Experimental Diesel Particulate Filter Capabilities at PNNL

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Emission Control Technologies
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U.S. Department of Energy

Exhaust Emissions Science Laboratory

► The Pacific Northwest National Laboratory's (PNNL) Exhaust Emissions Science Laboratory (EESL) is a research center intended to support the mission of DOE's Office of FreedomCAR and Vehicle Technology .

► The principal activities conducted are:

- Probing and understanding performance-limiting nanometer to micrometer scale phenomena in aftertreatment devices;
- Experimentation and modeling focused on microscale aspects of emissions reduction technology;
- The use of unique analytical observatories to characterize each emissions phenomenon.

► **PNNL models the fundamentals to make the industry/academic led DPF models more robust.**

Acknowledgments
Principal Contributors

- ▶ PNNL - Micro-modeling Project
  - Heather Dillon
  - Gary Maupin
  - Tim Peters
  - Mark Steward
  - Nat Saenz
  - George Muntean

- ▶ DOE - CLEERS Team Members

- Dow Automotive CRADA
  - Cheng Li
  - Frank Mao
  - Alek Pyzik

- ▶ Delphi
  - Tom Harris

Dyno Test Capabilities

Engines are used to generate 'real' soot under various duty cycles and fuels.

- ▶ 4kW Diesel Generator Set
- ▶ 2.4L Quad-4 gas engine
- ▶ Cummins ISB Diesel
- ▶ VW Jetta TDI on a chassis dyno
- ▶ Two engine dynamometer stands.
  - 600 ft-lb hydro-mechanical
  - 400 ft-lb eddy-current
- ▶ Chassis dyno – 150 HP continuous duty
- ▶ Complete control systems
  - Programmed test profiles
  - Steady-state and transient
  - Data acquisition system
- ▶ Heated wet or dry exhaust sample transfer lines

Aerosol Characterization Capabilities

- ELPI and SMPS with particle size detection down to 10 nm
- PTR-MS (HC analysis)
- SPLAT-MS (Particle analysis)
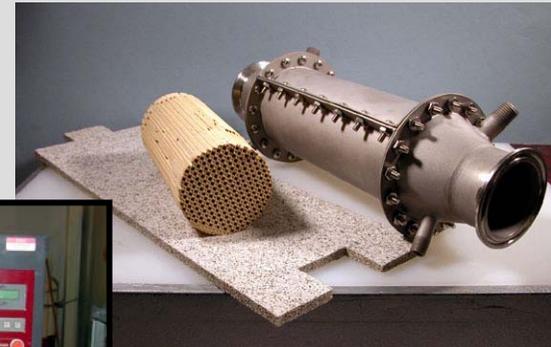
PTR-MS
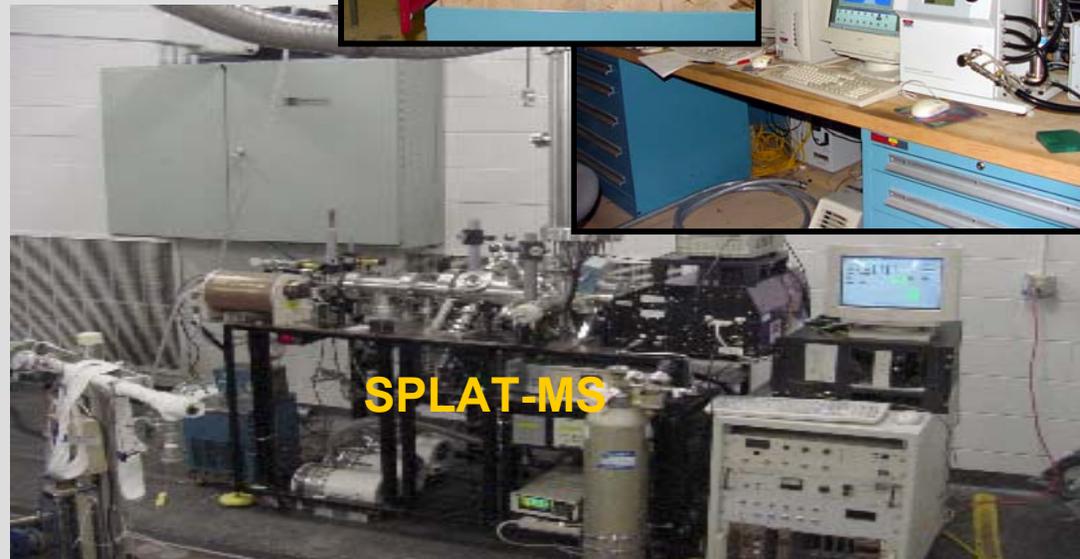
SPLAT-MS

DPF Fundamentals
Focus Areas

Pressure Drop

Filtration Efficiency

Regeneration

**Micro-modeling
Validation Requirements**

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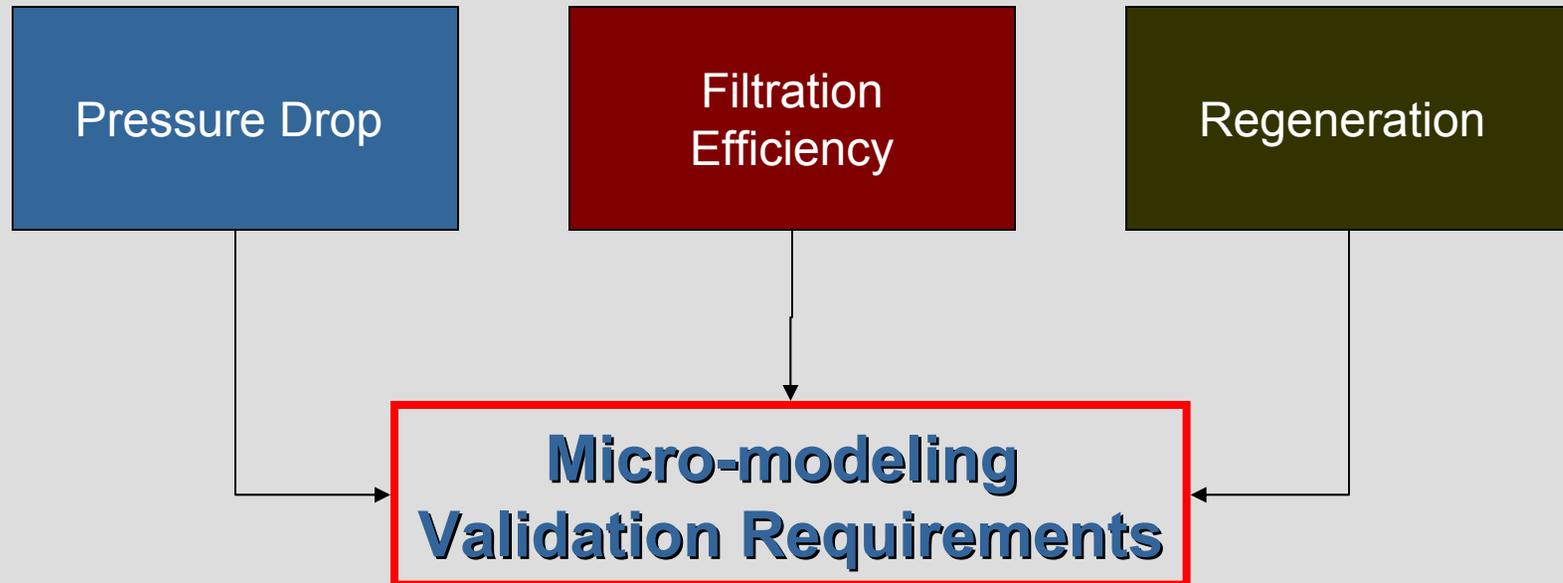
Experimental Set Up
for Micro-modeling Validation

