



The ExoClean™ Filter System for "Stop & Go" Duty Cycle Vehicles: Experience, Durability and Improvements

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Aaqius & Aaqius

VENTURE BUSINESS COMPANY

MEMBER OF AAQIUS NETWORK

Presentation Outline

Introduction

Description of the Active Filter System

Refuse Trucks Applications (OEM & Retrofit)

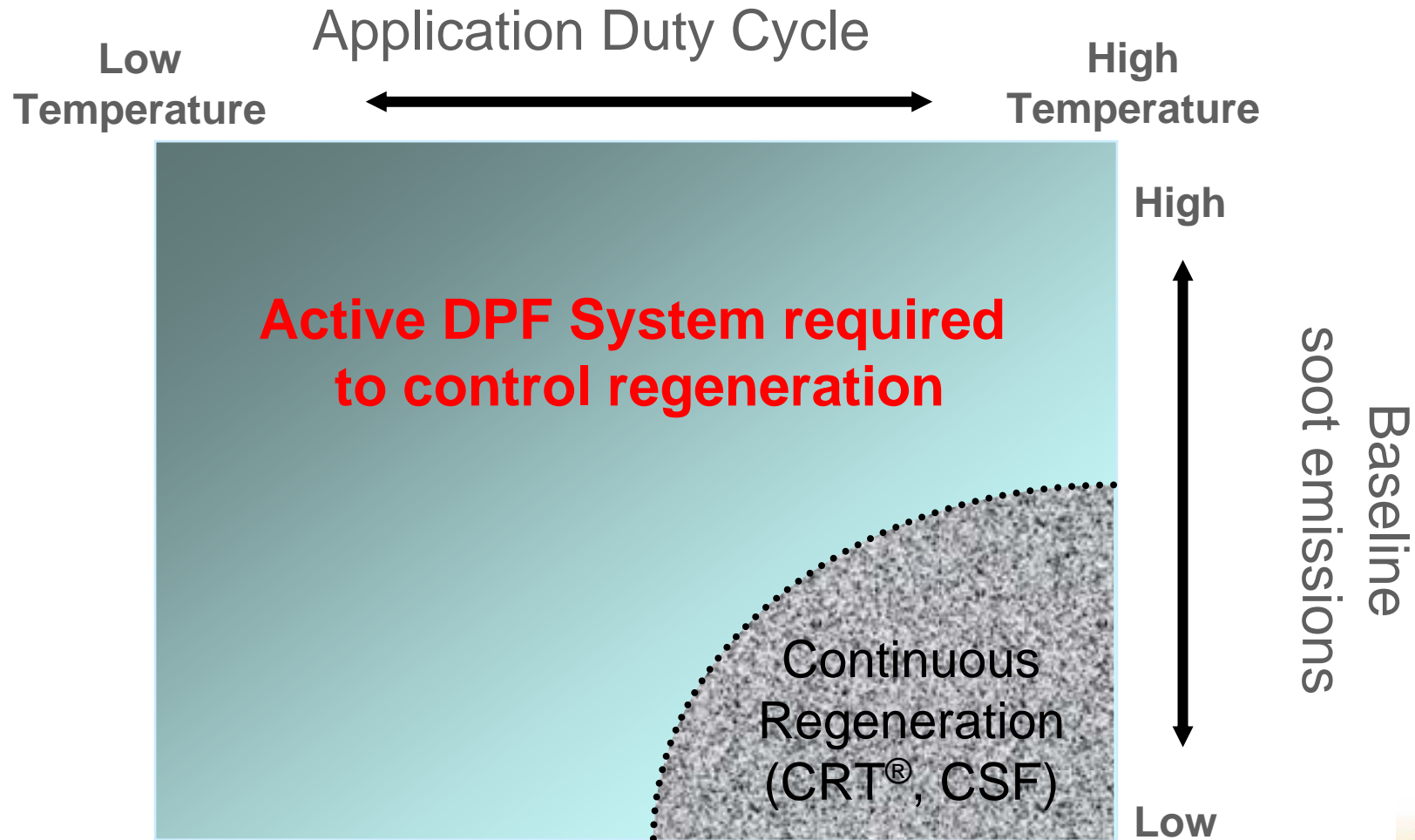
Improvement with Fuel-Borne Catalyst

Retrofit Application Experiences:

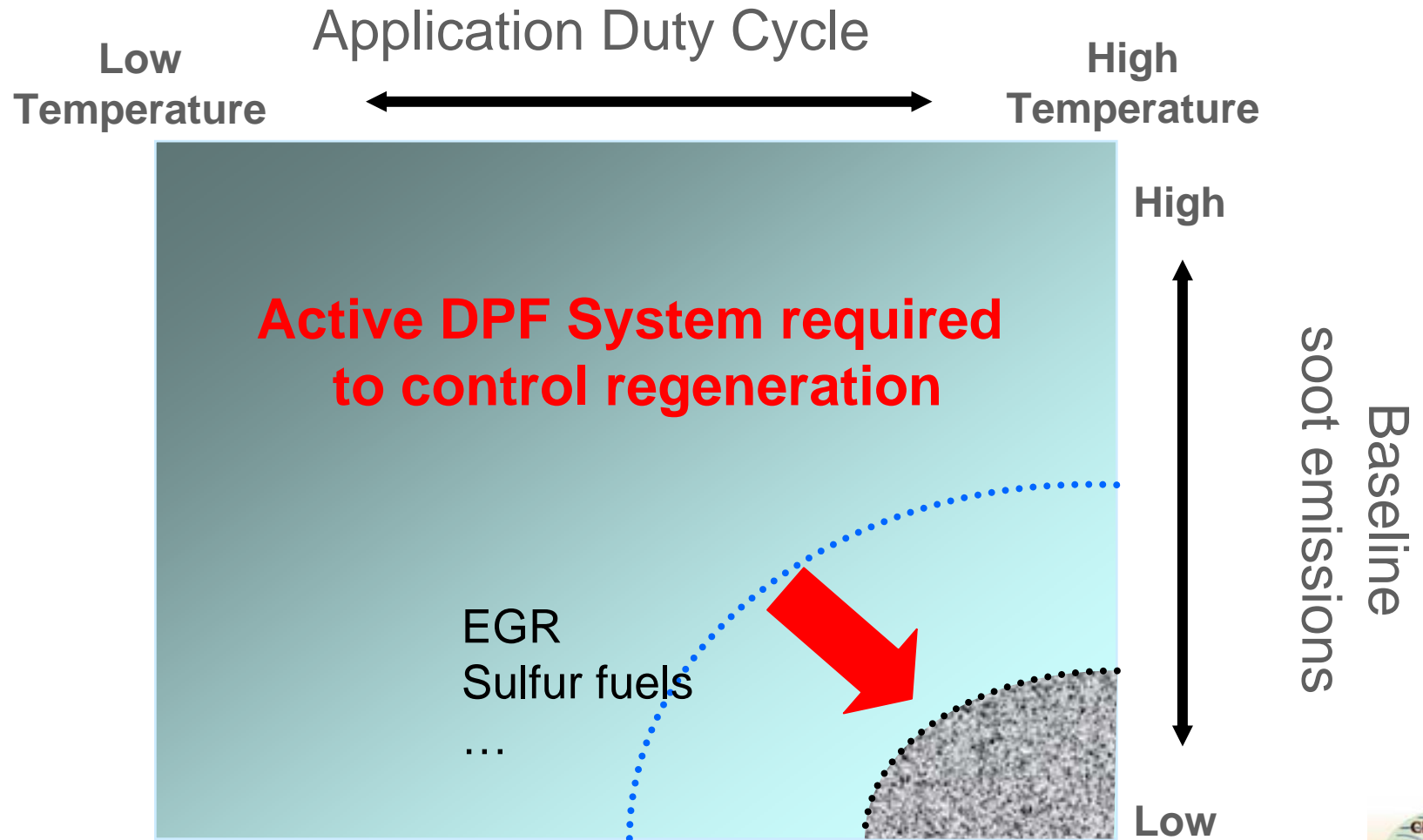
Light-Duty and Urban Transit Bus

Conclusions

Which DPF System for which Application



Reliable and Robust Design for the Application



Key parameters for DPF applications

- Efficiency: PM and secondary emissions (NO_2)
- Flexibility: driving cycle, fuels quality...
- Reliability: to guaranty complete DPF regeneration whatever the driving conditions
- Robustness and Durability
- Vehicle integrations: cost, maintenance, volume...
- Cost OEM/Retrofit equipments
- Operation costs , maintenance constraints...



