UCR College of Engineering- Center for Environmental Research & Technology

EVALUATION OF THE EUROPEAN PMP METHODOLOGIES USING CHASSIS DYNAMOMETER AND ON-ROAD TESTING OF HEAVY-DUTY VEHICLES

Diesel Engine Efficiency & Emissions Research Conference

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Overview

- Background
- Objectives
- Experimental setup
- Results
  - Integrated data
  - Real time data
- Conclusion

Background

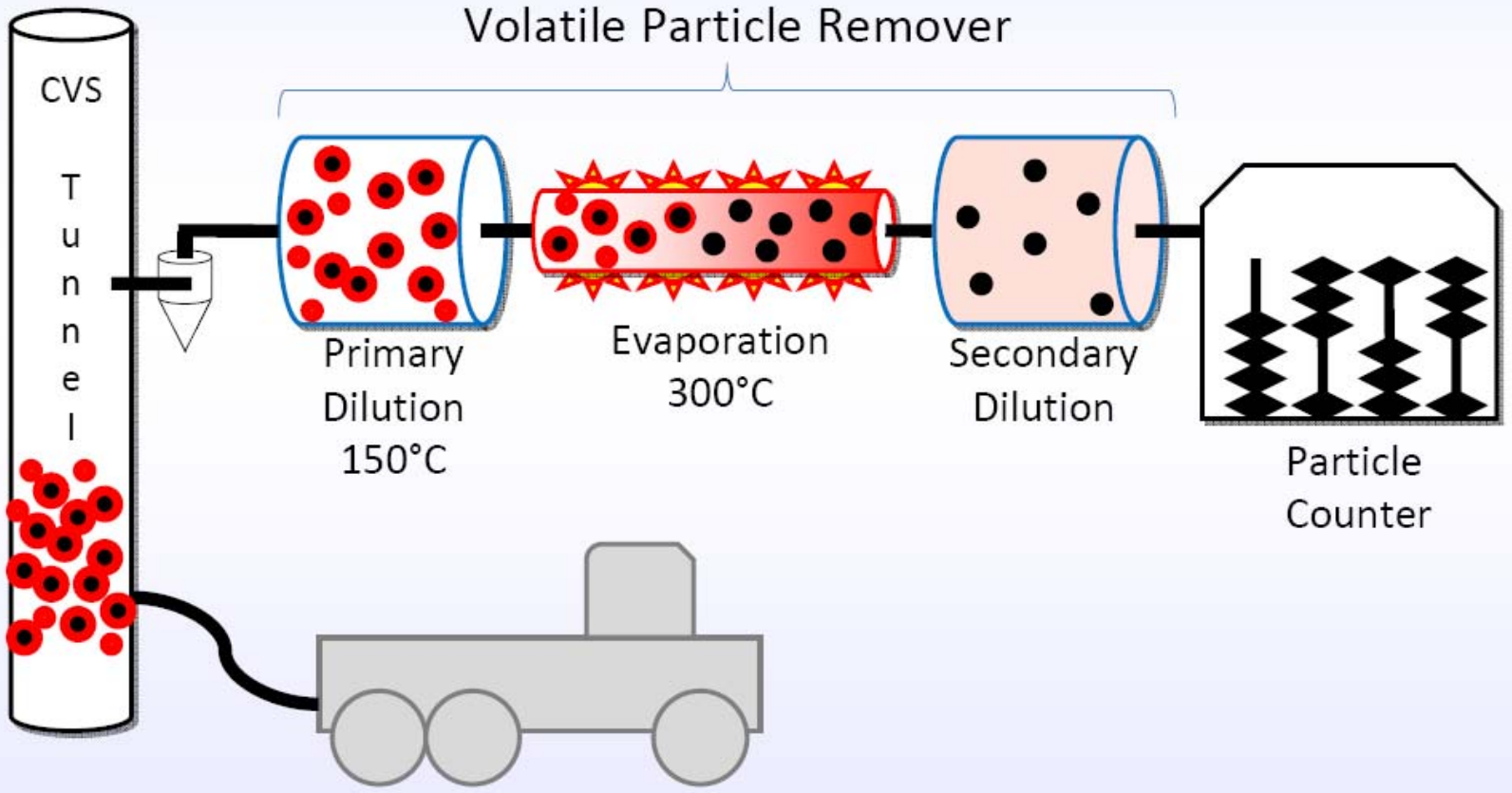
- Current gravimetric method have increasing difficulty quantifying post-DPF PM mass emissions accurately.
  - Background contribution
  - Insensitive to DPF fill state

- Euro 5/6 standard includes measurement of solid particles (>23nm) as an additional new metric of particles emitted from light-duty diesel vehicle.

