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A Comparison of Gasoline and Ethanol Fueled Engines in Terms of Total Fossil Fuel Consumption

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Mahmood Ahmad Baluch

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Dr. Craig W. Somerton
Major professor

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A COMPARISON OF GASOLINE AND ETHANOL FUELED ENGINES IN TERMS OF TOTAL FOSSIL FUEL CONSUMPTION

By

Mahmood Ahmad Baluch

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ABSTRACT

A COMPARISON OF GASOLINE AND ETHANOL FUELED ENGINES IN TERMS OF TOTAL FOSSIL FUEL CONSUMPTION

By

Mahmood Ahmad Baluch

Crude oil reserves are being depleted everyday and the drilling of new oil wells is becoming uneconomical. Alternative fuels are being investigated to ensure availability of fuels and to reduce the dependence on the few oil exporting countries.

An investigation into consumption of fossil fuel in the production of gasoline and ethanol has been carried out.

It covers a comparative study about the consumption of these fuels in vehicles, on the basis of energy only. The study also includes other related aspects such as the effect on emission, modifications required on the engine to operate on ethanol blended gasoline, and sensitivity analysis of the production of fermentation ethanol.

The results show that far less fossil fuels are consumed in the production of fermentation ethanol from corn than gasoline. However, more ethanol blended gasoline is consumed to cover same distance than gasoline and this trend increases as the quantity of ethanol is increased in the blend.

to my parents and family for their

devotion and patience

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NOMENCLATURE

BATF	Bureau of Alcohol, Tobacco and Firearms
bbl	Barrel
Btu	British Thermal Unit
CAFE	Corporate Average Fuel Economy
CHO	Aldehydes
CNG	Compressed Natural Gas
CO	Carbon Mono Oxide
E.P.A.	Environmental Protection Agency
etc.	Etceteras
Eth	Ethanol
°F	Degree Fahrenheit
Fert	Fertilizer
gal	Gallon
gas	Gasoline
HC	Hydrocarbons
lbm.	Pound Mass
LNG	Liquid Natural Gas
m^3	Cubic Meter
MON	Motor Octane Number
NO_2	Nitrogen Per Oxide
RON	Research Octane Number

SO_2	Sulfur Dioxide
UBF	Unburned Fuel
US	United States
USDA	United States Department of Agriculture
$	Dollar
%	Percent

CHAPTER 1

INTRODUCTION

Fossil fuels, particularly crude oil is the primary fuel used for transportation all over the world. Rapidly depleting reserves of crude oil and increasing pollution problem have been a source of concern. Most countries have suffered the energy shortage problem in 1970s, when supply of crude oil was stopped for one reason or the other by the few oil exporting countries.

The United States imports about 50 percent of its crude oil requirement, which creates a cash outflow of $10 million per hour [1]. The U.S. can no longer depend on oil reserves outside its control to meet its energy needs, specially during critical moments. At the present rate of use, U.S. petroleum reserves represent about a 16 years of supply [4]. Precedence of the 1970's energy crisis, need to supplement and prolong life of depleting oil reserves, and desire to control pollution demand a search for an alternative fuel to gasoline. Alternative fuels include electricity, hydrogen, liquid and/or compressed natural gas, alcohols, their blends with unleaded gasoline, and synthetic fuel from oil shales and tar sands.

Alcohol fuels have been investigated as alternative to gasoline for many decades. Thus, a great deal is already known about their compatibility with internal combustion engines. In the past the high cost of alcohol fuels, compared to gasoline, was a deterrent to their use. However, environmental and long-term supply issues have recently renewed interest in their use as an alternative fuel.

The alcohols, of primary interest as alternative to gasoline are ethanol and methanol since these can be readily produced in large quantities [15]. Alcohols have an advantage over gasoline since these can be produced (although at high cost presently) by using a very small quantity of irreplaceable petroleum reserves which will be exhausted inevitably. As long as the sun shines, and plants grow, alcohols will be unique because they possess the attribute of perennial renewal. However one must remember that there is a considerable consumption of fossil fuel in agricultural production.

