COORDINATING RESEARCH COUNCIL

CRC Emissions Committee Projects

Dr. Mani Natarajan
Marathon Ashland Petroleum LLC
Coordinating Research Council, Inc. U.S.A.

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Presentation Overview

- CRC Introduction
- Emissions Committee Overview
- I will highlight Three Emissions Committee projects of interest today:

  - E-66 Diesel Particulate Measurement Research

  - ACES Project

  - AVFL-10b Standard Diesel Exhaust for Catalyst Evaluation
- Summary

CRC Introduction

- Coordinating Research Council, Inc. organized 63 years ago
- Mechanism for auto and petroleum industries to work with government
- Research on Fuels and Emissions issues
- Operated through Committee action
- Website address: www.crcao.com

Emissions Committee Introduction

- Committee Chairmen – Michael Ingham, ChevronTexaco and Gary Herwick, GM
- 12 auto/oil committee members
- 15 industry/gov't working group members
- 10 Active Projects in 2005
- AVFL is a sister Committee which addresses advanced vehicles, fuels and lubricants

CRC Emissions Committee Projects

- E-65-3 Fuel Permeation from automotive fuel systems
- E-67 Vehicle Exhaust Emissions from Ethanol fuel blends
- E-74 CO/RVP Effects
- E-23 Remote Sensing
- E-55/59 HD Chassis Emissions

CRC Emissions Committee Projects (cont.)

- E-66 Diesel Particulate Research
- E-69 Kansas City Light Duty PM
- E-72 MIL Survey
- E-75 Diesel Speciation Data
- ACES Project

E-66 Diesel Particulate Measurement Research

- 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)
- Particle instruments were provided in kind by Dekati, TSI, Horiba, and Sensors.

Project E-66 Objectives

- To develop a reference filter method for PM measurement that <u>accounts for</u> or <u>minimizes</u> 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

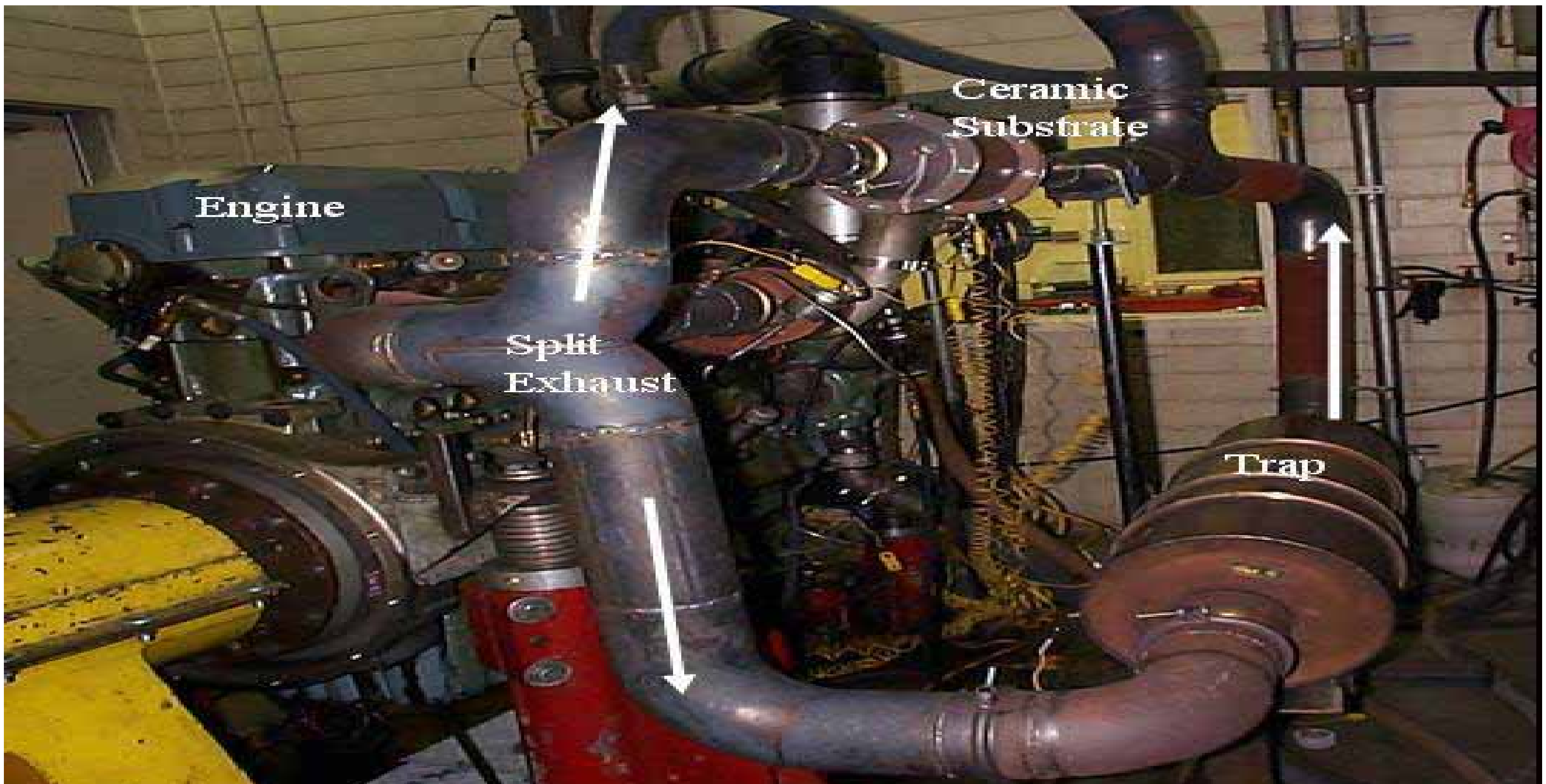
- To correlate PM measured using CVS with PM measured using a partial flow sampling system

