Experimental Determination of Fuel Sulfur Effects on Oxidation and Lean-NO_X Diesel Engine Catalysts

Authors: W. Scott Wayne
Nigel Clark
Mirdul Gautam
Donald W. Lyons
Jason Snyder

Thanks to: Wendy Clark, John Orban, Shouxian Ren, John Storey and Shawn Whitacre and the DECSE Research Team

West Virginia University
Morgantown, West Virginia

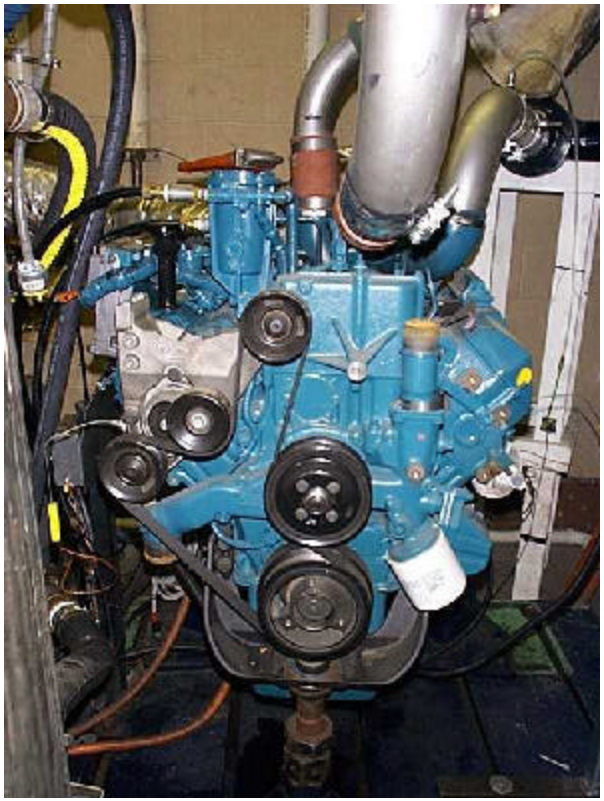
Objectives

- Evaluate diesel oxidation catalyst (DOC) and lean-NO_x catalyst technology for the first 250 hours of operation
  - Determine optimal reductant rates for lean-NO_X catalyst operation
- Determine the effects of fuel sulfur concentration on the aftertreatment devices

