CHEMICAL CHARACTERIZATION OF PARTICULATE MATTER EMISSIONS FROM A CATALYZED TRAP EQUIPPED NATURAL GAS FUELED TRANSIT BUS

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Project Objectives

- **Reduction of exhaust emissions from current (2001 ULEV compliant) natural gas fueled vehicles**
  - **Recognize the problem (PM/gaseous; regulated/unregulated)**
    - Natural gas engine designs need to focus more on cylinder materials, design of ring packs, valve stem seals, etc., **to minimize oil consumption.**
  - **Identify the nature of the problem by conducting a detailed speciation of the exhaust (Round 1)**
  - **Design an exhaust aftertreatment system to tackle specific pollutants**
  - **Install exhaust aftertreatment system on the vehicle and conduct another speciation study (Round 2)**
  - **Operate the vehicle in the field for 6 months and monitor performance.**
  - **Conduct speciation study after 6 months (Round 3)**

Project Objectives

- **Engine**
  - **Cummins C8.3G+ (6-cylinder, 8.3 liter, 280 hp@2400 rpm)**
  - **Certified with a catalyst for California ULEV levels**
    - **NOx: 1.53 g/bhp-hr**
    - **NMHC: 0.21 g/bhp-hr**
    - **Total PM: 0.008 g/bhp-hr**
    - **CO: 0.8 g/bhp-hr**
- **Vehicle**
  - **Orion, standard 40-foot, high-floor design**
- **Laboratory**
  - **WVU Transportable Laboratory with a dedicated "Clean Tunnel" with on-site GC**

Chemical Characterization

- **Particulate Matter**
  - **TPM, PM_{10}, $PM_{2.5}$, PM_1**
- **Volatile Organic Compounds**
  - **Low molecular weight alkanes and olefins (C_2 – C_5)**
  - **Low molecular weight aromatics (BTEX)**
- **Elemental & Organic Carbon**
- **PAHs and n-PAHs**
- **Hopanes and Stearanes**
- **Elemental Compounds**
- **Ionic Species**
- **Carbonyls**
- **PM Size Concentration and Distributions**

Test Vehicle Installed On The Chassis Dynamometer

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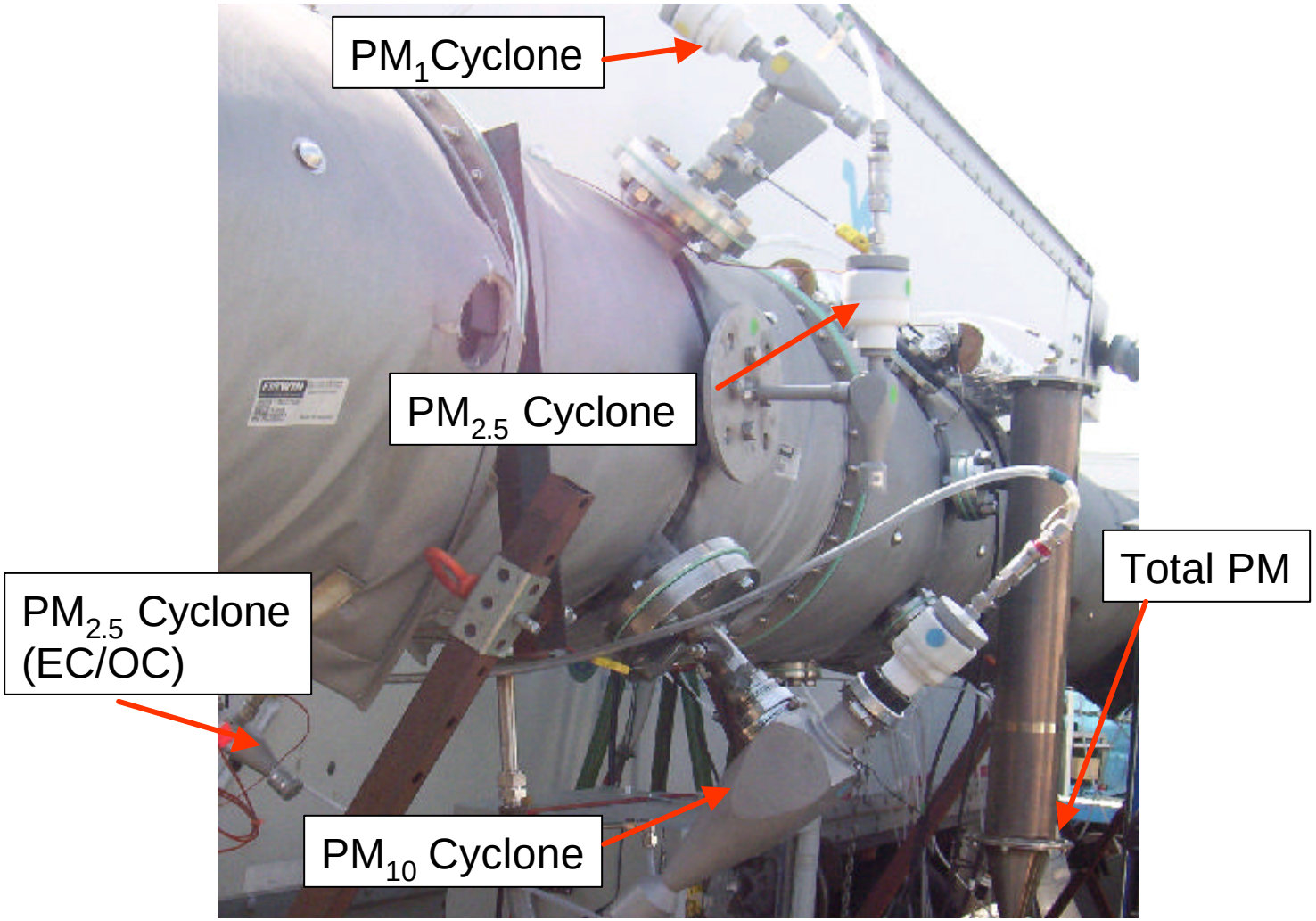
“Clean Tunnel” With Sampling Ports/Trains



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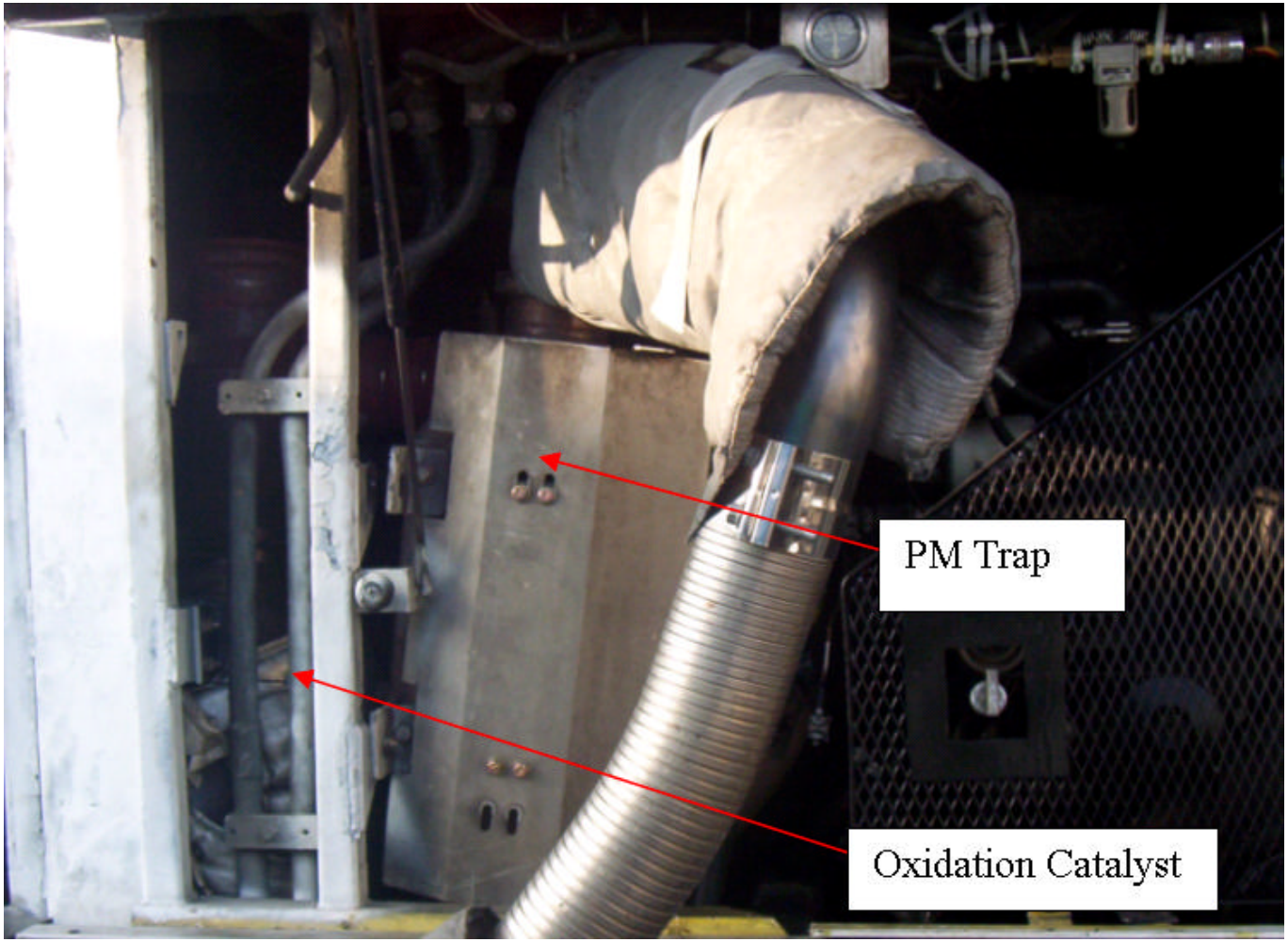
PM Filter followed by an Oxidation Catalyst in the Transit Bus Exhaust System