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)- best estimate for 2007 lubricant chemical limits
- Fuel
  - Ultra low sulfur diesel (ULSD) fuel by Sinclair- best estimate for 2007 ULSD fuel

Engine Specifications and Exhaust Configuration

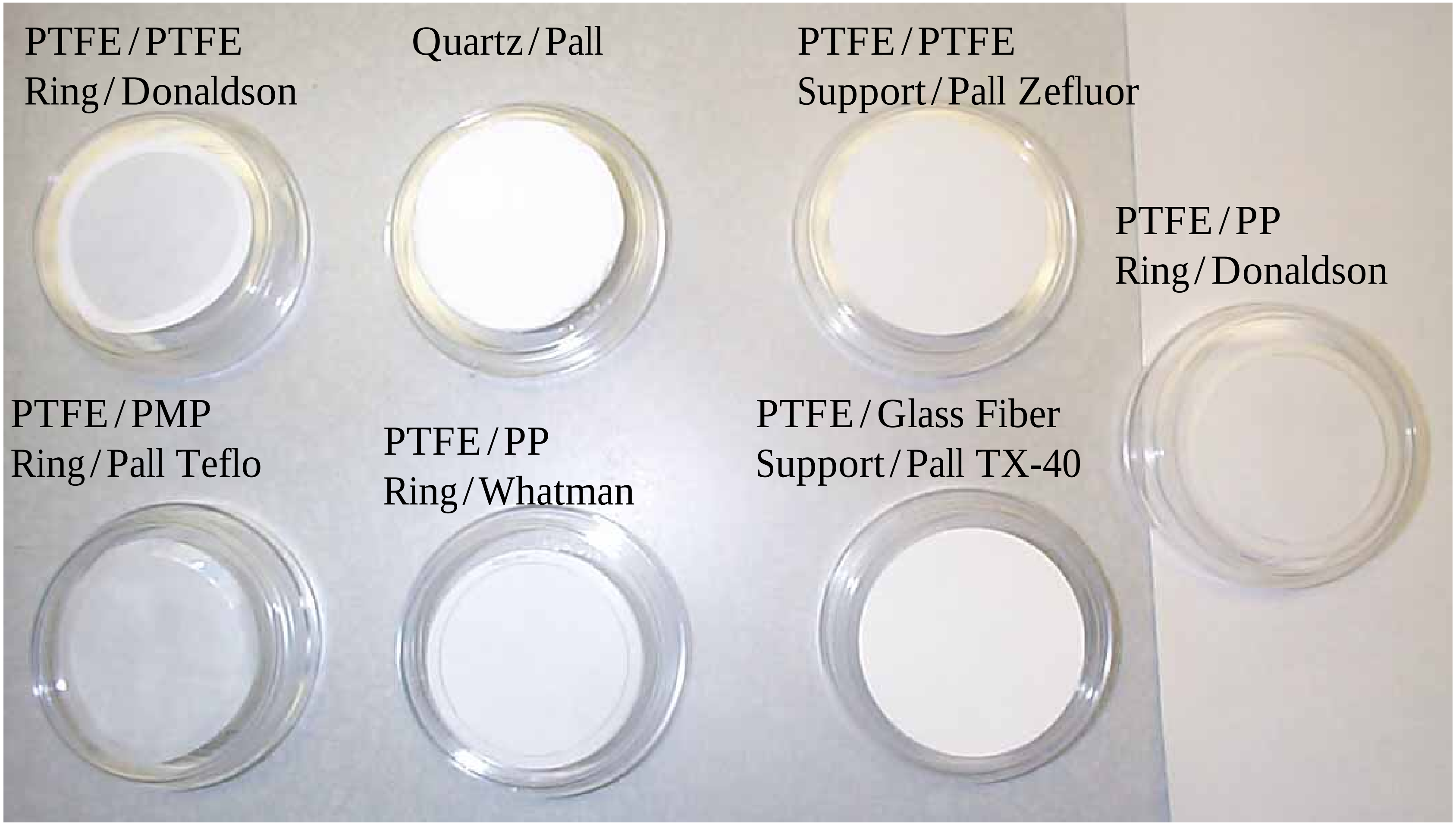
1998 DDC Series 60



