13th CRC ON-ROAD VEHICLE EMISSIONS WORKSHOP

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Session 8: Heavy Duty Buses

Oxidation Catalyst Effect on CNG Transit Bus Emissions

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ABSTRACT

Recently, the California Air Resources Board (CARB) has reported that tailpipe emissions samples from a compressed natural gas (CNG)-fueled transit bus without after-treatment had measurable levels of some toxic compounds and nanoparticle (<50 nm) and mutagen emissions (Ames assay) that in some cases were greater than that of a similar diesel transit bus equipped with after-treatment including oxidation catalyst and particulate trap and fueled by ultra-low sulfur diesel (ULSD). Therefore, CARB has investigated the effectiveness of oxidation catalyst (OC) control for CNG bus applications. This study includes results for regulated non-methane hydrocarbon (NMHC) emissions, non-regulated hydrocarbon emissions of toxic risk significance, and total particulate matter (PM). Two driving cycles were investigated: the Central Business District (CBD) cycle and Steady-State (SS) cruise condition at 55 mph.

The catalyst showed reduction of total PM, total hydrocarbons (HC), NMHC, and carbon monoxide (CO). Formaldehyde (HCHO) emissions were reduced by the catalyst by over 95% over both CBD and SS cycles. 1,3-butadiene emissions were reduced to levels below detection. However, measurements were highly variable. Toxic aromatic HC's such as benzene also appeared to be reduced by the catalyst, but a larger data set is required to establish statistical significance. Little effect of the catalyst was found on methane (CH_4) and NO_X.

Background

- CARB has reported benefits offered by diesel transit bus with CRT and ECD-1 relative to benefits offered by CNG transit bus without after-treatment

- This study focuses on evaluation of oxidation catalyst for CNG bus applications

References: **12th CRC On-Road Vehicle Emissions Workshop, Apr. 15-17, 2002**

SAE Tech. Paper 2003-01-1900

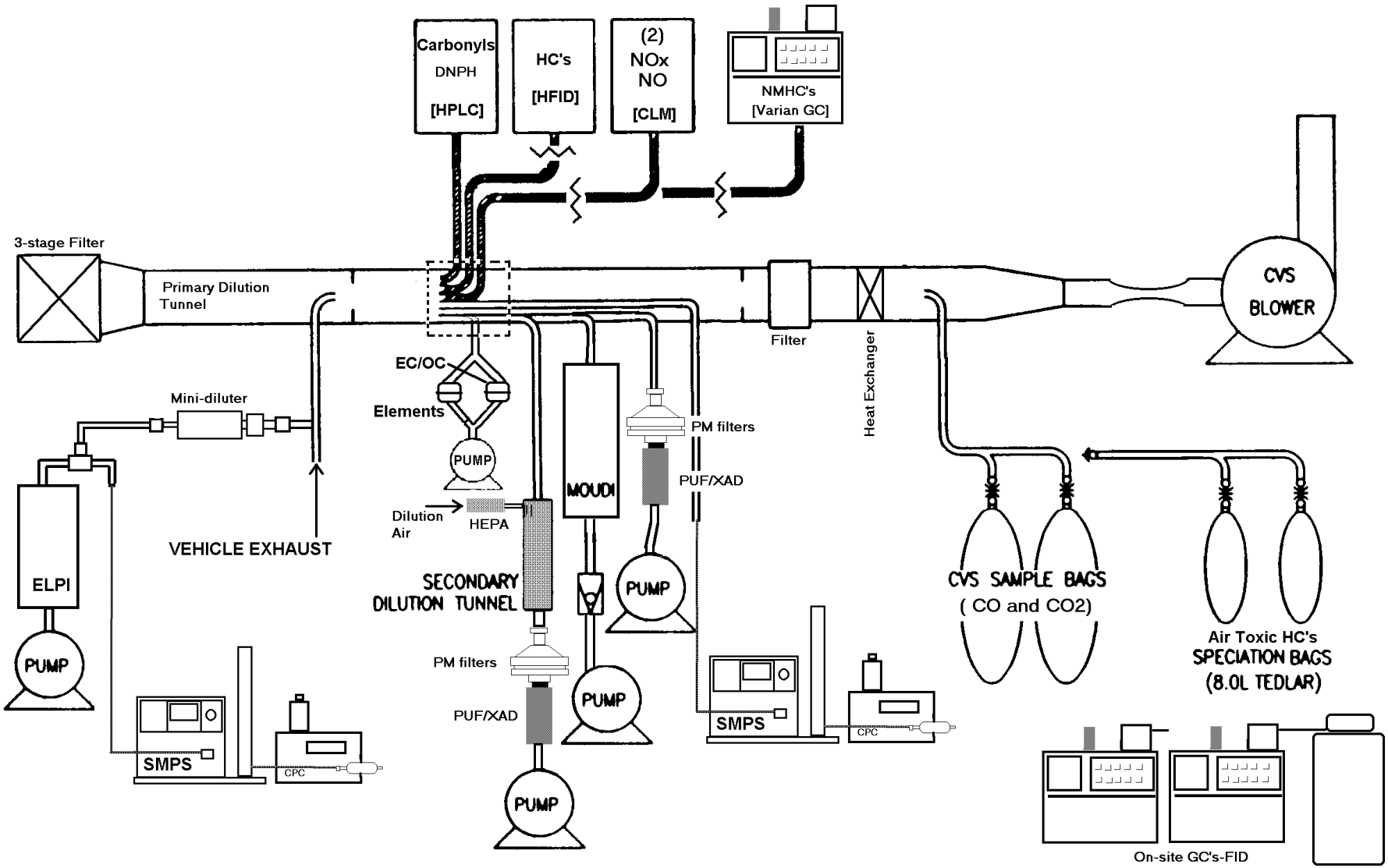
Environ. Sci. Technol. 2002, Vol. 36, No. 23, pp.5041-5050

