Exhaust Emissions and Fuel Economy From Automobiles Using Alcohol/Gasoline Blends Under High-Altitude Conditions

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by

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ABSTRACT

This paper describes the results of emissions tests on ten passenger cars operated on fuel blends containing methanol and ethanol. The purpose of the program was to determine the immediate exhaust emission and fuel economy changes due to use of alcohol/gasoline blends under high altitude conditions. The vehicles represented the 1973-1978 model years and were randomly selected from private owners in the Denver area. The vehicles were tested both as-received and after tune-up. The test procedures used were the Federal Test Procedure (exhaust emissions only) and the Highway Fuel Economy Test. In each case, four different fuels were used: Indolene Clear and blends of Indolene Clear containing 10% ethanol, 20% ethanol and 10% methanol. Exhaust emission levels for hydrocarbons, carbon monoxide, oxides of nitrogen, aldehydes and unburned alcohol were measured. Fuel economy was measured and recorded using the carbon balance technique. The results indicate significant decreases in CO emissions with slight increases in NOx emissions. HC emissions of these vehicles were often erratic, although average values decreased slightly with the increasing percentage of alcohol in the fuel. In general, total aldehydes and amount of unburned alcohol were found to increase with the addition of larger amounts of alcohol. Fuel economy was found to decrease slightly. Evaporative emission test results on a single vehicle indicate that greater hot-soak losses can be expected with the use of these blends.

INTRODUCTION

The ability to use alcohol as a motor fuel, either alone or in a blend with gasoline has been studied a number of times over the past several decades. Scattered emission test results, primarily with methanol blends, have confirmed that unadjusted engines will tend to run leaner because of the higher oxygen content and lower energy content of the alcohol/gasoline blend. Because the costs of alcohols are still somewhat greater than of gasoline there has been no real economic incentive for the widespread use of blended fuel. Lately, however, there has been increased interest in alcohol/gasoline blends as a new market for grain and agricultural waste products, as an energy extender and a way to immediately enlean carburetors in high altitude areas. Some legislators are encouraging the trial use of these blends by proposing tax breaks on their production and sale. The U.S. Department of Agriculture is planning to guarantee a number of loans to developers who wish to establish facilities for the production of alcohol.

Probably the biggest proponent for the use of alcohol in motor fuel is the State of Nebraska. The blend they advocate is named "Gasohol" and consists of 90% unleaded gasoline and 10% anhydrous ethanol. The Colorado State Legislature and EPA's Region VIII have expressed an interest in such a fuel as an immediate and relatively inexpensive way to "retrofit" existing vehicles with leaner carburetors. While some emission tests results do exist, such as preliminary results from a program at the Bartlesville Energy Research Center of DOE, they do not include the consideration of the blends for use at high altitude conditions.

PURPOSE

The basic purpose of this study was to develop information on the immediate effects of alcohol/gasoline blends on exhaust emission and fuel economy of passsenger cars operated at high altitude. This study was designed to provide appropriate test data on a vehicle fleet which included the latest models in both an "as-received" and tuned-up condition. Results from tests on two different alcohols would be compared to a baseline test performed on Indolene Clear test fuel. Test data included exhaust emissions (HC, CO, NOx, aldehydes and unburned alcohol) and fuel economy information as well as the results of a limited driveability evaluation. The results will be useful for the various technical personnel concerned with fuel blends and will assist legislators with decisions whether to encourage the use of such blends. This project could provide the first step in a comprehensive program to evaluate these fuels in other areas. Such areas include starting ability, temperature effects, engine durability, fuel system deterioration, formation of larger quantities of unregulated emissions, evaporative emissions and necessary engine parameter adjustments for use of higher concentration blends. Some of these areas may be investigated in other work by EPA or others.

DESIGN OF TESTING

Basic Design

This effort involved the procurement and testing of ten vehicles in the Denver area. The desired fleet was chosen on a sales-weighted basis while the vehicles themselves were procured randomly from private owners in the Denver area. The standard incentive package offered to prospective participants was a $100 U.S. Savings Bond, the use of a late model loan car and a full tank of fuel upon the return of the test vehicle. These vehicles were to be tested both as-received and after tune-up with Indolene Clear fuel and three alcohol/gasoline blends: of 10% ethanol, 20% ethanol and 10% methanol. Thus, each vehicle received eight test sequences. The test sequence included a 1975 FTP (exhaust emissions only), an HFET, and a limited evaluation of driveability. The work itself was performed under contract to EPA by Automotive Testing Laboratories, Inc. of Aurora, Colorado.

Narrative Test Procedures (See flow chart attached as Figure 1)

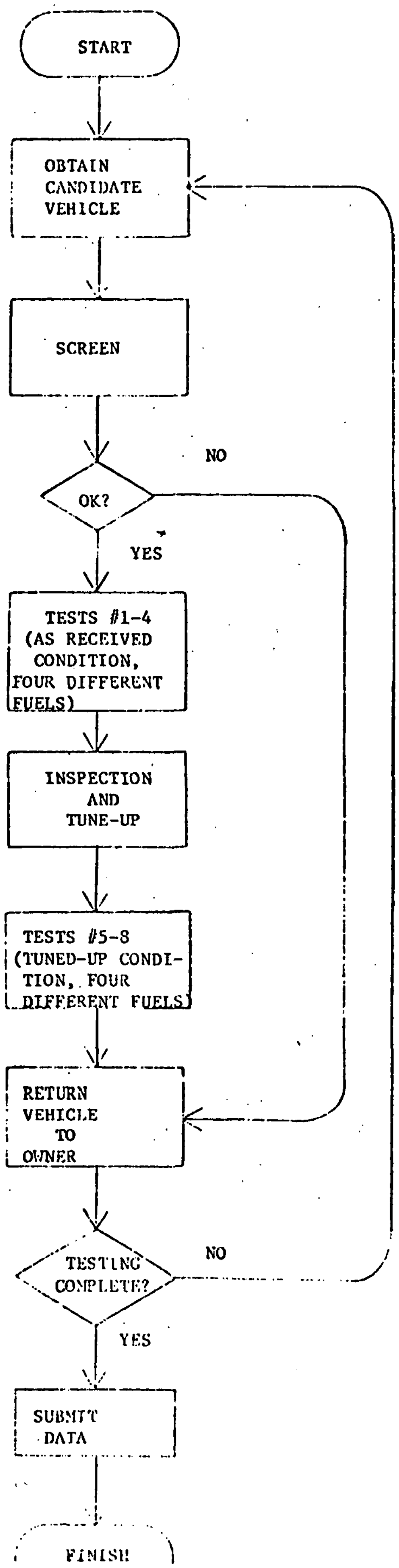
Obtain candidate vehicles - The Project Officer supplied the list of candidate vehicles. Potential test vehicles were drawn from the general public using commercially available mailing lists or other means designed to ensure overall randomness of the sample.

