Solid and Total Exhaust Particle Mass, Number, and Size Emissions from a Diesel Powered Generator

Imad A. Khalek, Ph.D., Southwest Research Institute, Department of Engine and Emissions Research; 8th Nanoparticle Conference, Zurich, Switzerland, 2004.

Diesel particulate matter (PM) consists of volatile and solid materials. The solid fraction is dominated by soot with a small fraction of metallic ash derived from the lubricating oil. The volatile fraction consists of unburned and partially burned fuel and lubricating oil in addition to sulfate. Thus, it is important to characterize both the volatile and the solid fraction in order to better understand the nature of PM emissions and better control them.

Diesel powered generators can contribute significant PM emissions to the atmosphere, particularly at high load, and now the US EPA is tasked to regulate emissions from these sources by June 2006. Previously, it was the responsibility of individual states to impose regulations on stationary sources. This presentation covered both volatile and solid PM emissions from a 3.8 kW naturally aspirated diesel powered generator using US 2D fuel. The work was performed using a solid particle measurement system (SPMS^{TM}) which was described during the 7th Nanoparticle Conference.

In this work, the diesel powered generator was derated to 75 percent of its rated power output due to the high emission of PM and smoke. After derating, the PM concentration ranged from a 100 mg/m^3 at high load to 1 mg/m^3 at light load. The volatile fraction ranged from 20 percent at high and partial load to more than 90 percent at light load. The number mean diameter ranged from 70 nm at high load to about 20 nm at light load and the mass mean diameter ranged from 140 nm at high load to about 60 nm at light load.

It is generally thought that the accumulation mode (50 nm to 200 nm) of the size distribution emitted from diesel is mainly soot or solid particles. This work showed that under high volatile fraction and high growth of particles the accumulation mode can be mostly dominated by volatile material rather than soot. In addition, this work revealed that volatile particles may contain a solid nuclei below 20 nm in diameter. The same phenomenon was previously observed with an on-highway diesel engine and the size of the solid nuclei was below 15 nm in diameter. It is likely that the solid nuclei consist of solid metallic ash derived from the lube oil.

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- This work was funded by SwRI Committee for Internal Research and Development. The main goal of this work is to study engine exhaust PM emissions from a stationary source and implement a unique aftertreatment system for PM removal. Information on such system will be available later.

Regulatory Note

- EPA is tasked to propose federal emissions standard for stationary diesel engines by June 29, 2005, and finalize the standard by 28 June 2006

