ALTERNATIVE FUELS FOR TRANSPORTATION APPLICATIONS

STEPHEN E. BLAKE

Editor's note: At the TRB's 64th Annual Meeting in January 1985, two sessions were devoted to the subject of alternative fuels. A number of issues related to alternative fuels were explored in the papers presented at these sessions; summaries of those presentations are provided in this article.

Stephen E. Blake is Environmental Specialist, TRB

During the next 20 years, alternative fuels for transportation applications will play an increasingly important role in the fueling of this country's transportation fleet. This statement might appear somewhat suspect given the current "oil glut" and the continuing efforts to conserve our natural resources. Why then will alternative fuels become important? Primarily because petroleum is a finite, nonrenewable resource. In addition, the instability of the oil-producing nations warrants an examination and development of sources of fuel that would reduce the dependence of the United States on foreign governments. Given these concerns, what are the available options?

In a presentation on "Commercialization of Alternative Fuels in the United States," Eugene Ecklund, U.S. Department of Energy, stated that "it is possible to reduce the nation's dependence on petroleum by use of other fuels that will not necessarily replace petroleum products, providing it makes social and economic sense to do so." Therefore, research and development and applications work on new fuels have included those fuels that can be used in limited quantities, often for only a limited period of time. These are designated as substitutes. Those fuels that can serve to extend and eventually replace petroleum products are designated alternatives. Based on dependence on indigenous resources, the available options include two substitutes—liquified petroleum gases (propane) and methane; and three alternatives—hydrogen, alcohols, and synthetic fuels.

Whether a substitute or an alternative is the most economic and cost-efficient option can be determined by a variety of factors. Among those that resulted from the energy crisis in the mid-1970s are vehicle size and fuel-economy concerns. Other factors include changing vehicle design, acquisition and operating costs, vehicle range, refueling requirements, maintenance, and safety.

Electric Vehicles and Brayton and Stirling Automotive Engines

Electric vehicles provide a means of replacing petroleum by utilizing alternative fuels at the generating plant. However, the shortcomings of electric vehicles (limited range, bulky battery packs, and costs of battery replacement) limit the operational applications of these vehicles. Unless en route recharging is developed successfully or major breakthroughs in battery technology occur, electric vehicles are likely to be used for short-trip light-duty deliveries, commuting, or business services, primarily in densely populated urbanized areas. Electric vehicles are currently utilized in commercial fleets; further commercialization will be dependent on new battery technology.

The problems associated with Brayton and Stirling engines are somewhat different; they stem from costs and the process of innovation. Danilo Santini, Argonne National Laboratory, stated: "It has been shown that automotive engine innovation in the past has been costly, especially to lower-income consumers, and that potential future adoption of Stirling and Brayton engines is unlikely to be any different."

The TAPCUT study (Argonne National Laboratory, 1982) predicts that the Stirling and Brayton engines will have very specific and different markets.

State-of-the-art electric vehicles (U.S. Department of Energy).

The most likely market for the Stirling engine will be as a specialized urban vehicle, whereas the best market for the Brayton engine will be as a specialized suburban and intercity vehicle. The report suggests that neither engine has the properties necessary to become a universal replacement for all-purpose vehicles using advanced Otto-cycle and diesel engines, but that proper use of these vehicles could ultimately help efficiently mitigate national problems of urban air pollution and excessive fuel consumption.

Characteristics of Substitute and Alternative Fuels

Liquified Petroleum Gases (Propane)
The use of liquified petroleum gases centers on propane, which is a relatively high-octane fuel that provides improved efficiency, emissions, and cold starting compared with gasoline. At ambient temperatures, propane is a gas and the vehicle fuel systems components provide for pressure reduction so that the fuel enters the combustion chamber in gaseous form. This results in a power loss of 5 to 20 percent. Although liquid propane has approximately 70 percent of the energy per unit volume of gasoline, it is economically attractive on both a volumetric and operational basis.

The Ford Motor Company manufactures an automobile (available on special order) that is optimized for propane, with performance features approaching those of gasoline. However, most vehicles are retrofitted in the field and provide for dual-fuel operation, using gasoline as a backup fuel. This usually costs $1,000 to $1,500 per vehicle.

Approximately 1.5 million propane vehicles are in operation in the United States. A nationwide network of propane dealers exists that would allow, with proper planning, a driver to travel from coast to coast, refueling during conventional business hours.

The safety of propane is comparable to that of gasoline with the exception of the explosive nature of escaping gas. All propane tanks are equipped with an automatic cutoff valve that decreases the risk of explosion in the event that fuel lines and valves are damaged. Because LPG is a by-product of petroleum refining, it could only replace approximately 2 percent of petroleum use. However, imports currently exceed vehicular use, and worldwide supplies will continue to exceed use for a number of years.

Methane
This is the major constituent in natural gas and a good, high-octane fuel. Similar to propane, it is in a gaseous form at ambient conditions, thereby offering good distribution in the engine intake system, improved cold starting, and reduced emissions compared with gasoline. Fuel cost on an energy basis is less than that of petroleum, and it is unlikely that future prices will rise substantially. The physical requirements of vehicular modification are similar to those for propane, except that fuel shortage is a greater problem. Cylindrical tanks, similar to the ones used for industrial gas storage, are used and pressurized to 2,400 psi [compressed natural gas (CNG)]. Only one-sixth the energy of gasoline is contained per unit volume, thereby severely limiting range. If the fuel is liquified natural gas (LNG), its energy density is about two-thirds that of gasoline. However, this creates other problems; cryogenic, insulated storage is then required to maintain the fuel at a temperature lower than its 259° F boiling point.

