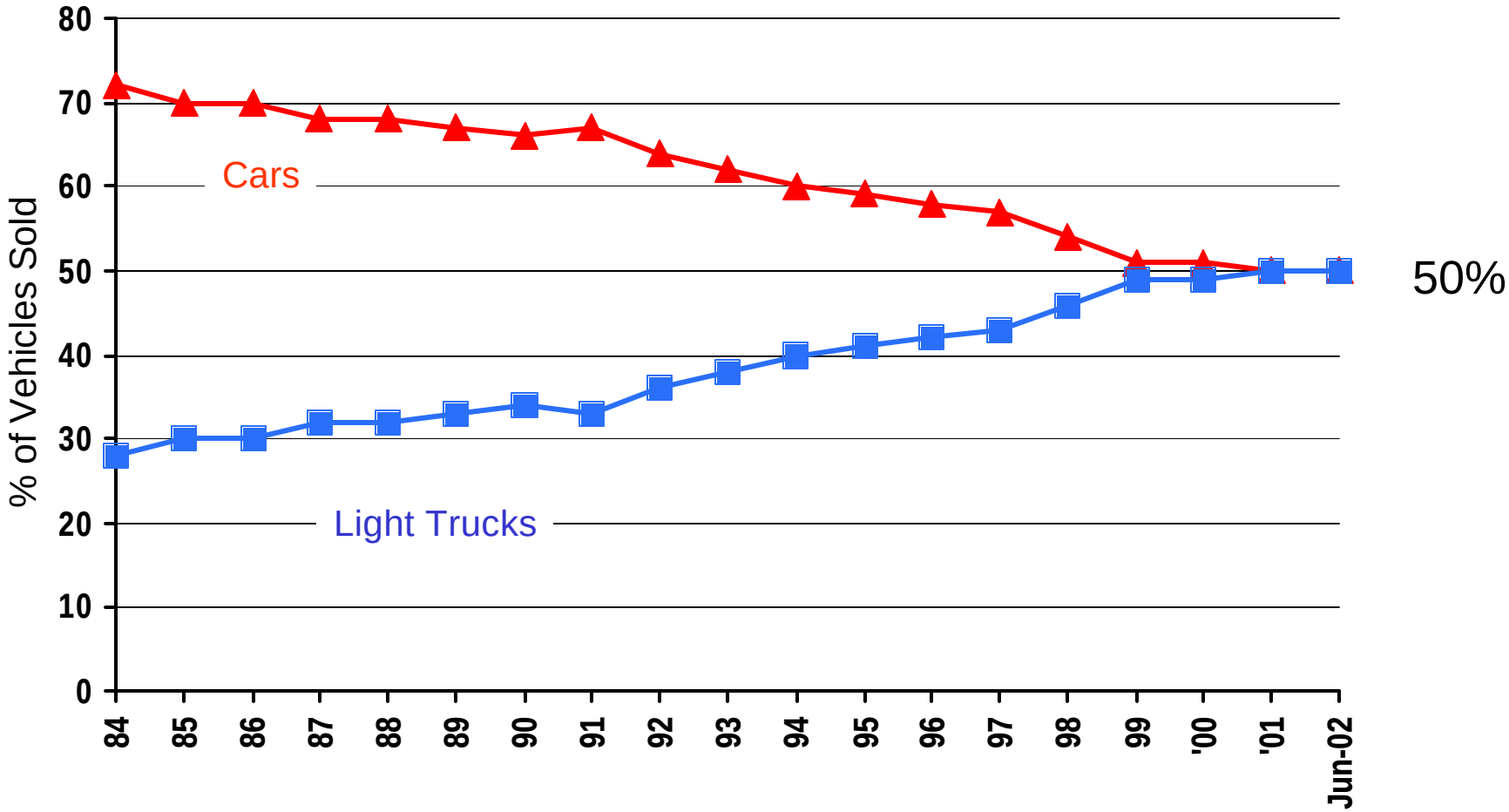
Cummins/DOE
Light Truck Diesel Engine
Progress Report

August 2002

Technical Program Overview

- **Partnership, Cummins and U.S. Department of Energy**
- **Focus**
  - **Development of technologies that will result in a product in the near term**
  - **Emissions**
    - **U.S. Tier 2 6000-8500 lb GVW**
    - **NO_x = 0.07 g/mi; PM = 0.01 g/mi**
  - **Fuel economy - 50 percent MPG improvement over 1997 gasoline powered vehicle it replaces**
- **Acknowledgment**
  - **Contractual funding from DOE**
  - **Vehicle and installation design assistance from Dodge Truck Engineering**
  - **Engine Development Team at Cummins**

