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THE ISSUE: FUEL CELL TECHNOLOGY

by
Jason H. Gross, Research Analyst

Introduction

Concerns regarding the prevalence of foreign oil and the environmental effects of petroleum-derived fuel have created an interest in alternative sources of power. One such alternative that can be adapted to vehicles and power utilities is the fuel cell. Fuel cells are a power source that is derived from an electrochemical reaction that burns clean, is highly efficient, and operates on domestically available fuel sources.

Fuel cells were first created in 1839 by William Grove. Grove, a British attorney and physicist, discovered that four large cells, each containing hydrogen and oxygen, could produce electric power.

In his experiments, Grove used the power to split water into different cells. In the 1960's, the National Aeronautics and Space Administration (NASA) demonstrated the potential effectiveness of fuel cells by using them to provide power during its space flights. It was important for NASA to use fuel cells because they did not emit pollution or heat, critical factors on a sealed spacecraft. As a result of NASA's successful use of the fuel cell, private industry began to recognize its commercial potential. Unfortunately, technical and monetary constraints barred fuel cells from being economically competitive with existing energy technologies of the time.

As a result of the work at the DOE, hundreds of companies utilizing incentive programs have begun working toward making fuel cells economically and technologically viable. Companies are being driven to this end by technical, economic, and social forces. These companies are also finding advantages in high performance characteristics, reliability, durability, low cost, and environmental benefits. Currently corporations continue to research and develop fuel cell technology for the future.

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How they work

All internal combustion engines, batteries, and fuel cells convert one form of energy into another more usable and stable form of energy. Internal combustion engines, in use in most cars, generate power from high temperature internal combustion of fuel mixed with oxygen from the atmosphere. The energy stored in the fuel is converted to thermal energy in order to generate mechanical energy. Fuel cells and batteries are different because fuel cells are electrochemically based.

Unlike internal combustion engines, fuel cells convert chemical energy directly into electrical energy without combustion and the wasteful loss of energy through thermal production. This process is relatively cool and water is the only emission. Still, a fuel tank and oxygen from the air are needed for a fuel cell to operate.

Fuel cells convert chemicals into energy up to three times more efficiently than an internal combustion engine converting fuel to power. Fuel cells produce electricity, water, and heat by using fuel and oxygen in the air. As hydrogen flows into the fuel cell on the anode side, a platinum catalyst facilitates the separation of the hydrogen gas into electrons and hydrogen ions. The hydrogen ions pass through a membrane at the center of the fuel cell, with the help of another platinum catalyst, then combine with oxygen and electrons on the cathode side, producing water. The electrons cannot pass through the membrane and flow from the anode to the cathode on an external circuit. The circuit contains a motor, which generates an electric load by consuming the power generated by the cell. Each single cell makes about 0.7 volts, enough to power a light bulb. To multiply output to power a car, cells must be stacked in series.

While hydrogen-based fuel cells are the relative mainstream in fuel cell technology, fuel cells employing methanol as a fuel source are under development. As in the hydrogen/air fuel cell, oxygen from the surrounding air acts as an oxidant, but instead of hydrogen, liquid methanol is the fuel being oxidized by the anode. Methanol fuel cell technology has thus far lagged behind the more conventional hydrogen fuel cell. However, recent advances in direct methanol fuel cell research and development have brought us close to a mainstream methanol fuel cell.

Methanol (CH3OH) is a clear and odorless liquid that is used in manufacturing and chemical products. It acts as a hydrogen carrier for fuel cell applications. Most methanol today is produced from natural gas in commercial facilities. The process includes two steps. First, natural gas is converted into a synthesis gas stream. Second, catalytic synthesis of methanol from the gas is performed to transform the gas into a liquid.

Methanol can be used as a power source for fuel cell power plants, but is highly portable and can be used as a carrier in portable devices such as vehicles and cellular phones. Methanol is a superior fuel for turbines and can significantly reduce nitrogen oxide (NOx) emissions. Methanol can be derived from wood products out of formaldehyde resins that naturally occur in wood. Methanol is also produced from natural gas and landfill methane production systems. The United States produces nearly one-fourth of all the world's methanol. U.S. production meets about one-half of the U.S. requirements and the remaining supply is imported from Trinidad, Chile, Venezuela, and Canada. Methanol fuel cells contain several unique problems related to their fuel source. In order to achieve high current, the amount of platinum catalyst is greater in the methanol fuel cell than it is in the hydrogen fuel cell. Also, as methanol fuel crosses through the membrane from the anode to the cathode, the amount of undesired methanol decreases the overall performance of the air cathode, which in turn wastes fuel. Methanol fuel cells are considered a zero emission vehicle.