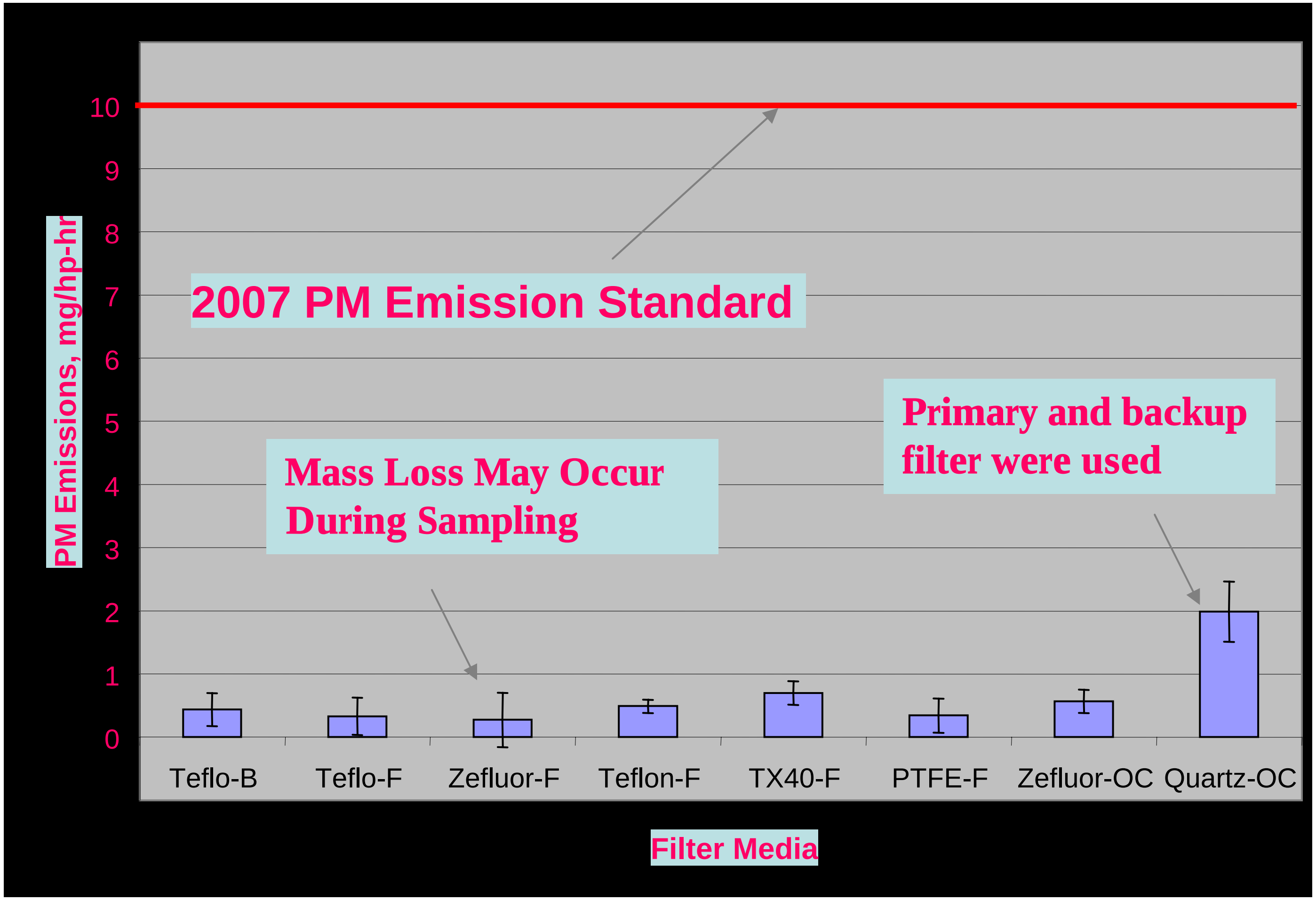
Particle Instruments Used

- Scanning Mobility Particle Sizer (SMPS, TSI)
- Engine Exhaust Particle Sizer (EEPS, TSI)
- Quartz Crystal Micro Balance (QCM, Sensors)
- Dekati Mass Monitor (DMM-230, Dekati)
- Semi-Continuous OC/EC (Sunset Laboratories, Limited Use)
- MEXA-1370 PM (Horiba, Very Limited Use)

