

同志社大学 学術フロンティア共同研究プロジェクト
「次世代ゼロエミッション・エネルギー変換システム」
技術セミナー

「エンジン排気微粒子の健康影響と
計測技術および生成・排出特性」

エンジン排気中の微粒子計測事例(運転条件の影響)

ヤンマー(株) 中央研究所
岡田 周輔

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Particulate Matter Emission from Diesel Engine

1. Back Ground
2. PM Emission
from current off-road Diesel Engine
3. Effect of Engine Operating Condition
(By Filter Method)
4. Effect of Engine Operating Condition
(By ATOFMS – Specific particle)

Particulate Matter Emission from Diesel Engine

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Back Ground

DIESEL ENGINES

- **Advantages:**
 - Higher Thermal efficiency
 - Lower CO₂, THC, CO
- **Disadvantages:**
 - Higher NO_x, **PM**

Health effect

Lung cancer
Mortality
Asthma

Environmental effect

Photochemical smog
Acid rain
Enlargement of Ozone hole



Sulfur compounds, Organics,.....
1 ~ 20% of Total PM mass
90% of Total PM number

Kittelson, D.B., "Engines and Nano-Particles : A Review"
 Vol.29, No.5/6, pp575-588, 1998

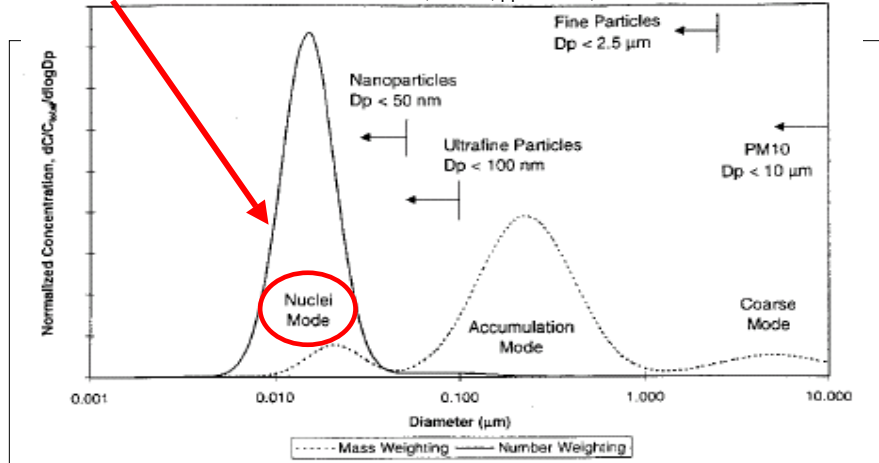
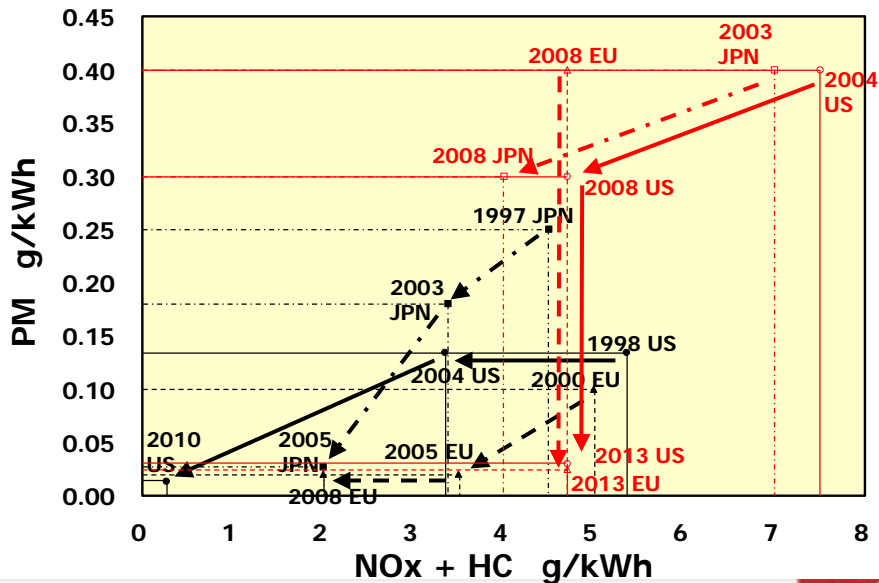


Fig. 3. Typical engine exhaust size distribution both mass and number weightings are shown.

Emission Regulation for On-Road HDD & Off-Road Diesel



Particulate Matter Emission from Diesel Engine

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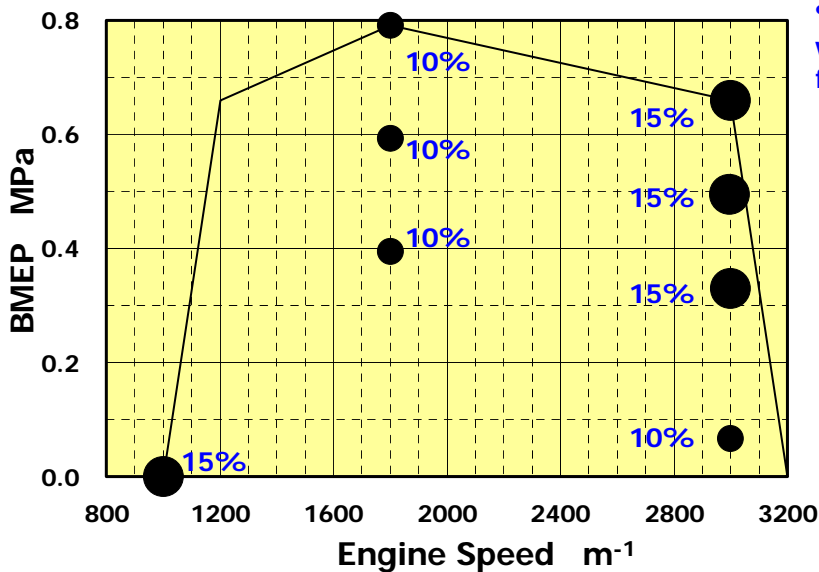
Test Research Engine



Test Research Engine Specification

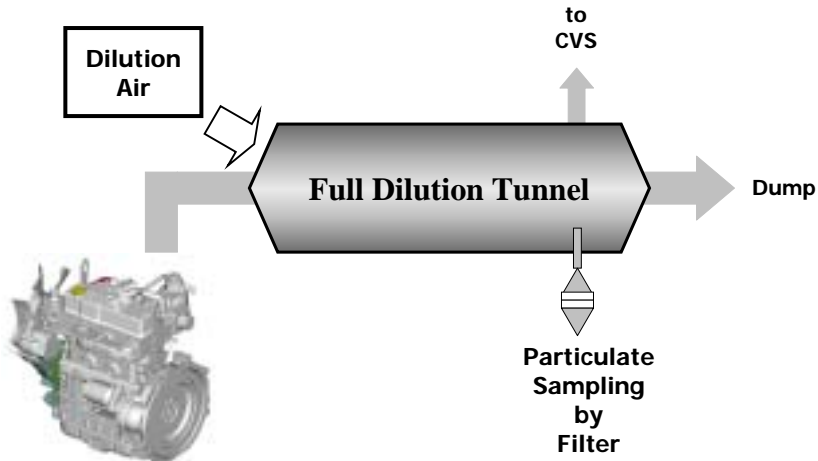
Combustion system	Direct injection
Intake	NA
Number of valve	4
Number of cylinder	4
Bore	84 mm
Stroke	94 mm
Displacement	1995 cm ³
Injection system	Mechanical Injection
Rated Speed	3000m ⁻¹
Max. Output	32.9 kW
BMEP	0.66 MPa
Max. Torque	126Nm@1800m-1

C1 mode test cycle (steady state)

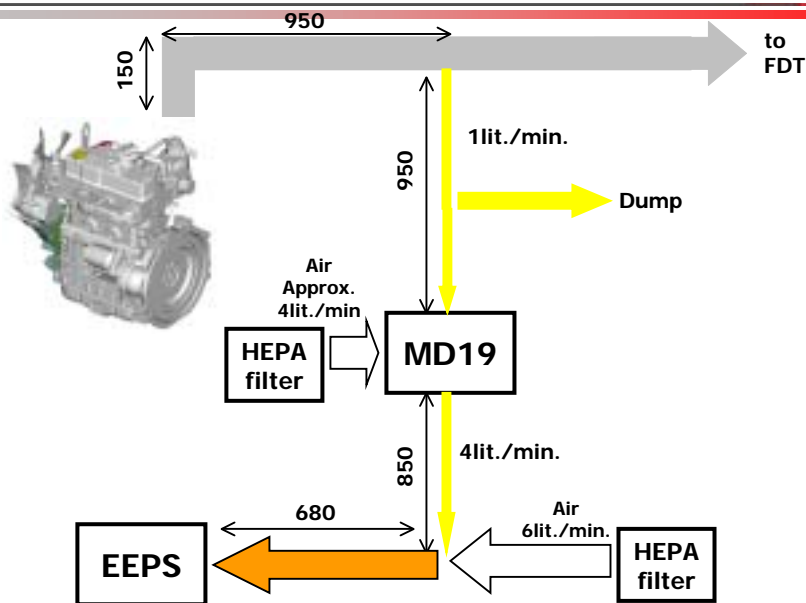


% : weighting factor

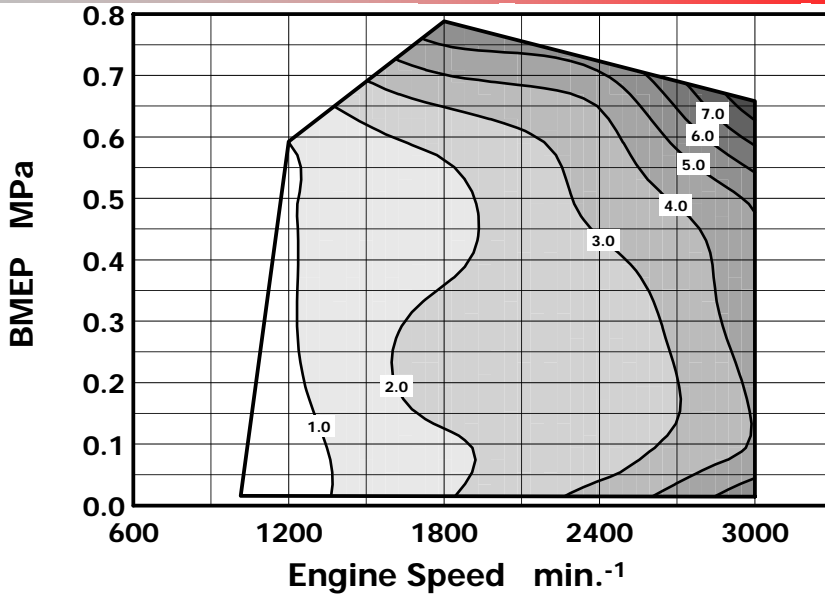
The schematic of test bench for PM sampling



