Effects of Advanced Combustion Technologies on Particulate Matter Emissions Characteristics

John M. E. Storey, Teresa L. Barone, Samuel A. Lewis, Vitaly Y. Prikhodko, James E. Parks, James P. Szybist

Oak Ridge National Laboratory

2008 DEER Conference

August 4 – 7, 2008

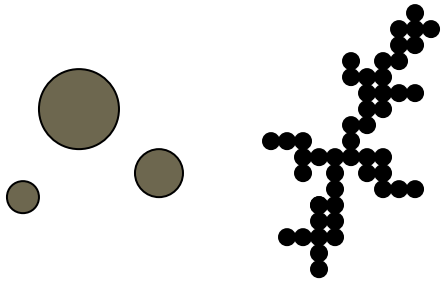
Acknowledgement:
Dr. James Eberhardt, OVT

This presentation does not contain any proprietary or confidential information

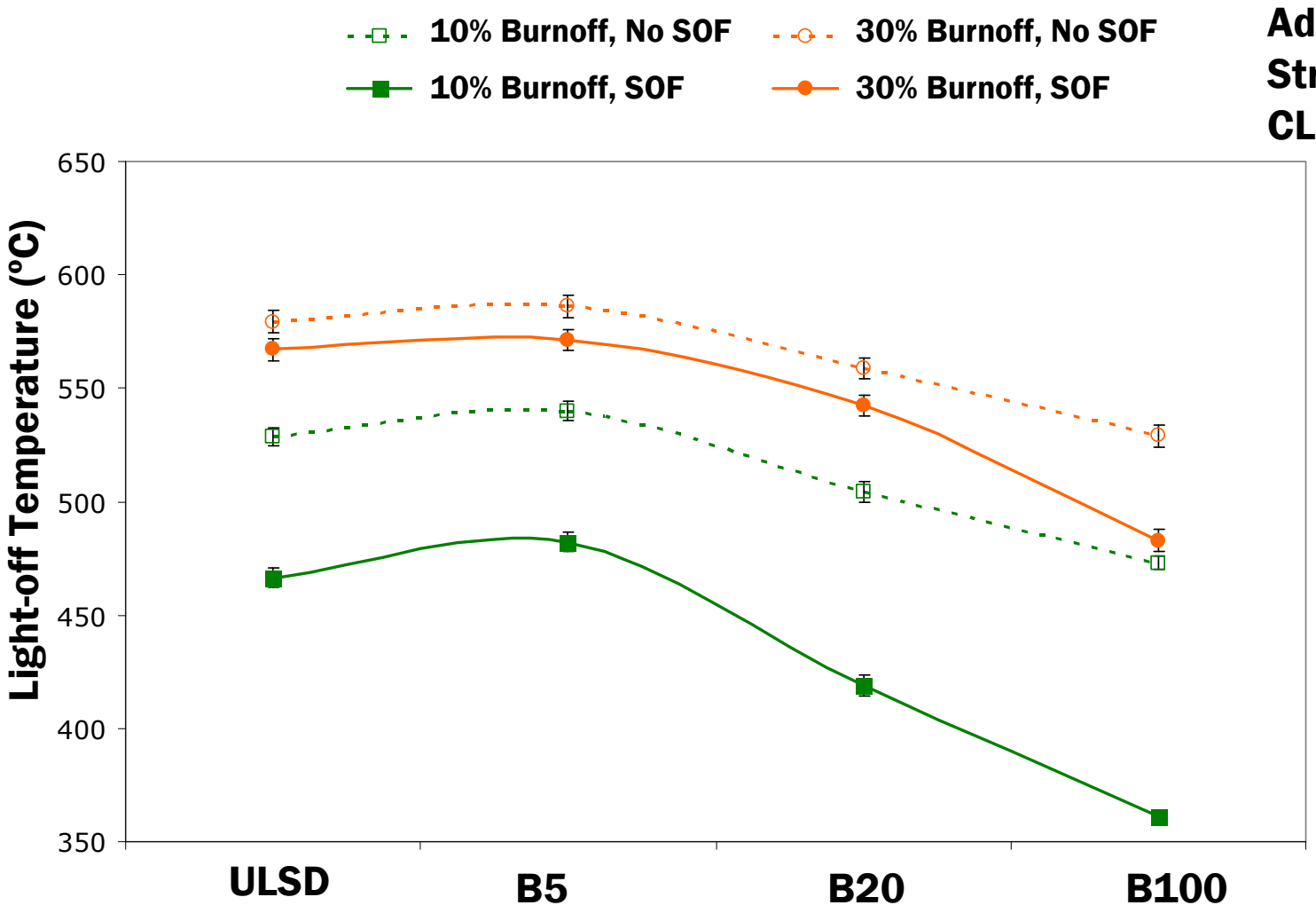
PM Characteristics of Advanced Combustion still Critical For Aftertreatment-Equipped Engines

- High-efficiency clean combustion alters PM properties
  - size, surface area, density
  - Soluble Organic Fraction chemistry
- EGR coolers may foul differently
  - Fall paper describes influence of biodiesel PM on cooler fouling

  (SAE *2008-01-2473*)
- System models should incorporate differences
  - Loading behavior will depend on size, morphology
  - Light-off behavior will depend on SOF



PM SOF chemistry Affects Soot Light-off Temperature in a Diesel Particulate Filter



Adapted from Strzelec, CLEERS 2008

Soluble Organic Fraction (SOF) Reduces Light-off Temperature for ULSD and Biofuels

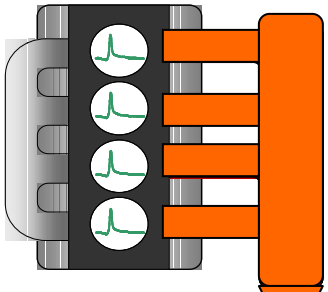
Experimental Plan

- Two engines
  - PCCI: 1.7 L TDI with full-pass control
  - HCCI: single cylinder research engine
- Light Duty Ad Hoc modes 1-4 for PCCI

