Gasohol As A Vehicle Fuel

In Subarctic Climates

FINAL REPORT

by

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in cooperation with

U.S. Department of Transportation
Federal Highway Administration

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A field demonstration of gasohol as a vehicle fuel substitute was conducted in Fairbanks, Alaska from March 1980 through March 1981. It was found that light duty vehicles operated on gasohol experienced no problems with engine starting, running or shutdown beyond the normal problems experienced with those same vehicles when operated on gasoline in subarctic conditions. No perceptible change in vehicle performance was found when the fuel was switched back and forth from gasohol to gasoline. No significant change in vehicle fuel mileage could be determined between the use of gasohol and gasoline. Phase separation of the gasohol mix in the vehicle fuel tanks was not apparent and had no discernible effect on performance. Cold start and warm idle carbon monoxide emissions were generally found to be slightly reduced by use of gasohol. The study concludes that gasohol is an acceptable alternative to gasoline as a motor fuel for light duty vehicles in a cold climate such as Fairbanks, Alaska.
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Abstract

A field demonstration of gasohol as a vehicle fuel substitute was conducted in Fairbanks, Alaska from March 1980 through March 1981. It was found that light duty vehicles operated on gasohol experienced no problems with engine starting, running or shutdown beyond the normal problems experienced with those same vehicles when operated on gasoline in subarctic conditions. No perceptible change in vehicle performance was found when the fuel was switched back and forth from gasohol to gasoline. No significant change in vehicle fuel mileage could be determined between the use of gasohol and gasoline. Phase separation of the gasohol mix in the vehicle fuel tanks was not apparent and had no discernible effect on performance. Cold start and warm idle carbon monoxide emissions were generally found to be slightly reduced by use of gasohol. The study concludes that gasohol is an acceptable alternative to gasoline as a motor fuel for light duty vehicles in a cold climate such as Fairbanks, Alaska.
Introduction

Gasohol, a blend of ninety percent regular unleaded gasoline and ten percent anhydrous ethyl alcohol (ethanol), is being introduced on a national scale as a method of stretching domestic gasoline supplies in an effort to mitigate the effect of an unstable world petroleum supply. The many studies (e.g. References 1 through 7) that have been done to determine the acceptability and effects of gasohol use have produced slightly conflicting results, but most acknowledge that it can be used in conventional automobiles without modification to the engine and with little effect (positive or negative) on performance under "normal" climatic conditions.

Currently, most fuel grade ethanol is produced from corn or wheat, thus gasohol at the pump is most commonly found in midwestern states. However, ethanol can be produced from other grains, sugar crops, and almost any starchy plant. It is therefore reasonable to assume that if present trends continue, fuel grade ethanol production could rise to a point where, for a light duty motor fuel, gasohol could become more the rule than the exception. Should this occur, Alaskans could be faced with using this alternative fuel without benefit of any experience with gasohol in arctic or subarctic climes. The major concern is that if the fuel is contaminated by water, a phenomenon called phase separation can occur. That is, water absorbed by the alcohol begins to settle out of the mixture resulting in two phases, gasoline-alcohol and alcohol-water. As the amount of water content increases, so does the extent of phase separation, and this condition is exaggerated at any level of water contamination as ambient temperature drops. However, the effect of phase separation on vehicle performance has never been properly addressed as it relates to a cold climate such as occurs over much of Alaska.

Faced with this situation, the Alaska Department of Transportation and Public Facilities, Research Section, assumed the task of determining: 1) whether or not gasohol could be an acceptable substitute for gasoline
in unmodified light duty vehicles in a subarctic climate; 2) could
gasohol and gasoline use be switched intermittently without significant
effect on vehicle performance; and 3) what effect does gasohol use have
on vehicle exhaust emission of carbon monoxide during cold start (idle
to warm up) and at warm idle. The political, economic or the energy
balance aspects of gasohol use were not considered as part of this study.
Methodology

To make the determination of the acceptability of gasohol as a vehicle fuel substitute in subarctic climes, it was felt that the direct approach of a field-use demonstration would be most meaningful. Since the literature did not indicate specific experience of extended use of gasohol in very cold climates, the anticipation of problems was purely speculative. It seemed that the best and least expensive way to identify potential problems was simply to obtain a supply of gasohol and use it to fuel a representative group of in-use vehicles. The vehicles' performance would be systematically observed with both gasohol fuel and with gasoline. Then, if problems were observed, each could be diagnosed and analyzed in depth and the investigation would evolve by itself.

