Requirements Driven Diesel Catalyzed Particulate Trap (DCPT) Design and Optimization

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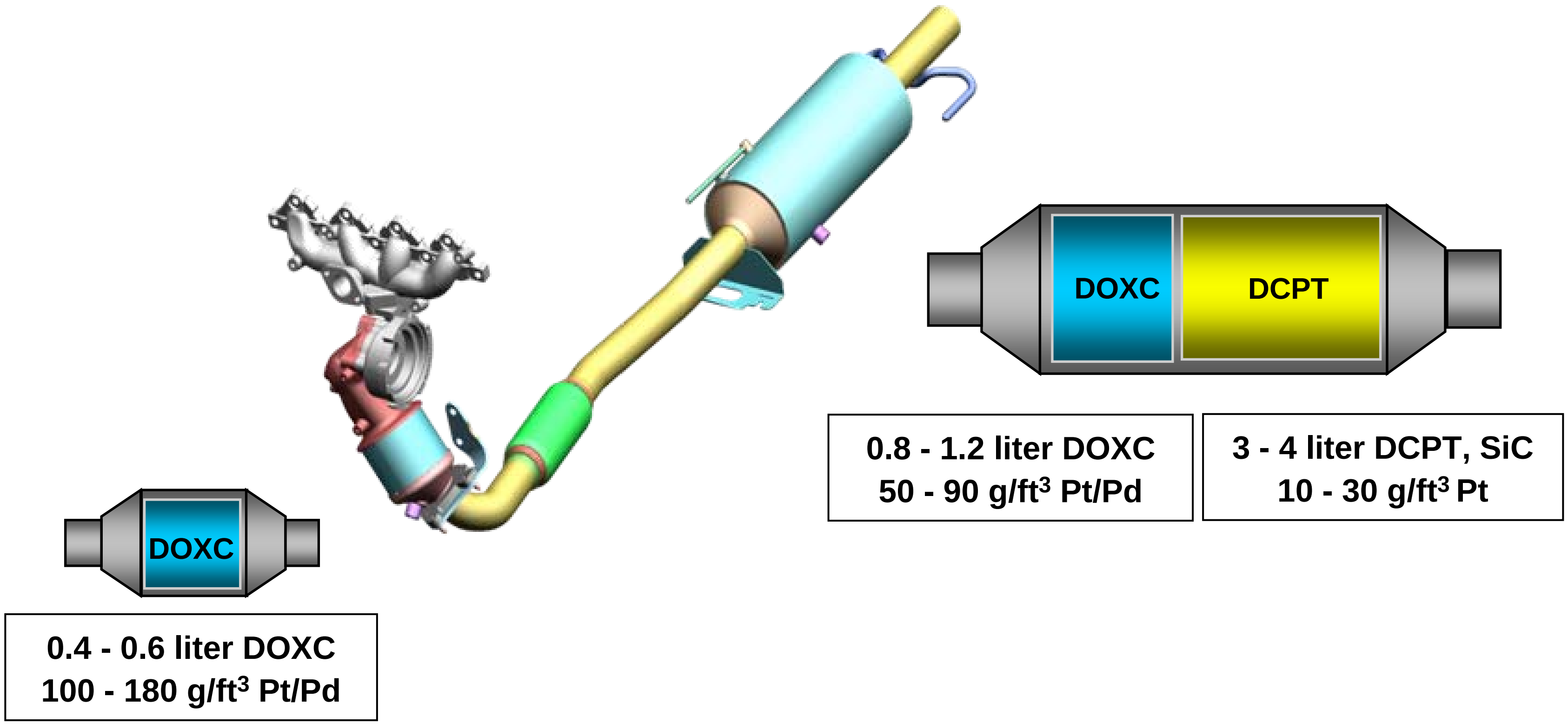
Euro 4/5 Light Duty Diesel Exhaust System Design

- Close-coupled DOXC (<u>D</u>iesel <u>Ox</u>idation <u>C</u>atalyst)
- Under-floor DOXC-DCPT (<u>D</u>iesel <u>C</u>atalyzed <u>P</u>articulate <u>T</u>rap)



Rationale for DCPT With Low Pt Loading - Supported by the Accompanying Data Sets 1 - 4

1. Backpressure: To minimize the pressure drop across the DCPT, a minimal amount of washcoat must be used, and it must be deposited entirely within the walls (pores) of the filter.
2. Emissions Control – With a minimal amount of washcoat, the intrinsic catalytic activity of the DCPT will be limited. For optimal Pt utilization, the DOXC's should possess most of the Pt, and be designed to be completely responsible for emissions control.
3. Active Regeneration – Soot combustion will produce "secondary CO". The DCPT must control this emission, but a low loading of Pt is sufficient for this purpose. The DCPT should also exhibit some capability for the oxidation of hydrocarbon (HC) that slips through the DOXC's during regeneration.
4. Passive Regeneration - Pt on the DOXC and the DCPT promotes the oxidation of NO to NO_2, enabling NO_2-assisted soot oxidation. There is a clear trade-off between Pt loading (and cost) of the DCPT and the extent of passive regeneration.

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Low Washcoat Load –
Effect on Backpressure

