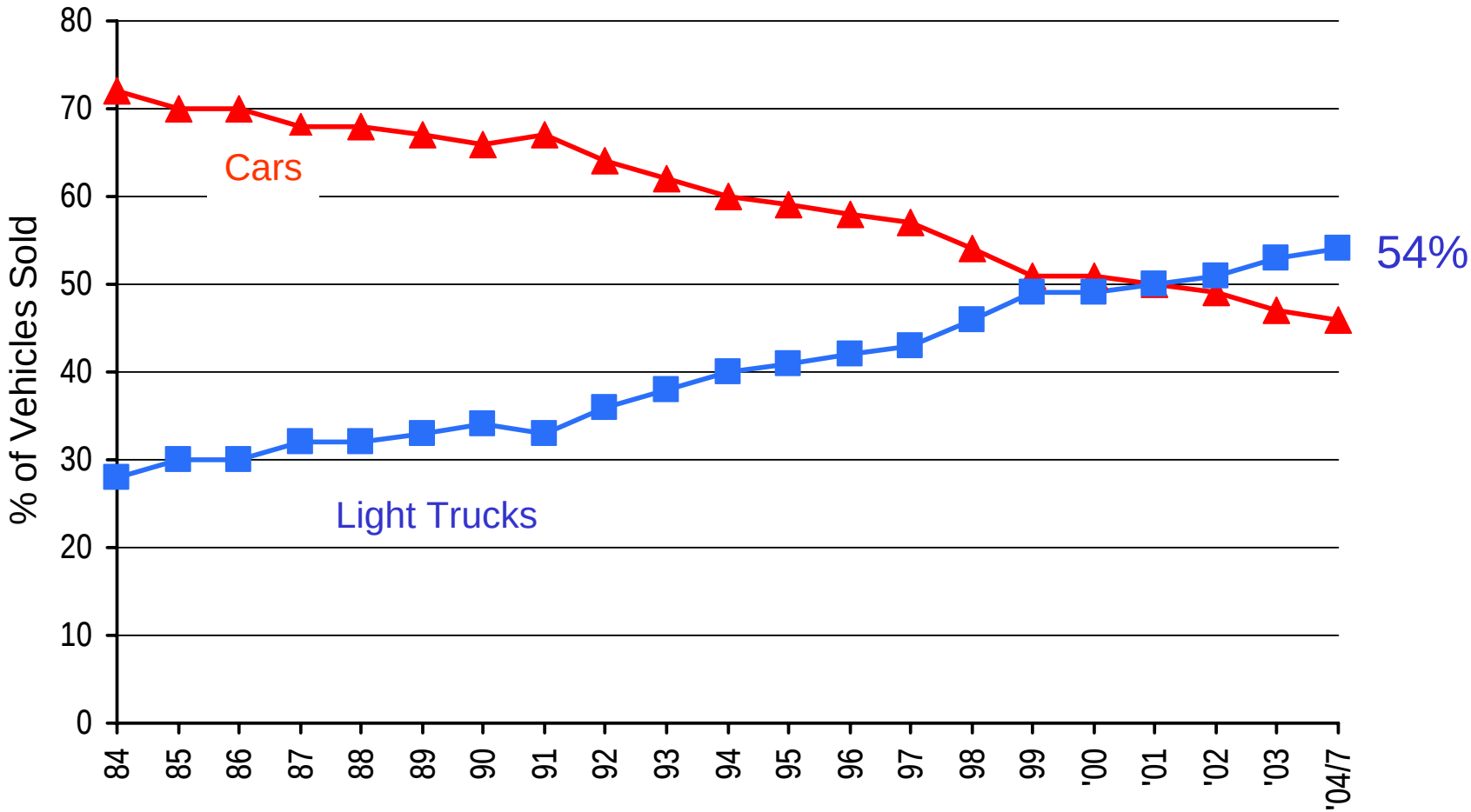
Cummins
Light Truck
Clean Diesel Engine

September 2004

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**
  - **Partnership funding from DOE**
  - **Vehicle and installation design assistance from Dodge Truck Engineering**
  - **Engine Development Team at Cummins**

