The Influence of Cigarette Base Paper Properties on their CO_2 Diffusivities and the Correlation with ISO Smoking Yields

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- Cigarette paper diffusivity;
- Aims of the study;
- Experimental design;
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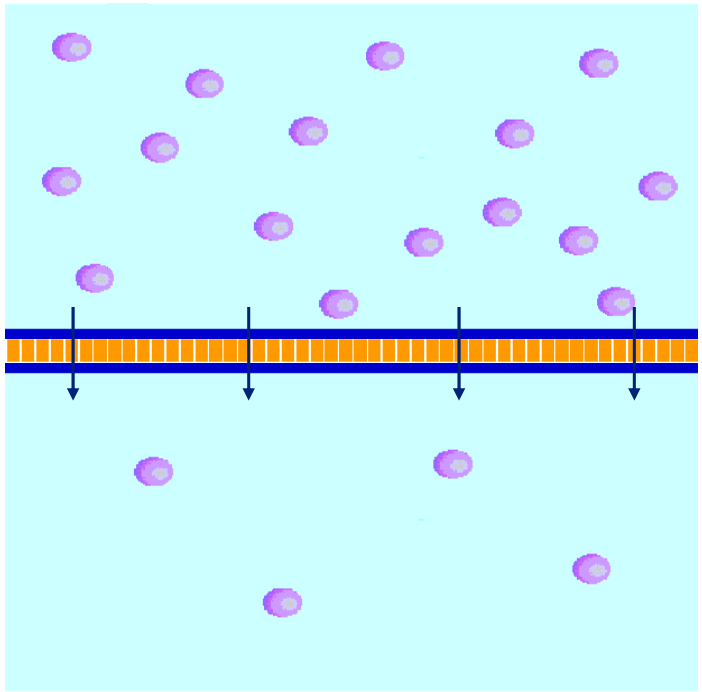
- Effect of diffusivity on smoke yields;
- Conclusions.

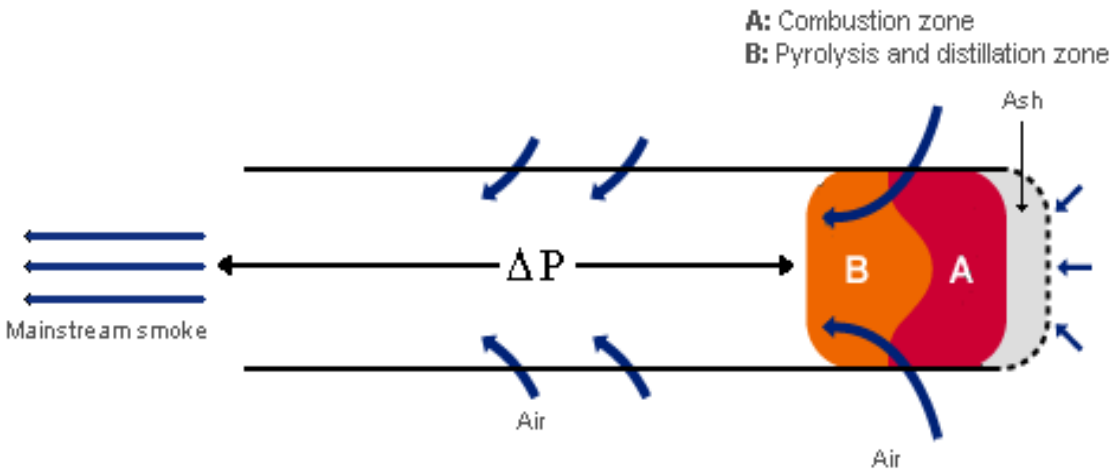
Introduction

- Cigarette paper plays a significant role in (amongst other factors):
  - **Cigarette manufacture**
    - Tensile strength and stretch
  - **Visual appearance**
    - Opacity and whiteness
  - **Mainstream smoking yields**
    - Increasingly regulation-driven environment.
    - Effects of changing cigarette paper physical parameters on mainstream smoke yields is of interest to product developers
  - **LIP Performance (ASTM E2187-04)**
    - Not specifically addressed here

Cigarette Paper Diffusivity vs Permeability

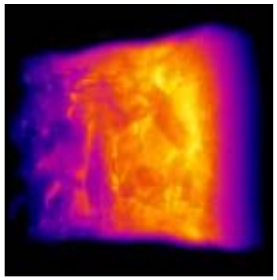


Diffusion: driven by concentration gradient

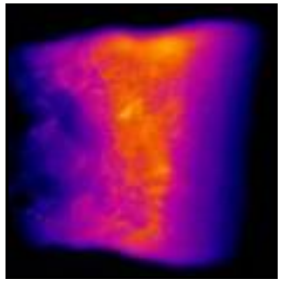


Permeability: driven by pressure gradient

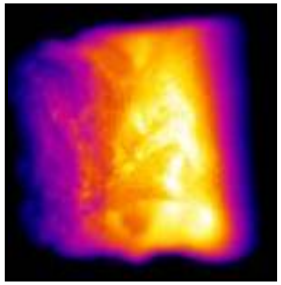
Why is Diffusivity Important?



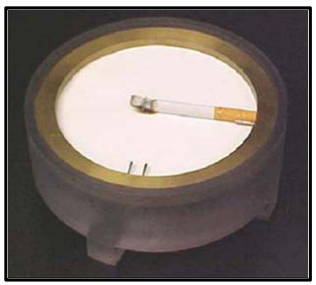
Burning coal approaching banded region



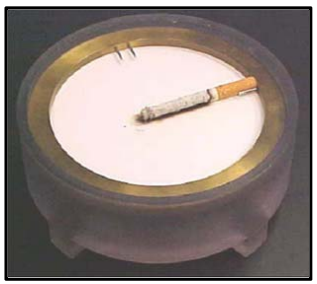
Burning coal shrinks while burning through band



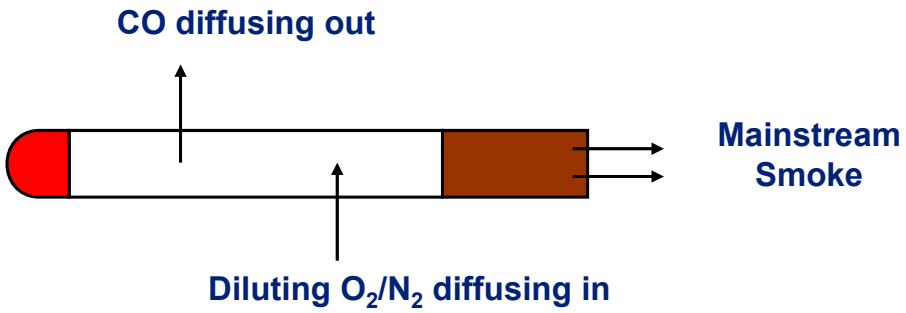
Coal expands and heats up after burning through band