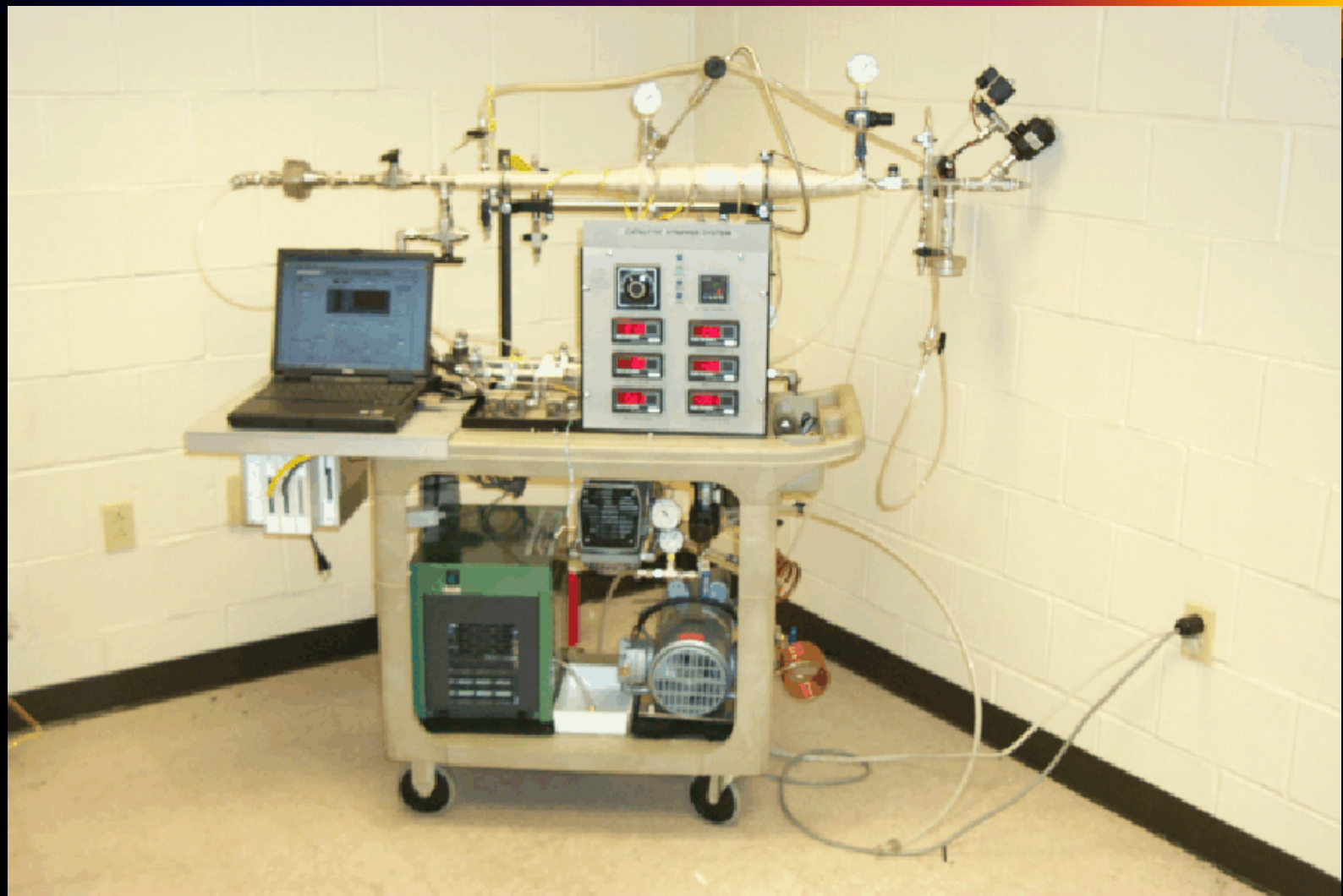
Diesel Powered Generator (Stationary Source)

Engine:	Yanmar
Model No. :	L70EE-DE15A
Displacement:	0.3 Liter
Configuration:	Single Cylinder/Water Cooled
Aspiration:	Naturally Aspirated
Max Output:	4.4 kW/3600 rpm
Generator:	Diesel America West
Model No.:	MR1-4000E-C2
Max Output:	4 kw/3600 rpm
Cont. Output:	3.8 kW/3600 rpm

Load Bank

Stand-Alone SPMS™ (Patent Pending)

(Presented last year during the 7th ETH conference)