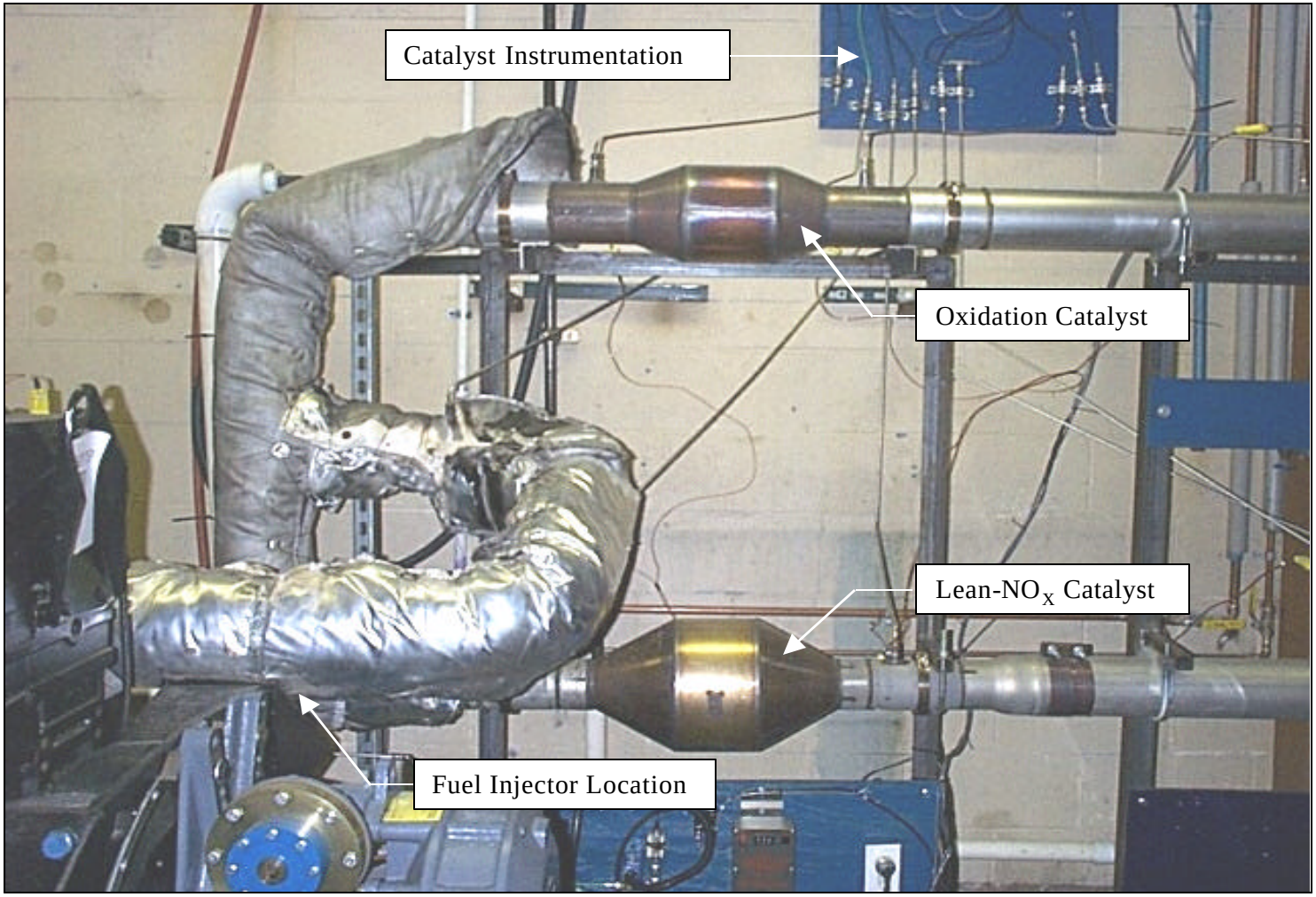
Test Engines and Fuels

- **Cummins ISM370ESP** (10.8 liter)
  Rated Power (370 hp at 2100 rpm)
  Rated Torque (1350 ft-lb at 1200 rpm)
- **Navistar T444E** (International) (7.3 liter)
  Rated Power (210 hp at 2300 rpm)
  Rated Torque (520 ft-lb at 1500 rpm)
- The four sulfur levels of diesel fuel used in the evaluations were 3ppm, 30ppm, 150ppm and 350ppm

Aging Engines



Catalyst Aging Configuration (Split Flow)



Setup for Split Exhaust in the Engine Test Cell

- Split ratio is equal to the CO_2 produced with the split exhaust divided by the CO_2 generated by the full flow case
- Exhaust back pressure was balanced for the appropriate split using two valves and a dummy catalyst

