Comprehensive Characterization of Particulate Emissions from Advanced Diesel Combustion

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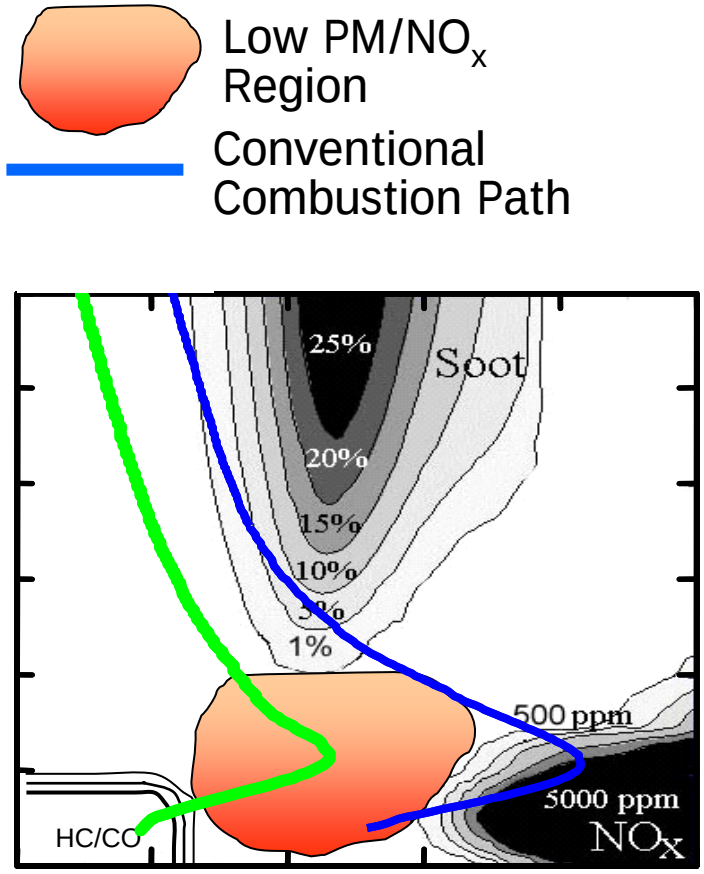
SAE 2007-01-1945 JSAE 20077142

Acknowledgements

- Honda R&D
- Horiba Instruments, Inc.
- Oak Ridge Nat. Lab.
- Corning
- Cummins Filtration
- BP-Amoco
- Argonne National Lab
- Johnson-Matthey

Conventional Diesel Versus Low Temperature Combustion (LTC)

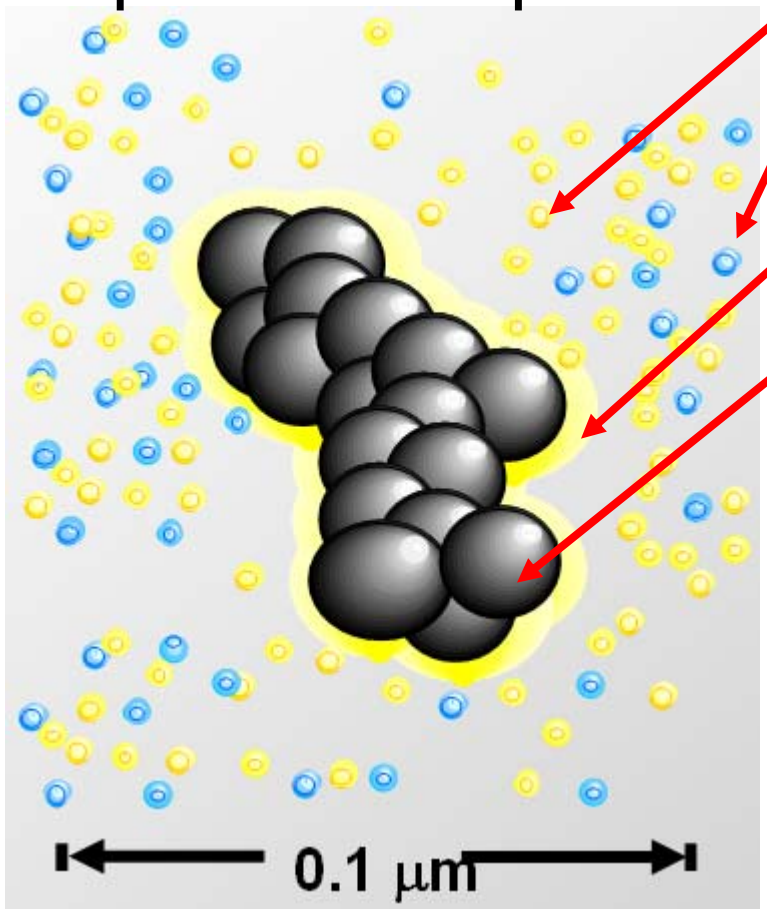
- Conventional combustion operates through PM and NO_x peninsulas
- Goal of LTC is to operate in Low PM/NO_x region
- Must be careful of HC/CO region



Concept originally from Kamimoto et al, SAE 880423

Diesel Particulate Matter (PM)

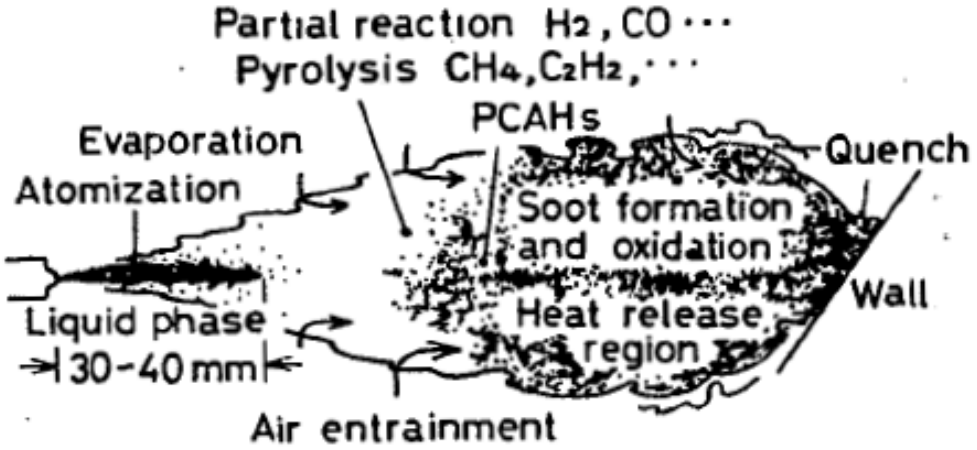
Shape and Composition



Condensed Organic Compounds
(VOC+sulfate+H_2O+ trace metals)