Exhaust in

Bypass → Exhaust out

DPF

Bypass valve

Pressure and Temperature

Particulate Measurement System

Single Channel Configuration replaces full DPF
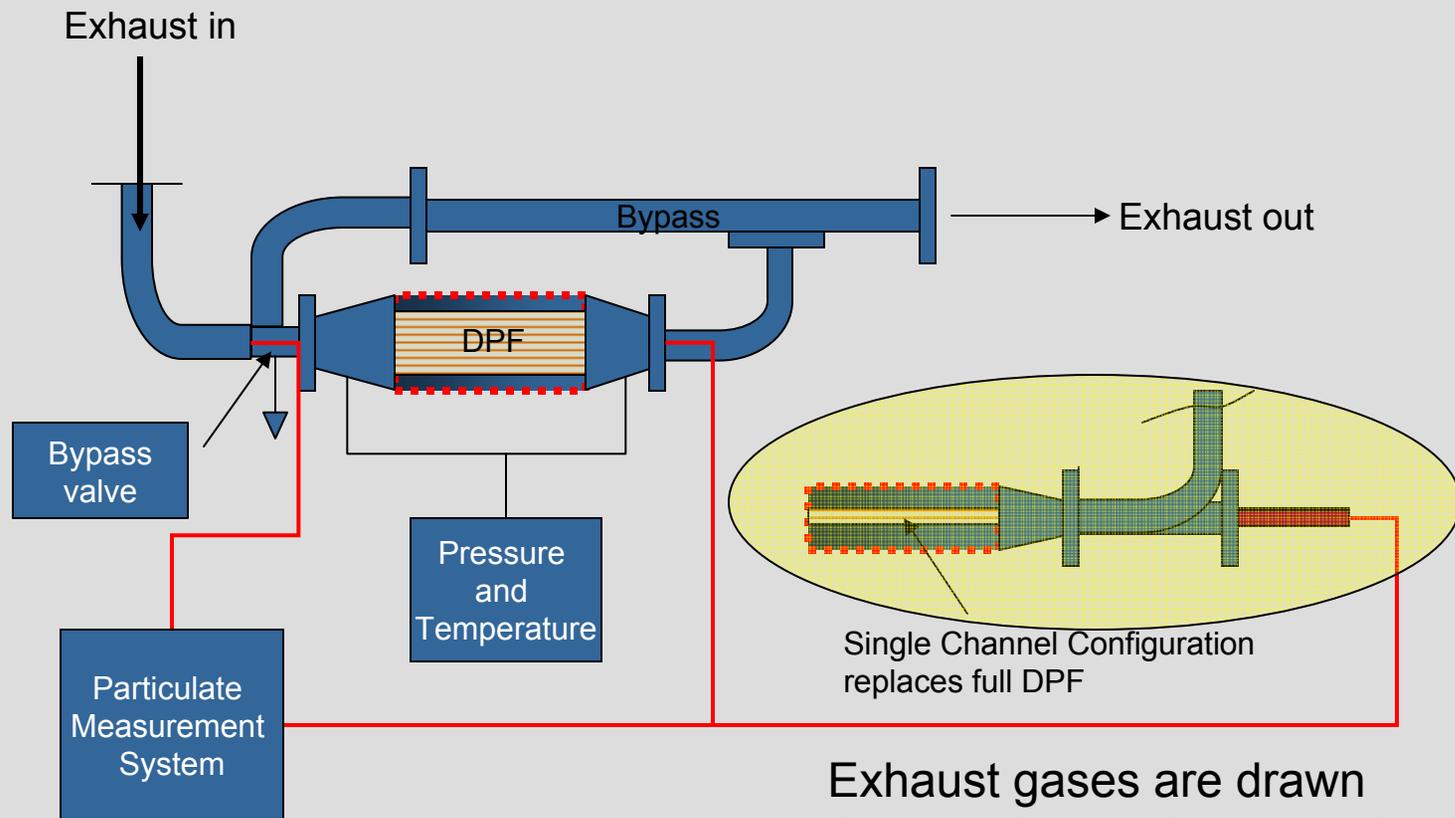
Exhaust gases are drawn through the single channel filter using a vacuum pump

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Single Channel Filter Vehicle Exhaust Assembly

SCF
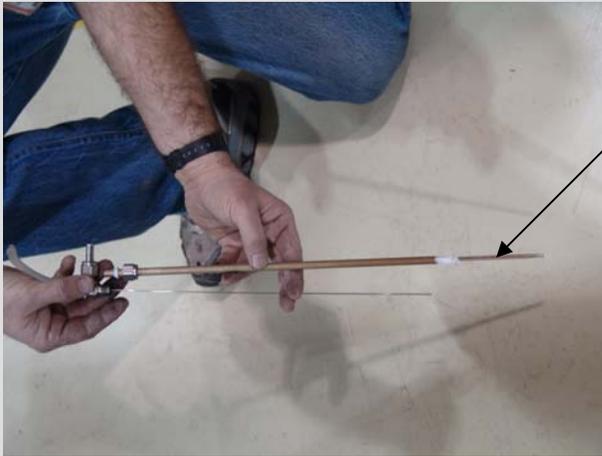
SCF attached to S.S tubing.

SCF assemble inserted in S.S exhaust elbow

SCF assemble enclosed in S.S exhaust pipe.