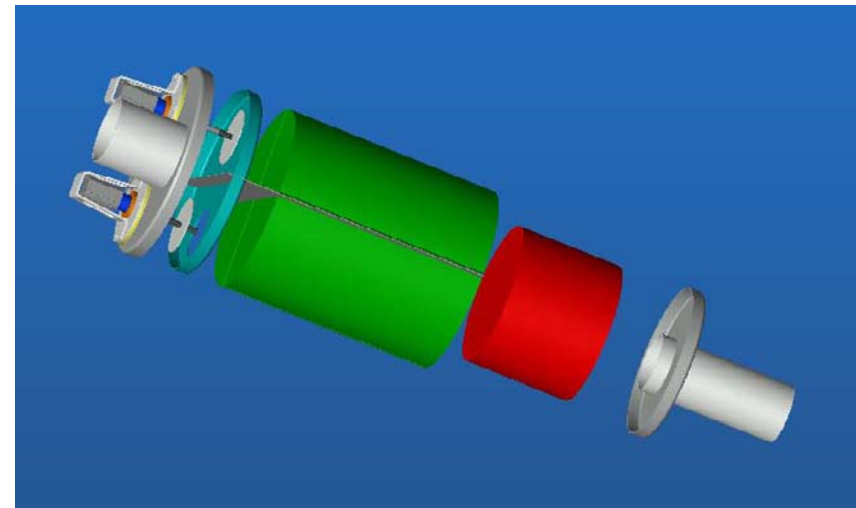
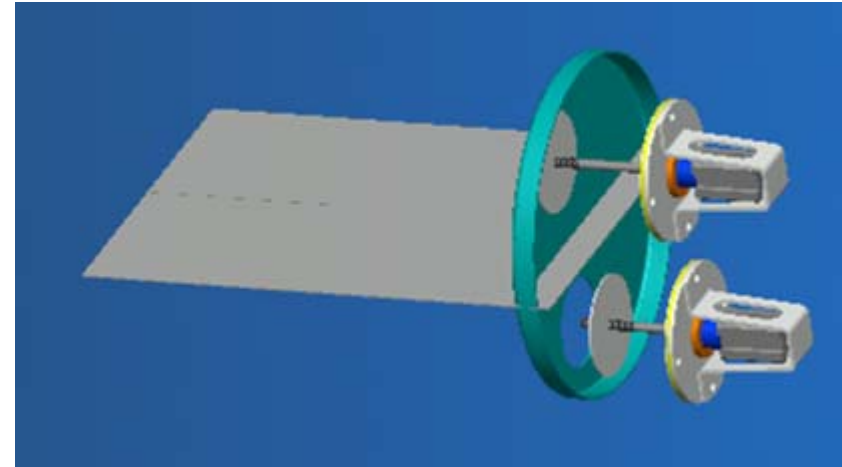
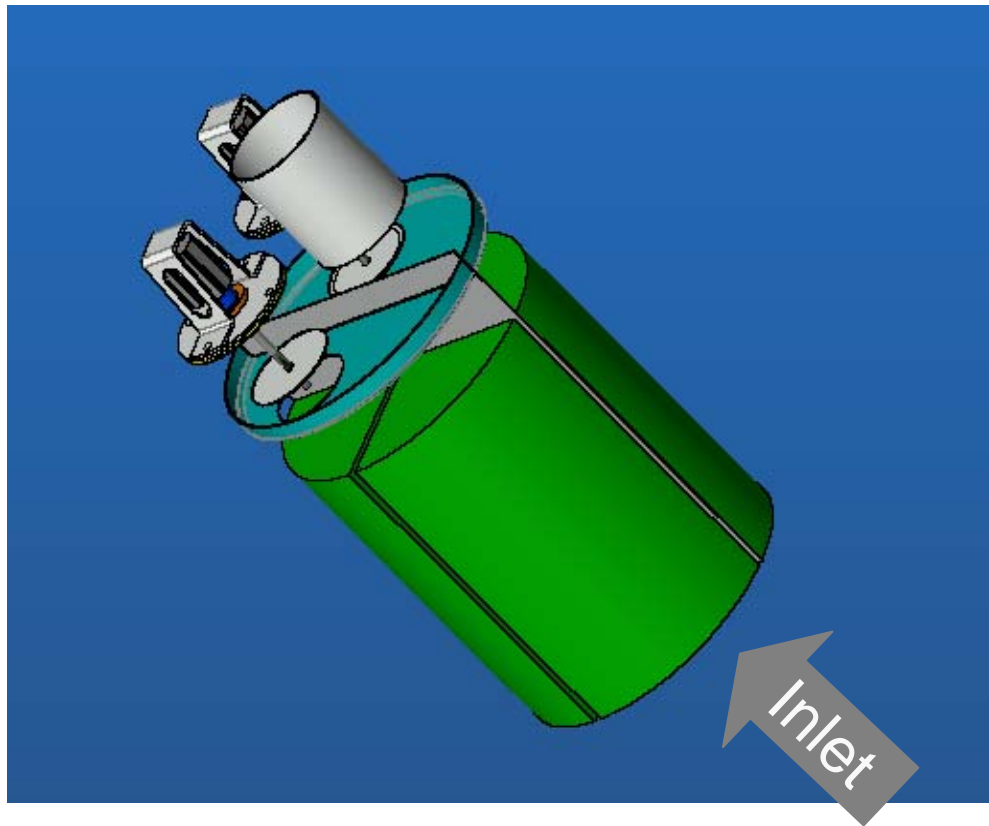
Strategy of the New Active Filter System

- To control filter regeneration, a new Active DPF System was developed, to ensure fully controlled filter regenerations.
- ExoClean™ is based on two main principles:
 - adapted volume of filtration (Exhaust Valve Control System)
 - global thermal management:
 - *thermal insulation*
 - *heat injection in front of the filter*
- The DPF System is applicable to the opacity number $<2.5\text{m}^{-1}$: EURO 1-3 vehicles and some EURO 0
- High flexibility with fuel sulfur content

ExoClean



Principle of Exhaust Valve Control System (EVCS)