Objectives

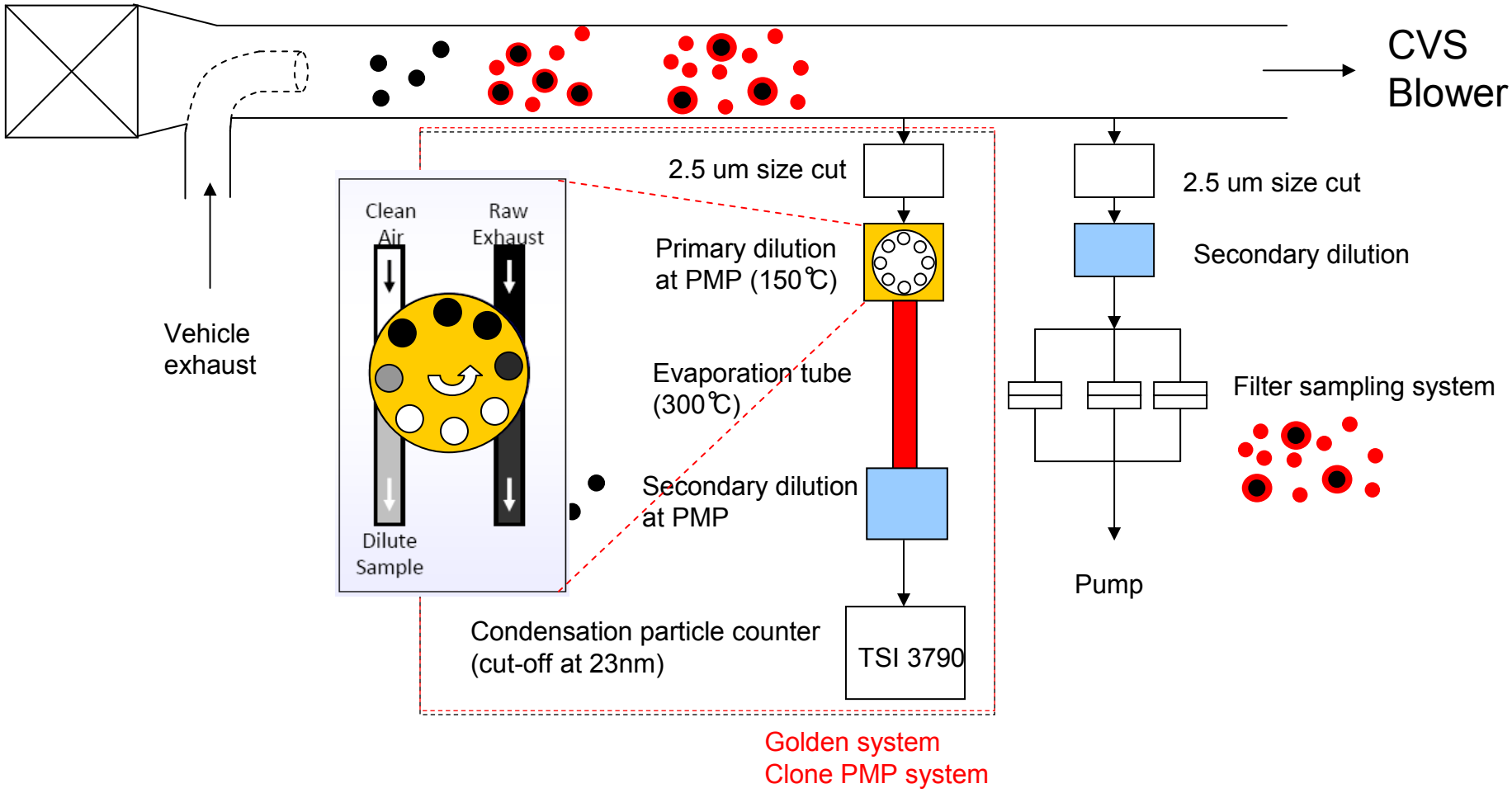
- Critical evaluation of the proposed European PMP method for determining particle emissions from heavy-duty diesels and its potential in California for PM measurement and in-use screening.
- Evaluate PMP under both laboratory and on-road conditions.
- Particle mass vs particle number.

PMP Schematic



Courtesy of W. Robertson at CARB

Gravimetric vs PMP measurements



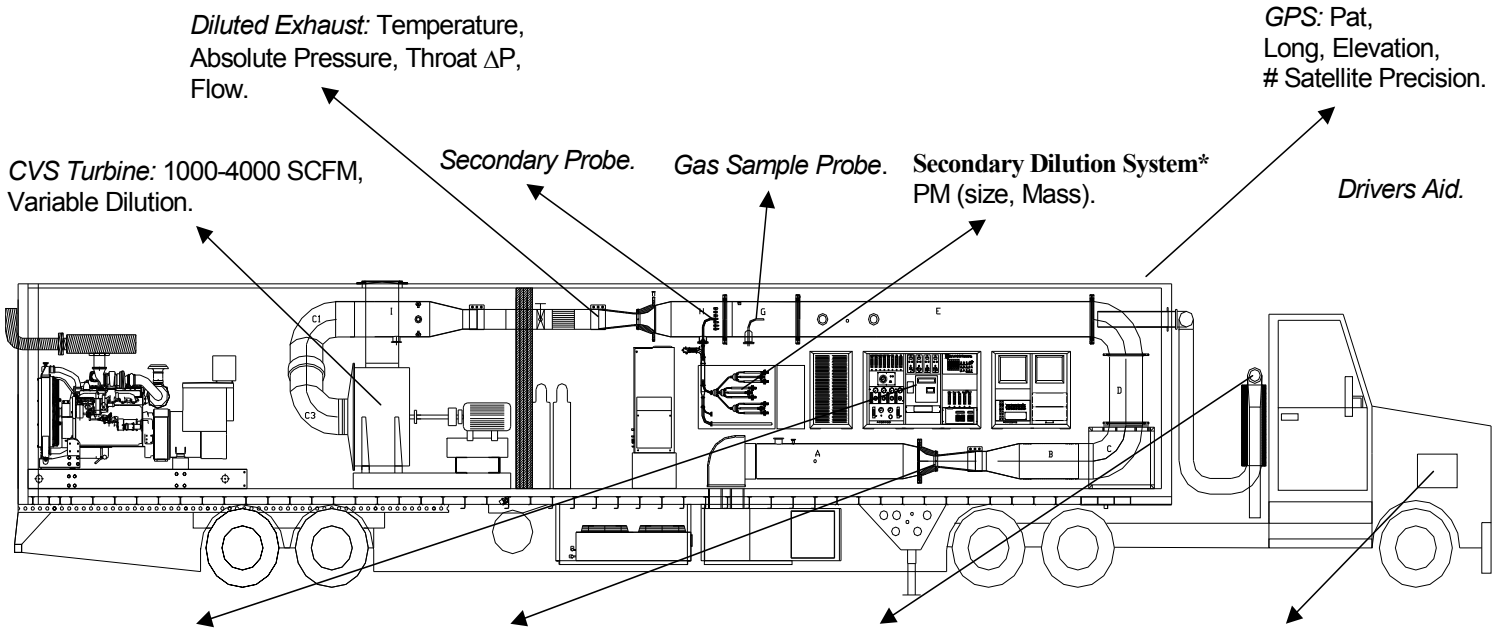
Courtesy of W. Robertson for MD-19 diagram

Experimental conditions

	Lab test	On-road test
Base	Chassis dynamometer	Mobile Emission Lab
PMP system	Clone system	Clone & Alternative (ISO 8178) systems
Vehicle	1999 International 4900	Freightliner class 8
Engine	International DT 466E (7.6L)	Caterpillar C-15 (14.6L)
Fuel	ULSD	ULSD
Lube oil	SAE 15W-40	SAE 15W-40
DPF	Engelhard DPX	JM CRT
Vehicle weight	27,000 lb	65,000 lb
Cycles	2x UDDS (35 min) 50 mph Cruise (45 min) Idle (40 min)	UDDS (18 min) ETC Cruise (10 min) CARB Creep (4 min) Flow-of-traffic

Lab testing (at CARB MTA lab)

