Mid-level Ethanol Blend Study: Chassis Dynamometer Study of Flex Fuel Vehicles

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Executive Summary

The objective of this study was to determine the fuel efficiencies and emission profiles of flex fuel vehicles operating on different ethanol blends (E10, E20, E30, and E85). Nine vehicles were supplied by the State of Nebraska Transportation Services Bureau vehicle fleet. The vehicles tested were flexible fuel sedans with 3.0 L and 3.5 L engines and pickups with 4.7 L engines. An automotive repair company, "The Shop, Inc.", was contracted with to support the chassis dynamometer testing of the vehicles according to outlined test procedures. The dynamometer was able to simulate road and vehicle operating conditions while measuring engine speed, torque and horsepower produced at the wheels.

Three vehicle models were evaluated using three replicate vehicles with similar mileage. The 3.0 L sedans were tested to simulate light-load at vehicle curb weight (vehicle and operator). The 3.5 L sedans and 4.7 L pickups were tested to simulate medium- and heavy-load, respectively, at the gross vehicle weight rating (GVWR) operating on a 1.5% incline. The GVWR represents the maximum hauling capacity of the vehicle. The vehicles were instrumented to monitor fuel consumption, operating temperatures and emission composition (O2, CO, CO2, NOx, and total unburned hydrocarbons (HC)). Fuel trim and injector pulse width data also were observed from the vehicle computer system using a diagnostics monitor. The vehicles were operated at a prescribed drive cycle to simulate a typical 30 minute trip at speeds of 35, 50, and 65 mph. The average fuel efficiencies and power output for each model was analyzed.

Theoretically, there should be no change in the amount of force or power required to move a vehicle a given distance in a given amount of time. However, the power available from a given engine depends on the efficiency of the engine for a specific fuel or fuel blend. The data for the vehicles/engines, prescribed drive cycle and fuels evaluated illustrated the amount of energy used per mile decreased as the ethanol content increased. The E85 fuel blend consumed less BTU's per mile than all other ethanol fuel blends evaluated. This improved conversion of energy (BTU's) for the E85 fuel blend was 13%, 9%, and 14% respectively for the light-, medium-, and heavy-loads when compared to E10.

Better energy efficiency, BTU's per mile, is a great attribute for a fuel, but energy density also is an important consideration. Energy density, BTU's per gallon of fuel decreases as ethanol concentration increases. When compared to the E10 ethanol blend, E20, E30 and E85 fuel blends have 3.5%, 7.1% and 26.5% less BTU's per gallon. To represent both of these factors, consumers most often reference efficiency as the miles driven per gallon of fuel consumed (fuel mileage). When comparing fuel mileage, the higher ethanol blends tended to appear less efficient, although to a lesser degree than the energy density would suggest because of the improved energy

efficiencies for the higher ethanol blends. For example, the E85 fuel blend had 26.5% less energy per gallon than E10, but the fuel mileage only decreased 16%, 19% and 14% for the three models tested. Both the energy density and energy efficiency affect overall fuel economy, but individually they are not good indicators of fuel economy. Many reports highlight the lower energy content of ethanol fuel blends but very few highlight the higher energy conversion efficiency of ethanol fuel blends.

Fuel economy combines fuel efficiency and fuel price. Fuel prices fluctuated greatly in 2007 and 2008, but have been more stable in 2009. To evaluate fuel economy, retail fuel prices were obtained from a regional fuel distributor (Bosselman's Pump & Pantry, Grand Island, NE) for July 28, 2009. This distributor installed an ethanol blender pump in 2009 that commercially sold each of the fuel blends evaluated. The typical price spreads for the fuels at this location for the summer of 2009 were 2 cents per gallon between E10, E20, and E30 fuel blends and 46 cents per gallon between E10 and E85. The E85 fuel blend had the lowest fuel costs per mile for the heavy- and light-loaded vehicles and nearly equal costs for the medium-loaded vehicles. However, the E20 and E30 fuel blends tended to have slightly higher fuel costs per mile, with the exception of the E30 fuel blend in the light-load situation, which had slightly lower fuel costs per mile than the E10 fuel blend. Fuel economy issues are further discussed in Appendix B – Predicting Equivalent Prices for Ethanol Fuel Blends.

The consumption of fuel or energy per horsepower hour also is a direct indication of the efficiency of a vehicle. In the evaluations, more fuel was consumed per horsepower hour on a volume basis with the higher ethanol fuel blends than with the E10 fuel blend. However, the amount of energy (BTU's) consumed per horsepower hour actually decreased with the E85 fuel compared to the E10 fuel.

Fuel trim is a percent adjustment of fuel delivery rates from the manufacturers programmed fuel map. The low- and medium-loaded vehicles operated with a large range of fuel trim. The heavy-loaded vehicles had small fuel trims, -2.6 to -0.6%, suggesting the vehicles computer system did not have to compensate its program as much as the ethanol content changed. Overall, the vehicles fuel trim tended to adjusted less when operated on the E20 and E30 ethanol fuel blends.

Maximum horsepower and torque for each vehicle was determined by conducting a second gear "sweep". The 3.5 L and 4.7 L vehicles tended to generate higher horsepower and torque from the E10 to E30 fuel blends. The 4.7 L vehicles tended to increase in horsepower and torque with the E85 blend. The 3.0 L vehicles generated more torque and horsepower with the E10 and E85 fuel blends, but decreased slightly with the E20 and E30 fuel blends.

Emission compositions were observed after the catalytic converter with the vehicles operating at 65 mph and steady state conditions. The medium- and light-loaded vehicles, which represented low and high mileage vehicles, respectively, had no carbon monoxide emissions. However, the heavy-loaded vehicles with the larger engines emitted carbon monoxide, but the level of emissions decreased as the ethanol content of the fuel increased. The low mileage, medium-loaded vehicles had lower NOx emissions than the older, high mileage, light-loaded vehicles or the heavy-loaded vehicles.

From an overall operational standpoint, the medium- and heavy-loaded vehicles maintained or improved maximum torque and horsepower with the E20 and E30 ethanol fuel blends without giving up much fuel efficiency (mpg) while having better average emissions when operated at 65 mph steady state conditions.

Conclusions from the evaluation of the outlined ethanol fuel blends should be limited to the specific vehicles evaluated because the evaluation of 9 vehicles from 3 different models and manufacturers is not a large enough sample size to represent all flex fuel vehicles/engines. However, the evaluation of these specific vehicles does provide some insight about general trends that may be observed. Further work should evaluate a much broader set of flex fuel vehicles.

Introduction

The objective of this study was to determine the fuel efficiencies and emission profiles of flex fuel vehicles at various ethanol gasoline fuel blends. Programs are in place to support the introduction of ethanol blender pumps at retail fuel stations. A blender pump allows fuel blends other than regular gasoline (E0) and E85 to be mixed at the pump to produce E10, E20 and E30 blends. This provides more options for the consumer; but only requires the fuel station to support two fuel storage tanks. Flexible fuel vehicles are designed to operate on ethanol: gasoline fuel blends from 0% to 85% ethanol, on a volume basis. This is a very wide range for the vehicles and manufacturers to compensate for changes in fuel density, energy content, and conversion efficiencies. As the ethanol concentration changes from 0 to 85%, fuel density can change from 6.1 to 6.4 lbs per gallon and the energy content can range from 115,000 BTU per gallon to 81,595 BTU per gallon. Energy density is further discussed in Appendix A – Energy Content and Density of Ethanol Fuel Blends.

Figure 1 Blender pump

To accomplish the outlined objective, the fuel flow rate, exhaust emissions and engine and exhaust temperatures were recorded while operating the vehicles on a chassis dynamometer for a prescribed drive cycle, while the fuel supply was alternated to evaluate the select fuel blends.

Materials and Methods

Vehicles Tested

Flexible fuel vehicles were obtained from the State of Nebraska Transportation Services Bureau. The vehicles tested were Ford Taurus's (3.0 L), Chevy Impala's (3.5 L) and Chrysler Dodge Ram 1500 (4.7 L) pickups. Three vehicles of each make and model were tested. Each model of vehicles selected had similar mileage except the pickups which had a wider range of miles.

Figure 2 Chassis dynamometer

Test Equipment

An automotive repair company, "The Shop, Inc., Lincoln NE" was contracted to test the vehicles on a Mustang chassis dynamometer. The dynamometer was able to simulate road conditions and measure engine speed, torque and horse power produced at the wheels. All vehicles were operated with the same prescribed drive cycle.

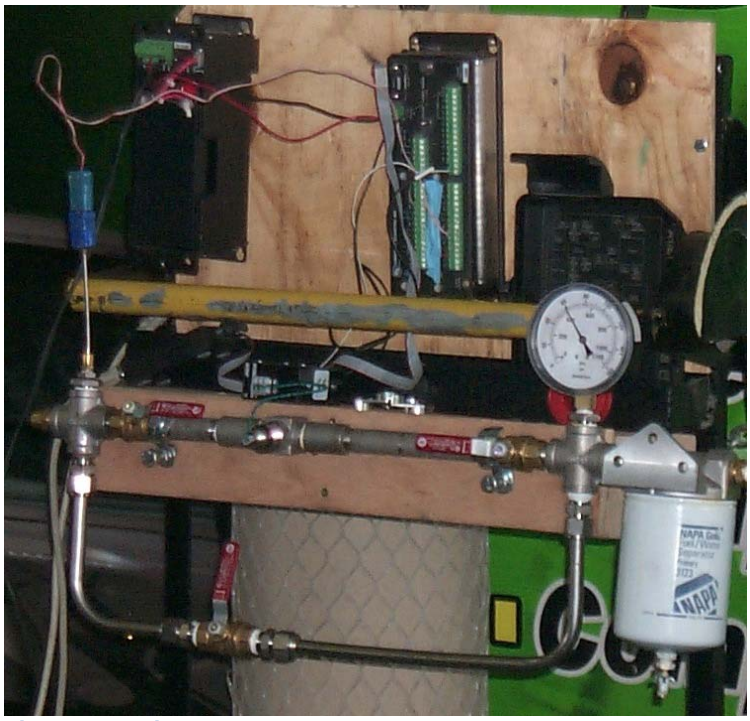

Figure 3 Fuel measurement system

Fuel volume and temperature were recorded with a turbine flow meter from Omega Engineering and a thermocouple. These were connected to a Campbell Scientific data logger that recorded readings every 15 seconds. The vehicles also were equipped with thermocouples to measure ambient air temperature, exhaust manifold temperature, engine temperature at the thermostat, tailpipe temperature and engine ambient temperature. Exhaust emissions from the vehicles were analyzed with a 5-gas analyzer

from Bridge Analyzers, Inc. Fuel trim and pulse widths were recorded using a Snap-On MODIS diagnostic tool.

Fuel

The fuel was purchased from the State of Nebraska Transportation Services Bureau's fueling station on 17th and N Streets in Lincoln NE. The E10 and E85 fuel blends were analyzed to verify their ethanol contents. The method used to analyze the fuels was: (1) 100 ml of fuel were measured in a 250 ml graduated cylinder, (2) distilled water was added up to the 250 ml mark of the graduated cylinder, (3) the solution was mixed and left to sit for a minimum of 5 min, (4) the amount of gasoline was determined by reading the volume of the top petroleum layer, (5) the percent ethanol was determined by subtracting the volume of gasoline from the 100 ml of fuel initially put into the volumetric cylinder. These results were used to calculate fuel ratios to make the E20 and E30 blends.

Figure 4 Fuel ethanol content testing

Test Cycle

The vehicles were driven onto and secured to the chassis dynamometer. The basic vehicle maintenance performed was to replace the air filter, clean the mass air flow sensor, and check and adjust tire pressure and engine oil levels. The fuel from the vehicle's fuel tank was drained by disconnecting the fuel line near the fuel rail and activating the fuel pump. Once the fuel was drained from the fuel tank, test fuel was flushed through the system to remove any fuel left in the line. At this time 5 to 10 gallons of test fuel were put into the fuel tank. The fuel line was routed to pass through a flow meter and temperature sensor then back to the fuel rail. The vehicles computer module was reset by disconnecting the negative battery cable and jumping it to the positive terminal for a few seconds.

The vehicle was then put through the drive cycle outlined in Table 1.

Table 1. Drive Cycle			
Pre drive cycle		Test Cycle	
Time (min)	Action	Time (min)	Action
		0 to 1	Turn on engine and idle
-10 to -9	Turn on engine and idle	1 – 4	35 mph
-9 to -7	35 mph	4 – 7	50 mph
-7 to -5	50 mph	7 – 25	65 mph w/ cruise
-5 to -3	65 mph	25 – 28	50 mph
-3 to 0	Coast to stop	28 – 30	Coast to stop
		Conduct power sweep	
Turn off engine		Turn off engine	

Definitions

Fuel trim is the amount (percentage) the computer module enriches or retards fuel delivery to adjust the air: fuel ratio to 14.7 from a set of prescribed values. A positive fuel trim means the vehicle's computer system has sensed a lean air: fuel mixture and is attempting to enrich the mixture. A negative fuel trim means the vehicle's computer system has sensed a rich air: fuel mixture and is attempting to lower the mixture.