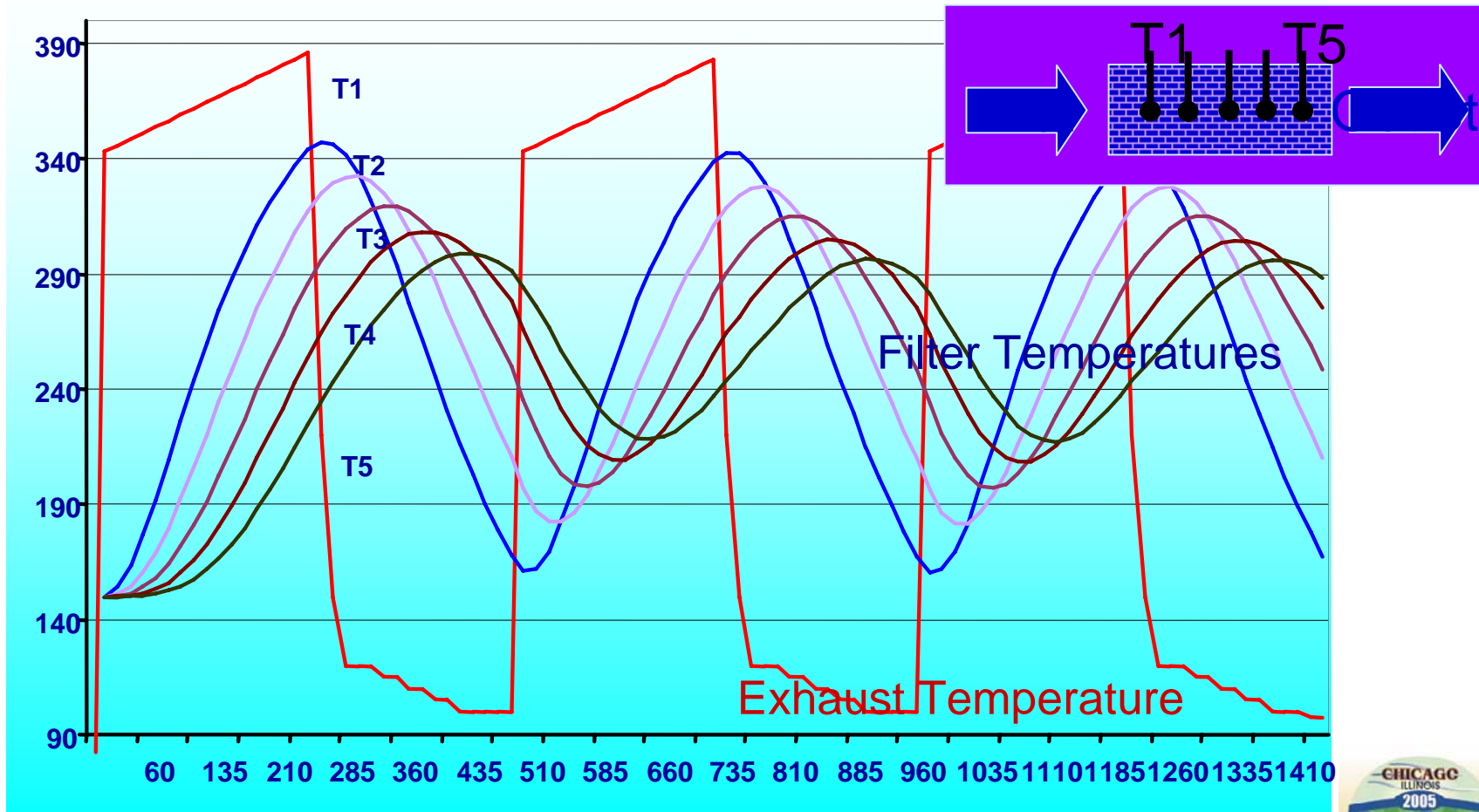


Typical thermal profile of DPF w/o EVCS

Cycle simulating the Refuse Trucks Driving and Collection Phases

Full
Load

Idle

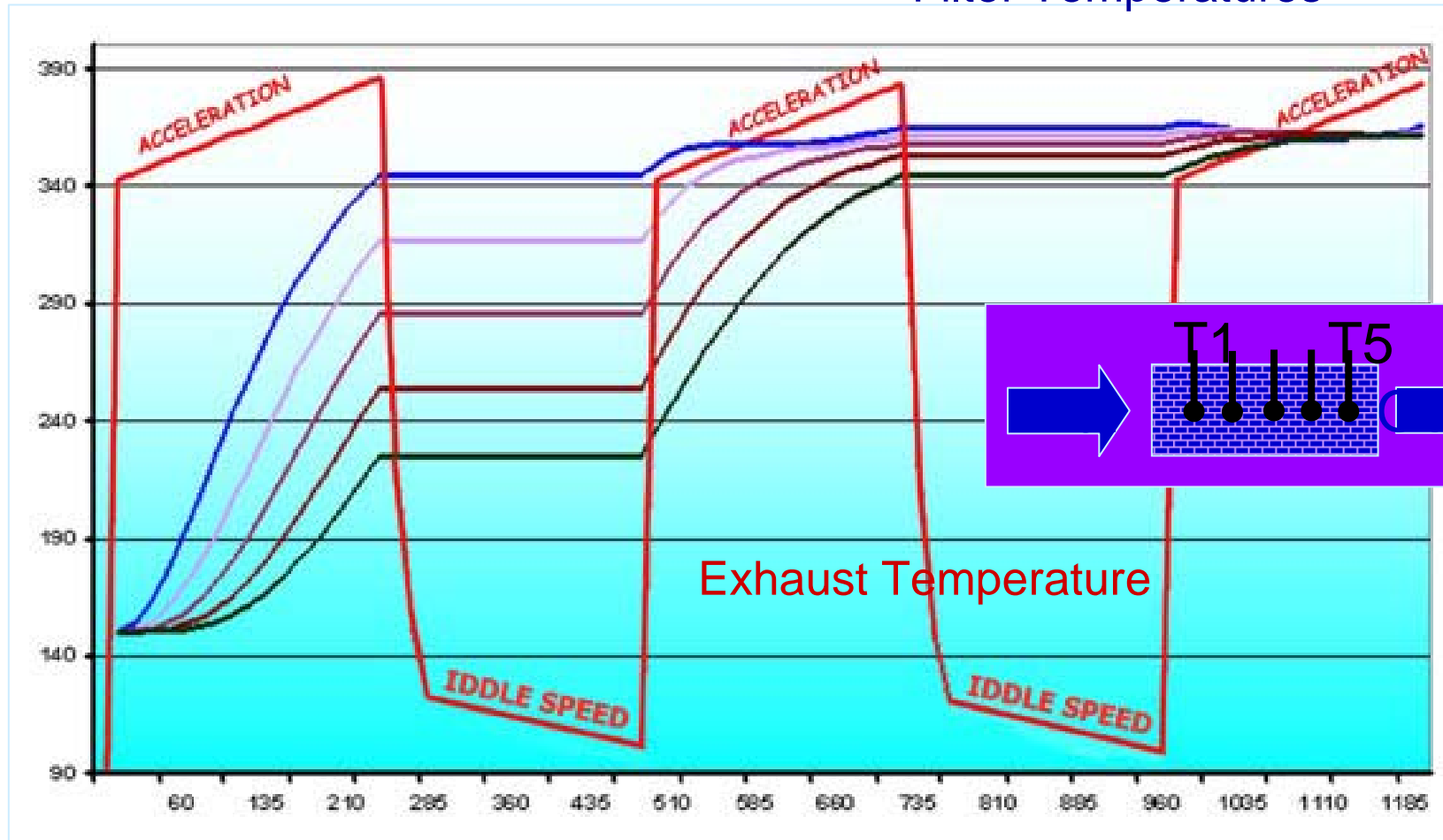


The EVCS Effect on the Filter Thermal Profile

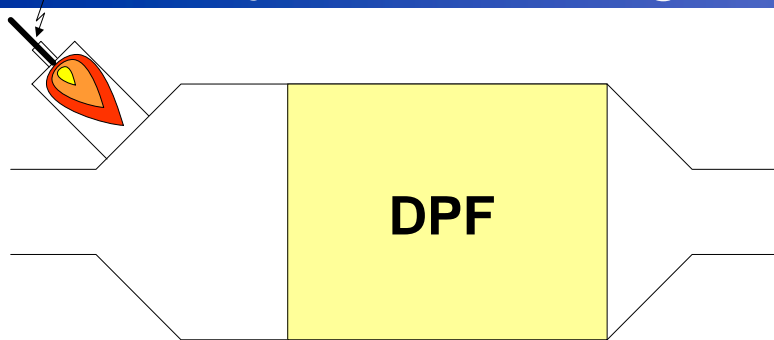
Full
Load

Idle

Filter Temperatures

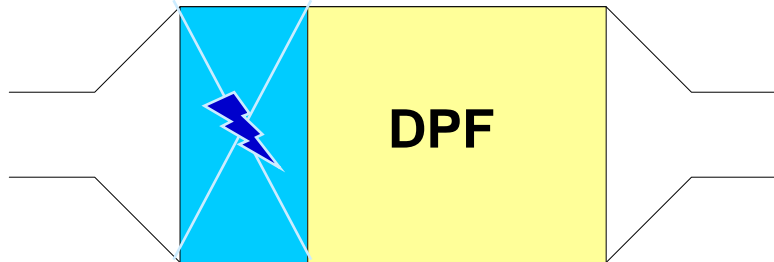


Heat Injection Management vs. Market Segment



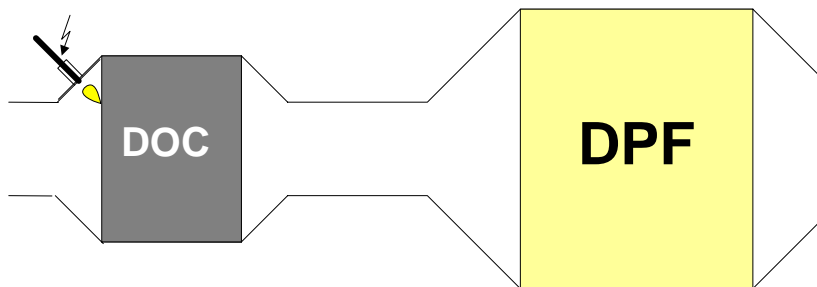
**Fuel
Burner**

**Off-Road,
Construction Machines
Stationary Applications**



**Electrical
Heater**

**Off-Road,
Construction Machines
Stationary Applications
Mobile Applications
(Retrofit)**



**Catalytic
Fuel
Combustion**

**Off-Road,
Construction Machines
Mobile Applications
(OEM, Retrofit)**

Description of ExoClean™ (w/ EPFI)