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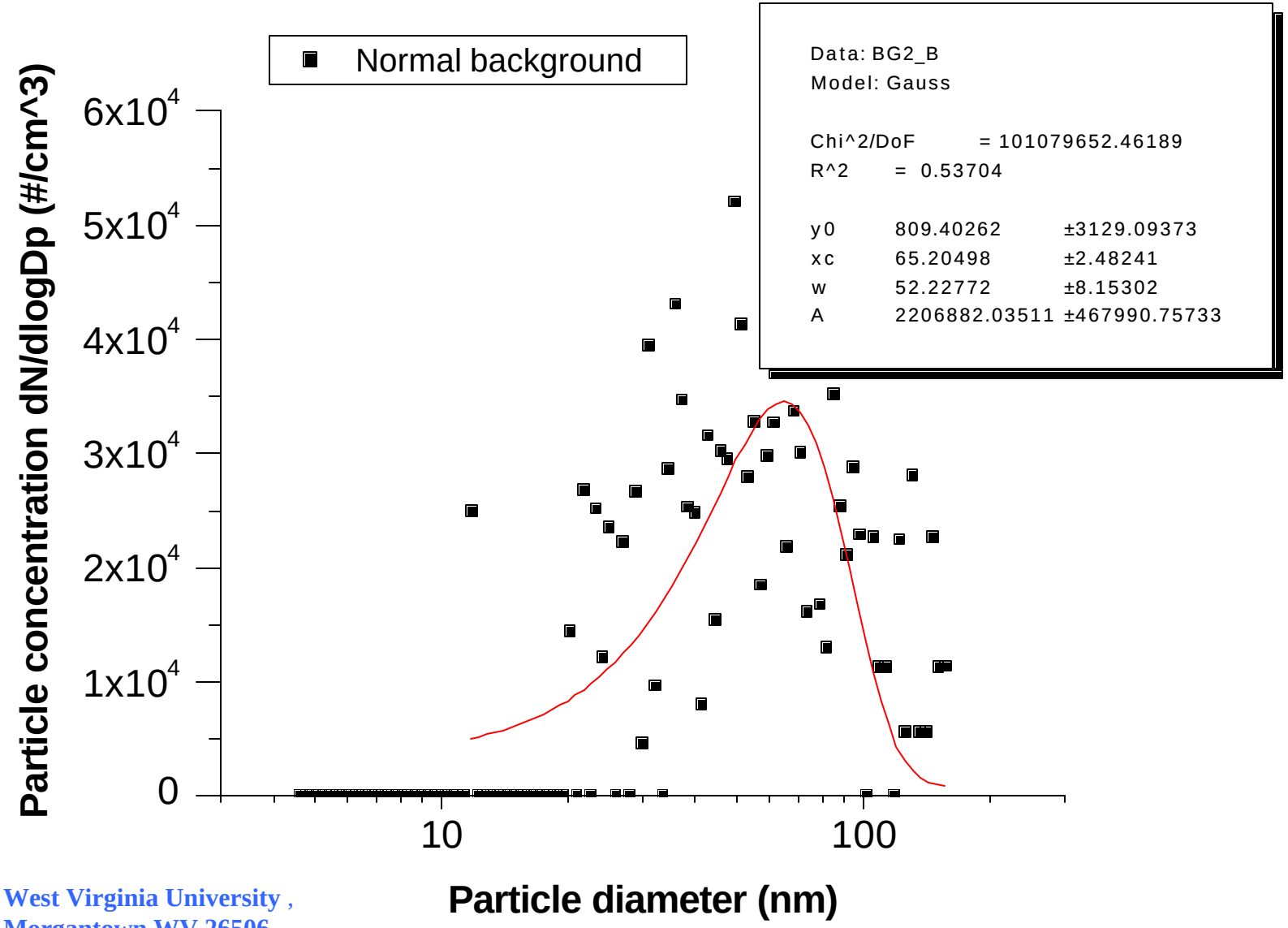
WVU/Lubrizol-ECS
Catalyzed Filter and Oxidation Catalyst

- **Diesel Particulate Filter**
  - **Silicon Carbide segmented honeycomb (11.25 in x 12 in)**
  - **200 square CPI cell density**
  - **Pt coated on proprietary wash-coat for passive regeneration over duty cycles producing exhaust temperature 280^{o}C - 320^{o}C for >25% of the time**

- **Oxidation Catalyst**
  - **Cordierite monolith (10.5 in x 6 in)**
  - **400 square CPI cell density**
  - **Pd coated on proprietary wash-coat**

Tunnel Background (Round 1)



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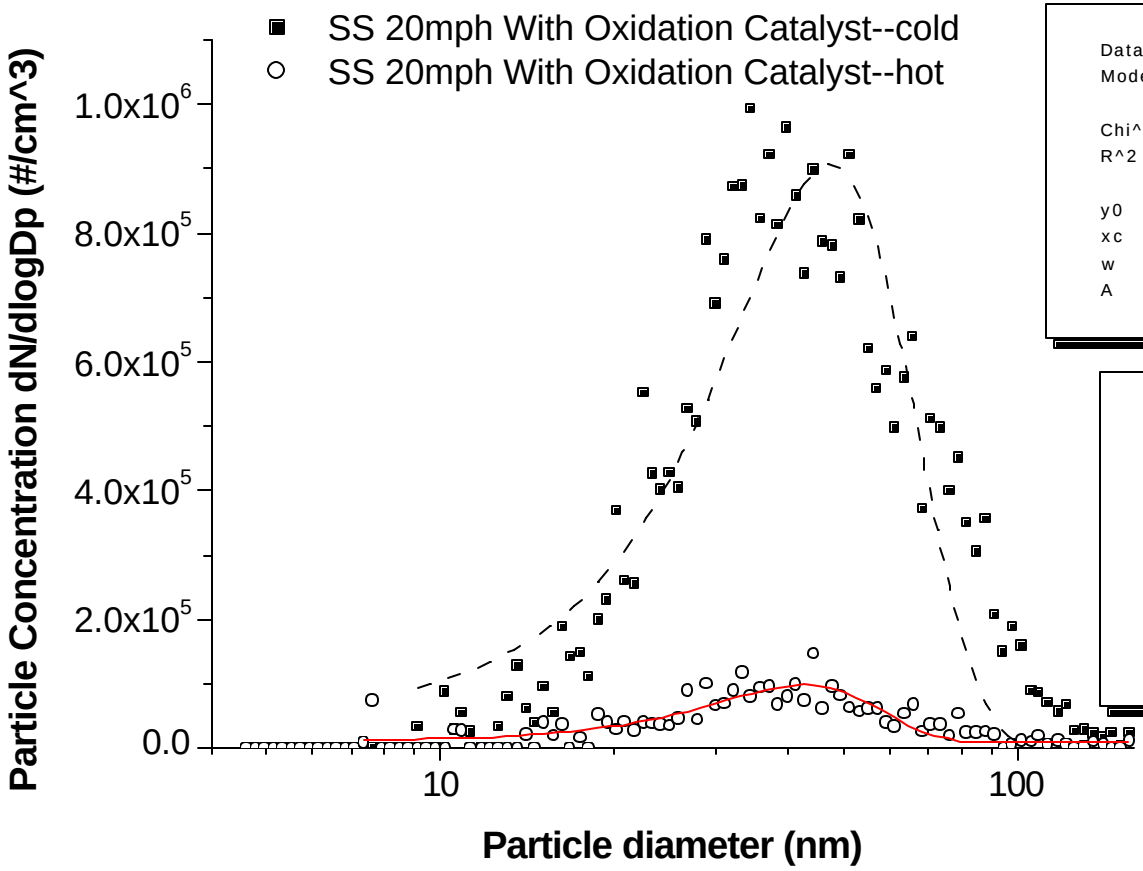
Sunline Transit Bus Steady State Operation 20 Mph With Oxidation Catalyst (Round 1)