Filter Media Used

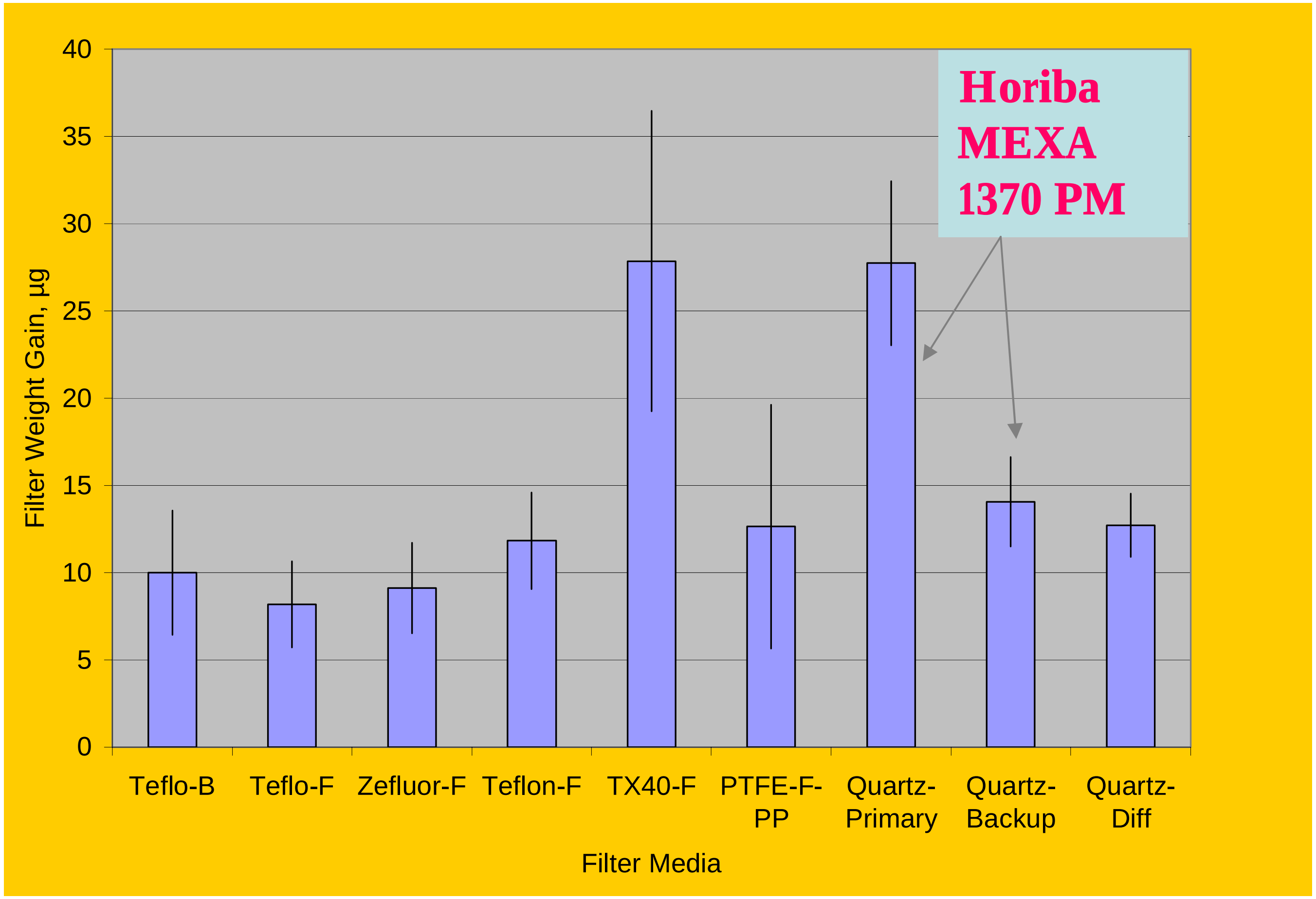


Wall-Flow Trap with Proper PM Sampling Led to Emission Levels at 10 % of 2007 PM Standard or Lower



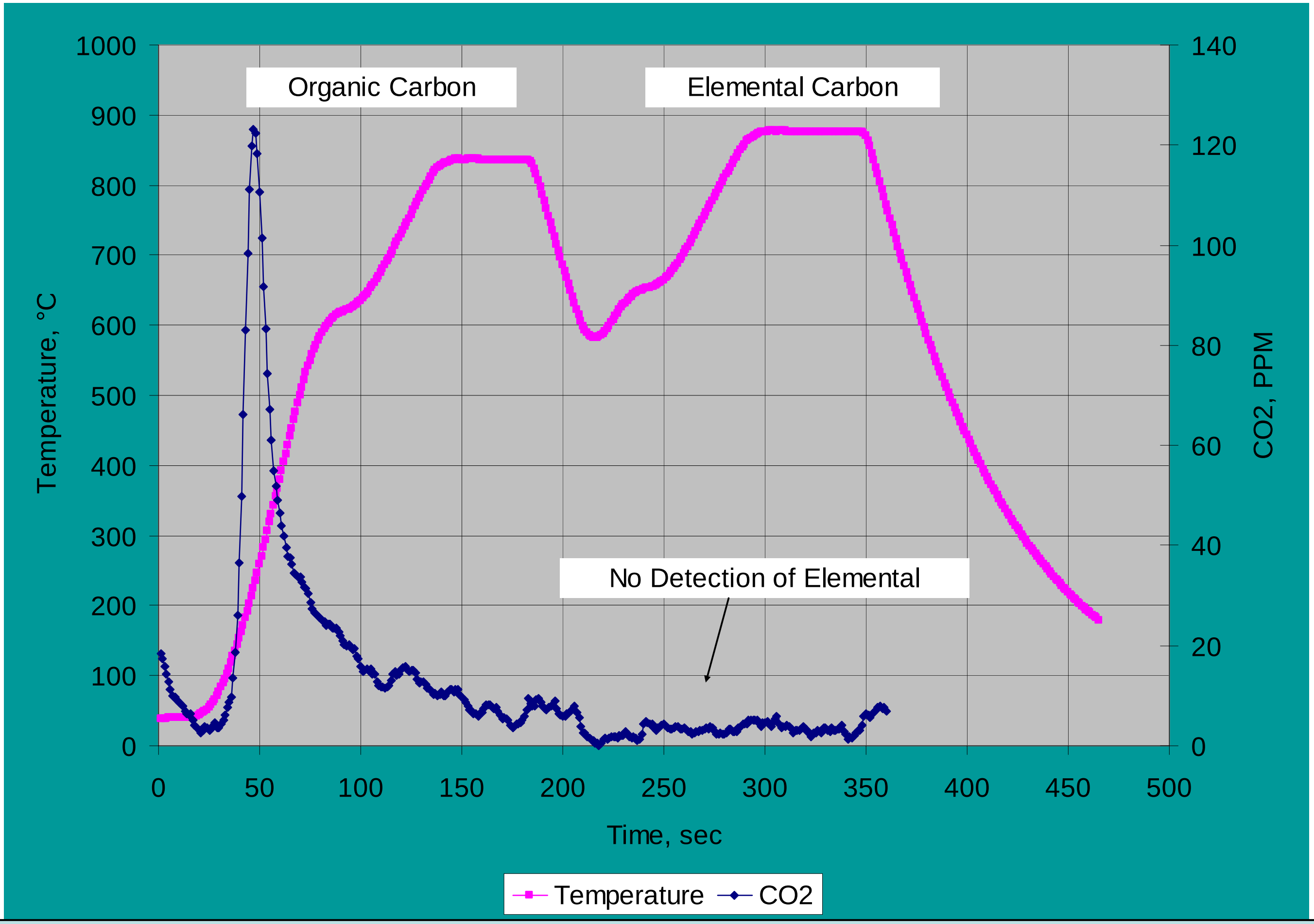
Filter Weight gain for the Teflo filter media during an FTP transient cycle was very low on the order of 5 µg, with a coefficient of variation of more than 50 percent.