SAE Tech. Paper 2002-01-1722

Scope

- Chassis dynamometer testing at CARB's Heavy-Duty Emissions Laboratory in Los Angeles
- CBD Cycle and Steady-State 55mph Cruise
- Exhaust Emission Profile Speciation:
  - Criteria gases and PM
  - Other pollutants of interest: NMHC, NO2, CO2
  - Un-regulated toxic hydrocarbons: aromatics, carbonyls, PAHs
  - Extractions for Ames Assay
  - Elements and EC/OC emissions
  - Ultrafine particle (<100nm) sizing

CARB's Chassis Dynamometer Laboratory

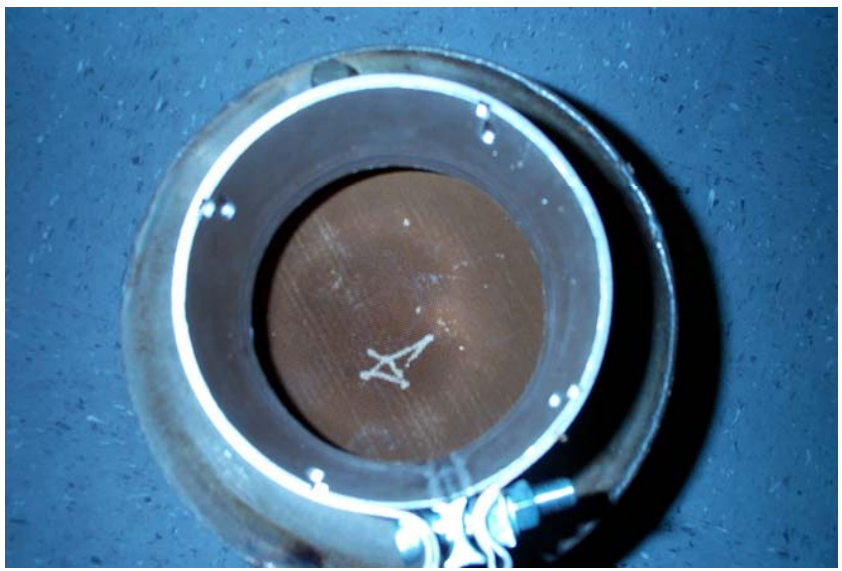


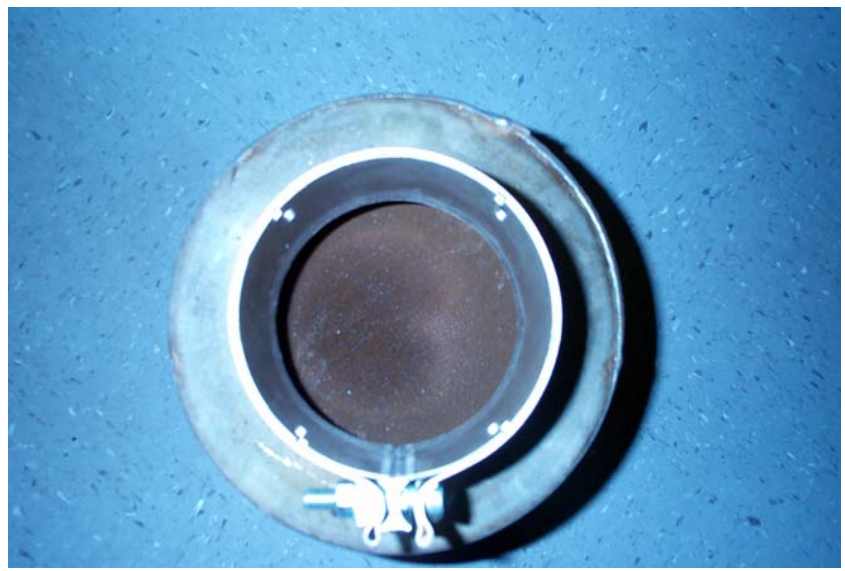
TEST BUS

(CWstprt CNG w/OxiCat)

	CWstprt
engine	2001 Cummins Westport C Gas Plus
chassis	New Flyer 40 passenger
after-treatment	OEM Catalyst
fuel	pipeline fuel meeting CARB spec's

