

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

U.S. Department of Energy's

9th Diesel Engine Emissions Reduction Conference

Newport, Rhode Island

August 24-28, 2003

J. Wayne Miller, Kent Johnson, John Lee, Marla Mueller, Bonnie Soriano, Bill Welch

Supporting contributors: David R. Cocker III, Kathalena Cocker, Jim Lents, Don Pacocha, Sandip Shah,
Alex Santos, Peggy Taricco

**University of California, Riverside
Bourns College of Engineering
Center for Environmental Research and Technology**

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

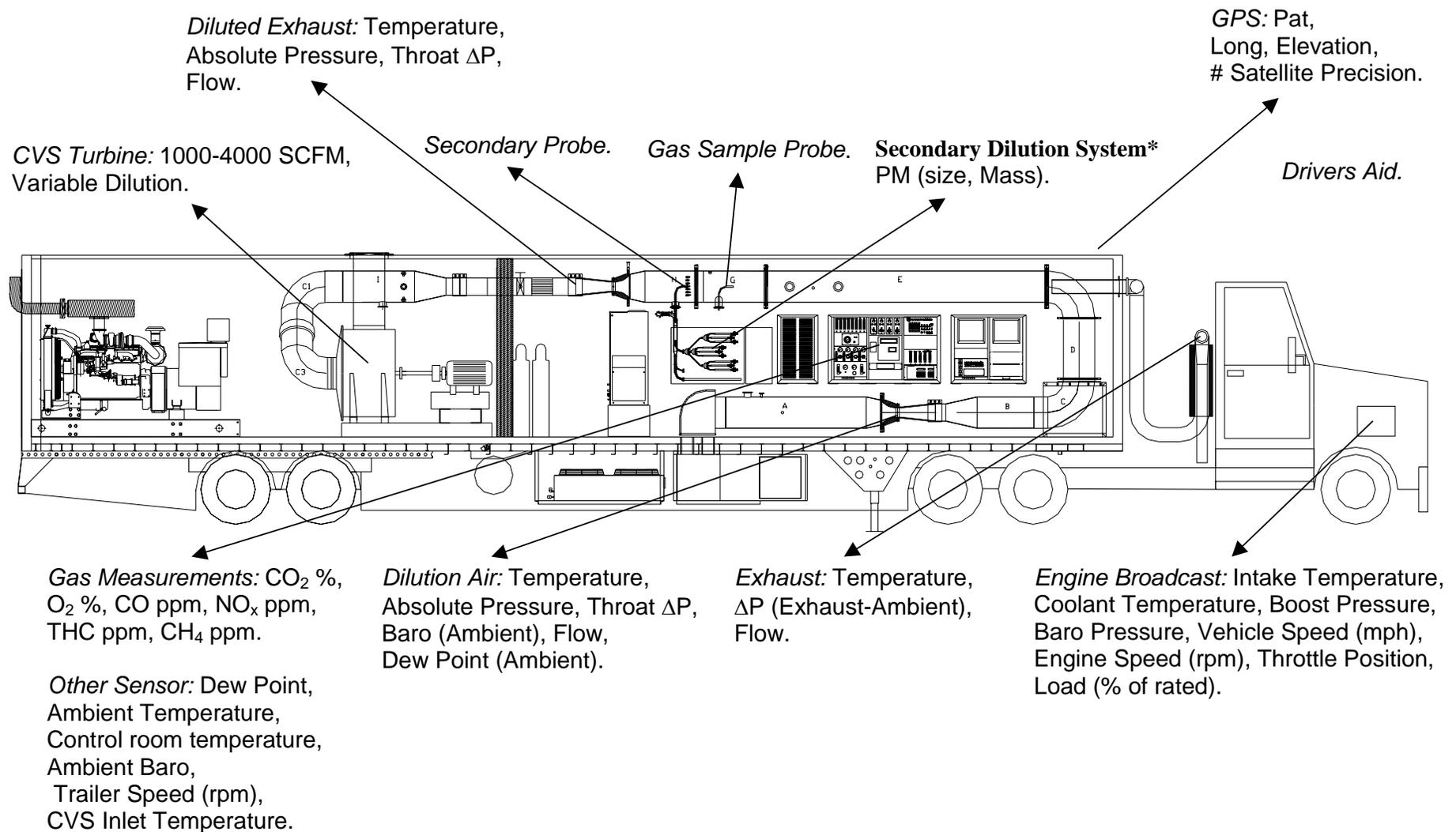
EPA's AP-42 Emission Factors - Small Diesel

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
NO _x	0.031	18.85	4.41	D
CO	6.68E-03	4.06	0.95	D
SO _x	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

