ECD Demonstration Program

- Program History
- Program Design
- Emission Data
- Mileage Accumulation
- Program Status

EC-D Background 1st Quarter 99

- Initial testing illustrated modest emission benefits from fuel change
- Diesel Exhaust Treatment Advances
  - European experiences particulate filters
  - Sulfur sensitive
- EC Diesel's catalyst enabling ability not yet evaluated
- Next step…. Large scale demonstration program
  - Target urban diesels
  - Fuel and catalyst evaluation
  - Desire for results to be widely accepted

EC D Demonstration Program Participants

- **Agencies**
  - National
    - DOE and NREL major supporter & working group member
    - EPA review and comment on test program
  - California
    - CARB, SCAQMD and CEC are members of working group
- **Academia**
  - West Virginia University
  - UC Riverside
- **Industry**
  - Engelhard and Johnson-Matthey with support from Corning, NGK-Lock and Fleetguard Nelson
  - Cummins, Detroit Diesel, Ford and International
- **Fleet operators**

EC D Demonstration Program Deliverables

- Emission data
  - reduction from fuel change
  - reduction from fuel change and passive regenerating particulate filters
- Toxic, speciation and sizing data
  - with and without catalyst
- Durability information
  - low sulfur/aromatic high cetane fuel
  - passive regenerating particulate filters

EC D Demonstration Program Participants

	ECD w/ Johnson Matthey	ECD w/ Engelhard	ECD with original muffler	CARB w/ original muffler	Total
ARCO	5	5	9	10	**29**
San Diego Schools	5	5	10	10	**30**
LA City	5	5	2	3	**15**
LA MTA	2		8	8	**18**
Tram vehicles	5	0	15		**20**
Hertz Equipment Rental	5	5	5	5	**20**
Ralphs Grocery	5	5	5	5	**20**
Total	**32**	**25**	**54**	**41**	**152**

Emissions Test Plans

- Main Plan prepared 11/99
  - NREL, industry participants, CARB, SCAQMD, CEC, DOE
  - Reviewed by U.S. EPA
  - First round- Test five heavy vehicle fleets using WVU transportable dynamometer
  - Second round- Retest the same vehicles, examine possible performance or emissions deterioration, improve test procedures, compare toxic emissions
- Hertz Plan prepared by UC Riverside 11/99
- Toxic, Speciation and PM Sizing Plan
  - Developed in 2000 by CARB, SCAQMD, NREL, Industry participants
  - Testing to be completed in final round

Fuel Analysis Results

1st Round of testing

Test Fuel Properties (1 Sample)

Property	CARB	ECD	ECD-1
Cetane Number	54.1	64.7	51.3
Sulfur, ppm	121	7.4	13.1
SFC Aromatics			
Total, vol%	22.5	10.9	23.8
PNA, wt%	4.1	0.9	2.8

Quick Review of Round 1

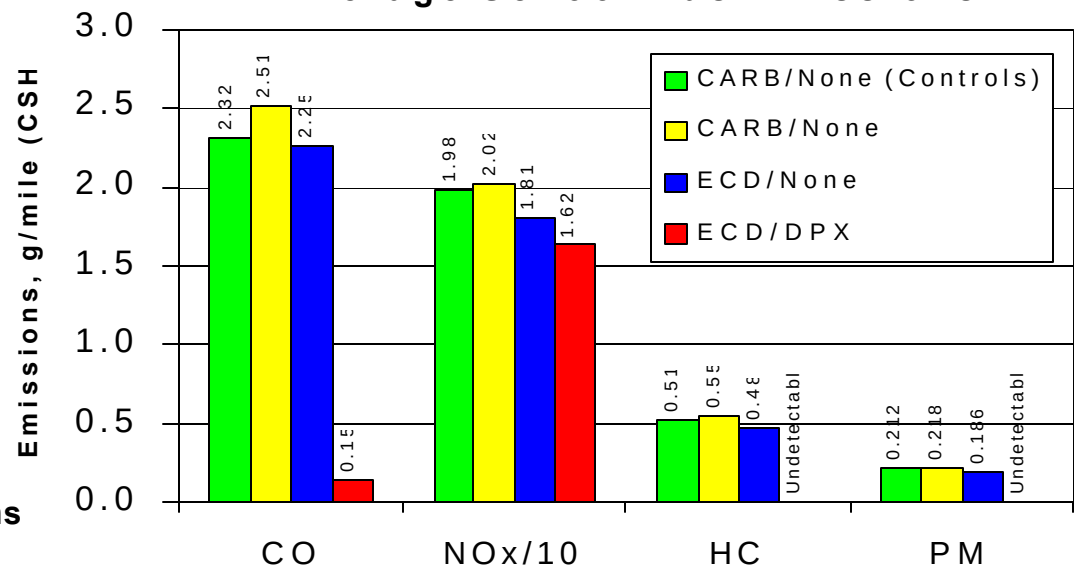
- Kenworth chassis
- 1995 & 96 Cummins M11 10.8 liter turbocharged diesel, 330hp
- 10 spd. manual transmission
- Johnson Matthey CRT
- 32,200 lb test weight