US Passenger-Car & Light-Truck Market



Light Truck Major Segments

8.4M Vehicles

Vans 22%

Sport Utility Vehicles 39%

Pickup Trucks 39%

2001 Sales

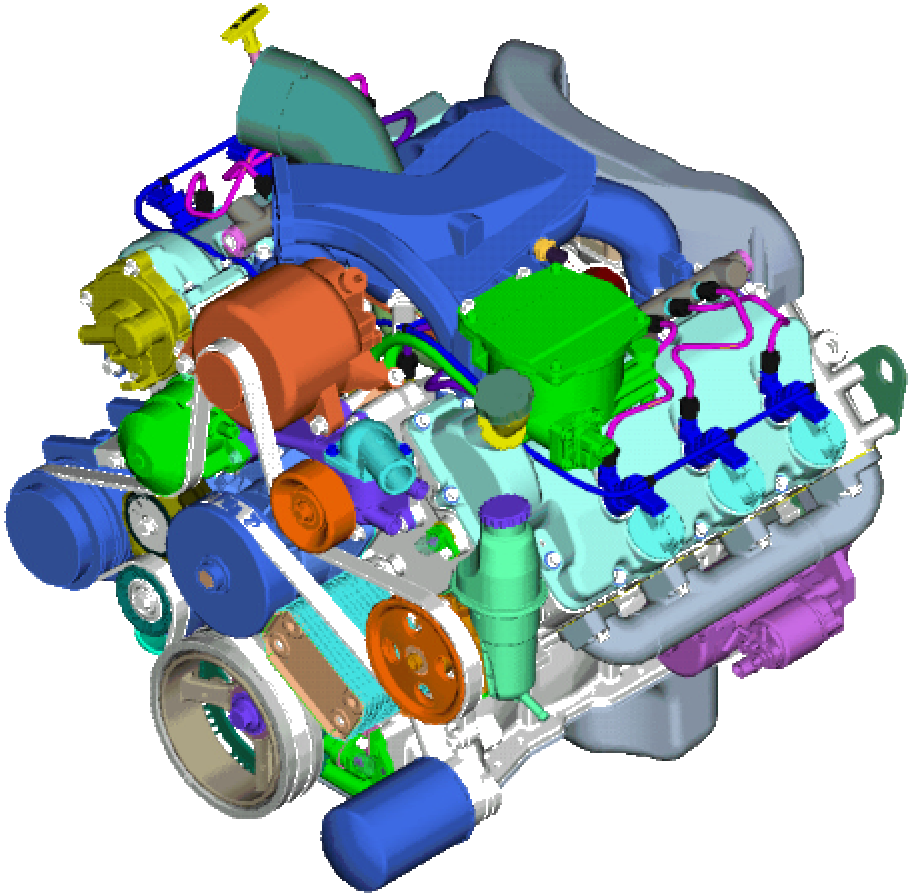
V Family Goals and Status

Description	Actual (status)	
	V6	V8
Emissions	Tier 2 Interim demonstrated, Tier 2 final, met on laboratory basis.	
Noise, dBa	68.7 Interior, Cruise @ 65 mph, Durango	65.0 Interior, Cruise @ 65 mph, BR 1500
Fuel Economy, MPG	22.1 Combined, Durango (+60%)	21.7 Combined, BR1500 (+60%)
Quality/Reliability	Not yet evaluated.	
Rated Speed	4000 rpm (5000 max.)	
Useful Life km(mi)	4000 hr Total Development Testing (equivalent usage >965,000(600,000)	
Performance	11.9 sec, 0-60 mph, Durango	9.95 sec, 0-60 mph, BR1500 4x4
Displacement, liter	4.2	5.6
Power, kW(hp) @ rpm	177(237) @ 3600	224(300) @ 4000 Interim target met.
Torque Peak, Nm(ft-lb)	475(350)	623(460)
Warm-Up	Not yet evaluated.	
Serviceability	No Adjustments Diesel fuel filter added.	
Cold Start	Not yet evaluated.	
Weight, kg(lb)	301(663)	379(835)