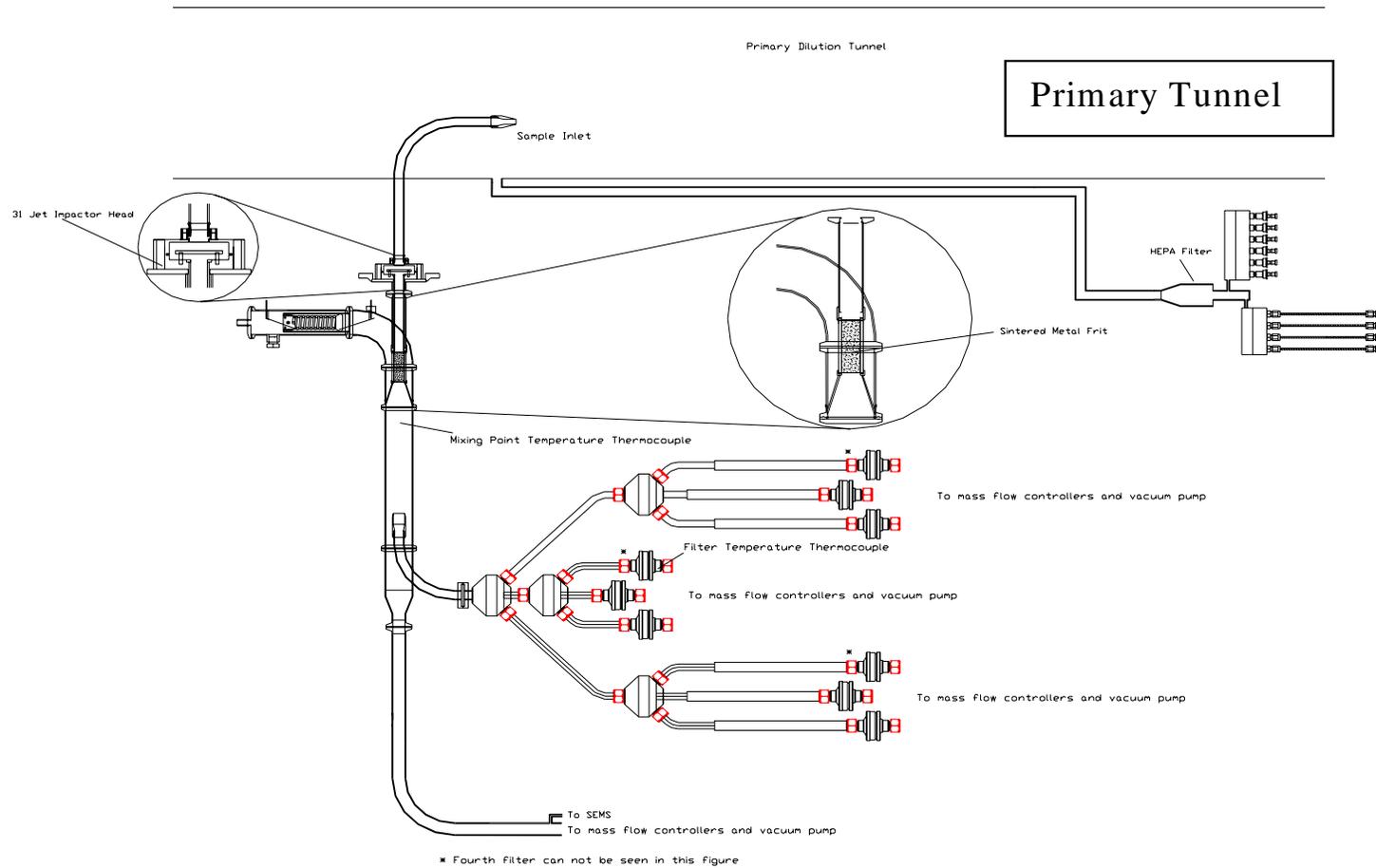
UCR's Mobile Emission Lab



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



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	CO₂	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)



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

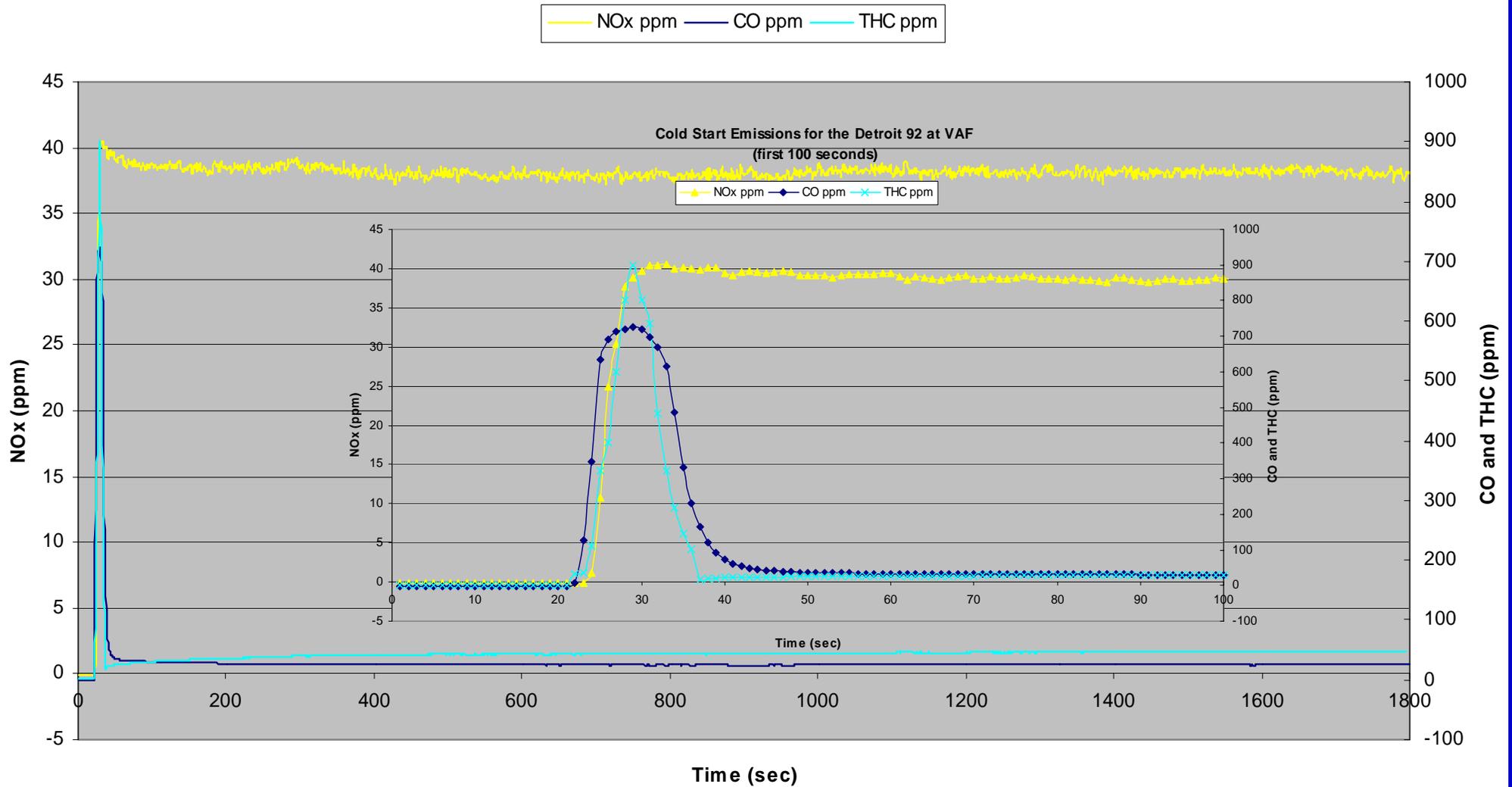
Example:

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

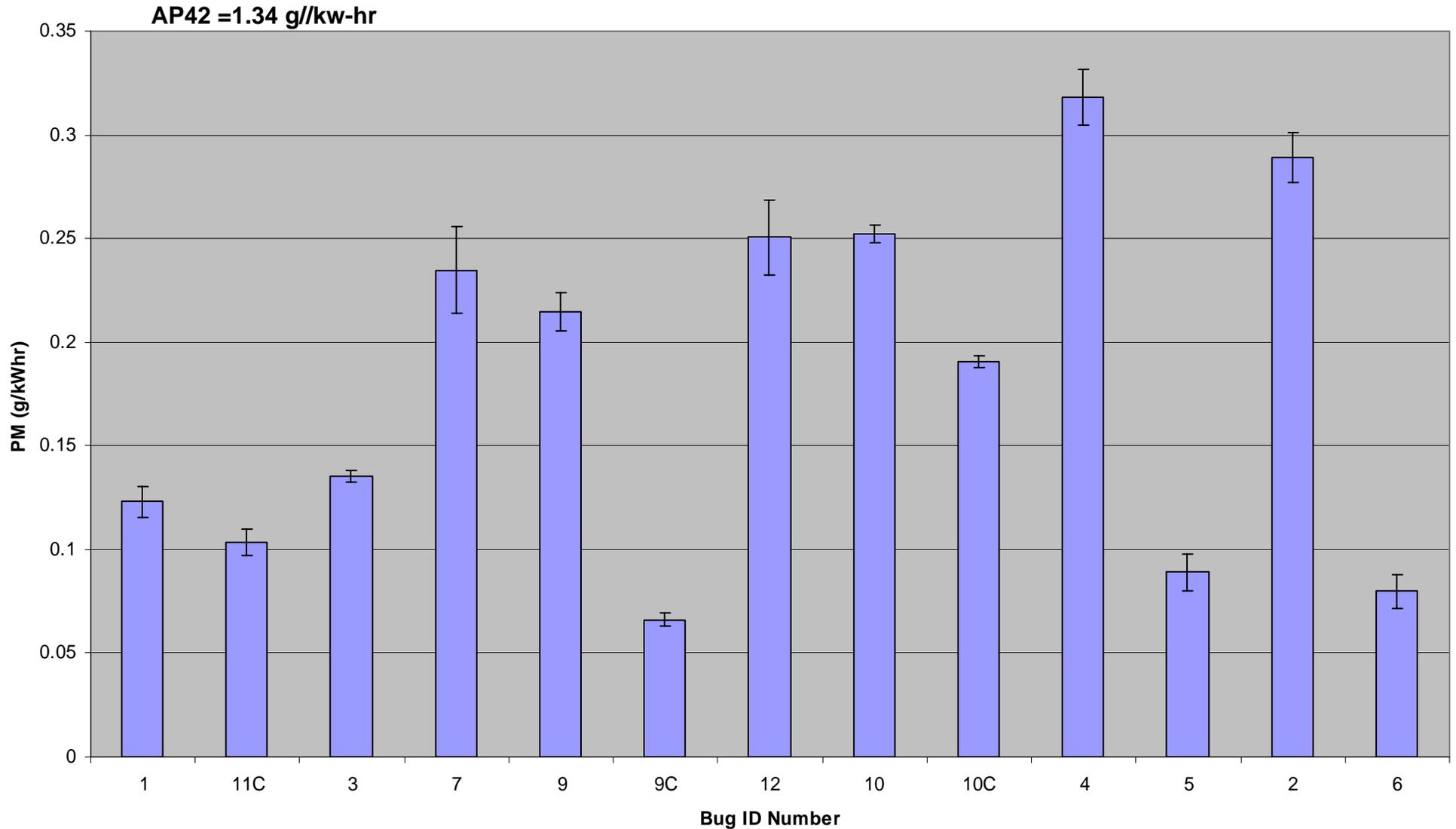
Where:

