Improved Lifetime Pressure Drop Management For DuraTrap® RC Filters With Asymmetric Cell Technology (ACT)

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Diesel Technology Development
Science and Technology,
Corning Inc.

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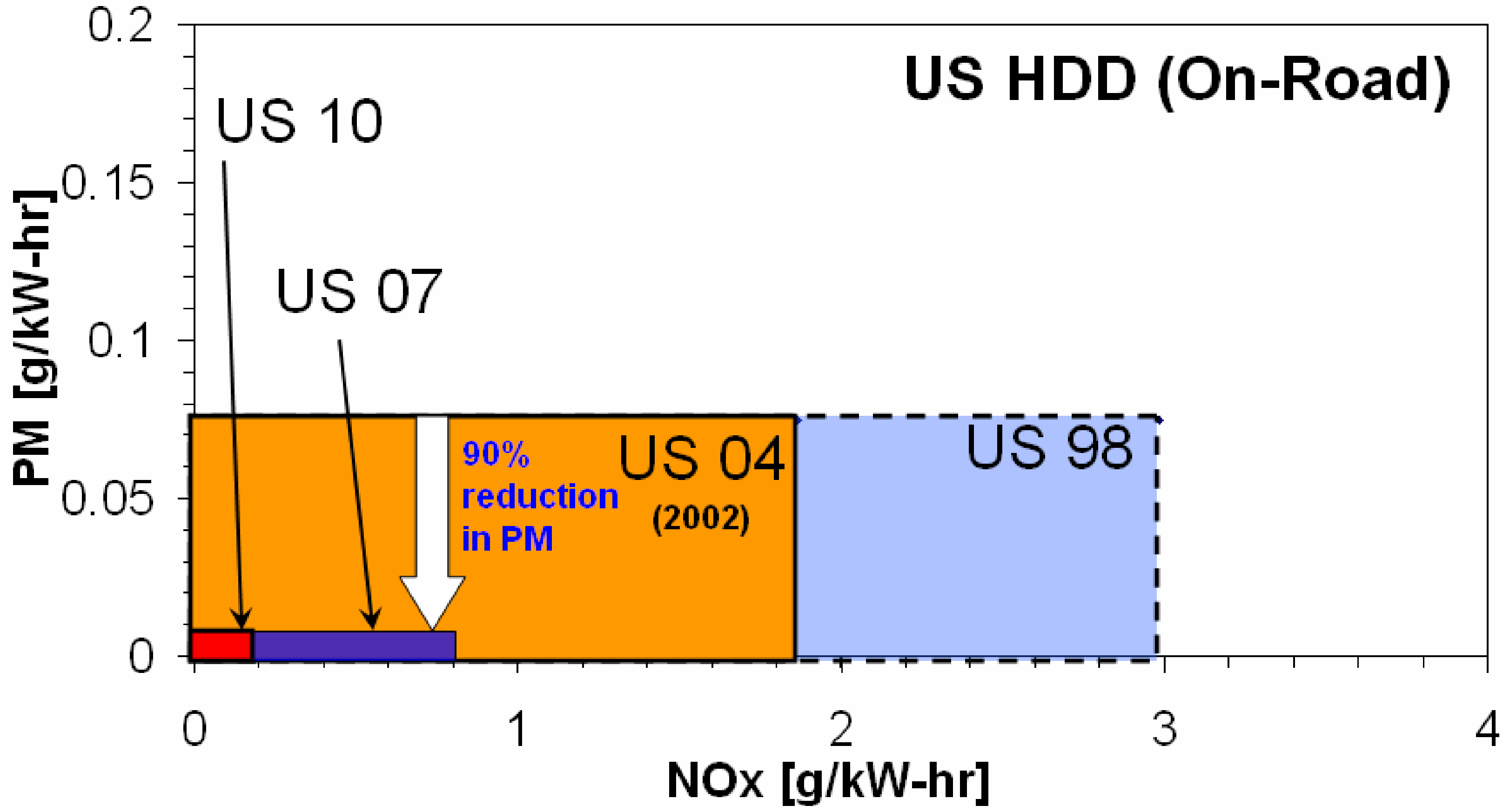
Discovering Beyond Imagination

DETROIT MICHIGAN 2006 DIESEL ENGINE EFFICIENCY & EMISSIONS RESEARCH CONFERENCE

Overview

- Introduction & Objectives
- Materials & Testing Methodology
- Results & Discussion
  - Engine Testing
  - Post Test Analysis
- Conclusions

Tightening of future emission legislation
- After treatment & advancements in engine technology



US legislation (on-road HDD) requires PM reduction to 10% of its current levels by 2007

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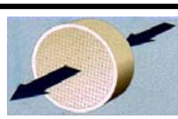
Diesel Emissions Control Systems

HC & CO

Substrates

Catalyzed



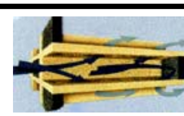
Celcor® LFA substrates

Cell geometries: 200/12, 300/8, 300/5, 400/7

PM

Filters

Catalyzed



DuraTrap® filters

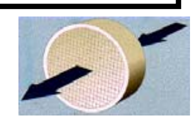
CO 100/17, 200/12

RC 200/19, 270/16 ACT*

NOx

Substrates

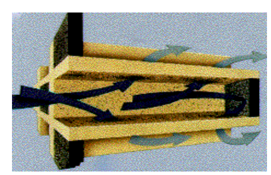
Catalyzed



Celcor® LFA substrates

Cell geometries: 300/5, 300/8, 400/4, 400/7

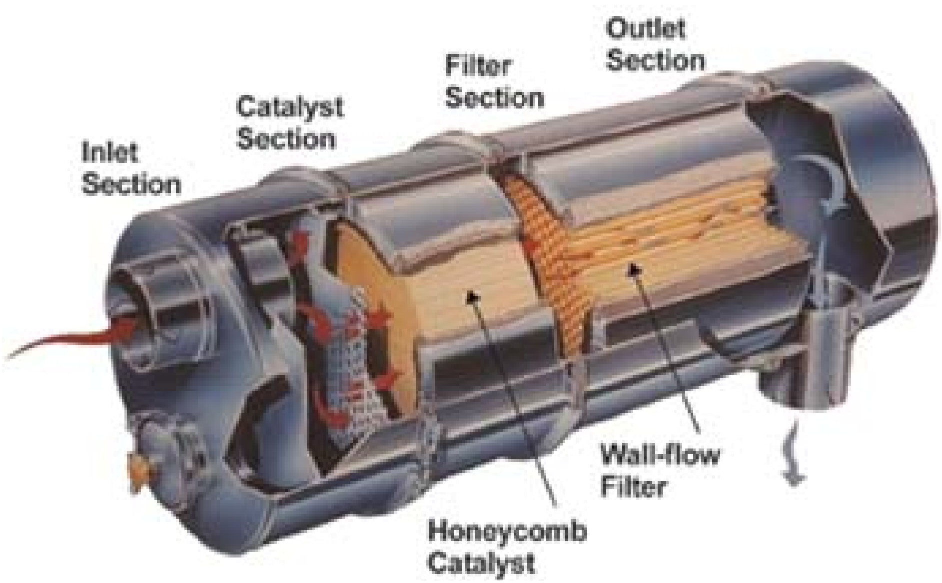
Integrated system
“Future”



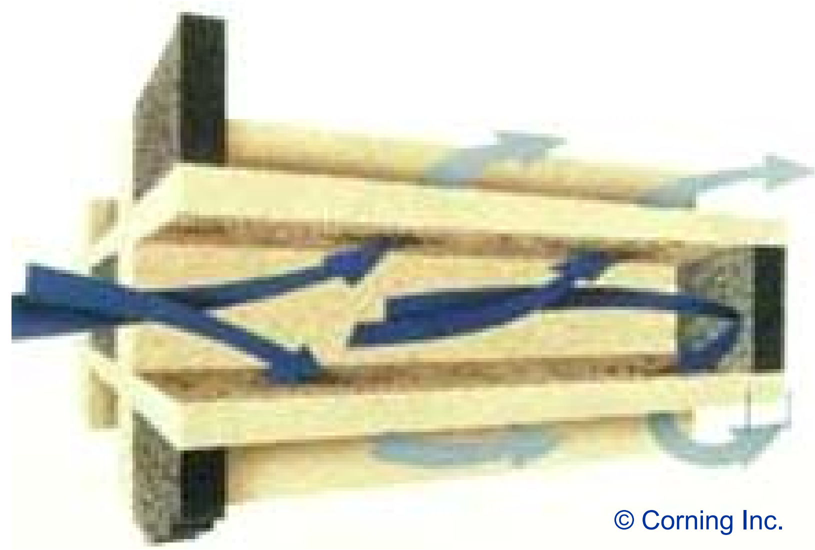
* **Asymmetric Cell Technology**

Diesel Particulate Filters needed for low PM emissions
- Wall-flow monolith filters as primary choice of industry

- Honeycomb substrate with checkerboard plugging
- PM trapped on/inside walls
- Periodic regeneration of combustible fraction of the PM



Source: Diesel Technology Forum website



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Ash accumulation in DPF
- Non-combustible fraction of PM accumulates in the filter

- Typical Ash components are
  - Sulfates, phosphates, oxides of calcium, zinc, magnesium etc
    - formed by combustion of lubricating oil additives like detergents, acid neutralizers, anti-wear agents, corrosion inhibitors …
  - Metal oxides (Fe, Cu, Cr, Al) from wear
    - From the engine or the exhaust system

- Ash accumulation & composition varies significantly, depending upon
  - engine type and runtime
  - Operating conditions,
  - type of fuel & additives,
  - lubricating oil & additives
  - metallurgy of the exhaust system components

Ash implication on performance & mitigation

- Accumulated ash increases the flow resistance through the filter
  - Increased back pressure
    - Higher fuel consumption
    - Lower power output & dynamic response
    - Lower heat rejection (exhaust)

