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Strategies for Integrated Emission Control

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Abstract

- The preferred industry strategies for reducing vehicle emissions require reliable, fuel-efficient, cost-effective and durable performance. Active diesel particulate filter regeneration strategies used for new diesel vehicles have been central to meeting emissions performance standards. The range of field experience gained with vehicles in service has provided valuable insight into systems enhancements needed for the future. As diesel engine and vehicle manufacturers and suppliers work to achieve new levels of reliability in emission system performance and durability, this experience is being used to guide the design of next generation PM control as well as integration requirements with NOx reduction systems.

- In retrofit vehicle applications, low temperature operating regimes, exhaust temperature profiles and the condition of engines in extended service has limited the applicability of wall-flow ceramic diesel particulate filters. Older vehicles account for a high proportion of emissions to the atmosphere, and practical solutions providing the highest available emissions reductions are needed.

- A bimetallic platinum–cerium fuel borne catalyst (FBC) system used in conjunction with diesel particulate filters has been shown to deliver reliable performance in new vehicle and retrofit applications. The integration of FBC use into these DPF design strategies includes offering an extended operating temperature envelope for filters, reduced fuel consumption relative to alternative approaches, and substantially lower platinum group metal utilization, to minimize both cost and ongoing operating costs. The use of this fuel-borne catalyst system to solve field problems by providing reliable and continuous regeneration performance will be described. The mechanisms of action of the fuel-borne catalyst with a range of filter types and regeneration strategies will be provided, in addition to approaches for effective integration to achieve combined PM and NOx reduction.

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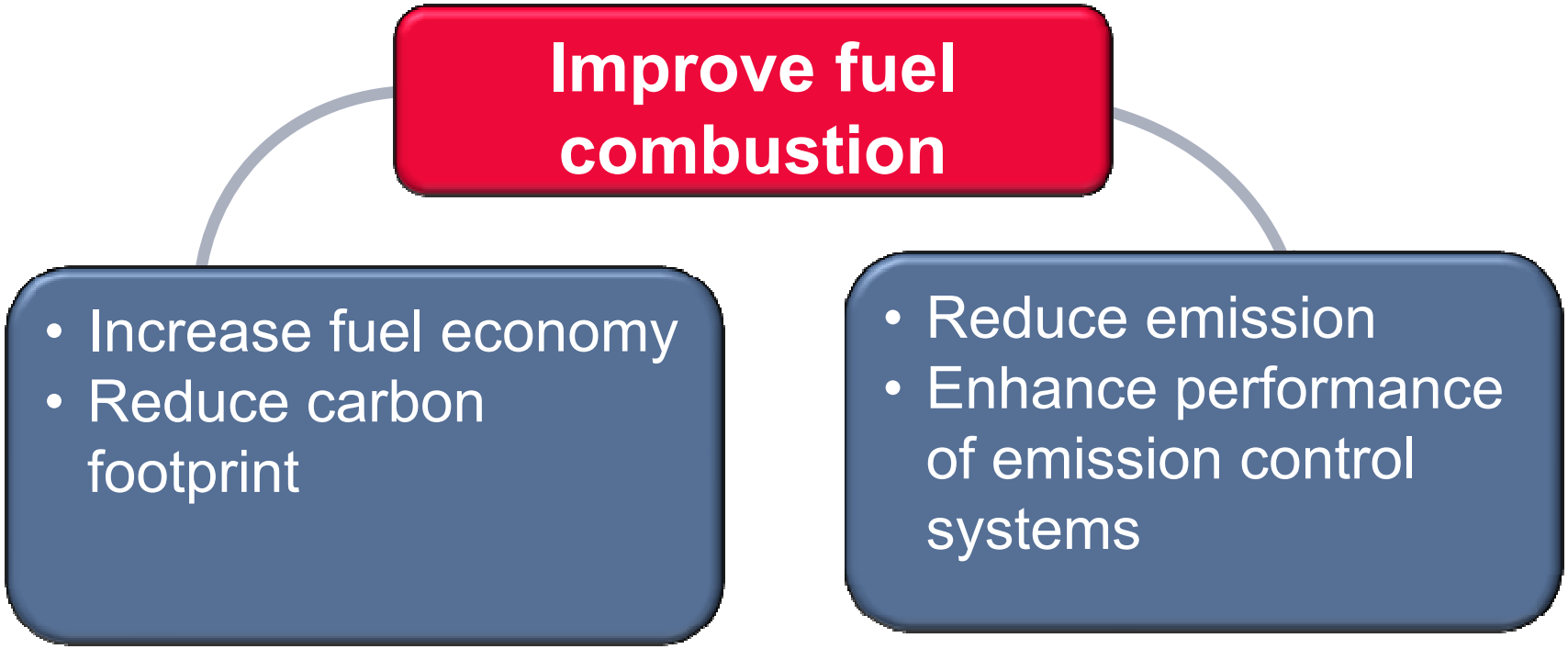
Platinum Plus fuel-borne catalysts



Unique combination of both in-cylinder and post-combustion catalytic effects

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The Platinum Plus catalyst difference

Catalysts are an essential part of any emission control strategy

Traditional catalyst:

- Single phase catalytic activity
  - ✓ Solid state
- Treats exhaust stream after leaving engine

Platinum Plus fuel-borne catalyst:

- Unique triple-phase catalytic activity
  - ✓ **Solid state**
  - ✓ **Liquid state**
  - ✓ **Gaseous state**
- Catalytic action begins in combustion chamber
- Continues through control device

