Emissions Testing of Amtrak Unit #500

May 25, 2011
GE Transportation
Prepared by: Doug Glenn

On May 23, 2011 Amtrak Unit #500 was delivered to GE Transportation's locomotive emissions test facility in Erie, Pennsylvania. The unit had completed a one year test on B20 biodiesel fuel sponsored by Amtrak, Oklahoma Department of Transportation and the Federal Railroad Administration. GE was asked to conduct an emissions test on the unit at completion of the 1 year program to help understand emissions output with B20 fuel. The unit was delivered with a fuel tank full of B20 biodiesel for emissions testing. Inbound inspection of the unit revealed no visible leaks and no active alarms or faults. Unit #500 was built in 1991 and has an FDL 12 cylinder engine with a Tier 0 emissions upgrade.

The unit was pulled into the test facility and connected for emissions testing. This consisted of locating the unit under a stack containing sample probes for gaseous and particulate matter sampling as well as instrumentation for smoke opacity readings. Connections to the low pressure fuel system were made so that fuel consumption of the locomotive could be measured during testing. Electrical power from both the main and auxiliary alternators was measured. The unit was then tested according to procedures of 40 CFR Part92.

Two test cycles were completed on the unit. One cycle was completed using on-board B20 in the fuel tank. The other cycle was completed using petroleum diesel fuel. Fuel samples of both the on-board B20 and the petroleum diesel fuels were collected for analysis. The fuel analysis is included in Appendix A.

Plots of individual modal emissions are shown in figures 1-5. Data for low idle shows an unusually high difference in emissions and fuel consumption between B20 and diesel fuel. This anomaly in the data appears in gaseous, PM and fuel consumption data. Therefore the anomaly is unlikely a measurement issue as multiple measurement systems detected the same event. As it is not known what caused the anomaly and because the other two unloaded modes (idle and dynamic brake) show no such discrepancy, it would seem reasonable to conclude the event is just as likely an engine operating issue as it would be a result of fuel differences. Therefore, in Table 1 duty cycle composite emission test results are shown utilizing only 10 modes for B20 and diesel. This is accomplished by redistributing the low idle weighting factor to the idle mode for both B20 and diesel fuel. For completeness, Appendix B has a table similar to Table 1 and presents the duty cycle emissions data utilizing all eleven modes.

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	Unit#	Amtrak #500		
	Test Dates	May 23 and 24, 2011		
	10 MODES			
	Line Haul Duty Cycle Results			
	BSHC	**BSCO**	**BSNOx**	**BSPM**
	(gm/hp-hr)	**(gm/hp-hr)**	**(gm/hp-hr)**	**(gm/hp-hr)**
B20 Fuel	0.38	0.9	8.3	0.13
Diesel Fuel	0.40	0.8	7.9	0.14
Tier 0 Limits	1.00	5.0	9.5	0.60
	Switch Duty Cycle Results			
	BSHC	**BSCO**	**BSNOx**	**BSPM**
	(gm/hp-hr)	**(gm/hp-hr)**	**(gm/hp-hr)**	**(gm/hp-hr)**
B20 Fuel	0.69	1.2	10.6	0.24
Diesel Fuel	0.72	1.2	10.2	0.24
Tier 0 Limits	2.10	8.0	14.0	0.72
	Smoke Opacity Results			
	Steady State	**30 sec**	**3 sec**	
B20 Fuel	12	16	35	
Diesel Fuel	11	15	34	
Tier 0 Limits	30	40	50	

Table 1 – Amtrak #500 Emissions Results (10 modes)

The tested emissions results and Tier 0 limits are shown above. Figures 1-5 below show how low idle gaseous emission, PM and fuel rate differ between the two fuels during their respective test runs.

