# Post Mortem of 120k mi Light-Duty Urea SCR and DPF System

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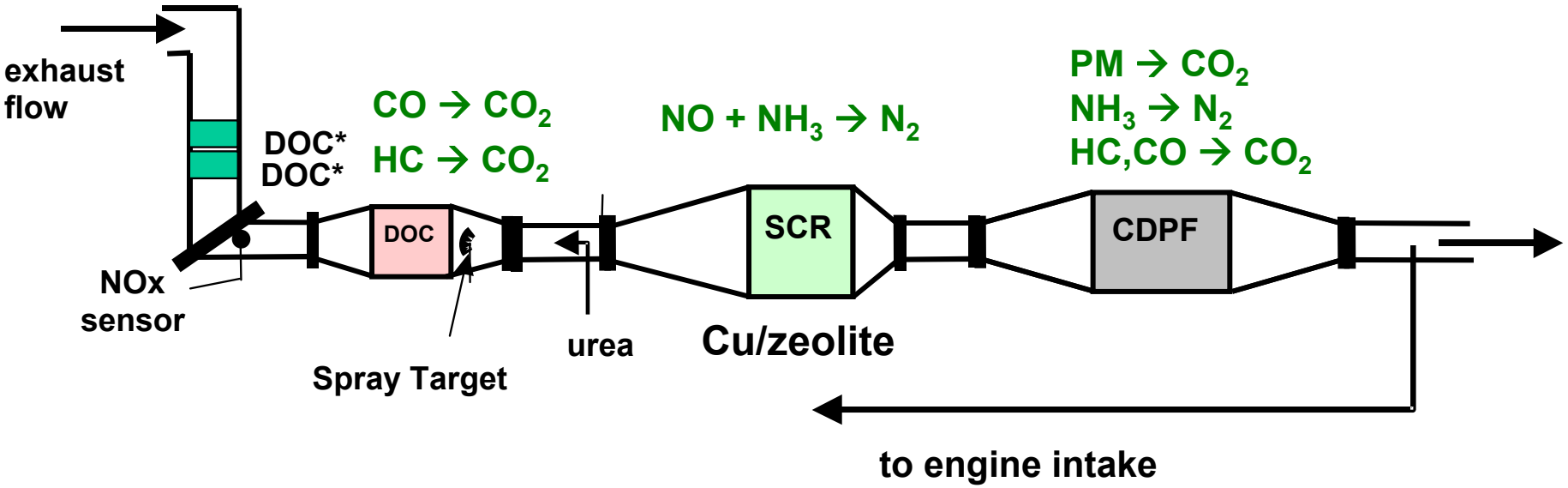
# Introduction

- System basics and aging
- Physical property measurements
- Chemical property measurements
- Conclusions

# 120k mi Engine Aged Diesel System

90% FTP-75 NOx conversion, 0.07 g/mi TP NOx




* Note: Downpipe DOCs replaced at 50k mi.

# Diesel Fuel Properties

Program fuel was typical of US low sulfur diesel.

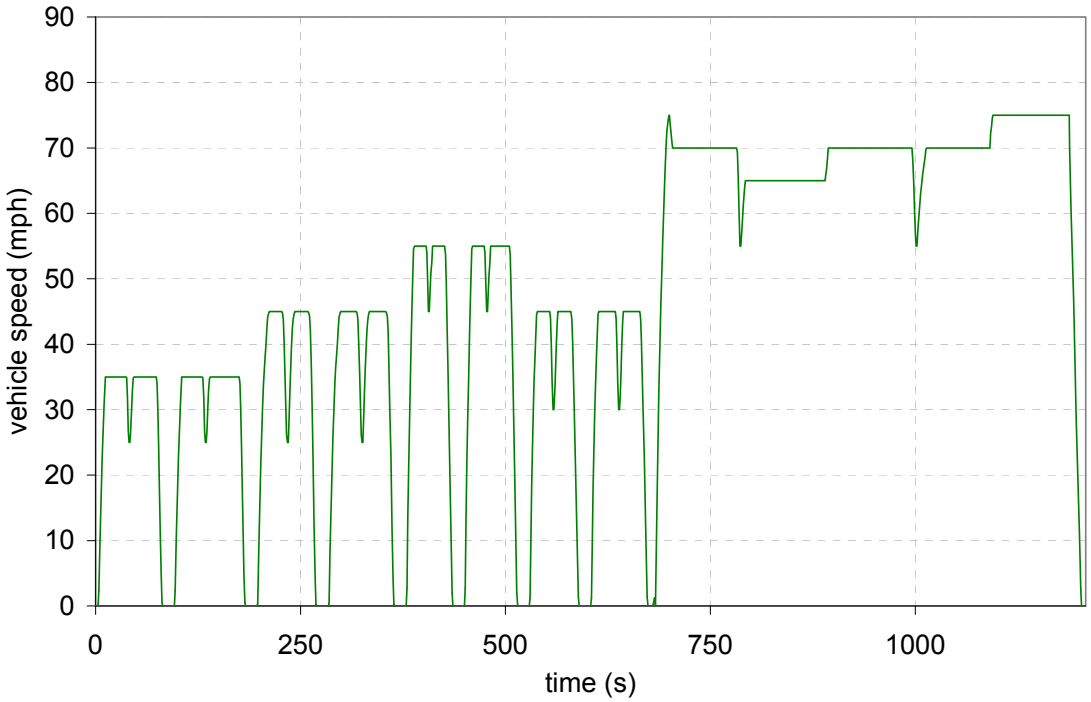
| Fuel Property | Proposed Program Min/Max | Program Fuel Delivered |
|---|---|---|
| **Sulfur, ppm** | 10 / 15* | **12.5** |
| **Density, kg/m$^3$** | 820 / 850 | **841.1** |
| **Aromatics, vol. %** | 25 / 32 | **29.5** |
| **Polyaromatics, wt. %** | 6 / 11 | **11.0** |
| **Cetane number** | 44 / 48 | **44.9** |
| **T50, C** | 250 / 280 | **249** |
| **T90, C** | 300 / 320 | **307** |

* As delivered to the vehicle

# Durability Test Definition (Engine Dyno Aging)

- Full-size Urea SCR – CDPF system was aged for 120k mi on engine dyno with a total of 643 CDPF regenerations.

