

Fleet Performance Results Using Biodiesel (B20)

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NREL's Fleet Test and Evaluation Team

- Focused on evaluating advanced technologies in medium and heavy vehicle applications
- Main goals:
 - Facilitate the transition of advanced technologies from R&D to the marketplace
 - Provide potential users with accurate and unbiased information on vehicle performance and costs
- Completed B20 fleet projects
 - United States Postal Service (USPS) engine teardown
 - Denver Regional Transportation District (RTD) bus evaluation
- Biodiesel Blend Evaluation Team – Active Projects
 - USPS Cargo Vans
 - St. Louis Metro Transit Buses
 - Water Separator Working Group

USPS Engine Analysis – Description

- Comparison of engines and fuel systems operating on B20 to diesel
- Eight Postal Service vehicles total from Southern Florida fleets
 - Four 1996 Mack tractors
 - Four 1993 Ford cargo vans
- Engine and fuel system teardown
 - Measured component wear
 - Sludge analysis
- Maintenance history analysis
 - Engine and fuels system costs



USPS Engine Analysis – Results

- No major differences noted between B20 and diesel
- Measured wear considered normal for accumulated mileage
- Sludge noted on top of cylinder heads of Mack B20 engines
- Fuel injector wear in Mack B20 engines



USPS Engine Analysis – Conclusions

- Mack cylinder head sludge suspected cause is out-of-specification B20 fuel
- Both Mack B20 engines required injector nozzle replacement
 - May be attributable to B20 use and off-spec. fuel
- Mack tractors had similar maintenance costs with the exception of injector replacement
- Differences not observed in Ford cargo vans

RTD In-use Evaluation – Description

- Comparison of transit buses operating on B20 to diesel
- Nine mechanically identical transit buses
 - 2000 Orion V; Cummins ISM
 - Five operated on B20, four on diesel
- “Skip” route in Boulder, CO – identical duty cycle
- Data collection began in late July 2004
- NREL documented vehicle performance and operation (mileage accumulation, fuel use, maintenance costs) and analyzed results