- 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

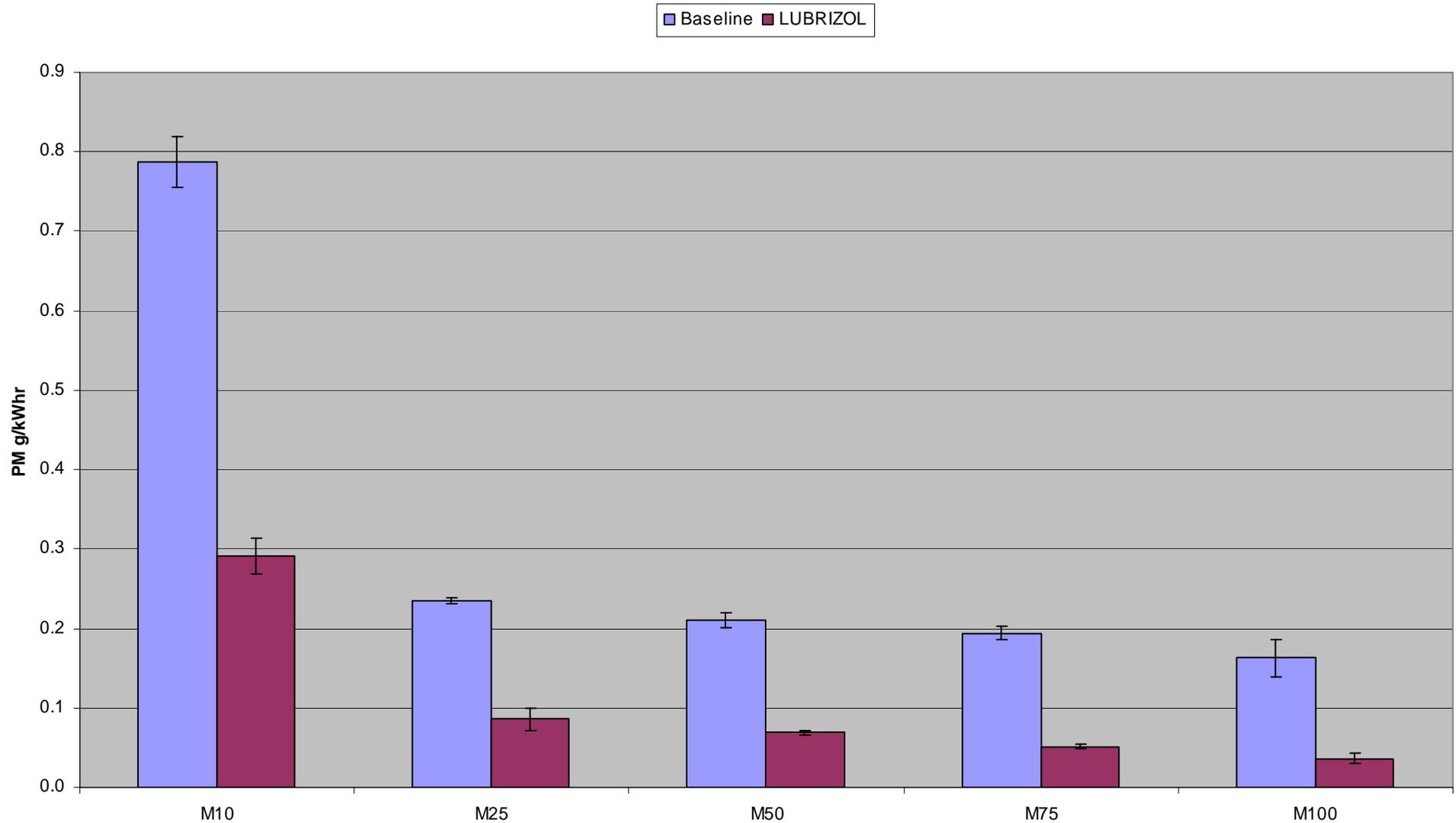


PM_{2.5} Emission Factors

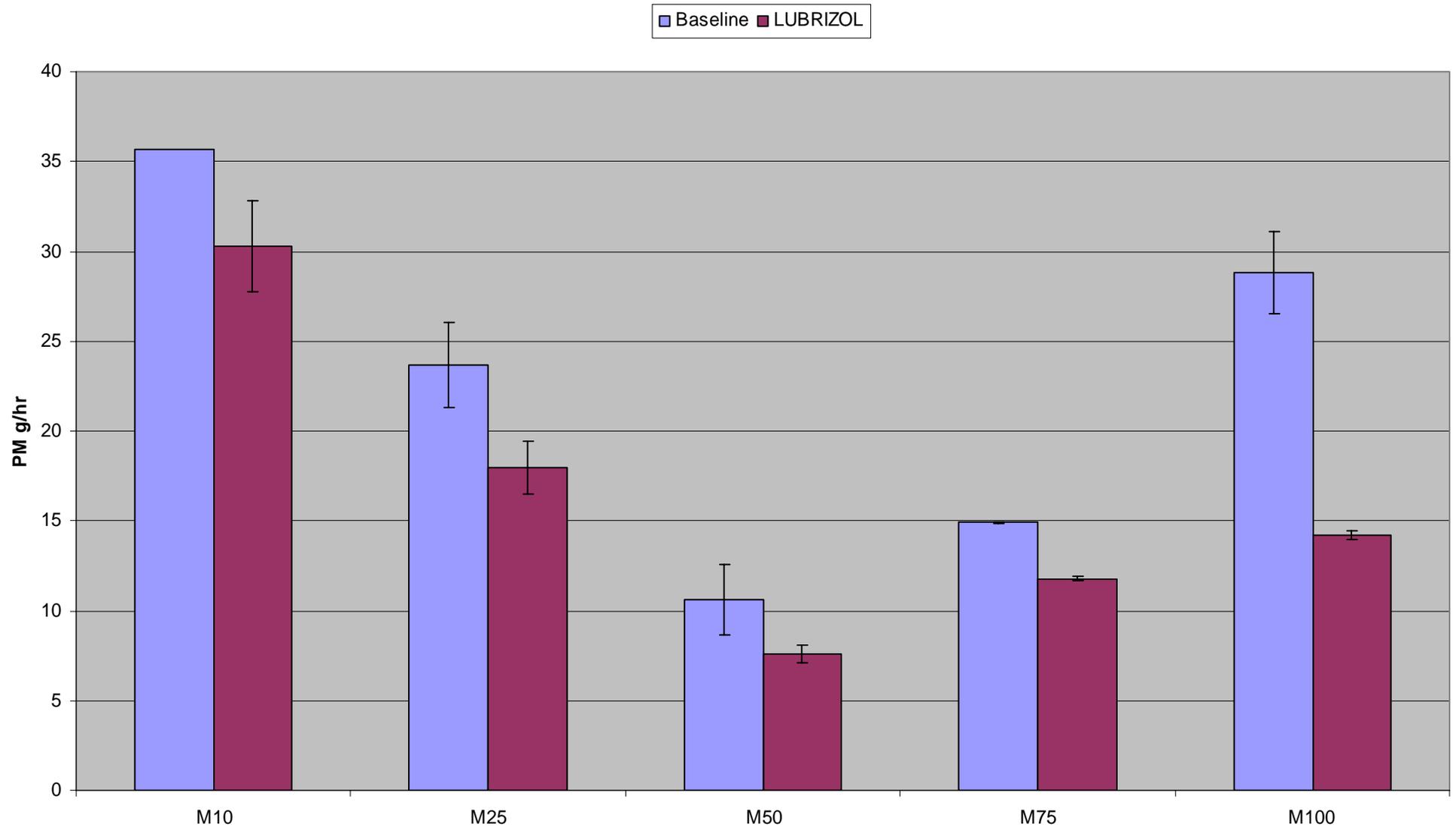