Performance of Different Filter Media at Engine Rated Power
(CRT-DPF without Bypass)



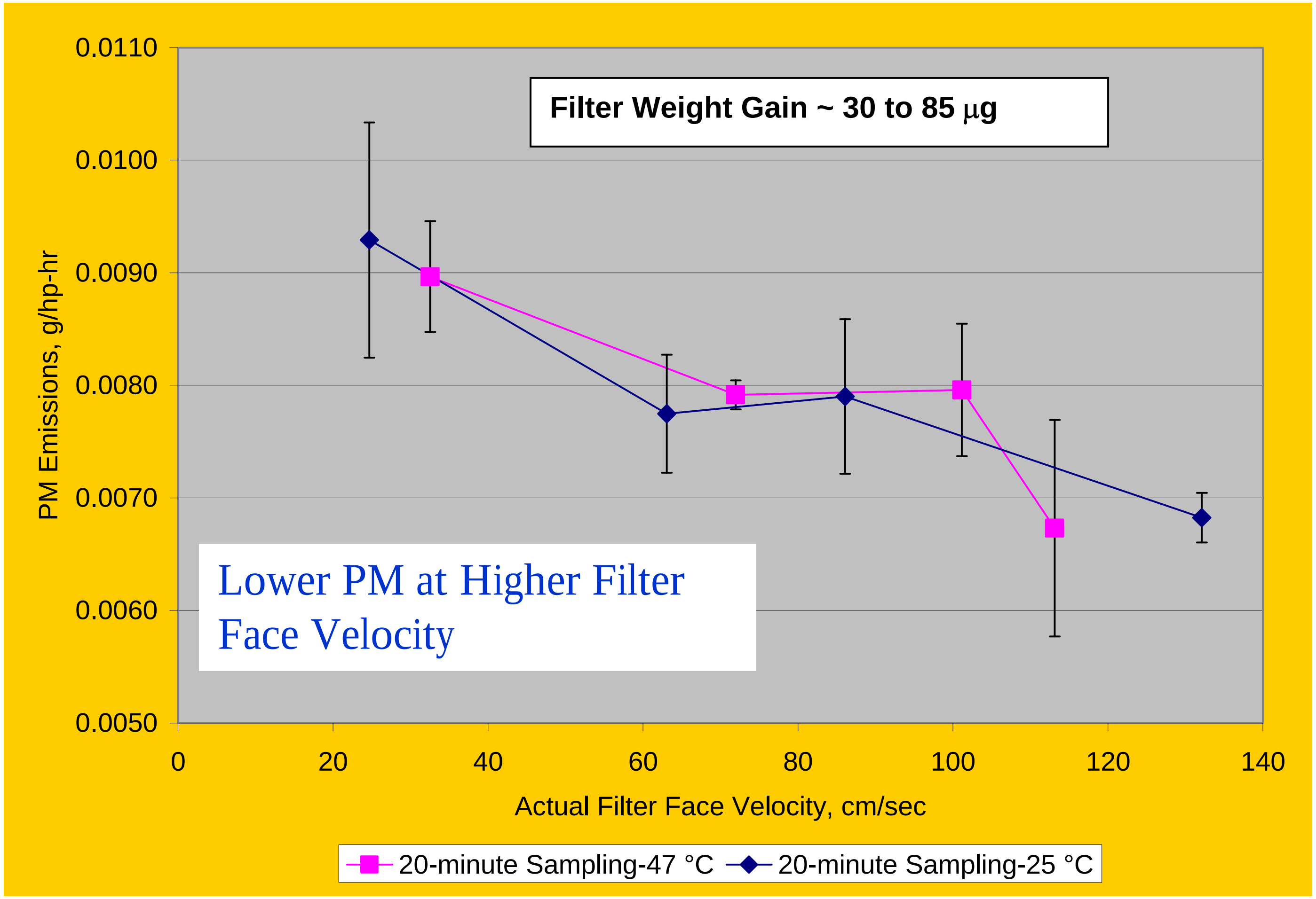
TX-40 Filter Media Collected 2.5 times higher PM than the Teflon Membrane Filter Media. At this engine operating condition, the PM is likely dominated by sulfuric acid.