Soot coated SCF

Clean SCF
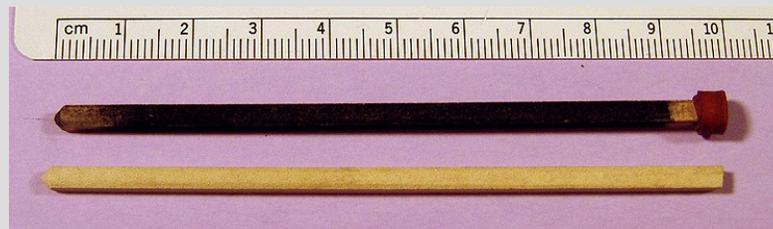
Single Channel Filter (SCF) cut from DPF

Micro-modeling Validation Experiments

▶ Document Soot Deposition
- Macro
- SEM

▶ Measure Pressure drop
- Wall Flow
- Soot Cake Structure
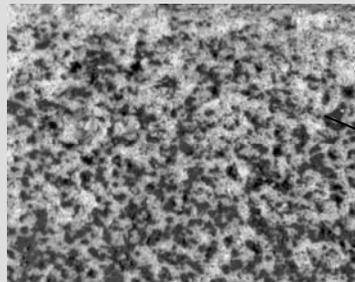
Initial deep bed soot deposition

Initial soot cake layer

8/06/04
2 Hour Run
1 Liter / Min
95 ftlbs, 2400 rpm
4 cm Effective Length

Deep bed soot

HTML photo

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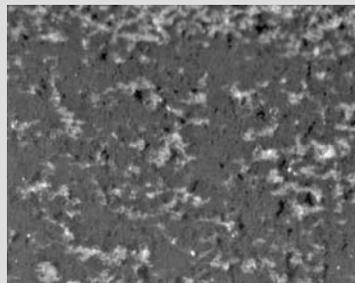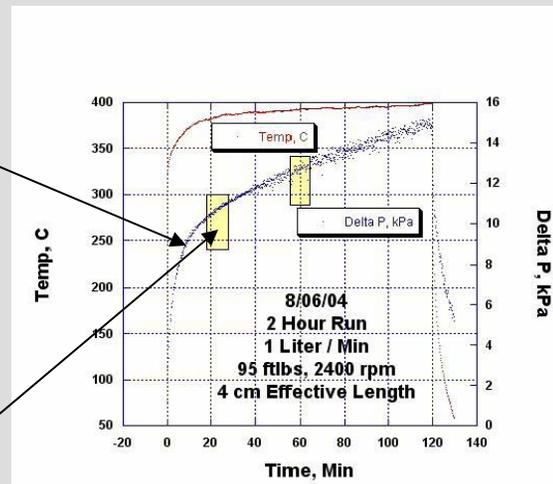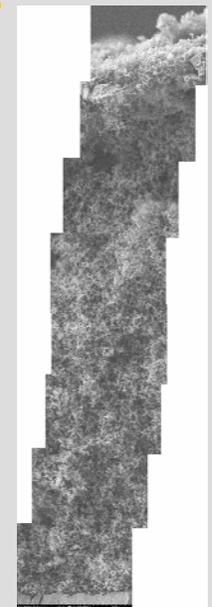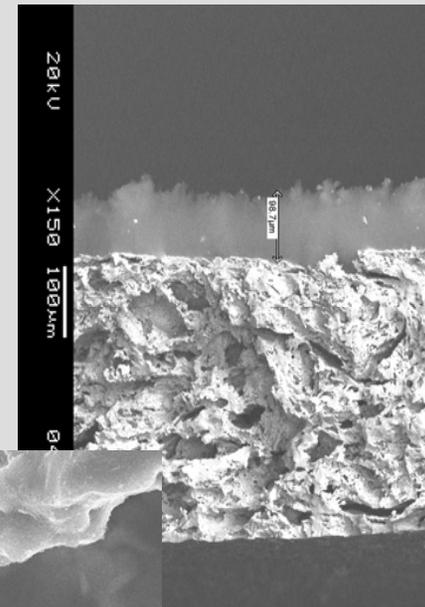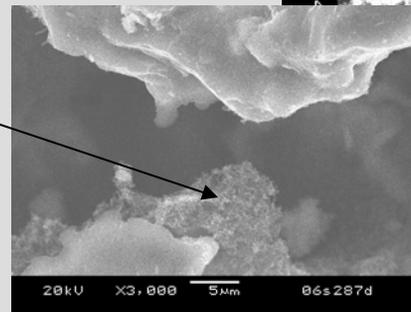
Complex Substrate Structures
e.g., DOW ACM

Soot Deposition
Deep Bed and
Soot Cake is not
well defined
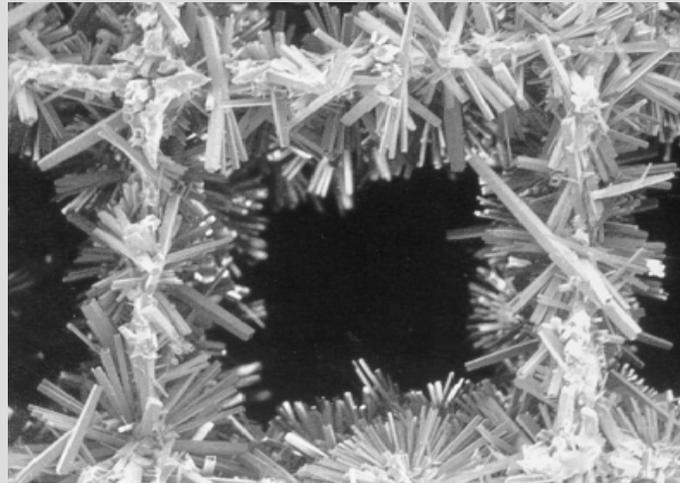
Pressure Drop
In addition to wall
porosity and soot
cake structure,
surface roughness
becomes a significant
factor
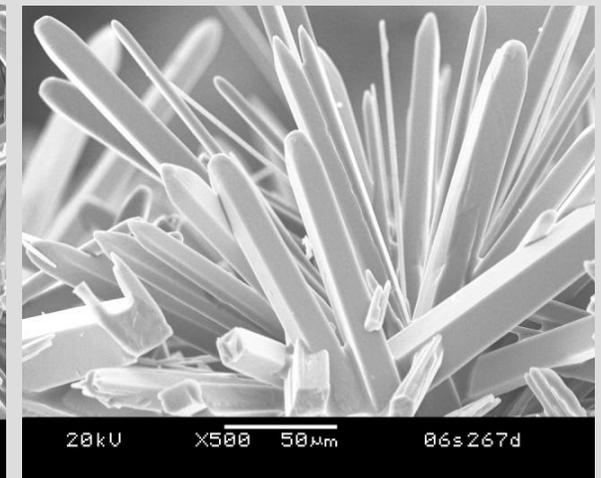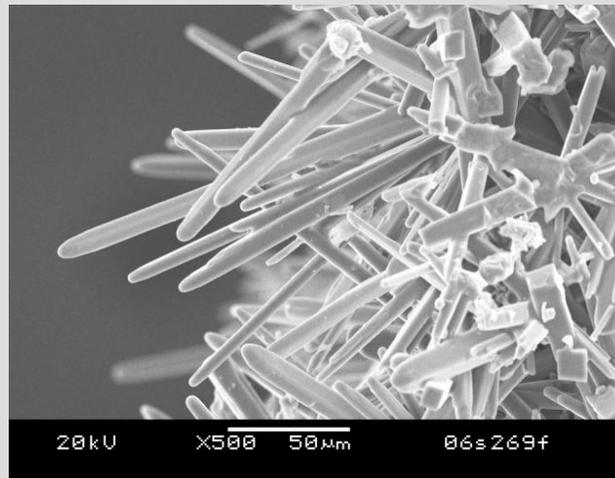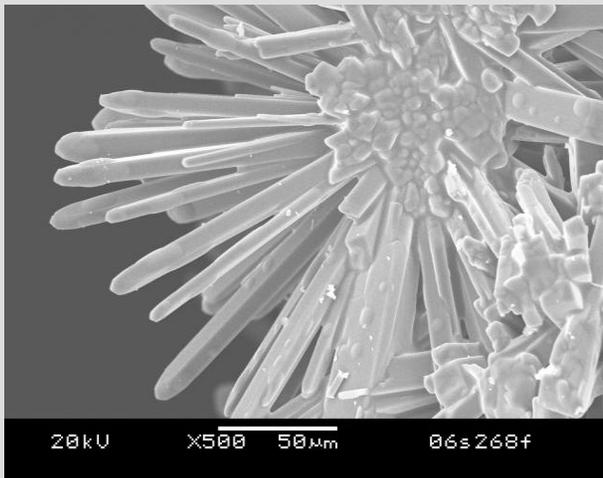
DOW ACM DPF
Audi R10 Racing Car