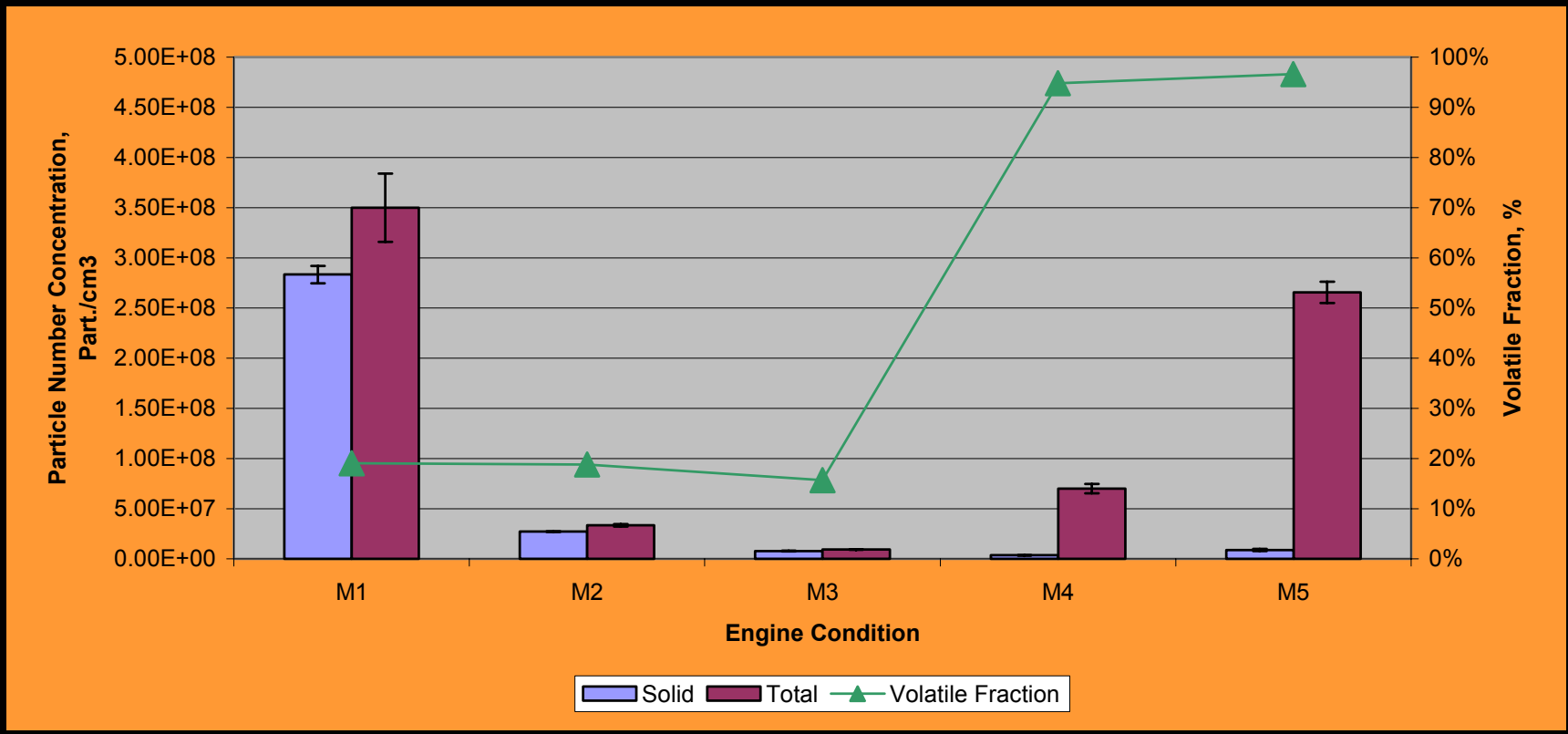


Test Matrix

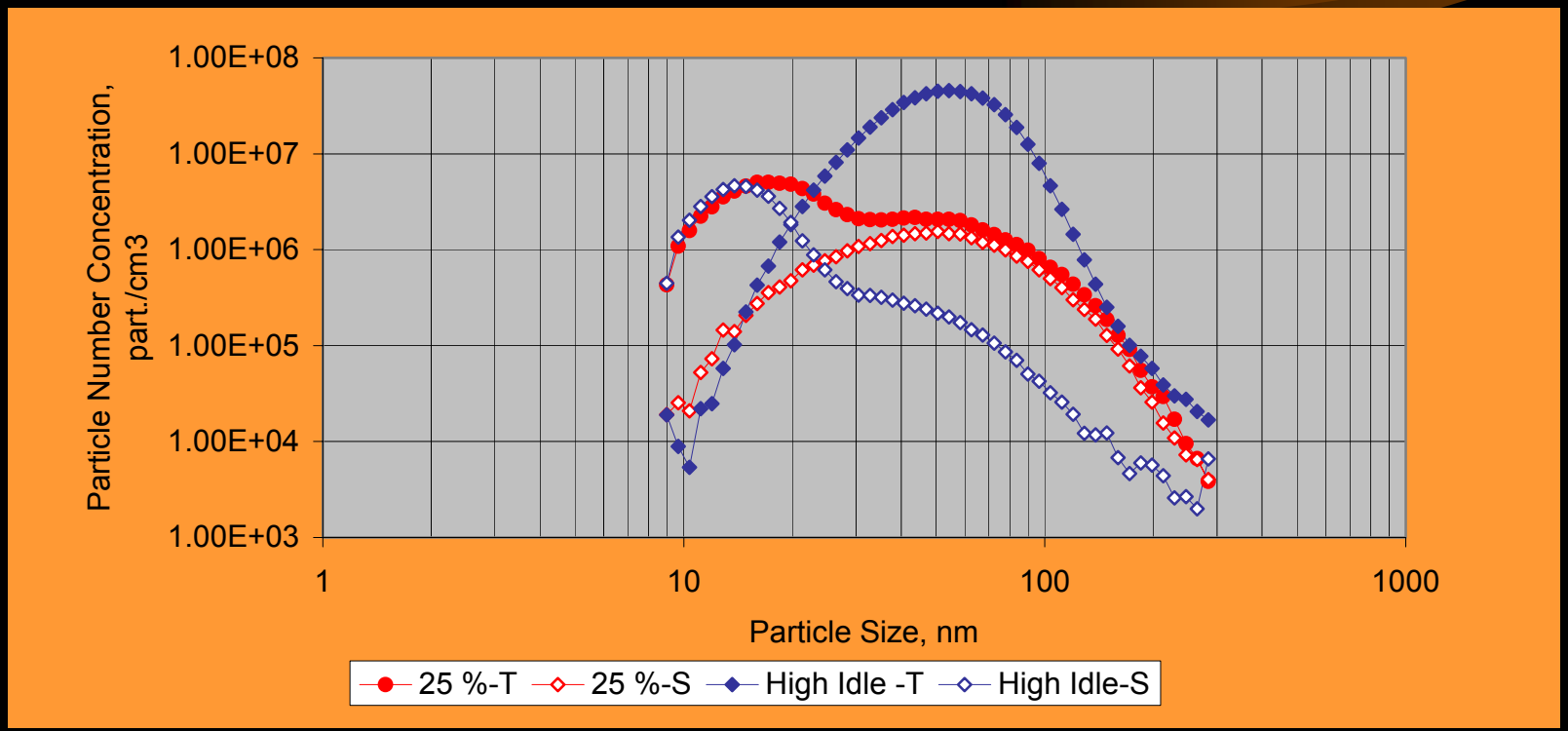
	Power, kW	Loading , %[a]	Solid Particle Mass Collection	Solid Particle Size and Number	Total Particle Mass Collection	Total Particle Size and Number	Dilution Ratio
M1	3.23	100	Yes	Yes	Yes	Yes	203
M2	2.42	75	Yes	Yes	Yes	Yes	189
M3	1.62	50	Yes	Yes	Yes	Yes	128
M4	0.81	25	Yes	Yes	Yes	Yes	81
M5	0	0	Yes	Yes	Yes	Yes	67

[a]The load was normalized to the 3.23 kW condition. At higher load, the engine had a very high level of particle mass concentration of more than 600 mg/m^3.