US Passenger-Car & Light-Truck Market



Source - Automotive News

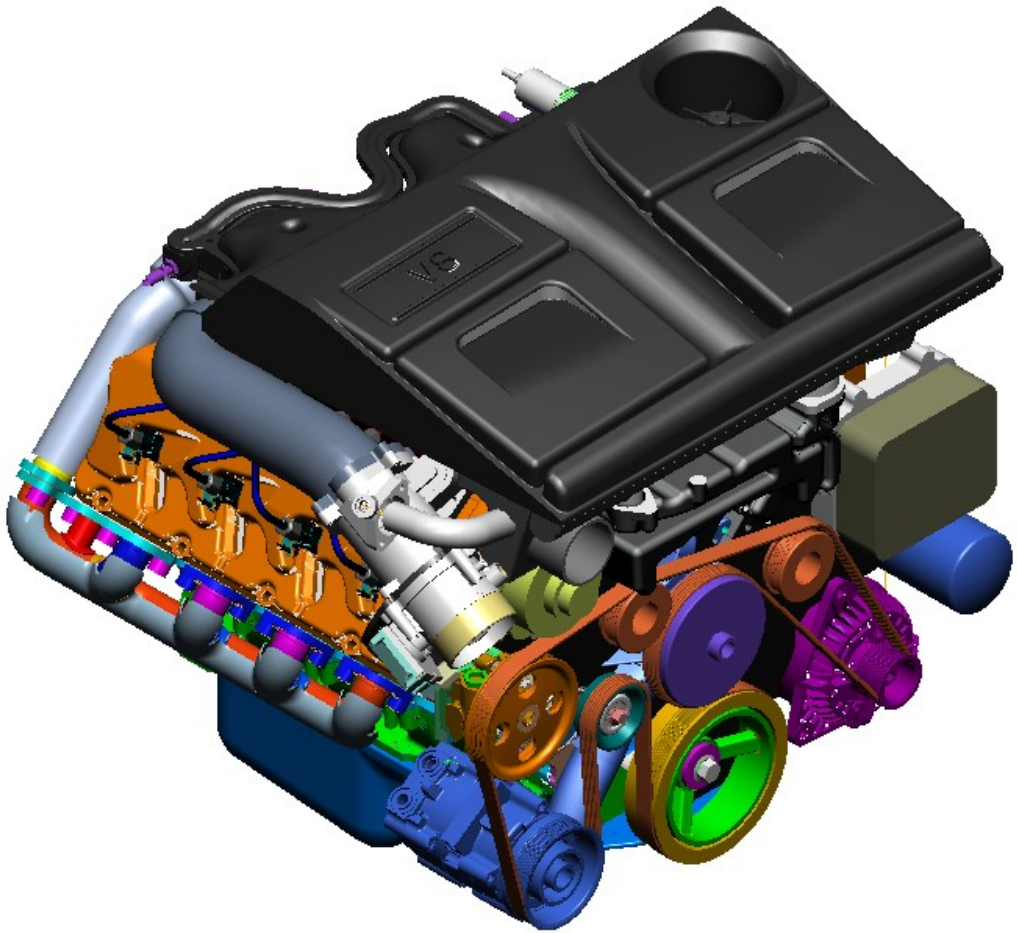
V Family Goals and Status

Description	Target		Actual (Status)	
	V6	V8	V6	V8
Emissions	EPA Tier 2 & CA LEV II		Tier 2 Bin 10 Interim Demonstrated, Tier 2 Bin 5 Final, Met in Vehicle	
Noise, dBa	69 Hood Open, Equal to Gas		72.7 db, Bare Engine in Test Cell	65.0 Interior, Cruise @ 65 mph, 1500 Pickup
Fuel Economy, MPG	50 % Better than Gas		22.1 Combined, Durango (+60%)	21.7 Combined, BR1500 (+60%)
Quality/Reliability	Equal to Gas, <2 RPH First Year and <10 RPH Five Years		Focus in Phase 3	
Rated Speed	4000 rpm (5000 max.)		4000 rpm (5000 max.)	
Useful Life km(mi)	B10 > 325,000 (200,000)		Focus in Phase 3	
Performance	Gasoline-Like (9-10 sec 0-60 mph)		9.6 sec, 0-60 mph, 5940 lb PTW	8.8 sec, 0-60 mph, 6200 lb PTW
Displacement, Liter	4.2	5.6	4.2	5.6
Power, kW(hp) @ rpm	190 (250) @ 4000	260 (350) @ 4000	189(254) @ 3600 WG 201(270) @ 3800 VNT	224 (300) @ 4000, Interim Target Met
Torque Peak, Nm(ft-lb)	455(335), 569(420) max.	597(440), 760(560) max.	569 (420)	623 (460)
Warm Up	75 C(167 F) Coolant in 10 min. @ -30 C(-22 F)		49C in 10 min @ -30C	Focus in Phase 3
Serviceability	Equal to Gasoline		No Adjustments, Diesel Fuel Flter Added	
Cold Start	< 20 sec. @ -30 C (-22F)		7.1 sec (1.2 sec Glow) @ -30C	Focus in Phase 3
Weight, kg(lb)	295 (650)	340 (750)	301 (663)	357 (788)