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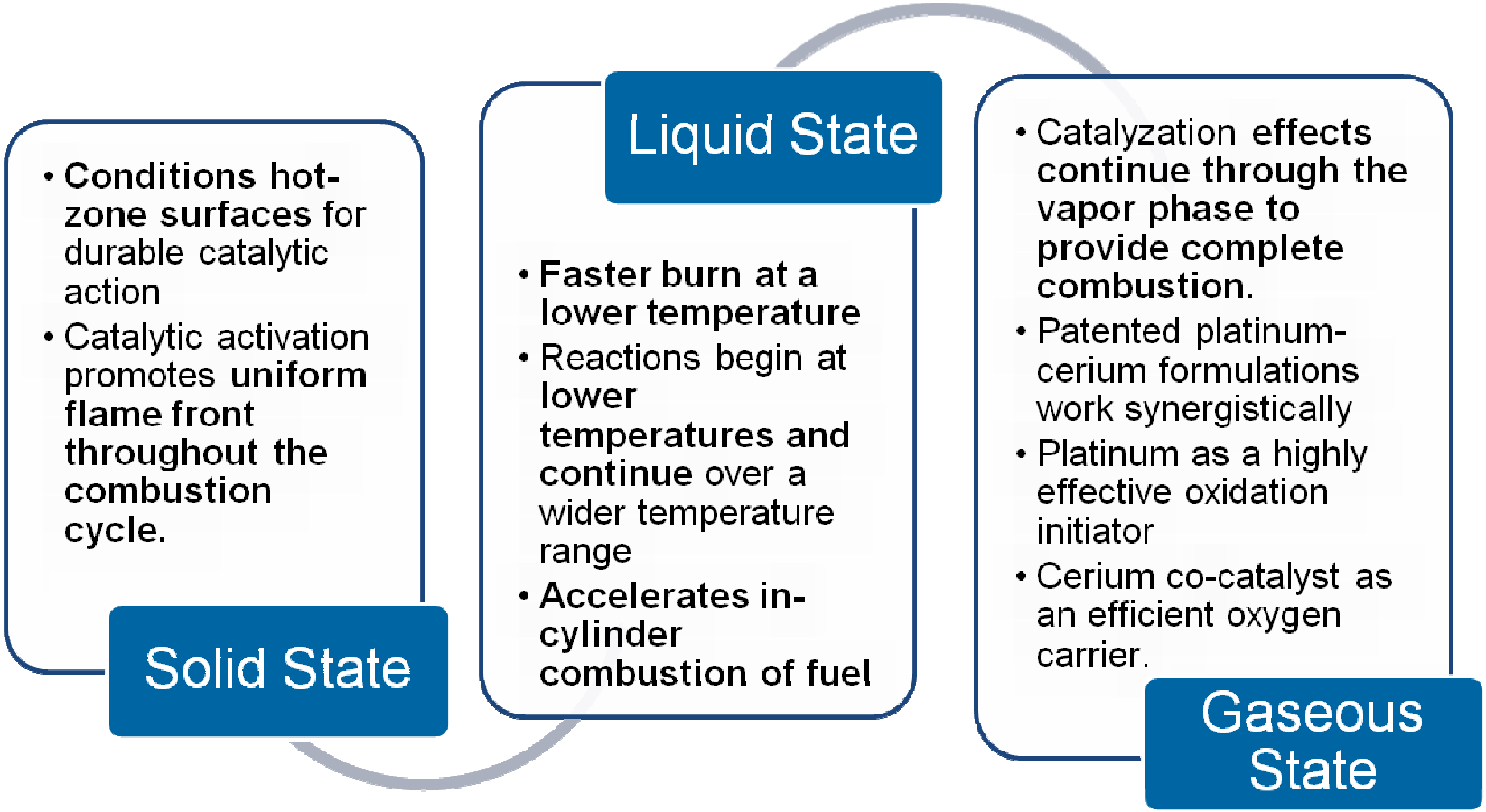
Unique three phase catalytic activity

Creating a new level of performance and emission control



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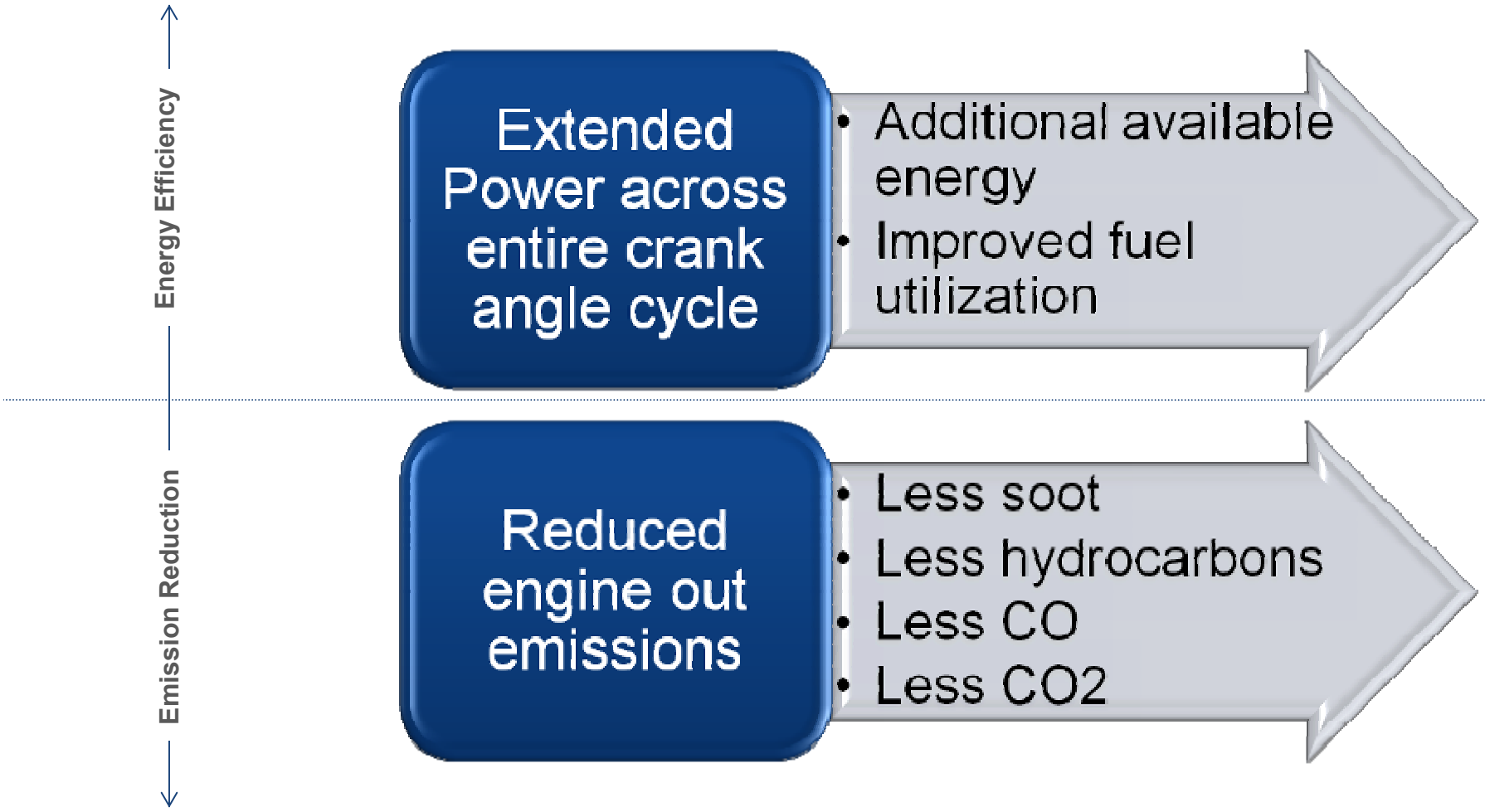
Net effects of enhanced in-cylinder catalytic combustion