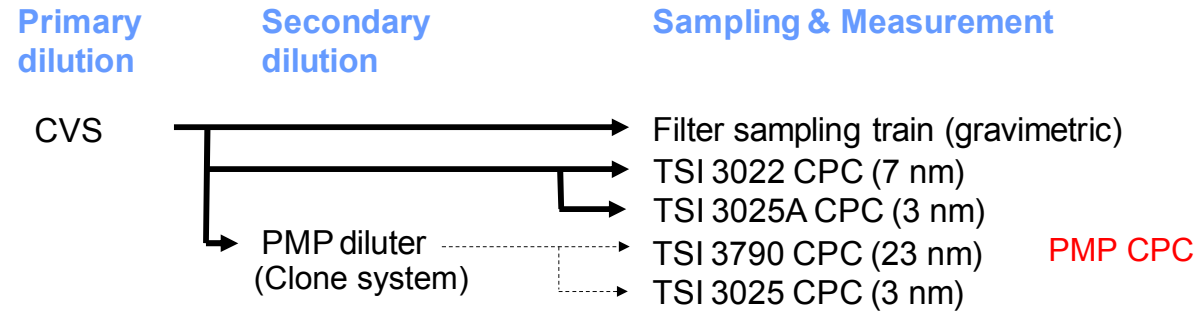
UCR/CE-CERT's Mobile Emission Lab (MEL) for On-Road Testing



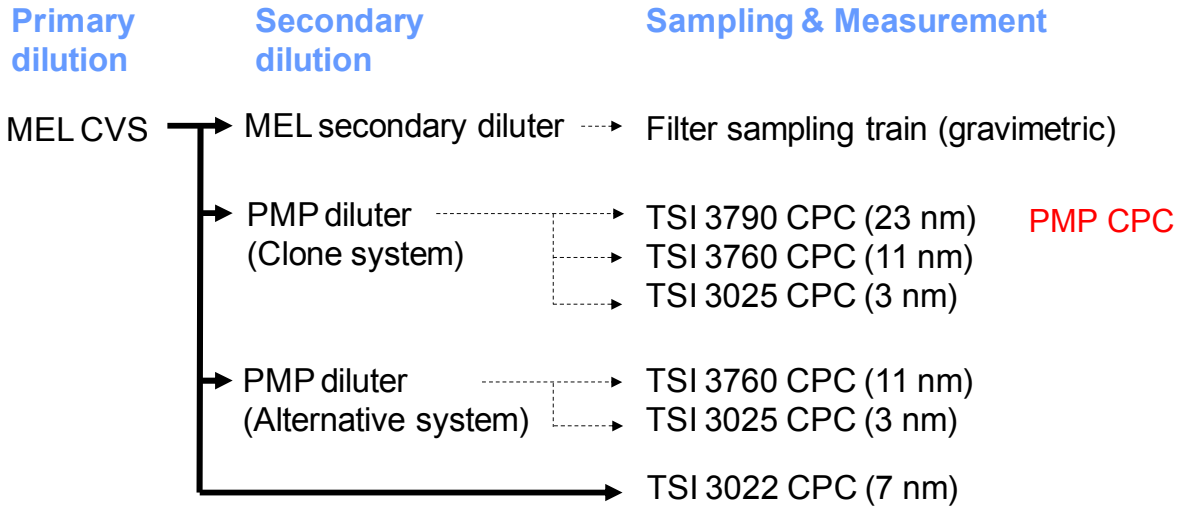
Cocker et al. Environ. Sci. Technol. **2004, 38, 6809-6816**

Flow diagram of PM measurement system

Lab test



On-road test

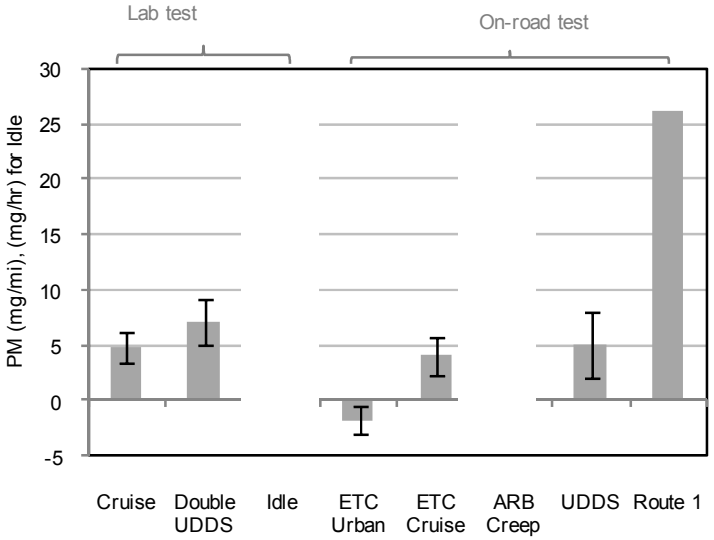


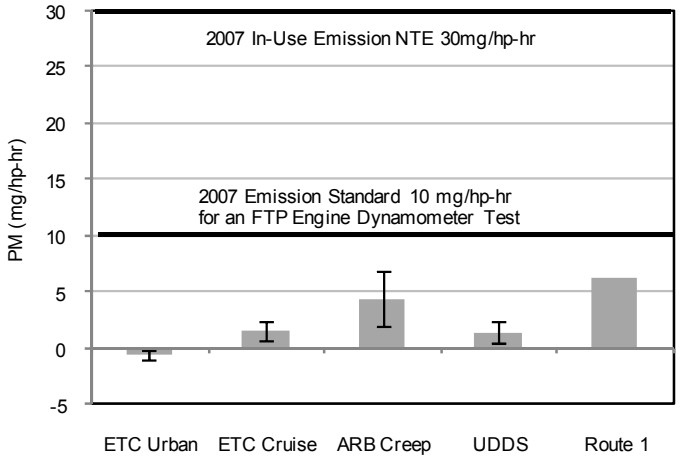
F-SMPS and EEPS at MEL CVS and PMP diluter