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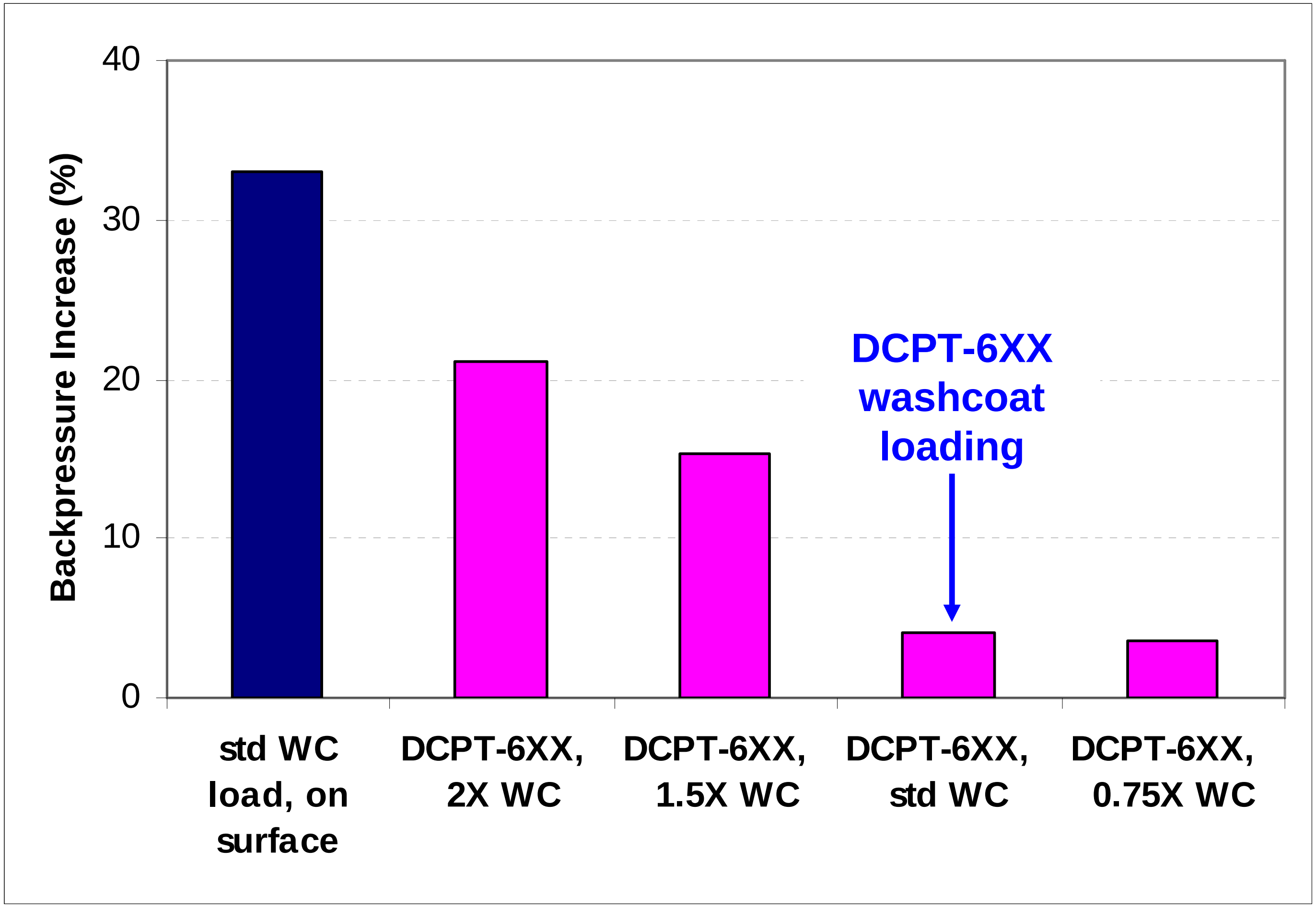

- Low back-pressure cordierite filters were used in this coating study
- DCPT-6XX washcoat (WC) loading varied from 0.75 to 2 times the standard value
- Washcoat placement on the inlet channel surface was achieved through process adjustment

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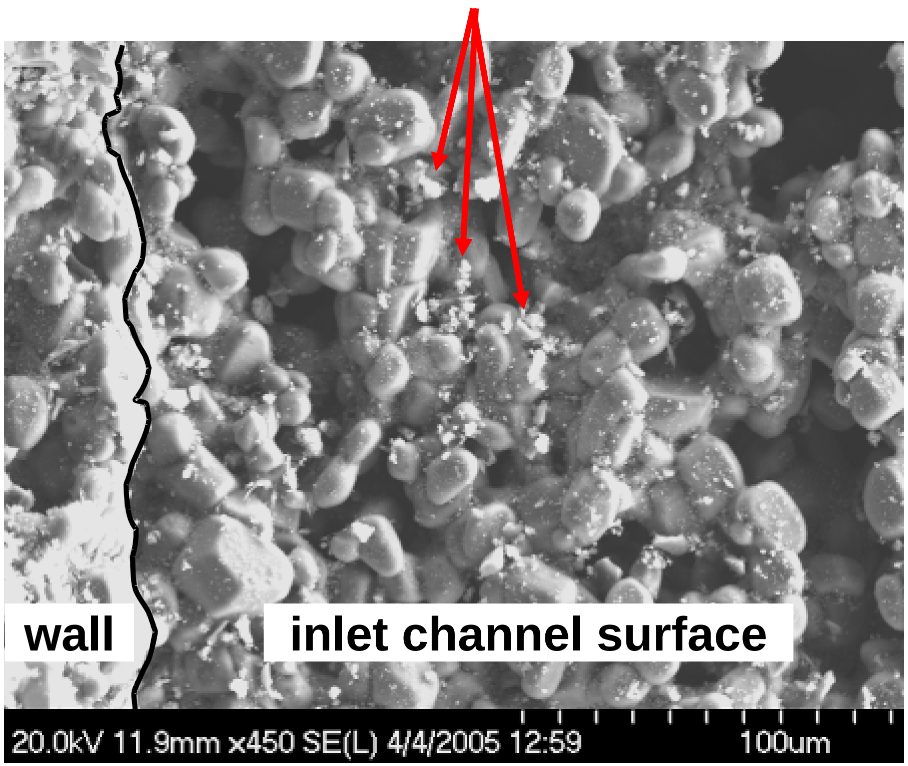
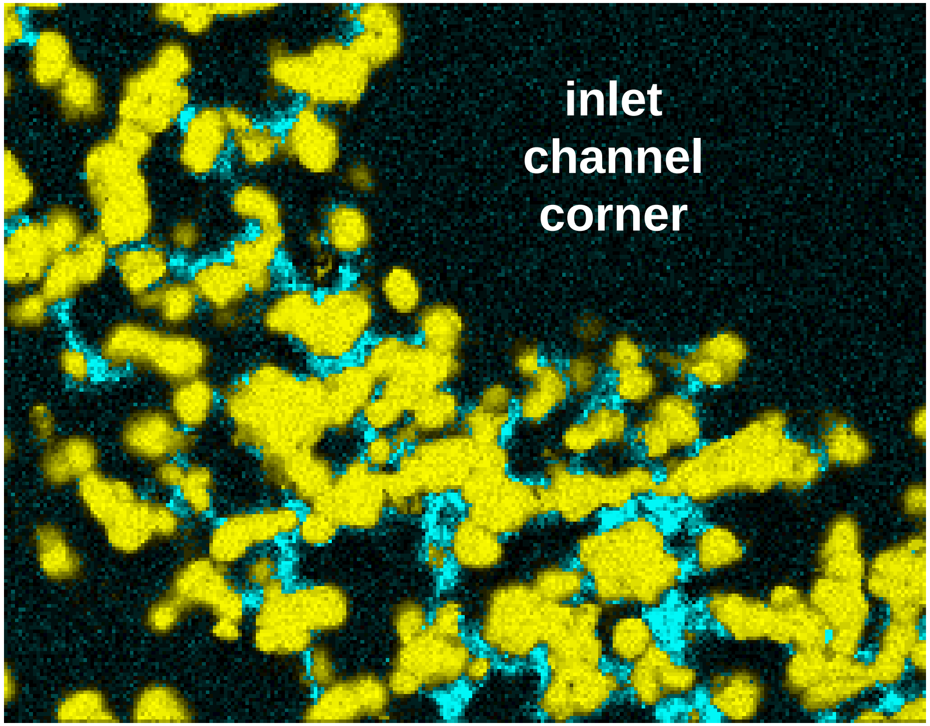
DCPT-6XX –
"In-Wall" Washcoat Placement



