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# Investigation of the Application of the European PMP Method to Clean Heavy Duty Vehicles

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(JRC)



# Overview

- CARB's Interest in the Particle Measurement Protocol (PMP)
- PMP basic concepts
- Hardware implementation and observations from Heavy Duty vehicle applications of PMP
- Concluding remarks and future work

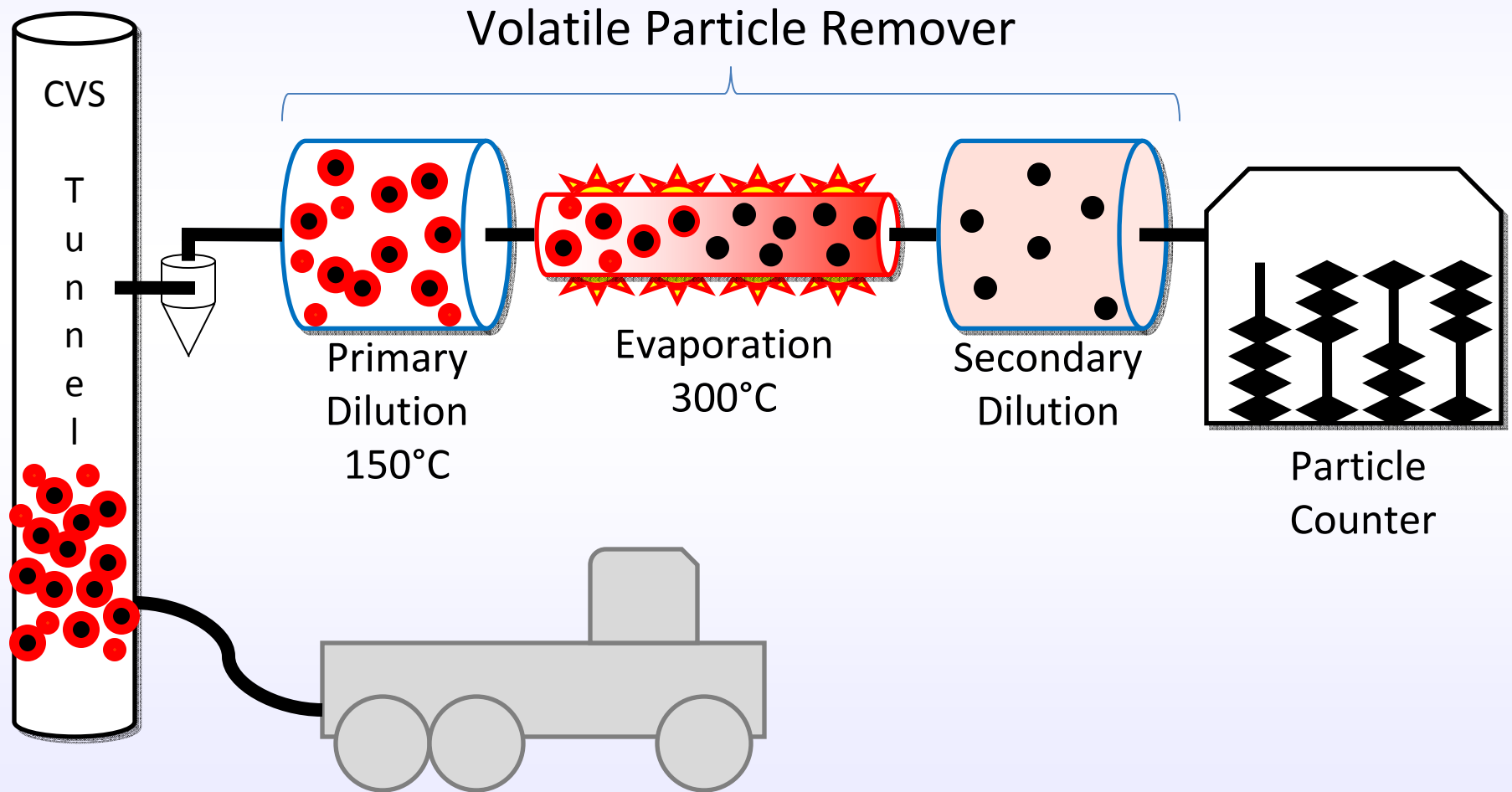
# PMP Interest Drivers

- Agency mission: Protection of Human Health
- Ultrafine PM association with respiratory, cardiovascular diseases and premature death
- Memorandum of Understanding (MOU) for Research between CARB and JRC
  - Informal participant in international LD inter-laboratory exchange study
  - Conducting HD vehicle on-road PMP testing