Meets Goal

Partially Meets Goal; Plan in Place

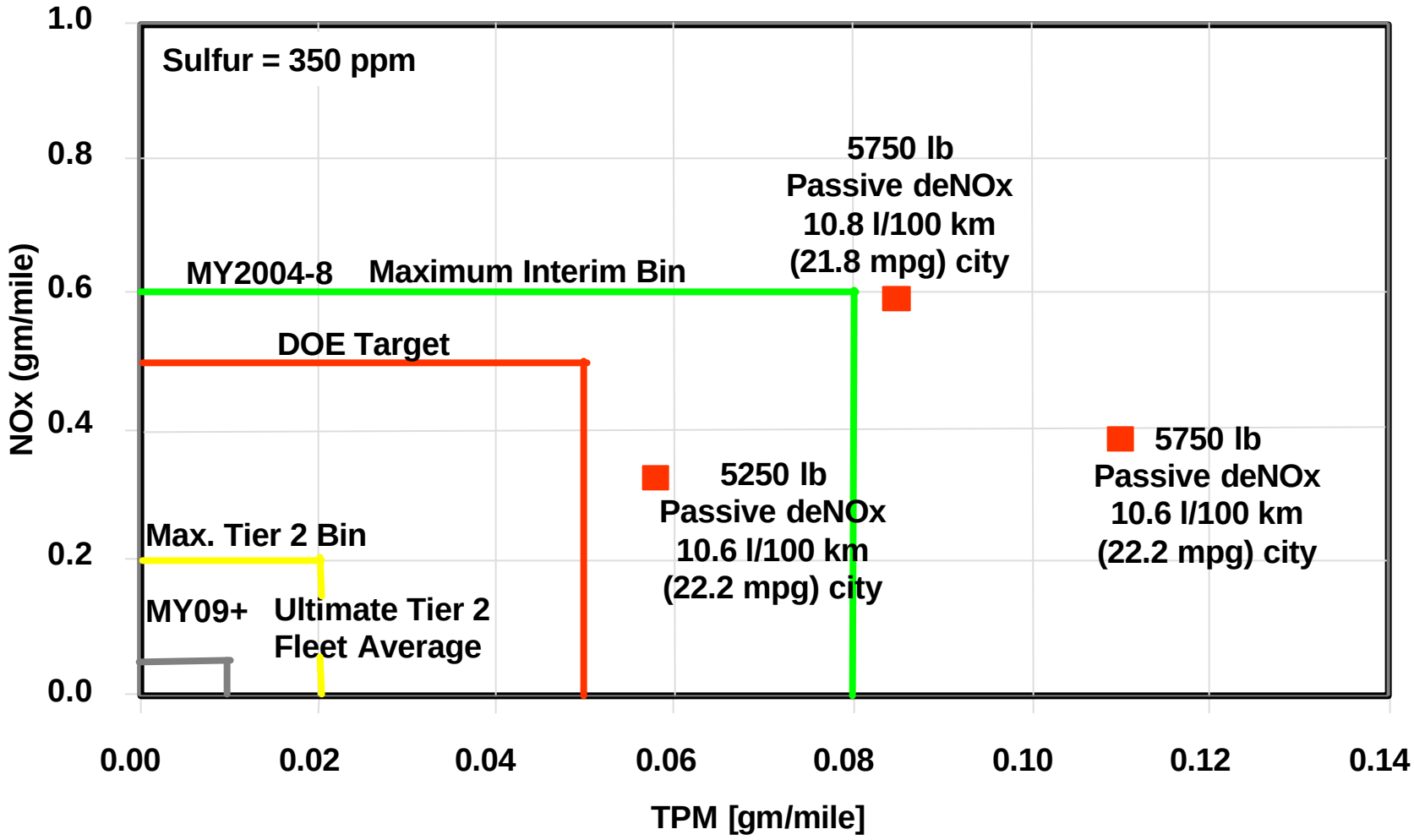
Light Duty Automotive Engine - V6



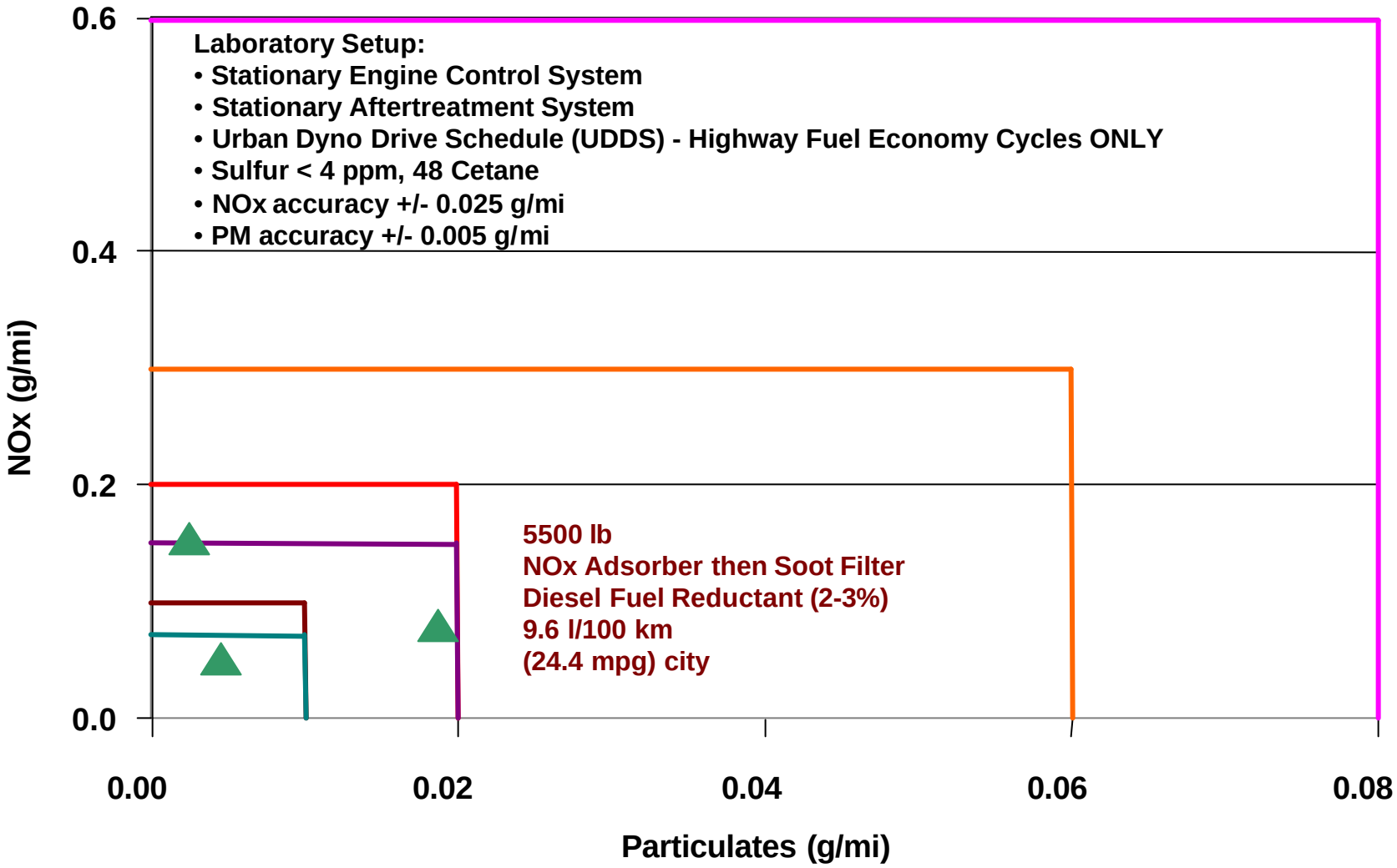
Light Truck Diesel
Subsystem Description

Subsystem	Description
Configuration	90° V
Displacement	4.2 L V6 5.6 L V8
Bore and Stroke	94 X 100 mm
Valvetrain and Drive	Single overhead cam, chain-driven
Valve System	Four valves per cylinder with hydraulic lash adjustment
Fuel System	High-pressure common rail (HPCR)
Control System	Full electronic
Emissions Control	Modulated-cooled EGR plus deNOx catalyst (Interim)
	4-Way Catalyst (Tier 2, Bin 5)
Aspiration	Wastegated turbocharged
Intercooling	Vehicle mounted air-to-air
Block	Cast iron, thin-walled
Head	High temperature alloy aluminum
NVH Control	Deep skirted block, with bedplate
Accessories	Common automotive V-8 gasoline
Accessory Drive	Single serpentine belt, self-adjusted