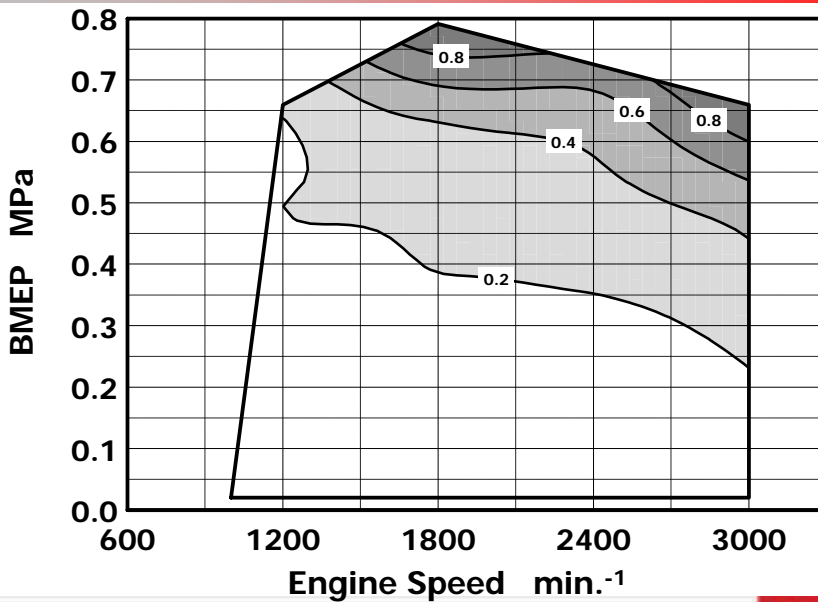
PM size distribution measurement system



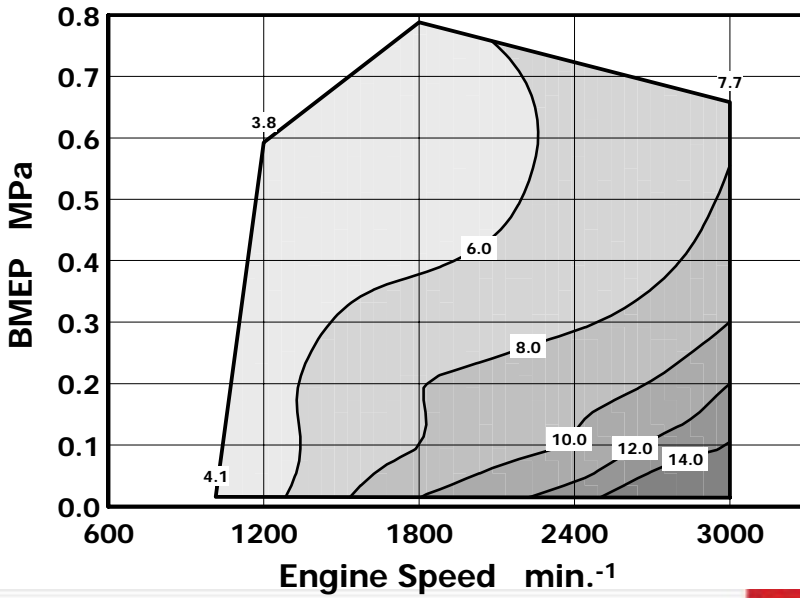
PM emission [g/h]



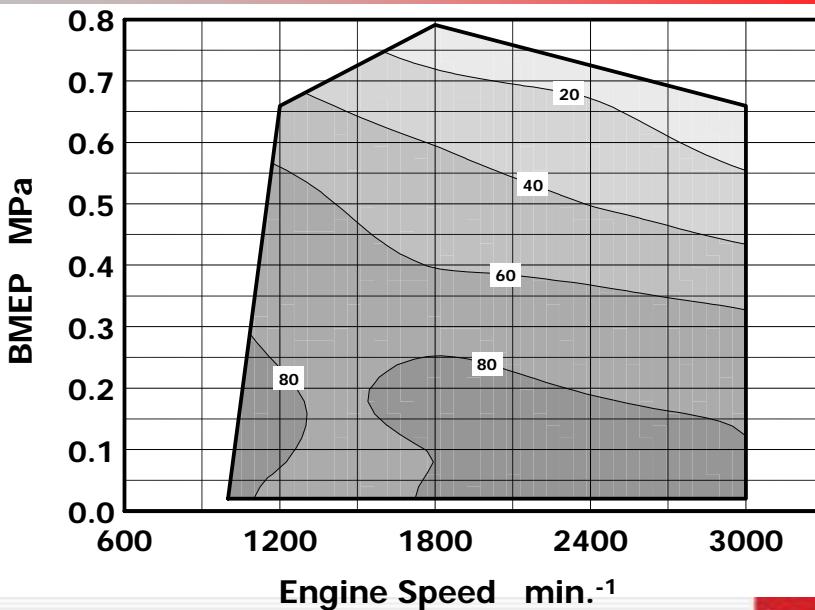
Normalized BSU



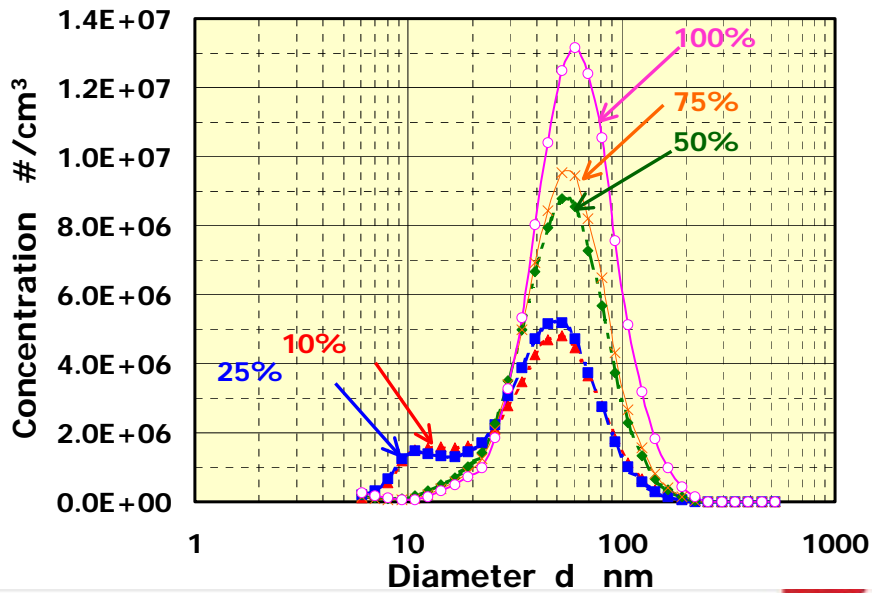
THC emission [g/h]



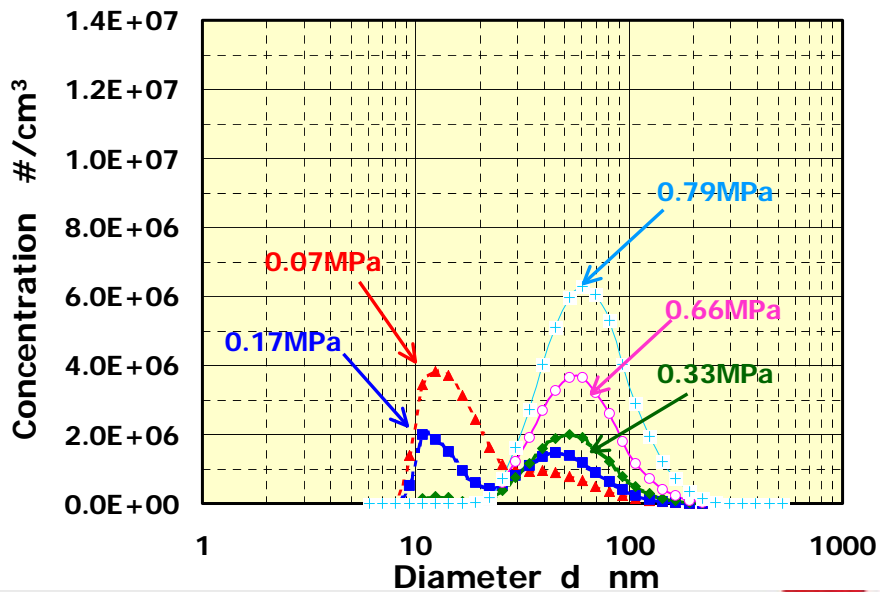
SOF / PM [%]

