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USE OF MID-RANGE ETHANOL/GASOLINE BLENDS IN UNMODIFIED PASSENGER CARS AND LIGHT DUTY TRUCKS

Grant Bonnema
Gregory Guse
Neil Senecal
Rahul Gupta
Dr. Bruce Jones
Professor Kirk L. Ready

Minnesota Center for Automotive Research, Minnesota State University

ABSTRACT

This one-year project focused on the effects on fuel economy, emission characteristics, driveability, and component compatibility of in-use light duty vehicles running on blends of 30% and 10% ethanol. The test sample included 15 vehicles of various years, makes, and models.

The procedures used for testing each of the fuels' mileage, emissions, driveability, oil analysis, and material compatibility are described.

E10 fuel contains 90% gasoline and 10% ethanol by volume. E30 contains 70% gasoline and 30% ethanol by volume. These were the two fuels used in this test.

The results of the study revealed that volumetric fuel economy decreased when using E30. There were no driveability or material compatibility problems experienced during the study. Emissions results showed that some emissions were higher when running on E30, some were lower. All emissions were low and well below federal standards.

INTRODUCTION

Ethanol was used as a fuel extender during both WW I and WW II. This was done because petroleum based fuels were needed on the war front. After both wars, ethanol use declined sharply, largely because of its higher cost compared to gasoline. Ethanol again came into favor as a fuel extender during the Arab Oil Embargo of 1973 and also during the early 1980's when oil prices again skyrocketed.

Meanwhile in Brazil, even more attention was being paid to ethanol. Due to the Arab Oil Embargo, the Brazilian government put together a pro-alcohol committee called Proalcohol in 1975. Its purpose was to finance distillery projects in an effort to produce ethanol from sugar cane efficiently. At this point Brazil still imported 80% of its oil. Brazil already had a large foreign debt and high inflation [1]. In Brazil, a blend of 22% ethanol was used for several years because it was believed at the time that 22% was all the more ethanol a non-feedback fuel system could run successfully on without modification [2].

By 1981, the cost per kilometer for automobile travel was approximately 40% less using ethanol as opposed to gasoline. In the years following, the use of ethanol in Brazil has been unstable due mainly to economic reasons concerning oil prices [3].

In the U.S., the federal government in some geographical areas during the early 90's mandated oxygenated fuel. Ethanol is an effective oxygenate and is one that is highly favored in corn producing areas. One of its strong points is its lessening of the U.S. dependence on foreign oil, especially since the U.S. is importing more oil than ever before [4].

The capability exists to operate on higher concentrations of ethanol, because most vehicles on the road today in the U.S. have feedback fuel systems. This study was conducted to document the effects of operating vehicles on E-30 with no modifications.

This study was conducted on 15 vehicles, which were provided by Corn Plus shareholders. These vehicles were running on two blends of ethanol fuel: 10% ethanol content (E10) and 30% ethanol content (E30). The goal of the study was to compare the fuel economy (on-road and dynamometer), emissions, driveability characteristics, oil analysis, and material compatibility of the sample vehicles on each fuel.

All vehicles were tested at the Minnesota Center for Automotive Research (MnCAR), at Minnesota State

University, Mankato (MSU) using the HOT-505 test procedure. The Hot 505 test cycle is the third phase of the Environmental Protection Agency (EPA) Federal Test procedure (FTP) for vehicle emissions. In this test procedure, the vehicles were driven on the dynamometer for a 505 second test cycle. Prior to testing, both fuels were measured for ethanol content and specific gravity using the water separation method and the hydrometer test respectively.

The test procedure was developed by the researchers and each fuel was evaluated following this procedure. The results were compared using statistical analysis. The research performed at MnCAR determined the difference in fuel economy and tailpipe emissions for the two fuels.

The ultimate goal was to provide evidence to the EPA regarding the performance of in-use vehicles on higher concentrations of ethanol than the current 10% blends.