- PMP entering EURO5/6 standards
- Understand utility of proposed PMP method
- Explore PM material not counted by PMP

# PMP Basic Concepts

- Counting method establishing new operational definition of PM emissions
- Particle requirements:
  - Must exceed 20 nm size threshold
  - Must be “solid” particles
- Emphasizes soot aggregates

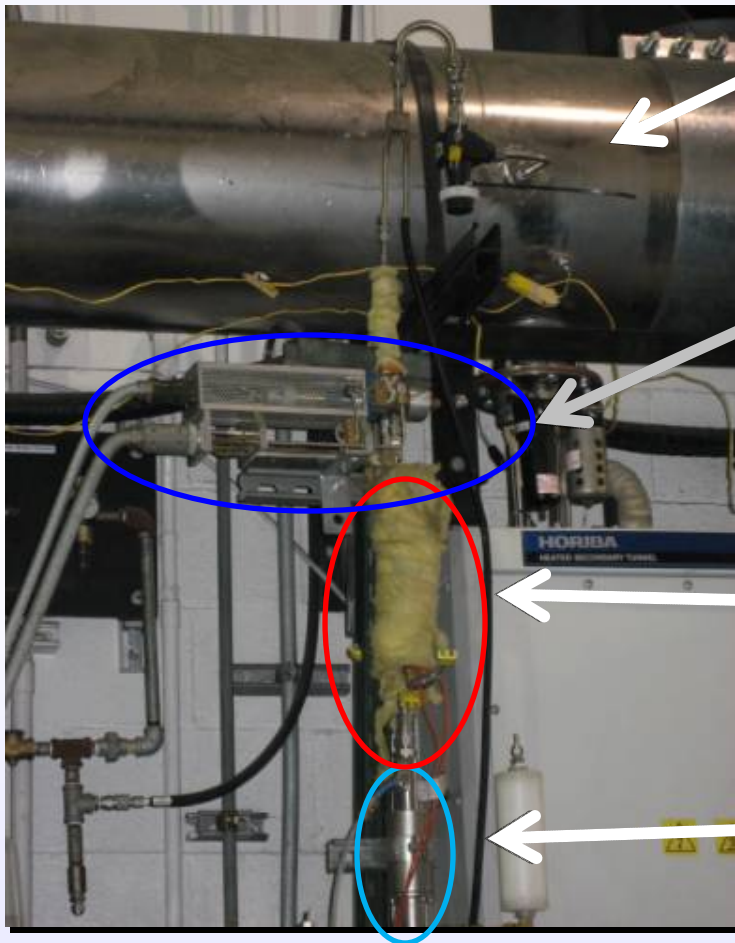
# PMP Schematic



# Experimental Challenges

- Measuring tailpipe concentrations and total emission numbers for clean vehicles
  - Post-DPF solid particle concentrations in CVS can be on order of tunnel background
  - Double dilution of PMP can yield very low count rates
- Determining DPF soot trapping efficiency
  - Engine-out vs. post-DPF particle concentrations exceed dynamic range of particle counters
  - High turn-down of dilution ratio required