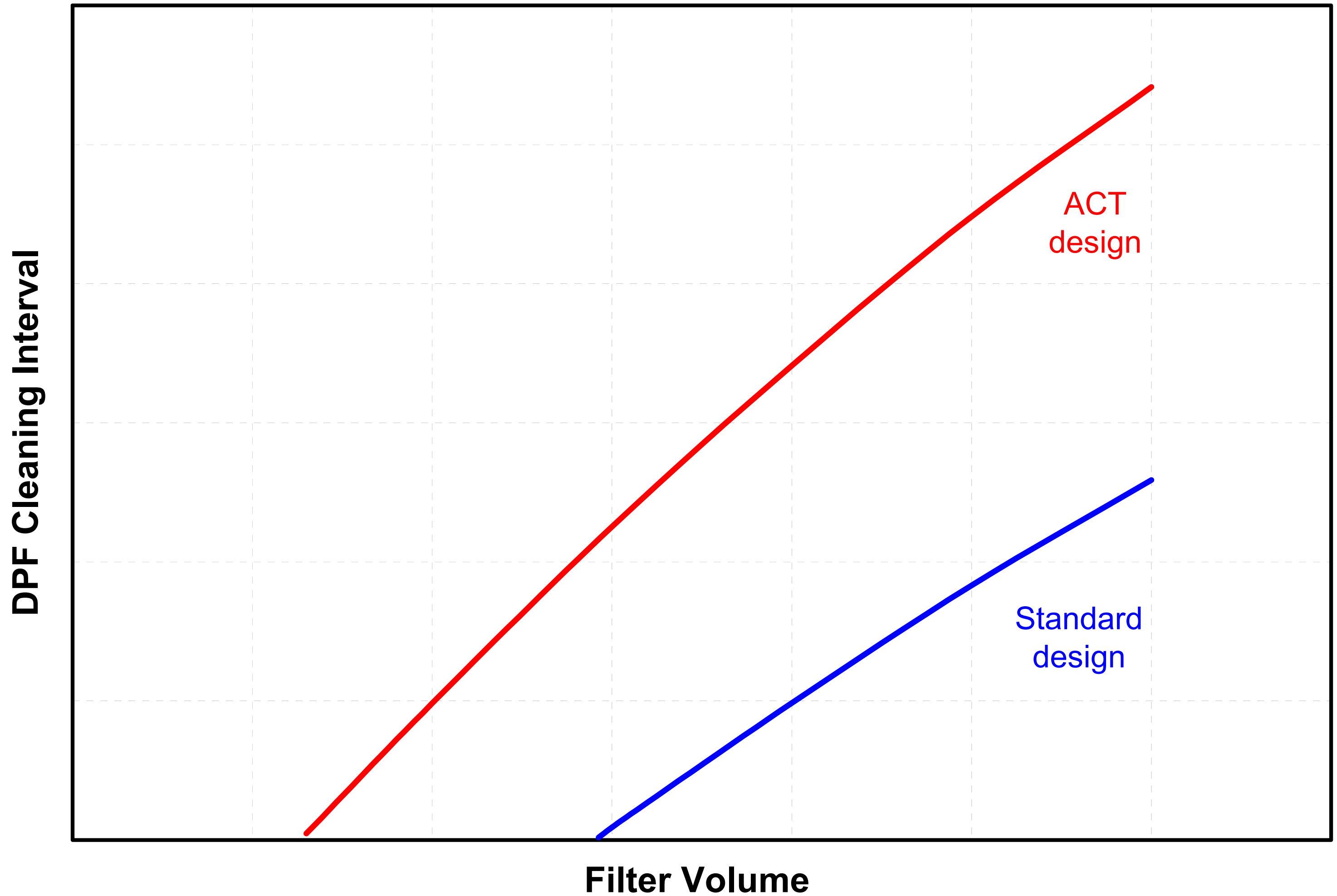
- Reduction of effective filter volume
  - Lower soot capacity
    - Higher regeneration frequency

- Mitigation
  - Filter design
    - Filter geometry
    - Channel geometry
  - Periodic Ash cleaning

Asymmetric Cell Technology
- Channel design for improved ash storage capacity

- Larger inlet channel volume
- Equal bulk density → similar regeneration performance
- Similar physical properties
- Equal mechanical and thermo-mechanical durability performance compared to Standard, due to proprietary design
- Potential to use a smaller filter volume

Service interval for DPFs
- Impact of DPF design aspects



Significant increase in service interval for ACT design than standard.

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Objectives

- Characterize Pressure drop with ash accumulation for DuraTrap® RC (on-engine)
- Demonstrate performance benefit of ACT
- Evaluate the impact of long term engine exposure on material stability/durability

Materials
- DPFs evaluated in current study

– DuraTrap® RC
- Uncatalyzed
- Filter Volume :17 Liters
- Filter dimensions Ø10.5”x12”
- $d_{h,inlet} / d_{h,outlet} = 1.0$

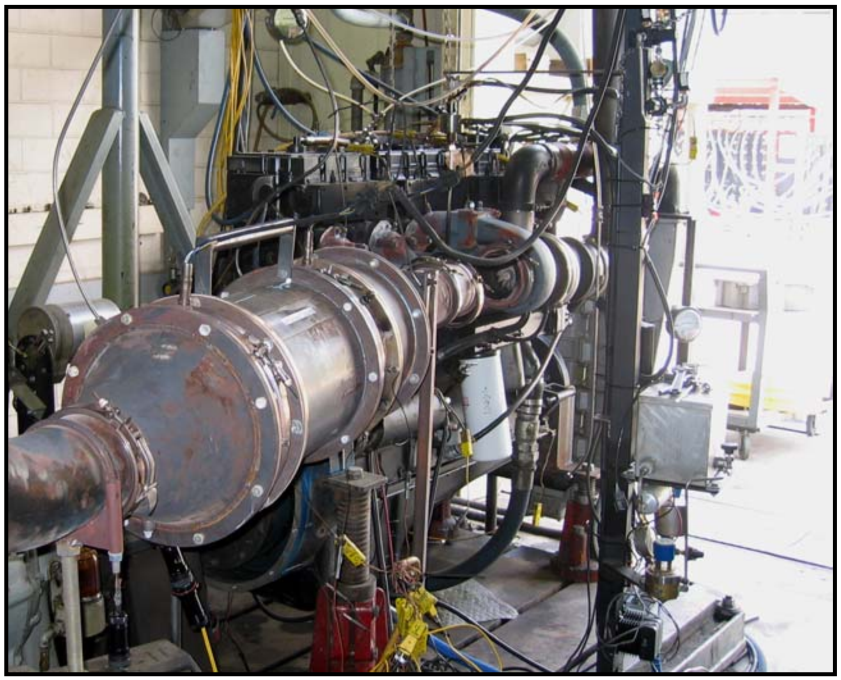
– DuraTrap® RC ACT*
- Uncatalyzed
- Filter Volume :17 Liters
- Filter dimensions Ø10.5”x12”
- $d_{h,inlet} / d_{h,outlet} = 1.3$

Design/Geometry	Cell Density [CPSI]	Web Thickness [mils]	Inlet OFA [%]	Cell Diameter [in.]	
				INLET CHANNEL	OUTLET CHANNEL
DuraTrap®RC	200	19	27	0.053	0.053
DuraTrap®RC ACT*	270	16	34	0.051	0.038

Test Cells specifications

Ash Loading Test Cell:

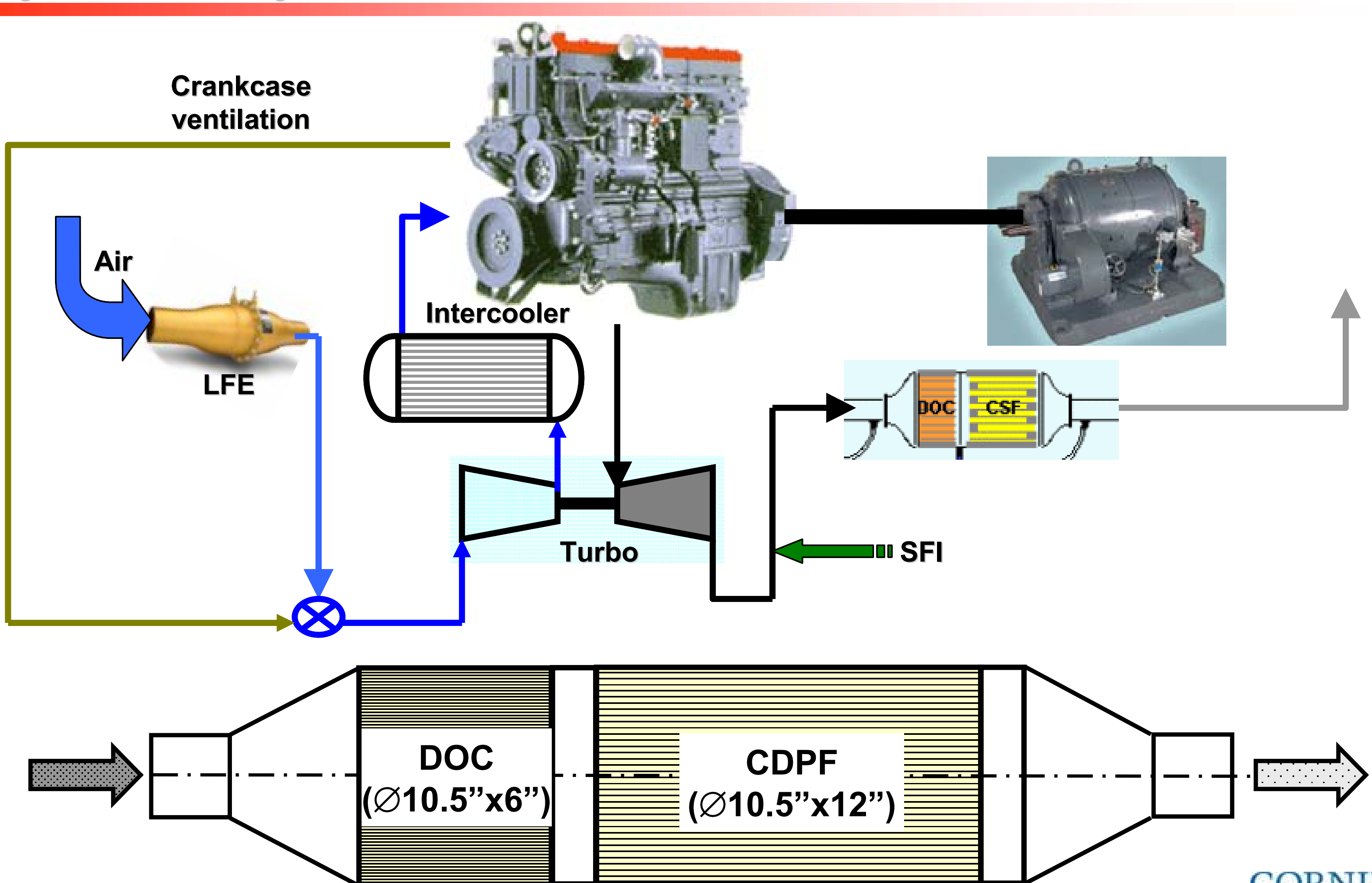
- Cummins N14
  - 6 cylinder-Inline
  - Rated Power :460 HP @ 1800RPM
  - Torque at rated : 1300lb-ft.
- Mid-west Eddy-current Wet-gap dynamometer
- UEGO Sensors