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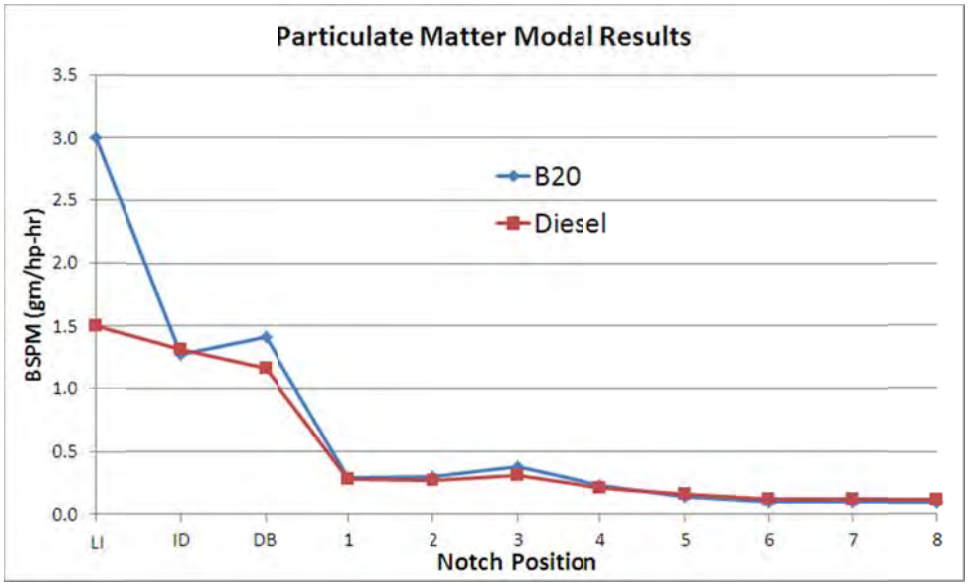