The advantage to methanol as opposed to hydrogen as a fuel is that methanol is a liquid fuel source. This means less infrastructure is required to supply large quantities of methanol to the population using fuel cell equipped vehicles. Additionally, direct methanol fuel systems do not require bulky, heavy storage systems for containing the fuel source, as is the case with hydrogen based fuel cell systems. Because of their simplicity and cost, direct methanol fuel cell systems present an attractive alternative to the more conventional hydrogen fuel cell systems.

Methanol is also known as wood alcohol, and is produced from methane gas from landfills, reforming natural gas and from a variety of biomass resources such as grain products like corn. At ambient temperatures, methanol is a liquid, which carries as a major component hydrogen as a fuel source. Methanol tanks can be installed at existing service stations for approximately $62,000. Because of the minimal investment costs methanol has much lower infrastructure costs associated with it than the equivalent hydrogen fuel cell technology. For an investment of $2.7 billion, methanol pumps can be fully installed in one-quarter of national service stations. Additionally the cost for methanol is extremely economical, expecting to retail for around 80 cents per gallon.

Benefits

Because fuel cells do not rely on combustion, instead relying on chemical reactions to generate electricity, fuel cell vehicles are 70-90 percent more efficient than conventionally powered vehicles. Fuel cell vehicles produce no emissions, and even lack a tailpipe to emit the usual harmful gases of conventional vehicles. The advantages of fuel cells over conventional power generating systems are efficiency, low chemical, acoustic, and thermal emissions, location flexibility, reliability, low maintenance, excellent part load performance, modularity, and fuel flexibility. Fuel cells have the potential to provide environmental, energy, and economic benefits to advance critical national economic, political, and environmental goals. The modular design of fuel cells allows a convenient placement of the power source near the end user, an arrangement called distributed generation.

Due to higher efficiency and lower oxidation temperatures, fuel cells emit less carbon dioxide (CO2) and nitrogen oxides per kilowatt of power generated than conventional generating systems. Also, the noise and vibration characteristics in traditional power generation are practically nonexistent in a fuel cell powered system. Fuel cells' potential to provide zero or near zero emissions has been a significant motivating force in the development of fuel cell technology. Direct hydrogen/air systems are the only fuel cells which have zero emissions. On board processing of gasoline, methanol, and other carbon-based fuels into hydrogen rich gas can create small amounts of emissions, water, and CO2.

Another benefit of fuel cells is their relative energy security resulting from reliance on renewable and domestically produced energy sources. Oil imports supply almost 60 percent of U.S. demand. If fuel cell vehicles penetrated the market by 10 percent, the U.S. would reduce oil consumption by 130 million barrels a year. If 10,000 fuel cell equipped vehicles were running on renewable hydrogen, we would save 7 million gallons of gasoline a year.

Drawbacks

Negative aspects of fuel cell use include short operating life, high equipment costs, lack of infrastructure, and lack of field use and experience. There are also significant cost and technological barriers and market forces making fuel cells relatively expensive. Negative market forces include federally regulated emission standards and deregulation of the energy industry, which deters fuel cell commercialization. The higher costs associated with developing fuel cell power create a market bias against fuel cell implementation. Electric and gas utilities have traditionally helped pioneer new technologies but have been reluctant to pioneer high risk technologies that have a prohibitively higher cost as compared to lower cost conventional energy generating systems.

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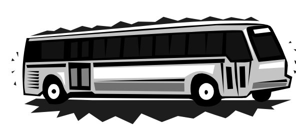
Implementation

Automobiles are the single largest users of oil products and one of the single largest polluters in the world, with over 200 million vehicles on the road in the U.S. Cleaning up the environmental hazards and fuel consumption concerns in automobiles are among the largest motivators in developing fuel cell technology.

Because of the compact nature of fuel cells, automobiles are one of the best users of fuel cell technology and such technology is already in use in several automobile demonstration programs. Because of the cleanliness of fuel cells, implementation in American cars would result in millions of pounds of emissions being eliminated from our atmosphere each year. Currently no fuel cell equipped vehicles are available to the general public, but they are in use in municipal fleets in high population centers such as Chicago, Illinois, and Vancouver, B.C.

Mass transportation and fleet vehicle applications are well suited to fuel cell power because cells provide continuous electrical energy supply at high levels of efficiency and power density. Additionally, fuel cell powered vehicles have few moving parts so the power system requires little or no maintenance, an important factor in high demand applications such as mass transit. Future research and development must be made in fitting fuel cells into vehicles. Major automobile manufacturers such as DaimlerChrysler and Ford are currently streamlining and adapting fuel cells to vehicle applications.



