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Final Results from the State of Ohio Ethanol-Fueled Light-Duty Fleet Deployment Project

Preprint

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ABSTRACT

The state of Ohio established a project to demonstrate the use of ethanol flexible-fuel vehicles (FFV) in their fleet operations. This study includes ten FFVs and three gasoline vehicles operated by five state agencies. The two-year project included data collection on vehicle maintenance and fueling, cost of operation, and fleet management comments. The project also included emissions testing of two ethanol FFVs and two standard gasoline vehicles.

INTRODUCTION

In 1996, the state of Ohio established a project to demonstrate the use of ethanol (E85) flexible-fuel vehicles (FFV) in their fleet operations. Flexible-fuel refers to the technology that enables the vehicles to use all gasoline, all E85 fuel, or any combination of the two fuels. This project was conducted with participation and cooperation of the groups listed in Table 1.

This study includes ten FFVs and three gasoline vehicles operated by five state agencies. The standard gasoline vehicles are being used as controls for a baseline comparison. The two-year project includes data collection on vehicle operations. The vehicles included in this study were delivered to state agencies during the Spring and Summer of 1996, and data collection began in October. The operational data collected for this study include vehicle maintenance and fueling, cost of operation, and fleet management comments. In addition, emissions testing was performed on two ethanol FFVs and two standard gasoline vehicles. Data collection for this project was completed in March 1998. This report summarizes the project results.

OBJECTIVES

The primary objectives of this project included the following:

- Establish and operate ethanol-fueled vehicles in the state of Ohio fleet
- Use ethanol fuel in operation of the fleet
- Collect and compare operations, maintenance, cost, and emissions data for selected ethanol and gasoline vehicles
- Evaluate the selected ethanol-fueled fleet and the selected gasoline-fueled fleet for at least 18 months
- Report findings of the project.

RESULTS AND DISCUSSION

This study includes four categories of data:

- Vehicle descriptions – vehicle systems (specifications) and the expected vehicle usage
- Vehicle operations – fuel consumption, engine oil consumption, maintenance (scheduled, unscheduled, and warranty), costs, and a description of any safety incidents
- Emissions testing – performed by Automotive Testing Labs in East Liberty, Ohio
- Fuel analysis – performed by Core Laboratories in Carson, California.

The data collection depended completely on the cooperation and participation of each state agency involved in the study. The data was collected from existing data collection systems used by each state agency, which included paper and electronic databases. Each state agency provided monthly fuel logs, fuel receipts, and maintenance receipts for each study vehicle to Battelle. The data were processed for quality control and for analysis purposes. During data analysis, all data inconsistencies were checked for data entry error.

VEHICLE DESCRIPTIONS – Table 2 shows the state agencies involved in the study and the number and type of vehicle operated. Table 3 describes the program vehicles. The major differences between the E85 fleet

Table 1. Groups Participating in Study

Participants	Role/Responsibilty
State of Ohio, Department of Administrative Services; State Agencies using study vehicles	Purchased vehicles, served as host fleet for study, and funded emissions testing
Council of Great Lakes Governors	Provided grant to support purchase of vehicles and fuel
Public Utilities Commission of Ohio, Biomass Energy Program	Provided grant to support purchase of vehicles and fuel
Ohio Corn Growers Association	Provided ethanol refueling equipment and coordinated fuel delivery
U.S. Department of Energy/National Renewable Energy Laboratory	Provided funding for data collection, analysis, and reporting
Battelle (under contract to NREL and State of Ohio)	Responsible for collection, analysis, and reporting on vehicle performance and operations data, and for coordinating emissions testing

Table 2. State Agencies and Vehicles in Study

Agency	Number of Vehicles	FFV or Gasoline	Function
Department of Administrative Services	1	FFV	Car pool operatons; promotional events
Public Utilities Commission	4	FFV	Car pool operations
Department of Agriculture	5	FFV	Individual use in the Columbus area
Office of Industrial Commission	1	Gasoline	Car pool operations
Department of Commerce/Liquor Control	2	Gasoline	Liquor control agent use in Columbus and New Lexington
Total	10 3	FFV Gasoline	

Table 3. Vehicle Descriptions for E85 and Gasoline Fleets

Specifications	E85 Fleet	Gasoline Fleet
Number of vehicles	10	3
Make	Ford	Ford
Model	Taurus	Taurus
Model year	1996	1996
Engine displacement (L)	3.0	3.0
Engine max. horsepower	140	140
Engine configuration	V-6	V-6
Compression ratio	9.0:1	9.0:1
Fuel tank capacity (gal.)	18.4	16
Air conditioning (Y/N)	Yes	Yes
Axle Ratio	3.77:1	3.77:1

and gasoline-control fleet (other than materials changes and engine calibration for the ethanol fuel) are the fuel used and the size of the fuel tank. The E85 vehicles have a slightly larger fuel tank to offset the energy density difference between ethanol and gasoline. In other words, it takes slightly more volume of E85 fuel to drive the same distance as the gasoline-only vehicles.