Injector pulse width is the amount of time (milliseconds (ms)) the fuel injectors are open and allowing fuel to be pumped into the cylinder during the intake cycle.

Miles per gallon calculated (mpgc) is the miles per gallon calculated by dividing the average vehicle speed by the average fuel consumption at that speed.

Miles per gallon trip (mpgt) is the miles per gallon calculated for the whole test cycle. It divides the trip mileage by the amount of fuel consumed.

Energy (BTU's) per mile (BTU/m) is the average amount of energy the engine burned while traveling one mile. It was calculated by dividing the energy density of the fuel by the miles per gallon.

Energy (BTU's) and fuel use per horsepower hour relates to how the vehicle converts energy or fuel into horsepower. These were determined by dividing the energy fuel consumption rate by the average horsepower generated at a specific speed.

The reported power and torque values are those generated at the wheels and not by the engine. Torque and power are related. Torque is the rotational work done (ft-lbs, length of lever arm multiplied by the force), while power is the rate at which the work is transmitted. Therefore, the maximum torque developed at the wheels may be at a lower speed than the maximum horsepower developed at the wheels.

Results and Discussion

Tables 2 through 4 list the average fuel efficiencies and power outputs for the light-, medium- and heavy- loaded vehicles. The light-loaded vehicle simulated the curb weight of the vehicles, the medium- and heavy-loaded vehicles simulated the vehicles climbing a 1.5% incline at the gross vehicle weight rating, which included the vehicles curb and load weight. Appendix C has the model and individual vehicle test summaries.

The amount of fuel or energy per horsepower hour is a direct indication of the efficiency of the vehicles. Among all vehicle models it took more fuel, on a volume basis, with the higher ethanol fuel blends but it did not increase as much for the E20 or E30 fuel blends. However, the amount of energy used per horsepower hour decreased with the E85 fuel blend (Figure 7).

All three models showed a lower change in mileage (miles per gallon) between E10 to E30 fuel blends then from E30 to E85 fuel blends (Figure 5). Fuel use increased for the medium- and heavy-loaded vehicles as the ethanol content increased. For the light-loaded vehicles, fuel use actually decreased suggesting the vehicles may have been loaded too lightly for good comparisons. When referencing the amount of energy (BTU's) used per mile, it can be observed that as the ethanol content increased, the amount of energy used per mile decreased showing increased energy efficiency (Figure 6).

Fuel economy combines fuel efficiency and fuel price. Fuel prices fluctuated greatly in 2007 and 2008, but have been more stable in 2009. To evaluate fuel economy, retail fuel prices were obtained from a regional fuel distributor (Bosselman's Pump & Pantry, Grand Island NE) for July 28, 2009 that recently installed an ethanol blender pump that commercially sold each of the fuel blends evaluated. The prices presented in Tables 2, 3 and 4 represent the typical price spreads for the fuels at this location for the summer of 2009 (2 cents per gallon between E10, E20, and E30 fuel blends and 46 cents per gallon between E10 and E85). Figure 11 illustrates the E85 fuel blend had the lowest fuel costs per mile for the heavy- and light-loaded vehicles and nearly equal costs for the medium-loaded vehicles. However, the E20 and E30 blends tended to have slightly higher fuel costs per mile other than the use of E30 in the light-load situation, which was slightly lower than the E10 fuel blend.

The maximum horsepower and torque generated by the vehicles were determined by conducting a second gear “sweep” (Figures 8 and 9). The vehicle was put into second gear and the speed was increased until the vehicle shifted into second gear. The accelerator was then pushed to the floor and the engine speed increased to 5,700 or 5,900 rpm. When accelerating, a vehicle operates with a rich air: fuel ratio allowing the vehicle to accelerate quickly. Maximum torque and horsepower do not occur at the same engine speed. The 3.5 L and 4.7 L vehicles tended to generate higher horsepower and torque from the E10 to E30 fuel blends. The 4.7 L vehicles tended to increase in horsepower and torque at the E85 blend. The 3.5 L vehicles decreased in maximum torque and horsepower from the E85 blend because the vehicles operated in a lean condition. The 3.0 L vehicles generated more torque and horsepower at the E10 and E85 fuel blends, but decreased slightly with the E20 and E30 fuel blends. This may have been related to the age of and miles on the vehicles tested.

Fuel trim is the measurement of how much a vehicle’s computer is adjusting the prescribed fuel delivery, which is pre-programmed by the manufacturer. Ideally the fuel trim should stay within ±10% of 0. The light- and medium-loaded vehicles operated with a large range of fuel trim with a negative fuel trim at the low ethanol content fuels and with increasing trim as the ethanol content increases. The heavy-loaded vehicles had small fuel trims, suggesting the vehicle computer system did not have to compensate its program as much as the ethanol content changed.

The injector pulse width increased as ethanol content increased. From E10 to E30 blended fuels, there was a change of only 10% in the pulse width, when the fuel blend increased to E85, the pulse width increased by 26 to 36%. The change in pulse width was equivalent, or greater, than the change in energy content, which could have meant that there was some compensation for fuel temperature taking place. (See Appendix A for discussion of fuel and energy densities.)

Emissions composition (Table 5) was monitored, after the catalytic converter, while the vehicles were operating at 65 mph and steady state conditions. The emission data were recorded and converted into grams per mile using the theoretical mass air flow rate of the engine. The medium- and light-loaded vehicles had no carbon monoxide emissions, but with the heavy-loaded vehicles, where a larger engine was involved, carbon monoxide was emitted but decreased as the fuel ethanol content increased. The low mileage, medium-loaded vehicles had lower NOx emissions than the older, high mileage and light-loaded vehicles or the heavy-loaded vehicles. The light-loaded vehicles all had similar carbon dioxide emissions because the vehicles did not have to shift to lower gears. The medium- and heavy-loaded vehicles tended to shift down and then back up during the 65 mph test cycle. This had an effect on the

emission profile, because the engine speed would increase for a period of time and then down shift, increasing the mass air flow rate going through the engine.

Table 6 displays the average equilibrium temperatures for the vehicles while operating on the evaluated fuel blends at 65 mph. The data show the exhaust, post muffler and engine temperatures for the 3.5 L and 4.7 L vehicles were higher than the 3.0 L. This is expected due to the larger load and engine sizes for those vehicles.