Screen - Willing owners whose vehicles appear to meet the vehicle configuration criteria were contacted to verify the information provided and to obtain any missing items. At this time, the owner was questioned with regard to vehicle age and mileage, types of usage, and extent of possible modifications. He was also asked to allow minor adjustments to be performed, if necessary, and informed of the incentive package and possible test duration.

Upon arrival at the laboratory, the candidate vehicle was physically examined to determine its suitability for the program. During this cursory inspection, a sample of tank fuel was drawn and tested for lead content. The owner was also interviewed to complete the questionnaire.

The outcome of this portion of the sequence was to accept or reject the vehicle for further testing. A modest amount of emission control malperformance on some vehicles was acceptable. However, vehicles which had undergone misadjustments or modifications which were not readily, inexpensively or ultimately restorable were to be rejected from the sample at this point. Rejection would result from clearly worn or defective internal engine parts, extensive modifications, improper use, or indications that the vehicle used leaded fuel (if the vehicle required unleaded fuel). If accepted, the owner completed the remaining loan vehicle and test agreement forms and his vehicle was retained for the program.

Figure 2: Sequence of Testing



Test - The actual test sequence on each vehicle began with the removal of the current fuel and addition of test fuel to 40% of tank fuel volume. Each test fuel used in this project originated from the same batch of Indolene clear. Alcohol/gasoline blends were formulated by the addition of 100% ethanol or methanol. The vehicle was then driven for at least twenty minutes on city streets to ensure the test fuel had fully purged the system. During this time, a driveability evaluation of the vehicle in a warmed-up condition was conducted. Cold-start operation was evaluated and recorded during the subsequent FTP driving cycle.

The dynamometer driving sequence consisted of a cold start FTP and HFET. A total of four cold start dynamometer test sequences were required for each state of tune on each vehicle. One test sequence was performed with each of the following four fuels: Indolene Clear, a 10% ethanol blend (Gasohol), a 20% ethanol blend and, finally, a 10% methanol blend. Thus, eight sequences were conducted on each of ten vehicles for a total of eighty tests.

The dynamometer test sequence began after the prescribed soak period. Appropriate dynamometer settings (inertia weight, horsepower, air conditioning load) and vehicle starting procedures were those listed in the material furnished by EPA for use in the FY77 Passenger Car Testing Program. All test settings and vehicle specifications were "as-certified."

Inspection and tune-up - Following the "as-received" series of tests, each vehicle received a thorough underhood inspection followed by a tune-up. The tune-up included all recommended maintenance for a vehicle with the age and mileage of the test vehicle. As a minimum for very new vehicles, parameters to be adjusted during the tune-up were ignition timing, idle mixture and idle speed. Disabled or defective components were replaced or repaired regardless of age or mileage.

Return vehicle to owner - The contractor prepared the vehicle for return to its owner as well as fulfilled the provisions of the incentive package.

Testing complete? - Once the prescribed number and types of vehicles had been procured and successfully tested, the testing portion of the project was complete.

Emission Measurements

During each test cycle on each test sequence, the following emission measurements were made:

Oxides of nitrogen, hydrocarbons, carbon monoxide, and carbon dioxide - Standard exhaust emission test procedures and calculations were employed in the measurement of these emissions. The flame ionization detector was used to measure unburned HC. Chemiluminescent methods were used for measurement of NOx emissions and CO and CO_2 exhaust emissions were measured with a nondispersive infrared analyzer.

Aldehydes and ketones The measurement of aldehydes (formaldehyde, acetaldehyde, isobutyraldehyde, crotonaldehyde, hexanaldehyde, and benzaldehyde) and ketones (acetone and methylethylketone) in exhaust was accomplished by bubbling the exhaust through glass impingers containing 2,4 dinitrophenylhydrazine (DNPH) in dilute hydrochloric acid. The exhaust sample was collected continuously during the test cycle. The aldehydes and ketones (also known as carbonyl compounds) reacted with the DNPH to form their respective phenylhydrazone derivatives. These derivatives are insoluble or only slightly soluble in the DNPH/HCl solution and are removed by filtration followed by pentane extractions. The filtered precipitate and the pentane extracts are combined and then the pentane is evaporated in a vacuum oven. The remaining dried extract contains the phenylhydrazone derivatives. The extract was dissolved in a quantitative volume of toluene containing a known amount of anthracene as an internal standard. A portion of this dissolved extract was injected into a gas chromatograph and analyzed using a flame ionization detector. The detection limits for this procedure under normal operating conditions are on the order of 0.005 ppm carbonyl compound in dilute exhaust.

Alcohols - Unburned alcohols were collected using a separate bag arrangement similar to the one employed for the basic test. Analyses were conducted using a gas chromatograph.

Evaporative Emissions - Measurement of evaporative emissions were not originally included in the basic plan of this project. Because of the need for data in this area, a small experiment was conducted after the main portion of the effort was complete. These results are found in Appendix A.

PROGRAM RESULTS

Test Vehicle Procurement

A total of ten passenger cars were procured randomly from private owners in the Denver area. Model years of vehicles were grouped in terms of their level of emission control technology. The pre-catalyst vehicles of the 1973 and 1974 model years were grouped together. The 1975 and 1976 vehicles were grouped on the basis of their use of first generation catalyst systems. The 1977 and 1978 models represented those produced after certification testing of vehicles was actually conducted at high altitude.* A list of the basic characteristics of vehicles in the test fleet are shown in Table 1.

*Although 1978 models were technically not required to meet standards at high altitude, many had been tested at the time of Clean Air Act Amendments. The systems present in this fleet were ones designed to meet those standards.

