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Alcohol Fuels for Spaceship Earth

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ABSTRACT

Foreign crude oil imports currently provide raw material for production of half of the liquid fuels consumed in the United States and represents a cash outflow of almost $8 million per hour. Recent events have dramatically illustrated the substantial vulnerability of such imports. Ethanol is a liquid fuel that can substitute domestic renewable resources for imported petroleum products now and increasingly in the next few years.

Alcohol fuels and in particular gasohol, a blend of 10% agriculturally derived anhydrous ethanol and 90% unleaded gasoline, will in the near term be the primary alcohol fuel.

This paper describes the market for gasohol produced from fermentation ethanol, the basic ethanol production process, effective feedstocks, typical plant design and a rereview of the state of the art.

INTRODUCTION

Interestingly enough, it was alcohol fuel which ushered in the space age, following the propellant research of Dr. Robert H. Goddard. The 20 year old Wernher von Braun began experimenting with it in 1932 and 10 years later launched the first man-made object to reach space, the alcohol fueled V-2 Rocket. It was a magnificent display of power--10 tons of alcohol and oxygen propellants converting energy at the rate of half a million horsepower--thrusting the rocket at 3,800 miles per hour. That remarkable energy source now offers our greatest hope for renewable supply of precious energy to continue to power our spaceship Earth.

As it turns out, we have been tardy in our utilization of ethyl alcohol--ethanol--even though it has long had its ardent proponents. Henry Ford well knew ethanol's potential and fought hard, though unsuccessfully, to fuel the automobile era with power alcohol. He saw it as the basis for rural self-sufficiency and agricultural prosperity. He even built the Model "A" with an adjustable carburetor to burn either alcohol or gasoline or a combination of both--what we now call "gasohol." Despite an illustrious list of proponents: Theodore Roosevelt; Dow Chemical chemist, William Jay Hale; Henry Wallace; and Everett Dirkson, Henry Ford lost his thirty year battle for power alcohol to cheap oil. From about 1939 until the late 1970's, the only American automobiles using alcohol fuels were race cars.

ALCOHOL FUELS

Today, the "race" is on to rediscover non-fossil alcohol fuels as an alternative or extender to decrease our dependence on foreign and rapidly diminishing supplies of petroleum. Currently, the only alcohol fuel is ethanol or industrial grade grain alcohol used either as blending stock with gasoline to produce gasohol or as a commercial motor fuel for a suitable equipped vehicle. However, methanol (derived from petroleum or natural gas rather than wood) offers promise as an octane-enhancer and component for diesel or other motor fuels, and tertiary butyl alcohol (TBA) is under test as an octane-enhancer. For now, the introduction of gasohol has paved the way toward eventual large scale use of alternative, non-fossil fuel.

GASOHOL

Gasohol is a mixture of gasoline and ethanol, at a ratio of nine to one, which can be used in unmodified present day automobiles without modification, provided a stable, dry fuel is delivered and the user is taught to maintain a clean, dry fuel system.

From an environmental standpoint, ethanol reduces hydrocarbon and CO emissions but may increase emission of aldehydes and may be involved in the evaporative emissions of hydrocarbons. Gasohol enhances the octane by 2 or 3 numbers relative to regular unleaded gasoline, thus improving performance and reducing or eliminating engine knock. Ethanol does not result in improved fuel economy and may loosen scale or other deposits in the fuel systems of older cars so they must be carefully filtered.

In 1979 Americans consumed about 495 million gallons of gasohol, displacing about 50 million gallons of gasoline. Currently, higher producion cost of ethanol over gasoline limits use but as petroleum costs rise, the gap should close. Soon a gasohol ratio of 25% ethanol and 75% gasoline will be feasible with only slight changes in carburetors and manifolds, and present technology can already produce vehicles which use 100% power alcohol.

ETHYL ALCOHOL

Ethanol is ethyl alcohol--C_2H_5OH--the time honored result of bioconverting glucose through a process of fermentation with yeast. It's the same alcohol that powers the martini, keeps instruments from freezing, fuels laboratory burners, and is the "almost universal" solvent used in making medical elixirs, industrial esters, and food extracts. It's ingestive attractiveness is so great that governments tax it heavily and it must be "denatured" (poisoned) before industrial use.