cross-section sample mounted in epoxy



- Si in SiC
- washcoat element

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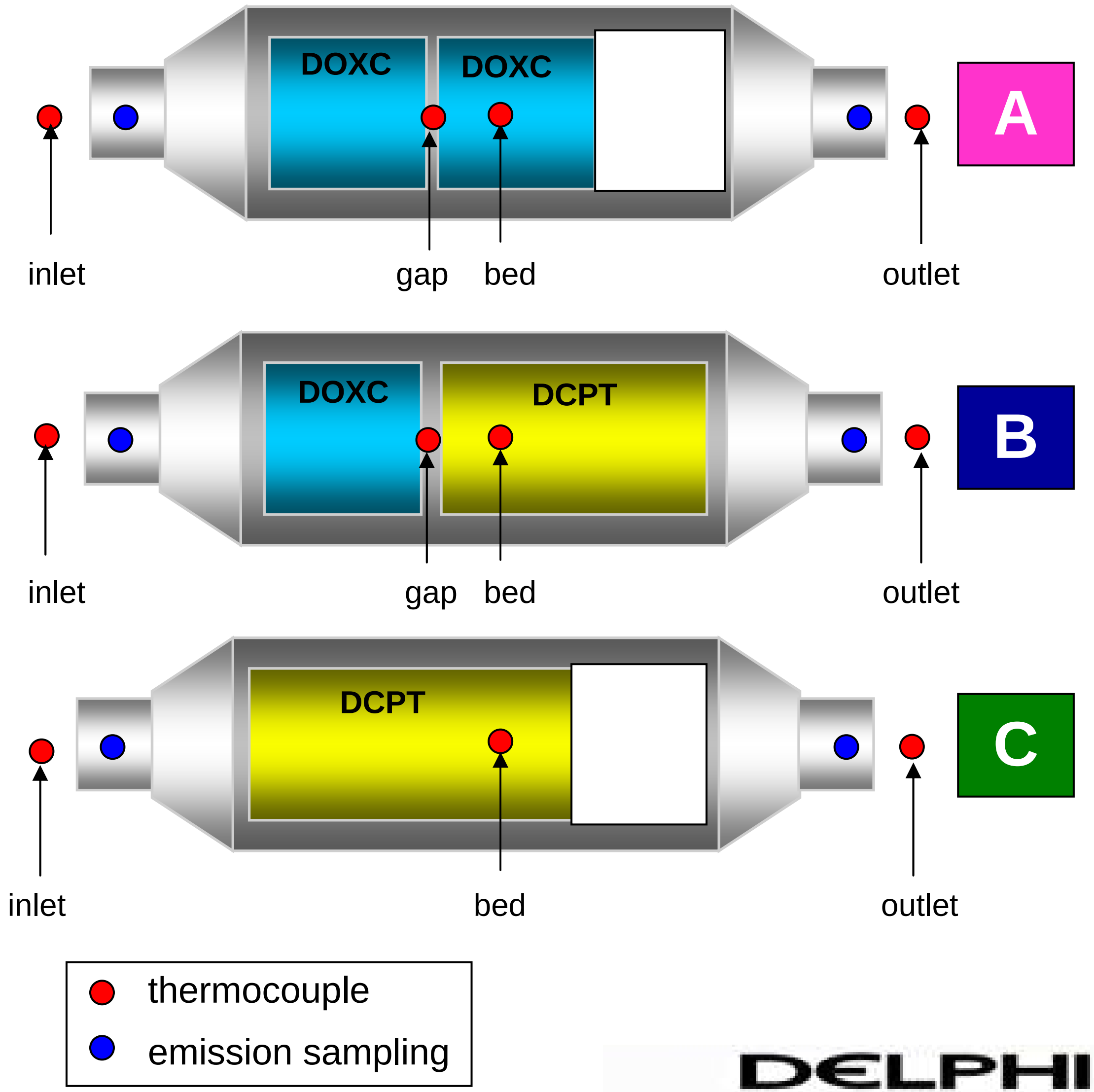
DOXC vs. DCPT for Emissions Control – Light-Off Testing Protocol

- Light-off testing with slow and fast temperature ramps can be used to delineate differences in intrinsic catalytic activity and thermal inertia
- Test conditions: Kia 2.9L engine; 2900 rpm / 90 Nm; temperature ramp controlled with heat exchanger
- DOXC: 5.66 X 3”, 400/6.5, 70 g/ft^3 Pt
- DCPT-6XX: 5.66 X 6”, 300/12, cordierite, 70 g/ft^3 Pt
- Aging: in oven at 700 C for 16 hr in 10% steam



