2007 Diesel Particulate Measurement Research (E-66 Project)

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Acknowledgments

- The E-66 Project is Sponsored by:
  - Coordinating Research Council (CRC)
  - Department of Energy/National Renewable Energy Laboratory (DOE/NREL)
  - Environmental Protection Agency (EPA)
  - Engine Manufacturers Association (EMA)
  - California Air Resources Board (CARB)

Background

- Filter Media Problem:
  - SwRI results for EPA demonstrated a filter media influence on PM emissions from a heavy-duty diesel engine with a trap and mostly volatile PM
  - Results by Ford were similar to the above for diesel vehicle PM emission level below 10 mg/mi
  - Internal SwRI data for ULEV gasoline engine also showed a filter media influence on PM emissions
  - Ambient aerosol researchers have recognized the problem of gas phase adsorption (positive artifact) and desorption (negative artifact) from filters, during ambient PM sampling, long time ago.

E-66 Project Objectives

- To develop a reference filter method for PM measurement that accounts for or minimizes positive and negative measurement artifact associated with gas phase adsorption or desorption from a filter media during PM sampling
- To evaluate alternative real time PM sampling methods that correlate well with the newly developed filter method
- To correlate PM measured using CVS with PM measured using a partial flow sampling system

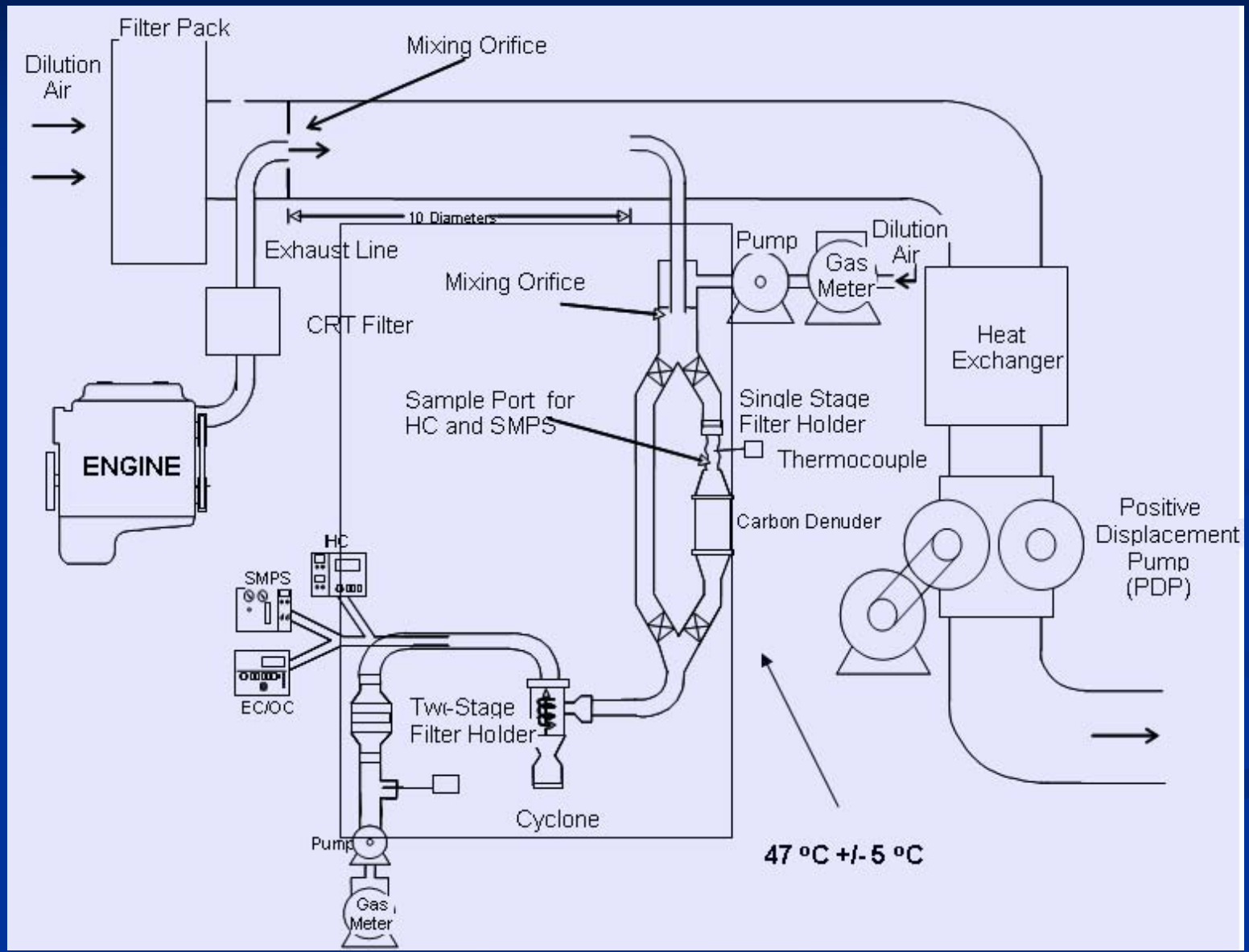
Diesel Engine, Trap, Oil, and Fuel for E-66

