West Virginia University
Transportable Heavy Vehicle Emissions Testing Laboratory

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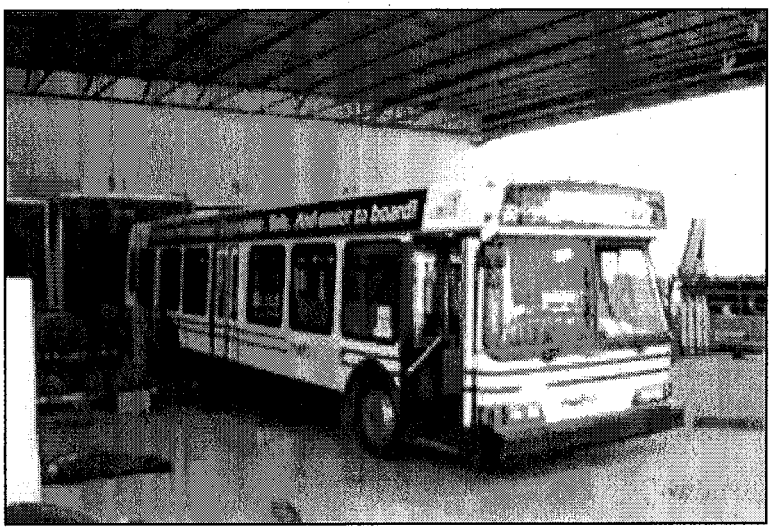
Washington Metropolitan Area Transit Authority

Biodiesel Fuel Comparison Final Data Report



Presented to:

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The West Virginia University measured the exhaust emissions from a Flxible Transit bus with a 1990 Cummins L10 engine operated on standard federal type-1 diesel fuel (D1), ultra-low sulfur type-1 diesel fuel (ULSD1) and on a blend or 20% biodiesel and 80% ULSD1 fuel (BD20). During the ULSD1 and BD20 tests the transit bus was equipped with an Engelhard DPX catalyzed particulate filter. The vehicle was exercised over a chassis dynamometer test cycle that was developed from data logged from WMATA buses during normal passenger service in the Washington D.C. Metropolitan Area. All measurements were made in accordance with the guidelines set forth the Code of Federal Regulations CFR40 Part 86 Subpart N.

Oxides of nitrogen emissions (NOx) are plotted in Figure 1. Each bar represents the average of three consecutive test runs. The error bars represent the maximum and minimum test run values. There was no significant change in the NOx emissions as a result of changing from standard D1 fuel to ultra-low sulfur D1. As expected, NOx emissions increased slightly from 26.74g/mile to 28.98g/mile when switching to the BD20 blend. Although the NOx emissions for the ULSD1/DPX configuration appears to show a reduction in NOx, the catalyzed particulate filter does not affect generally affect NOx emissions. However, it does affect the balance of NO and NO_2 in the exhaust. The apparent reduction in NOx emissions is most likely due to differing ambient temperature and humidity.

Particulate (PM) emissions are shown in Figure 2. There was no significant change in PM emissions as a result of switching to the BD20 blend. The catalyzed particulate trap reduce PM emissions by greater than 98%. The ULSD1 fuel showed slightly higher PM emissions than those produced by the D1 fuel.

Carbon monoxide (CO) emissions are plotted in Figure 3 and hydrocarbon (HC) emissions are shown in Figure 4. The catalyzed particulate filter also oxidizes carbon monoxide and hydrocarbons. Switching to the BD20 blend caused an apparent reduction in CO emissions of approximately 90%. The BD20 fuel blend also produced a reduction in HC emission of approximately 92%. Fuel economy results are plotted in Figure 5. Within the bounds of measurement error, fuel economy was not significantly affected by any of the fuels tested in this study.

Based on the results of this limited investigation, switching to a 20% biodiesel blend produced a small increase in NOx emissions and reductions in CO and HC emissions. The use of ultra-low diesel fuel or a blend of biodiesel and ultra-low sulfur diesel fuel in conjunction with catalyzed particulate filters can substantially reduce PM, CO and HC emission without any significant affect on fuel economy.