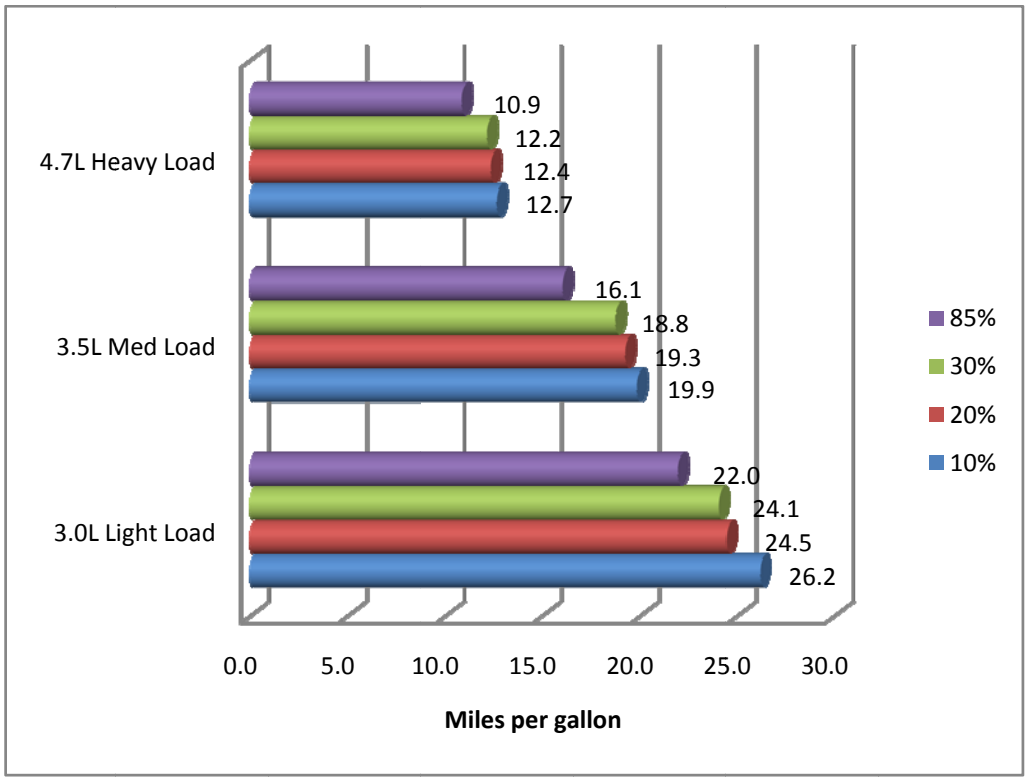

Figure 5 Fuel mileage comparison - trip mileage

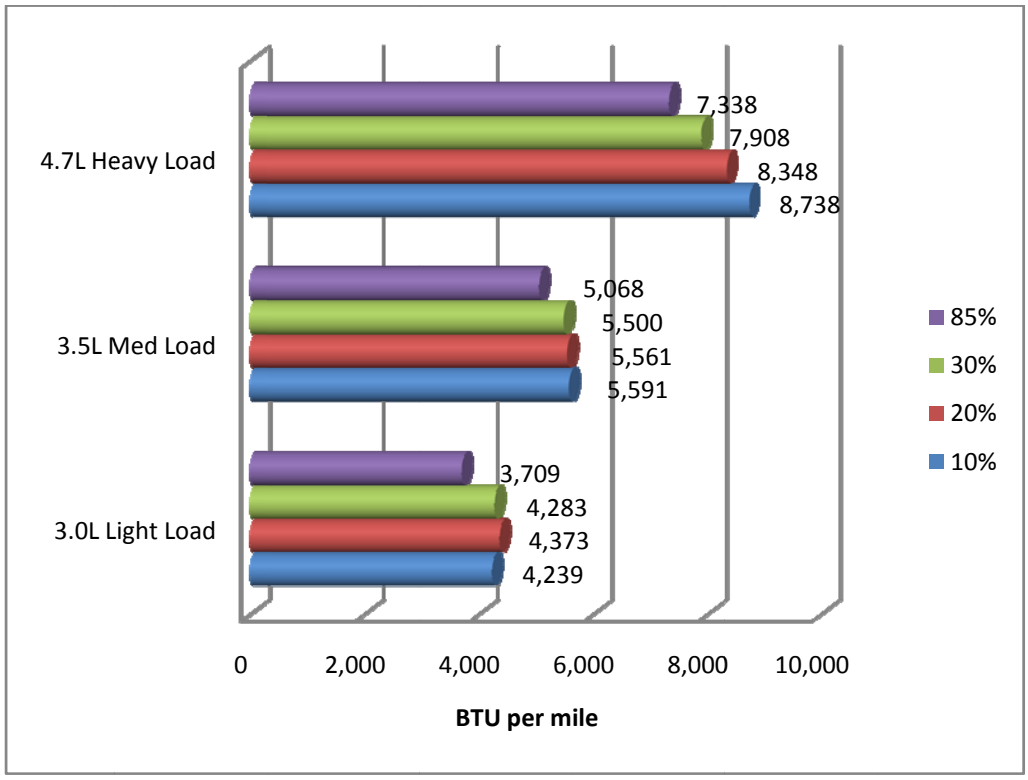

Figure 6 Energy mileage comparison - trip cycle

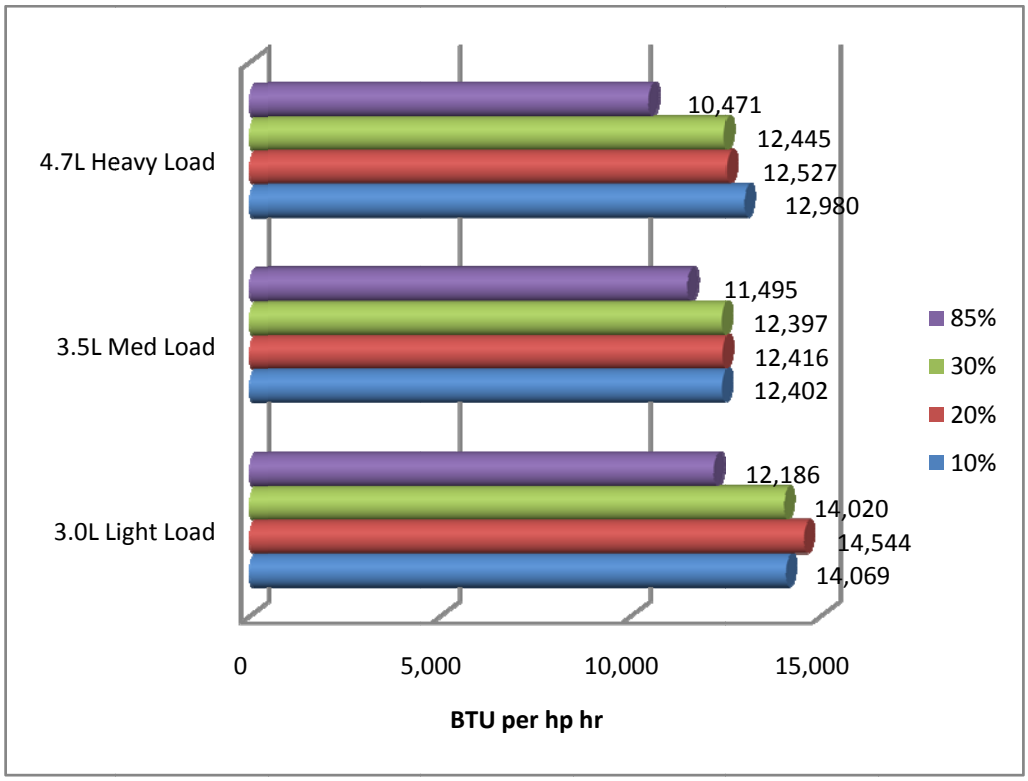

Figure 7 Energy efficiency comparison - 65 mph

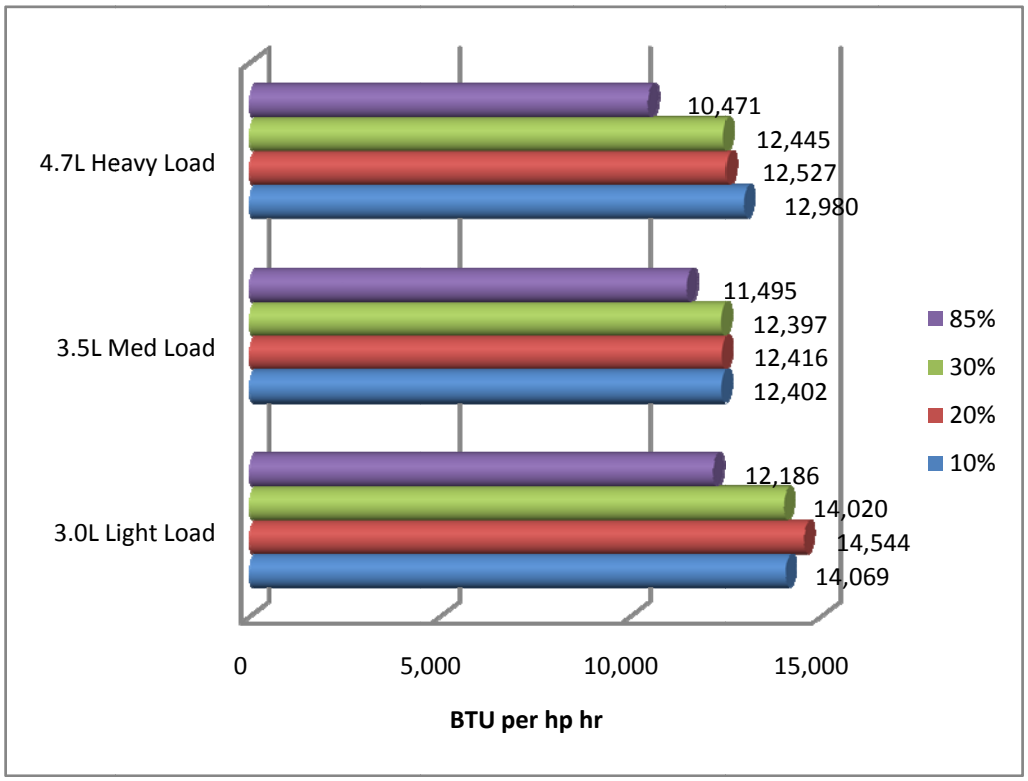

Figure 8 Maximum horsepower - second gear sweep

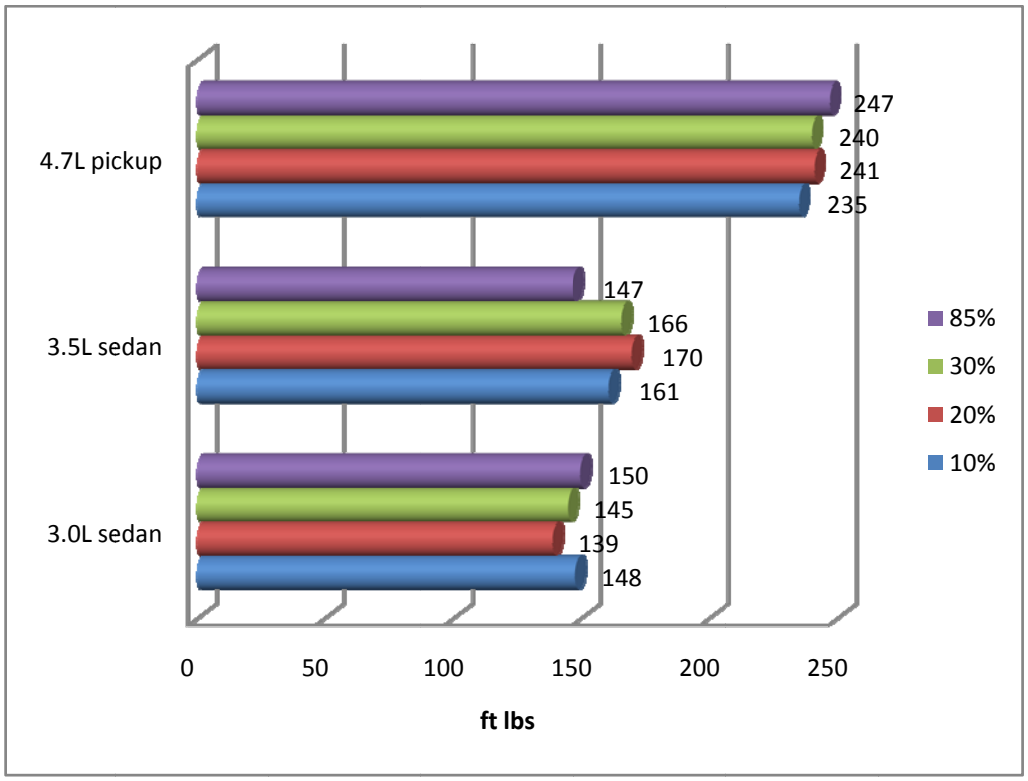

Figure 9 Maximum torque - second gear sweep

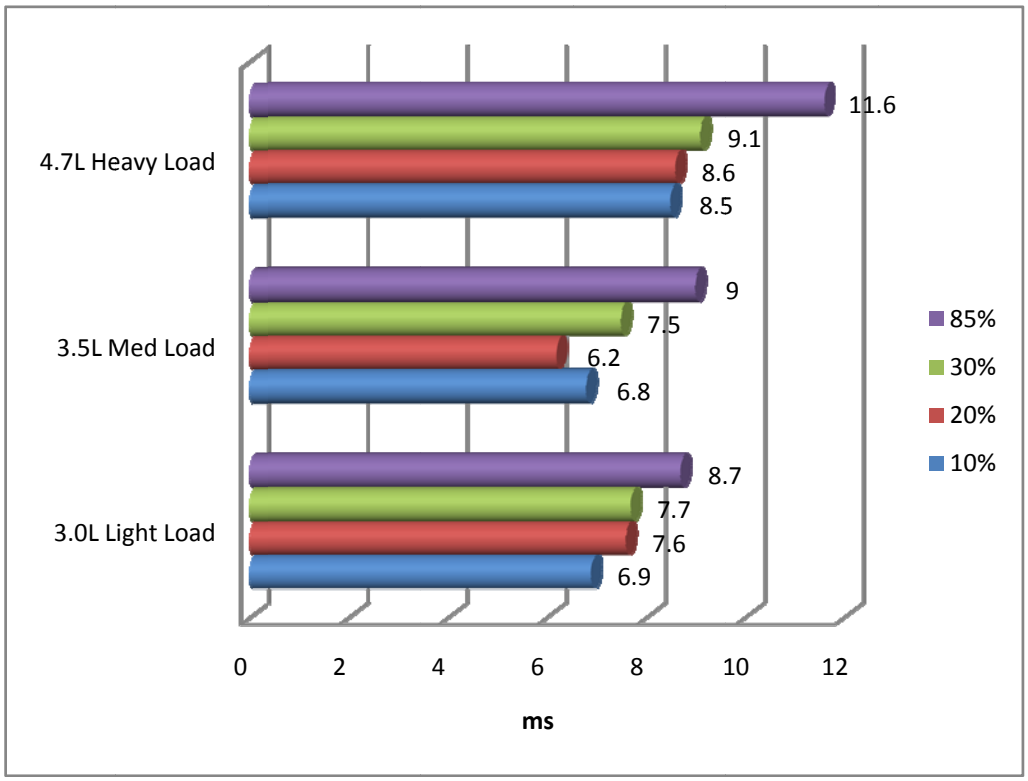

Figure 10 Average injector pulse width - 65 mph

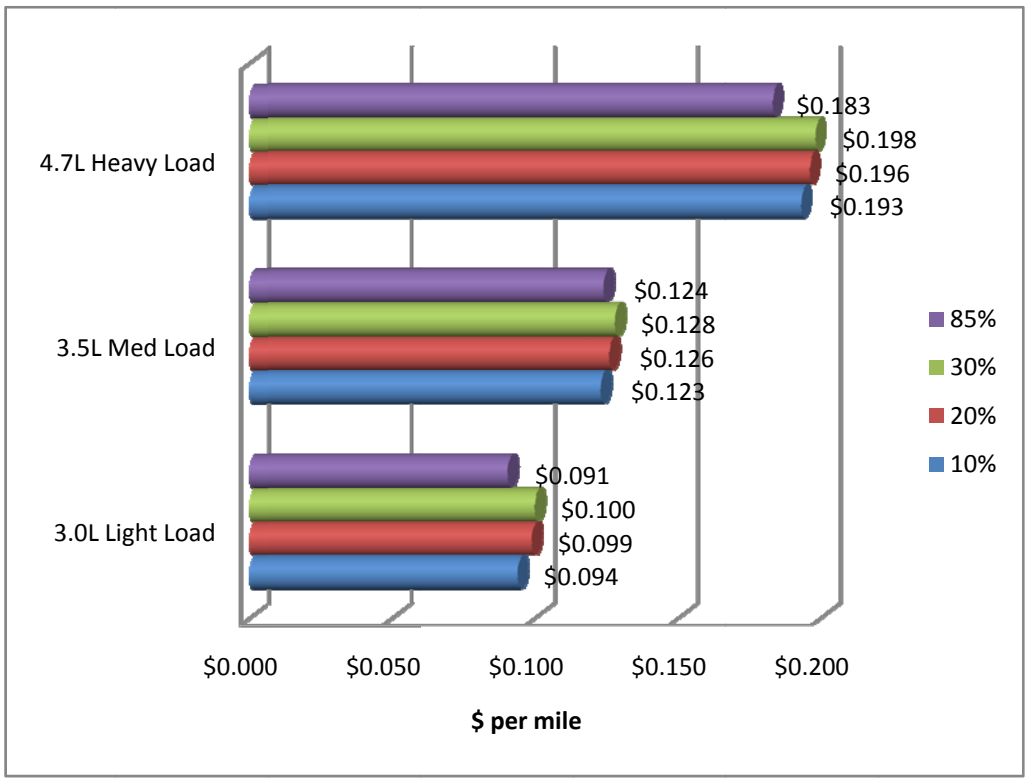

Figure 11 Cost per mile

Table 2. Light-Load (3.0 L Engine)				
Fuel Ethanol Content	10%	20%	30%	85%
BTU content (BTU/gal)	111,070	107,140	103,210	81,595
% change in BTU's per gallon	0%	-3.5%	-7.1%	-26.5%
Cost per gallon[1]	$2.45	$2.43	$2.41	$1.99
% change in cost per gallon	0%	-0.8%	-1.6%	-18.8%
BTU/$	45,335	44,091	42,826	41,003
65 mph				
Hp	22.5	22.1	22.6	22.9
Gph	2.85	3.00	3.07	3.42
Mpg	22.8	21.7	21.2	19.0
BTU's per mile	4,879	4,930	4,868	4,294
Gallons per hp hr	0.127	0.135	0.136	0.150
BTU per hp hr	14,085	14,506	14,026	12,204
Fuel Trim %	-1.8%	-0.5%	0.3%	10.7%
Injector Pulse Width (ms)	6.9	7.6	7.7	8.7
% change in pulse width	0%	9%	12%	26%
50 mph				
Hp	12.5	12.1	11.9	13.1
Gph	2.21	2.30	2.23	2.35
Mpg	22.6	22.0	22.5	21.2
BTU's per mile	4,907	4,870	4,594	3,843
Gallons per hp hr	0.178	0.191	0.188	0.180
BTU per hp hr	19,746	20,420	19,370	14,658
Test Cycle				
Mpg	26.2	24.5	24.1	22.0
% change in mpg	0%	-6%	-8%	-16%
BTU's per mile	4,239	4,373	4,283	3,709
% change in BTU's per mile	0%	3%	1%	-13%
Cost per mile	$0.094	$0.099	$0.100	$0.091
% change in cost per mile	0%	5.3%	6.4%	-5.2%
Other				
Average max hp (2nd gear)	116	108	108	122
Average max torque (2nd gear)	148	139	145	150

[1] Retail fuel prices were obtained from a regional fuel distributor (Bosselman's Pump & Pantry, Grand Island NE) for July 28, 2009.