Data: SS 20mph with cat cold
Model: Gauss

Chi^2/DoF = 14102545157.70303
R^2 = 0.86379

y0	-3741.47652	±26882.40612
xc	47.34166	±0.76992
w	36.18543	±2.0348
A	41264889.31164	±2966796.1965

Data: SS 20mph with cat hot
Model: Gauss

Chi^2/DoF = 294888399.39383
R^2 = 0.74812

y0	5318.76959	±3234.95684
xc	42.91572	±0.95994
w	28.99202	±2.35115
A	3266736.64037	±313992.14651

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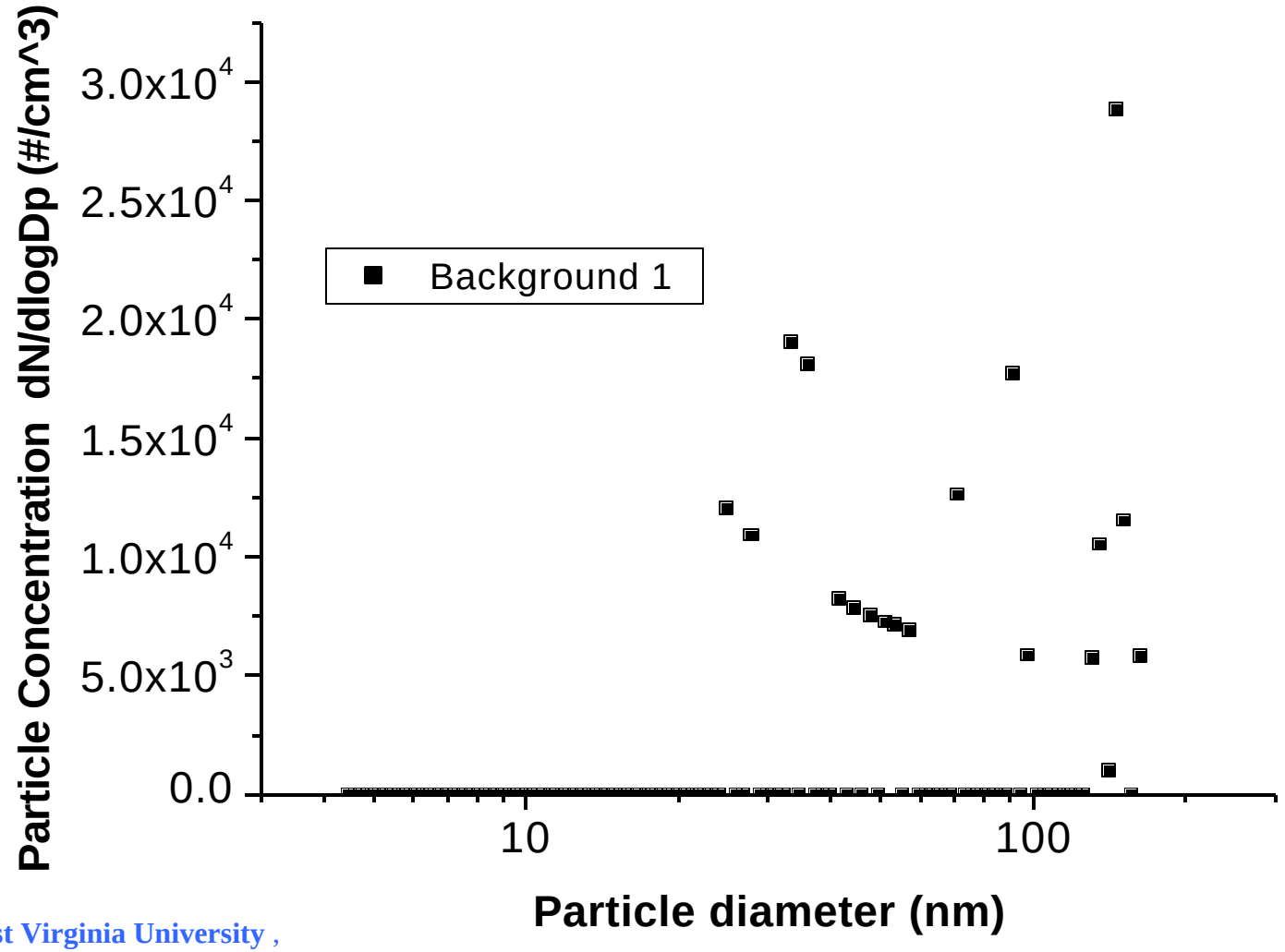
Tunnel Background (Round 2)



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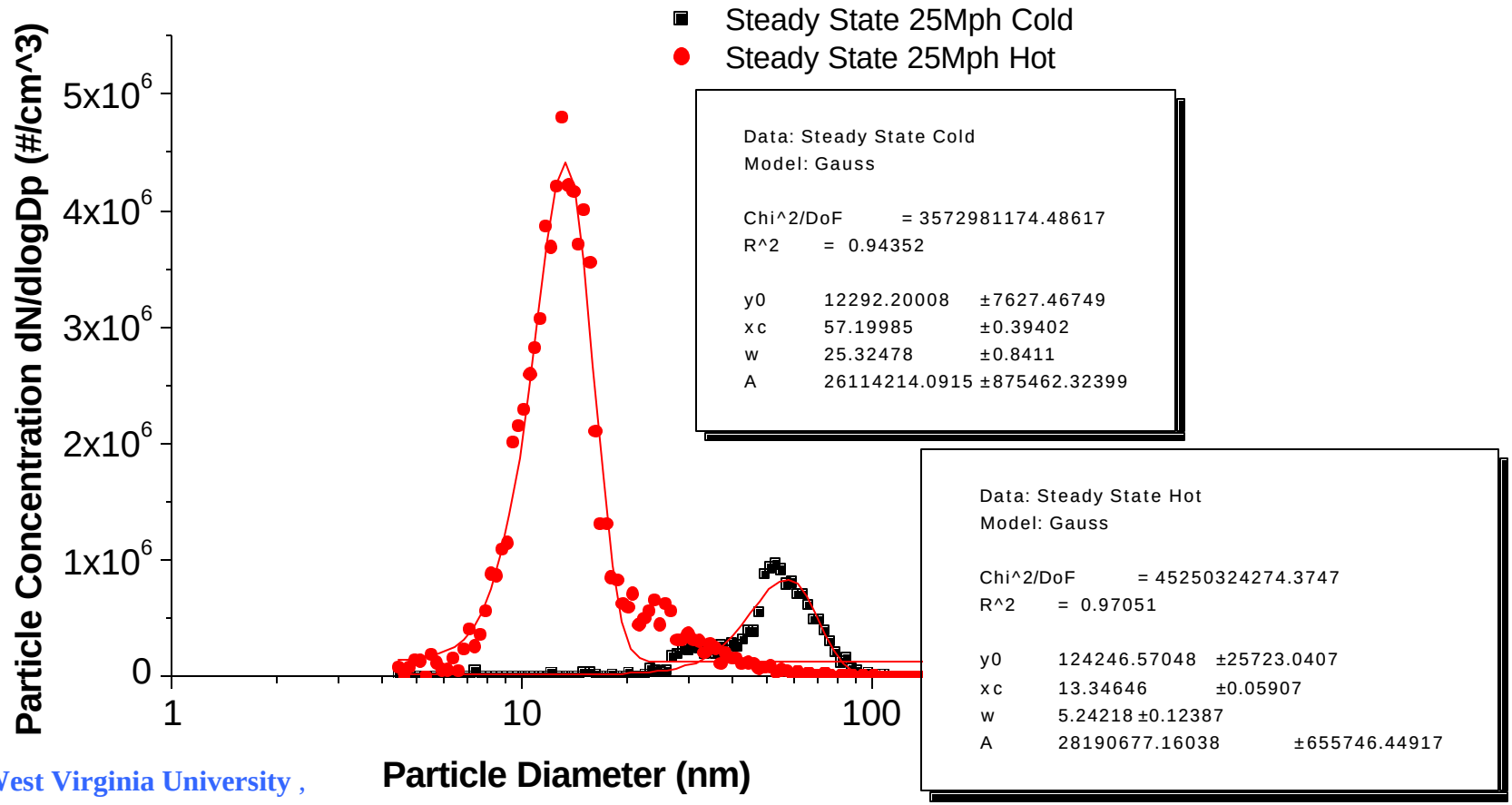
Sunline Transit Bus Steady State Operation 25 Mph with PM Filter Only – No Oxidation Catalyst (Round 2)