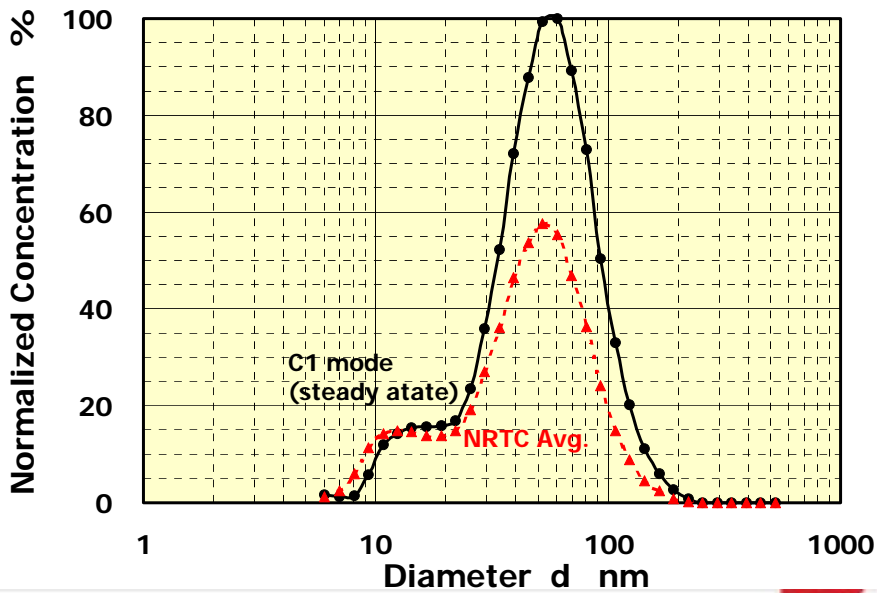


PM size distribution @ 3000m⁻¹

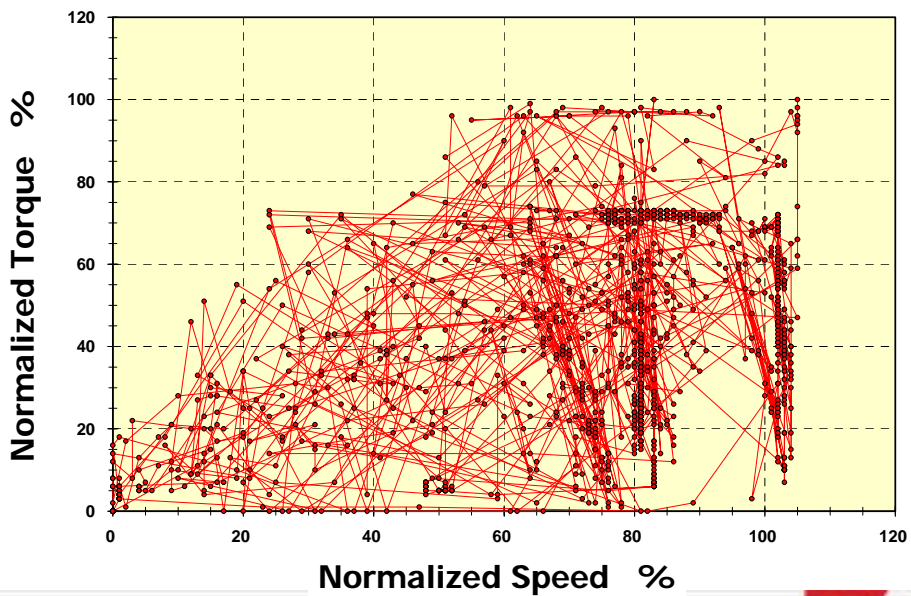


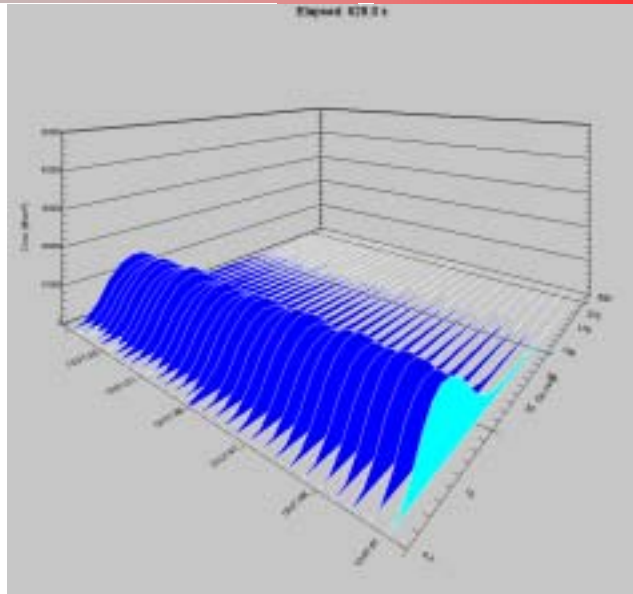
PM size distribution @ 1800m⁻¹



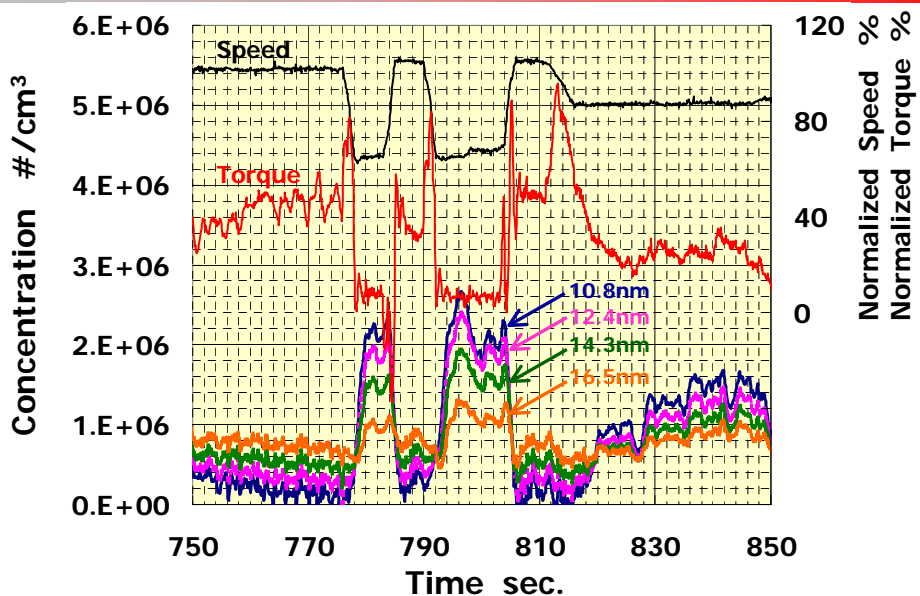


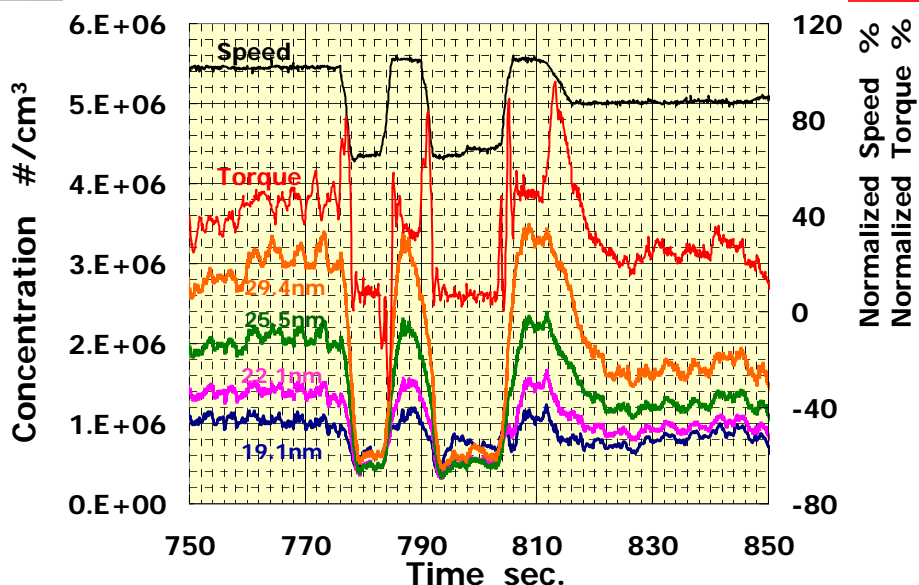
NRTC (Non-Road Transient Cycle)





Number Concentration of particles (10.8, 12.4, 14.3, 16.5nm)





ACKNOWLEDGMENTS

The authors would like to thank Nobuo Senaha, Yuki Takagi, Hiroyoshi Honjoh (Tokyo Dylec Corp.) for their support for this study. The EEPS instrument and MD-19 raw gas dilutor were supported by Tokyo Dylec Corp.