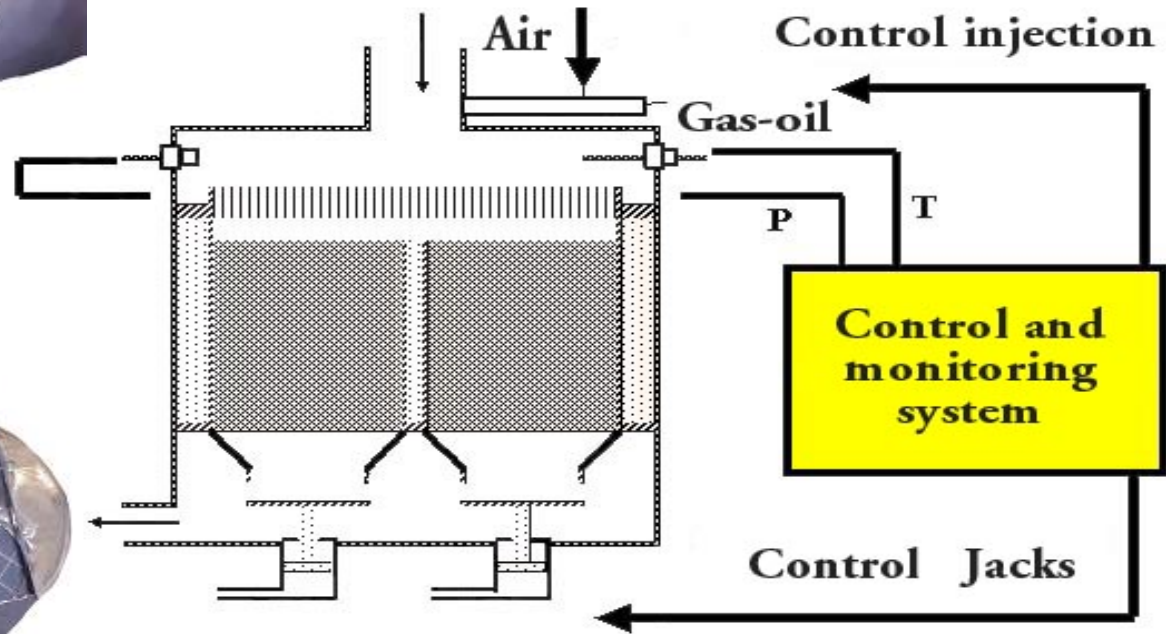


**Diesel Oxidation Catalyst
For Catalytic Fuel Combustion**



Injector System

**Filter
packaging**

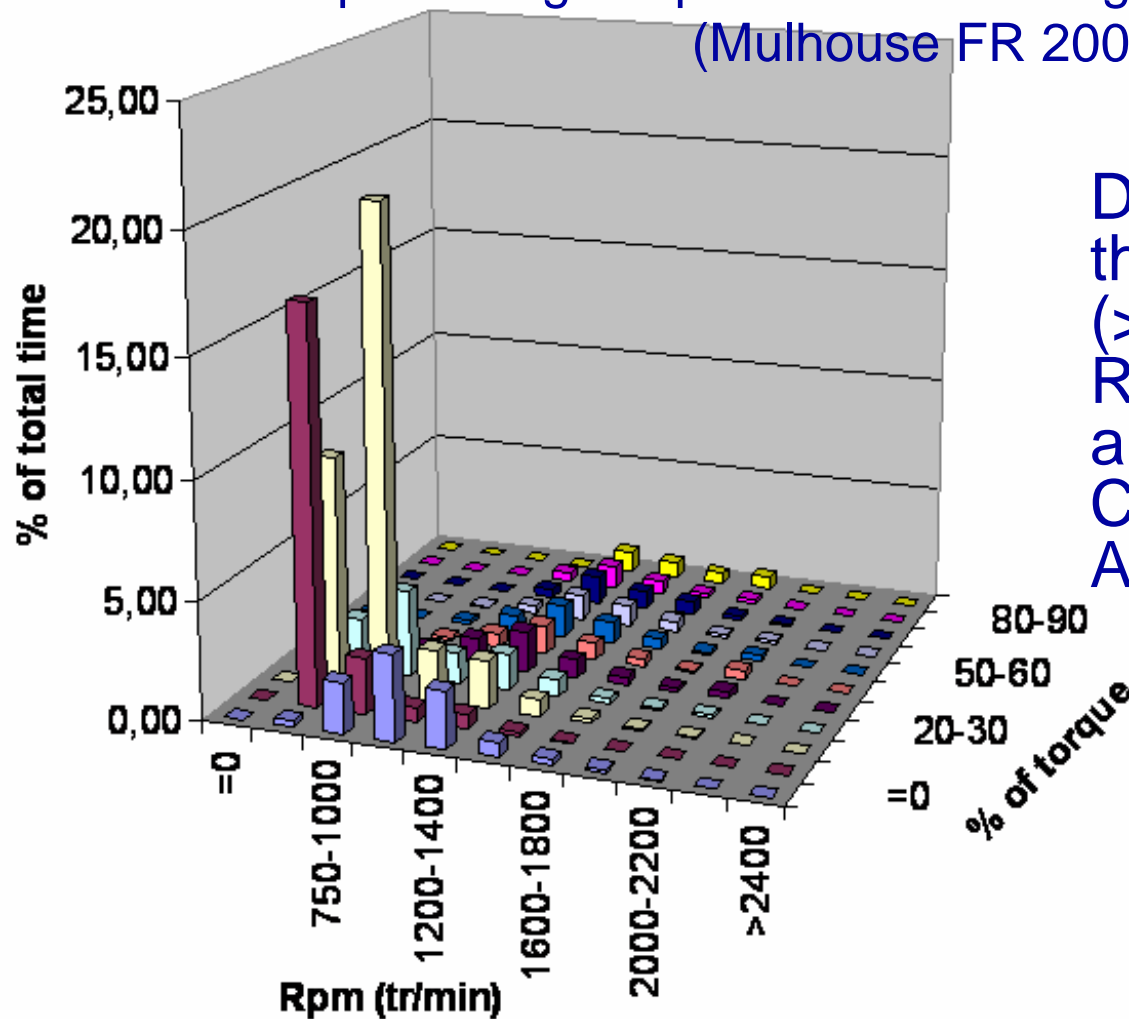


Exhaust Valve Control System



But severity of Refuse Trucks application...

Example of engine rpm and load during Refuse Truck haulage
(Mulhouse FR 2005)



Due to the constrain of this "Stop & Go" cycle (> 80% of time), Renault Trucks selected and developed with COMELA supplier a new Active DPF system :