Pass

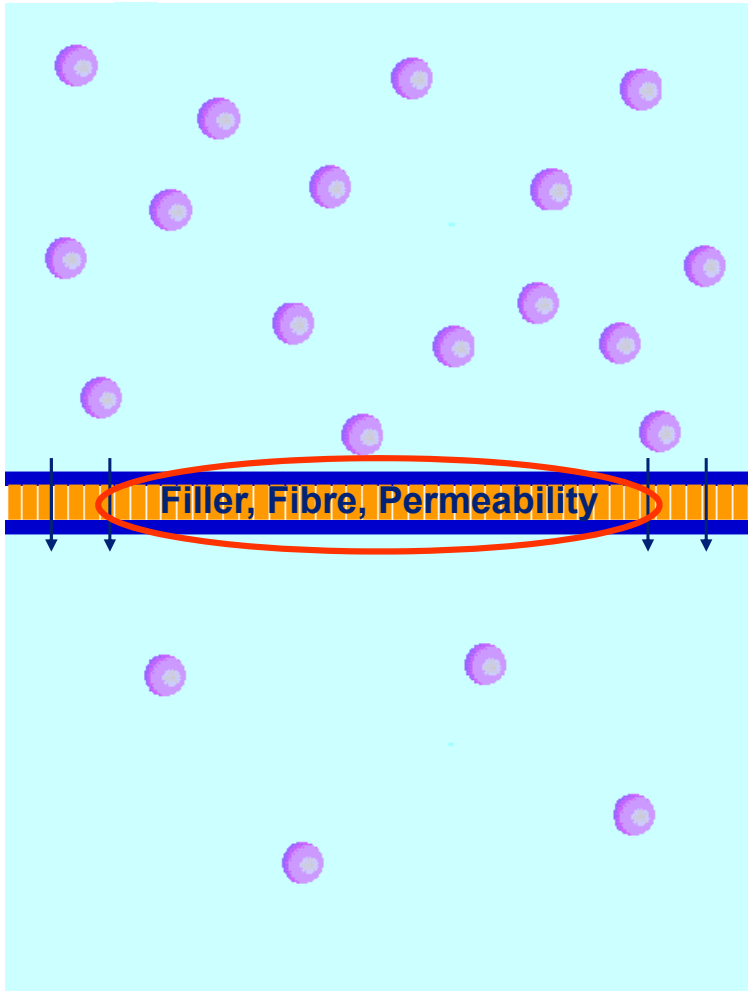


Fail

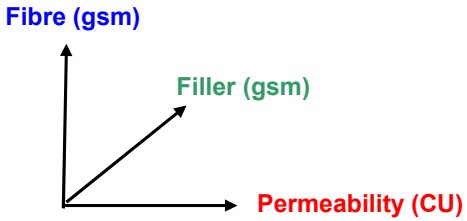


Aims of the Study

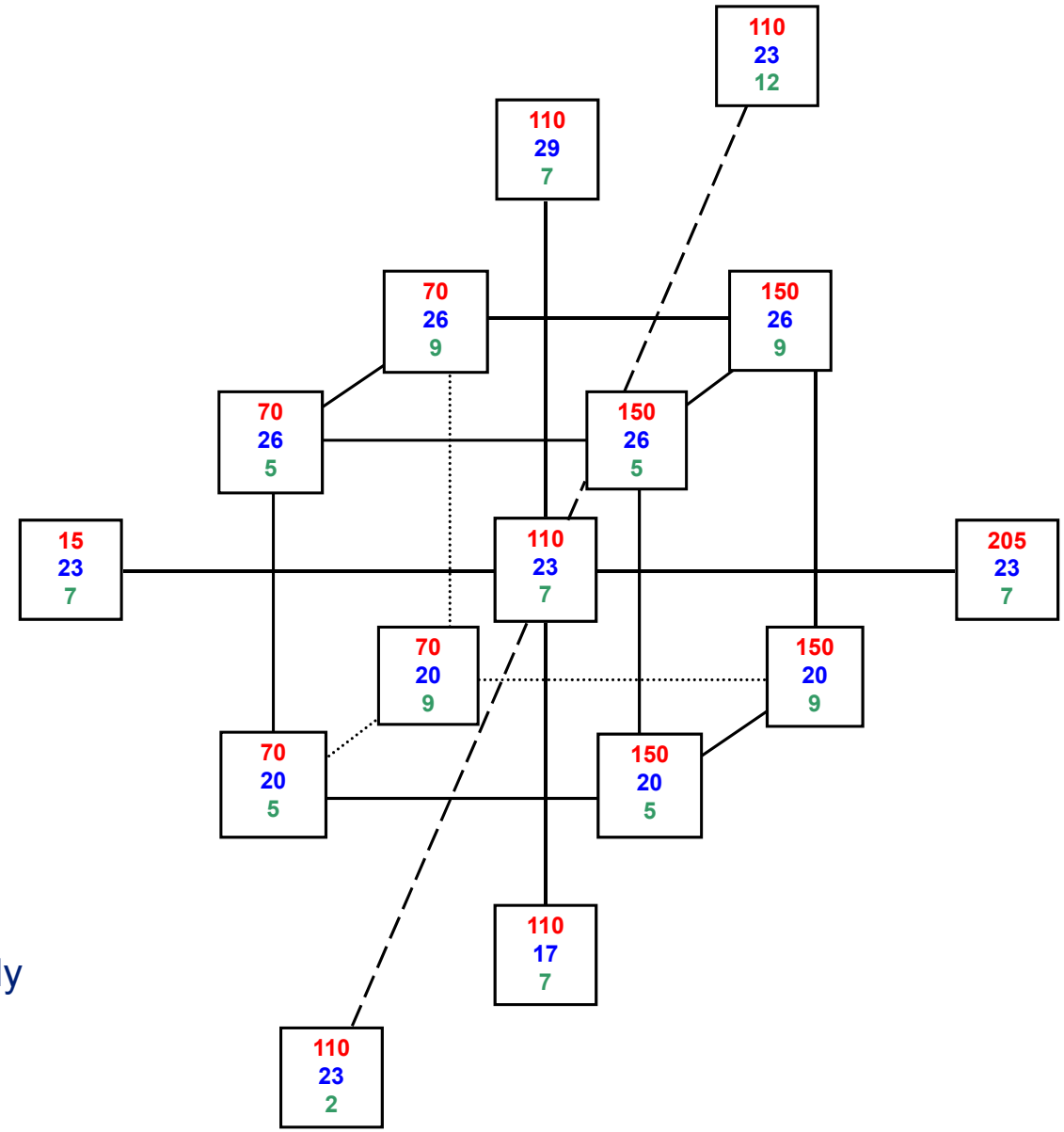
- Well designed existing systematic experiment.
- Q. How do the filler and fibre contents and paper permeability influence diffusivity?
- Q. What effects does diffusivity have on mainstream smoke yields?



Schematic of Experimental Design



Note:
- No burn additive
- Wood furnish



- Statistically designed experiment
- Based on a Central Composite design
- Minimum number of experiments to fully characterise variables
- Wide operating window

Limitations

- Correlation study (diffusivity vs smoke yields)
  - Do not yet know how to fully control diffusivity
- No burn additive