Generally, ethanol is produced from feedstocks of grain, sugar beets or sorghum but it can be made from virtually any biomass: cheese, whey, agricultural wastes and food processing by-products, weeds, and even garbage. This results in several valuable by-products: carbon dioxide; yeast; some higher alcohols; acetic acid; and some fiber and nutrients suitable for animal food.

TEN STEPS TO ETHANOL

Alcohol production from grain is a commercial process without any technical impediment to building a grain fuels industry. It requires 10 relatively simple steps to produce 190 proof ethanol suitable for fuel and, most importantly, lends itself to relatively small scale production, by farmers for example. While production of 200 proof, or 100% anhydrous or "rectified," ethanol generally requires a larger scale plant, it can be accomplished by re-processing the product of the small scale plants.

Step One

Let's look at a modern small scale plant and see how it works. Grain is milled so that the resulting meal can pass a 20-mesh screen. This assures that the carbohydrate is accessible and the solids can be removed with a finer screen. Meal is stored in a bin.

Step Two

Then the meal is mixed with water to make mash in one of the three cooker fermenters. These operate on a staggered schedule: one starting; one fermenting; and one pumping out.

Cooking begins by steam injection during slurry-mixing and the liquefying enzyme is blended in simultaneously. Sulfuric acid and sodium hydroxide are injected to neutralize the pH value. The temperature is kept at 200 degrees fahrenheit (the optimum enzyme activity temperature) until most of the starch is converted to dextrin.

Dextrin is then saccharified to glucose by means of another enzyme after the mash is cooled to 135 degrees with circulating water and after the pH is adjusted to between 3.7 and 4.5 by injecting sulfuric acid or sodium hydroxide. The mash temperature is then dropped to 85 degrees by adding water and continued circulating cooling.

The pH fermentation can begin. Distillers yeast is dispersed from its tank and allowed to ferment for 30 to 36 hours. This results in beer with about a 10% volume of ethanol and 90% water.

Step Three

After a batch is complete, it is pumped to the beer well and the fermenter is hosed down to remove any residue. A full beer well allows the distillation section of the plant to run continuously.

Step Four

Beer is fed from its well to the beer still through a heat exchanger that passes it counter-current to the hot stillage from the bottom of the still. This heats up the beer to its boiling temperature of about 175 degrees fahrenheit and recovers some of the heat from stillage.

Step Five

Beer is pumped to the still for distillation. Steam is injected from a boiler at the bottom to provide necessary heat. Vapors move continuously up and flow to the rectifying column for further distillation. Liquids move continuously down to the bottom of the beer still. They contain water and a high-protein by-product called "stillage," which is pumped to the stillage tank through the previously identified heat exchanger described in Step 4.

Step Six

In the rectifying section, alcohol vapors from the rectifying column are cooled by water circulated through a condenser. A portion of the condensed ethanol is pumped to the top of the rectifying column where it helps in the distillation process. The rest of the condensed ethanol flows to the molecular sieves column for the anhydration process.

Step Eight

Stillage from the beer still is stored in a tank which provides surge capacity when a truck is unavailable to haul the stillage to a feeder operation.

Step Nine

The final 4% to 6% of water remaining with the ethanol is removed by means of two molecular sieve columns where the alcohol liquids from the condenser are passed through the sieves. When one column reaches saturation, the flow is switched to the second. To regenerate the first column, carbon dioxide from the fermentation phase passes through an exchanger which is heated by steam from the boiler and then rises through the first column to evaporate water in this regeneration process.

Step Ten

The resulting 200 proof alcohol from the molecular sieves columns is put in the ethanol storage tank. This tank provides storage during the times a tank truck is unavailable to transport the alcohol to markets.

STATE OF THE ART

Although commercial production of beverage ethanol from grain feedstocks is as old as recorded history, only recently has the process been well understood. The modern sciences of biochemistry, genetics, chemistry, and process engineering have all converged to create a truly effective ethanol brewing and distilling system.