**Ford High Speed Cycle (HSC)**



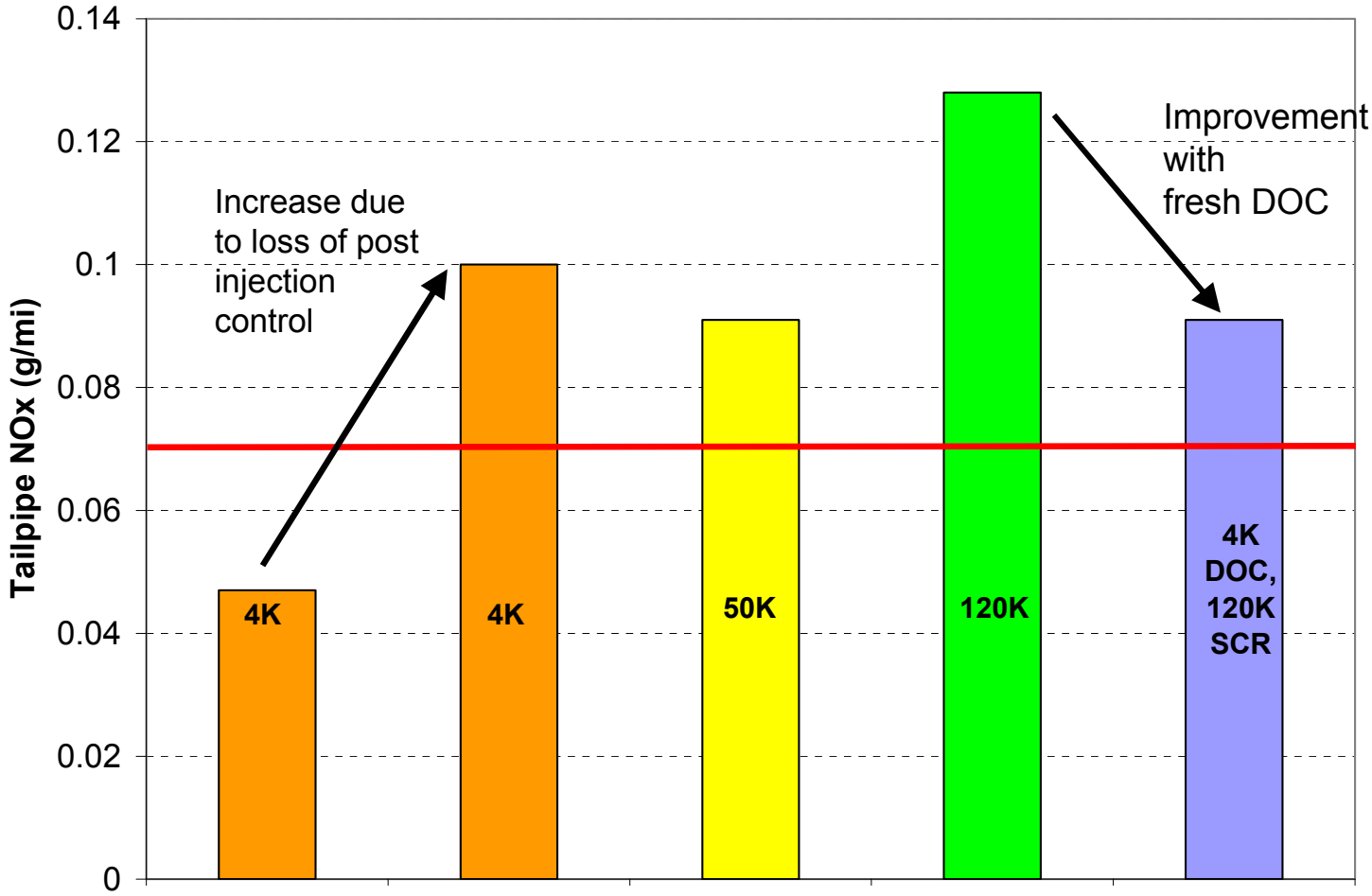

- Typical time at high temperature in SCR

  ~ 6 min per regen

- 643 regens x

  6 min/regen x h/60min = 64 h

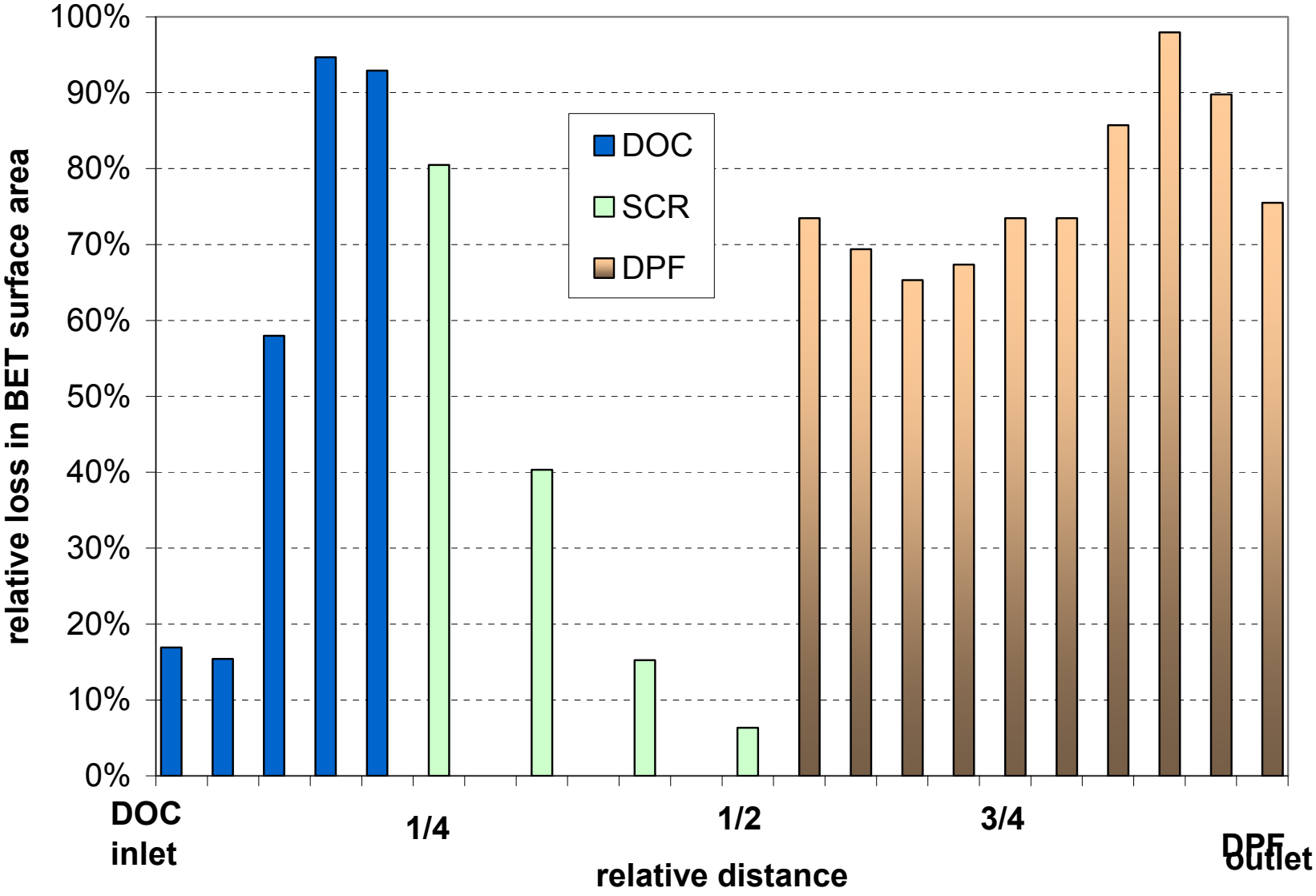
# Vehicle System Performance



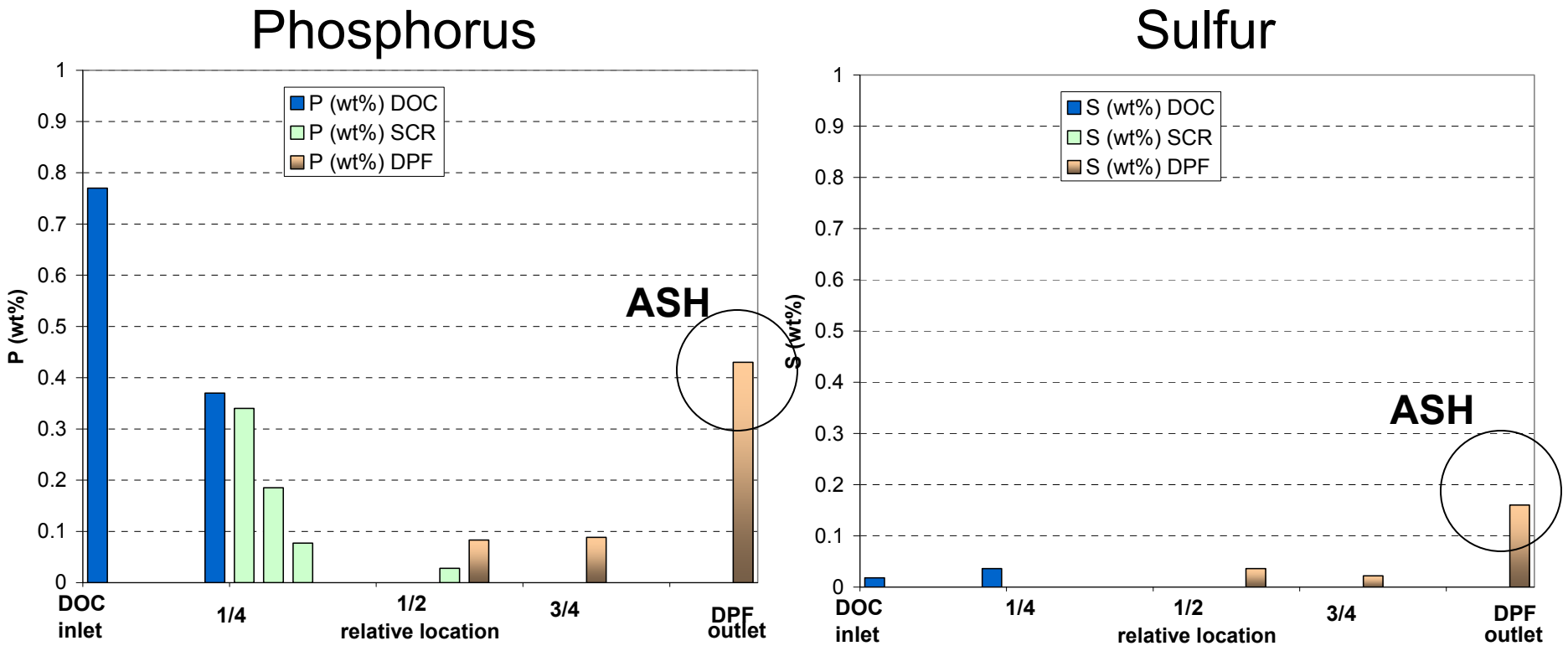

- Loss of DOC activity resulted in higher NOx emissions at 120k mi

# Physical Property Measurements

# Surface Area Loss

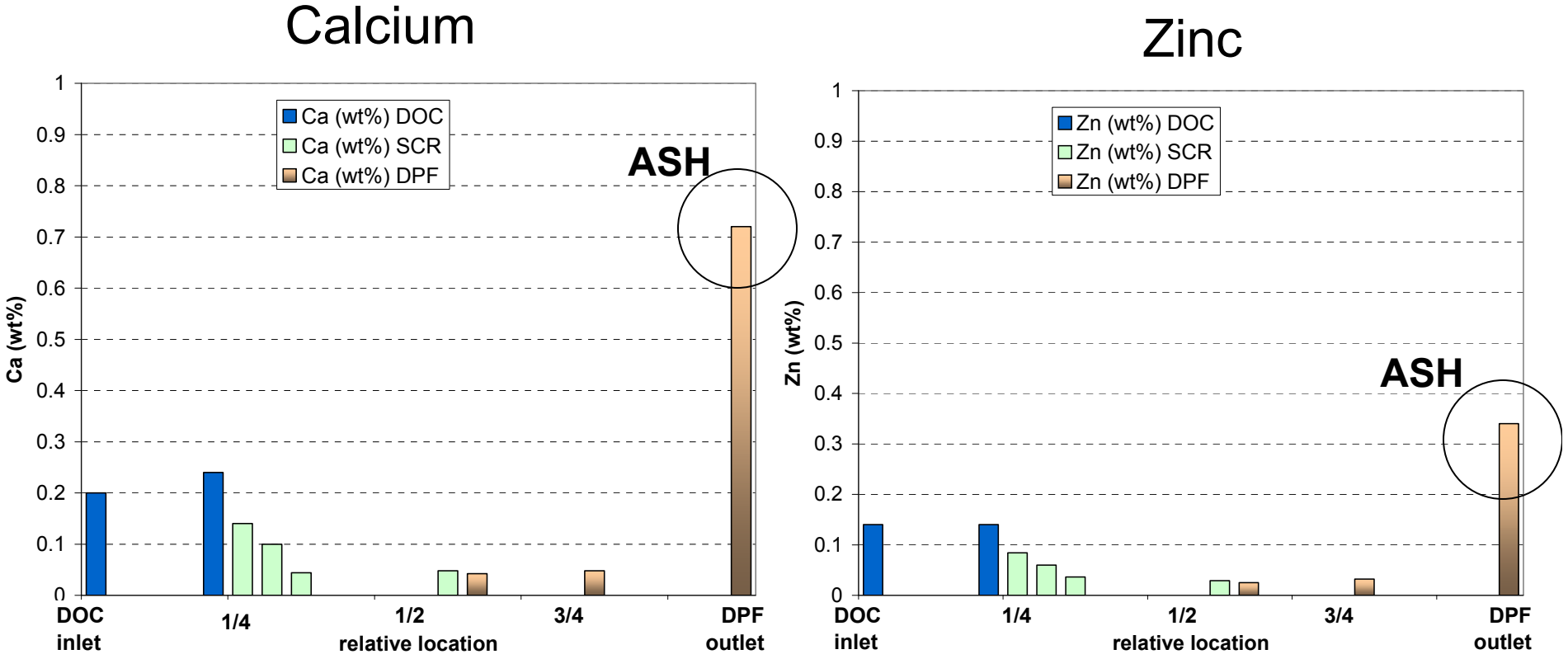