Table 3. Medium-Load (3.5 L Engine)				
Fuel Ethanol Content	10%	20%	30%	85%
BTU content (BTU/gal)	111,070	107,140	103,210	81,595
% change in BTU's per gallon	0%	-3.5%	-7.1%	-26.5%
Cost per gallon	$2.45	$2.43	$2.41	$1.99
% change in cost per gallon	0%	-0.8%	-1.6%	-18.8%
BTU/$	45,335	44,091	42,826	41,003
65 mph				
Hp	34.3	34.0	34.3	34.0
Gph	3.83	3.94	4.12	4.79
Mpg	17.0	16.5	15.8	13.6
BTU's per mile	6,534	6,493	6,532	6,000
Gallons per hp hr	0.112	0.116	0.120	0.141
BTU per hp hr	12,390	12,405	12,395	11,495
Fuel Trim %	-9.9%	-5.3%	2.9%	26.3%
Injector Pulse Width (ms)	6.8	6.2	7.5	9.0
% change in pulse width	0%	-10%	9%	32%
50 mph				
Hp	21.7	21.7	21.3	21.7
Gph	2.60	2.64	2.67	3.14
Mpg	19.3	19.0	18.8	16.0
BTU's per mile	5,765	5,629	5,480	5,100
Gallons per hp hr	0.120	0.122	0.125	0.145
BTU per hp hr	13,328	13,071	12,901	11,838
Test Cycle				
Mpg	19.9	19.3	18.8	16.1
% change in mpg	0%	-3%	-6%	-19%
BTU's per mile	5,591	5,561	5,500	5,068
% change in BTU's per mile	0	-1%	-2%	-9%
Cost per mile	$0.123	$0.126	$0.128	$0.124
% change in cost per mile	0%	2.4%	4.1%	0.8%
Other				
Average max hp (2nd gear)	142	144	148	139
Average max torque (2nd gear)	161	170	166	147

Table 4. Heavy-Load (4.7 L Engine)				
Fuel Ethanol Content	10%	20%	30%	85%
BTU content (BTU/gal)	111,070	107,140	103,210	81,595
% change in BTU's per gallon	0%	-3.5%	-7.1%	-26.5%
Cost per gallon	$2.45	$2.43	$2.41	$1.99
% change in cost per gallon	0%	-0.8%	-1.6%	-18.8%
BTU/$	45,335	44,091	42,826	41,003
65 mph				
Hp	50.8	52.1	52.0	54.4
Gph	5.96	6.08	6.27	6.93
Mpg	10.7	10.5	10.3	9.3
BTU's per mile	10,347	10,237	10,016	8,744
Gallons per hp hr	0.117	0.117	0.120	0.127
BTU per hp hr	13,035	12,514	12,431	10,393
Fuel Trim %	-2.6%	-1.0%	-1.4%	-0.6%
Injector Pulse Width (ms)	8.5	8.6	9.1	11.6
% change in pulse width	0%	0%	7%	36%
50 mph				
Hp	34.5	33.0	40.4	33.3
Gph	3.81	3.91	4.01	4.51
Mpg	13.1	12.8	13.1	11.1
BTU's per mile	8,459	8,348	7,908	7,338
Gallons per hp hr	0.110	0.118	0.099	0.135
BTU per hp hr	12,271	12,678	10,253	11,043
Test Cycle				
Mpg	12.7	12.4	12.2	10.9
% change in mpg	0%	-2%	-4%	-14%
BTU's per mile	8,738	8,348	7,908	7,338
% change in BTU's per mile	0%	-1%	-3%	-14%
Cost per mile	$0.193	$0.196	$0.198	$0.183
% change in cost per mile	0%	1.6%	2.6%	-5.2%
Other				
Average max hp (2nd gear)	195	197	198	202
Average max torque (2nd gear)	235	241	240	247

Table 5. Emission Composition (grams per mile)					
Fuel Ethanol Content		10%	20%	30%	85%
3.0 L Engine High Mileage (65 mph)	CO	0	0	0	0
	O2	0	0	0	0
	NOx	0.03	0.02	0.03	0.05
	HC	0.02	0.02	0.01	0.01
	CO2	521	519	520	520
3.5 L Engine Low Mileage (65 mph)	CO	0	0	0	0
	O2	0	0	0	0
	NOx	0	0	0	0
	HC	0.02	0.01	0.01	0.0
	CO2	546	629	491	491
4.7 L Engine Medium Mileage (65 mph)	CO	3.7	3.6	3.3	0.7
	O2	0	0	0	0
	NOx	0.2	0.1	0.1	0.1
	HC	0.02	0.03	0.02	0.02
	CO2	856	879	901	803

Table 6. Temperature Data					
Fuel Ethanol Content		10%	20%	30%	85%
3.0 L Engine High Mileage (65 mph) (°F)	Post Muffler	575	557	553	552
	Exhaust Manifold	598	601	601	591
	Engine	236	236	233	234
	Engine Ambient	194	191	190	192
	Ambient	85	82	79	83
3.5 L Engine Low Mileage (65 mph) (°F)	Post Muffler	806	804	802	796
	Exhaust Manifold	872	880	871	861
	Engine	285	292	293	293
	Engine Ambient	185	189	188	190
	Ambient	70	69	69	71
4.7 L Engine Low Mileage (65 mph) (°F)	Post Muffler	843	863	854	806
	Exhaust Manifold	934	935	945	888
	Engine	332	336	341	320
	Engine Ambient	141	138	139	141
	Ambient	80	79	78	82

Summary of Observations

The following observations are drawn from the evaluations of four ethanol fuel blends used to power 9 vehicles operating on a chassis dynamometer for a prescribed drive cycle. In relationship to the U.S. auto fleet, this is a very small selection of vehicles, so these observations should only be considered representative of the specific vehicles and models evaluated. However, these observations may serve as an indicator for other vehicles/engines that would need to be validated through evaluations of larger data sets.

- ✓ The E85 fuel blend provided better energy conversion, lower energy use (BTU's) per mile, than all other fuel blends evaluated.
- ✓ Energy density, BTU's per gallon, decreases as the ethanol concentration increases. As a result, the E85 fuel blend has 26.5% less energy per gallon then the E10 fuel blend, but fuel mileage only decreased 16%, 19%, and 14% for the three models tested.
- ✓ Energy density alone is not an accurate indicator of fuel efficiency.
- ✓ The E85 fuel blend had the lowest fuel costs per mile for the heavy- and light-loaded vehicles and nearly equal costs for the medium-loaded vehicles.
- ✓ The E20 and E30 fuel blends tended to have slightly higher fuel costs per mile other than the use of E30 in the light-load situation, which was slightly lower than the E10 fuel blend.
- ✓ On a horsepower hour basis, more fuel was consumed on a volume basis as the ethanol concentration increased, but the amount of energy (BTU's) consumed per horsepower hour actually decreased with the E85 fuel blend compared to the E10 fuel blend.
- ✓ The maximum horsepower and torque produced by the heavy-loaded, 4.7 L, vehicles tended to increase as the ethanol concentration increased from the E10 to E85 fuel blend. The medium-loaded, 3.5 L, vehicles tended to generate higher horsepower and torque from the E10 to E30 fuel blends. The light-loaded, 3.0 L, vehicles tended to generate higher horsepower and torque from the E10 and E85 fuel blends, but generated slightly less with the E20 and E30 fuel blends.
- ✓ The fuel trim for the heavy-loaded vehicles was very small, a -2.6 to -0.6%. The fuel trim for the light- and medium-loaded vehicles was much larger, ranging from a -9.9% to 26.3%, however the vehicles fuel trim adjusted less when operated on E20 to E30 fuels.
- ✓ Carbon monoxide emissions were detectable with the heavy-loaded, 4.7 L, vehicles, but the level of emissions decreased as the ethanol content of the fuel increased. No carbon monoxide emissions were detectable with the light- and medium-loaded vehicles.

- ✓ From an operational standpoint, the vehicles tended to generate good maximum torque and horsepower at the E20 to E30 blends without giving up much fuel efficiency (mpg), none in the medium-loaded vehicles, while having better average emissions at 65 mph.

Figure 12 Dodge Ram 1500 pickup on dynamometer

Appendix A – Energy Content and Density of Ethanol Fuel Blends

There are several fuel properties that are important when researching fuels. Two of the properties that we have focused on are the specific gravity and the heating value (energy content) of the fuels. Specific gravity is the ratio of the density of the fuel to the density of water. Because gasoline and diesel use wide varieties of chemicals (gasoline uses C4 to C12 chains, while diesel uses C8 to C25 chains) the specific gravity and energy content can vary among fuel lots, truck loads, seasons, or years. The fuels heating value is the amount of energy that is available from the fuel. There are two heating values that are usually reported: a higher and lower heating value. The higher heating value refers to the gross amount of heat released when the ignited fuel and the steam produced is allowed to condense back to water. The lower heating value is the net amount of heat released when the fuel is ignited and steam is not allowed to cool to a liquid. Therefore, between the two values is the heat of vaporization in the combustion product mixture. The Society of Automotive Engineers information report number J1498, references an equation to estimate the lower heating value from a measured higher heating value.

Fuel samples were taken of all fuels tested to determine the gross energy content and specific gravity of the fuel blends. A Parr adiabatic bomb calorimeter was used to determine the gross energy content (higher heating value) of fuel samples and specific gravity was determined by using hydrometers.

Figure A.1 shows the bomb calorimetry measurements were very similar to referenced data. Specific gravity was lower then what was calculated algebraically but was still acceptable given the wide range of specific gravity reported for gasoline (0.72 to 0.78).

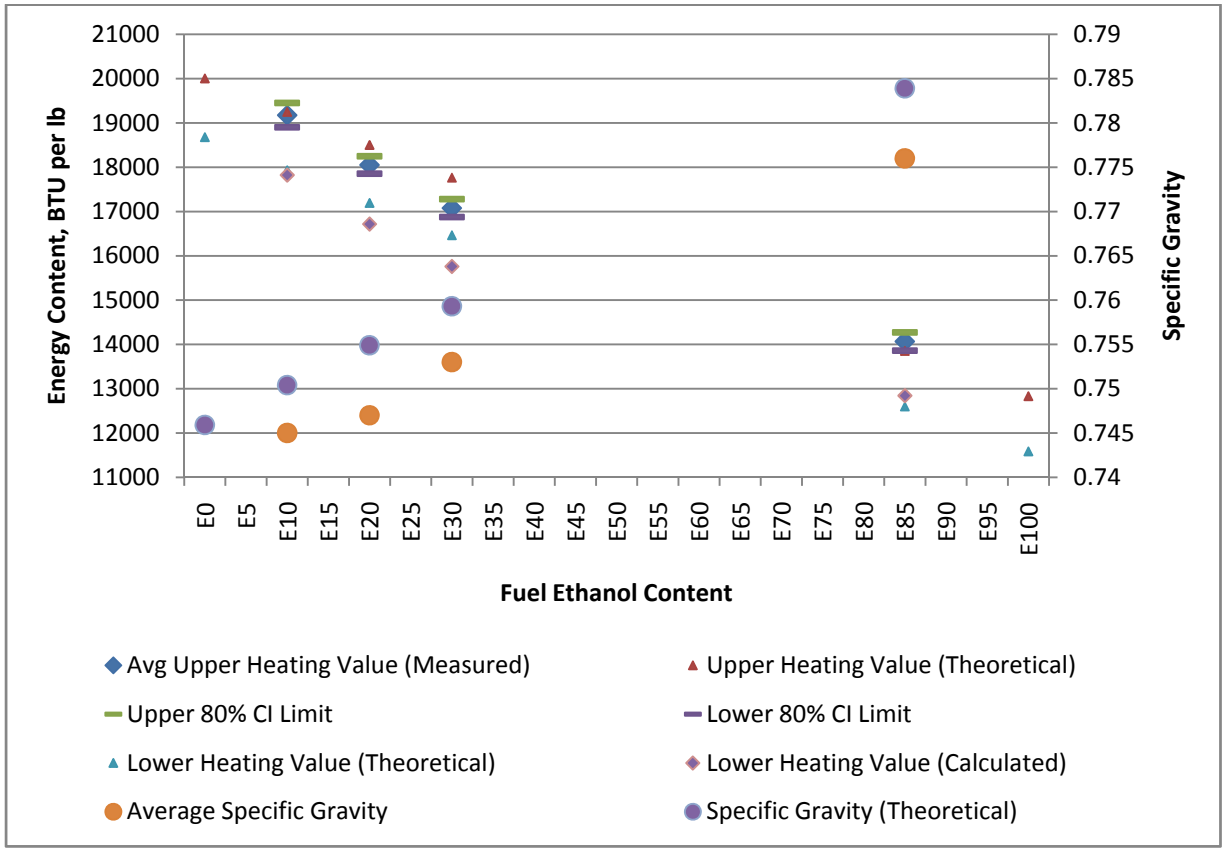

Figure A.13 Energy content and specific gravity measurements

Appendix B – Predicting Equivalent Prices for Ethanol Fuel Blends

Fuel costs per mile are typically the issue of greatest concern for vehicle operators. Similarly, fuel margins are typically the issue of greatest concern for fuel distributors and retailers as they pass wholesale products and prices on to retail customers. However, ethanol representatives may want to better understand a fuels overall efficiency to best represent the products value to consumers. With the data presented in an energy efficiency format, BTU per mile, the fuel economy question can be viewed quite differently. If the cost for an E10 ethanol blend is known on a cost per gallon basis, and the energy efficiency of ethanol fuel blends are known for given vehicles/engines, then the data could be used to predict an equivalent cost for other ethanol blends. For example, Figure B.1 uses the energy efficiency rates for the medium-loaded vehicles tested to illustrates the equivalent price for E20, E30, and E85 based on the known cost of an E10 ethanol blend at $2.45 per gallon (45,335 BTU/$).

