Summary

- FFVs will look and operate just like conventional vehicles but will be more challenging to build and to service.
- The fuel will require some special care in handling, but then so does gasoline, M85 will just add some new concerns.
- Manufacturers - and purchasers - of add-on's will have to consider some new considerations.

If you think FFVs might be in you future, it might be a good idea to start exploring that future possibility with your conversion suppliers, so they can have warning of your new requirements.

To achieve the greatest benefit from an FFV in terms of reducing smog formation and our energy dependence on foreign sources, you must accept the responsibility of maintaining them and keeping them running efficiently.

ALTERNATIVE FUEL SUPPLY
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To understand the supply characteristics of alternative fuels it is important to first understand the supply characteristics of the two predominant traditional motor fuels--gasoline and diesel. I will review the properties of traditional fuels and contrast those properties with those of the leading alternative fuels.

Petroleum Based, Traditional Fuels

Gasoline is a molecular mixture and therefore, it boils between a range of temperatures from about 80 degrees F to 437 degrees F. Its density ranges from about 6 to 6.5 pounds per gallon. Net energy of gasoline is about 18,000 BTUs per pound or about 115,000 BTUs per gallon. Another important characteristic of gasoline is its market demand. Currently there are about 110 billion gallons per year of gasoline consumed in the U.S. The wholesale cost of gasoline is about 70 cents per gallon (May, 1990) before taxes.

Diesel fuel is also a molecular mixture, but has a higher boiling range and is denser than gasoline. Diesel fuel boils from 370 degrees F to 700 degrees F. It's density is about 6.8 to 7.3 pounds per gallon. Net energy of diesel is about the same as gasoline per pound, but on a gallon basis it is higher, 130,000 BTUs per gallon. The U.S. market for diesel fuel is about 20 billion gallons per year. The wholesale cost is about 55 cents per gallon (May, 1990) before taxes.

If gasoline and diesel were introduced today, it is likely there would be considerable safety concerns. Both fuels have several safety concerns. Because gasoline and diesel fuels, however, have been in widespread use for almost 100 years, we have developed safe handling systems or have learned to live with any detrimental safety impacts. Similarly, many handling problems associated with alternative fuels could have been solved if they were given the attention that has been given to gasoline and diesel fuel. Before alternative-fueled vehicles can enter widespread use, however, supply and handling problems will have to be overcome.

An advantage of current petroleum fuels is that production and distribution systems are in place, established, and working. The distribution system supplies high volumes of petroleum products at very low costs. While the cost varies, moving petroleum products from refinery to product terminals via pipelines costs about one to two cents per gallon. Delivery from the terminals to service stations or commercial users in urban areas adds about another two cents. As can be seen, the petroleum industry has established an efficient delivery and distribution system.

Contrasting the existing motor fuel energy system with the pressure to convert to alternative fuels, two questions result: who should accept the costs of establishing new fuels in the market place and, which fuel(s) should be established?

Alternative Fuels

The discussion here will focus on four alternative fuels--methanol, ethanol, natural gas, and liquified petroleum gas. Reformulated gasoline and diesel fuels will also be discussed. Reformulated fuels are significantly different from traditional fuels and can be considered as alternative fuels, even though petroleum is a main component.

Methanol. One reason for the emphasis on methanol is that many consider it to be the leading alternative fuel. It was cited in the original Clean Air Act Amendment proposed by the Bush Administration. Its use is highly touted and it is certainly the fair-haired fuel of California's energy policy where a lot of methanol experimentation is being conducted and more is being proposed.

Structurally, the fuel is an oxygen-containing hydrocarbon. But unlike gasoline and diesel fuel, methanol has one set boiling point because it's structurally consistent throughout rather than a molecular mixture. It boils at or about 149 degrees F. Its density is like current fuels, at 6.6 pounds per gallon. But the net energy content is a major drawback - methanol's net energy content is 8,600 BTUs per pound or about 57,000 BTUs per gallon. Therefore, methanol has roughly half the energy content of diesel fuel. A vehicle would require twice as many gallons of methanol as diesel fuel to do the same work.

Unfortunately, the supply of methanol is very limited. The current world supply from plants currently in operation is about seven billion gallons. If methanol were burned in motor vehicles instead of petroleum fuels, the world methanol supply would meet about two to three percent of the U.S. motor vehicle fuel requirement.