# Distribution of Poisons



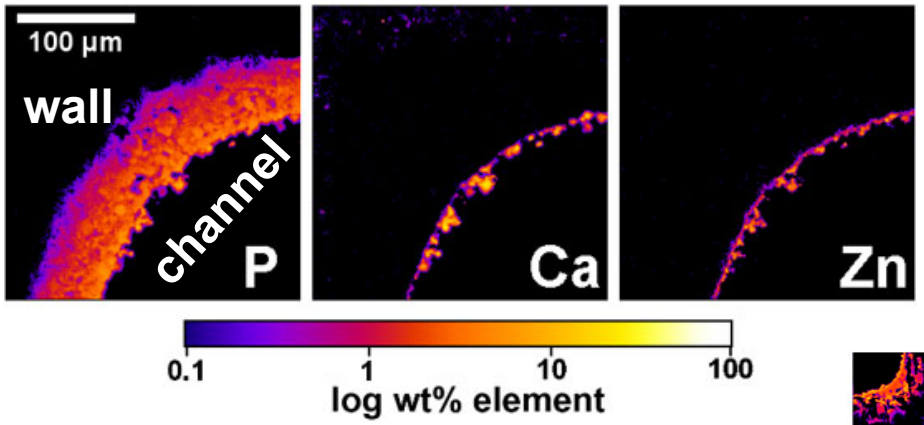

- Phosphorus was highest in DOC inlet and in DPF ash
- Sulfur was low throughout except in DPF ash

# Distribution of Poisons (con't)



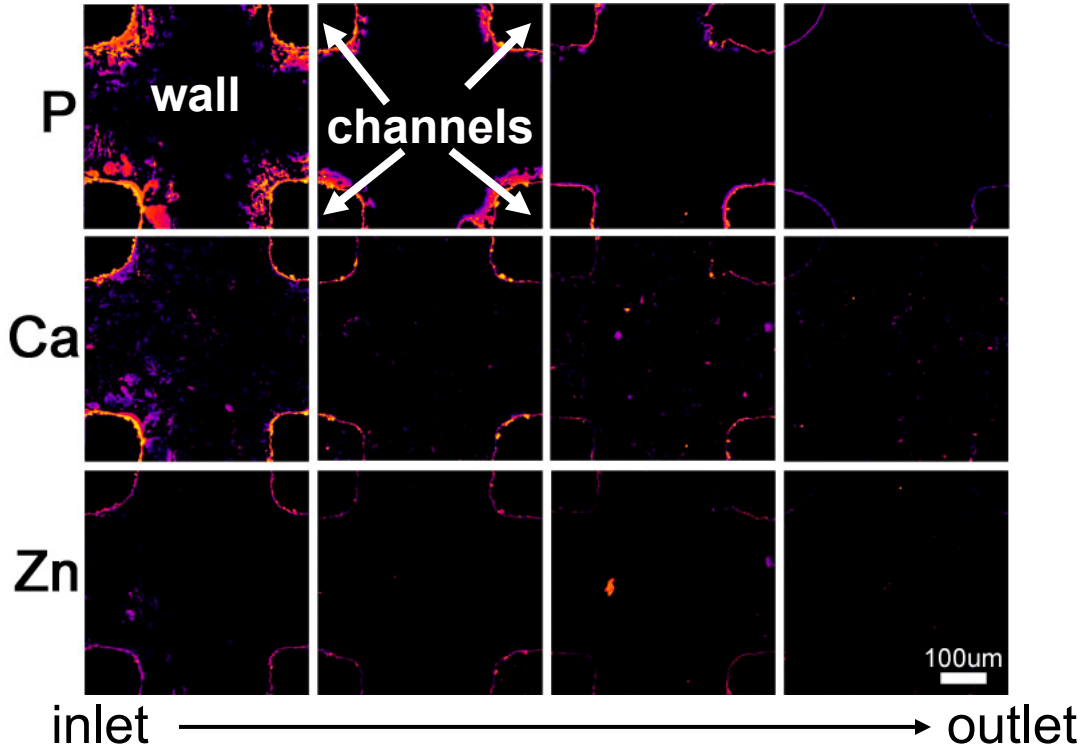

- Some background Ca is in DOC and SCR substrates
- Ca and Zn were highest in DPF ash

# Distribution of Washcoat Poisons




**DOC inlet shows Ca and Zn on surface, P penetration into washcoat**

**SCR catalyst has Ca, Zn, and P