100,000-Mile Evaluation of Transit Buses Operated on Biodiesel Blends (B20)

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Diesel Engine-Efficiency and
Emissions Reduction Conference
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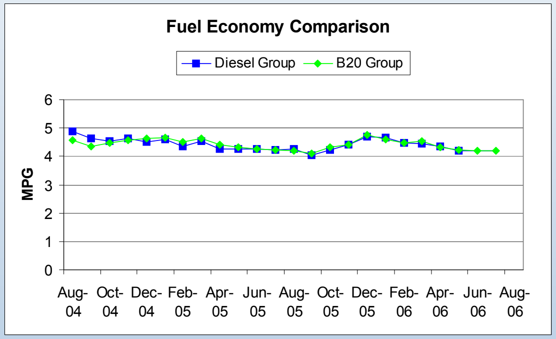
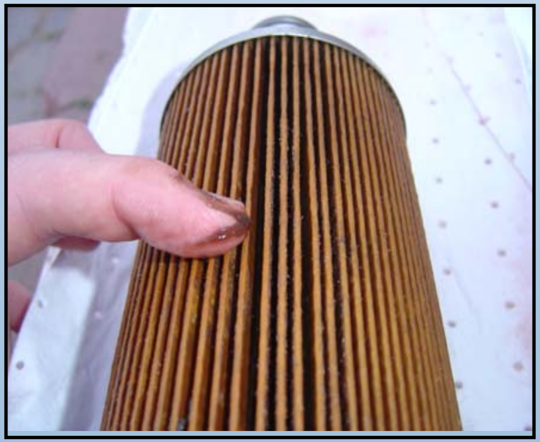
Agenda

- Project objectives and approach
- Mileage accumulation, fuel economy
- Road Calls and Maintenance
- Fuel, fuel filter analysis
- Oil analysis
- Chassis dynamometer emission results
- Conclusions

B20 Fleet Evaluation – Objectives

- Compare vehicles operating in the field on B20 and conventional diesel over 24 months:
  - Engine performance
  - Fuel economy
  - Vehicle maintenance cost
  - Fuel-induced variations in operation and maintenance
  - Lube oil performance
  - Emissions



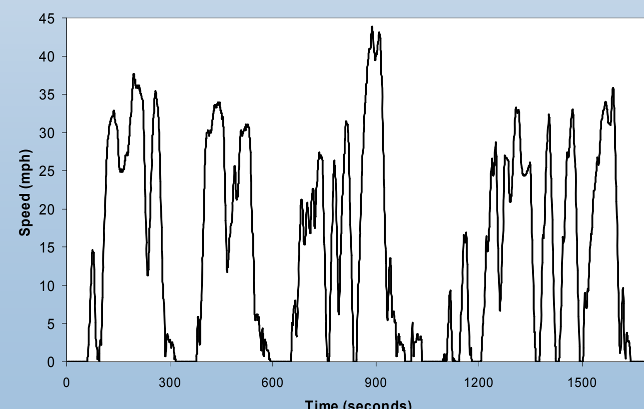


- Exhibit high degree of experimental control in vehicle selection and duty cycle
- Aid engine OEMs in exploring affects of B20 on engine durability
- Aid potential B20 users in understanding costs, benefits, and differences in operation

