

New Cordierite Diesel Particulate Filters for Catalyzed and Non-Catalyzed Applications

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Corning

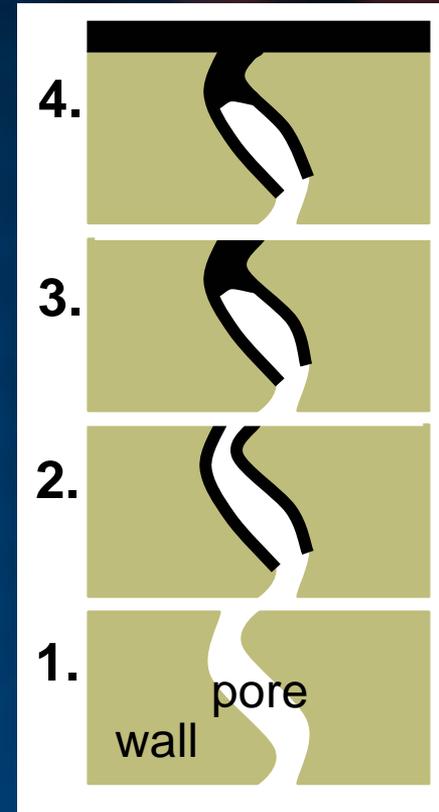
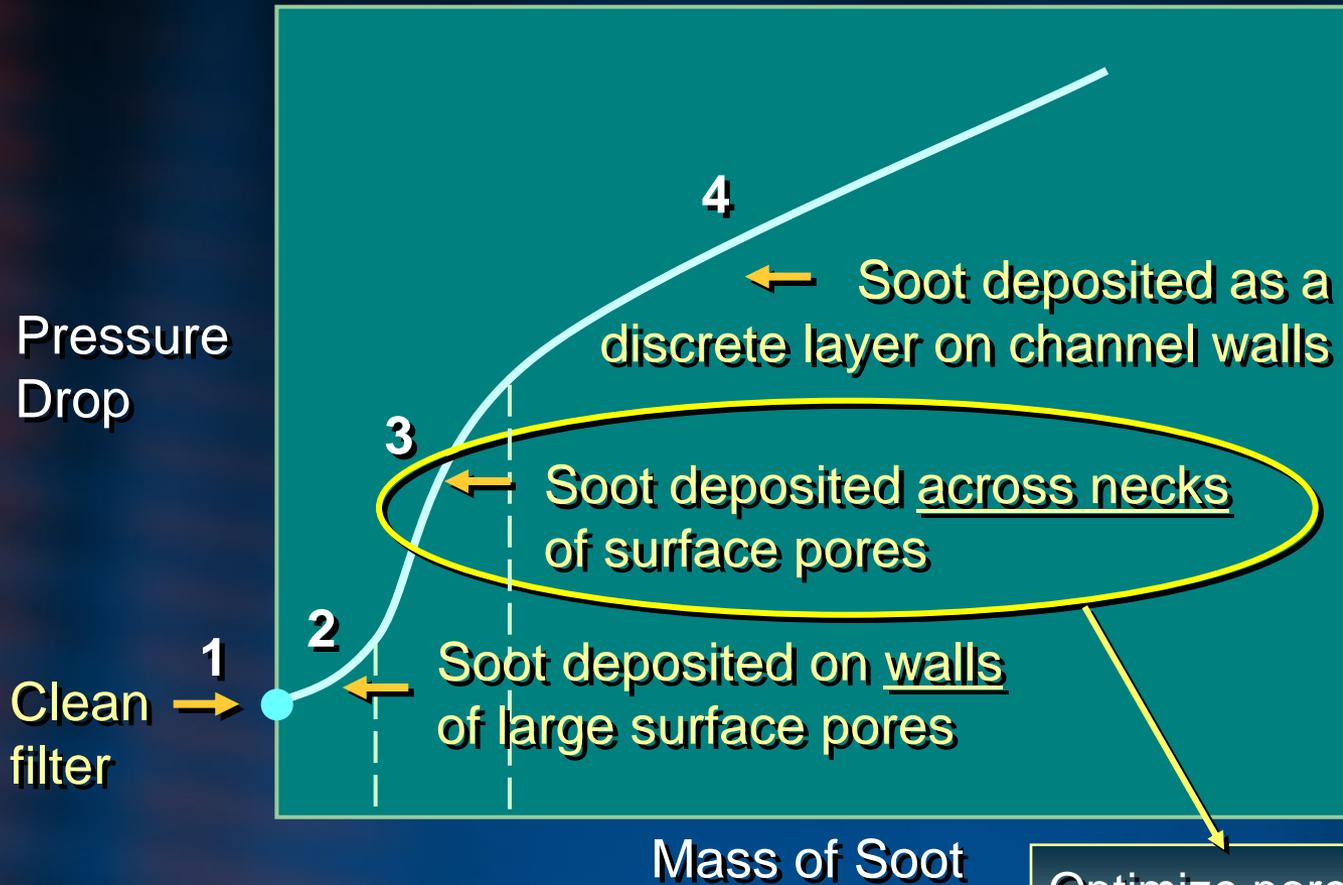
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Johnson Matthey



Outline

- General overview of pressure drop behavior
- Relationship of pressure drop to pore microstructure for bare cordierite filters
- Effects of catalyst on pressure drop
- Optimization of pore microstructure for pressure drop, filtration efficiency, strength, and thermal mass