In the U.S., interest in ethanol as a motor fuel was stimulated, during 1970s, by the shortage of gasoline during the energy crisis. Since ethanol can be fermented from grain, corn, and other biomass, its production was encouraged to reduce the U.S. dependence upon imported fuel [4]. The raw material for commercial scale ethanol production is readily available in various forms. The major feed stocks are: corn, wheat, sorghum, barley, potatoes,sugar beets, sweet sorghum, sugar cane, and fodder beets.Therefore, the past several years have seen an increased emphasis on domestic alternatives, and pressure to produce low cost fermentation ethanol from biomass resources.

The use of ethanol as a fuel, supplement the imported crude oil as a domestic renewable resource with the added benefit of superior anti knock properties. Use of ethanol, either as substitute of gasoline or a blend with gasoline, not only cuts down the amount of crude oil imported but also reduces the regulated emission products (HC, CO, and NO_x) in exhaust gases [16].

Ethanol, either pure or blended with gasoline, is being used in over 40 countries in different proportions. Any country's use of alternative fuels depends on the severity of its need to reduce imports to balance payments, cut down its dependence on other countries, and the availability of indigenous natural resources. Brazil, Cuba, the Philippines, having large supply of sugar cane, are busy in research in this field. Since 1975, Brazil has had a huge program in operation to cause a national change from the use of petroleum to alcohol fuels. Brazil is now using 20 percent alcohol blends regularly and large fleets of government or industry owned cars run on 100 percent alcohol.

Gasohol, a blend of 10 percent anhydrous fermentation ethanol and 90 percent unleaded gasoline, was marketed in mid 1970s in the U.S. In 1982, the U.S.E.P.A. mandated reduction in the lead content of gasoline that required refiners to seek other agents to increase the octane number of finished gasoline. Ethanol, is an effective "Octane enhancer", when blended with gasoline. The use of ethanol as fuel for vehicles in the U.S. has grown from insignificance in 1977 to nearly 900 million gallons in 1990 [14].

This work includes a comparative study of consumption of gasoline and ethanol fuels on the basis of their energies only. It covers other aspects such as effect on emission, modifications required on engines and related systems, sensitivity analysis of cost of production of ethanol. It also includes an investigation into the consumption of fossil fuel energy in their production. The study is based on production of ethanol from corn only. All the statistical data used in this work is based on 1990's production of corn and fossil fuel in Michigan or nearby states.

1.0 Literature Review

Several studies have been carried out to evaluate alcohols as an alternative fuel from different technical points of view such as, their production, fuel economy, emission control, drive ability, engine compatibility and modifications, impact on food etc.

The fermentation ethanol industry has emerged through a combination of government incentives and new technologies, which enabled large scale production of ethanol from domestic resources, particularly corn. The falling cost of production of ethanol along with growing consumer acceptance of ethanol blended gasoline are responsible for the jump in the ethanol production. Hohmann [14], examines the likelihood of obtaining further reductions in the cost of ethanol by the introduction of new technologies. He expects that cost reductions to the tune of 5-7 cents per gallon are likely by 1996, which can further be increased to 9-15 cents per gallon by the year 2001.

Bata [16], used a 1978 Ford, 2.3 liter, in line four cylinder with an overhead cam shaft, 9:1 compression ratio, cogged belt drive and two barrel carburetor, engine mounted on a super flow SF-800 dynamometer to investigate the effects of using anhydrous ethanol blended in unleaded gasoline fuel on exhaust emissions (CO, HC, and CHO). In this work, he found that the product CO decreased as the percent of alcohol in the blend was increased. The effect of alcohol on HC was insignificant whereas CHO emissions were markedly increased, however the UBF was slightly increased.

Tyner [19], in his paper discusses the moral issues in using corn for the production of ethanol. He concludes that use of feed grains for alcohol production may involve tradeoffs in the price and quality of meat, poultry and dairy products. However, it would not directly affect the availability of food at lower to moderate levels of alcohol production but it may happen at higher levels of alcohol production.