Particulate Matter Emission from Diesel Engine

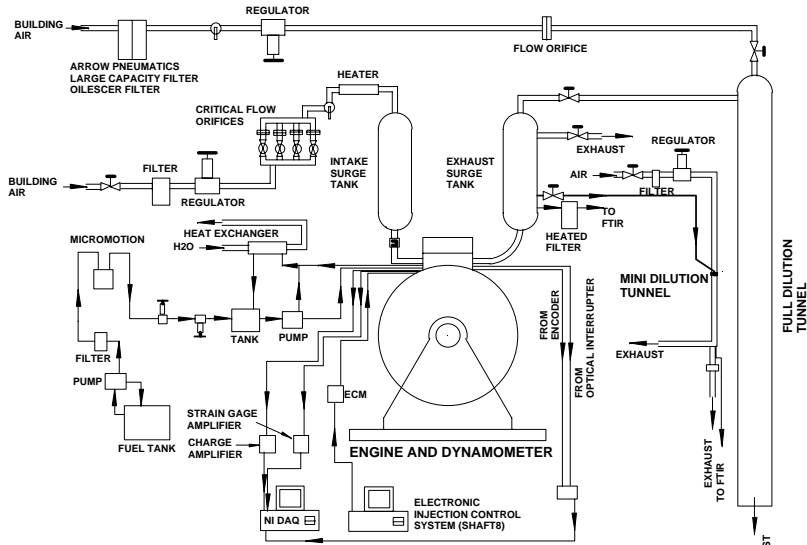
1. Back Ground
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from current off-road Diesel Engine
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Test Engine

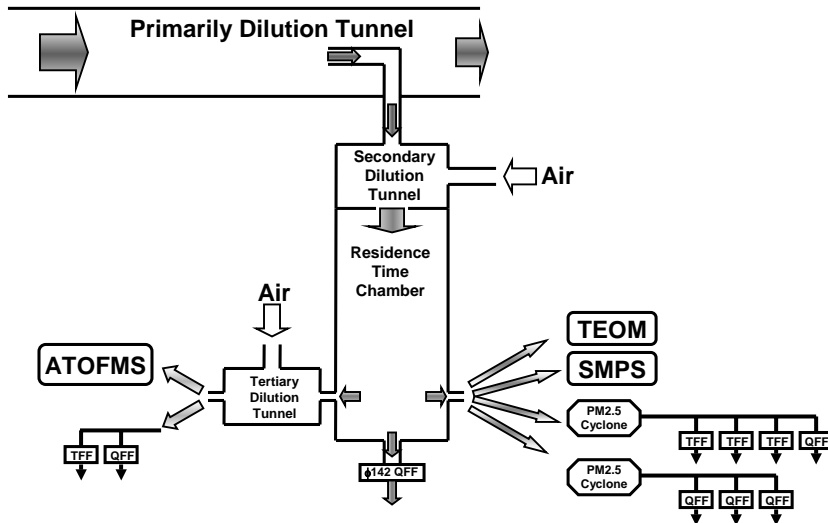
Engine Type	Cummins N14
Number of cylinder	Single cylinder
Combustion system	Direct injection
Bore	139.7 mm
Stroke	152.4 mm
Displacement	2336 cm ³
Compression ratio	13.1 : 1
Swirl ratio	1.4
Combustion chamber	Shallow dish
Chamber diameter	97.8 mm
Injection system	Unit Injector
Nozzle	8 X ϕ 0.2 mm
Spray Angle	152°
Length/Diameter of hole	4.1



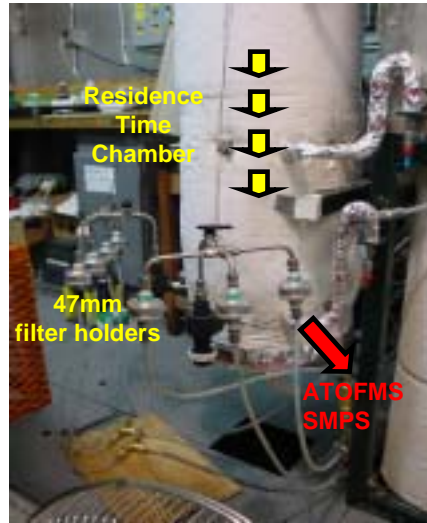
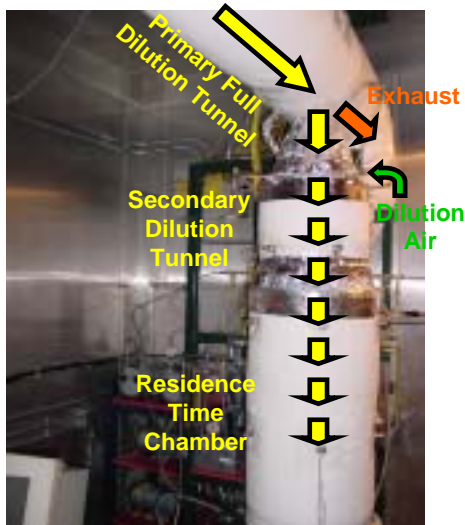
Engine Test Bench



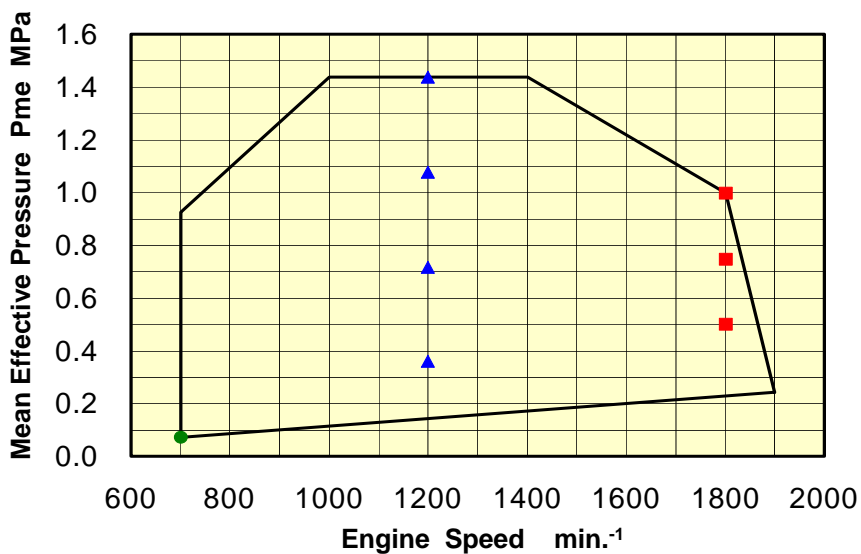
Sampling System



Sampling System



Engine Operating Conditions



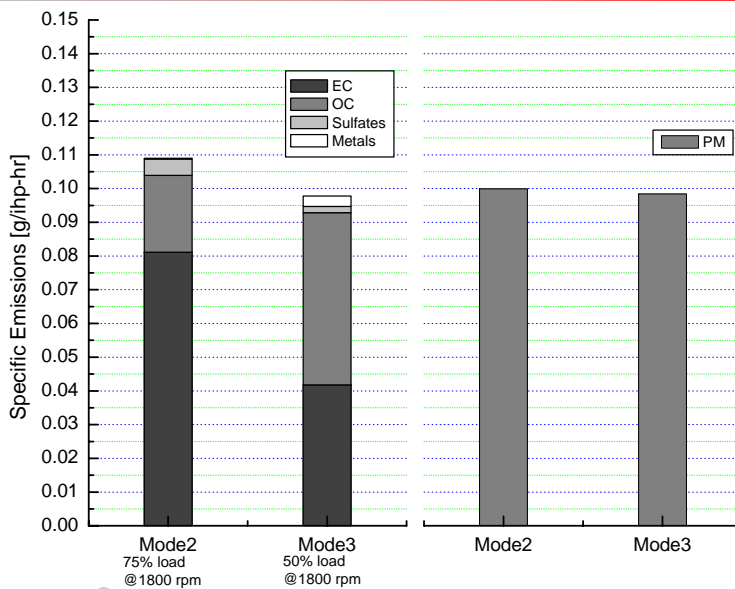
Test Fuel

Property		Units	
Density (@15°C)		kg/m ³	865
Viscosity (@40°C)		mm ² /s	2.595
Specific Gravity (16/16°C)			0.8684
Distillation	IBP	°C	180.6
	50%	°C	257.8
	90%	°C	309.4
	EPT	°C	345.6
Flash point		°C	70
Cetane number			39.1
Gross Heating Value		kJ/kg	43506
Sulfur		ppm	352
SFC	Aromatics	wt%	49.2
	Mono-Aromatics	wt%	29.6
	PNA's	wt%	19.6
H / C			1.689
Selected Trace Metals	Magnesium (Mg)	ppm	< 0.1
	Calcium (Ca)	ppm	< 0.1
	Manganese (Mn)	ppm	< 0.1
	Iron (Fe)	ppm	< 0.1
	Lead (Pb)	ppm	< 0.1

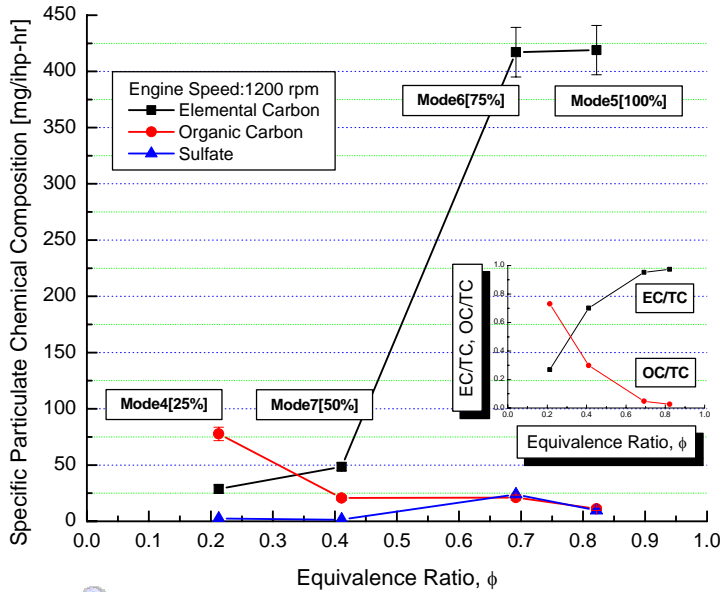


Comparison of EC, OC, Sulfate, Metal and PM emission

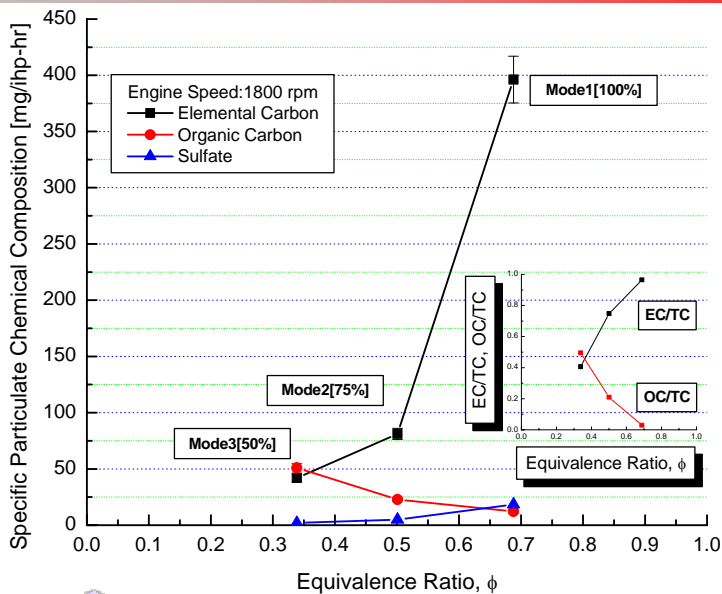
@ Mode2 (1800min-1, 75%) and Mode3 (1800min-1, 50%)