Pressure Drop versus Soot Loading

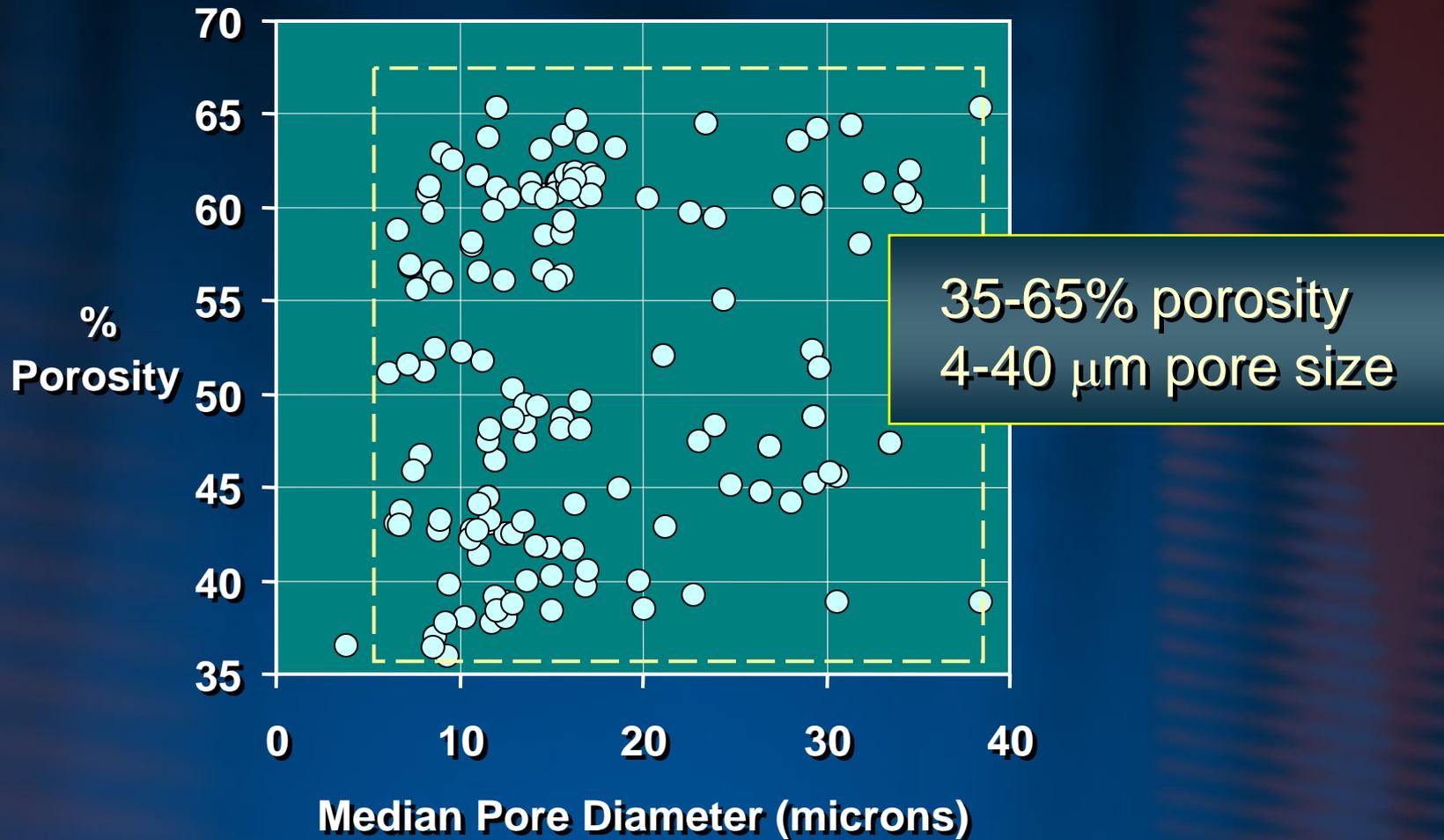


Optimize pore microstructure to minimize effect of soot in wall

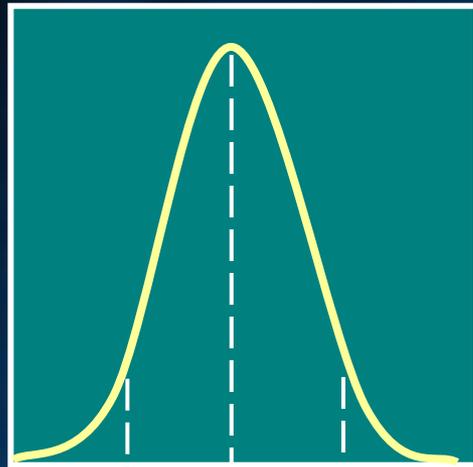
Experimental Study

- Objective: Quantify relationship between pressure drop and pore microstructure and utilize to design optimized filter
 - Fabricated 2" x 6" cordierite filters (200 cpsi) with over 100 different pore microstructures
 - Characterized %porosity, median pore size, and width of pore size distribution by mercury porosimetry
 - Measured clean and artificial soot-loaded pressure drop vs flow rate at room temperature
 - Derived a model for pressure drop in terms of pore parameters
 - Catalyzed selected candidates to determine optimum pore microstructure for catalyzed filter

Porosity and Median Pore Size



Pore Size Distribution



d_{10} d_{50} d_{90}
Pore size →

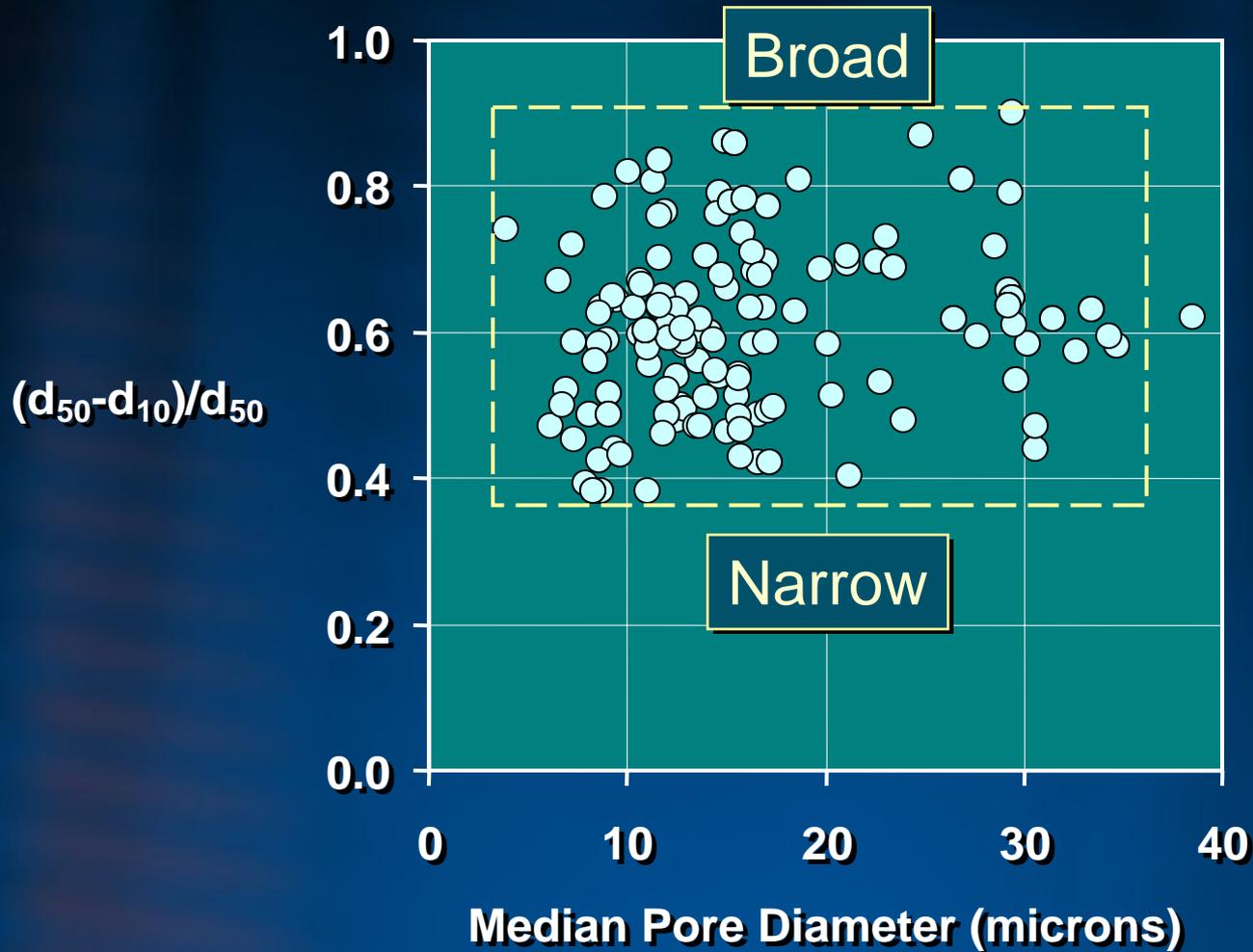
Measures of the width of the pore size distribution curve:

Full width: $(d_{90}-d_{10})/d_{50}$

Coarse fraction: $(d_{90}-d_{50})/d_{50}$

Fine fraction: $(d_{50}-d_{10})/d_{50}$

Pore Size Distribution



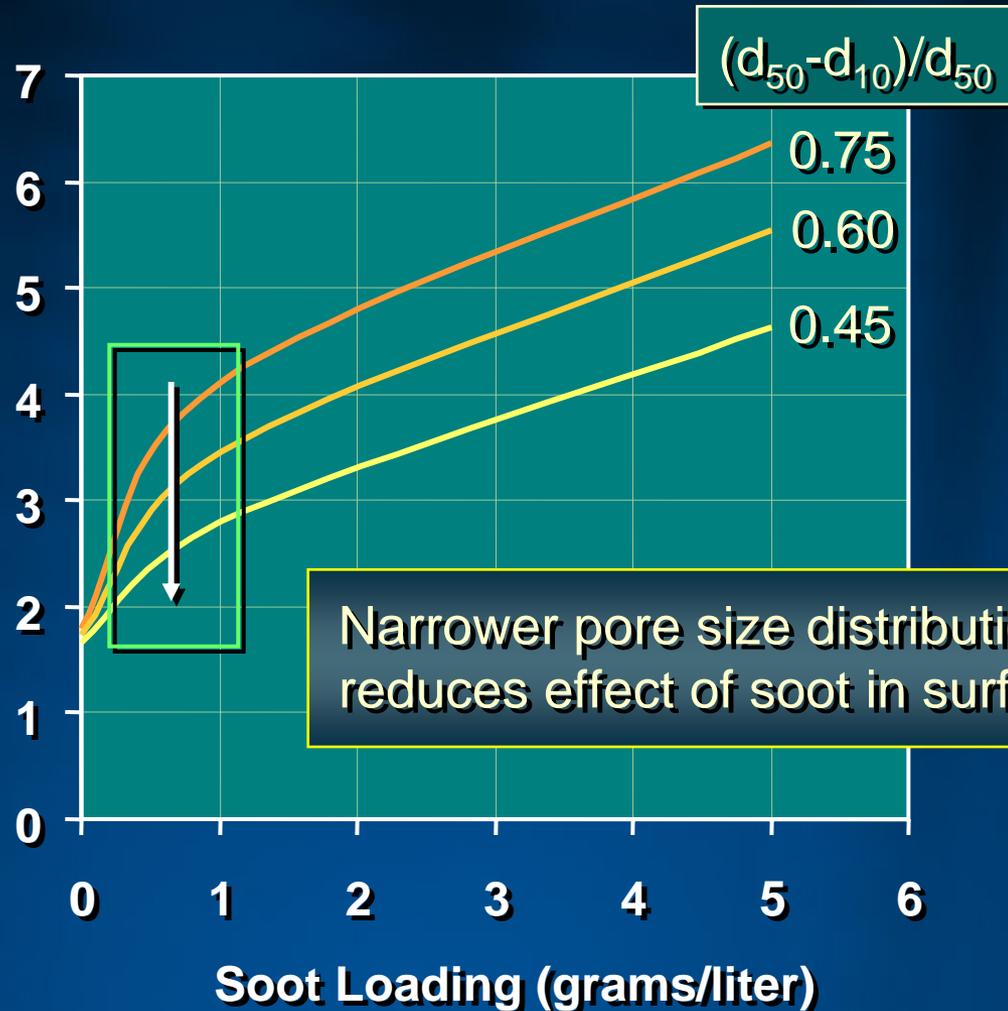
Key Learnings from Data Analysis

- **Clean pressure drop** decreases for larger values of $(\%porosity)(median\ pore\ size)^2$
 - Consistent with models of flow through cylindrical capillary pores
 - Median pore size is dominant
- **Soot-loaded pressure drop** decreases for larger values of $\%porosity$ and smaller values of $(d_{50}-d_{10})/d_{50}$, narrower pore size distribution
 - Better pore connectivity
 - Lower gas velocity through pore necks
 - Less dense packing of soot in near-surface pores

Curves Computed from Regression Equations: Effect of Pore Size Distribution

50% Porosity
 $d_{50} = 12 \mu\text{m}$

Pressure
Drop (kPa)

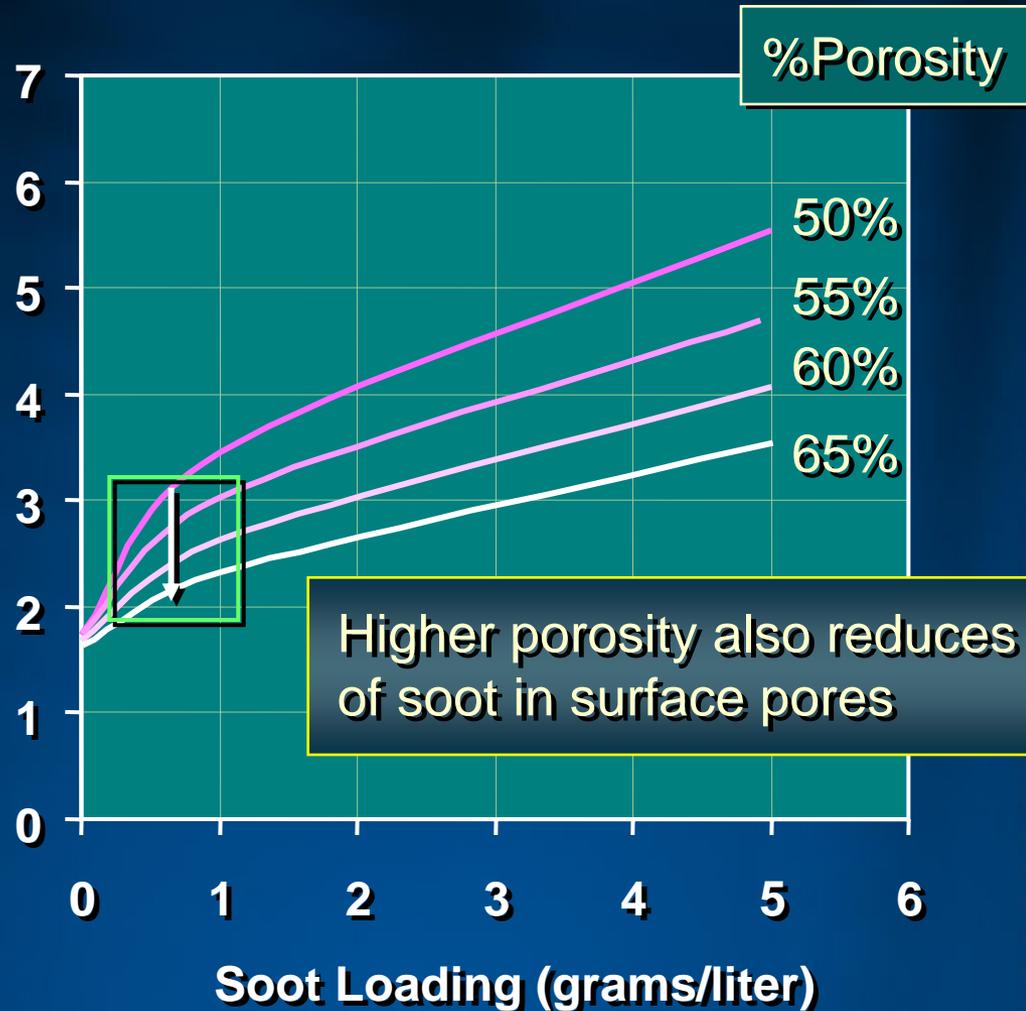


2" x 6"
200/12
144,000 hr⁻¹

Curves Computed from Regression Equations: Effect of Porosity

$$\frac{(d_{50}-d_{10})}{d_{50}} = 0.60$$
$$d_{50} = 12 \mu\text{m}$$

Pressure
Drop (kPa)



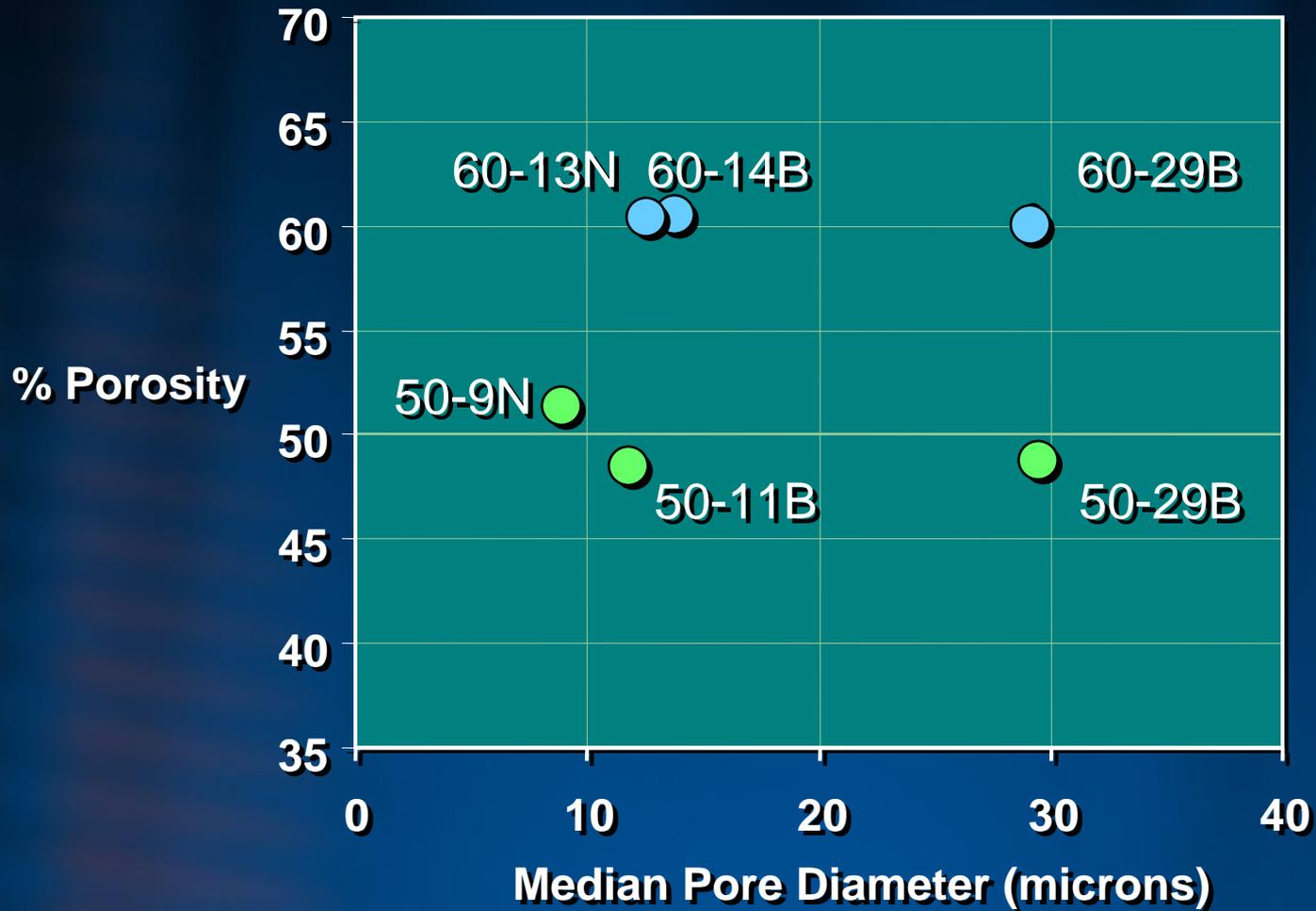
Higher porosity also reduces effect
of soot in surface pores