Catalyst for DDC Series 50G Transit Bus

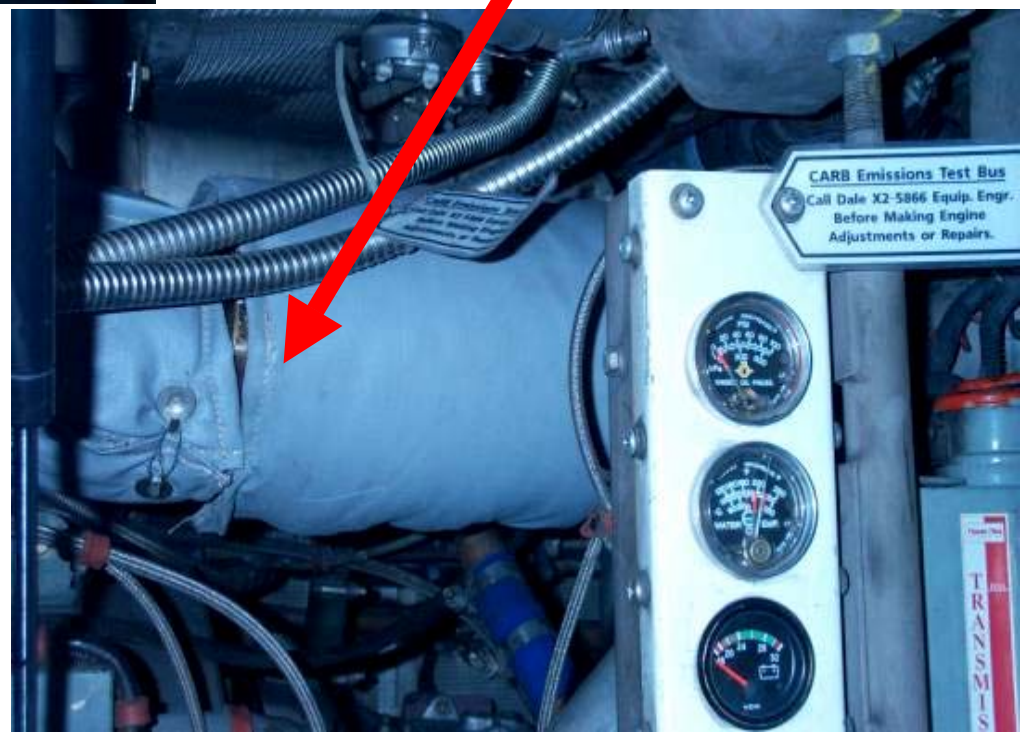