- Engine:
  - 1998 DDC Series 60, 12.7 liter, heavy-duty on-highway diesel engine
- Diesel PM Filter
  - Johnson Matthey CRT
- Oil
  - Experimental oil (supplied by Lubrizol)- current guess at the 2007 lubricant chemical limits
- Fuel
  - Ultra low sulfur diesel (ULSD) fuel by Sinclair- current guess at the 2007 ULSD fuel

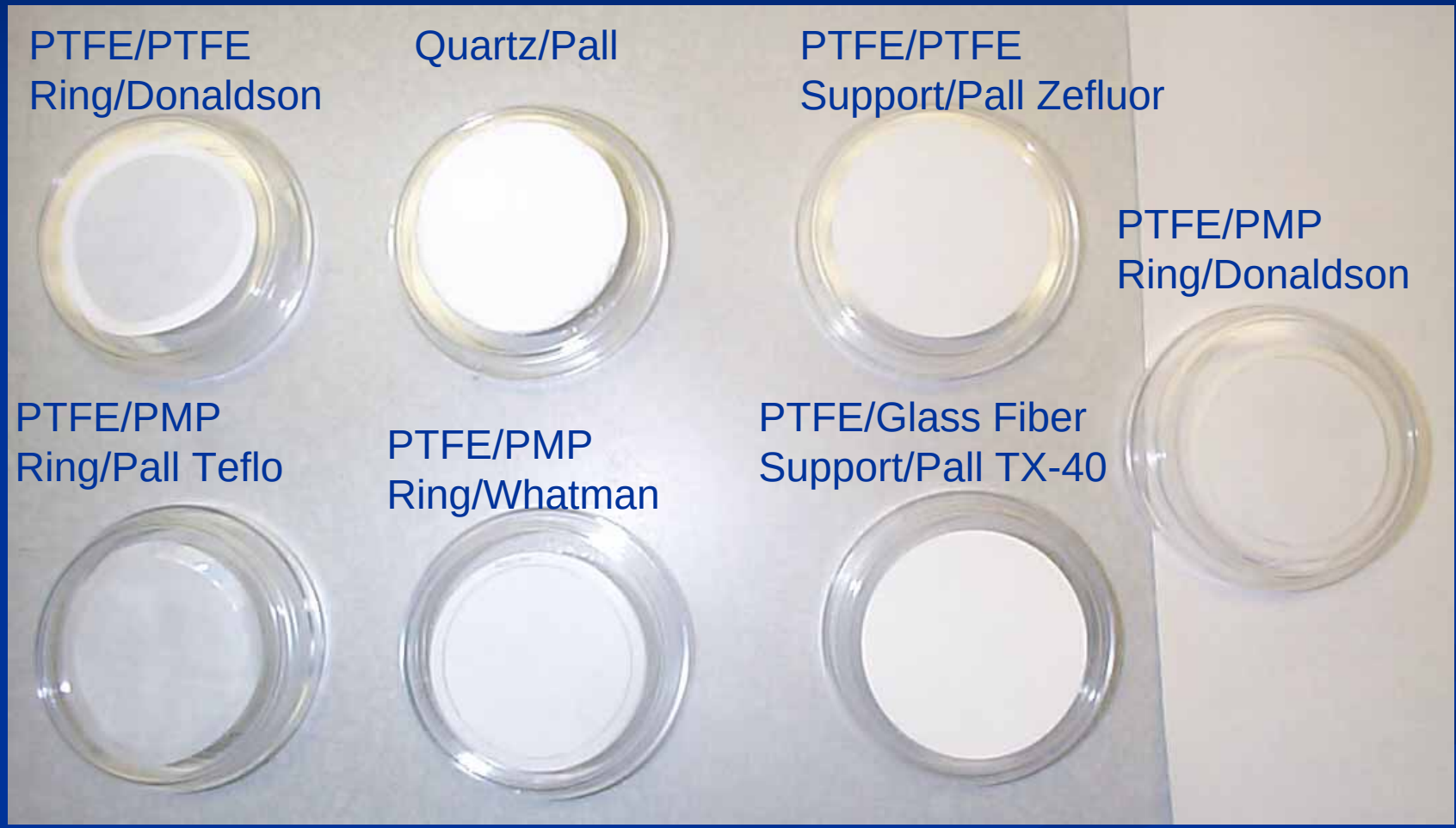
Work Underway at SwRI

- For Phase I of E-66, four tasks are to be completed :
  - Task 1-(Completed) Develop and characterize a honeycomb ceramic substrate denuder for the removal of organic carbon and THC at 25 °C and 47 °C.
  - Task 2-(Completed) Set up a 2007 measurement system that includes the denuder in the sampling train and study the effect of filter media
  - Task X-(Completed) Collect samples for nitro-PAH chemical analyses (This task is funded by DOE/NREL and approved by E-66 Panel Committee)
  - Task 3-(Underway) Determine the effect of filter face velocity on PM measurement
  - Task 4-(Underway) Investigate the performance of several real time PM sampling methods in parallel to the filter method

Experimental Setup (2007 PM Sampling System With and Without Carbon Denuder)