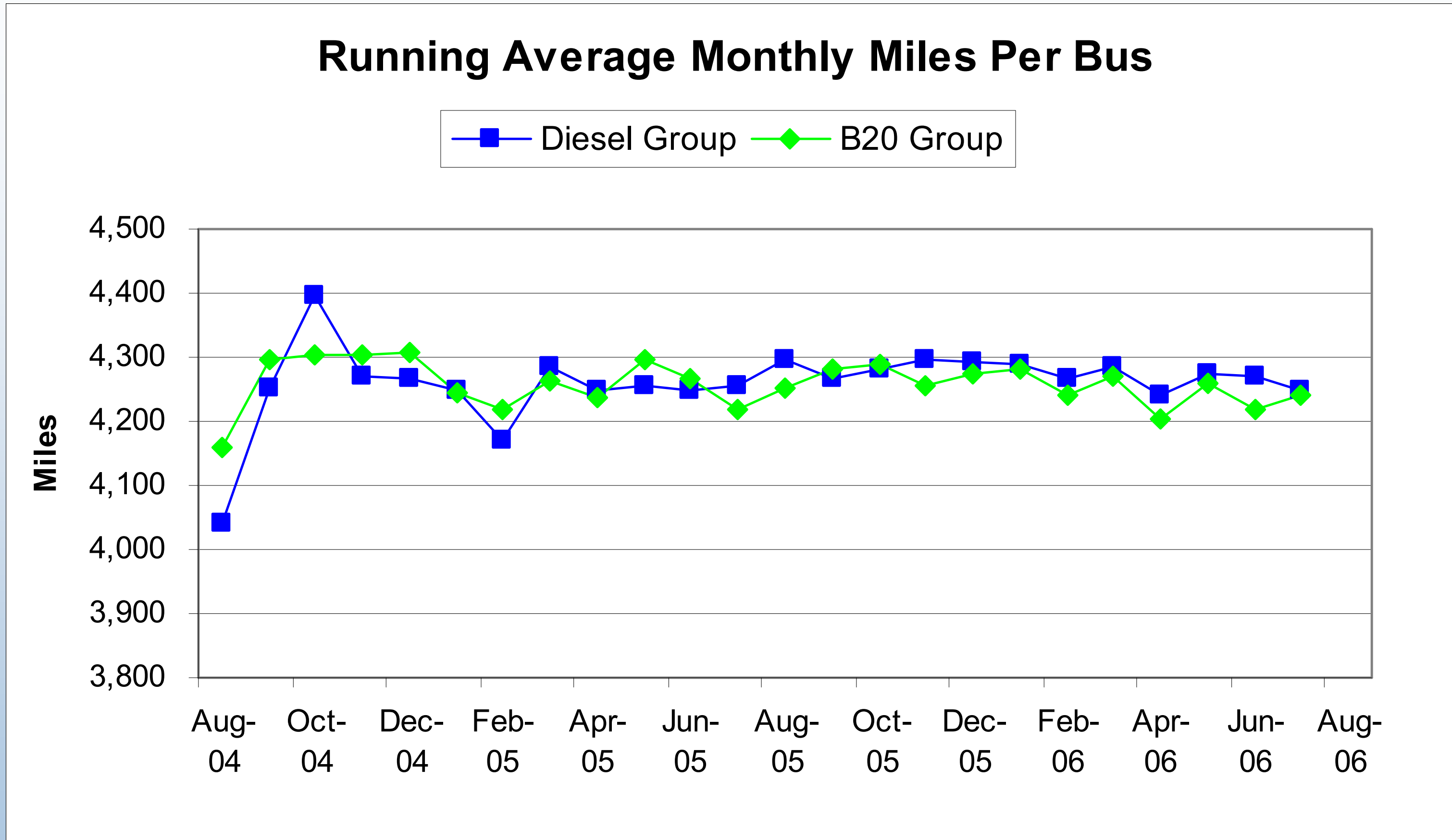
B20 Fleet Evaluation – Approach

- 9 mechanically identical Denver RTD transit buses:
  - 2000 Orion V; Cummins ISM
  - 5 operated on B20, 4 on diesel
- Dedicated to Skip Route in Boulder – identical duty cycle
- RTD submitted data electronically from their internal database
  - Fuel, Labor, Parts
- In-use fuel economy and maintenance costs analyzed by NREL

- Fuel delivery and vehicle tank sample analysis
- Periodic oil sampling at drain interval and analysis
- Two study buses emissions tested on chassis dyno at NREL's ReFUEL facility