Mode	1	2	3	4	5
RPM	1500	1500	2000	2300	2600
BMEP	0.8	2.6	2	4.2	8.8

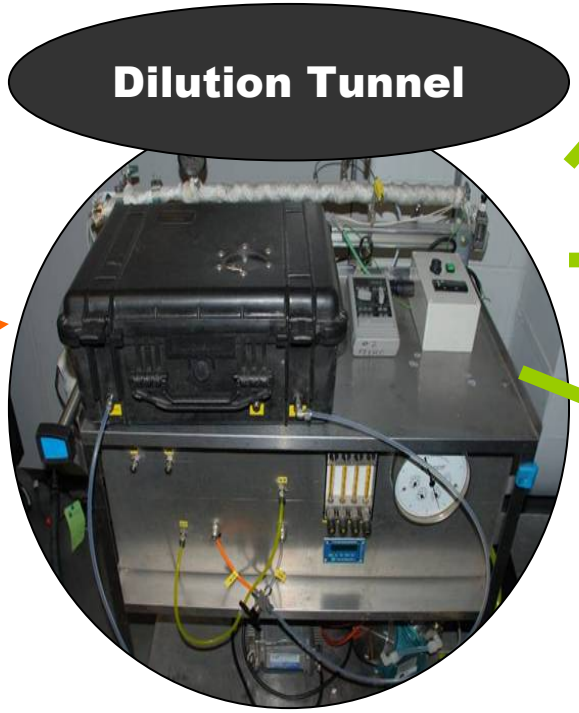
- HCCI: 1800 RPM, varied fuel rate, intake T
  - Loads from 1.6 – 3.1 IMEP
- Particle mass, size, and chemistry
- Extensive HC speciation
  - Covered in SAE 2008-01-2431

Set-up for Comparison of Advanced Combustion and Conventional Diesel PM



Engine: 4 cylinder
1.7L turbo DI

Dilution Tunnel

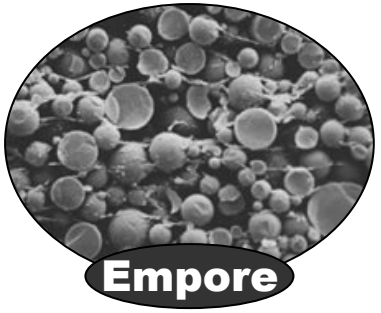


SMPS

Particle Size Distribution

Total PM
SOF/insoluble
SOF speciation

PM Filters



Empore

Selective capture of semi-volatiles (C10-C18) GC/MS speciation

Exhaust

Pre-mixed Charge Compression Ignition (PCCI) Effects on PM Chemical Composition and Size

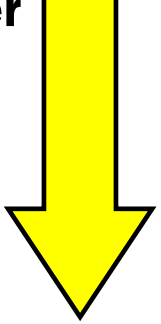
Soluble Organic Fraction

- Filter Collection
- Microwave Extraction
- Gravimetric Measurement

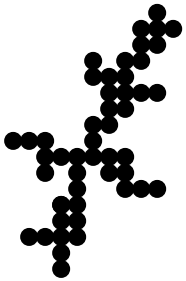
Speciation:
Napthalenes
3 — 6 Ring PAHs

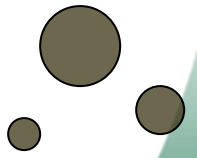
Mean Diameter

Surface Area

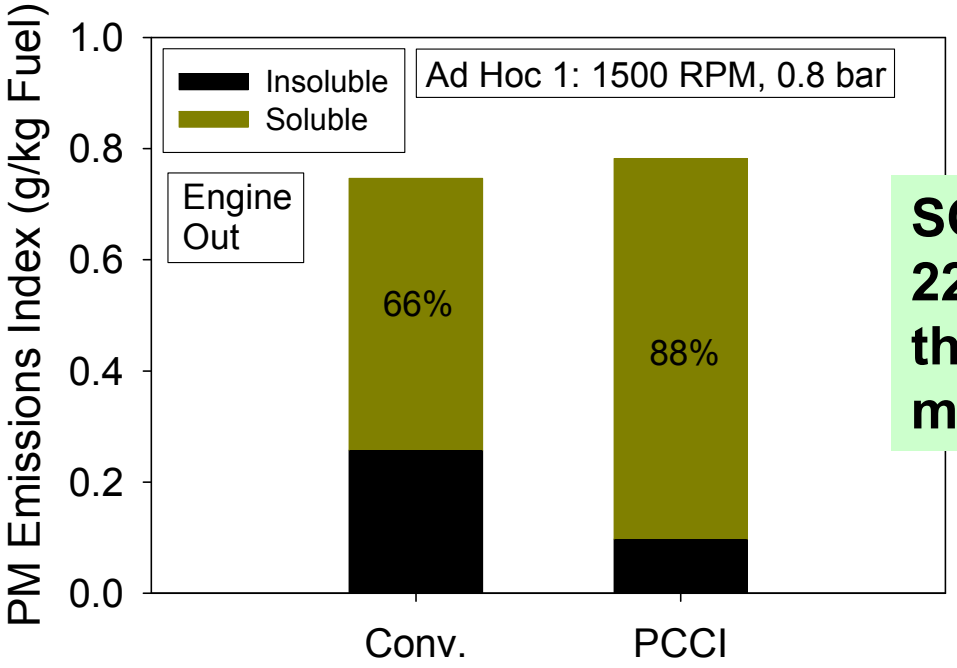


Size Distribution Measurements by Scanning Mobility Particle Sizer (TSI Model 3936)