Cigarettes and Analysis

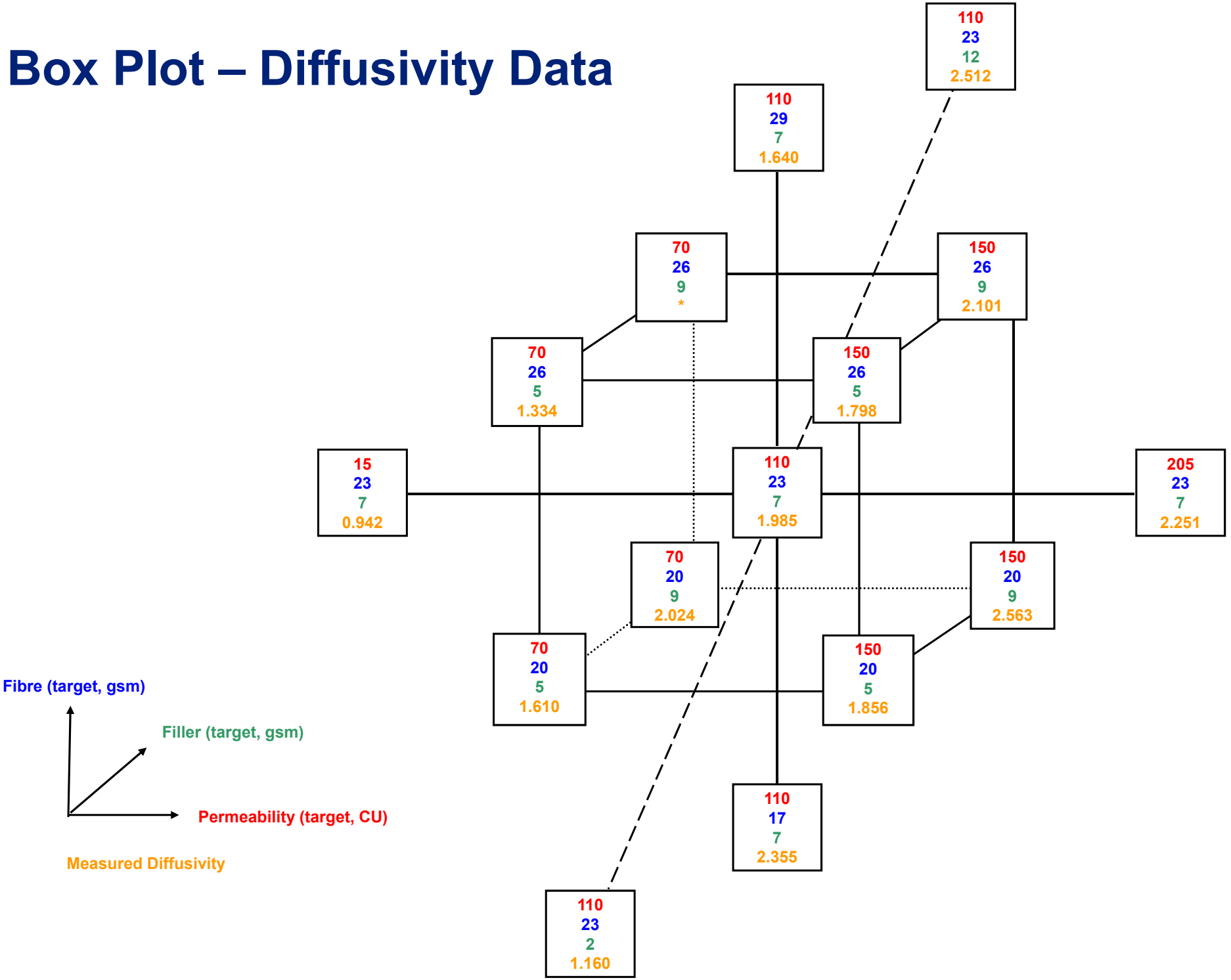
Cigarettes manufactured on a Molins Mark 8 cigarette maker running at 750 cigarettes per minute, without filter ventilation.

Cigarette Parameter	Values and Units
Physical Measurements	
Cigarette length	84 mm
Tobacco column length	64 mm
Circumference	24.75 mm
Filter Measurements	
Filter length	20 mm
Filter Pressure Drop	70 mm W.G.
Filter material	Cellulose Acetate
Tobacco Rod Weight	690 mg
Blend Chemistry	
Nicotine	2.3 %dwb
Reducing sugars	11.5 %dwb
Total sugars	13.0 %dwb

Note: %dwb = % dry weight basis

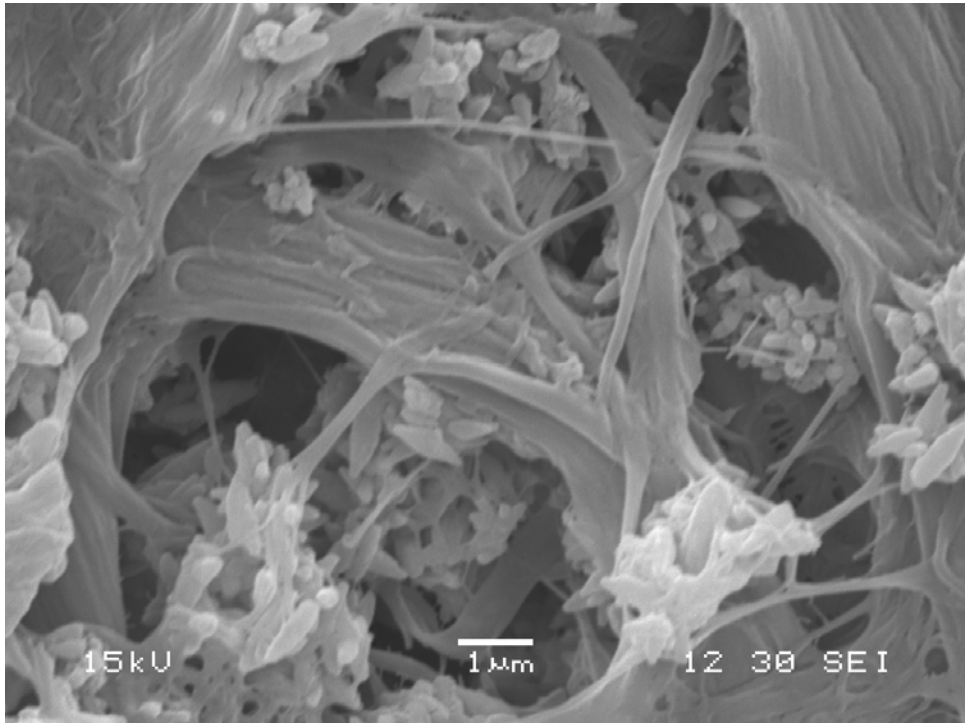
- 20 port Filtrona model 400 linear smoking machine.
- Smoked to the ISO standard butt length of filter + 8mm or overtip + 3mm, whichever is the greater.
- NFDPM, Nicotine and CO yields, puff number, static burn rate.
- Diffusivity measurements performed on a Sodim Instrumentation diffusivity meter.