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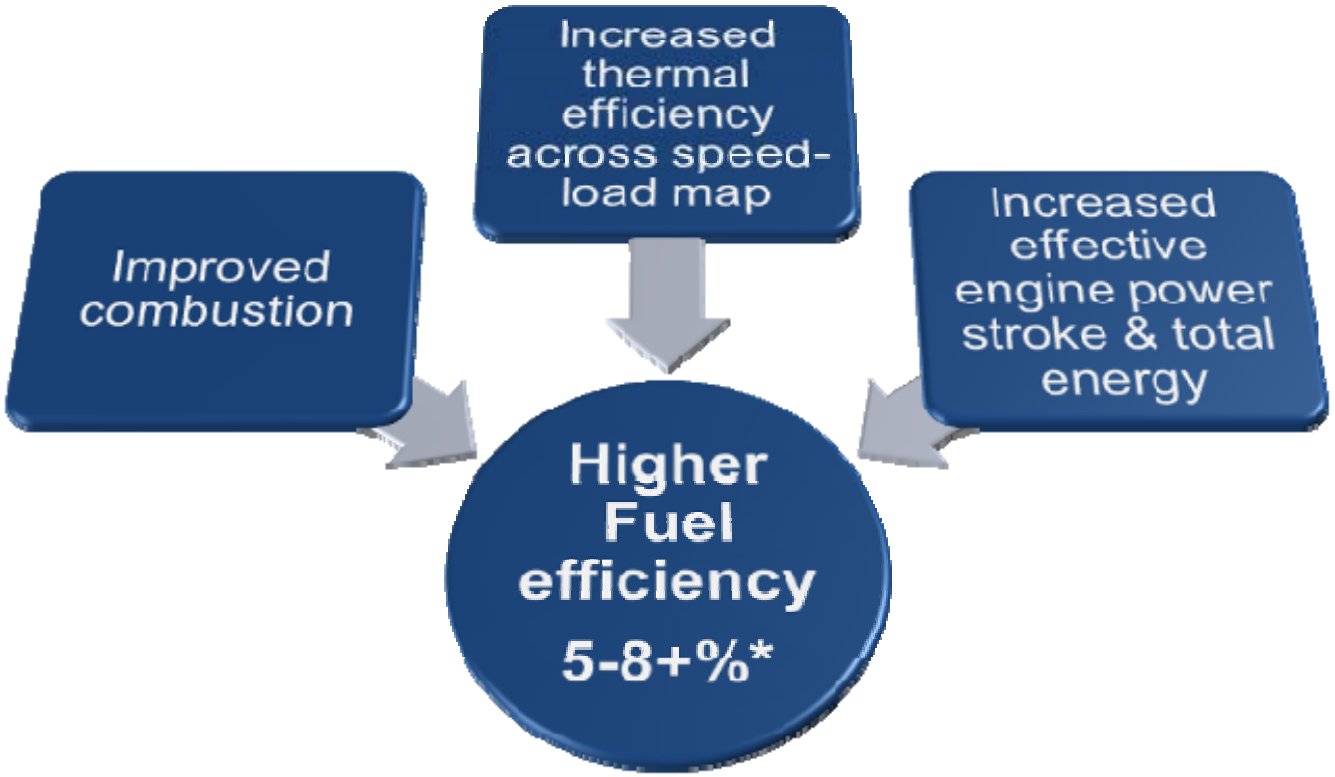
Fuel economy and carbon benefits



What does this mean for my fleet?

- $660,000 saving for each 3 million gallons diesel (at $4/gal diesel)

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Fuel efficiency: Engine dyno performance

- Engine type, manufacturer, test cycle, conditioning and fuel contribute to outcome

OEM Program
(1996 Cummins B Series)

MECA Program
(1998 DDC Series 60)

EPA Cert'd Lab Program
(1998 DDC Series 60)

EPA Cert'd Lab Program (B20)
(1991 DDC Series 60)

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Fuel efficiency: Field performance

Engine	Application	Fuel Economy Increase
Mack, Class 8	Long haul	9.5%
Mack, 350 HP	Waste (Front Loader)	7.3%
Cummins, ~200 HP	Waste (Container)	11.7%
International, ~195 HP	Waste (Recycle)	11.2%
International Class 7	Urban Beverage (TX) (pre-1994 engines)	16.2%
International Class 7	Urban Beverage (LA)	10.1%