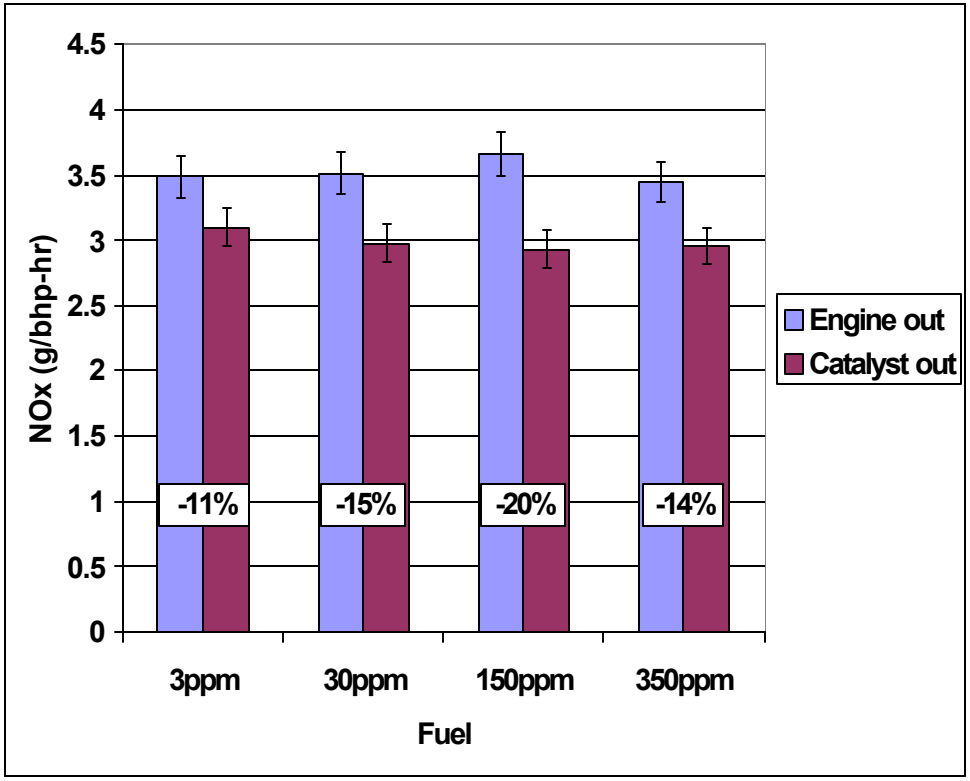
Steady State Evaluation Cycles

- The table below contains set points of the six modes used in characterizing emissions of the aftertreatment devices
- Data were not taken on modes 1 (idle) and 6 (cool down)

	OICA (Cummins ISM)			Nav9 (Navistar T444E)		
Mode	Time (min)	Speed (rpm)	Torque (ft-lb)	Time (min)	Speed (rpm)	Torque (ft-lb)
1	2	700	0	2	700	0
2	20	1888	248	20	1000	81
3	20	1585	595	20	1250	122
4	20	1888	992	20	2000	122
5	20	1282	1244	20	2200	406
6	5	1200	-100	5	1200	-100

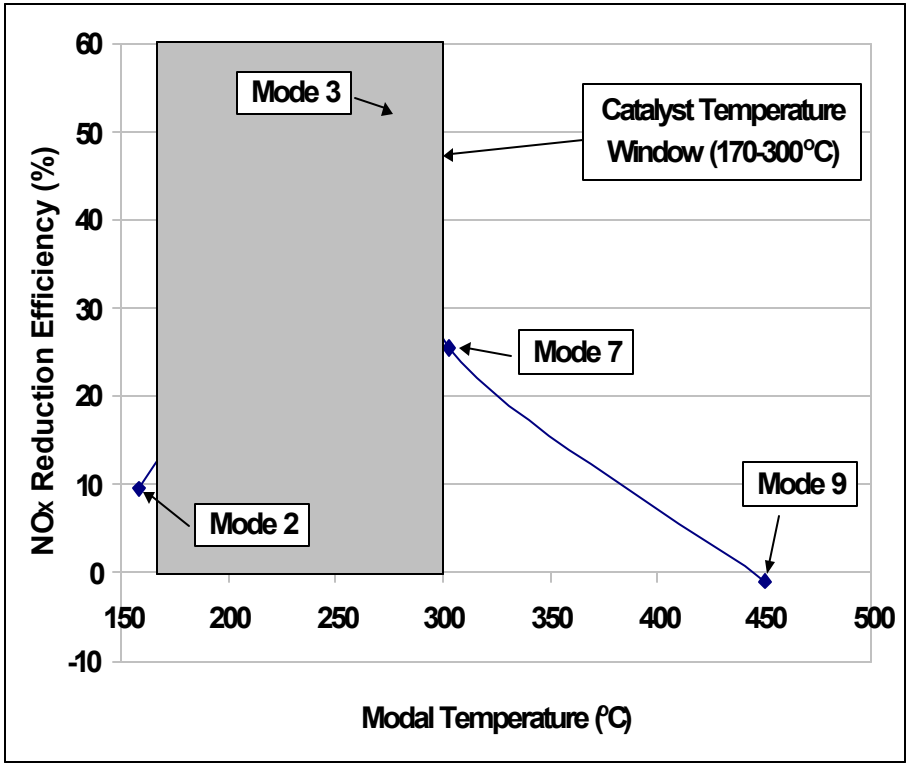
Low Temperature Catalyst Out and Engine Out NO_X Emissions for Fresh Catalysts