Emission Results

Shown in table 2 are the average exhaust emission results for the entire fleet. The results for the regulated pollutants versus concentration of alcohol in the fuel are displayed graphically in Figures 2,3, and 4. Tables 3, 4 and 5 list the average results for vehicles in each of the model year groups. Attached as Appendix B is the complete set of data sheets on each vehicle in the fleet. These data indicate a general decrease in HC and CO emissions with greater concentrations of alcohol while increases in NOx, total aldehydes and unburned alcohols were found. Levels of all pollutants (other than NOx) were found to be more closely related to control technology rather than use of alcohol in the fuel.

Fuel Economy

The average fuel economy results for the entire fleet over both the FTP and the HFET are listed in Table 6. These values were calculated using the carbon balance technique. Several changes in the constants in the basic formula were necessary because the number of carbon atoms per volume of alcohol/gasoline blends differ from those of pure gasoline. Thus, correction factors were developed that could be applied to the fuel economy values calculated by the typical formula for gasoline. For a 10% ethanol blend, this factor is 0.969, for 20% ethanol it is 0.933 and for 10% methanol it is 0.950. Since these alcohols possess a lower heating value than gasoline, the fuel economy of vehicles in terms of miles-per-gallon of fuel shows a slight penalty. In terms of use of gasoline, however, the alcohols do act as an extender and result in greater fuel economy in terms of miles-per-gallon of gasoline.

An important aspect in the use of any resource is the expenditure to achieve a unit of output. For this study, this parameter is defined as fuel cost per mile travelled. In order to equal the cost/mile for gasoline, these results indicate a driver must pay just over one cent per gallon less for Gasohol and almost two cents less for a gallon of a 20% ethanol blend. A 10% blend of methanol should be priced almost three cents less per gallon. From an overall economic standpoint, cost-per-mile equivalency should be achieved when ethanol can be produced with a "retail price equivalent" of 75-80% that of gasoline. The corresponding figures for methanol are 55-60%.

Driveability

A thorough and proper evaluation of vehicle driveability is a sophisticated process which requires a great deal of expertise. Such an evaluation was beyond the scope of this project. As a part of this work, however, a modest evaluation was conducted during the preconditioning phase and during the first few minutes of dynamometer operation. Based on a review of these results and conversations with the contractor personnel who drove these vehicles, there appeared to be no noticeable difference in performance between pure gasoline and either of the two 10% blends. Likewise, there was little difference in operation on 20% ethanol except for the two occasions in which the vehicles stalled and could not readily be restarted.

CONCLUSIONS

On an immediate basis for high altitude areas, a moderate blend of alcohol in gasoline appears to be a feasible way to extend gasoline supplies and to help reduce HC and CO exhaust emission levels from light duty motor vehicles. On the other hand, there are a number of findings from this study which should be considered.

1. Average NOx, aldehyde and unburned alcohol emissions from vehicles in the test fleet were found to increase slightly due to the use of alcohol/gasoline blends. These aspects must be considered from the standpoint of overall air quality impact on a case-by-case basis.

2. Operation of a current vehicle on an alcohol/gasoline blend containing over 10% alcohol may require internal carburetor adjustments or retrofit to avoid excessively lean operation.

3. A properly-tuned vehicle will emit equal or lesser amounts of HC and CO than can be obtained by use of alcohol/gasoline blends although these situations are not incompatible.

4. Fuel economy will be found to decrease. Thus, blends using alcohol, which is currently more expensive than gasoline, cannot equal gasoline in terms of cost per mile. Naturally, tax breaks, subsidies or other pricing measures could neutralize this situation.

5. Based only on the results of evaporative emissions tests on a single vehicle, greater hot-soak losses can be expected with the use of these blends.

The precise values resulting from this study must also be considered in light of the fact they were obtained in a laboratory situation and did not address the long-term effects of alcohol in the fuel of current in-use vehicles.

Table 1 - Test Vehicle Information

VEHICLE NUMBER	YEAR/MAKE	MODEL	CID/CYL	ODOMETER
8001	78 Ford	Granada	302/8	10,000
8002	78 Chevrolet	Monte Carlo	350/8	10,719
7003	77 Dodge	Aspen	225/6	23,000
7004	77 Ford	Granada	302/8	16,830
7005	77 Chevrolet	Monte Carlo	350/8	15,700
5006	75 Dodge	Coronet	318/8	27,542
5007	75 Ford	Torino	351/8	48,135
5008	75 Buick	Regal	350/8	31,310
4009	74 Ford	Torino	351/8	48,135
3010	73 Chevrolet	Chevelle	350/8	10,500

Table 2 - Fleet Average FTP Exhaust Emission Levels In Grams per Mile

State of Tune	Fuel	N	HC	CO	NOxc	Total Aldehydes	Unburned Alcohols
As-Rec'd	Indolene Clear	10	2.44	43.4	1.73	0.052	0.007
"	10% Ethanol	10	2.13	32.9	1.86	0.056	0.007
"	20% Ethanol	9*	1.84	23.7	2.06	0.078	0.010
"	10% Methanol	10	2.12	30.3	1.95	0.060	0.021
Tuned	Indolene Clear	10	1.64	29.5	1.75	0.043	0.011
"	10% Ethanol	10	1.41	16.8	1.90	0.061	0.018
"	20% Ethanol	9*	1.48	17.4	1.92	0.055	0.023
"	10% Methanol	10	1.62	19.0	2.13	0.061	0.015

*There were two separate cases in which the vehicle stalled and could not be restarted to complete the test. Thus, the entire fleet is not represented in these averages.