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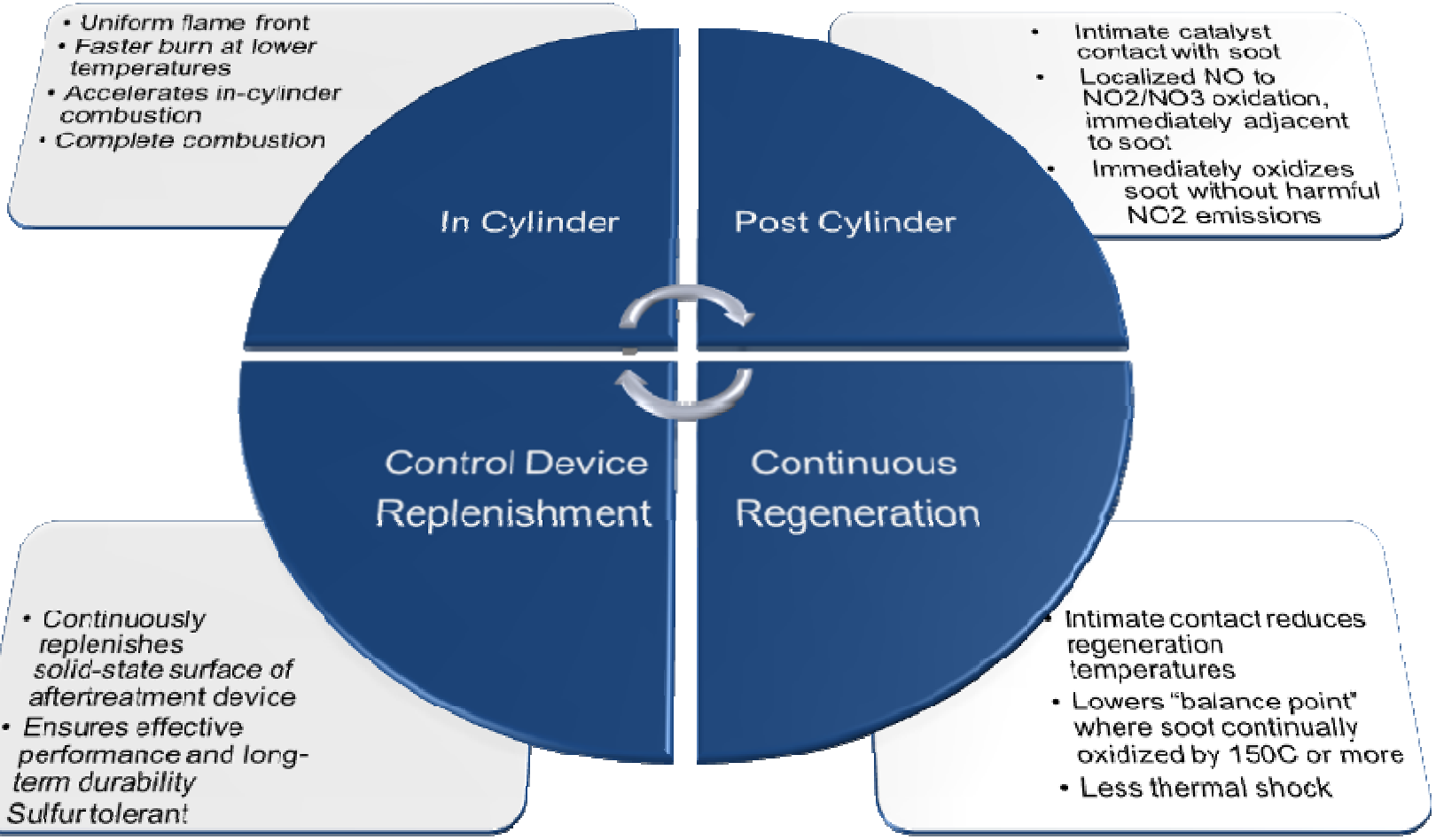
Complete emissions strategy

Platinum Plus multi-mode action



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Multi-mode emissions benefits

- Significantly **reduced levels of PM, HC, CO, NOx and CO2**
- **Long-term durability of filter systems** by replenishing catalytic activity of control devices
- Opportunity **to reduce the levels of precious metals** in control devices designed for the use with Platinum Plus
- **Continuous or passive regeneration** across a wider temperature range during exhaust temperature spikes
- Full regeneration in the most difficult of drive cycles - **widens range of DPF applications**
- Facilitates use of DPFs for variable fuel applications (high sulfur)
- Lower burn temperature **reduces the chance for hazardous run-away regeneration**
- **No harmful secondary emissions**, such as NO2.

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Platinum Plus: Balance points vs in-service regeneration

- 'Balance points' provide trendlines assuming continuous oxidation
  - Primarily applicable to fixed catalyst system comparisons
- The advantage of Pt-Ce FBC's is that they work by combined mechanisms of a critical ignition temperature controlled burn off & balance point
- Balance point comparisons do not take into account a main advantage of critical ignition temperature burn off with FBC at low NO_2 emission
- Other charts show the saw tooth nature of a DPF regeneration Pt Plus
- Unlike fixed catalyst systems, only short intervals of peak temperature are required to initiate Pt-Ce FBC-mediated regeneration

