# A Highway Test of Gasohol

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**Tests were conducted using two 1976 Ford Torinos in which the fuel economy using gasohol was compared with that obtained using unleaded gasoline. It was found that gasohol gave 3% fewer miles per gallon than the unleaded gasoline under typical summer highway driving conditions in North Dakota. This difference was found to be statistically significant at the 99% level of confidence. The reduced fuel economy with gasohol appears to be directly proportional to the lower energy content of gasohol.**

The use of alcohol for fuel is not new. Alcohols have been used throughout the world as petroleum fuel substitutes and during war periods in Europe their use was extensive. However, with the large supply and relatively low cost of petroleum since World War II, the use of alcohol fuel has been minimal. Today, the energy crisis and our growing dependence on foreign petroleum has prompted much concern for future energy sources and efficient utilization. Interest in alcohol fuel is returning.

Results of fuel economy tests with the use of alcohol are contradictory. Some reports note good fuel economy with alcohol-gasoline blends (10, 12, 13, 14, 16, 18). Other tests show a drop in fuel economy (1, 4, 5, 6, 7, 8, 9, 17, 19, 20, 21). One test notes that fuel economy while using gasohol is temperature dependent (15).

In a two-million-mile road test done in Nebraska, fuel economy was reported to be 5% better with gasohol compared with unleaded gasoline. Gasohol exhaust emissions were about one-third lower in carbon monoxide. There was no unusual engine wear or carbon buildup. There was no starting, vapor lock, or driveability problems (16). More recently however, the fuel economy with gasohol has been reported in Nebraska to be temperature dependent. At temperatures below about 67°F, gasohol-fuel vehicles obtained more miles per gallon. At an ambient temperature of 67°F, fuel economy was the same for gasohol and gasoline. Above that temperature the fuel economy was less while using gasohol (15).

Many tests indicate that miles per gallon go down, but miles per Btu go up. At the Department of Energy's Bartlesville Energy Research Center, a carefully controlled dynamometer test of gasohol resulted in no significant difference in fuel economy when testing cars used in the Nebraska test or when using a 1975, 1976 or 1977 car. However, highway fuel economy tests suggested a decrease of approximately 2% associated with gasohol. In addition, fuel energy economy data (miles per Btu) suggested a slight improvement associated with gasohol (19). Other tests have been done with methanol. However, from an engineering viewpoint results of studies with methanol could also be used to predict the behavior of ethanol under similar circumstances. Fuel economy is generally decreased by methanol addition unless the engines are optimized for methanol-gasoline operation (1). Six cars using 10% methanol in gasoline showed a 3% loss in mileage and a 2% gain in efficiency (7). Use of methanol resulted in higher indicated specific fuel consumption (6). A chassis dynamometer study showed that changes in fuel economy due to the addition of 10% methanol to the base fuel were essentially those indicated by the leaner stochiometry of the blend. Generally, the miles traveled per gallon of blend decreased while the miles traveled per million Btu's increased slightly (8). In a 50,000 mile road test, four 1974 cars run on a 10% methanol blend gave 4.4% poorer fuel economy than gasoline (5). A 45 vehicle fleet was operated for a period of about one year throughout West Germany and West Berlin using a 15 volume % methanol mixture. The specific fuel consumption varied according to both vehicle type and driving conditions. In general, methanol-gasoline blends gave a poorer fuel economy on a volumetric basis by about 3% to 6%. On an energy basis, the 15% methanol blend improved the fuel economy by between 2% and 5% (9).

It has been pointed out that differences in fuel economy associated with the addition of alcohol to gasoline are dependent on the original carburetor setting (4). Alcohol, which contains oxygen, has the effect of leaning out the mixture. If the initial setting is rich the fuel economy will be improved. If the initial setting is less rich, fuel economy is about the same. If set lean, the mixture becomes too lean and fuel economy is decreased. So in order to have optimum fuel economy, proper adjustment of the carburetor to the fuel being burned is needed. Older cars were normally set slightly rich, so that a leaning out effect would tend to improve efficiency. Newer cars with emission control systems are already set lean and further leaning out would not result in the same improvement (3, 20). With lean settings, fuel economy may be expected to be decreased with alcohol-gasoline blends.

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In order to help resolve this problem of uncertainty regarding comparative fuel consumption with gasohol and gasoline, a road test that would be amenable to statistical evaluation was designed. Comparisons were then made of the efficiency of each fuel.

### Procedure

Two 1976 Ford Torinos were used as test vehicles (See Fig. 1). Each vehicle was equipped with a 351 cubic inch displacement V-8 engine, automatic transmission, two-barrel carburetor, power steering, cruise control, radial tires, and air conditioning. Prior to use in the experimental program they were used as fleet vehicles in the Agricultural Experiment Station. Car 2-998 had approximately 38,000 miles. Car 2-999 had approximately 48,000 miles. A drain valve was added to the bottom of the fuel tank of each car to expedite the removal of unused fuel. (See Fig. 2)

Figure 1

Figure 2

The properties of the two test fuels are listed in Table 1 and Table II. The gasohol was a blend by volume of 10% ethyl alcohol and 90% unleaded gasoline. The ethyl alcohol was specially denatured alcohol Formula No. 28-A.

**Table I. Distillation Properties of Gasohol/Gasoline Test Fuels**

| Temperature, $^{o}F$ | Unleaded Gasoline | Gasohol |
|---|---|---|
| | % Evaporated | |
| 90 | Initial | |
| 95 | | Initial |
| 149 | 19.3 | 32.5 |
| 245 | 63.8 | 68.0 |
| 374 | 96.8 | 97.0 |
| 413 | | End Point |
| 414 | End Point | |
| Residue, % | 0.7 | 1.0 |
| Loss, % | 1.8 | 1.5 |

Performed by: State Laboratories Department
Petroleum Inspection Division
Bismarck, North Dakota 58501

Ethanol is a single compound that boils at 172°F, while gasoline is a mixture of compounds that boil over a range of temperatures. Thus, ethanol's volatility is a constant while gasoline's volatility can be tailored over a range by adjusting the relative amounts of different hydrocarbons in the mixture. In a distillation test, gasohol distills much more rapidly at temperatures below 172°F. At higher temperatures the effect becomes small. The difference is volatility between gasohol and gasoline affects the starting, warm-up, acceleration, vapor lock, crankcase dilution and other driveability characteristics of an automobile engine (2, 7). Volatility requirements change with the seasons of the year.

**Table II. Properties of Gasohol/Gasoline Test Fuels**

| | Unleaded Gasoline | Gasohol |
|---|---|---|
| API Specific Gravity | 62.5 | 60.8 |
| Color | Green | Green |
| Corrosion | None | None |
| Vapor pressure, pounds | 9.0 | 9.5 |
| Motor Octane No. | 82.6 | 84.9 |
| Research Octane No. | 91.8 | 96.0 |
| Road Octane No. | 87.2 | 90.5 |

Performed by: State Laboratories Department
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Specific gravity is determined by using hydrometers. The most important use of specific gravity is in the calculation of volume delivered at 60°F as practically all petroleum products are sold on that basis (11).

Color requirements are enforced on gasoline to insure that the customer obtains the correct grade of product (11).

The corrosion test, using a polished copper strip, has been a standard test on gasoline for a number of years.

The corrosive agent, if present, is usually free sulphur and a limit is set to prevent the sale of motor fuel which may attack metals in the fuel and induction system of the engine. Excess sulphur is undesirable in motor fuels as its combustion products, in the presence of water, form dilute sulphorous and sulphuric acids. These may cause serious corrosion of cylinder walls and bearings especially during winter months (11). Copper and brass corrosion and plastic gauge float degradation have been reported in cars using methanol-gasoline fuels (2).

The vapor pressure test indicates the initial tendency towards vaporization. During the warmer months maximum limits are placed on vapor pressure to guard against vapor lock. During the winter season a higher vapor pressure is permitted as there is less chance for vapor lock and it permits changes in the products conducive to easier starting of the motor (11).

Gasohol does have a higher octane rating than unleaded gasoline. However, laboratory octane readings do not tell the whole story. Octane ratings made during road driving under conditions that most commonly reveal knocking show only small increments for alcohols. These increments are more nearly similar to the small Motor Octane increments associated with the alcohol than they are to the larger Research Octane increase. The strikingly high Research Octane rating of alcohols translate into little or no advantage in road driving for late-model automobiles (2).

These tests were performed during July and August of 1978. One replication of the test was done each day until 26 tests were completed. The cars were fueled each morning. They left on a trip at about 9 a.m. and returned at about 2 p.m. One 30 minute stop was made along the way. All driving was highway driving. During the test period the ambient temperature ranged from 58°F to 94°F with an average temperature of 74°F.

Unleaded gasoline was purchased from filling station pumps and stored in fuel storage tanks. Gasohol was prepared by adding 5 gallons of Specially Denatured Alcohol Formula 28-A to a fuel storage tank and then adding the appropriate quantity of unleaded gas to obtain a mixture of 90% unleaded gas and 10% alcohol by volume.

The fuel storage tanks were kept outside but were brought inside to be weighed on a platform scale each time fuel was removed from or added to them. To transport these tanks a tractor with a front mounted loader was used. All measurements of quantities of fuel handled were determined by measuring the change in weight of the field service tanks. Once the tank had been placed on the scale, the car which was to use fuel from that fuel storage tank for that day was filled from it. As fuel was removed from the tank the amount was registered on the scale. The cars were filled with approximately 90 pounds of fuel, or roughly 15 gallons, each morning. The amount of fuel put in each car was recorded as well as the starting mileage for that day. The type of fuel each car used was determined by random sampling.

After both cars had been serviced, they were driven approximately 200 miles each day. The routes were north of Fargo on Interstate Highway 29, west of Fargo on Interstate Highway 94, or south of Fargo on Interstate 29. While on the road, the drivers maintained a space of approximately one-half mile between each other. For the first half of the trip one driver took the lead, and for the last half of the trip the other driver took the lead. The drivers of the cars used their cruise controls to maintain a constant speed of 55 mph and the air conditioners were used continuously.

At the end of each trip, the fuel which remained in the fuel tank of each car was pumped into the appropriate storage tank (See Fig. 3). By recording the amount of fuel put in the car each morning and the amount of unused fuel at the end of the day, it was possible to determine the net amount of fuel which each car had used for that day. A record was also made of the mileage for that day. Using this information, the fuel economy of each car was determined for that particular day.

**Figure 3**

**Results and Conclusions**

The two test vehicles were each driven 5,200 miles. Records were kept of their gasoline consumption and are presented in Table III. These results show that both cars had a 3% decrease in mileage when they used gasohol.

A two-way analysis of variance of the cars and the fuel mileages was performed (Table IV). The vehicles show a highly significant difference in their fuel consumption. This indicates that one car performed better on both fuels than the other car did. But, both cars experienced a similar decrease in mileage of 3% while using gasohol as compared to unleaded gasoline. This difference in fuel economy was highly significant. There were no interactions between the cars and the fuel used. By estimating the energy content of gasoline on the low side (115,000 Btu/gal) and that of ethanol on the high side (85,000 Btu/gal), a gallon of gasohol would contain 112,000 Btu, or 3% less than straight gasoline. Engine performance results reflect these differences. Drivers reported no noticeable difference in vehicle operation.

Another road test in which cars were driven on the highway under winter driving conditions was performed during February and March, 1979. From this test we hope to learn more about the comparative performance of gasohol and unleaded gasoline. One of the specific questions which will be answered is if the difference in fuel

Table III. Mileage Results, North Dakota State University Gasohol Road Test, Summer, 1978