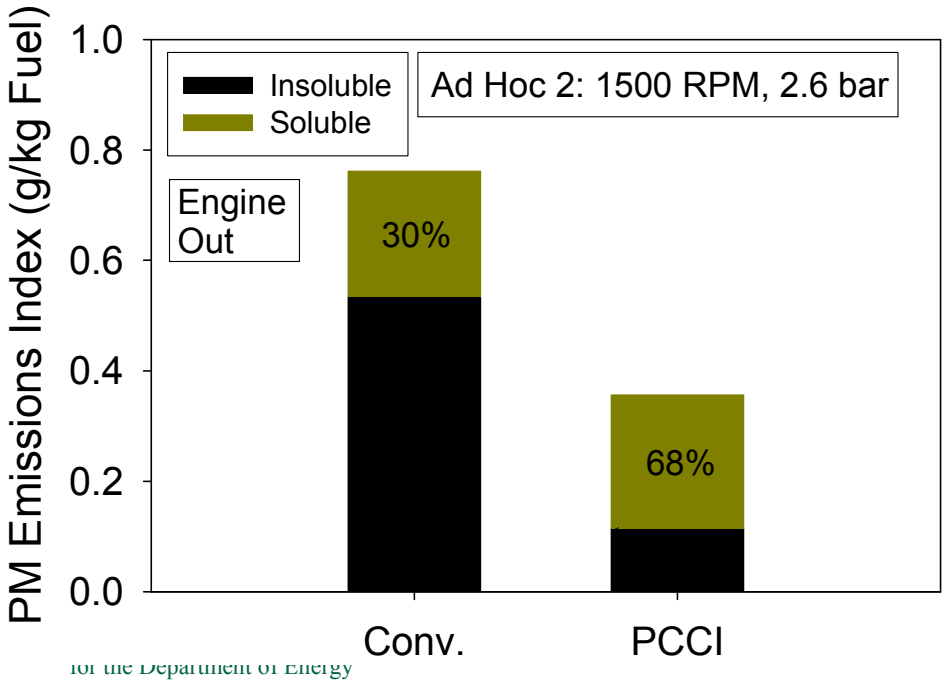


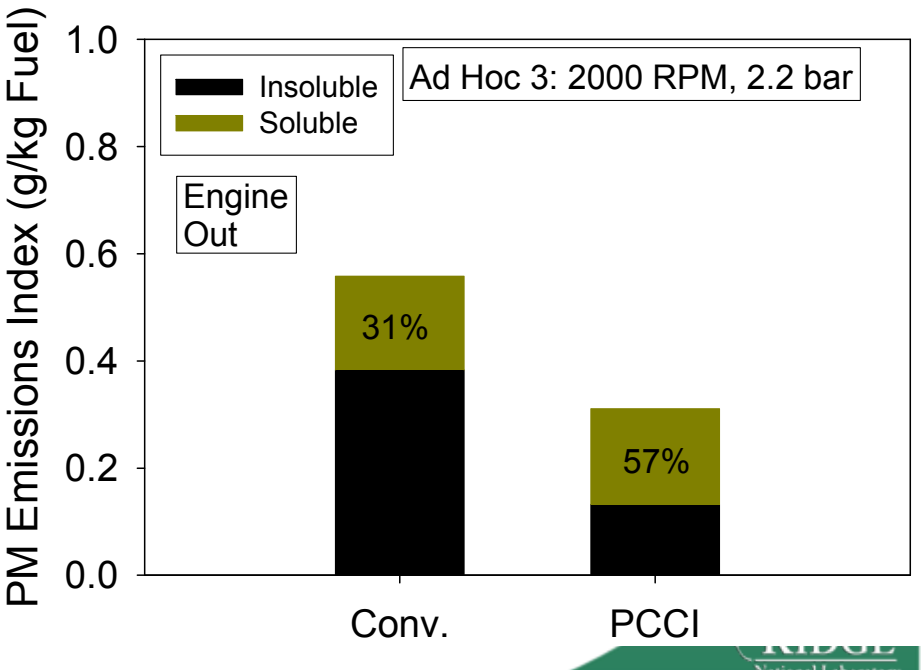


Soluble Organic Fraction (SOF) increases with PCCI



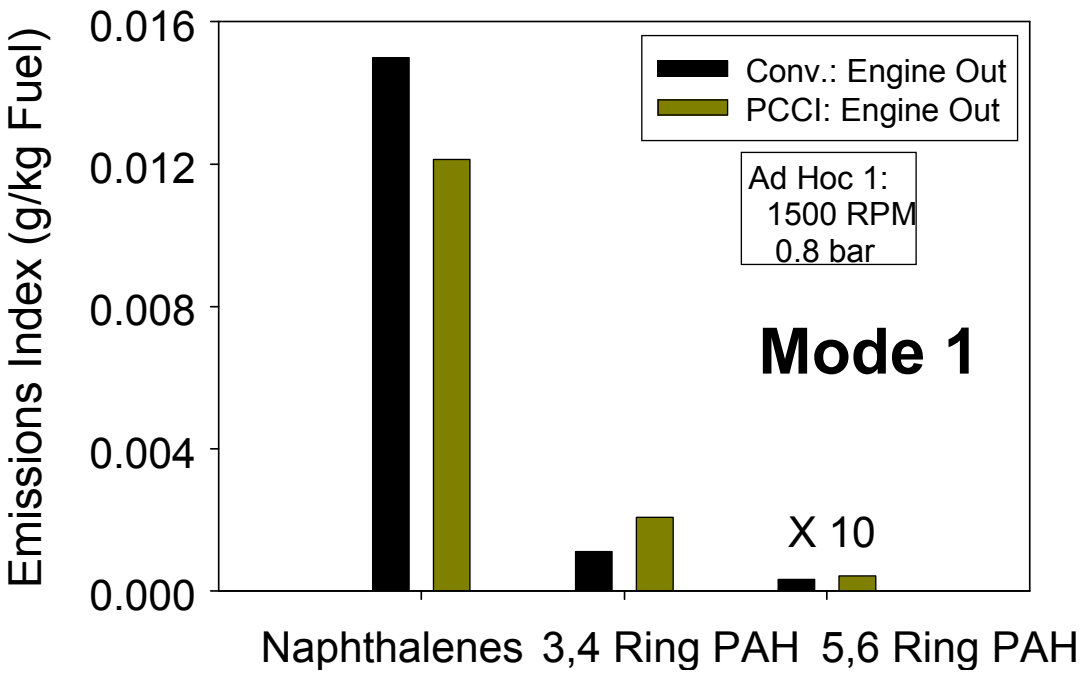
SOF for PCCI mode 22 – 38 % greater than for Conventional mode