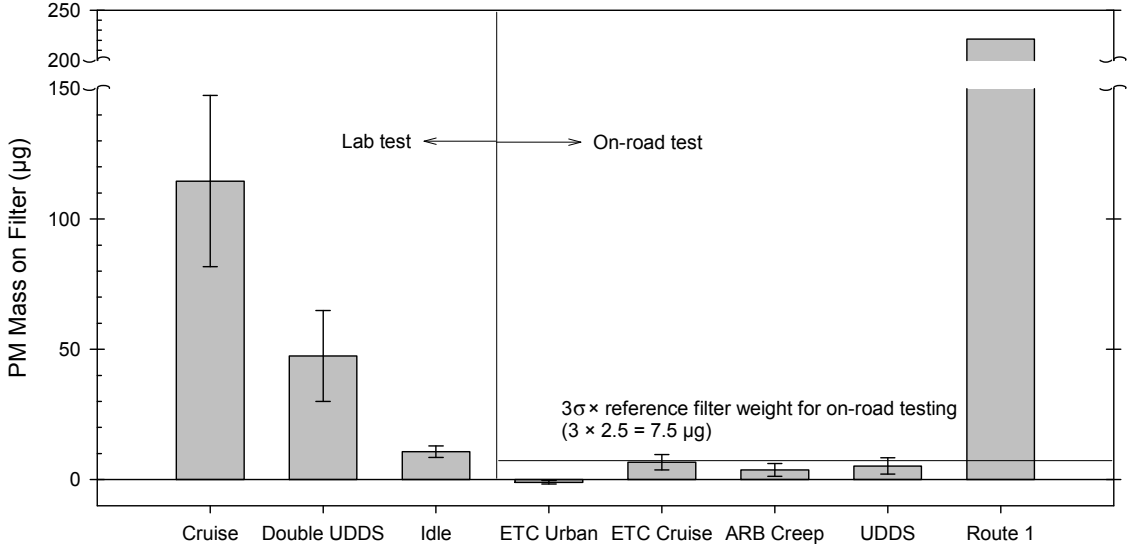
Integrated Results
(using Clone PMP system)

PM mass

(from gravimetric method)







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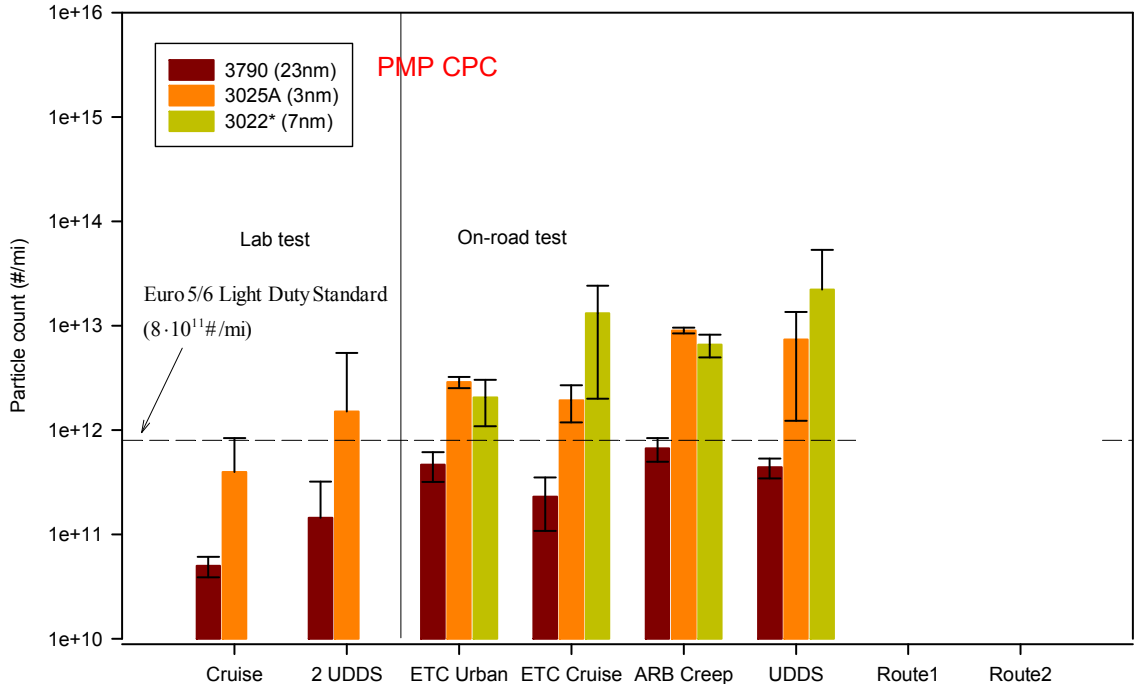
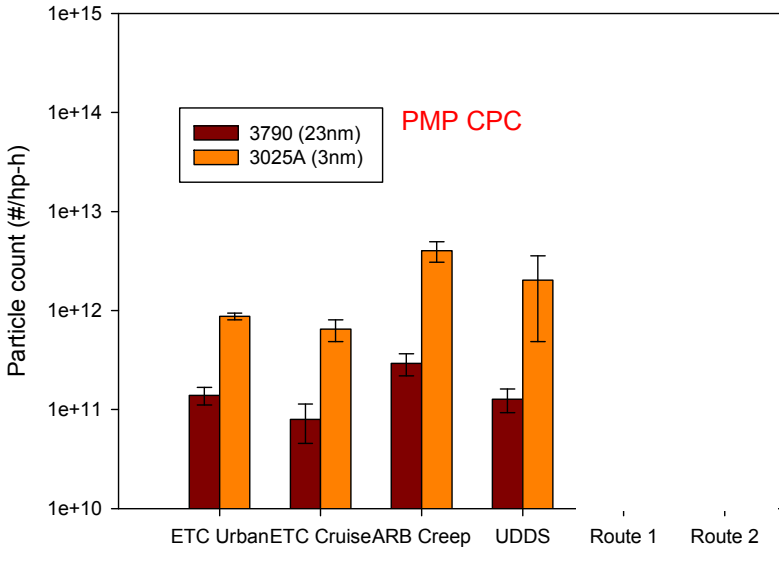
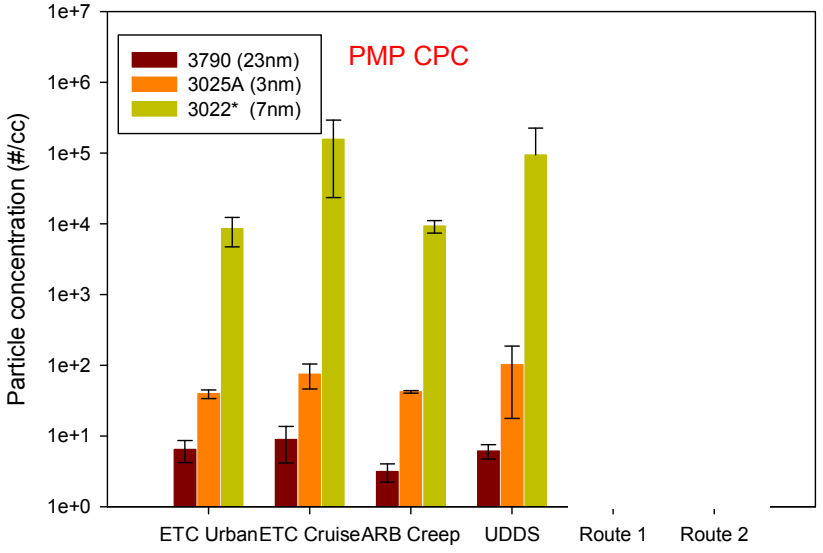
PM number