Adsorbed Organic Compounds
(VOC+sulfate+H_2O + trace metals)

Elemental Carbon (EC)
Agglomerate



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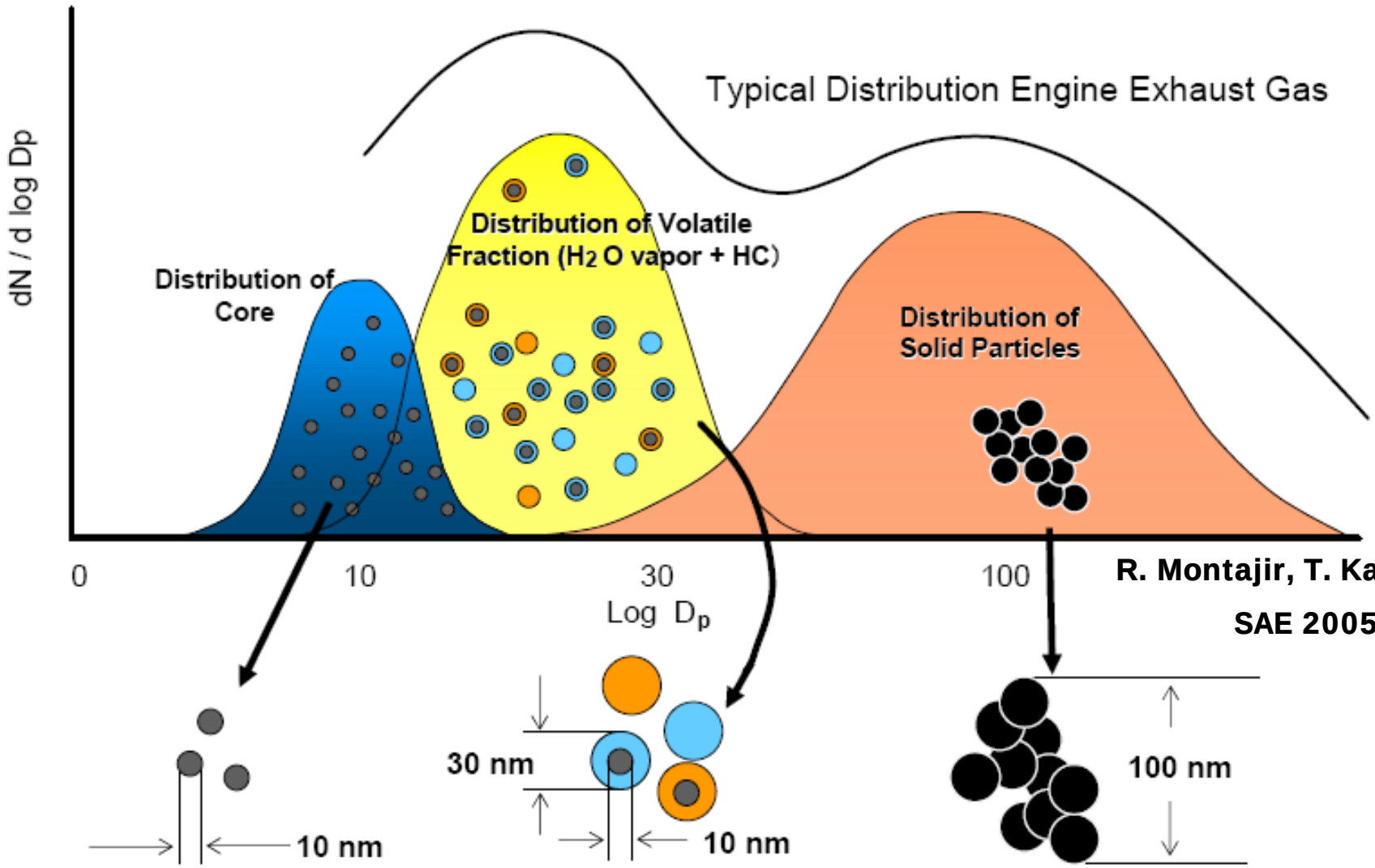
Conceptual Size Distribution



R. Montajir, T. Kawai et al.

SAE 2005-01-0187

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Goal of Research

Particulate Instruments

- AVL Smoke Meter 415S (mass conc.)
- R&P TEOM (mass conc.)
- Teflon Gravimetric (mass conc.)
- TSI SMPS (particle size distribution)
- Horiba MEXA 1370PM (chemical speciation)
- NIOSH EC/OC (chemical speciation)
- Microwave Extraction Soot/SOF (chemical speciation)

Goal of Research

Analysis Technique

- AVL Smoke Meter 415S: Empirical-based opacity correlation of filtered PM
- R&P TEOM: PM mass is filtered on the end of an oscillating micro-balance and changes in frequency are correlated with PM mass concentration
- Teflon Gravimetric: Filtered PM mass is measured with high sensitivity balance after electro-static charges are neutralized
- TSI SMPS: Selected particle sizes over a range (7-279 nm) are counted to give a particle size distribution
- Horiba MEXA 1370PM: PM chemical composition analysis by thermal desorption
- NIOSH EC/OC: PM chemical composition analysis by thermal-optical desorption
- Microwave SOF Extraction: 50/50 hexane and acetone solvent extracts soluble organic fraction of PM