| Day | Car 2-998 Mileage, mpg Gasohol | Car 2-998 Mileage, mpg Gas | Car 2-999 Mileage, mpg Gasohol | Car 2-999 Mileage, mpg Gas |
|---|---|---|---|---|
| 1 | 16.86 | | 16.99 | |
| 2 | | 16.62 | 16.14 | |
| 3 | | 17.98 | 15.86 | |
| 4 | 17.76 | | 16.72 | |
| 5 | 16.37 | | | 15.94 |
| 6 | | 17.99 | | 17.96 |
| 7 | 16.50 | | | 17.09 |
| 8 | | 16.60 | 16.53 | |
| 9 | 15.78 | | | 16.47 |
| 10 | | 17.56 | 16.92 | |
| 11 | 17.18 | | | 16.44 |
| 12 | | 16.48 | 16.36 | |
| 13 | | 17.49 | 15.63 | |
| 14 | | 18.17 | | 16.30 |
| 15 | | 17.32 | 15.27 | |
| 16 | | 17.54 | 16.41 | |
| 17 | 16.70 | | | 17.44 |
| 18 | 17.21 | | | 16.51 |
| 19 | 16.81 | | | 16.49 |
| 20 | | 17.62 | | 15.86 |
| 21 | 17.22 | | | 16.90 |
| 22 | 17.44 | | 16.08 | |
| 23 | 15.88 | | | 16.51 |
| 24 | | 16.84 | 15.45 | |
| 25 | | 17.02 | | 16.40 |
| 26 | 16.21 | | 14.99 | |
| Mean | 16.76 | 17.33 | 16.10 | 16.44 |
| Standard Deviation | 0.60 | 0.57 | 0.63 | 0.58 |
| Standard of Error of the Mean | 0.17 | 0.16 | 0.18 | 0.16 |
| | Difference of Mean = 3.25% | | Difference of Mean = 3.22% | |

Table IV. Analysis of Variance of Cars and Fuels

| Parameter | SS | df | MS | F |
|---|---|---|---|---|
| Car | 5.8827 | 1 | 5.8827 | 16.55** |
| Fuel | 3.9160 | 1 | 3.9160 | 11.02** |
| Car x Fuel | 0.0024 | 1 | 0.0024 | 0.01ns |
| Error | 17.0624 | 48 | 0.3555 | |
| TOTAL | 26.8635 | 51 | | |

** Significant at 1% level
ns Non-significant

economy between gasohol and unleaded gasoline is temperature dependent as suggested by Scheller (15). Other comparisons will also be made between summer and winter performance of the fuels and cars. Tests will be continued to find the optimum conditions for the use of gasohol.

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North Dakota farmers have come to expect that disease problems in their crops will be solved with the appearance of disease resistant varieties. A great deal of success has been achieved in controlling some plant diseases with resistance in improved crop varieties. Stem and leaf rust of hard red spring wheat, spot and net blotches of barley, rust and downy mildew of sunflowers, and wilt and rust of flax no longer cause serious annual losses in crop production. However, the same genetic principles that are used in the improvement of crop varieties also function in the biology of the plant disease organisms. The genetic composition of plant disease organisms changes. This means that the crop variety which was immune to a disease five years ago may become susceptible to a new race today or tomorrow. Therefore, a constant collecting and testing of isolates of the plant disease microorganisms is continued to determine if there have been serious changes in their ability to attack North Dakota crops. Again, these activities require space, people and money. Without such a testing and surveying activity, the sudden failure of North Dakota crops because of their susceptibility to a plant disease organism will occur more frequently and unexpectedly.

When a gene which governs resistance in a crop variety suddenly is no longer effective in controlling a plant parasite, new genes for resistance must be found and identified. Genes which govern resistance in a crop variety are identified by checking the variety with tester races of a particular plant parasite or by making crosses or test-crosses with the crop variety and then testing the progeny with tester races. This work again involves considerable effort from the project personnel and requires time, space and money.

Many examples of activities which are not 'new' may be found within the research projects of your North Dakota Experiment Station. Some of these activities are also carried out by the Cooperative Extension Service personnel. An example of such an activity is the Plant Diagnostic Laboratory. In this case plant samples are sent to the Plant Diagnostic Laboratory by the county agents for identification of the plant, insect or disease. Information on the nature of the problem and its control is returned to the North Dakota citizen.

The personnel and financial resources as well as physical plant facilities of the North Dakota Agricultural Experiment Station are not limitless. Additional activities require an evaluation of ongoing programs. Such evaluations are brought about through annual reports and reviews of each project plus larger periodic reviews. There are external reviews of departments every three to four years. Although some projects are terminated upon their completion, others, such as the testing of crop breeders' advanced lines or the testing of isolates of plant parasites for virulence for disease resistance, must be continued if North Dakota agriculture is to be well served.

A recent trend of the Administration of the United States Government has been not to increase federal support for state experiment stations through the formula funding known as the Hatch Act. These Federal officials supported by educational factions both within and without the land grant universities would substitute grant funding to support specific and basic research in place of the present Hatch funding. Grant funds would be available only for certain

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