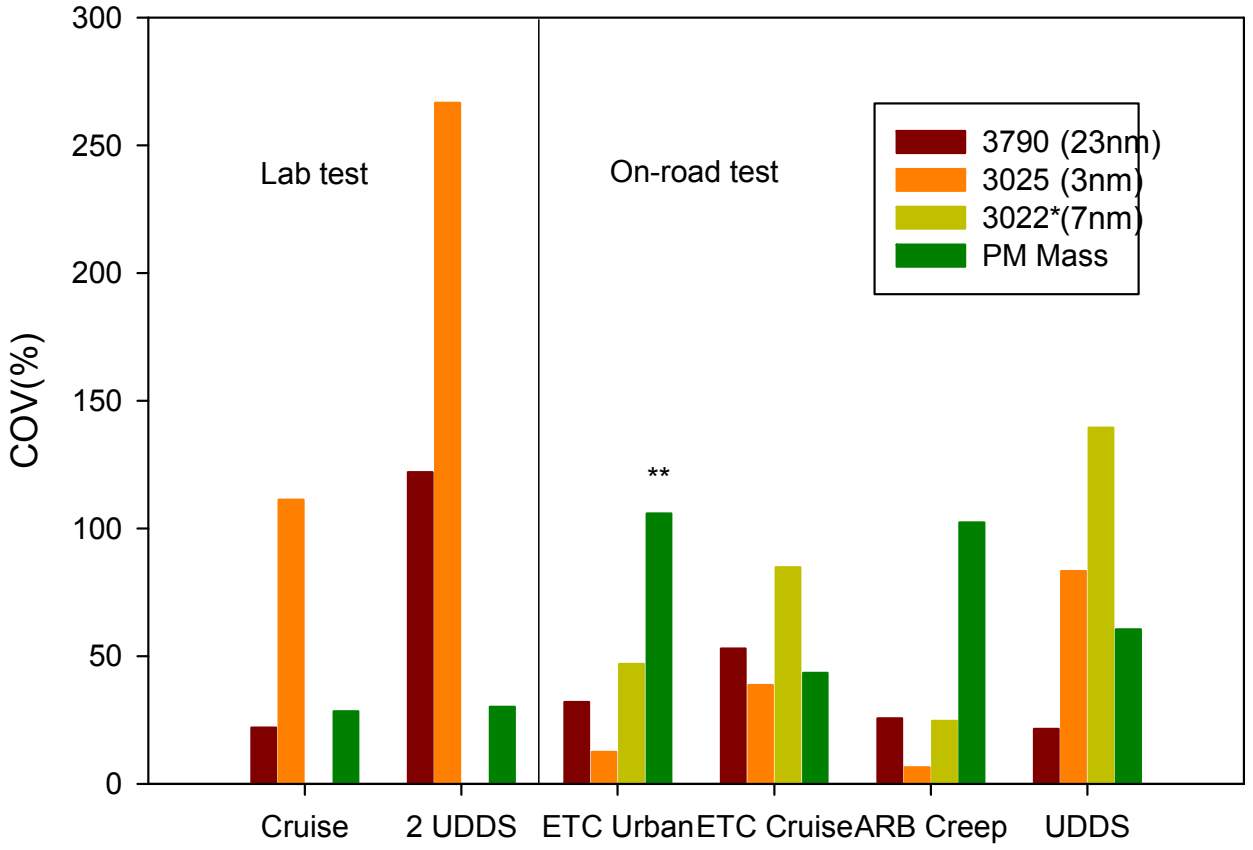






* Means at VS and ** means at MEL PMP system

Coefficient of Variation (COV)

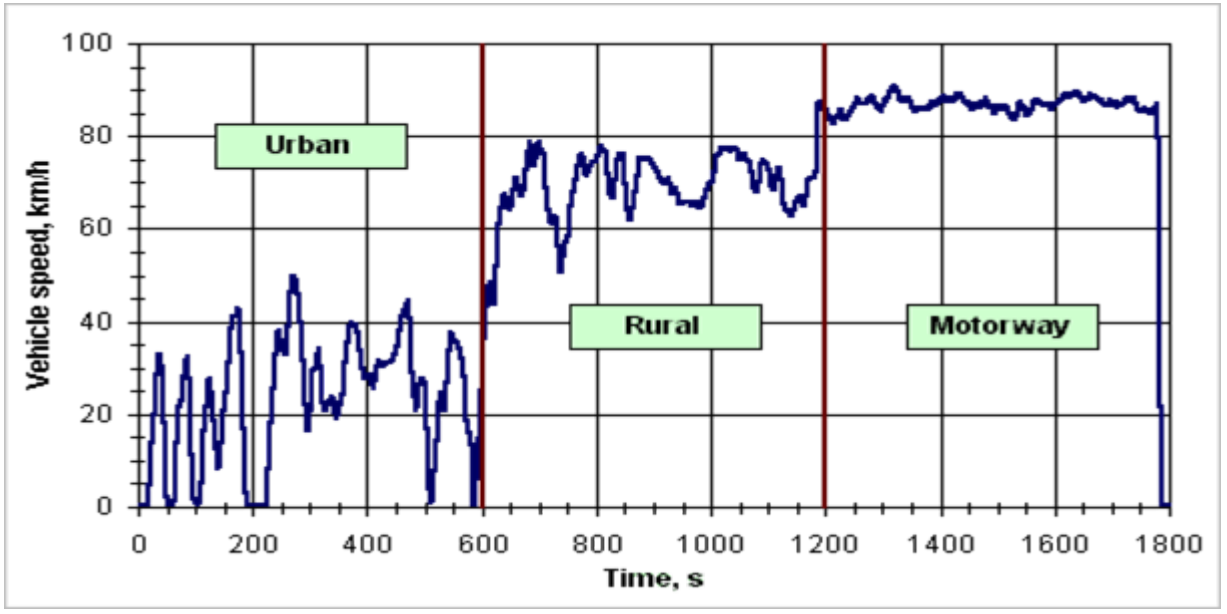


Results

(Real time data)

Concentrations normalized to those at CVS for comparison.