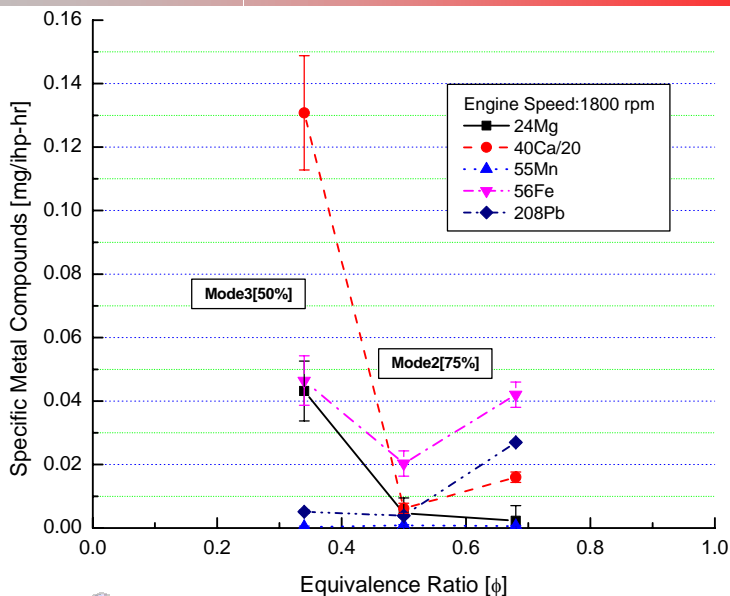
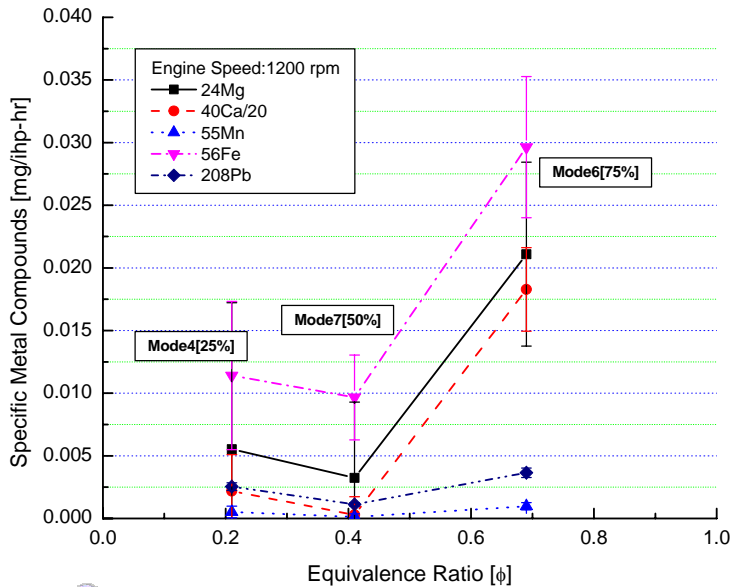


EC, OC, Sulfate @ 1200rpm

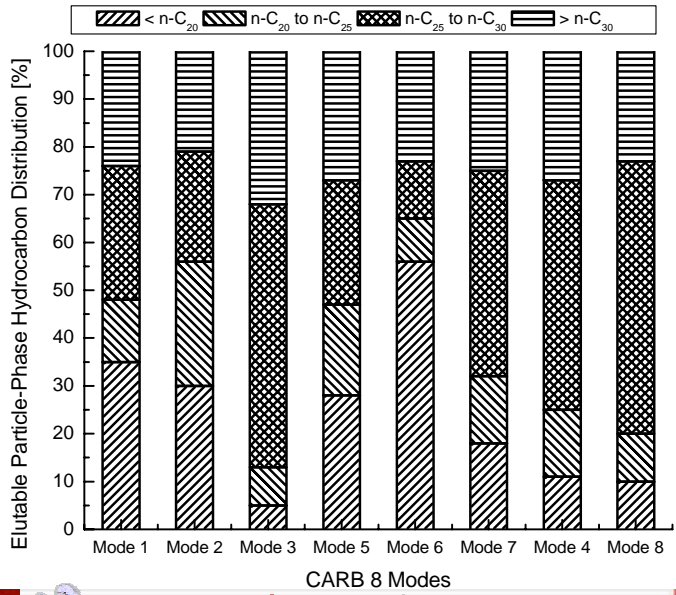


EC, OC, Sulfate @ 1800rpm

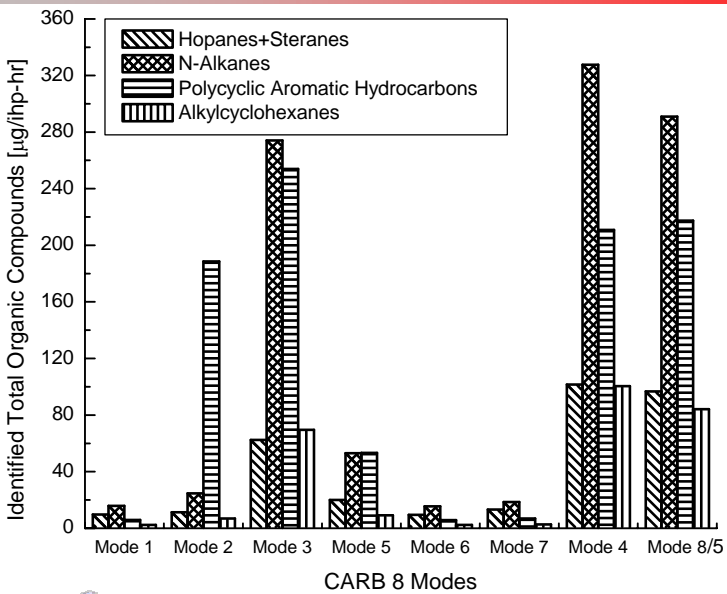




HC Distribution



Identified total organic compound



Particulate Matter Emission from Diesel Engine

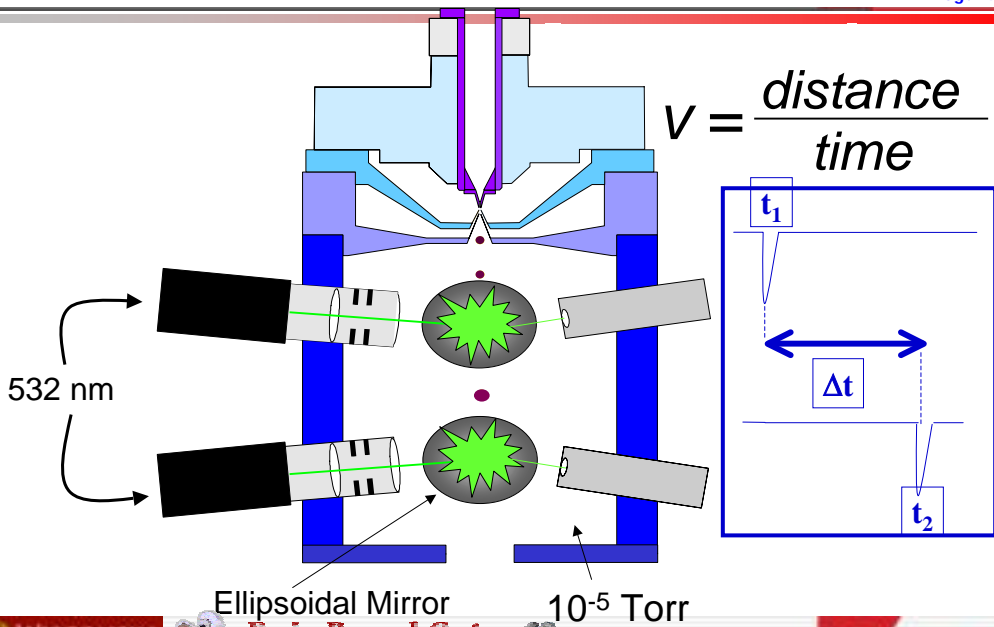
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ATOOFMS