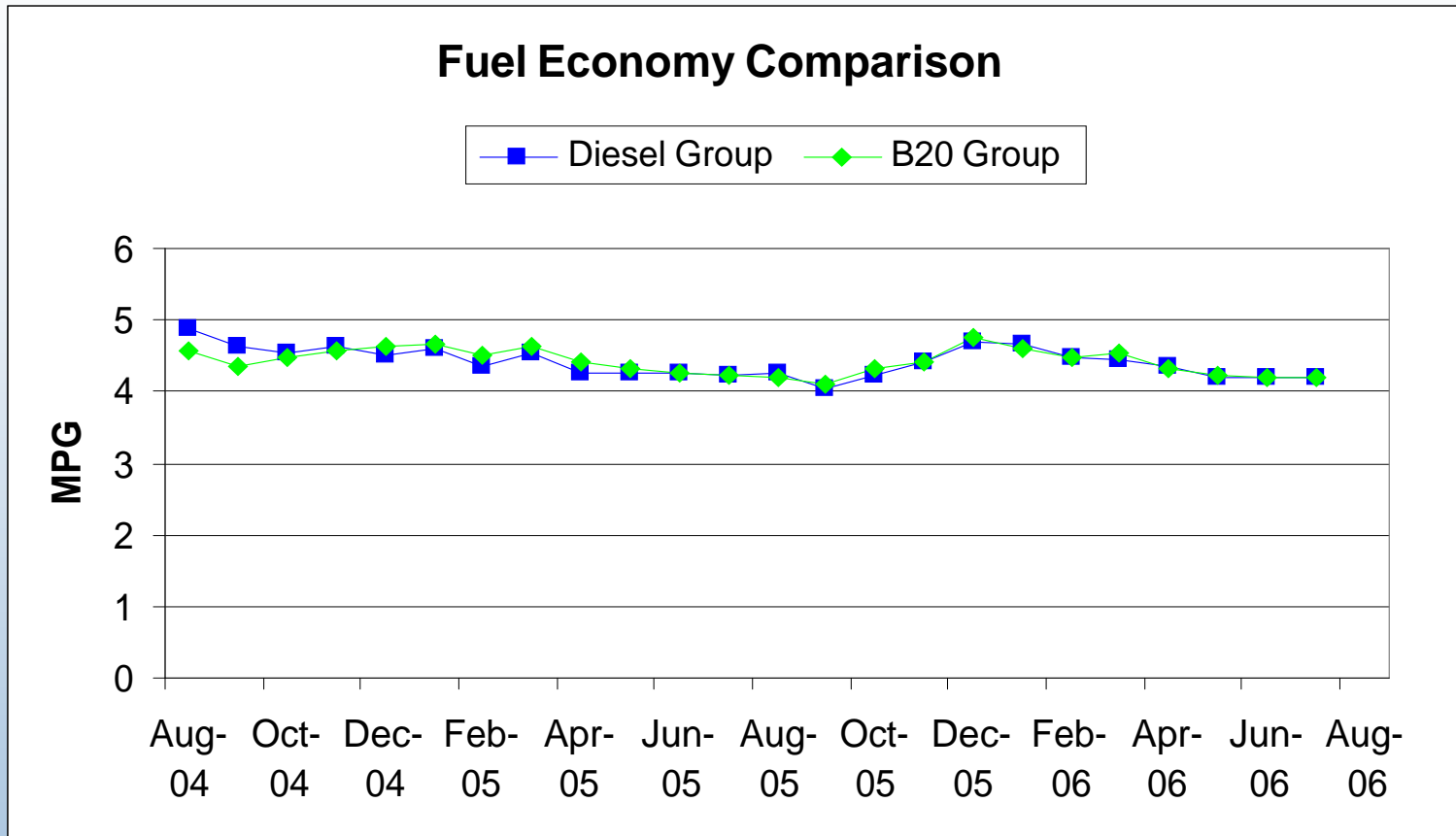


RTD In-Use Evaluation – Analysis

- Two year data analysis
August 2004 – July 2006
- Fuel and Maintenance
 - Mileage accumulation
 - Fuel economy
 - Maintenance costs
 - Road calls
 - Fuel Analysis
 - Blend level
 - Oil Analysis
 - Wear Metals
 - TBN, ZDDP, soot
- Other
 - Emissions testing
 - Filter Plugging
 - Component analysis