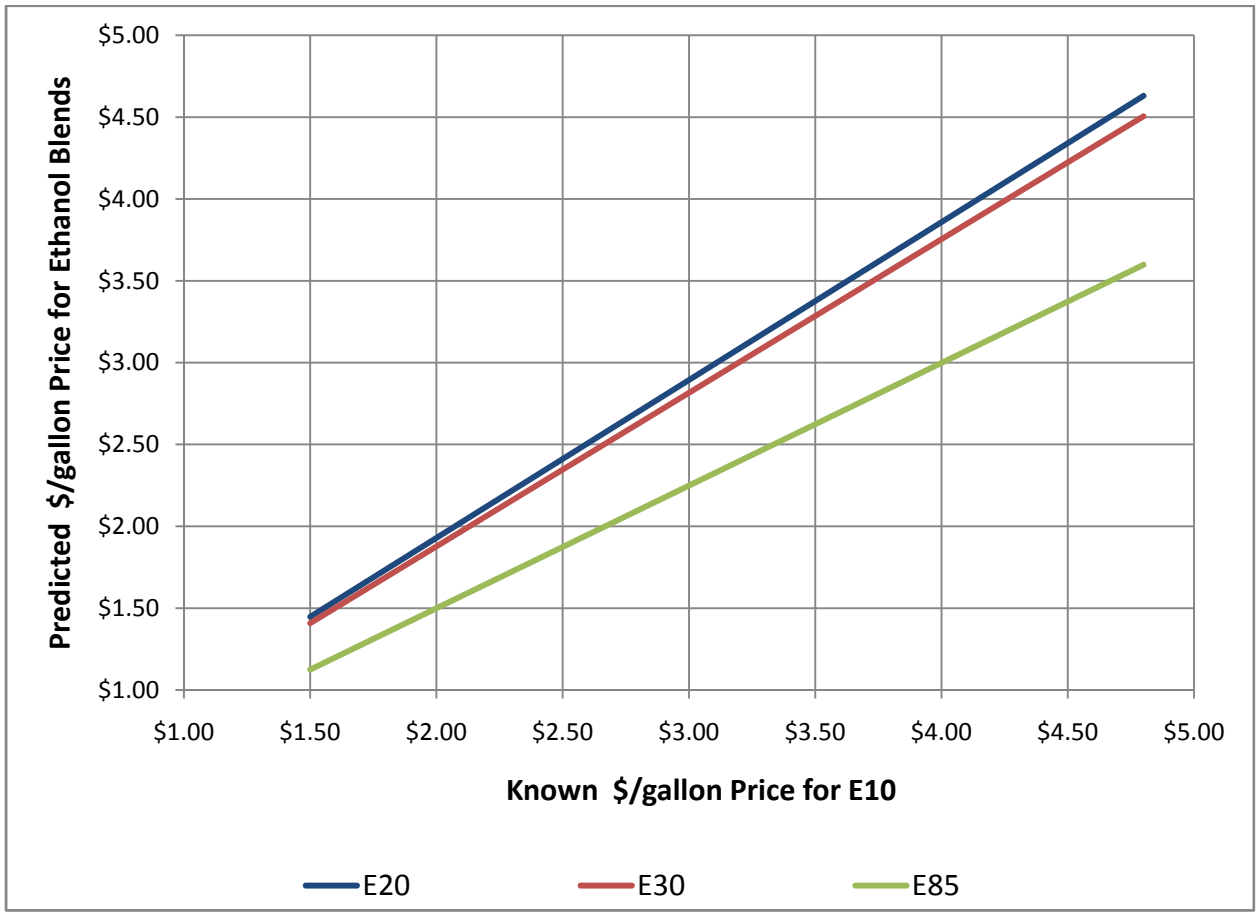

Figure B.14 Equivalent price predictions for ethanol fuel blends

Appendix C – Model and Individual Vehicle Test Summaries

Vehicle mileage at 50 mph.

Fuel Type	Engine Speed (rpm)	Average Power (HP)	Gallons per hour	Average Fuel Temp °F	Miles per gal
E10	1763	12.5	2.21	86	22.6
	16	0.5	0.12	13	1.3
E20	1751	12.1	2.30	79	22.0
	8	0.4	0.28	9	2.8
E30	1755	11.9	2.23	77	22.5
	7	0.1	0.15	3	1.5
E85	1755	13.1	2.35	81	21.2
	9	0.3	0.11	6	1.0

Vehicle mileage at 65 mph.

Fuel Type	Engine Speed (rpm)	Average Power (HP)	Gallons per hour	Average Fuel Temp °F	Miles per gal
E10	2267	22.5	2.85	96	22.8
	9	0.6	0.04	12	0.3
E20	2262	22.1	3.00	92	21.7
	5	0.9	0.16	11	1.2
E30	2264	22.6	3.07	91	21.2
	8	0.4	0.11	7	0.8
E85	2265	22.9	3.42	96	19.0
	8	1.3	0.20	7	1.1

Vehicle trip mileage.

Fuel Type	Mileage
E10	26.2
	0.6
E20	24.5
	0.7
E30	24.1
	0.9
E85	22.0
	1.2

Flex Fuel Vehicle Test Summary

Test Date: 4/14/09 – 4/23/09

Owner of vehicles: State of Nebraska

Description of Vehicle

Make: Ford

Model: Taurus Flex Fuel.

Year mfg: 2000, 2002, 2003

Engine: 3.0 V6

Odometer: 79,000 to 98,000 miles

Tire size: P215 60 R16

Gross Vehicle Weight: 4,685 lbs

Dynamometer Set Weight: 3,625 lbs

Maintenance before test:

Maintenance before tests included pressurizing tires to 35 psi, adding oil if needed, replacing air filter, and cleaning mass air flow meter

Tables reflect the average (top) and standard deviation (bottom) of the three cars.

Vehicle fuel trim and injector pulse width at 50 mph.

Fuel Type	Average Fuel Trim	Average Injector Pulse Width (ms)
E10	-1.2	6.0
	1.0	2.1
E20	-0.1	6.7
	1.1	1.0
E30	-0.3	6.8
	0.6	1.6
E85	8.3	8.7
	7.2	1.2

Vehicle fuel trim and injector pulse width at 65 mph.

Fuel Type	Average Fuel Trim	Average Injector Pulse Width (ms)
E10	-1.8	6.9
	4.0	2.0
E20	-0.5	7.6
	2.3	1.5
E30	0.3	7.7
	2.3	1.7
E85	10.7	8.7
	10.6	1.6

Maximum power at wheels.

Fuel Type	Max Power (hp)	Vehicle Speed (mph)	Engine Speed (rpm)	Gear
E10	116	57	4698	2
	9	4	329	
E20	108	56	4626	2
	1	1	92	
E30	108	58	4773	2
	0	2	144	
E85	122	57	4709	2
	20	1	63	

Maximum torque at wheels.

Fuel Type	Max Torque (Ft lbs)	Vehicle Speed (mph)	Engine Speed (rpm)	Gear
E10	148	40	3392	2
	11	3	150	
E20	139	41	3474	2
	5	1	61	
E30	145	40	3524	2
	8	5	88	
E85	150	40	3550	2
	12	6	206	

Average engine temperatures at 65 mph

Fuel Type	Exhaust (°F)	Tailpipe (°F)	Engine (°F)	Engine Ambient (°F)	Ambient (°F)
E10	598	575	236	194	85
	77	75	41	3	15
E20	601	557	236	191	82
	82	105	41	4	13
E30	601	553	233	190	79
	81	101	43	6	9
E85	591	552	234	192	83
	85	92	41	5	10

Average exhausts emissions at 65 mph

Fuel Type	CO (%)	NOx (ppm)	O2 (%)	HC (ppm)	CO2 (%)
E10	0	8	0	5	14
	0	6	0	1	0
E20	0	4	0	5	14
	0	1	0	1	1
E30	0	7	0	3	14
	0	6	0	1	0
E85	0	12	0	2	14
	0	11	0	1	1

Average exhausts emissions at 65 mph

Fuel Type	CO g/mile	NOx g/mile	O2 g/mile	HC g/mile	CO2 g/mile
E10	0	0.030	0	0.019	521
E20	0	0.015	0	0.019	519
E30	0	0.026	0	0.011	520
E85	0	0.045	0	0.007	520

$$TMA\ \left(\frac{kg}{hr}\right) = \frac{60\ x\ RPM\ x\ \rho(air) x\ Displacement}{2\ x\ 1000}$$

$$\frac{g}{mile} = \frac{TMA\ x\ 1000\ x\ \%\ concentration}{mph\ x\ 100}$$

$$\frac{g}{mile} = \frac{TMA\ x\ 1000\ x\ ppm}{mph\ x\ 1000000}$$

Vehicle mileage at 50 mph.

Fuel Type	Engine Speed (rpm)	Average Power (HP)	Gallons per hour	Average Fuel Temp °F	Miles per gal
E10	1750		2.32	75	21.5
E20	1750		2.37	73	21.1
E30	1750		2.06	73	24.2
E85	1750		2.35	76	21.2

Vehicle mileage at 65 mph.

Fuel Type	Engine Speed (rpm)	Average Power (HP)	Gallons per hour	Average Fuel Temp °F	Miles per gal
E10	2258	23	2.87	87	22.6
E20	2258	23	2.97	85	21.9
E30	2258	23	3.11	85	20.9
E85	2258	23	3.22	91	20.1

Vehicle trip mileage.

Fuel Type	Trip Mileage (miles)	Fuel Consumption (gal)	Mileage (mpg)
E10	26.9	1.0	25.9
E20	26.9	1.1	24.8
E30	27.0	1.1	24.3
E85	26.8	1.1	23.3

Vehicle fuel trim and injector pulse width at 50 mph.

Fuel Type	Average Fuel Trim	Average Injector Pulse Width (ms)
E10	0	-
E20	0	-
E30	0	-
E85	12	9.5

Vehicle fuel trim and injector pulse width at 65 mph.

Fuel Type	Average Fuel Trim	Average Injector Pulse Width (ms)
E10	2	-
E20	-2.5	-
E30	-1	-
E85	17.5	7.75

Flex Fuel Vehicle Test Summary

Test Date: April 14, 2009

Owner of vehicle: State of Nebraska, license number 11724.

Description of Vehicle

Make: Ford.
Model: Taurus - Flex Fuel.
Year mfg: 2002.
Engine: 3.0L V6.
Vin# IFAFP523352A179817.
Odometer: 98188 miles.
Tire size: *P215 60 R16*
Date of last service: *01/13/09*
Odometer of last service: *96,932* miles.
Fuel Pressure: 42 to 52 psi
Gross Vehicle Weight: 4,684 lbs
Dynamometer Set Weight: 3,625lbs

Maintenance before test: replaced air filter, cleaned mass air flow meter, pressurized tires to 35psi, disconnected battery before each fuel type was tested.

Maximum power at wheels.

Fuel Type	Max Power (hp)	Vehicle Speed (mph)	Engine Speed (rpm)	Gear
E10	126.2			2
E20				
E30				
E85	145.2			2

Maximum torque at wheels.

Fuel Type	Max Torque (Ft lbs)	Vehicle Speed (mph)	Engine Speed (rpm)	Gear
E10	149.3			2
E20				
E30				
E85	145.2			2

Average engine temperatures at 65 mph

Fuel Type	Exhaust (°F)	Tailpipe (°F)	Engine (°F)	Engine Ambient (°F)	Ambient (°F)
E10	537	645	224	196	75
E20	537	646	223	195	73
E30	539	635	221	194	71
E85	525	620	223	196	75

Average exhausts emissions at 65 mph

Fuel Type	CO (%)	NOx (ppm)	O2 (%)	HC (ppm)	CO2 (%)
E10	0	14.7	0.0	4.8	14.3
E20	-	-	-	-	-
E30	-	-	-	-	-
E85	0	1.5	0.0	1.1	14.3

Vehicle mileage at 50 mph.