TEST BUS

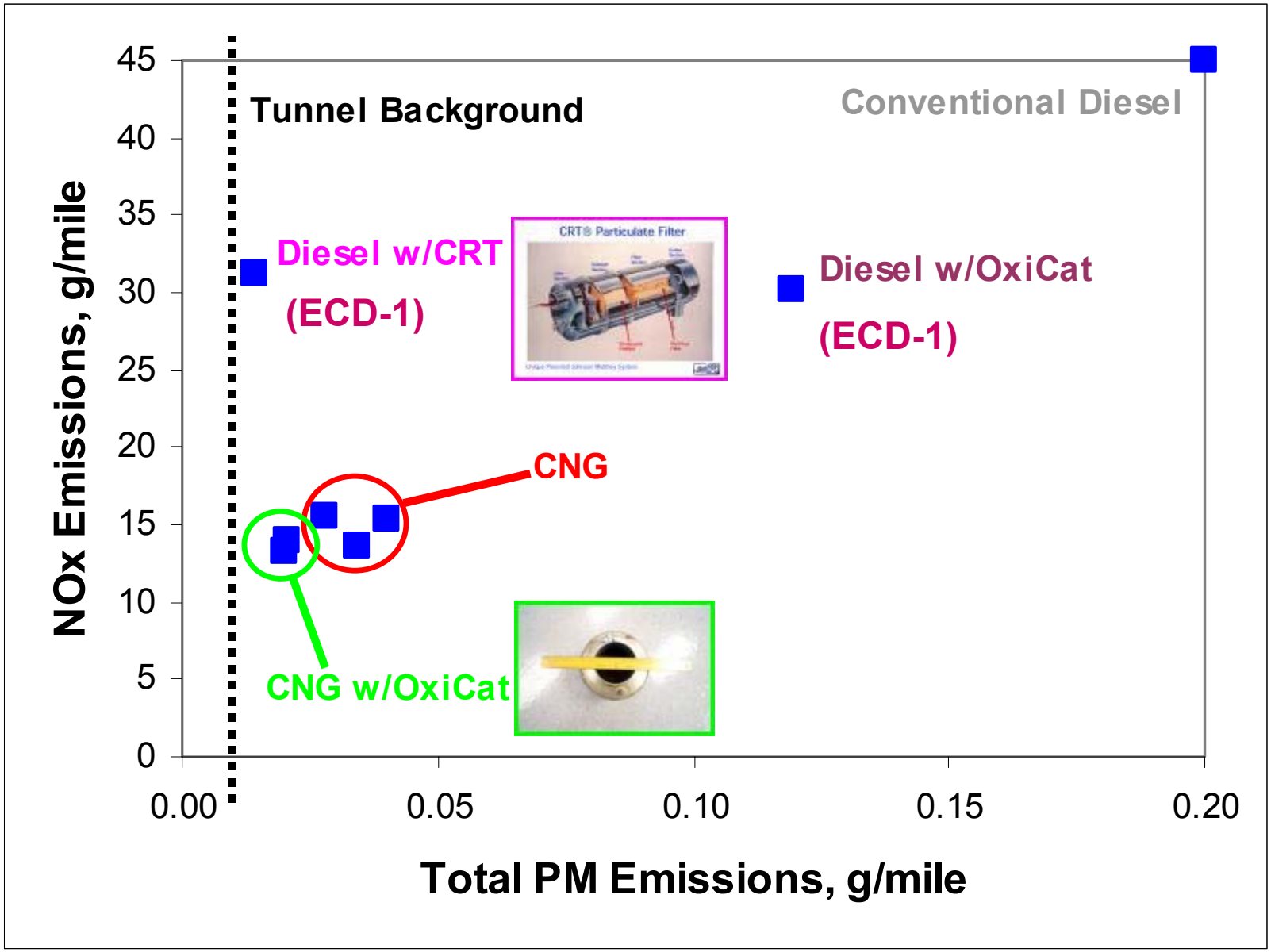
(DDC CNG w/OxiCat)