The Department of Agriculture has five E85 vehicles that are assigned to individuals at the department, with most of the use in the Columbus area. All the other vehicles in this study are used as pool vehicles that are assigned to multiple users over time as individuals require a passenger vehicle.

FACILITY DESCRIPTIONS AND CAPITAL COSTS – There were no maintenance facilities changes required for the ethanol vehicles. Ethanol refueling for this project was provided from two stations – at the Department of Agriculture in Reynoldsburg, Ohio, which is an eastern suburb of Columbus, and at the Ohio Department of Transportation (ODOT) central garage, which is located in western Columbus. The Department of Agriculture ethanol refueling station is a temporary 500-gallon tank and was in operation before this project began. The ODOT facility was originally planned to open during the Summer of 1996, but permitting issues delayed the opening until March 1997. The cost of the new ODOT ethanol station was approximately $28,000 for a 5,000-gallon tank, barrier, refueling nozzle and hose, and installation. The cost of the 1996 model year Taurus for the state was approximately $13,200, with a $1,000 premium for the ethanol FFV option.

VEHICLE OPERATIONS – The following discussion addresses vehicle usage, fuel usage and fuel economy, fuel usage costs, maintenance costs, warranty repairs, and total operating costs. The analysis for operations and costs is divided into total analysis of all data collected and the last year of data collection (April 1997 through March 1998). Discussing the data in two parts (from the project's inception and from the last year) enables analysis of trends and also removes any start-up issues for operating costs for the last year period.

<u>Vehicle Usage</u> – Vehicle usage is calculated on a monthly-per-vehicle basis. The vehicle usage during the study period (per month) has been 7 percent higher for the gasoline-control (GC) vehicles (GC - 1,199 miles; E85 - 1,121 miles) than for the ethanol vehicles. During the last year, the vehicle usage was actually 3 percent higher for the ethanol vehicles (GC - 1,151 miles; E85 - 1,181 miles). These numbers indicate that the vehicle usage has been about the same for the two types of vehicles. The average monthly mileage per vehicle for each fleet is equivalent to approximately 14,000 miles per year for each vehicle type. There have been no problems affecting vehicle usage, such as significant down time or reduced operation of the ethanol fleet.

<u>Fuel Usage and Fuel Economy</u> – Table 4 summarizes the fuel usage and economy for the study vehicles for the total study period and for the last year. The ethanol usage for the E85 fleet averaged 61 percent by volume for the total data set; ethanol usage was an average of 67 percent by volume for the last year of data (April 1997 through March 1998). The ethanol fuel usage has increased significantly after the opening of the new fueling station at the ODOT facility.

Table 4. Fuel Economy and Fuel Usage Results

Vehicle	End Odometer (3/31/98)	All Data		Last Year	
		Miles per Energy Equivalent Gallon (MPEG)	Percent Usage of E85 by Volume	Miles per Energy Equivalent Gallon (MPEG)	Percent Usage of E85 by Volume
Flexible-Fuel Vehicles					
32-311	30,190	26.7	56.7	26.4	61.8
14-164	23,648	27.7	85.7	27.2	81.6
14-178	19,808	27.0	75.8	27.4	76.7
14-220	26,699	25.6	73.9	25.4	68.9
14-221	37,315	29.1	80.2	29.0	84.5
14-222	25,126	27.6	93.5	28.1	89.7
54-125	23,030	27.8	33.8	28.9	62.6
54-181	20,444	28.8	38.1	28.3	75.3
54-218	21,788	27.2	28.1	27.5	50.9
54-219	21,358	27.4	33.5	27.8	56.0
Average	**24,941**	**27.5**	**63.4**	**27.5**	**72.3**
Gasoline-Only Vehicles					
92-107	24,800	27.8	N/A	27.8	N/A
24-151	38,400	25.3	N/A	25.3	N/A
24-202	24,086	21.6	N/A	22.3	N/A
Average	**29,095**	**24.6**	**N/A**	**24.9**	**N/A**

The five vehicles used by the Department of Agriculture (14-164, 14-178, 14-220, 14-221, 14-222) used an average of 82 percent ethanol fuel for the total data collection period and 80 percent ethanol fuel for the last year. The vehicle used by the Department of Administrative Services (32-311) used 57 percent ethanol fuel for the total data collection period and 62 percent ethanol fuel for the last year. The four vehicles used by the Public Utilities Commission (54-125, 54-181, 54-218, 54-219) used only 33 percent ethanol fuel for the total data collection period, but this increased significantly to 61 percent ethanol fuel use for the last year.

