West Virginia University

CAFEE
Center for Alternative Fuels, Engines and Emissions

Characterization of Atmospheric Dispersing Exhaust Plume during On-Road Operation of Latest Technology Heavy-Duty Trucks

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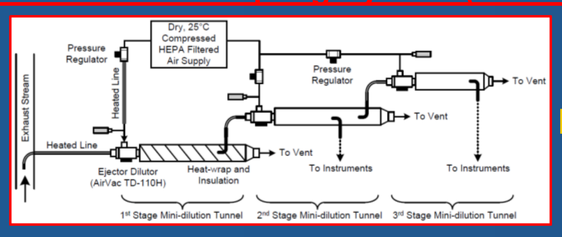
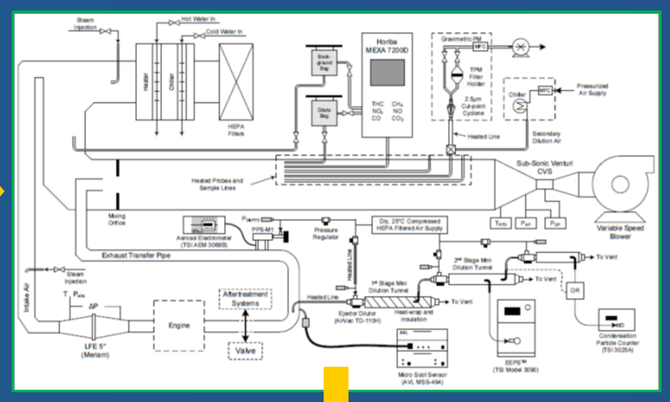
Introduction and Objective

Partial-Flow Sampling System (PFSS)

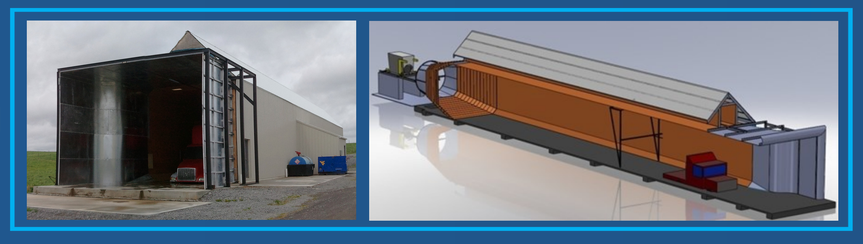


Full-Flow Constant Volume Sampling System (CVS)



On-Road Chase or Dispersing Plume Studies

Full-Flow Wind-tunnel Dispersing Plume Studies



- Assess the likelihood of reproducing real-world PM size distributions collected from the exhaust plume, by using two methodologies: CVS and Partial-Flow sampling
  - ⇒ Differences in dilution rates occurring in dispersing plume => enhancement/suppression of nucleation
  - ⇒ Importance of local turbulence intensity inside plume in enhancement of nucleation mode particle formation
  - ⇒ Impact of real-world background aerosols on particle formation/evolution in dispersing plume
- Compare PM development in real-world exhaust plume vs. full-scale wind-tunnel vs. full-flow CVS vs. partial flow sampling
- Compare PM morphology and composition via TEM/EDX analysis of PM samples obtained through plume and laboratory sampling

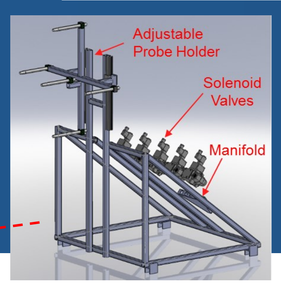
Particle Properties and Characteristics

- PM metrics
  - ⇒ Total particle number concentration via CPC (TSI Inc.); i) raw exhaust, ii) plume
  - ⇒ Total particle number concentration compliant with UNECE PMP method via SPCS-2100 (Horiba Inc.); plume
  - ⇒ Particle active surface information via EAD (TSI Inc.); plume
  - ⇒ Particle mass information via AVL MSS (AVL GmbH) and DMM (Dekati); plume
  - ⇒ PM black carbon information via aethalometer AE33 (Magee Scientific); plume
  - ⇒ Particle number and size distribution via EEPS™, model 3090 (TSI Inc.); i) ambient air, ii) plume
- Raw gaseous emissions (Semtech-DS) used to monitor engine/after-treatment activity (i.e., DPF regeneration) and to compute local dilution ratio based on CO2 with gaseous concentration in plume measured via FTIR (mks 2030)
- TEM grids containing PM samples will be analyzed at the West Virginia University Shared Research Facilities using a JEOL JEM-2100 LaB6 Transmission Electron Microscope to analyze particle morphology
- An Energy-Dispersive X-ray analysis will also be performed to obtain information about PM composition on a particle basis