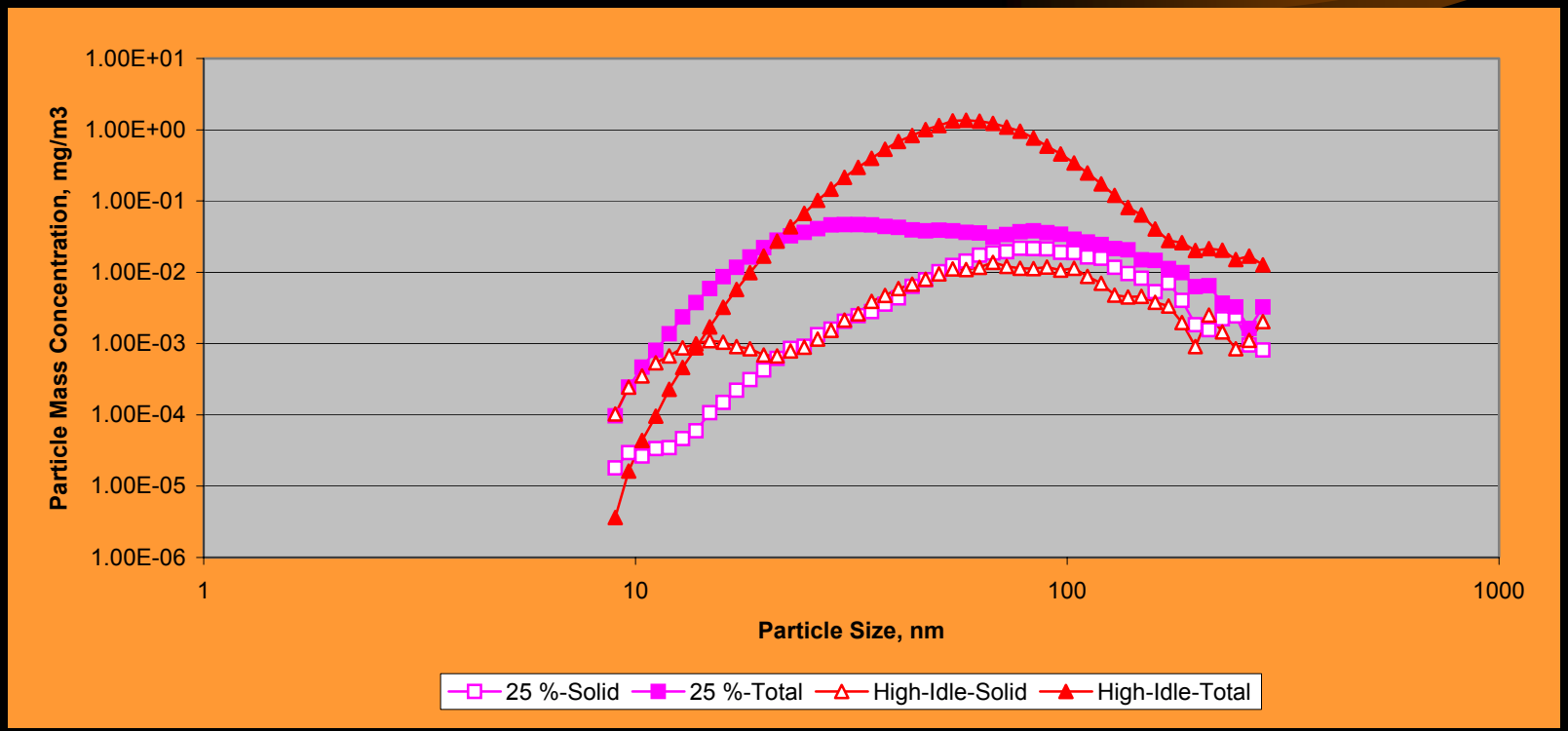
Solid and Total Particle Number Emissions