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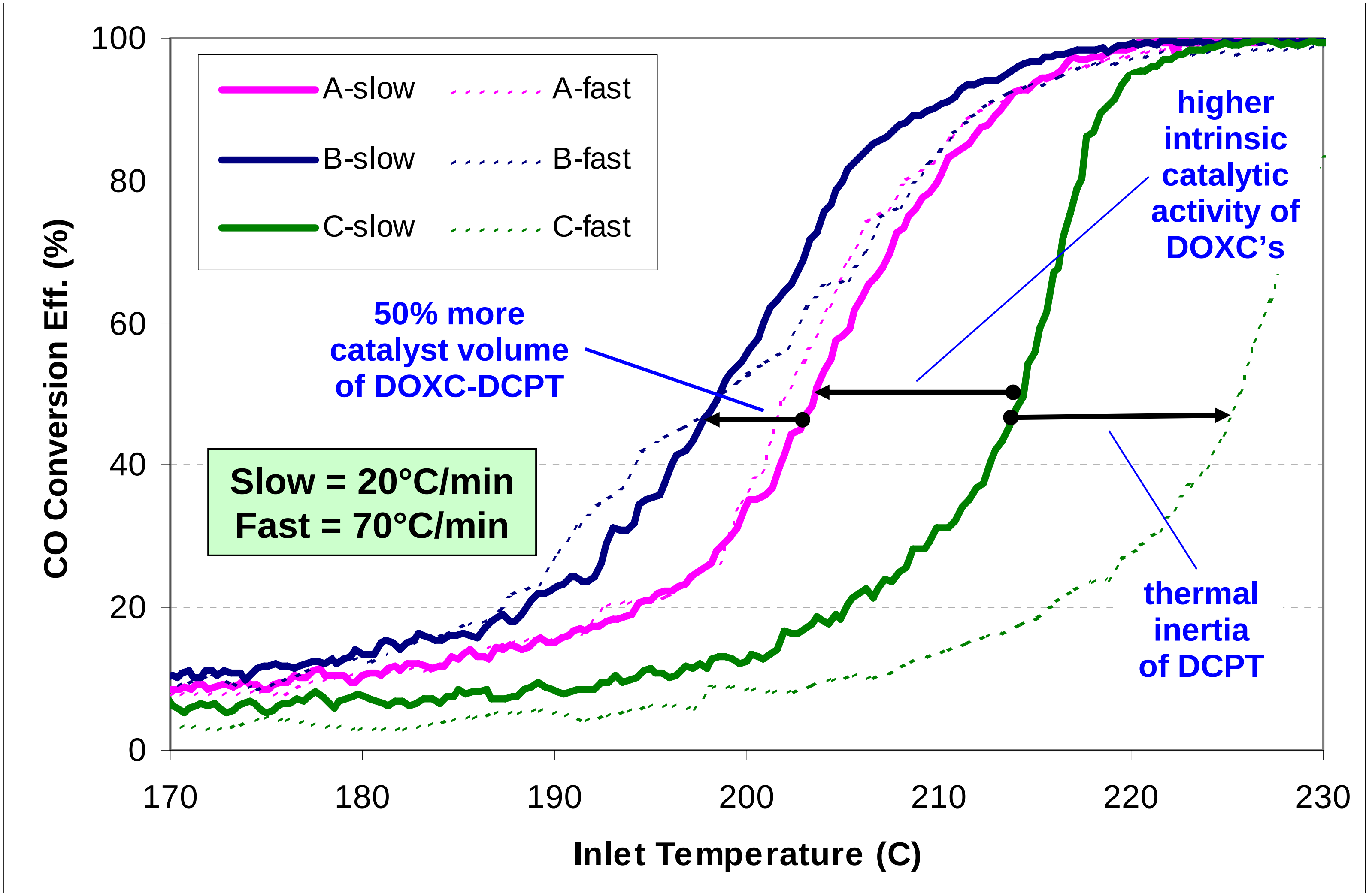
Light-Off Test Results – CO



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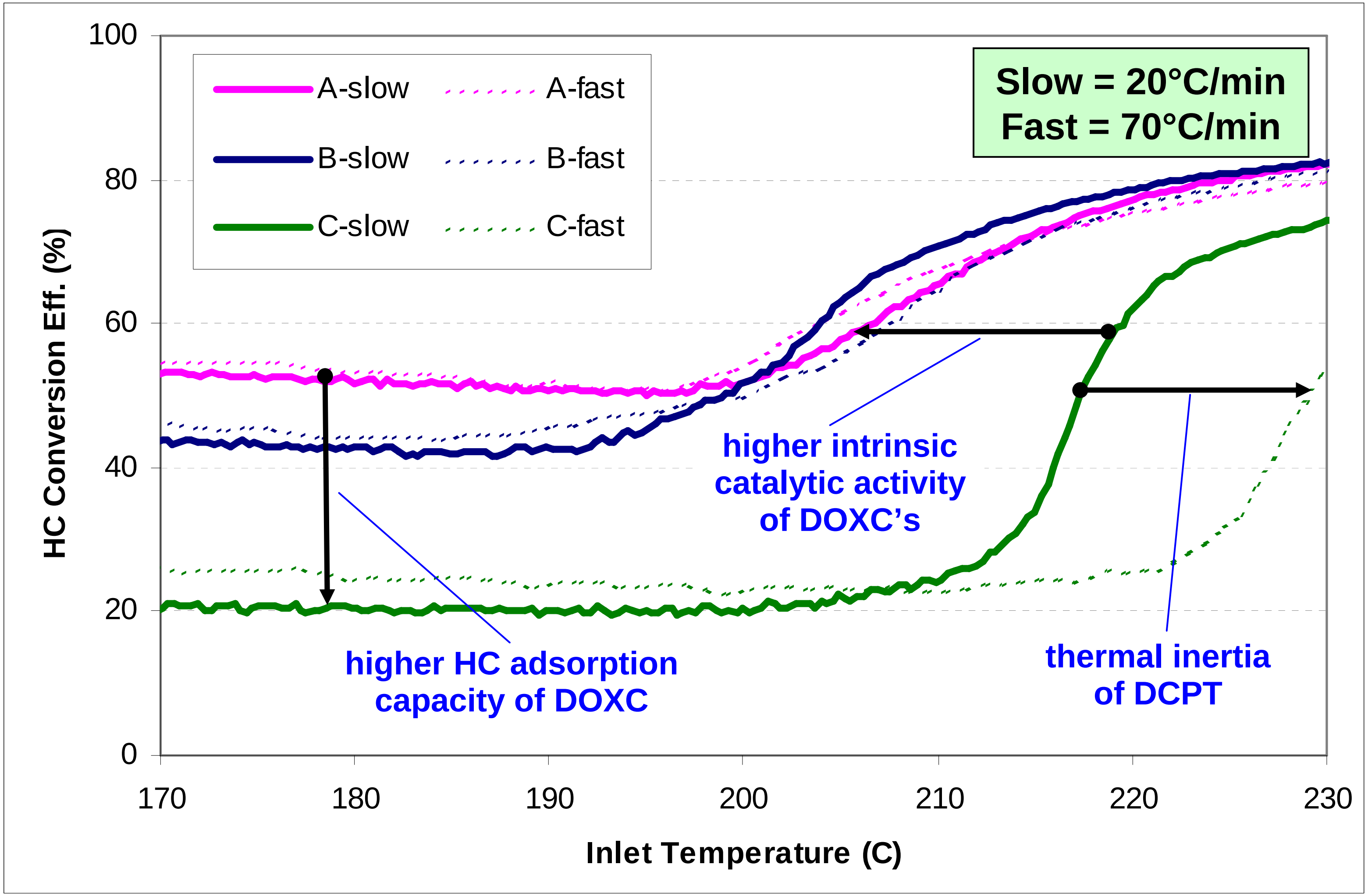
Light-Off Test Results - HC