Tom Kristensen poses with the new Audi R10

There are no visual signs that a diesel power unit is at work in the back of the R10. It goes without saying that the V12 TDI is equipped with a pair of **diesel particle filters** for the 24 Hours of Le Mans.

Filtration Characteristics
Substrate Structure
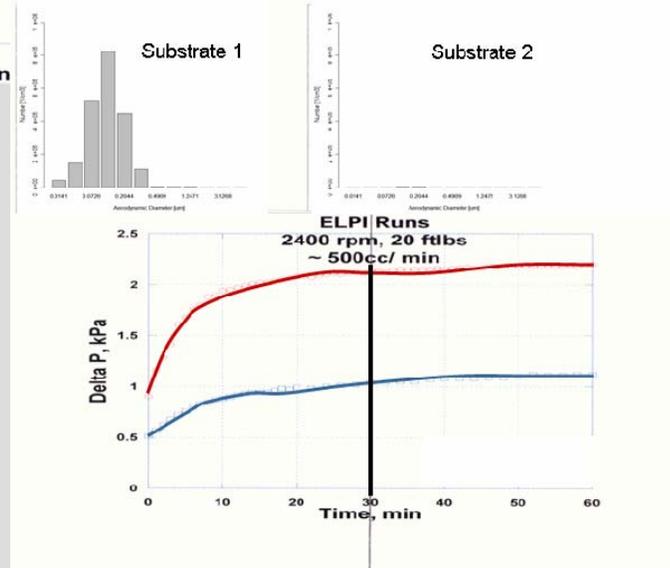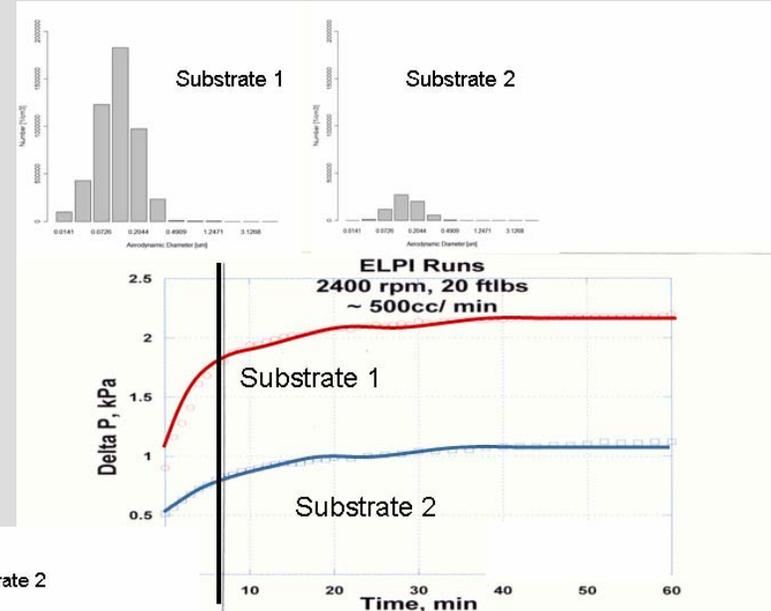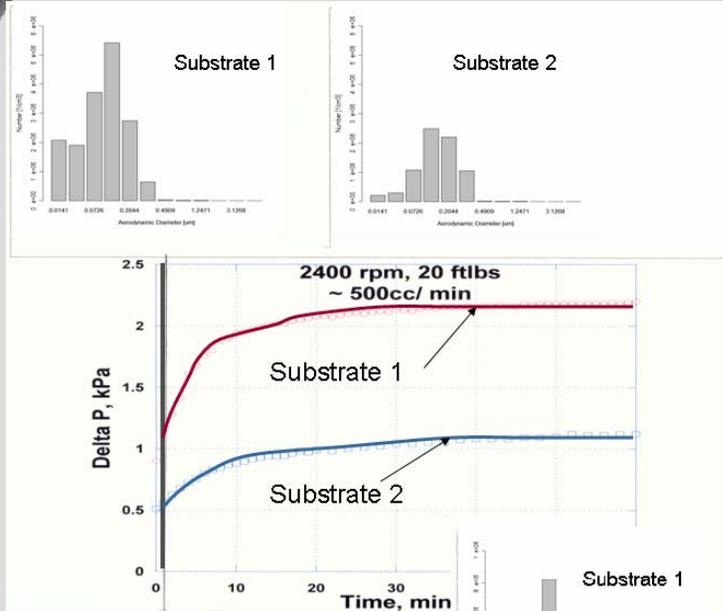
ELPI results indicate the structure has an effect on particle distribution exiting the filter.