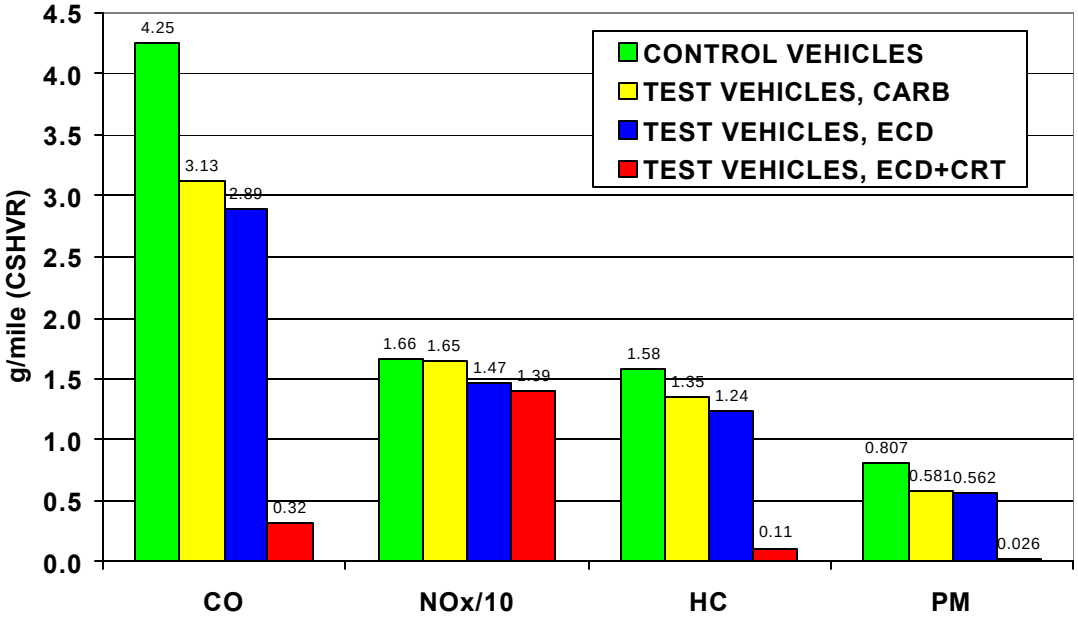
- 1998 American Transportation 3000RE / International chassis
- International 530E 8.7 liter I6 turbo, 275 hp
- Automatic transmission, 5 speed
- Engelhard DPX
- 32,200 lb test weight