Figure 1 – Modal Particulate Results

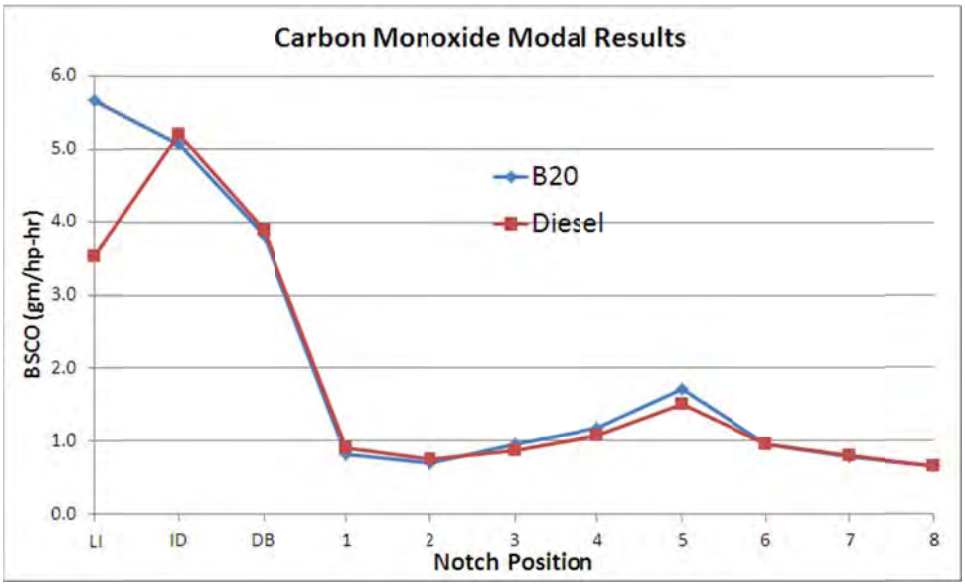

Figure 2 – Modal Carbon Monoxide Results

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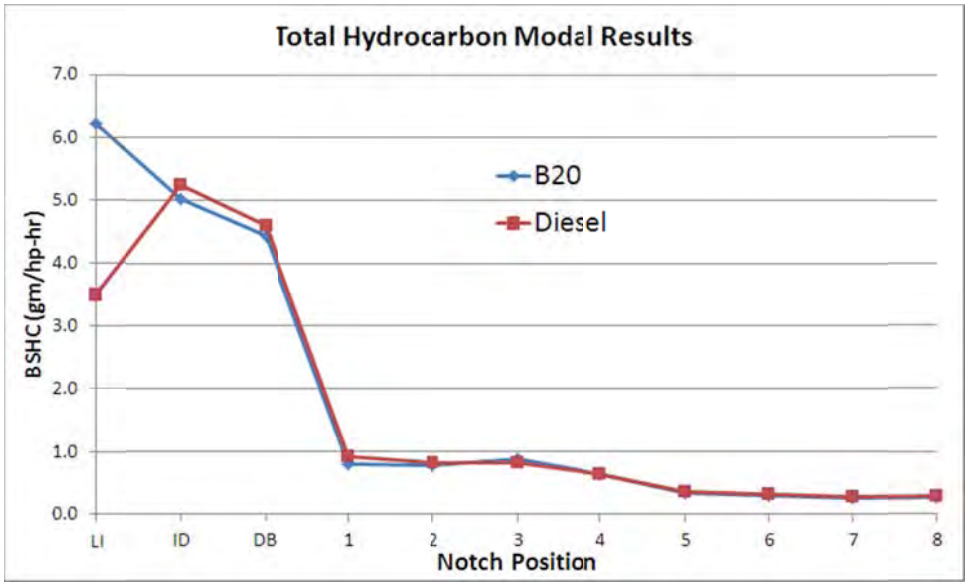

Figure 3 – Modal Total Hydrocarbon Results

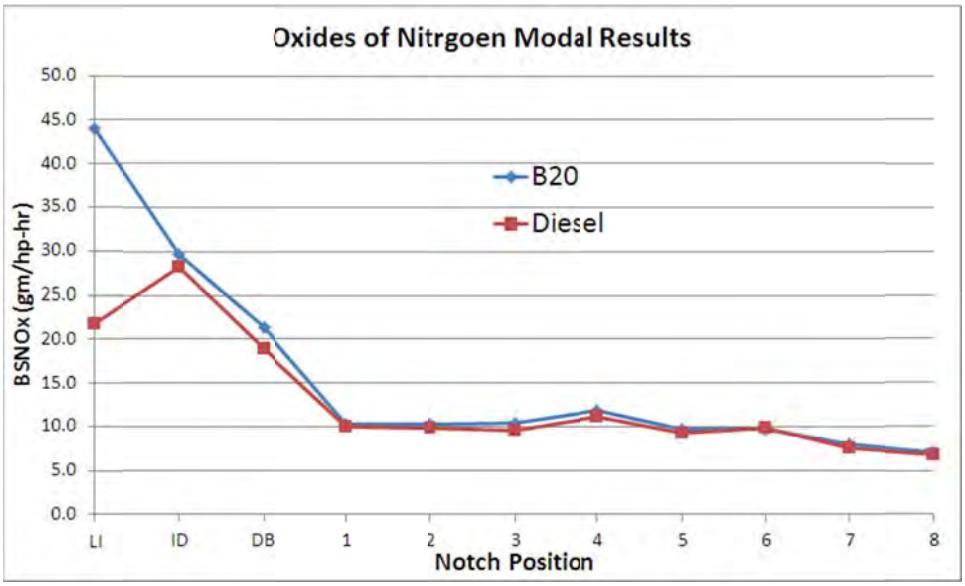

Figure 4 – Modal Oxides of Nitrogen Results

Fuel consumption results for this testing showed that notch 8 B20 consumption increased 1.3% by mass or 0.5% by volume. Individual modal results for brake specific fuel consumption are shown in figure 5 below.