Figure 2: HC Emissions vs Percent Alcohol

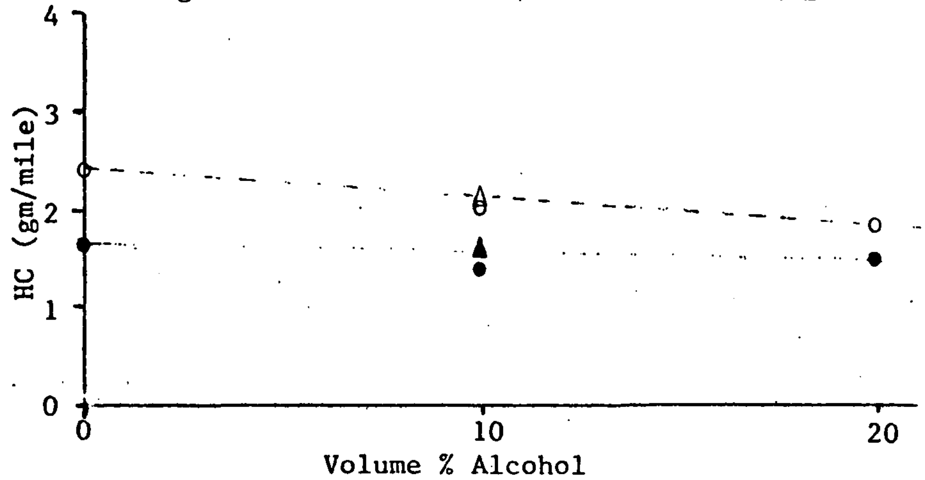


Figure 3: CO Emissions vs Percent Alcohol

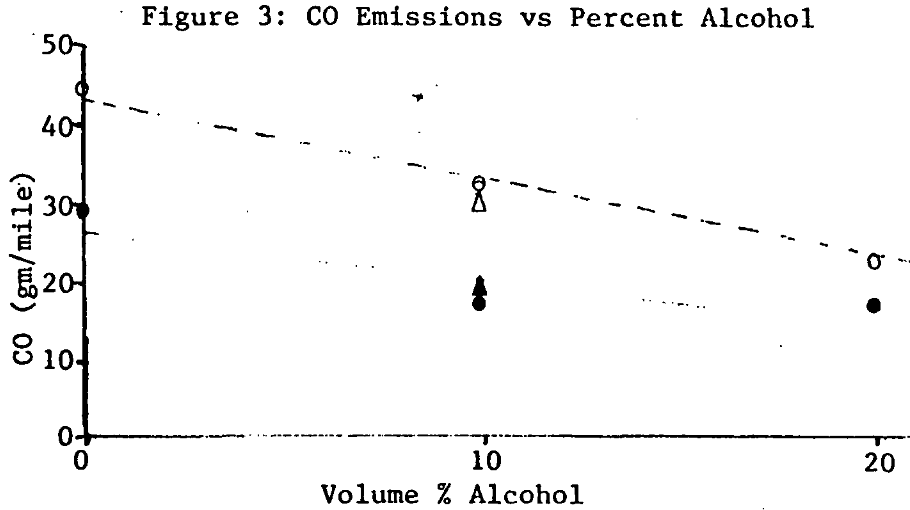
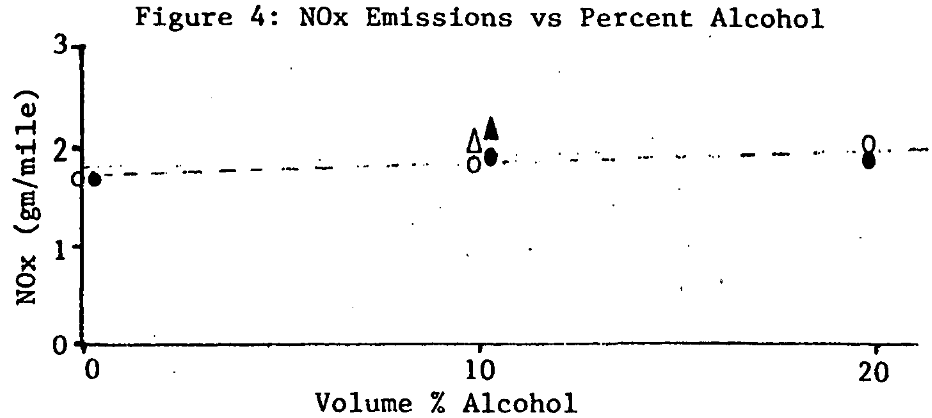


Figure 4: NOx Emissions vs Percent Alcohol



As Received	Tuned Up
o Ethanol	● Ethanol
Δ Methanol	▲ Methanol
– – – – –	————

Table 3 - Average FTP Exhaust Emission Levels for the 1977 and 1978 Models in Grams per Mile

State of Tune	Fuel	N	HC	CO	NOxc	Total Aldehydes	Unburned Alcohols
As-Rec'd	Indolene Clear	5	1.68	22.8	1.10	.027	.003
"	10% Ethanol	5	1.30	16.0	1.18	.031	.006
"	20% Ethanol	4*	1.54	19.3	1.08	.029	.005
"	10% Methanol	5	1.55	16.7	1.21	.028	.007
Tuned	Indolene Clear	5	.90	12.4	1.18	.026	.009
"	10% Ethanol	5	1.00	10.6	1.25	.024	.008
"	20% Ethanol	4*	.99	8.0	1.56	.023	.008
"	10% Methanol	5	1.13	6.2	1.47	.023	.016

*There were two separate cases in which the vehicle stalled and could not be restarted to complete the test. Thus, the entire 1977-78 vehicle group is not represented in these averages.

Table 4 - Average FTP Exhaust Emission Levels for the 1975 and 1976 Models in Grams per Mile

State of Tune	Fuel	N	HC	CO	NOxc	Total Aldehydes	Unburned Alcohols
As-Rec'd	Indolene Clear	3	2.68	46.7	2.13	.048	.011
"	10% Ethanol	3	2.51	37.0	2.09	.062	.007
"	20% Ethanol	3	1.20	8.6	2.15	.054	.008
"	10% Methanol	3	1.77	22.8	2.26	.045	.006
Tuned	Indolene Clear	3	1.82	40.9	1.80	.039	.004
"	10% Ethanol	3	.98	9.5	1.94	.100	.018
"	20% Ethanol	3	.84	9.7	2.10	.025	.023
"	10% Methanol	3	1.20	18.3	2.49	.033	.019

Table 5 - Average FTP Exhaust Emission Levels for the 1973 and 1974 Models in Grams/Miles

State of Tune	Fuel	N	HC	CO	NOxc	Total Aldehydes	Unburned Alcohols
As Rec'd	Indolene Clear	2	4.00	89.8	2.69	.109	.012
"	10% Ethanol	2	3.67	72.0	3.23	.100	.015
"	20% Ethanol	2	3.42	55.3	3.90	.188	.029
"	10% Methanol	2	4.08	75.5	3.37	.140	.071
Tuned	Indolene Clear	2	3.24	55.1	3.00	.114	.027
"	10% Ethanol	2	3.12	43.1	3.47	.110	.044
"	20% Ethanol	2	3.37	47.0	3.30	.172	.051
"	10% Methanol	2	3.45	52.1	3.14	.198	.006