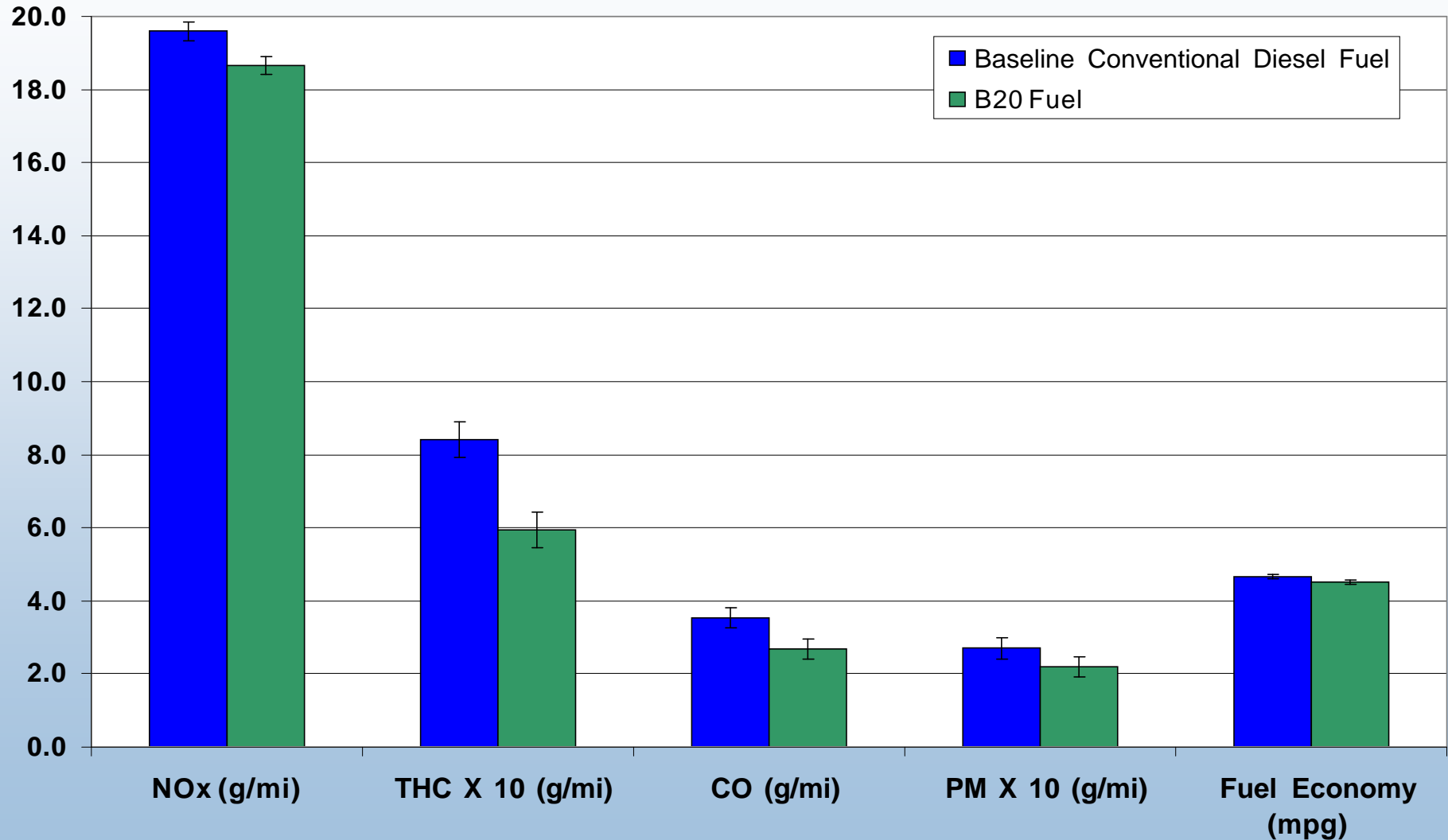


RTD In-Use Evaluation – Fuel Economy



- 4.41 mpg diesel, 4.41 mpg B20

RTD In-Use Evaluation – Emissions



RTD In-Use Evaluation – Conclusions

- On-road fuel economy – no difference
- Total maintenance costs – similar
- Fuel System and Engine maintenance costs – no significant difference
- Road calls – similar for both groups
- Filter plugging issues and plant sterols
- B20 splash-blending issues, generally B20 in tank
- Limited lube oil data suggests no harm with B20 use
- Significant emissions reductions including NO_x

B20 Fleet Evaluation Team

- Early NBB requests of OEMs
 - Warranty support for B20
 - All wanted more field data
- Major OEMs, industry experts, and stakeholders participation
- Biodiesel proponents: “No B20 issues in the field”
- OEMs: “Prove it with quantifiable data”
- Active since 2003

Team Members

- Bosch
- Case New Holland
- Caterpillar
- Cummins
- DaimlerChrysler
- Delphi Diesel Systems
- Department of Defense
- Engine Manufacturers Association
- Fleetguard
- Ford Motor Co.
- General Motors
- International
- John Deere
- National Biodiesel Board
- National Renewable Energy Laboratory
- Parker - Racor
- Siemens Diesel Systems
- Stanadyne Corp.
- Volkswagen AG
- Volvo Truck

USPS Cargo Van Evaluation - Approach

- 10 identical Postal Service cargo vans
 - 2004 International trucks
 - DT466 (7.6L) engines
 - 5 on B20, 5 on D2



Vehicle Information	Evaluation Trucks (B20 and Diesel)
Number of Trucks	5 B20, 5 Diesel
Chassis Manufacturer/Model	International Model 27-11
Chassis Model Year	2004
Engine Manufacturer/Model	International DT466 (7.6L)
Engine Ratings Max. Horsepower Max. Torque	225 hp @ 2,000 rpm 620 lb-ft @ 1,400 rpm
Diesel Fuel System Capacity	50 gal
Transmission Manufacturer/Model	Allison MD 3060-3000 HS
Curb Weight	18,270 lb
Gross Vehicle Weight Rating (GVWR)	42,100 lb

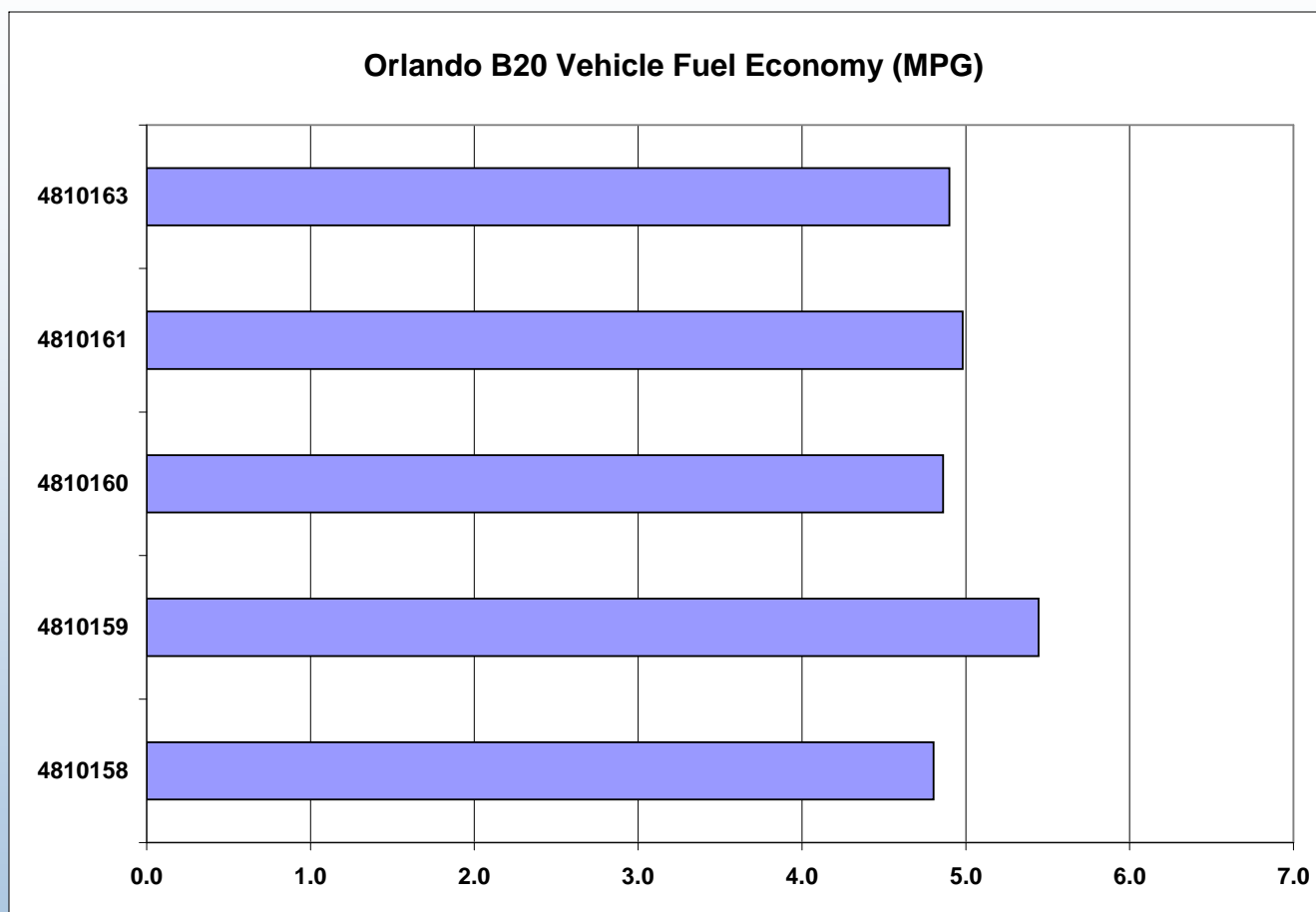
USPS Cargo Van Evaluation - Approach

- B20 vehicles operated at Orlando Postal Service facility, diesel comparison at West Palm Beach
- Operational data collection
 - Fueling data from USPS database
 - Labor, parts from maintenance records
- Fuel sampling and analysis
 - Streicher Mobile Fueling
- Lube oil collection
 - International a partner for oil analysis



Type of Data	Frequency Recorded	Data Items
Vehicle Specification and Performance Expectations		
Vehicle System Descriptions	Start of data collection and changes as needed	Shown in Appendix A
Vehicle Operation		
Vehicle Operating Cycle	Start of data collection and changes as needed	General description of daily use of vehicles; more detailed information if available
Vehicle Use in Service	At each time use is measured	Odometer reading
		GPS data (if needed)
Fuel Consumption	Each time a vehicle is fueled	Amount of fuel
		Odometer reading
		Date
	Each time the fuel price changes at a given site	Price per unit
Engine Oil Consumption and Changes	Each time oil is added	Amount of Oil
		Odometer reading
		Date
	Each time oil is changed as recommended by the engine manufacturer	Price per quart
		Amount of oil
		Odometer reading
Date		
Maintenance	For each work order	Type of maintenance: scheduled, unscheduled, road call, system category
		Labor hours
		Date of repair
		Number of days out of service
		Odometer reading
		Parts replaced
		Parts cost
		Description of reported problem
		Description of repair performed
Safety Incidents	Each occurrence	Description of each accident or incident involving the test or control vehicles, including collisions, and maintenance and fueling incidents