glaze decreasing in thickness as distance from inlet increases, some P penetration**



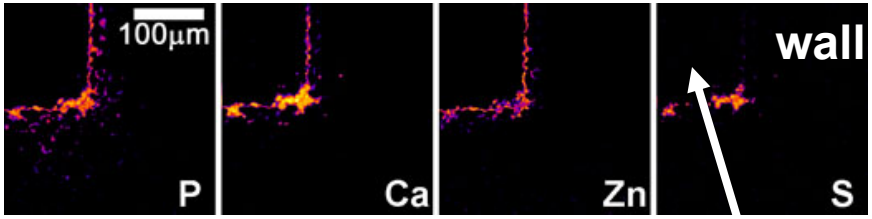
# DPF Ash Accumulation

- Ash removal was performed at 44k, 79k and 112k miles.
- Ash primarily made of $CaSO_4$, $Ca_{19}Zn_2(PO_4)_{14}$, and $CaZn_2(PO_4)_2$

Total Ash Removed = 919 g

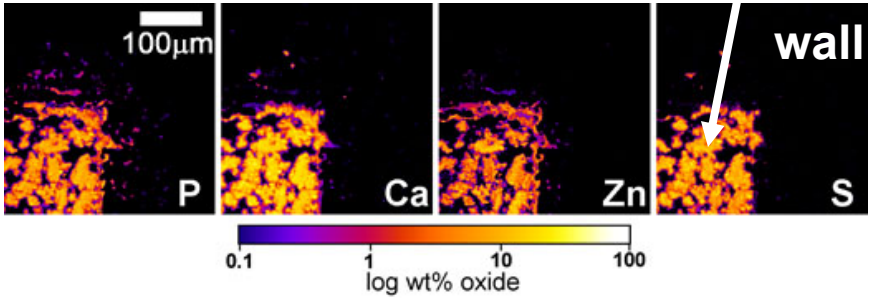
| Engine Hours | Equiv. mi | Ash (g) |
|---|---|---|
| 940 | 44k | 112 |
| 1688 | 79k | 419 |
| 2375 | 112k | 388 |