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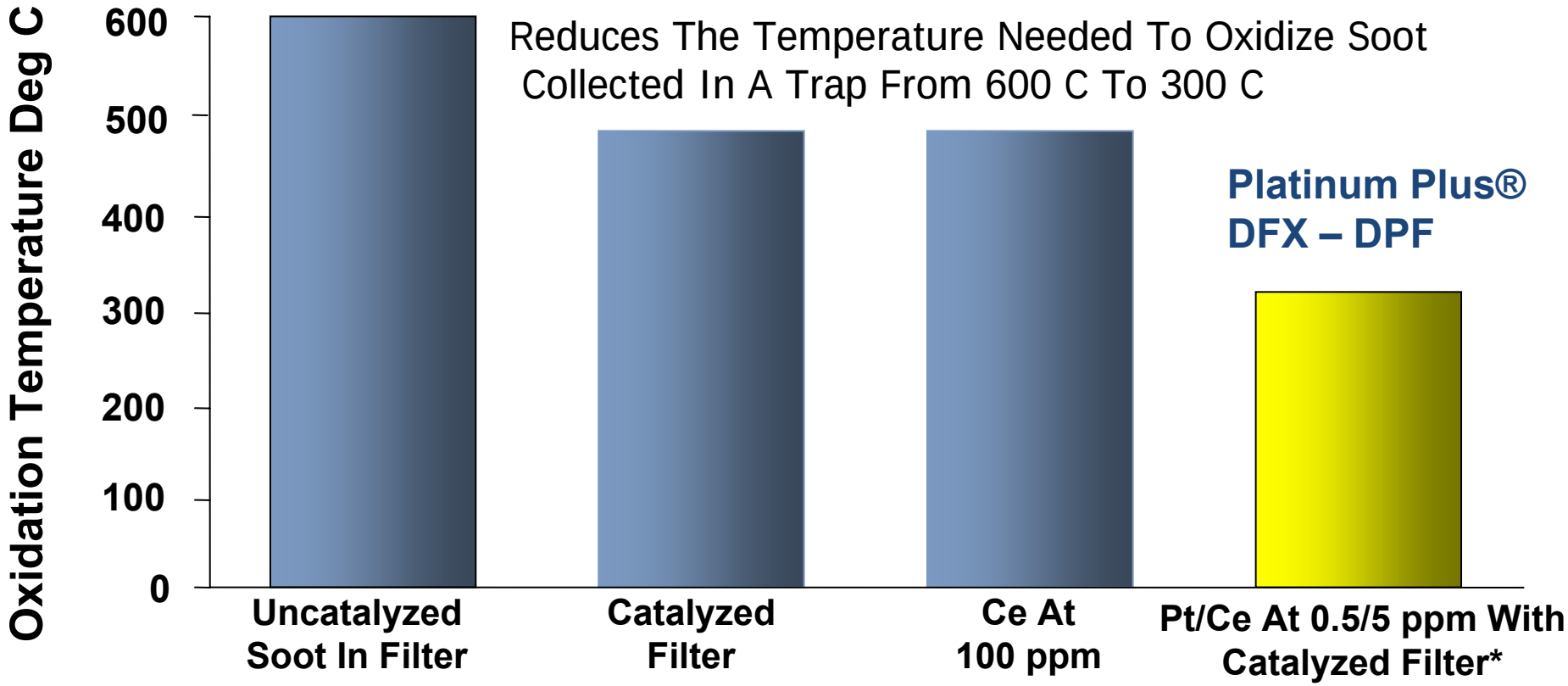
Platinum Plus: Comparison of balance points

* Catalyzed Either By Coating Or By Using Fuel Borne Catalyst Conditioning



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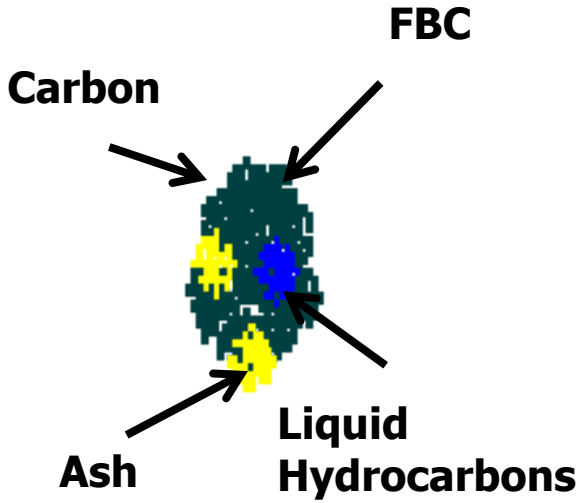
FBC reduces regeneration temperatures

- **Reduced engine-out PM emission**
- **Catalyst intimate contact with PM**
  - ✓ more complete combustion of solid carbon, hydrocarbon / SOF
  - ✓ uniformly distributed across PM size range
  - ✓ no increase in ultrafines
  - ✓ localized carbon oxidation mediated via NO_2 / NO_3
- **Continuous regeneration under extended low temperature condition**
  - ✓ balance point, critical onset temperature mechanisms
  - ✓ reduce need for active regen, increase DPF durability
- **DPF surface catalyst replenishment process**
  - ✓ reduced or eliminated Pt / surface coating requirement



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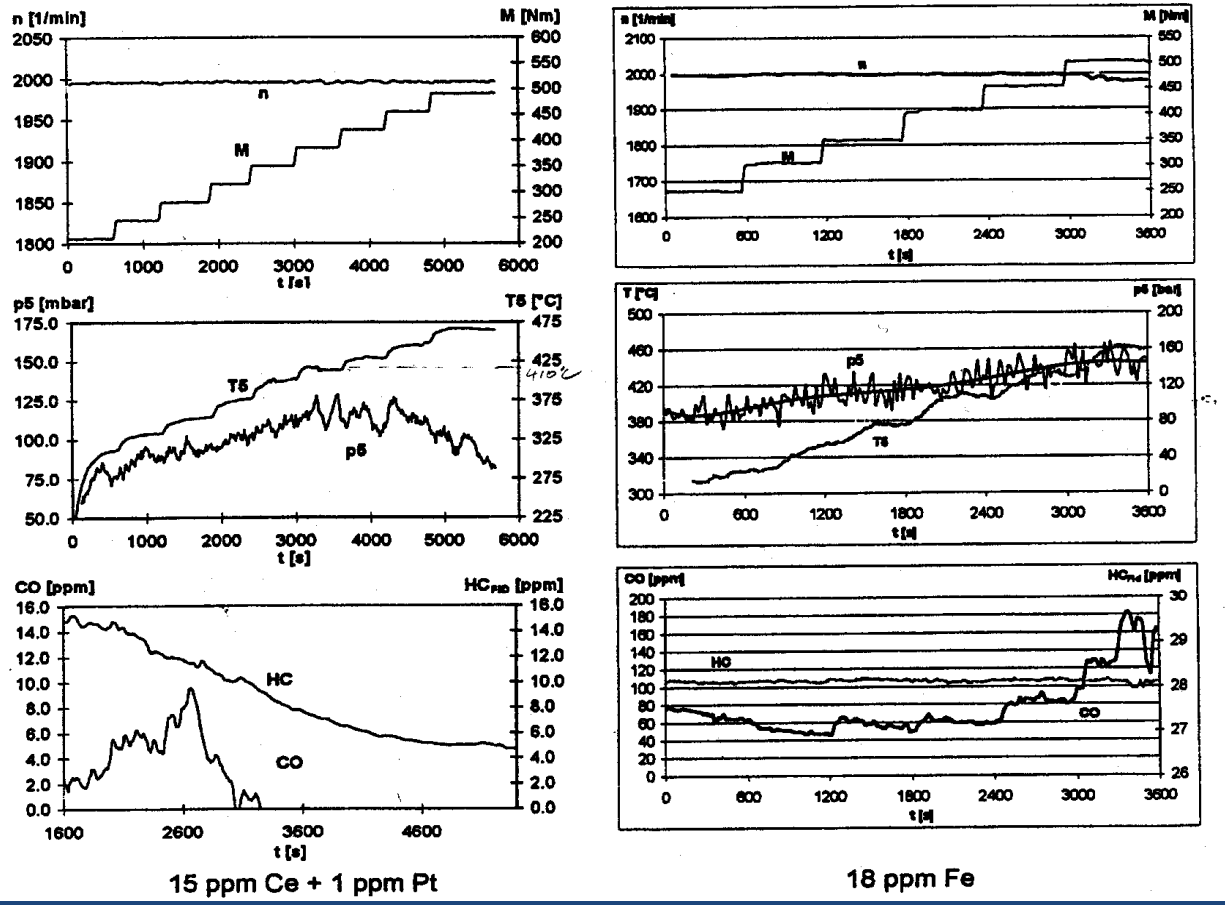
References: see SAE 2006-01-1517; Krishna & Makkee, *Topics in Catalysis 42-43*, 229-236 (2007)