The fuel economy for the ethanol fleet has been consistently higher than the gasoline control vehicles (12 percent higher for the total data collection period and 10 percent higher for the last year, all on an energy equivalent basis). One of the gasoline control vehicles (24-202) has had a consistently lower fuel economy than the other two gasoline vehicles and all of the ethanol vehicles. This vehicle has been reported to have a slightly different duty cycle, specifically longer idle time and more city driving.

Vehicle 24-202 had a fuel economy of 22.3 mpg, and the other two gasoline control vehicles averaged a fuel economy of 26.6 mpg, which is only slightly lower (3 percent) than the ethanol vehicles (on an energy equivalent basis). Based on the results from the emissions testing (shown later), the fuel economies of the ethanol flexible-fuel vehicles using E85 were three to four percent higher on an energy equivalent basis compared to using 100 percent gasoline. When the ethanol flexible-fuel vehicles using E85 were compared to the gasoline-only vehicles, their average energy equivalent fuel economy was two percent higher (also based on emissions test data).

Other than the lower fuel economy for vehicle 24-202, the fuel economies are consistent with the controlled emissions testing results. On an energy equivalent basis, the ethanol vehicles have a slightly higher fuel economy than the gasoline-only vehicles.

The energy equivalence for ethanol fuel calculations are based on documented net energy content (lower heating value) of ethanol fuels and gasoline shown in Table 5. Fuel sample analysis was also performed to verify the energy equivalence calculations for the data collection. For energy equivalence calculations, there were several grades of ethanol fuel used – E65, E70, and E85. The E65 and E70 fuel grades were used to account for one fuel load to ODOT and one fuel load to Department of Agriculture, which had lower than intended ethanol content. The fuel analysis results and definitions of the ethanol fuel grades are discussed later.

Fuel Usage Costs – Fuel usage costs represent the fuel cost per volume with the fuel economy taken into account. In other words, the cost of the actual fuel used per mile is the fuel usage cost. The average gasoline cost per gallon (same grade gasoline) has fluctuated significantly during the data collection period – $1.03 to $1.33. The gasoline cost was under $1.10 per gallon for the last four months of the data collection. The average gasoline cost per gallon has been $1.23 for the total data collection period and $1.18 for the last year. These gasoline costs were taken from the fleet's actual fuel purchase receipts from commercial stations in the Columbus area.

Table 5. Lower Heating Values and Energy Equivalence for Fuels Used

Fuel	Lower Heating Value (BTU/gal.)	Test Fuel/ Baseline Gasoline	Baseline Gasoline/ Test Fuel
Gasoline	115,400	1.000	1.000
Ethanol (100%)	75,591	0.655	1.527
E85	83,553	0.724	1.381
E70	89,524	0.776	1.289
E65	91,515	0.793	1.261

Source: Alternative Fuels Data Center data for the lower heating value of gasoline and 100 percent ethanol; E85, E70, and E65 lower heating values were calculated from the gasoline and 100 percent ethanol numbers

The E85 fuel price was $1.88 per gallon at the Department of Agriculture station. The E85 fuel price at the ODOT station was an average of $1.30 per gallon. The lower E85 fuel price at ODOT was due to the larger size of the fuel tank (i.e., larger tank means more fuel, which means lower transportation costs per gallon) and because the fuel for this tank was provided through a cooperative that purchased a large quantity of fuel for distribution in the Ohio Valley area.

The fuel usage costs for the ethanol vehicles are based on the gasoline and E85 fuel usage because both fuels have been used in these vehicles. The average monthly fuel costs per volume for the E85 fleet has fluctuated between $1.20 and $1.63. Figure 1 shows the monthly average fuel prices per gallon for each vehicle type. For the E85 vehicles, the average fuel cost per gallon (all fuel) was $1.50 for the total data collection period and $1.52 for the last year.

Fuel usage costs for the two study vehicle types have been calculated on a per-1,000-mile basis for comparison purposes. For the total data collection period, the fuel usage costs per 1,000 miles was $50.09 for the gasoline fleet and $65.54 for the E85 fleet. The higher fuel usage cost per 1,000 miles for the E85 fleet is consistent with the fuel cost, usage, and fuel economy. For the last year, the fuel usage costs per 1,000 miles was $47.48 for the gasoline fleet and $68.16 for the E85 fleet. For the last year, the fuel usage cost difference between the gasoline and E85 vehicles is higher than for the total data collection period because of the higher usage of ethanol fuel during the last year and the higher cost of the ethanol fuel.