Characterization Test Cell:

- Volvo D12 (MY2003)
  - 6 Cylinder-Inline
  - Rated Power :460 HP @ 1800RPM
  - Torque at rated : 1300lb-ft.
- Mid-west Eddy-Current Wet-Gap dynamometer
- UHEGO Sensors
- Emissions-Raw (CO, CO_2, NO/NOx, O_2,THC)

System lay-out for DPF evaluation



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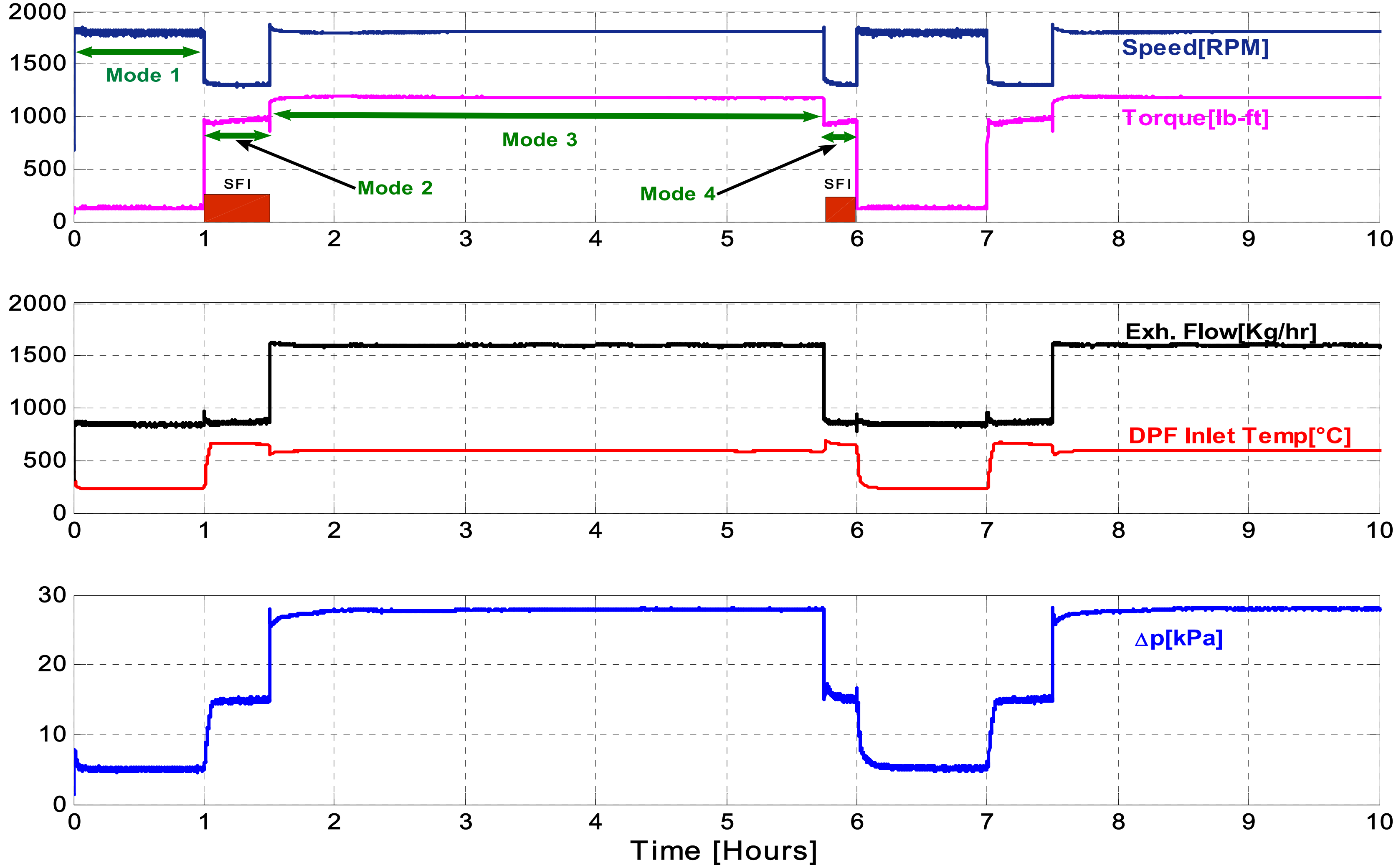
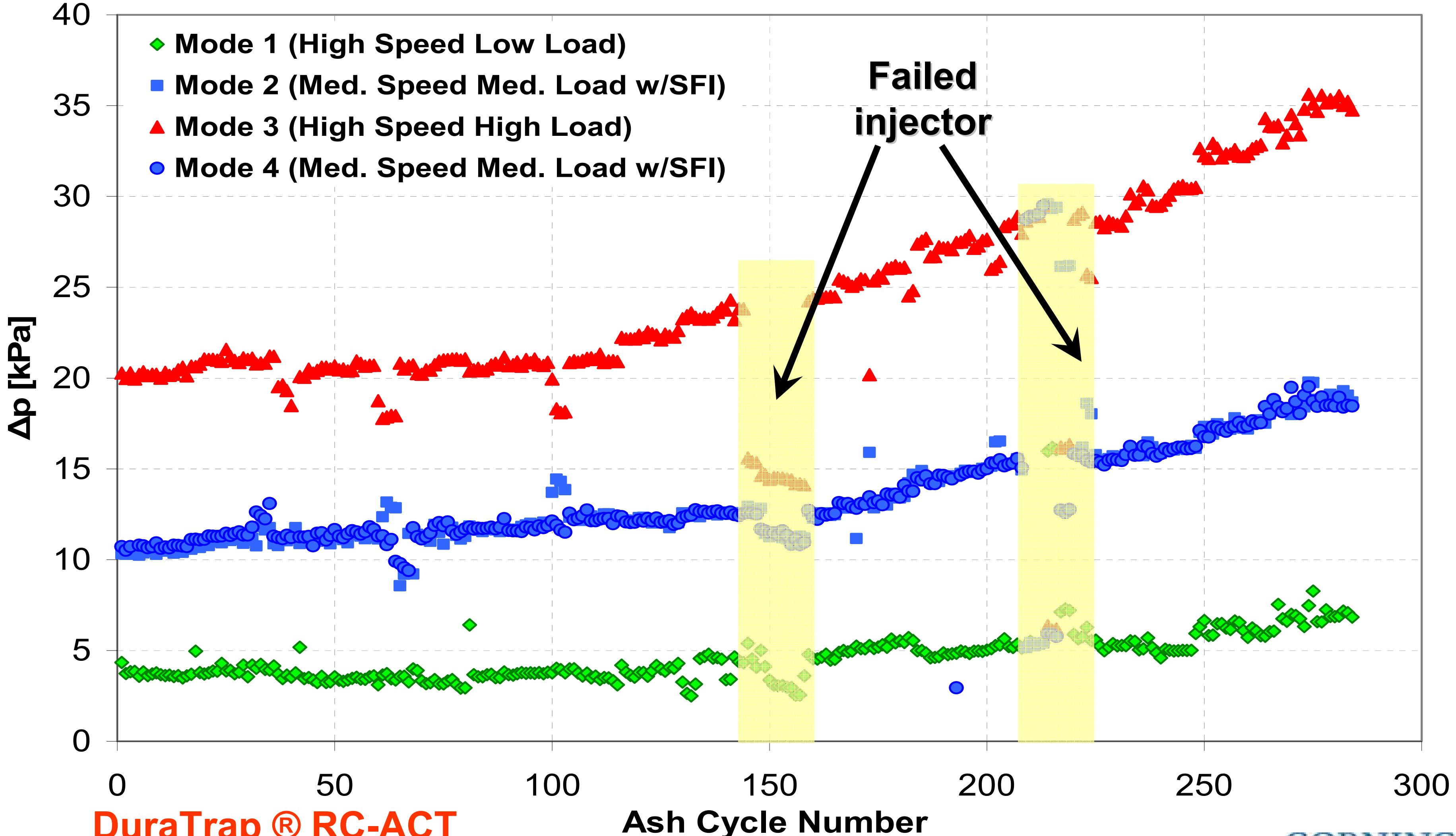
Ash accumulation cycle