Platinum Plus: Comparison of balance points



Regeneration Properties Substantially Improve With Pt-Ce FBC

Regeneration with Platinum Plus:

120 mbar @ 410C

vs.

160mbar @460C

Emissions with Platinum Plus:

HC: 4-16 vs 28 ppm

CO: 2-10 vs 40-180 ppm

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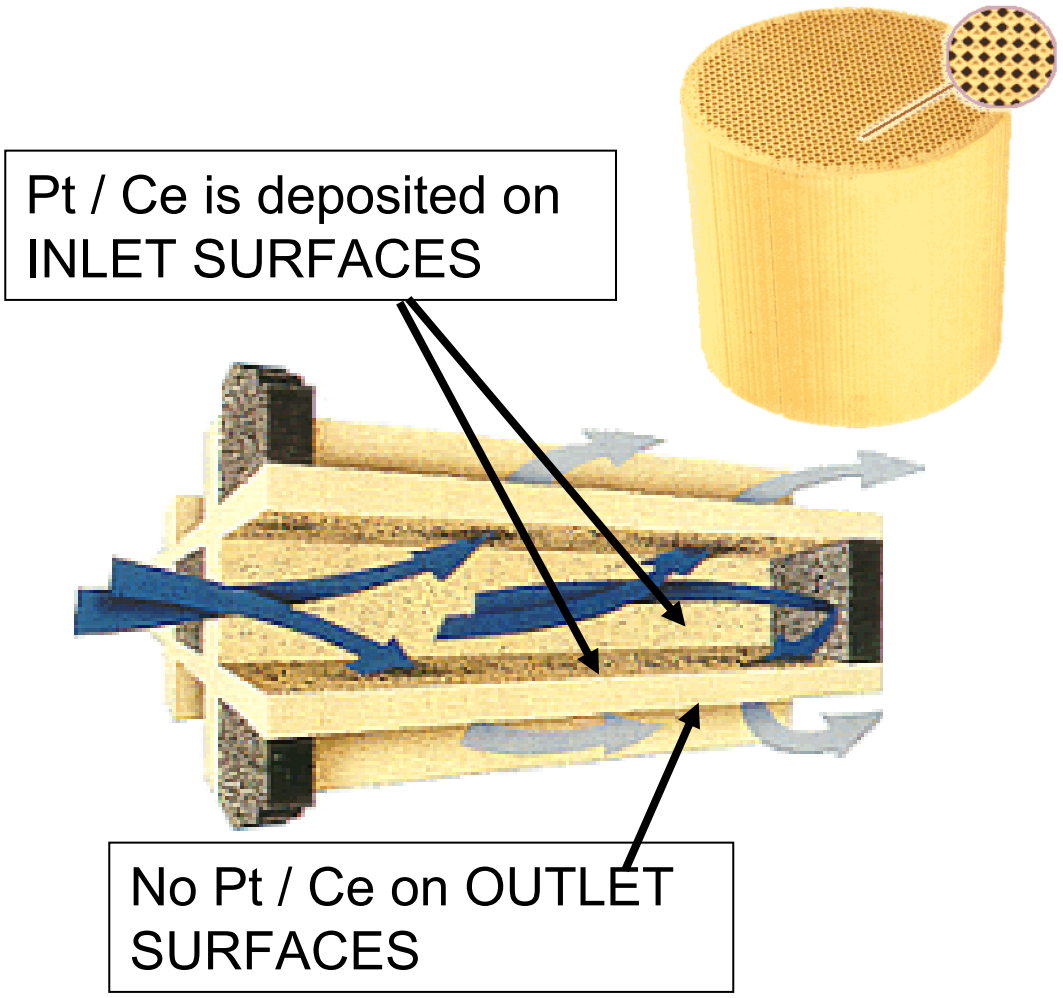
Pt/Ce deposition in uncatalyzed or lightly catalyzed DFP



Mass Balance

- Generally < 10 % of FBC Pt reaches DPF

Form

- Pt is stabilized finely dispersed on cerium
  - ✓ Ce Oxide (CeO_2)
  - ✓ Pt Metal / Pt Oxide

Distribution

- Deposited on 'inlet' surfaces of the wall-flow filter
- Reduces soot regen temps