Average Emissions From Round 1

Each bar is average of 2 vehicles, 3 runs per vehicle

Average Tanker Truck Emissions



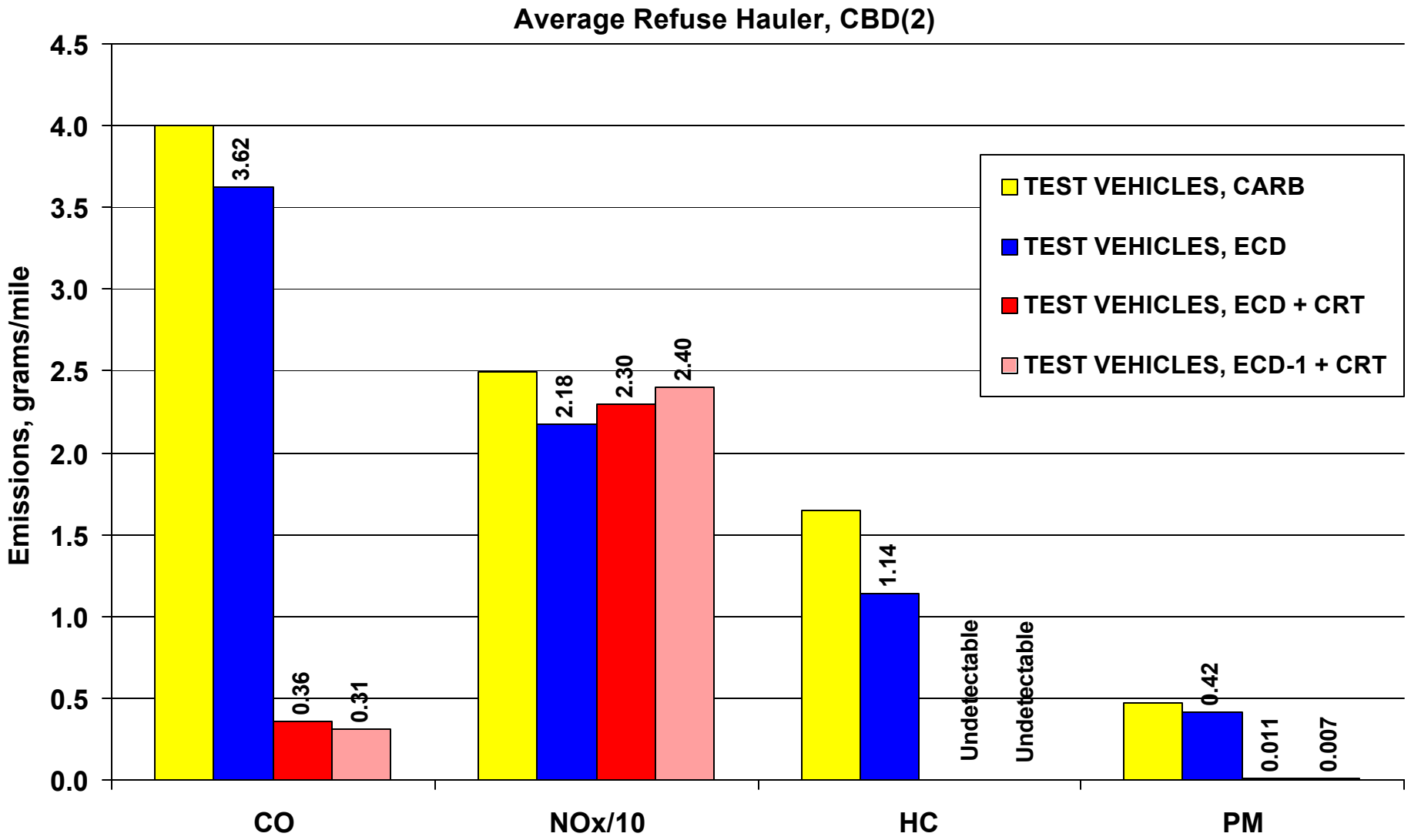


LA City Refuse Haulers

- 1999 Peterbuilt
- Cummins ISM 10.8L 305 HP
- Automatic 5 speed transmission
- 58,000 lbs GVW, 40,600 lbs test weight
- Johnson Matthey CRT

