The California Demonstration Program for Control of PM from Diesel Backup Generators (BUGs)

U.S. Department of Energy"s

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Today's Topics

- Current state of understanding about emissions from diesel backup generators.
- Approach to measurement of PM emissions.
- Background on California PM demonstration program for diesel backup generators.
- Emission results for:
  - Uncontrolled sources
  - Controlled sources
- Future work

EPA's AP-42 Emission Factors - Small Diesel

Pollutant	SMALL DIESEL (< 600 hp)			
	Emission Factor (lb/hp-hr) (power output)	Emission Factor (g/kW-hr) (power output)	Emission Factor (lb/MMBtu) (fuel input)	Emission Factor Rating
NOx	0.031	18.85	4.41	D
CO	6.68E-03	4.06	0.95	D
SOx	2.05E-03	1.25	0.29	D
PM_{10}	2.20E-03	1.34	0.31	D
CO_2	1.15	699.20	164	B
Aldehydes	4.63E-04	0.28	0.07	D
TOC		0.00		
Exhaust	2.47E-03	1.50	0.35	D
Evaporative	0.00	0.00	0.00	E
Crankcase	4.41E-05	0.03	0.01	E
Refueling	0.00	0.00	0.00	E

UCR’s Mobile Emission Lab

Schematic of UCR's Heavy-duty Mobile Emission Laboratory (MEL)

Diluted Exhaust: Temperature, Absolute Pressure, Throat ΔP, Flow.

GPS: Pat, Long, Elevation, # Satellite Precision.

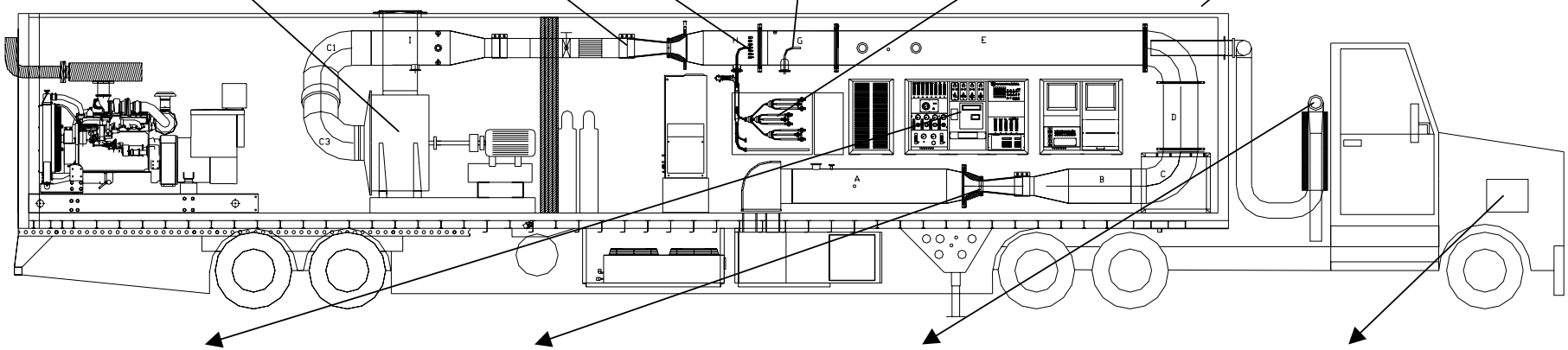
CVS Turbine: 1000-4000 SCFM, Variable Dilution.

Secondary Probe.

Gas Sample Probe.

Secondary Dilution System*
PM (size, Mass).

Drivers Aid.



Gas Measurements: CO_2 %, O_2 %, CO ppm, NO_x ppm, THC ppm, CH_4 ppm.

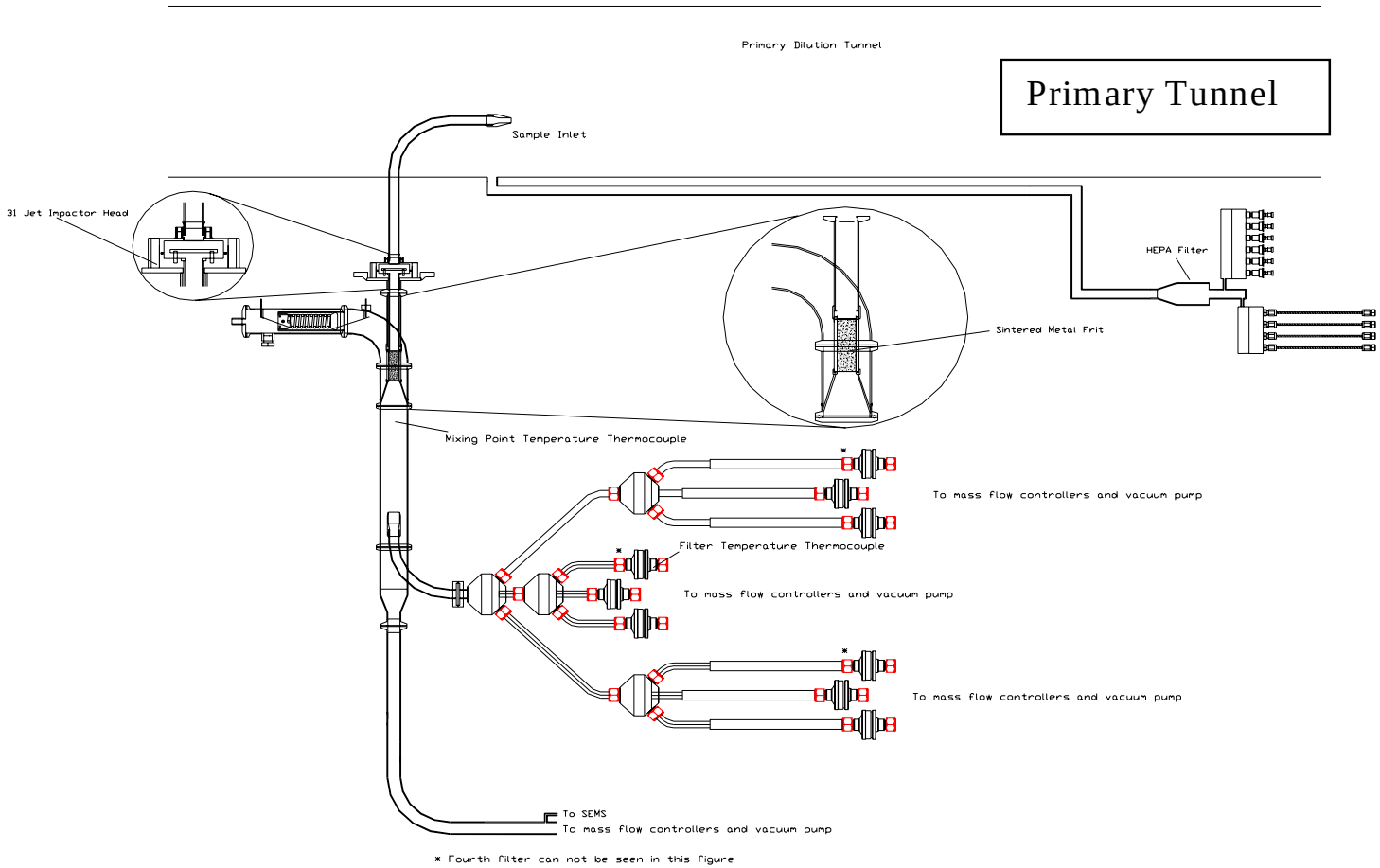
Other Sensor: Dew Point, Ambient Temperature, Control room temperature, Ambient Baro, Trailer Speed (rpm), CVS Inlet Temperature.