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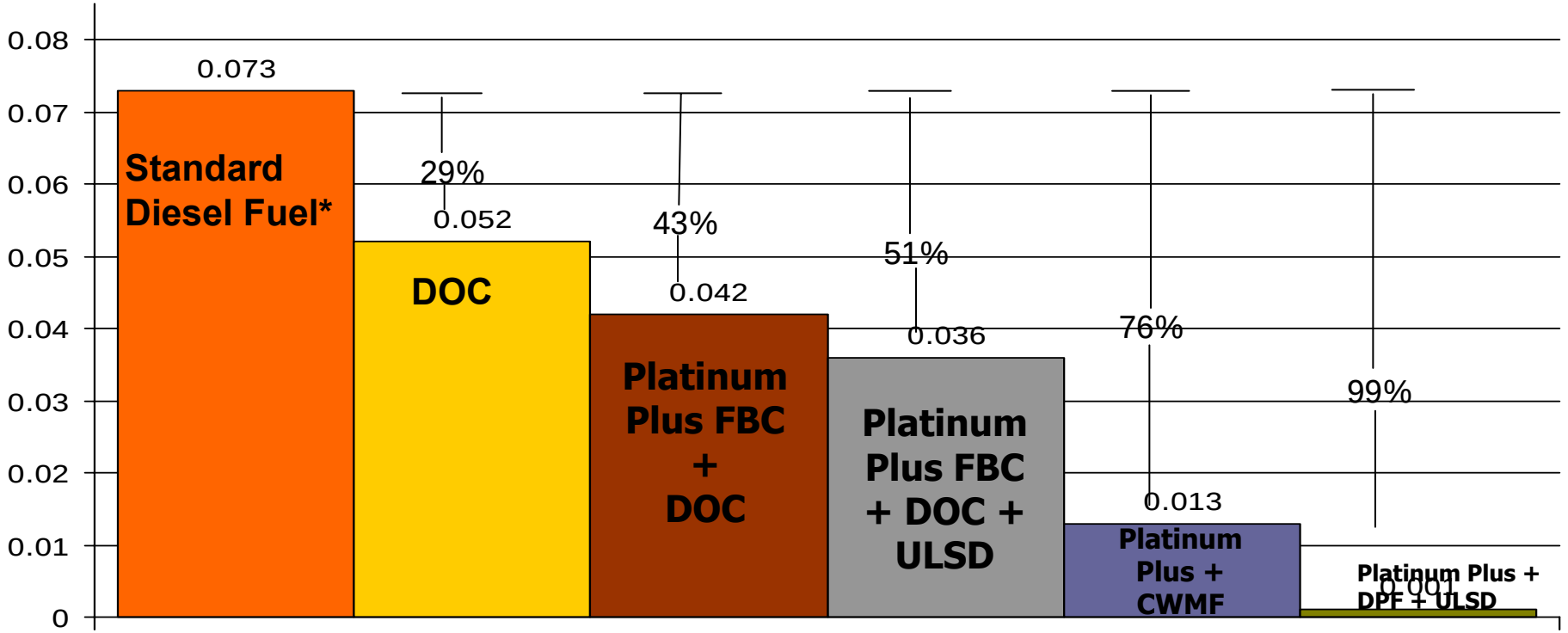
Pictures Courtesy of Corning Incorporated & www.dieselnet.com.

FBC with emission control devices

Comparative PM Emission Reduction

1998 DDC Series 60 Units: PM g/bhp-hr. (*368 ppm S Fuel)



FBC=Fuel Borne Catalyst (Pt/Ce Additive); DOC=Diesel Oxidation Catalyst
DPF= Diesel Particulate Filter; CWMF=Catalyzed Wire Mesh Filter
ULSD @ 54 ppm

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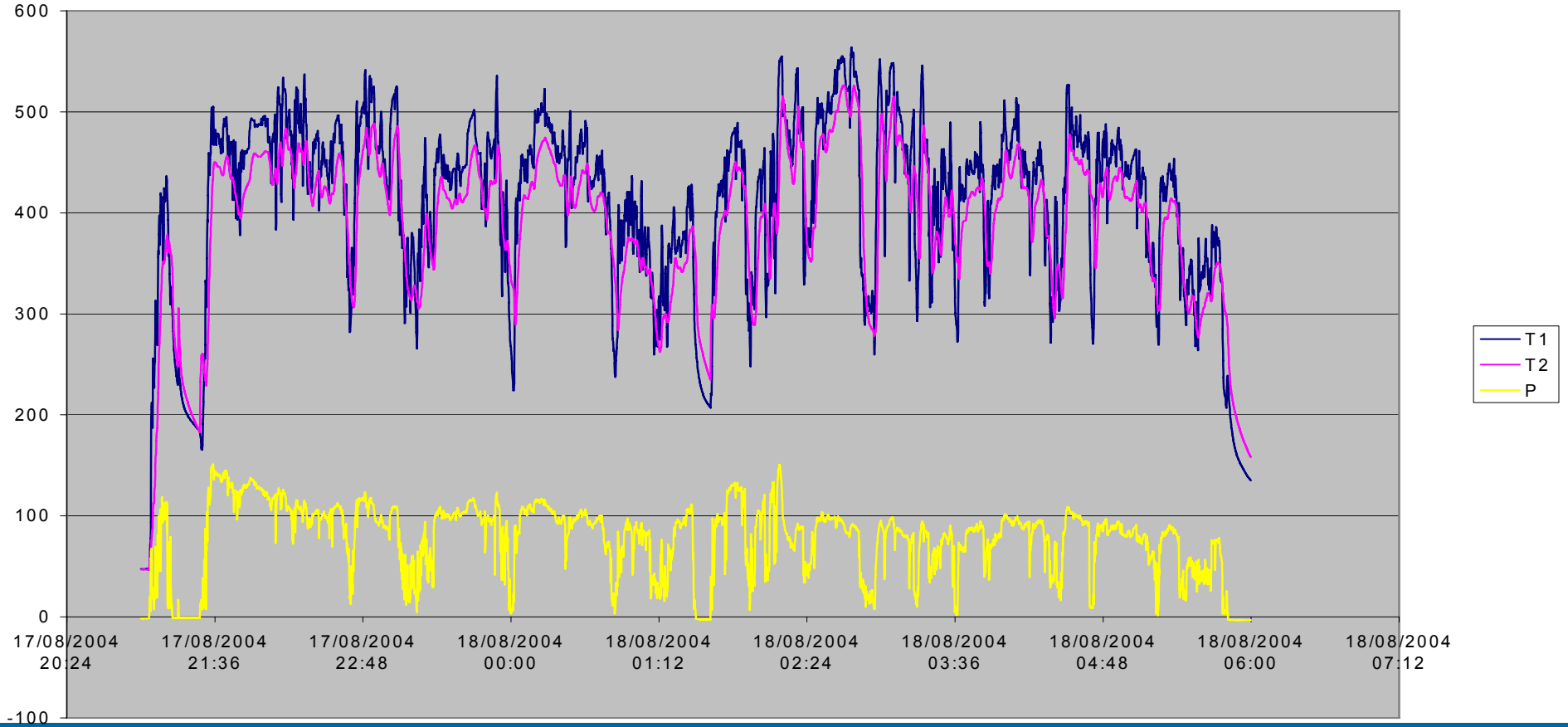
Light duty filter regeneration