2" x 6"
200/12
144,000 hr⁻¹

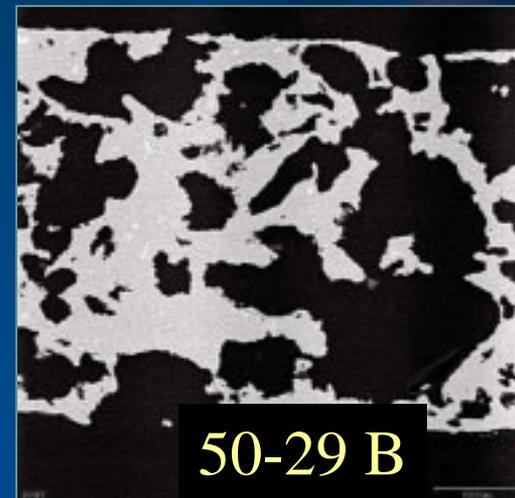
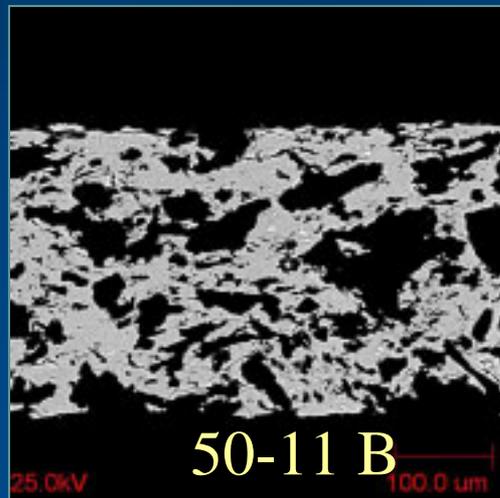
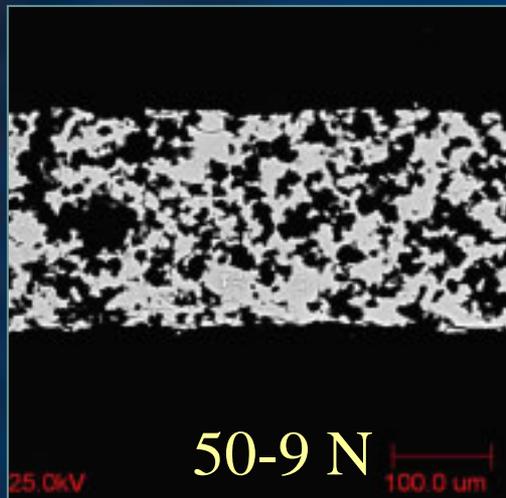
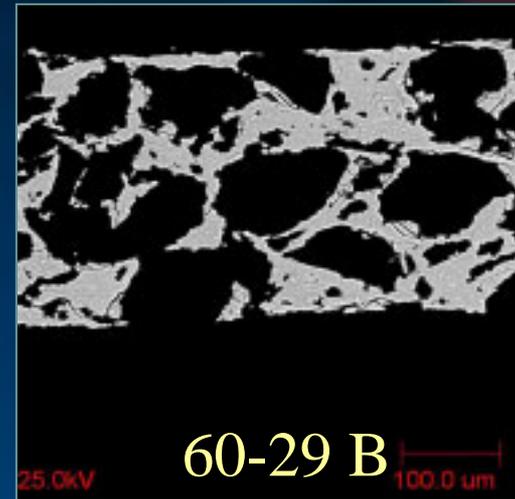
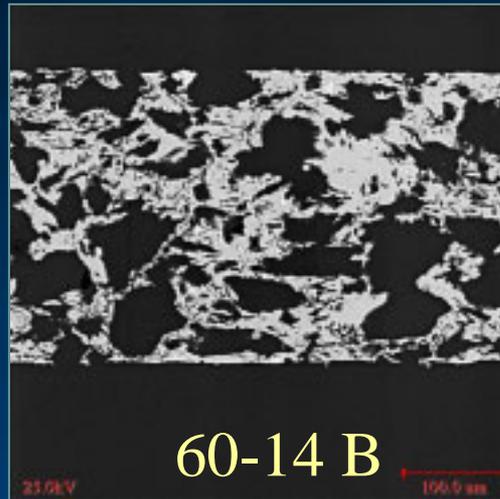
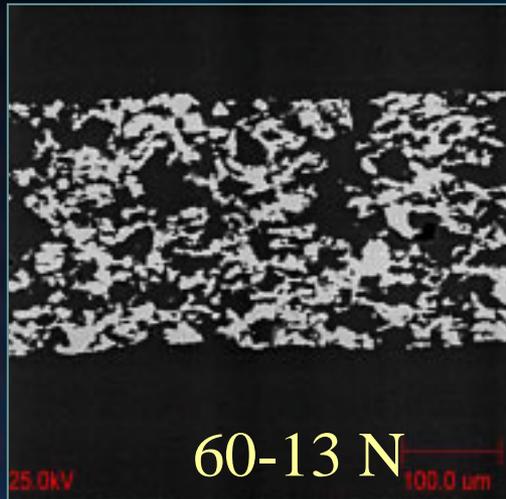
Catalysis Coating Study

- Six cordierite materials with range in pore microstructures
- 2" x 6" filters, 200 cpsi, 12 mil walls
- Artificial soot loaded and pressure drop tested
- Soot burned out at 650°C
- Catalyzed and soot-loaded pressure drop re-measured
- Two catalyst systems examined
 - Detailed results for System "A"
 - Summary of System "B" versus "A"