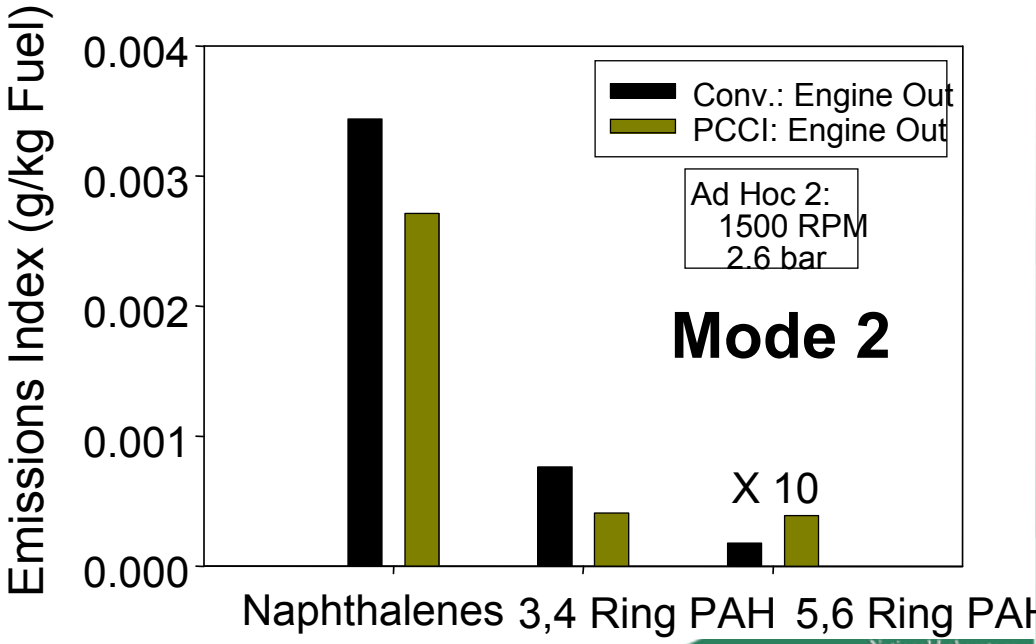


Speciation of SOF Identifies Soot Precursors

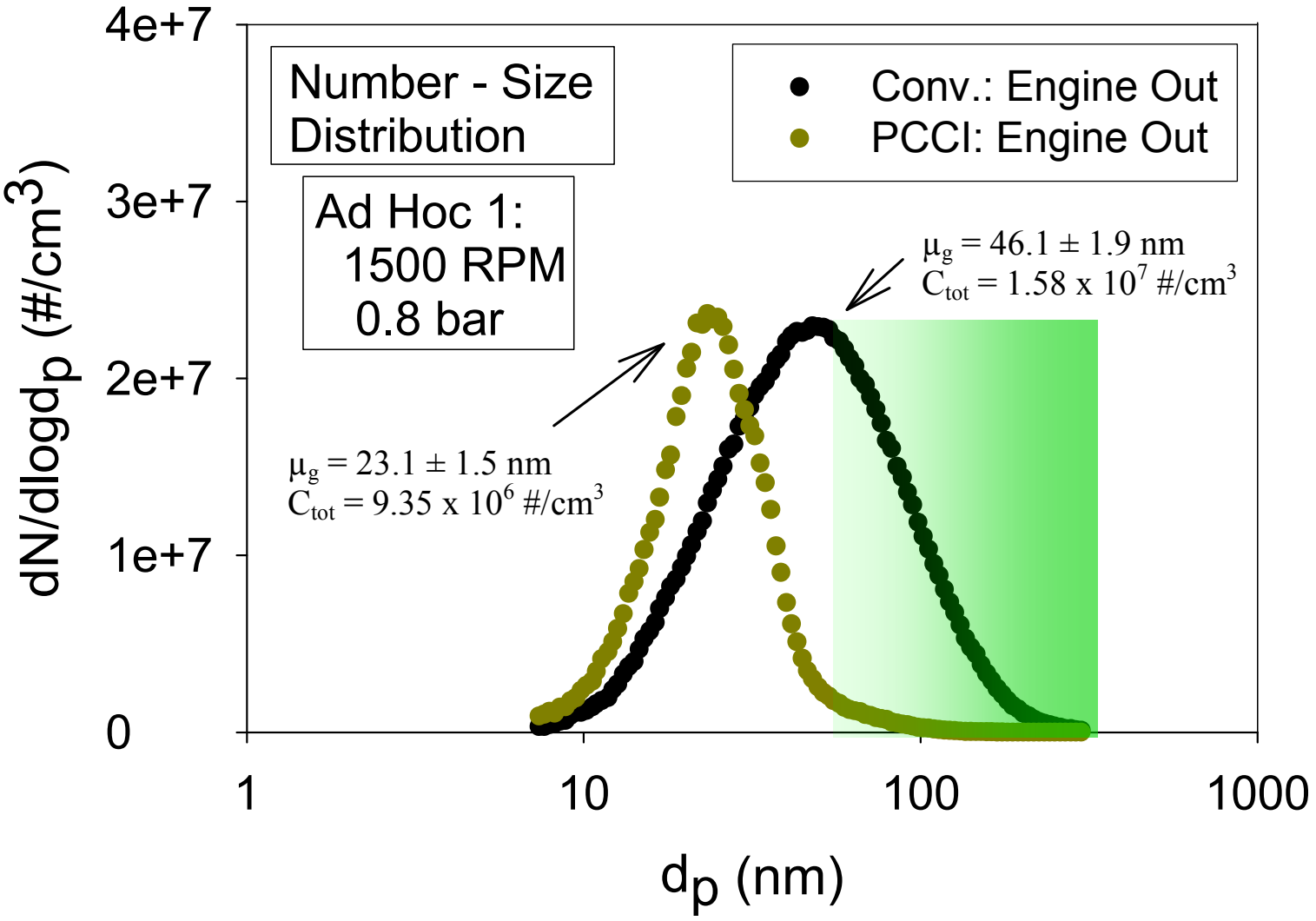
3, 4 ring PAHs higher at low load, Mode 1 point