Thring [15], examined alternative fuels for spark ignition engines such as, synthetic fuels, alcohols, methane gas, LNG, CNG, hydrogen gas. He studied the use of alcohol as motor spirit under two heads, i.e., effects on engines, and its handling problems. He concludes that alcohols, primarily methanol and ethanol, offer possible alternatives but suffer from certain disadvantages (e.g., low calorific value) that makes these two less attractive. However, these will be used in certain areas where suitable feed stocks are available.

CHAPTER 2

RESULTS AND DISCUSSION

2.0 Need to change over from gasoline to ethanol

Presently the cost of ethanol is not competitive with gasoline without Federal and State government subsidies, but with the development of technology and other innovations it is expected to become so in near future. However, there are certain other factors which over ride cost factor and demand use of ethanol as motor fuel.

2.0.1 To reduce undesirable emissions

The quality of air we breathe has been a public concern for several decades. Emission of SO_2, HC_s, CO, lead, and NO_2 (the so called "criteria pollutants") have commanded our attention for nearly thirty years. Chloroflourocarbons, green house gases (CO_2 and methane), and toxic air pollutants gained our attention rapidly in the last decade because of their suspected impact on the earth's atmosphere and human health.

Motor vehicles emit green house gases and toxic air pollutants. Petroleum fuels consumed by motor vehicles in the U.S. contributed 31.8 percent of the total CO_2 emission in 1986. CO_2, a green house gas, is contributing to what some scientists believe may be a gradual warming up of earth's climate. Benzene, a known human carcinogen, is emitted during refueling of gasoline powered motor vehicles. Less is known about the impact of emissions from vehicles using alternative fuels on potential global warming.

The motor vehicle's pollution problem can not be solved by stringent emission control technologies and C.A.F.E. requirements only. However an alternative fuel or mixing some additive in gasoline may solve this problem. The present interest in ethanol as motor fuel, results from the hope that it may reduce exhaust emissions.

2.0.2 To supplement oil reserves/ensure economic availability of fuel

The U.S. imports about 50 percent of its need of crude oil which creates a cash outflow of $ 10 million per hour. At the present rate of production and use, petroleum reserves within the U.S. control represent about 16 years of supply. Precedence of the 1970's energy crisis, and expected increase in the price of imported oil, demands search and use of alternative fuels.

It is expected that by the year 2000, there will be dire need to use fuels obtained from sources other than oil wells mainly due to the uneconomical availability of conventional crude oil. These will be obtained either from one source or a combination of sources depending on the demand and availability of the raw materials. In view of the depleting oil reserves and the desire for energy independence, some compromise on the properties of these fuels may be inevitable. This may affect fuel economy, drive ability, vehicle performance, fuel system and engine durability and fuel integrity etc. These fuels may either substitute or supplement the conventional fuel. The fermentation ethanol obtained from corn is one of the various alternate fuels being researched.

2.0.3 To improve yield and octane rating

Because of the adverse effects of lead compounds, used as octane enhancer, the conversion to unleaded gasoline was mandated some years ago. The change in refinery operations, required to produce fuel of a given octane rating with out lead additives, reduced the quantity of fuel obtained from crude oil. The octane boosting process requires additional energy in the refining process.

Addition of ethanol to gasoline not only gives the required octane boost but it saves the supplementary energy expenditure in the refining process and also improves the yield . Therefore, the requirement of crude oil is reduced by the amount of ethanol used in the blend and the crude oil saved by using ethanol as octane enhancer.

2.0.4 To reduce unemployment

Recent estimates by the U.S.D.A suggest that about 78 million acres of land, presently not being used for crops, has a high potential for cropland development. The development of such a vast area into cropland could translate to a 33% increase of corn production which will be a significant increase in the ethanol feedstock resources. It will also solve the problem of unemployment.

2.1 Comparison of fuel consumption

The effect on fuel economy by blending ethanol with unleaded gasoline is somewhat clouded by the fact that the effects are different depending on the method used to measure fuel economy. Consumption of a fuel in the engine depends on many factors such as heating value, stoichiometric air to fuel ratio, specific gravity, vapor pressure, viscosity, specific heat etc.