- accelerated by load profile and low DPF volume/engine power output
- high load factor ~0.74; >70% of accumulation time in Mode 3



Pressure drop development with ash accumulation

- Initial pressure drop increase moderate
- More pronounced pressure drop impact with higher cycle number



DuraTrap ® RC-ACT

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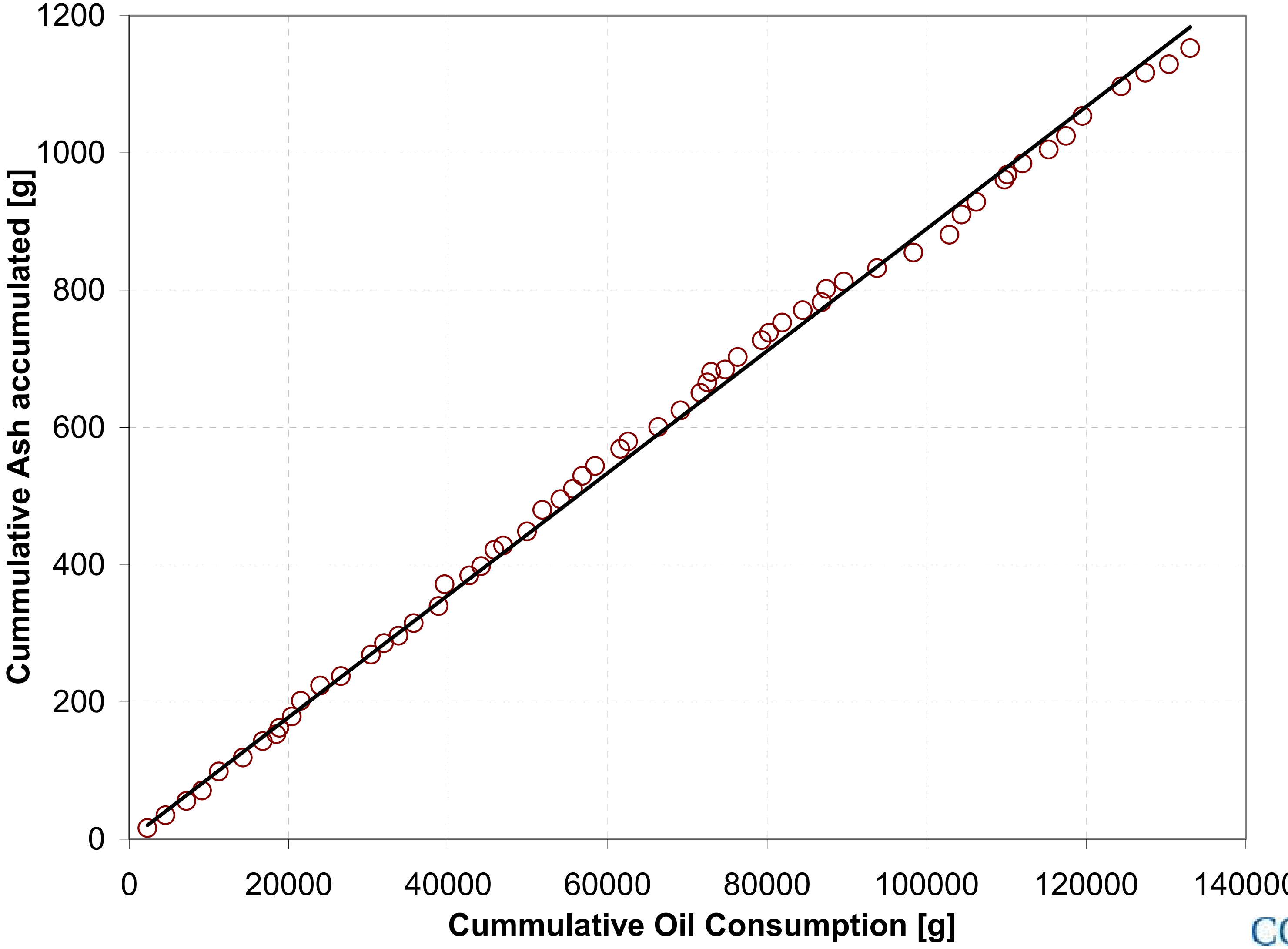
Ash accumulation vs. Oil Consumption

- Ash accumulation tracks well with oil consumption
- Ash finding rate in the DPF about 55-60%



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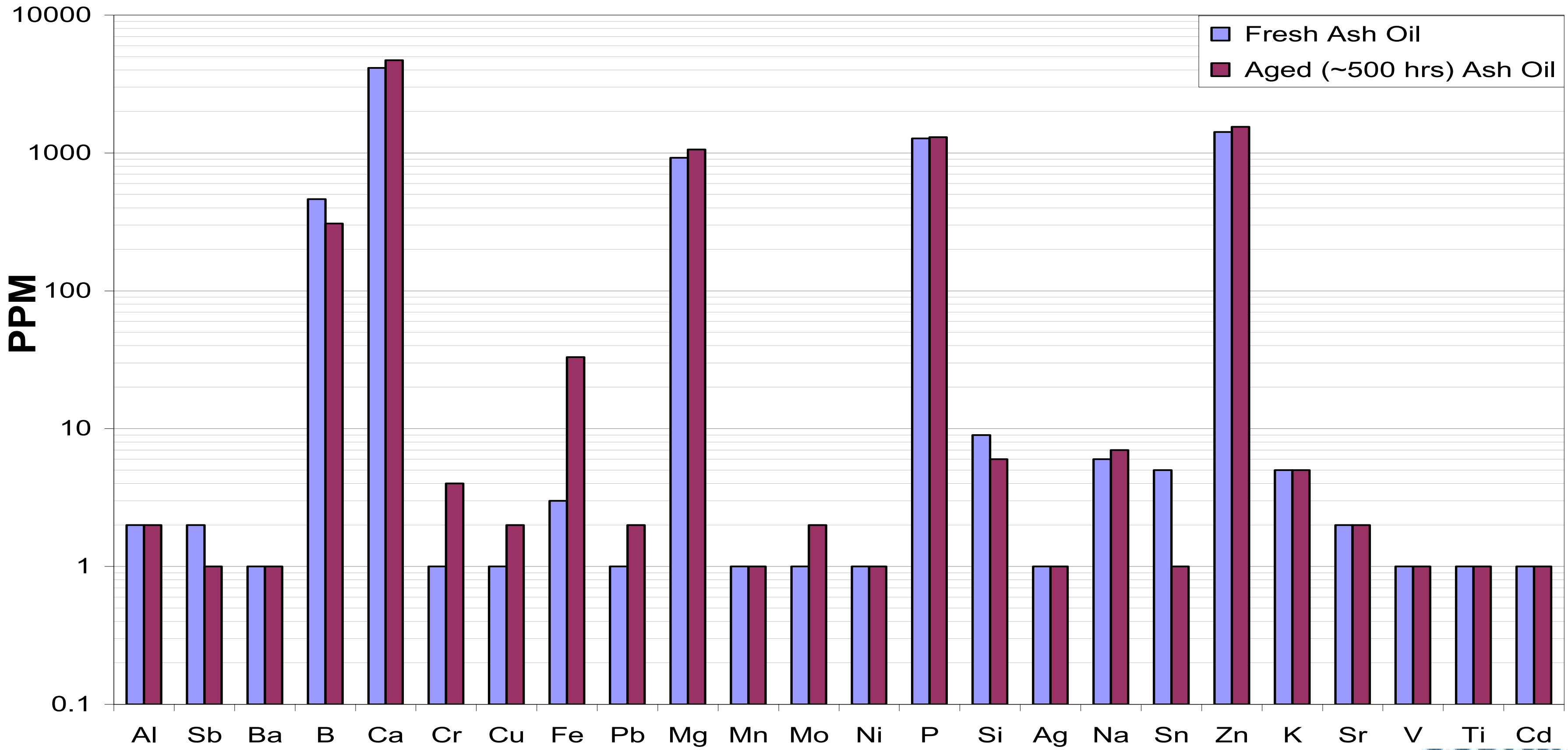
Reason for lower ash finding rate

	Fresh Ash Oil	Aged (500 hrs) Ash Oil
Ash Content, mass %	1.69	1.83
Sulfur Content, wt%	0.921	0.889



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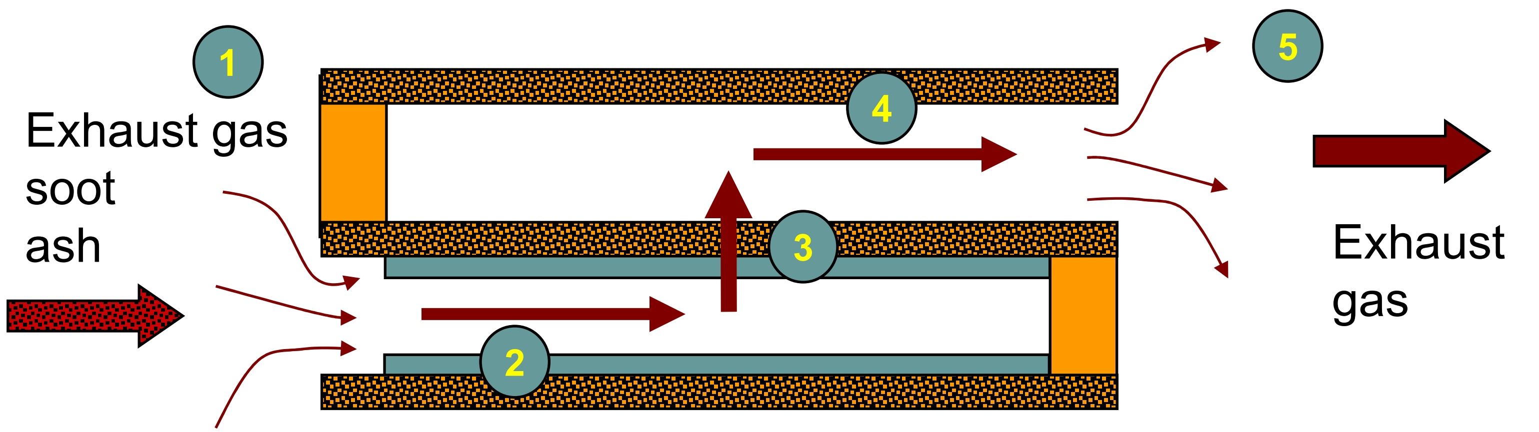
Pressure Drop: Fundamental Influences