VEHICLE SELECTION

PRE-SELECTION INSPECTION OF VEHICLES

Vehicle candidates for this study were initially inspected using a Sun sST 1500 ignition oscilloscope. Of main interest were the absence of misfires and the consistency of firing kV. Of the vehicles chosen for the study, one needed an ignition tune-up before participation.

Once satisfactory ignition performance was demonstrated on the oscilloscope, each vehicle's emissions were checked using an OTC 5 GAS infrared exhaust gas analyzer.

Before beginning the baseline emissions testing, each vehicle had its engine oil & filter, and fuel filter changed.

A digital indoor/outdoor thermometer was installed in each vehicle after baseline testing at MSU. The purpose of this was to help vehicle owners record environmental conditions in the event of any driveability problems.

An odometer correction factor was determined for each vehicle when the vehicles were in for the first round of testing, which was used to achieve more accurate fuel economy data from the on-road fuel economy portion of the study. This was accomplished by driving each vehicle on a section of U.S. Highway 169 for 10 miles where the mile markers were known to be accurate and used to determine a mathematical correction factor for each vehicle.

TRAINING SEMINAR

The participants in the study were asked to attend a training seminar, which was to eliminate some of the variables that could result due to the type of data each participant was asked to supply. This was also done to insure the tests were repeatable from vehicle to vehicle.

The meeting involved a description of the participants' part in the study, the procedures that were done in the MnCAR Lab and the tests run in the MnCAR Lab.

The participants' part of the study included the collection of the following data:

- An accurate description of maintenance performed on their vehicles.
- An accurate description of fuel mileage on the road
- All driveability complaints.
- An accurate sample collected and sent in of their oil to be analyzed by TITAN E.O.A. Laboratory in Denver Colorado.

For each of the procedures the participants were given the appropriate form to fill out and a self addressed stamped envelope in which to return their results to the researchers. The forms can be found in appendix "A".

This meeting was held, prior to vehicle screening to insure every vehicle would be ready for testing. In which participants were asked to have their vehicle's fuel filter, engine oil, and engine oil filter changed prior to vehicle pre-screening selection. They were also requested to use a specified fuel and continue on the same fuel for the duration of the study.

The other purpose of this meeting was to show the operators the style of recording necessary for repeatability and to answer any questions.

VEHICLES SELECTED

1. 1996 Oldsmobile Achieva 3.1L
2. 1998 Dodge Caravan 3.3L
3. 1985 Oldsmobile Cutlass Ciera 2.5L
4. 1997 Chevrolet K3500 7.4L manual
5. 1994 Buick Regal 3.1L
6. 1997 Chevrolet K1500 5.7L
7. 1998 Ford F-250 5.4L
8. 1992 Ford Taurus 3.8L
9. 1997 Ford F-150 5.4L
10. 1990 Chevrolet C1500 4.3L
11. 1992 Chevrolet K1500 5.7L
12. 1990 Dodge Caravan 3.3L
13. 1991 Cadillac Sedan DeVille 4.9L
14. 1992 Geo Metro 1.0L manual
15. 1985 Ford Econoline 150 4.9L

PROCEDURES

EMISSIONS AND FUEL ECONOMY TESTING

Before vehicles were tested for emissions, a sample of fuel was taken from the vehicle's fuel tank and the percent of ethanol present by volume determined by water separation. It was found in several instances that fuel alcohol content was not correct. In such cases the fuel was drained, the correct fuel added, and the vehicle preconditioned for 160 kilometers before baseline testing was begun.

Vehicles were then tested for emissions using the Hot 505 trace of the LA4 drive cycle. Equipment used included a California Analytical emissions analyzer and a SuperFlow eddy current chassis dynamometer (Fig.1).

During each Hot 505 test, levels of HC, CO, CO_2, and NOx were measured and displayed in grams per mile. In addition, the fuel economy was measured during the test cycle.

Engine oil operating temperature was recorded on each vehicle. This was determined by using a digital multi-meter with an adjustable length temperature probe inserted down the dipstick tube. Two fans were placed in front of the vehicle for cooling purposes. The vehicle was operated on the dynamometer at highway speeds until oil temperature stabilized.