Table 6 - Fleet Average Fuel Economy

State of Tune	Fuel	N	Miles per gallon of fuel FTP	Miles per gallon of fuel HFET	Miles per gallon of gasoline FTP	Miles per gallon of gasoline HFET
As Rec'd	Indolene Clear	10	13.67	19.10	13.67	19.10
"	10% Ethanol	10	13.50	18.70	15.00	20.78
"	20% Ethanol	9*	12.79	18.25	15.99	22.81
"	10% Methanol	10	13.00	18.15	14.44	20.17
Tuned	Indolene Clear	10	13.43	18.53	13.43	18.53
"	10% Ethanol	10	13.16	18.00	14.62	20.00
"	20% Ethanol	9*	12.75	17.59	15.94	21.99
"	10% Methanol	10	13.02	17.59	14.47	19.54

*There were two separate cases in which the vehicle stalled and could not be restarted to complete the test. Thus, the entire fleet is not represented in these averages.

September 20, 1978

Evaporative Emissions from High Altitude Cars Fueled with Gasohol

John T. White, Project Manager, TAEB

Michael Walsh, Deputy Assistant Administrator for Mobile Source Air Pollution Control

THRU: Ralph C. Stahman, Chief, TAEB
Charles L. Gray, Director, ECTD

At the present time, we are compiling a report from our recent program on alcohol/gasoline blends in Denver. This project examined the effect of different blends on exhaust emissions and fuel economy using a fleet of ten 1973-1978 model year passenger cars. Preliminary results were used by MSED in the recent waiver hearings. As a result of those proceedings, concern was expressed that evaporative emission levels may suffer with use of these blends because the alcohol could reduce the effectiveness of the charcoal in retaining fuel vapors. Based on this concern, we immediately modified our test program to add some further tests that would directly address this issue. The purpose of this memorandum is to provide you with data from this work. Although this study was conducted under high altitude conditions, we feel that basic discussions and conclusions regarding evaporative emissions are valid.

Attached is a table which lists the emission levels and canister weights at each step in a six-test procedure. A 1978 Buick Regal with a 305 CID engine was used in this study. The initial two test sequences were conducted with Indolene Clear fuel to establish a baseline. The remaining four tests were run on a mixture of 10% ethanol/and 90% Indolene Clear. This mixture is known as Gasohol. If the theory about reduced effectiveness of the evaporative control system is true, we would expect to see higher diurnal losses and, perhaps, increasing canister weights.

As shown on the table, this was not the case. Diurnal losses did not exhibit any increase and canister weights fluctuated without a discernable trend. From this, we conclude that the canister was able to handle the vapors effectively and operated properly through the charge and purge cycles included in each test sequence. Evaporative losses, however, did show an increase during the hot soak phase. The reason for this is the generally higher volatility of the alcohol at hot-soak temperatures. In addition, the engine itself may tend to become hotter because of the leaner mixture.

In confirmation of our work on the earlier ten vehicles, CO emissions on the FTP showed an identifiable decrease, NOx emissions increased slightly and HC emissions remained essentially unchanged.

The vehicle used for this project belong to our contractor and is used as a loaner when procuring test vehicles from private owners. Since completing these six tests, it has been loaned out with a full tank of gasohol fuel. We plan to continue with the use of this fuel and to test this vehicle on several later occassions. Several other late model vehicles of various descriptions will also be examined in this manner.

This information should be useful in comparison with other inputs you have received on this topic. If you have any questions or comments on this effort, please contact one of us.

Attachment

cc: T. Tupaj (w/ attach.)

TAEB:WHITE:jb:2565 Plymouth Rd:9-20773

Emission Test Results
Indolene - Gasohol Fuel
1978 Buick Regal w/ 305 CID Engine
Denver

Test	Fuel		----------FTP----------				Evaporative Emissions(g)			-----Canister Weights(g)-----			
#	Type	Date	HC	CO	NOx	MPG	Diurnal	Hot Soak	Total	Before Prep	After Prep	Before Diurnal	After Hot Soak
1	Indolene	9-8	0.99	32.1	1.18	15.6	2.6	1.8	4.4	*	*	*	*
2	Indolene	9-9	0.88	25.9	1.28	15.8	2.2	3.6	5.8	*	*	*	*
3	Gasohol	9-15	0.93	23.8	1.31	15.6	2.7	4.5	7.2	972	946	959	963
4	Gasohol	9-16	0.87	20.0	1.20	15.9	2.4	6.3	8.7	950	934	**	950
5	Gasohol	9-18	1.02	25.9	1.31	15.5	2.7	7.0	9.7	955	933	952	959
6	Gasohol	9-19	0.83	19.1	1.86	15.8	2.2	4.5	6.7	949	932	949	952

*Test program modified to obtain canister weights after Indolene tests were run.

**Missing data point.

"GASOHOL" EVALUATION -- SUMMARY OF TEST RESULTS SITE DENVER

VEHICLE NO. 8002 VIN 1237U82407377 ODOMETER 10719 INERTIA WT./HP 3500/10.7

YEAR/MAKE 78 CHEV. MODEL MONTE CARLO CID/CYL 350/8 TRANS A CARB 2V

AS RECEIVED SERIES

TEST NO.	DATE	1975 FTP (gm/mi) HC	CO	NOX	UNBURNED ALCOHOL (mg/mi)	ALDEHYDES (mg/mi)	FUEL ECONOMY (MPG) FTP	HFET
1. IND CLEAR	7-10-78	.81	11.86	.88	3.54	24.39	15.38	22.85
2. 10% ETH	7-12	.77	7.01	1.04	2.74	25.17	15.63	22.17
3. 20% ETH	7-13	1.10	5.90	1.10	7.28	29.00	14.80	20.61
4. 10% METH	7-14	1.36	8.09	1.04	3.72	30.91	14.94	21.90

Inspection and Maintenance Results:

BASIC TIMING FOUND TO BE 5° ADVANCED. THIS WAS RESET TO SPECS.