Thermal OC/EC Filter Analysis for FTP Transient Cycle



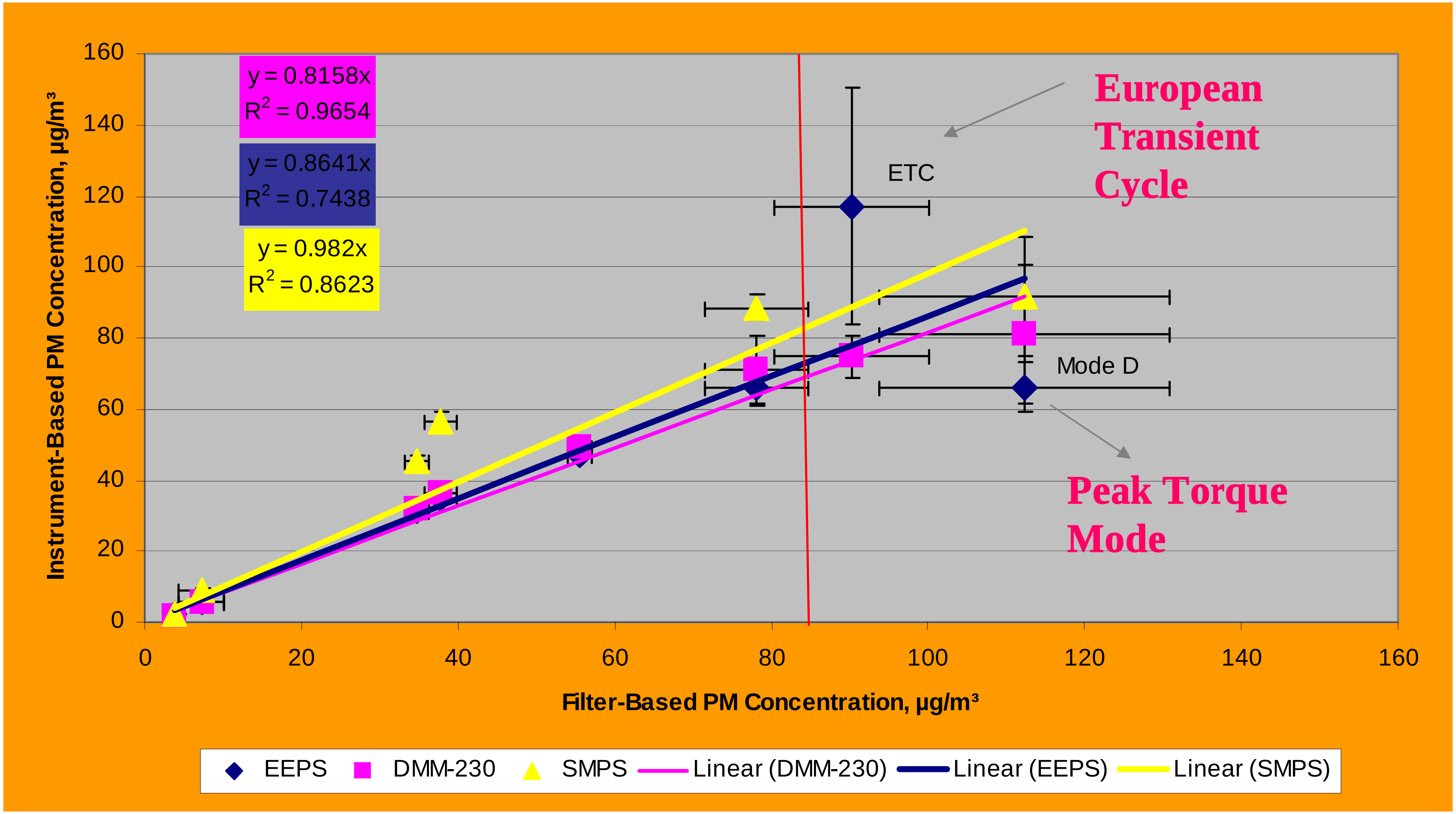
Mainly Organic Carbon PM Downstream of CRT-DPF

PM Emissions at Different Filter Face Velocities-FTP Transient Cycle-20 minutes Sampling (CRT-DPF with Bypass)