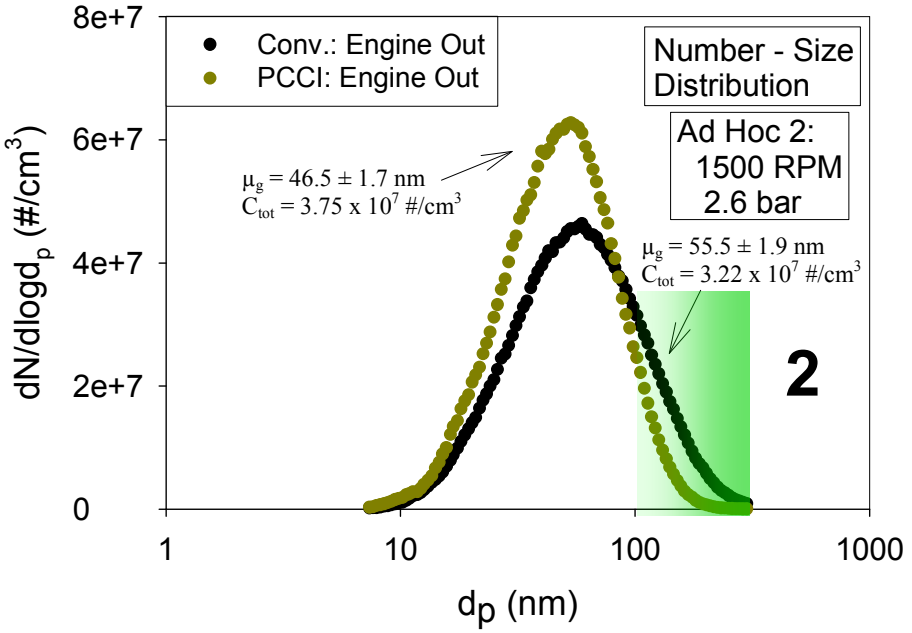
5, 6 ring PAHs higher at moderate load point



PCCI Particle Diameter Shrinks to about Half of Conventional Operation at Ad Hoc Mode 1



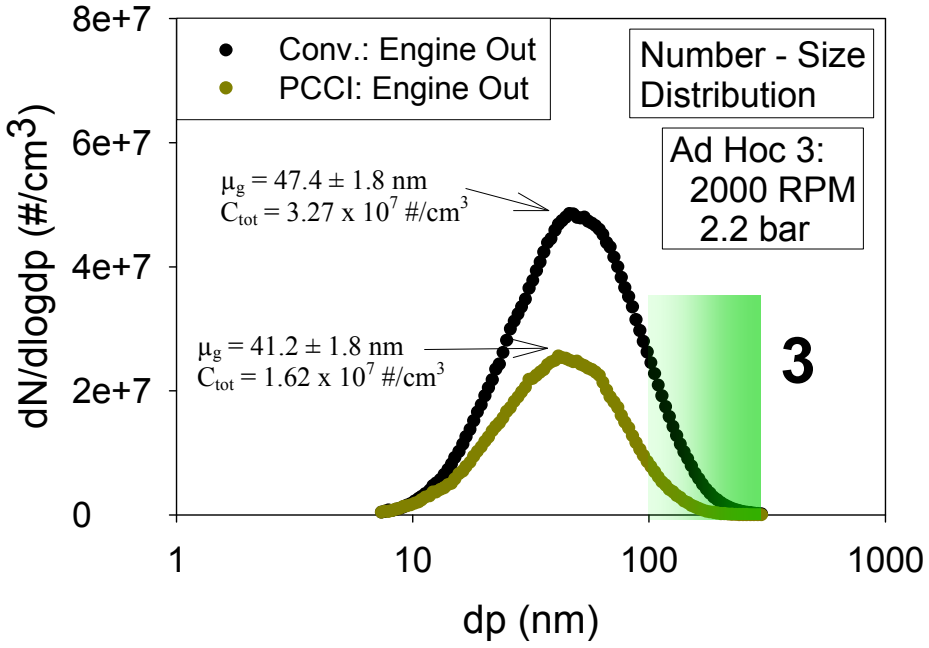
Number - Size Distributions at Higher Speeds and Loads