TUNED-UP SERIES

TEST NO.	DATE	1975 FTP (gm/mi) HC	CO	NOX	UNBURNED ALCOHOL (mg/mi)	ALDEHYDES (mg/mi)	FUEL ECONOMY (MPG) FTP	HFET
5. IND CLEAR	7-15-78	.68	11.05	.73	4.08	21.81	14.52	19.97
6. 10% ETH	7-16	.93	9.13	.78	6.50	22.60	14.15	19.40
7. 20% ETH	7-17	ENGINE STALLED - WOULD NOT RESTART						
8. 10% METH	7-18	1.19	4.31	.84	19.36	38.35	13.89	17.43

Comments:

"GASOHOL" EVALUATION -- SUMMARY OF TEST RESULTS SITE DENVER

VEHICLE NO. 7003 VIN NH29C7B191452 ODOMETER 23,000 INERTIA WT./HP 3500/12.3

YEAR/MAKE 77 DODGE MODEL ASPEN CID/CYL 225/6 TRANS A CARB 2V

AS RECEIVED SERIES

TEST NO.	DATE	1975 FTP (gm/mi) HC	CO	NOX	UNBURNED ALCOHOL (mg/mi)	ALDEHYDES (mg/mi)	FUEL ECONOMY (MPG) FTP	HFET
1. IND CLEAR	8-8-78	.98	6.94	1.08	4.66	29.09	15.32	18.65
2. 10% ETH	8-8	.79	5.33	1.17	4.07	27.61	15.51	19.09
3. 20% ETH	8-9	.85	5.29	1.17	.84	20.39	14.62	17.56
4. 10% METH	8-14	.87	6.97	1.22	13.89	14.29	15.28	18.22

Inspection and Maintenance Results:

FAST IDLE RPM FOUND TO BE TOO SLOW
CHOKE SETTING WAS TOO LEAN. EACH WAS ADJUSTED TO SPEC.

TUNED-UP SERIES

TEST NO.	DATE	1975 FTP (gm/mi) HC	CO	NOX	UNBURNED ALCOHOL (mg/mi)	ALDEHYDES (mg/mi)	FUEL ECONOMY (MPG) FTP	HFET
5. IND CLEAR	8-15-78	.82	8.26	1.06	5.80	16.32	15.04	18.49
6. 10% ETH	8-16	.68	5.84	1.25	3.13	6.62	15.30	17.91
7. 20% ETH	8-17	.84	5.09	1.41	6.13	15.93	14.67	17.32
8. 10% METH	8-18	1.11	4.65	1.36	7.25	7.15	14.89	17.51

Comments:

"GASOHOL" EVALUATION -- SUMMARY OF TEST RESULTS SITE DENVER

VEHICLE NO. 8001 VIN 8W81F169340 ODOMETER 10,000 INERTIA WT./HP 3500/8.6

YEAR/MAKE 78 FORD MODEL GRANADA CID/CYL 302/8 TRANS A CARB 2V

AS RECEIVED SERIES

TEST NO.	DATE	1975 FTP (gm/mi) HC	CO	NOX	UNBURNED ALCOHOL (mg/mi)	ALDEHYDES (mg/mi)	FUEL ECONOMY (MPG) FTP	HFET
1. IND CLEAR	8-8-78	4.64	81.21	.66	3.09	28.98	14.45	24.73
2. 10% ETH	8-7	2.89	56.97	.96	14.69	29.90	14.62	23.92
3. 20% ETH	8-10	2.96	61.16	.84	5.99	37.77	14.28	23.53
4. 10% METH	8-10	3.09	58.74	.95	2.32	18.36	14.50	22.84

Inspection and Maintenance Results:
IDLE MIXTURE AND CHOKE SETTINGS WERE FOUND TO BEE TOO RICH. THESE WERE ADJUSTED

TUNED-UP SERIES

TEST NO.	DATE	1975 FTP (gm/mi) HC	CO	NOX	UNBURNED ALCOHOL (mg/mi)	ALDEHYDES (mg/mi)	FUEL ECONOMY (MPG) FTP	HFET
5. IND CLEAR	8-14-78	1.19	20.23	1.04	0	12.11	16.40	24.23
6. 10% ETH	8-15	1.15	16.82	1.29	13.14	17.94	15.81	23.06
7. 20% ETH	8-16	1.16	11.86	1.68	4.71	15.39	16.28	23.79
8. 10% METH	8-17	1.03	8.48	2.15	5.84	12.19	16.71	23.97

Comments:

"GASOHOL" EVALUATION -- SUMMARY OF TEST RESULTS SITE DENVER

VEHICLE NO. 7004 VIN 7W35F537427 ODOMETER 16,830 INERTIA WT./HP 4000/13.2

YEAR/MAKE 77 FORD MODEL GRANADA CID/CYL 302/8 TRANS A CARB 2v

AS RECEIVED SERIES

TEST NO.	DATE	1975 FTP (gm/mi) HC	CO	NOX	UNBURNED ALCOHOL (mg/mi)	ALDEHYDES (mg/mi)	FUEL ECONOMY (MPG) FTP	HFET
1. IND CLEAR	7-10-78	1.24	8.72	.93	4.42	16.94	13.67	18.18
2. 10% ETH	7-12	1.25	6.29	1.07	3.40	20.53	13.79	18.27
3. 20% ETH	7-13	1.26	4.93	1.21	5.31	19.42	12.78	18.31
4. 10% METH	7-14	1.48	4.64	1.24	4.89	34.34	13.47	17.72

Inspection and Maintenance Results:

BASIC TIMING WAS FOUND TO BE 4° ADVANCED, IDLE MIXTURE WAS TOO RICH, AIR FILTER ELEMENT WAS VERY DIRTY. EACH OF THESE PROBLEMS WAS CORRECTED

TUNED-UP SERIES

TEST NO.	DATE	1975 FTP (gm/mi) HC	CO	NOX	UNBURNED ALCOHOL (mg/mi)	ALDEHYDES (mg/mi)	FUEL ECONOMY (MPG) FTP	HFET
5. IND CLEAR	7-15-78	1.15	4.63	1.29	25.34	23.74	14.22	18.38
6. 10% ETH	7-16	1.61	3.55	1.12	7.92	23.90	12.64	16.05
7. 20% ETH	7-17	1.39	3.05	1.60	7.46	26.22	13.72	18.40
8. 10% METH	7-18	1.79	4.54	1.47	38.22	34.18	13.95	18.01

