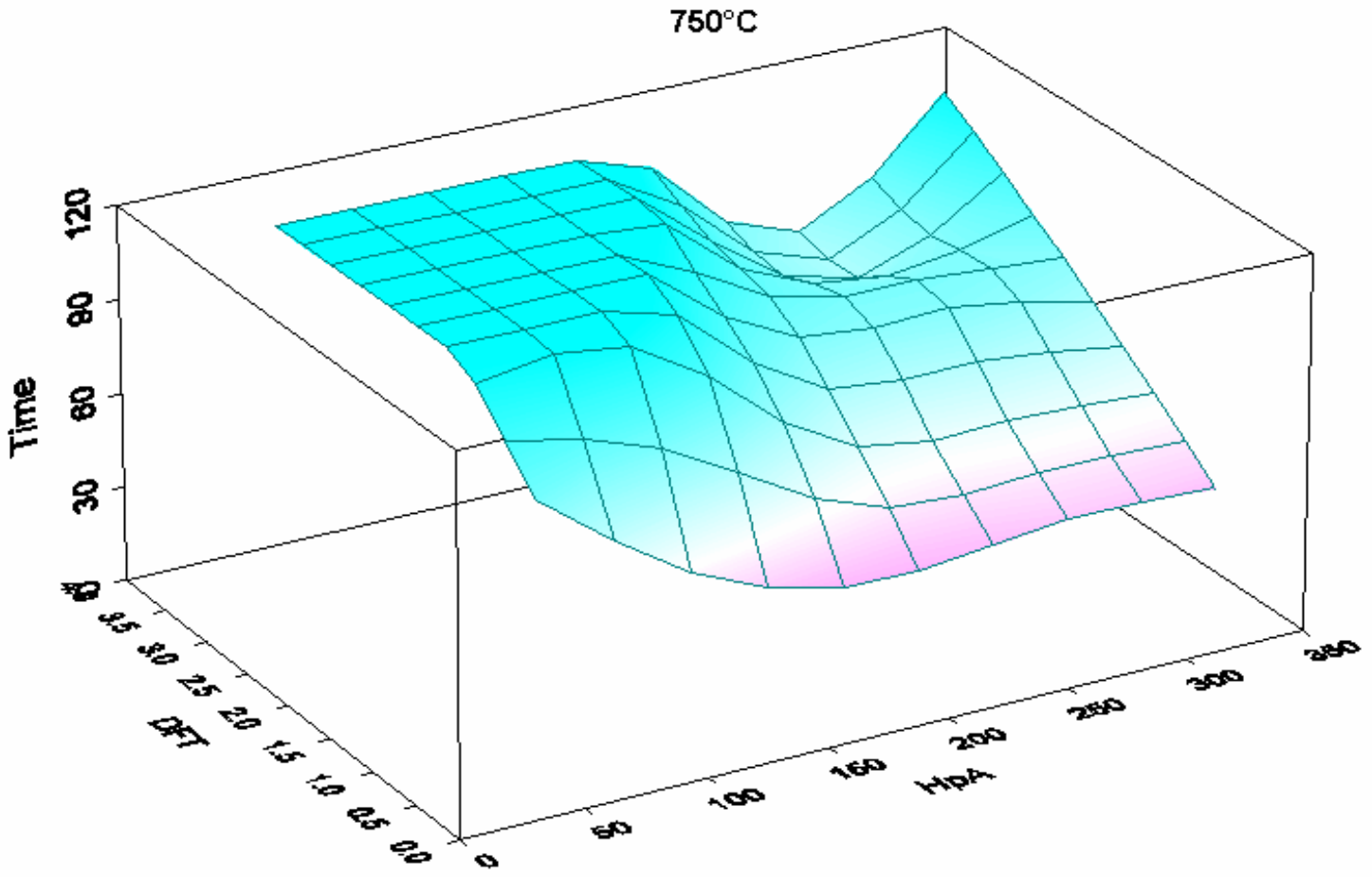


Figure 10

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?