# PMP Implementation

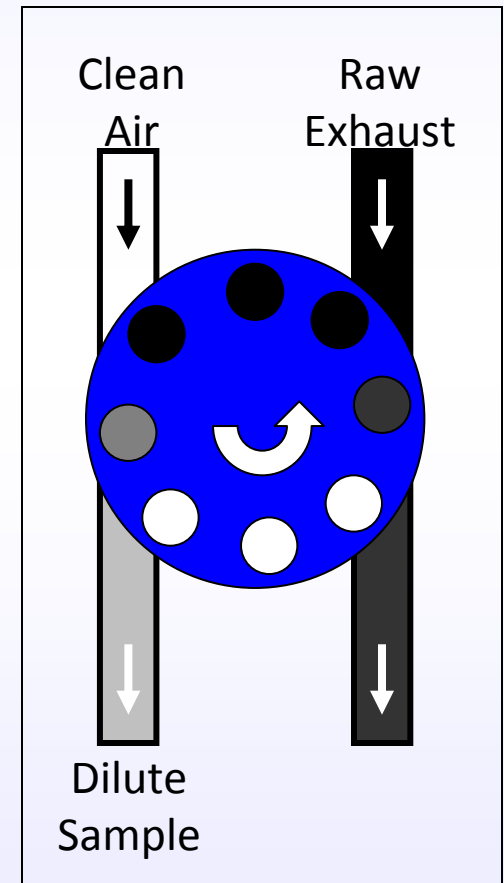


CVS Tunnel

Primary Diluter  
*High Ratio Rotating Disk*

Evaporation Tube

Secondary Diluter  
*9:1 Ejector*



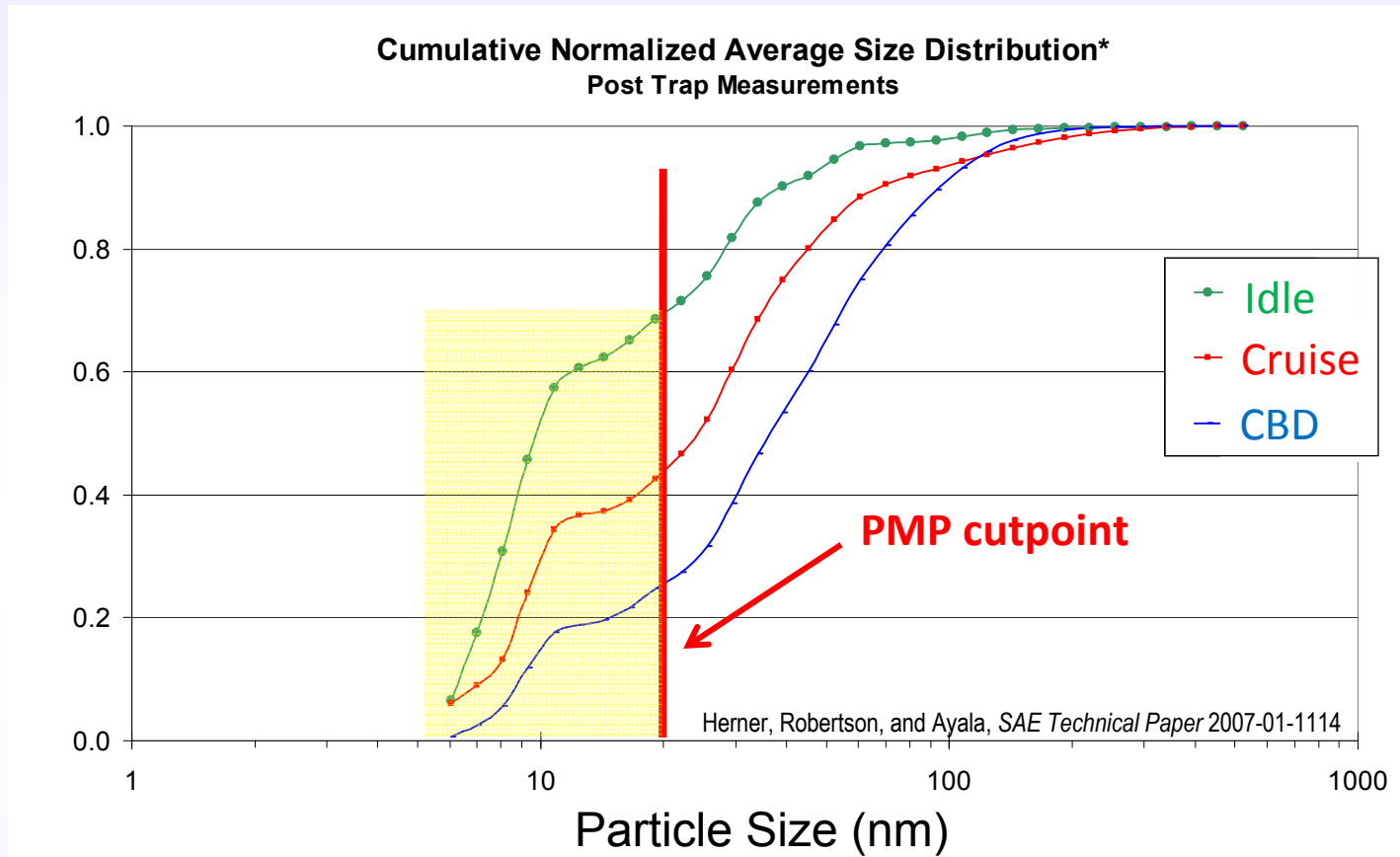


# Traditional Hardware

- First PMP system implemented
  - Rotating disk based primary dilution
  - Used for European PMP protocol development & Light Duty inter-laboratory exchange study
  - Used in this study
- Advantages
  - Easy access to wide range of dilution ratios
  - Dilution ratio passively resistant to sample pressure fluctuations (intrinsic to rotating disk design)
- Challenges
  - PMP required 150°C operation can contribute to rotating disk durability issues (evaluate sampling effects of 80° or 120°C operation?)
  - Some exhaust streams can yield inconveniently low particle count rates even at minimum dilution ratio (perhaps optimize counter for higher count rate per unit concentration?)

# Other Strategies

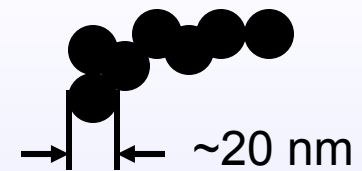
- Mass flow controller based PMP systems appearing
  - More easily access low overall dilution ratios
  - Very high dilution ratios may require care
  - Must actively compensate for sample pressure fluctuations
- Non-PMP solid particle sampling
  - Eliminate semivolatiles with combination of oxidation catalysts and/or vapor trapping of hydrocarbons and sulfur
  - Allows maximization of low particle count rates via operation without dilution if needed



- 25-75% of apparently **solid** particle counts can be below PMP cutpoint
- Possible importance of sub 20nm particles dependent on composition

# PMP Solid Particles Operationally Defined

- PMP parameter magnitude determined by engineering choices embodied in the PMP specified system
  - Volatile Particle Remover: Dilution & Temperatures
  - Particle Counter: Cutpoint
- Solid particles below cut point
  - Countable without lost of precision
  - Likely other than soot: Primary soot particles on the order of 20nm cut point
- Worth counting <20nm on per particle toxicity basis?



# Conclusions

- PMP Protocol well suited for detection of soot aggregate particles in presence of nucleating semivolatiles
- Is adaptable to heavy duty applications
- Instrument refinement continuing
- Room for future work: Is PMP all we need?

# Future Work

- Broader CARB study of HD PMP underway
  - Chassis testing completed
  - On-road testing in analysis phase
- CARB seeking continued involvement in European HD PMP evaluation
- CARB study of HD vehicle PM toxicity underway
  - Multiple analytical methods, aftertreatment technologies
  - Inform policy decisions on volatile vs. solid particles
- Light-duty study of inter-laboratory “Golden Vehicle”
  - Testing completed, Findings being written up