The raw material used to make methanol is usually natural gas. Methanol can also be made from coal, from garbage, and other forms of biomass. However, using feed stocks (not natural gas) results in methanol that is at least twice as expensive. Unfortunately, the conversion from natural gas to methanol results in a loss of about 35 percent of the energy initially contained in natural gas.

To be competitive with petroleum fuels, methanol production requires large sources of cheap natural gas. Currently, most of the methanol that is on the market comes from the chemical industry where it is produced for use as a chemical. To manufacture methanol in large volumes will require large sources of raw materials. Unfortunately, the largest low cost sources of natural gas are not in the United States. Some of the foreign countries with large natural gas reserves are not too friendly to the U.S.

To be competitive, methanol plants would probably have to be put near the largest reserves of natural gas. While U.S. natural gas reserves are significant, so to is the U.S. demand for energy. In addition, U.S. natural gas reserves are widely scattered and, therefore, it would be expensive to collect and to centralize gas at conversion plants. The most likely candidate locations for new plants are outside the U.S. and one of the primary candidates would be the Middle East, although there are some other areas around the world that would make good locations for new plants. Consequently, if methanol is viewed as a replacement for petroleum fuels, methanol does not do much to reduce U.S. energy dependence on foreign energy supplies.

Historically, the price of methanol has been quite stable and current prices are about 40 to 45 cents per gallon. However, in the last few years, prices have varied. Prices have risen from a low of 25 cents per gallon in 1986 to a high of 70 cents per gallon in 1988. Thus prices have tended to be volatile during the late 1980s but have settled at 40 to 45 cent per gallon range. One additional element related to the price of methanol is that as production increases and as more relatively cheap foreign natural gas is consumed as feed stock, the price could rise significantly as more expensive methods to extract gas are used.

In summary, the evaluation of methanol as a motor fuel leads to three important conclusions. Some are equally applicable to alternative fuels discussed later. These conclusions are:

- The supply and current methanol production capacity are too limited to displace any consequential portion of the U.S. motor vehicle fuel energy demands in foreseeable future.
- Methanol is substantially more expensive than both gasoline and diesel fuel at current market prices. Therefore, there are no market forces that would drive consumers to use methanol.
- In the absence of normal market incentives, industry is not going to invest in the plants necessary to produce methanol in substantial volumes.

In addition to supply/capacity problems, the development of an efficient, high volume methanol distribution system seems problematic. It is generally impractical to ship low volumes (less than one to ten million gallons) of any fuel through existing pipelines. The physical properties, however, of methanol present even greater problems for shipment through existing pipelines than just reaching a volume threshold.

Few, if any pipelines, can handle water-soluble materials like methanol. In addition to being water soluble, methanol is also very corrosive. Diesel fuel and gasoline are insoluble in water and normal housekeeping practices are adequate to separate water from petroleum fuels. This is not the case with methanol. With methanol, some difficult steps have to be taken to keep the system dry and to keep products shipped through the pipeline dry. Also, because methanol has different solvent properties than petroleum fuels, the tanks and pipelines would have to be cleaned to ensure the purity of the methanol handled. In addition, there is some concern that the corrosiveness of methanol may preclude it from transportation and storage in existing tanks and pipelines.

Making methanol available in large quantities will require a substantial investment in a supply and distribution infrastructure. On the other hand, limited qualities of methanol are likely to be readily available with delivery by jumbo rail cars or by barge.

Methanol's primary market is likely to be with self fuelers because of the supply and serious handling problems associated with methanol. Its future use is limited by supply and costs. There are opportunities, however, to increase the efficiency of methanol manufacturing. Improved efficiency in methanol production facilities may reduce plant costs.

The main difficulty of adding new methanol manufacturing capacity is the investment required for methanol plants. Initial capital costs makeup about half the cost of methanol production. If facility costs can be decreased, then there would be greater incentives for increasing supplies. In addition, if the conversion of natural gas to methanol can be done more efficiently, the demands for natural gas feed stocks and the cost of production would decline.

Ethanol. Like methanol, ethanol is an oxygenated hydrocarbon. Pure ethanol consists of one molecule and, therefore, it boils at a specific temperature, 172 degrees F. Its density is about 6.62 pounds per gallon. The net energy content of ethanol is about 11,500 BTUs per pound or 76,000 BTUs per gallon. Although ethanol has more energy per gallon than methanol, it is still less-energy dense than traditional petroleum fuels by a factor of about 1.5 to 1.75.