Filter Media Used

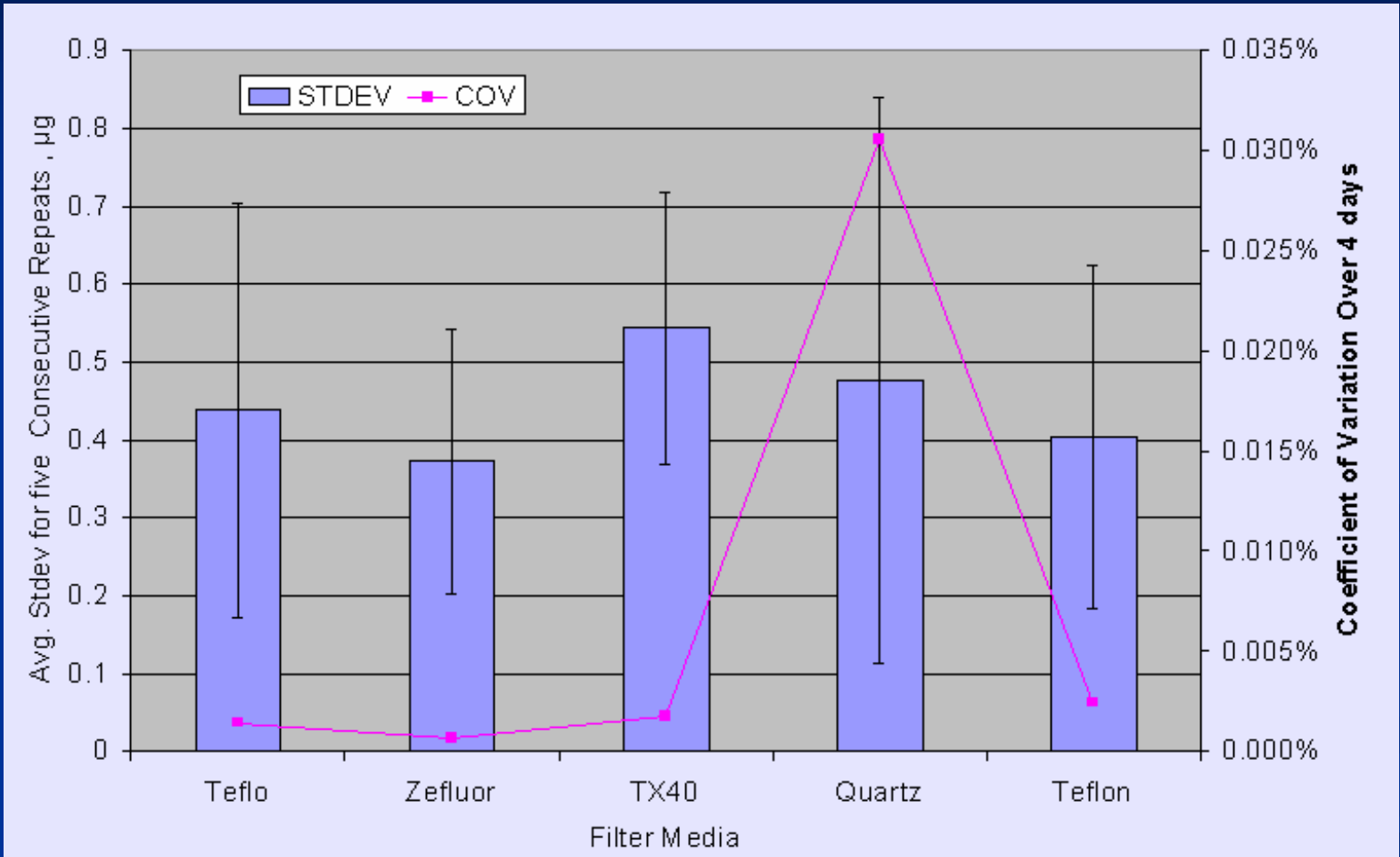


Highlights of E-66 Phase I Findings

Task 1-Carbon Denuder Development and Characterization

- Ideal denuder performance characteristics in sampling train upstream of filter for PM collection
  - 100 percent removal of organic carbon
  - 100 percent penetration of particles and droplets
  - No organic carbon vapor release during sampling
  - Consistent regeneration and removal efficiency
- Ideal denuder performance will result in:
  - The removal of gas phase organic carbon-Potential Positive Artifact
  - The ability to characterize losses from filter during sampling by placing a back-up carbon filter-Measuring Negative Artifact
- Carbon denuder design failed to provide the following:
  - High organic carbon removal (>90 %), thus eliminating the possibility of studying negative artifact during sampling
  - Consistent regeneration and removal efficiency, thus complicating the issue of eliminating positive artifact
- Action Item:
  - Study the potential of developing a denuder with consistent removal efficiency and regeneration scheme