Dilution Air: Temperature, Absolute Pressure, Throat ΔP, Baro (Ambient), Flow, Dew Point (Ambient).

Exhaust: Temperature, ΔP (Exhaust-Ambient), Flow.

Engine Broadcast: Intake Temperature, Coolant Temperature, Boost Pressure, Baro Pressure, Vehicle Speed (mph), Engine Speed (rpm), Throttle Position, Load (% of rated).

Schematic of Secondary Sampling System



Inside the Mobile Laboratory

Verification of Secondary System for Measuring PM

- Verification testing performed at CARB HDDT test facility – March 19, 2002
- 2000 Freightliner Tractor, CAT C-15
- CARB provided the difference in measurements between CARB/UCR labs

Test Cycle	THC	CO	NO_x	CO_2	PM
Hot UDDS	12%	18%	8%	2.7%	0.1%

Objectives for Diesel Backup Generator (BUGs) Project

- **Cooperative project of the California Energy Commission and the California Air Resources Board**
- **Measure emissions from representative BUGs based on:**
  - **Size (>300kw)**
  - **Market share**
  - **Age/emission standards**
- **Measure "real world" emissions**
  - **Regulated gaseous emissions**
  - **Regulated particulate matter ($PM_{2.5}$) emissions**
  - **Speciated VOCs and SVOCs, including toxics for selected units**
- **Develop emission factors for AP-42.**
  - **Uncontrolled and controlled emission factors.**

PM Demonstration-Test Matrix

- Size Ranges
  - 15 engines (300 to 750 kW)
  - 3 engines (1000 to 2000 kW)
- Age Ranges
  - Pre 1987
  - 1987-1996
  - Post 1996
- Manufacturers
  - Caterpillar
  - Cummins
  - Detroit Diesel Corporation

PM Control Technologies Selected for Demonstration

- Emulsified Fuel
- Diesel Oxidation Catalysts
- Passive Filters
- Active Filter

Field Testing of Backup Generators (BUGs)

RENTAL POWER
RENTAL POWER
600 kw load bank
600 kg
Steps: 1kw @ 415volt

Testing Protocol for Backup Generators

1. Cold start/idle for 30 minutes
2. ISO-8178B -- Type D2 constant speed

Mode	1	2	3	4	5
Speed	rated speed				
Load	100%	75%	50%	25%	10%
Weighting Factor	0.05	0.25	0.3	0.3	0.1

Example:

$$GAS_x = \frac{\sum_{i=1}^{n} M_{GASi} \times W_{Fi}}{\sum_{i=1}^{n} P_i \times W_{Fi}}$$

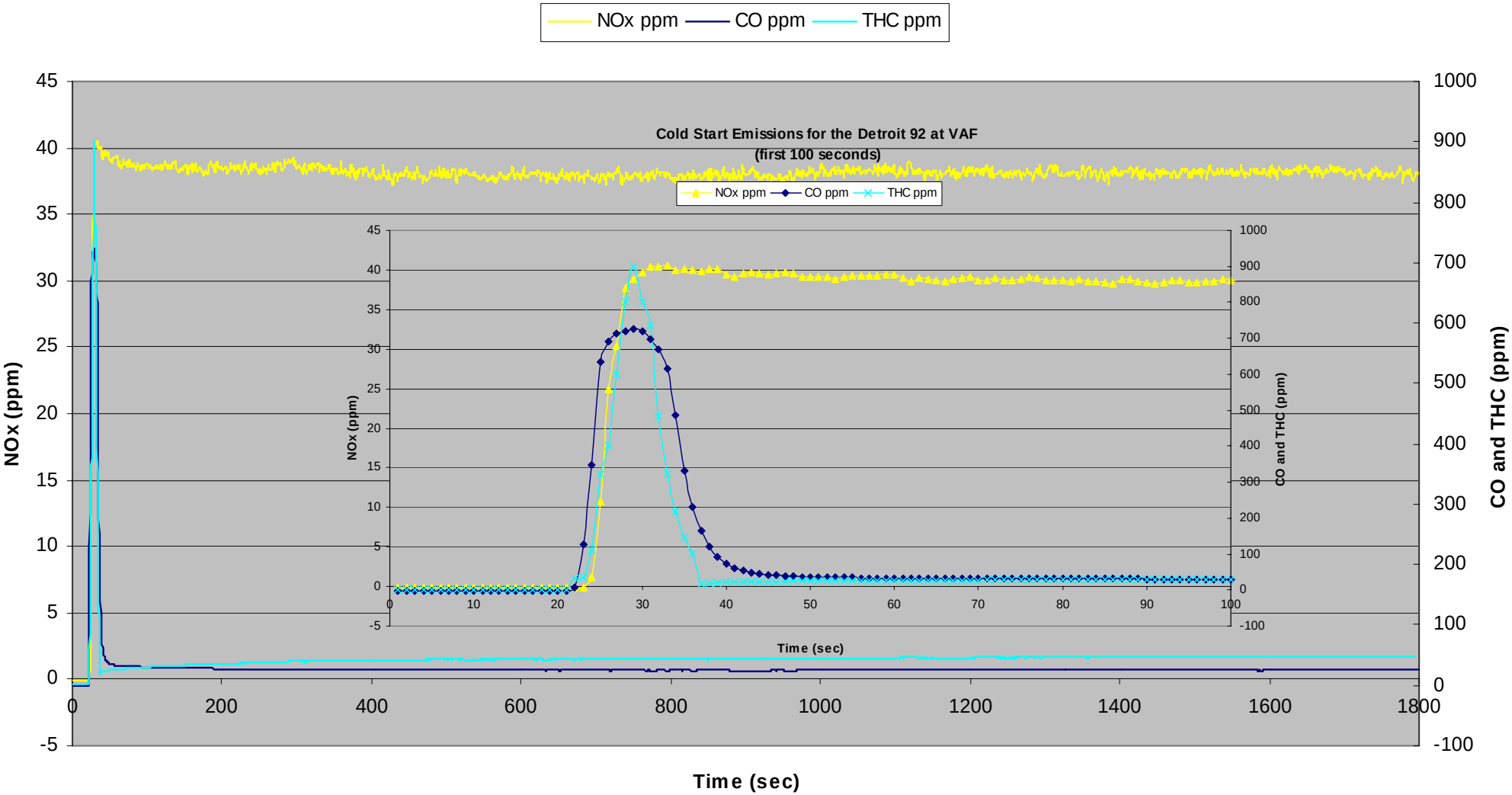
Where:

GAS_x **= overall emission factor of a given pollutant (lb/hp-hr or g/kW-hr)**

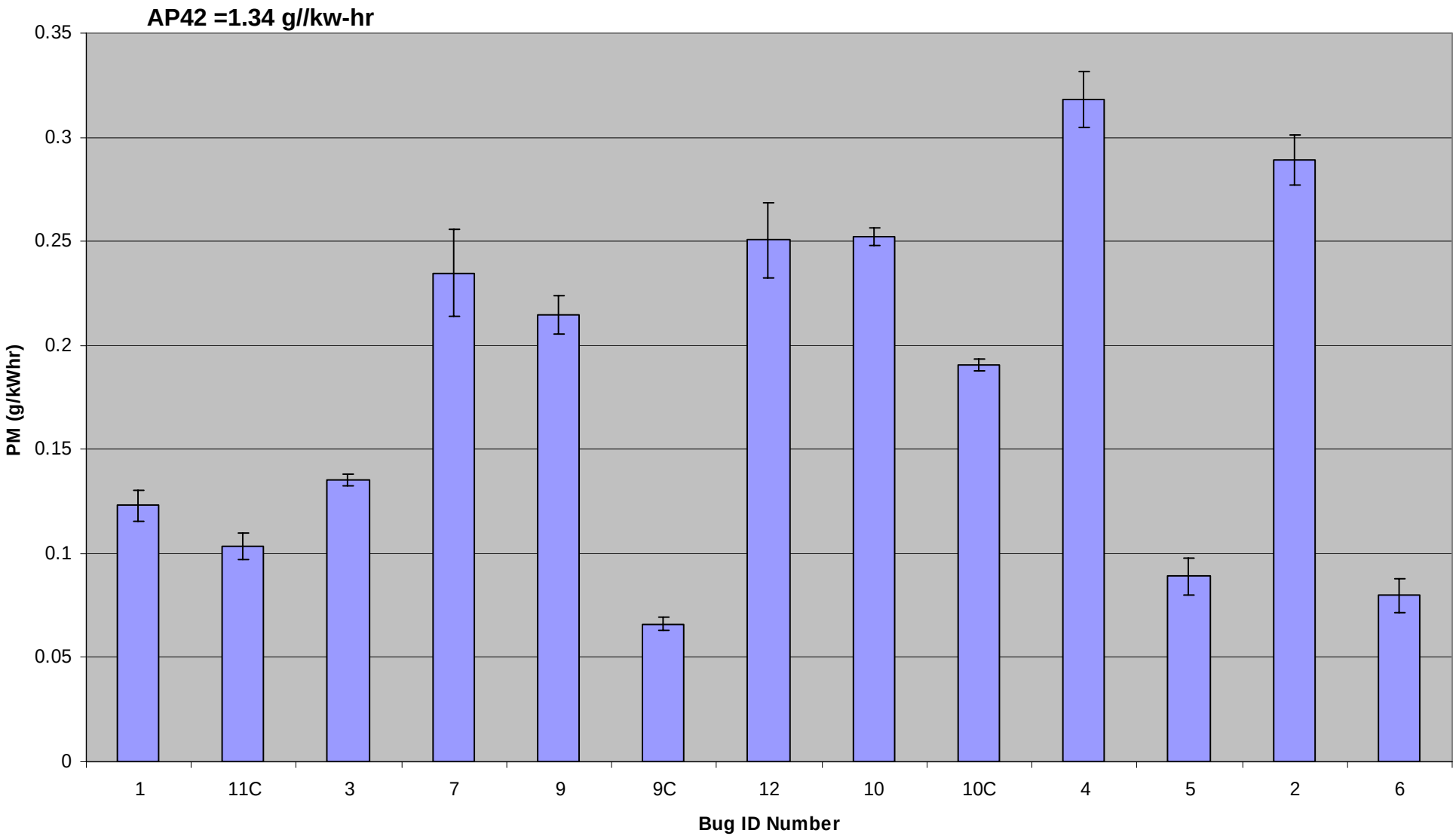
M_{GASi} **= emission factor of given pollutant at Mode i**