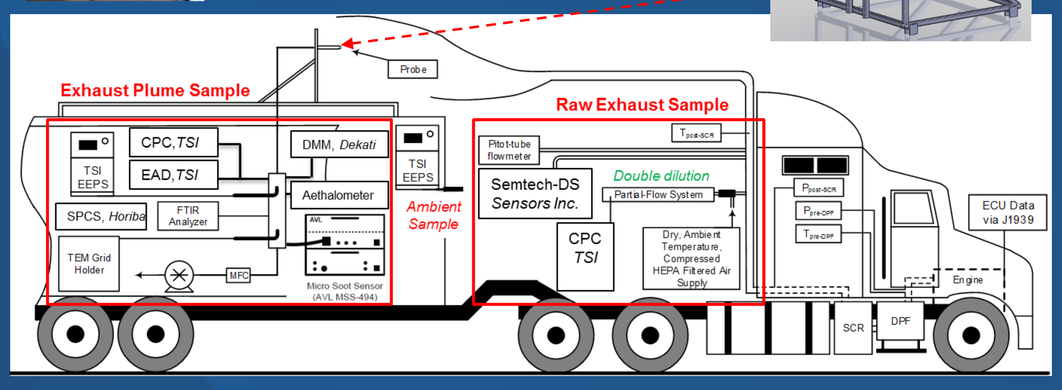
Scientific Approach

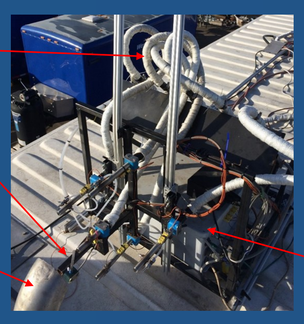
Heated manifold (47±5ºC)
- maintain constant flow through probe
- split sample to different instruments
- attach sample holder for TEM grids

Exhaust Plume Sample Extraction Cart



- 5 sampling probes with adjustable position
- Each probe is equipped with
  - ⇒ Thermocouple
  - ⇒ Continuous CO2 measurement via dedicated NDIR sensor
  - ⇒ Anemometer for wind speed measurements (center probe only)
- Sampling lines were characterized for particle losses using AVL APG

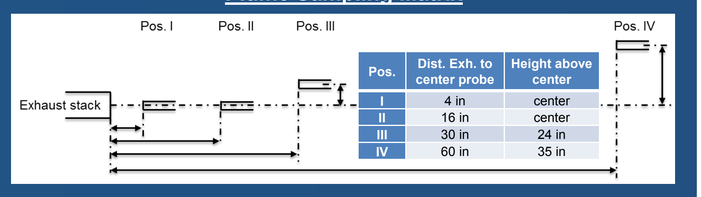




Test Vehicles

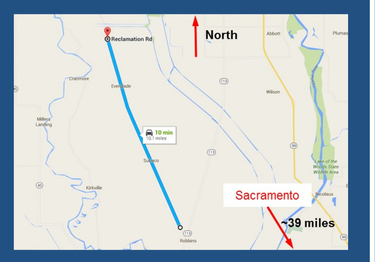
Vehicle	Engine Model	After Treatment System
Vehicle 1 (MY 2008)	Cummins ISX 525	DPF only
Vehicle 2 (MY 2014)	Detroit Diesel DDC15	DPF and SCR
Vehicle 3 (MY 2014)	Cummins ISL-G 320 (Natural gas)	Three-way catalyst

Plume Sampling Matrix



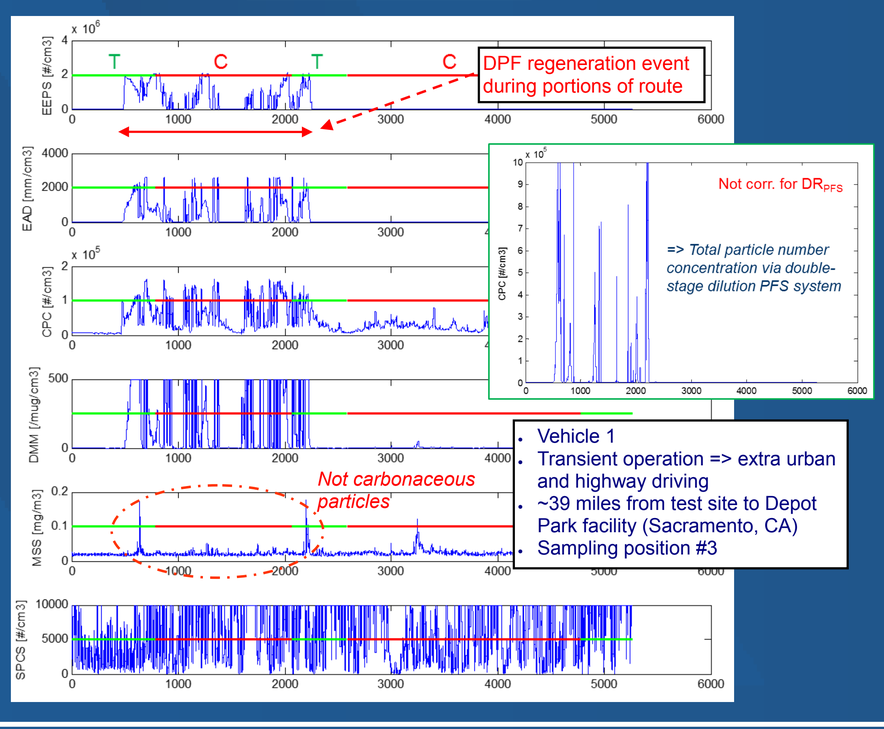
Pos.	Dist. Exh. to center probe	Height above center
I	4 in	center
II	16 in	center
III	30 in	24 in
IV	60 in	35 in

- Two vehicle operating conditions
  - ⇒ Transient vehicle operation
    - ◊ Highway (I-5) and urban driving => Depot Park facility (SW Sacramento, CA) to Robbins (NW of Sacramento, CA)
  - ⇒ Steady-state vehicle operation
    - ◊ Reclamation Road, ~39 miles north of Sacramento, CA
    - ◊ Steady-state at 2, 35, and 45 mph
- Test route characteristics
  - ⇒ Length: ~10.1 miles
  - ⇒ Average grade ~0.4% (peak ~1.6%)

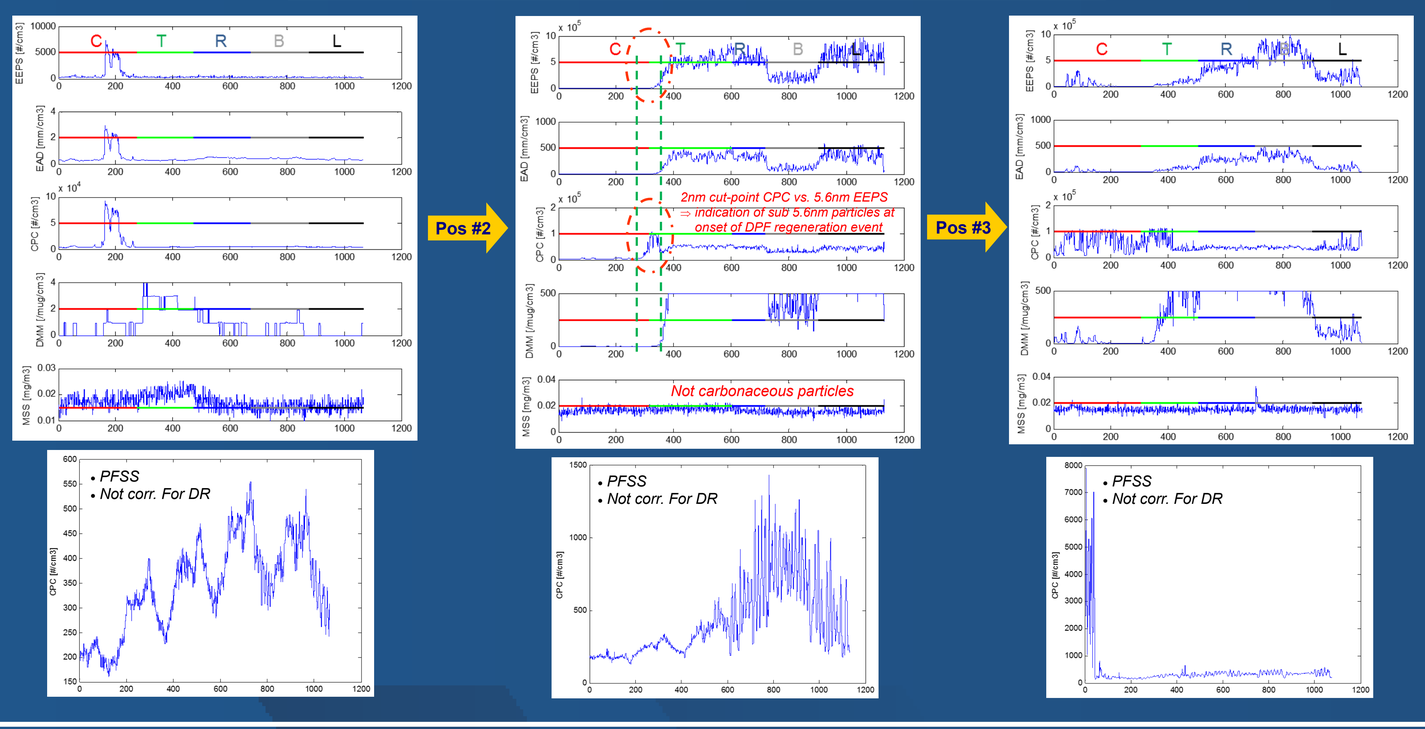


Results and Discussion

Transient Vehicle Operation



Steady-Sate Vehicle Operation, Vehicle 2, 35mph, 3 different sampling positions



20th ETH Conference on Combustion Generated Nanoparticles
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