Regeneration
Real Time IR / Optical Camera

IR camera

Quartz
Window

Quartz
Window
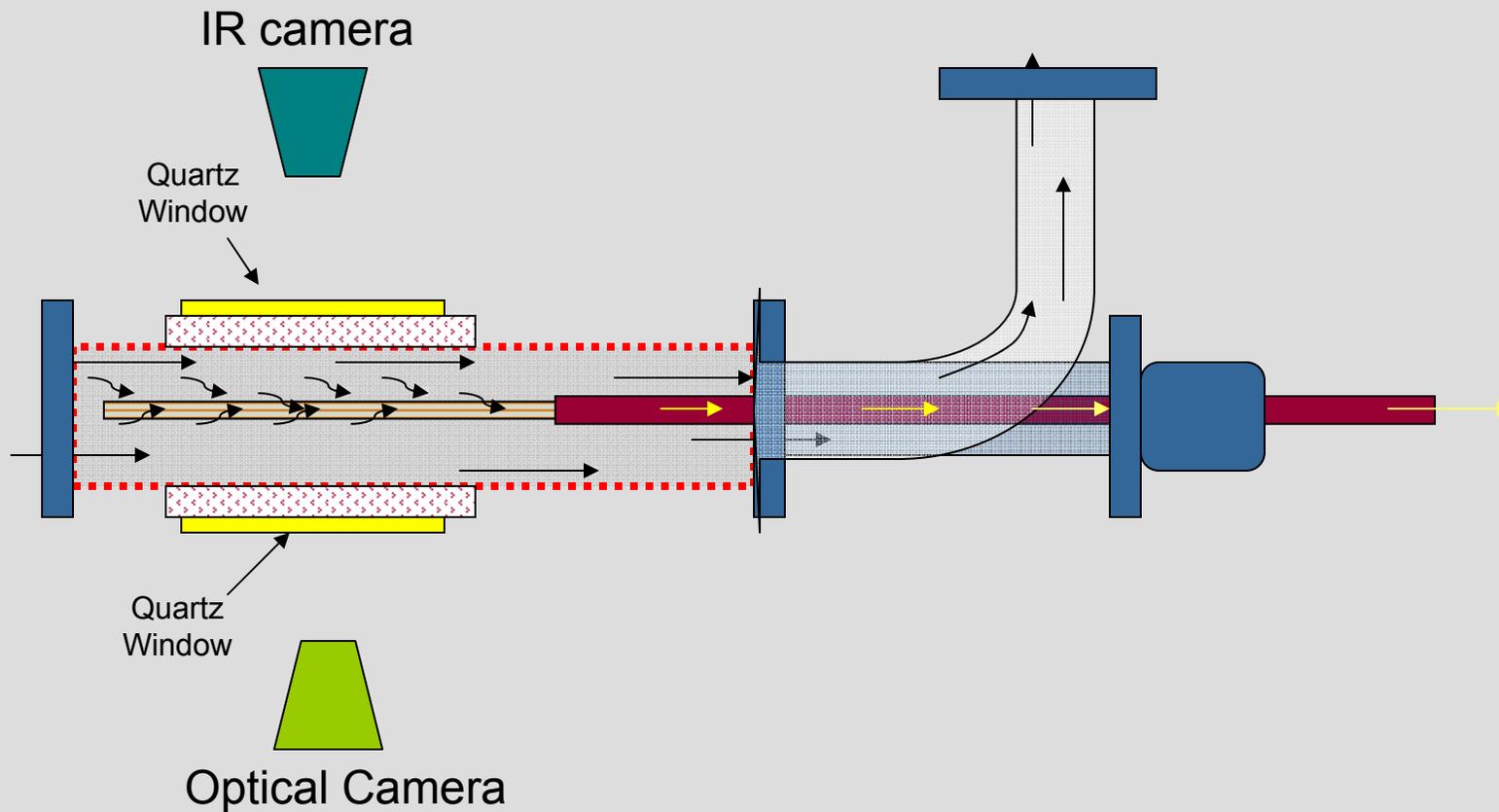
Optical Camera

IR / Optical Access for Soot Oxidation Studies

Regeneration - IR camera
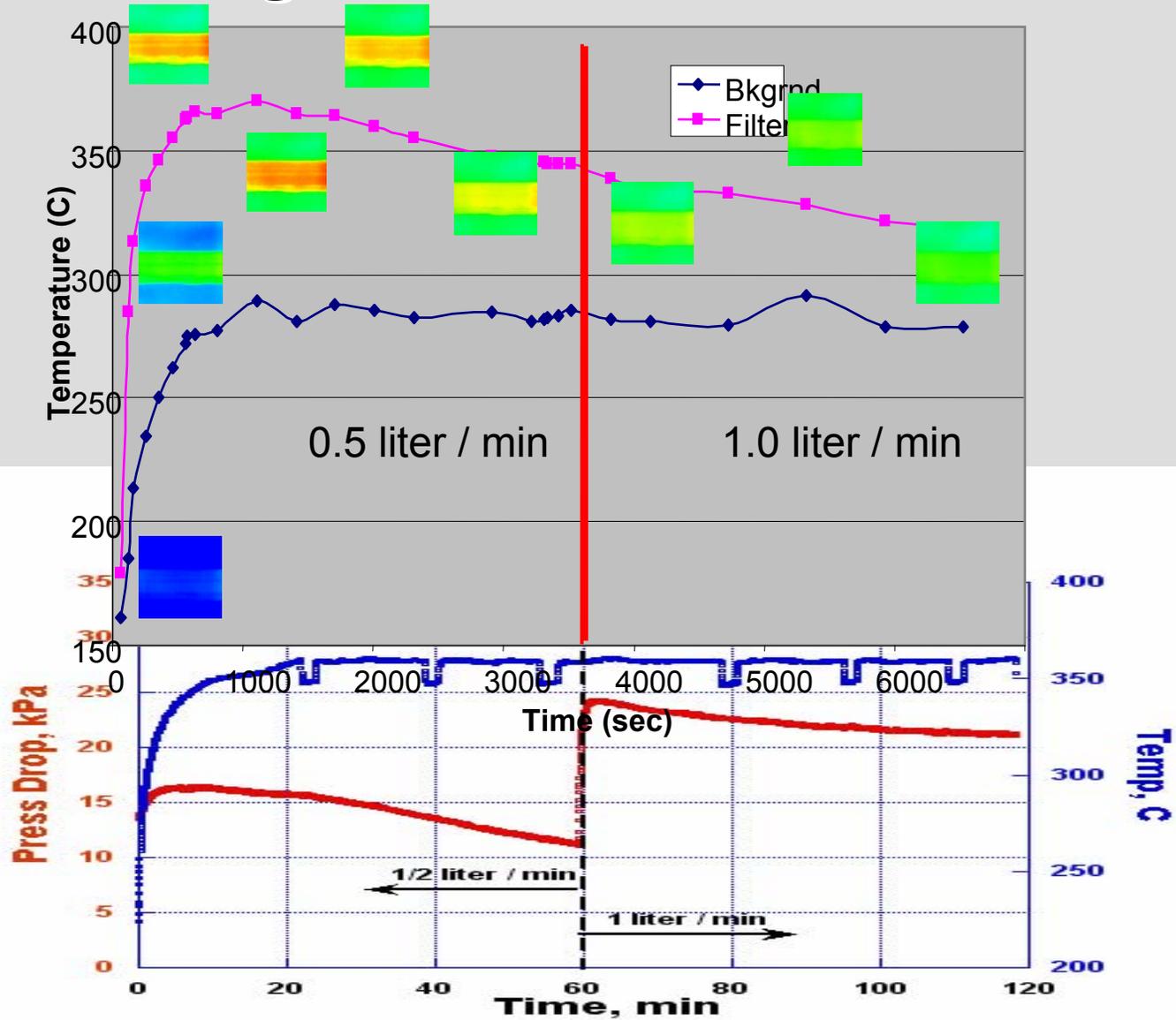
Regeneration System using Dual SCF Configuration