Porosity and Median Pore Size



Examples of Pore Microstructures



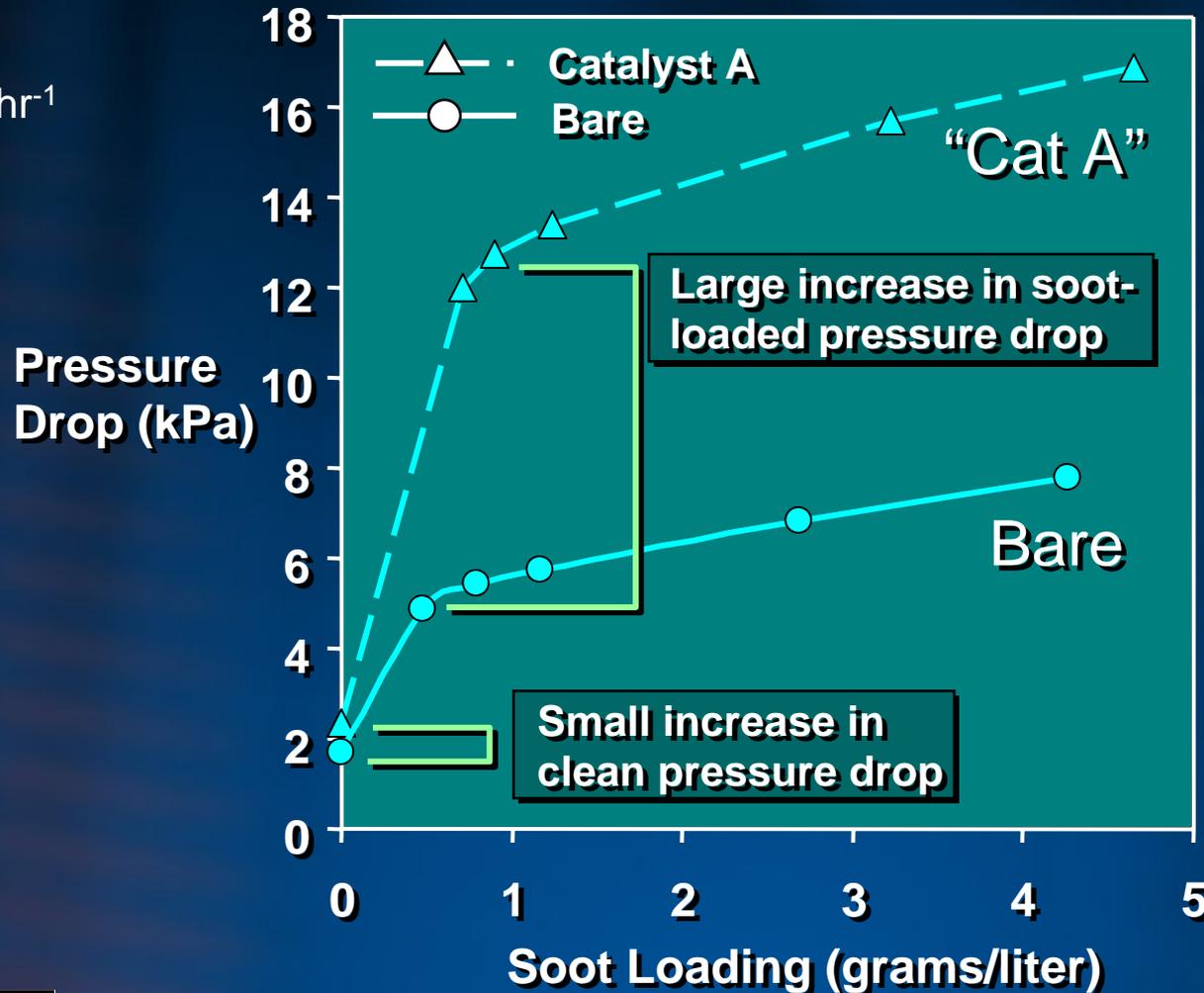
100 μm

Soot-Loaded Pressure Drop of Catalyzed Filters



Bare & Catalyzed Pressure Drop: 50% Porosity

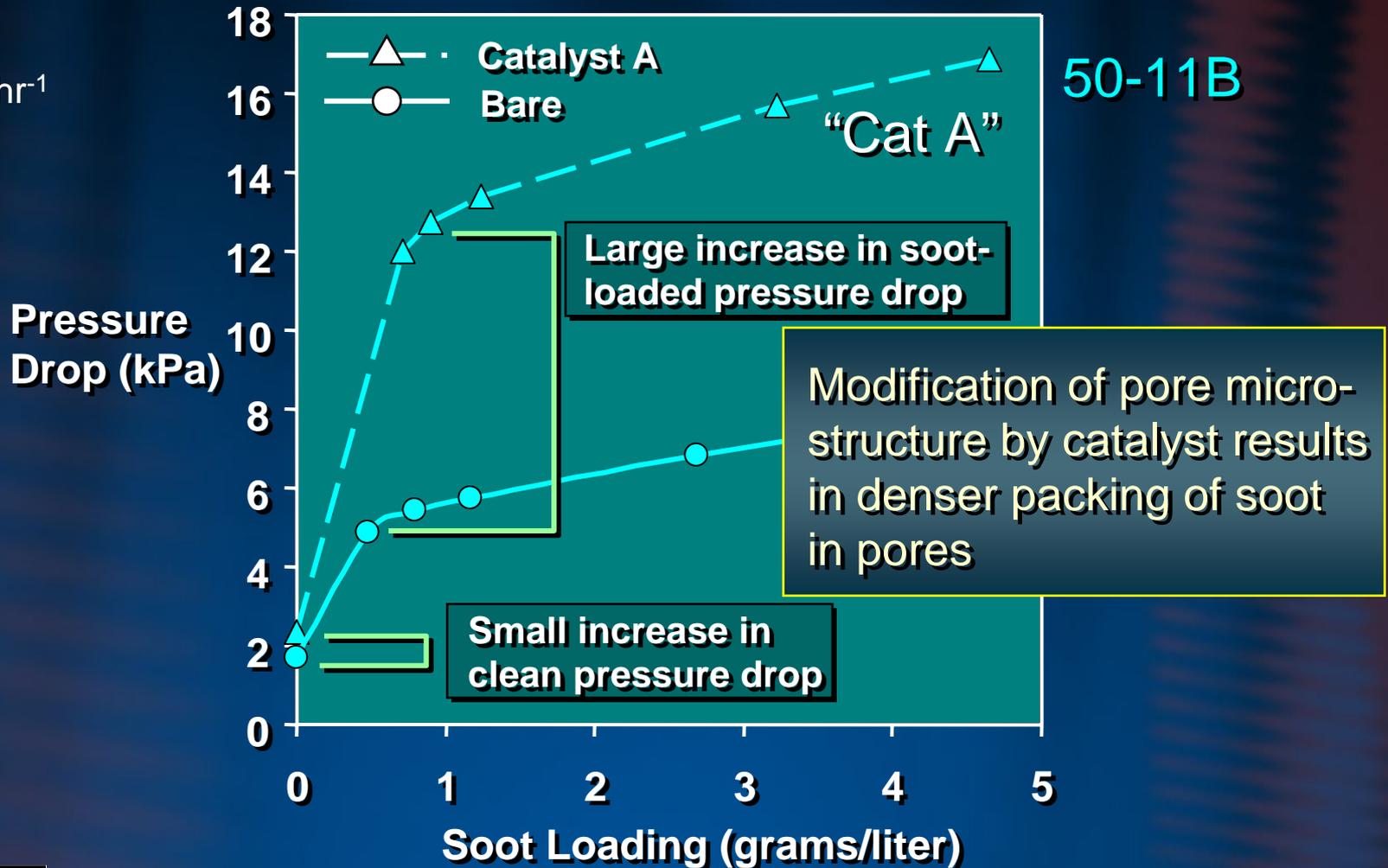
2" x 6"
200/12
144,000 hr⁻¹



50-11B

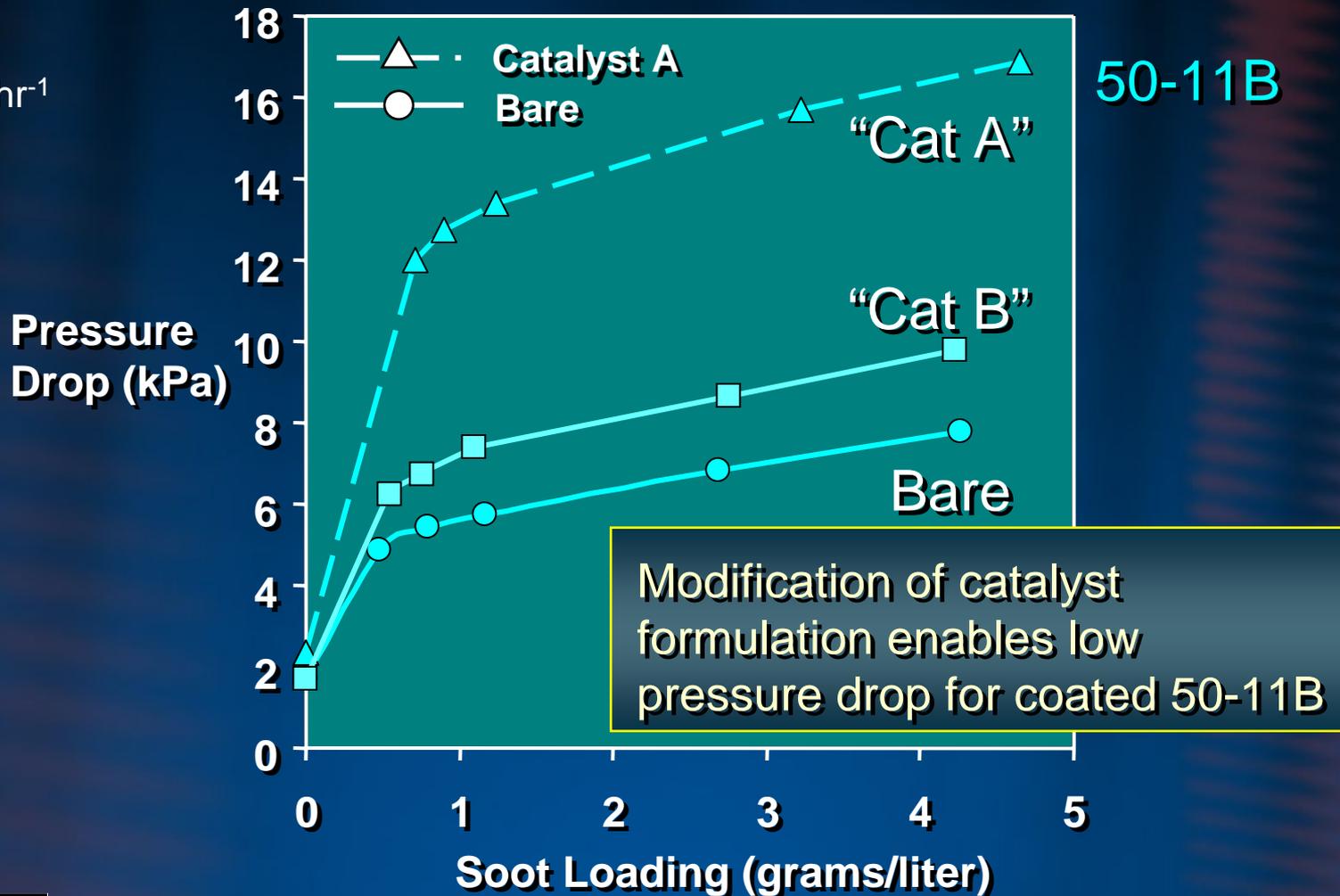
Bare & Catalyzed Pressure Drop: 50% Porosity