Fuel Type	Engine Speed (rpm)	Average Power (HP)	Gallons per hour	Average Fuel Temp °F	Miles per gal
E10	1781	12.1	2.24	82	22.3
E20	1743	11.8	2.53	74	19.8
E30	1753	11.8	2.29	78	21.9
E85	1749	13.3	2.46	80	20.3

Vehicle mileage at 65 mph.

Fuel Type	Engine Speed (rpm)	Average Power (HP)	Gallons per hour	Average Fuel Temp °F	Miles per gal
E10	2276	21.9	2.88	92	22.6
E20	2260	21.3	2.85	86	22.8
E30	2260	22.4	2.94	90	22.1
E85	2264	21.5	3.42	93	19.0

Vehicle trip mileage.

Fuel Type	Trip Mileage (miles)	Fuel Consumption (gal)	Mileage (mpg)
E10	26.9	1.0	25.8
E20	26.8	1.1	25.0
E30	26.8	1.1	24.9
E85	26.8	1.2	21.7

Vehicle fuel trim and injector pulse width at 50 mph.

Fuel Type	Average Fuel Trim	Average Injector Pulse Width (ms)
E10	-2	7.4
E20	1	7.4
E30	0	7.9
E85	13	9.3

Vehicle fuel trim and injector pulse width at 65 mph.

Fuel Type	Average Fuel Trim	Average Injector Pulse Width (ms)
E10	-6	8.3
E20	2	8.6
E30	3	8.9
E85	16	10.6

Flex Fuel Vehicle Test Summary

Test Date: April 17, 2009

Owner of vehicle: State of Nebraska, license number 12178.

Description of Vehicle

Make: Ford.
Model: Taurus - Flex Fuel.
Year mfg: 2003.
Engine: 3.0L V6.
Vin# IFAFP52303G148022.
Odometer: 97,568 miles.
Tire size: *P215 60 R16*
Date of last service: *05/22/08*
Odometer of last service: *89,068* miles.
Fuel Pressure: 38 to 50 psi
Gross Vehicle Weight: 4,684 lbs
Dynamometer Set Weight: 3,625lbs

Maintenance before test: replaced air filter, cleaned mass air flow meter, pressurized tires to 35psi, disconnected battery before each fuel type was tested, added 1 quart of oil.

Maximum power at wheels.

Fuel Type	Max Power (hp)	Vehicle Speed (mph)	Engine Speed (rpm)	Gear
E10	113.2	60	4930	2
E20	107.3	57	4691	2
E30	107.7	56	4671	2
E85	112.8	56	4664	2

Maximum torque at wheels.

Fuel Type	Max Torque (Ft lbs)	Vehicle Speed (mph)	Engine Speed (rpm)	Gear
E10	157.9	38	3286	2
E20	135.4	41	3517	2
E30	150.7	36	3461	2
E85	163.3	36	3404	2

Average engine temperatures at 65 mph

Fuel Type	Exhaust (°F)	Tailpipe (°F)	Engine (°F)	Engine Ambient (°F)	Ambient (°F)
E10	573	583	281	195	79
E20	572	584	282	191	76
E30	571	585	281	193	79
E85	561	588	280	194	80

Average exhausts emissions at 65 mph

Fuel Type	CO (%)	NOx (ppm)	O2 (%)	HC (ppm)	CO2 (%)
E10	0	3.9	0	6.1	14.3
E20	0	3.1	0	4.0	14.5
E30	0	2.7	0	3.9	14.4
E85	0	23.7	0	3.4	14.2

Vehicle mileage at 50 mph.

Fuel Type	Engine Speed (rpm)	Average Power (HP)	Gallons per hour	Average Fuel Temp °F	Miles per gal
E10	1759	12.8	2.08	100	24.1
E20	1759	12.3	1.99	89	25.1
E30	1763	12.0	2.35	79	21.3
E85	1765	12.9	2.25	87	22.2

Vehicle mileage at 65 mph.

Fuel Type	Engine Speed (rpm)	Average Power (HP)	Gallons per hour	Average Fuel Temp °F	Miles per gal
E10	2266	22.6	2.81	109	23.1
E20	2268	22.1	3.17	104	20.5
E30	2273	22.3	3.15	98	20.6
E85	2273	24.1	3.62	104	17.9

Vehicle trip mileage.

Fuel Type	Trip Mileage (miles)	Fuel Consumption (gal)	Mileage (mpg)
E10	59.2	2.2	26.9
E20	26.9	1.1	23.7
E30	26.8	1.2	23.1
E85	27.0	1.3	21.0

Vehicle fuel trim and injector pulse width at 50 mph.

Fuel Type	Average Fuel Trim	Average Injector Pulse Width (ms)
E10	-1.5	4.5
E20	-1.25	6.0
E30	-1	5.7
E85	0	7.4

Vehicle fuel trim and injector pulse width at 65 mph.

Fuel Type	Average Fuel Trim	Average Injector Pulse Width (ms)
E10	-1.5	5.5
E20	-1	6.5
E30	-1	6.5
E85	-1.5	7.8

Flex Fuel Vehicle Test Summary

Test Date: April 23, 2009

Owner of vehicle: State of Nebraska, license number 10460.

Description of Vehicle

Make: Ford.
Model: Taurus - Flex Fuel.
Year mfg: 2000.
Engine: 3.0L V6.
Vin# IFAFP5321YG187418.
Odometer: 79,880 miles.
Tire size: *P215 60 R16*
Date of last service: *12/10/09*
Odometer of last service: *89,068* miles.
Fuel Pressure: 36 to 55 psi
Gross Vehicle Weight: 4,680 lbs
Dynamometer Set Weight: 3,625lbs

Maintenance before test: replaced air filter, cleaned mass air flow meter, pressurized tires to 35psi, disconnected battery before each fuel type was tested.

Maximum power at wheels.

Fuel Type	Max Power (hp)	Vehicle Speed (mph)	Engine Speed (rpm)	Gear
E10	108	54	4465	2
E20	109	55	4561	2
E30	108	59	4875	2
E85	109	58	4753	2

Maximum torque at wheels.

Fuel Type	Max Torque (Ft lbs)	Vehicle Speed (mph)	Engine Speed (rpm)	Gear
E10	137	42	3498	2
E20	142	40	3431	2
E30	140	43	3586	2
E85	140	44	3696	2

Average engine temperatures at 65 mph

Fuel Type	Exhaust (°F)	Tailpipe (°F)	Engine (°F)	Engine Ambient (°F)	Ambient (°F)
E10	685	496	202	190	102
E20	694	441	203	188	96
E30	692	440	198	183	88
E85	687	447	200	186	94

Average exhausts emissions at 65 mph

Fuel Type	CO (%)	NOx (ppm)	O2 (%)	HC (ppm)	CO2 (%)
E10	0	4	0	5	14
E20	0	4	0	6	13
E30	0	11	0	3	14
E85	0	10	0	1	13

Vehicle mileage at 50 mph.

Fuel Type	Engine Speed (rpm)	Average Power (HP)	Gallons per hour	Average Fuel Temp °F	Miles per gal
E10	1514	34	3.81	86	13.1
	36	0.5	0.05	5	0.3
E20	1512	33	3.91	87	12.8
	44	2.8	0.18	3	0.6
E30	1586	40	4.01	85	13.1
	88	11.1	0.16	2	0.8
E85	1518	33	4.51	94	11.1
	44	2.2	0.01	4	0

Vehicle mileage at 65 mph.

Fuel Type	Engine Speed (rpm)	Average Power (HP)	Gallons per hour	Average Fuel Temp °F	Miles per gal
E10	1860	51	5.96	106	10.7
	168	5.5	0.13	6	0.3
E20	1908	52	6.08	105	10.5
	203	3.6	0.18	5	0.3
E30	1991	52	6.27	102	10.3
	330	5.4	0.25	3	0.3
E85	1738	54	6.93	105	9.3
	32	3.9	0.12	3	0.2

Vehicle trip mileage.

Fuel Type	Mileage
E10	12.7
	0.1
E20	12.4
	0.2
E30	12.2
	0.3
E85	10.9
	0.2

Flex Fuel Vehicle Test Summary

Test Date: 6/3 – 6/9/2009

Owner of vehicles: State of Nebraska

Description of Vehicle

Make: Chrysler

Model: Dodge Ram 1500 Flex Fuel

Year mfg: 2005, 2006, 2008

Engine: 4.7 V8

Odometer: 2,500 to 37,000 miles

Tire size: P245/70R17 – P265/70R17

Gross Vehicle Weight: 6,600 lbs

Dynamometer Set Weight: 6,600 lbs + 1.5% grade

Maintenance before test:

Maintenance before tests included pressurizing tires to 35 psi, adding oil if needed, checking air filter and replacing if needed.

Tables reflect the average (top) and standard deviation (bottom) of the three cars.

Vehicle fuel trim and injector pulse width at 50 mph.

Fuel Type	Average Fuel Trim	Average Injector Pulse Width (ms)
E10	-0.3	6.3
	0.8	0.7
E20	-0.5	6.3
	1.0	1.2
E30	1.2	7.6
	1.6	0.8
E85	-1.4	8.5
	-1.1	0.8

Vehicle fuel trim and injector pulse width at 65 mph.

Fuel Type	Average Fuel Trim	Average Injector Pulse Width (ms)
E10	-2.6	8.5
	1.6	0.4
E20	-1.0	8.6
	2.6	0.6
E30	-1.4	9.1
	3.5	0.6
E85	-0.6	11.6
	0.9	0.5

Maximum power at wheels.

Fuel Type	Max Power (hp)	Vehicle Speed (mph)	Engine Speed (rpm)	Gear
E10	195	68	4687	2
	24	8	397	
E20	197	67	4598	2
	25	9	455	
E30	198	67	4637	2
	26	9	420	
E85	202	67	4642	2
	26	5	305	

Maximum torque at wheels.

Fuel Type	Max Torque (Ft lbs)	Vehicle Speed (mph)	Engine Speed (rpm)	Gear
E10	235	55	3844	2
	15	7	274	
E20	241	56	3906	2
	19	6	251	
E30	240	53	3703	2
	21	9	423	
E85	247	53	3806	2
	19	5	287	

Average engine temperatures at 65 mph

Fuel Type	Exhaust (°F)	Tailpipe (°F)	Engine (°F)	Engine Ambient (°F)	Ambient (°F)
E10	934	843	332	141	80
	79	7	24	7	3
E20	935	863	336	138	79
	72	12	25	2	1
E30	945	854	341	139	78
	39	22	21	3	8
E85	888	806	320	141	82
	31	18	19	5	5

Average exhausts emissions at 65 mph

Fuel Type	CO (%)	NOx (ppm)	O2 (%)	HC (ppm)	CO2 (%)
E10	0.07	39	0	4.0	14.7
	0.03	9	0	2.1	0.1
E20	0.06	35	0	5.1	14.8
	0.02	9	0	1.7	0.1
E30	0.06	31	0	3.5	14.6
	0.02	3	0	1.9	0.7
E85	0.01	22	0	3.8	14.5
	0.01	4	0	0.2	0.3

Average exhausts emissions at 65 mph

Fuel Type	CO g/mile	NOx g/mile	O2 g/mile	HC g/mile	CO2 g/mile
E10	3.7	0.2	0	0.02	856
E20	3.6	0.1	0	0.03	879
E30	3.3	0.1	0	0.02	901
E85	0.7	0.1	0	0.02	803

$$TMA\left(\frac{kg}{hr}\right) = \frac{60\ x\ RPM\ x\ \rho(air) x\ Displacement}{2\ x\ 1000}$$

$$\frac{g}{mile} = \frac{TMA\ x\ 1000\ x\ \%\ concentration}{mph\ x\ 100}$$

$$\frac{g}{mile} = \frac{TMA\ x\ 1000\ x\ ppm}{mph\ x\ 1000000}$$

Vehicle mileage at 50 mph.

Fuel Type	Engine Speed (rpm)	Average Power (HP)	Gallons per hour	Average Fuel Temp °F	Miles per gal
E10	1471	34	3.76	88	13.3
E20	1461	30	4.11	85	12.2
E30	1688	53	4.12	83	13.8
E85	1468	31	4.50	95	11.1

Vehicle mileage at 65 mph.

Fuel Type	Engine Speed (rpm)	Average Power (HP)	Gallons per hour	Average Fuel Temp °F	Miles per gal
E10	1902	47	5.90	107	12.5
E20	1879	52	6.00	105	10.7
E30	1903	48	6.10	99	10.6
E85	1701	54	6.80	106	9.6

Vehicle trip mileage.

Fuel Type	Trip Mileage (miles)	Fuel Consumption (gal)	Mileage (mpg)
E10	26.5	2.08	12.7
E20	26.5	2.10	12.6
E30	26.6	2.13	12.5
E85	26.5	2.38	11.1

Vehicle fuel trim and injector pulse width at 50 mph.