The cost of retrofitting vehicles for a CNG dual-fuel system is approximately

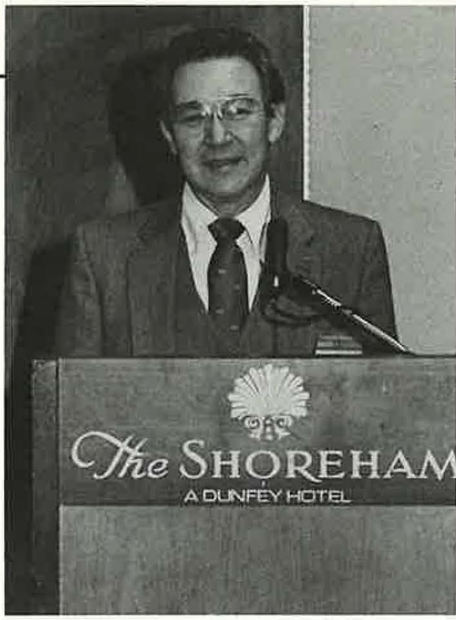
$1,000 to $1,500, but provisions for refueling are required. For a typical fleet refueling system, this operation will cost approximately $100,000 to $150,000. The two methods for refueling CNG vehicles are "fast fill" and "slow fill." "Fast-fill" refueling takes about 5 minutes by utilizing a high-volume, high-pressure source to fill the vehicle. "Slow-fill" refueling takes several hours and is used primarily for overnight parallel servicing of a number of vehicles. With the additional weight of the storage system and the lower energy output, approximately a 10 to 20 percent loss in power occurs.

Methane is as safe as, if not safer than, gasoline, depending on the circumstances; in open air methane dissipates in the atmosphere, but in confined spaces it can be dangerous. Therefore, areas that could trap leaking methane, such as automobile trunks and garage ceilings, must be vented. Because of these factors, restrictions exist in many areas that inhibit the use of methane-fueled vehicles.

Hydrogen

Although hydrogen has many industrial uses, it is not readily available as a fuel. Because of its clean-burning characteristic, it is an attractive alternative. However, its high-flame temperature can result in oxides of nitrogen (NOx) emissions significantly higher than those of gasoline vehicles.

Hydrogen-fueled vehicles would suffer from the same deficiencies that plague other gaseous-fueled vehicles—power loss and heavy fuel-storage systems. Although considerable technical information exists to permit the use of experimental hydrogen vehicles, it is unlikely that there will be significant use of these vehicles in the next several decades.



Daniel Maxfield, U.S. Department of Energy, offers opening remarks at the session on alternative fuels at TRB's Annual Meeting.

Alcohols

Ethanol and methanol are the alcohols generally discussed as vehicular fuels and constitute a category referred to as oxygenated hydrocarbons. The characteristics of this group are high-octane ratings, lower NOx emissions, and lower emissions of hydrocarbons. To achieve these results with straight alcohol fuels, it is necessary to utilize high-compression engines. The technology is available for vehicles to operate on straight alcohol, and approximately 1,000 experimental vehicles are operating in commercial fleets. However, it is unlikely that straight alcohol will be commercialized without government intervention.

The typical use of alcohols has been as blends with gasoline. In 1983 nearly 1 billion gallons of oxygenated hydrocarbons were used in gasoline. Both use and manufacturing capacity are growing. Although methanol is widely used as an industrial chemical, excess supply and capacity exist in all regions of the world. Because excess cannot be absorbed in the chemical market, pressure is generated to use it as a vehicular fuel. The amount available, however, represents only 1 percent of gasoline in the United States, but resources are plentiful.

One of the problems of increased use of alcohol fuels is the loss of revenue to state highway and transportation departments due to the exempting of gasoline-alcohol blended fuels from state and federal taxes. This loss in revenue will become more significant as greater amounts of gasoline are blended with alcohol fuels. An examination of this problem is warranted at the state and federal levels.

Synthetic Fuels

These fuels are made by liquifying oil shale or coal and are gasoline-like or diesel-like in composition. Therefore, there is little concern about vehicle operations, performance, and design. Similarly, transportation, storage, transfer, safety, and other factors should be largely the same as for existing products.

Research and development of synthetic fuels is being conducted by the U.S. Department of Energy. If this program is successful, fuels used 15 to 20 years from now will be derived from syncrades.

Summary

In the area of fuels for transportation, there is movement away from a nearly monolithic fuel structure to a multilayered structure with a number of fuels finding their particular niche. During the next 15 to 20 years, this diversification should continue with the result being a system far more efficient than the current one. Design of vehicles, cost of fuel, and fuel availability will change to reflect this trend. Although gasoline-alcohol blends will dominate the transportation fuel sector, propane, natural gas, and straight alcohol fuels will each have a market in the future. The only fuel that will not be used to a significant extent will be hydrogen.