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DOXC vs. DCPT for Emissions Control – DOXC Is The Clear Winner

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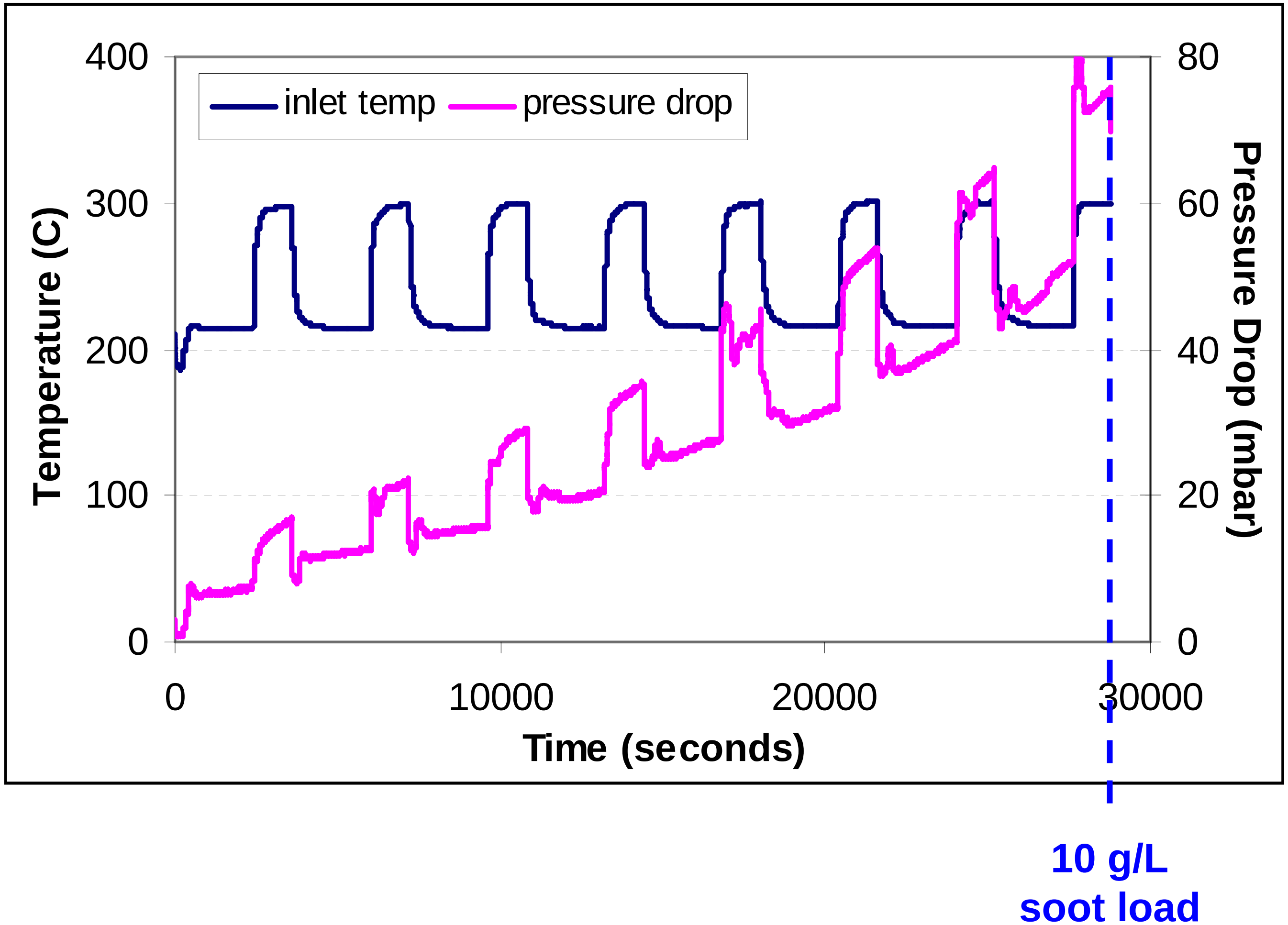
- The DOXC washcoat technology exhibits much higher intrinsic catalytic activity for CO and HC relative to the DCPT technology
  - Approximately 1/5 less washcoat support material in DCPT-6XX
- Relative to the DOXC, the DCPT exhibits significant thermal inertia
- The DOXC washcoat, which contains zeolite, exhibits approximately 100% higher capacity for HC adsorption at lower temperatures than the DCPT washcoat
- The DOXC-DCPT combination performs better than the DOXC-DOXC combination for CO
  - HC performance is not quite as good – again, the DOXC provides more HC storage capacity

Active Regeneration – Engine Testing Protocol

- DOXC-DCPT converter designs:
  - DOXC: 5.66 X 3”, 400/6.5; DCPT: 5.66 X 6”, 300/12 (cordierite)
  - Case 1: DOXC with 90 g/ft^3 Pt; blank filter
  - Case 2: DOXC with 90 g/ft^3 Pt; DCPT-6XX, PGM-free
  - Case 3: DOXC with 90 g/ft^3 Pt; DCPT-6XX with 10 g/ft^3 Pt
- Converter aging:
  - Engine-aged for 50 hours
  - DOXC-DCPT gap temperature of 810°C
  - Post-injection 50% of time (10 minute intervals)
- Active Regeneration Test:
  - Post-injection with target of 620°C in the DOXC-DCPT gap
  - Test duration: 5 minutes