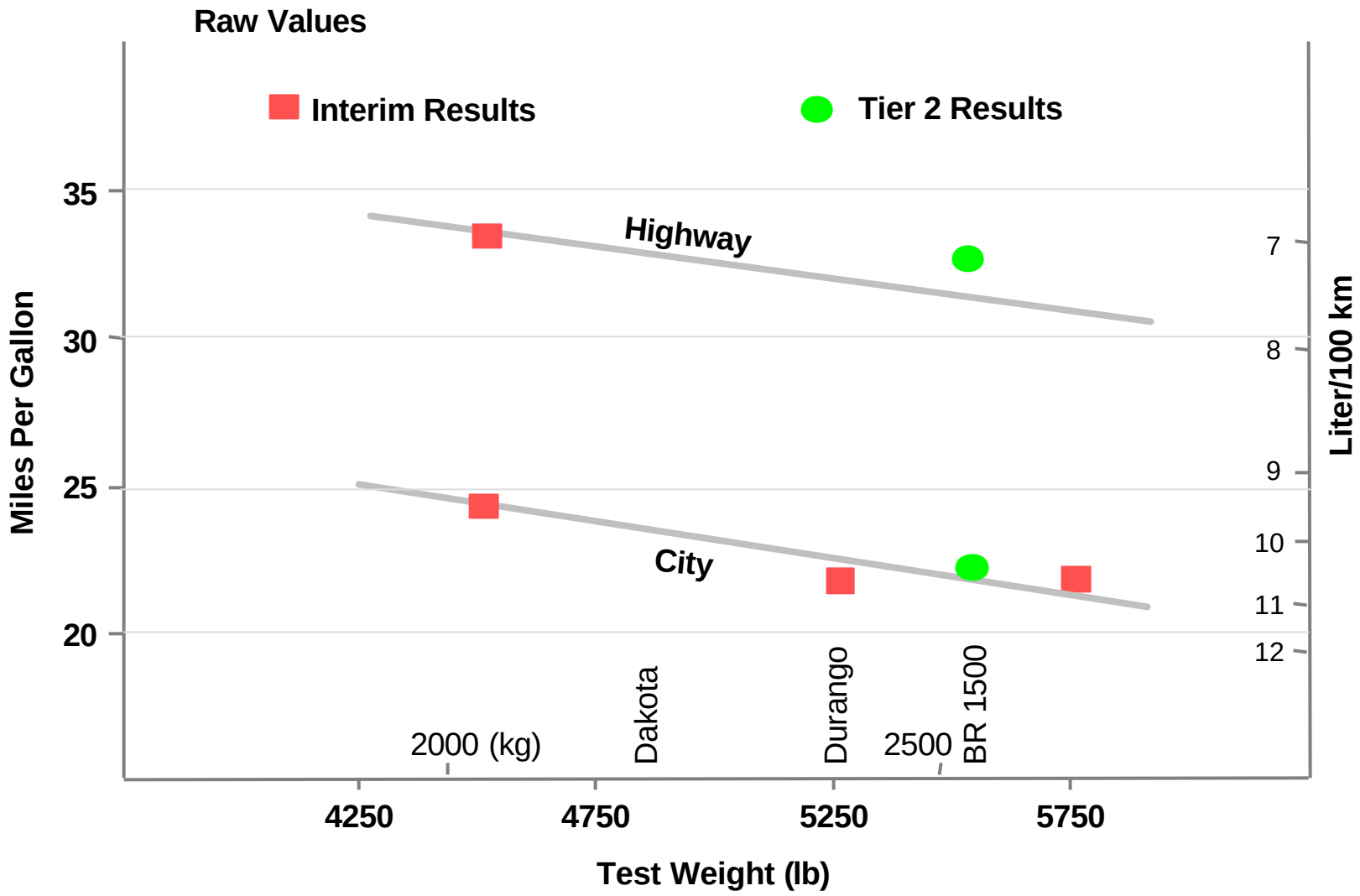
Demonstrated Emissions
Interim Results



Demonstrated Emissions
Tier 2 Results



Demonstrated Fuel Economy

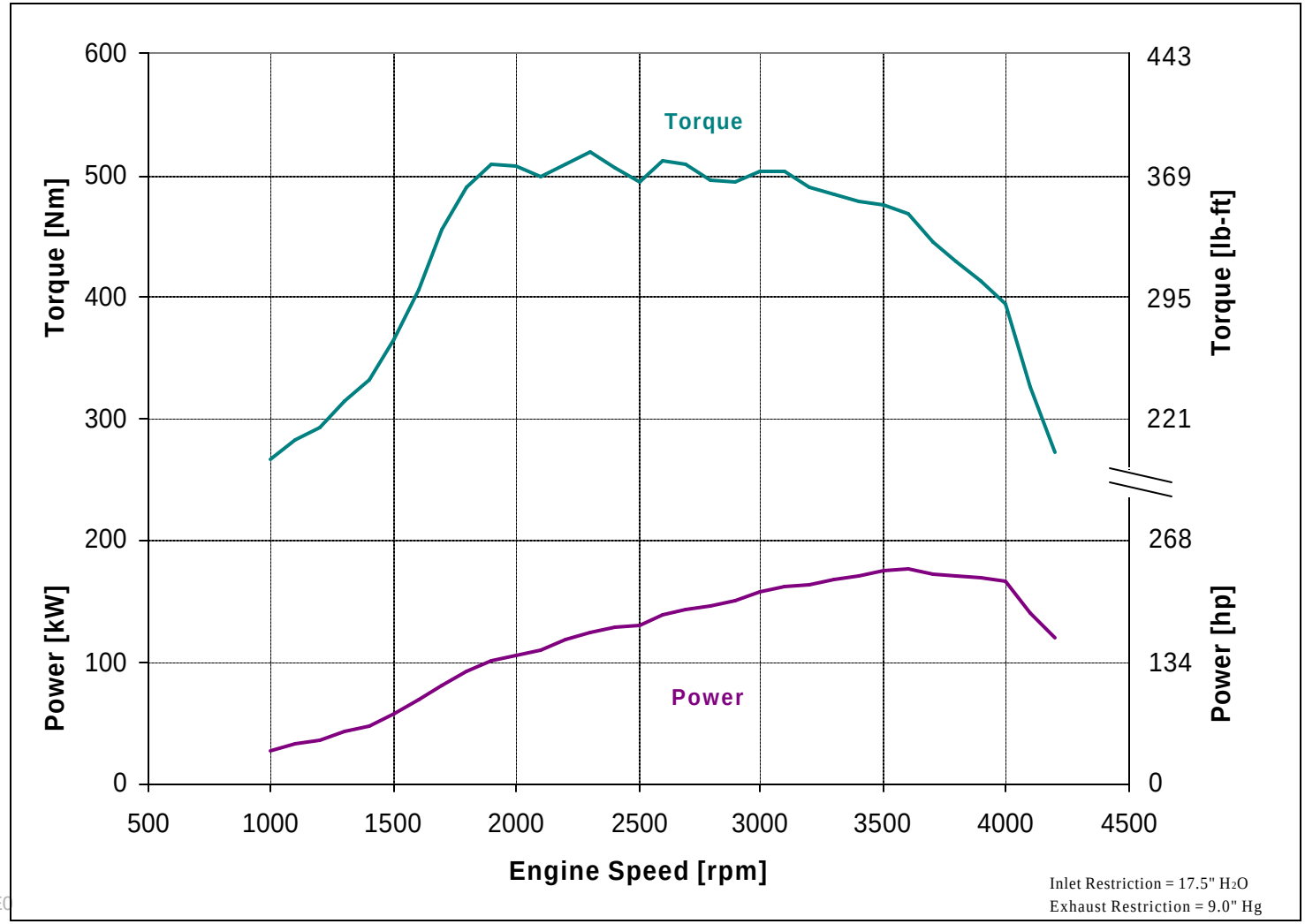


Typical Results

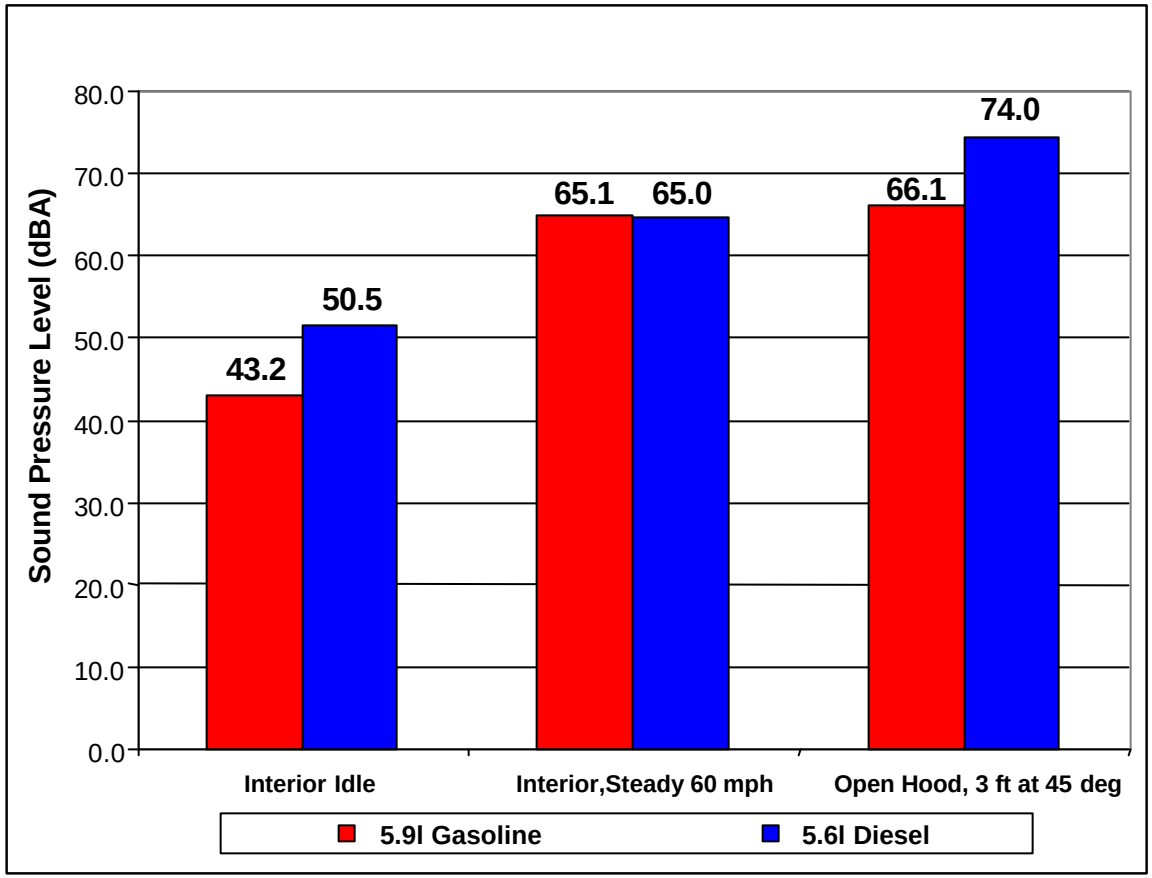
	City, mpg*	Highway, mpg*	Combined, mpg*	Combined gal/mi	CO_2
Dodge Durango					
- Gasoline	12	17	13.8	0.072	
- Diesel	20.3	25.0	22.1	0.045	
			+60% Improve	37% Reduction	27% Reduction
Dodge Ram 1500					
- Gasoline	12	16	13.5	0.074	
- Diesel	19.8	24.6	21.7	0.046	
			+61% Improve	38% Reduction	