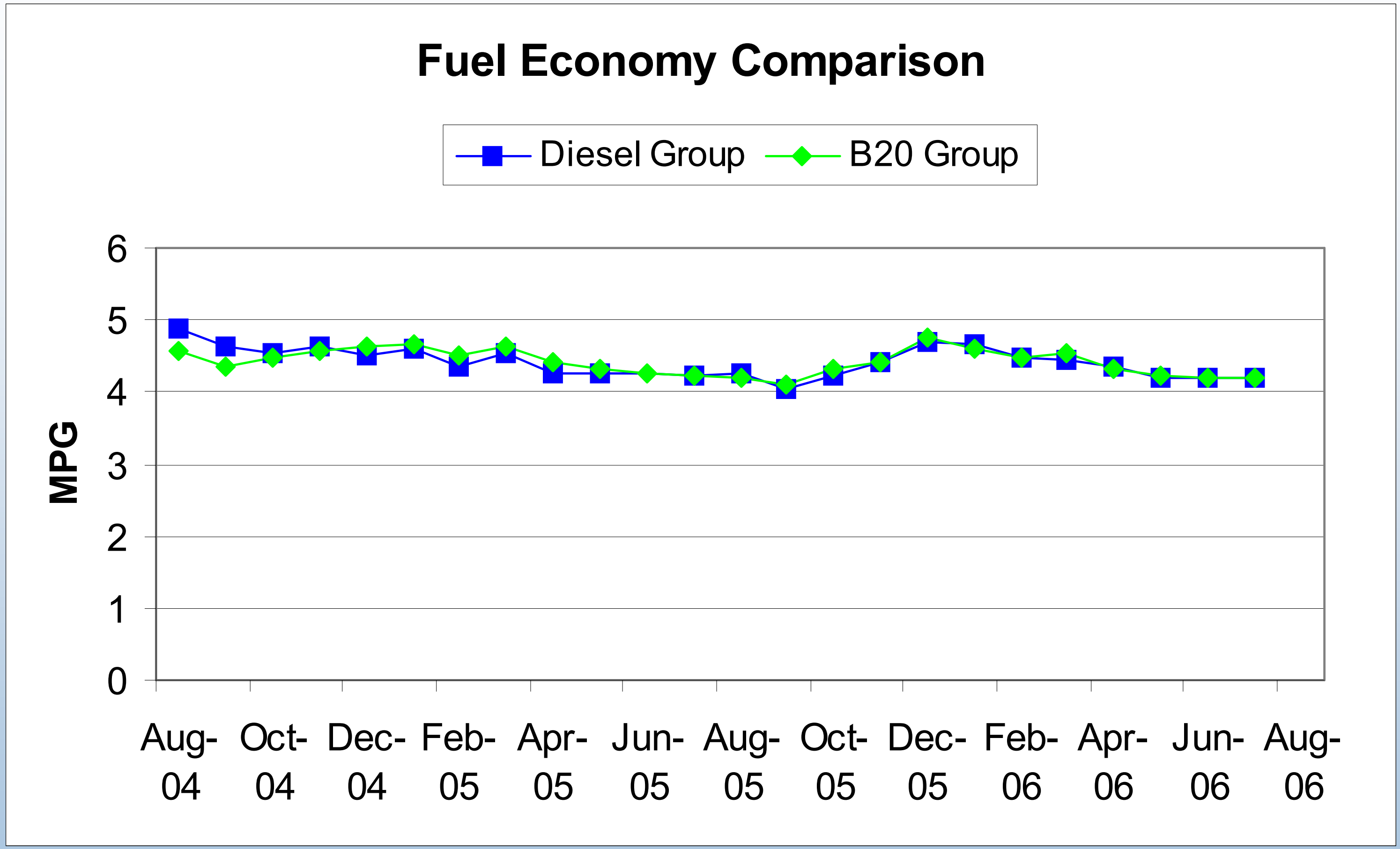


Mileage Accumulation



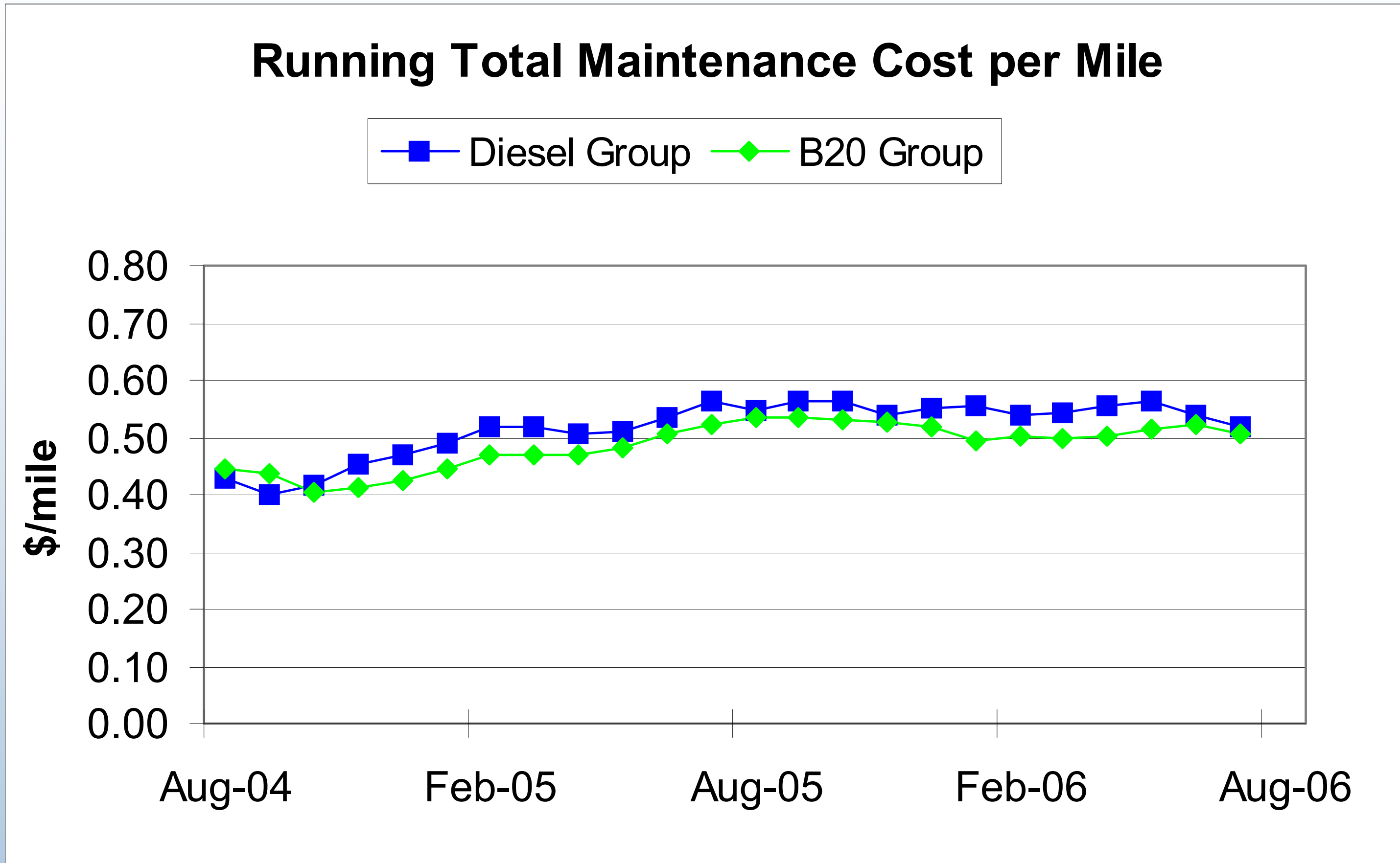
- 4,200 miles per month per bus

On-road Fuel Economy



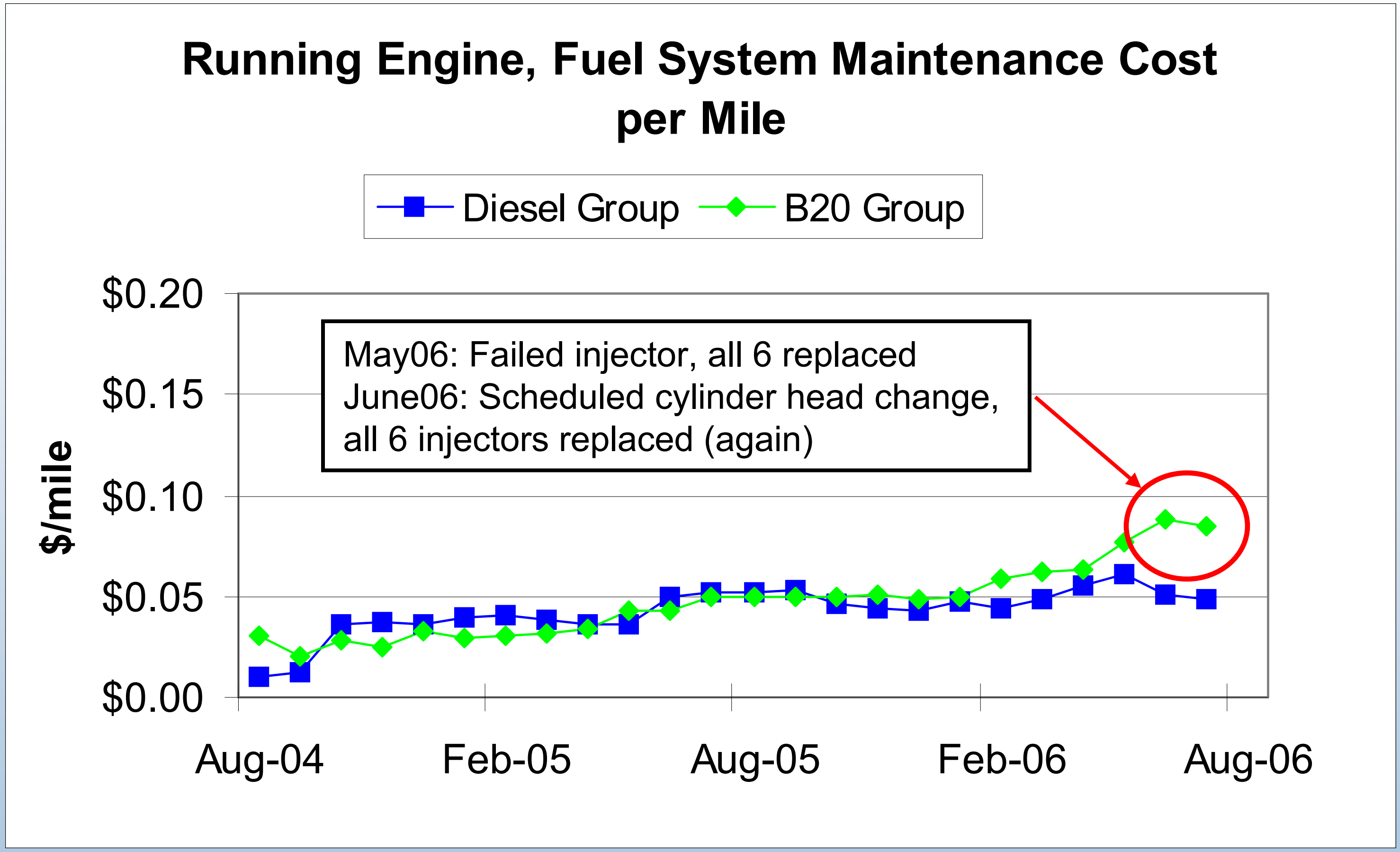
- 4.41 mpg Diesel, 4.41 mpg B20

Maintenance Costs - Total



- 24-month average maintenance costs:
  - $0.54/mile Diesel, $0.51/mile B20
  - Diesel transmission repairs drive difference