- NO_X reduction efficiencies (averaged over 4 modes) of approximately 15% were achieved
- Reduction efficiencies were based on weighted emissions for the whole test



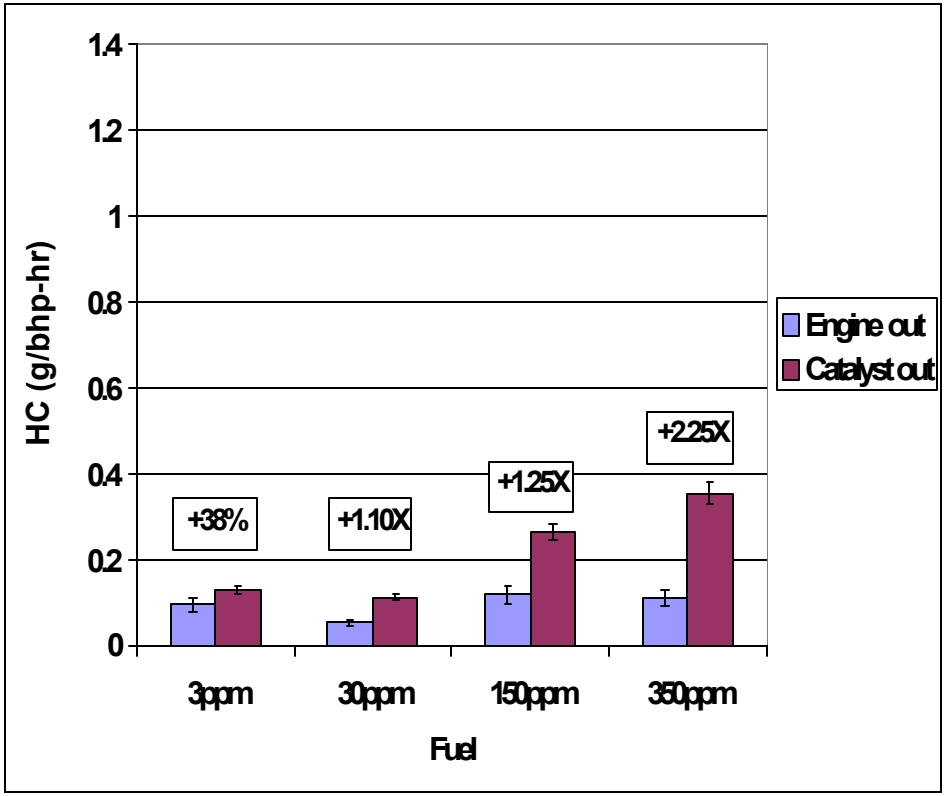
Low Temperature Catalyst NO_X Reduction Efficiencies

- The temperature window for the low temperature catalysts is 170°-300°C
- Only the modes that reached temperatures within this window showed significant NO_X reduction