ExoClean

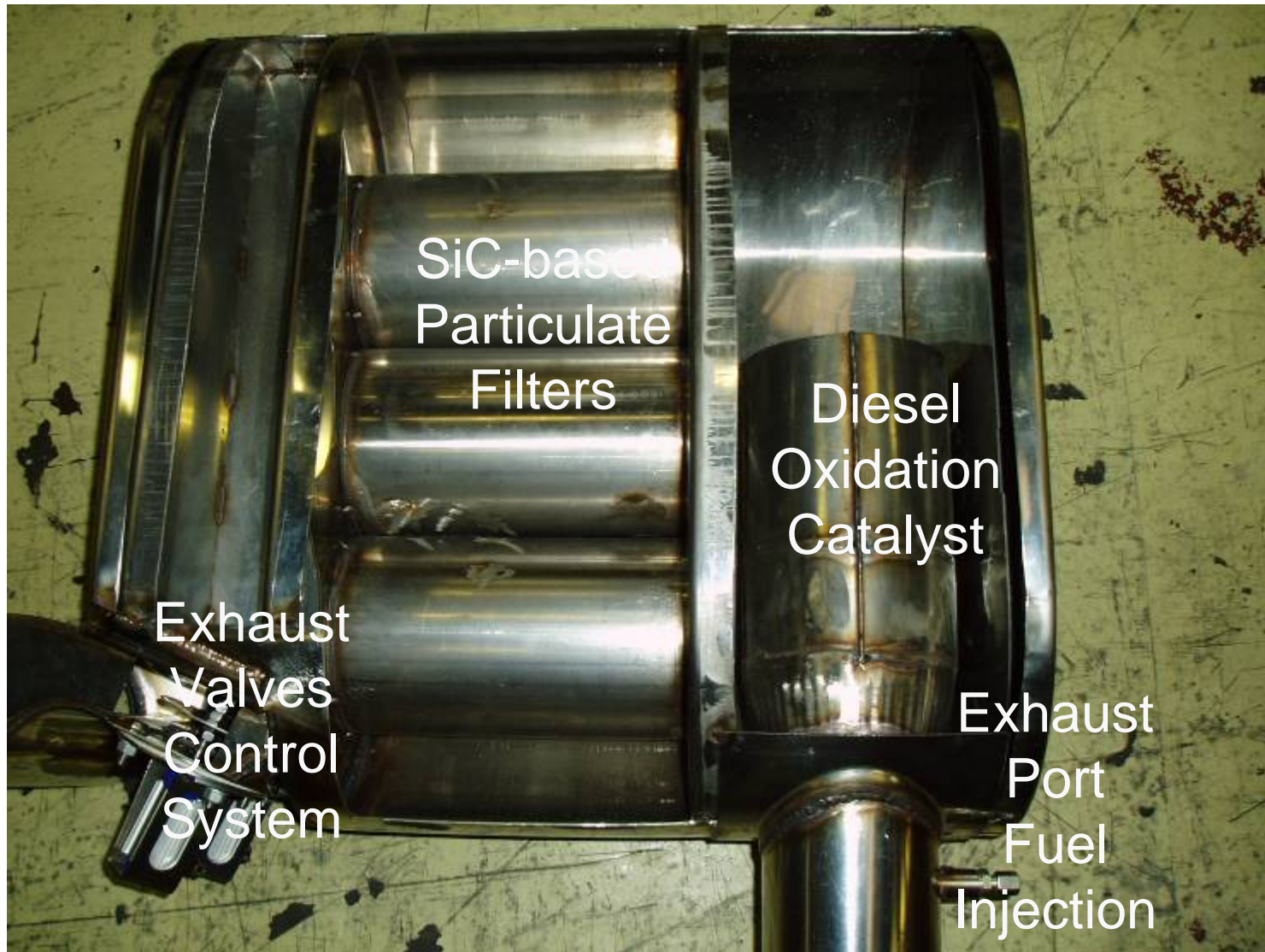
OEM Refuse Trucks Applications (“Stop & Go”)

Offered as option with EURO III calibration, with Premium DCI 11 320 engine:

- 11 liter engine displacement
- Max. power : 330 kW @ 1900 rpm
- Max. torque : 2130 Nm @ 1200 rpm
- Contains six SiC filter units (5.66"x10")
- Packaged within standard muffler volume



Open view of ExoClean™



Field Applications (Neuchatel - CH)

Refuse Trucks Premium DCI 11 in NEUCHATEL

<50ppm of Sulfur

620 hours field operation

Temperature (°C)	Time %	Pressure (mbar)	Time %
< 200	87.8	< 148	99.1
200 - 250	5.4	148 - 248	0.7
250 - 300	3.6	248 - 348	0.2
300 - 330	1.3	348 - 400	0
330 - 400	1.5	400 - 500	0
> 400	0.5	>500	0

Refuse Trucks Retrofit Applications

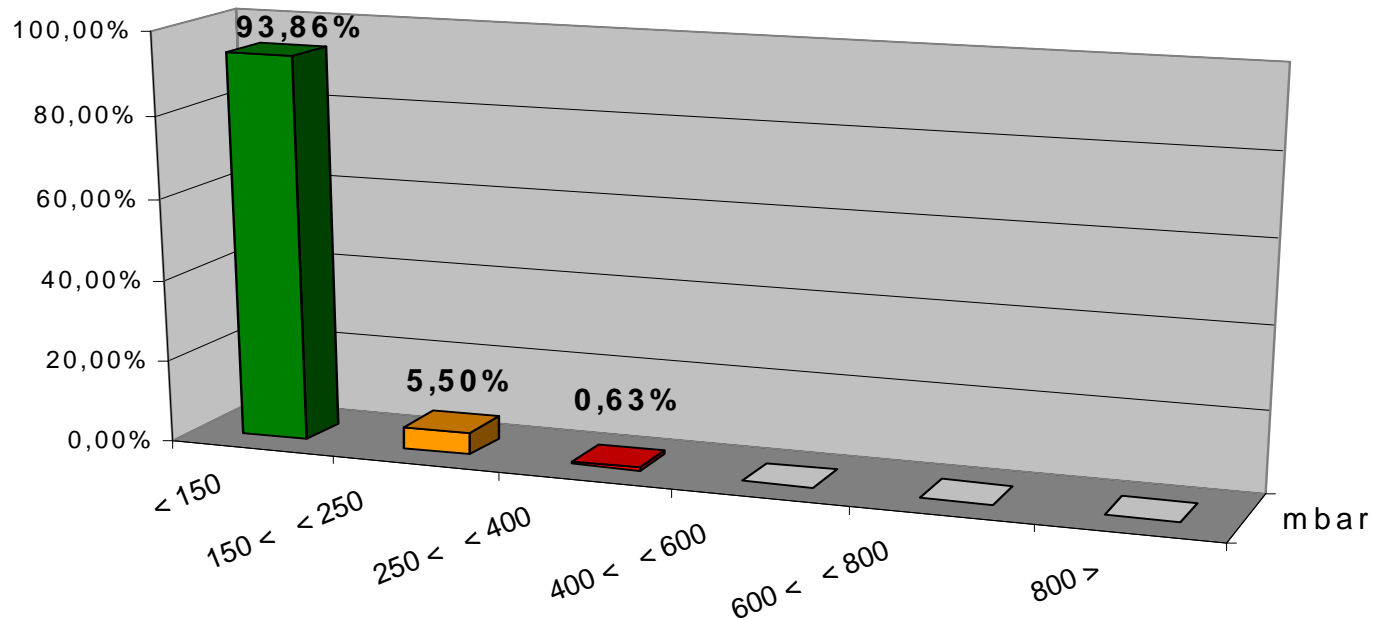
- Renault Trucks Premium MIDR 62045
- 9.84 liters engine displacement / 6 cyl. / DIS
- 20-tons Refuse Truck with EURO II calibration,
- fitted with 6 SiC filters units (20m² filtration area)
- placed in the existing muffler volume



Evaluation with Standard fuel (350ppm Sulfur) over a 12 months national program (2003)



Regular low back-pressure over field test



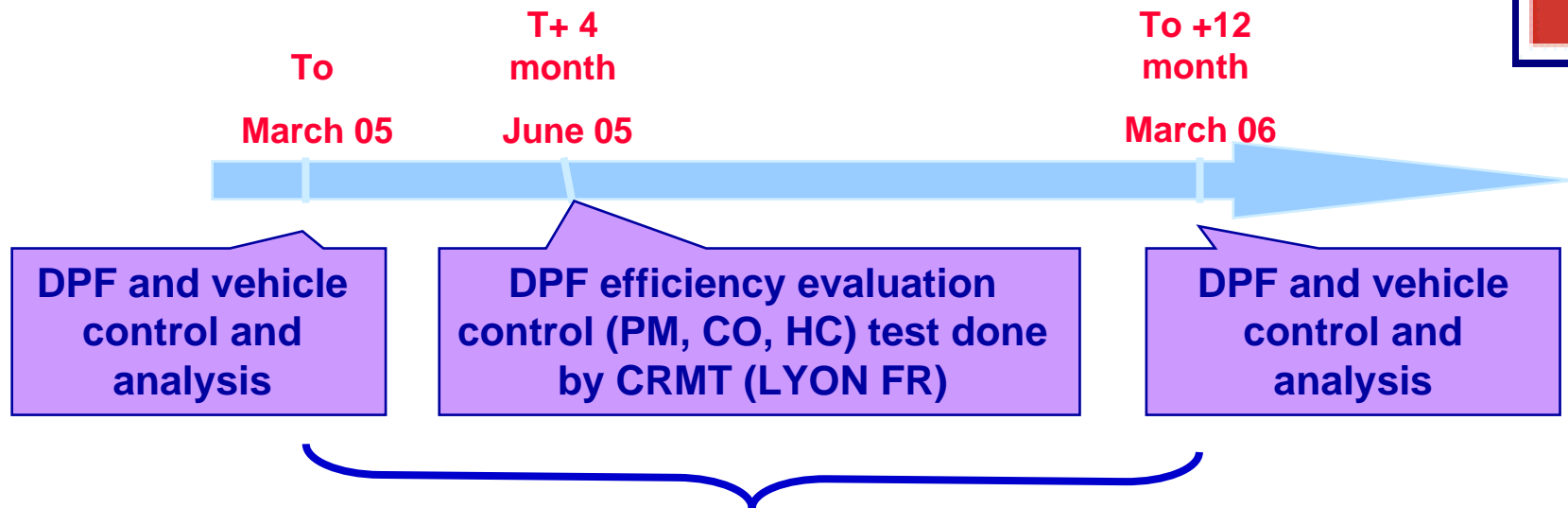
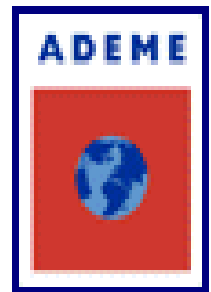
Backpressure is maintained lower than 150mbar over 94% of the 12 months field test (and under 350ppm sulfur)