Box Plot – Diffusivity Data



Response Surface Regression

- Minitab 15
- Effect of:
  - Filler;
  - Fibre;
  - Permeability



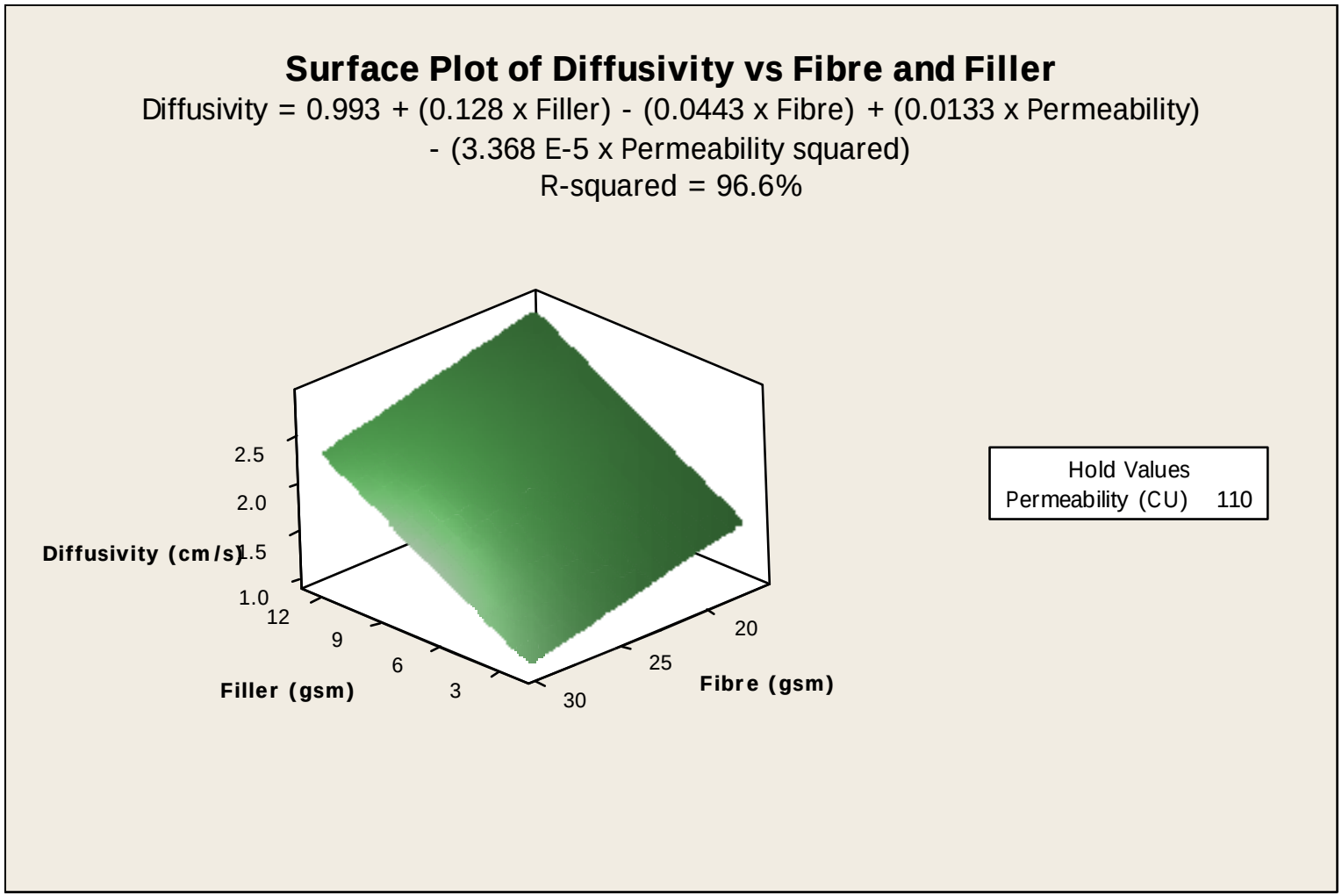
50 CU Cigarette Paper (CP50-23VGM 1.0 KCM) – Top Side (× 10 000 Magnification)

on diffusivity and physical characteristics (*e.g.* tensile strength, opacity).

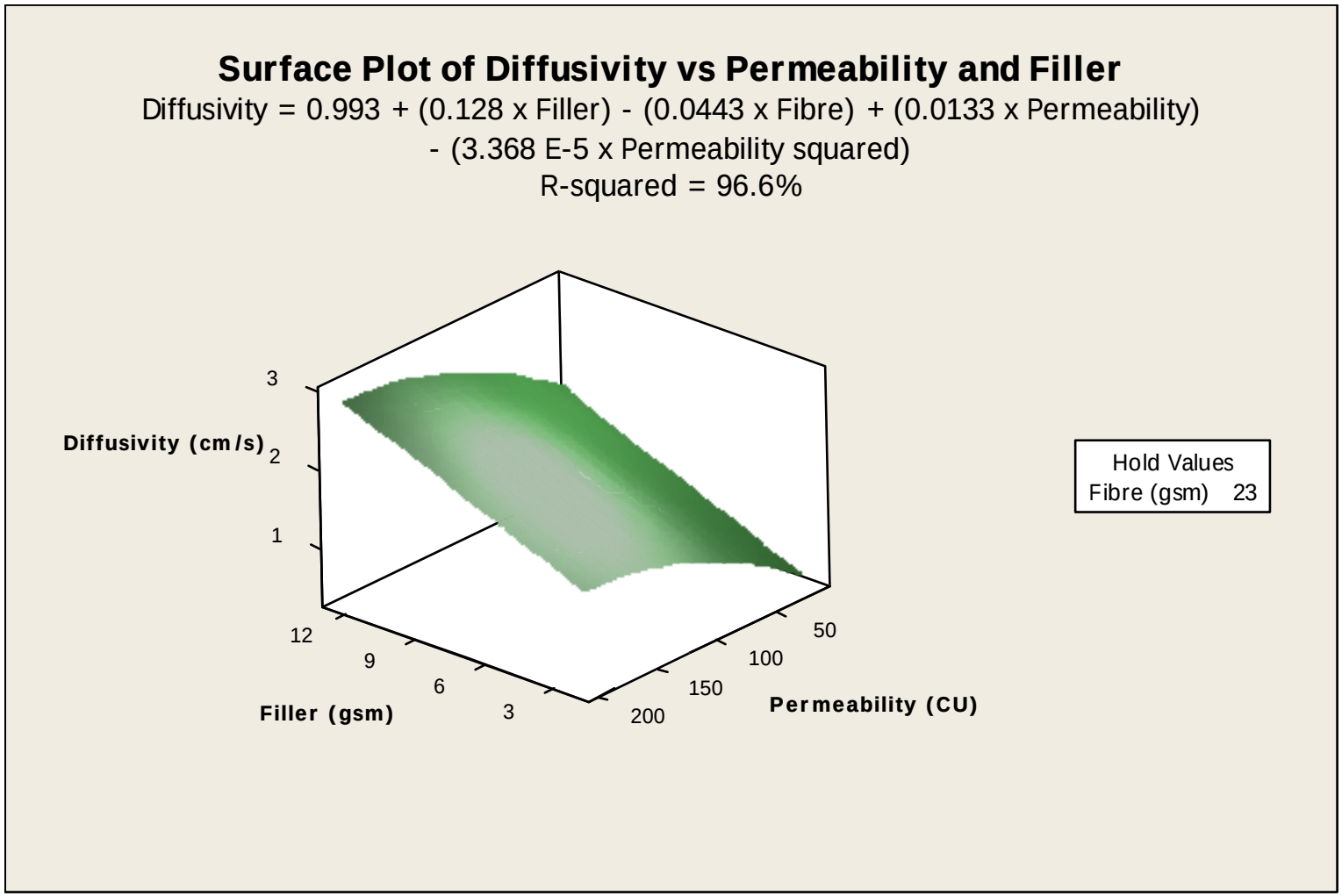
- Effect of diffusivity on smoking yields.

- (Quadratic equations do not explain the data, but do represent the relationships mathematically).