Meets Goal

Partially Meets Goal; Plan in Place

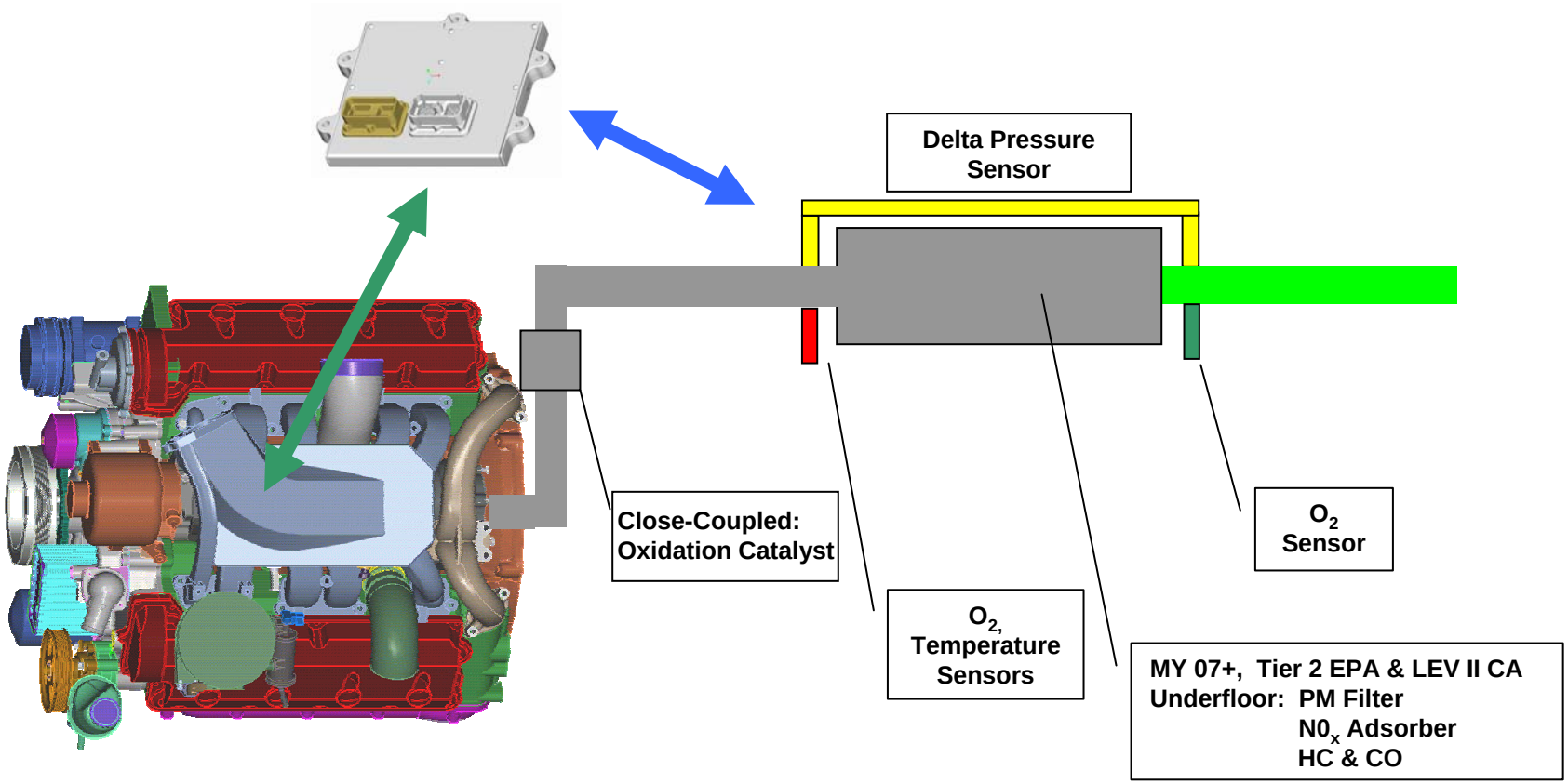
Phase 3 Engine with Integrated Air Cleaner



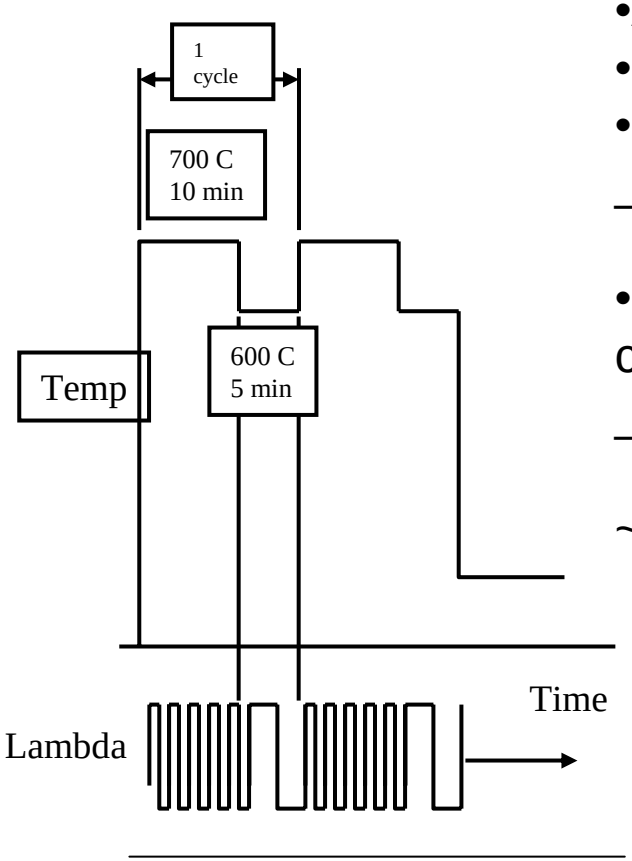
Light Truck Diesel Subsystem Description

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 4-Way Catalyst (Tier 2, Bin 5)
Aspiration	Variable-Nozzle or Wastegated turbocharged
Intercooling	Vehicle mounted air-to-air
Block	Cast iron, thin-walled
Head	High temperature alloy aluminum
NVH Control	Ladderframe
Accessories	Common automotive V-8 gasoline
Accessory Drive	Single serpentine belt, self-adjusted