IR camera

Quartz Window

Quartz Window

Optical Camera

Dual SCF system allows for comparison of 2 catalyst technologies or a reference SCF.
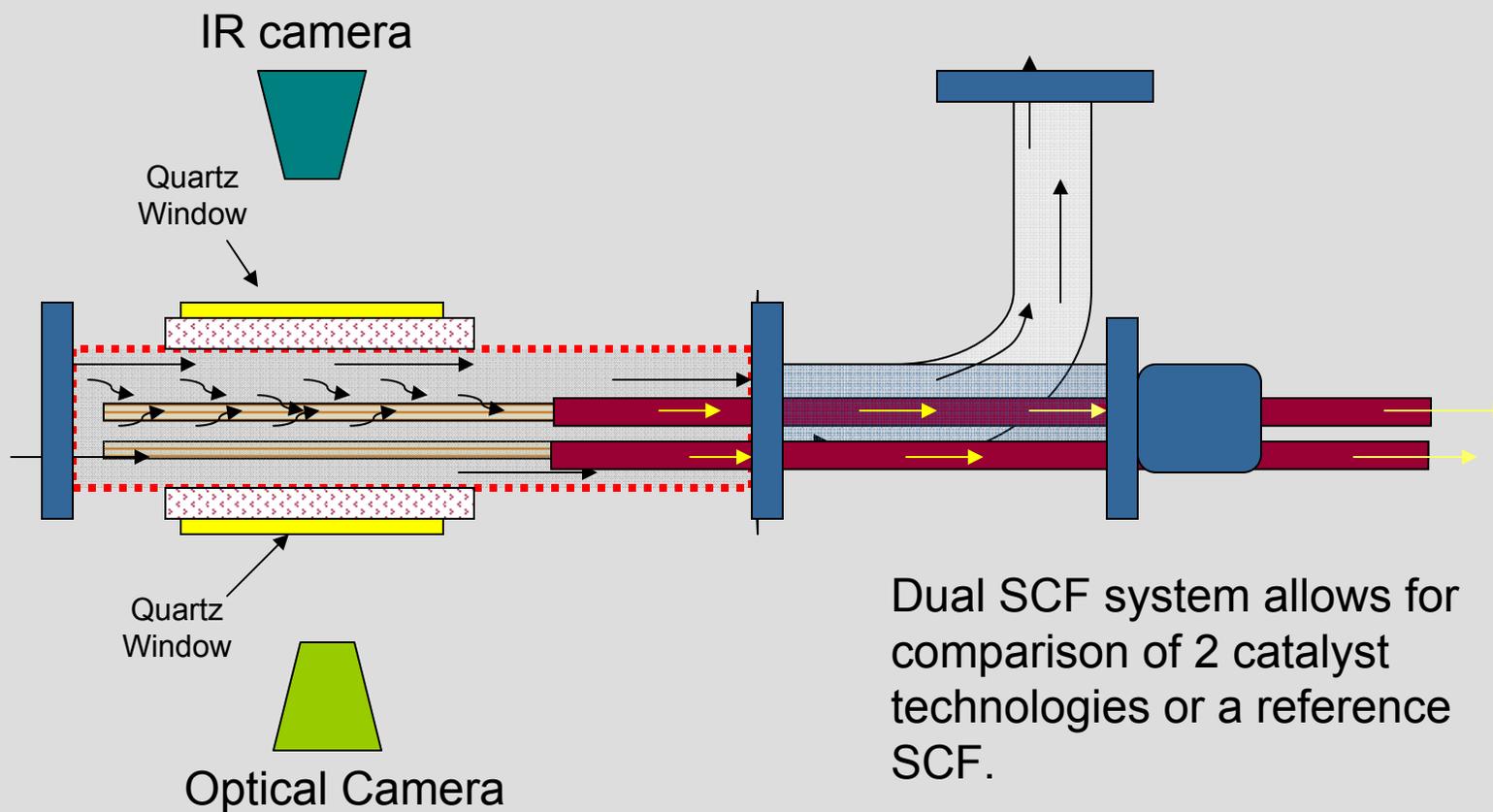
Regeneration IR camera
Dual System