Initial fuel change on all applicable vehicles was done by using the vehicle's own in-tank electric fuel pump. Either a fuel line was disconnected or the schraeder valve on the fuel rail was tapped while the fuel pump relay terminals were jumped. Vehicles with returnless fuel systems or variable duty cycle fuel pumps quickly inspired more creative methods of draining the fuel.

Fig. 1

The designated test procedure was established through a series of trial tests. Variables found during the testing included oil temperature, tire pressure, dynamometer start up, calibration, coast down, and propane verification. These variables were accounted for in the following ways.

Oil Temperature

The oil temperature of the engine and drivetrain needed to be as constant as possible in order to maintain the same viscosity or (thickness) during the tests. Viscosity of oil increases as oil temperature decreases. When oil is more viscous, more energy is needed to pump the oil and a different frictional relationship on the bearing surfaces is created. Running the vehicle on the emissions dynamometer raised the engine and drivetrain oil temperature. All of the vehicles received oil changes before testing. By changing the oil before testing both viscosity and contamination issues were addressed.

Dynamometer Start Up

The eddy current emissions dynamometer in the MnCAR's lab uses electricity to control inertia weight and horsepower load on its rollers. This drag simulates the resistance that the vehicles would experience driven on the road at different speeds. Due to the dynamometer being cold, any possible variance was reduced, by starting and warming up the dynamometer. Following procedure for the dynamometer start up is included in the Appendix "B".

Coast Down

Coast down verification test informs the users of the amount of parasitic loss the dynamometer will have. The measured values are compared with the calculated values, which must be within a predetermined tolerance. If not, a parasitic loss check was performed to recalibrate the dynamometer parasitic losses.

Calibration

Calibration was completed using four specified gas mixtures from high-pressure cylinders (as shown in Fig. 2). This provided a base line of two different ranges (high and low) to compare the measured emissions from the vehicles. The ZERO/CALIBRATION is included in the HOT505 procedure that is in Appendix "C".

Propane Verification

A Calibration grade propane bottle with 99.5% propane was used. Propane was injected into the system while in the test mode and the analyzer compared the value it measured with the known value of the propane. The readings were required to be within 5% of the known value to pass. Refer to Appendix "D" for the procedure.

Fig. 2

Tire Pressure

Through preliminary testing a variance in performance due to tire pressure was found. The tire air pressure was set at 5 PSI greater than the recommended tire inflation rating, as printed on the tire sidewall. This was done to prevent tire overheating on the dynamometer. While the vehicle ran on the dynamometer a higher tire temperature was produced causing a corresponding higher tire pressure. Measuring the tire pressure prior to each test run compensated for this variable.

Fuel Change

After the first set of tests, fuel was switched in each vehicle. The fuel draining was accomplished by disconnecting the fuel line at the fuel rail and using a jumper wire at the fuel pump relay connector located in the under-hood area.

After the fuel change, vehicles were driven on a designated test route that was 160 kilometers long. The route included mostly highway driving and some stop and go traffic. This driving method was used to ensure that the vehicle's engine management computer's "Block Learn" had fully adapted to the new fuel.

After the 160-kilometer drive, vehicles were brought back to the MnCAR lab for testing on the new fuel and the same warm up procedure was followed for this section of the testing.

Individual Hot 505 Tests

The testing described in this report was conducted in accordance with the United States Environmental Protection Agency procedures on E10 and E30 fuels. All tests run on the dynamometer were based on the Federal Test Procedure as described in the Federal Register Part 86, Subpart B. The tests were limited to the hot transient portion of the driving cycle. The vehicles were not in the "cold start" mode prior to testing. This type of testing is commonly referred to as "Hot 505", which is 505 seconds long. This cycle simulates driving on the highway and in the city. In this procedure, vehicle emissions and fuel economy values, using the carbon balance of calculation, are obtained.

