Methods and Characterization of Ultrafine Particles in Various Engine Exhaust Aerosols

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Overview

- The universe of ultrafine particle sources
- CARB’s research priorities and characterization of ultrafine particle emissions
- Challenges associated with measurement
- California’s contributions to the European PMP advances
The anthropogenic sources of ultrafine particles are numerous (stationary, mobile, industrial, occupational, atmospheric conversion).

Biswas and Wu, J. Air & Waste Manage. Assoc. 2005
Mobile sources are a key focus

Ultrafine particle emissions:
- Not a “diesel-only” problem
- Ultrafine particles originate almost exclusively from combustion processes
- Diesel, gasoline, LNG, LPG, CNG, jet aircraft engines have all been identified as sources of ultrafine particles emissions
The technology roadmap to lower HD diesel engine emissions is clear

• Ultrafine particles constitute a small fraction of PM mass, but dominate the fraction of particle number (and surface area)

• PM mass emission control may not equal particle number emission control

• Ultrafine particles have different chemical composition from fine or coarse particles. They consist almost exclusively of organic and elemental carbon*

• “Ultrafine particles” still an emerging environmental area

• Agreed-upon methodologies for measurement of ultrafine particle emissions do not exist

* Herner et al., J. Air & Waste Manage. Assoc. 2005
Under the research priorities*
“Reduction of emissions and characterization of air pollutants,” CARB has significant on-going investigations of emission control technologies and methods for sampling for ultrafine particles

*2001-2010 Strategic Plan for Research
April 2003 Update
Ultrafine Particle Emissions for CNG and Trap-equipped Diesel

- Comparison of cycles (cycle mean concentrations)
- Particle number distribution peaks at 8nm for CNG and at 80nm for trap-equipped diesel
- Average concentrations vary between cycles

* Error bars represent 1 standard deviation of repeated samples.

Oxidation Catalyst Control on CNG Emissions

Mini-diluter

Cummins w/Oxi Cat
DDC CNG-3 w/Oxi Cat
DDC CNG-3

No OC
With OC

55 mph Cruise/No correction for DR

Ayala & Holmen, CRC On-Road Emissions Workshop, San Diego, 2003
**Strong Dependence on Engine Operation**

*(OC-equipped CNG engine)*

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**Idle**
*(No correction for DR)*

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**Transient Cycle (CBD)**
*(No correction for DR)*

Each color represents one cycle

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Ayala & Holmen, CRC On-Road Emissions Workshop, San Diego, **2003**
DPF reductions confirmed in laboratory tests

- Partial flow
- No heating
- Two Stage dilution
- Low dilution ratios (8x8)

Ayala and Herner, *J. of Lubricants and Fuels*, SAE Transactions, 2005
New fast sizing instruments allow for examination of transient emissions

No correction for dilution
Note different scales

Ayala and Herner, *J. of Lubricants and Fuels*, SAE Transactions, 2005
PM is operationally defined*

Laboratories for certification of compliance with mass emission standards

Different measurement methods

Nucleation
Condensation
Coagulation
Evaporation

Exposure

Different vehicle emission behavior

*CFR Part 1065
Nucleation Mode Particles in Exhaust Emissions and in the Ambient

Effect of DPF

• Some research evidence suggests that a DPF can cause higher numbers of ultrafine particles while still reducing PM (nucleation of volatile material)

• Effect of sampling conditions and application to real world conditions poorly understood

H. Burtscher / Aerosol Science 36 (2005) 896–932

Particle numbers measured on the roadway appear to be different than laboratory measurements
Advancing international cooperation with new EU-DG-JRC & CARB partnership

MOU subject areas:

• Mass emission measurement (in laboratory and on board vehicle)
• Ultrafine particle emissions & PMP
• Source apportionment
• Climate change
The PMP Protocol

- New proposed solid particle number emission standard for CI and GDI light-duty vehicles
- Proposed protocol for measurement
- Counting solid particles is more accurate than gravimetric mass weighing

Picture courtesy of P. Dilara
CARB Evaluation of the European PMP Protocol on a Trap-Equipped Diesel Vehicle

Significant number of sub-30* nm particles

* 30nm and smaller = nucleation mode particles

Herner and Ayala, CRC On-Road Emissions Workshop, San Diego, 2006
Post trap particle counting statistics appear superior to gravimetric measurement

Percent Deviation from Average – CBD

Gravimetric N=10, Particle count N=2. Particle count measured raw exhaust according to PMP.

Herner and Ayala, CRC On-Road Emissions Workshop, San Diego, 2006
Summary

• The sources of ultrafine particles are numerous. Mobile sources is one area of keen interest.

• Ultrafine particles constitute a small fraction of PM mass, but dominate the fraction of particle number.

• Some credible research evidence suggests that PM mass emission control may not equal particle number emission control.
  – *Is the laboratory measurement of ultrafine particles capturing the ultrafine particles found on the road?*
  – *Agreed-upon methodologies for measurement of ultrafine particle emissions are needed*

• New instrumentation offers significant potential.

• European developments are an important advancement that foster debate and promote progress.