Vehicle Selection:

Five State of Alaska fleet vehicles representing three different engine makes were "volunteered" for this purpose. These particular vehicles were chosen for their relatively high level of daily in-town use. In-town use was defined as being operated within fuel capacity range of the DOTPF regional complex on Peger Road in Fairbanks, which was required because it was not practical to provide the gasohol at any other location. Other than a normal tune up, no modifications were made to the vehicles' engines.

Fuel:

Denatured anhydrous ethyl alcohol was purchased in 55 gallon drums from a supplier in Bellingham, Washington. The gasohol was then mixed on-site by pumping 100 gallons of the alcohol into a metered 1,000 gallon gravity feed tank and then adding 900 gallons of regular unleaded gasoline from a fuel distributor truck. Mixing was achieved by the agitation produced from the incoming volume of gasoline (at about 60 gpm).

When the vehicles were operated on gasoline, fuel was obtained from the State fleet gas pumps at the Peger Road complex. Regular
leaded or regular unleaded gasoline was used depending on the requirement of the individual vehicles. The determination of when a vehicle was to operate on gasoline rather than continue on gasohol was usually made when that vehicle, in the course of the driver's duties, required it to operate out of range of the gasohol supply. Other periods were randomly selected by temporary closures of the gasohol supply for several days, forcing all the vehicles to use gasoline.

Evaluation:

The vehicle's starting, running and shutdown performance were subjectively rated by each operator every time the vehicle was used over a twelve month period. This information, along with beginning/ending mileage, percent of city or highway driving, ambient air temperature and the rater's initials were recorded on the form shown in Exhibit 1 for later analysis. Fuel mileage records on both gasohol and gasoline consumption were also kept through the evaluation period.

In addition to the field demonstration, the vehicles' fuel tanks and the storage tank were examined for phase separation. Laboratory phase separation tests were also performed. Three of the test vehicles' exhaust emissions were measured for carbon monoxide during cold start and warm idle while operating on gasohol and on gasoline.
### GASOHOL PROJECT

<table>
<thead>
<tr>
<th>Date</th>
<th>Odometer Start</th>
<th>Odometer End</th>
<th>Problems (Identify from List)</th>
<th>% of Driving City</th>
<th>% of Driving Country</th>
<th>Air Temp/Driver's Initials</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Starting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Running</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Shutdown</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Possible Problem List (Fill in blank for other than listed problems)

**Starting**
- A. None
- B. No start at all
- C. Long cranking time
- D. Fire & die repeatedly
- E. Rough cold idle
- F.
- G.

**Running**
- A. None
- B. Rough warm idle
- C. Lack of power
- D. Stalling
- E. Trouble restarting
- F.
- G.

**Shutdown**
- A. None
- B. Dieseling
- C.
- D.
Field Demonstration

The initial five vehicles used in the study were:

<table>
<thead>
<tr>
<th>Vehicle No.</th>
<th>Make and Model</th>
<th>Year</th>
<th>Engine</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ford 1/2 ton Pick-up</td>
<td>1979</td>
<td>300 cu. in 6 cyl.</td>
</tr>
<tr>
<td>2</td>
<td>Dodge 1/2 ton Pick-up</td>
<td>1977</td>
<td>318 cu. in. V-8</td>
</tr>
<tr>
<td>3</td>
<td>Dodge 1/2 ton Pick-up</td>
<td>1980</td>
<td>318 cu. in. V-8</td>
</tr>
<tr>
<td>4</td>
<td>Chevrolet Malibu Sedan</td>
<td>1977</td>
<td>305 cu. in. V-8</td>
</tr>
<tr>
<td>5</td>
<td>Chevrolet Malibu Sedan</td>
<td>1979</td>
<td>305 cu. in. V-8</td>
</tr>
</tbody>
</table>

As described in methodology, these vehicles were chosen for their relatively high level of use within range of the gasohol supply tank located at the DOTPF Peger Road complex.

The individuals who routinely operated these vehicles in the course of their jobs were briefed on the intent of the demonstration and were instructed on how to fill out the evaluation form (Exhibit 1). The operators were not given a standard on which to base their ratings, but instead were allowed to subjectively evaluate the vehicles' performance individually. This permitted the data to be analyzed for personal bias when more than one person routinely drove the same vehicle. That is, what was consistently noted as a problem by one person may have been ignored as no problem by others. Comparison of gasohol/gasoline evaluations also aided the analysis of the data.