Prime-Path-System with 4-Way Catalyst System



Catalyst Aging Cycle Description



- Average Fuel Sulphur Level = 9.5 ppm, 20 mpg
- Average Oil Sulphur Level = 4000 ppm, 25K miles/qt
- 3.6 ltr NOx adsorber
- Sulphur Tolerance of 1 gm-S/ltr catalyst

- One DeSOx cycle per ~2200 miles (~110 gallon fuel consumed)

~ 68 DeSOx cycles prior to 150K emissions check

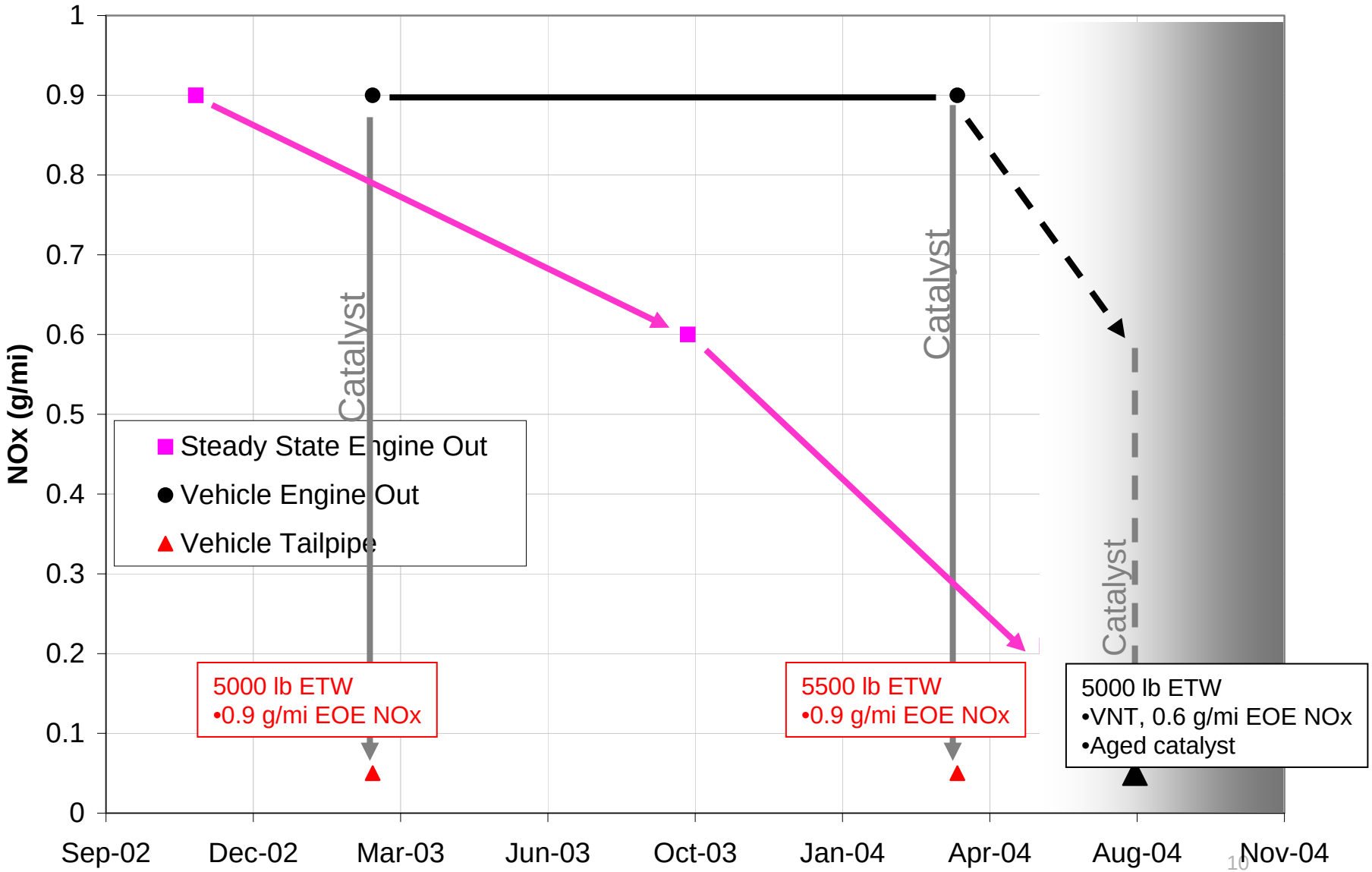
Chassis Test Results - Bag Results
V6 - 5000 lb. - 12.7 hp@50 mph

Test	CO [g/mi]	CO2 [g/mi]	NOx [g/mi]	NMHC [g/mi]	FE [mpg]	PM [g/mi]
FTP-75 FUL limits	4.2	-	0.07	0.090	-	0.01
FTP-75	0.399	480.27	0.033	0.089	21.12	0.006
FTP-75	0.367	491.67	0.038	0.056	20.32	-
	0.241	519.18	0.074	0.043	19.16	-
bag 1	0.971	547.87	0.141	0.222	18.47	0.008
	1.051	583.44	0.181	0.269	17.08	-
	1.121	578.14	0.243	0.207	17.15	-
bag 2	0.272	475.03	0.003	0.057	21.37	0.004
	0.200	475.27	0.000	0.000	21.04	-
	0.060	517.34	0.002	0.001	19.24	-
bag 3	0.207	439.17	0.009	0.049	23.11	0.007
	0.166	453.40	0.003	0.000	22.05	-
	0.018	478.05	0.080	0.000	20.83	-

- Start
- 1600 mi
- Aged & Alt.