middle of filter




outlet of filter

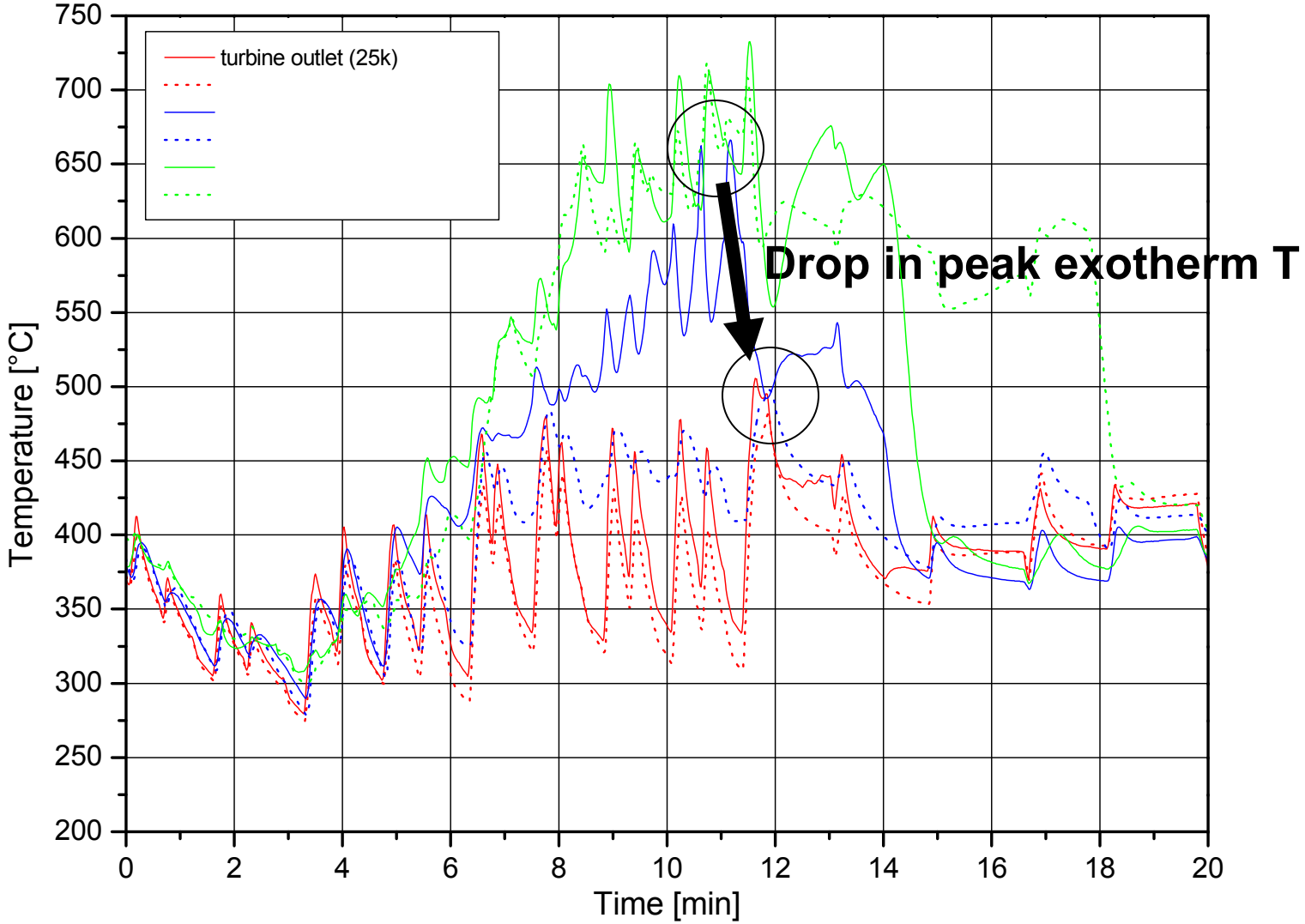
channel



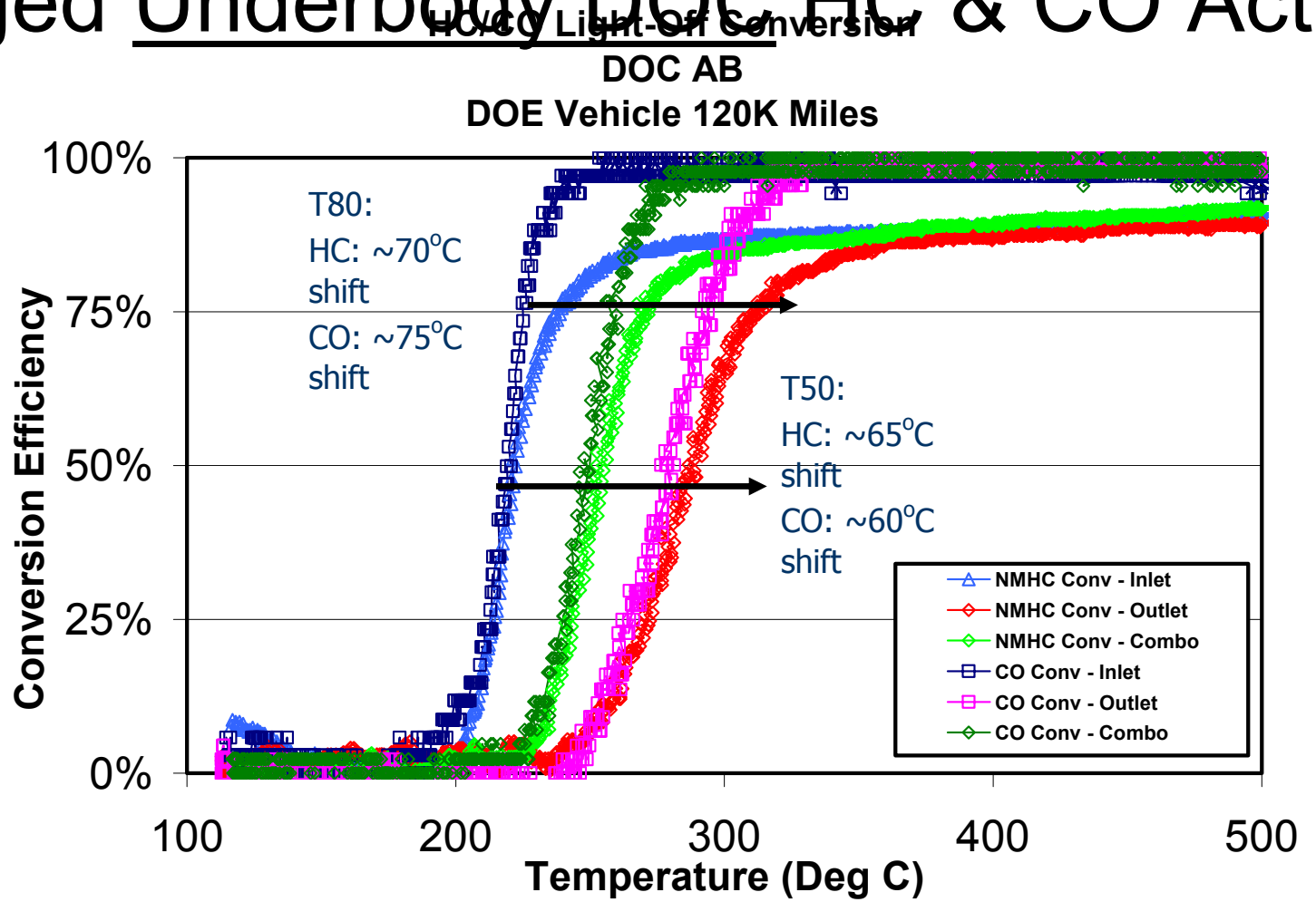

- Ash mainly in channel, not in wall

# Chemical Property Measurements

# Activity of Aged Downpipe DOCs (Exotherm Generation at 25k and 50k mi)

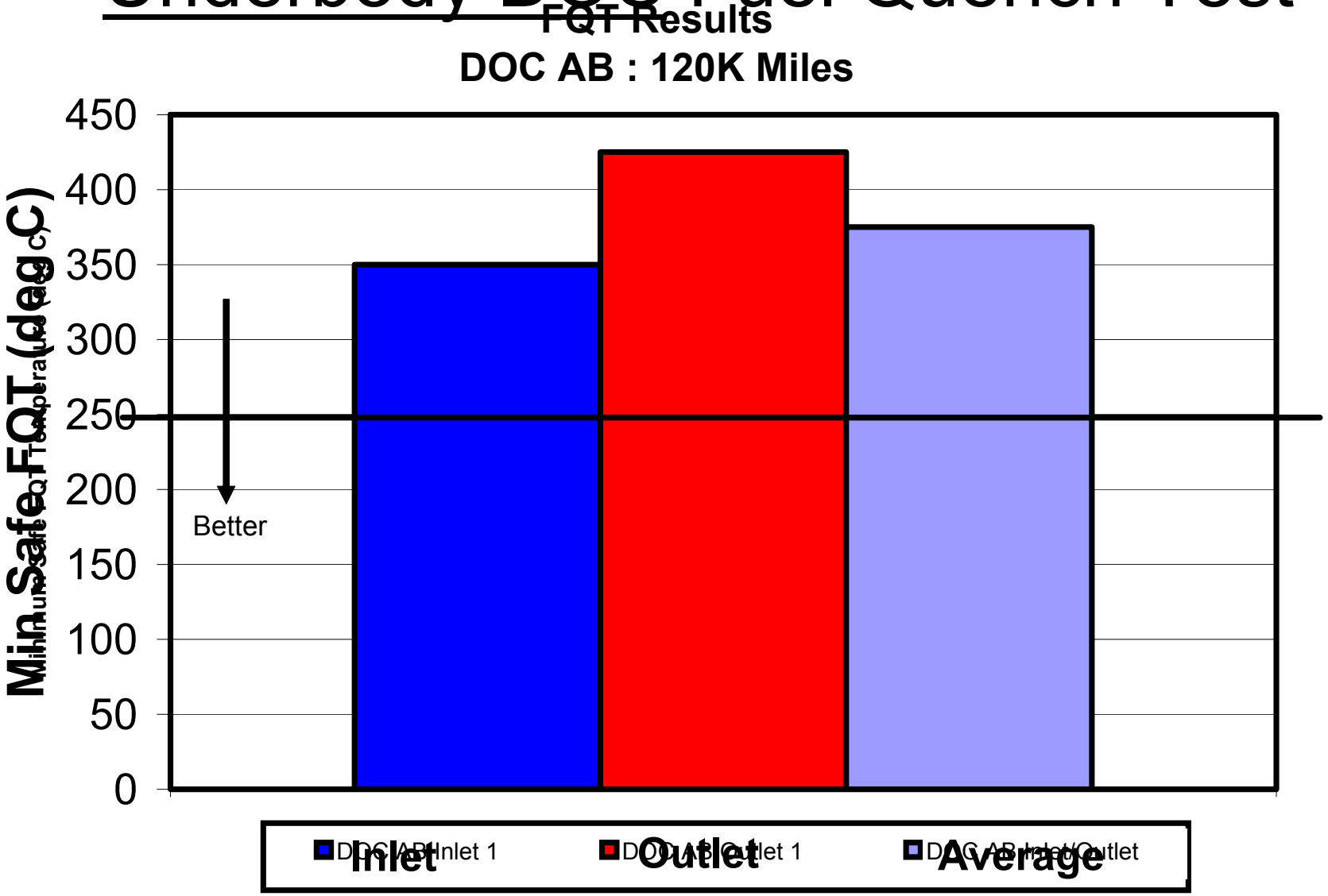


# Aged Underbody DOC HC & CO Activity




- **Key deactivation of inlet is chemical poisoning due to phosphorous deposition**
- **Key deactivation of outlet is due to fuel combustion required for DPF regen**