BUG Emissions with Fuel Change

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



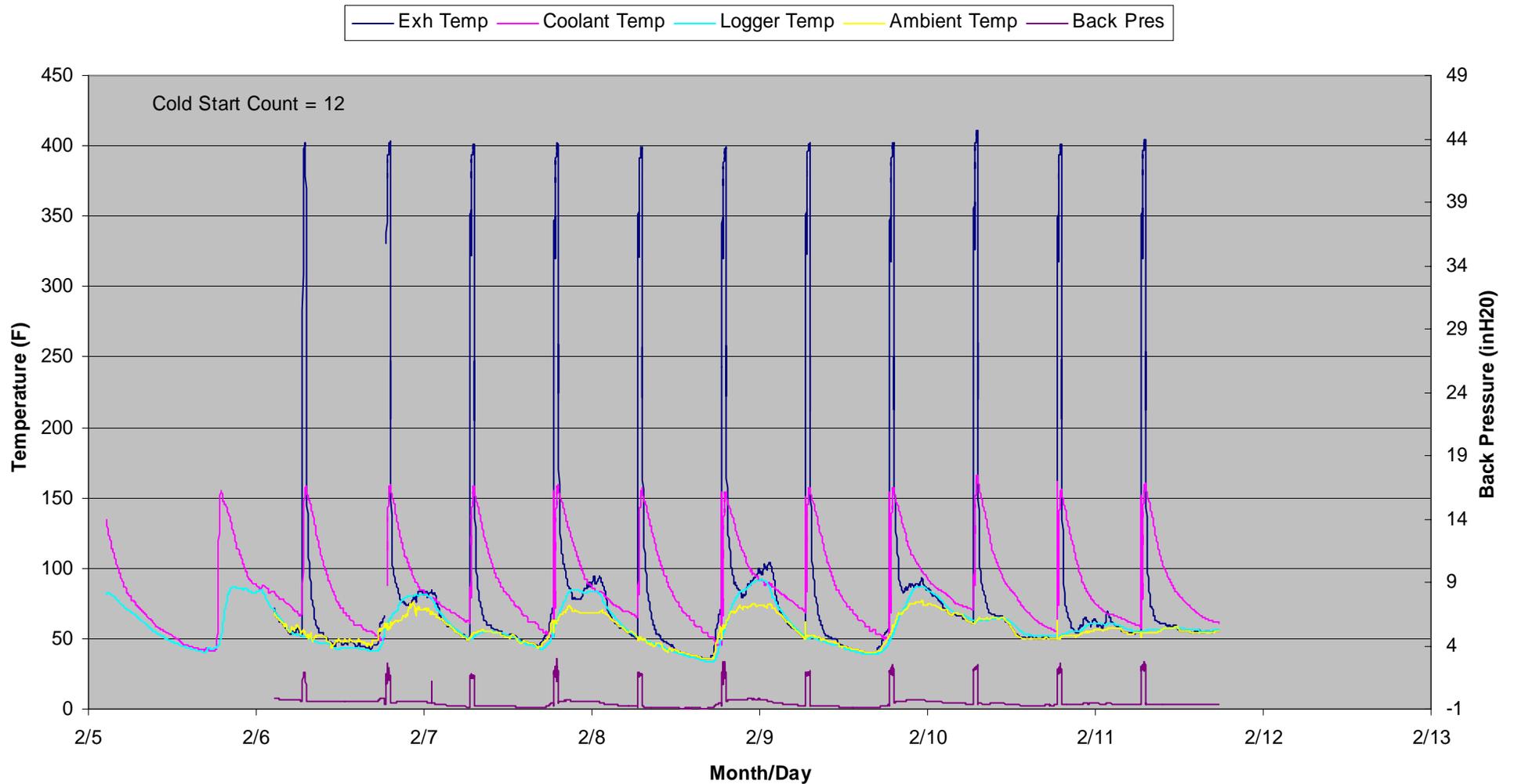
PM_{2.5} Emission Factors: Diesel-water Emulsion with Older BUG