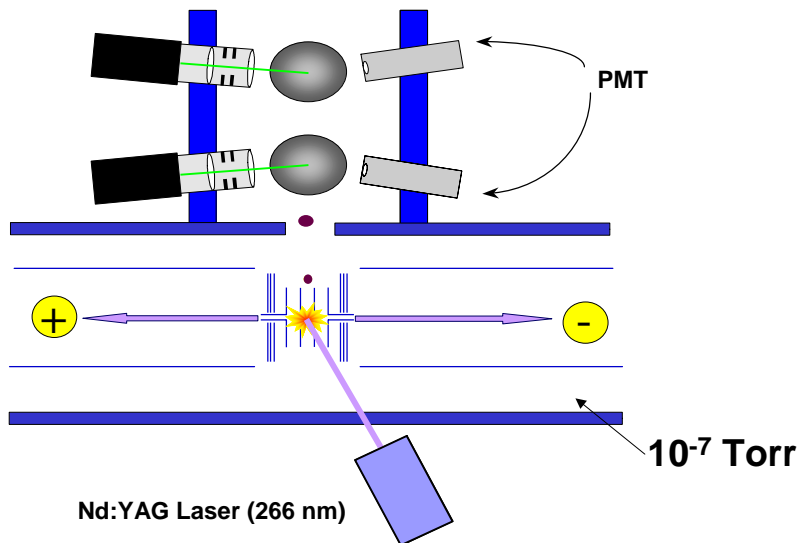
ATOOFMS : Aerosol Time-Of-Flight Mass Spectrometer

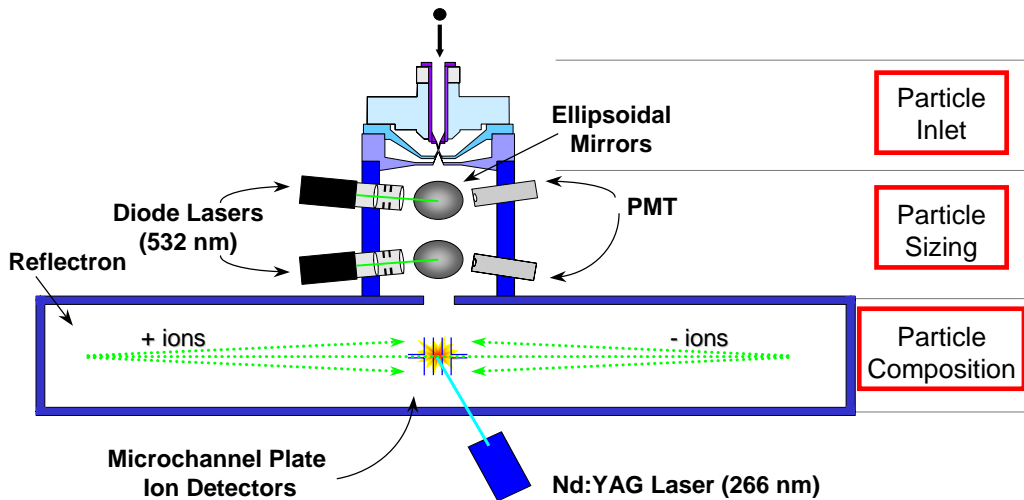
- Single Particle Mass Spec Instruments
- have been developed over the past decade
 - Real time instruments
 - Size individual particles
 - Semi-quantitative measure of individual particle chemical composition
 - Portable
- ATOFMS was developed at UC-Riverside under the direction of Prof. Kim Prather
- ATOFMS was commercialized by TSI in 1999

Particle Sizing



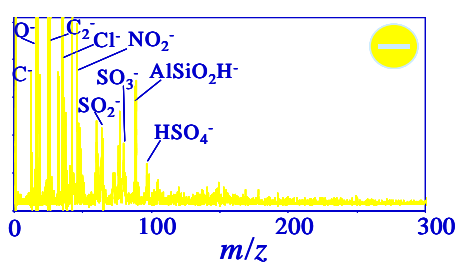
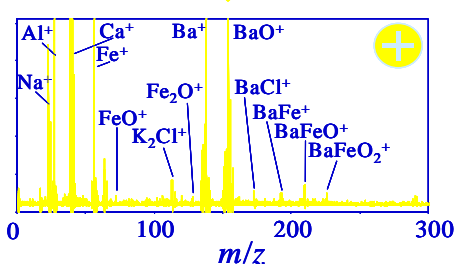
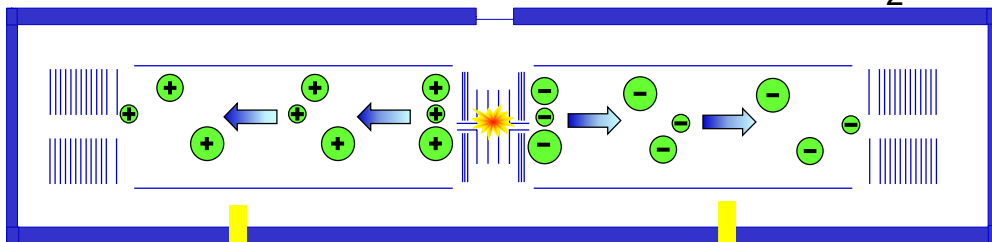
Ionization



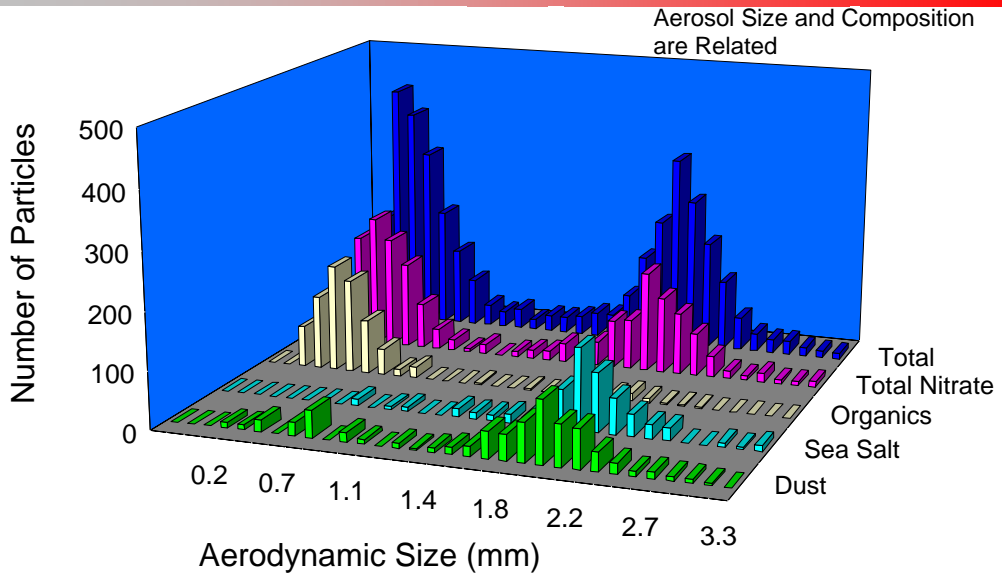


Mass Spectrometry

$$E = \frac{1}{2}mv_i^2$$



Example

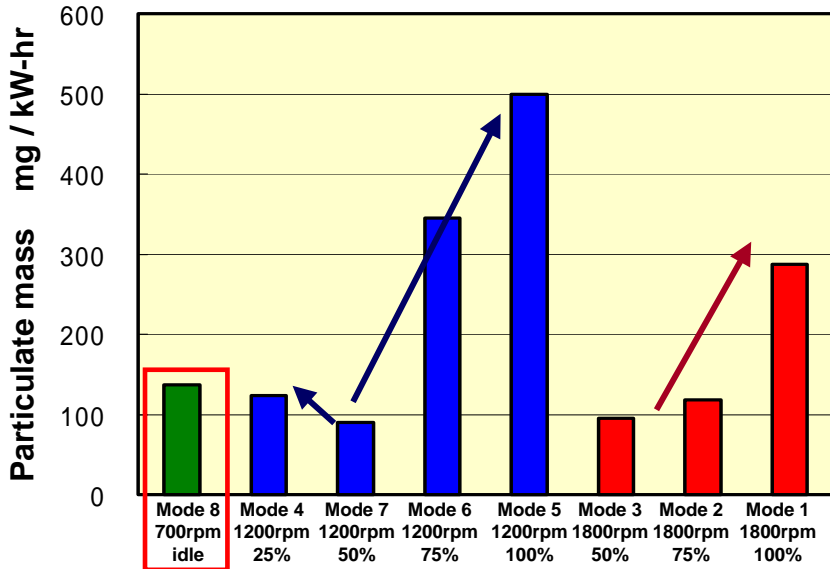


Fuel

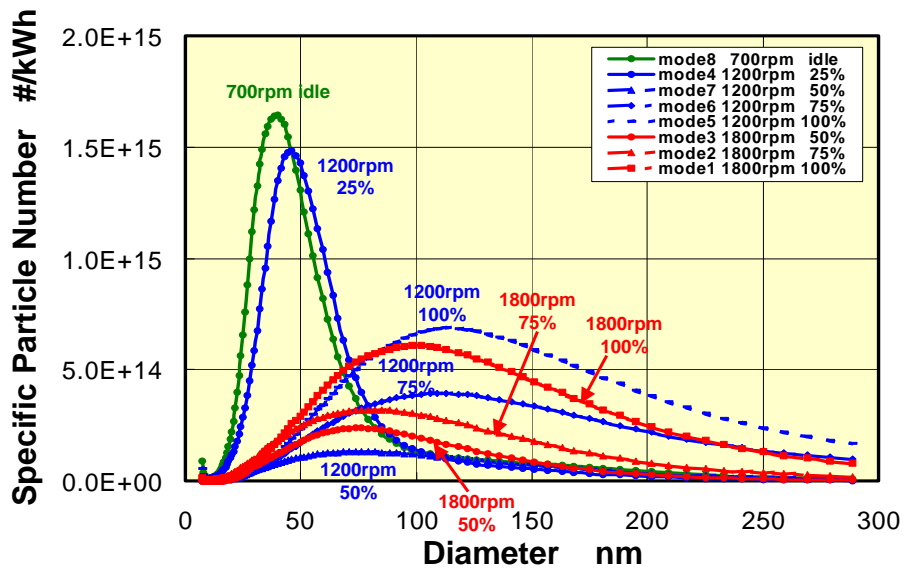
Property	Units		
Density (@ 15°C)	kg/m ³	830.5	
Viscosity (@ 40°C)	mm ² /s	2.43	
API Gravity (16/16°C)		38.8	
Distillation	IBP	°C	177.8
	50%	°C	259.4
	90%	°C	324.4
	EPT	°C	356.1
Flash point	°C	65	
Cetane number		52.9	
Gross Heating Value	kJ/kg	45644	
Sulfur	ppm	14	
SFC	Aromatics	wt%	22.1
	Mono-Aromatics	wt%	19.4
	PNA's	wt%	2.7
H / C		1.889	
Selected Trace Metals	Magnesium (Mg)	ppm	< 0.1
	Calcium (Ca)	ppm	< 0.1
	Manganese (Mn)	ppm	< 0.1
	Iron (Fe)	ppm	< 0.1
	Lead (Pb)	ppm	< 0.1