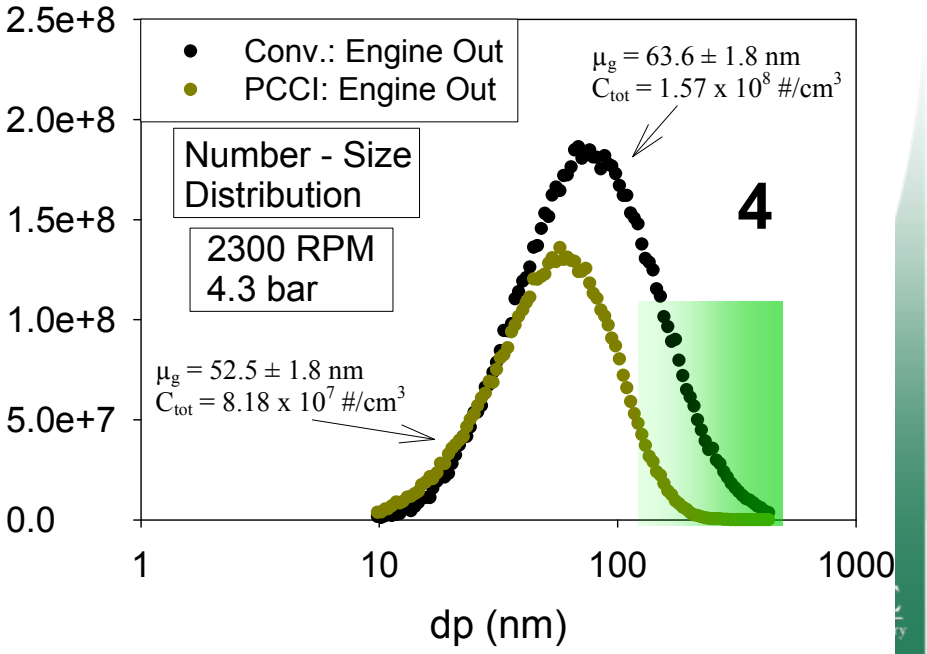


PCCI/Conventional number concentration varies with engine operating conditions

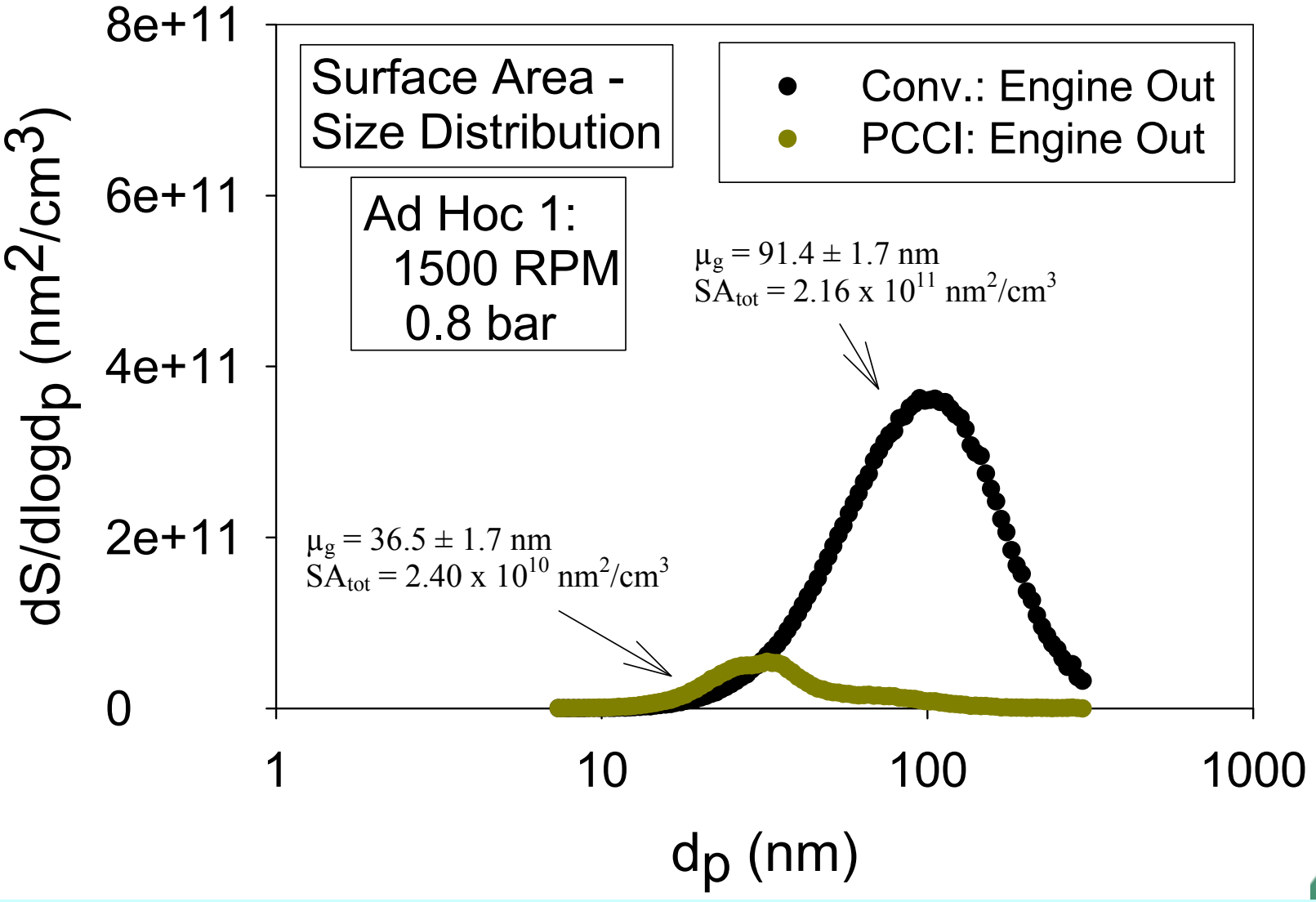
Geometric mean diameters ~5–10 nm smaller for PCCI PM