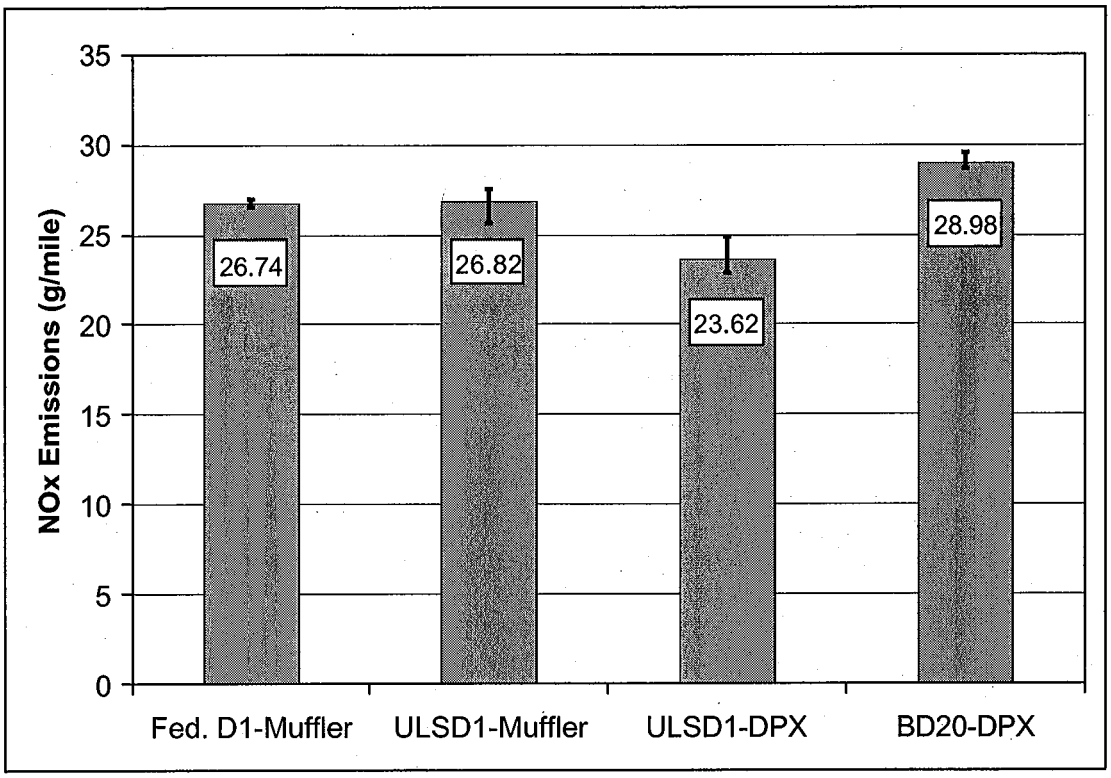

Figure 1: Oxides of Nitrogen Emissions

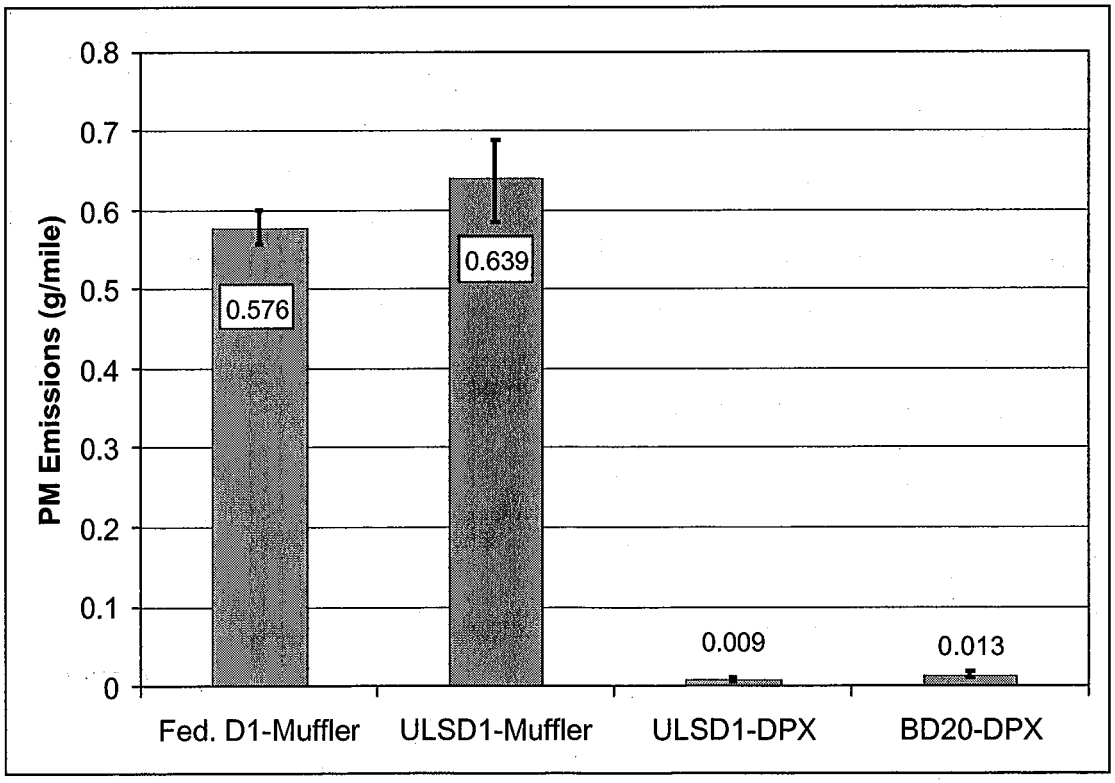

Figure 2: Particulate Emissions

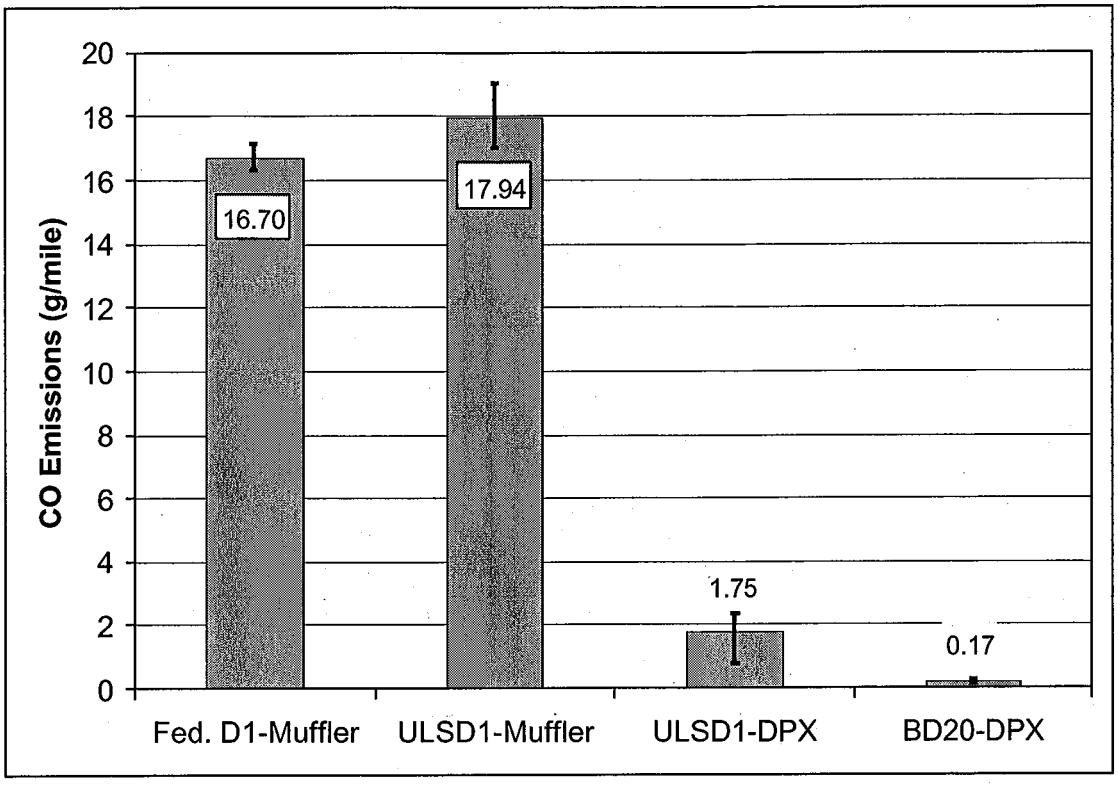

Figure 3: Carbon Monoxide Emissions

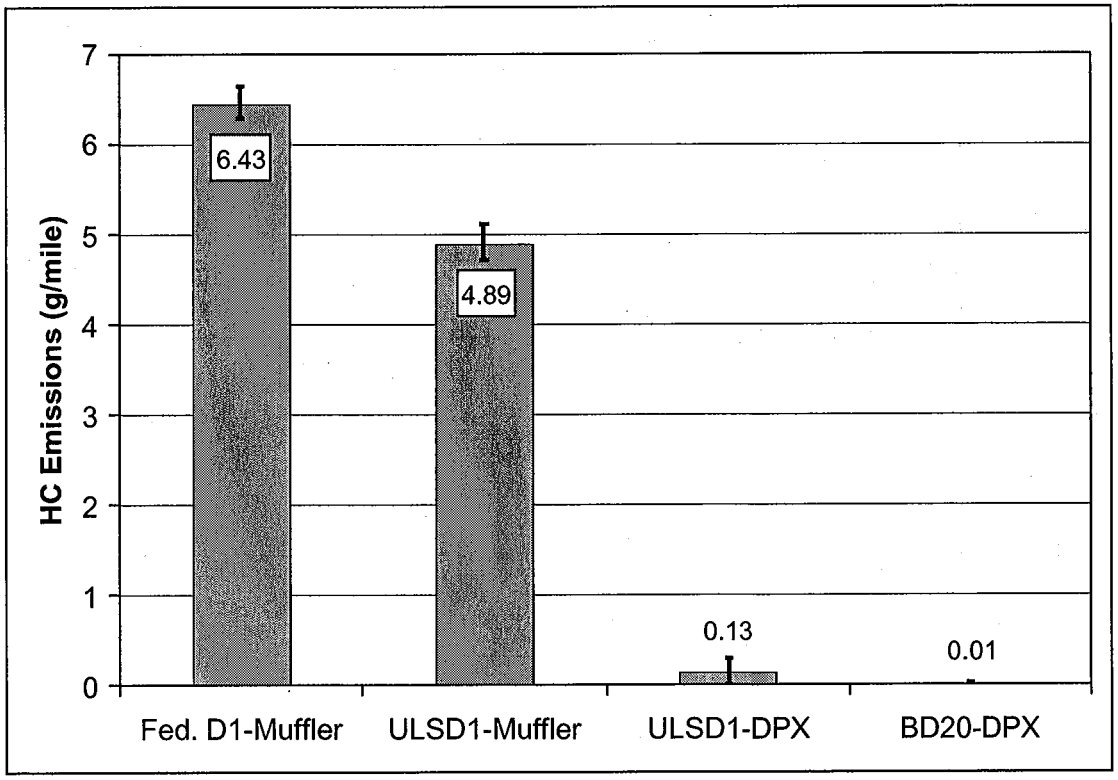

Figure 4: Hydrocarbon Emissions

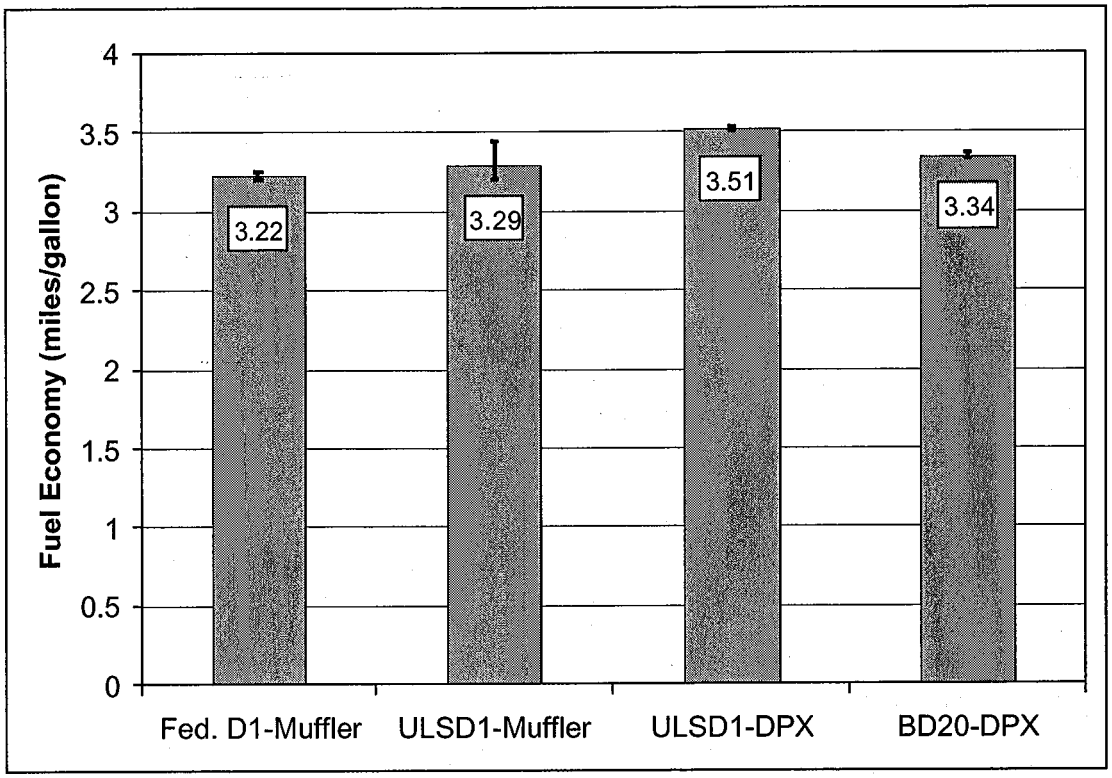

Figure 5: Fuel Economy

Test Sequence Number: 3784
WVU Test Reference Number: WMATA-9456-ULSD1-2WMATA

Fleet Owner Full Name	Washington Metropolitan Area Transit Authority
Fleet Address	3500 Pennsy Drive
Fleet Address (City, State, Zip)	Landover, MD 20784
Vehicle Type	Transit Bus
Vehicle ID Number (VIN)	1GF5BAEK6LD101818
Vehicle Manufacturer	Flxible Corp.
Vehicle Model Year	1990
Gross Vehicle Weight (GVW) (lb.)	39500
Vehicle Total Curb Weight (lb.)	27000