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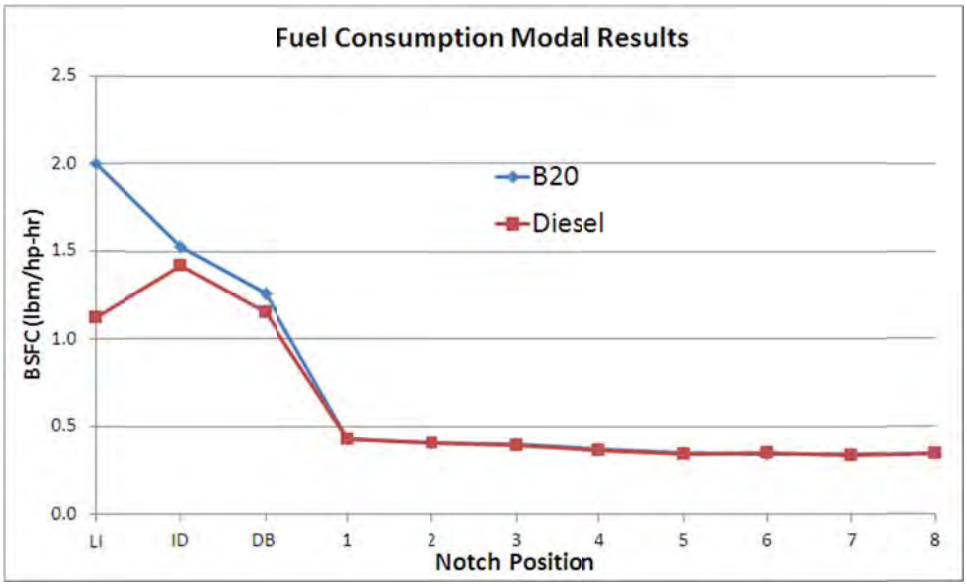

Figure 5 – Fuel Consumption Modal Results

The modal power results for each test are shown in figure 6. This illustrates the locomotive was able to make full power on B20.

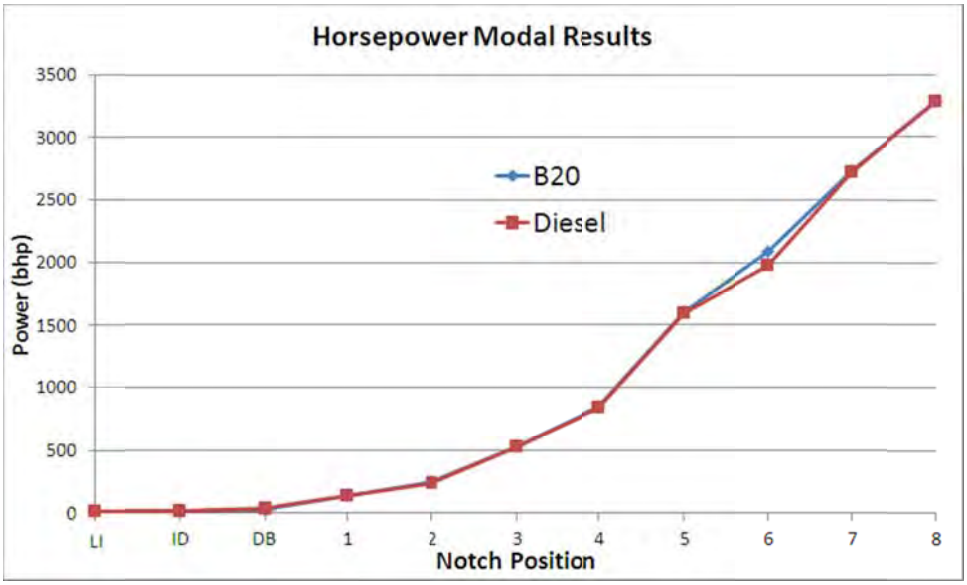

Figure 6 – Modal Power Results

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CONCLUSION

Amtrak unit #500 was delivered to GE Transportation for emissions testing on B20 and diesel fuel. These results show that both fuels continue to meet Tier 0 emissions standards. There is an increase in BSNOx of about 5% which is expected with biodiesel. Additionally, a 1.3% (by mass) fuel consumption increase with B20 was observed at notch 8. Full power at all modes was achieved with B20 fuel. The fuel consumption hit when considering volumetric consumption was 0.5%.

Results for particulate, total hydrocarbons and carbon monoxide show an unusually high difference at low idle between B20 and diesel fuel. This trend is not understood and is different than the idle and dynamic brake points. The fact that multiple independent measurement systems detect a difference at low idle suggests the observation was real. What is not understood is what caused the deviation.

In reviewing fuel analysis results, the aromatic content was slightly high (37.7% vs. 35% max) for ASTM D7467. The B20 acid number was very good at 0.06 mg KOH/g verses 0.3. Oxidation stability was good and the measured biodiesel content was 16.3% by volume.