The entire U.S. supply of ethanol for motor vehicle fuel is about 700 million gallons per year. The current supply represents only about one-half of one percent of the energy provided by gasoline. Clearly, there are limited supplies of ethanol and most of it is consumed as an adjunct to gasoline in gasohol.

Ethanol is blended with gasoline at the terminal rather then at the refinery. This is done for several reasons. First, the use of ethanol blended fuels are quite dispersed and it would cost even more to deliver blended fuels to the terminal than it does to blend the fuel at the terminal. The second reason is one shared with methanol. Ethanol has a high affinity for water and makes refinery blending and pipeline transporting impractical because it will absorb water. Third, the terminal blending allows fuel suppliers to use ethanol in states that provide the best tax incentives. Ethanol is used only in those states that provide favorable tax treatment.

Most fuel ethanol is made from corn, although it can made from other grains. Ethanol manufacturing consumes about 280 million bushels of corn annually, or about four percent of the normal U.S. corn crop. Manufacturing costs range from about $.90 to $1.80 per gallon depending on the size and efficiency of the plant and the method used to mill the grain. The overall energy balance for ethanol is essential even. That is, the energy required to grow and process the grain approximately equals the energy contained in ethanol and its byproducts. Ethanol's market price is currently around $1.10 to $1.20 per gallon.

About 80 percent of the normal U.S. corn crop (about seven to eight billion bushels) finds a ready market in animal feed, food, and corn sweeteners. The remainder is exported or stored. Converting ethanol not used for feed or food would add only about three to four billion more gallons of ethanol per year. This is equivalent, on an energy basis, to about two percent of the total energy consumed as gasoline. Increasing corn production above current levels would require planting on marginal land and increase the demand for irrigation and fertilizer. This would tend to drive up the cost of ethanol and make the energy balance worse (energy used to produce ethanol versus energy derived from ethanol) and even result in a negative energy balance. Therefore, it is extremely difficult to see that ethanol will ever be a source of a major portion of motor fuel energy. It is likely that the major role for ethanol will be serving as an oxygenate.

Compressed Natural Gas. Compressed Natural Gas (CNG) is predominately methane. It boils at or about 216 degrees below zero F. Its energy content is about 1,000 BTUs per cubic foot and it actually has more energy on a per pound basis than gasoline or diesel fuel. The biggest difficulty with CNG is squeezing enough of it together to provide a motor vehicle with a reasonable range.

CNGs most attractive characteristic is that a distribution system is already in place, because CNG is also used in many U.S. homes for heating and cooking. Furthermore, natural gas is relatively inexpensive. It costs about two dollars per million BTUs at the well head, about half the price on an energy unit basis, of crude oil.

One disadvantage of CNG is the location of the world's natural gas supplies. Currently, the quantity of natural gas delivered to the U.S. exceeds the demand for natural gas. This creates the false impression that there are large supplies of natural gas. In reality, the U.S. has a relatively small natural gas reserve. In fact, the U.S.'s natural gas reserves amount to about the same proportion of the world's supply as its petroleum reserves. Therefore, the U.S. is likely to find itself still dependent on foreign supplies if a major switch were made to CNG as a motor fuel.

Another disadvantage of natural gas is compressing it for use in vehicles. Besides the cost of transporting natural gas from the well head, the gas will have to be compressed. Only when the gas is compressed to 4,400 to 3,400 psi is it practical to use in motor vehicles. The investment in compressors will be significant. The cost for a fast fill facility could easily reach $250,000 per site. In addition, CNG vehicles must have heavy tanks which further limits the amount of cargo the vehicle can carry and increases the vehicle's cost. In fact a recent study conducted by AMOCO found that a fleet operator would have to tank CNG at less than four dollars per million BTUs (including taxes, cost of the gas, and capital recovery costs of the fixed facility) to be equivalent in cost to conventional fuels. Once excise taxes are added to CNG, it also loses its cost advantage. For example, the State of Illinois currently taxes natural gas at one dollar per one million BTUs and the equivalent federal excise taxes would be about 80 cents per one million BTUs. When taxes, the cost of the gas, the cost of refill stations, and the costs associated with fuels tanks are added, CNG is not cost competitive in comparison to petroleum fuels.