The following procedure was established to eliminate as many variables as possible:

- Check under-hood fluid levels, record and repair any deficiencies.
- Take a fuel sample from the vehicle and measure its ethanol content and specific gravity.
- Inspect vehicle's ignition system using the Sun sST 1500 ignition oscilloscope.
- Once satisfactory ignition performance demonstrated on the oscilloscope, check each vehicle's emissions using the OTC 5 GAS infrared analyzer.
- Run start up and warm up procedures on the dynamometer.
- Drive vehicle onto rolls and center vehicle on rolls.
- Restrain vehicle down using proper restraints and block non-drive wheels using wheel chocks.
- Insert oil temperature probe into the engine oil dipstick slot.
- Check the tire pressure and adjust pressure as required.
- Enter vehicle, fuel and test information in the computer and load the emissions test.
- Warm up vehicle on dynamometer for 5 minutes at 50 MPH. Make sure vehicle is warmed up to the proper operating temperature. Check tire pressure and readjust it to the proper operating pressure as determined by the researchers.
- Run tests three times beginning with 5-minute dynamometer warm up at 50 MPH.
- Remove oil temperature probe and replace engine oil dipstick.
- Remove vehicle from dynamometer and drain fuel and refill with a new test fuel with different ethanol content.

All tailpipe emissions and dynamometer fuel economy data were gathered using the procedure described above. A set of three tests was conducted on each fuel and analyzed for differences in emissions and fuel economy.

ON-ROAD TESTING

Engine oil samples were collected from all E-30 vehicles during oil changes and sent to TITAN E. O. A. Laboratory for analysis. Specific substances measured included Chromium, Copper, Iron, Lead, Tin, Aluminum, Silicon, Antimony, Barium, Boron, Cadmium, Calcium, Magnesium, Molybdenum, Nickel, Phosphorus, Silver, Sodium, Titanium, and Zinc. A sample of the test report can be found in Appendix "E".

The first sheet which they filled out was the on the road fuel economy form. This form was used in the study to compare actual fuel economy on the road to the fuel economy found while the cars were run on the Hot 505 cycle in the MnCAR Lab.

The second form which they were asked to record was any maintenance done on their vehicles which may change the results, including oil change, new tires, or any other data which may affect the results of the study.

The third sheet the participants were asked to fill out was the driveability complaint form. This form collected any complaints they had while driving on E-30. If they had any noticeable differences, including cold starting problems, vapor lock, rough running, or hard starting conditions, they were to note them on that form.

OIL ANALYSIS

Their owners collected engine oil samples during routine oil changes from their vehicles. This was done to monitor any effects due to the E-10 and E-30 blends.

The following procedure was use to collect the sample in preparation for laboratory examination:

- When making a routine oil change, make sure the engine is hot.
- Open the oil sample box, and remove the plastic bottle, plastic bag and label.
- Remove off the top of the bottle, and have it ready to catch the oil.
- Remove the oil plug, and let the oil run out for about 3-4 seconds, place the bottle under the drain plug hole, in order to catch some of the oil. Note: ¾ filled should be sufficient.
- After the sample has been taken, replace the plastic top and close tightly.
- Remove and clean off any excess oil that may have run on the outside of the bottle.
- Fill out the information on the label, and stick the label around the bottle.
- Place the bottle into the plastic bag, and seal it.
- Place the bagged bottle back into the box and mail to Titan E.O.A. laboratory.

RESULTS AND DATA /ANALYSIS

ANALYSIS OF FUEL ECONOMY

On-Road Fuel Economy

The on-road fuel economy was calculated using the mileage and volumetric values as recorded in the driver logbooks. All distance values were corrected using the odometer correction factor for each vehicle. The on-road fuel economy data was then compared using:

- Miles per gallon
- Equivalent miles per gallon gasoline
- Cost per mile
- Btu per mile

As shown on table 1.0.