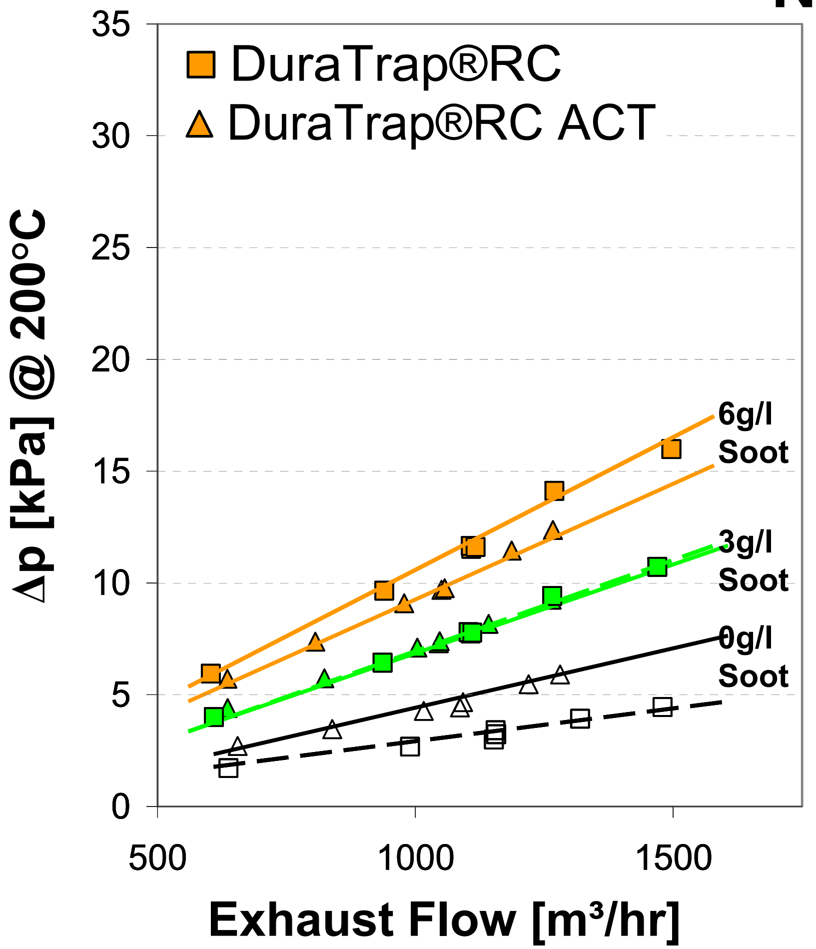


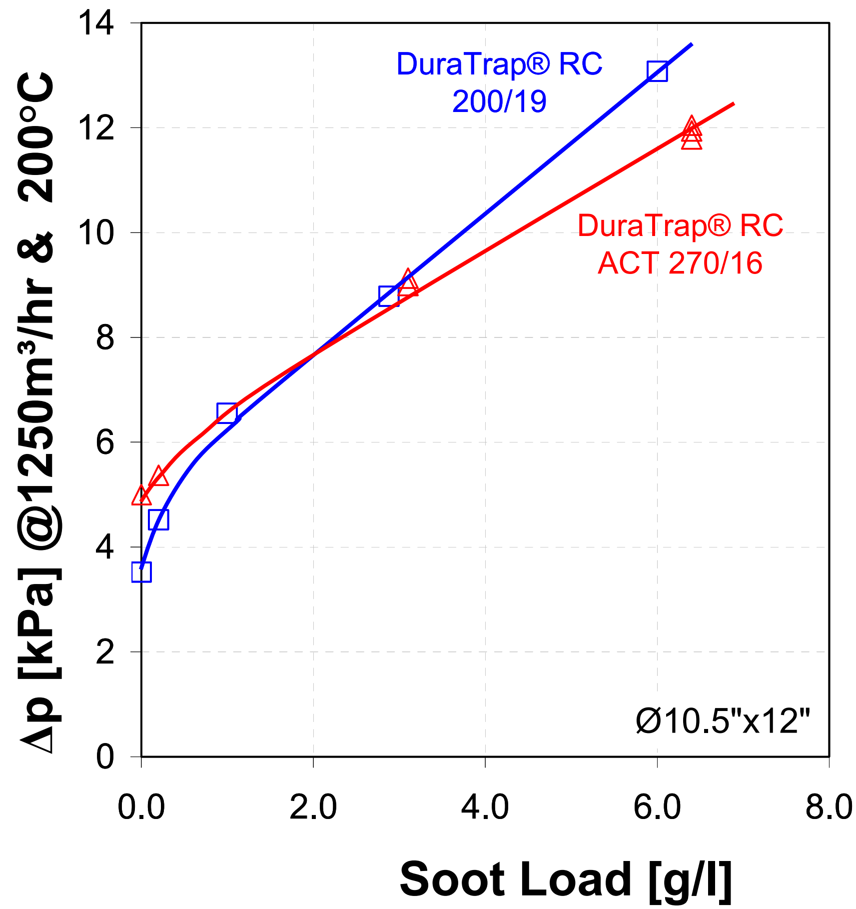
Contribution		Key Parameter	Filter characteristics
1	Inlet losses (Contraction)	Mainly OFA	Geometry
2	Frictional losses along the inlet channel walls	Mainly hydraulic diameter of channel, length	Geometry
3	Frictional losses from flow through wall and soot & ash layer	Permeability of wall (also fraction of soot & ash), wall thickness, filtration area	Wall properties & geometry
4	Frcitional losses along the outlet channel wall	Mainly hydraulic diameter of channel, length	Geometry
5	Outlet losses (Expansion)	Mainly OFA	Geometry

Pressure drop effects

- Geometric and micro-structural impact

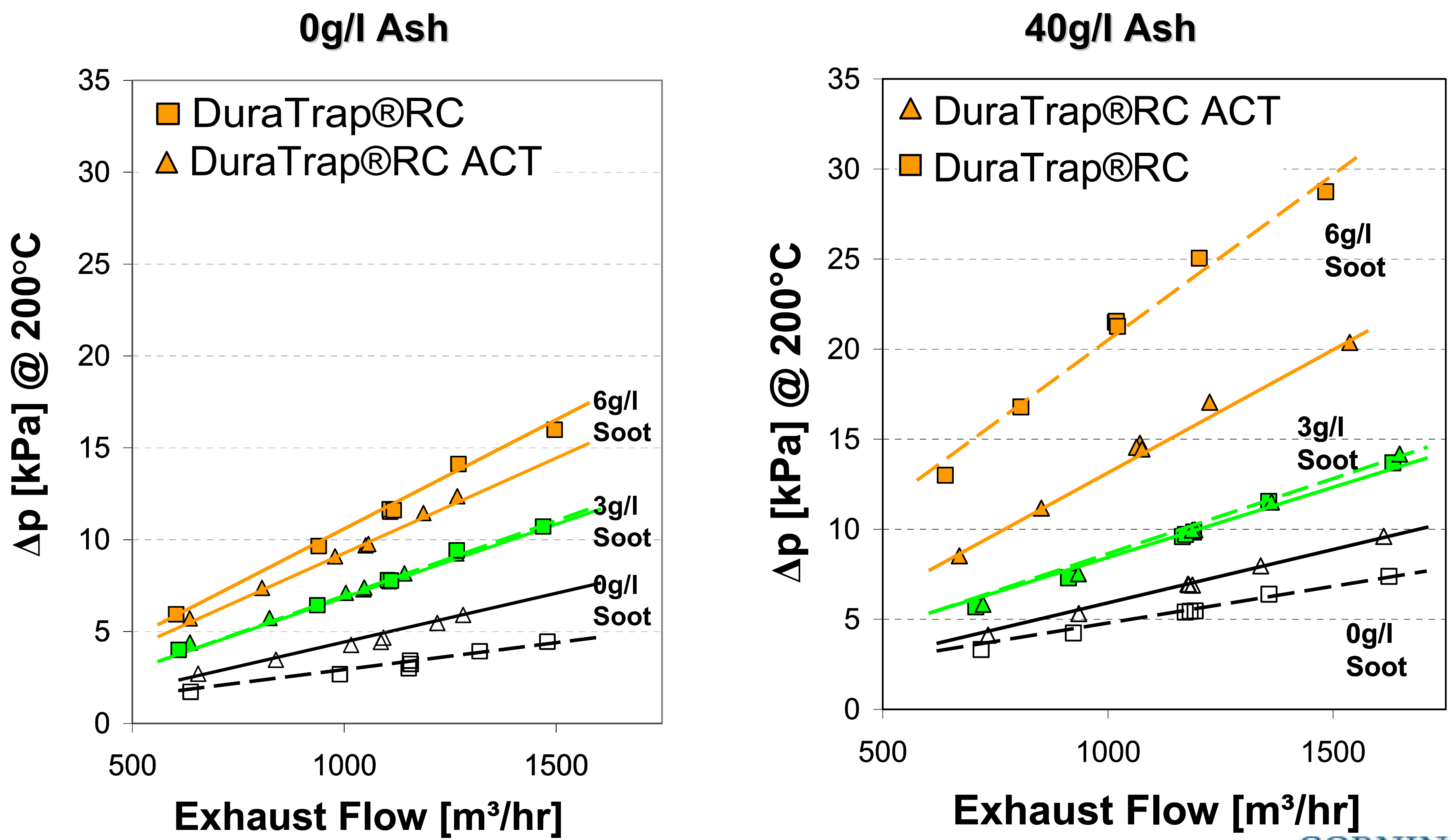
No Ash





Pressure Drop as a function of Flow

- Increasing advantage of ACT design at all operating flows with increasing ash & soot in the filter