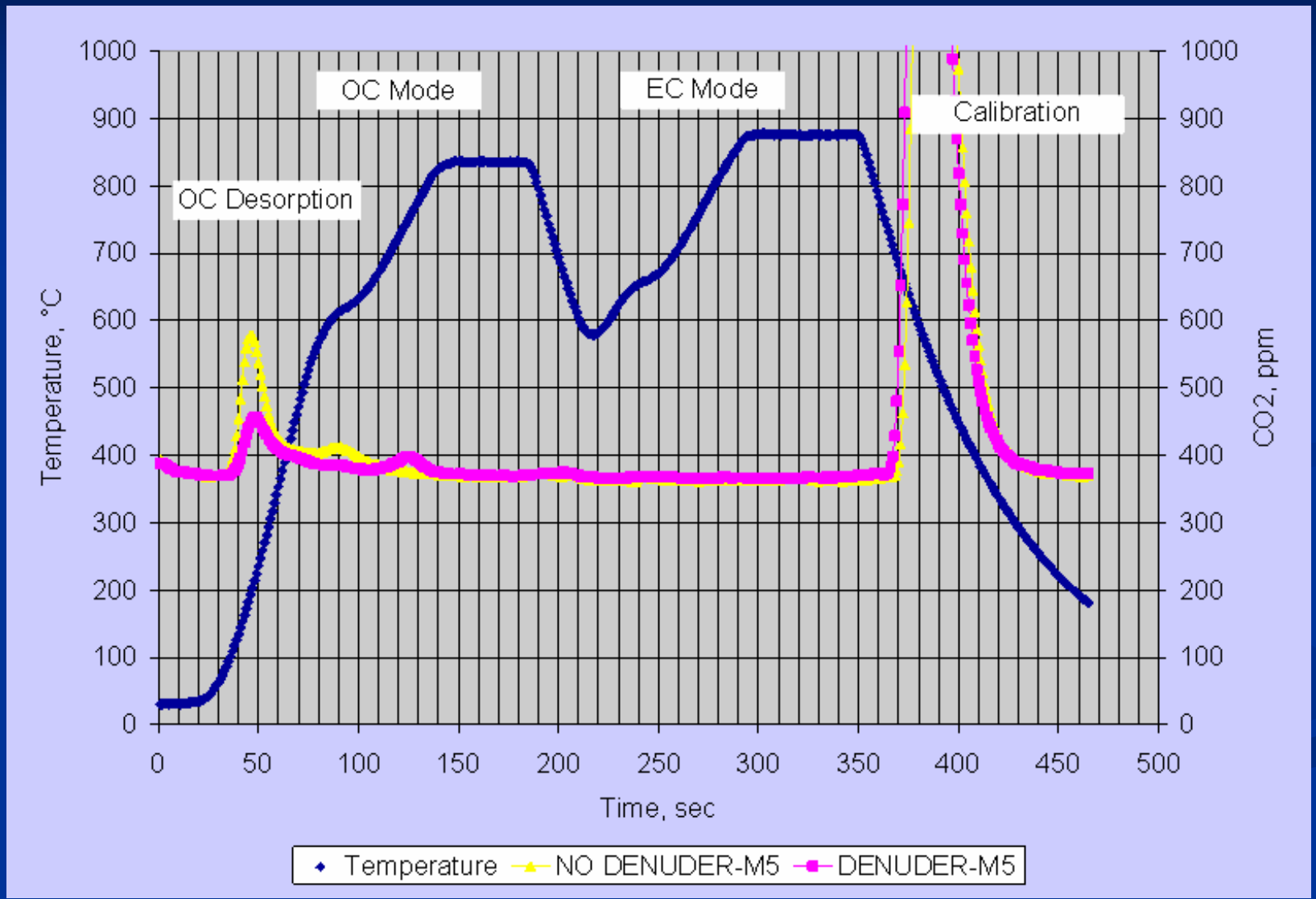
Excellent Repeatability and Very Low Variability in Weighing Clean Filter Media