Existing commercial processes produce ethanol from renewable resources based on yeast fermentation of six carbon-atom sugars (hexoses such as glucose). Processes which convert crops with sugar content, such as sugar cane, take essentially two steps--the sugar content is fermented to a mixture of water and up to 15 percent ethanol--and the latter is separated from the water by distillation. For crops containing starch, such as corn, one extra step is required--the starch is converted by enzymes into sugar prior to fermentation. Fibrous cellulosic material, such as corn stover or wheat straw, can theoretically be treated with chemicals or enzymes to produce fermentable sugars and methods are now under development.

The main difference between existing beverage ethanol production and that for fuel use, is the desirability of making a 200 proof or water free product. The extra equipment required to upgrade industrial production (up to 190 proof) and beverage production (up to 160 proof) to anhydrous ethanol is a major cost factor in the conversion of existing facilities.

However, the relative simplicity of the ethanol process lends it to small scale production for as little as 10 gallons per hour. If we are to produce enough power alcohol to make a significant difference in dependence on oil as quickly as the federal program has suggested, we must achieve a widespread use of large and small ethanol plants by individual farms, farm cooperatives, and agri-businesses throughout America.

Because of the time lag involved in building and operating large facilities, small scale operations must be constructed as rapidly as possible. Basic information has already been provided in "Fuel from Farms--A Guide to Small Scale Ethanol Production," a manual prepared by SERI and sponsored and distributed by DOE. It presents the current status of on-farm fermentation ethanol production, as well as an overview of some key technical and economic factors.

Significantly, a small scale ethanol plant lends itself well to automation and is not labor intensive during operation. Modern control devices, electronic warning units, and automatic relays add reliability and efficiency.

Studies to date indicate the positive but limited economic viability of operating a small scale ethanol plant. Ways to further enhance their operation are not being considered. For example, heat--therefore energy investment--is required in both the cooking of the mash and distillation of ethanol, just as it is for making gasoline and mining coal. So intensive efforts are underway to conserve energy in small scale plants and by expanded use of alternative fuels. By-products can be developed for cattle feed or industrial uses.

NET ENERGY BALANCE

Rapid growth in alcohol production capacity will contribute to achieving our energy goals. Alcohol plants require energy to cook the mash and distill the alcohol. When this energy comes from coal, wood, agricultural residues, waste heat, geothermal energy, or solar energy, the nation benefits in particular.

Questions have arisen over whether a net energy gain results from the production of alcohol fuels. Numerous studies have examined this issue and most conclude that the net balance is small but positive. Estimates differ, depending on the feedstock and process employed. However, all studies conclude that power alcohol production if fueled with a domestic nonpetroleum energy source could significantly reduce the nation's dependence on imported oil. Improvement in technology efficiency and use of feedstock byproducts will improve the net energy balance. A plant using food processing residue for feedstock and coal for fuel may achieve a net reduction in imports approaching its total production. Also, the use of coal in the alcohol production process improves the oil savings attainable through increased use of gasohol.

The use of coal or non-fossil fuels for alcohol production is highly preferable to use of oil or natural gas. Ethanol conversion facilities can readily be designed to use other fuels. Small-scale on-farm plants can utilize corn stover as a boiler fuel, and larger plants can rely on coal to produce process steam. The ethanol production process can then be viewed as a means of converting less versatile energy forms, such as coal, distressed crops or solar energy, into premium transportation fuel. Ethanol production using low grade fuels can be compared to electric power generation, in which 9,000 to 10,500 Btu's of coal are converted into 3,413 Btu's equivalent of electricity.

FEDERAL PROGRAMS

Without incentives, in 1980 production of ethanol is not economically attractive when compared to gasoline, although rising world oil prices continue to improve alcohol's position. Net production costs for ethanol, after credits for sale of the by-products, are approximately $1.30 per gallon compared to wholesale unleaded gasoline prices of $.85 to $.95 per gallon.

Subsidies already available, combined with the proposed new federal subsidies, are rapidly changing the prospects for ethanol production. Indeed, primarily as a result of the 4¢ per gallon federal excise tax exemption signed into law in November of 1978, our capacity to produce ethanol increased from almost zero to about 80 million gallons by the end of 1979.