Maintenance Costs – Engine, Fuel System



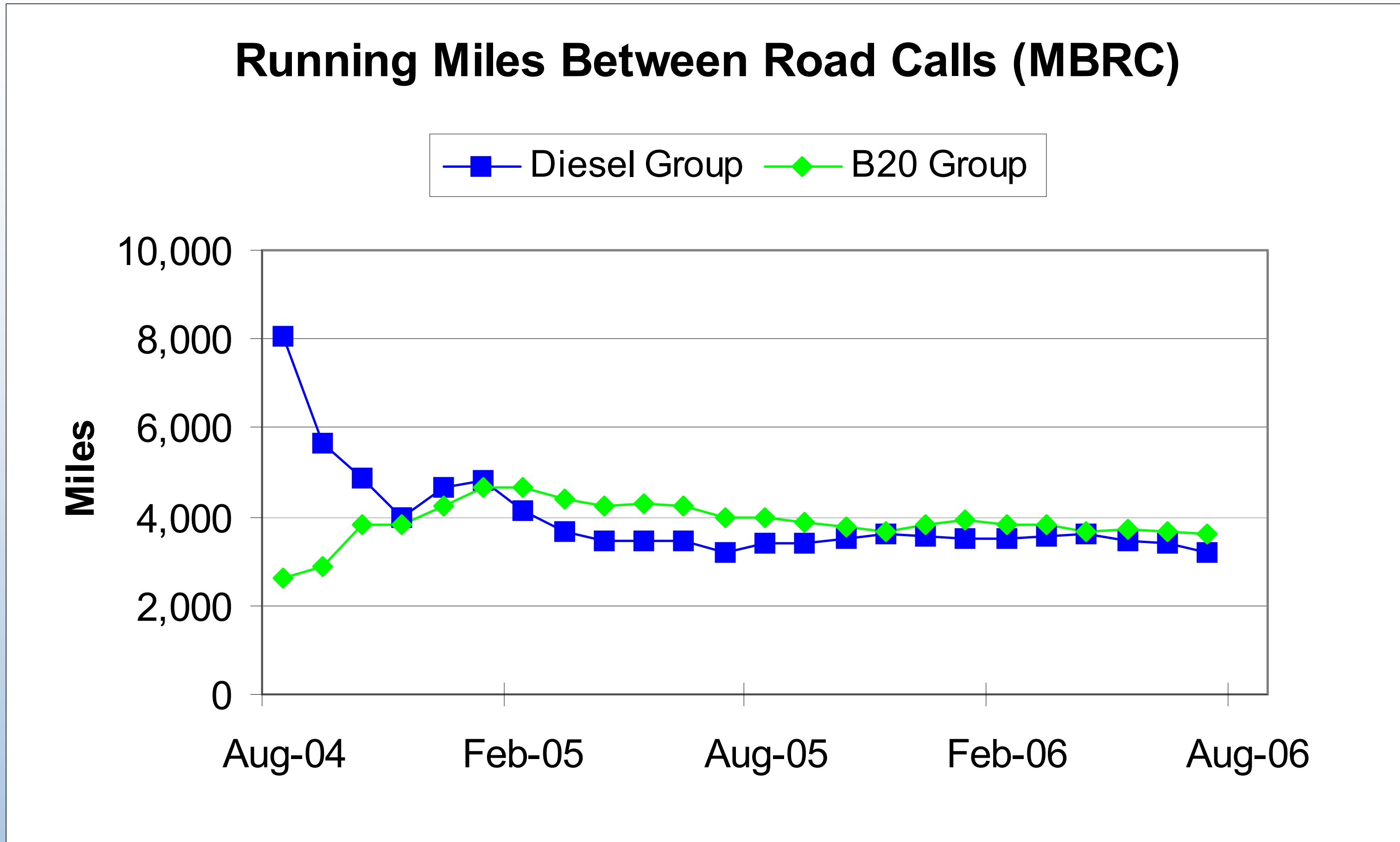
- 24-month average engine and fuel system maintenance costs:
  - $0.05/mile Diesel, $0.07/mile B20