Average Refuse Hauler Emissions

Round 1 Data Each Bar is 2 vehicles, 3 runs per vehicle

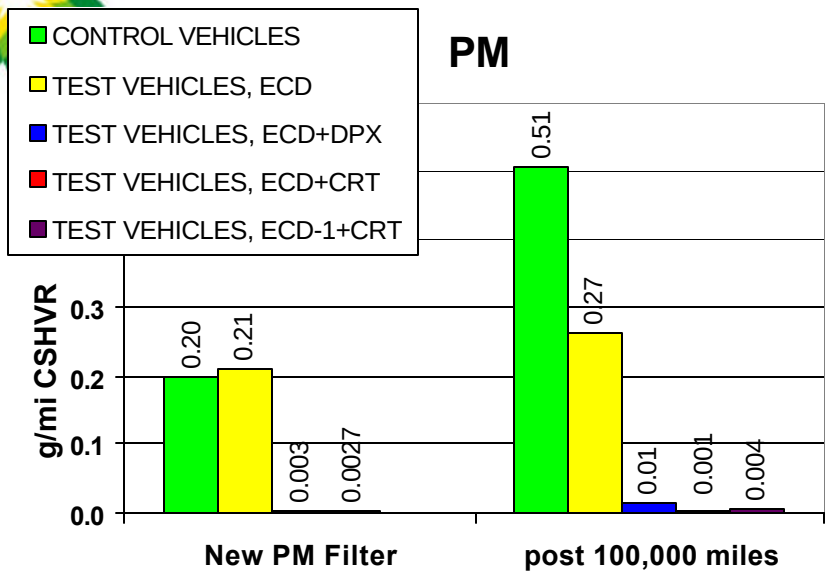


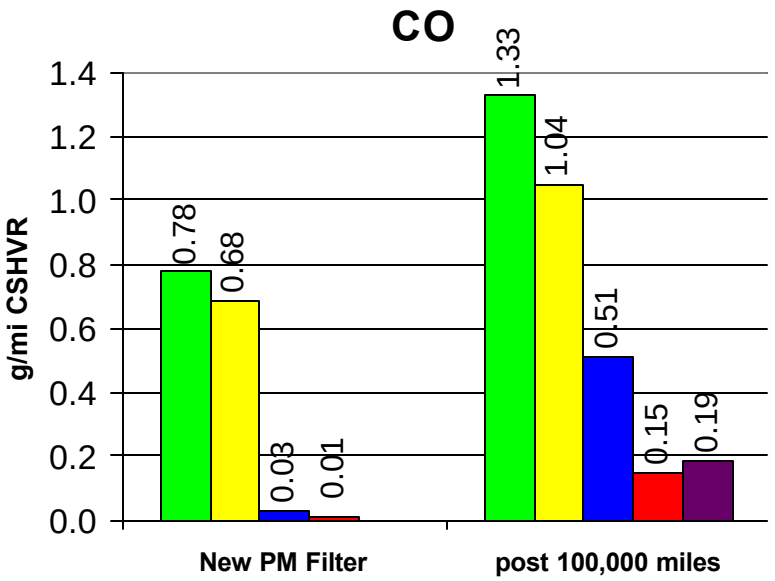
Ralphs Grocery Trucks

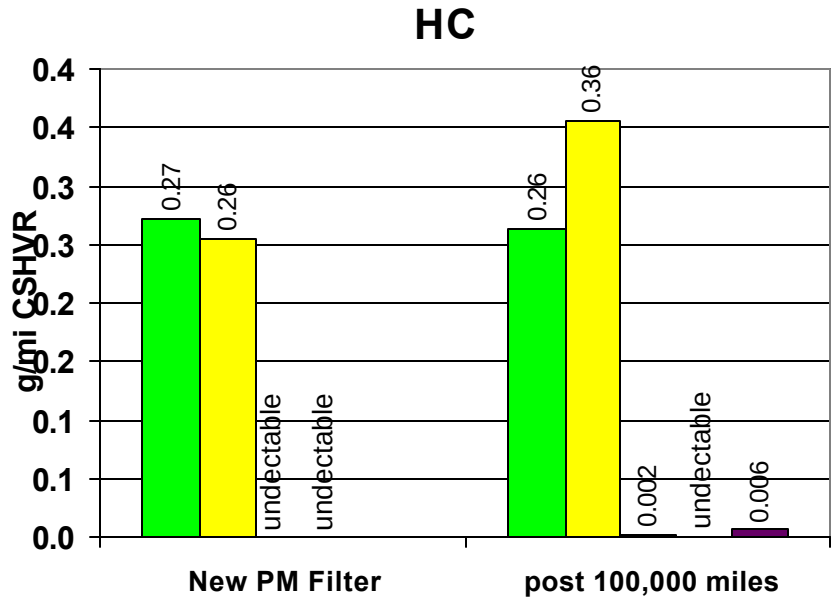
- 1999 Sterling L-line chassis,
- 1998 Detroit Diesel Series 60,
- 12.7 liter turbocharged diesel, 430hp
- 10 spd. manual transmission
- Johnson Matthey CRT and Engelhard DPX
- 42,000 lb test weight
- Twenty trucks tested to investigate vehicle-to-vehicle variability