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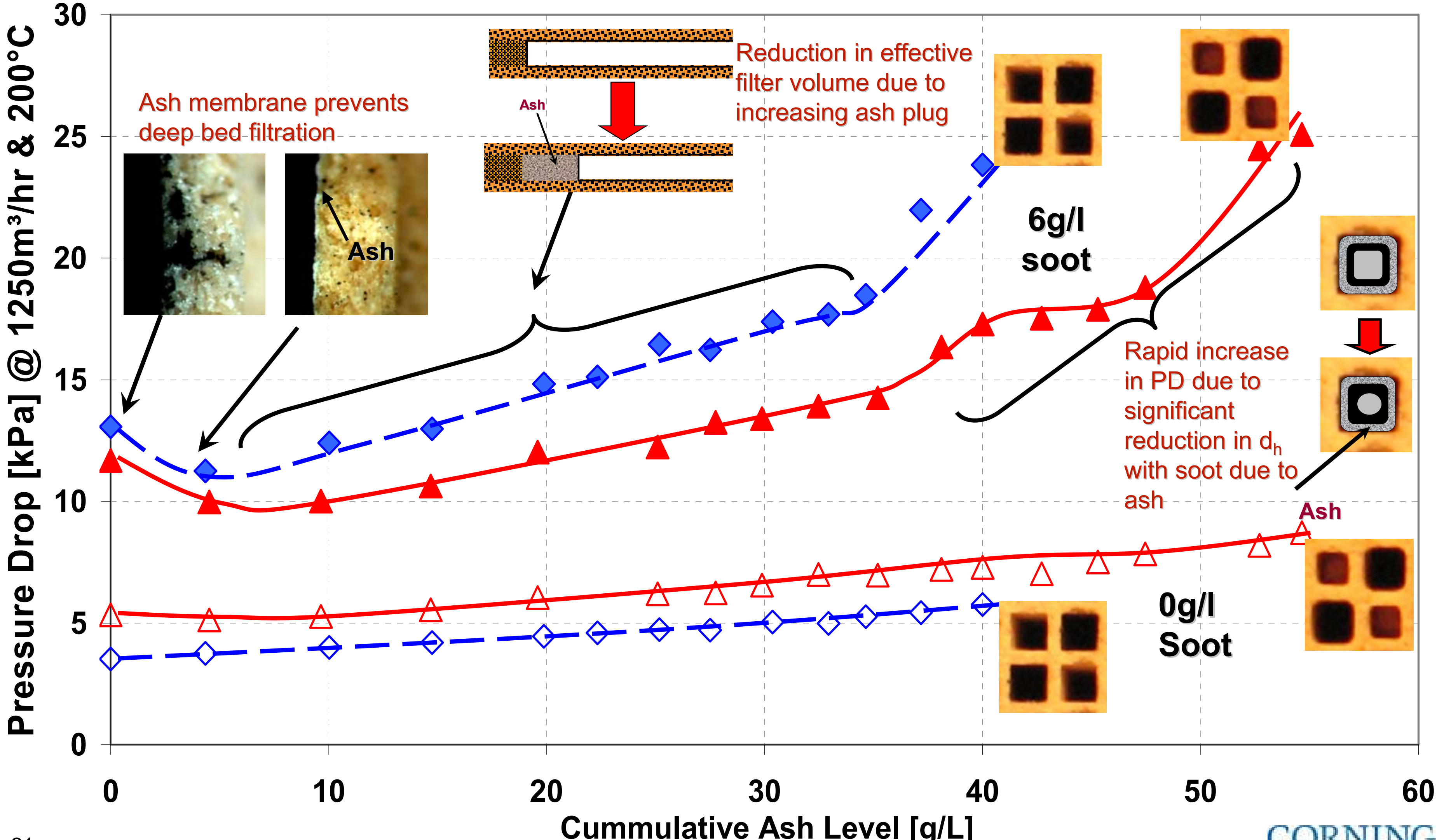
Δp increase with ash loading

– Higher pressure drop for ACT in the clean state
– Roughly 30% increase in the ash capacity with ACT design



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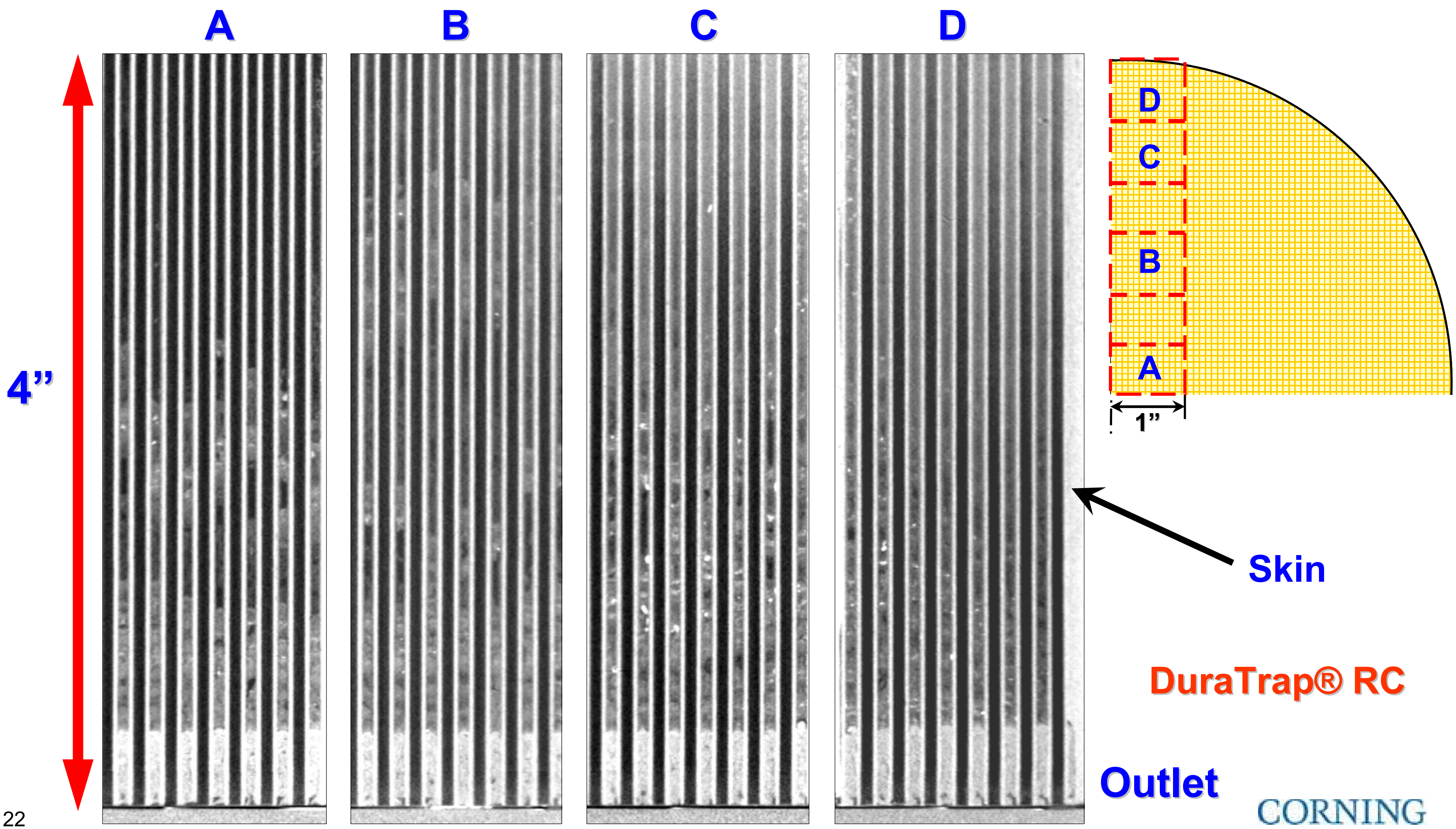
Detailed view of the bottom

- Low density ash/voids present in between ash plugs
- Lower concentration of high density ash in near skin channels