Oxidation Catalyst

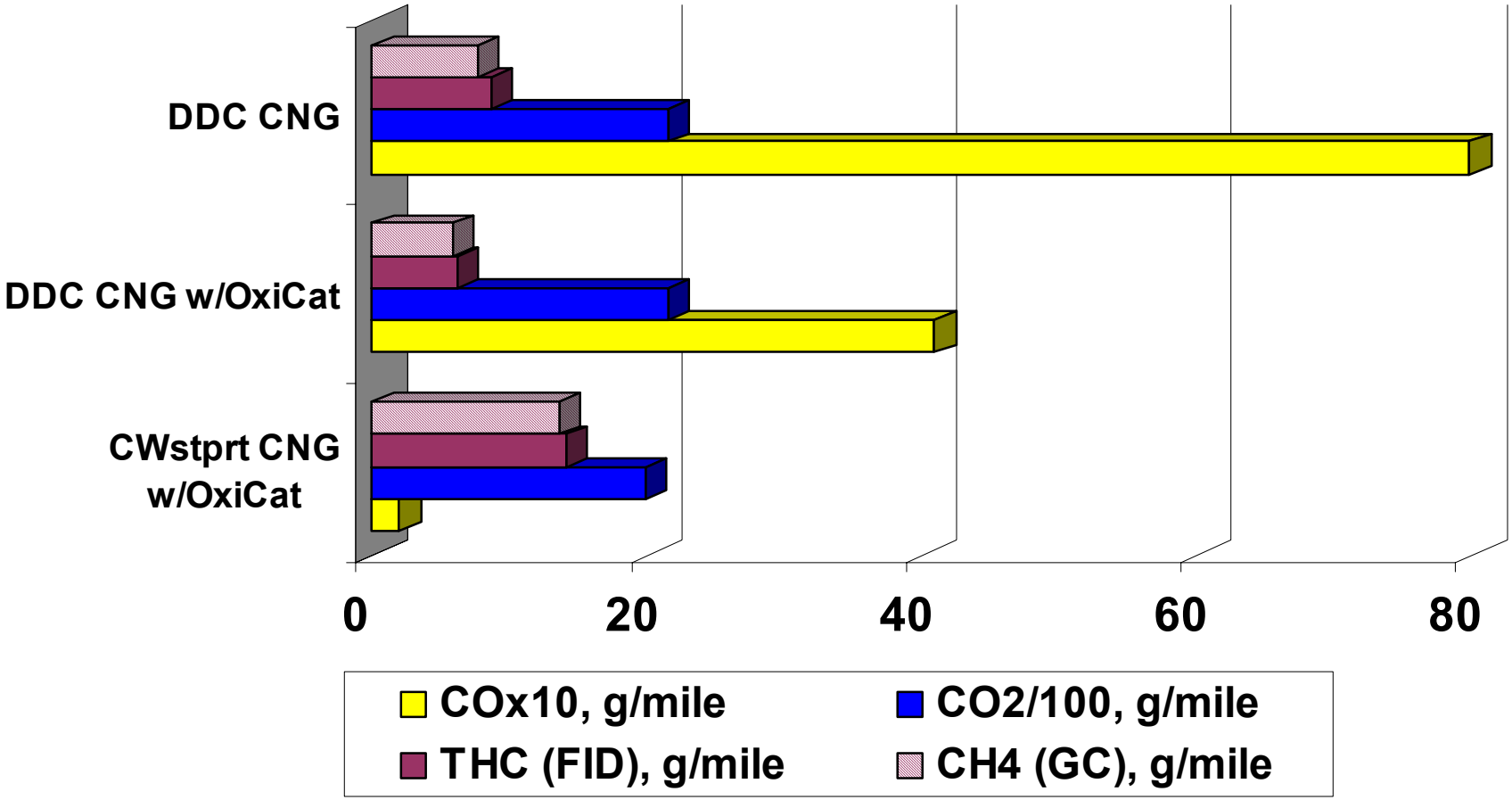


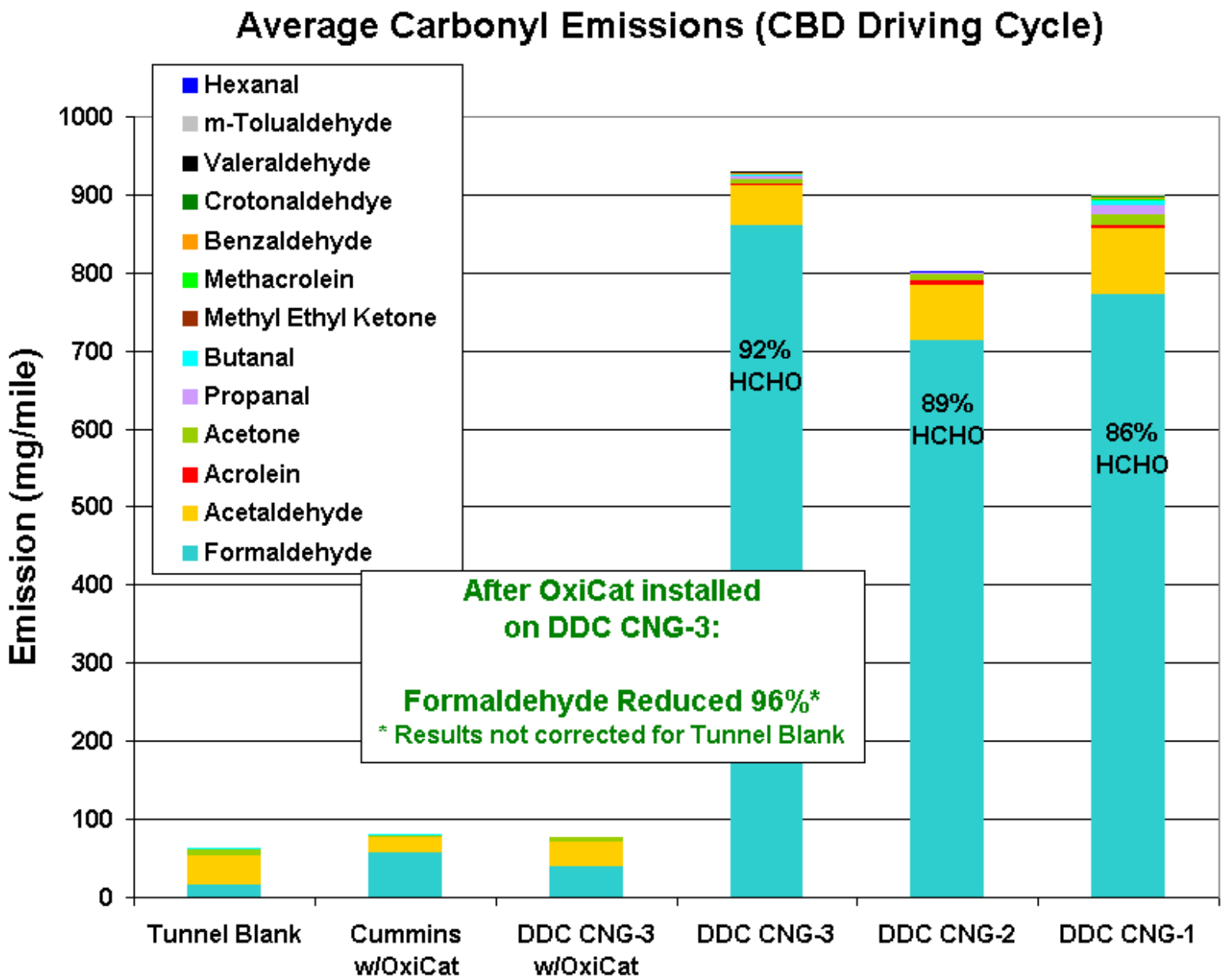
	DDC CNG w/OxiCat
engine	2000 DDC Series 50G
chassis	New Flyer 40 passenger
after-treatment	with and without OEM catalyst
fuel	pipeline fuel meeting CARB spec's