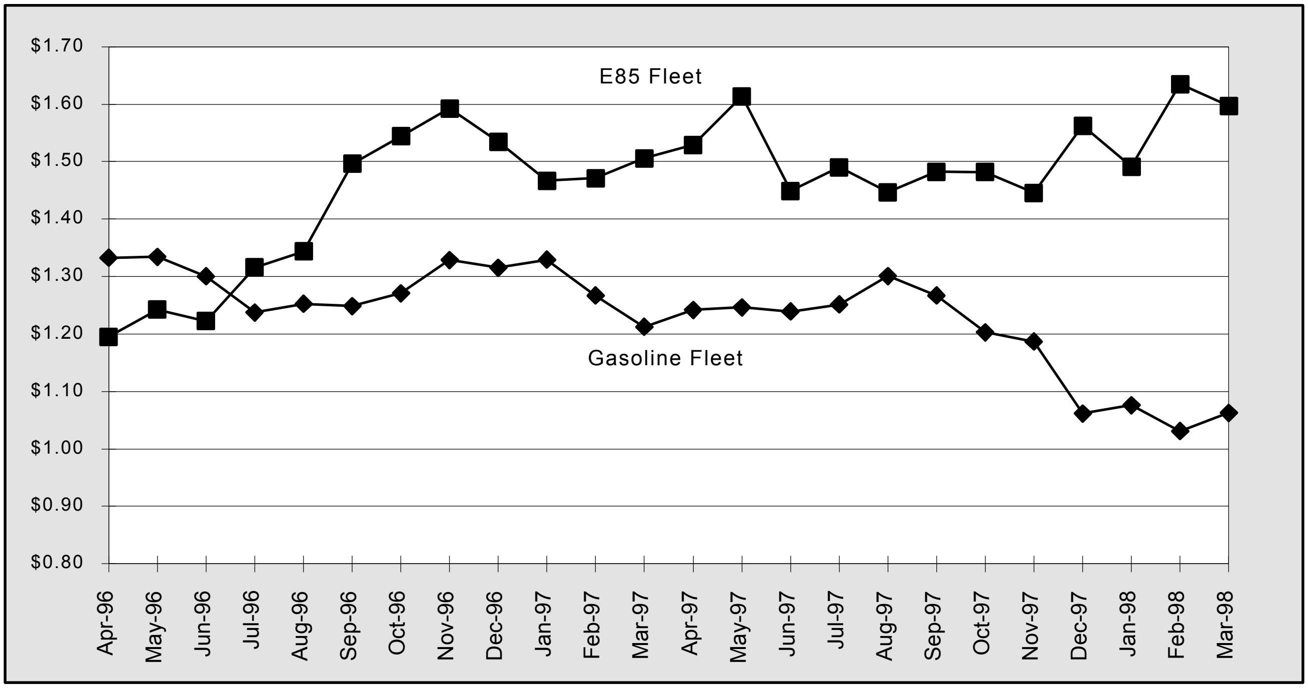

Figure 1. Average Monthly Fuel Price Per Gallon

Maintenance Costs – Maintenance costs shown in this report include actual parts costs, actual labor costs, and other costs. The other costs represent recycling costs, disposal costs of parts and engine oil, and maintenance costs that could not be separated into parts and labor. For the analysis shown in this report, the body system and wheels and tires maintenance costs have been removed from the maintenance cost totals. The costs for the body system and wheels and tires are shown separately as part of Table 6. The body system maintenance items include accidents causing body damage (vehicle 54-219 - $1,654.77; 32-311 - $454.85; 32-311 - $96.86; 24-151 - $940.15), car washes, windshield wiper replacements, and windshield wiper fluid additions. The wheels and tires maintenance costs include tire rotations, wheel balancing, and tire repairs.

Table 6. Breakdown of Body, Tire, Wheel, and All Other Maintenance Costs

Maintenance Costs $ per 1,000 Miles	Total – All Data		Last Year	
	GC	E85	GC	E85
Body	11.89	9.64	1.53	12.56
Tires and wheels	1.66	0.20	2.12	0.34
All other	7.69	8.81	9.64	8.47
Total	21.24	18.65	13.29	21.37

As shown in Tables 7 and 8, the maintenance costs for the gasoline control vehicles was lower (14 percent) for all data on a per 1,000 mile basis. The higher cost for the ethanol vehicles was due to the higher engine oil cost (special low ash oil) for oil changes. The ethanol vehicles have been using standard engine oil for the last 6 to 12 months of the data collection with Ford's permission, which has reduced the maintenance costs for the ethanol vehicles significantly. For the last 12 months, the maintenance costs for the gasoline control vehicles have been 12 percent higher.