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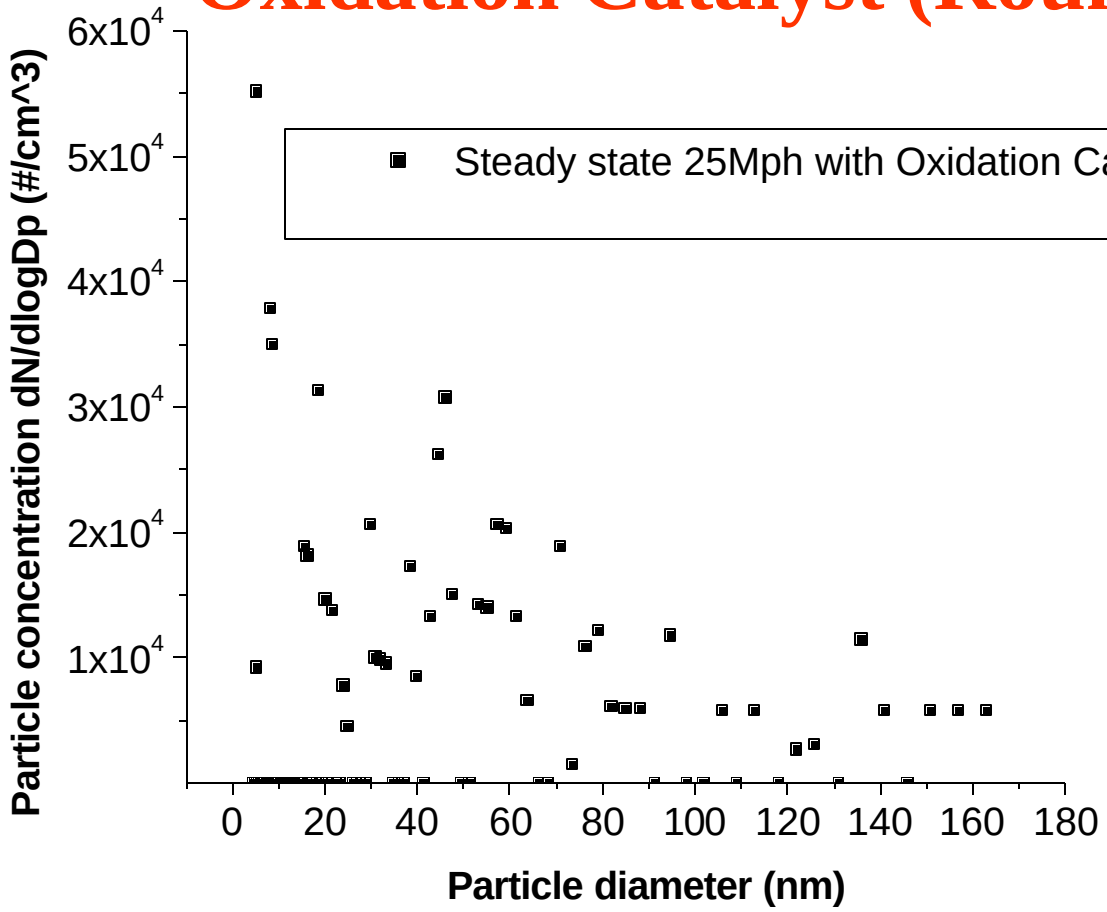
Sunline Transit Bus Steady State Operation 25 Mph with PM Filter and Oxidation Catalyst (Round 2)



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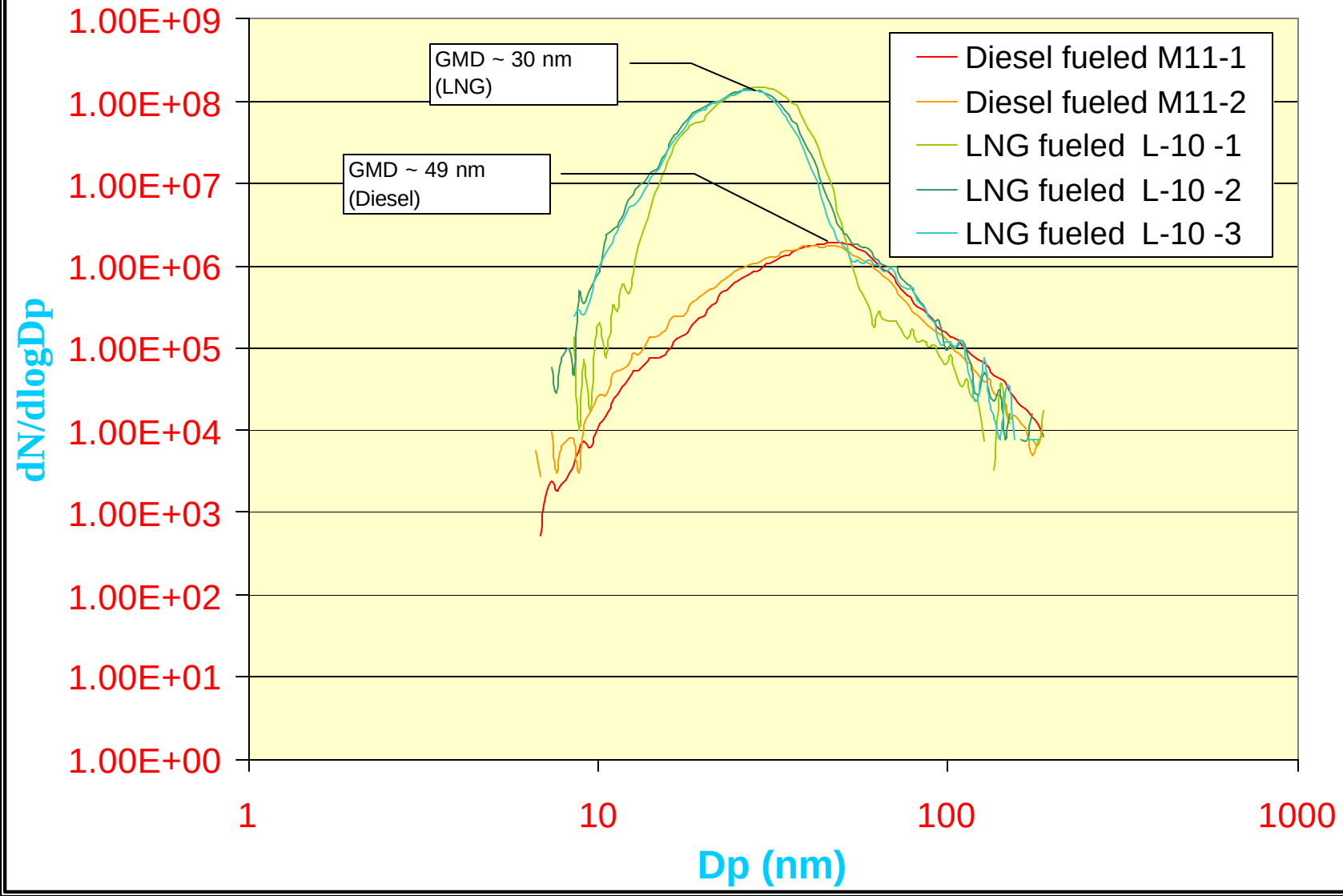
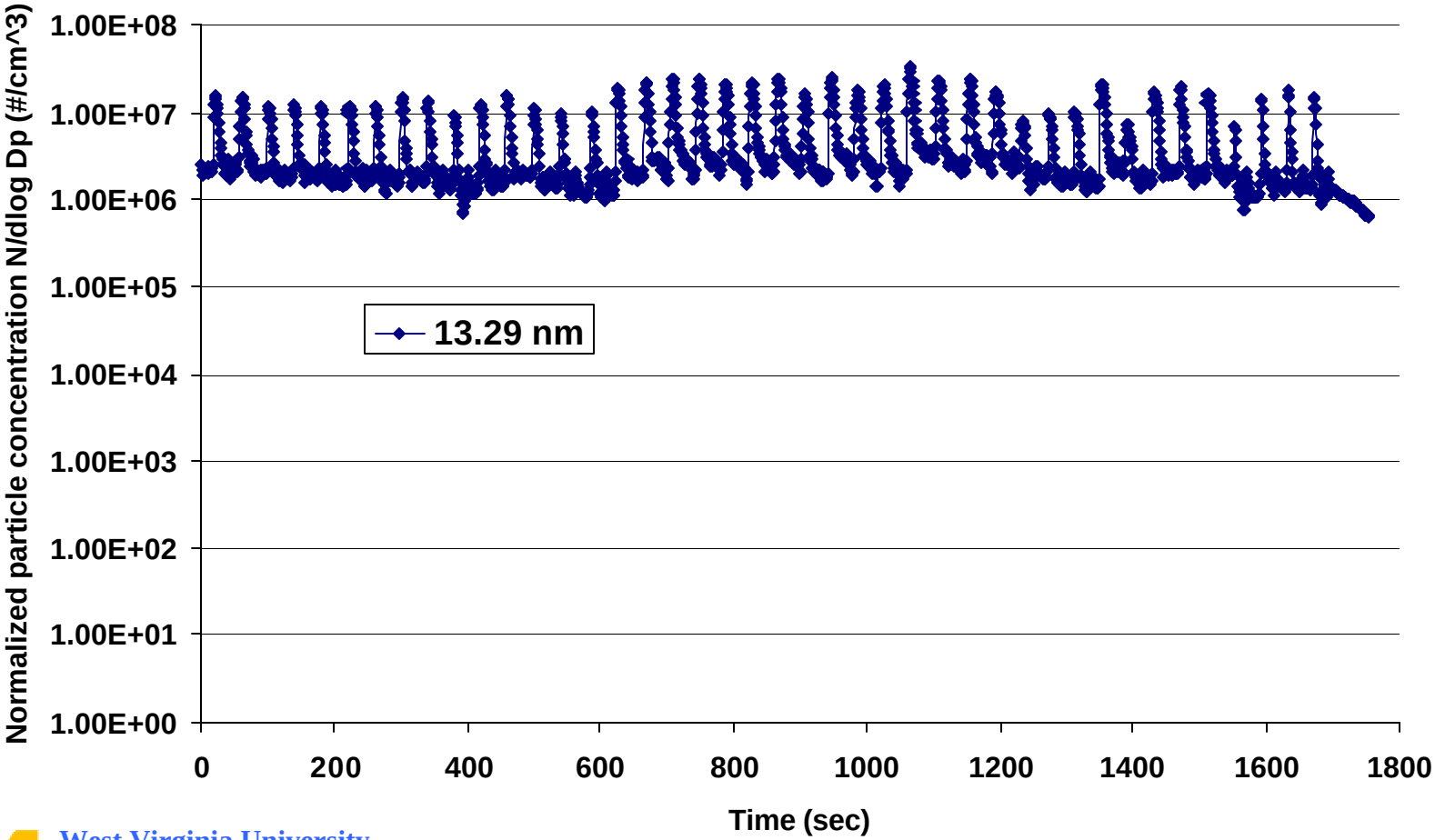
1999 Study