P_i **= load value at Mode i + auxiliary loads**

Cold Start Emissions for the Detroit 92 at VAF

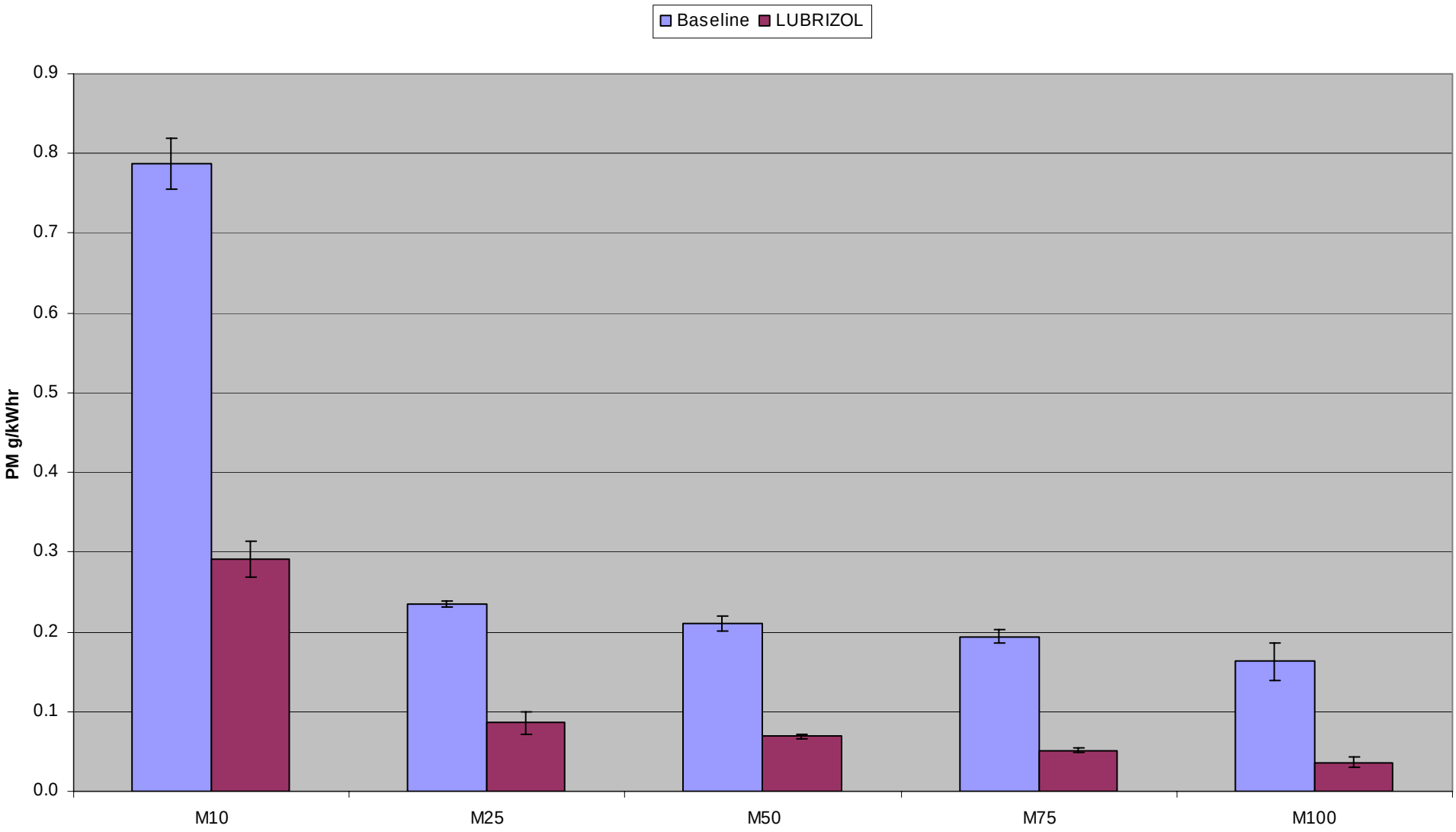


$PM_{2.5}$ Emission Factors



BUG Emissions with Fuel Change