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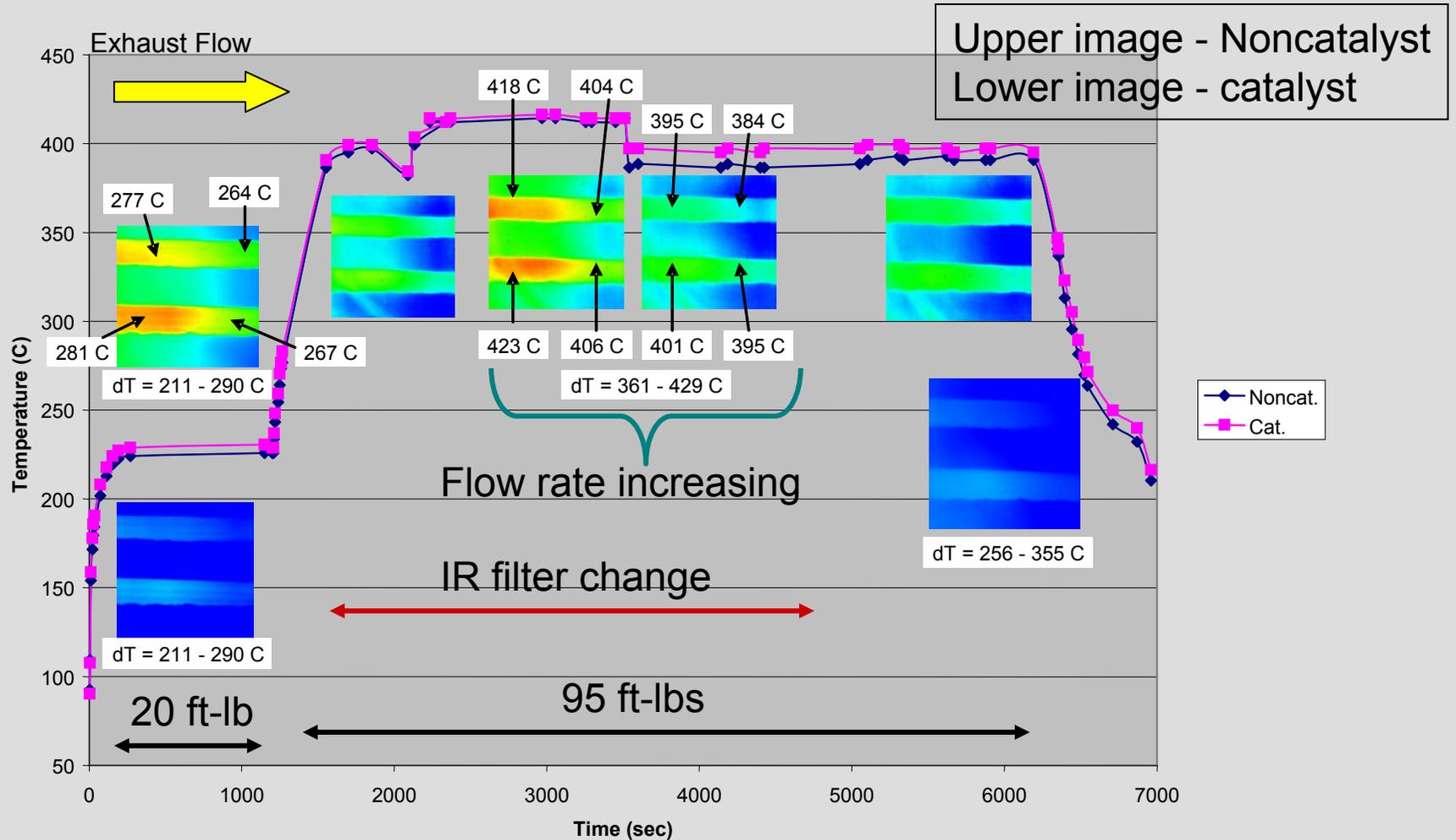
Infra Analysis of Soot Oxidation of full Brick
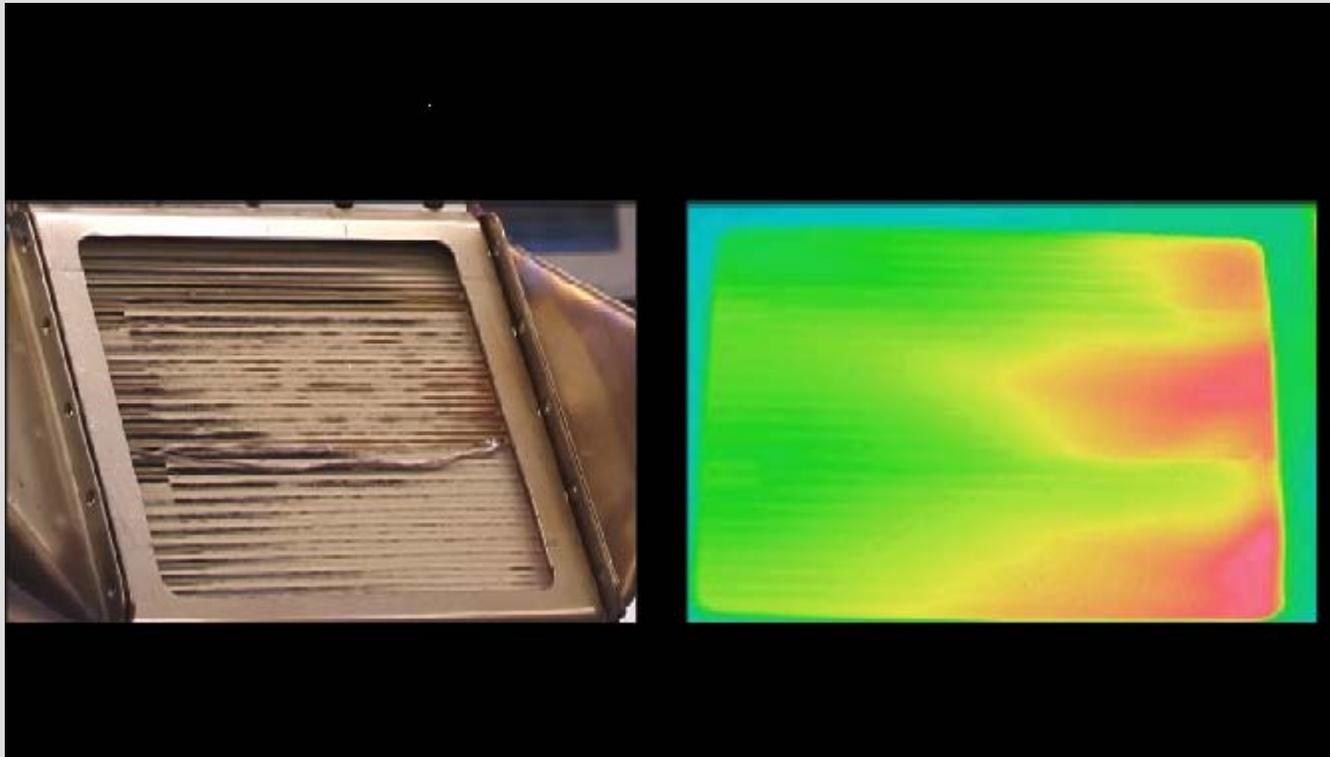
Variations in radial and axial soot deposition makes it difficult to support LB modeling of oxidation reactions