*Adjusted values for vehicle labeling

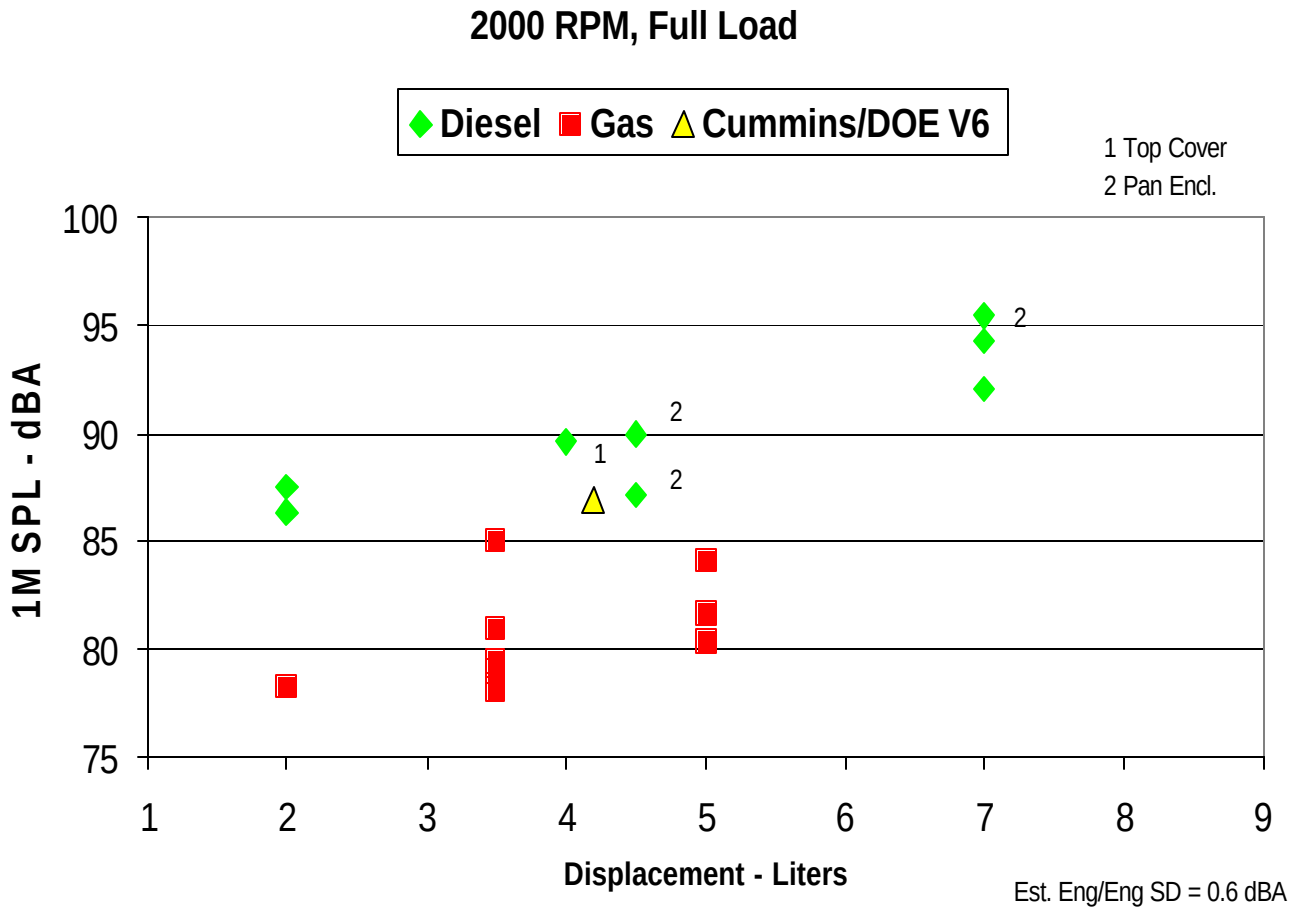
V6 Performance Results



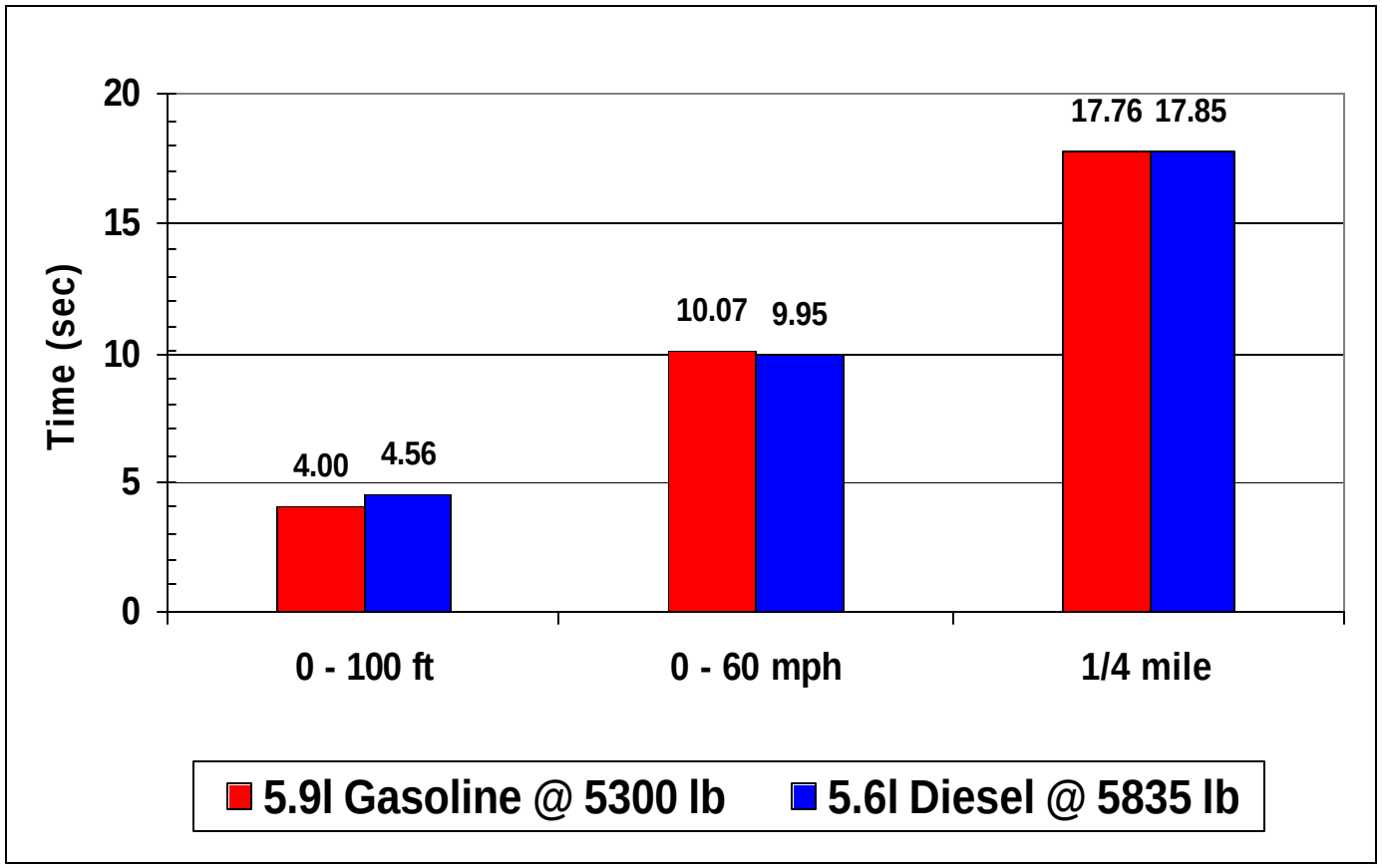
Noise Test Results
V8 in Ram 1500



Competitive Noise Comparison



Acceleration Test Results
V8 in Ram 1500



Current Focus

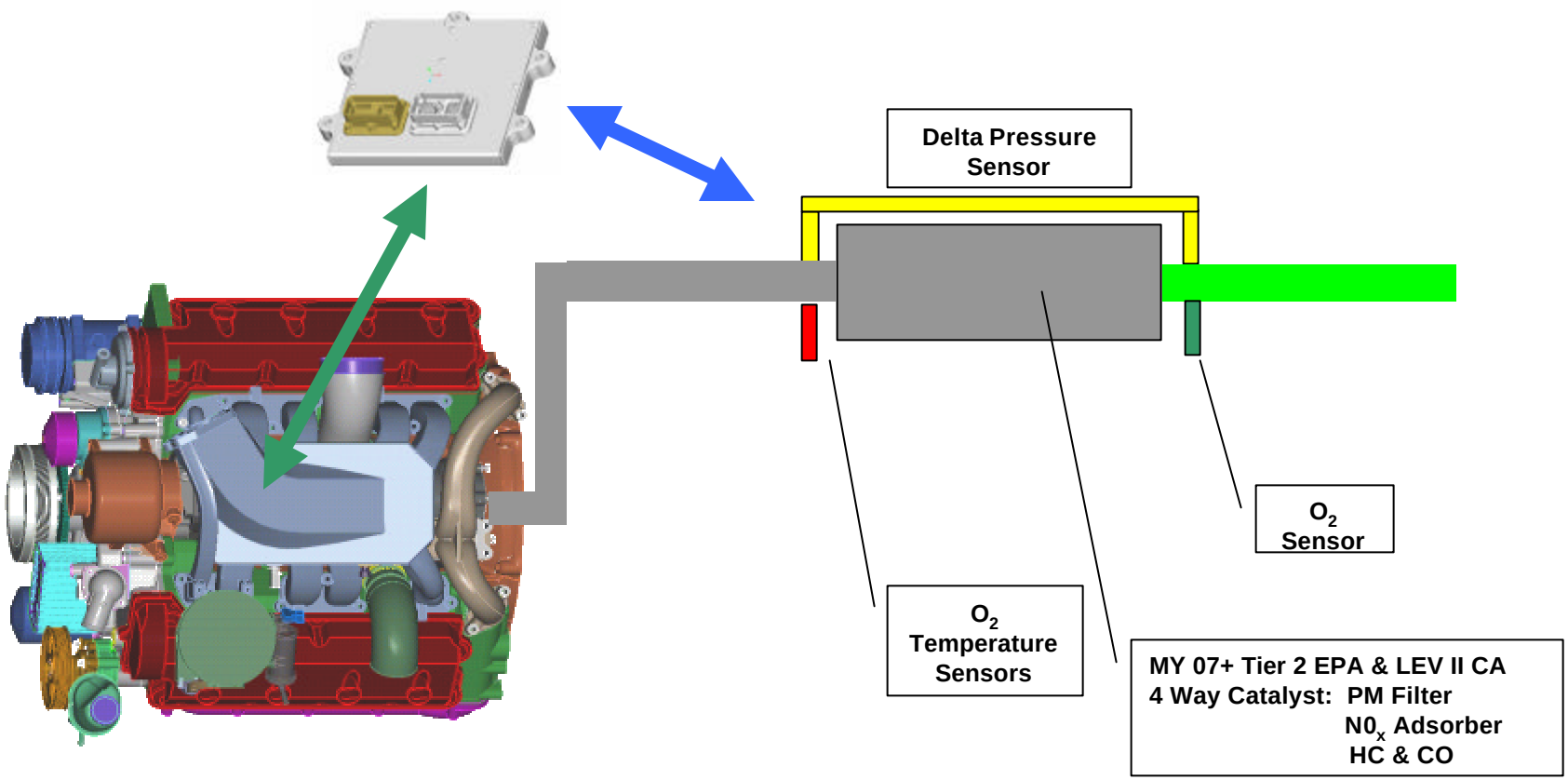
- **What needs improvement in this picture**
  - **Emission System**
    - ~ **Lower Cost, Simpler**
    - ~ **More Robust**
    - ~ **Compact**
    - ~ **Reliability**