2" x 6"
200/12
144,000 hr⁻¹



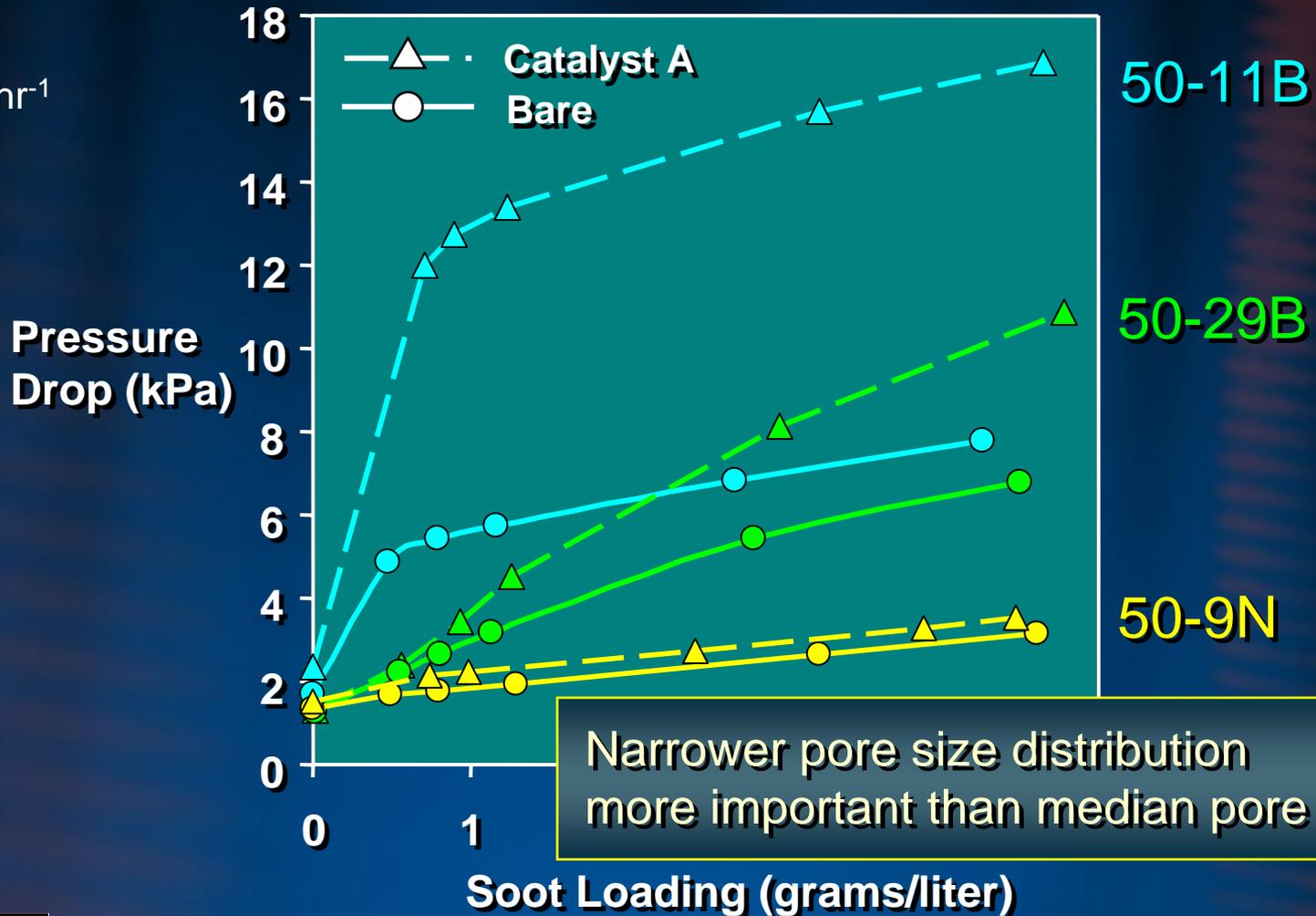
Bare & Catalyzed Pressure Drop: 50% Porosity

2" x 6"
200/12
144,000 hr⁻¹



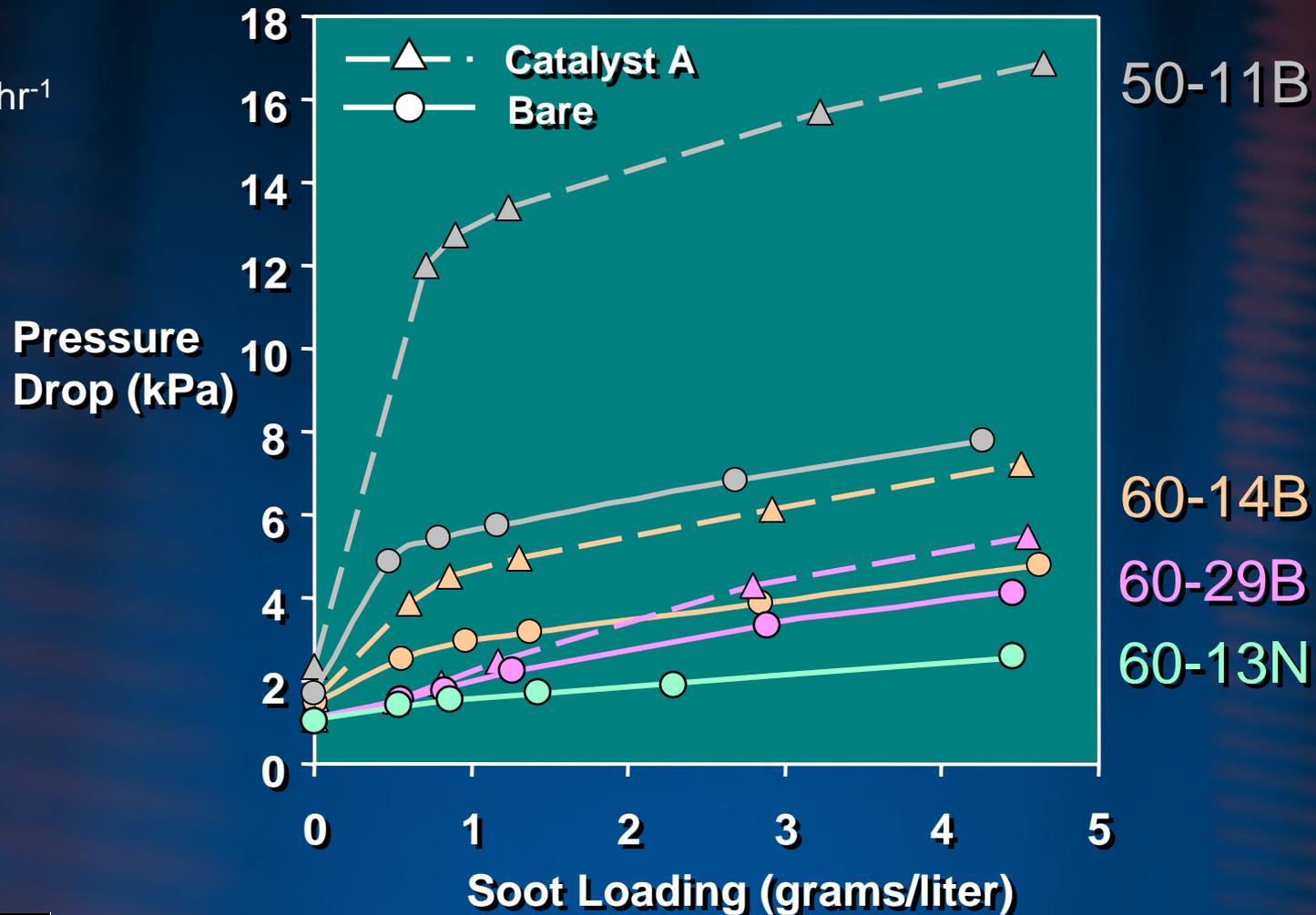
Bare & Catalyzed Pressure Drop: 50% Porosity