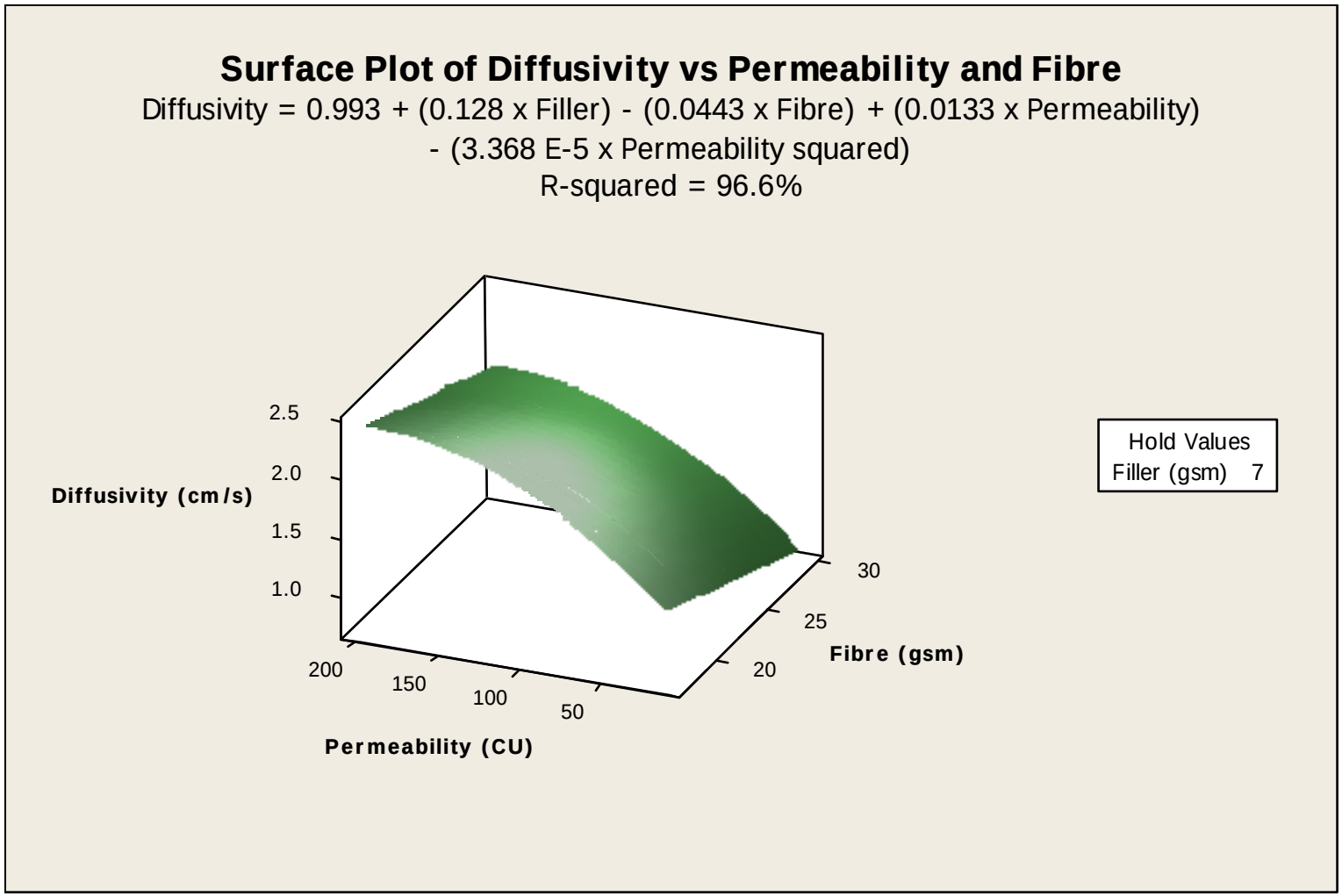
Diffusivity vs Filler and Fibre



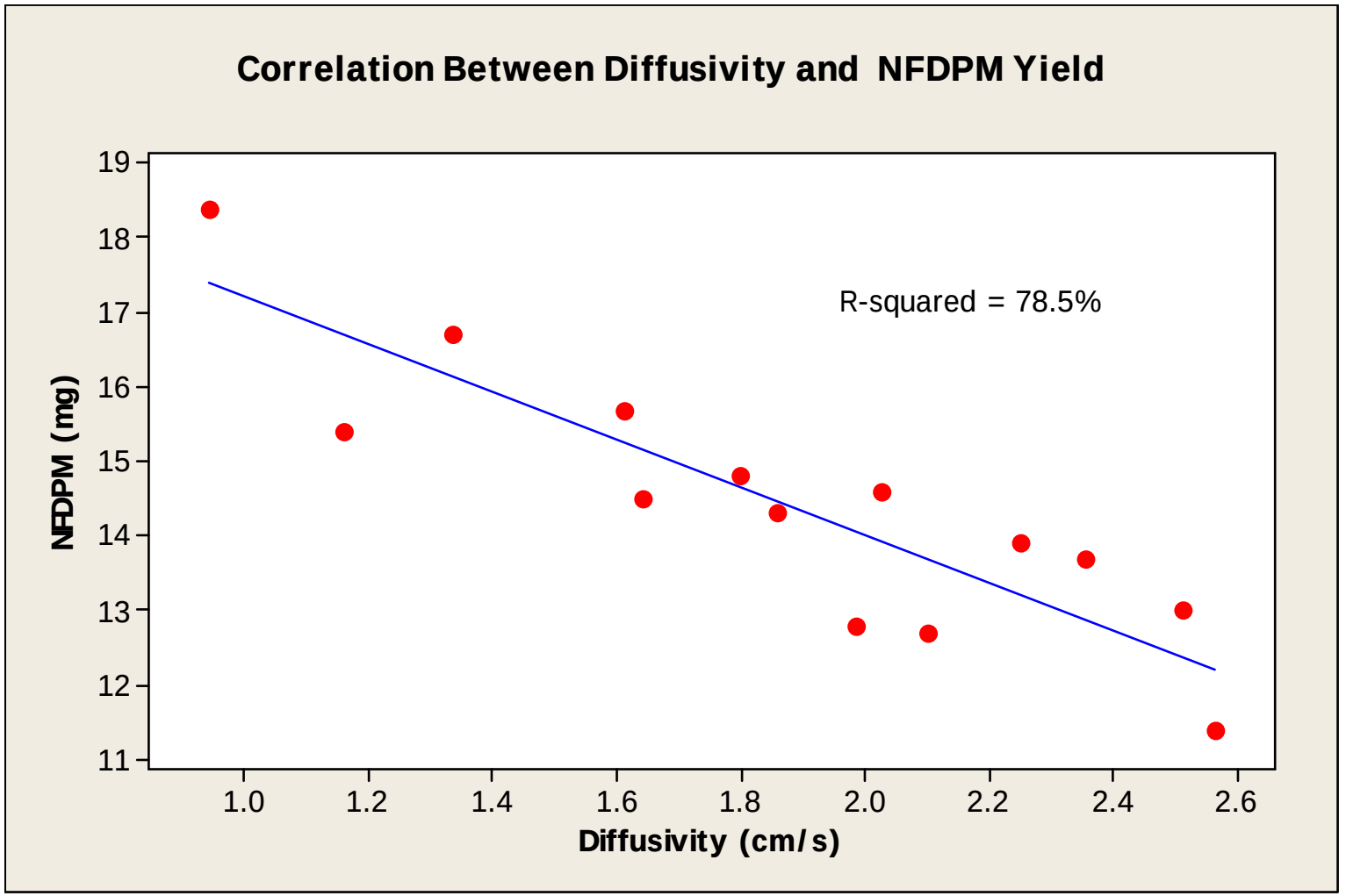
Diffusivity vs Filler and Permeability



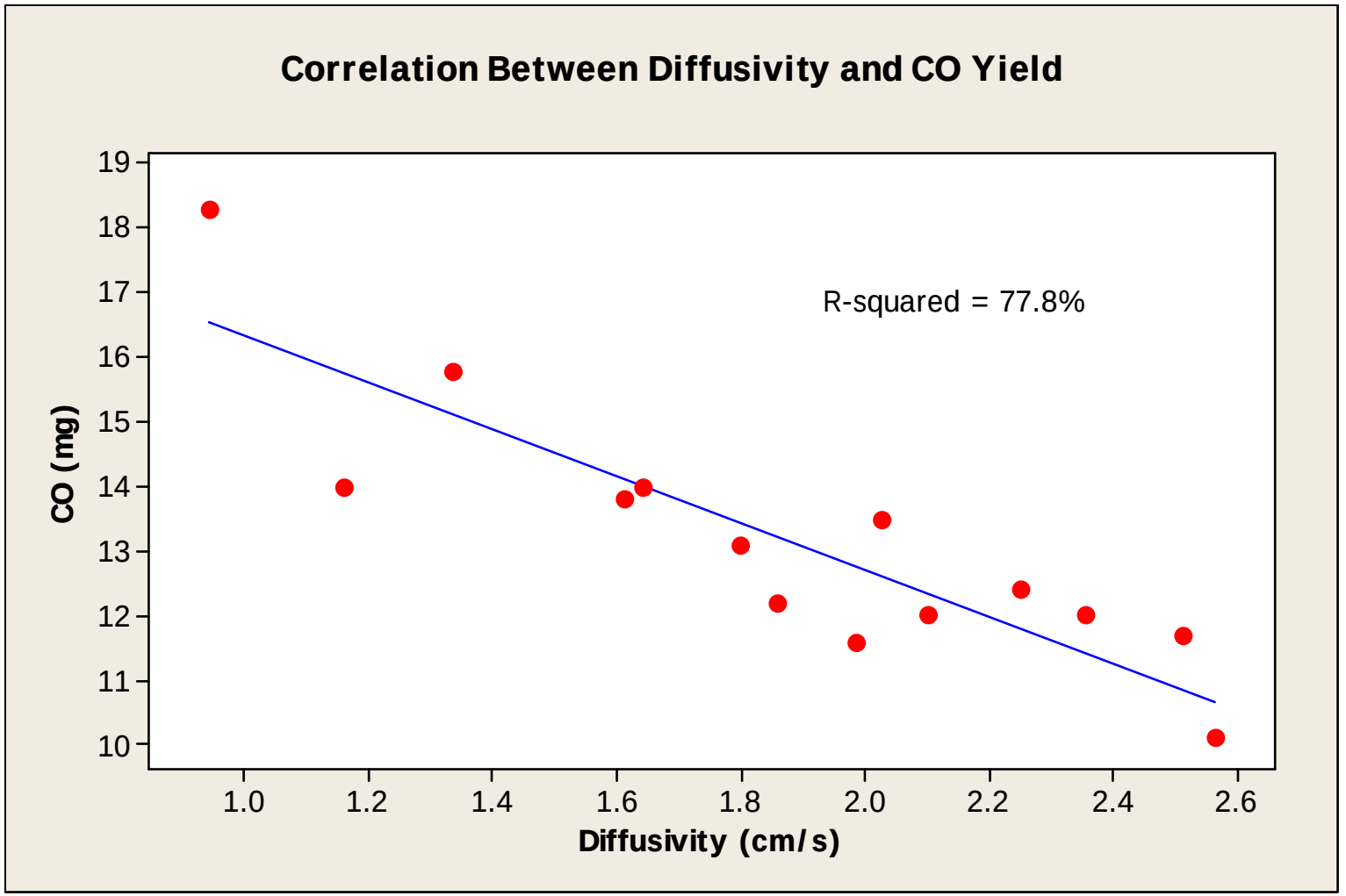
Diffusivity vs Permeability and Fibre



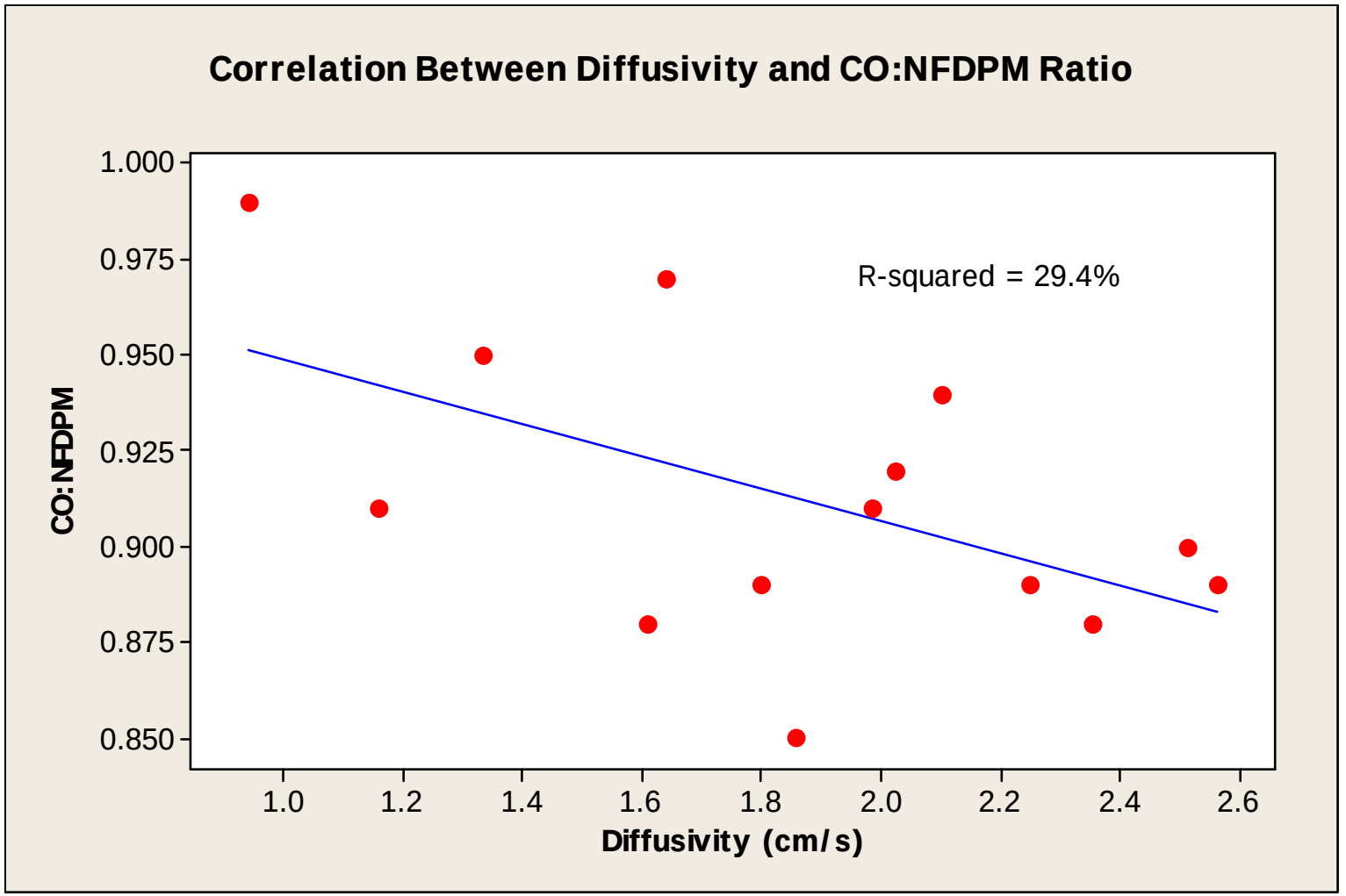
Effects of Diffusivity on Smoke Yields



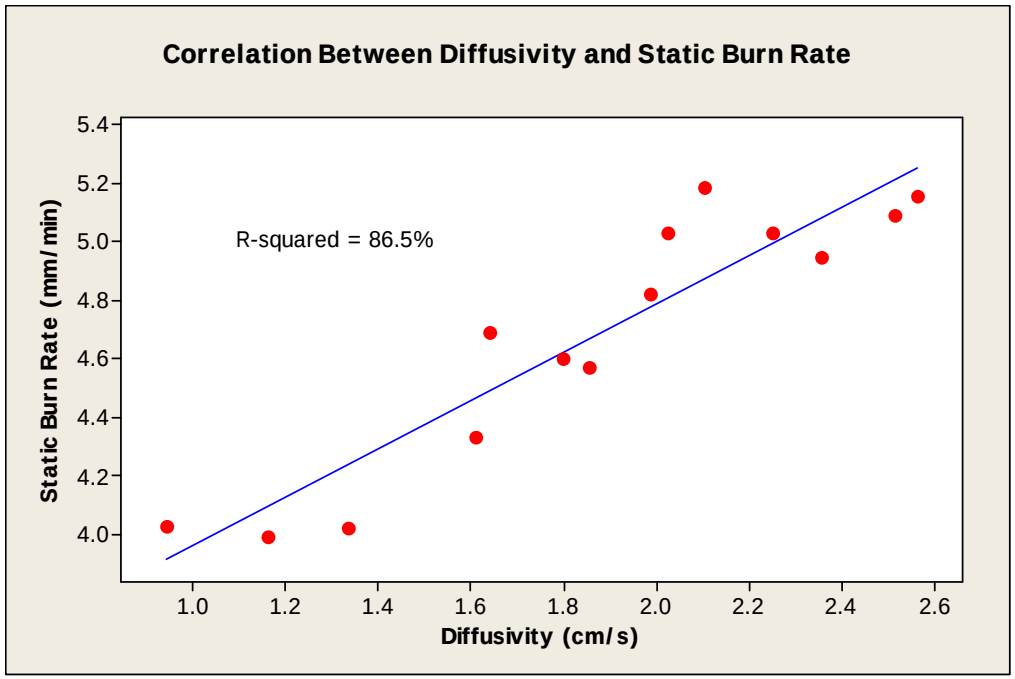
Effects of Diffusivity on Smoke Yields

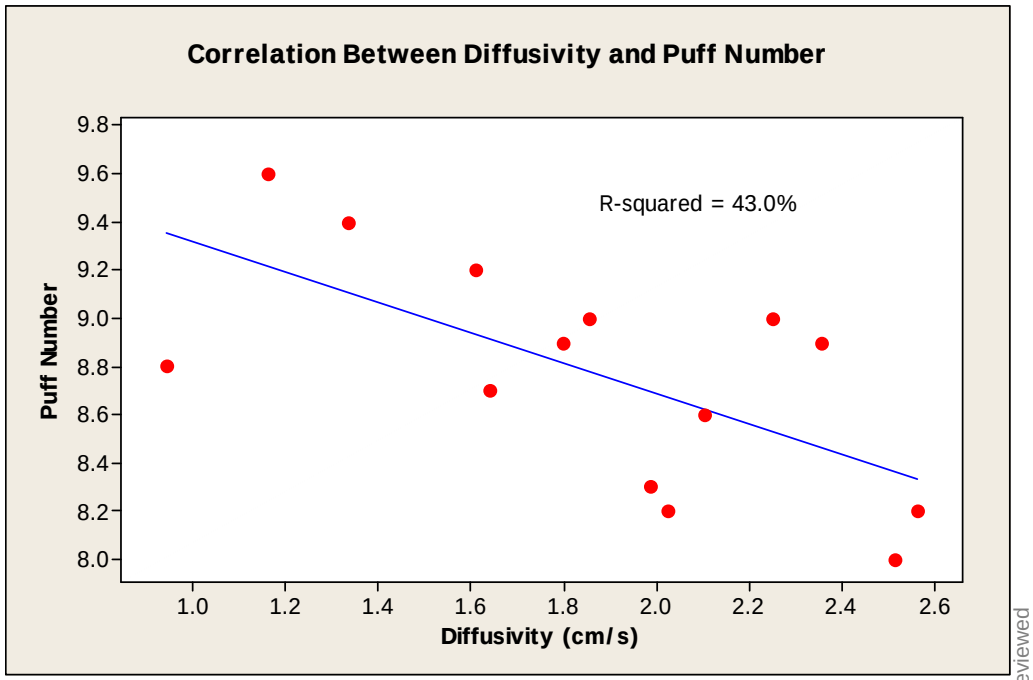