BUG Emissions with Control Device

Maintenance Cycle

Cold Start Temp Profile for a 3406C CAT BUG

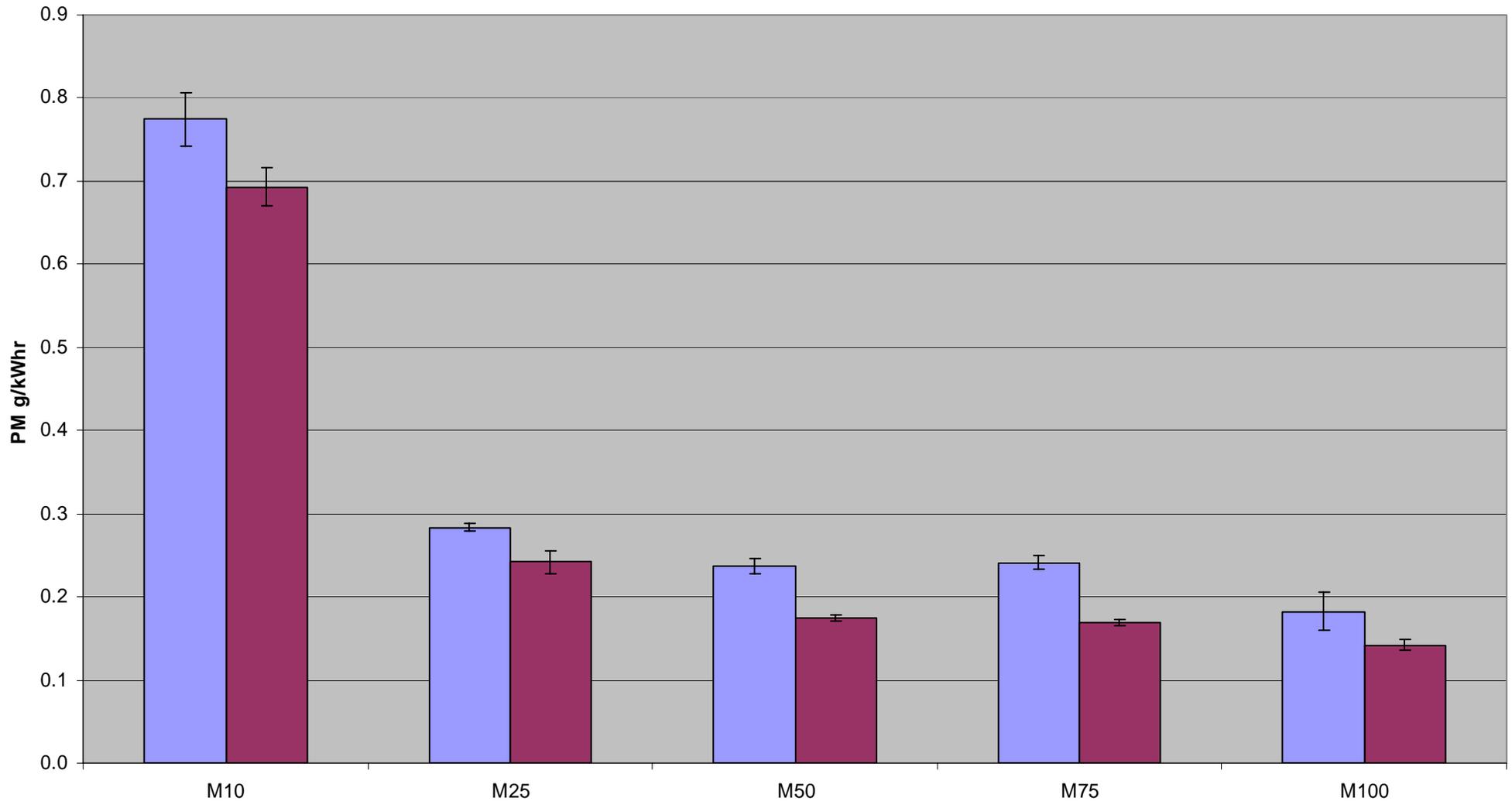


Diesel Oxidation Catalyst