Engine Operating Conditions

Case	Engine Speed [RPM]	IMEP [bar]	Inj. Press. [bar]	Inj. Timing [dATDC]	Intake O2 [%]	Intake T [°C]	Intake P [kPa]	Exhaust T [°C]	Exhaust P [kPa]
1	2500	10.25	1160	-12.8	16.3	64	83	435	105
2	2500	5.5	1160	-12.8	15.6	64	83	270	102
3	2500	5.5	1160	-38.5	9.7	65	68	270	84
4	2500	5.5	650	-38.5	8.7	65	66	270	81

Case 1 (Conv) :

- Medium Speed
- High Load
- High Injection Pressure
- Normal Injection Timing
- 30% EGR

Case 2 (Conv) :

- Medium Speed
- Medium Load
- High Injection Pressure
- Normal Injection Timing
- 50% EGR

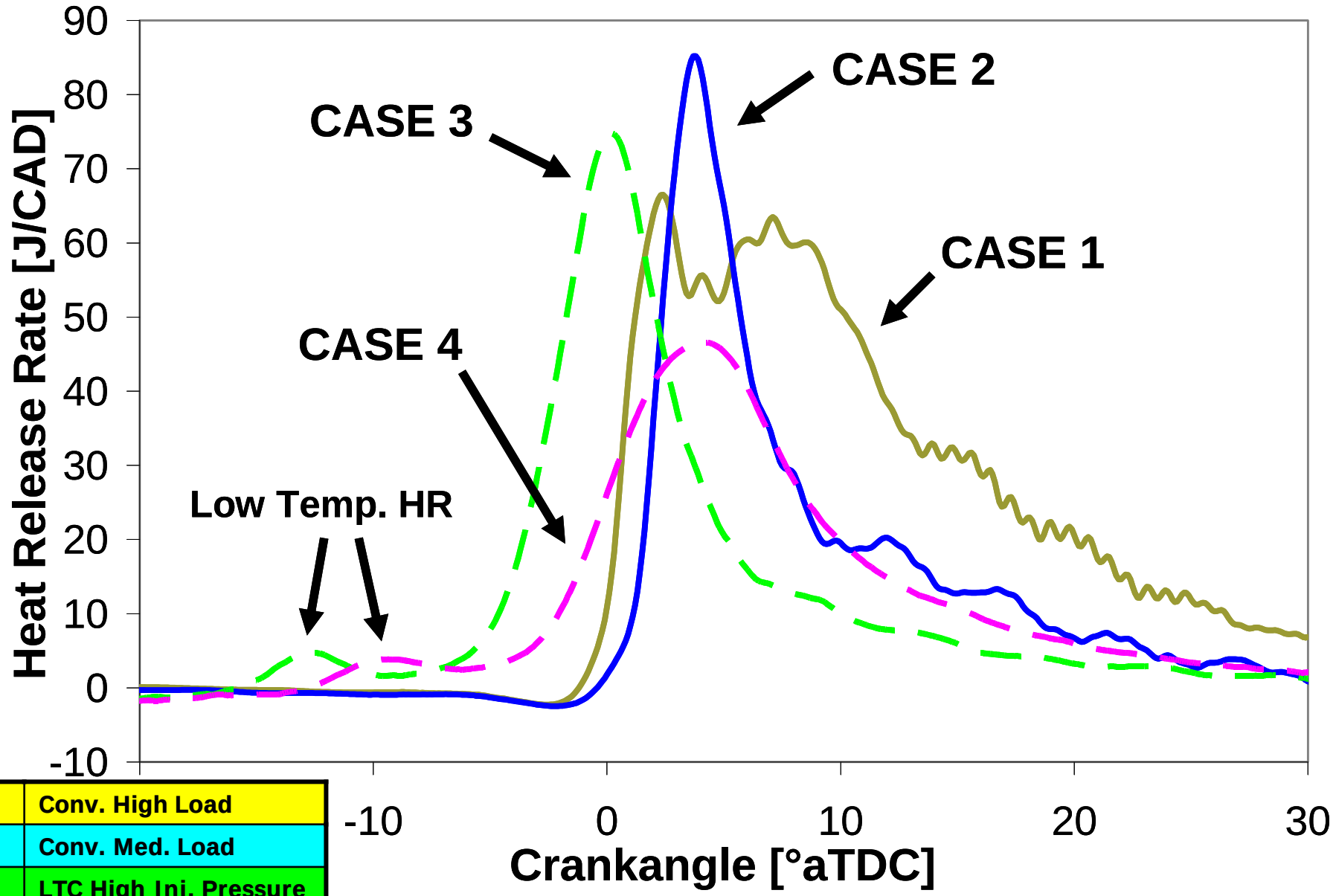
Case 3 (LTC) :

- Medium Speed
- Medium Load
- High Injection Pressure
- Early Injection Timing
- 60% EGR

Case 4 (LTC) :

- Medium Speed
- Medium Load
- Low Injection Pressure
- Early Injection Timing
- 65% EGR