Renault Trucks-ADEME evaluation

In progress: 1 year ADEME program of EXOCLEAN™ system evaluation on EURO III Premium Refuse Trucks (6L and 11L)

- ✓ 6 vehicles equipped with ExoClean™
- ✓ Financial support by ADEME



1 year EXOCLEAN and vehicle performance evaluation:

temperature, DPF pressure, Fuel consumption, default, DPF injector control,...

Renault Trucks-ADEME evaluation

After 4 month of evaluation (June 2005)

- ✓ Back pressure maintained lower than 200 mbars over 99% of time
- ✓ Impact on fuel consumption lower than 2%
- ✓ Test done by CRMT (Lyon) showed :
 - ✓ No impact of ExoClean™ on Engine max torque and power
 - ✓ PM measurement done by opacimeter full flow and μ -dilution tunnel showed soot (dry) emission at 0 mg/m³ and VOF emission around 1 mg/m³
 - ✓ Very high catalyst efficiency on CO and HC (< 5 ppm)
 - ✓ No impact on NO_x emission
 - ✓ No impact on CO₂ emission
- ✓ DPF Exoclean Volvo solution for Refuse Truck application showed high efficiency and reliability on very severe condition.



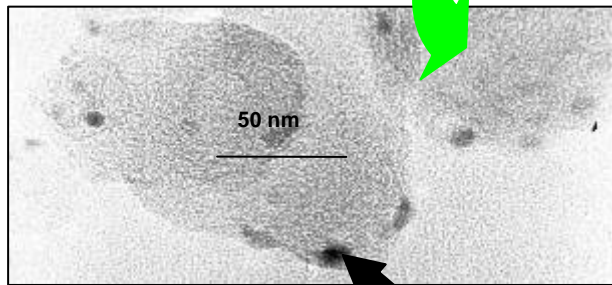
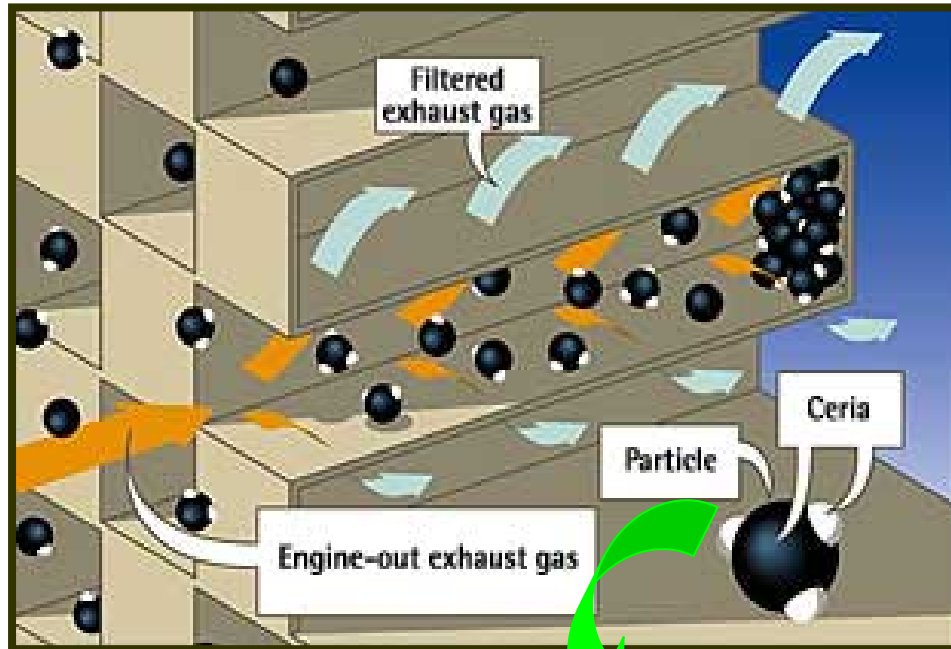
Global Improvement of ExoClean

To improve performance, extend the market segments, reduce global cost, better vehicle integration and limited maintenance...

- Combination with Fuel-Borne Catalyst and Automatic On-Board Dosing System
- New Filter Design and Materials
- Downsizing of the DPF System to target the LDV, SUV and Sedan vehicles
- Packaging / chassis integration: cylindrical shapes, modules
- Combination with NOx reduction approaches
 - y Water-based Fuel emulsion
 - y SCR-based technologies
 - y EGR technologies