Comments:

"GASOHOL" EVALUATION -- SUMMARY OF TEST RESULTS SITE DENVER

VEHICLE NO. 7005 VIN 1H57L7K428587 ODOMETER 15,700 INERTIA WT./HP 4500/10.7

YEAR/MAKE 77 CHEVY MODEL MONTE CARLO CID/CYL 350/8 TRANS A CARB 2V

AS RECEIVED SERIES

TEST NO.	DATE	1975 FTP (gm/mi) HC	CO	NOX	UNBURNED ALCOHOL (mg/mi)	ALDEHYDES (mg/mi)	FUEL ECONOMY (MPG) FTP	HFET
1. IND CLEAR	8-7-78	.76	5.56	1.99	1.14	37.58	13.58	18.34
2. 10% ETH	8-8	.81	4.47	1.66	4.06	50.45	12.99	17.99
3. 20% ETH		ENGINE STALLED - WOULD NOT RESTART						
4. 10% METH	8-10	.95	4.87	1.61	9.61	37.64	12.93	17.73

Inspection and Maintenance Results:
CHOKE SETTING WAS FOUND TO BEE TOO LEAN. AIR FILTER WAS VERY DIRTY. THESE WERE CORRECTED ALONG WITH REPLACEMENT OF THE DISTRIBUTOR CAP, ROTOR, AND SPARK PLUGS

TUNED-UP SERIES

TEST NO.	DATE	1975 FTP (gm/mi) HC	CO	NOX	UNBURNED ALCOHOL (mg/mi)	ALDEHYDES (mg/mi)	FUEL ECONOMY (MPG) FTP	HFET
5. IND CLEAR	8-16-78	.69	17.92	1.78	7.91	16.48	13.09	18.27
6. 10% ETH	8-17	.65	17.66	1.84	8.20	13.80	12.43	17.08
7. 20% ETH	8-18	.60	12.05	1.57	15.33	15.54	12.26	17.31
8. 10% METH	8-18	.55	8.85	1.57	10.50	19.39	12.18	16.28

Comments:

"GASOHOL" EVALUATION -- SUMMARY OF TEST RESULTS   SITE DENVER

VEHICLE NO. 5006   VIN WP23G5G194484   ODOMETER 27,542   INERTIA WT./HP 4000/13.2

YEAR/MAKE 75 DODGE   MODEL CORONET   CID/CYL 318/8   TRANS A   CARB 2V

AS RECEIVED SERIES

TEST NO.	DATE	1975 FTP (gm/mi) HC	CO	NOX	UNBURNED ALCOHOL (mg/mi)	ALDEHYDES (mg/mi)	FUEL ECONOMY (MPG) FTP	HFET
1. IND CLEAR	8-17-78	2.67	44.17	2.22	11.77	31.94	14.17	18.96
2. 10% ETH	8-18	2.32	34.63	1.81	15.87	34.87	14.04	18.81
3. 20% ETH	8-21	.61	5.31	1.61	11.48	24.11	13.65	18.00
4. 10% METH	8-21	1.06	14.68	1.90	4.32	14.38	13.67	18.06

Inspection and Maintenance Results:

IDLE MIXTURE WAS FOUND TO BE RICH. CHOKE SETTING WAS TOO LEAN. BASIC TIMING WAS 8° ADVANCED. HEATED AIR INLET TUBE WAS DISCONNECTED. THESE PROBLEMS WERE CORRECTED ALONG WITH A CARBURETOR REBUILD AND REPLACEMENT OF SPARK PLUGS.

TUNED-UP SERIES

TEST NO.	DATE	1975 FTP (gm/mi) HC	CO	NOX	UNBURNED ALCOHOL (mg/mi)	ALDEHYDES (mg/mi)	FUEL ECONOMY (MPG) FTP	HFET
5. IND CLEAR	9-7-78	1.13	21.07	1.72	3.66	14.62	12.81	18.65
6. 10% ETH	9-8	.63	9.30	1.69	26.69	19.86	12.53	19.15
7. 20% ETH	9-9	.62	7.88	1.49	6.35	5.76	11.90	16.72
8. 10% METH	9-11	1.04	16.73	1.82	6.93	15.21	11.94	17.17

Comments:

"GASOHOL" EVALUATION -- SUMMARY OF TEST RESULTS SITE DENVER

VEHICLE NO. 5008 VIN VH57J5H163642 ODOMETER 31310 INERTIA WT./HP 4000/13.2

YEAR/MAKE 75 BUICK MODEL REGAL CID/CYL 350/8 TRANS A CARB 4V

AS RECEIVED SERIES

TEST NO.	DATE	1975 FTP (gm/mi) HC	CO	NOX	UNBURNED ALCOHOL (mg/mi)	ALDEHYDES (mg/mi)	FUEL ECONOMY (MPG) FTP	HFET
1. IND CLEAR	7-10-78	3.00	74.41	1.15	16.62	32.89	12.54	18.04
2. 10% ETH	7-12	2.69	64.20	1.12	2.54	38.15	12.19	17.05
3. 20% ETH	7-13	.59	4.04	1.39	5.20	29.26	11.87	16.01
4. 10% METH	7-14	1.93	39.22	1.34	5.20	18.68	11.08	16.85

Inspection and Maintenance Results:
FAST IDLE SPEED WAS TOO SLOW. THIS WAS ADJUSTED AS WAS THE IDLE MIXTURE.