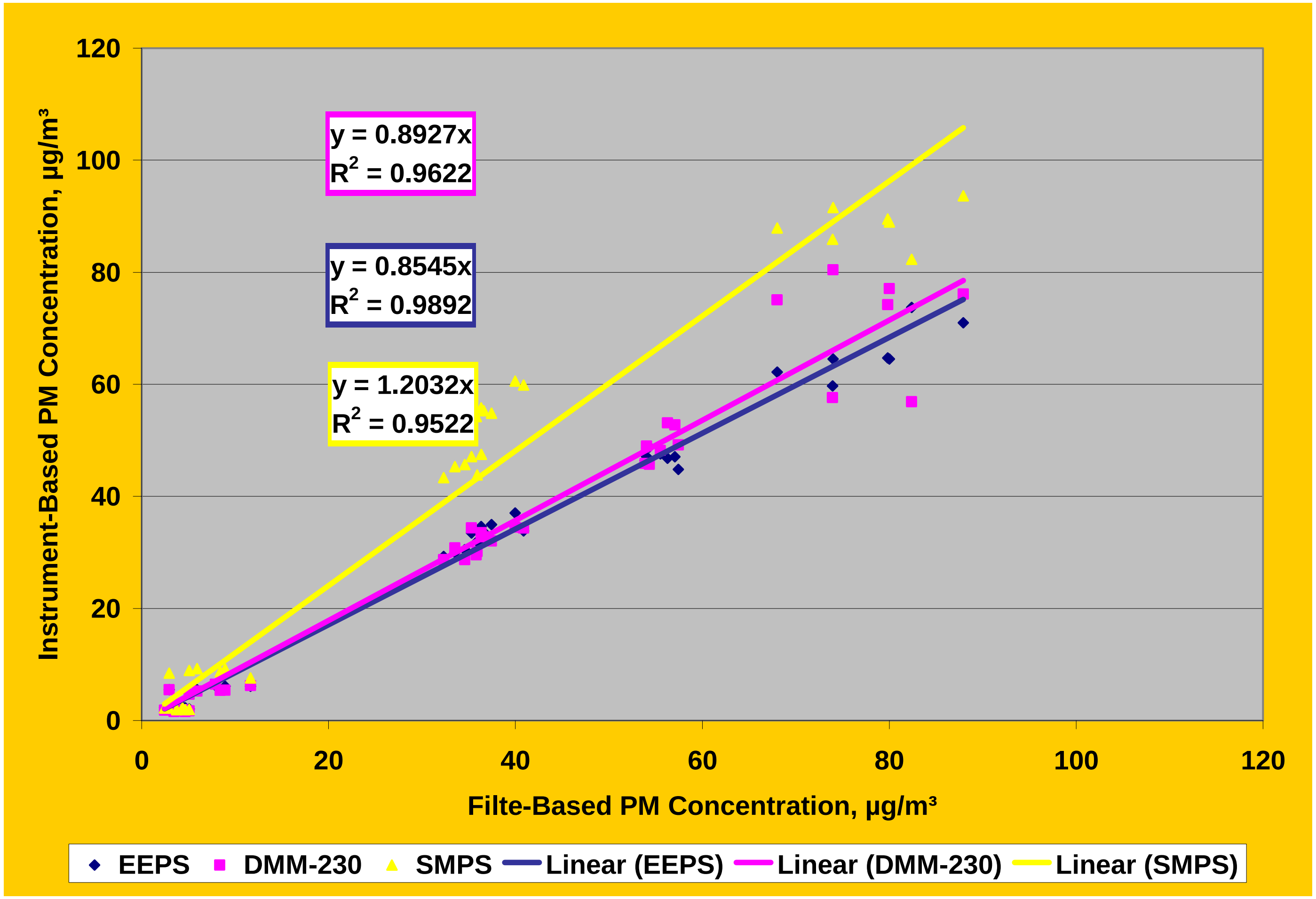


Correlation Between Filter-Based and Instrument-Based PM Emissions

(CRT-DPF with Bypass)



Improved Correlation Between Filter-Based and Instrument-Based PM Emissions, Excluding Mode D and ETC (CRT-DPF with Bypass)



E-66 Phase 1 Main Conclusions

- Teflon membrane filters minimize PM positive artifact collection during PM sampling.
- PM emissions from a 1998 diesel engine equipped with a CRT-DPF is dominated by volatile PM at a level below 0.001 g/hp-hr or 10 percent of the 2007 PM standard.
  - It is important to note that this engine and exhaust configuration does not meet the 2007 NOx standard. The PM emissions from an engine that complies with the 2007 standard may be different.
- Filter face velocity seems to alter PM emissions.
  - More work is underway to study the effect of filter face velocity and PM loading on volatile and solid PM measurement.
- Real time instruments such as the EEPS and DMM-230 seem to correlate well (R^2 >0.95) with the filter-based method.
- More work is underway to better understand the interaction between different dilution variables and PM measurement.

Advanced Collaborative Emissions Study (ACES) – Emissions Characterization

Advanced Collaborative Emissions (ACES) Project

- A Significant Opportunity: evaluating new technologies before widespread use
- Collaborative effort with interest and support from
  - Industry (engine, fuels)
  - Government agencies (CARB, EPA, DOE)
  - Other stakeholders
- Industry to provide prototype engines/control technologies for
  - Emissions characterization (Coordinating Research Council)
  - Health effects testing (HEI)

ACES Goals

- Produce health-relevant characterization of emissions from latest technology heavy-duty diesel engines/control systems (CRC)
- Develop and apply best available methods for assessing health implications of these methods (HEI)
- Provide a report of the results and a commentary evaluating the emissions and effects from these new engine/control systems to inform future risk assessments of diesel exhaust (HEI)

Emissions Characterization

- To be done through the Health Effects Institute and Coordinating Research Council
- Phase 1: 2007 engines
- Timing: 2005-2006
- Phase 2: 2010 engines
- Timing: 2007-2009