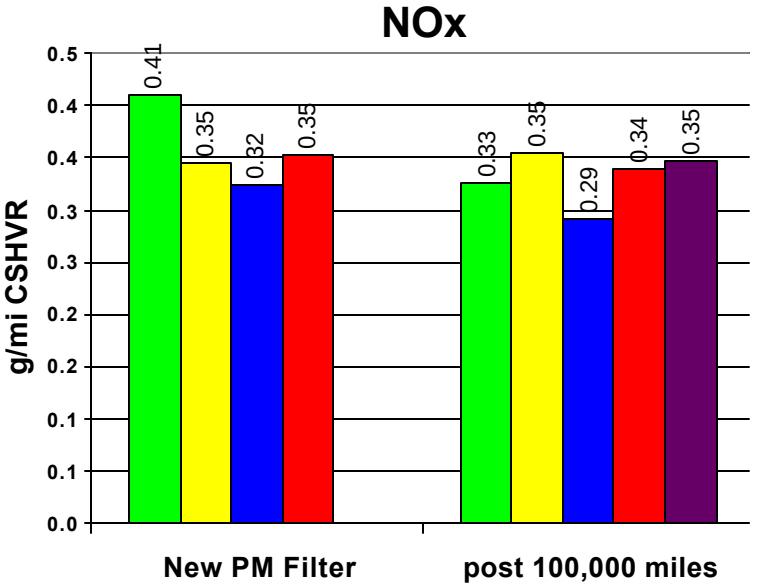
Average Grocery Truck Emissions

Each Bar is 5 vehicles, 3 runs per vehicle



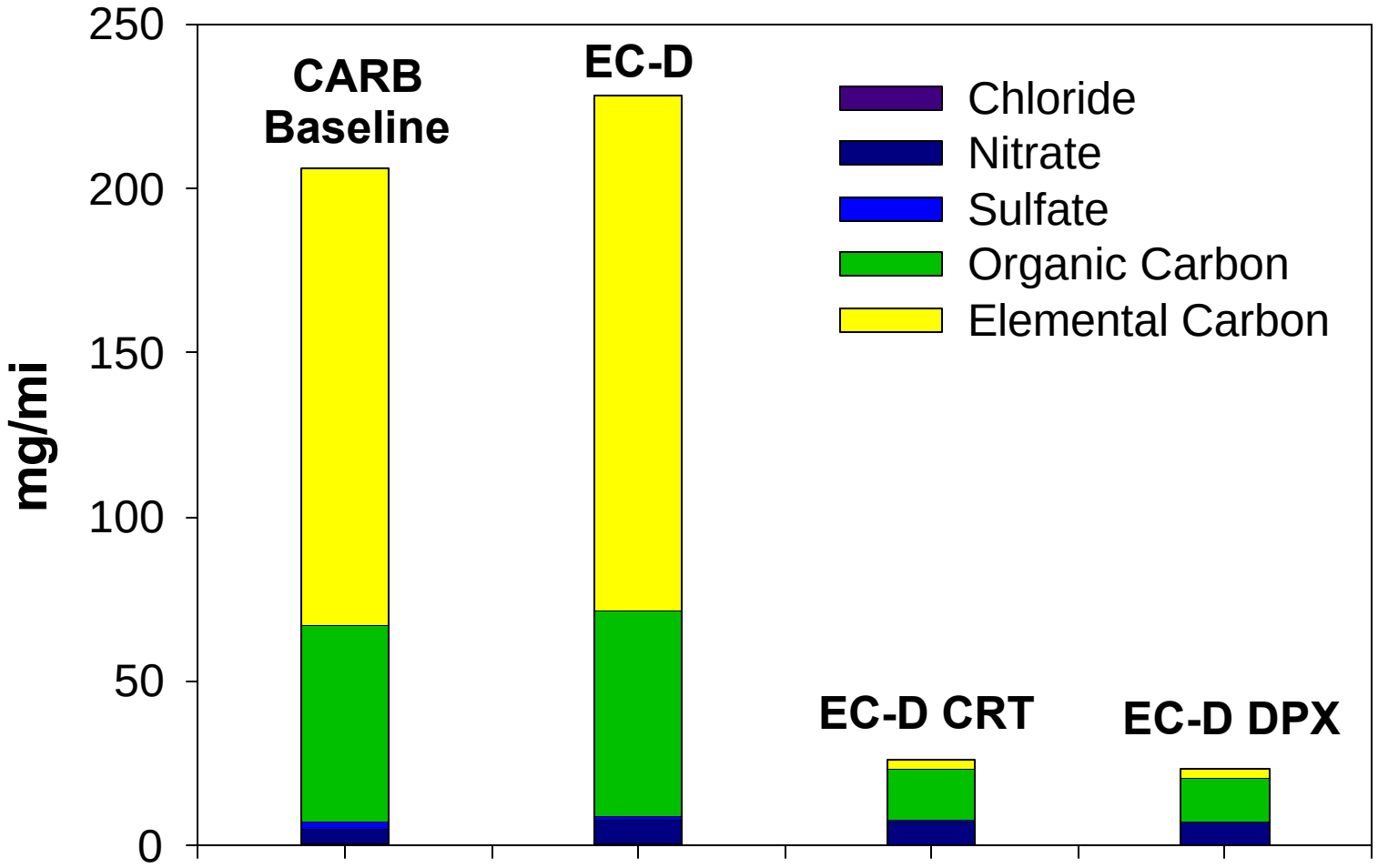






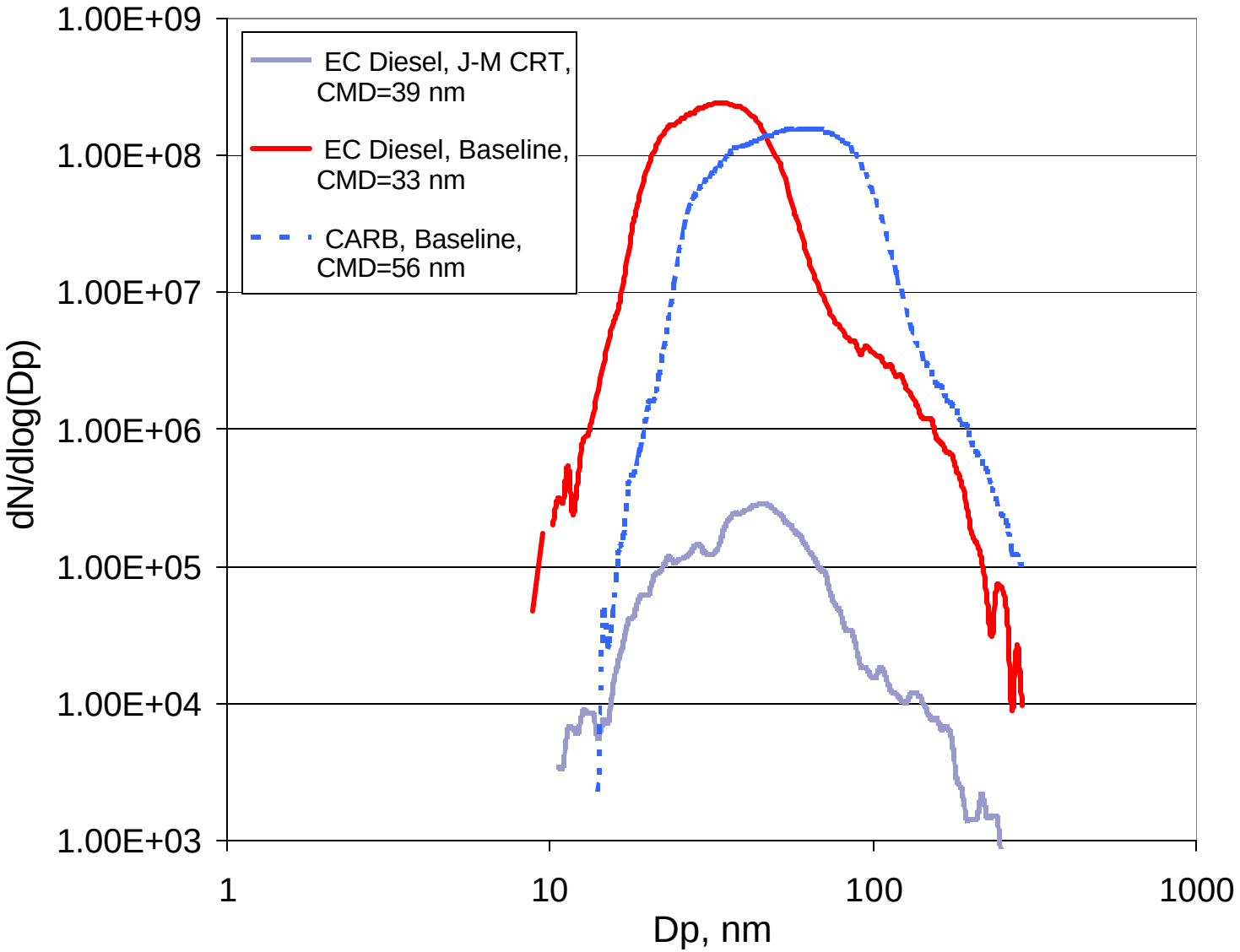
Particulate Matter Make Up

Round 1 Grocery Truck Data



Particle Size Distribution

Grocery Truck at Steady 45 mph by SMPS



Speciation Testing

- Speciation Testing consisted of of 4 diesel fueled and 2 CNG fueled
  - Diesel with and without filters
  - filters have over 1 years operation
- Special speciation test plan was developed
  - enhanced emissions sampling
  - allow detailed analytical characterization
  - particle sizing analysis of the exhaust
- Goals to study what impact fuels and passive catalyzed particulate filters have on:
  - unregulated toxic emission species
  - particle size distribution

Speciation Matrix

part of second round emission testing

Vehicle / Fuel	School Bus	Grocery Truck (2)	Diesel Transit Bus	CNG Transit Bus (2)
CARB	No catalyst	No Catalyst	No Catalyst	
ECD	No Catalyst With DPX	With CRT	With CRT	
ECD-1	No Catalyst With DPX	No Catalyst With CRT With DPX	No Catalyst With CRT	
Fischer Tropcsh Diesel	No Catalyst With DPX			