On-Road Fuel Economy Data

E30 Vehicles	MPG E30	$/Mile E30 *	MPGE of E30	BTU/Mile E30
1996 Oldsmobile Achieva 3.1 L	24.5	0.051	27.6	4255.0
1998 Dodge Caravan 3.3 L	18.3	0.069	20.6	5684.0
1997 Chevrolet K3500 7.4 L	8.7	0.145	9.8	12024.1
1994 Buick Regal 3.1 L	25.9	0.049	29.2	4023.0
1997 Chevrolet K1500 5.7 L	12.8	0.099	14.4	8171.1
1998 Ford F-250 5.4 L	11.5	0.109	13.0	9028.9
1997 Ford F-150 5.4 L	12.8	0.098	14.4	8133.2
1990 Chevrolet C1500 4.3L	16.6	0.076	18.7	6281.4
1992 Chevrolet K1500 5.7 L	13.3	0.095	14.9	7859.4
1990 Dodge Caravan 3.3 L				
1992 Geo Metro 1.0 L	36.6	0.034	41.2	2848.7

E10 Vehicles	MPG E10	$/Mile E10 *	MPGE of E10	BTU/Mile E10
1985 Oldsmobile Cutlass 2.5 L	21.8	0.058	22.6	5192.5
1992 Ford Taurus 3.8 L	30.8	0.041	31.9	3674.1
1991 Cadillac Sedan Deville 4.9 L	21.6	0.058	24.4	4817.4
1985 Ford Econoline 150 4.9 L	17.6	0.071	19.8	5915.6

Table 1 $1.259/gal.Fuel

Formulas used to calculate on-road fuel economy data are:

- Miles/gallon = averaged total mileage and total fuel and multiplied by the odometer correction factor.
- The conversion factors were derived from the conversion charts found in the Bosch publication called "AUTOMOTIVE HANDBOOK (3rd. Ed.) "
- .765 Kg/l was used for the density of gasoline and .79 was used for the density of ethanol.
- 42.7 MJ/Kg was used for the specific caloric value of gasoline and 26.8MJ/Kg was used for the specific caloric value of ethanol.
- Cost/mile = cost/ gallon divided by miles/ gallon.
- BTU per mile = ethanol content BTU/gallon divided by miles/ gallon.
- Mile per gallon of gas equivalent = BTU/gallon gas divided by BTU/mile of specified fuel.

<u>Analysis of On-Road Fuel Economy Tests</u>

The purpose of recording on-road fuel economy information was not to compare the results of E10 and E30, but to gather information and monitor fuel economy throughout the project. The fuel economy logs were evaluated periodically to look for dramatic decreases in fuel economy that might be linked to any driveability or material compatibility problems that may have occurred.

If any significant decreases in fuel economy were noted, the owner of the vehicle was contacted to determine if a problem existed or if the use of the vehicle had changed significantly during that time. There were no significant fluctuations in fuel economy that were not attributed to a changed in weather or type of driving conditions.

<u>MnCAR Dynamometer Fuel Economy</u>

Fuel economy measurements were also taken during each Hot 505 test conducted on the MnCAR emissions dynamometer. The data displayed in Table 2 represents the means value for a set of three tests on each fuel.

All fuel property values were obtained from the Bosch Automotive Handbook. The MnCAR fuel economy data was then compared using:

- Miles per gallon
- Equivalent miles per gallon gasoline
- Cost per mile
- Btu per mile