Active Regeneration – Soot Loading



- **Protocol designed to simulate city and highway driving conditions**
- **Some catalytic soot oxidation occurs in the DOXC and DCPT during the high-temperature portion of the cycle**
- **Four converters are loaded in parallel and simultaneously, with flow balancing between the legs**

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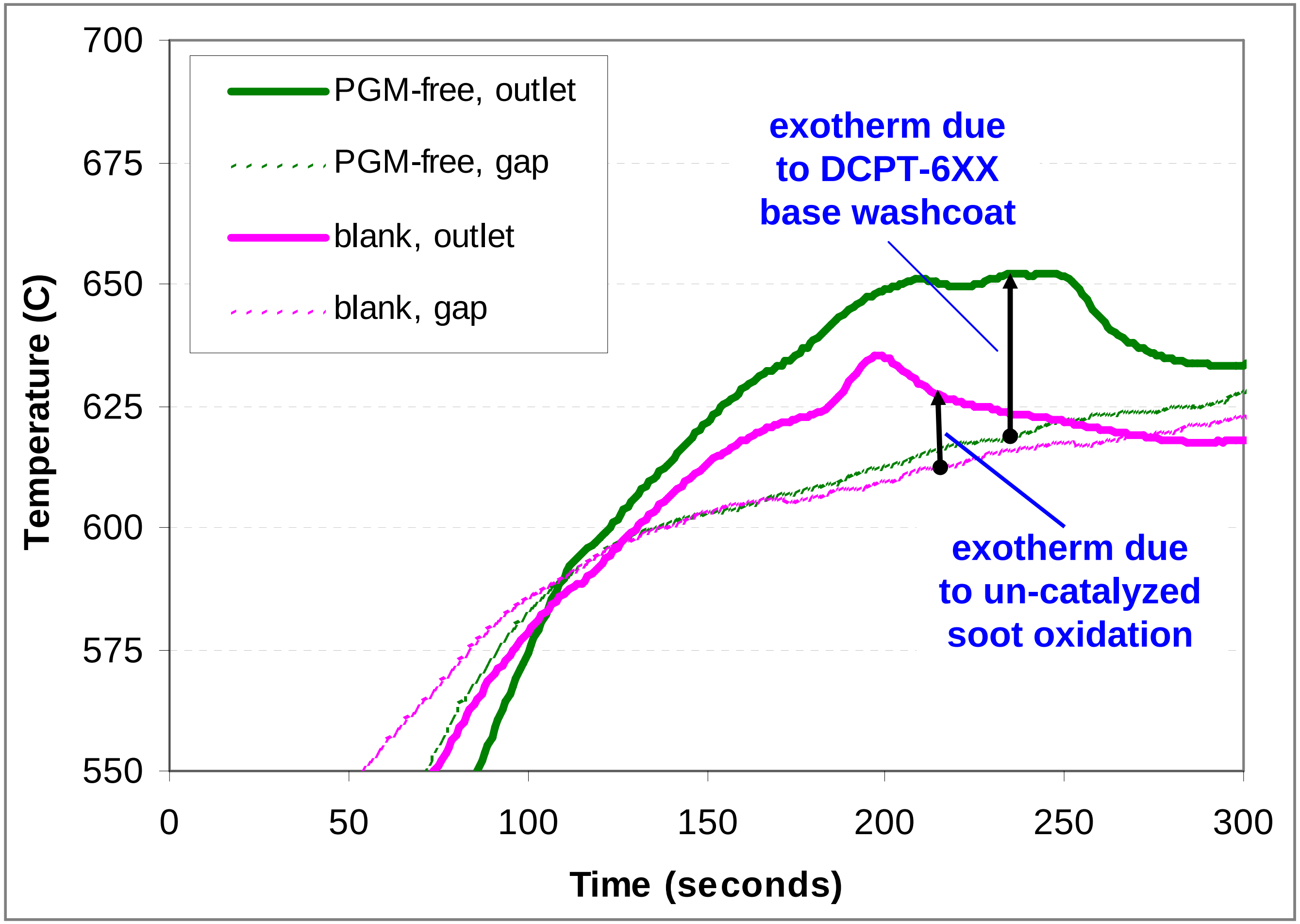
Active Regeneration –
Test Results - Heat Generation



	Soot loading (g/L)
Blank filter	10.1
DCPT-6XX, PGM-free	7.9

- **The difference in temperature between the DOXC-DCPT gap and the DCPT outlet reflects the rate of soot oxidation**
- **The DCPT-6XX base washcoat promotes oxidation**