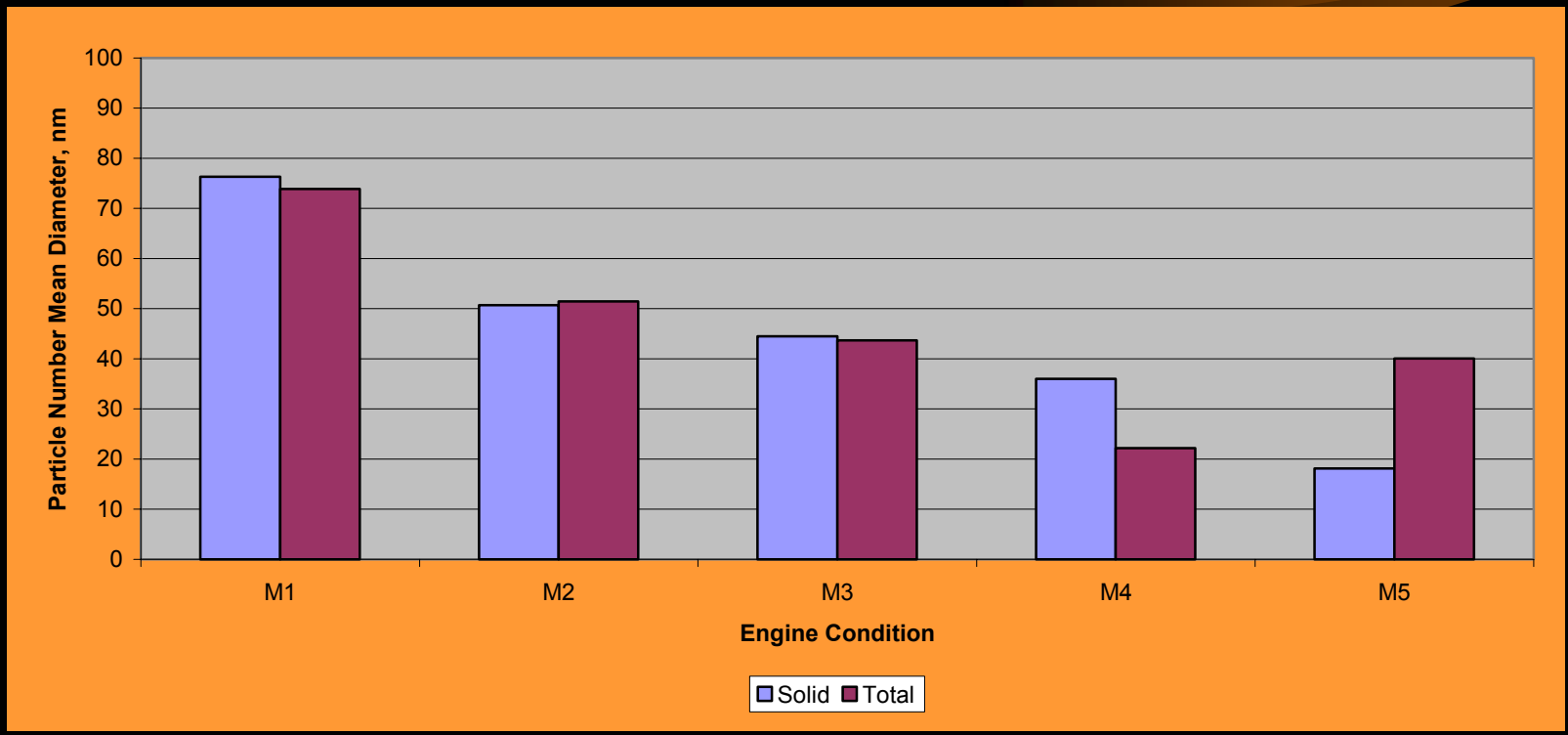
Total and Solid Particle Number-Weighted Size Distribution (Diesel Powered Generator)