Fewer particles in fraction > 100 nm = less mass





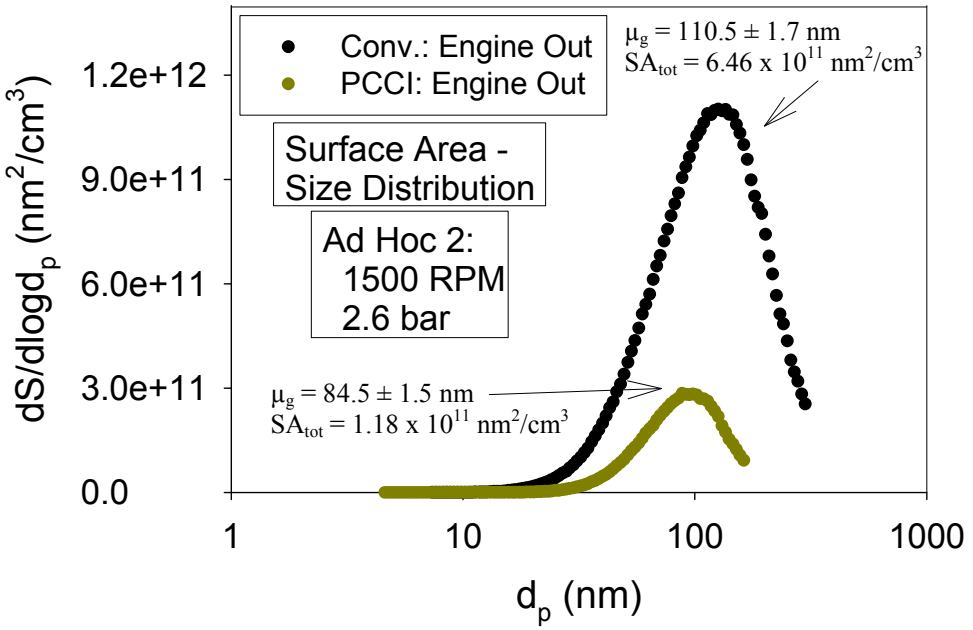
PCCI Operation Reduces PM Surface Area

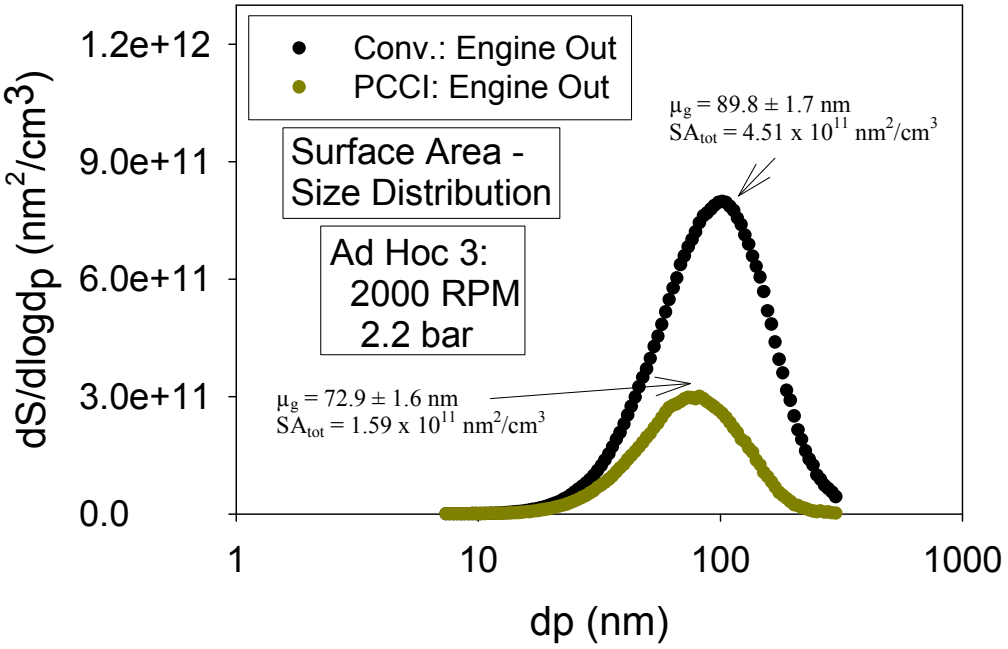


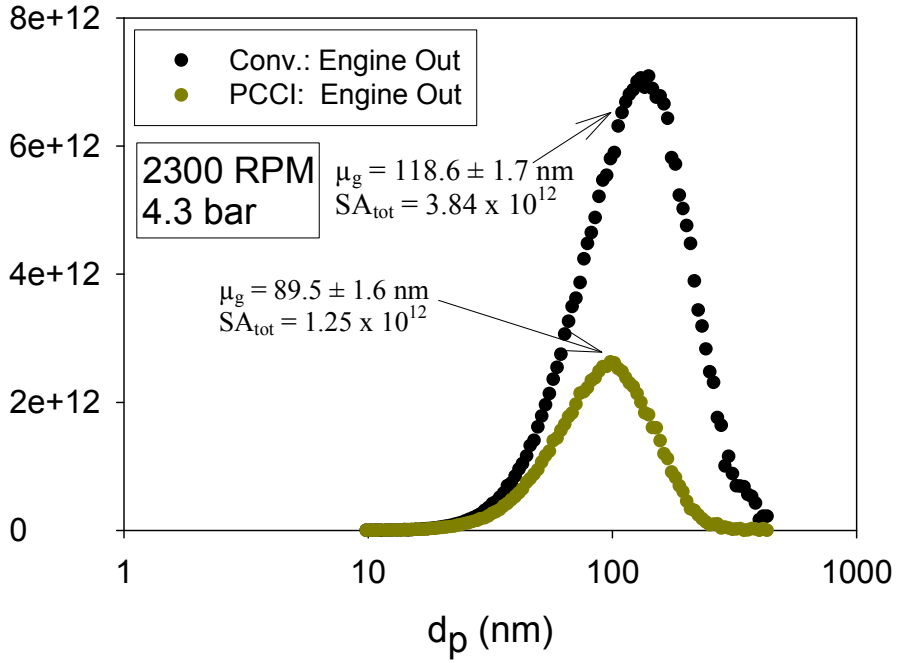
PCCI PM total surface area concentration only 10% of that for conventional mode at Ad Hoc Mode 1