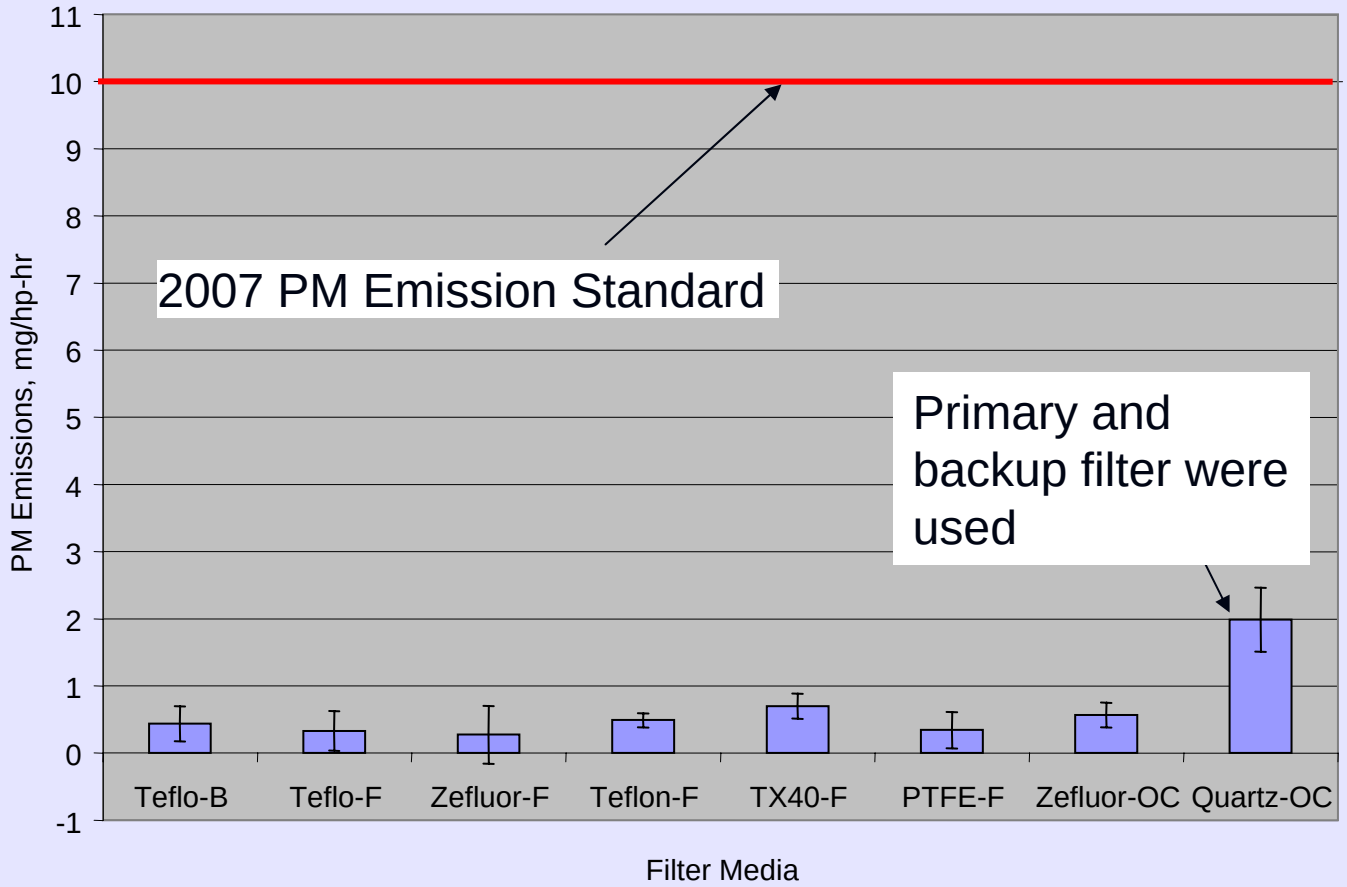
Repeatability: +/- 0.5 µg, Variability: +/- 2.5 µg