Average NO_X and PM Emissions - CBD



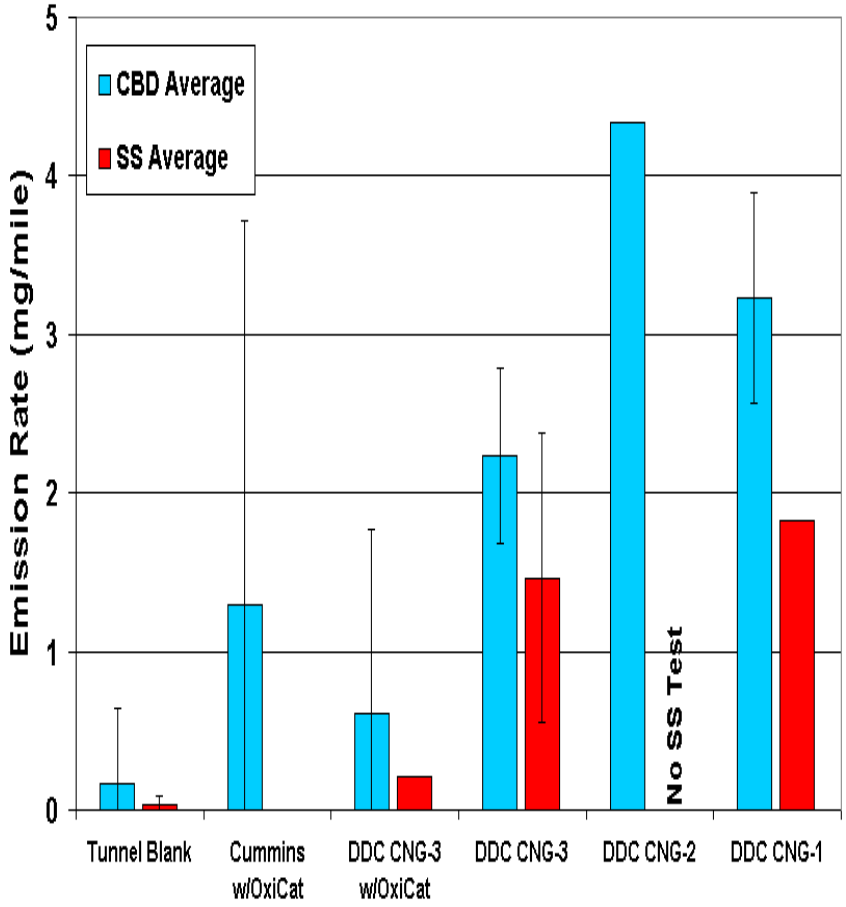
Average HC, CO2, and CO Emissions - CBD




Average Carbonyl Emissions (CBD Driving Cycle)
Hexanal
m-Tolualdehyde
Valeraldehyde
Crotonaldehdye
Benzaldehyde
Methacrolein
Methyl Ethyl Ketone
Butanal
Propanal
Acetone
Acrolein
Acetaldehyde
Formaldehyde
Emission (mg/mile)
1000
900
800
700
600
500
400
300
200
100
0
92% HCHO
89% HCHO
86% HCHO
After OxiCat installed on DDC CNG-3:
Formaldehyde Reduced 96%*
* Results not corrected for Tunnel Blank
Tunnel Blank
Cummins w/OxiCat
DDC CNG-3 w/OxiCat
DDC CNG-3
DDC CNG-2
DDC CNG-1

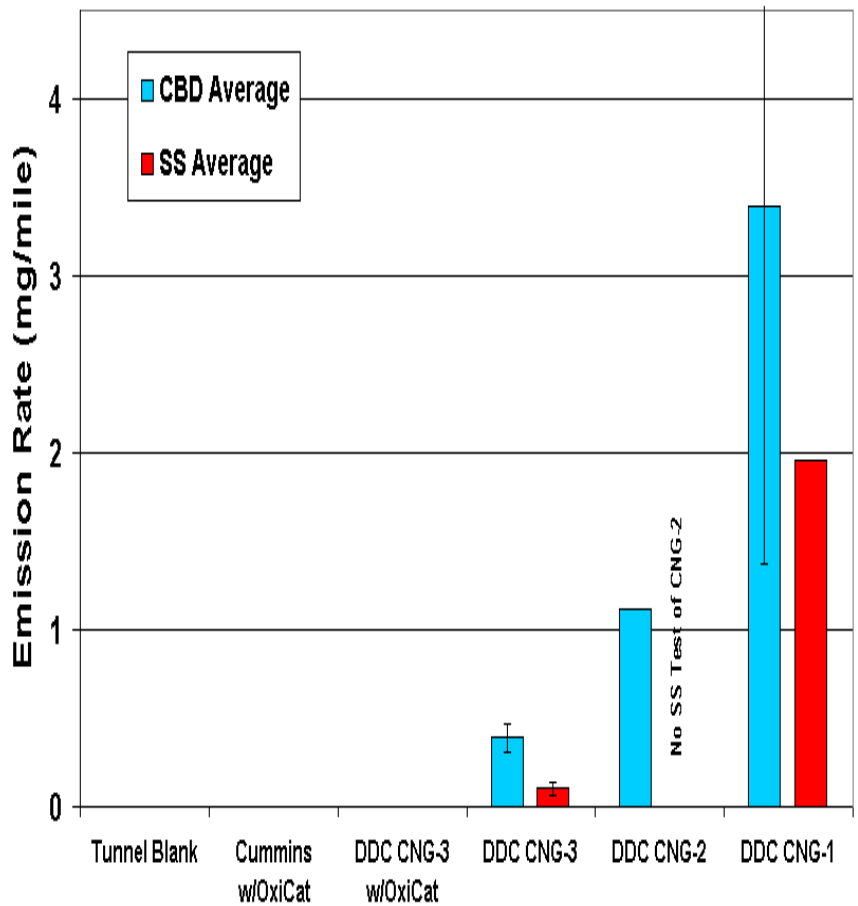
Benzene Emission by Driving Cycle

(Error bars represent 2 std. dev. of replicate measurements)