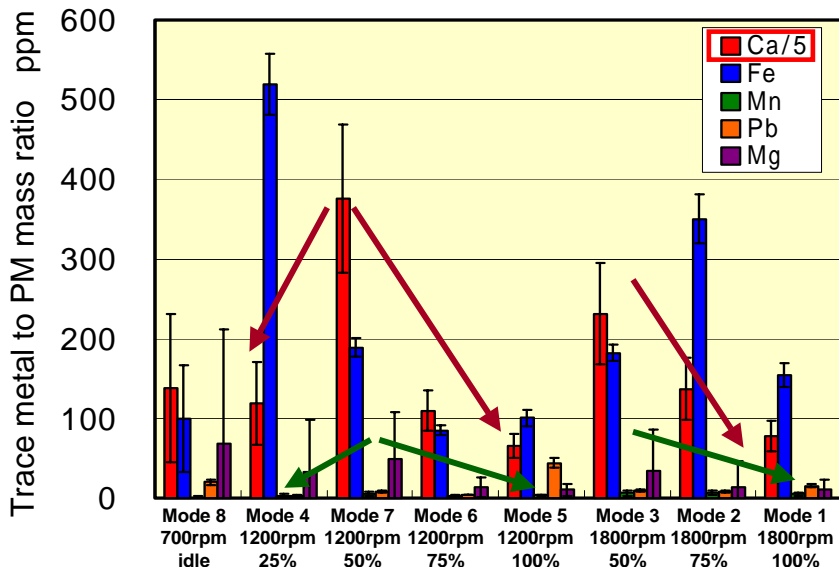
Specific PM Emission



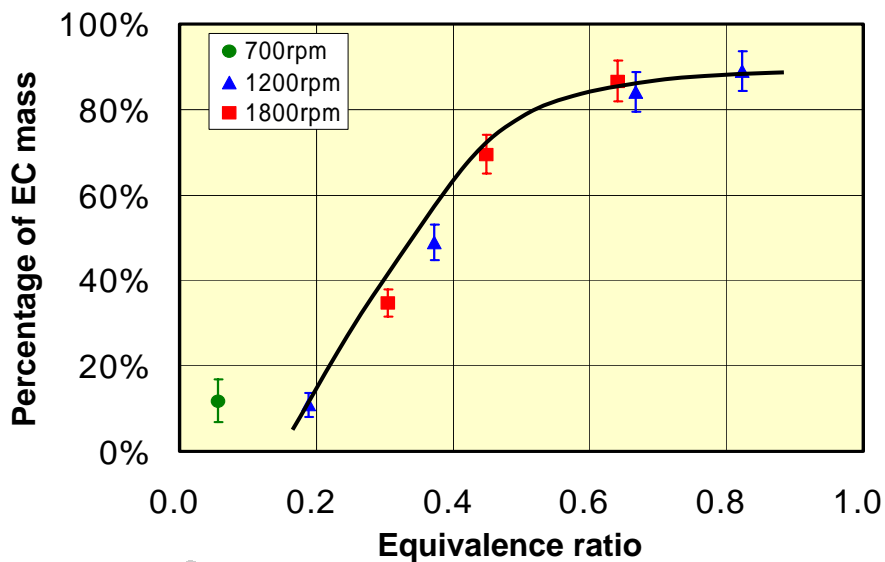
PM Number Distribution



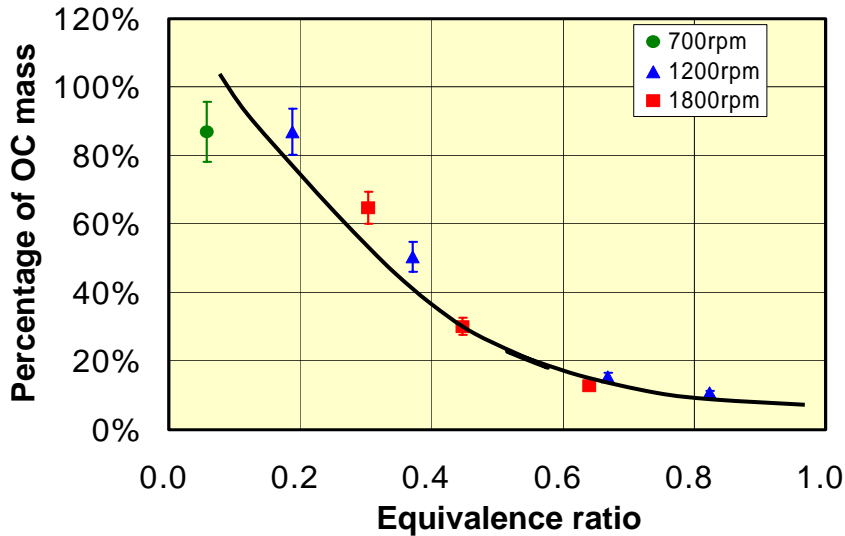
Percentage of Trace Metals



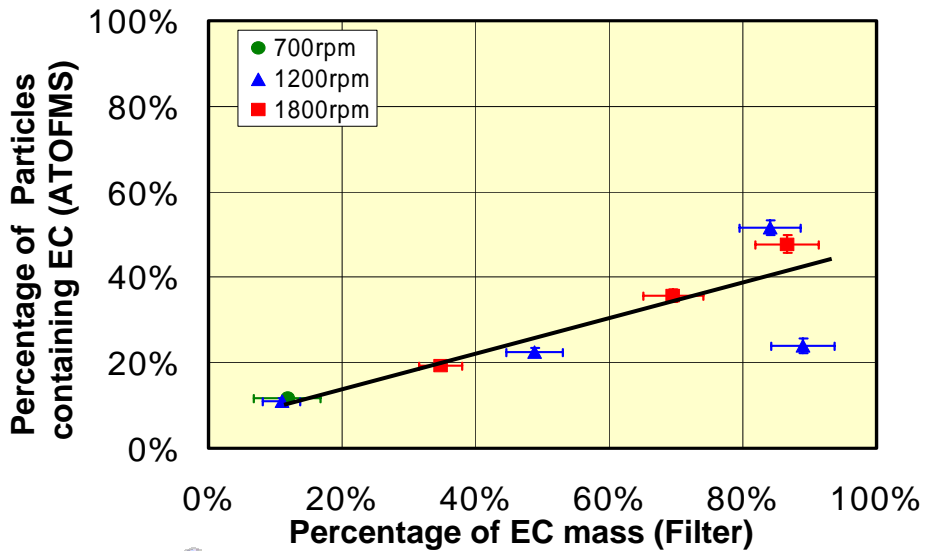
Percentage of EC Emission



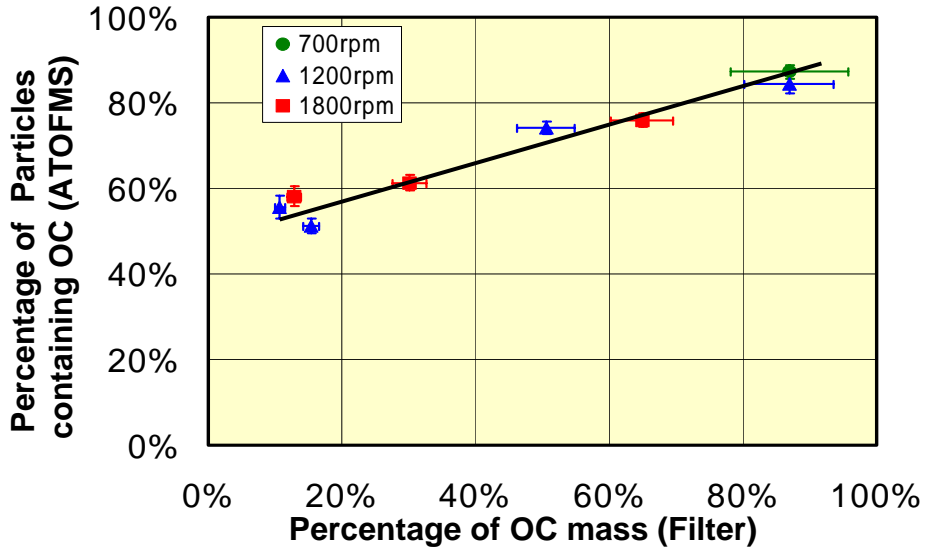
Percentage of OC Emission



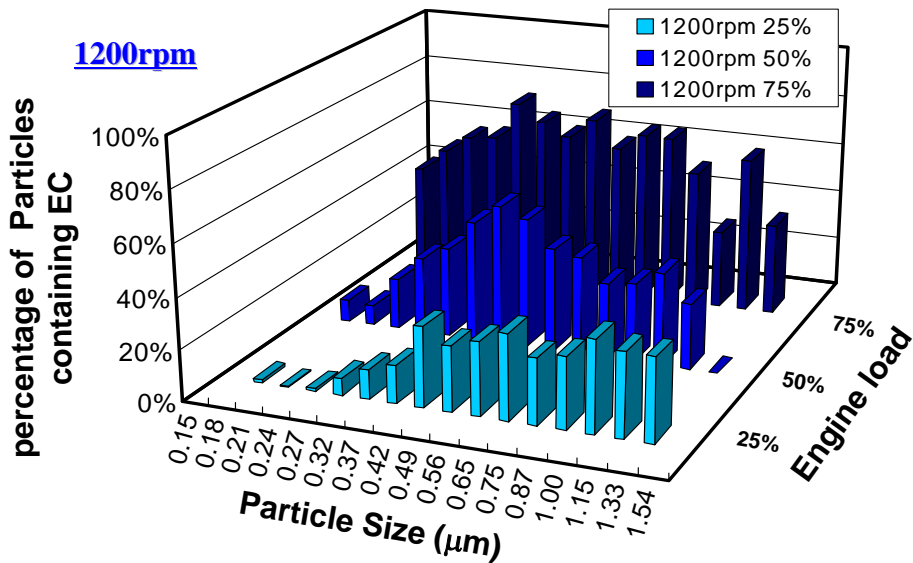
ATOFMS vs. Filter



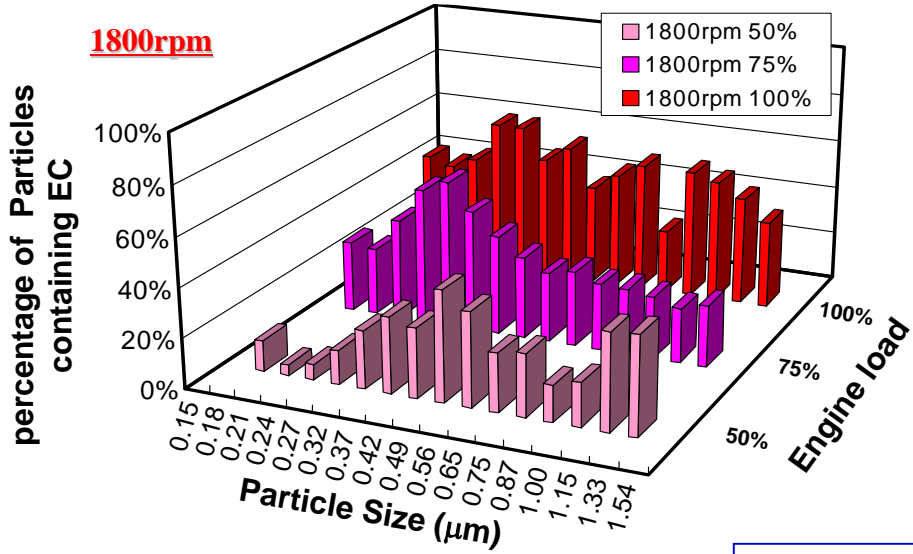
ATOFMS vs. Filter



Particle Distribution w/ EC

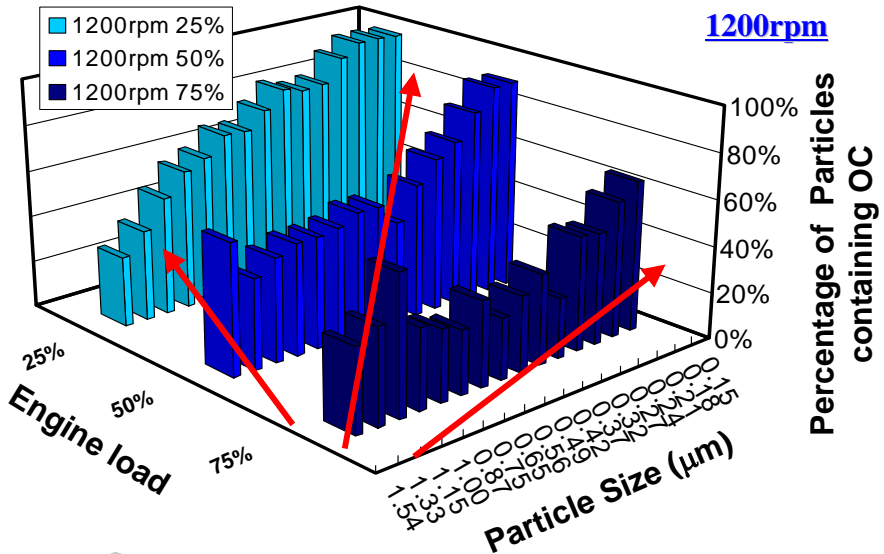