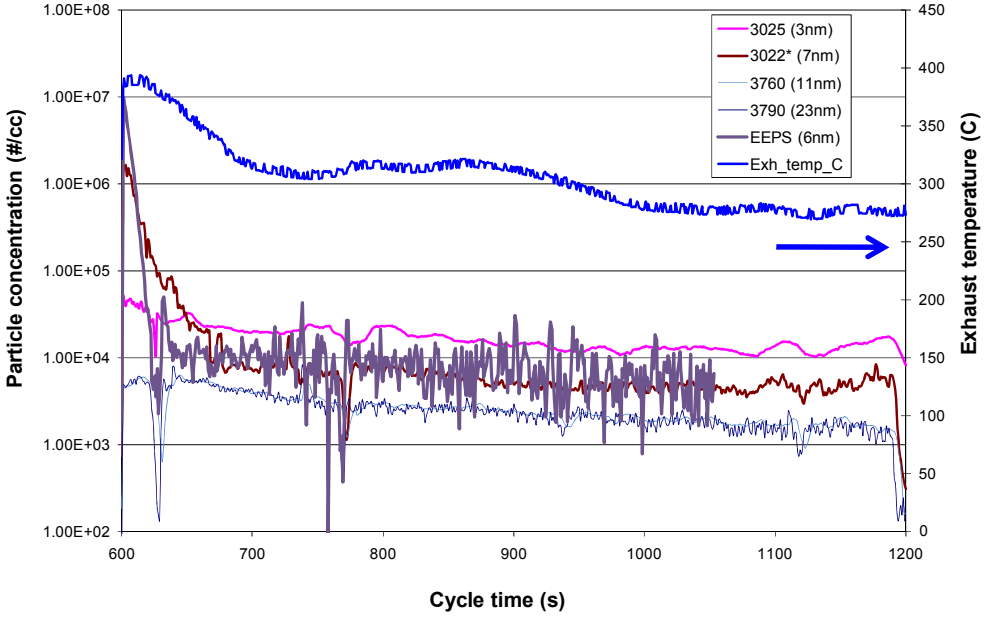
ETC (European Transient Cycle)



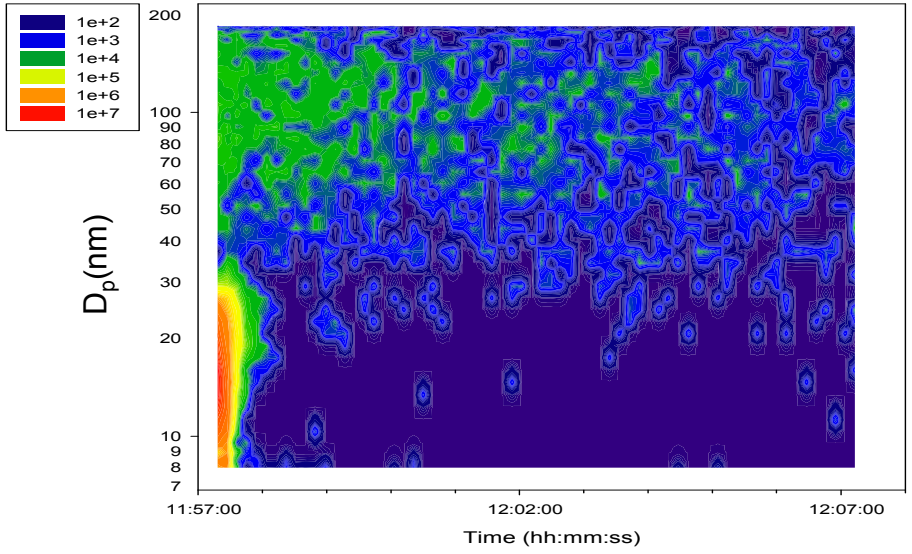
European Transient Cycle (ETC) Cruise

A spike showed up in the beginning of ETC cruise cycles all the time due to gear shift before the cycle.