Comparison of Particle Size Distributions LNG-fueled and Diesel-fueled Transit Buses



Sunline Transit Bus Transient Operation Quad CBD; PM Filter Only (Round 2)



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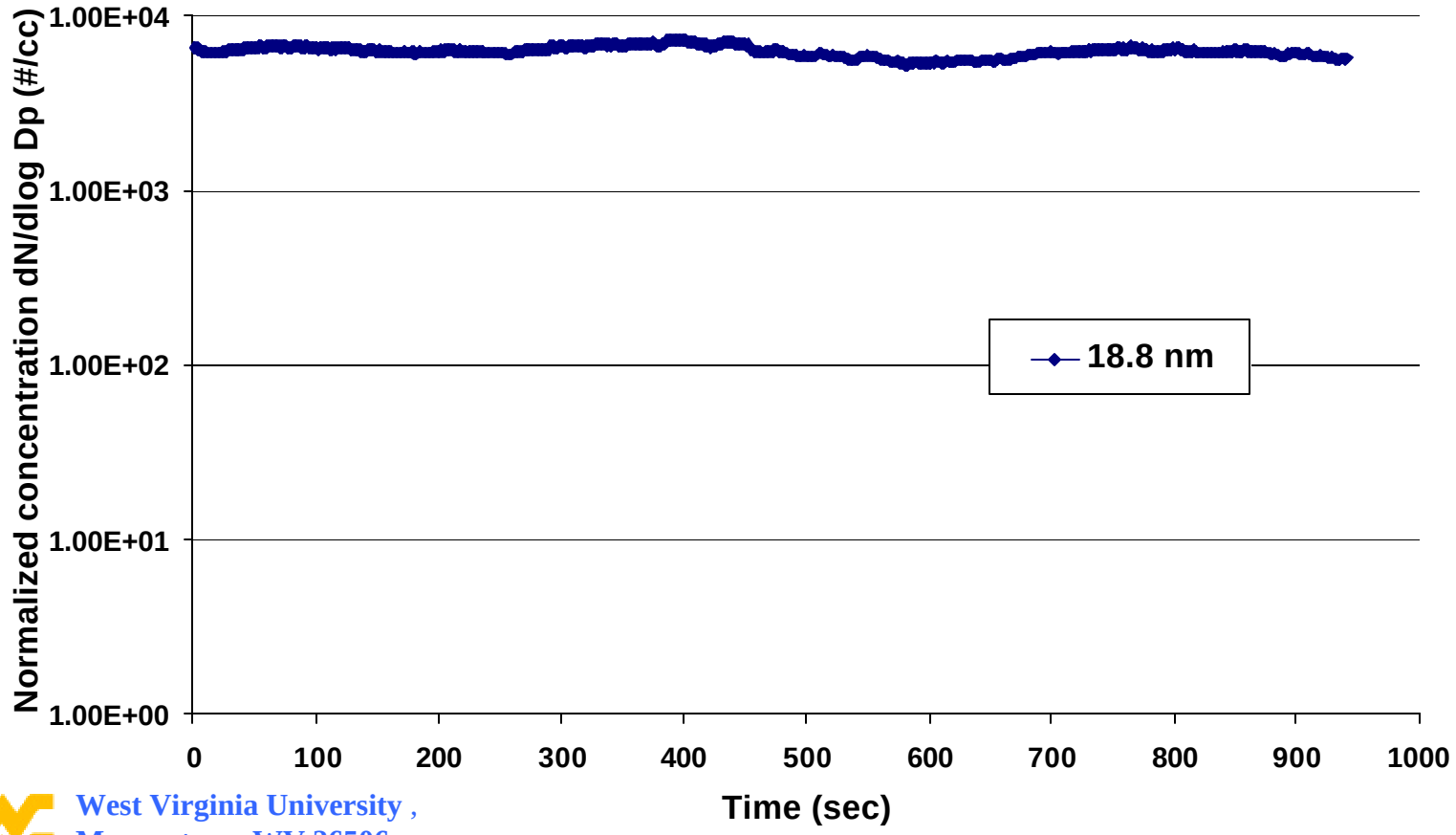
Transit Bus Transient Operation Quad CBD; PM Filter and Oxidation Catalyst (Round 2)