Active Regeneration – Test Results - Control of Secondary CO Slip

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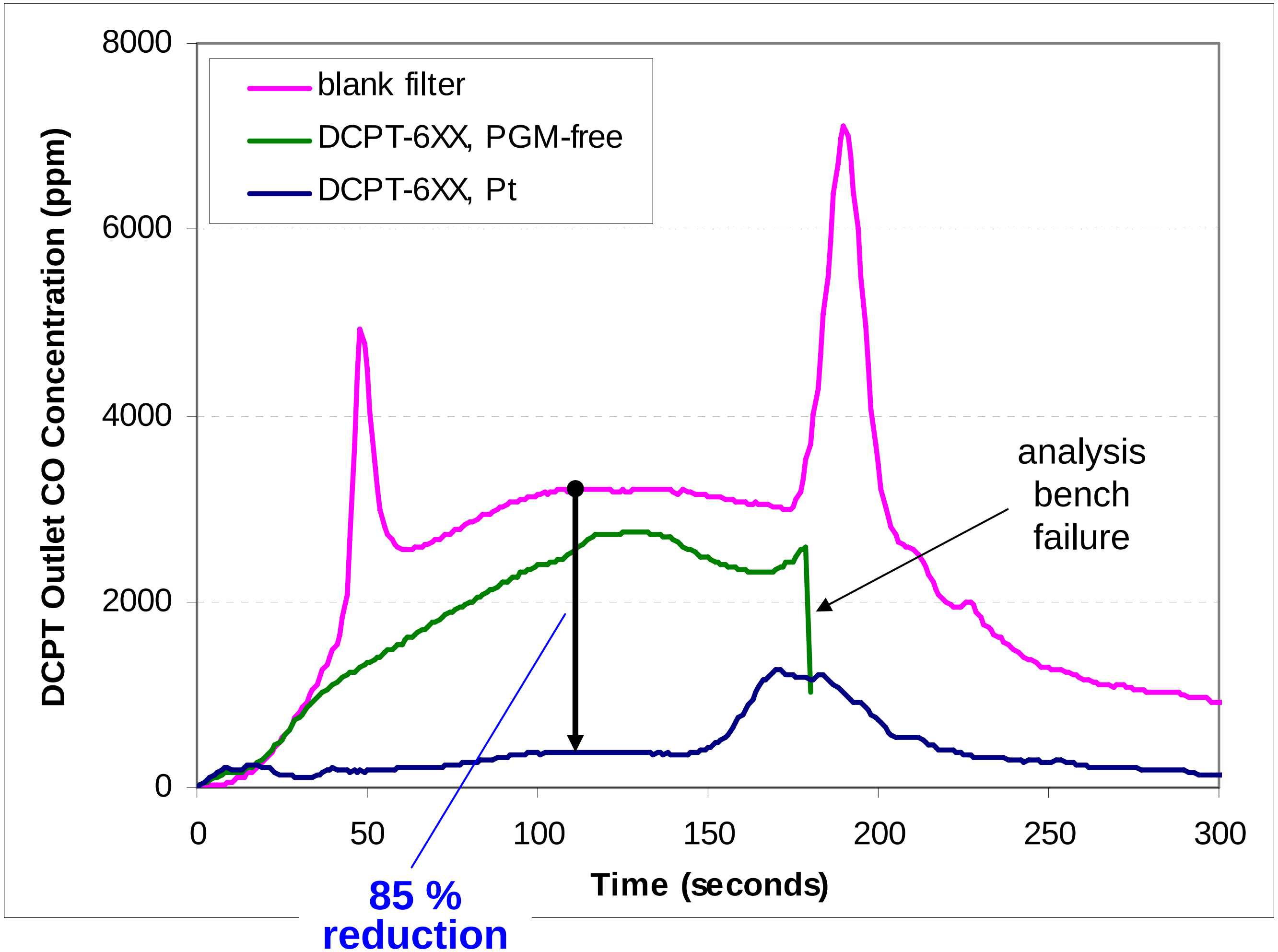

- With the blank (uncoated) filter, non-uniform combustion produce random pulses of CO
- The DCPT-6XX base washcoat minimizes the pulses, but CO slip is still significant
- With only 10 g/ft^3 Pt, DCPT-6XX provides excellent control of secondary CO

Active Regeneration –
Results - Oxidation of Post-Injected HC

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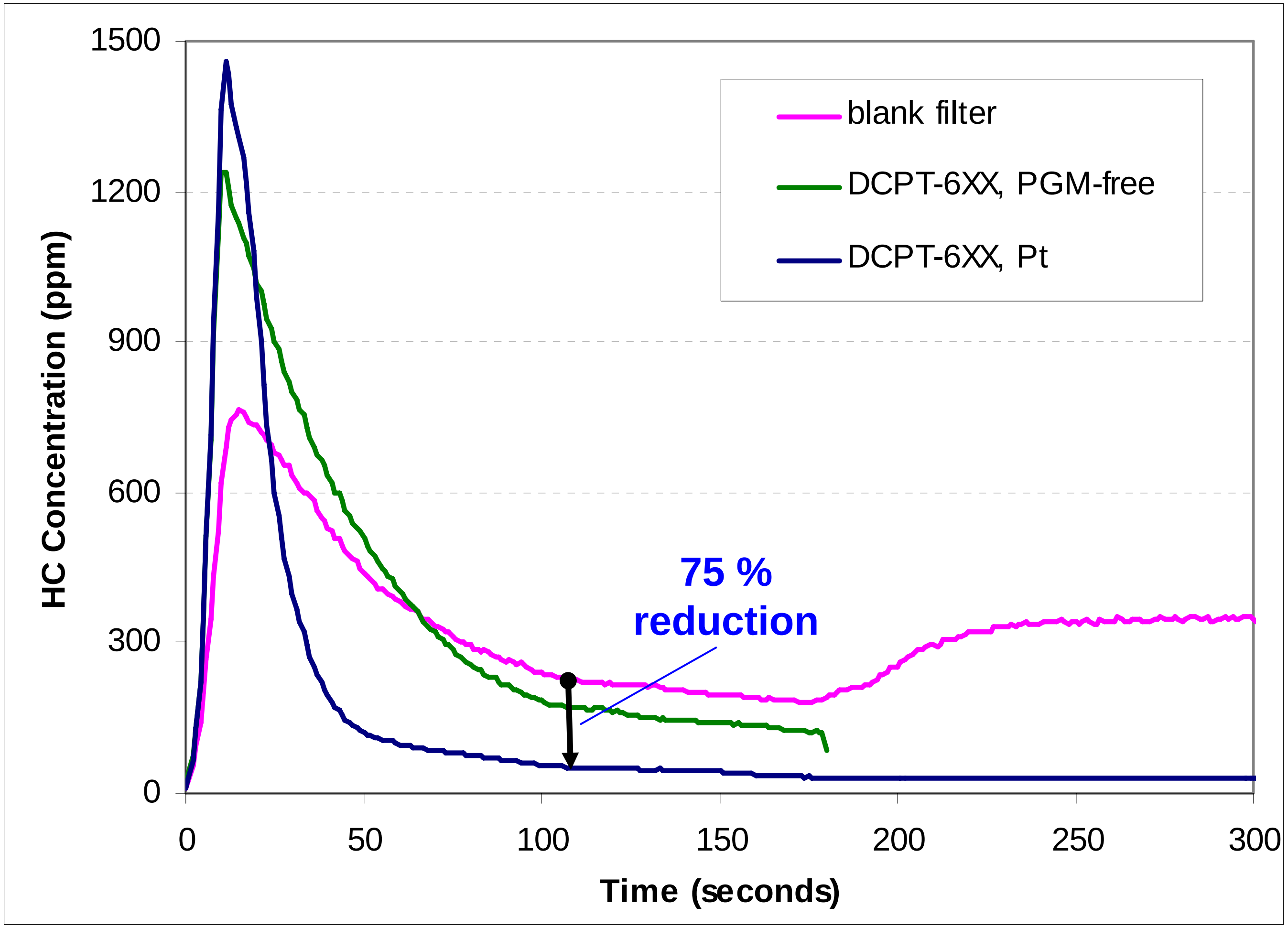