    - ~ **Fuel Variability Tolerance**
  - **Overall System**
    - ~ **Improved Control of Variability**
    - ~ **Very Low (Precise) Emissions**
    - ~ **Sensor Technology Applied to Diesels**

Cost/Robustness

+

Variability

Prime Path
System with 4-Way Catalyst



Regeneration Strategy

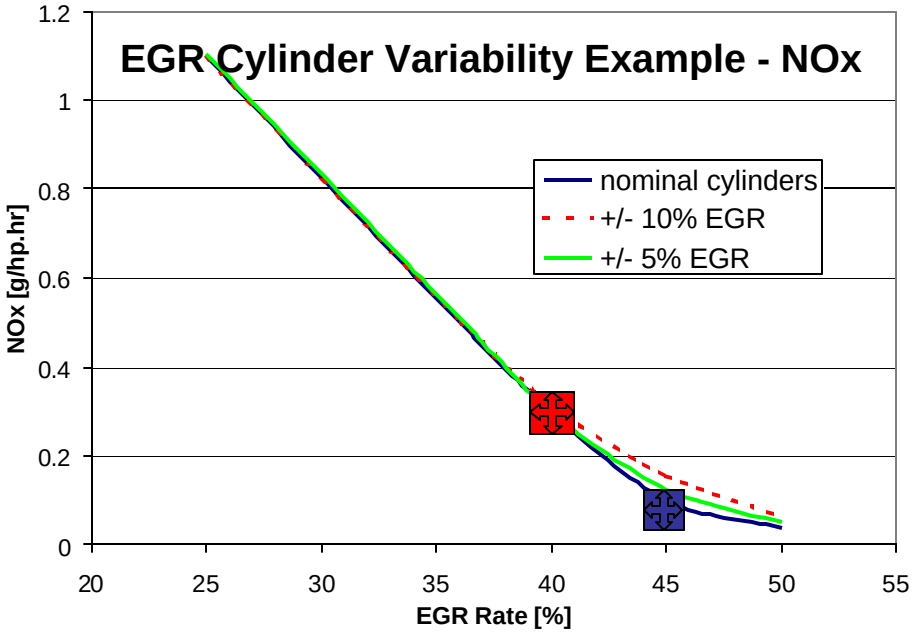
Condition	Engine Out	Thermal Management	Combustion Condition
NO_x Regen	Rich	+	Pilot + Main Injection
Soot Regen	Lean	+	Pilot + Main + Post
Sulfur Regen	Rich	+	Pilot + Main + Post