Heat Release Rate



1	Conv. High Load
2	Conv. Med. Load
3	LTC High Inj. Pressure
4	LTC Low Inj. Pressure

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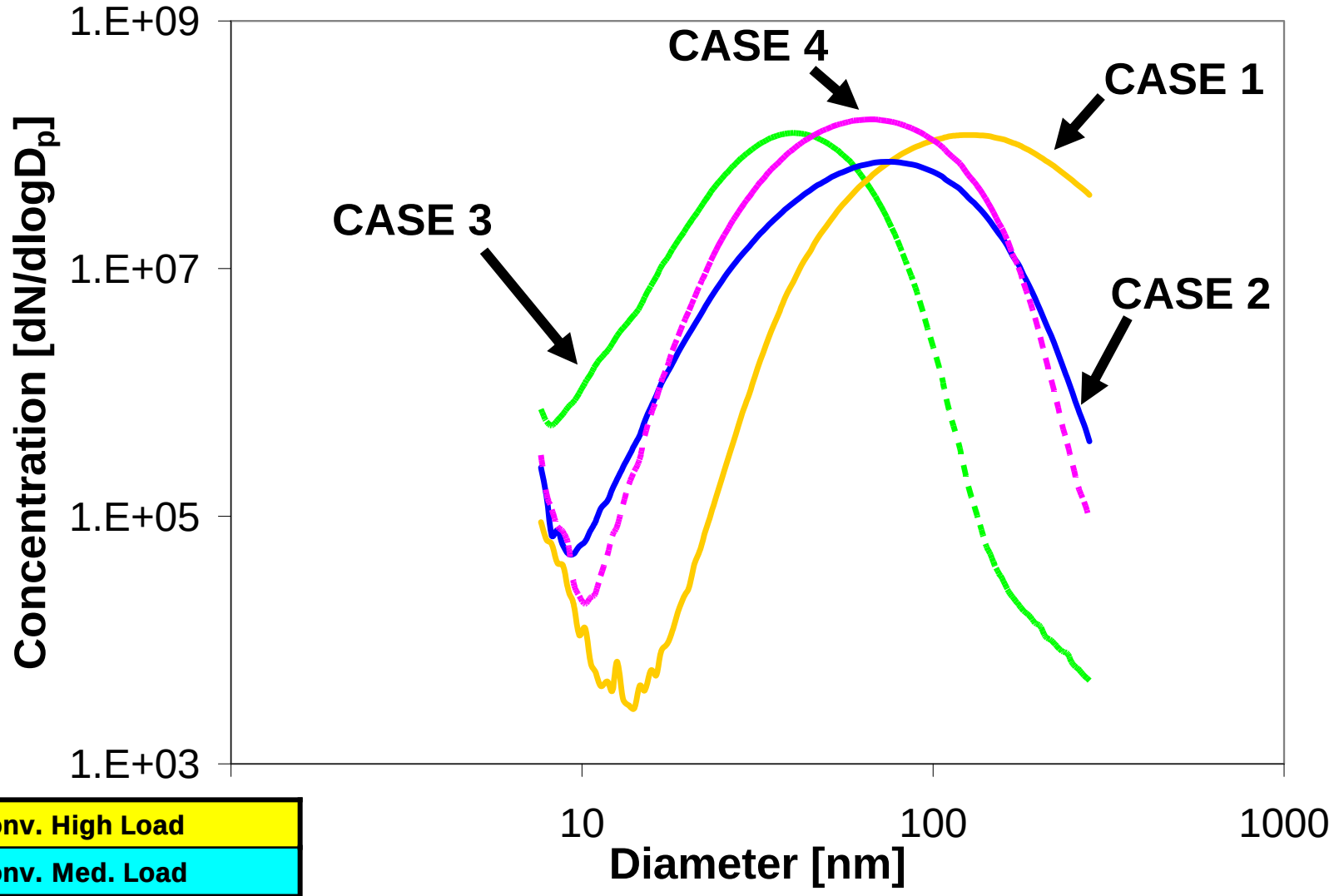
SMPS Particle Size Distributions



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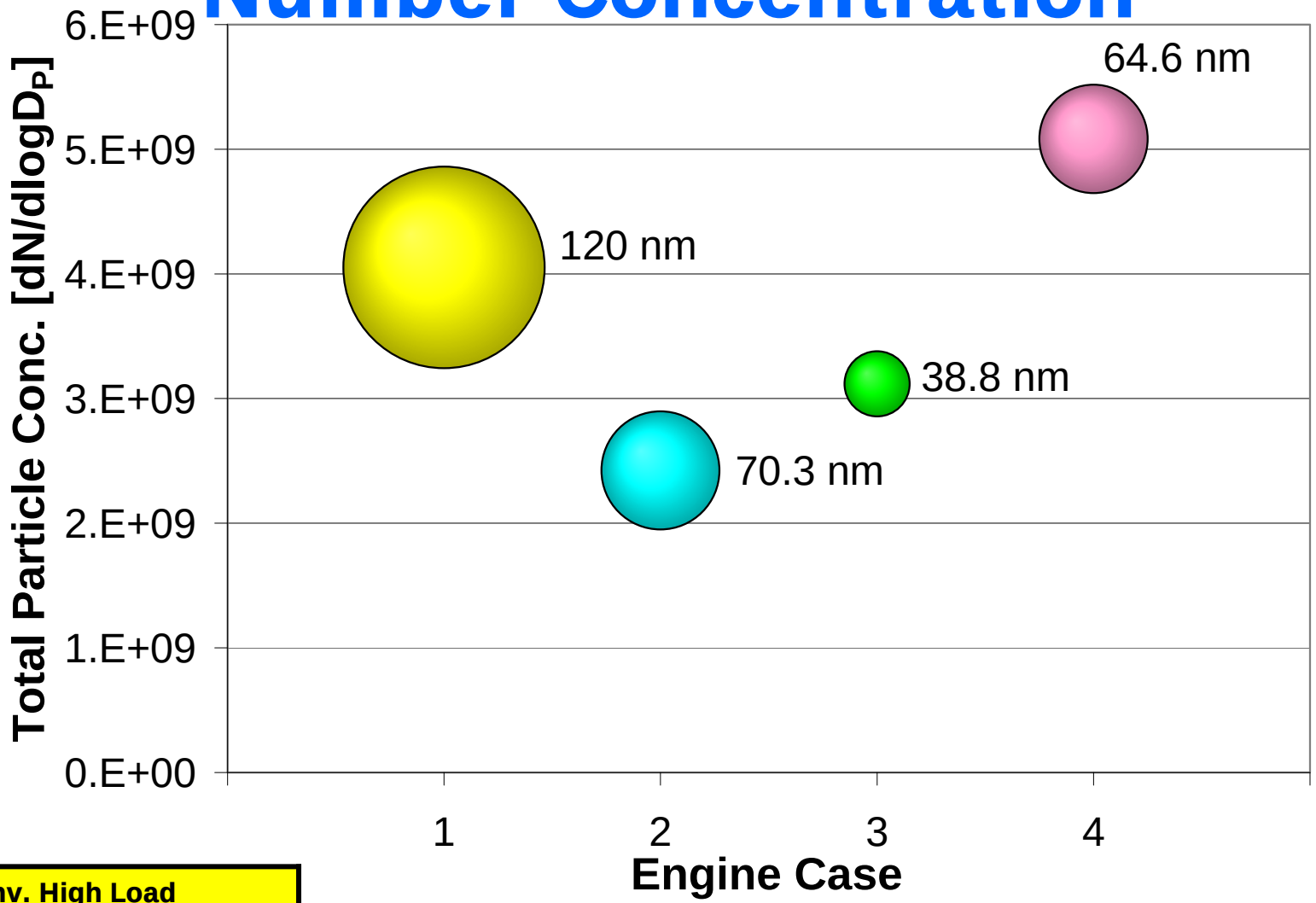
Mean Particle Diameter and Total Number Concentration