Because of the costs associated with CNG and distribution difficulties, it is doubtful the CNG will receive widespread use without regulation encouraging its use. Nevertheless, CNG has the greatest potential of all the alternative fuels because it has an existing distribution system and its cost, on an energy basis, is closest to the cost of petroleum fuels.

Liquefied Petroleum Gas. Liquefied petroleum gas (LPG) is a mixture of propane and butane. It is a gas, but can be compressed to a liquid at or about 300 pounds per square inch. On a per pound basis, it has more energy than gasoline or diesel fuel but only about 75 percent of the energy on a per gallon basis.

The total U.S. production is about 20 billion gallons per year. Most LPG is obtained as a byproduct of petroleum and natural gas extraction. Some of it is also generated in chemical plant and refinery operations. It is used in a variety purposes--chemical feed stock, process fuel, fuel for space heating and cooking, and about 2 billion gallons are being used for motor vehicle fuel.

LPG is transported from the production source mainly in jumbo rail tank cars and then distributed in trucks with capacities ranging from two thousand to six thousand gallons. Obviously, this is a more expensive distribution system than the one used to distribute petroleum products. Its current wholesale price is about twenty cents per gallon.

The largest drawback of LPG is that it is a crude oil and natural gas byproduct. Therefore, it is difficult to increase supply of LPG without increasing crude oil and natural gas production. Therefore, its share of the market will always be limited by the cap on LPG supply. Even if all the LPG were shifted from other uses, it would provide only ten percent of motor vehicle energy needs. Also, other fuels would have to be found for the uses that LPG no longer serves.

Reformulated Gasoline and Reformulated Diesel Fuel. These are included with the alternative fuels because they will be significantly different from the gasoline and diesel fuel used today. The objective of future fuel reformulation is primarily to improve the emission properties of the fuel. Actually, reformulated fuel is not a new idea. Removing lead from fuel to create unleaded gasoline is an example of fuel reformulation.

A new era of reformulation is starting. It begins with reductions in Reid Vapor Pressure (RVP) to help control fuel volatility. Another step of reformulation is blending in oxygenates to help control carbon monoxide emissions. Other reformulations will involve reducing benzine, an identified carcinogen, and other aromatic compounds. Reformulation is also likely to include a reduction of olefin, a hydrocarbon structure, to reduce reactive hydrocarbon emissions in older vehicles without catalytic converters. Closer control of the 90 percent distillation temperature, the temperature at which 90 percent of the fuel is evaporated, is also being considered to reduce hydrocarbon emissions. Reformulation will incur some additional costs and have some impact on reformulated fuel supply as the necessary processes are incorporated into the refining process. These factors are likely to translate as cost increases in the range of ten cents per gallon. However, there is a lot of work left to be done to determine the desired properties of reformulated gasoline.

Reformulated fuels are particular attractive compared to other alternative fuels because they can use existing distribution systems. Another attraction is that existing vehicles can burn reformulated fuels without modification. This would mean that emissions from all vehicles, not just those modified to burn alternative fuels, would be reduced.

Reformulating diesel fuel is more familiar than reformulating gasoline. The specific composition changes of diesel fuel include a ten fold reduction of sulfur content--sulfur is a direct contributor to particulate emissions. Furthermore, because there is a relationship between aromatic content and cetane, aromatic levels will cap at what they are today by requiring a minimum of 40 cetane index. These two changes require an investment at most refineries and result in about a five-cent cost increase.

Future reformulation of diesel fuel may include a reduction in aromatic and other additives to reduce engine emissions and/or prolong the engine's emission--reducing features. This may include additives that reduce engine deposits to keep emission control systems clean.

Reformulated diesel fuel benefits from its acceptance in the market place and from its proven, efficient distribution system. It would also have a broad impact by improving the emissions of all diesel engines regardless of their age or technology.

Conclusions

This presentation has explored the leading alternative fuels from a distribution and marketing perspective. Clearly, there are no easy answers.

It is likely that the future fuel market will see a larger variety of fuels, each with its own specifications and properties. Except reformulated gasoline and diesel fuel, all will suffer from problems related to distribution, compatibility with existing engines, and cost per unit of energy. Clearly, any shift to an alternative fuel will only be achieved through a governmental mandate or regulation. This is even true for a shift to reformulated fuels due to the necessary expenditures to produce reformulated fuels.