CPCs Under PMP



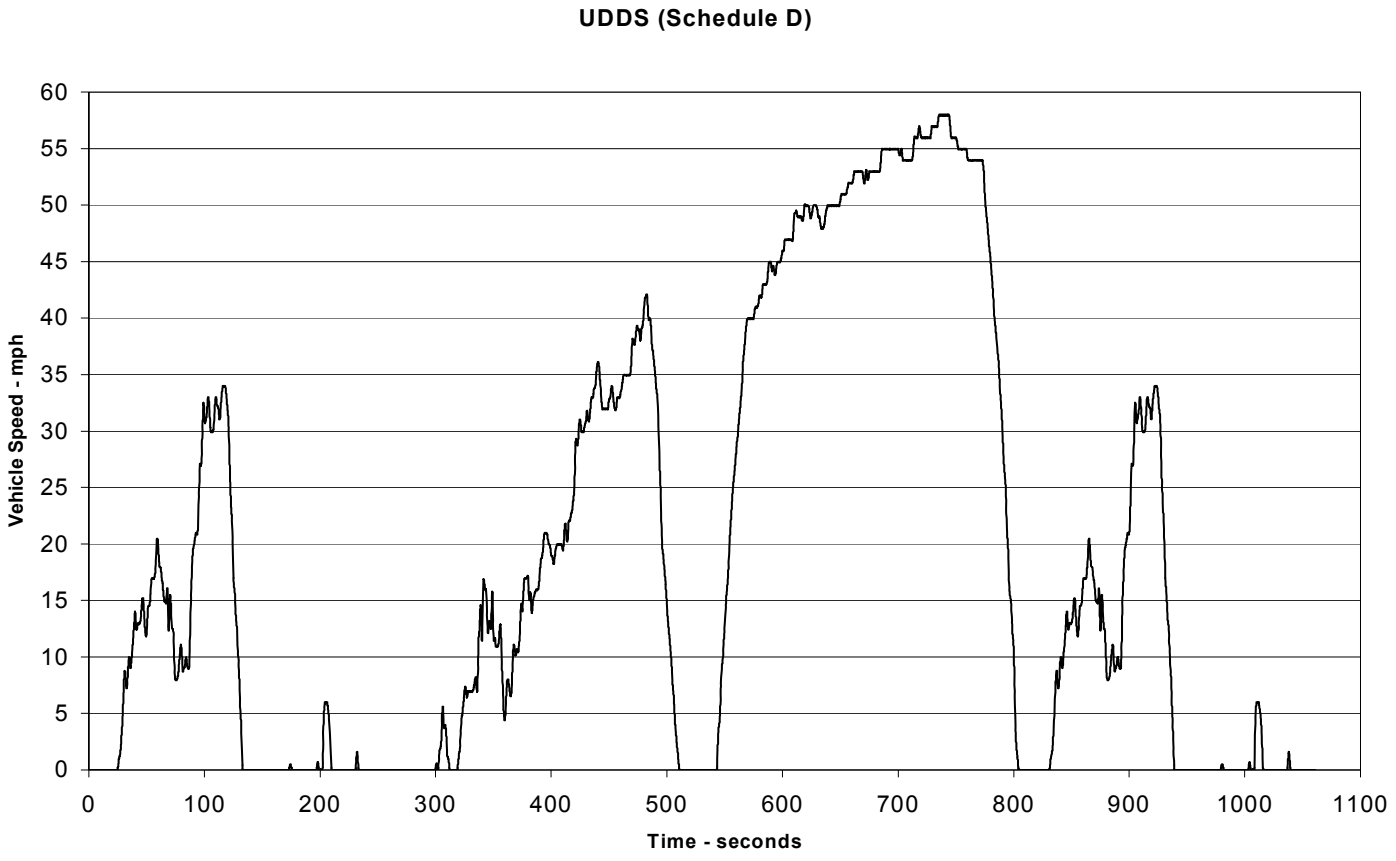
F-SMPS at CVS



3 hypotheses:

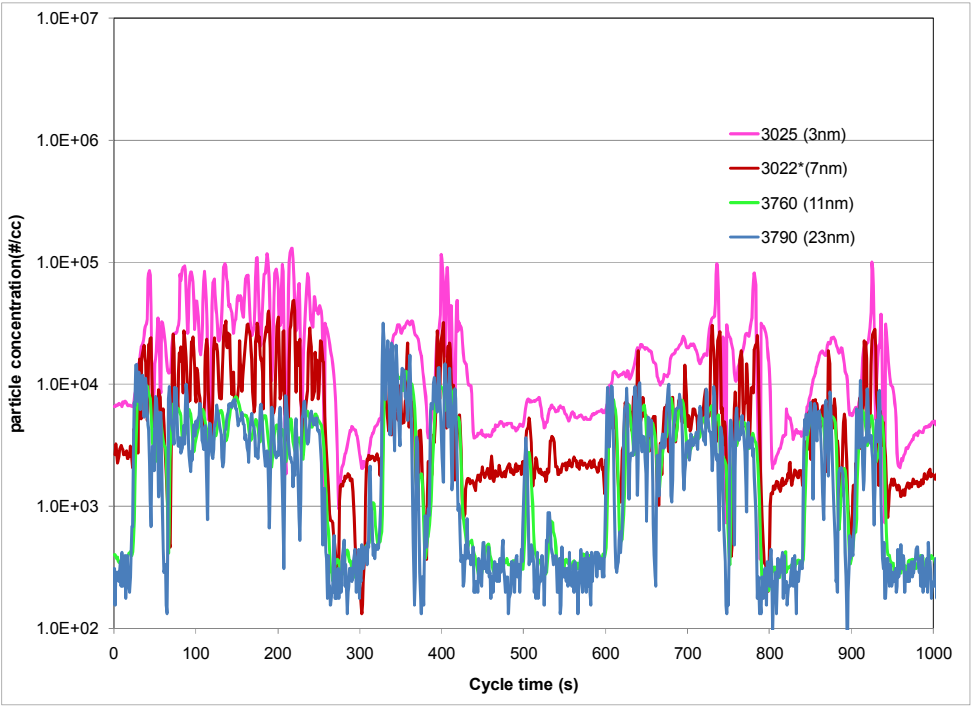
- **Solid particle penetration-**
  - **-> Size distribution from previous studies using EEPS and DMS**
  - **-> Need to confirm with f-SMPS or nano-SMPS**
  - **-> Continuous ash particle emissions at DPF?-> Unlikely**
- **Partial evaporation of large particle**
- **Re-nucleation of sulfate**

Driving cycle (UDDS)

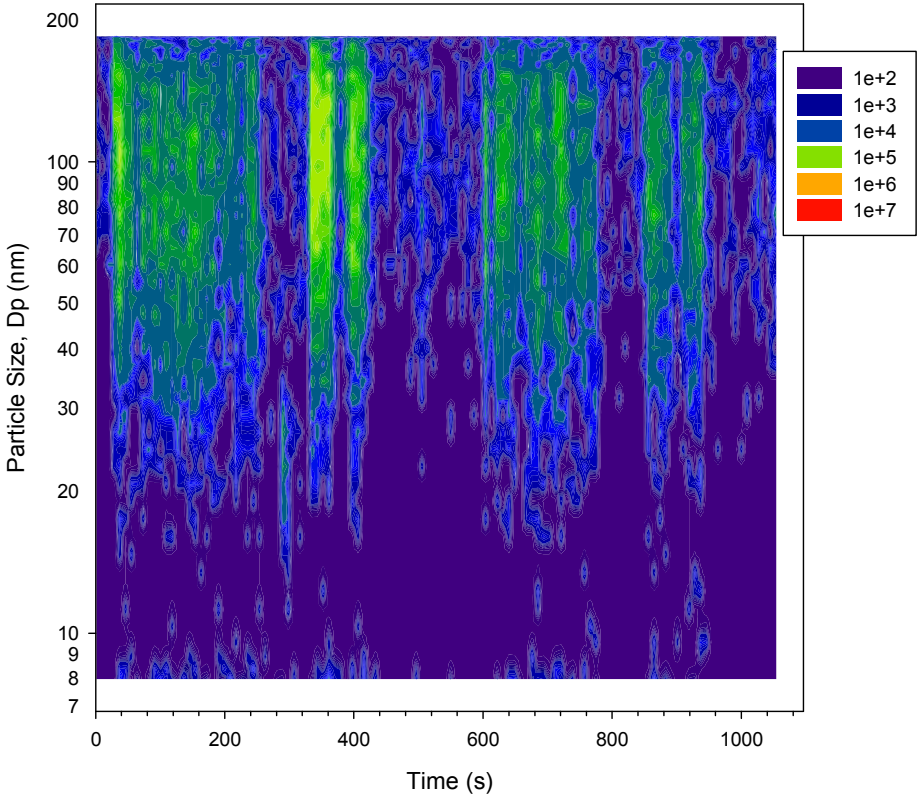


US EPA Urban Dynamometer Driving Schedule (UDDS)