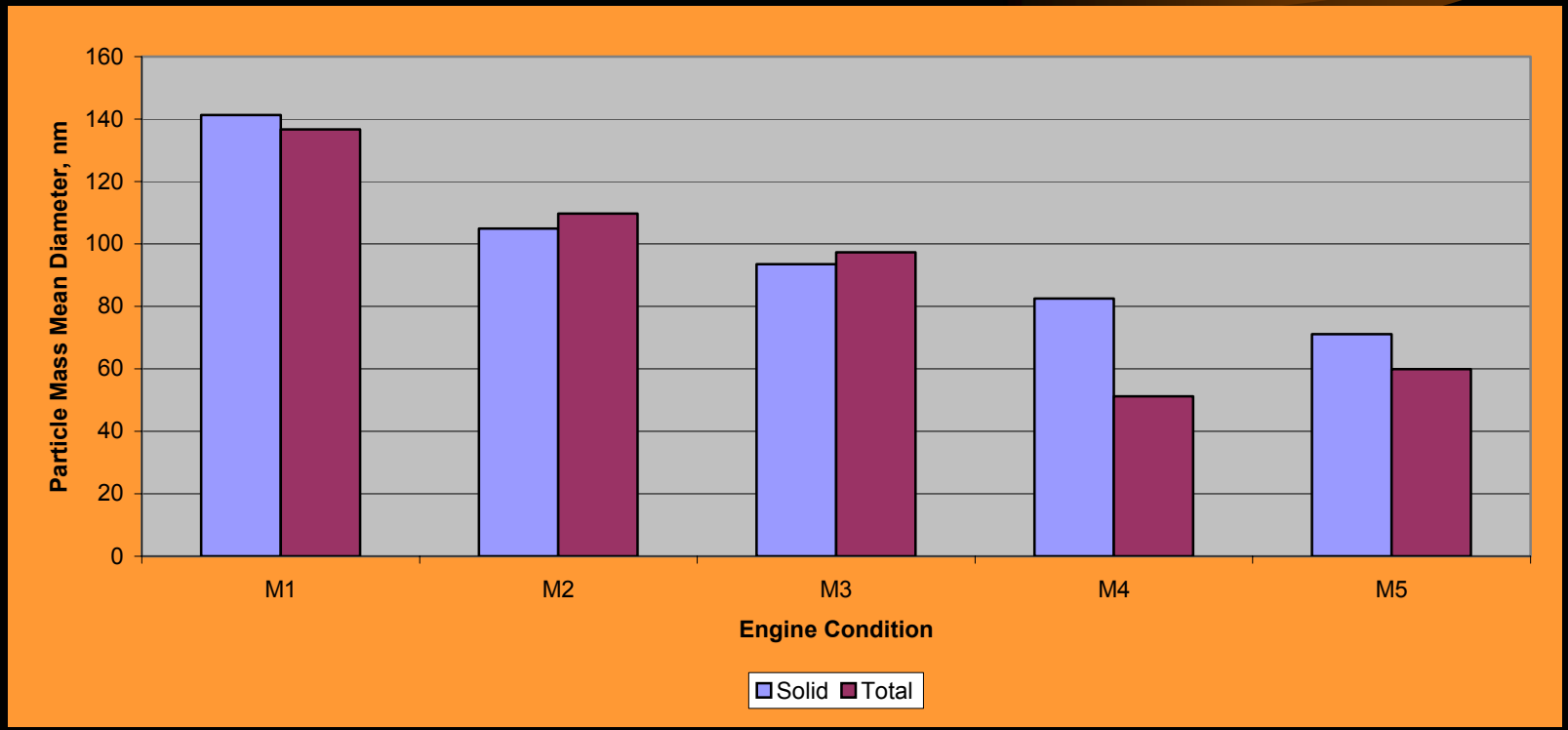
Total and Solid Particle Mass-Weighted Size Distribution (Diesel Powered Generator



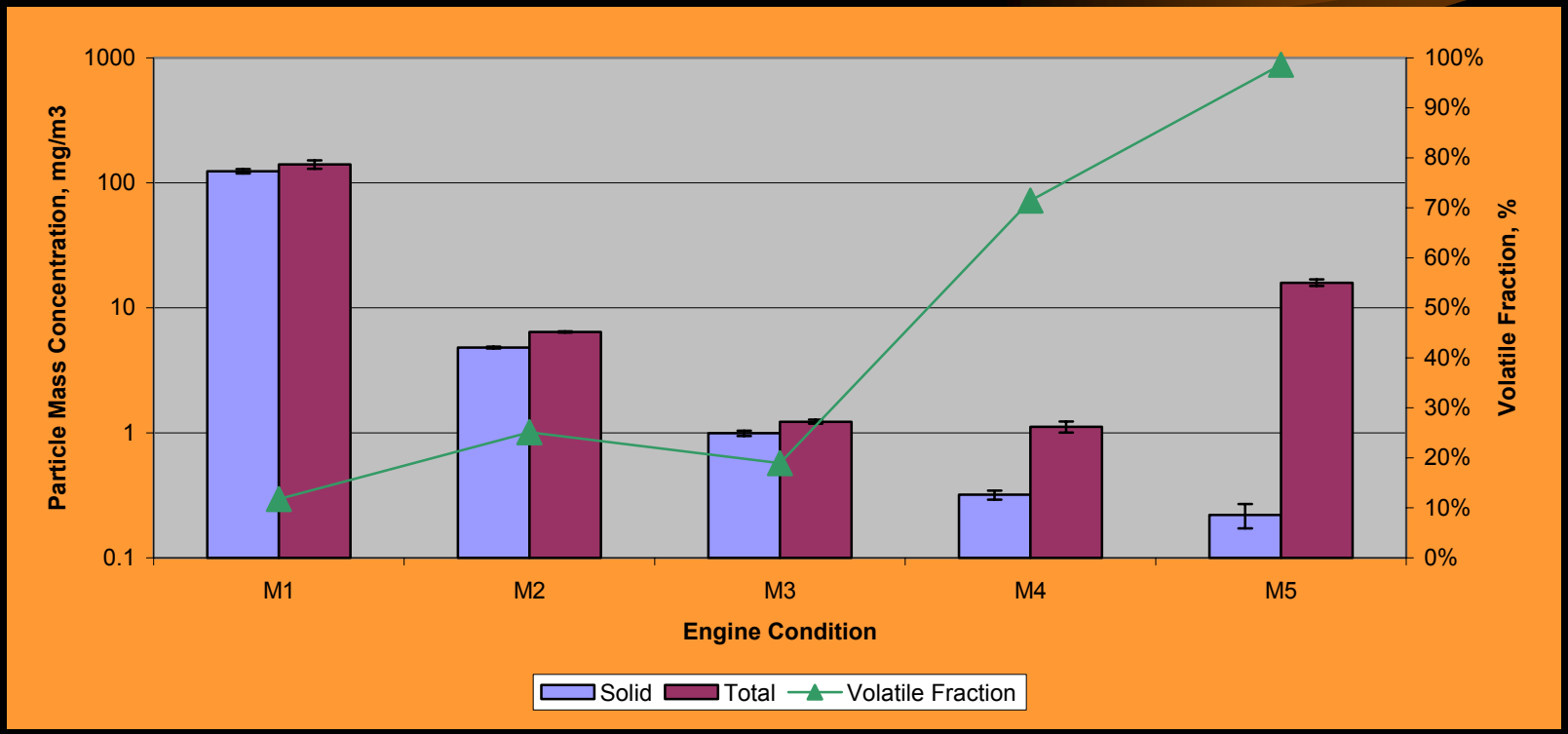
Particle Number Mean Diameter



Particle Mass Mean Diameter



Solid and Total Particle Mass Emissions (SMPS)



Summary

- Engine emissions data revealed that some of the volatile droplets contain a solid core. It is possible to attribute such core to ash derived from the lube oil. In previous work, this was observed with heavy-duty on-highway diesel engine.

- Volatile fraction ranged from over 95 percent to less than 25 percent for heavy and light engine loads, respectively. The high volatile fraction at light load which is typically coupled with a low temperature may limit the effectiveness of an oxidation catalyst to reduce PM emissions

- The accumulation mode of the size distribution (50 nm to 100 nm) cannot always be assumed to be composed of soot or solid particles. A significant fraction of volatile droplets can be present in this mode due to high particle nucleation and growth.

- PM mass and number concentration emitted from a diesel powered generator was very high, particularly at high engine load. Due to an expected new federal regulations, the PM emissions emitted from these engines need to be reduced significantly.