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Size and Mass Statistics

Case	1	2	3	4
Total Number Conc. [#/cc] x10^9	4.05	2.42	3.12	5.08
Geometric Mean Particle Diameter [nm]	120	70.3	38.8	64.6
Mode Diameter [nm]	126	76	40	69
Teflon Filter Mass [g/kg_fuel]	2.4	0.39	0.08	0.47

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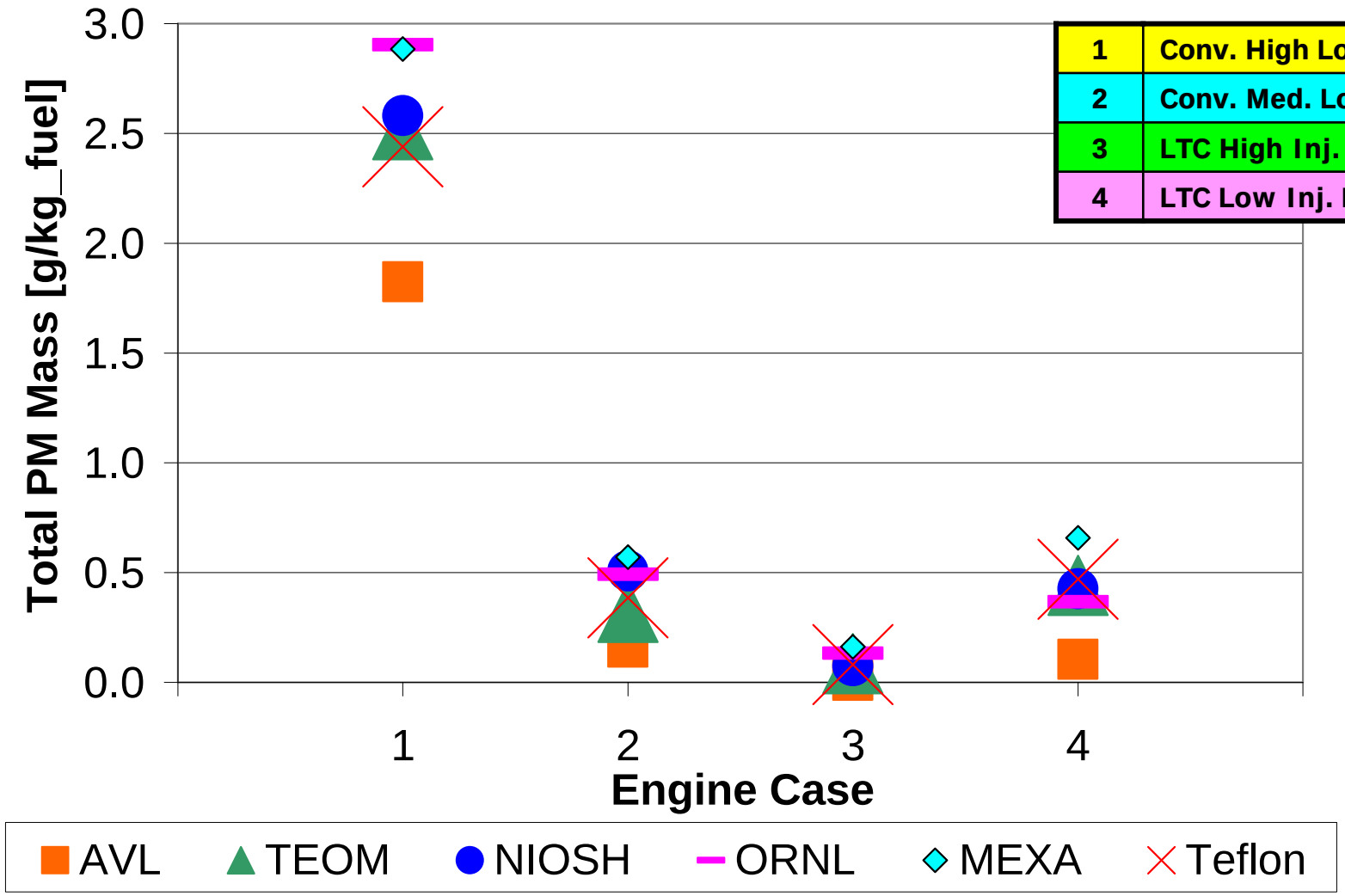
Total PM Mass Concentration