TUNED-UP SERIES

TEST NO.	DATE	1975 FTP (gm/mi) HC	CO	NOX	UNBURNED ALCOHOL (mg/mi)	ALDEHYDES (mg/mi)	FUEL ECONOMY (MPG) FTP	HFET
5. IND CLEAR	7-16-78	2.67	67.12	1.08	4.18	34.66	12.35	17.89
6. 10% ETH	7-17	.87	13.91	1.51	7.35	13.85	12.54	17.25
7. 20% ETH	7-18	.54	3.82	1.44	7.07	25.30	12.19	16.77
8. 10% METH	7-18	1.18	19.46	1.24	38.44	24.51	12.32	17.20

Comments:

"GASOHOL" EVALUATION -- SUMMARY OF TEST RESULTS SITE DENVER

VEHICLE NO. 5007 VIN 5A31H157692 ODOMETER 39,030 INERTIA WT./HP 4500/14.0

YEAR/MAKE 75 FORD MODEL TORINO CID/CYL 351/8 TRANS A CARB 2V

AS RECEIVED SERIES

TEST NO.	DATE	1975 FTP (gm/mi) HC	CO	NOX	UNBURNED ALCOHOL (mg/mi)	ALDEHYDES (mg/mi)	FUEL ECONOMY (MPG) FTP	HFET
1. IND CLEAR	8-3-78	2.37	21.45	3.03	4.30	79.29	12.87	16.71
2. 10% ETH	8-4	2.52	12.29	3.36	3.28	112.68	12.69	16.60
3. 20% ETH	8-7	2.41	16.56	3.46	7.01	108.64	12.21	15.81
4. 10% METH	8-9	2.34	14.55	3.54	7.19	103.42	12.45	15.86

Inspection and Maintenance Results:

BASIC TIMING WAS FOUND TO BE 4° ADVANCED, CHOKE SETTING WAS VERY LEAN. VACUUM BREAK DIAPHRAGM WAS LEAKING. THESE WERE CORRECTED AND THE ROTOR IN THE DISTRIBUTOR WAS REPLACED.

TUNED-UP SERIES

TEST NO.	DATE	1975 FTP (gm/mi) HC	CO	NOX	UNBURNED ALCOHOL (mg/mi)	ALDEHYDES (mg/mi)	FUEL ECONOMY (MPG) FTP	HFET
5. IND CLEAR	8-10-78	1.67	34.70	2.61	5.11	66.25	11.80	16.36
6. 10% ETH	8-14	1.44	5.41	2.61	18.67	267.37	12.31	16.58
7. 20% ETH	8-16	1.37	17.38	3.36	55.64	44.13	11.45	15.56
8. 10% METH	8-17	1.37	18.64	4.42	10.66	58.30	11.59	15.70

Comments:

"GASOHOL" EVALUATION -- SUMMARY OF TEST RESULTS SITE DENVER

VEHICLE NO. 4009 VIN 4B31H147674 ODOMETER 48,135 INERTIA WT./HP 4000/13.2

YEAR/MAKE 74 FORD MODEL TORINO CID/CYL 351/8 TRANS A CARB 2V

AS RECEIVED SERIES

TEST NO.	DATE	1975 FTP (gm/mi) HC	CO	NOX	UNBURNED ALCOHOL (mg/mi)	ALDEHYDES (mg/mi)	FUEL ECONOMY (MPG) FTP	HFET
1. IND CLEAR	8-18-78	4.84	100.09	3.24	13.31	61.91	13.57	19.14
2. 10% ETH	8-21	4.48	73.74	4.16	13.30	69.98	13.65	19.11
3. 20% ETH	8-21	3.52	46.38	5.16	27.26	117.70	11.53	19.83
4. 10% METH	8-23	4.44	63.28	4.33	82.84	68.71	13.57	18.43

Inspection and Maintenance Results:
IDLE MIXTURE WAS TOO RICH. IDLE RPM WAS TOO SLOW, CHOKE SETTING WAS TOO LEAN. THESE WERE ADJUSTED AND THE OIL AND FILTER WERE REPLACED

TUNED-UP SERIES

TEST NO.	DATE	1975 FTP (gm/mi) HC	CO	NOX	UNBURNED ALCOHOL (mg/mi)	ALDEHYDES (mg/mi)	FUEL ECONOMY (MPG) FTP	HFET
5. IND CLEAR	8-23-78	3.51	48.78	3.86	38.29	67.95	13.73	18.13
6. 10% ETH	8-25	3.52	34.47	4.75	59.71	80.93	13.70	19.43
7. 20% ETH	8-25	3.59	45.27	4.21	67.98	125.70	13.13	19.17
8. 10% METH	8-28	3.66	40.76	4.21	3.88	159.65	13.53	19.58

Comments:

"GASOHOL" EVALUATION -- SUMMARY OF TEST RESULTS SITE DENVER

VEHICLE NO. 3010 VIN 1C35H3K546852 ODOMETER 46,424 INERTIA WT./HP 4500/12.7

YEAR/MAKE 73 CHEV. MODEL CHEVELLE (STA. WAG.) CID/CYL 350/8 TRANS A CARB 2V

AS RECEIVED SE..

TEST NO.	DATE	1975 FTP (gm/mi) HC	CO	NOX	UNBURNED ALCOHOL (mg/mi)	ALDEHYDES (mg/mi)	FUEL ECONOMY (MPG) FTP	HFET
1. IND CLEAR	8-19-78	3.17	79.56	2.15	9.90	156.14	11.98	17.91
2. 10% ETH	8-21	2.87	70.22	2.31	16.75	130.10	11.26	16.46
3. 20% ETH	8-23	3.33	64.28	2.65	29.84	258.15	10.73	16.80
4. 10% METH	8-23	3.72	87.72	2.41	58.66	210.76	10.15	16.23

Inspection and Maintenance Results: TIMING WAS FOUND TO BE 3° ADVANCED, CHOKE SETTING WAS TOO LEAN, HEATED AIR INLET TEMP SENSOR WAS DEFECTIVE, IDLE MIXTURE TOO RICH. THESE PROBLEMS WERE CORRECTED AND THE OIL, ~~ATS~~ FILTER AND THE AIR FILTER WERE REPLACED. THE CARBURETOR LINKAGES WERE ALSO CLEANED.

TUNED-UP SERIES

TEST NO.	DATE	1975 FTP (gm/mi) HC	CO	NOX	UNBURNED ALCOHOL (mg/mi)	ALDEHYDES (mg/mi)	FUEL ECONOMY (MPG) FTP	HFET
5. IND CLEAR	8-25-78	2.97	61.39	2.15	15.26	159.82	11.79	16.11
6. 10% ETH	8-25	2.73	51.71	2.19	27.94	139.75	11.48	16.66
7. 20% ETH	8-28	3.15	48.71	2.40	33.47	218.90	10.86	15.64
8. 10% METH	8-28	3.24	63.53	2.08	8.94	236.19	11.14	15.59

Comments: