In-Use Evaluation of Transit Buses Operated on Biodiesel Blends (B20) by St Louis Metro

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Agenda

• Project Objectives / Approach
• Implementation and usage
• On-road fuel economy
• Reliability
• Maintenance costs
• Fuel system durability
• Fuel analysis
• Lube oil analysis
• Conclusions
B20 Fleet Evaluation – Objectives

• Compare vehicles operating in the field on B20 and ULSD over 12 months:
  – Engine performance
  – Fuel economy
  – Vehicle maintenance cost
  – Fuel-induced variations in operation and maintenance
  – Lube oil performance

• 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

Fuel Economy Comparison

![Fuel Economy Comparison Graph](image)
B20 Fleet Evaluation – Approach

• 15 mechanically identical Metro transit buses:
  – 2002 Gillig Phantom
  – 2002 Cummins ISM (2004 cert with EGR)
  – 8 operated on B20, 7 on ULSD

• B20 and ULSD buses housed in different garages, but have been assigned to similar routes for duty cycle parity
  – 13.75 and 14.57 mph average speeds
  – Metro submits data electronically from their internal database
  – Fuel, Labor, Parts

• Fuel sample collection and analysis - partnership with HWRT (B20 supplier)

• Lube oil sampling and analysis program with Cummins
  – Oil sampled at ~2,000-mile intervals
Implementation and Usage

• Metro reports fairly seamless transition to biodiesel/ULSD B20 blend
  – UST fuel storage, B20 added to residual fuel until B0 \(\rightarrow\) B20
  – Instituted a 2000 mile fuel filter replacement schedule during transition (normally 6000 mile)
  – First experience with ULSD, phased in simultaneously with B20 (10/06)

• Based upon 12 months (10/06 – 9/07) of operational data
  – 394,116 miles driven by B20 buses (49,267 per bus average)
  – 90,983 gallons B20 consumed
3.58 mpg ULSD, 3.52 mpg B20 (-1.71%)
Difference not statistically significant
Road Calls

- Average Total MBRCs comparable
  - 2,375 ULSD, 2,627 B20
Engine, Fuel System Road Calls

- Average engine/fuel system MBRCs comparable
  - 6,924 ULSD, 8,211 B20
Maintenance Costs - Total

- June and August 2007 spikes driven by scheduled (brakes and radiator) maintenance, and other non-engine or fuel system repairs
Maintenance Costs - Total

12-month average maintenance costs:
- $0.566/mile ULSD, $0.568/mile B20
- Merged after 9 months
- Not a statistically significant difference
Maintenance Costs – Engine, Fuel System

- 12-month average engine and fuel system maintenance costs:
  - $0.053/mile ULSD, $0.072/mile B20
## Fuel System Part Replacements

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<th>Fuel</th>
<th>Part Replaced</th>
<th>Oct-06</th>
<th>Nov-06</th>
<th>Dec-06</th>
<th>Jan-07</th>
<th>Feb-07</th>
<th>Mar-07</th>
<th>Apr-07</th>
<th>May-07</th>
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- **Fuel filters (28 to 13)**
  - Weighted in first 2 months (2000 mile change interval to account for the solvent effect)
  - Feb-07 – likely due to unseasonably cold temps dropping below the cloud point of the fuel
  - Cloud Point stable
  - Fuel injector replacement higher with B20 than ULSD (15 to 3)
  - Evidence of operability issues led to injector replacement
## Fuel Injector Replacements

- Failures on bus order group as early as 100k miles
- B20 buses had higher mileage at start of evaluation
- No pattern in B20 miles before failure
- No red flags with fuel quality (free/total glycerin)
- Cummins warranting injectors on bus order group

<table>
<thead>
<tr>
<th>Unit No</th>
<th>Fuel</th>
<th>Evaluation Start Mileage</th>
<th>B20 Miles Before failure</th>
<th>Injectors Replaced</th>
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Average Miles: 127,392; Standard Deviation: 2,664

ULSD Miles: 107,658; Standard Deviation: 13,306
Fuel Analysis

• 15 B100, 30 B20 samples collected and analyzed
• Focused analytical approach led by NREL with assistance from SwRI
• Covered Feb-July 2007 (6 of 12 months)

B100 Results

• Free/total glycerin within spec
• Na+K, Ca+Mg, P within spec
• Flashpoint 14/15 met spec
• Bottom line - B100 met specs tested for
Fuel Analysis

B20 Results

• Cloud Points ranged -10C to -15C
  – No seasonal variation, within Metro spec

• B20 samples analyzed for blend content
  – The blend level of the samples was determined using ASTM D7371 with an accuracy of +/- 2%
  – 47% Nominal B20 (B17-23); 14/30 samples
Lube Oil Analysis

• 64 oil samples analyzed by Cummins
  – 833–6477 oil miles
  – 6000 miles change interval
• Despite apparent scatter, tight dataset for lube oil data

- Soot loading lower with B20 than ULSD, but both quite low
Lube Oil Analysis

- Viscosity as indicator of fuel dilution
  - Viscosity appears lower with B20, but B20 and ULSD samples “in-grade” throughout drain period

- TBN slightly lower with B20, but both B20 and ULSD show sufficient TBN retention at end of drain
Lube Oil Analysis

- Iron as indicator of wear
  - Slightly Lower with B20, especially with high mileage

- Lead as indicator of corrosion
  - Slightly Higher with B20, especially with high mileage
Conclusions

• No statistically significant difference between buses running on B20 and ULSD
  – On-road fuel economy
  – Reliability (Road Calls)
  – Total maintenance costs

• Difference in Fuel System and Engine maint. costs driven by fuel injector replacements
  – Skewed toward B20 buses; failure mode unknown

• No other observed fuel system durability issues
  – Biodiesel blend variability (<B20)
  – Lube oil data suggests no harm with B20 use
  – TBN decrease, fuel dilution increase (but still “in-grade”)
  – Some potential benefits (soot, wear metals)
Special Thanks

- US DOE – Kevin Stork
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- Metro – Lyle Howard, Jill Coffin
- Cummins – Shawn Whitacre
- HWRT – Matt Schrimpf