Fuel-Borne Catalyst to facilitate soot combustion

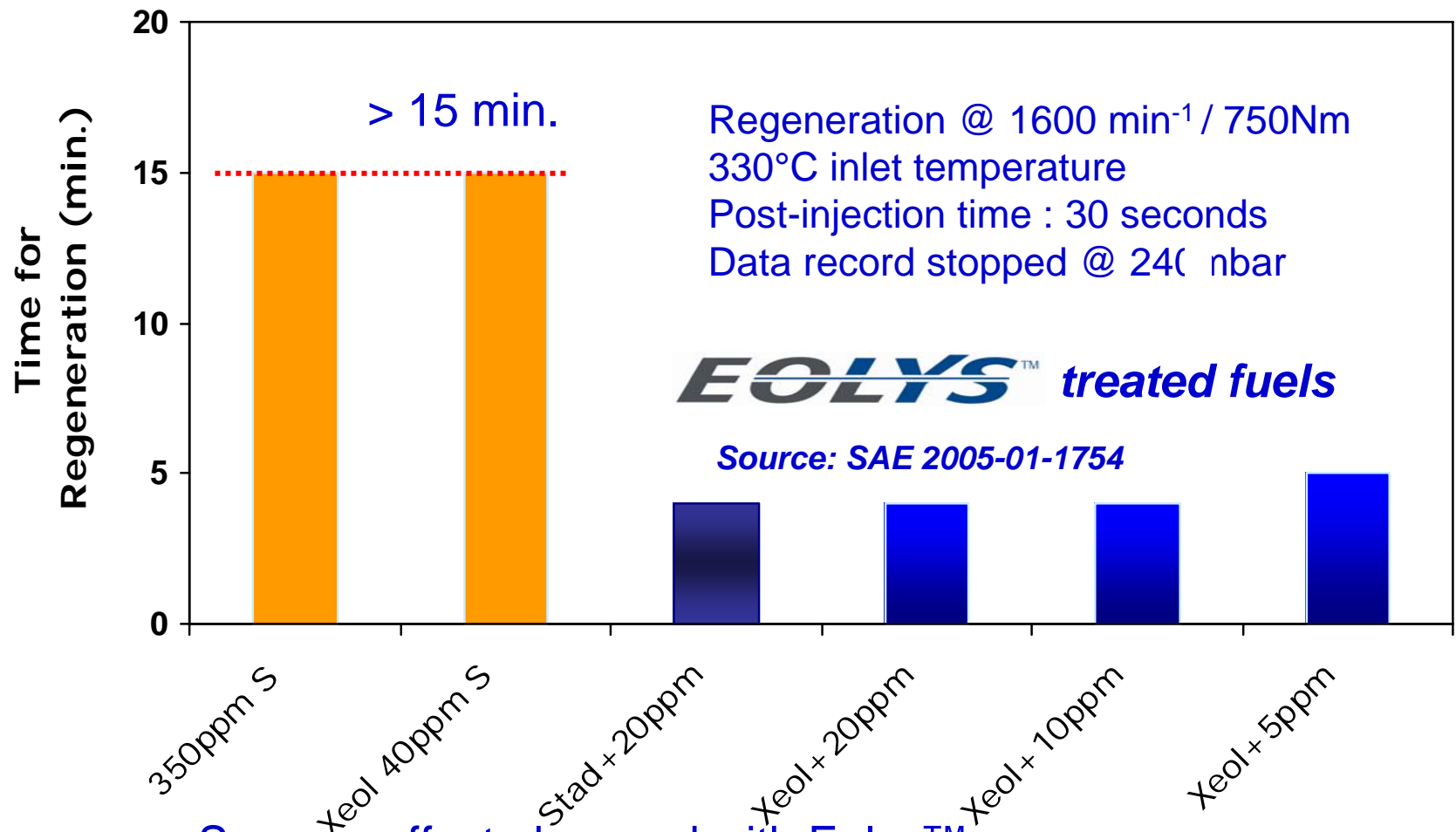


FBC

- To lower the temperature of soot ignition, decreasing thus the engine stress (oil dilution...)
- To allow a fast regeneration, whatever the driving cycle
- To favor the diffusion of the combustion process to the entire soot layer, due to multiple contact points, avoiding thus pyrolytic carbon formation
- To supply in a continuous way a fresh nano-crystal catalyst, insensitive to sulfur poisoning
- To limit secondary emissions (NO₂/NO_x ratio.)

Source:
Rhodia Electronics & Catalysis

Eolys™: fast and complete DPF regeneration

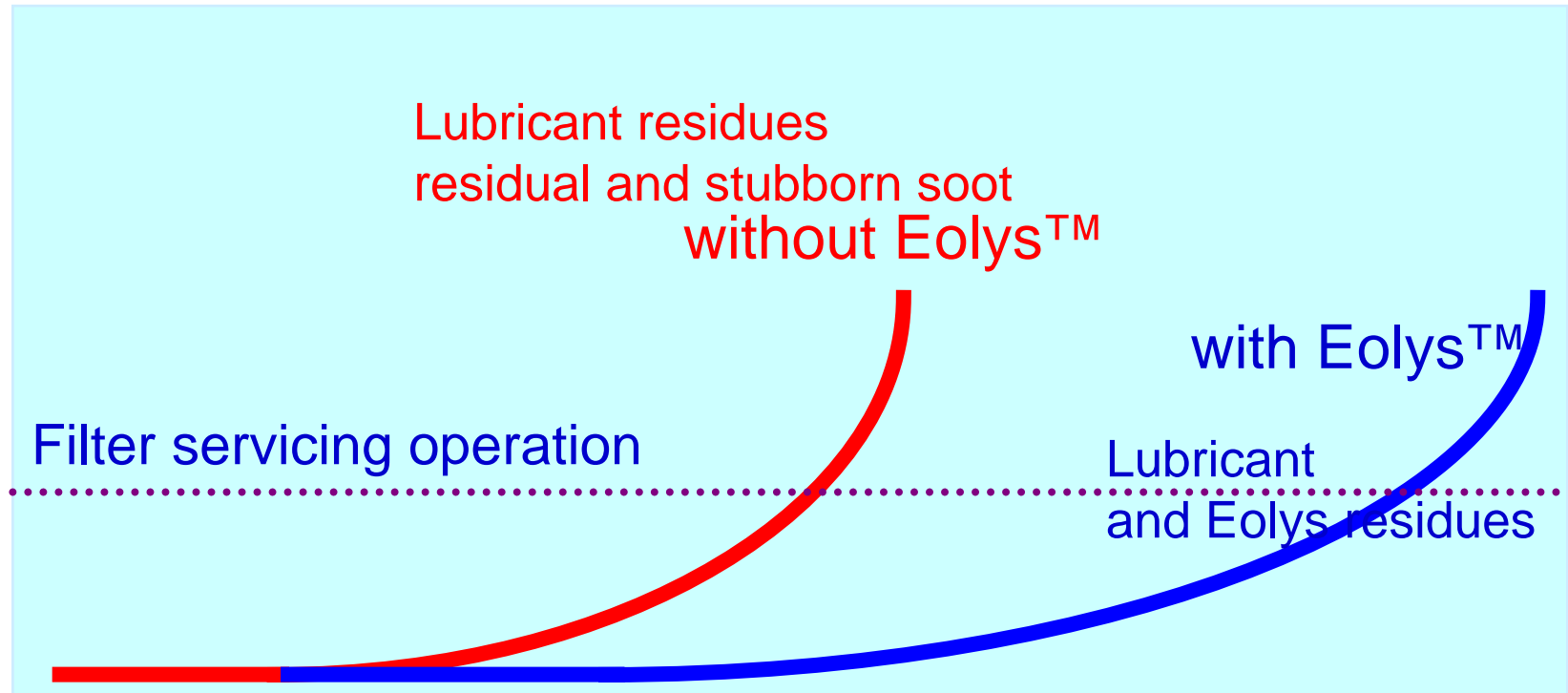


Synergy effect observed with Eolys™,
with reduction of the recommended dosing rate
for complete and fast DPF regeneration

Eolys™ reduces filter servicing

Residual Back-Pressure Evolution (after DPF Regeneration)

Back-pressure evolution



Vehicle operation time

Source: SAE 2005-01-1754

Synergy effect with Eolys™

The dosing rate of Eolys™ is reduced to 10-7ppm, with:

- reduction of the DPF soot loading
- limit the filter maintenance

	w/o EOLYS™	w/ EOLYS™
<i>Maintenance frequency (Euro II)</i>	70-140,000 km 12-18 months	> 150,000 km > 24 months

Flexibility with Sulfur fuel level: Standard (350ppmS), Xeol™(40ppmS), GECAM™ (water emulsion, 30ppmS)

VERT Filter Test Verification: done

VERT Filter Test Verification

3 SiC filter units (= 12.45 liters)

Catalytic Fuel Combustion (= 3.2 liters)
(Pt loading: 1.77g/liter)

Eolys™ DPX10 @ 10ppm

Diesel fuel: < 10ppm Sulfur



PZAG (%) counts 20 – 300 nm

VFT1 : 99.731% VFT3 : 98.845% (after 2000 hour)

**ExoClean™ passed the VERT Filter Tests
and is listed in the VERT Filter List (March 2005)**

Light-Duty Urban Buses Retrofit Applications

Public Transportation Fleet in CASTRES
with Mercedes-Benz Sprinter (6 tons)

Commercial standard fuel (350ppm of Sulfur)

1900 to 2000 hours field operation:
average speed of 9.2 km/h

Eolys-DPX10 target: 10ppm
and measured: 7 to 19ppm



Field Experience (Castre - FR)



Commercial standard fuel (350ppm of Sulfur)
1900 to 2000 hours field operation (fleet)
(average speed 9.2 km/h)

Temperature (°C)	Time %	Pressure (mbar)	Time %
< 200	97.25	< 100	95.76
200 - 250	1.64	100 - 148	3.56
250 - 340	0.90	148 - 300	0.68
340 - 400	0.17	300 - 400	0.00
400 - 450	0.04	400 - 500	0.00
> 450	0.01	> 500	0.00

Urban Transit Bus (Mexico – 500ppm Sulfur)



Mercedes Benz
10 tons – 40 passengers
Medium Duty
2003 model year
OM-906-LA Engine
6 liters engine displacement
280hp @ 2300rpm



ExoClean « 4 cartridges » design
Eolys DPX10 (Ce/Fe) @ 25ppm dosing rate

Mexico Field Experience (Urban Transit Bus)

Installation in May 2005

> 3 months in field operation under 500ppm of Sulfur

Temperature (°C)	Time %	Pressure (mbar)	Time %
< 200	57.28	< 48	77.95
200 – 260	13.55	48 – 100	14.46
260 – 300	8.28	100 – 200	7.42
300 – 340	6.87	200 – 300	0.16
340 – 400	7.59	300 – 400	0.01
> 400	6.42	> 400	0.00

Delivery Trucks (Mexico City - 500ppm Sulfur)

Mercedes Benz
Medium Duty Truck
1995 model year
OMC 366-LA EPA 94 certification
7 liters engine displacement
190hp @ 2300rpm