The Farm Act of 1977 began the effort to provide loan guarantees for building pilot plants. Now federal and state legislators are encouraging ethanol production through: grants to build facilities in economically depressed areas; plans for a Synthetic Fuels Corporation; the Agricultural, Forestry and Rural Energy Act of 1979 which aims at making rural America energy self-sufficient and biomass energy oriented; and the Gasohol Motor Fuels Act of 1979.

The U.S. Department of Energy has established the Office of Alcohol Fuels as a major DOE entity under its Assistant Secretary for Conservation and Solar Energy. The Office was formed to encourage the development and utilization of alcohol fuels and is responsible for providing research, engineering, testing, evaluation, and demonstration skills needed to develop programs to support the objectives of the President's Alcohol Fuels Program. The Office provides financial incentives, marketing analysis, technical support, educational programs and procurement guidance for projects involving alcohol fuels. It serves as a point of contact on alcohol fuels for DOE, acts as liaison among federal, regional, state, and local agencies, and with consumers. Its four Office divisions are: Financial Incentives Programs; Technology Development and Utilization; Information, Liaison, and Public Response; and Program Control and Evaluation. Its alcohol fuels strategies are designed to implement the President's Program.

Recognizing the obstacles has led the government to adopt a program encouraging domestic production of ethanol.

PRESIDENT'S ALCOHOL FUELS PROGRAM

On January 11, 1980, the White House announced an expanded Alcohol Fuels Program to accelerate production. The immediate goal is to quadruple current capacity by the end of 1980 and the President's target is to produce 500 million gallons of ethanol during 1981. If this amount were all blended to make gasohol, it would account for 10 percent of our anticipated demand for unleaded gasoline in 1981.

The program includes a variety of incentives, from tax credits to loan guarantees, which focus on two main objectives: to permit gasohol to compete economically with unleaded gasoline at the pump; and to stimulate new investment in ethanol production facilities.

Key elements of the President's Program include: permanent exemption for gasohol from the federal gasoline excise tax; a 40¢ per gallon production tax credit; a $3 billion Federal credit program; proposal for an Energy Security Corporation to financially assist construction of ethanol plants; a revision of the oil entitlements program to include ethanol production; and a 10% ethanol investment tax credit above the existing general 10% credit applied to alcohol production facilities. Also, the Program calls for use of gasohol in federal vehicles; U.S. Department of Agriculture support in raising feedstocks; and USDA/DOE research and development programs to improve production methods. With the President's Program in place, an equivalent federal subsidy of almost 50¢ per gallon of alcohol will be available to producers, thus improving the economic prospects for ethanol production.

Other administrative government actions and policies are helping make ethanol production attractive. The Environmental Protection Agency has approved gasohol and made plant environmental approval easier to obtain. The U.S. Department of Treasury's Bureau of Alcohol, Tobacco and Firearms has streamlined the permit process and adopted bonding methods more appropriate to fuel-alcohol production.

IMPACTS OF ETHANOL PRODUCTION

Conversion of crops with significant human food value to fuel is, of course, undesirable. Fortunately, production of fermentation ethanol does not make this an "either-or" consideration. Much of the cereal grain (including most of the corn) currently produced in the United States is used as animal feed which must contain protein and carbohydrates. While fermentation of cereal grains to produce ethanol uses most of the carbohydrate, almost all of the protein is recovered in the stillage coproduct. This high protein source can be fed directly to animals and carbohydrate requirements can be met by using high energy forage which has no value as human food. This procedure, along with the use of spoiled perishable crops, distressed and marginal crops, provides a feedstock base for ethanol production that doesn't displace human food crops and enhances the agricultural economy.

The ability of American agriculture to produce a surplus is well known but the impact of ethanol production on it as a whole must be considered. The production of more ethanol than is obtainable from surplus and distressed crops will require cultivation of land that is currently fallow and will shift emphasis to specialized high-yield crops. This switch may allow a decrease in use of fertilizers, pesticides, and herbicides, production and transportation of which require petroleum fuels and natural gas.