Vehicle Tested Weight (lb.)	32100
Odometer Reading (mile)	49802
Transmission Type	Automatic
Transmission Configuration	3
Number of Axles	2
Engine Type	Cummins L10
Engine ID Number	34678506
Engine Displacement (Liter)	10
Number of Cylinders	6
Engine Rated Power (hp)	240
Primary Fuel	ULSD1
Particulate Trap Manufacturer	Engelhard
Test Cycle	2WMATA
Test Date	5/30/02
Engineer	A. Williams
Driver	J. England

Emissions Results (g/mile) **Fuel Economy**

Run Seq. No.	CO	NO_x[1]	NO_x[2]	FIDHC	PM	CO_2	mile/gal	BTU/mile	Miles
3784-2	2.13	23.2	c	0.30	0.0057	2798	3.52	36246	8.59
3784-3	2.33	24.9	c	0.10	0.0105	2812	3.51	36417	8.59
3784-4	0.79	22.8	c	e	0.0102	2821	3.50	36503	8.58
3784 Average	1.75	23.6	c	0.20	0.0088	2810	3.51	36389	8.59
Std. Dev.	0.84	1.1	c	0.14	0.003	12	0.01	131	0.01
CV%	47.9	4.7		69.3	d	0.4	0.4	0.4	0.1

Test Purpose:
WMATA Transit Bus running on ULSD with an Engelhard DPX aftertreatment device.

Special Procedures:
Runs 2, 3, & 4 are double WMATA cycles. Run 5 is the background.

Observations:
NOx 2 analyzer removed and sent to California Analytical for repairs.

Test Sequence Number: 3809
WVU Test Reference Number: WMATA-9456-ULSD1-WMATA

Fleet Owner Full Name	Washington Metropolitan Area Transit Authority
Fleet Address	3500 Pennsy Drive
Fleet Address (City, State, Zip)	Landover, MD 20784
Vehicle Type	Transit Bus
Vehicle ID Number (VIN)	1GF5BAEK6LD101818
Vehicle Manufacturer	Flxible Corp.
Vehicle Model Year	1990
Gross Vehicle Weight (GVW) (lb.)	39500
Vehicle Total Curb Weight (lb.)	27000
Vehicle Tested Weight (lb.)	32100
Odometer Reading (mile)	49802
Transmission Type	Automatic
Transmission Configuration	3
Number of Axles	2
Engine Type	Cummins L10
Engine ID Number	34678506
Engine Displacement (Liter)	10
Number of Cylinders	6
Engine Rated Power (hp)	240
Primary Fuel	ULSD1
Test Cycle	WMATA
Test Date	6/14/02
Engineer	S. Rosepiler
Driver	J. England

Emissions Results (g/mile) **Fuel Economy**

Run Seq. No.	CO	NO_X[1]	NO_X[2]	FIDHC	PM	CO_2	mile/gal	BTU/mile	Miles
3809-2	17.8	25.6	25.3	4.72	0.59	2826	3.44	37105	4.30
3809-4	19.0	27.4	27.0	4.86	0.69	3007	3.24	39483	4.20
3809-5	17.0	27.5	27.2	5.10	0.64	3051	3.19	40021	4.19
3809 Average	17.9	26.8	c	4.89	0.64	2961	3.29	38870	4.23
Std. Dev.	1.0	1.0	c	0.19	0.05	119	0.13	1552	0.06
CV%	5.6	3.9		4.0	8.1	4.0	4.1	4.0	1.5

Test Purpose:
WMATA Transit bus running on ULSD1 with standard muffler.