$PM_{2.5}$ Emission Factors: Diesel-water Emulsion with Newer BUG



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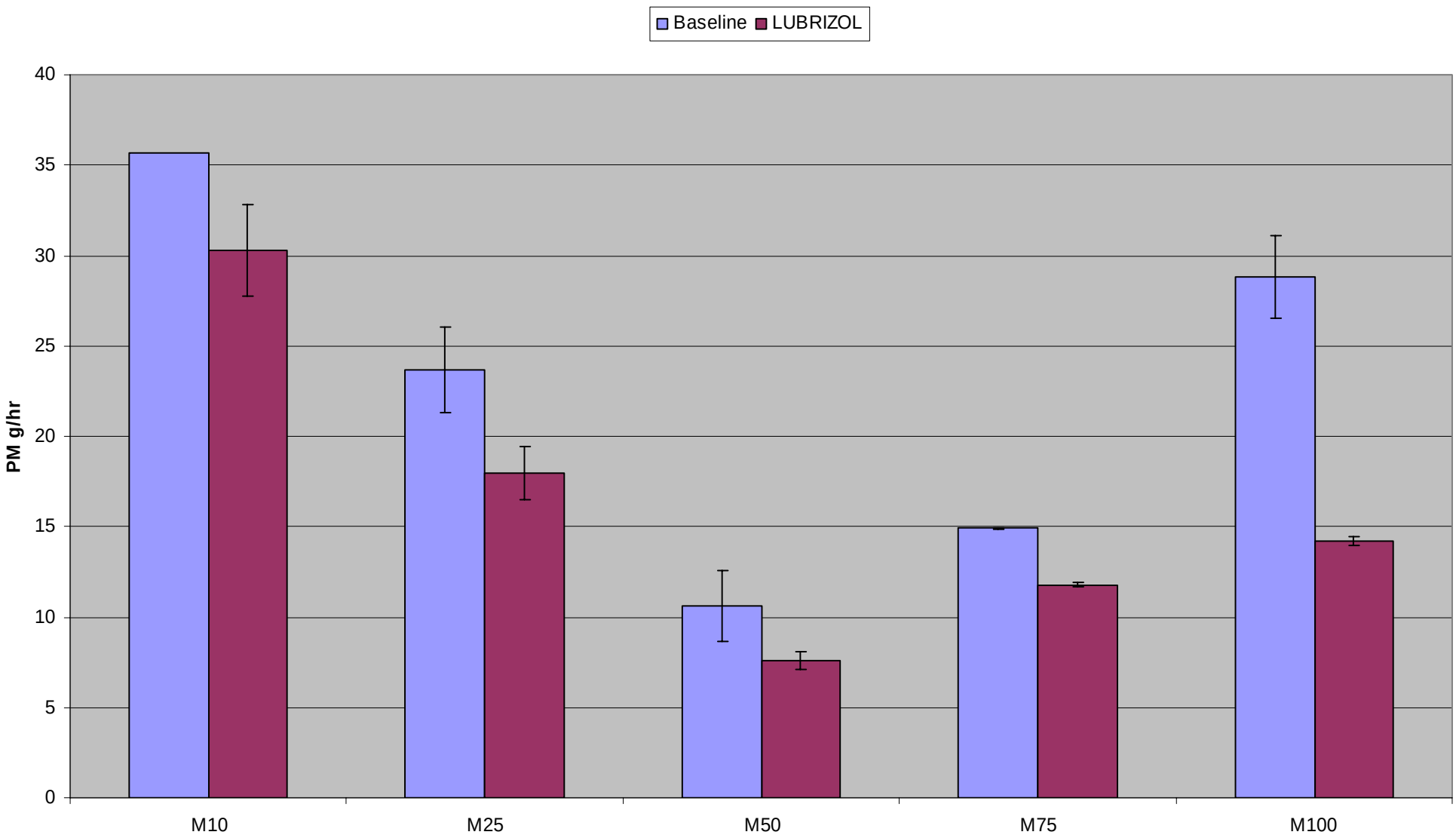
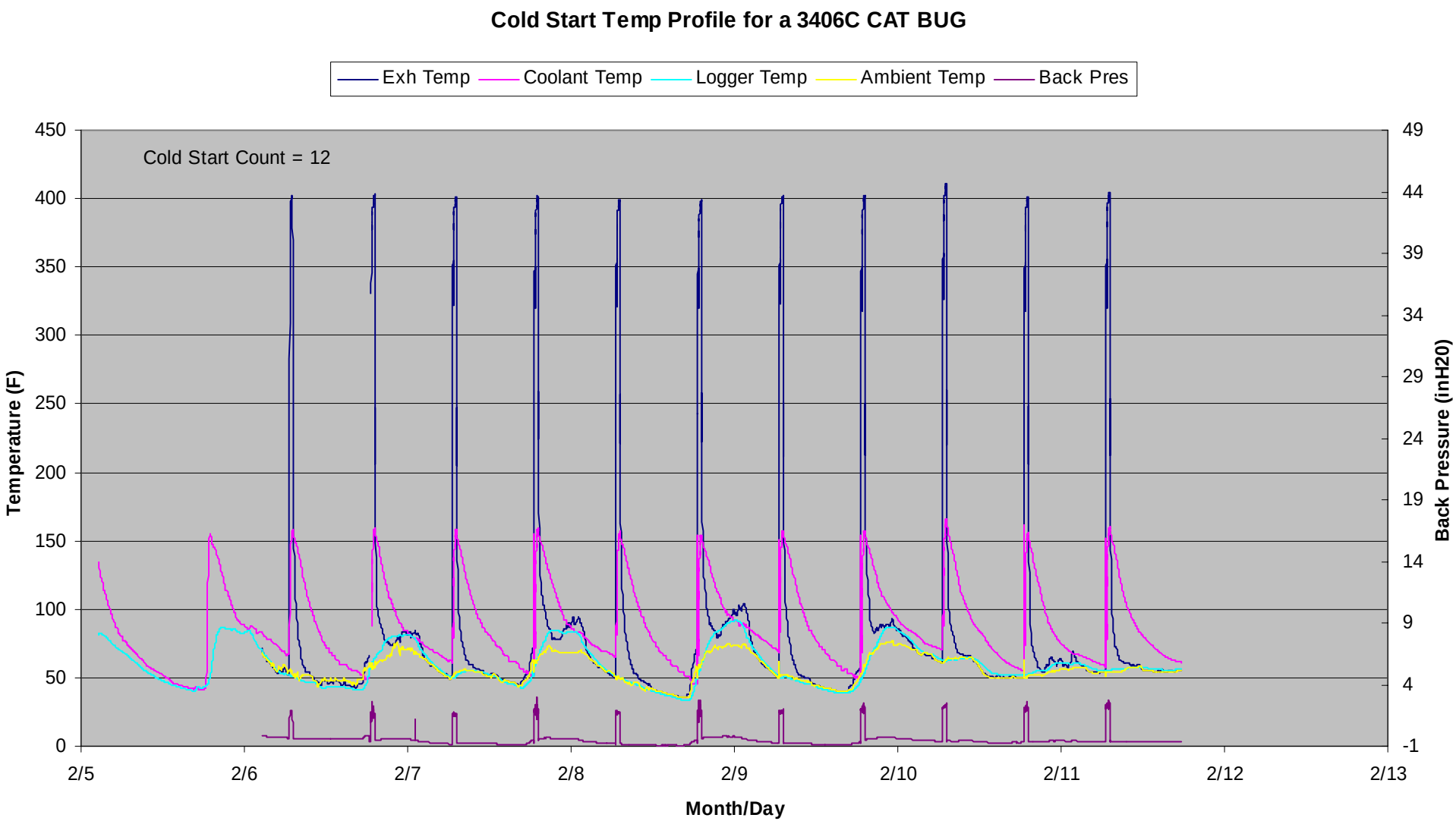
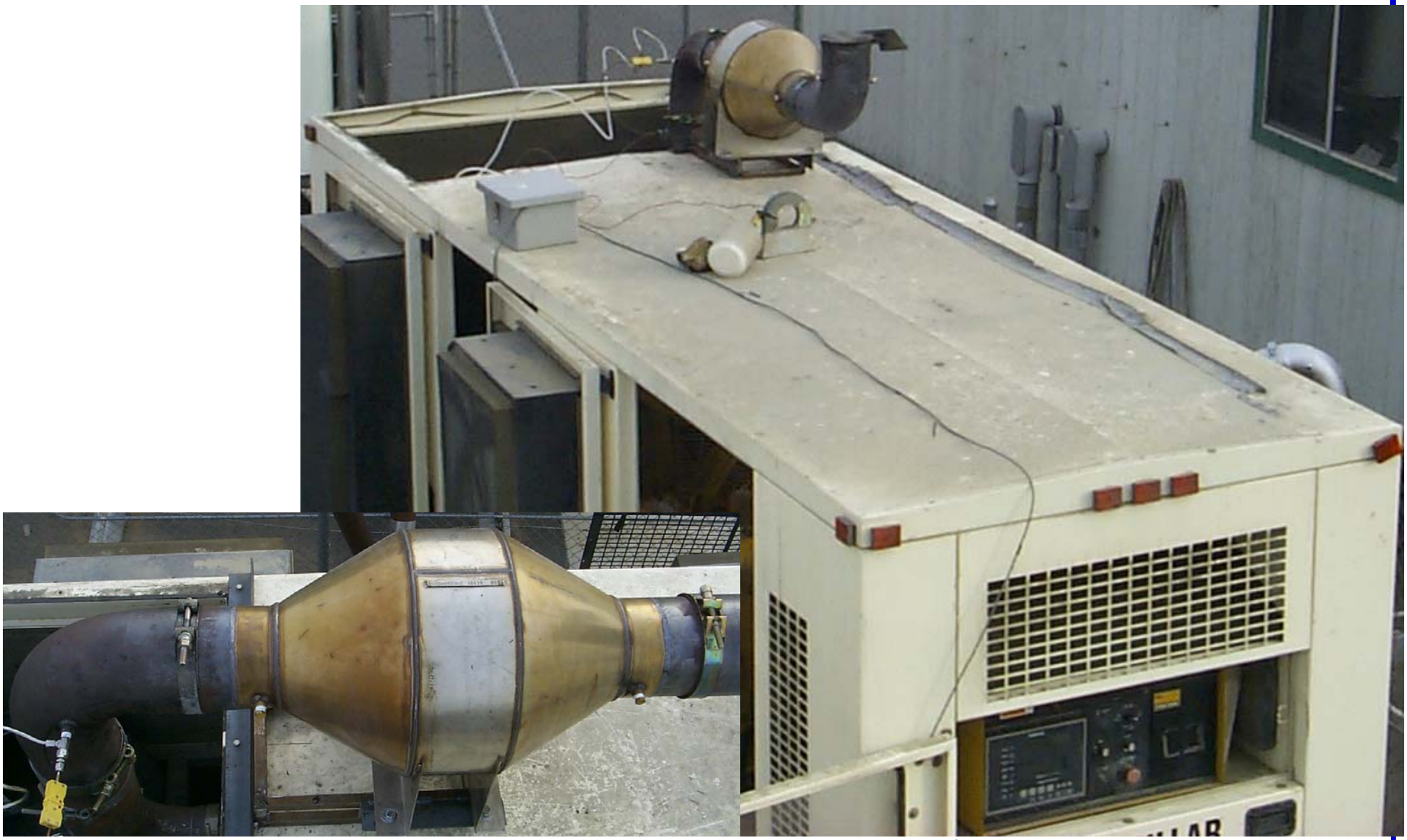