CNG				No Catalyst

Speciation Test Elements

part of second round emission testing

1 HC

2 CO/CO2

3 NOx

4 TEOM

5 TPM

6 SVOC TX40 filter

7 SVOC PUF/XAD/PUF

8 NMHC Tedlar bags

9 Carbonyls DNPH cartridge

10 PM 2.5 Teflon filter

11 PM 2.5 quartz filter

12 PM 10 T60A20 filter

13 Dioxins or SVOC TX40 filter

14 Dioxins or SVOC PUF/XAD/PUF

15 Bioassay TX40 filter

16 Bioassay PUF/XAD/PUF

Additional analysis

- EC/OC
- Full scan GC/MS for non target analytes and SVOCs

Speciation Test Status

- **Analysis**:
  1. VOCs, PM(mass) – DRI complete, transmitting to WVU
  2. Dioxin/Furan – DRI complete, transmitting to WVU
  3. Bioassays – testing media background
  4. Carbonyls, Inorganic – DRI to transmit to WVU in August
  5. SVOCs. EC/OC – DRI to transmit to WVU in September

- **Data Management**:
  1. Analytical data sent to WVU
  2. WVU converts to proper units
  3. Data sent to NREL for QA/QC
  4. NREL serves as repository and distributes data to ECD working group

Mileage Accumulation

	Ralphs as of 6/24/01	ARCO as of 7/31/01	San Diego as of 6/1/01	LA MTA as of 7/2/01
	136,596	112,000 *	47,008	51,900