Initial Filter Weight: 90,000 µg to 240,000 µg

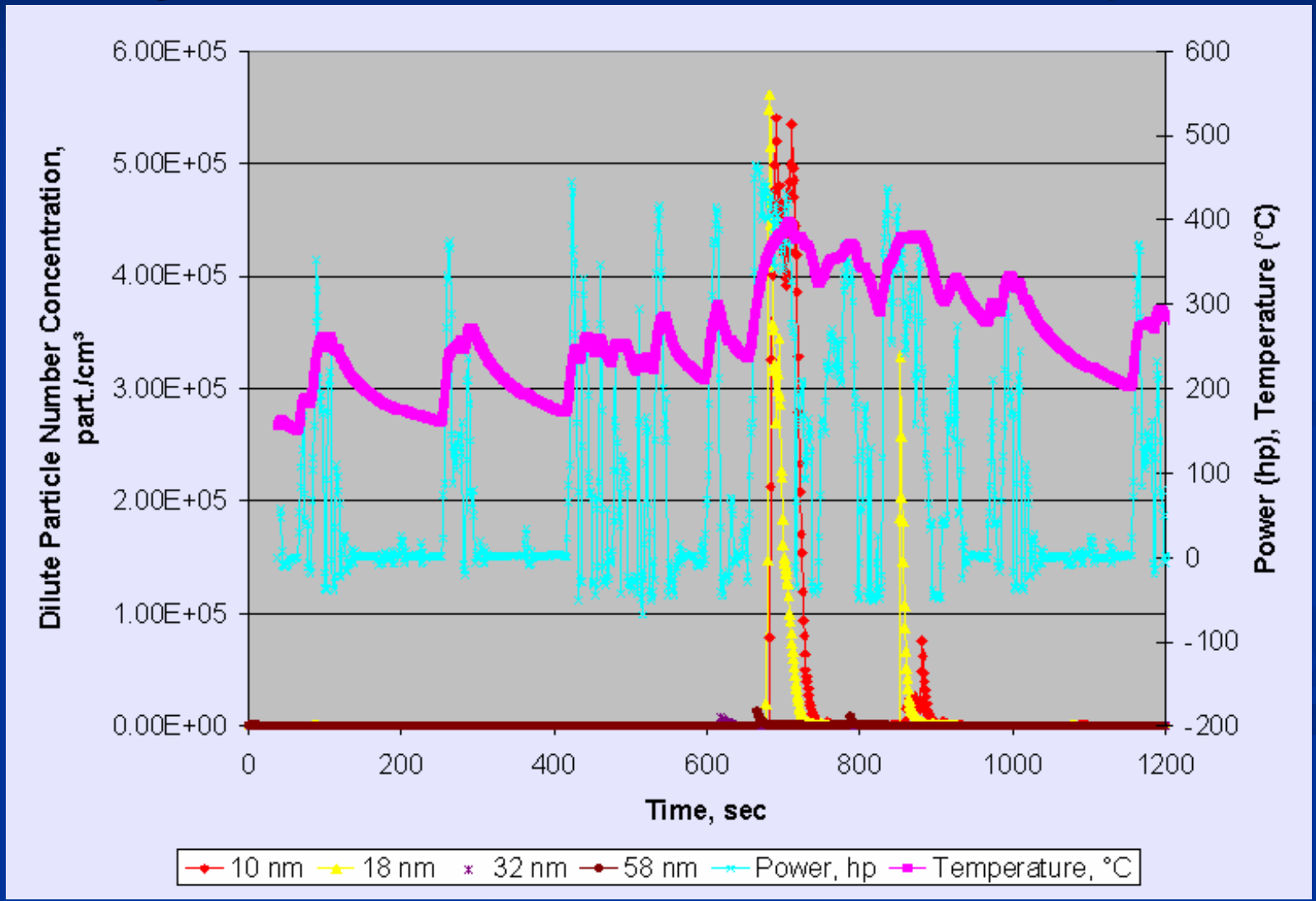
Mainly Organic Carbon PM Downstream of CRT Trap



Wall-Flow Trap with Proper PM Sampling Led to Emission Levels at 10 % of 2007 PM Standard or Lower



Nanoparticles Continue to Form Under High Engine Load and Exhaust Temperature, Even Though the Mass Emissions Extremely Small



Task 2- Summary

- The use of gravimetric technique for PM measurement at 5 percent of 2007 PM emission standard is not practical. It produces variability that may exceed 50 percent with very little PM mass (< 5 µg) to deposit on a filter during a 20-minute FTP transient Cycle.
- A decision was made to add a bypass around the trap in the exhaust to increase the emission level to 70 percent of 2007 PM emission level.
- Comparing the performance of different filter media with the new configuration is near completion.

Task X-Nitro-PAH Artifact Formation

- Catalyzed traps like the CRT are known to convert NO to NO_2. NO_2 present in dilute exhaust during PM collection may react with PAH on the filter and promote the formation of nitro-PAH. This phenomenon is currently under investigation.

Remainder of Phase I Activities

- The filter face velocity experiments will be completed by mid October
- The comparison of different real time PM instruments with the filter method will be completed by mid November. The instruments to be used are:
  - Engine Exhaust Particle Sizer (EEPS)-TSI
  - Quartz Crystal Microbalance (QCM)-Sensors
  - Dekati Mass Monitor (DMM 30)-Dekati
  - Scanning Mobility Particle Sizer (SMPS, Steady-State Only)-TSI

Overall Project Schedule