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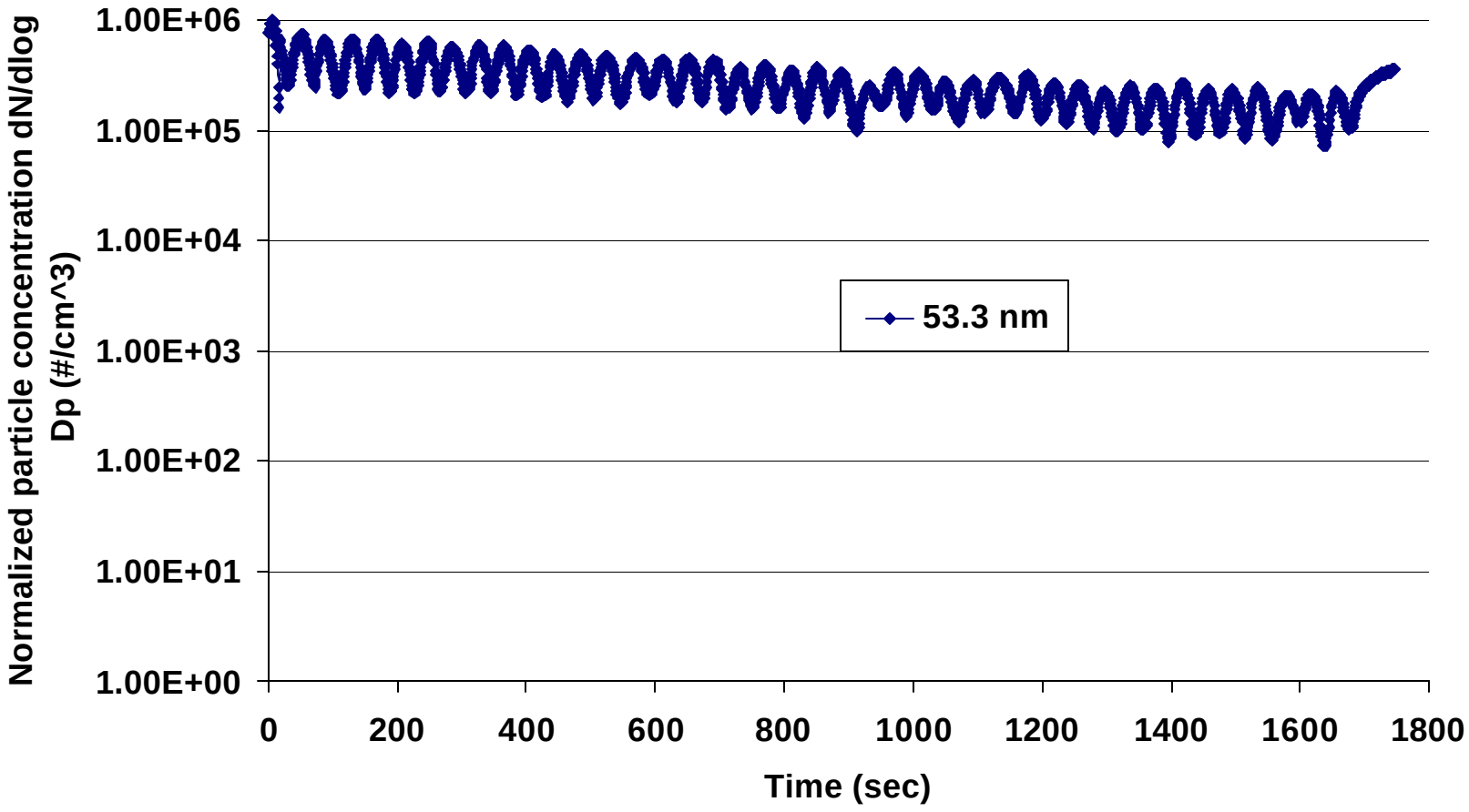
Transit Bus Transient Operation
Quad CBD; PM Filter Only (Round 2)



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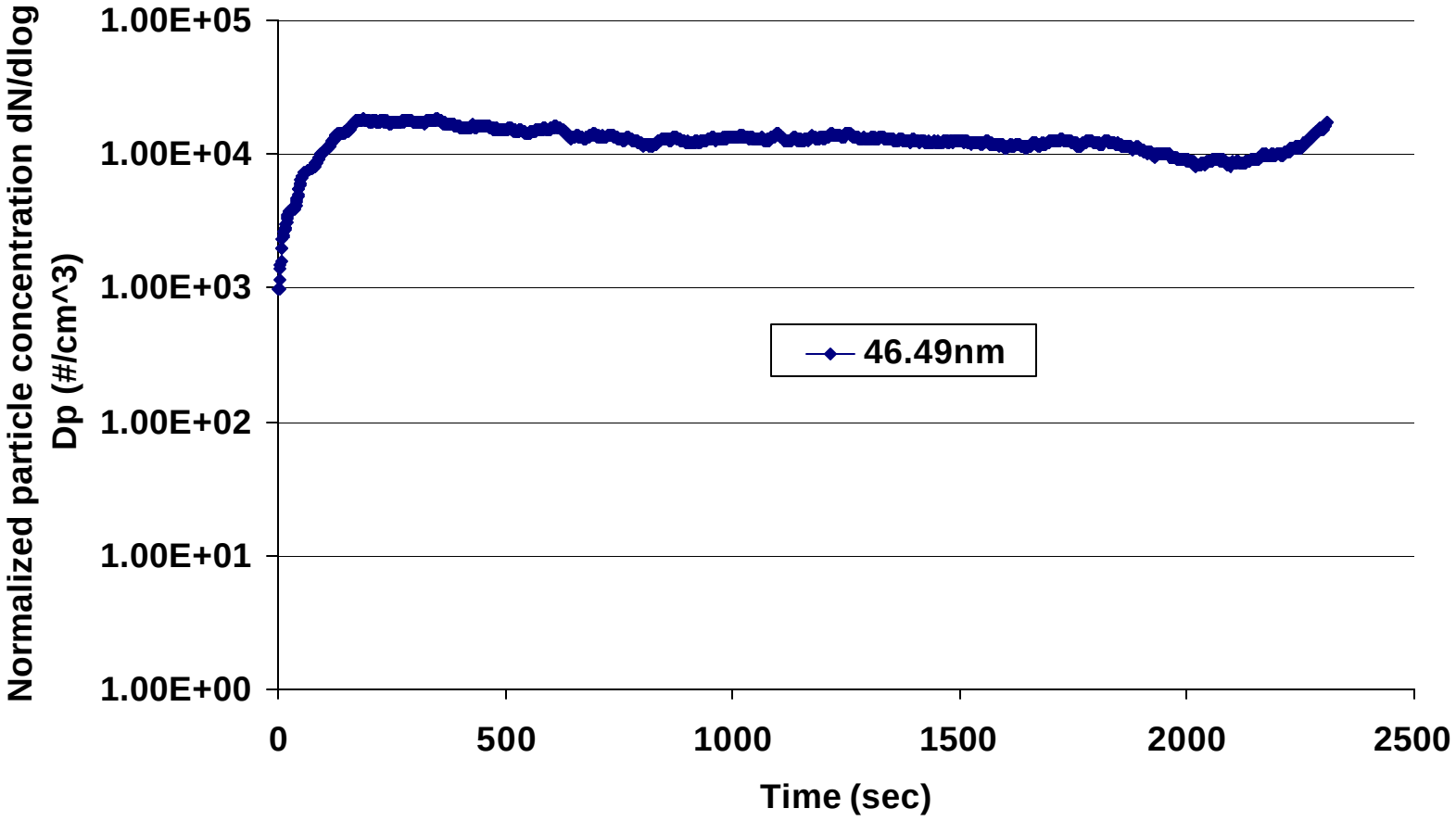
Transit Bus Transient Operation Quad CBD; PM Filter and Oxidation Catalyst (Round 2)



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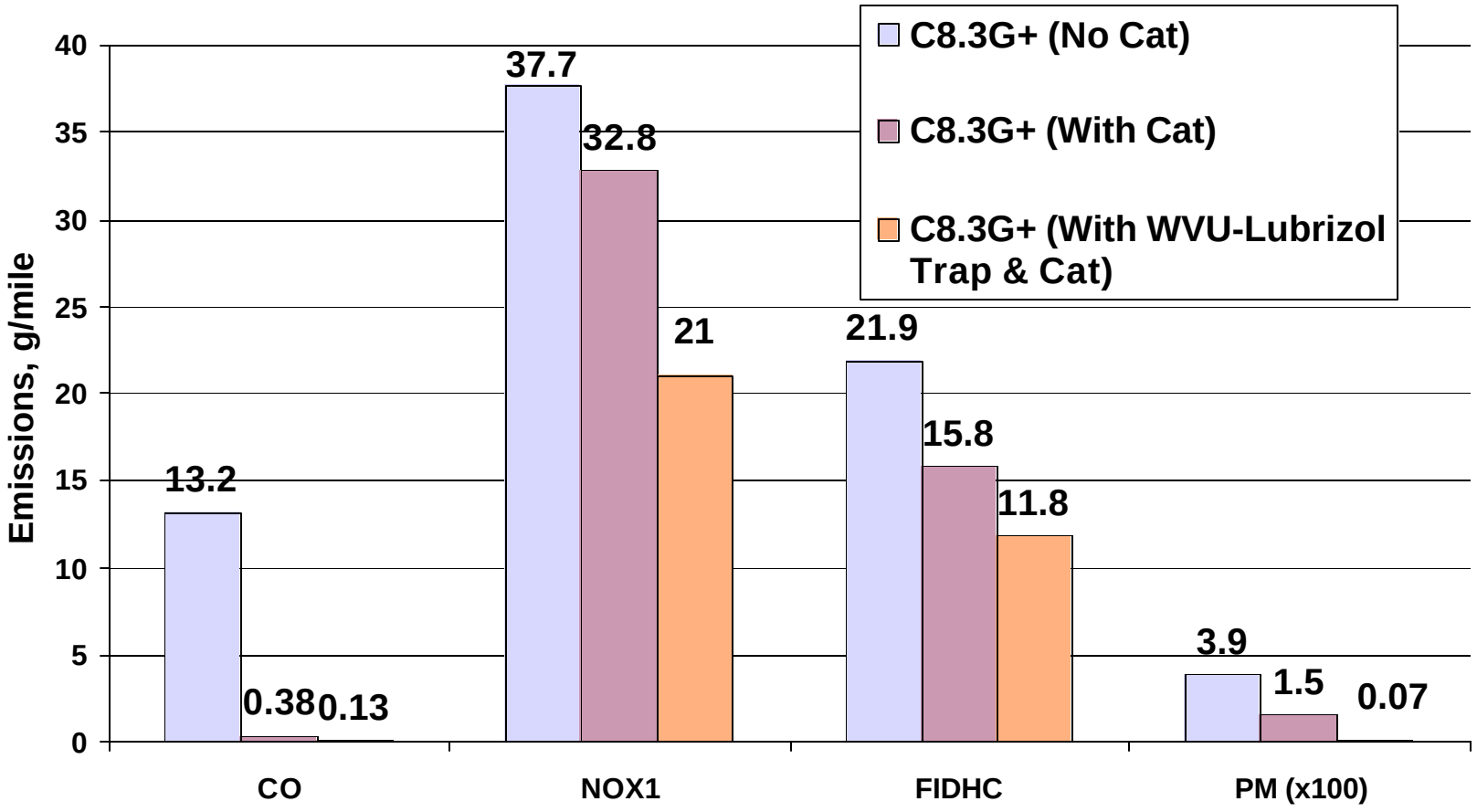
Regulated Emissions