Table 7. Breakdown of Scheduled and Unscheduled Maintenance Costs for All Other Maintenance Costs

Maintenance Costs $ per 1,000 Miles	Total – All Data		Last Year	
	GC	E85	GC	E85
Scheduled	7.42	8.36	9.07	7.71
Unscheduled	0.27	0.45	0.57	0.76
Total	7.69	8.81	9.64	8.47

Table 8. Breakdown of Parts, Labor, and Other Maintenance Costs for All Other Maintenance Costs

Maintenance Costs $ per 1,000 Miles	Total – All Data		Last Year	
	GC	E85	GC	E85
Parts	3.38	3.89	3.84	3.32
Labor	3.09	3.16	3.37	3.47
Other	1.22	1.76	2.42	1.68
Total	7.69	8.81	9.64	8.47

The gasoline control vehicles were in service a little longer than the ethanol vehicles (a difference of three to four months or approximately 5,000 miles per vehicle), which contributed to higher maintenance costs. Only four of the ten ethanol vehicles were in service in April 1996, and those four vehicles were held to low mileage for the first few months for the study. The three or four more months of operation of the gasoline control vehicles led to a few preventive maintenance actions that were not performed on the ethanol vehicles, such as a brake adjustment/cleaning, coolant flush and refill, and an air filter change. The maintenance costs on all of the vehicles were so low (except for the body system maintenance costs which are not being included here) that these extra maintenance actions made a significant impact on a per- mile basis. The unscheduled maintenance costs for both vehicle types were low.

The major issue in the higher maintenance costs for the gasoline control vehicles is the low maintenance costs for the PUCO FFVs (54-125, 54-181, 54-218, 54-219). The PUCO FFVs saw minimal maintenance as compared to the other vehicles in the study. The maintenance was stretched as close to 5,000 miles between oil changes as possible (the maximum allowed by Ford), and the PUCO FFVs never used the low ash engine oil. When the PUCO FFV maintenance costs are removed, the other six FFVs have a maintenance cost of $10.28 per 1,000 miles for the last year as compared to the $9.64 for the gasoline control vehicles. Also, when the PUCO FFV maintenance costs are removed, the other six FFVs have a maintenance cost of $11.44 per 1,000 miles for all data as compared to the $7.69 per 1,000 miles for the gasoline control vehicles. These maintenance cost comparisons are more in line with the expected results from the study. The ethanol vehicles have a slightly higher maintenance cost (seven percent) due mostly to the special, more expensive engine oil.

Vehicle 14-222 (an FFV) had a maintenance issue that may have been fuel-related. The vehicle had a low-power problem that was traced to a spark plug coil. The spark plugs were replaced at the state agency's cost, and the coil pack was replaced under warranty. No more problems were reported with the vehicle.

<u>Unscheduled Maintenance and Warranty</u> – During the data collection, there were seven unscheduled maintenance actions for the gasoline control vehicles: broken window, windshield seal (warranty), transmission shifter cable (warranty), two tire repairs, service engine light with no trouble found (warranty), and brake cleaning and adjustment. Of these seven repair actions, three were warranty repairs. For the ethanol vehicles, there were 12 unscheduled repairs: two for accident/body damage, two for engine oil addition, three for a seal in the wiring of the fuel system (warranty/recall), driver seat, power steering fluid spill, tie rod replacement (warranty), spark plug and fuel filter replacement, and spark plug and coil pack replacement (warranty for the coil). Of these 12 unscheduled repairs, five were warranty repair actions.

<u>Total Operating Costs</u> – As shown in Table 9, the total operating cost on a per 1,000 mile basis (excluding the body system and wheels and tires maintenance costs for both types of vehicles) was higher for the ethanol vehicle operation for all data and for the last year. The difference in operating costs was due almost entirely to the higher fuel cost for E85.

Table 9. Total Operating Costs

Operating Costs $ per 1,000 Miles	Total – All Data		Last Year	
	GC	E85	GC	E85
Fuel Usage	50.09	65.54	47.48	68.16
Maintenance	7.69	8.81	9.64	8.47
Total	57.78	74.35	57.12	76.63

<u>Survey of E85 Fleet Managers</u> – A survey of fleet managers in the state who have E85 vehicles was conducted to gather general feedback from the fleet managers on how the Ford Taurus FFVs were operating in comparison to other similar vehicles in their fleet. There were 25 surveys distributed and 13 were returned. Results from the returned surveys are summarized below:

- All responding fleet managers felt that there were few or no problems with the vehicles
- The FFVs were about the same in comparison of operations with gasoline vehicles
- The operating range of the FFVs was acceptable
- The availability of E85 fuel was the major concern with the FFVs and the state program
- Oil changes were expensive because of the special engine oil (this requirement has been removed by Ford).