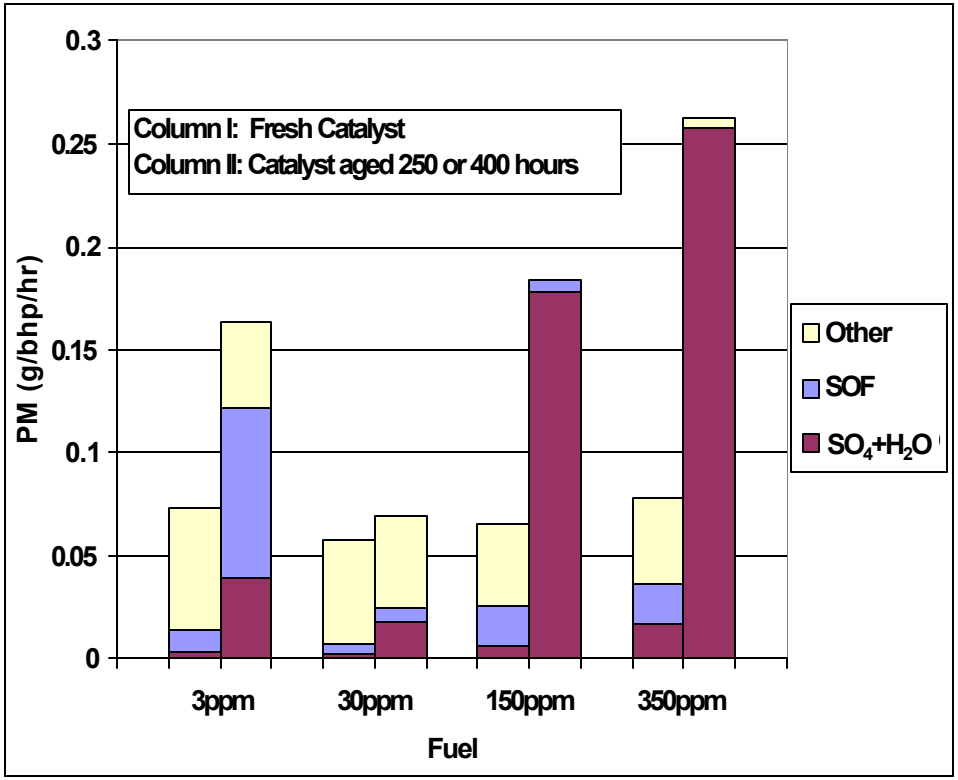
Low Temperature Catalyst Out and Engine Out HC Emissions for Fresh Lean-NO_X Catalysts

- Fuel sulfur directly impacts the production of HC emissions
- 150ppm and 350ppm fuel sulfur levels increased 1.25 and 2.25 times over engine out emissions



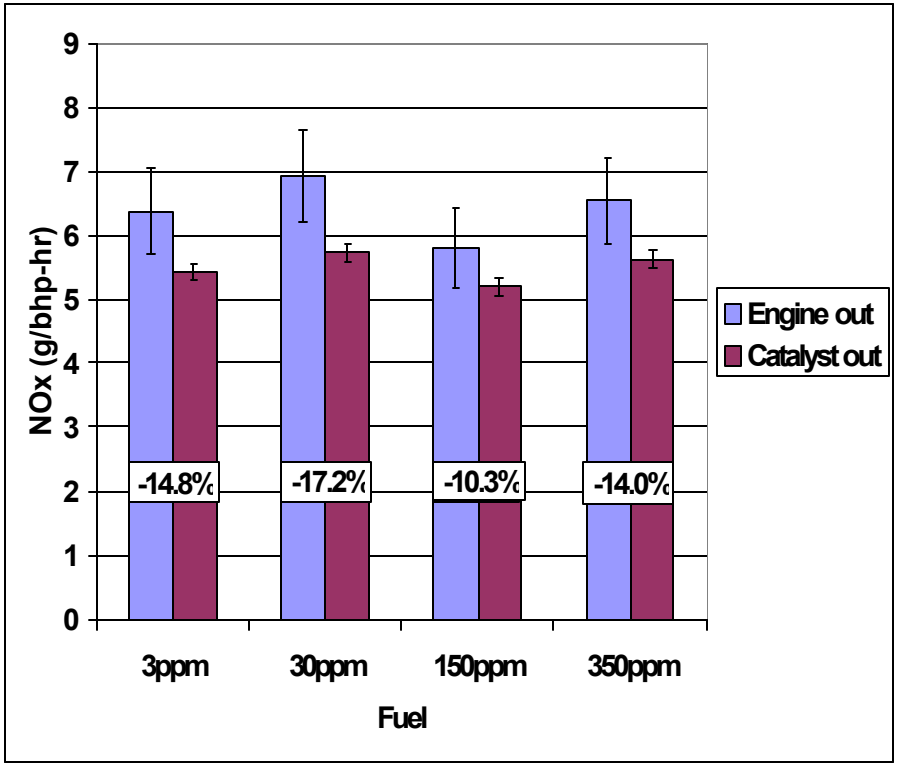
Low Temperature Lean-NO_X Catalyst PM Emissions