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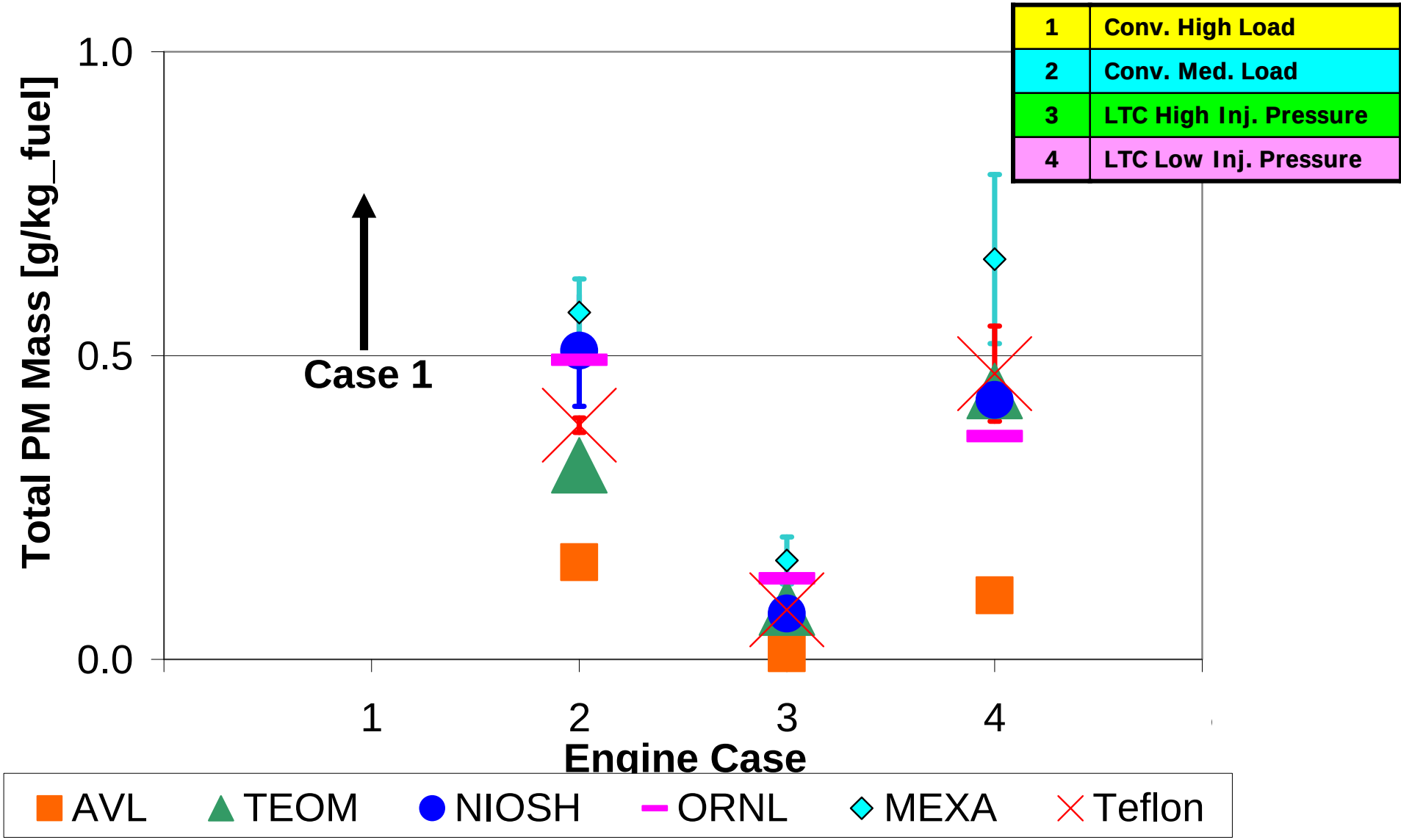
Total PM Mass Concentration (zoom)



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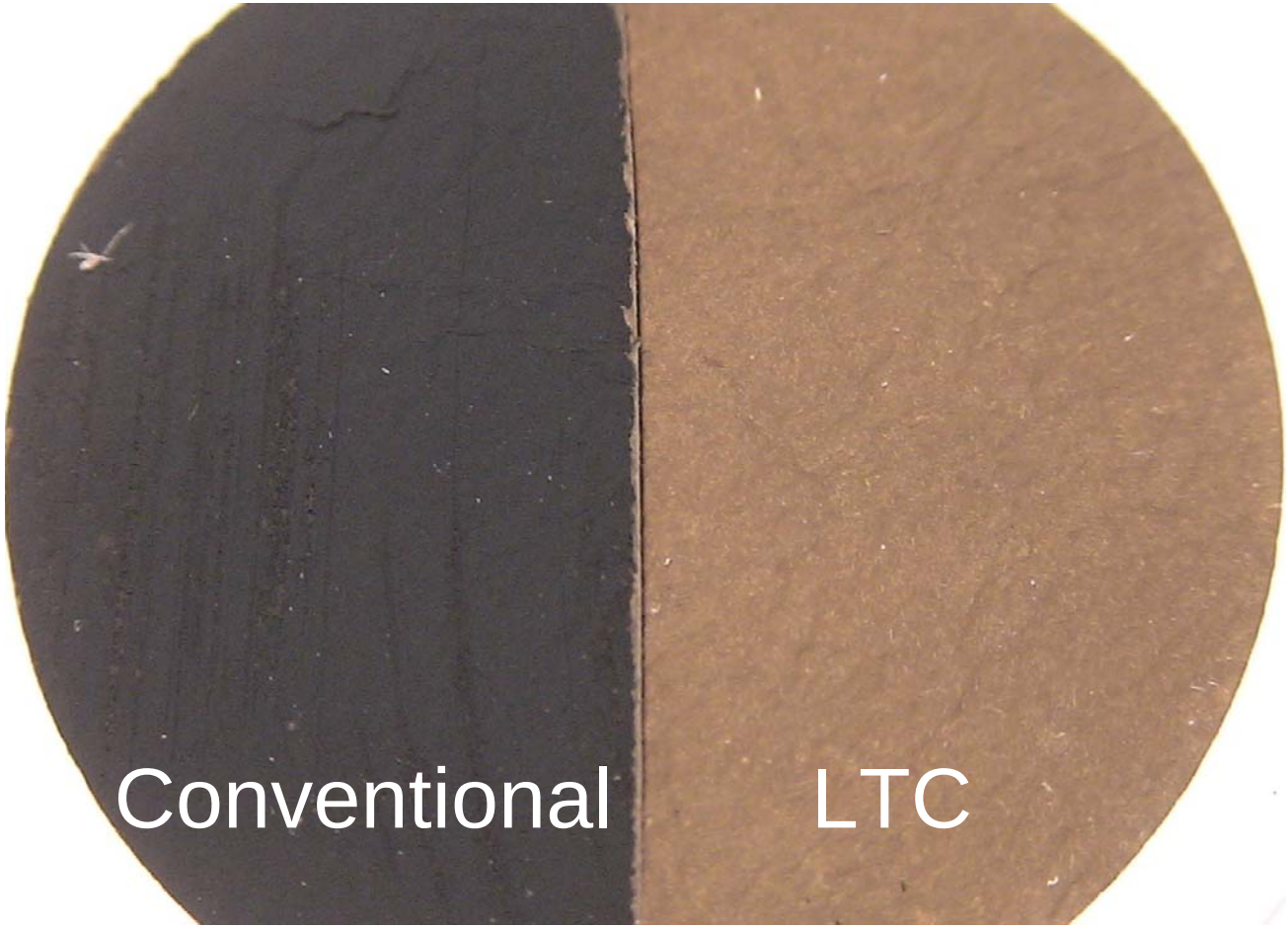
Filter Analysis