EMISSIONS TESTING RESULTS – The Automotive Testing Labs, Inc. (ATL) in East Liberty, Ohio, conducted emissions testing on the study vehicles during May and June 1997, and provided the results shown here. The Federal Test Procedure (FTP) was performed twice for each test vehicle on each test fuel. Table 10 shows the number of FTP tests performed and fuels used by vehicle.

Table 10. Number of FTP Emissions Tests

Vehicle	Odometer	License Plate No.	Number of FTP Tests	
			RFG	E85
FFV Taurus	13,700	32-311	2	2
FFV Taurus	14,200	14-222	2	2
Std. Gasoline Taurus	14,700	24-202	2	N/A
Std. Gasoline Taurus	15,200	92-107	2	N/A

The gasoline baseline fuel selected for this program was California Phase 2 Certification gasoline (designated RFG). This is a clean-burning gasoline selected to provide the "best" modern gasoline for comparison of the FFVs to conventional gasoline vehicles. All of the FFV and gasoline vehicles in the test program received duplicate tests with the RFG fuel. The E85 fuel consisted of 85 percent ethanol blended with the base RFG fuel. Table 11 shows the properties of the liquid test fuels. The RFG and E85 fuels for this program were supplied directly to ATL by the Phillips Petroleum Company through a contract with NREL.

Table 11. Liquid Test Fuel Properties

Test Fuel Analysis	RFG	E85
Fuel blend	100% RFG	85% ethanol, 15% RFG
Specific gravity	0.739	0.781
Carbon (wt.%)	84.1	57.3
Hydrogen (wt.%)	13.8	13.3
Oxygen (wt.%)	2.1	29.3
Estimated net heat of combustion (BTU/gal.)	111,780	82,600
Reid vapor pressure (psi)	6.9	7.5

Although the U.S. Environmental Protection Agency (EPA) regulates methanol-fueled vehicle exhaust (and evaporative) hydrocarbons (HC) as total hydrocarbon equivalent (THCE), there is no equivalent regulation for ethanol. The calculations employed for ethanol tests are not defined by the Code of Federal Regulations (CFR). ATL, through an agreement with NREL and other contract laboratories, modified existing methanol calculations for use with ethanol. The CFR defines THCE as including HCs as well as the equivalent HC portion of formaldehyde and methanol (40 CFR 86-99):

$$THCE = HC + \frac{13.8756}{32.042} CH3OH + \frac{13.8756}{30.0262} HCHO$$

The Tier 1 EPA HC certification standards for methanol vehicles are written in terms of the non-methane portion or non-methane hydrocarbon equivalent (NMHCE).

The changes to the methanol calculations consisted of substitutions of ethanol molecular weights for methanol weights and the documenting of acetaldehyde rather than formaldehyde results. Acetaldehyde is the major product of the incomplete combustion of ethanol (as formaldehyde is for methanol).

The average emissions results from the vehicles tested in this program are shown in Table 12. These results followed the expected trends in terms of the relative emissions levels of the FFV and standard gasoline models. Similar work performed by ATL for NREL with earlier models of the FFV Ford Taurus supports the data from this program.

The differences between the FFV and standard gasoline emissions results are a by-product of calibration compromises between E85 and RFG operation in the FFV. As control technology improves, it is reasonable to believe that the differences between E85 and RFG operation will decrease. Regardless of test fuel or vehicle type, all of the emissions results from this program were well below the applicable useful life standards.

Table 12. FFV and Standard Gasoline Vehicles – Average Emissions Results

Type	FFV		Std. Gas
Fuel	E85	RFG	RFG
Regulated Emissions			
NMHC(E) (g/mi.)	0.149	0.101	0.114
THC(E) (g/mi.)	0.189	0.117	0.132
CO (g/mi.)	1.33	1.01	1.39
NO_x (g/mi.)	0.09	0.08	0.22
Greenhouse Gases			
CO_2 (g/mi.)	389.8	412.1	407.6
Methane (g/mi.)	0.046	0.021	0.023
Aldehydes			
Formaldehyde (g/mi.)	0.00226	0.00099	0.00127
Acetaldehyde (g/mi.)	0.01302	0.00030	0.00035
Fuel Economy			
MPG (actual)	15.81	21.08	21.32
MPEG	21.40		

NMHCE and CO emissions differences were minor between the vehicle/fuel combinations. Interestingly, FFV oxides of nitrogen (NO_x) emissions results were lower than the corresponding standard gasoline NO_x results. In the past, FFV and standard gasoline Taurus engines have generally produced very similar NO_x emissions levels (Kelly, et al., 1996).