Distributed generation is another potential alternative use of fuel cells. Worldwide electric power production is based on a centralized, grid-dependent network. This has disadvantages -- high emissions, transmission losses, delays for new plant construction, and capacity. Distributed generation is the integrated or stand-alone use of modular resources by utilities, utility customers, and third parties in applications providing alternatives to producing power via the centralized power production system. Distributed generation uses small fuel cell plants in homes and businesses, which supplement or replace conventional electrical supply systems. Because of the cleanliness, efficiency, small footprint, and production potential of fuel cells, it is conceivable that small fuel cell systems could be placed close to the areas where power is needed. For instance, a home could use fuel cells right in the home, much like using a home heating furnace, to provide electrical power. Some of the advantages to distributed generation include: peak shaving which allows the end consumer to take advantage of time of day pricing; cogeneration; uninterrupted and high power quality; less pressure on utilities to meet electrical supply demand; and effective servicing of remote locations. Also since fuel cells are highly efficient, produce low emissions, site flexible, reliable, and modular they provide a unique and potentially important source of energy production.

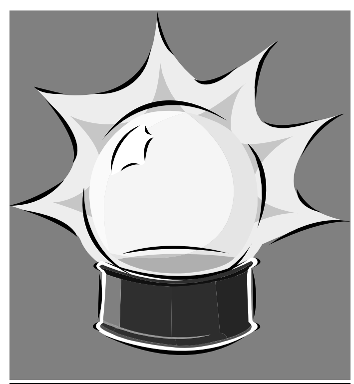
Infrastructure

The cost of infrastructure to produce the necessary fuel for fuel cell power is a significant barrier to the widespread implementation of fuel cell technology. In order for fuel cells to operate in the marketplace, hydrogen and methanol must be available to the end users. Although the costs of providing a hydrogen infrastructure are expensive, the reforming of the current natural gas infrastructure may be possible, thus reducing the cost of providing hydrogen for fuel cell users. Considering that gasoline is expensive to produce, generate and use, even as compared to hydrogen and methanol, an investment in alternative fuels for use in fuel cells is relatively inexpensive in the long term. Although the initial capital expenditures for methanol and hydrogen may be high, the life cycle of the hydrogen and methanol equipment is much longer. Also the infrastructure cost per fuel cell vehicle is less over the life of the vehicle when the total cost of the fuel, emissions, transportation and production of the fuel is taken into account. When all factors are considered, developing the infrastructure for fuel cells has a net cost which is lower than sustaining the current carbon-based fuel system into the foreseeable future.

The Future

Future developments in fuel cell technology potentially include:

- Further development and streamlining of fuel cell plants.
- Small power plant development (for homes and municipalities).
- Progress by car manufacturers in developing methanol fuel cell vehicles.
- Utilities use of fuel cells as an alternative or supplement to petroleum derived fuel.
- Infrastructure development and fuel convergence.
- Methanol development as an alternative to pure hydrogen.



Conclusion

Fuel cells offer a high degree of operational efficiency, zero emissions, and reduced reliance on foreign petroleum. If the technological and infrastructure barriers can be remedied, fuel cells provide enormous environmental, economic, and political benefits. If these benefits are to be realized we must commit to the technological and infrastructure developments that are required for fuel cell advancement.

Editor's Note

Green Papers will be issued periodically by the Joint Legislative Air and Water Pollution Control and Conservation Committee staff. As indicated by the subtitle, each Green Paper will be a monograph on a specific environmental issue that has come to the attention of or is being dealt with by the committee. Each Green Paper is intended to provide a more in-depth look at specific issues than normally permitted by other committee publications, such as the committee's monthly newsletter the *Environmental Synopsis*.

Each Green Paper may also be found on the committee's new Internet website, in addition to on-line editions of the *Environmental Synopsis*, and other committee news and events. Please visit the website at **http://jcc.legis.state.pa.us.**

The Joint Conservation Committee is a bipartisan committee consisting of 18 members of the state House and Senate which conducts studies, holds hearings and makes recommendations to the General Assembly on air and water pollution laws, mining practices and land reclamation. Recent issues that the committee has focused upon include land use and growth management issues, sewer and water infrastructure, and Pennsylvania's Heritage Park program.

For more information about the committee, or to be added to the mailing list for future Green Papers or the *Environmental Synopsis*, call the committee office at (717) 787-7570.