Color difference between PM from Conventional and LTC diesel combustion

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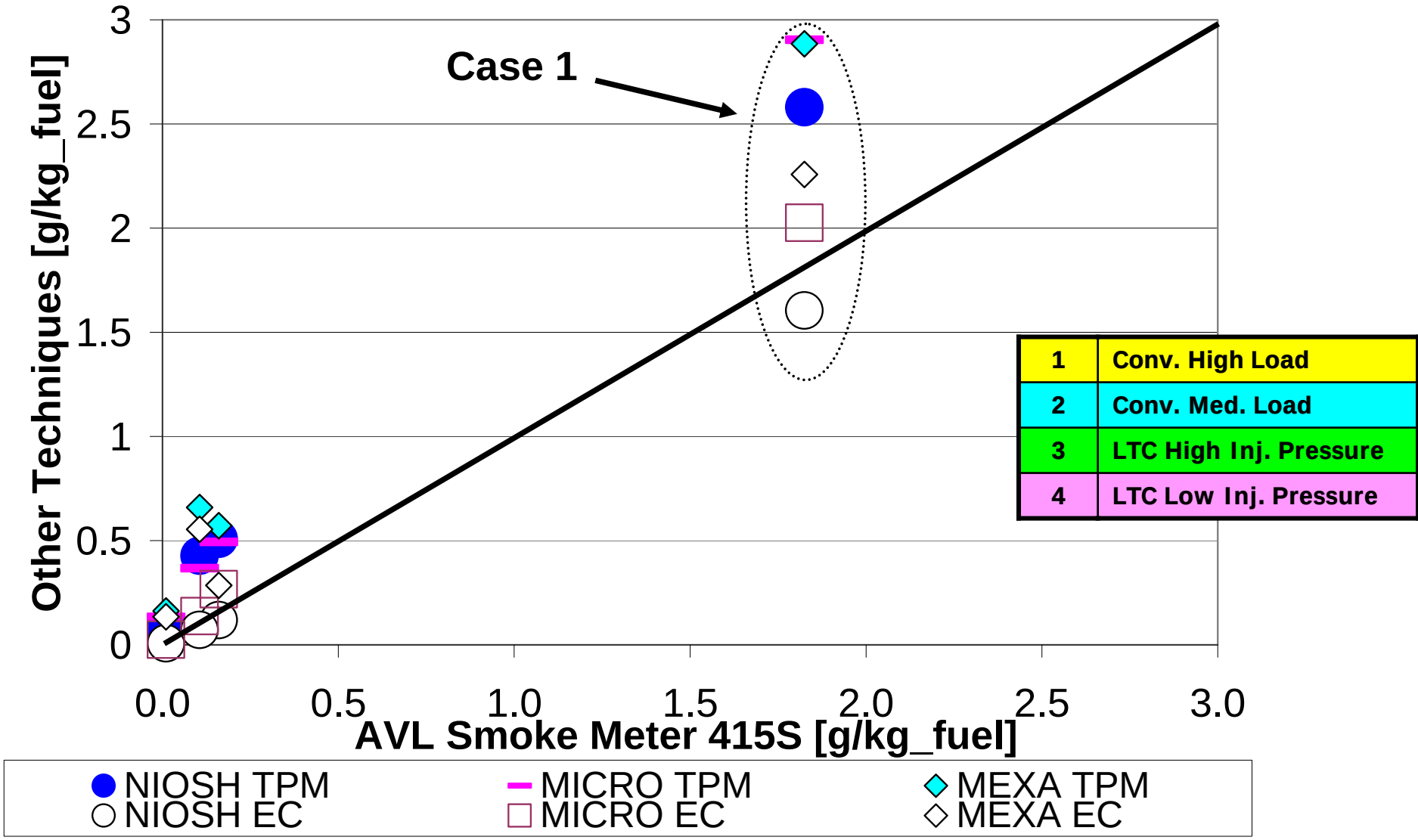
Elemental Carbon Comparison