CPCs under PMP



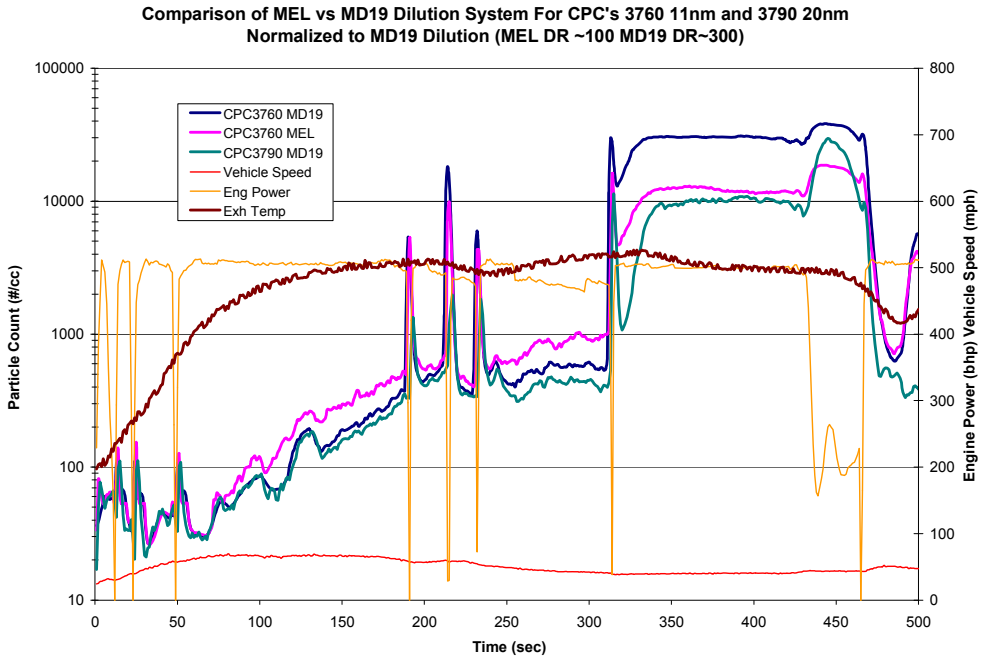
F-SMPS at CVS



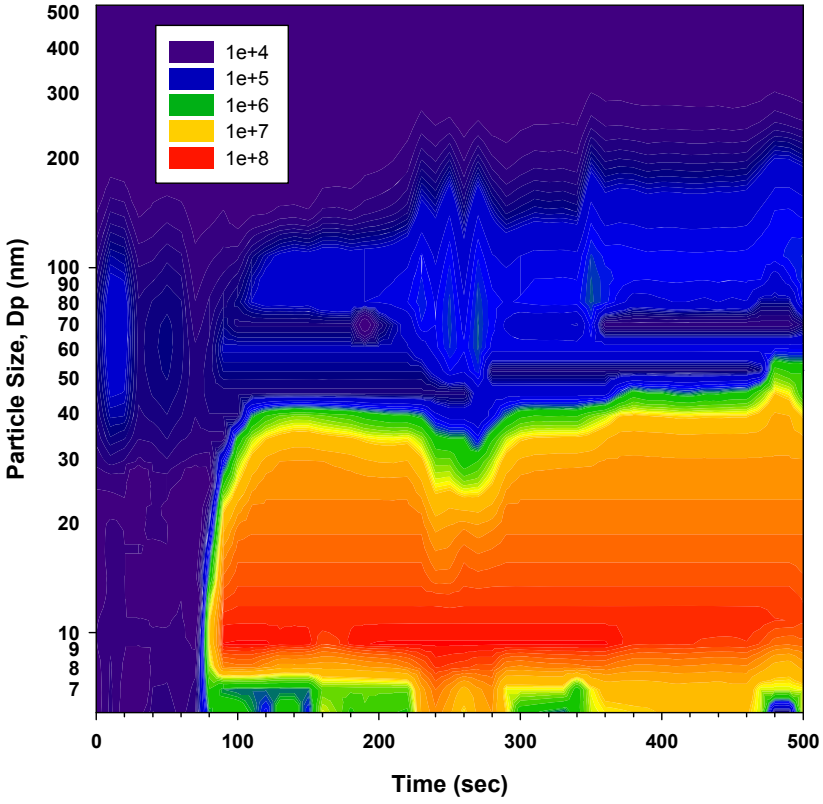
Real time data (flow-of-traffic)

CPCs under PMP

Hydrated sulfate concentration contributes to 45% of mass



EEPS at CVS



Conclusion

- The overall combined laboratory and on-road results indicate that particle number can provide a superior measurement for current wall-flow DPFs with particle emission levels well below the 2007 US PM mass standard, but not necessarily at higher PM levels near the standards.

- The DPF-equipped medium and heavy-heavy-duty-vehicle 3790 PMP number emissions are lower than the European light duty standard of 8.0×10^{11} #/mi. The emissions range from 6.7×10^{11} to 0.5×10^{11} #/mi depending on the cycle, vehicle/technology, and other test conditions used.

- Under more aggressive, on-road driving conditions, significant nucleation was observed, indicated by very high count levels below the PMP system. These particles had a large sulfate contribution indicating that the nucleation mode particles could be due to the conversion of SO_2 to SO_3.

Conclusion

- The particle number measurements for the low cut point CPCs below the PMP system were approximately an order of magnitude higher than those for the PMP-compliant CPC and the other high cut point CPCs below the PMP system. This indicates the presence of a significant fraction of solid sub-23nm particles that are not being counted by the PMP approach.
  - Advantage is nucleation particles that can contribute to variability are removed.
  - Disadvantage removes the ability to characterize very small particles that survive the heating in the VPR.
- For the on-road tests, the coefficients of variation (COVs) for the particle number counts below the PMP were all lower than those for the PM mass measurements for nearly all testing scenarios.
- For the laboratory tests, however, outliers were found on both the 50 mph cruise and the UDDS. The development of statistical techniques for the removal of outlier tests for particle number should be considered. Also, while the PM mass measurements have a lot of scatter at current wall-flow DPF tailpipe levels, the particle number measurements have outliers that can be removed using statistics.

Acknowledgements

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  - Mr. Jon Andersson of Ricardo
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