Effects of Diffusivity on Smoke Yields



Effects of Diffusivity on Smoke Yields





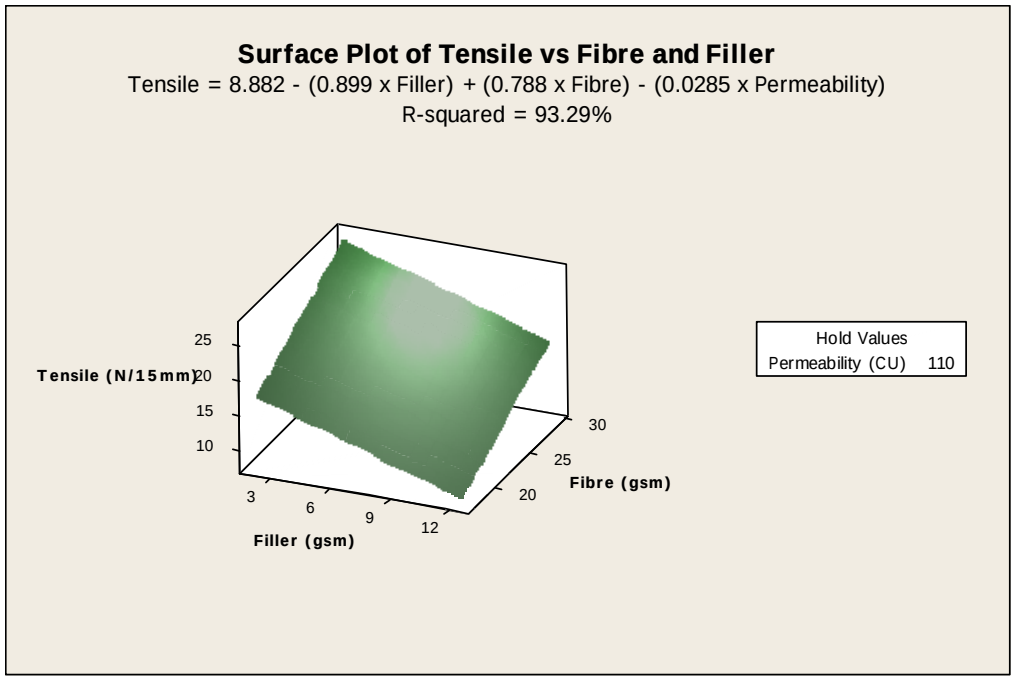
Effect of Diffusivity on…

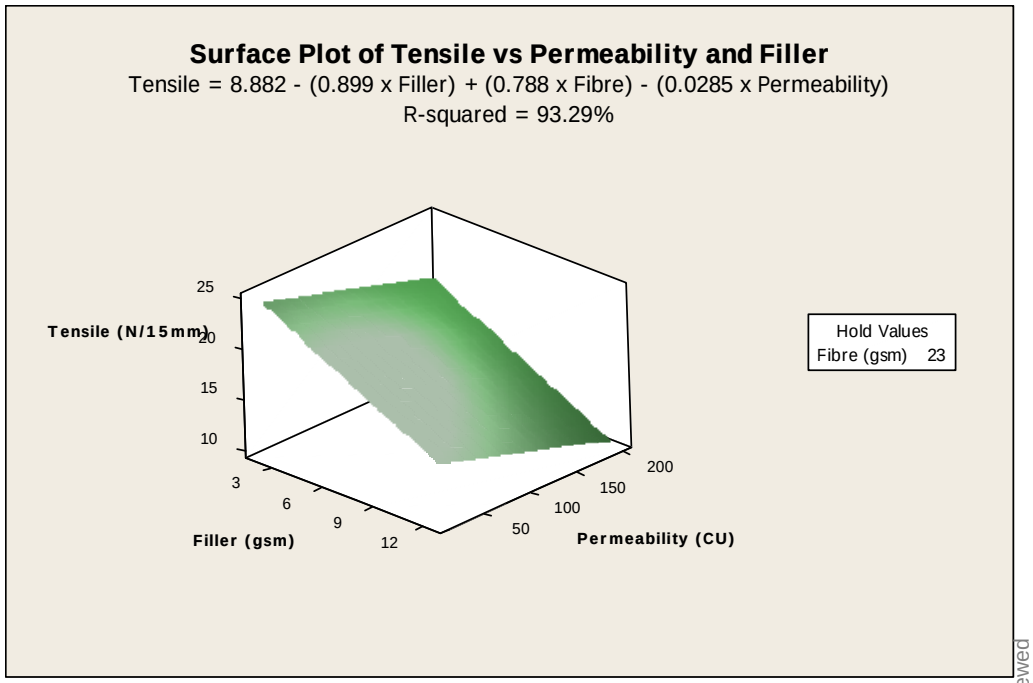
Diffusivity Trend	Response	Response Trend
INCREASE	NFDPM and CO	DECREASE
INCREASE	CO:NFDPM	DECREASE
INCREASE	Static Burn Rate	INCREASE
INCREASE	Puff Number	DECREASE
INCREASE	LIP pass rate	DECREASE

Therefore high diffusivity advantageous for lowering smoke yields