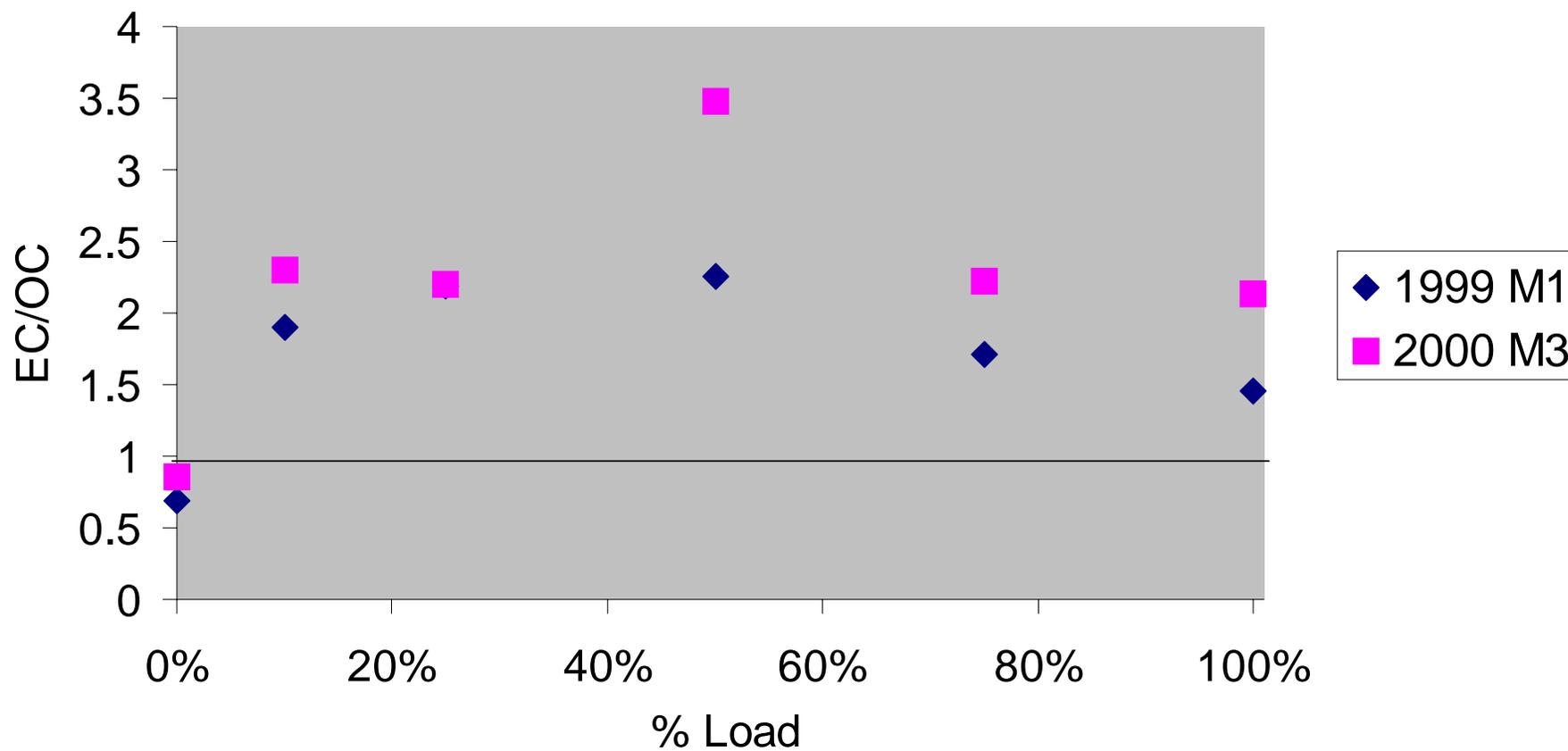


PM_{2.5} Emission Factors with Diesel Oxidation Catalyst

Baseline DOC



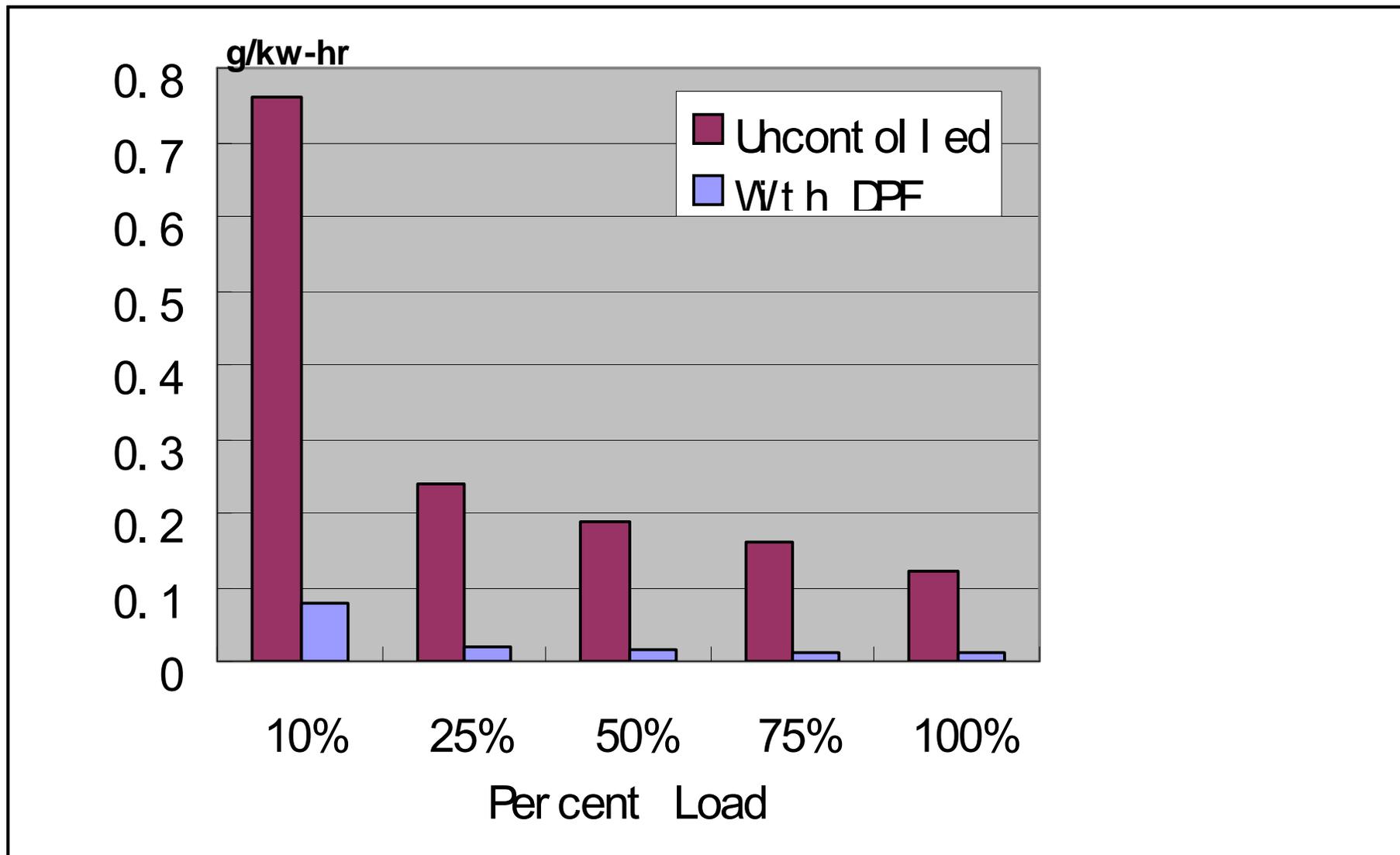
Measurement of Elemental and Organic Carbon