USPS Cargo Van Evaluation - Status



- Cargo vans in service early 2005
 - 325,000 miles on B20 (since new)
 - Over 65,000 gallons consumed

USPS Cargo Van Evaluation - Status

- Maintenance records received
 - Being entered into NREL database
 - Analysis period TBD
- Fuel samples
 - B100 (B99) deliveries
 - Vehicle fuel samples taken when problem occurs
 - Filter plugging, 2 received since November 2006

Method	Test	Result	Units
EN 14538	Sodium (Na) Content	0.7	ppm Wt
D93a-06	Potassium (K) Content	<0.1	ppm Wt
	Calcium (Ca) Content	<0.1	ppm Wt
	Magnesium (Mg) Content	<0.1	ppm Wt
	Flash Point (PMCC) Proc. "A"	153	deg C
D2709-06	Sediment & Water by Centrifuge	<0.025	Vol %
D2500-05	Cloud Point	12	deg C
D664-06a Mod	Total Acid Number-Modified	0.54	mg KOH/g
D6584-05e1	Glycerin, Free	0.025	Wt %
	Glycerin, Total	0.049	Wt %
D4951-06	Phosphorus (P) Content	<0.0001	Wt %
EN 14112	Oxidation Stability Induction Period @ 110°C	5.32	hr

USPS Cargo Van Evaluation - Status

- Oil Samples
 - 6 week maintenance intervals
 - Wear metals, soot, fuel dilution

Fuel	VIS100	Soot	TBN	Wear Metals (PPM)									
Dil%	CST	%		Al	Cr	Si	Cu	Fe	Mo	Na	Pb	Ni	Sn
0	11.34	0	10.43	1	0	5	0	2	3	9	0	0	0
2.88	11.43	0.1	8.19	3	1	5	7	19	6	5	2	0	0
3.03	15.10	0.4	5.05	4	1	6	18	44	5	13	5	0	0
4.94	11.58	0.4	7.29	0	0	2	8	20	5	3	0	0	0

St. Louis Metro In-use Evaluation – Description

- Comparison of transit buses operating on B20 to ULSD
- 15 mechanically identical transit buses
 - 2002 Gillig Phantom; Cummins ISM (2004 emissions certification) with EGR
 - 8 operated on B20, 7 on ULSD
- Drive cycles matched between B20 and diesel groups
 - Average speed
 - Stops per mile
 - Passengers per mile
- Project underway Oct 06
- NREL documenting vehicle performance and operation (mileage accumulation, fuel use, maintenance costs) and analyze results



Biodiesel Water Separator Effectiveness Testing

Working Group

- 6 companies participating
- Testing plan agreed upon by working group after reviewing initial proposals from SWRI. New plan is being priced.

Testing Overview

- NREL and NBB will supply fuel samples to SWRI that are representative of what is available in the marketplace.
- Down-selection of biodiesel fuels will be based on fuels best meeting ASTM D-6751 requirements.
- Down-selection of ULSD/F will be based on SAE J1488 recommended values for IFT greater than 25 mN/m and MSEP value greater than 80.
- Additional testing will be done on the biodiesel blends prior to SAE J1488-Emulsified Water Removal Test Method testing.
- Any blend sample showing less than 95% efficiency will have B100 properties analyzed.

Biodiesel Blend Evaluation Team – Moving Forward

- USPS new cargo van evaluation
 - 10 identical 2004 International trucks
 - DT466 (7.6L) engines
 - Fuel and maintenance comparisons
 - Fuel and oil analysis
- St. Louis Metro bus evaluation
 - 15 identical 2002 Gillig buses
 - Cummins ISM (with EGR)
 - Fuel and maintenance comparisons
 - Fuel and oil analysis
- Working groups
 - Water separator effectiveness
- Biodiesel quality surveys
 - Separate B100 and B20 surveys
 - BQ9000 properties and metals (B100)



Information

- SAE Paper 2005-01-3641 Operating Experience and Teardown Analysis for Engines Operated on Biodiesel Blends (B20)
 - www.nrel.gov/vehiclesandfuels/npub/pdfs/38509.pdf
- SAE Paper 2006-01-3253 100,000-Mile Evaluation of Transit Buses Operated on Biodiesel Blends (B20)
 - www.nrel.gov/vehiclesandfuels/npub/pdfs/40128.pdf
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