However, in this work the comparison, between pure gasoline and ethanol blended gasoline, is done on the basis of their lower heating values only. Fuel consumption of gasoline is taken as 27.5 miles per gallon, being C.A.F.E standard for 1990 model cars. Two comparisons are being done here; one is for miles per gallon and the other is for miles per Btu.

2.1.1 In terms of miles per gallon

Formula used to calculate the consumption of a vehicle fueled with ethanol blended gasoline in different ratios is given below. Results so obtained are shown in Table 2.1 and Figure 2.1. Since ethanol has much lower heating value than gasoline, the heating value of their blend in any proportion will always be lower than the gasoline alone. This is the reason why fuel consumption of the ethanol-gasoline blend is more than gasoline.

$$\frac{Y}{27.5} = \frac{[(1-x)\ \hat{h}_{gas} + (x)\hat{h}_{eth}\ ]}{\hat{h}_{gas}}$$

Y = mpg of x% of ethanol in gasoline

$\hat{h}_{gas}$ = the lower heating value of gasoline (116,485 Btu / gal)

$\hat{h}_{eth}$ = the lower heating value of ethanol (76,152 Btu / gal)

2.1.2 In terms of miles per btu

Formula used for calculating " miles per Btu" for a vehicle is given below. Data used in this calculation is taken from Table 2.1 for different blends of ethanol in gasoline. Results so obtained are shown in Table 2.2 and Figure 2.2.

These results indicate that with the increase in the percentage of ethanol in the blend, better milage per btu is obtained. It must be appreciated that an assumed value of processing energy for ethanol has been used in the calculations. It is hoped that a better picture may emerge if exact figures for this assumption are available.

$$\frac{Miles}{Btu} = \frac{Miles}{gal} x \frac{galofeth}{Btu} x\%ofeth + \frac{Miles}{gal} x \frac{galofgas}{Btu} x\%ofgas$$

S.No.	% of Ethanol	Mpg
1.	0	27.5000
2.	10	26.5478
3.	20	25.5956
4.	30	24.6434
5.	40	23.6912
6.	50	22.7390
7.	60	21.7868
8.	70	20.8346
9.	80	19.8824
10.	90	18.9303
11	100	17.9781

Table 1 : Showing percent of ethanol in the blend and corresponding consumption in mpg

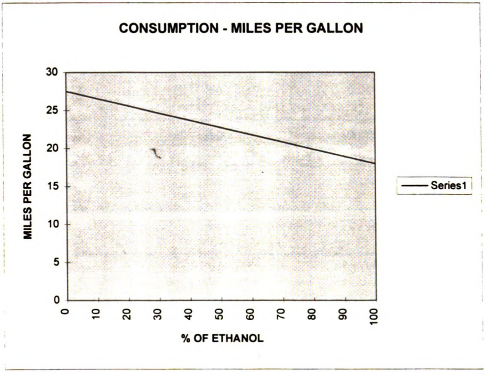

Fig.2.1. Graph showing fuel consumption in terms of miles / gallon

S.No.	% of Ethanol	Miles per Btu
1.	0	0.00010
2.	10	0.00032
3.	20	0.00052
4.	30	0.00071
5.	40	0.00088
6.	50	0.00104
7.	60	0.00118
8.	70	0.00130
9.	80	0.00141
10.	90	0.00150
11	100	0.00157

Table 2 : Showing percent of ethanol in the blend and corresponding consumption in miles per Btu

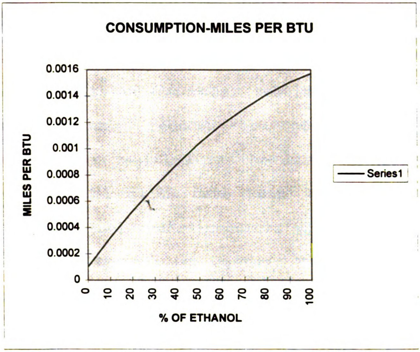

Fig 2.2. Graph showing fuel consumption in terms of miles/Btu

2.2 Effects on emission

Approximately 128 billion gallons of gasoline and diesel fuel were burnt in 1988 by vehicles only. The number of vehicles on the road is increasing every day and so is the amount of fuel being burnt. These vehicles emit a large share of pollutants in the air we breathe, i.e. 66% of CO_2,50% of NO_2, and 37% of HC_s. Vehicle exhaust and evaporative emission controls, required by the U.S.E.P.A, have significantly reduced the pollutants emitted by individual motor vehicles in the last two decades. These pollution control gains have been achieved by improving combustion and fuel system controls and by adding catalytic convertors to the exhaust system. However, the continual increase in the number of vehicles on the roadways and the increasing number of miles driven offset a large portion of these improvements in pollution control.