MnCAR Dynamometer Fuel Economy Data

	E 30 MPG	E10 MPG	% Diff.	E30 $/Mile	E10 $/Mile	% Diff.	E30 MPGE	E10 MPGE	% Diff.	E30 BTU/Mile	E10 BTU/Mile	% Diff.
1996 Oldsmobile Achieva	19.80	23.20	-14.66	0.064	0.054	17.17	22.29	24.10	-7.50	5264.6	4869.8	8.11
1998 Dodge Caravan	19.00	21.65	-12.26	0.066	0.058	13.98	21.38	22.49	-4.91	5487.7	5218.4	5.16
1985 Oldsmobile Cutlass	-------	24.50	--------	--------	0.051		---------	25.45	-------		4611.4	------
1997 Chevrolet K3500	11.92	12.70	-6.18	0.106	0.099	6.59	13.41	13.19	1.68	8748.6	8895.9	-1.66
1994 Buick Regal	21.60	22.26	-2.96	0.058	0.057	3.06	24.32	23.12	5.17	4825.9	5075.4	-4.92
1997 Chevrolet K1500	12.66	13.91	-9.02	0.099	0.091	9.92	14.25	14.45	-1.39	8237.0	8122.1	1.41
1998 Ford F-250	11.70	12.82	-8.70	0.108	0.098	9.53	13.17	13.31	-1.05	8909.3	8816.1	1.06
1992 Ford Taurus	18.18	18.42	-1.28	0.069	0.068	1.29	20.47	19.13	7.00	5733.7	6135.1	-6.54
1997 Ford F-150	12.74	14.28	-10.75	0.099	0.088	12.05	14.34	14.83	-3.27	8182.0	7914.4	3.38
1990 Chevrolet C1500	19.26	21.50	-10.42	0.065	0.059	11.63	21.68	22.33	-2.91	5413.6	5256.0	3.00
1992 Chevrolet K1500	14.04	15.58	-9.89	0.090	0.081	10.97	15.80	16.18	-2.33	7427.1	7253.8	2.39
1990 Dodge Caravan												
1991 Cadillac Sedan Deville	-------	17.19	--------	--------	0.073	--------	---------	17.85	-------	------------	6574.2	-------
1992 Geo Metro	33.93	38.14	-11.05	0.037	0.033	12.42	38.19	39.62	-3.59	3072.6	2962.2	3.73
1985 Ford Econoline 150	-------	16.34	--------	--------	0.077	--------	---------	16.97	-------	------------	6916.3	-------

Table 2 * $1.259/gallon

Formulas used to calculate data were:

- Miles/gallon = given data.
- .765 Kg/l was used for the density of gasoline and .79 was used for the density of ethanol.
- 42.7 MJ/Kg was used for the specific caloric value of gasoline and 26.8MJ/Kg was used for the specific Caloric value of ethanol.
- Cost/mile = cost/ gallon divided by miles/ gallon.
- BTU per mile = ethanol content BTU/gallon divided by miles/ gallon.
- Mile per gallon of gas equivalent = BTU/gallon gas divided by BTU/ mile of specified fuel.

Analysis of MnCAR fuel economy Tests

By analyzing the fuel economy of E10 and E30 it was clear that E10 had an advantage over E30 in volumetric fuel consumption. Fuel economy values on E30, in miles per gallon, ranged from 1.28% to 14.66% lower for the vehicles in this study. The average decrease in mpg was 8.83% when this sample used E30.

As a result of consuming more fuel volumetrically per mile traveled, the cost per mile increased when the vehicles used E30. This was not a surprising outcome to the researchers.

However, when comparing the two fuels based on the energy used to travel a mile, differences between E10 and E30 decreased significantly. Two comparisons were made based on this idea.

The Miles Per Gallon Equivelant (MPGE) is a calculation of the fuel economy of both fuels as compared to gasoline. The BTU per Mile calculation represents the amount of energy in Btu's that is consumed per mile of travel. Both of these values equal energy content when comparing the fuel economy in miles per gallon. Three of the vehicles actually used less energy to travel a mile when they were running on E30.

ANALYSIS OF EMISSIONS

Levels of HC, CO and NOx were measured during both the spring and fall rounds of dynamometer testing. Three test runs using the Hot 505 drive cycle trace from the Federal Test Procedure were used. The first set of tests was conducted with E10 and then the fuel was changed to E30 for the second stet of tests.

A summary of the emissions results can be found in the tables in Appendix F.

The results of the emission testing are still being evaluated at this time. Upon first inspection no definite pattern or trend has been identified relating to the emissions differences between the vehicles running on E10 vs. E30. Not only do some vehicles respond differently to each fuel but also differences exist between the results of testing conducted during the spring and fall testing periods.

It should be noted that in almost every case the emission levels were low, and well below federal standards.