The ambient temperature varied from −41°F to +85°F during the test period. Winter temperatures were routinely observed between −10°F to −30°F. The month of December 1980 provided three weeks of continuous −25°F to −40°F temperatures. Summer temperatures were generally between +40°F to +70°F with occasional warmer days in the high 70's and low 80's. No sustained hot weather was experienced.

Circumstances unrelated to the use of gasohol forced dropping of Vehicles #3 and #4 from the test fleet before the end of the project. Vehicle #3 was removed from the study in October 1980 due to lack of
continued cooperation by the operator to tolerate the inconvenience of fueling at the gravity feed gasohol tank. It was decided to suspend use of the vehicle rather than force an unwilling person to develop the performance data. Vehicle #4 was removed from State service in September 1980, forcing termination of it as a test vehicle. The data collected on these two vehicles for their duration in the study was valid and consistent with that from the other vehicles.

Analysis of Data:

Vehicle #1, 1979 Ford Pick-Up, 300 Ci-6
Odometer reading at start of test: 11,035 miles
Miles accumulated during test: 10,475 miles

This vehicle was operated by ten or more drivers, but 72 percent of the use was by four individuals. The overall evaluation indicated a starting problem 37 percent of the time and a running problem 42 percent of the time while on gasohol. This compared with 60 percent and 7 percent respectively while using gasoline. The starting problems for both fuels were nearly always "long cranking time." "Lack of power" was the only running problem indicated. Further analysis revealed that one driver who accounted for 15 percent of the vehicle operation made 33 percent of the starting problem responses and only 5 percent of the "start okay" comments. Another individual who operated the truck 19 percent of the time accounted for 34 percent of the running problems but only 9 percent of the "run okay" remarks. There was no definite pattern to the problem responses with respect to air temperature although the majority of the running problems (lack of power) were indicated when the temperature was above 50°F.

Conclusion:

There is no clear indication that gasohol presented any problems to the operation of this vehicle that were not inherent while running on gasoline. It appears that individual subjectivity overshadowed any effect that use of gasohol in this vehicle may have made.
Vehicle #2, 1977 Dodge Pick-Up, 318 CI-V8
Odometer reading at start of test: 7,063 miles
Miles accumulated during test: 7,631 miles

This vehicle was operated by only one driver throughout the test period. No starting or running problem was indicated by this individual while using either gasoline or gasohol.

Conclusion:
Use of gasohol did not seem to have any effect on the performance of this vehicle which could be perceived by the operator under any of the conditions experienced.

Vehicle #3, 1980 Dodge Pick-Up, 318 CI-V8
Odometer reading at start of test: 21,471 miles
Miles accumulated during test: 5,383 miles

This vehicle was operated by one person nearly all the time. No starting problems and only one (less than one percent) "lack of power" response was recorded, and this was at a time that the ambient temperature was 46°F. Intermittent use of gasoline had no perceptible effect on performance. Use of gasohol in this truck was discontinued on October 15, 1980 so no extreme cold conditions were experienced.

Conclusion:
Use of gasohol did not appear to effect the performance of this vehicle under any of the conditions experienced, to the degree that it could be perceived by the operator.

Vehicle #4, 1977 Chevrolet Malibu, 305 CI-V8
Odometer reading at start of test: 27,563 miles
Miles accumulated during test: 3,171 miles

This vehicle had several operators none of which indicated any starting or running problems while using gasohol. No gasoline evaluation
was made for this vehicle. Use of this vehicle was terminated in September 1980 so no further evaluation was possible.

Conclusion:

Use of gasohol did not seem to effect the performance of this vehicle under any of the conditions experienced.

Vehicle #5, 1979 Chevrolet Malibu, 305 CI-V8
Odometer reading at start of test: 7,441 miles
Miles accumulated during test: 7,768 miles

This vehicle was operated by about ten individuals, five of whom accounted for 83 percent of the driving. The overall evaluation indicated a starting problem 16 percent of the time and a running problem 14 percent of the time. The starting problems were generally "long cranking time" or "rough cold idle," while the running problems were most often either "lack of power" or "hesitation when cold." No individual operator bias could be defined, but a temperature pattern was evident. Forty eight percent of "bad start" responses were at temperatures greater than 40°F (42 percent of operation was at greater than 40°F) and 35 percent were at -30°F to +10°F (8 percent of operation). The running problem responses were fairly evenly spread out, but 64 percent were indicated at below 30°F which corresponded to 43 percent of the total responses. The evaluation of performance while operating on gasoline was virtually the same as that for gasohol.

Conclusion:

There was no clear indication that gasohol was detrimental to the operation of this vehicle. There is no explanation for the disproportionate percentage of poor starts at ambient temperatures above 40°F. The high poor start data from -30°F to +10°F would be expected for any vehicle in this climatic region and no specific complaint could be linked to gasohol use.
Fuel Consumption:

The variations in fuel consumption caused by seasonal temperature changes and the ratio of city versus highway driving prevented a quantitative comparison of the data based solely on gasohol/gasoline use. Therefore, the effect of gasohol use on vehicle mileage is inconclusive.
Laboratory Phase Separation Tests

Laboratory Tests:

Approximately one gallon of gasohol was made by combining anhydrous ethanol with regular unleaded gasoline at a 1 to 10 volumetric ratio. From this, fourteen 100 ml test samples were prepared by adding gasohol to various amounts of distilled water ranging from 0.05 percent to 0.90 percent of the volume of the total sample. The water contained a minute amount of a water soluble dye to make the separated phase more visible. A fifteenth control sample was also prepared, containing only gasohol and no water.

The fifteen samples were then placed in an environmental chamber and systematically subjected to ten discrete temperatures ranging from +70°F to -70°F. The samples were allowed to stabilize for at least two hours at each temperature before being examined for phase separation. The results of these observations are shown in Table 1.

As is evident from the table, there is a general increase in the volume of the separated phase of the samples as either the water content increased or the temperature decreased. Note that at 0.25 percent water content (which is equivalent to 3.2 fluid ounces of water in ten gallons of fuel) or less, the mixture exhibited no or only negligible phase separation at any temperature down to -70°F. This is consistent with the findings of phase separation tests performed at the University of Nebraska (2).

It was also observed during performance of these tests, that a sample which had significant separation at a low temperature would recombine as it warmed up if it were agitated. For example: the sample which had 0.50 percent water content exhibited 4.4 percent separation at -70°F, but when warmed to +70°F and shaken, no separation could be seen even after several minutes of settling time had passed.
TABLE 1
TEMPERATURE CAUSED PHASE SEPARATION
IN 10% ETHANOL 90% GASOLINE MIXTURE
CONTAINING 0.0 TO 0.9 PERCENT WATER

<table>
<thead>
<tr>
<th>% H₂O</th>
<th>70</th>
<th>40</th>
<th>30</th>
<th>15</th>
<th>0</th>
<th>-10</th>
<th>-20</th>
<th>-30</th>
<th>-40</th>
<th>-70</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
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<td>N</td>
</tr>
<tr>
<td>0.05</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>0.15</td>
<td>N</td>
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<td>N</td>
<td>N</td>
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<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>0.20</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>0.25</td>
<td>N</td>
<td>N</td>
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<td>N</td>
<td>N</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
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<tr>
<td>0.30</td>
<td>N</td>
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<td>N</td>
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<td>0.1</td>
</tr>
<tr>
<td>0.35</td>
<td>N</td>
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<td>0.1</td>
<td>0.15</td>
<td>0.3</td>
<td>1.1</td>
<td>1.4</td>
<td>1.5</td>
<td>2.5</td>
<td>3.0</td>
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<tr>
<td>0.40</td>
<td>N</td>
<td>0.15</td>
<td>0.3</td>
<td>0.7</td>
<td>1.0</td>
<td>1.8</td>
<td>2.3</td>
<td>2.4</td>
<td>3.4</td>
<td>3.9</td>
</tr>
<tr>
<td>0.45</td>
<td>N</td>
<td>0.3</td>
<td>0.9</td>
<td>1.6</td>
<td>1.8</td>
<td>2.3</td>
<td>2.8</td>
<td>3.0</td>
<td>3.9</td>
<td>4.2</td>
</tr>
<tr>
<td>0.50</td>
<td>N</td>
<td>0.6</td>
<td>1.5</td>
<td>2.0</td>
<td>2.5</td>
<td>2.8</td>
<td>3.0</td>
<td>3.4</td>
<td>4.0</td>
<td>4.4</td>
</tr>
<tr>
<td>0.60</td>
<td>0.15</td>
<td>0.9</td>
<td>1.9</td>
<td>2.8</td>
<td>3.0</td>
<td>3.4</td>
<td>3.5</td>
<td>3.9</td>
<td>4.2</td>
<td>4.4</td>
</tr>
<tr>
<td>0.70</td>
<td>1.0</td>
<td>1.4</td>
<td>2.3</td>
<td>3.4</td>
<td>3.5</td>
<td>3.9</td>
<td>4.0</td>
<td>4.0</td>
<td>4.2</td>
<td>4.5</td>
</tr>
<tr>
<td>0.80</td>
<td>1.75</td>
<td>2.2</td>
<td>2.8</td>
<td>3.7</td>
<td>3.7</td>
<td>4.2</td>
<td>4.4</td>
<td>4.4</td>
<td>4.6</td>
<td>5.0</td>
</tr>
<tr>
<td>0.90</td>
<td>2.4</td>
<td>2.8</td>
<td>3.0</td>
<td>3.9</td>
<td>3.9</td>
<td>4.2</td>
<td>4.4</td>
<td>4.4</td>
<td>5.0</td>
<td>5.1</td>
</tr>
</tbody>
</table>

N indicates no apparent separation; values are in percent of total volume.

Field Tests:
The gasohol supply tank was examined periodically for evidence of phase separation by drawing off approximately five gallons of fuel from the bottom of the tank. The amount of separation was never measured to be greater than 1.0 percent of the sample at -30°F.

In preparation of the gasoline emission testing, the fuel tanks of vehicles #1, #2 and #5 were drained and their contents examined. No evidence of phase separation was found in any of the fuel at 0°F.
Emission Testing

Vehicles #1, #2 and #5 were selected for carbon monoxide (CO) emission testing as being representative of the three engine types used in the gasohol demonstration. Testing was performed in early March 1981, after the gasohol evaluation was completed. Each vehicle's exhaust was measured for CO concentration during a cold start sequence and at warm idle, first while operating on gasohol and again on gasoline. Between the two sets of testing, the vehicle's fuel tanks were drained and the engines run till "out of gas." Spark plugs and gas filters were replaced, the tanks filled with gasoline and then the vehicle was driven about twenty continuous miles before the second round of tests were performed.

The CO measurement was accomplished by means of a "big bag" sampler as developed by Coutts (8) which gathers an integrated sample of exhaust gas over a specific period. The cold start test used three bags; Bag One: 0 - 2 minutes, Bag Two: 2 - 6 minutes, and Bag Three: 6 - 10 minutes. The warm idle sample merely required the bag to be full to determine the CO concentration. For the cold start tests the vehicles were allowed to soak for a minimum of eight hours at ambient temperature. The exhaust pipes were then hermetically connected to the sampler and then the engines were started. The warm idle samples were taken after the vehicle engines had reached normal operating temperature (about 190°F).

Results of the emission testing is summarized in Figures 1 and 2.

Analysis of the test results indicate that the use of gasohol had a substantial effect on reducing CO emissions from a cold start with Vehicle #1 (23 percent reduction) and Vehicle #5 (22 percent reduction). Vehicle #2 however, shows a very large anomalous increase (130 percent) most of which was produced in the first four minutes. Without having positively determined the cause, it is presumed that malfunctioning of the automatic choke may have contributed to this result. Accepting this
FIGURE 1
CO EMISSION TEST SUMMARY

gms CO, AIR TEMP 30° ± 5°F

Bag 1: 0 - 2 minutes; Bag 2: 2 - 6 minutes; Bag 3: 6 - 10 minutes

( ) denotes suspect data

VEHICLE #1, 1979 FORD PICK-UP

<table>
<thead>
<tr>
<th>Date</th>
<th>Gasohol</th>
<th>Gasoline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bag 1</td>
<td>174</td>
<td>173</td>
</tr>
<tr>
<td>Bag 2</td>
<td>77</td>
<td>86</td>
</tr>
<tr>
<td>Bag 3</td>
<td>4.6</td>
<td>4.4</td>
</tr>
<tr>
<td>Warm Idle</td>
<td>7.7</td>
<td>7.9</td>
</tr>
</tbody>
</table>