There appears to be widespread agreement that, compared to gasoline, ethanol containing fuels have the positive feature of generating less CO when combusted. This is primarily attributed to the "leaning effect" of the ethanol. On the other hand, there is a near consensus that such fuels have the negative feature of causing higher CHO emissions. For HC and NO_2 emissions the picture is somewhat ambiguous, with some researchers reporting lower HC and/or NO_2

emissions for ethanol containing fuels, while others report higher emission levels of these species. In most cases the percentage differences in NO_2 and true HC release for alcohol fuels and gasoline were comparatively modest.

Much of the apparent inconsistency in NO_2 and HC emissions comparison, for alcohol versus gasoline, among various investigations may be attributed to differences in test procedures, emission control equipment, and engine operating parameters, particularly the equivalence ratio.

Ethanol has a greater cooling effect on the intake charge than gasoline, and this effect persist throughout the engine cycle. Since the formation of NO_2 varies with the time temperature histories of each portion of the charge, this reduction in the temperature causes a reduction in exhaust emission of NO_2. Furthermore, since ethanol fueled engines can be made to run leaner, a further reduction in charge temperatures and NO_2 emissions could be achieved. These reductions in NO_2 are some what offset by any increase in compression ratio, but nevertheless, NO_2 emissions are about half the values obtained with gasoline.

Exhaust emissions of unburned HC are also reduced, partly because of the leaner operation possible with ethanol. The ability to operate leaner produces a reduction in CO. Ethanol has high octane number, and the octane number improvement resulting from the addition of lead compounds is poor. Therefore, there is no point in adding lead to them, and hence there is no exhaust emission of lead. There is usually only a negligible quantity of sulfur in ethanol, so there is no sulfurous emission with ethanol.

2.3 Sensitivity analysis

Presently ethanol is not competitive with gasoline without substantial government subsidies. However, the ethanol fuel industry is poised to adopt a wide range of technologies which would reduce costs at every stage of the production process.

The cost of producing ethanol will also be greatly reduced by the technological advances other than the innovations in the plant. It is expected that the longer term technologies would save approximately 9-15 cents per gallon over present cost. Energy and feedstock savings will result from technology which can convert some of the non starch portions of corn to ethanol. Development of certain micro organisms which speed up the process will also contribute to long term savings. Development of markets for co-products of ethanol production will create additional savings.

The science and art of production of fuel grade ethanol by fermentation are well established. Although yields and energy requirements appear to be close to the maximum and minimum values, respectively, but some improvements are still possible. These arise out of research in areas such as continuous fermentation, development of yeast strains that are more temperature tolerant, alcohol separation and dehydration methods than distillation.

Various government agencies also influence the production of fermentation ethanol which may affect the cost of ethanol. The U.S.D.A. may influence feedstock availability and prices. The B.A.T.F. requires permits for the production. The E.P.A. impacts on stillage disposal.

By way of projection, the price of oil and gasoline should continue to increase at a rate more than the general inflation rate, where as biomass based fermentation ethanol should increase only at the general inflation rate. Thus, one can reasonably assume that the ethanol price should become economically competitive with out government subsidy incentives with the passage of time.

Technological innovations in converting corn to ethanol along with the technical developments will possibly lower all the three components of production costs: feedstock, capital, and operating costs. In near term, the adoption of innovations in new facilities will result in lower equipment and ingredient costs, and slight increase in ethanol yield over current plants.