DRIVEABILITY ANALYSIS

Driveability data was recorded for the purpose of analyzing the performance of each fuel in "real world" conditions. Data was recorded by study participants on cards with choices of words and phrases, which could be used to best describe abnormal performance. An example of the card provided to the participants can be found in Appendix "F". During the duration of the test there were no driveability complaints during the spring, summer, and early fall months. In this study, there were no reports of cold starting, vapor lock, or hard starting conditions that have been associated with higher concentrations of ethanol. The complaints were to be documented at the time in which they occurred.

During the duration of the study there were no driveability complaints. The cars all seemed to start with no long duration of cranking. There were also no reported cases of hesitation with the E30 blend of fuel.

OIL ANALYSIS

Each vehicle was provided an oil analysis bottle in which the participants collected a sample of the used oil during their regularly scheduled oil change. The samples were then analyzed, from which the particulates found were separated and the amount of possible fuel line and other fuel components damaged were measured. These results were then compared to the variance from the norm.

The results from the oil analysis showed that there was no noticeable wear on engine components due to the E30 blend of fuel. There were however, two vehicles with higher levels of silicon. One vehicle had a very dirty engine compartment, which may have been the cause for higher levels of silicon. The other one was due to improper oil capture during the draining procedure.

MATERIAL COMPATABILITY

Fuel compatibility was tested using the driveability complaint forms from the test participants. There was no conclusive data showing harm as a result of running on the higher blend of ethanol. The data collected from the general maintenance forms also showed no fuel system damage during the duration of this study. No apparent danger to any engine or fuel system components by running on the E30 blend of fuel was found.

CONCLUSIONS

Of greatest importance to this project was the discovery of the stubbornness of some vehicles to fully learn a fuel of different ethanol concentration. A half-hour of dynamometer driving was not sufficient in most cases for a complete block learn adjustment. Driving the vehicle on the highway for approximately 100 miles proved to be much more effective. In some cases it would have been desirable to operate the vehicle for a greater length of time on the highway.

Another concern was the change in frictional horsepower loss of the dynamometer from day to day. It became a daily practice to check the frictional horsepower loss of the dyno. This was done by means of a set procedure including dynamometer warm-up, a coast down check, and a parasitic loss check.

A daily propane verification procedure was added to insure consistent exhaust gas analyzer performance.

Additional effort was also made after the first round of testing to inform volunteer participants by telephone and mail about the goal of the study and what it required of them.

CONCLUSIONS FROM DATA

There was a reduction in volumetric fuel economy on E30. However, the reduction in fuel efficiency based on Btu/mile was significantly lower.

No apparent trend in vehicle emissions was identified. Some emissions increased while others decreased. Almost all emissions were below federal standards.

Oil sample analysis reveals a couple of cases of high silicon content and one case of water-diluted oil and high copper content. According to TITAN Laboratories this may have been due to improper oil sample collection.

There was not one driveability problem reported during the study. Ambient temperatures during the study ranged from below 0 to above 90 degrees Fahrenheit.

There were no fuel system compatibility problems experienced by any participants.

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DEFINITIONS / ACRONYMS

E10	motor fuel containing 10% ethanol and 90% gasoline
E30	motor fuel containing 30% ethanol and 70% gasoline
HC	hydrocarbons
CO	carbon monoxide
CO_2	carbon dioxide
NO_x	oxides of nitrogen
BTU	British thermal unit
FTP	federal test procedure
MnCAR	Minnesota Center for Automotive Research
Hot 505	505 seconds of the FTP with the vehicle at operation temperature
FID	flame ionization detection (HC)
CLD	chemiluminescent detection (NO_x)
IR	infrared (CO and CO_2)
NDIR	non-dispersive infrared
MSU	Minnesota State University, Mankato
Aldehyde	specific type of hydrocarbons commonly produced by burning alcohol based fuels
Cat	catalytic converter
MPI	multi point injection
TBI	throttle body injection
gm/mile	grams per mile
DIS	distributor ignition system
EDIS	electronic distributorless ignition system
kV	kilo volts