As expected, acetaldehyde (and to a lesser extent formaldehyde) emissions were elevated through the use of the E85 fuel. This is an expected result because acetaldehyde is a product of the incomplete combustion of ethanol. However, as the amount of ethanol in the fuel increases, the benzene and 1,3-butadiene (both potent toxics) emissions levels will decrease. This decrease can be explained by the dilution of 1,3-butadiene and benzene in the exhaust by the presence of unburned ethanol and its combustion products rather than gasoline combustion products. Because hydrocarbon speciation was not performed as part of this program, 1,3-butadiene and benzene emissions could not be reported.

ETHANOL FUEL ANALYSIS RESULTS – Transportation-grade ethanol fuel is specified in standard protocol ASTM D 5798 Standard Specification for Fuel Ethanol (Ed75-Ed85) for Automotive Spark-Ignition Engines. For transportation-grade ethanol, the notation E75 up to E85 represents that the fuel contains up to 70 percent and 80 percent respectively by volume ethanol including up to 0.5 percent methanol. The remaining 20 to 30 percent of fuel essentially contains gasoline (including denaturant). Transportation-grade ethanol is transported in a combination of 95 percent ethanol by volume and 5 percent denaturant (minimum 2 percent required), usually gasoline (or hydrocarbons).

Transportation-grade ethanol is denatured to prevent consumption and evasion of taxes associated with consumable ethanol.

The designation E85 or E75 should be interpreted as mixtures of 85 percent and 75 percent by volume of transportation-grade ethanol, which already is made up of 5 percent gasoline. Transportation-grade ethanol fuel specifications, material compatibility, fuel quality, fuel transport and delivery, fuel handling, and safety are described in the *Guidebook for Handling, Storing, & Dispensing Fuel Ethano*l, which is available from the U.S. Department of Energy (DOE) Alternative Fuels Data Center (AFDC), ***www.afdc.doe.gov.***

As part of this study, limited ethanol fuel sample analysis for both ethanol fueling sites was performed by Core Laboratories of Carson, California. The ethanol fuel sample analysis was included in the project to determine the ethanol content, heating value, and water content of the fuels being dispensed at the Department of Agriculture and ODOT fueling facilities. Ethanol fuel sample analysis results are shown in Table 13.

The first two samples taken (one from each site) showed that the ethanol content was much lower than expected (64 and 67 percent). However, based on discussions with the fuel suppliers, this appeared to be a one-time event. All other fuel samples since the first two have been close to the E85 specification. This fuel composition information was used to validate conversion factors used for calculations to assess in-use vehicle fuel economy.

Table 13. Ethanol Fuel Sample Analysis Results

Test	Method	ODOT1	ODOT2	ODOT3	DAG1	DAG2	DAG3	DAG4	DAG5
Date sample taken		6/17/97	9/19/97	5/5/98	6/4/97	7/1/97	7/30/97	9/24/97	1/27/98
Methanol (LV%)	ASTM D-4815	<0.01	<0.01	<0.10	<0.01	0.21	0.22	0.18	<0.10
Ethanol (LV%)	ASTM D-4815	63.99	83.66	86.19	66.53	77.60	76.86	77.86	83.67
Specific gravity (60/60)	ASTM D-1298	0.7788	0.7839	0.7806	0.7826	0.7826	0.7822	0.7835	0.7794
Heating value, gross (BTU/lb.)	ASTM D-240	14798	14063	14479	14798	14466	14489	14305	15522
Water, Karl Fischer (ppm)	ASTM D-1744	4250	6277	5031	4724	6008	6242	6154	5194

SUMMARY

Results from this project show that the ethanol FFVs are operating well and meeting the requirements of the state agency operators. The ethanol vehicles are operating at a usage level similar to the gasoline control vehicles. The fuel economy is slightly higher for the ethanol fleet for in-use data and from the results of the emissions testing. The fuel usage cost for the ethanol fleet is significantly more expensive than the gasoline fleet, as expected, because of the higher cost of ethanol fuel as compared to gasoline.

The maintenance costs are slightly lower for the ethanol fleet from the in-use data. However, one site with FFVs had extremely low maintenance costs because of extending the engine oil change interval to the maximum allowed by Ford and by not using the special low ash engine oil (no longer a requirement). With the four FFVs from the one site removed from the maintenance cost calculations, the ethanol fleet (six vehicles) has a seven percent higher maintenance cost than the gasoline control vehicles. This difference in maintenance costs is consistent with the higher engine oil costs. The difference in maintenance costs is expected to be reduced due to the discontinued use of the higher cost, low ash engine oil.