Maintenance Costs – Engine, Fuel System

	Diesel	B20
Fuel pump	2	1
Fuel injector	1	13

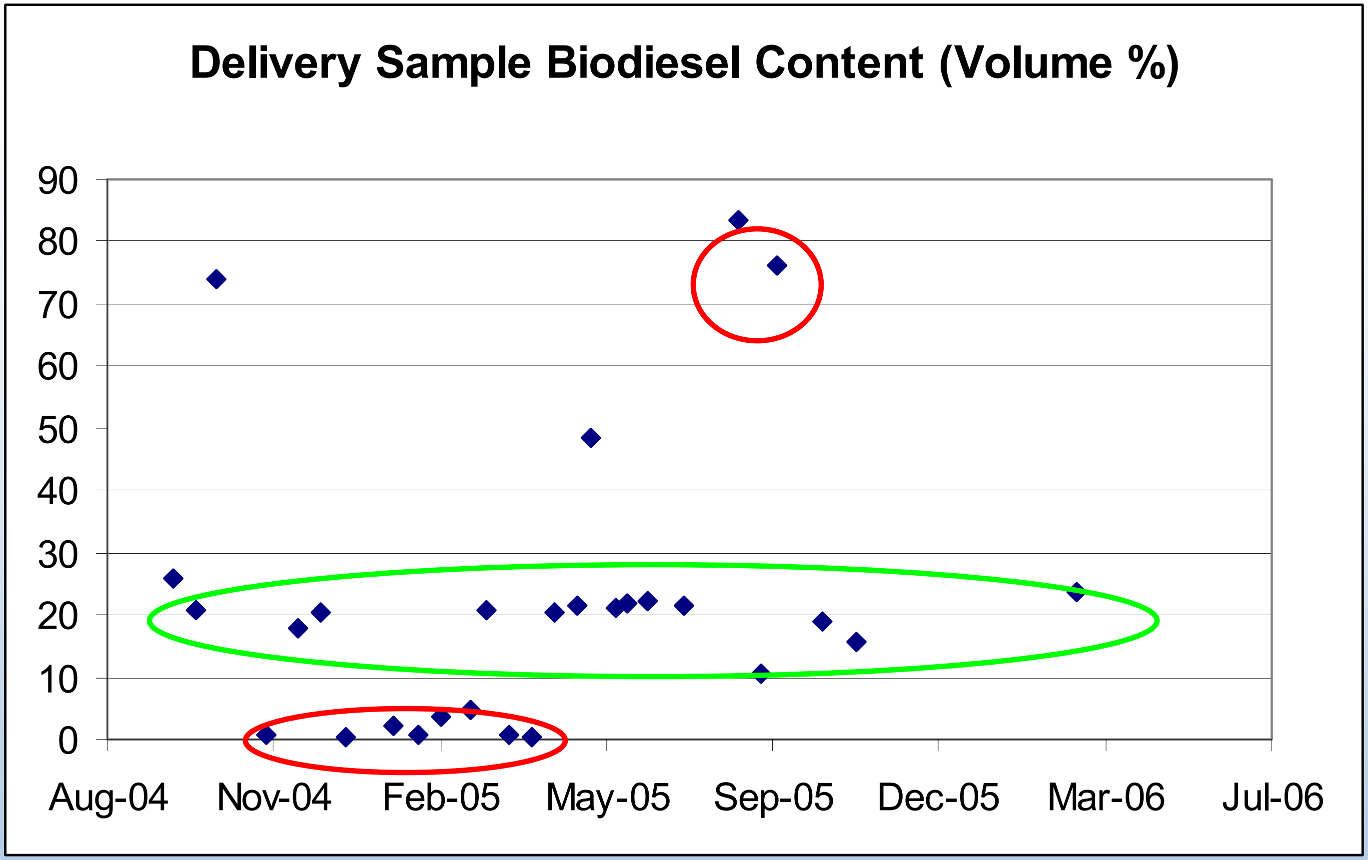
- Injector discrepancy driven by replacement of full set, then cylinder head replacement
- No reason to suspect B20 fuel currently
  - – Further investigation planned

Road Calls



- Average MBRCs are comparable
  - 3,197 Diesel, 3,632 B20

Fuel Analysis



- Biodiesel content of delivery samples scattered
  - Changes to fuel blending & sampling implemented May ‘05
- Vehicle samples taken are near B20
- **Knowledge of sampling point is important**

Fuel Analysis

- March 2006 vehicle fuel sample analysis
  - Acid value, peroxides, aldehydes (alkanals) determined by Saftest™
  - Acid value and peroxides consistently low as compared to NREL B20 fuel quality survey
  - Alkanals indicate some oxidative degradation, but are not high

Vehicle Number	B100 Content Volume %	Acid Value mgKOH/g	Peroxide Saftest™ ppm	Aldehyde Saftest™ mmol/mL
2207	20.3	<0.1		58.212
2208	18.4	<0.1	13.22	57.902
2209	17.4	<0.1	11.59	55.696
2210	18.7	<0.1	16.75	73.35
2211	19.7	<0.1	11.42	61.546

Fuel Analysis

- Composite March 2006 vehicle fuel samples had more detailed analysis
  - Higher cetane number
  - Lower sulfur content
  - 2.4% lower B20 energy content

Analysis	ASTM Method	B20 Composite	Diesel Composite
Water & Sediment vol %	D2709	0.01	0.01
Cloud Point ºC	D2500	-13	-14
Sulfur ppm	D5453		**324**
Sulfur ppm	D2622	**272**	
Aromatics vol %	D1319		25.6
Olefins vol %			1.3
Saturates vol %			73.1
C mass%	D5291	84.7	86.6
H mass%		12.9	13.2
Derived Cetane Number	D6890	**51**	**48**
LHV BTU/lb	D240	**17,860**	**18,307**

B20 Fuel Filter Plugging

Three filter plugging events:

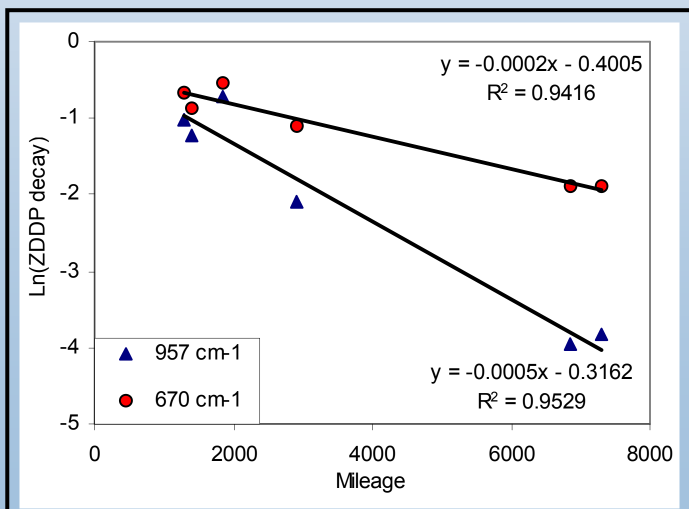
1. April 2005 – 2 buses
   - Brown slime
   - Unknown cause
   - Biocide applied to next fuel delivery

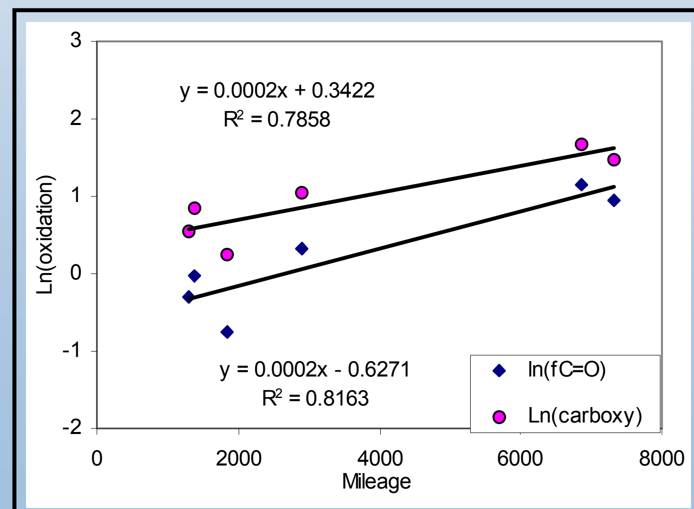
Bus	% Biodiesel	CFPP ºC	Water (ppm)	Bug Alert™
2207	18.4	-24	72	139 (med)
2208	16.9	-25	77	27 (low)
2209	19.2	-25	88	57 (low)
2210	20.3	-25	97	1 (very low)
2211	15	-30	78	93 (low-med)

2. June 2005 – 1 bus
3. July 2006 – 2 buses
   - B20 storage tank low in both cases
   - Sediment plugged dispenser and fuel filters

Lube Oil Analysis

- One set of oil drain samples (March, April 2006) analyzed by Cummins
- Exponential decay of ZDDP and TBN consistent with previous Cummins testing
- No difference in ZDDP decay between diesel and B20 samples
- TBN decay may be occurring more slowly in B20 samples





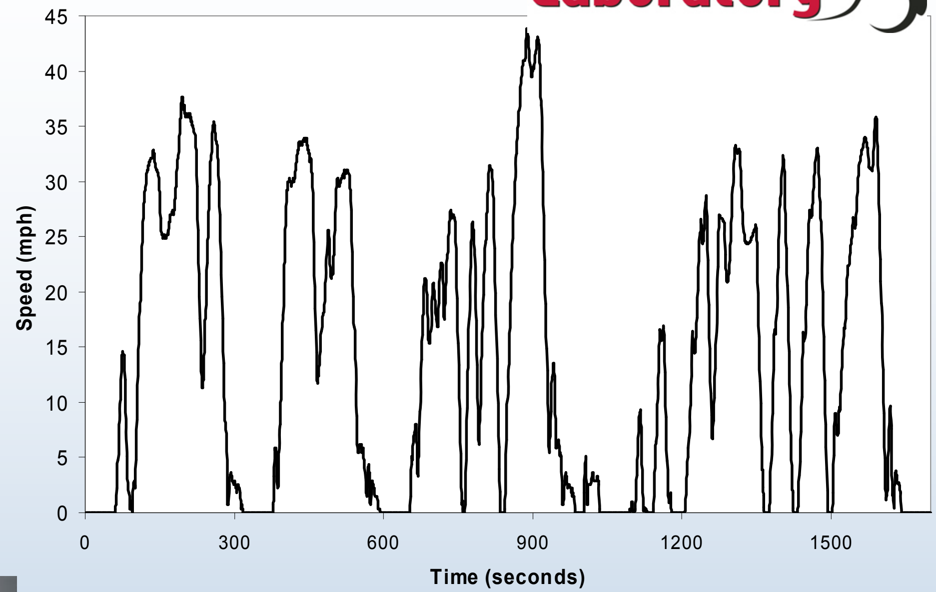
Lube Oil Analysis (cont'd)