2" x 6"
200/12
144,000 hr⁻¹



Bare & Catalyzed Pressure Drop: 60% Porosity

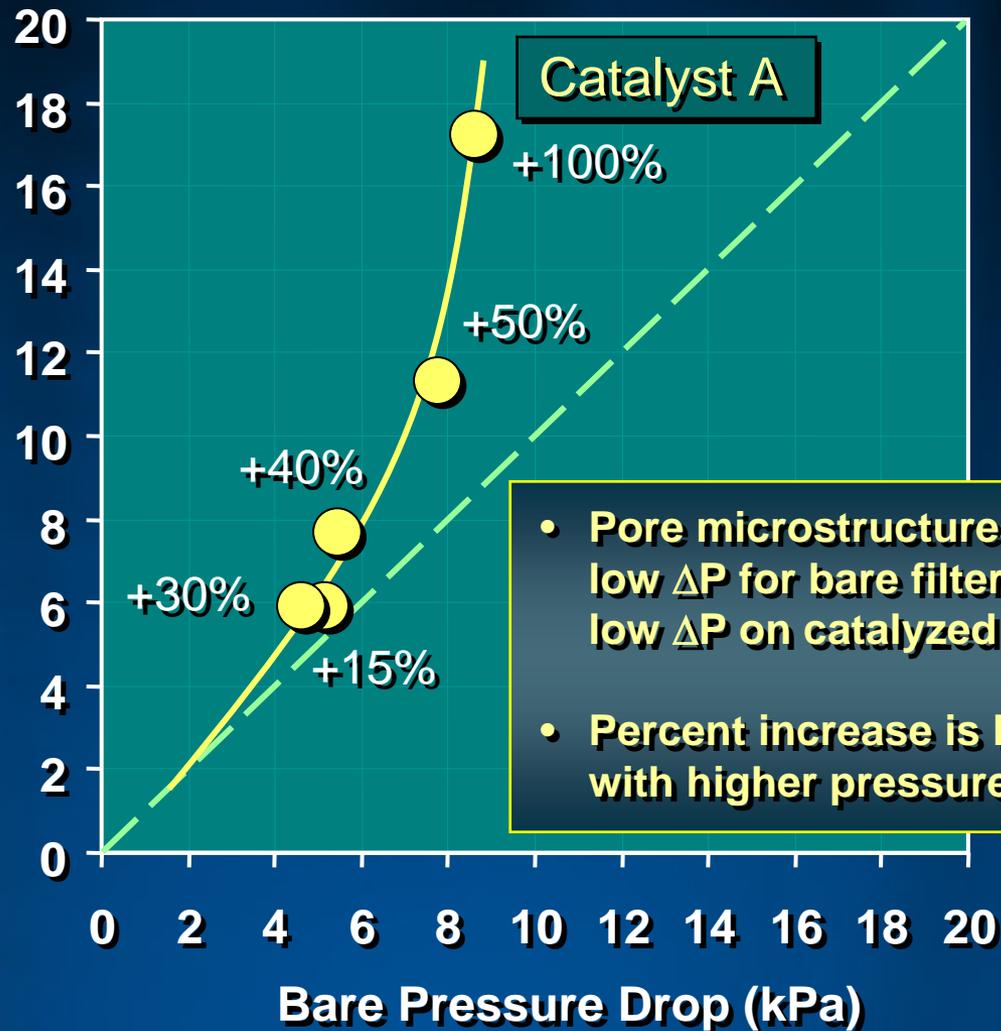
2" x 6"
200/12
144,000 hr⁻¹



Pressure Drop Summary (5 grams/liter soot loading)

2" x 6"
200/12
144,000 hr⁻¹

Catalyzed
Pressure
Drop (kPa)

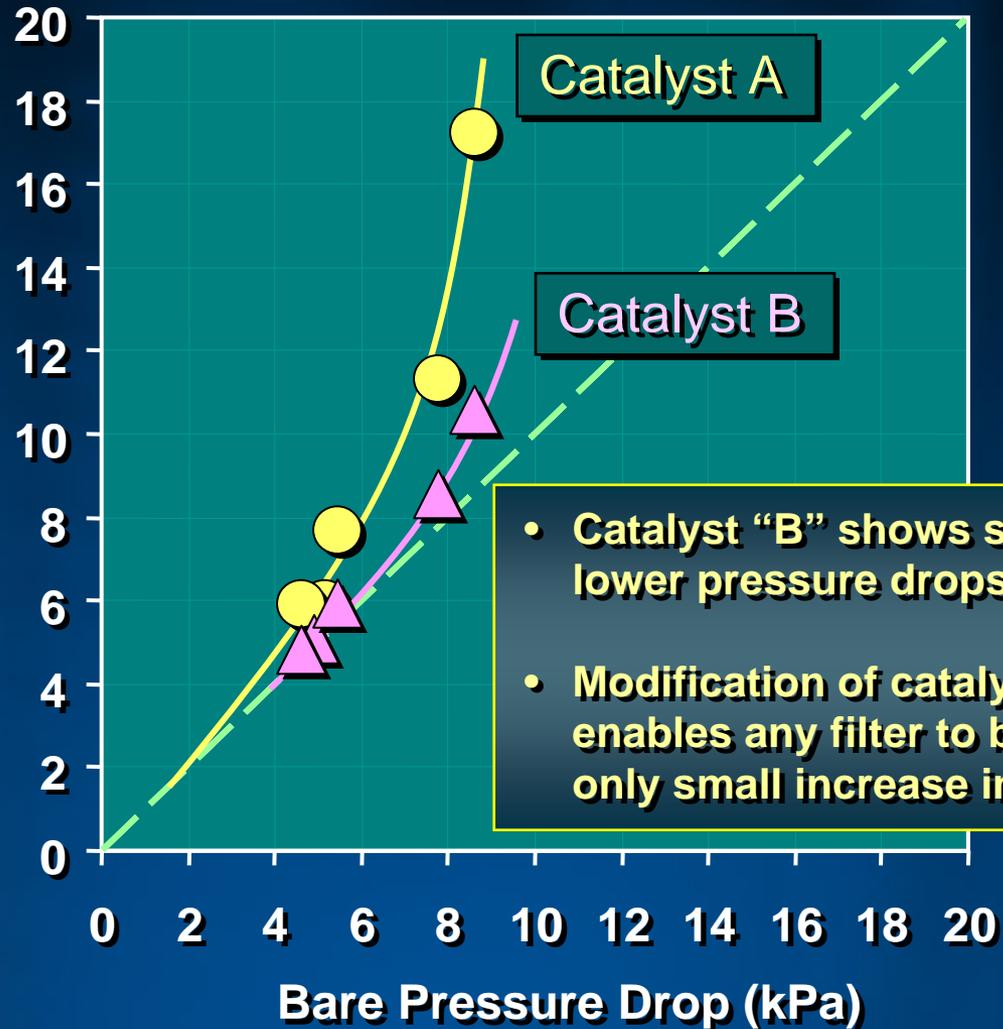


- Pore microstructures that yield low ΔP for bare filters also provide low ΔP on catalyzed filters
- Percent increase is larger for filters with higher pressure drop

Pressure Drop Summary (5 grams/liter soot loading)

2" x 6"
200/12
144,000 hr⁻¹

Catalyzed
Pressure
Drop (kPa)



- Catalyst "B" shows similar trend, lower pressure drops
- Modification of catalyst formulation enables any filter to be catalyzed with only small increase in pressure drop