(but not for LIP pass-rate!)

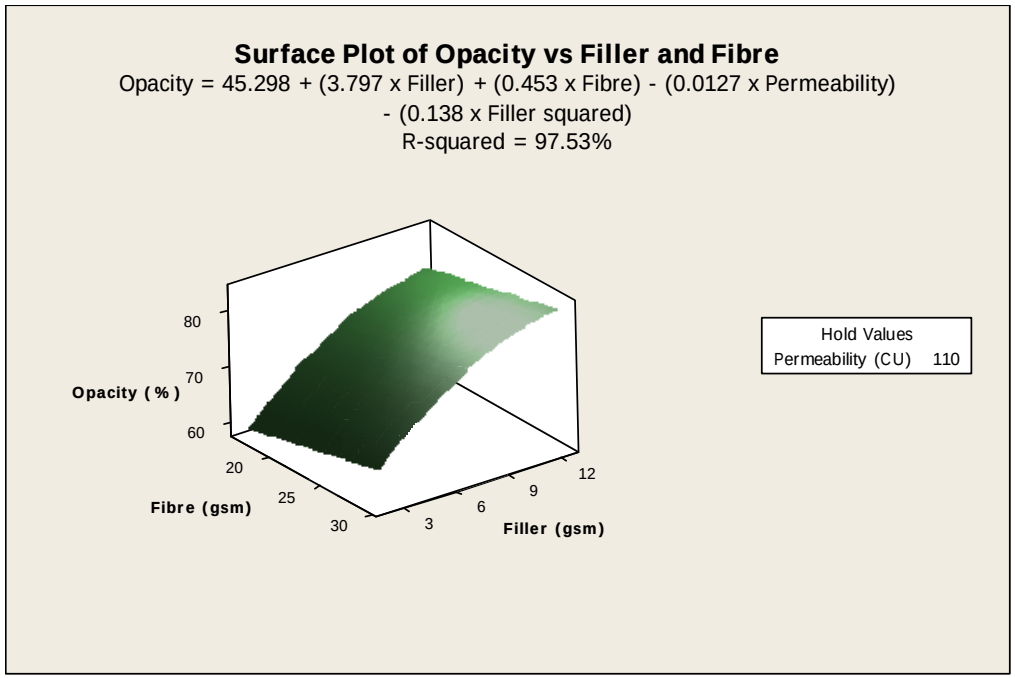
⟶ Balance between filler & fibre

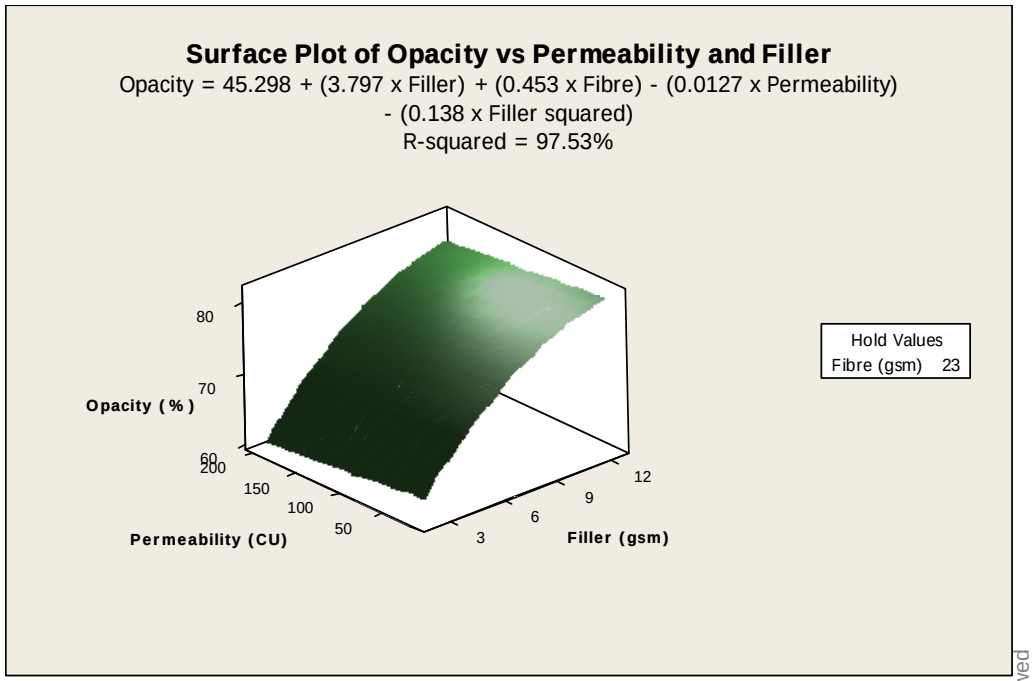
Tensile Strength vs Filler, Fibre and Permeability





Opacity vs Filler, Fibre and Permeability





Conclusions

- Base-paper parameters that influence diffusivity:
  - Increase filler content
  - Decrease fibre content
  - Increase paper permeability

  } Increase diffusivity

- Effect of CO_2 diffusivity on smoking yields:
  - NFDPM, CO, nicotine ↓
  - Puff number ↑
  - Static burn rate ↑

  } As diffusivity increases

- Diffusivity can explain differences in smoke yields for different papers

Acknowledgements

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- Thank you!

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we welcome your comments

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