Particle Distribution w/ EC

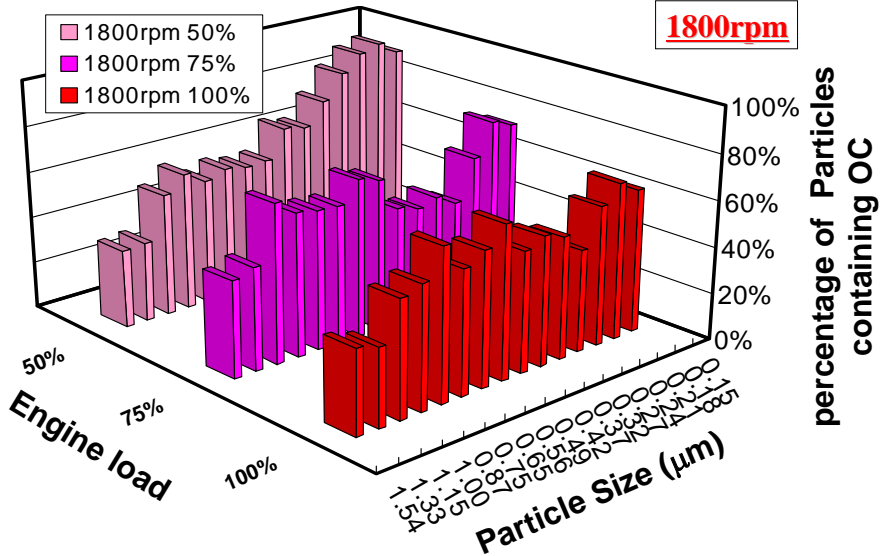


2003-01-0076

Particle Distribution w/ OC

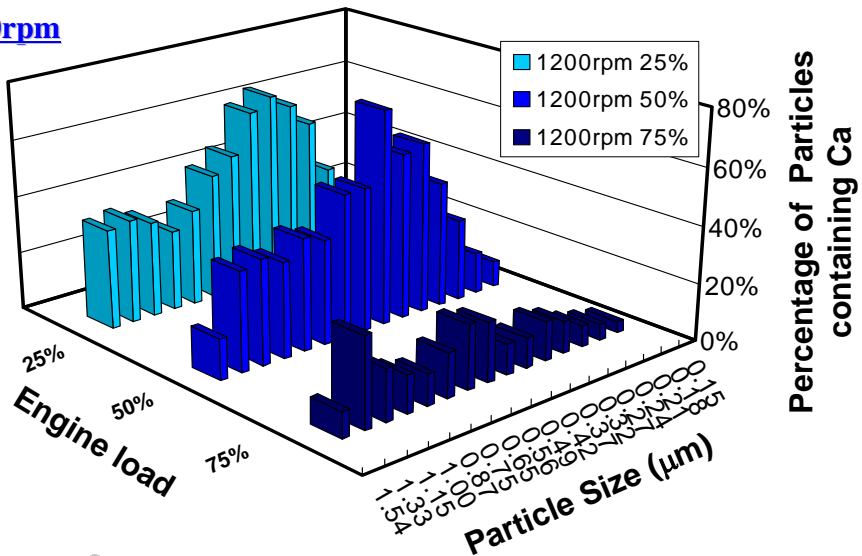


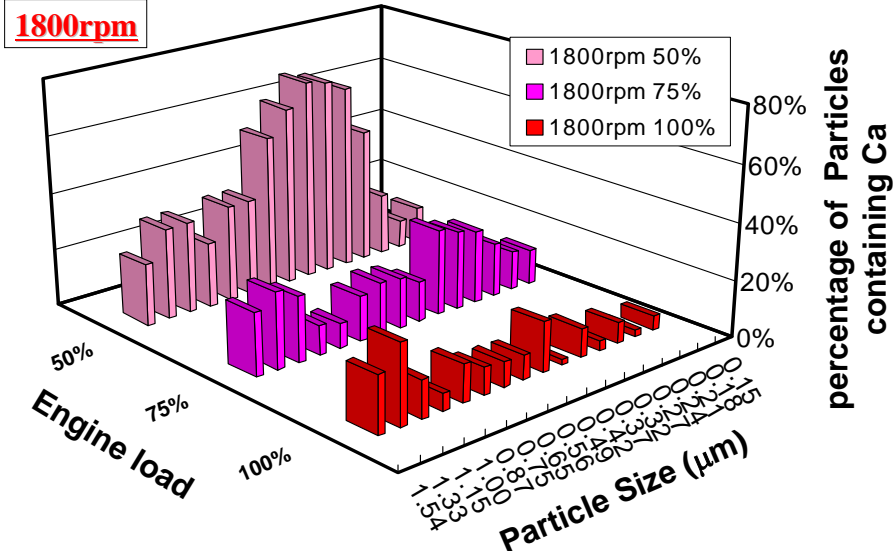
Particle Distribution w/ OC



Particle Distribution w/ Ca

1200rpm





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Army Research Office (ARO),
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of the University of Wisconsin-Madison.



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End

Thank you !