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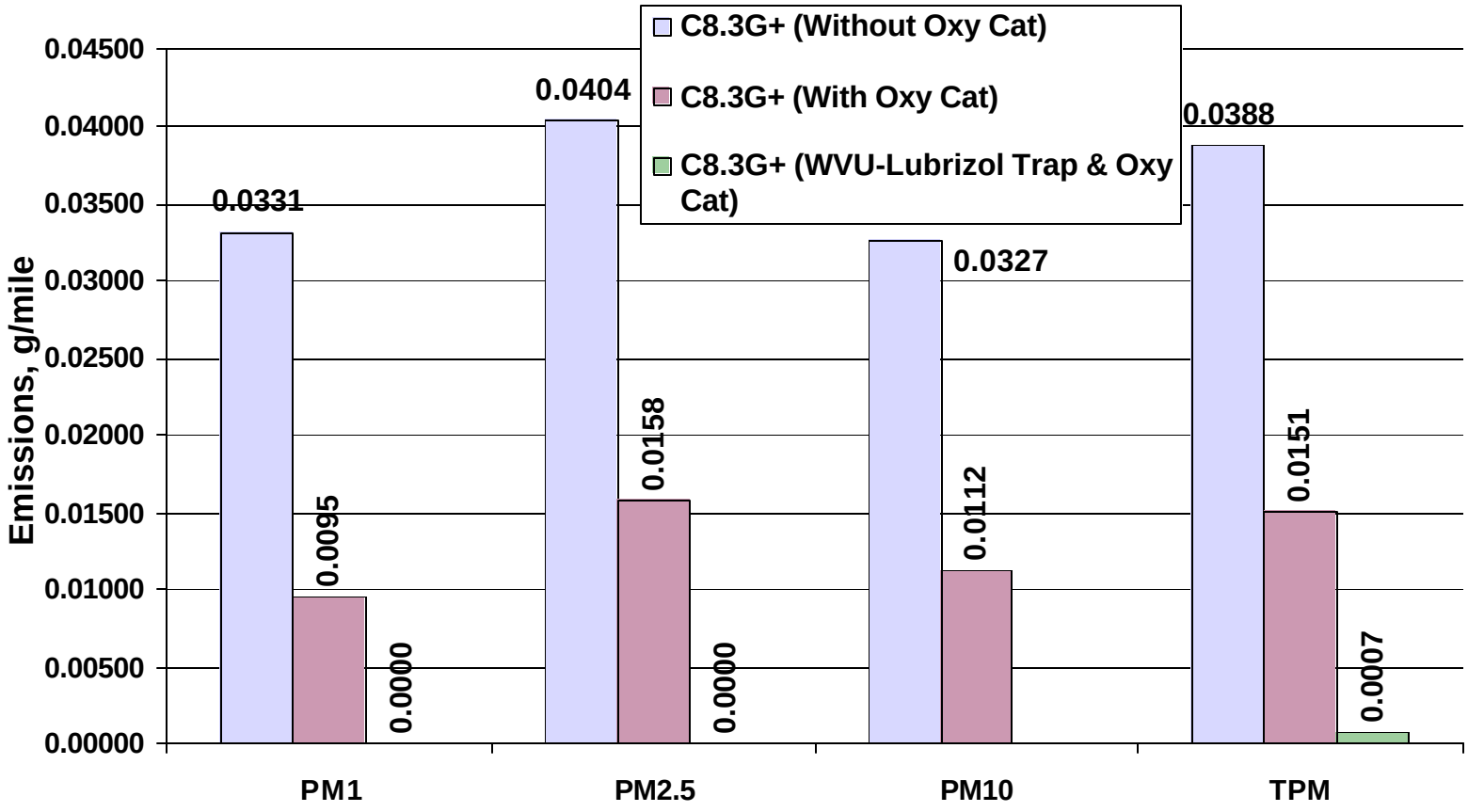
Bars are Average of 3 Replicate Runs

Total PM Emissions



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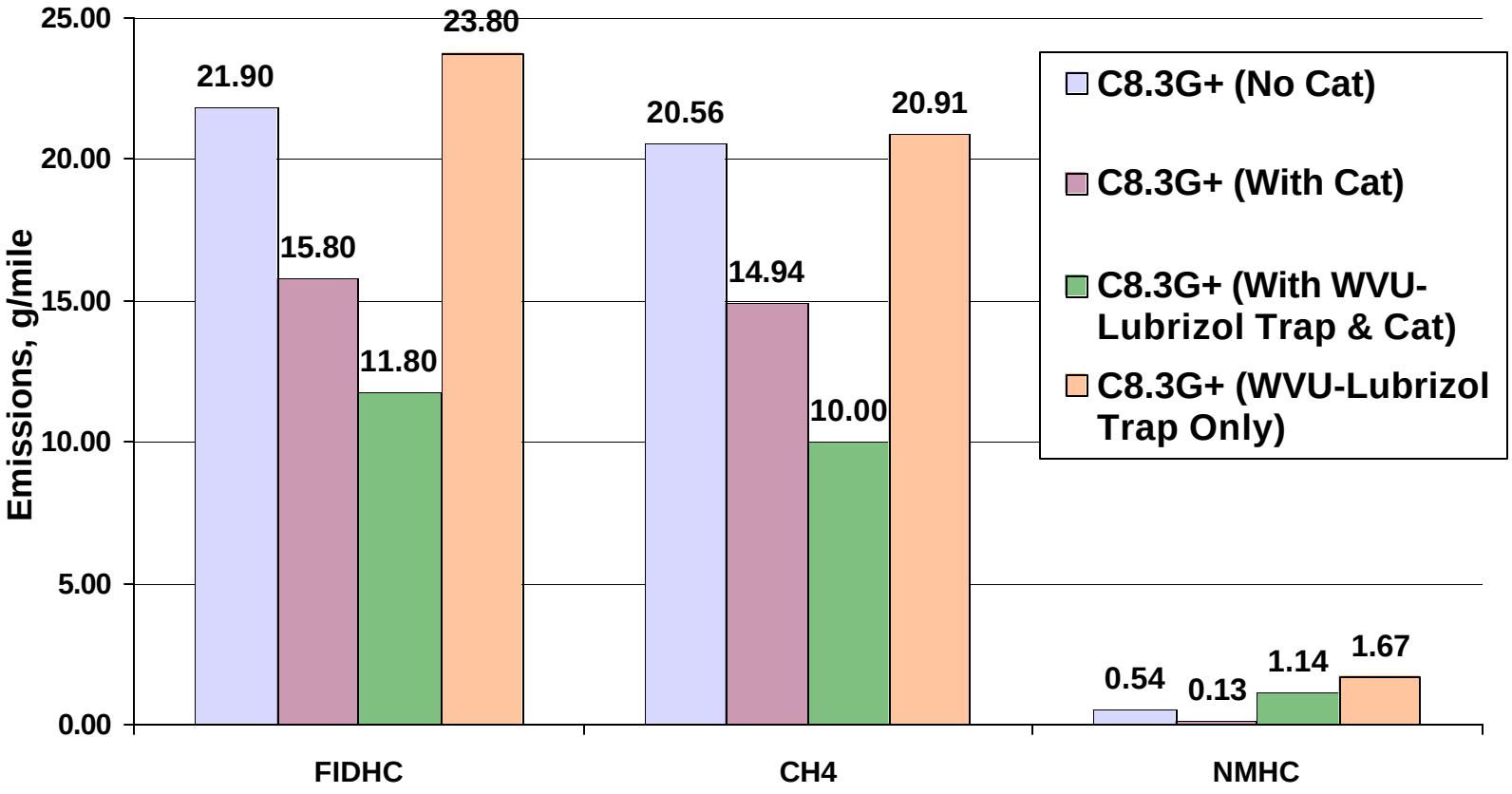
Methane and Non-Methane Hydrocarbons