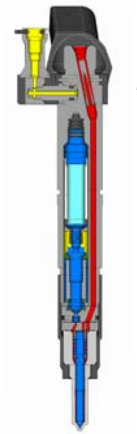
~150,000 mi
5400 ft

V6 Emissions Progression

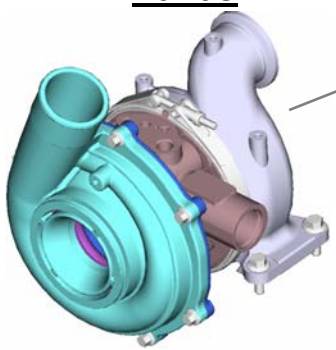


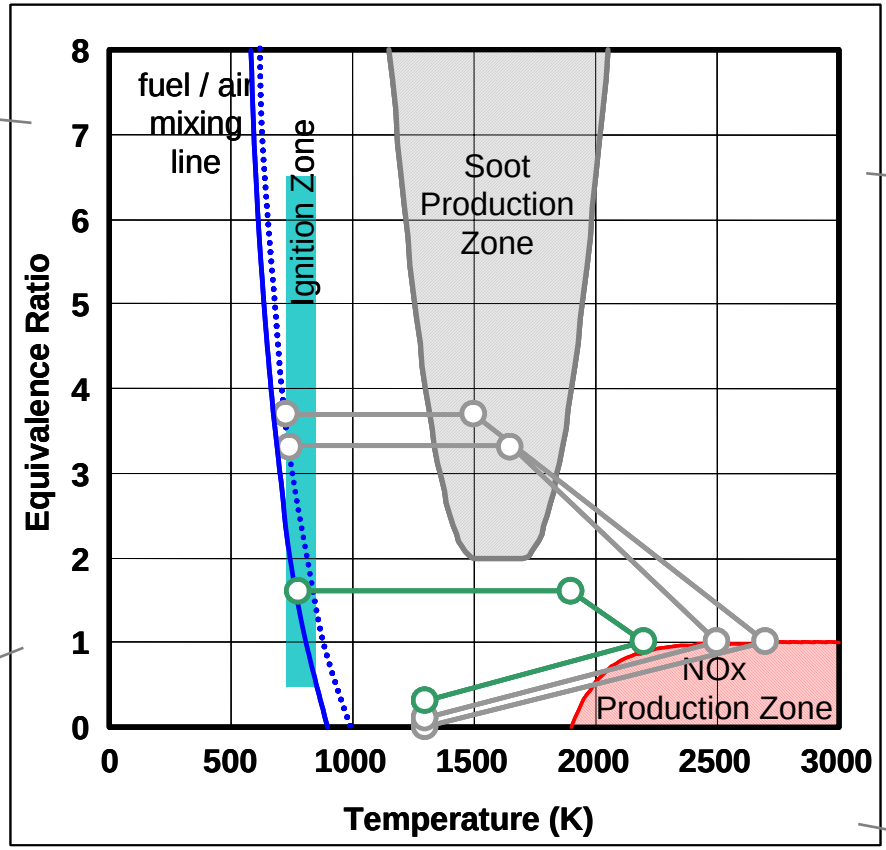
Combustion Parameter Development

Gen 3 Piezo Fueling

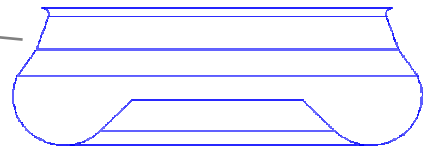


Variable-Nozzle Turbo

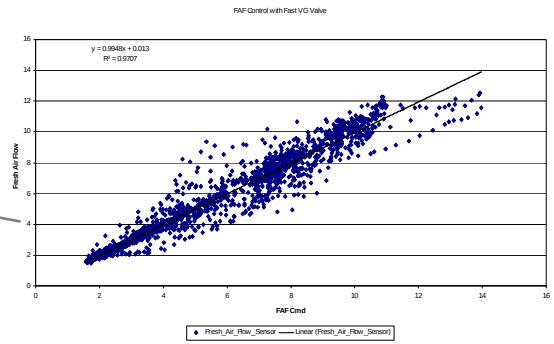




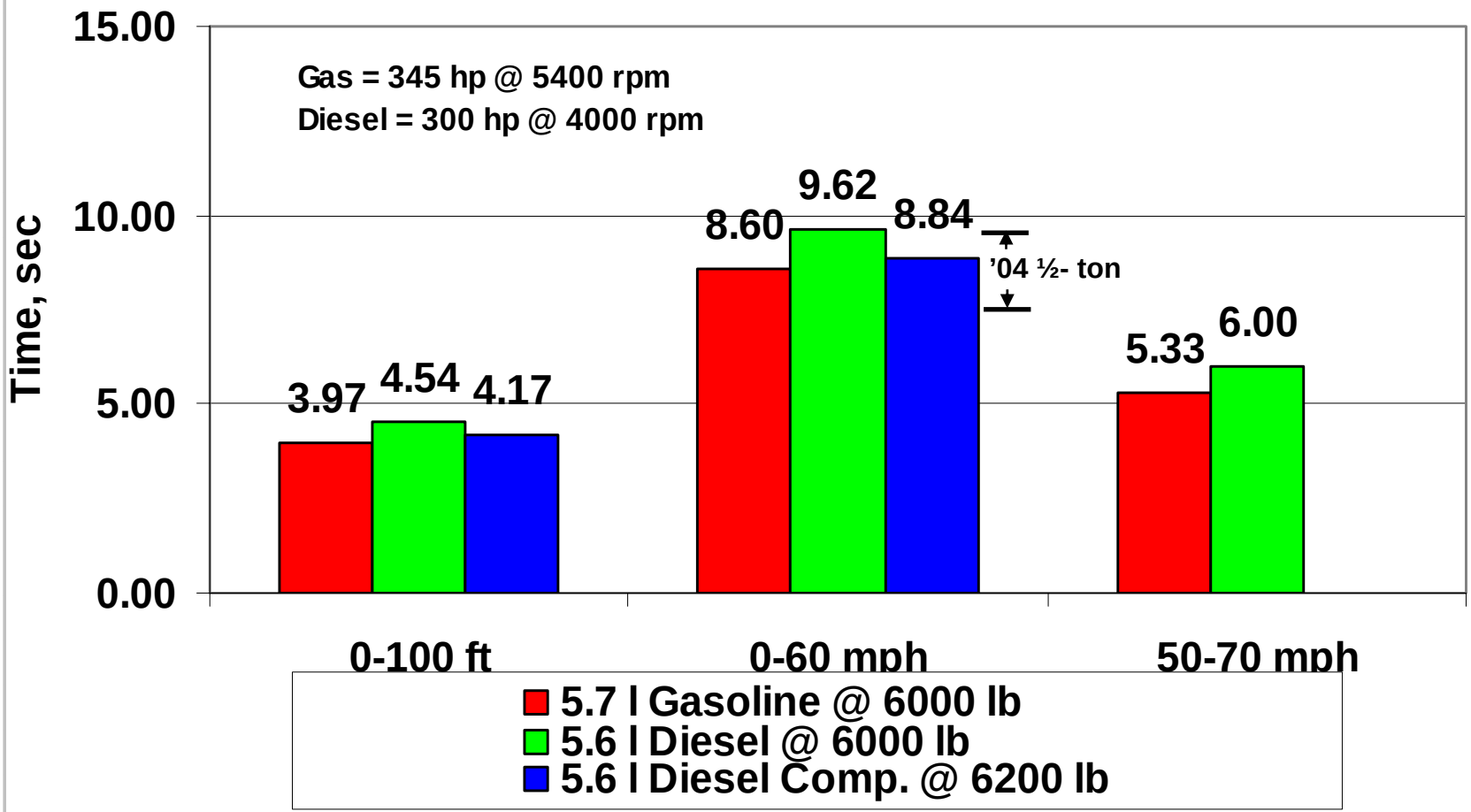
Advanced Combustion



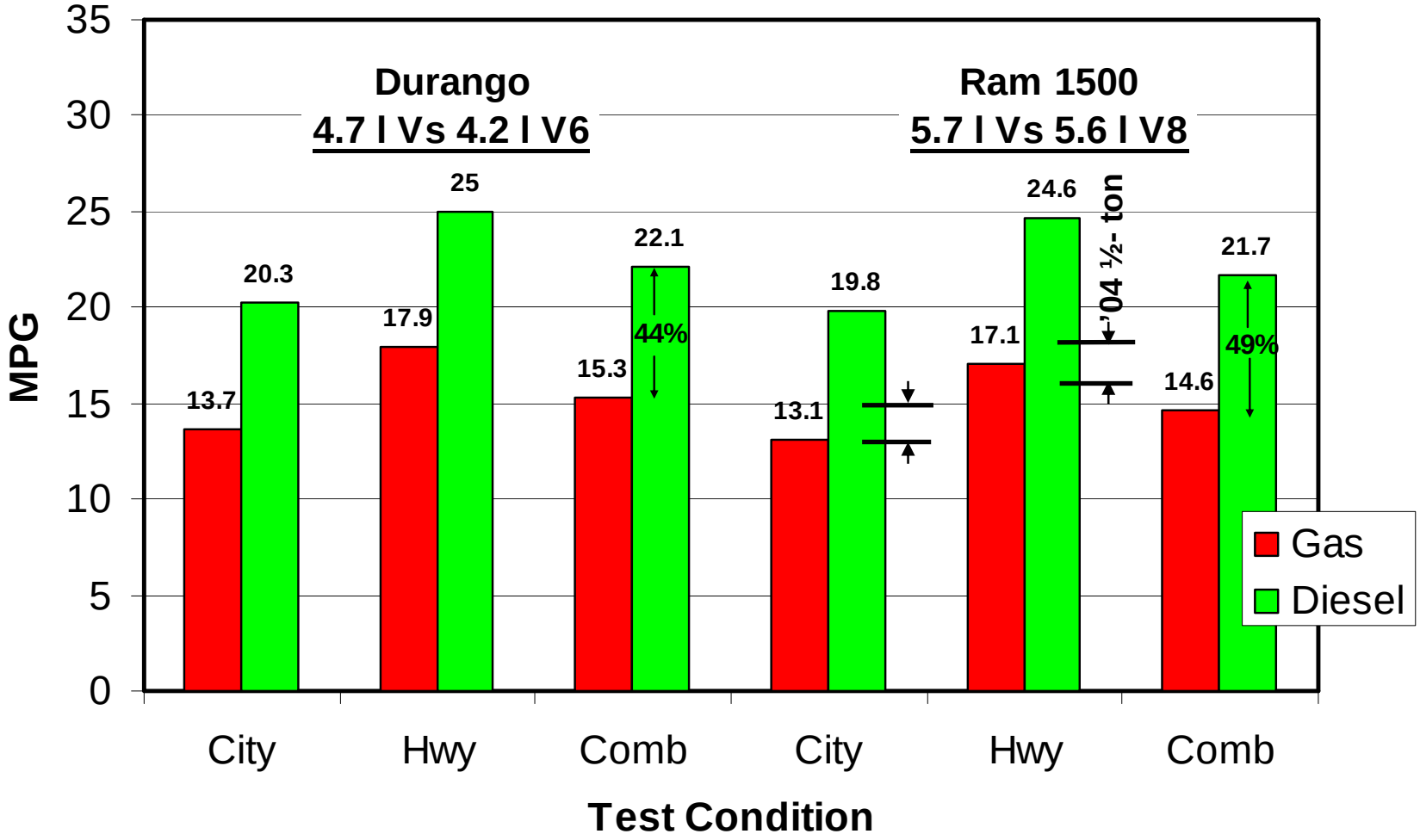