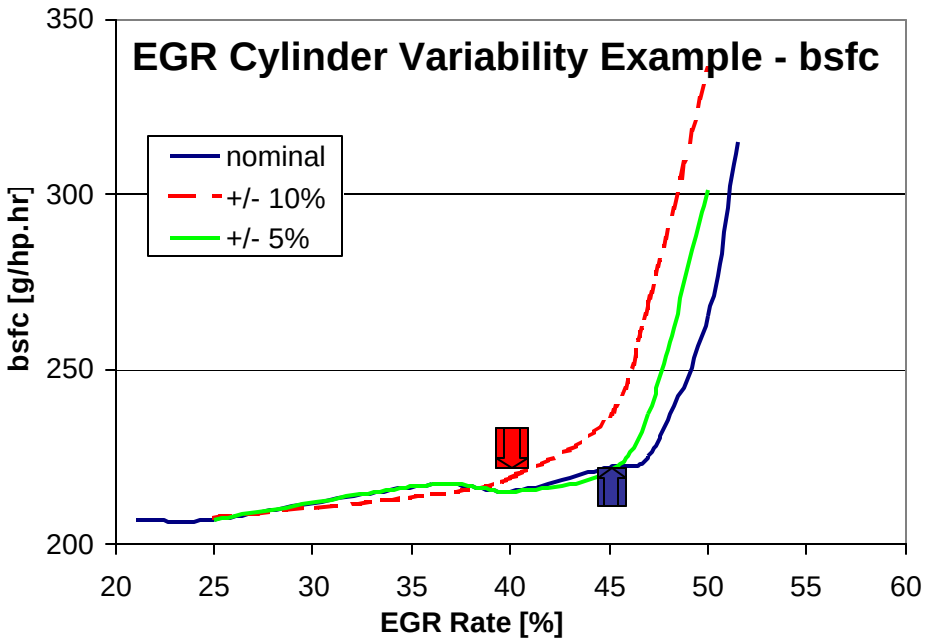
Variability

Variability Example

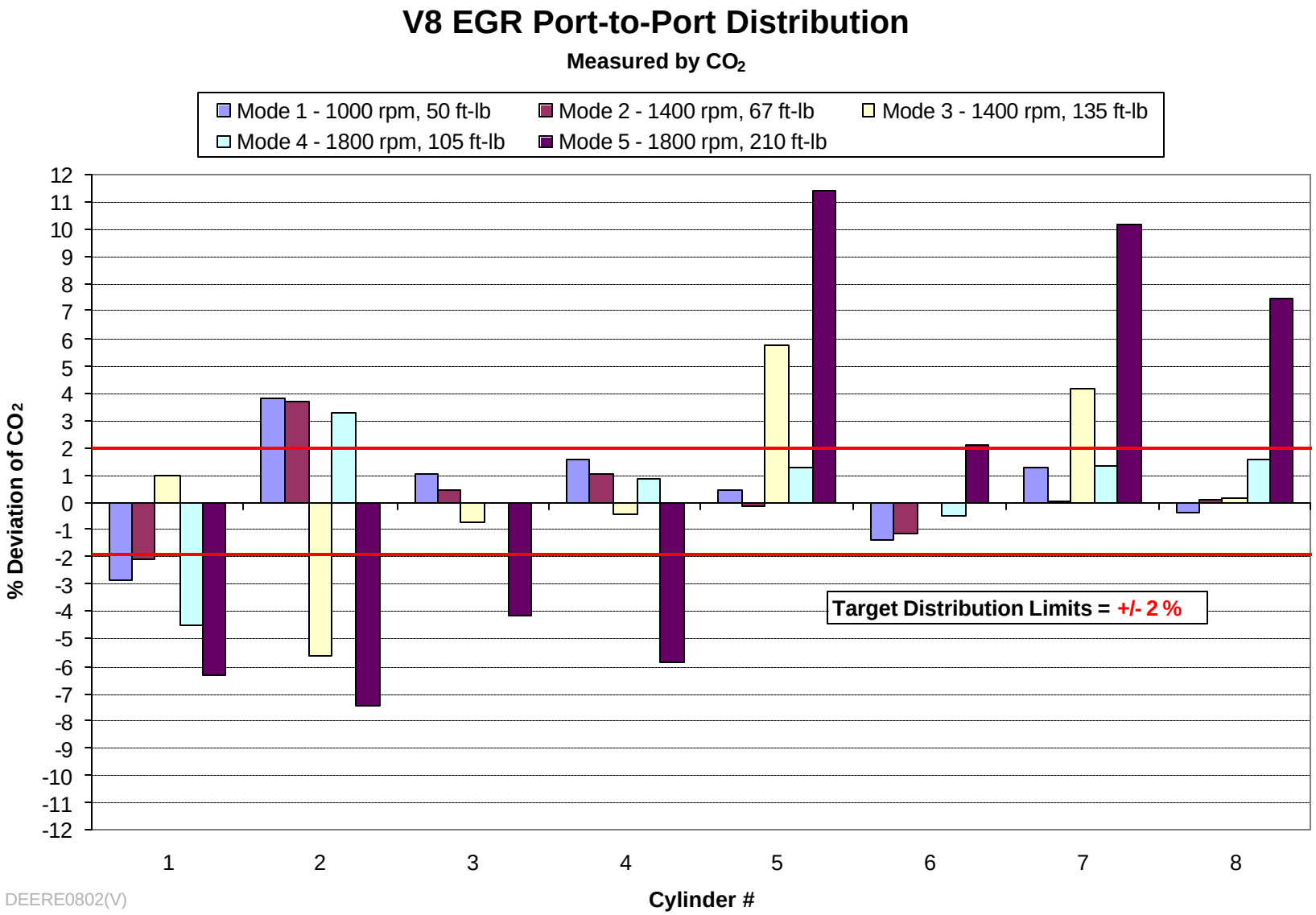
- **Engine condition 1500 rpm, 2.6 bar BMEP (~18 hp for V6-4.2)**
- **Consider a nominal target of 45% EGR**

	EGR,%	NO_x,g/hp-hr
- All cylinders nominal	**45**	**0.1**
- +/- 10% EGR target	**40**	**0.30**
- +/- 5% EGR target	**43**	**0.18**





EGR Measurements



Sources of Variability

- **EGR Distribution**
- **Swirl Port-to-Port**
- **Piston Bowls**
- **Spray Angle**
- **Spray Hole Size**
- **Shot-to-Shot Fueling & Timing**
- **Cylinder-to-Cylinder Air Flow**
- **Fuel**
- **Etc.**

Conclusions

- **Light Truck Diesel Family continues to show promise**
- **Fuel economy advantage is clear, approaching 60 percent**
- **Performance and sociability are gasoline-like**
- **Interim Tier 2 emissions, met using known technology**
- **Final Tier 2 emissions, demonstrated using advanced aftertreatment devices**
- **There is a path to market for the Light Truck Diesel**
  - **Cost/Robustness issues resolved**
  - **Variability issues minimized**