Pt/Ce FBC (0.5 ppm/ 7.5 ppm)

Mixed transient urban and highway driving

2.5 litre Ford Duratech



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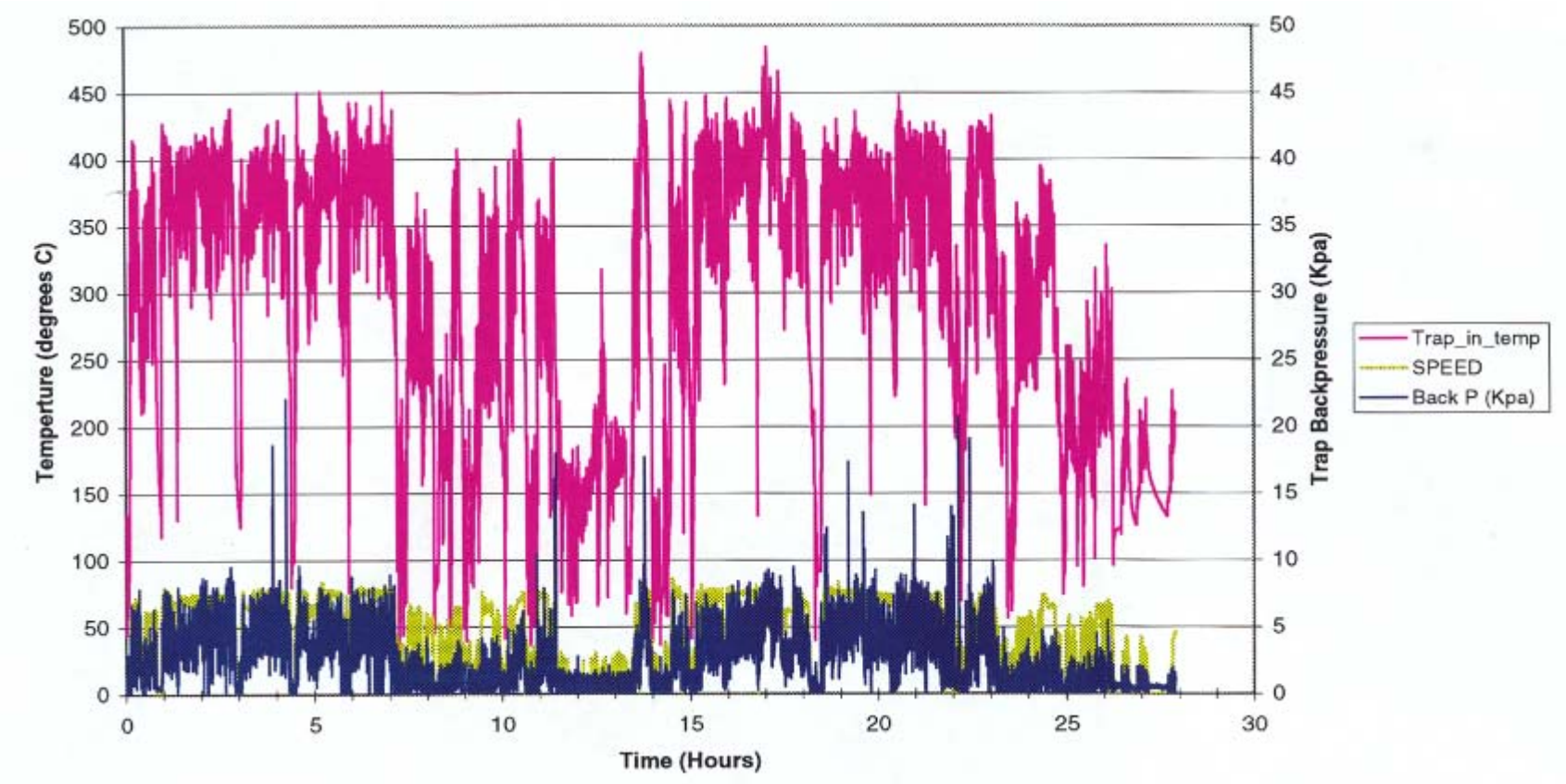
Heavy duty filter regeneration (highway)

Platinum Plus, no EGR, 1360 miles of predominantly interstate driving pulling a trailer of approx. 4000 lbs.



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Platinum Plus® integrated emission control

- ✓ Combustion enhancement to improve engine thermal efficiency
- ✓ Higher work potential achieved from engine
- ✓ Improves total fuel economy (average 5% - 8+%)
- ✓ Lowers CO_2 emissions
- ✓ Increases effectiveness of emission control devices
- ✓ Expands operating temperature range for DPF regeneration
- ✓ Reduces backpressure increase and need for active regeneration
- ✓ Allows lower lifetime use of platinum
  (up to 75% less Pt in diesel catalyzed filter)
- ✓ Low NO_2 emissions
- ✓ Lowest FBC levels (OEM lifetime solution)
- ✓ Reduces emissions from petroleum fuels and renewables

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