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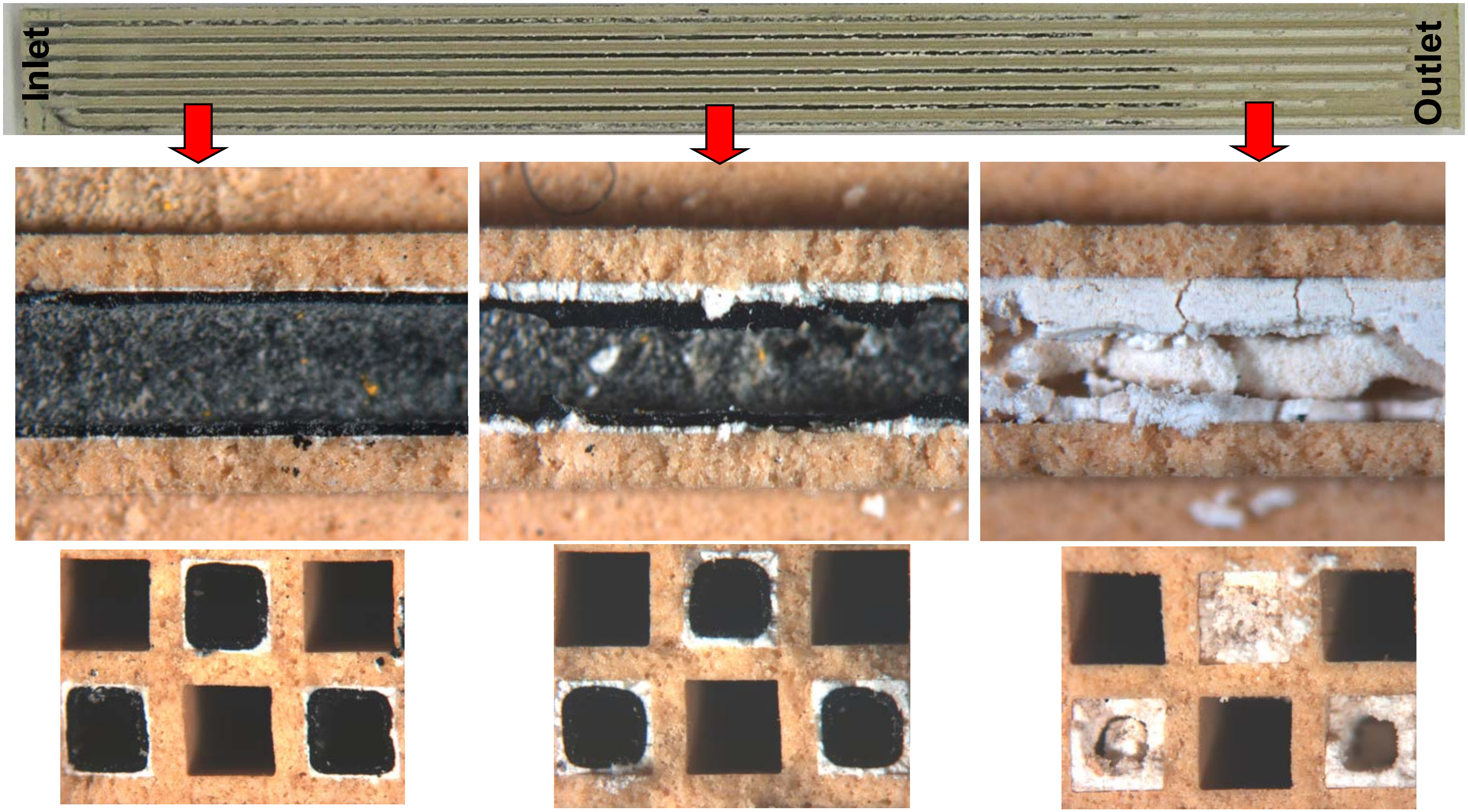
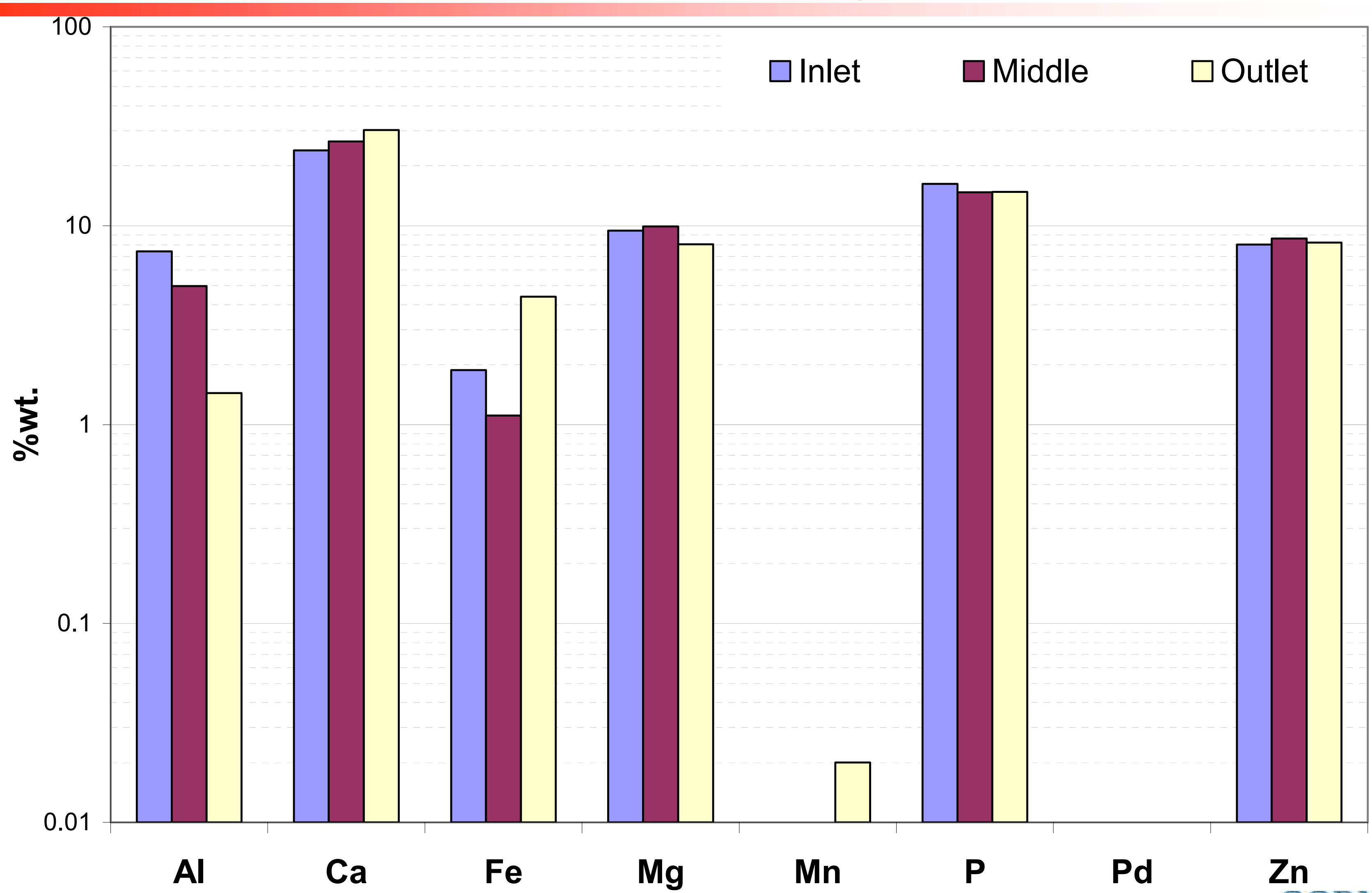
Ash distribution evaluation after dissection

- Large low density ash plug near the outlet of the filter
- High density ash layer on the wall (increasing from in- to outlet)



Chemical Analysis of ash in the filter
- Similar ash composition over the length of the filter



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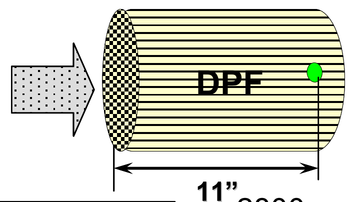
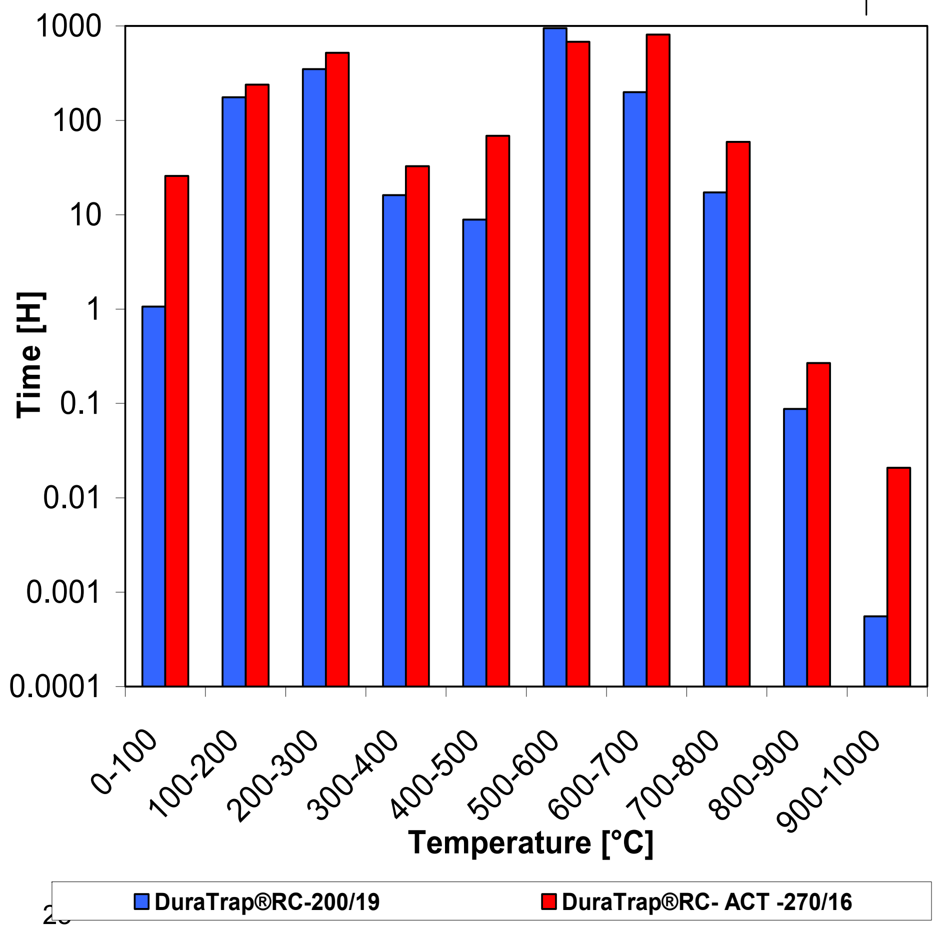
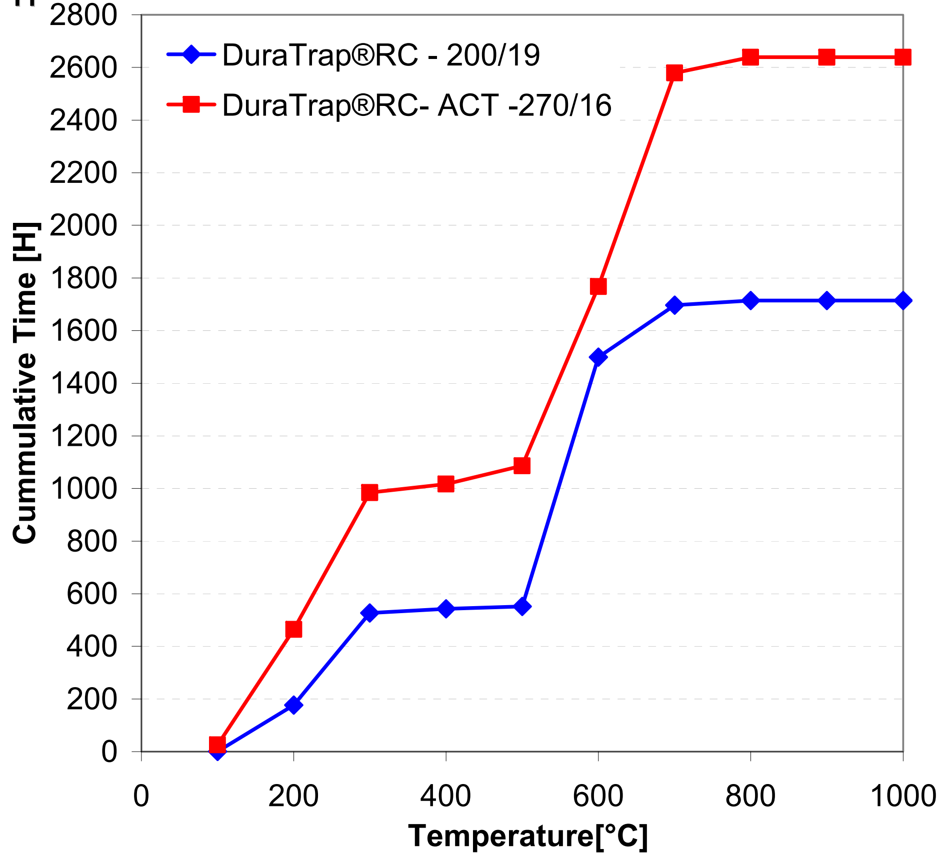
Time Temperature distribution