Surface Area-Size Distributions at Higher Speeds and Loads

Over varying engine operating conditions PCCI reduces PM surface area

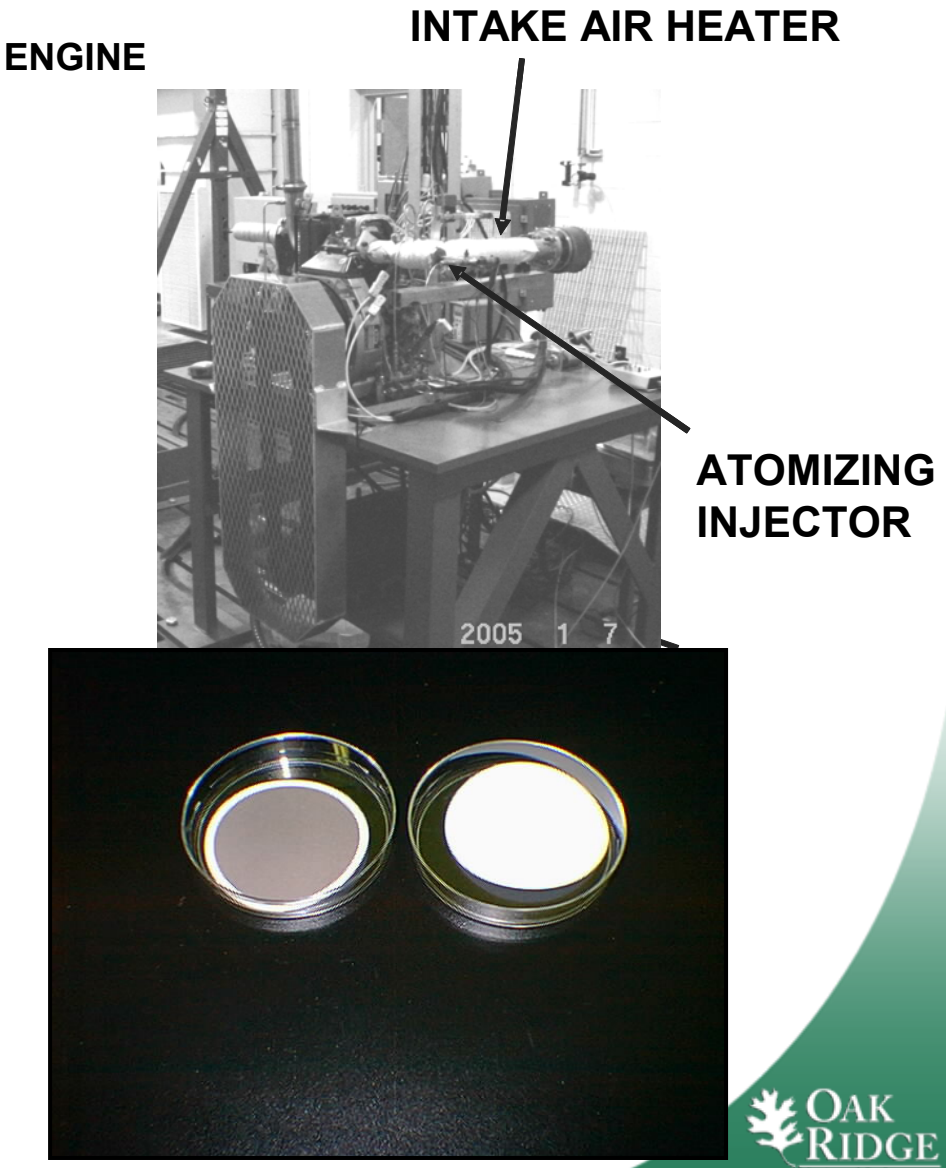




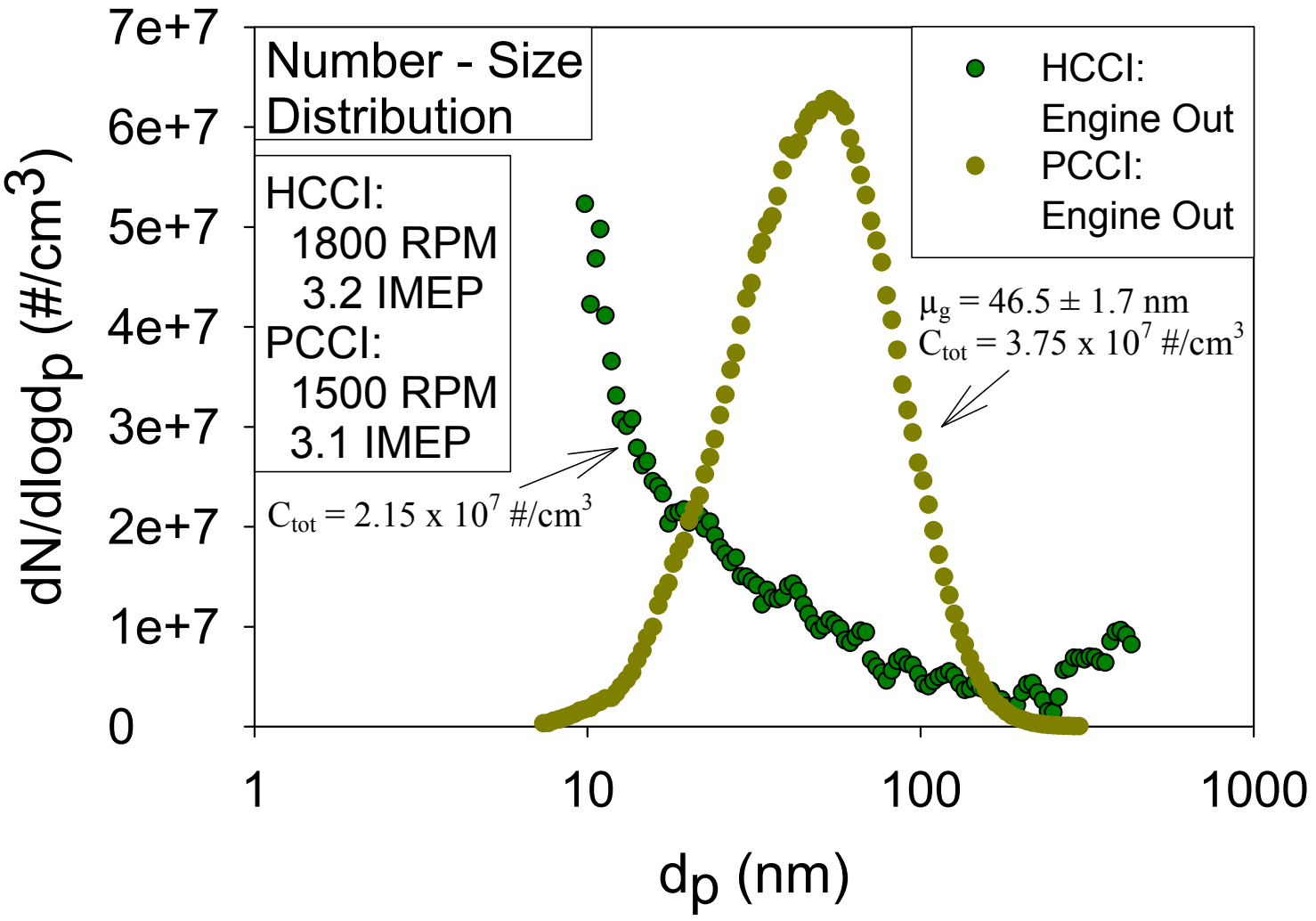


HCCI Experiments produced no visible PM

- Fueling rate used to change load
- Intake T set to best efficiency
- No torque measurement, so IMEP matched
  - PCCI: 1500 RPM, 3.1 IMEP
  - HCCI: 1800 RPM, 3.2 IMEP
- PM sizing done for comparison to PCCI
- PM filter measurements
  - No visible soot



Comparison of PCCI and HCCI: HCCI - nuclei mode particles from SOF condensation



Homogeneous charge compression ignition produced smaller particles than PCCI mode at a comparable IMEP value for different engines.

Conclusions

PCCI relative to conventional mode:

- Increase in SOF > 20% observed for three engine operating conditions (1500 RPM, 0.8 bar, 2.6 bar; 2000 RPM, 2.2 bar).
- SOF speciation suggests 3 – 6 ring PAH content elevated.
- PM mean diameter reduced by half at 1500 RPM, 0.8 bar.
- Total surface area concentration consistently reduced for four engine operating conditions.

PCCI relative to HCCI

- HCCI PM virtually all condensation nuclei for comparable IMEP