BUG Emissions with Control Device

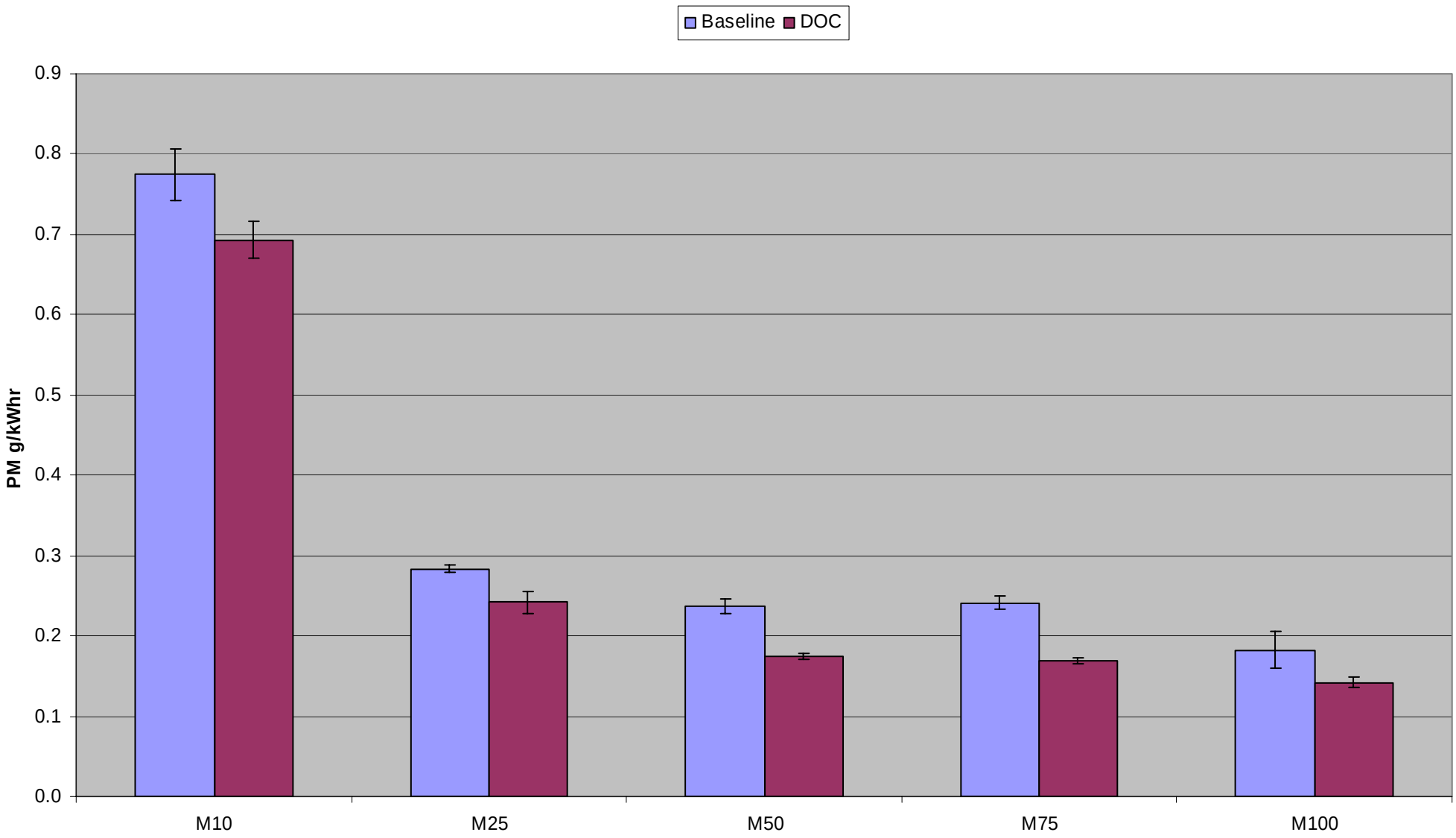
Maintenance Cycle



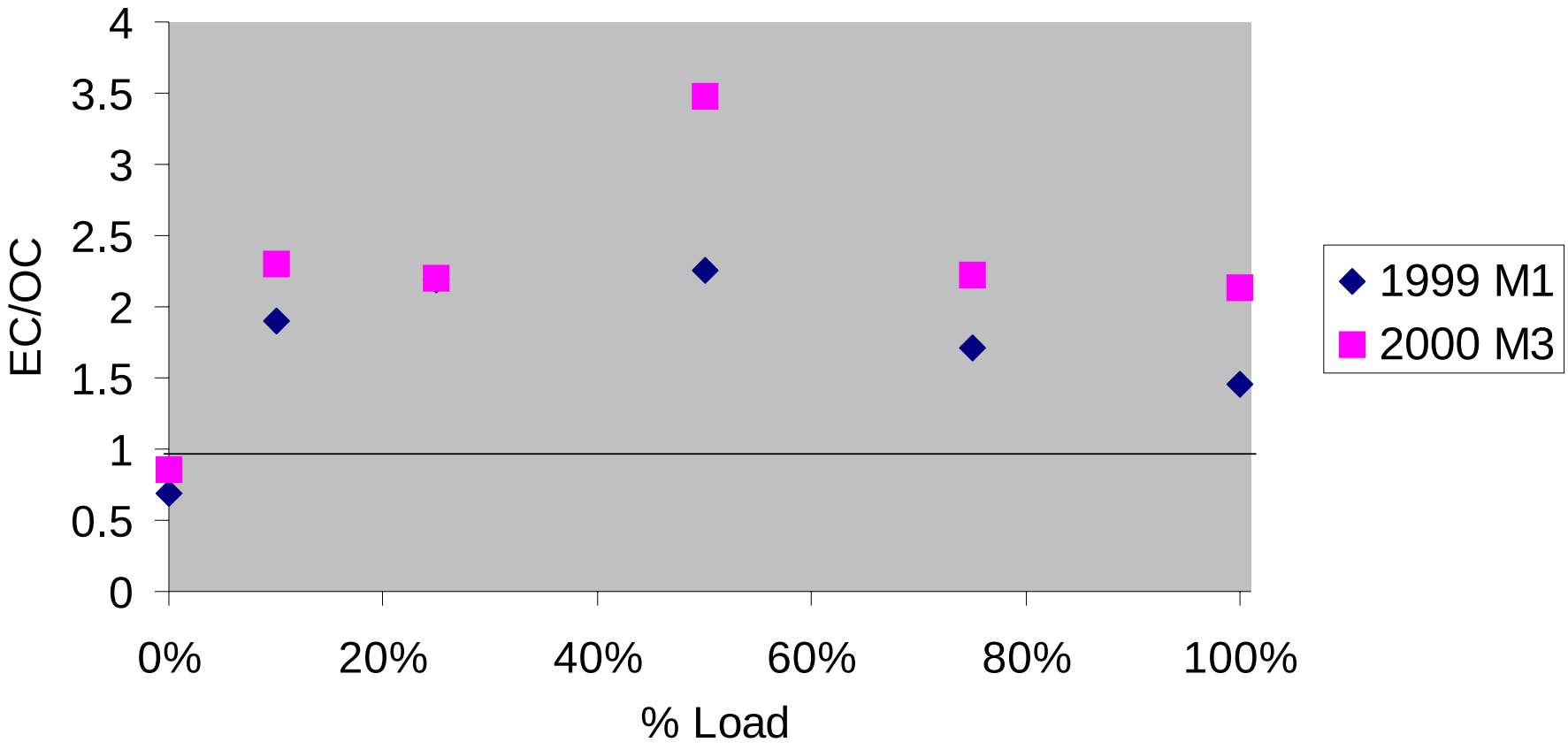
Diesel Oxidation Catalyst



$PM_{2.5}$ Emission Factors with Diesel Oxidation Catalyst

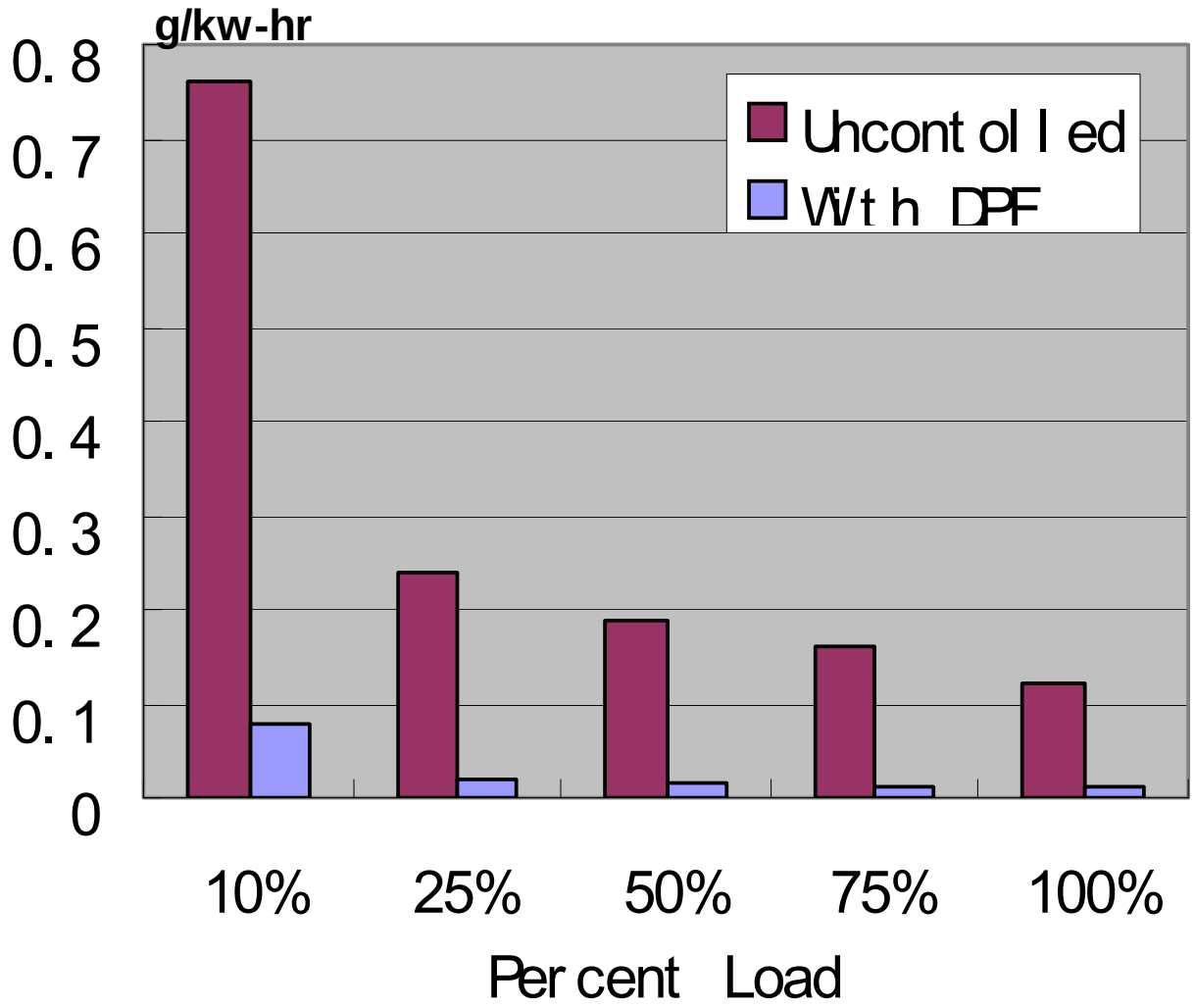


Measurement of Elemental and Organic Carbon



Passive Diesel Particle Filter

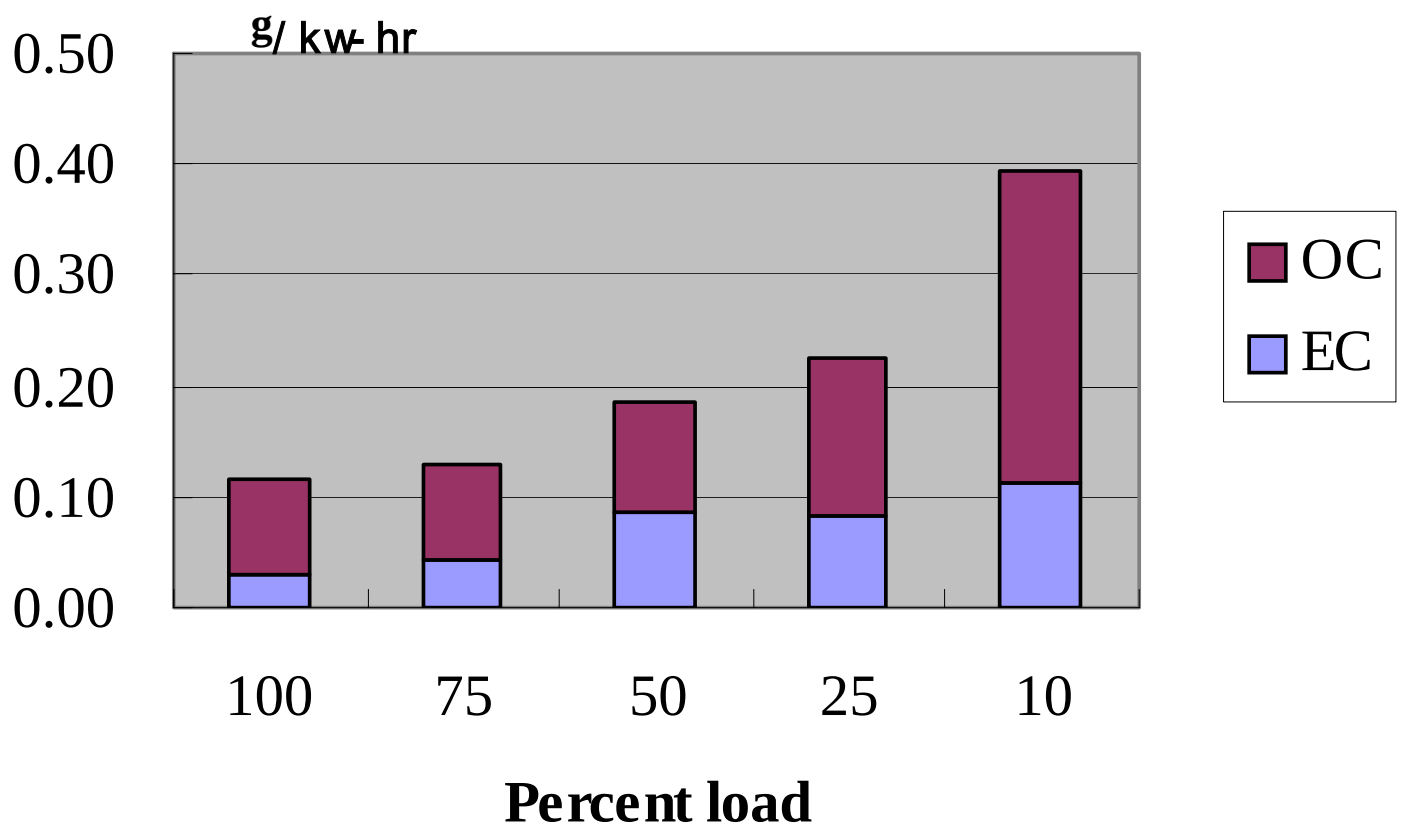
Control of New BUG with DPF



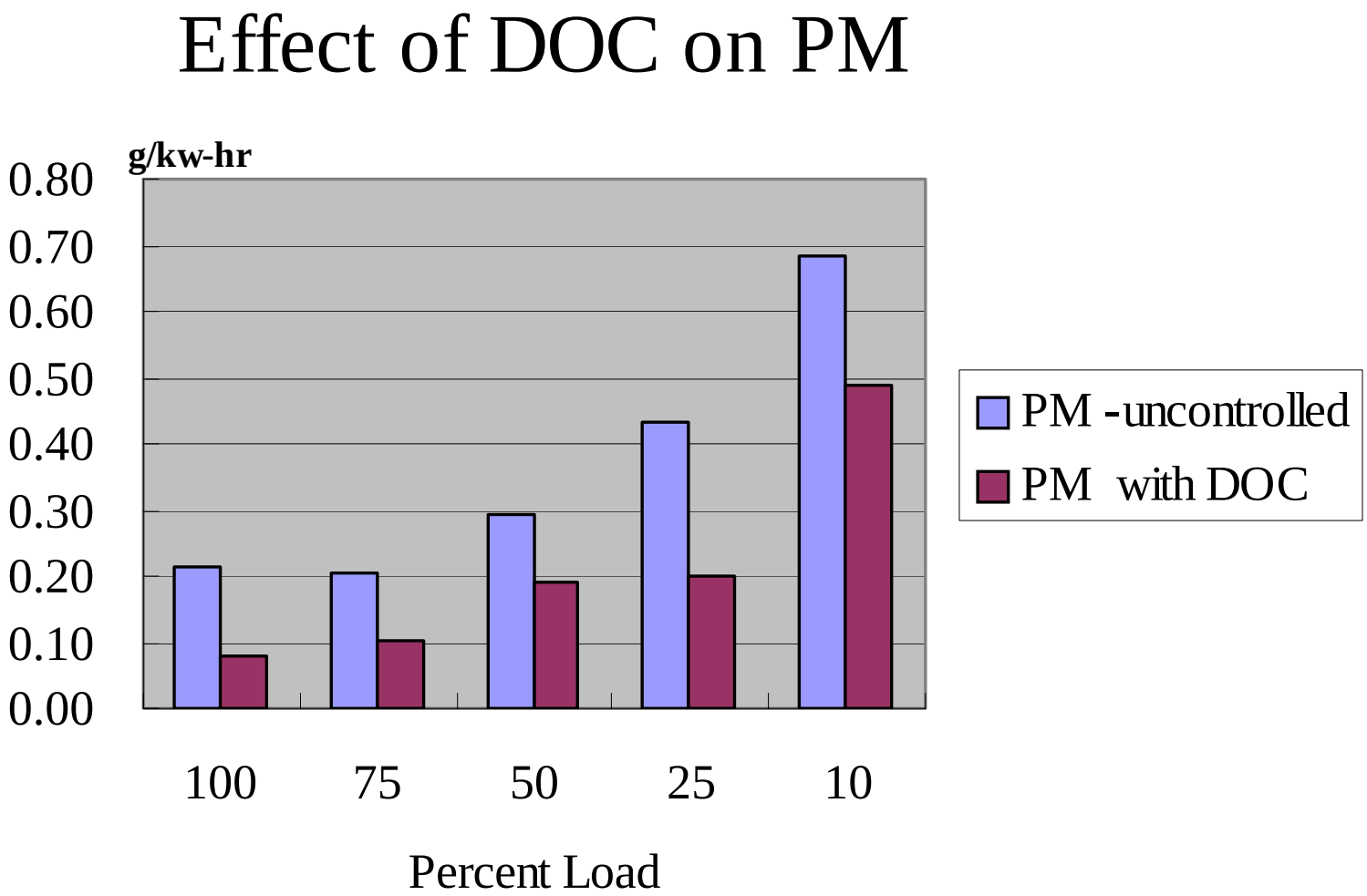
Active Diesel Particle Filter System

Control of Older Two-stroke BUG

Control of Older BUG



Control of Older BUG



Looking Ahead

- **Test larger (>1,000 hp) BUGS in uncontrolled mode.**
- **Complete demonstration of PM control for ongoing activities including:**
  - **Control of older 2-stroke diesel engines with a fuel borne catalyst and diesel oxidation catalyst.**
  - **Control with fuel borne catalyst additive and bare filter.**
- **Demonstrate combined system of PM control plus selective catalytic reduction (SCR) for control of PM and NOx.**
- **Transition of data to EPA's AP-42 tables for general use.**

Conclusions

- **Results showed that emission factors for the uncontrolled BUGs were less than in the AP-42 tables.**
- **With control technology, the PM emissions can be reduced from 15% to 99.8+%.**
- **Selection of the control technology depends on a number of factors, including PM characterization.**

Thank You Sponsors!

- US Environmental Protection Agency (US EPA)
- California Air Resources Board (CARB)
- California Energy Commission (CEC)
- South Coast Air Quality Management District (AQMD)
- Detroit Diesel Corporation
- International Truck & Engine
- Caterpillar
- Cummins
- Mack
- Volvo