VEHICLE #2, 1977 DODGE PICK-UP

<table>
<thead>
<tr>
<th>Date</th>
<th>Gasohol</th>
<th>Gasoline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bag 1</td>
<td>177</td>
<td>188</td>
</tr>
<tr>
<td>Bag 2</td>
<td>295</td>
<td>336</td>
</tr>
<tr>
<td>Bag 3</td>
<td>7.3</td>
<td>24</td>
</tr>
<tr>
<td>Warm Idle</td>
<td>1.0</td>
<td>2.3</td>
</tr>
</tbody>
</table>

VEHICLE #5, 1979 CHEVY MALIBU

<table>
<thead>
<tr>
<th>Date</th>
<th>Gasohol</th>
<th>Gasoline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bag 1</td>
<td>74</td>
<td>82</td>
</tr>
<tr>
<td>Bag 2</td>
<td>33</td>
<td>56</td>
</tr>
<tr>
<td>Bag 3</td>
<td>0.9</td>
<td>1.4</td>
</tr>
<tr>
<td>Warm Idle</td>
<td>.02</td>
<td>0.1</td>
</tr>
</tbody>
</table>
FIGURE 2

STATISTICAL ANALYSIS OF TEST DATA
(INCLUDING SUSPECT DATA)

COLD START (gms of CO)

<table>
<thead>
<tr>
<th>Bag 1</th>
<th>VEHICLE #1</th>
<th>Gasohol</th>
<th>Gasoline</th>
<th>VEHICLE #2</th>
<th>Gasohol</th>
<th>Gasoline</th>
<th>VEHICLE #5</th>
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<tr>
<td>S.D.</td>
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<td>55</td>
<td>67</td>
<td>38</td>
<td>57</td>
<td>6.5</td>
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<tr>
<td>C.V.</td>
<td></td>
<td>36</td>
<td>43</td>
<td>25</td>
<td>82</td>
<td>8</td>
<td>20</td>
<td>8</td>
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<tr>
<td>Mean</td>
<td></td>
<td>151</td>
<td>155</td>
<td>152</td>
<td>70</td>
<td>84</td>
<td>99</td>
<td>8</td>
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<table>
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<th>Bag 2</th>
<th>VEHICLE #1</th>
<th>Gasohol</th>
<th>Gasoline</th>
<th>VEHICLE #2</th>
<th>Gasohol</th>
<th>Gasoline</th>
<th>VEHICLE #5</th>
<th>Gasohol</th>
<th>Gasoline</th>
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<tbody>
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<td>5</td>
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<td>142</td>
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<tr>
<td>C.V.</td>
<td></td>
<td>18</td>
<td>41</td>
<td>12</td>
<td>138</td>
<td>26</td>
<td>22</td>
<td>53</td>
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<td>Mean</td>
<td></td>
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<td>140</td>
<td>300</td>
<td>103</td>
<td>53</td>
<td>70</td>
<td>8</td>
<td>99</td>
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<th>VEHICLE #1</th>
<th>Gasohol</th>
<th>Gasoline</th>
<th>VEHICLE #2</th>
<th>Gasohol</th>
<th>Gasoline</th>
<th>VEHICLE #5</th>
<th>Gasohol</th>
<th>Gasoline</th>
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</thead>
<tbody>
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<td>S.D.</td>
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<td>28</td>
<td>33</td>
<td>32</td>
<td>41</td>
<td>1.1</td>
<td>5.6</td>
<td>60</td>
<td>72</td>
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<tr>
<td>C.V.</td>
<td></td>
<td>147</td>
<td>80</td>
<td>107</td>
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<td>60</td>
<td>72</td>
<td>1.9</td>
<td>7.8</td>
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<tr>
<td>Mean</td>
<td></td>
<td>19</td>
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<td>37</td>
<td>1.9</td>
<td>7.8</td>
<td>8</td>
<td>99</td>
</tr>
</tbody>
</table>

TOTAL CO (gms)

<table>
<thead>
<tr>
<th>VEHICLE #1</th>
<th>VEHICLE #2</th>
<th>VEHICLE #5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bags 1, 2 &amp; 3</td>
<td>259</td>
<td>336</td>
</tr>
<tr>
<td>% Reduction</td>
<td>23</td>
<td>-130</td>
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</tbody>
</table>

WARM IDLE (% of CO)

<table>
<thead>
<tr>
<th>VEHICLE #1</th>
<th>VEHICLE #2</th>
<th>VEHICLE #5</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
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<td>5</td>
</tr>
<tr>
<td>S.D.</td>
<td>0.3</td>
<td>1.1</td>
</tr>
<tr>
<td>C.V.</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>Mean</td>
<td>8</td>
<td>8.1</td>
</tr>
<tr>
<td>% Reduction</td>
<td>1</td>
<td>36</td>
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</tbody>
</table>

N = Number of Tests
S.D. = Standard Deviation
C.V. = Coefficient of Variation
scenario suggests that the increase recorded is not a representative response. Therefore, this datum was not used in the conclusions of the effect of gasohol on cold start emissions.