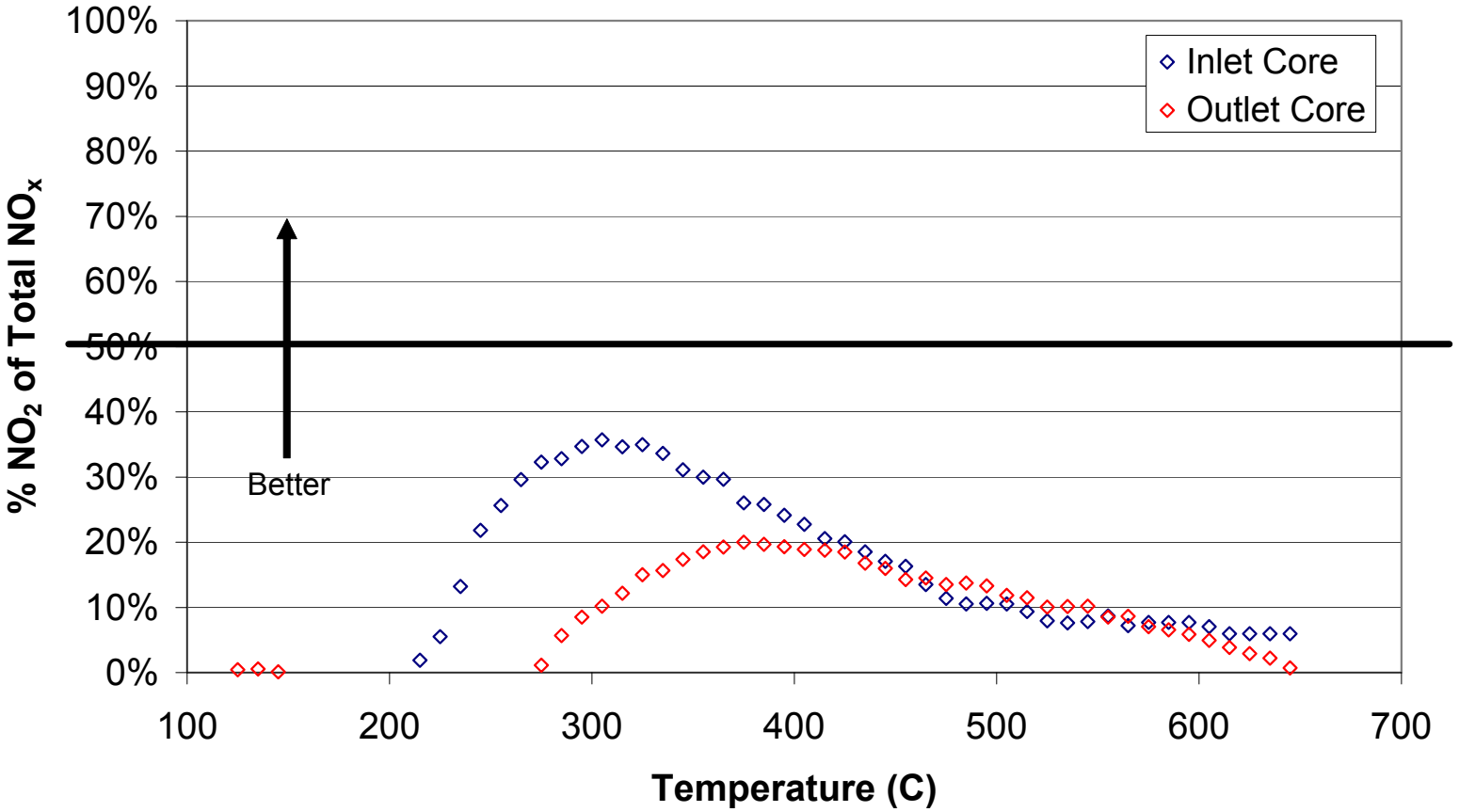
# Underbody DOC Fuel Quench Test




- **DOC outlet requires an inlet of 425°C to maintain DPF regeneration conditions**