	157,845	117,190	44,447	41,600
	152,394	129,190	43,294	
	160,220	176,000	42,538	
	152,930	182,000	40,249	
	164,762	192,000	46,951	
	152,128	196,000	43,914	
	144,994	204,000	44,622	
	131,030	239,000	44,332	
	150,579	250,637	43,608	
Min	131,030	117,190	40,249	41,600
Average	**150,348**	**187,335**	**44,096**	**46,750**
Max	164,762	250,637	47,008	51,900

* Filter removed for in lab durability testing at 112,000 miles excluded from average

EC Diesel Program Summary

- Round 1 emission results ECD with catalyzed PM filter delivered >90% PM, HC, CO reductions
- Round 2 emission testing
  - Ralphs fleet regulated emission demonstrate PM & HC reductions >90% after more than 100,000 miles of operation
  - Preliminary results from other retrofitted vehicles are consistent with Ralphs data public this fall
  - Speciation results public this fall
- Additional Information
  - Society of Automotive Engineers Publications
    - 2000-01-1854, 2000-01-2821, 2000-01-2815, 2001-01-0512 Available at www. sae.org
    - Two abstracts accepted for 2002 World Congress
- Web pages
  - http://www.ctts.nrel.gov/heavy_vehicle/what/ec_diesel.html
  - http://www. ecdiesel.com