Passive Diesel Particle Filter



Control of New BUG with DPF



Active Diesel Particle Filter System

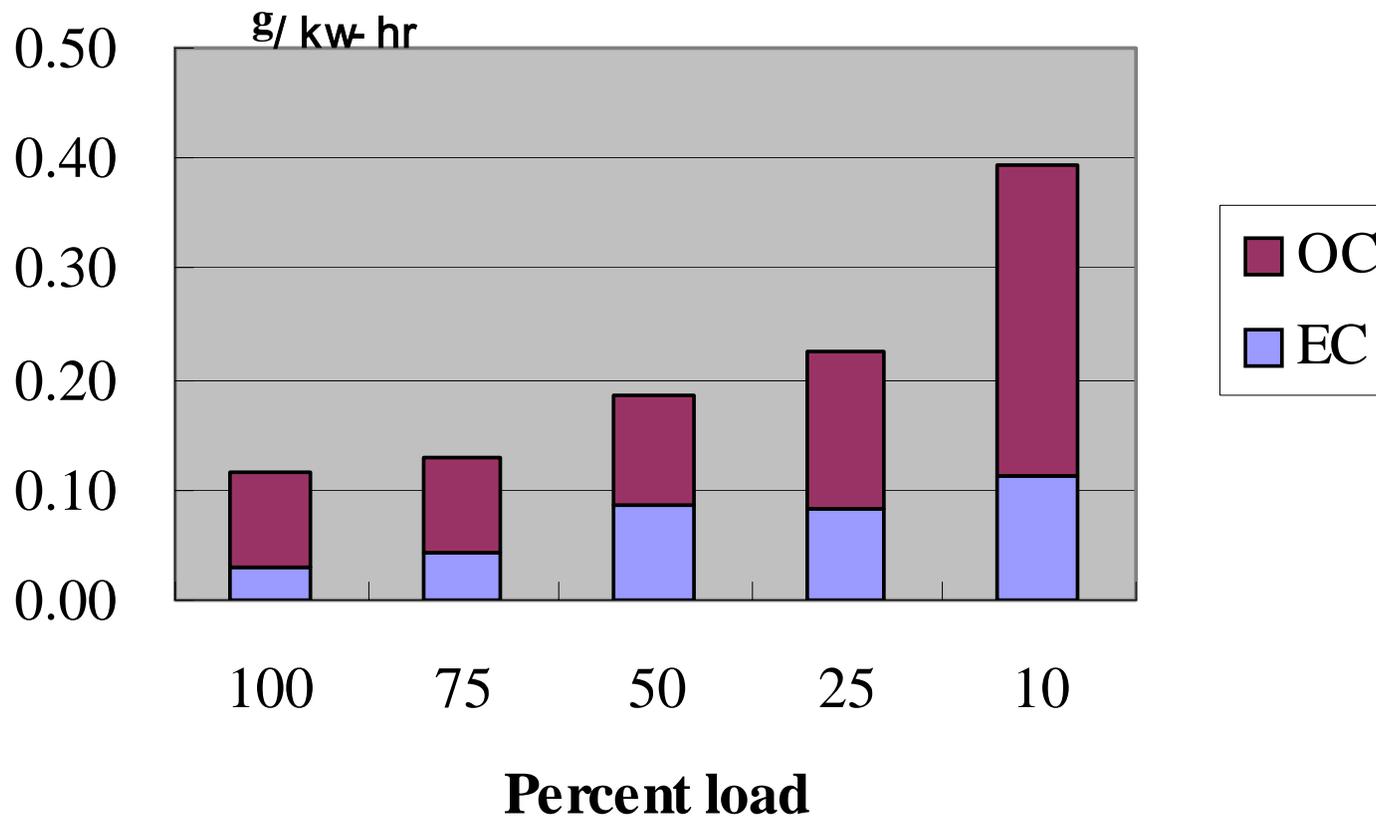


Control of Older Two-stroke BUG

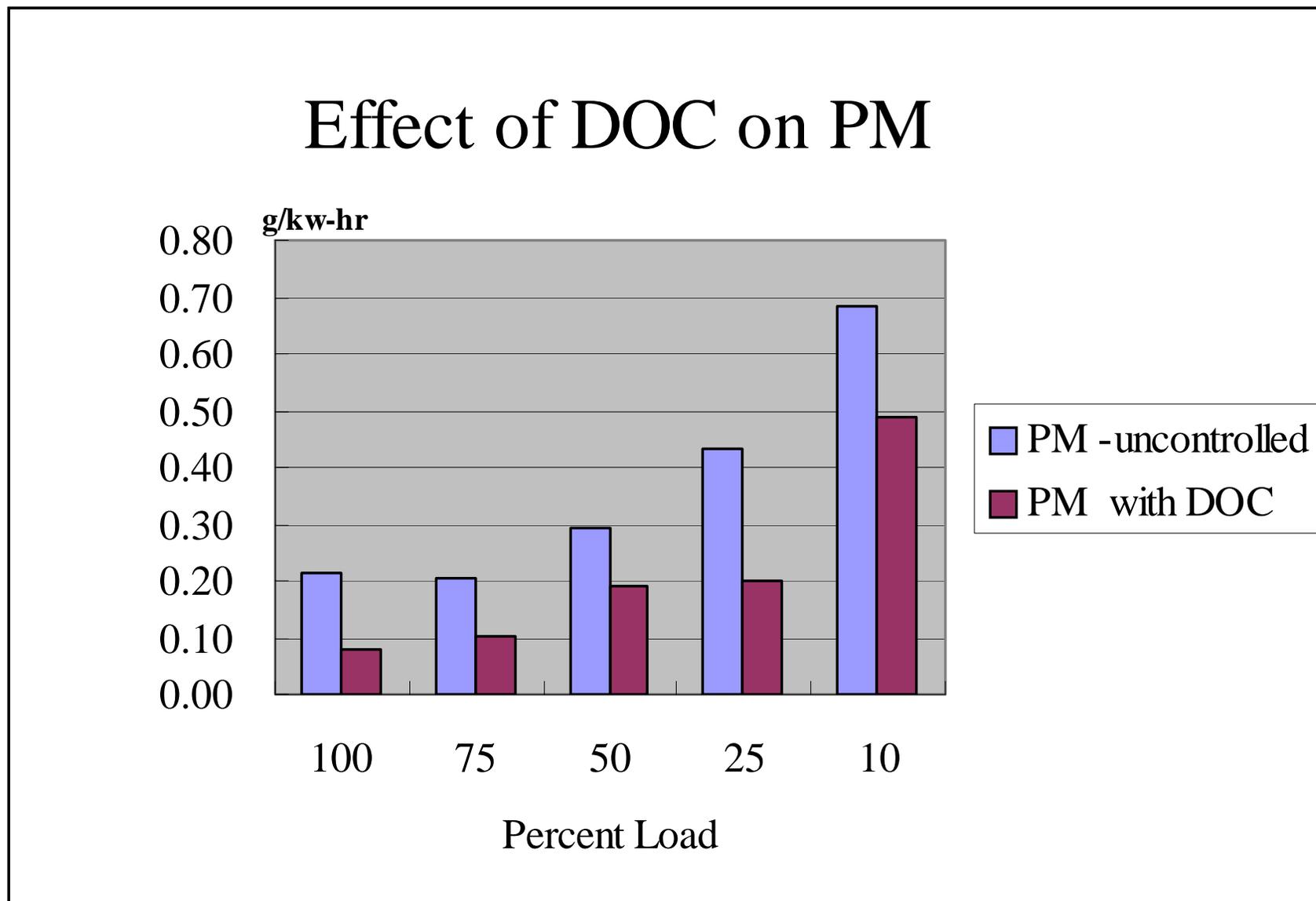


Control of Older BUG

EC & OC for Uncontrolled Old 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 NO_x.**
- **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