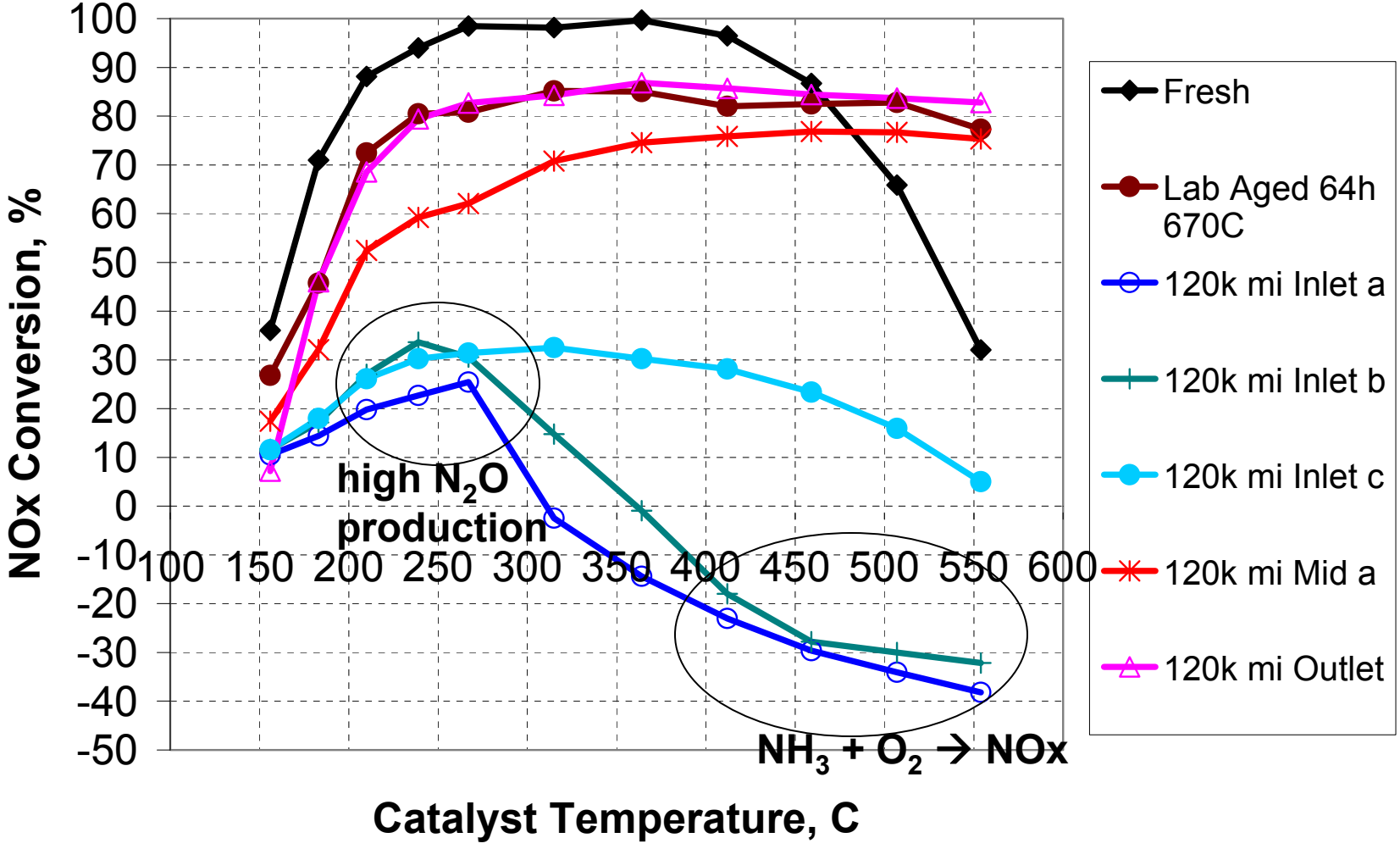
# Underbody DOC $NO_2/NO_x$ Activity

**DOC AB : 120K Miles**



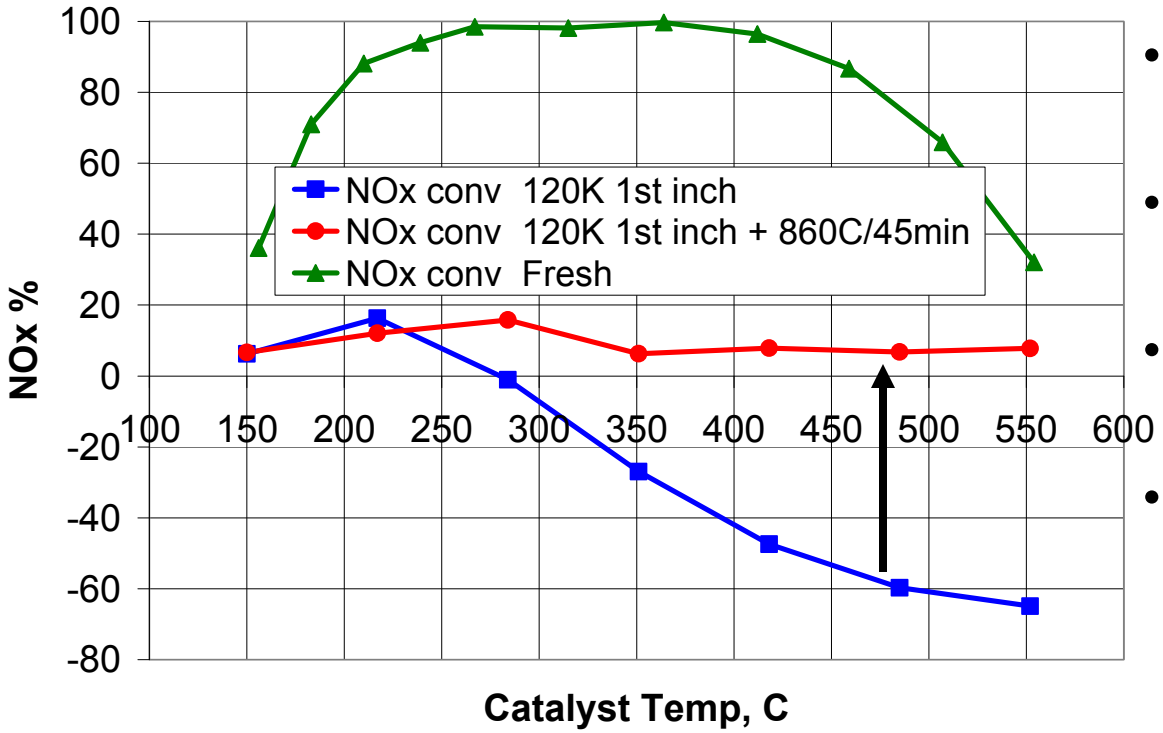

- **NO oxidation is more deactivated at the outlet of the 120k mi engine aged DOC**

# SCR NOx Activity




- **Activity of outlet similar to hydrothermally aged lab piece**
- **Activity of inlet exhibited behavior atypical of base metals**

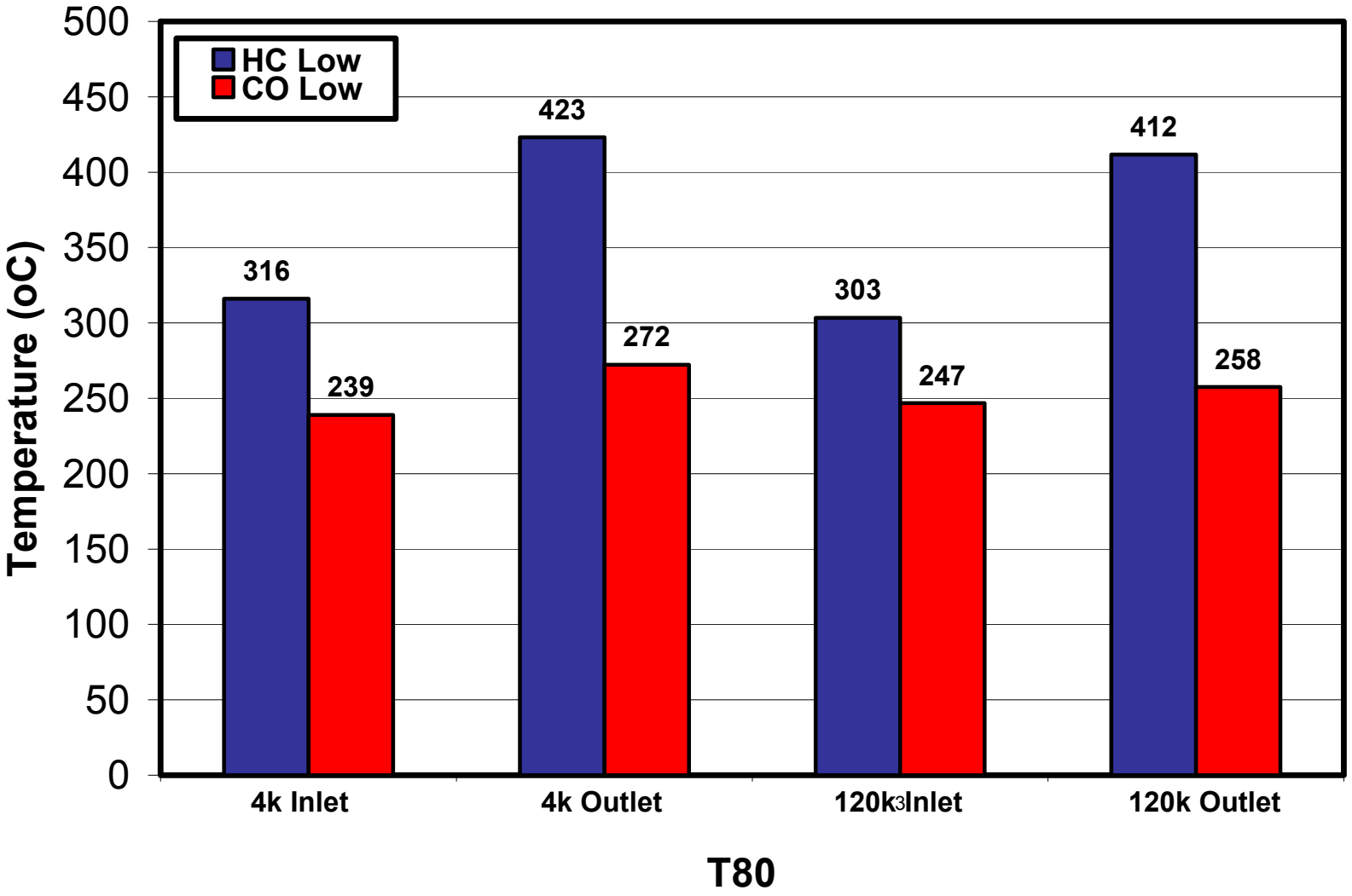
# Deactivation of SCR Inlet




- XRF results: no precious metals
- Ethylene hydrogenation test indicates presence of Pt
- Effects are reversed after 860°C treatment
- Pt below XRF detection limit of 0.002 wt% on SCR inlet is the most likely conclusion

| Catalyst | Ethylene Hydrogenation |
|---|---|
| Fresh | 0.051% |
| 120k engine, outlet | 0.027% |
| 120k engine, 1st (inlet) | 1.27% → Pt effect |
| 120k engine, 1st (inlet) + 860°C/45min | 0.030% |

# Aged DPF HC and CO Activity




- **Stable HC and CO lightoff for the 120k mi aging**

# Conclusions

| Catalyst Component | Key Results |
|---|---|
| **DOC** | • Downpipe catalysts were not durable for warm-up at 50k mi<br>• Underbody DOC inlet contained most poisons but outlet had most activity and surface area loss as result of high T exposure<br>• Loss of surface area resembles data from high T lab aged samples<br>• P deposits decreased from inlet to outlet<br>• Very little sulfur remained |
| **SCR** (Cu/Zeolite) | • SCR aging effects were most severe at inlet and progressively less effect to outlet<br>• P deposits decreased from inlet to outlet<br>• Very little sulfur remained<br>• Some activity loss due to Pt poisoning at inlet (most likely from DOC)<br>• Remainder of activity loss due to high temperature<br>• Outlet had activity similar to 670°C lab aged piece |
| **DPF** | • Fairly uniform surface area loss<br>• Ash primarily made of $CaSO_4$, $Ca_{19}Zn_2(PO_4)_{14}$, and $CaZn_2(PO_4)_2$<br>• Stable HC and CO lightoff for the 120k mi aging |

# Acknowledgements

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