2007 Heavy-Duty Diesel Engines

- Catalyzed particulate trap
- 4 prototypes to be tested
  - Cummins
  - Mack
  - Volvo
  - Detroit Diesel Corporation

2010 Heavy-Duty Diesel Engines

- Again, 4 engines with particle traps
- Manufacturers have not selected final NOx control system for production
  - NOx absorber
  - Selective catalytic reduction (SCR) – urea
  - Engine modifications
- Different manufacturers may use different approaches

2010 Heavy-Duty Diesel Engines

- Single engine of 4 characterized to be selected for detailed (and expensive) health testing
  - Will be hard to select single engine if different NOx control approaches used and if emissions are different
  - Rigorous selection criteria not yet set
- Duplicate engine will also be obtained and characterized

Emission Test Cycles

- EPA heavy-duty driving cycle
- Engine (not vehicle) testing
- Possibly some CARB driving cycles
  - Developed as part of CRC E55/59 program
  - 4 modes
  - Idle
  - Creep (very low speed, lots of idle time)
  - Transient (typical urban)
  - Cruise (on-highway with some acceleration/deceleration from idle)

Fuel Specifications

- Low sulfur diesel fuel
- Typical of fuel to be in-use in 2007-2010 time frame
- Specifications for
  - Cetane 40-45
  - Aromatics 35-45%
  - Polycyclic aromatic hydrocarbons 8-10%
  - Distillation range (initial, 10%, 50%, 90%, end points)
  - Sulfur 12-15- ppm
- Use single batch of fuel for all testing if possible

Oil Specifications

- Oil typical of those to be used in 2007-2010 engines
- Specifications
  - Sulfated ash 0.8-1.0%
  - Phosphorus 0.08-0.1%
  - Sulfur 0.25-0.50%

Emissions

- Regulated emissions
  – HC, CO, NOx, PM
  – Size distribution of PM
- Unregulated emissions
  – List of 800 compounds
  – List of 3 categories in order of importance
    - Must be measured – about 190 compounds
    - Should be measured if reasonable to do so
    - Measured if it done concurrently with higher priority compounds or at little additional cost

Measurement Issues

- Artifact formation for PM collection
- At low emission rates, artifact formation/loss of species on sampling media is likely to be very important
- Nitro-PAH compounds being formed?
- CRC E66 project examining improved methods of PM collection
- DOE's National Renewable Energy Laboratory is funding studies to investigate the amount/occurrence of nitro-PAH compounds on filters

AVFL-10b Standard Diesel Exhaust For Catalyst Evaluation

Objectives

- Assess the composition of light-duty diesel exhaust at several operating conditions
- Determine and define a representative recipe for a light-duty exhaust standard

AVFL-10b Status

- Test fuel: Sinclair ULSD
- Four vehicles were tested with the Federal Test Procedure, US06 and five steady-state modes
- Speciation data were collected for engine-out gaseous and semi-volatile vapor-phase emission
- Draft report is being reviewed

AVFL-10b Status (cont'd)

- Speciation data from all four vehicles are very similar

Five Most Abundant VOC

Transient Cycle (Table 5)

	Silverado	F-350	Sprinter	Jetta
1	Ethylene	Formaldehyde	Formaldehyde	Ethylene
2	Formaldehyde	Ethylene	Ethylene	Formaldehyde
3	Acetylene	Acetylene	Propylene	Acetaldehyde
4	Propylene	Propylene	Acetone	Propylene
5	1,3-Butadiene	2M-1 Butadiene	Acetylene	Acetylene

Steady Speed Cycle (Table 6)

	Silverado	F-350	Sprinter	Jetta
1	Ethylene	Ethylene	Ethylene	Ethylene
2	Formaldehyde	Propylene	Formaldehyde	Formaldehyde
3	Acetaldehyde	Formaldehyde	Propylene	Propylene
4	Propylene	Acetylene	1,3-Butadiene	Acetaldehyde
5	Acetylene	1 Butene	Acetaldehyde	Acetylene

AVFL-10b Status (cont'd)

- Speciation data from all four vehicles are very similar

Five Most Abundant Semi-Volatile HC

Transient Cycle (Table 7)

	Silverado	F-350	Sprinter	Jetta
1	Pentadecane	Tridecane	Decane	Tridecane
2	Tridecane	Tetradecane	Hexadecane	Naphthalene
3	Tetradecane	Pentadecane	Pentadecane	2-M Naphthalene
4	Dodecane	Dodecane	Heptadecane	Tetradecane
5	Hexadecane	Undecane	Octadecane	Hexadecane

Steady Speed Cycle (Table 8)

	Silverado	F-350	Sprinter	Jetta
1	Tridecane	Tridecane	Tetradecane	Tridecane
2	Pentadecane	Tetradecane	Pentadecane	Tetradecane
3	Tetradecane	Pentadecane	Tridecane	Pentadecane
4	Hexadecane	Hexadecane	Naphthalene	Hexadecane
5	Naphthalene	Dodecane	Dodecane	Dodecane

CRC Emissions Committee Projects – Summary

- CRC working with government & industry
- E-66 evaluates the 2007 level diesel PM measurement techniques
- ACES characterizes future diesel emissions and health effects
- AVFL-10b evaluates diesel exhaust for catalyst study