2.3.1 Feedstock cost

Feedstock cost is a measure of the net cost of the grain from which ethanol is produced. The net cost of corn is the difference between the cost of corn and the total revenues received from the sale of co-products. Over a period of 10 years, the net corn cost has been volatile, ranging from 10 to 67 cents per gallon of ethanol. This volatility is mainly due to the large swings in the price of corn, but changes in the co-product prices have also contributed. Average net corn cost (1981-1991) have been 44 cents per gallon of ethanol in a wet mill and 53 cents per gallon in a dry mill plant. Lower net feedstock costs can be achieved by either lowering the cost of corn, or raising the price of co-products, or both of them simultaneously.

Farm technologies which raise corn yields or reduce input costs may lower feedstock costs for ethanol production. Refinements and new, higher value uses for co-products are an even likelier source of new revenues and could reduce the cost of ethanol by as much as plant innovations.

2.3.2 Capital cost

Another component of producing ethanol is capital cost, which includes plant erection and modifications, replacement of worn equipment, and a rate of return on the initial investment.The primary capital expenditure in a wet milling plant, which accounts for the sizeable cost difference compared to dry milling plant, is recovery equipment for removing the germ, oil, and fiber from the corn kernel. In dry milling plants, nearly half of the capital expenditures are for equipment to process co-products.

In both dry and wet milling plants, high capital costs are associated with steps where the process slows or requires special equipment. Technological innovations which speed up the process or replace expensive equipment are therefore likely to lower capital costs. The construction of new ethanol production plants and the adoption of new technologies at existing plants is likely to lead to cost reduction.

Improved enzymes and fermenter designs can reduce the time needed to convert corn to ethanol and lower capital costs. Membrane filtration can allow the recovery of high value co-products such as lactic acid. Adoption of these and other innovations in the next five years is expected in new ethanol plants constructed to cope with the new demands resulting from "Clean Air Act" stipulations for cleaner burning fuel. Cost reduction of 5-7 cents per gallon are possible in the near term (1996). Older plants, having already invested in equipment, will be unable to take full advantage of capital cost savings, but can still save 3.5-5 cents per gallon. Improved enzymes and fermenter designs can reduce the time needed to convert corn to ethanol and lower capital costs.

2.3.3 Operating cost

Operating cost constitutes the final component of production costs and includes energy, enzymes, labor, management, taxes and insurance. Many technological innovations have focused on reducing operating costs raising the efficiency of inputs, particularly energy. Energy is the greatest operating cost, so innovations which conserve energy have been among the first adopted in the industry. Most large ethanol plants now receive steam and electricity at low cost from co-generation facilities which simultaneously produce both. The industry also has reduced energy costs by adopting more efficient means of alcohol dehydration. However, large savings in energy costs are not likely because the present level of efficiency is close to optimal.

The second largest operating cost is the cost of yeast and enzymes. Although this cost has fallen considerably in the past few years, particularly for enzymes, research may further lower the cost of propagating these organisms or reduce the volume needed. The use of improved yeast strains has lowered processing cost by more than 50%. It is estimated that over the next five years the average cost of ethanol production in the industry will decline by 5-7 cents per gallon because of further technological innovations. Improved yeasts, which tolerate high concentrations of ethanol, can further lower energy costs.

In the long term, i.e., by year 2001, a state-of-the-art corn conversion plant could reduce costs further by improving fermentation process and converting part of its co-products into ethanol through the conversion of corn fiber. Adding these technologies to a new plant will increase cost savings to 9-15 cents per gallon (7-11 % savings over the cost of production in a current state-of-the-art plant). Additional cost savings may result from incremental improvements to the production efficiency or unexpected breakthroughs, but are likely to be small compared with the projected savings, especially in the near term.

2.4 Modifications required on the engines and related system

Conventional spark ignition engines and their related systems are designed and manufactured keeping in view the properties of gasoline. Use of any alternative fuel will require certain modifications depending upon the change in properties. These may be major modifications performed by the manufacturer or minor ones done by the user.

There are two ways of using ethanol in spark ignition engines. The first is to use it as a blend with gasoline, in different proportions, in vehicles which are either modified or unmodified. The use of such a blend has the effect of producing a slightly leaner mixture, which improves the economy of vehicles with carburetors set rich. The second way is to operate vehicles on pure ethanol which requires major modifications on the engine and the fuel system.