Fuel Type	Average Fuel Trim	Average Injector Pulse Width (ms)
E10	-1.0	5.6
E20	-0.9	5.4
E30	-0.2	7.8
E85	-2.6	7.8

Vehicle fuel trim and injector pulse width at 65 mph.

Fuel Type	Average Fuel Trim	Average Injector Pulse Width (ms)
E10	-4.4	8.4
E20	-4.0	8.1
E30	-5.1	8.6
E85	-1.5	11.4

Flex Fuel Vehicle Test Summary

Test Date: June 3, 2008
Owner of vehicle: State of Nebraska,
License Number: 15653
Description of Vehicle
Make: Chrysler
Model: Dodge Ram 1500, Flex Fuel
Year mfg: 2008
Engine: 4.7 L V8
Vin# 1D7HU16N78J214883
Odometer: 2,600 miles
Tire size: P265/70R17
Date of last service: March 4, 2009
Odometer of last service: 25 miles
Fuel Pressure: 60 psi
Gross Vehicle Weight: 6,600 lbs
Dynamometer Set Weight: 6,600 lbs @1.5% Grade

Maintenance before test: Checked oil, air filter and tire pressure.

Maximum power at wheels.

Fuel Type	Max Power (hp)	Vehicle Speed (mph)	Engine Speed (rpm)	Gear
E10	222	77	5132	2
E20	227	77	5109	2
E30	228	77	5121	2
E85	232	73	4982	2

Maximum torque at wheels.

Fuel Type	Max Torque (Ft lbs)	Vehicle Speed (mph)	Engine Speed (rpm)	Gear
E10	253	63	4155	2
E20	263	62	4079	2
E30	265	63	4253	2
E85	269	59	4114	2

Average engine temperatures at 65 mph

Fuel Type	Exhaust (°F)	Tailpipe (°F)	Engine (°F)	Engine Ambient (°F)	Ambient (°F)
E10	930	835	331	177	82
E20	935	863	332	169	80
E30	920	843	329	167	76
E85	858	797	305	173	83

Average exhausts emissions at 65 mph

Fuel Type	CO (%)	NOx (ppm)	O2 (%)	HC (ppm)	CO2 (%)
E10	0.10	31	0	6	14.6
E20	0.07	34	0	7	14.7
E30	0.06	28	0	3	15.1
E85	0.01	24	0	4	14.6

Average exhausts emissions at 65 mph

Fuel Type	CO g/mile	NOx g/mile	O2 g/mile	HC g/mile	CO2 g/mile
E10	5	0.15	0	0.03	716
E20	3	0.07	0	0.03	724
E30	3	0.03	0	0.01	742
E85	0	0.11	0	0.02	647

$$TMA\left(\frac{kg}{hr}\right) = \frac{60\ x\ RPM\ x\ \rho(air) x\ Displacement}{2\ x\ 1000}$$

$$\frac{g}{mile} = \frac{TMA\ x\ 1000\ x\ \%\ concentration}{mph\ x\ 100}$$

$$\frac{g}{mile} = \frac{TMA\ x\ 1000\ x\ ppm}{mph\ x\ 1000000}$$

Vehicle mileage at 50 mph.

Fuel Type	Engine Speed (rpm)	Average Power (HP)	Gallons per hour	Average Fuel Temp °F	Miles per gal
E10	1549	35	3.81	90	13.2
E20	1536	34	3.78	90	13.2
E30	1535	33	4.09	88	12.3
E85	1550	34	4.52	90	11.2

Vehicle mileage at 65 mph.

Fuel Type	Engine Speed (rpm)	Average Power (HP)	Gallons per hour	Average Fuel Temp °F	Miles per gal
E10	2051	57	6.11	111	10.5
E20	2124	55	6.29	110	10.1
E30	2356	58	6.55	105	10.0
E85	1754	51	7.03	101	9.2

Vehicle trip mileage.

Fuel Type	Trip Mileage (miles)	Fuel Consumption (gal)	Mileage (mpg)
E10	26.6	2.11	12.6
E20	26.6	2.18	12.2
E30	26.7	2.25	11.9
E85	26.6	2.46	10.8

Vehicle fuel trim and injector pulse width at 50 mph.

Fuel Type	Average Fuel Trim	Average Injector Pulse Width (ms)
E10	-0.4	7.1
E20	0.7	7.7
E30	0.8	8.3
E85	0.3	9.3

Vehicle fuel trim and injector pulse width at 65 mph.

Fuel Type	Average Fuel Trim	Average Injector Pulse Width (ms)
E10	-1.6	8.9
E20	1.0	9.2
E30	-1.0	9.7
E85	0.2	12.2

Flex Fuel Vehicle Test Summary

Test Date: June 4, 2008
Owner of vehicle: State of Nebraska,
License Number: 13443
Description of Vehicle
Make: Chrysler
Model: Dodge Ram 1500, Flex Fuel
Year mfg: 2004
Engine: 4.7 L V8
Vin# 1D7HU6P95J633234
Odometer: 36,774 miles
Tire size: P245/70R17
Date of last service: April 21, 2009
Odometer of last service: 36,387 miles
Fuel Pressure: 60 psi
Gross Vehicle Weight: 6,550 lbs
Dynamometer Set Weight: 6,600 lbs @1.5% Grade

Maintenance before test: Checked oil, air filter and tire pressure.

Maximum power at wheels.

Fuel Type	Max Power (hp)	Vehicle Speed (mph)	Engine Speed (rpm)	Gear
E10	180	65	4561	2
E20	182	60	4236	2
E30	182	63	4427	2
E85	189	62	4391	2

Maximum torque at wheels.

Fuel Type	Max Torque (Ft lbs)	Vehicle Speed (mph)	Engine Speed (rpm)	Gear
E10	229	52	3738	2
E20	234	57	4020	2
E30	231	50	3642	2
E85	238	49	3545	2

Average engine temperatures at 65 mph

Fuel Type	Exhaust (°F)	Tailpipe (°F)	Engine (°F)	Engine Ambient (°F)	Ambient (°F)
E10	1015	849	356	165	82
E20	1008	851	362	165	79
E30	990	840	365	166	78
E85	920	794	341	164	77

Average exhausts emissions at 65 mph

Fuel Type	CO (%)	NOx (ppm)	O2 (%)	HC (ppm)	CO2 (%)
E10	0.04	35	0	3	14.8
E20	0.04	26	0	3	15.0
E30	0.04	31	0	2	14.8
E85	0.02	25	0	4	14.8

Average exhausts emissions at 65 mph

Fuel Type	CO g/mile	NOx g/mile	O2 g/mile	HC g/mile	CO2 g/mile
E10	2	0.24	0	0.02	1005
E20	3	0.07	0	0.02	1062
E30	3	0.05	0	0.02	1168
E85	1	0.14	0	0.02	859

$$TMA\left(\frac{kg}{hr}\right) = \frac{60\ x\ RPM\ x\ \rho(air) x\ Displacement}{2\ x\ 1000}$$

$$\frac{g}{mile} = \frac{TMA\ x\ 1000\ x\ \%\ concentration}{mph\ x\ 100}$$

$$\frac{g}{mile} = \frac{TMA\ x\ 1000\ x\ ppm}{mph\ x\ 1000000}$$

Vehicle mileage at 50 mph.

Fuel Type	Engine Speed (rpm)	Average Power (HP)	Gallons per hour	Average Fuel Temp °F	Miles per gal
E10	1521	34	3.86	81	12.8
E20	1539	35	3.83	85	13.1
E30	1535	35	3.83	84	13.1
E85	1537	35	4.51	97	11.1

Vehicle mileage at 65 mph.

Fuel Type	Engine Speed (rpm)	Average Power (HP)	Gallons per hour	Average Fuel Temp °F	Miles per gal
E10	1716	48	5.90	99	10.8
E20	1722	48	6.00	101	10.5
E30	1714	50	6.10	102	10.3
E85	1758	59	7.00	107	9.3

Vehicle trip mileage.

Fuel Type	Trip Mileage (miles)	Fuel Consumption (gal)	Mileage (mpg)
E10	26.4	2.07	12.8
E20	26.4	2.12	12.4
E30	26.2	2.16	12.2
E85	26.5	2.46	10.8

Vehicle fuel trim and injector pulse width at 50 mph.

Fuel Type	Average Fuel Trim	Average Injector Pulse Width (ms)
E10	0.5	6.3
E20	-1.3	5.8
E30	3.0	6.8
E85	-1.1	8.3

Vehicle fuel trim and injector pulse width at 65 mph.

Fuel Type	Average Fuel Trim	Average Injector Pulse Width (ms)
E10	-1.7	8.3
E20	-0.1	8.4
E30	1.9	9.1
E85	-0.6	11.3

Flex Fuel Vehicle Test Summary

Test Date: June 9, 2008
Owner of vehicle: State of Nebraska,
License Number: 14872
Description of Vehicle
Make: Chrysler
Model: Dodge Ram 1500, Flex Fuel
Year mfg: 2006
Engine: 4.7 L V8
Vin# 107HA16P66J183925
Odometer: 29,500 miles
Tire size: P245/70R17
Date of last service: Jan 31, 2009
Odometer of last service: 27,145 miles
Fuel Pressure: 60 psi
Gross Vehicle Weight: 6,600 lbs
Dynamometer Set Weight: 6,600 lbs @1.5% Grade

Maintenance before test: Checked oil, air filter and tire pressure.

Maximum power at wheels.

Fuel Type	Max Power (hp)	Vehicle Speed (mph)	Engine Speed (rpm)	Gear
E10	183	62	4368	2
E20	184	63	4448	2
E30	185	62	4364	2
E85	186	65	4554	2

Maximum torque at wheels.

Fuel Type	Max Torque (Ft lbs)	Vehicle Speed (mph)	Engine Speed (rpm)	Gear
E10	225	50	3639	2
E20	227	50	3618	2
E30	226	45	3313	2
E85	235	52	3758	2

Average engine temperatures at 65 mph

Fuel Type	Exhaust (°F)	Tailpipe (°F)	Engine (°F)	Engine Ambient (°F)	Ambient (°F)
E10	857	845	308	163	76
E20	863	876	313	165	78
E30	925	880	329	172	80
E85	887	826	313	174	87

Average exhausts emissions at 65 mph

Fuel Type	CO (%)	NOx (ppm)	O2 (%)	HC (ppm)	CO2 (%)
E10	0.07	49	0	3	14.6
E20	0.07	45	0	5	14.8
E30	0.08	34	0	6	13.8
E85	0.01	18	0	4	14.1

Average exhausts emissions at 65 mph

Fuel Type	CO g/mile	NOx g/mile	O2 g/mile	HC g/mile	CO2 g/mile
E10	4	0.28	0	0.02	847
E20	4	0.09	0	0.03	850
E30	4	0.09	0	0.03	791
E85	1	0.11	0	0.02	831

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$$\frac{g}{mile} = \frac{TMA\ x\ 1000\ x\ \%\ concentration}{mph\ x\ 100}$$

$$\frac{g}{mile} = \frac{TMA\ x\ 1000\ x\ ppm}{mph\ x\ 1000000}$$

Vehicle mileage at 50 mph.

Fuel Type	Engine Speed (rpm)	Average Power (HP)	Gallons per hour	Average Fuel Temp °F	Miles per gal
E10	1331	22	2.60	83	19.3
	2	1	0.17	3	1.2
E20	1345	22	2.64	82	19.0
	24	1	0.21	3	1.5
E30	1331	21	2.67	83	18.8
	4	1	0.24	6	1.6
E85	1331	22	3.14	88	16.0
	4	1	0.28	7	1.3

Vehicle mileage at 65 mph.

Fuel Type	Engine Speed (rpm)	Average Power (HP)	Gallons per hour	Average Fuel Temp °F	Miles per gal
E10	1903	34	3.83	102	17.0
	277	2	0.17	4	0.8
E20	2192	34	3.94	102	16.5
	413	1	0.05	2	0.2
E30	1709	34	4.12	103	15.8
	2	1	0.19	5	0.7
E85	1711	34	4.79	105	13.6
	-	1	0.22	8	0.6

Vehicle trip mileage.

Fuel Type	Mileage
E10	19.9
	0.8
E20	19.3
	0.4
E30	18.8
	0.7
E85	16.1
	0.7

Flex Fuel Vehicle Test Summary

Test Date: 5/1/09 – 5/14/09

Owner of vehicles: State of Nebraska

Description of Vehicle

Make: Chevy

Model: Impala LS Flex Fuel.

Year mfg: 2008

Engine: 3500 V6 (3.5L)

Odometer: 4,000 to 16, 000 miles

Tire size: P225 / 60 R16

Gross Vehicle Weight: 4,520 lbs

Dynamometer Set Weight: 4,520 lbs / 1.5% Gradient

Maintenance before test:

Maintenance before tests included pressurizing tires to 35 psi, adding oil if needed, replacing air filter, and cleaning /Checking mass air flow meter

Tables reflect the average (top) and standard deviation (bottom) of the three cars.