Future Regeneration Reactor Studies
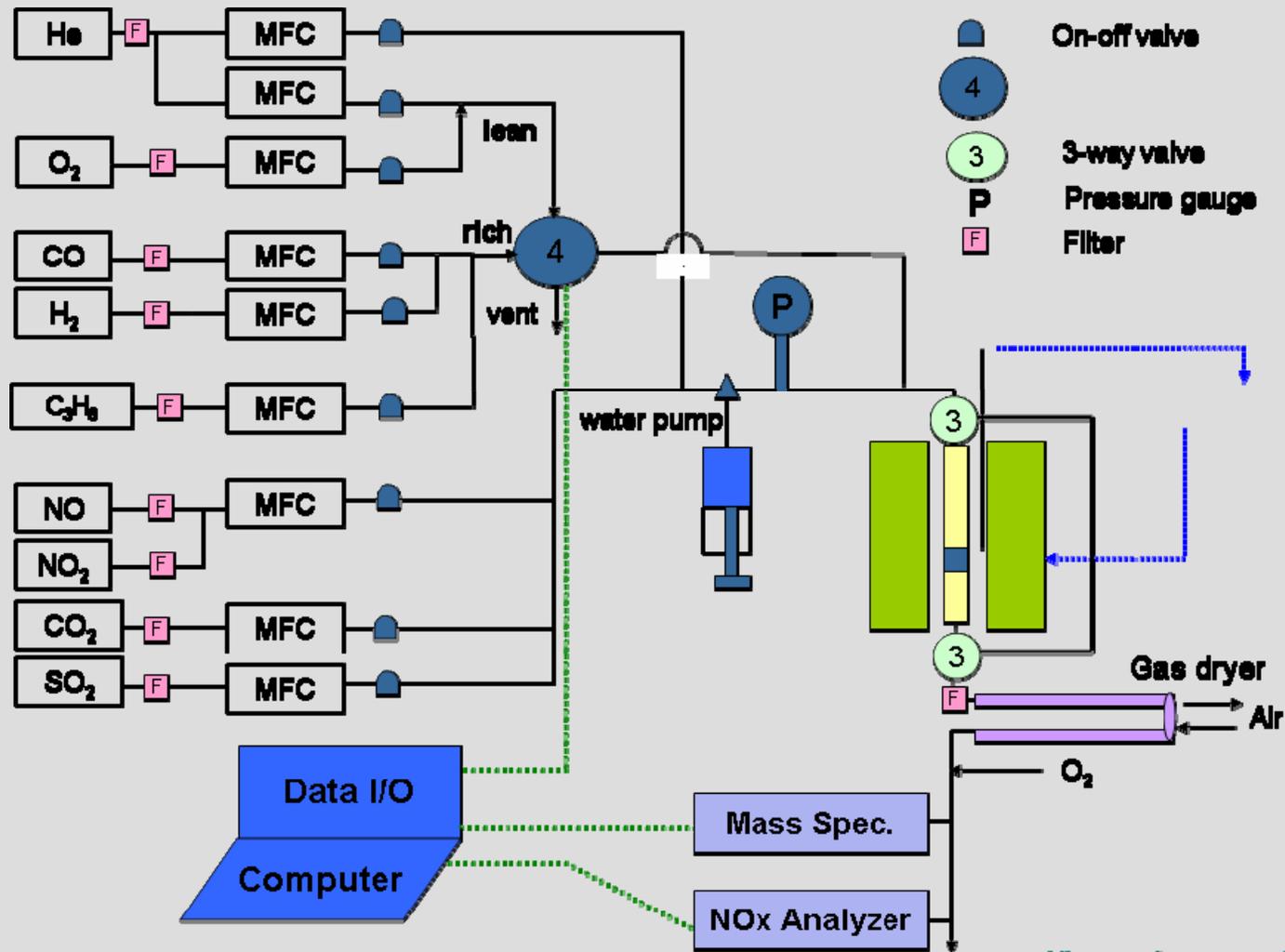
Single Channel Filter Reactor

Thermocouple for T control

¼" line

Gas In

¼" T-union

½"-1/4" reducing union

Soot on the filter

Furnace

½" line

Can't measure the sample weight change after oxidation! However, can estimate the change from the CO_2 formation

½"-5/16" custom made reducer (machine shop)

5/16" line

5/16"-1/4" reducing union

¼" line

¼" T-union

Gas out
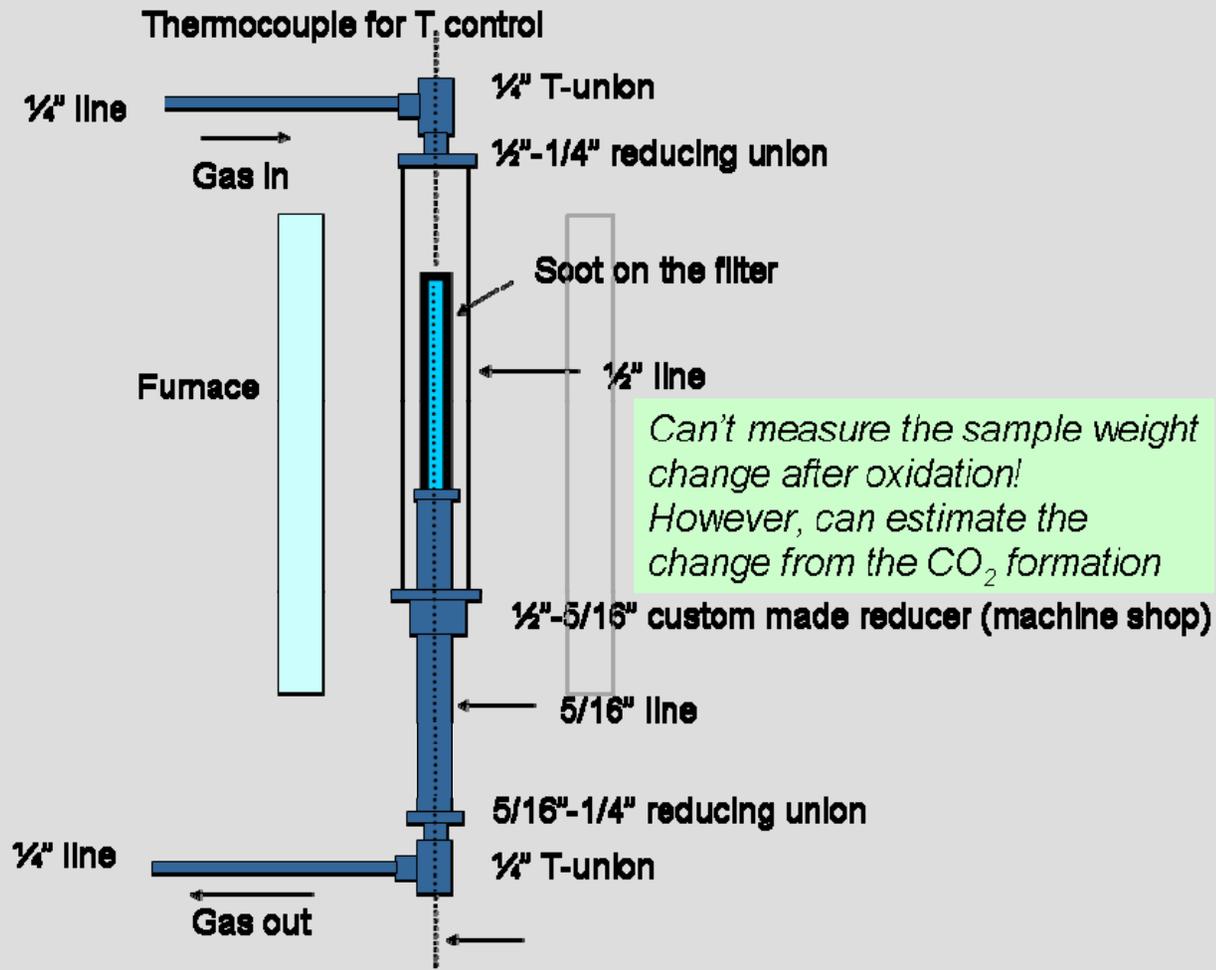
Summary

- ► Single channel filter can provide a simple mechanism for understanding fundamental processes.

- ► IR camera combined with traditional pressure drop / ELPI measurements can provide insight into substrate structure.

- ►