Precise Air Handling



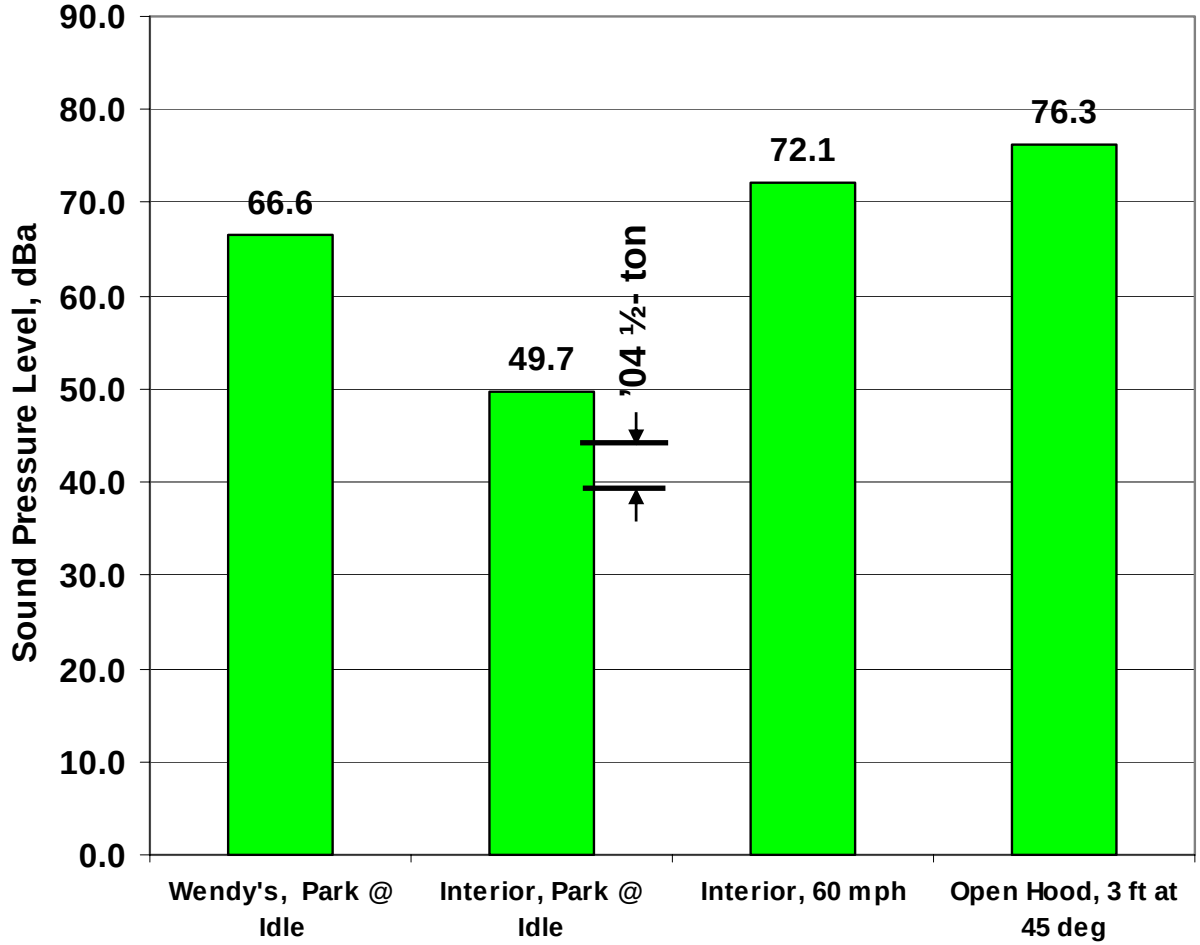
Acceleration Test Results



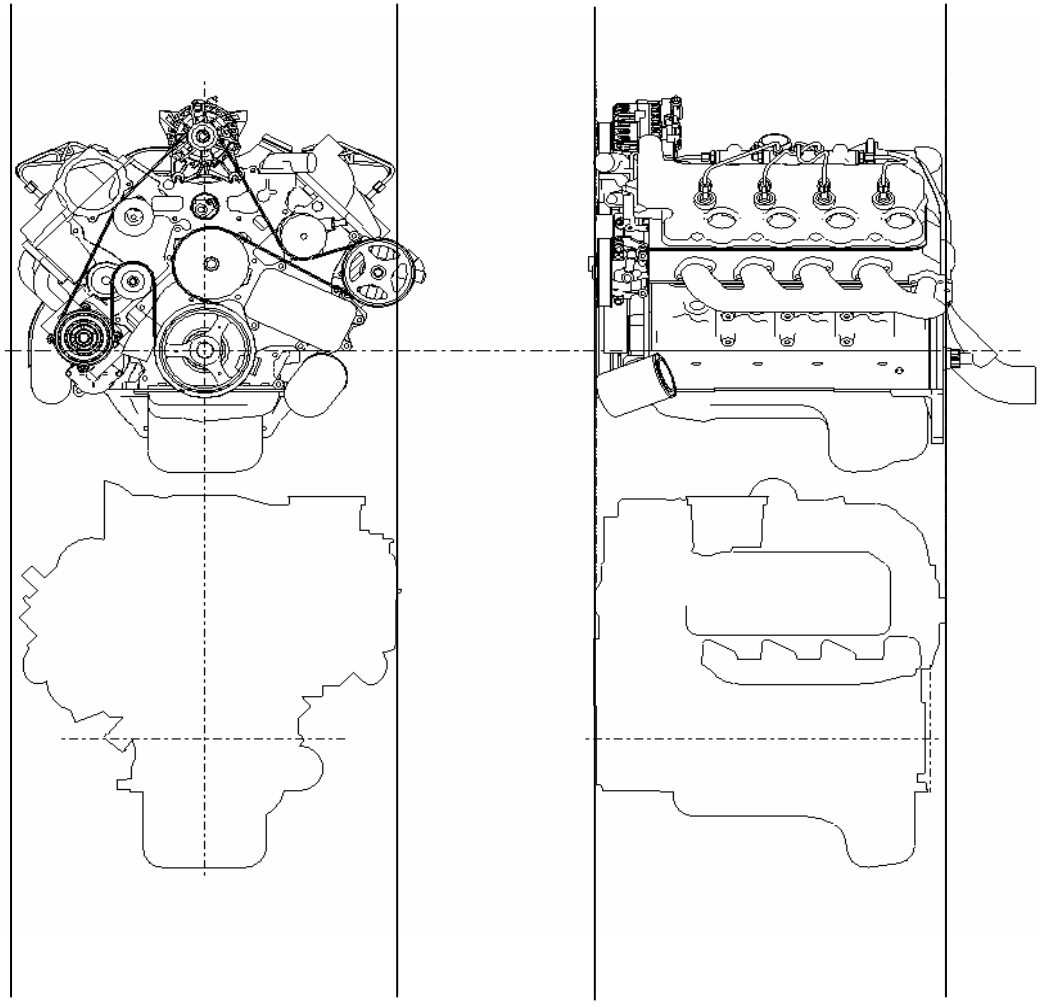
Fuel Economy Results



Noise Test Results V8 in Ram 1500



Comparison Phase 2 V6 vs Phase 3 V8



Base Engine Durability & Stability

- Cost Focused Areas

	Same as Gasoline	Gasoline Supply Base	Common V6/V8/ISB	V6/V8 Specific
Balance Shaft				
Cylinder Block				
Crankshaft				
Damper				
Power Cylinder				
Sensors				
Rear Seal Carrier				
Oil Pan				
Front Cover				
FEAD				
Chain Drive				
Turbocharger				
Exhaust Manifold				
Intake Manifold				
EGR System				
Fuel System*				
Valve Cover				
CCV System				
Cylinder Head				
Valve Train				

*** Based on high-volume European diesel usage**

Conclusions

- **Light Truck Diesel Family continues to show promise**
- **Customer features:**
  - **Performance, comparable to Top Rated gasoline**
  - **Fuel economy, advantage 44-49% (improves CAFE)**
  - **Noise, approaching gasoline**
  - **Smoke and odor, eliminated**
- **Cost approached on a fundamental basis**
  - **Lower Engine-Out Emissions**
  - **High-Volume Gasoline Supply Base**
- **Final Tier 2 emissions, met in a complete vehicle system**
- **There <u>is</u> a path to market for the Light Truck Diesel**