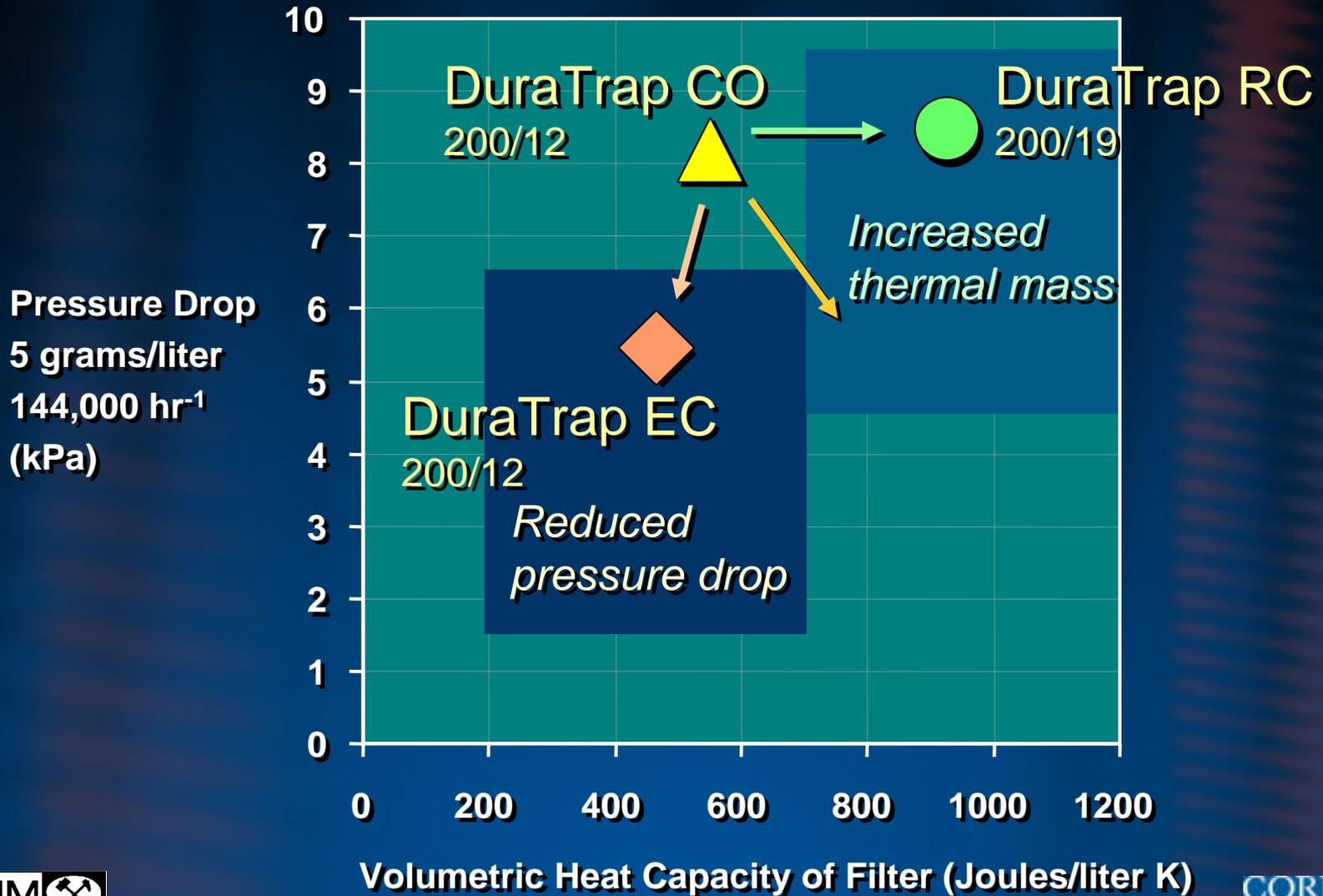
Thermal Durability during Regeneration



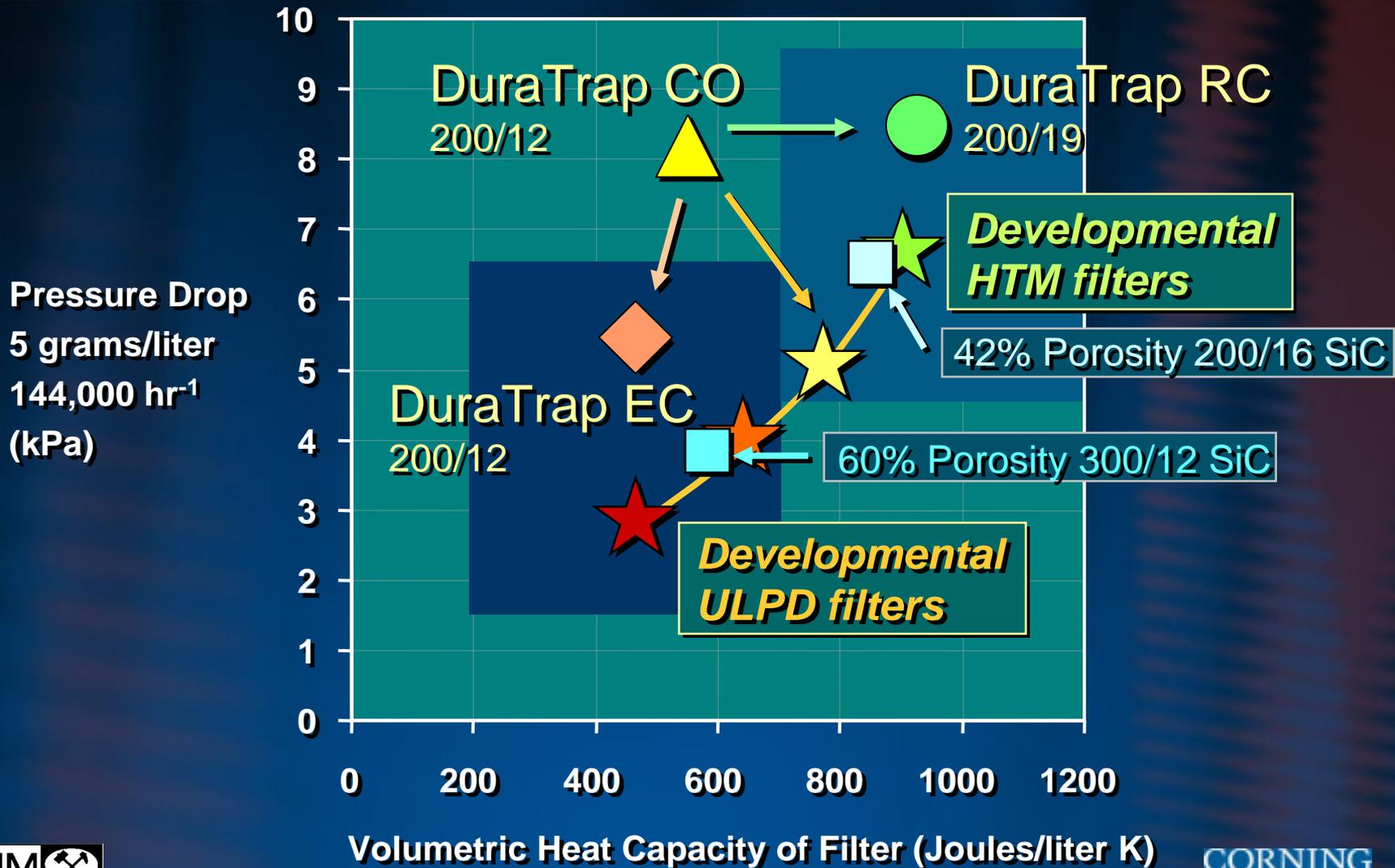
Regeneration and Volumetric Heat Capacity

- Temperatures reached during uncontrolled regenerations must be minimized for survivability of both filter and catalyst
- Peak temperature is reduced for filters with high “thermal mass” (heat capacity per unit volume)

Pressure Drop vs Volumetric Heat Capacity of Bare Filters



Pressure Drop vs Volumetric Heat Capacity of Bare Filters



Summary

- By tailoring the ceramic pore microstructure or catalyst formulation, very low pressure drops have been achieved for catalyzed cordierite DPFs
- Soot-loaded ΔP for bare or catalyzed filters is minimized for high pore connectivity (*high porosity or narrow psd*)
- Bare or catalyzed filters with moderate %porosity and fine, narrow pore size distribution yield soot-loaded ΔP equivalent to high-porosity filters with coarse, broad pore size distribution

Conclusion

- Research on effects of pore microstructure, cell geometry, and catalyst formulation have yielded new catalyzed cordierite DPFs with unique combinations of low ΔP , high %FE, and higher thermal mass, without sacrificing strength