Vehicle fuel trim and injector pulse width at 50 mph.

Fuel Type	Average Fuel Trim	Average Injector Pulse Width (ms)
E10	-11	5.9
	7	0.5
E20	-9	5.8
	10	0.2
E30	-2	6.3
	8	0.2
E85	24	8.0
	7.0	0.2

Vehicle fuel trim and injector pulse width at 65 mph.

Fuel Type	Average Fuel Trim	Average Injector Pulse Width (ms)
E10	-10	6.8
	9	0.6
E20	-5	6.2
	11	0.7
E30	3	7.5
	8	0.5
E85	26	9.0
	6	1.5

Maximum power at wheels.

Fuel Type	Max Power (hp)	Vehicle Speed (mph)	Engine Speed (rpm)	Gear
E10	142	97	5703	2
	4	1	58	
E20	144	98	5766	2
	2	1	28	
E30	148	94	5589	2
	4	3	136	
E85	139	95	5706	2
	9	3	46	

Maximum torque at wheels.

Fuel Type	Max Torque (Ft lbs)	Vehicle Speed (mph)	Engine Speed (rpm)	Gear
E10	161	55	2129	2
	7	10	1821	
E20	170	68	3925	2
	8	15	931	
E30	166	57	3368	2
	2	7	28	
E85	147	55	3410	2
	16	2	58	

Average engine temperatures at 65 mph

Fuel Type	Exhaust (°F)	Tailpipe (°F)	Engine (°F)	Engine Ambient (°F)	Ambient (°F)
E10	872	806	285	185	70
	126	50	41	15	2
E20	880	804	292	189	69
	102	36	33	3	5
E30	871	802	293	188	69
	117	50	41	12	7
E85	861	796	293	190	71
	107	32	32	6	8

Average exhausts emissions at 65 mph

Fuel Type	CO (%)	NOx (ppm)	O2 (%)	HC (ppm)	CO2 (%)
E10	0	0	0	4	15
	0	0	0	4	0
E20	0	0	0	2	15
	0	1	0	2	0
E30	0	0	0	4	15
	0	0	1	0	1
E85	0	1	0	6	15
	0	1	0	2	1

Average exhausts emissions at 65 mph

Fuel Type	CO g/mile	NOx g/mile	O2 g/mile	HC g/mile	CO2 g/mile
E10	0	0	0	0.015	546
E20	0	0	0	0.008	629
E30	0	0	0	0.013	491
E85	0	0.003	0	0.003	491

$$TMA\ \left(\frac{kg}{hr}\right) = \frac{60\ x\ RPM\ x\ \rho(air) x\ Displacement}{2\ x\ 1000}$$

$$\frac{g}{mile} = \frac{TMA\ x\ 1000\ x\ \%\ concentration}{mph\ x\ 100}$$

$$\frac{g}{mile} = \frac{TMA\ x\ 1000\ x\ ppm}{mph\ x\ 1000000}$$

Vehicle mileage at 50 mph.

Fuel Type	Engine Speed (rpm)	Average Power (HP)	Gallons per hour	Average Fuel Temp °F	Miles per gal
E10	-	21	2.53	83	19.7
E20	1329	21	2.47	81	20.3
E30	-	21	2.51	80	19.9
E85	-	22	3.04	88	16.4

Vehicle mileage at 65 mph.

Fuel Type	Engine Speed (rpm)	Average Power (HP)	Gallons per hour	Average Fuel Temp °F	Miles per gal
E10	-	34	3.72	99	17.5
E20	1715	33	3.89	104	16.7
E30	-	34	4.00	101	16.3
E85	-	35	4.69	105	13.9

Vehicle trip mileage.

Fuel Type	Trip Mileage (miles)	Fuel Consumption (gal)	Mileage (mpg)
E10	26.9	1.32	20.3
E20	26.9	1.37	19.7
E30	26.9	1.40	19.2
E85	26.9	1.64	16.4

Vehicle fuel trim and injector pulse width at 50 mph.

Fuel Type	Average Fuel Trim	Average Injector Pulse Width (ms)
E10	-16.8	5.6
E20	-14.8	6.1
E30	-1.6	6.3
E85	26.8	8.0

Vehicle fuel trim and injector pulse width at 65 mph.

Fuel Type	Average Fuel Trim	Average Injector Pulse Width (ms)
E10	-17.4	7.1
E20	-13.6	6.5
E30	2.2	7.7
E85	29.5	9.8

Flex Fuel Vehicle Test Summary

Test Date: May 1, 2009
Owner of vehicle: State of Nebraska
License Number : 15828
Description of Vehicle
Make: Chevy
Model: Impala LS Flex Fuel
Year mfg: 2008
Engine: 3500 V6 (3.5L or 3500 cubic inch)
Vin# 2G1WB55K881377079
Odometer: 7,951
Tire size: P225/60 R16
Date of last service: April 5, 2009
Odometer of last service: 4878
Fuel Pressure: 60 psi
Gross Vehicle Weight: 4520 lbs
Dynamometer Set Weight: 4520 lbs / 1.5% Gradient

Maintenance before test: Tires set to 35 psi, oil checked, air filter replaced, mass air flow sensor cleaned/checked.

Maximum power at wheels.

Fuel Type	Max Power (hp)	Vehicle Speed (mph)	Engine Speed (rpm)	Gear
E10	144.1	97.7	5660	2
E20	141.9	98.1	5794	2
E30	151.9	96.9	5745	2
E85	130.8	92.0	5740	2

Maximum torque at wheels.

Fuel Type	Max Torque (Ft lbs)	Vehicle Speed (mph)	Engine Speed (rpm)	Gear
E10	153.8	64.8	39.50	2
E20	177.6	84	5000	2
E30	165.5	53.3	3357	2
E85	137	56	3471	2

Average engine temperatures at 65 mph

Fuel Type	Exhaust (°F)	Tailpipe (°F)	Engine (°F)	Engine Ambient (°F)	Ambient (°F)
E10	749	763	239	168	68
E20	781	773	254	185	64
E30	749	758	246	175	69
E85	752	766	257	183	68

Average exhausts emissions at 65 mph

Fuel Type	CO (%)	NOx (ppm)	O2 (%)	HC (ppm)	CO2 (%)
E10	0	0	0	0	15.0
E20	0	1	0	2	14.7
E30	0	0	0	4	14.7
E85	0	0	0	8	14.4

Vehicle mileage at 50 mph.

Fuel Type	Engine Speed (rpm)	Average Power (HP)	Gallons per hour	Average Fuel Temp °F	Miles per gal
E10	1329	22	2.79	86	17.9
E20	1334	22	2.88	86	17.4
E30	1333	22	2.94	90	17.0
E85	1328	22	3.46	95	14.5

Vehicle mileage at 65 mph.

Fuel Type	Engine Speed (rpm)	Average Power (HP)	Gallons per hour	Average Fuel Temp °F	Miles per gal
E10	1707	33	4.03	107	16.1
E20	2431	35	3.94	102	16.5
E30	1710	35	4.34	109	15.0
E85	-	-	5.04	113	12.9

Vehicle trip mileage.

Fuel Type	Trip Mileage (miles)	Fuel Consumption (gal)	Mileage (mpg)
E10	26.9	1.41	19.0
E20	27.0	1.43	18.9
E30	27.1	1.51	18.0
E85	27.0	1.76	15.3

Vehicle fuel trim and injector pulse width at 50 mph.

Fuel Type	Average Fuel Trim	Average Injector Pulse Width (ms)
E10	-12.7	5.6
E20	-9.8	6.0
E30	-9.6	6.1
E85	16.4	7.8

Vehicle fuel trim and injector pulse width at 65 mph.

Fuel Type	Average Fuel Trim	Average Injector Pulse Width (ms)
E10	-12.7	6.1
E20	-9.4	5.4
E30	-4.3	7.8
E85	19.4	7.3

Flex Fuel Vehicle Test Summary

Test Date: May 6, 2009
Owner of vehicle: State of Nebraska
License Number : 15663
Description of Vehicle
Make: Chevy
Model: Impala LS Flex Fuel
Year mfg: 2008
Engine: 3500 V6 (3.5L or 3500 cubic inch)
Vin# 2G1WB55K381320160
Odometer: 4,111
Tire size: P225/60 R16
Date of last service: -
Odometer of last service: -
Fuel Pressure: 60 psi
Gross Vehicle Weight: 4520 lbs
Dynamometer Set Weight: 4520 lbs / 1.5% Gradient

Maintenance before test: Tires set to 35 psi, oil checked, air filter replaced, mass air flow sensor cleaned/checked.

Maximum power at wheels.

Fuel Type	Max Power (hp)	Vehicle Speed (mph)	Engine Speed (rpm)	Gear
E10	138	97.7	5769	2
E20	144.1	97.1	5739	2
E30	144	92.9	5524	2
E85	148	95.6	5654	2

Maximum torque at wheels.

Fuel Type	Max Torque (Ft lbs)	Vehicle Speed (mph)	Engine Speed (rpm)	Gear
E10	160.7	45.4	2967	2
E20	162.2	54.0	3375	2
E30	164	53.5	3348	2
E85	164.6	54.5	3404	2

Average engine temperatures at 65 mph

Fuel Type	Exhaust (°F)	Tailpipe (°F)	Engine (°F)	Engine Ambient (°F)	Ambient (°F)
E10	1000	860	314	195	70
E20	984	843	315	191	73
E30	982	856	324	197	76
E85	966	830	317	194	80

Average exhausts emissions at 65 mph

Fuel Type	CO (%)	NOx (ppm)	O2 (%)	HC (ppm)	CO2 (%)
E10	0	0	0	4	14.6
E20	0	0	0	0	14.0
E30	0	0	1	4	13.6
E85	0	2	0	6	13.8

Vehicle mileage at 50 mph.

Fuel Type	Engine Speed (rpm)	Average Power (HP)	Gallons per hour	Average Fuel Temp °F	Miles per gal
E10	1332	22	2.48	81	20.2
E20	1373	22	2.58	80	19.4
E30	1328	21	2.55	80	19.6
E85	1333	21	2.93	82	17.1

Vehicle mileage at 65 mph.

Fuel Type	Engine Speed (rpm)	Average Power (HP)	Gallons per hour	Average Fuel Temp °F	Miles per gal
E10	2099	36	3.74	100	17.4
E20	2430	34	3.98	100	16.3
E30	1707	34	4.03	100	16.1
E85	1711	33	4.64	98	14.0

Vehicle trip mileage.

Fuel Type	Trip Mileage (miles)	Fuel Consumption (gal)	Mileage (mpg)
E10	26.9	1.33	20.3
E20	27.1	1.41	19.2
E30	26.9	1.41	19.1
E85	27.0	1.63	16.6

Vehicle fuel trim and injector pulse width at 50 mph.

Fuel Type	Average Fuel Trim	Average Injector Pulse Width (ms)
E10	-2.5	6.5
E20	3.6	6.3
E30	5.9	6.5
E85	30.0	8.2

Vehicle fuel trim and injector pulse width at 65 mph.

Fuel Type	Average Fuel Trim	Average Injector Pulse Width (ms)
E10	0.4	7.3
E20	7.0	6.6
E30	10.7	6.9
E85	30.0	10.0

Flex Fuel Vehicle Test Summary

Test Date: May 14, 2009
Owner of vehicle: State of Nebraska
License Number : 15589
Description of Vehicle
Make: Chevy
Model: Impala LS Flex Fuel
Year mfg: 2008
Engine: 3500 V6 (3.5L or 3500 cubic inch)
Vin# 2G1WB55K681288871
Odometer: 14,000
Tire size: P225/60 R16
Date of last service: 1/26/09
Odometer of last service: 12,870
Fuel Pressure: 60 psi
Gross Vehicle Weight: 4520 lbs
Dynamometer Set Weight: 4520 lbs / 1.5% Gradient

Maintenance before test: Tires set to 35 psi, oil checked, air filter replaced, mass air flow sensor cleaned/checked.

Maximum power at wheels.

Fuel Type	Max Power (hp)	Vehicle Speed (mph)	Engine Speed (rpm)	Gear
E10	145	96	5680	2
E20	146	98	5764	2
E30	149	92	5498	2
E85	139	97	5723	2

Maximum torque at wheels.

Fuel Type	Max Torque (Ft lbs)	Vehicle Speed (mph)	Engine Speed (rpm)	Gear
E10	168	54	3380	2
E20	169	65	3400	2
E30	168	65	3400	2
E85	138	53	3355	2

Average engine temperatures at 65 mph

Fuel Type	Exhaust (°F)	Tailpipe (°F)	Engine (°F)	Engine Ambient (°F)	Ambient (°F)
E10	867	794	303	191	72
E20	876	797	306	191	69
E30	883	792	308	192	62
E85	864	791	304	193	64

Average exhausts emissions at 65 mph

Fuel Type	CO (%)	NOx (ppm)	O2 (%)	HC (ppm)	CO2 (%)
E10	0	0	0	7	15.1
E20	0	0	0	3	14.8
E30	0	-	0	4	15.1
E85	0	-	0	5	15.2