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APPENDIX A

Test Method	Description	Units	AM 500 CERT
			Cert 1
D2622_07	Sulfur Content	ppm	2886
D4052	API Gravity	--	36.1
	Specific Gravity	--	0.8444
	Density at 15°C	grams/L	844
D445	Viscosity at 40°C	cSt	2.523
D4809	***GROSS*** Heat of Combustion	BTU/lb	19622
		MJ/kg	45.64
		cal/g	10900.9
D4809	***NET*** Heat of Combustion	BTU/lb	18426
		MJ/kg	42.858
		cal/g	10236.4
D5186	Total Aromatics	mass %	27.6
	Mono-aromatics	mass %	20.4
	Polynuclear Aromatics	mass %	7.3
D5291	Carbon Content	wt%	86.22
	Hydrogen Content	wt%	13.11
D86	IBP	deg. F	349
	10%	deg. F	409
	50%	deg. F	495
	90%	deg. F	599
	FBP	deg. F	655
	Recovered	mL	97.9
	Residue	mL	1.5
	Loss	mL	0.6
D976	Cetane Index		46.9
D93	Flash Point	Deg. F	155
		Deg. C	67

Figure A1 – Petroleum Diesel Fuel Analysis

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Test Method	Description	Units	AM 500 LOCO
			Loco 1
D1319	Aromatics	vol%	37.7
	Olefins	vol%	0.8
	Saturates	vol%	61.5
D2709	Particulate	vol%	0.01
D4052	API Gravity	--	34.8
	Specific Gravity	--	0.8508
	Density at 15°C	grams/L	850.3
D445	Viscosity at 40°C	cSt	2.836
D4809	***GROSS*** Heat of Combustion	BTU/lb	19199
		MJ/kg	44.656
		cal/g	10665.9
D4809	***NET*** Heat of Combustion	BTU/lb	18011
		MJ/kg	41.893
		cal/g	10006.1
D5291	Carbon Content	wt%	85.02
	Hydrogen Content	wt%	13.02
D5453	Sulfur Content	ppm	65.8
D664	Acid Number - Inflection Point	mg KOH/g	0.06
	Buffer End Point	mg KOH/g	<0.05
D86	IBP	deg. F	341
	10%	deg. F	418
	50%	deg. F	534
	90%	deg. F	617
	FBP	deg. F	641
	Recovered	mL	97.9
	Residue	mL	1.4
	Loss	mL	0.7
D976	Cetane Index		49.5
D93	Flash Point	Deg. F	149
		Deg. C	64
EN14078	FAME Content - IR	vol%	16.3
EN140112m	Oxidation Stability - Rancimat	hour	> 24

Figure A2 – B20 Fuel Analysis

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APPENDIX B

This Appendix B presents the composite duty cycle emissions data for all 11 modes for both B20 and diesel fuel. Table 1 in the main body presented the composite duty cycle emissions excluding low idle, therefore only 10 modes. As can be seen in figure 1 – 5 in the main body, there is an anomaly with the low idle emissions and fuel consumption.

	Unit# Amtrak #500			
	Test Dates May 23 and 24, 2011			
	Line Haul Duty Cycle Results			
	BSHC	**BSCO**	**BSNOx**	**BSPM**
	(gm/hp-hr)	**(gm/hp-hr)**	**(gm/hp-hr)**	**(gm/hp-hr)**
B20 Fuel	0.38	0.9	8.3	0.13
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Tier 0 Limits	1.00	5.0	9.5	0.60
	Switch Duty Cycle Results			
	BSHC	**BSCO**	**BSNOx**	**BSPM**
	(gm/hp-hr)	**(gm/hp-hr)**	**(gm/hp-hr)**	**(gm/hp-hr)**
B20 Fuel	0.68	1.2	10.7	0.26
Diesel Fuel	0.68	1.2	10.0	0.24
Tier 0 Limits	2.10	8.0	14.0	0.72
	Smoke Opacity Results			
	Steady State	**30 sec**	**3 sec**	
B20 Fuel	12	16	35	
Diesel Fuel	11	15	34	
Tier 0 Limits	30	40	50	

Table B1 – Amtrak #500 Emissions Results (11 modes)

The tested emissions results with all 11 modes and Tier 0 limits are shown above.

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