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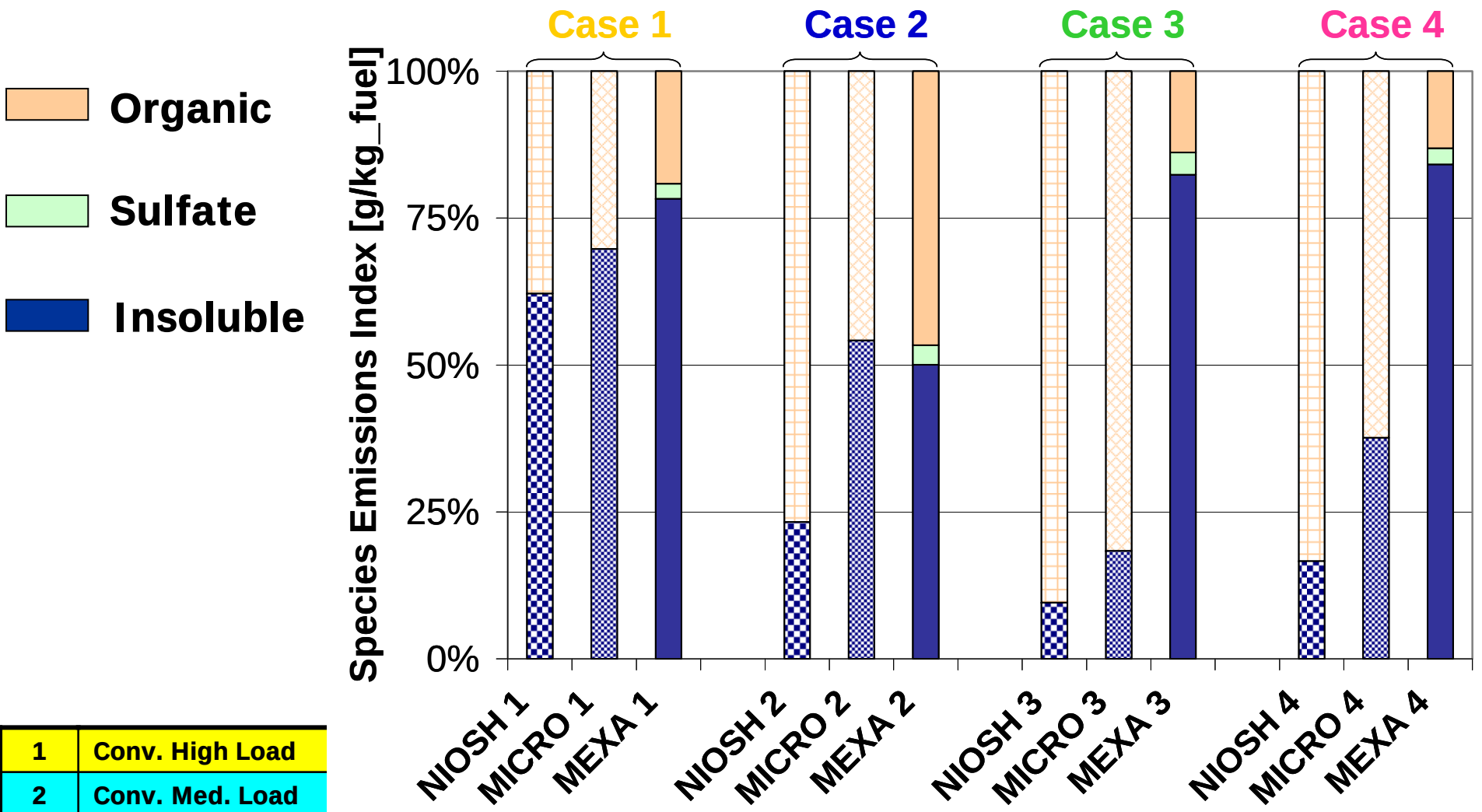
Normalized Chemical Speciation

(Artifact Corrected, Except MICRO)



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Organic Composition Analysis

Case	1	2	3	4
Unburned HC [g/kg_fuel]	.92	1.28	5.01	19.95
Maximum Combustion Temperature [K]	1772	1330	1612	1497
Combustion Efficiency [%]	99.7	99.6	96.5	**85.5**
NIOSH OC [%]	38	77	90	83
Microwave Extracted SOF [%]	34	44	**80**	59
MEXA SOF [%]	19	48	13	15

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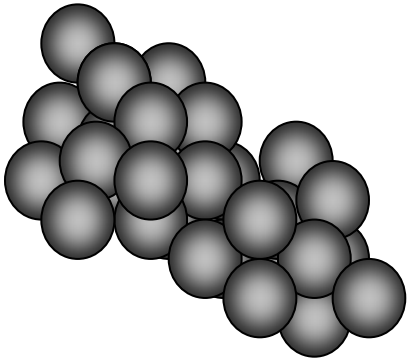
Conventional vs. LTC PM

- LTC accumulation mode occurs at smaller particle sizes
- LTC had very low PM mass concentrations
- LTC PM had higher organic content
- Higher HC emissions do not track with adsorbed SOF

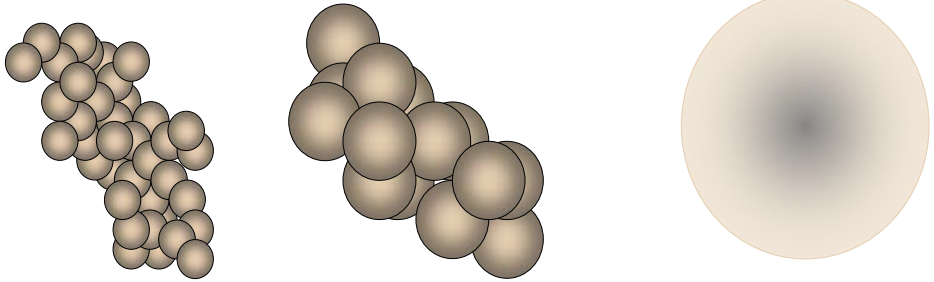
LTC PM Geometric Structure

What do the Case 3 accumulation mode particles look like?

CONVENTIONAL



LTC



A **B** **C**

[Kamimoto]

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Conclusions

- Same trends found among different instruments
- Low concentrations and higher OC content proved more difficult to measure
- AVL 415S tracks most closely with EC
- LTC and Conventional PM have very different number and mass concentrations, chemical composition, and size distributions

Thank You for Your Kind Attention