Special Procedures:
Run 1 is morning background, Runs 2, 4, and 5 are good runs.

Test Sequence Number: 3810
WVU Test Reference Number: WMATA-9456-D1-WMATA

Fleet Owner Full Name	Washington Metropolitan Area Transit Authority
Fleet Address	3500 Pennsy Drive
Fleet Address (City, State, Zip)	Landover, MD 20784
Vehicle Type	Transit Bus
Vehicle ID Number (VIN)	1GF5BAEK6LD101818
Vehicle Manufacturer	Flxible Corp.
Vehicle Model Year	1990
Gross Vehicle Weight (GVW) (lb.)	39500
Vehicle Total Curb Weight (lb.)	27000
Vehicle Tested Weight (lb.)	32100
Odometer Reading (mile)	49802
Transmission Type	Automatic
Transmission Configuration	3
Number of Axles	2
Engine Type	Cummins L10
Engine ID Number	34678506
Engine Displacement (Liter)	10
Number of Cylinders	6
Engine Rated Power (hp)	240
Primary Fuel	D1
Test Cycle	WMATA
Test Date	6/14/02
Engineer	S. Rosepiler
Driver	J. England

Emissions Results (g/mile) **Fuel Economy**

Run Seq. No.	CO	NO_X[1]	NO_X[2]	FIDHC	PM	CO_2	mile/gal	BTU/mile	Miles
3810-2	17.1	26.7	26.3	6.63	0.57	2925	3.24	38854	4.29
3810-3	16.6	26.5	26.0	6.29	0.56	2933	3.24	38937	4.28
3810-4	16.3	27.0	26.6	6.38	0.60	2974	3.19	39469	4.27
3810 Average	16.7	26.7	c	6.43	0.58	2944	3.22	39087	4.28
Std. Dev.	0.4	0.3	c	0.18	0.02	26	0.03	334	0.01
CV%	2.5	1.0		2.8	3.6	0.9	0.9	0.9	0.2

Test Purpose:
WMATA Transit bus with standard muffler running on D1

Special Procedures:
Run 1 is evening background for 6/14/2002, Runs 2, 3, and 4 are good runs.

Test Sequence Number: 3846
WVU Test Reference Number: WMATA-9456-BD20-WMATA

Fleet Owner Full Name	Washington Metropolitan Area Transit Authority
Fleet Address	3500 Pennsy Drive
Fleet Address (City, State, Zip)	Landover MD 20784
Vehicle Type	Transit Bus
Vehicle ID Number (VIN)	1GF5BAEK6LD101818
Vehicle Manufacturer	FIxible Corp.
Vehicle Model Year	1990
Gross Vehicle Weight (GVW) (lb.)	39500
Vehicle Total Curb Weight (lb.)	Not Available
Vehicle Tested Weight (lb.)	32100
Odometer Reading (mile)	51283
Transmission Type	Automatic
Transmission Configuration	3
Number of Axles	2
Engine Type	Cummins L10
Engine ID Number	34678506
Engine Displacement (Liter)	10
Number of Cylinders	6
Engine Rated Power (hp)	240
Primary Fuel	BD20
Particulate Trap Manufacturer	Engelhard
Test Cycle	WMATA
Test Date	7/17/02
Engineer	Barnett, Ryan
Driver	Leasor, Curtis

Emissions Results (g/mile) **Fuel Economy**

Run Seq. No.	CO	NO_X[1]	NO_X[2]	FIDHC	PM	CO_2	mile/gal	BTU/mile	Miles
3846-2	0.25	29.5	29.8	X	0.011	3035	3.35	38222	4.26
3846-3	0.15	28.9	14.5	0.018	0.011	3028	3.36	38134	4.24
3846-4	0.11	28.6	14.6	X	0.017	3058	3.32	38513	4.26
3846 Average	0.17	29.0	19.6	0.018	0.013	3040	3.34	38290	4.25
Std. Dev.	0.07	0.5	8.8	0.000	0.004	16	0.02	199	0.01
CV%	41.1	1.7		0.0	27.1	0.5	0.5	0.5	0.3

Test Purpose:
testing of WMATA biodiesel bus 9456

Special Procedures:
run 1 is conditioning, runs 2, 3, and 4 are the good ones,