A 10% blend of ethanol reduces the volumetric heat content by approximately 3.5% and result in leaning the mixture by a like amount. The main fuel metering jets in carburetors, of nearly all the vehicles, are fixed and only the idle jets are adjustable.

The stoichiometric air/fuel ratio of the blend will differ from that of gasoline as the percentage of ethanol in the blend is changed. Therefore, as more ethanol is added to the blend, the air/fuel mixture of a carburetor becomes less favorable and drive ability of the vehicle is affected which is worst at part load. It can be overcome by increased heating of intake manifold, either by exhaust heating, coolant heating or both.

Modification of the carburetor or fuel injection fuel-air metering system will be required to convert a spark ignition engine to run on straight ethanol. In some engines, it might involve simply enlarging the carburetor main metering jet to compensate for differences in the energy content and stoichiometry between ethanol and gasoline.

There are several reasons for enlarging the main metering jet of a carburetor in an ethanol fueled engine. The first reason is that ethanol requires air to fuel ratio of 9:1 to ignite in the engine where as gasoline requires 15:1 ratio. The difference between ethanol and gasoline is about 40%. Ethanol carries oxygen in the fluid, where as gasoline does not, that may explain why ethanol requires less air to ignite. Another reason is the difference in weight of ethanol and gasoline. Ethanol weighs 6.6 pounds per gallon; gasoline weighs 6.1 pounds per gallon. Even at 6.6 pounds, alcohol is a thicker fluid than gasoline and will not flow readily through a jet designed for gasoline. Although the difference in the two fuels by weight is only

10%, alcohol has only two-thirds of the energy that gasoline has. To compensate for this, one must add one-third for energy loss and 10% for difference in fuel weight; that necessitates the 40% enlargement of the main jet. However, the carburetor needs proper calibration for the fuel being used to obtain completely satisfactory engine performance at all operating ranges.

Ethanol offers about twenty numbers improvement in research octane number and ten numbers improvement in motor octane number. This should lead to a possible increase in compression ratio of the order of two to four, but this is not easily achieved because the pre ignition tendency of ethanol is much worse than the gasoline. Although, the pre - ignition problem can be mitigated to some extent by using cooler running spark plugs, but it tends to reduce the practical increase in compression ratio below that which could apply if only the octane numbers were important.

Ethanol is corrosive and reacts with lead, copper, magnesium, aluminum, brass, some plastics and elastomer. The components in a conventional fuel system which are likely to be attacked are the fuel tank (ternplate, lead/tin coated steel), fuel pump diaphragms, carburetor and fuel gauge floats, carburetor and fuel pump castings, and some sealing rings and washers. These items may require replacement and/or repair depending upon the amount of ethanol being used.

Experience with gasohol has shown that the solvent properties of ethanol loosen corrosion and dirt from the walls of fuel tanks and automobile fuel lines. This makes it advisable to flush and dry all storage tanks used with ethanol-gasoline blends. Vehicle fuel tanks, particularly with older vehicles, should be flushed with ethanol or the blend and the fuel filter be replaced after the first or second tankful. In addition, ethanol blends have led to the cracking of polyamide filter housings and to the degradation of polyurethene and polyester bonded fiber glass. These may require replacement as and when required.

Alcohol fuels are particularly sensitive to water contamination and may require special efforts to assure the distribution system is water tight. Ethanol often vaporizes less readily than gasoline. This often results in difficult cold engine starting at temperatures below 40°F and poor distribution of the air-fuel mixture to the engine cylinders. Volatility problems, like others associated with fuel alcohol, can also be solved by appropriate fuel and ignition system modifications.

2.5 Comparison of fossil fuel energy consumed in producing gasoline/ethanol

This comparison is based on the consumption of fossil fuel energy only. All the data used in this calculation is directly or indirectly related to the fossil fuel. Any other factor, that may be affecting production of gasoline or ethanol such as solar energy for corn, cost of transporting crude or corn to the respective plants etc is not being considered. Ethanol can be obtained from a fermentation of a number of crops but only corn is being considered in this work. The data used pertains to the state of Michigan or near by states.