The emissions testing showed that the ethanol FFVs have very low exhaust levels for this type of vehicle. The survey of fleet managers at the state who operate ethanol FFVs showed that the vehicles had very few problems or complaints. The primary issue was availability of the ethanol fuel.

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This project would not have been possible without the support and cooperation of personnel from each participating state agency.

APPENDIX A

State of Ohio E85 Fleet Summary Statistics 8/19/98

Fleet Operations and Economics — **Total (all data)** / **Last 12 Months**

	Total (all data) Gasoline Control	Total (all data) E85	Last 12 Months Gasoline Control	Last 12 Months E85
Number of Vehicles	3	10	3	10
Period Used for Fuel and Oil Op Analysis	4/96 - 3/98	4/96 - 3/98	4/97 - 3/98	4/97 - 3/98
Total Number of Months in Period	24	24	12	12
Fuel and Oil Analysis Base Fleet Mileage (2)	80,010	243,157	41,419	140,467
Period Used for Maintenance Op Analysis	4/96 - 3/98	4/96 - 3/98	4/97 - 3/98	4/97 - 3/98
Total Number of Months in Period	24	24	12	12
Maintenance Analysis Base Fleet Mileage (2)	86,345	244,376	41,419	141,686
Average Mileage per Car per Month	1,199	1,121	1,151	1,181
Fleet Fuel Usage in Gasoline Equiv. Gal.	3,253	8,842	1,662	5,101
Representative Fleet MPG (energy equiv.)	24.60	27.50	24.92	27.54
Ratio of MPG (AF/GC)		1.12		1.11
Average Fuel Cost as Reported	1.23	1.50	1.18	1.52
Total Fuel Cost $	4,007.69	15,936.66	1,966.52	9,574.92
Fuel Usage Cost $ per 1,000 Miles	50.09	65.54(1)	47.48	68.16(1)
Number of Make-up Oil Quarts per 1,000 Mi.	0.00	0.00	0.00	0.00
Oil Cost per 1,000 Miles	0.00	0.00	0.00	0.00
Total Scheduled Repair Cost per 1,000 Miles	7.42	8.36	9.07	7.71
Total Unscheduled Repair cost per 1,000 Miles	0.27	0.45	0.57	0.76
Total Maintenance Cost per 1,000 Miles (3)	7.69	8.81	9.64	8.47
Total Operating Cost per 1,000 Miles	57.78	74.35	57.12	76.63
Total Operating Cost per Mile	0.058	0.074	0.057	0.077

Maintenance Costs

	Gasoline Control	E85	Gasoline Control	E85
Fleet Mileage	86,345	244,376	41,419	141,686
Total Parts Cost per 1,000 Miles	3.38	3.89	3.84	3.32
Total Labor Cost per 1,000 Miles	3.09	3.16	3.37	3.47
Total Other Cost per 1,000 Miles	1.22	1.76	2.42	1.68
Total Maintenance Cost per 1,000 Miles (3)	7.69	8.81	9.64	8.47

Body System (01.00.00)

Total Parts Cost per 1,000 Miles	10.70	0.51	0.30	0.56
Total Labor Cost per 1,000 Miles	0.33	1.73	0.00	0.00
Total Other Cost per 1,000 Miles	0.86	7.40	1.23	12.00
Total Maintenance Cost per 1,000 Miles	11.89	9.64	1.53	12.56

Wheels and Tires (04.04.00)

Total Parts Cost per 1,000 Miles	0.14	0.04	0.29	0.07
Total Labor Cost per 1,000 Miles	1.52	0.16	1.83	0.27
Total Other Cost per 1,000 Miles	0.00	0.00	0.00	0.00
Total Maintenance Cost per 1,000 Miles	1.66	0.20	2.12	0.34

Notes

1. The fuel cost for the E85 vehicles is based on a rate of 61 percent for usage by volume. The other 39 percent by volume was gasoline. For the last 12 months, the E85 fuel cost was based on a rate of 67 percent for usage by volume and the other 33 percent was gasoline.
2. The mileage reported for fueling and maintenance for the gasoline and E85 vehicles is different because fueling data was missing for 92-107 and 14-178.
3. Maintenance costs for the body system and wheels and tires have been removed from all analysis. The actual costs for the body system are shown above but are excluded from the totals for maintenance. Body system maintenance items include accident/repair for body damage, car wash, and windshield wiper and fluid.