- Sulfate emissions increase due to increasing fuel sulfur levels
- With 350ppm fuel PM emissions for aged catalysts were 3.3 times higher than fresh catalyst due to a 14 fold increase in SO_4



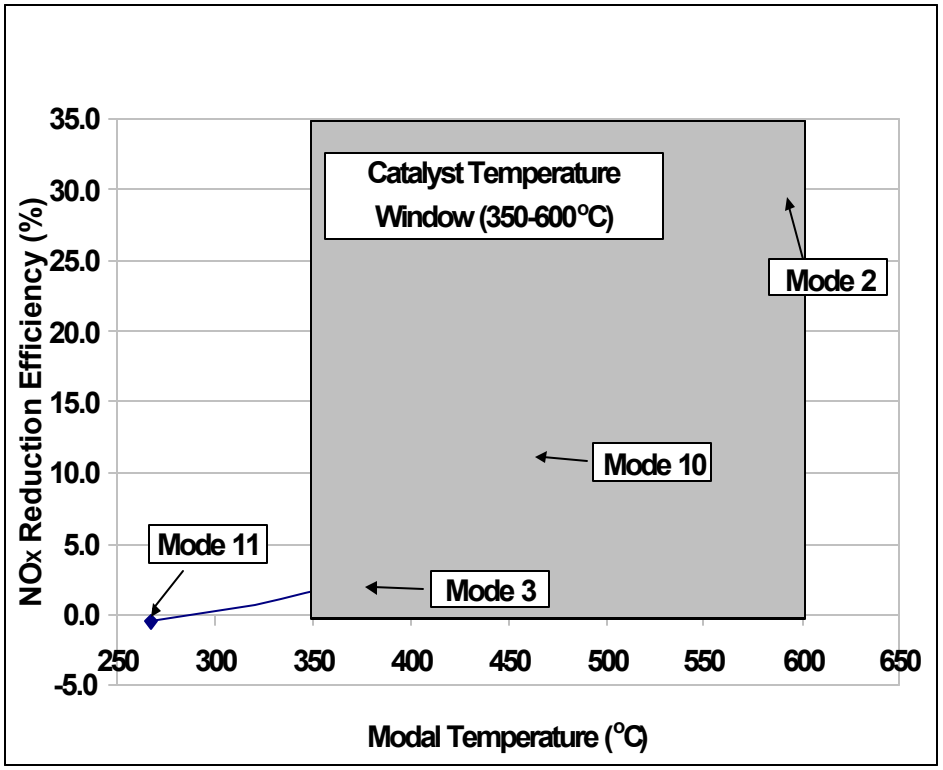
High Temperature Catalyst Out and Engine Out NO_X Emissions for Fresh Catalysts

- NO_X reduction efficiencies (averaged over 4 modes) of approximately 14% were achieved
- Reduction efficiencies were based on weighted emissions for the whole test



High Temperature Catalyst NO_X Reduction Efficiencies

- The temperature window for the high temperature catalysts is 350°-600°C
- Only the modes that reached temperatures within this window showed significant NO_X reduction