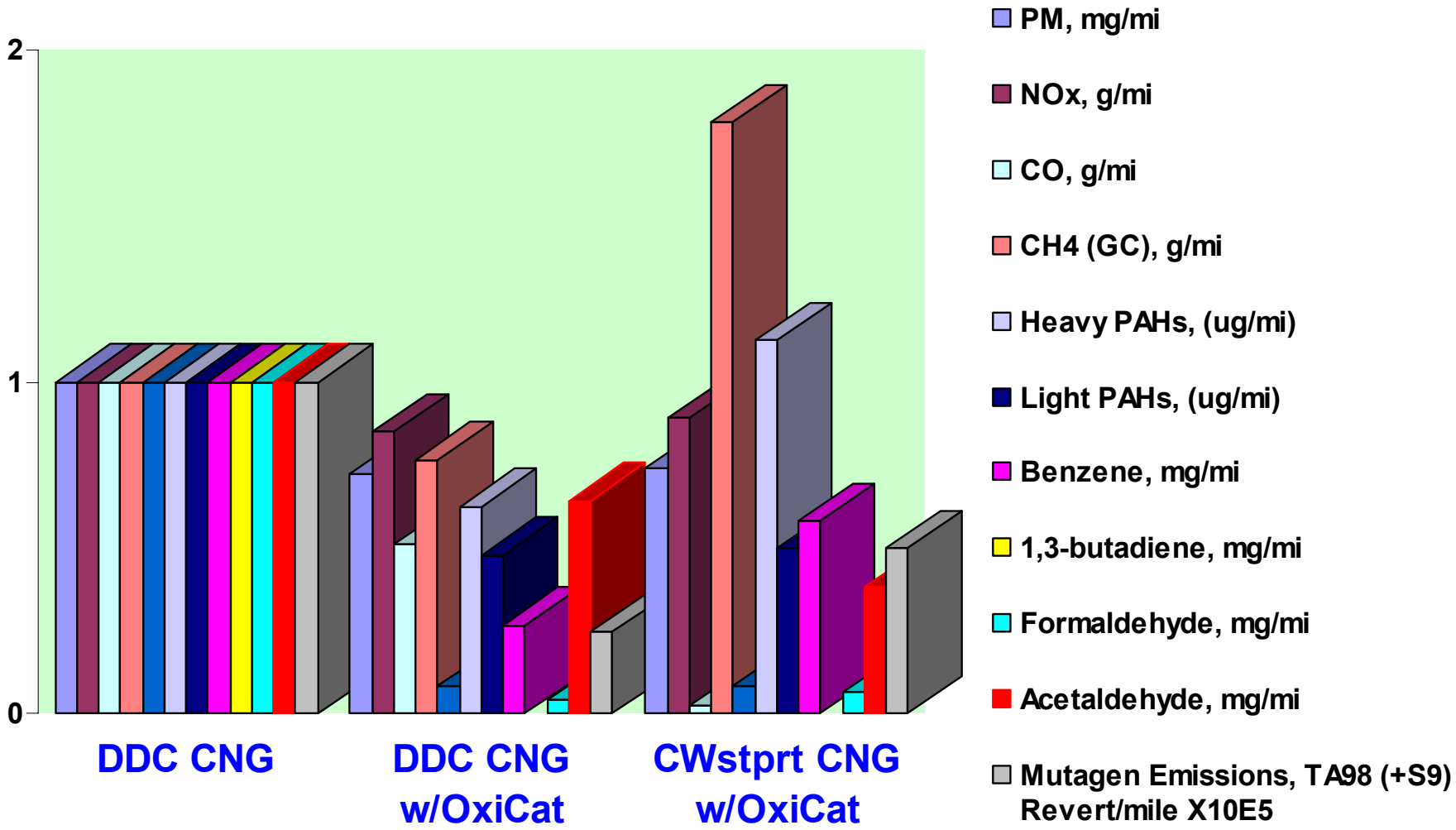


1,3 Butadiene Emission by Driving Cycle

(Error bars represent 2 std dev of replicate measurements)



Relative Comparison of Emissions - CBD



Summary and Caveats

- After-treatment for CNG bus (i.e. catalyst) results in significant reductions of emissions relative to uncontrolled levels.
- Specifically, CNG catalyst showed statistically significant reductions of PM, total HC, CO, NMHC, HCHO, CH3CHO
- Catalyst had little effect on NOx and CH4
- Benzene, 1,3-butadiene appeared to be reduced (but some measurement uncertainty)
- Results are “snap-shot” of two buses only.
- As technology evolves, emission profiles will change.
- After-treatment durability, deterioration, and vehicle maintenance effects were not investigated.
- Dilution tunnel background concentrations are important factors. Tunnel blank is not constant or negligible.