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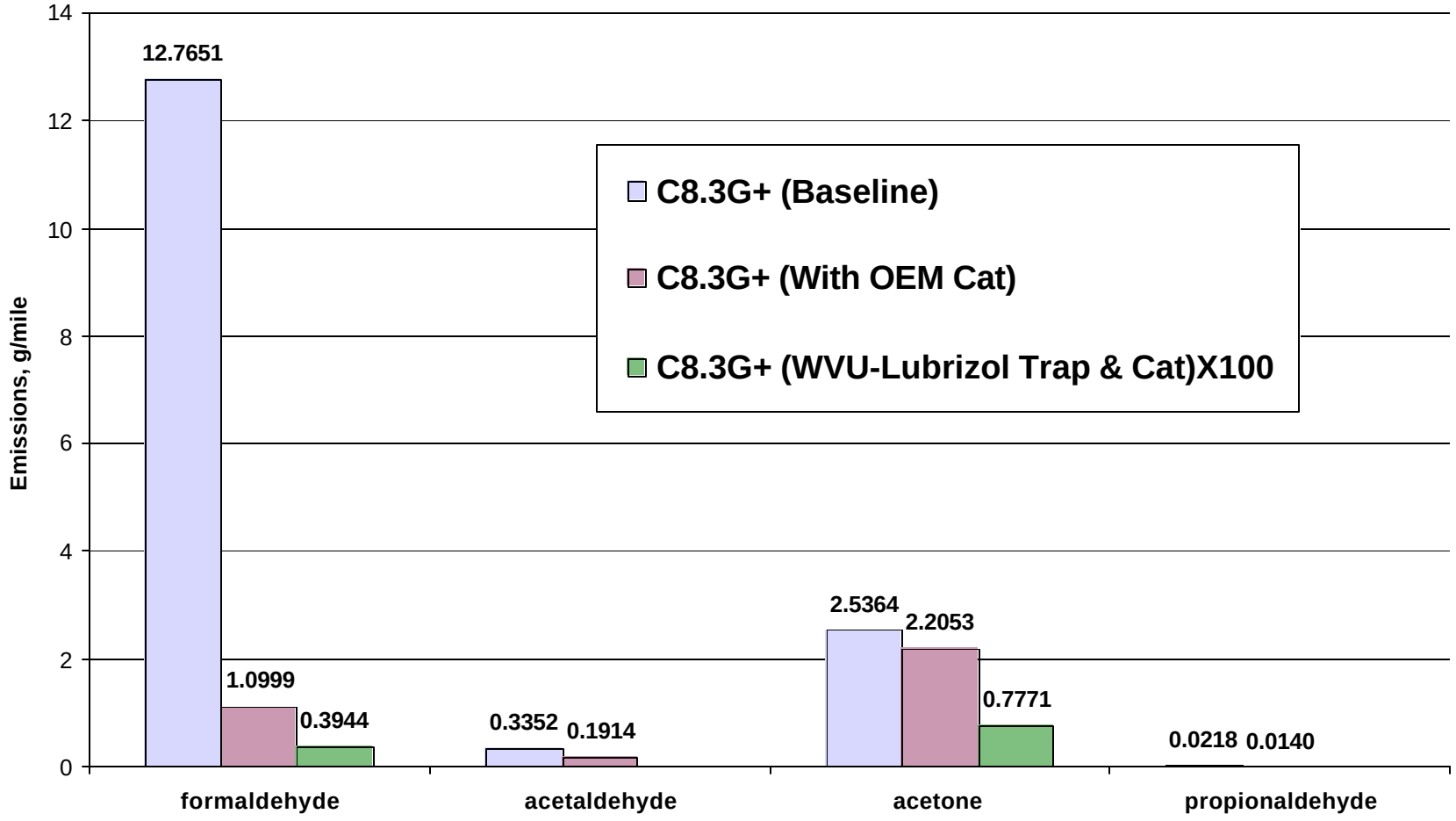
Carbonyls



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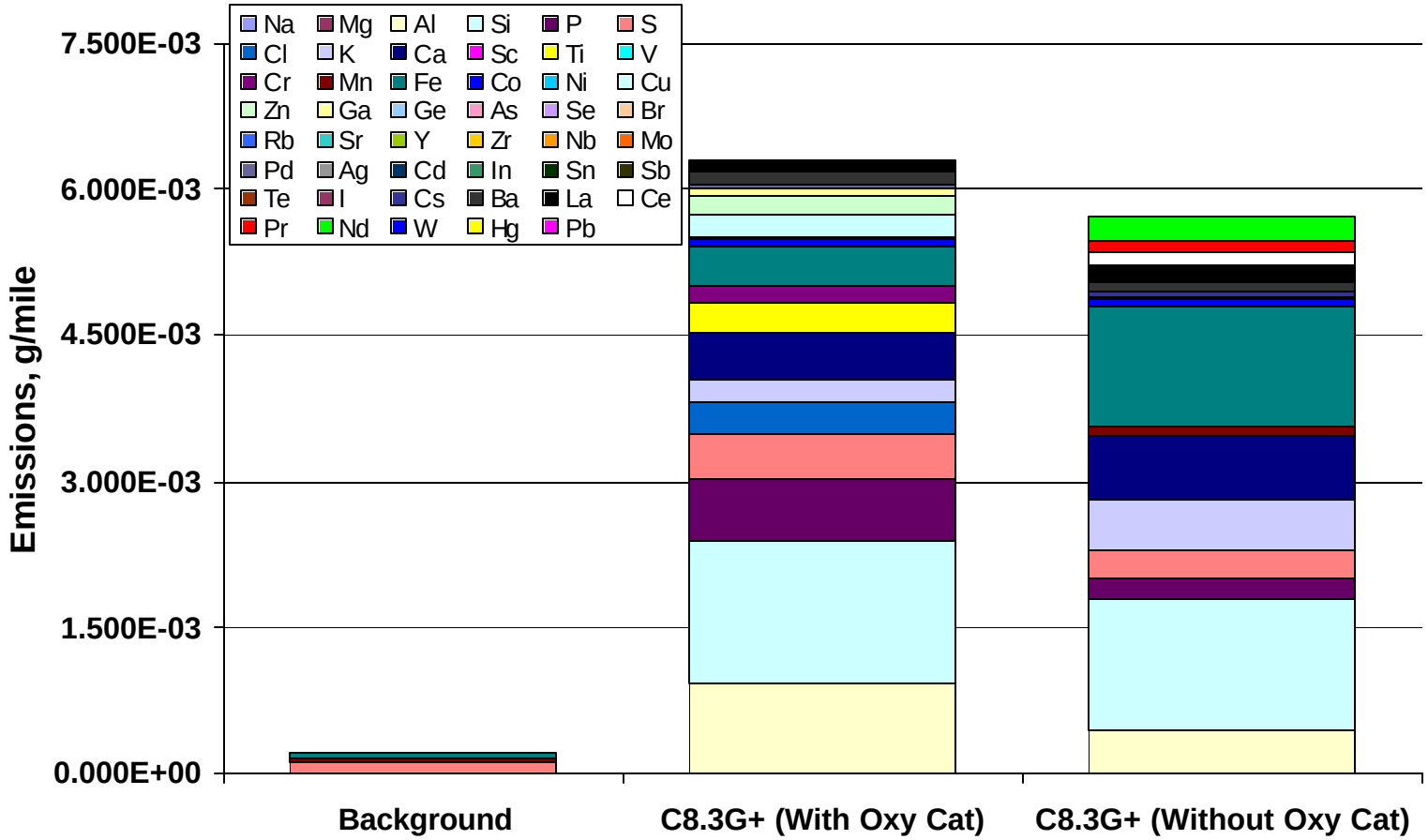
XRF Chemical Elements

C8.3G+ (with WVU-Lubrizol Trap & OC: Non-Detectable)



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