	Diesel	B20
Fuel Dilution	Low	Lower
Metals (evaporative)	No difference	
Metals (engine wear)	Low	Lower @ high mileage
Soot	Low	50% lower
Viscosity, viscosity index	No difference	

Bus Chassis Dynamometer Testing

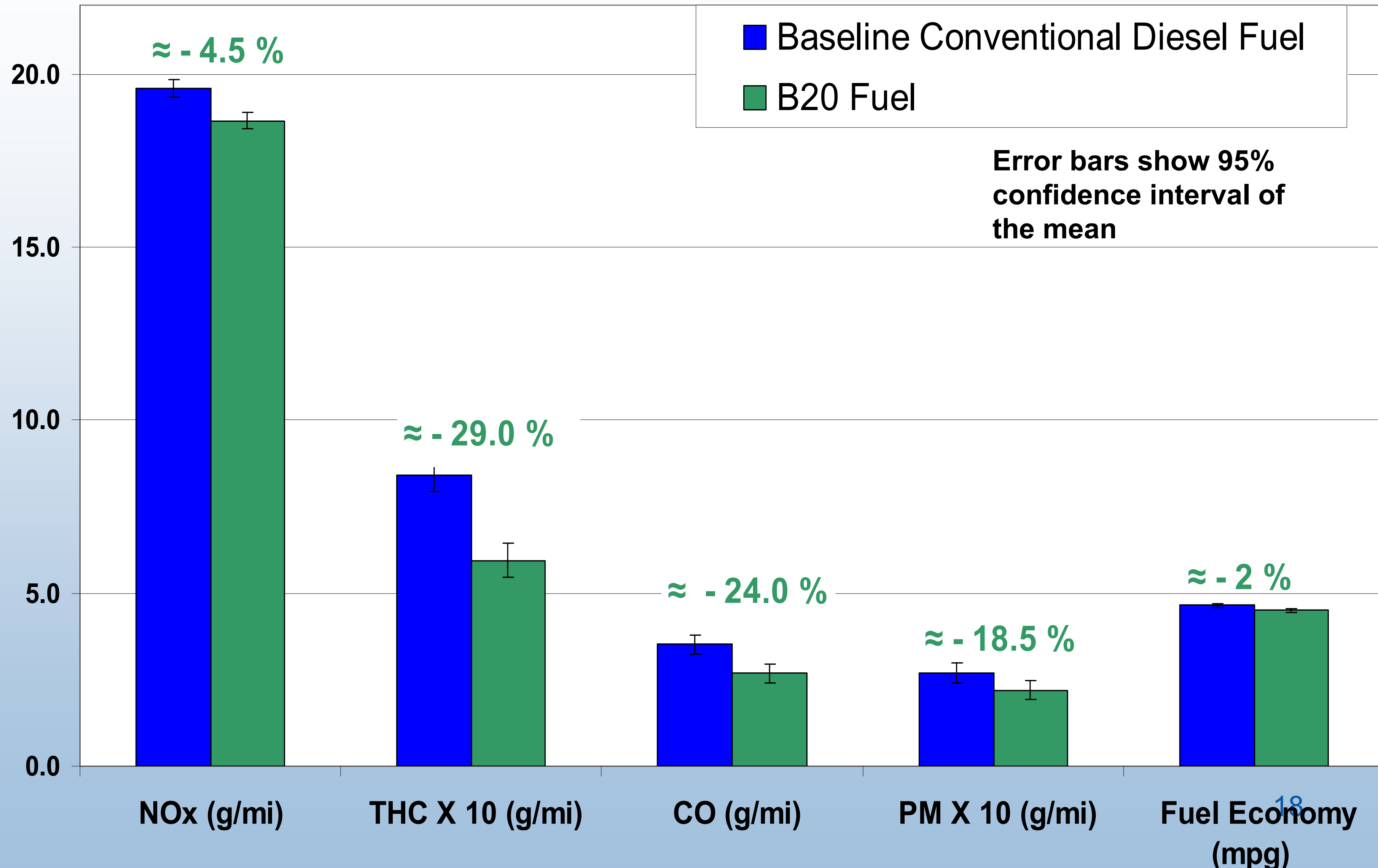
ReFUEL Laboratory

- 2 In-Use Buses tested
- Cummins ISM 2000 Engine – No EGR
- In-Use B20 vs. Conventional Diesel Fuel



	Skip Bus Route	CSHVC
Avg Speed	15.6 mph	14.2 mph
Max Speed	40 mph	44 mph
Stops/mile	0.78	0.75

Bus Chassis Dynamometer Test Results



Conclusions

- Usage – average mileage comparable
- On-road fuel economy – no significant difference
- Road calls – similar for both groups
- Total maintenance costs – similar
- Fuel System and Engine maintenance costs – no significant difference
- Early B20 splash-blending issues, generally B20 in-tank
- Limited lube oil data suggests no harm with B20 use, some potential benefits
- Significant emissions reductions including NOx

Special Thanks

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