This diversification, according to agricultural experts, may benefit farmers by modifying cultural practices and create new patterns of crop rotation. As commercial processes become available for small scale conversion of nongrain forage crops, which require less fertilizer and chemicals, the opportunity exists to achieve the equivalent value to current crops with decreased demands on soil and energy resources.

The impact of vastly increased ethanol production on the American economy is obvious. Reducing our dependence on foreign oil through gasohol/ethanol consumption is one of our most promising near-term domestic production methods to balance our foreign deficits. The technology is extant and we already have the agricultural capacity needed to produce this proven synthetic fuel. Moreover, national benefits derived from construction of ethanol facilities as well as those to farmers and plant operators will occur when and where the economy needs a boost. Economic improvement money will stay in rural America--in the form of capital investment, jobs, and land values. These in turn will strengthen the whole economy (weakened by soaring energy prices).

SUMMARY

How good is alcohol fuel? Based on gasohol's first year, it's made a great beginning and there is no insurmountable problem with its expanded use. "Try it, you'll like it, too," say most consumers. Its characteristics are a little different from gasoline but there are several potential advantages. Considering the alternatives, its an ideal solution to our present energy problems.

Think of it this way. All of us are on kind of a "Star Trek" journey and we've just learned that our spaceship Earth is rapidly exhausting its supplies of internal energy. The situation is critical and we must utilize some form of renewable energy source immediately or our civilization will die.

Someone suggests solar energy but we don't yet have the technology to use it directly. Then we hit on the idea of "indirect" solar energy, using living plant's ability to convert sunlight into carbohydrates and that of another kind of plant, yeast, to turn them into a marvelous potent fuel called alcohol. Just like in a space adventure we can have a happy ending. We must get busy using our technology and intelligence to produce Alcohol Fuels to Power Spaceship Earth.

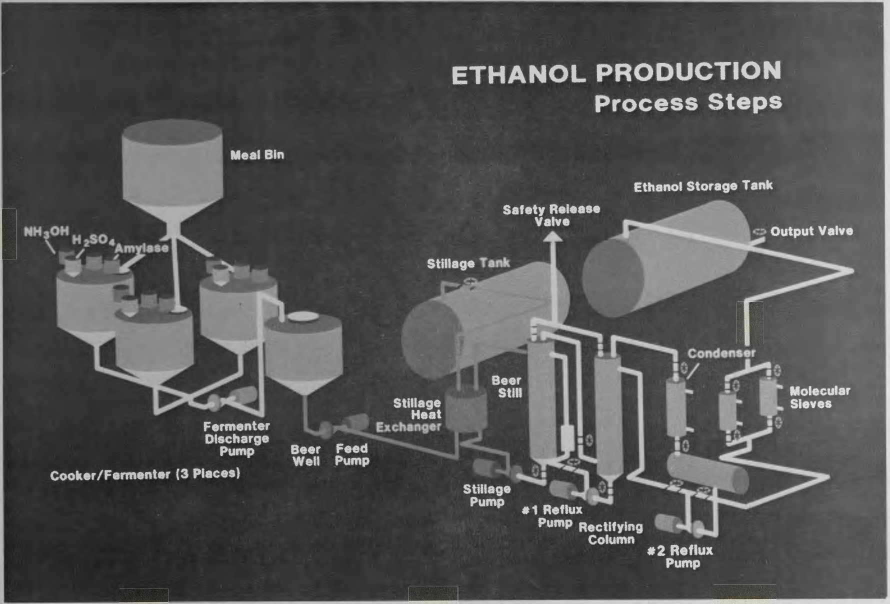
ETHANOL PRODUCTION
Process Steps
Meal Bin
NH_3OH
H_2SO_4
Amylase
Cooker/Fermenter (3 Places)
Fermenter Discharge Pump
Beer Well
Feed Pump
Stillage Heat Exchanger
Stillage Tank
Stillage Pump
Safety Release Valve
Beer Still
#1 Reflux Pump
Rectifying Column
Ethanol Storage Tank
Output Valve
Condenser
Molecular Sieves
#2 Reflux Pump

Figure 1