The warm idle emission tests suggest that gasohol does generally reduce CO; Vehicle #1 showed a reduction of only one percent, whereas Vehicle #2 showed 36 percent reduction and Vehicle #5, 46 percent. Vehicle #1 shows an unusually high CO emission for warm idle with either gasohol or gasoline, which was presumably caused by a mechanical problem particular to that vehicle.
Summary

The field demonstration indicates that substitution of gasohol for gasoline as a vehicle fuel in subarctic climates is not detrimental to the operation of the vehicle. No problems were perceived under any of the conditions experienced, with the starting, running or shut down performance of the test vehicles while operating on gasohol which were not also experienced when using gasoline, except for a tendency of Vehicle #1 to show a "lack of power" at temperatures above 50°F. There appeared to be no effect on performance by switching back and forth from gasohol to gasoline. Any effect that use of gasohol may have had on fuel consumption was not perceptible from the data. There was, however, an apparent effect by other considerations such as ambient temperature and the city/country driving ratio. This indicates that if there is an effect on mileage by use of gasohol, it is not as significant as the effects of the external driving environment.

Existence of the phenomenon of phase separation in water contaminated gasohol was confirmed by the laboratory tests with good correlation with a previous study (2). However, there was no evidence that phase separation had any effect on vehicle performance, nor was there any evidence that phase separation was routinely or even occasionally taking place in any of the test vehicles. Phase separation in the above ground gasohol storage tank was negligible and when the fuel tanks of Vehicles #1, #2 and #5 were drained in preparation for the gasoline comparison emission tests, no phase separation was apparent. Presumably any separation which may have been present in the fuel was consumed by the engine without obvious effect or was mixed back into the gasohol by the agitation of the moving vehicles. This is similar to the process by which water in fuel is burned when an alcohol base fuel antifreeze is used to "dry" the gasoline, thus preventing gasoline freeze-up or carburetor icing.

A positive effect was indicated on the reduction of carbon monoxide (CO) in the engine emissions by the use of gasohol during both cold
start and warm idle tests. However, the percent of CO reduction varied significantly from vehicle to vehicle so no statistical conclusion is presented.
Conclusions

This demonstration of the use of gasohol as a substitute for gasoline as a vehicle fuel in subarctic climes indicates:

1) Gasohol can be used year round without perceptible effect on vehicle performance.

2) Gasohol and gasoline can be used interchangeably without effect on vehicle performance.

3) No conclusion as to the effect of gasohol on fuel consumption was reached.

4) Carbon monoxide emissions are generally reduced during cold starts and warm idle by use of gasohol.

Note:

Due to the limited scope of this investigation, no conclusion about possible long term effects of gasohol use on the test vehicles is offered or implied. Nor was there any attempt to consider the compatibility of alcohol with other materials in the fuel, combustion, or lubrication systems of the vehicles tested.
Implementation Recommendations

This report with its conclusions is being distributed to those agencies within the State concerned with transportation energy and air quality. This report should be used in conjunction with and in support of the DOTPF staff report of the Alaska Energy Conservation Program, "Energy and Transportation," prepared by the Southeast Region Planning and Programming Systems Evaluation Section.
Acknowledgement

The Alaska Department of Transportation and Public Facilities acknowledges the funding assistance provided by the Federal Highway Administration under the Highway Planning and Research Program.

Recognition is extended to Tom Moyer of the Department of Environmental Conservation and Jack Coutts et al of Cold Regions Research and Engineering Laboratory for their cooperation and assistance with the project. Also thanks is given to the many State employees who collected the vehicle operation data which was essential to the success of the demonstration.
References

1. Scheller, Dr. William A., "Nebraska 2 Million Mile Gasohol Road Test Program," Department of Chemical Engineering, University of Nebraska, 1977.

2. Scheller, Dr. William A., "Tests on Unleaded Gasoline Containing 10% Ethanol," Department of Chemical Engineering, University of Nebraska, 1977.