2.5.1 Gasoline

Yield per bbl of crude = 45.8%

Energy per bbl of crude = 5.8×10^6 Btu

Gallons per bbl = 42

Processing energy = 10% of crude

$$\frac{Gal\ of\ Gasoline}{Btu} = \frac{Gal\ of\ Gasoline}{bbl\ of\ crude} \times \frac{bbl\ of\ crude}{Btu}$$

Gal of gasoline/Btu = $0.458 \times 42/(5.8 \times 10^6)$

Gal of gasoline/Btu = 3.32×10^{-6}

Processing energy = 0.332×10^{-6} gal/Btu

Net energy = 3.652×10^{-6} gal/Btu

2.5.2 Ethanol

Since the energy consumed in the processing of ethanol was not available, it has been assumed that it is equivalent to that consumed in refining of gasoline. Data used in this calculation is:

Gallon of Ethanol per Bushel of Corn	=	2.6
Bushel of Corn per Acre	=	115
Amount of Fertilizer (Ammonia) per Acre	=	220 lb
Gasoline consumed per Acre	=	10 gal
Amount of Natural Gas used in Ammonia	=	1 m^3/Kg
Lower heat value of Natural Gas	=	1000 Btu/ft^3 of NG
Lower Heat Value of Gasoline	=	116,485 Btu/gal
Processing energy	=	0.332×10^{-6} gal/Btu

2.5.3 Calculation

2.5.3.1 Fertilizer based

$$\frac{\text{Gal of Eth}}{\text{Btu}} = \frac{\text{Gal of Eth}}{\text{Bushel of corn}} \times \frac{\text{Bushel of corn}}{\text{Acre}} \times \frac{\text{Acre}}{\text{lbm of fert}} \times \frac{\text{lbm of fert}}{\text{ft}^3\text{ of NG}} \times \frac{\text{ft}^3\text{ of NG}}{\text{Btu}}$$

Gallon of Ethanol/Btu $= 2.6 \times 115 \times (1/220) \times (2.2046/35.315) \times (1/1000)$

$= 8.484 \times 10^{-5}$

2.5.3.2 Gasoline based

$$\frac{\text{Gal of Eth}}{\text{Btu}} = \frac{\text{Gal of Eth}}{\text{Bushel of corn}} x \frac{\text{Bushel of corn}}{\text{Acre}} x \frac{\text{Acre}}{\text{Gal of Gasoline}} x \frac{\text{Gal of Gasoline}}{\text{Btu}}$$

$$= 2.6 \text{ x } 115 \text{ x } (1/10)\text{x}(1/116485)$$

$$= 0.256 \text{ x } 10^{-5}$$

Net gallons of ethanol/Btu $= 8.484 \text{ x } 10^{-5}$

$$+ 0.256 \text{ x } 10^{-5}$$

$$+ 0.033 \text{ x } 10^{-5}$$

$$= 8.773 \text{ x } 10^{-5}$$

CHAPTER 3

3.0 Conclusion

It has been found that vehicles consume more ethanol blended gasoline than gasoline when compared on the basis of their heat values only. The fuel consumption increases as the quantity of ethanol is increased in the blend. However, less fossil fuel energy is consumed in ethanol blended gasoline.

Calculation, for the production of Ethanol and Gasoline, based on fossil fuel input only show that ethanol requires much less fossil fuel energy input than gasoline. It must be appreciated that solar energy is free for ethanol and this input remains un accounted for. This difference is likely to change if exact amount of fossil fuel energy required for processing is available.

Although presently use of ethanol as motor spirit is not economically competitive with gasoline, however, the new technologies in the industry, innovations in the production plants, development of markets for co-products, use of available farmland and improved agriculture technologies to increase corn production, will soon bring two fuels at par.

Parameter	Ethanol	Gasoline
Consumption	Dis-advantage	Advantage
Emission	Advantage	Dis-advantage
Consumptio/Energy	Advantage	Dis-advantage
Production process	Catching Up	Advantage
Engine Modification	Dis-advantage	Advantage
Energy Cost	Advantage	Dis-advantage

Table 3.0. Showing Comparison of Ethanol and Gasoline

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