- **The test protocol is designed to allow some post-injected HC to slip through the DOXC**
- **With 10 g/ft^3 Pt, DCPT-6XX rapidly brings HC slip under control**

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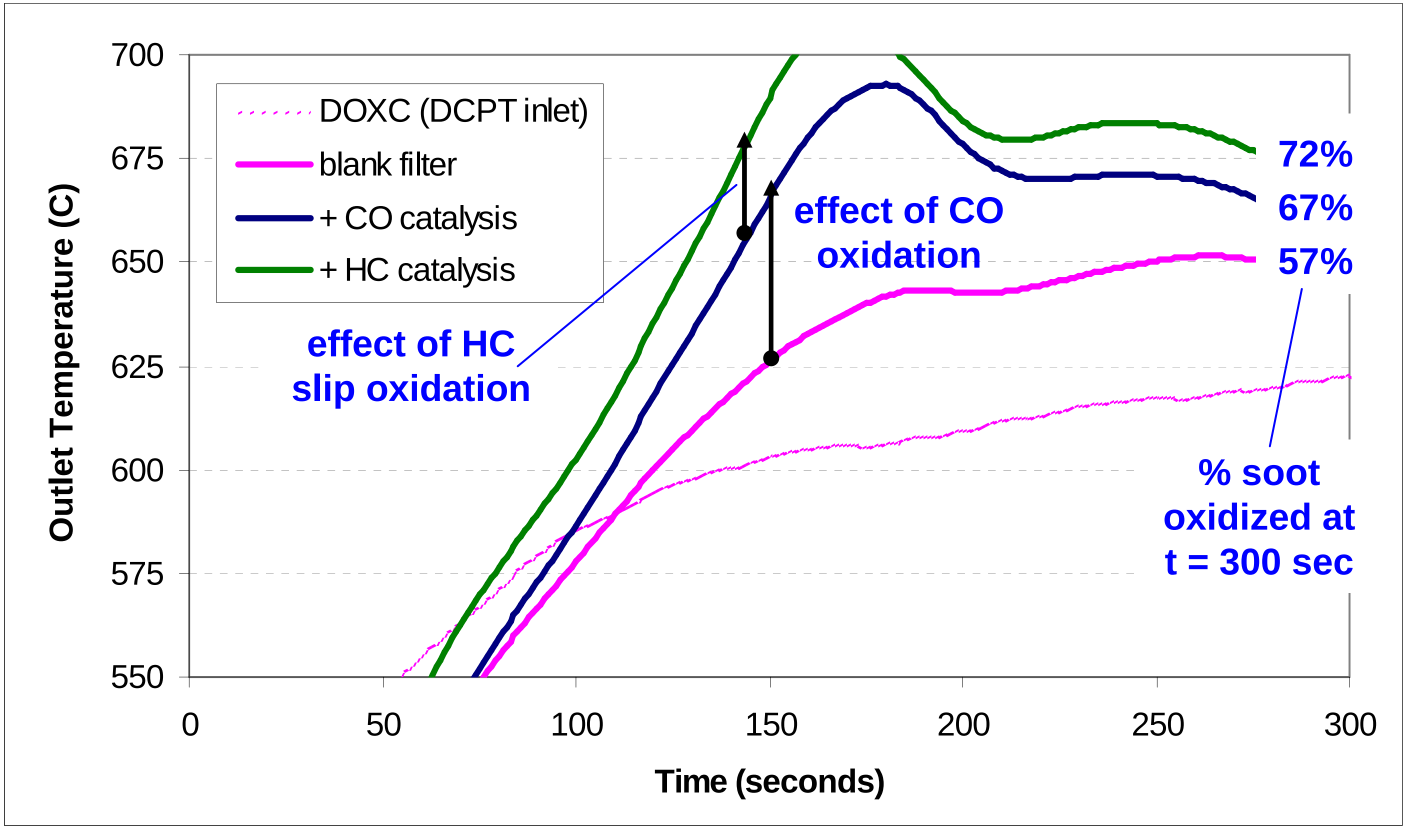
Active Regeneration – Simulation Results – Heat Generation



- **Catalysis of CO oxidation increases the heat produced and the extent of soot burned**
- **Increased HC slip through the DOXC should also enhance heat generation in the DCPT**

Input conditions: experimental values for flow rate, O_2, HC and inlet temperature
CO catalysis: thermal oxidation only, with higher value of CO selectivity factor
HC catalysis: T50 = 492 K
Filter: cordierite, 5.66 X 6”; Initial Soot loading: 10 g/L

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Passive Regeneration – Engine Testing Results

- Soot Loading
  - Same as for active regeneration test
- Passive Regeneration Test
  - 400°C at DOXC inlet
  - 30 minutes duration
  - Converter mass measurements used to calculate % soot oxidized

	Soot Loading (g/L)	Soot Oxidized (%)
Blank Filter	10.0	17
DCPT-6XX, PGM-free	7.8	21
DCPT-6XX, 10 g/ft^3 Pt	7.9	33

- DCPT-6XX with 10 g/ft^3 Pt enhances passive regeneration by 100%
- DCPT-6XX base washcoat is responsible for lower soot loads observed with the cyclical loading protocol

Conclusions

- With a Euro 4/5 system consisting of a warm-up DOXC and an underfloor DOXC-DCPT, it is possible to reduce the system cost dramatically by reducing the Pt loading on the filter
  - The two DOXC's can and should be completely responsible for emissions control under normal operating conditions
- The filter technology DCPT-6XX with 10 g/ft^3 Pt provides:
  - Minimal increase in backpressure relative to an uncoated filter
  - Excellent control of secondary CO slip during active regeneration
  - HC slip control capability
  - Significant increase in passive regeneration
- Modeling indicates that heat from the oxidation of secondary CO and HC slip in the DCPT can increase significantly the rate/completeness of regeneration

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Acknowledgments

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