Mexico Field Experience (Delivery Truck)

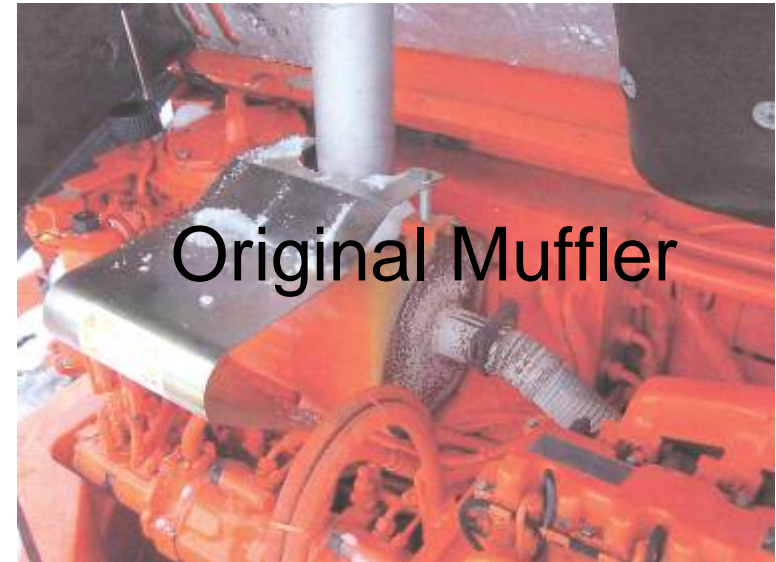
Installation in May 2005

3 months + field operation under 500ppm of Sulfur

Temperature (°C)	Time %	Pressure (mbar)	Time %
< 200	97.39	< 48	57.35
200 – 260	1.34	48 – 100	23.41
260 – 300	0.54	100 – 200	10.03
300 – 340	0.34	200 – 300	3.60
340 – 400	0.23	300 – 400	1.74
> 400	0.16	> 400	3.86

Back-pressure is too high and ExoClean Filter System parameters need adjustments

Example of work machine (mechanical digger)



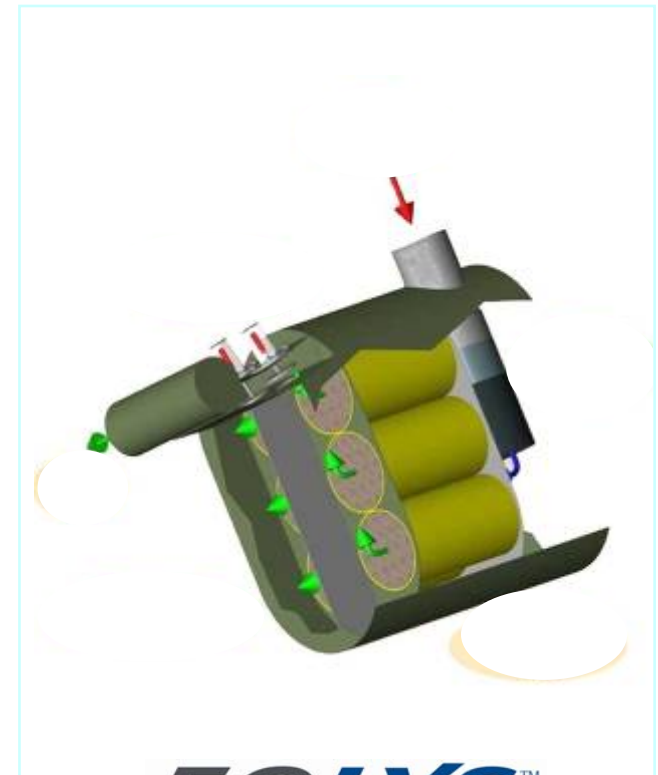
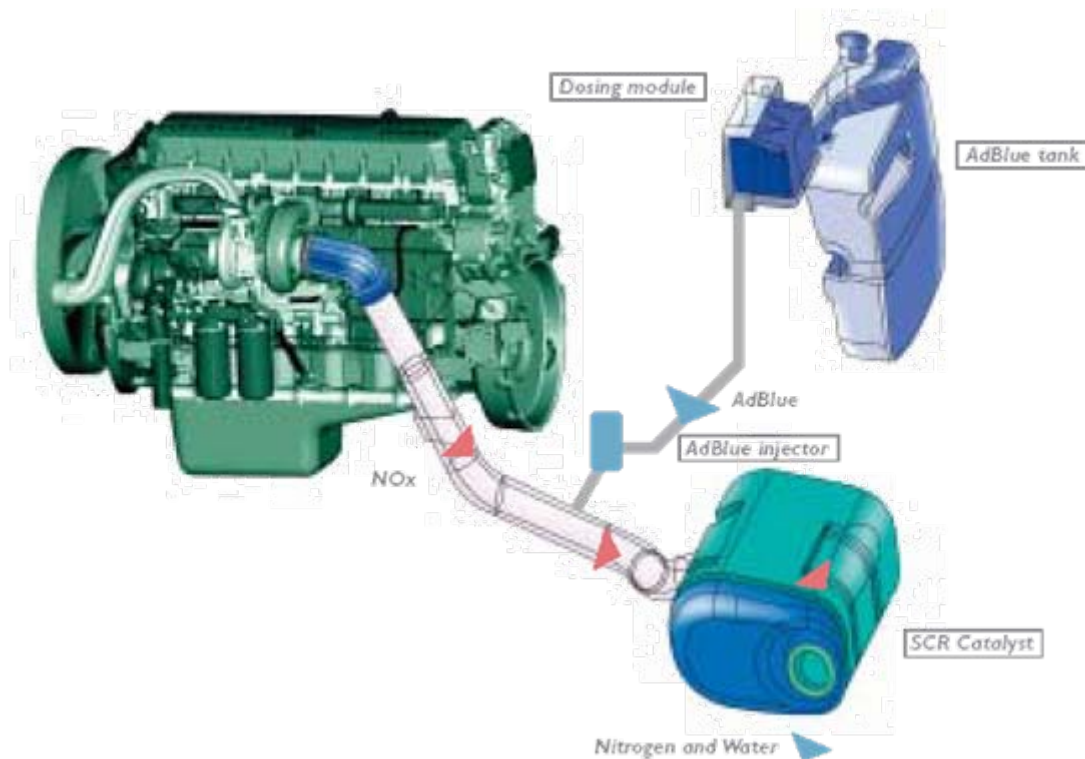
8 cartridge units design (dumper)



Example of work machine (grading machine)



ExoClean™ and Eolys™ will help the future LDV/HDV challenges in standard limits



EOLYS™

ExoClean™

**EURO4/US'10/Tier2Bin5
SCR Technology**

+

Conclusions

A new Active DPF System was developed for the “Stop-&-Go” Duty Cycle Applications (Urban buses, Refuse and Delivery Trucks), based on:

- ➔ Adapted Surface of Filtration (Exhaust Valve Control System)
- ➔ Global Thermal Management, using Heat Injection in the Exhaust (Catalytic Combustion, Back-Pressure Management, Fuel-burner, etc...)

Efficiency, reliability, flexibility and durability of the filter system have been demonstrated in retrofit program and OEM certifications:

- ➔ High efficiency on the Particulate Matter abatement
- ➔ Reliability of the Active Filter Regeneration Strategy
- ➔ Flexibility with the Sulfur content in the Fuels



Conclusions (contd')

RENAULT Trucks is currently offering this active filter system as an option for the EURO 3 Premium DCI 11 320 Diesel engine (Refuse Trucks, Diesel-powered Cradles)

Synergy effects were observed in the association with the Eolys™ Fuel-Borne Catalyst: limitation of the filter service maintenance and flexibility;

Long term durability and efficiency demonstrated on the really challenging Light Duty Urban Bus Applications.

ExoClean has got the VERT Certification and Durability Verification;

Next steps: downsizing and new filter design and media, association with NOx control strategies to offer a complete NOx/PM/CO₂ solution for Retrofit and OEM applications



Acknowledgement

The authors would like to thank :

- ➔ The French EPA (the ADEME)
- ➔ COMELA
- ➔ RENAULT Trucks
- ➔ RHODIA
- ➔ VEOLIA Environment / CREED



for making available the detailed results, products, graphs and pictures.





Thank you very much
for your kind attention