-1720 on engine hrs. [DuraTrap® RC] >> equivalent to number of regenerations for ~300k miles
- 2640 on engine hrs. [ACT] >> equivalent to number of regenerations for ~420k miles

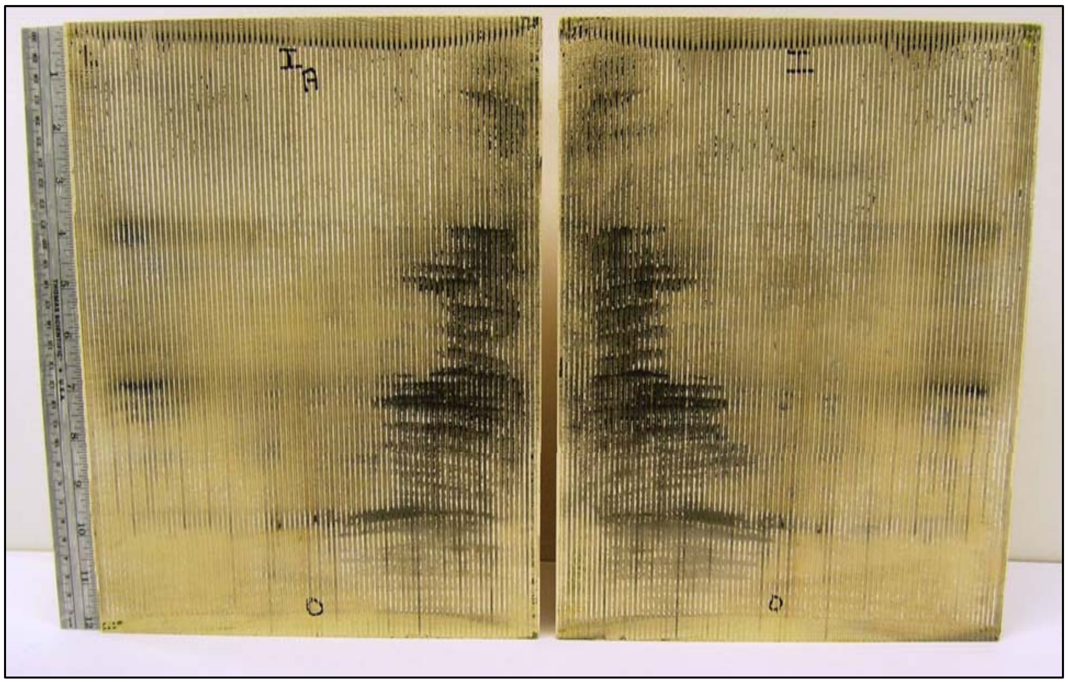






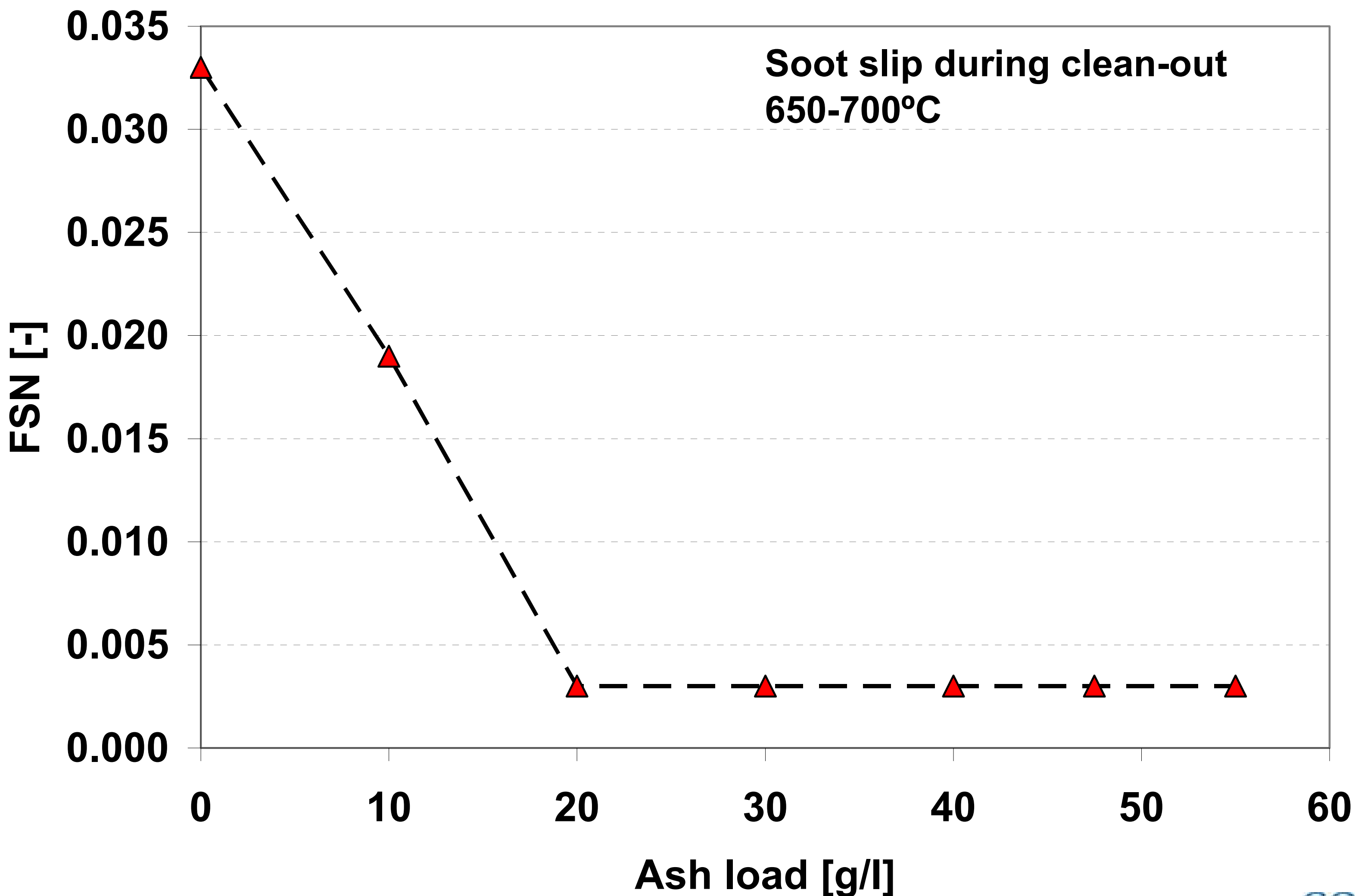
Post- testing physical Integrity

- Both filters showed no integrity degradation



Shown: DuraTrap® RC ACT

Smoke Number - DuraTrap® RC ACT filter
- excellent filtration performance over ash accumulation
- filtration improves with ash accumulation



Summary & Conclusion

- On-engine ash accumulation testing of DuraTrap® RC
  - Highest oil consumptions at high speed & load
  - Lube oil consumption linearly correlated to ash acc. in DPF
  - Lifetime Δp for DPF includes three phases:
    - Conditioning, filter volume reduction, inlet channel throttling

- Successful demonstration (on-engine) durability of DuraTrap® RC filters
  - Std: 1720 engine hours [regen. equivalent of ~300Kmiles]
  - ACT: 2640 engine hours [regen. equivalent of ~420Kmiles]

- 30% ash storage advantage of DuraTrap® RC 270/16 ACT compared to standard design

References

- Young D M, et. Al., "*Ash Storage Concept for Diesel Particulate*" SAE 2004-01-0948
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- EPA – website http://www.epa.gov

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