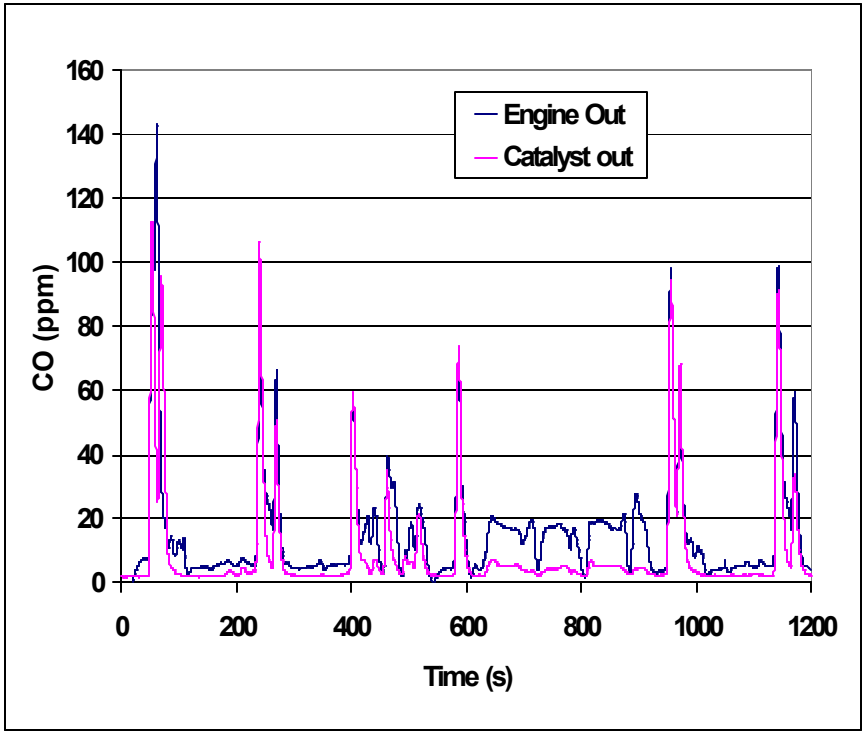


Continuous CO Data for DOC Prior to Aging With 3ppm Fuel (Cummins Engine FTP)

- Fresh catalysts show rapid onset of catalyst activity with low sulfur fuel
- % Reduction

  CO: 53.6%

  PM: 10.1%

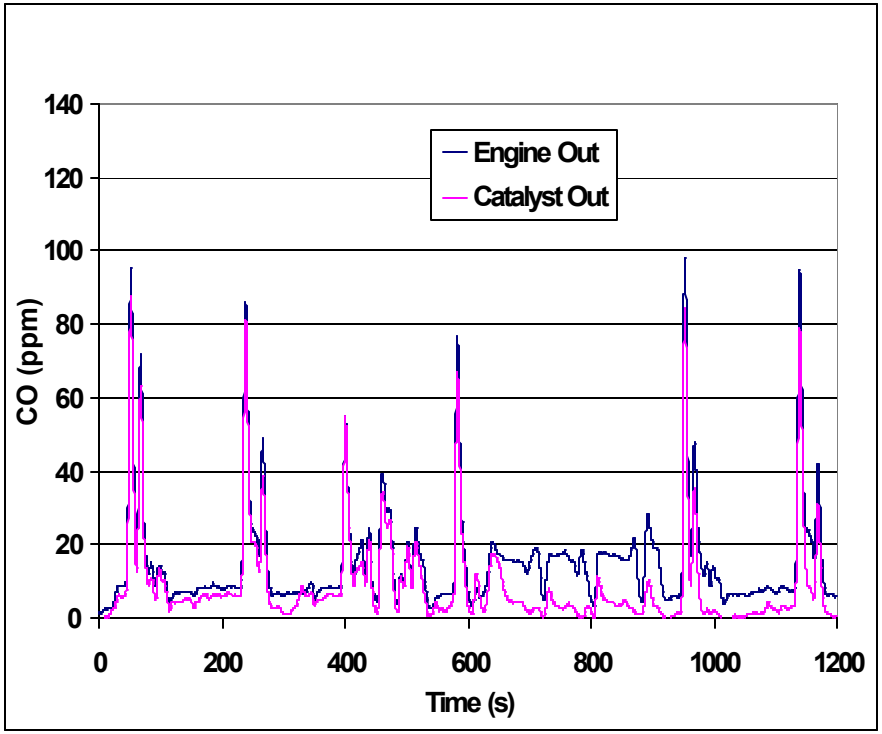


Continuous CO Data for DOC After 250 Aging Hours with 350ppm fuel (Cummins Engine FTP)

- Catalyst activity is impaired with catalyst age and high sulfur fuel
- % Reduction

  CO: 33.0%

  PM: 22.0%



Conclusions

- Lean-NO_X catalysts caused modest, but not substantial, reductions in NO_X emissions
- Statistically, there was no effect of fuel sulfur level on the NO_X reduction efficiencies
- Both the high and low temperature lean-NO_X catalysts increased the tailpipe production of HC due to the slip of injected reductant
- The low temperature lean-NO_X catalysts with 350ppm fuel showed an increase of 3.3 times of TPM over fresh catalysts
- Continuous CO data provide insight into catalyst deactivation by sulfur