OVERVIEW

A fuel cell is a device for directly converting the chemical energy of a fuel, such as hydrogen or a hydrogen-rich gas, and an oxidant into electrical energy. It also produces heat, which in some applications may be a useful byproduct. Small, specialized fuel cells were first successfully used in the Gemini space program. Recent technological advances with other types of fuel cells and small-scale demonstrations have encouraged the development of fuel cell technology for commercial land-based use.

The private sector has been conducting fuel cell research in the United States for more than 20 years. Federal funding also began more than 20 years ago with the National Aeronautics and Space Administration's (NASA) program. The Department of Energy (DOE) began funding fuel cell research in 1976. Although fuel cells are still under development for commercial use, these efforts are beginning to bear fruit. Several types of fuel cells are being investigated, but phosphoric acid fuel cells are nearly ready for commercial use in sizes ranging from a few kilowatts to a few megawatts.

The most promising near-term uses for fuel cell technology are for applications in the electric and gas utility industries. However, fuel cells have also been considered for automobile, train, and marine applications. The use of non-petroleum-fueled fuel cells in transportation is most desirable from the standpoint of oil displacement, but application of fuel cell technology to the transportation field in general and to the marine transportation area in particular is still in the early exploratory stage.

For marine applications, it has been suggested that fuel cells be employed to provide propulsion or auxiliary power for cruise ships, powered barges, ferry boats, offshore supply boats, push-tow boats, oceangoing tugs, submersibles, and even submarine tankers. Fuel cells have also been suggested for use as power sources for offshore oil platforms, for underwater facilities, and for refrigerated containers on containerships. Some of these possible applications may be technically feasible and cost-effective in a decade or so. Other potential applications (e.g., fuel-cell-powered submarine tankers) may take much longer to develop. In any case, successful development for commercial needs will depend on economic factors in addition to technical feasibility; likewise, successful development for military uses will also depend on mission requirements.

If fuel cells prove technically and economically feasible, they could conceivably replace many electrical generating systems in use today in a myriad of applications, from small transportation units to large power stations. Their advantages over existing systems could include higher efficiencies, lower cost, reduced emissions, and fewer maintenance problems. Many of the benefits fuel cells could provide to the utility industry could also apply in the marine field. Of special interest is the potential of fuel cells for high efficiency, since this efficiency may translate into fuel cost savings. Moreover, fuel cell efficiency is relatively constant over a broad range of power settings. Such a characteristic suggests that fuel cells might be efficiently employed in ships that frequently vary power demand—e. g., towboats, ferries, or offshore supply boats. Capability of using a variety of fuels is another potential advantage. In addition to the potential for providing main propulsion, fuel cells could also supply auxiliary power and other heat needs.

Several other characteristics of fuel cells could provide benefits for specific applications. The fact that fuel cell systems are of modular design enables flexibility in the arrangement of plant components and could lead to a more cost-effective layout of power and cargo spaces and of basic ship structure. However, overall space and volume requirements of the fuel cell system and fuel will probably be greater than for present systems. As with other electrical powerplants, the maneuvering problems of ships and tugs might be mitigated by the advantage fuel cells provide in enabling electric power to be quickly switched to various locations to reverse main propellers or to activate side thrust propellers or water jets. Fuel cells have few moving parts, suggesting minimal manning requirements. Since they produce little noise, they may have possible uses on anti-submarine warfare ships and seismic survey vessels.

Finally, fuel cells offer greater endurance than batteries for some types of submerged operation.

Despite these potential benefits, commercial marine applications for fuel cells are a long way off. None of the advantages stated above have been demonstrated for marine fuel cells, and a number of present problems constrain private development today. The marine market is not in itself large enough to drive fuel cell technology developments. Hence, it is not expected that fuel cells will penetrate marine markets before they become firmly established in the commercial utility sector. Even then, fuel cell systems will have a difficult time capturing a large share of the market, given competition from other systems. Shipbuilders will need to use and adapt products developed first either for the utility industry or for the Department of Defense (DOD). Moreover, potential cost advantages to onsite shore users due to large-scale production may not accrue to the marine industry.

Given these constraints, Federal assistance will be required if the Federal Government wishes to accelerate the development of fuel cells for the commercial marine sector. Though OTA has not evaluated the rationale for such Federal assistance, many reasons to do so have been advanced. For example, the Federal Government may wish to stimulate commercial development of marine fuel cells in order to reduce dependence on traditional fuels (e.g., diesel oil), to help ensure the transition to alternative fuels as traditional fuels become scarce, to help reduce pollutant emissions, or for other reasons. It has also been suggested that if the United States does not push development of fuel cells, as the Japanese are doing, a developing market in which the United States now has a technical lead will be lost.

Fuel cell technology may offer benefits to the military as well. However, development of fuel cell technology for military purposes can best be considered separate from development for commercial purposes. If fuel cells prove to be the best technology for specific military applications, cost constraints that would slow development in the commercial sector would be a less limiting factor.

Some Options for the Federal Government

The outlook for using fuel cells in the electric and gas utility industry appears promising. The Federal Government has supported private sector research and development (R&D) efforts since the 1960s. Continued Federal support of fuel cell development programs is probably necessary to advance the introduction of fuel cell technology into the land-based utility industry.

The use of fuel cells in the marine industry in the next 15 to 20 years is far less certain. When and if the commercial maritime industry decides that fuel cell power systems would provide significant cost and/or other advantages over competing power systems, these fuel cell systems must be adapted to the unique demands of the marine environment. Very little R&D on fuel cells for marine applications is currently underway inside or outside the government. Since the R&D program for land-based applications is so large in comparison, some believe that the proper course for the marine industry is just to monitor closely that R&D and select developments and applications as they may occur in the future. Others believe that unique marine requirements warrant specialized R&D efforts.

Specific research and development could be supported by the Federal Government and/or industry to improve the potential of fuel cells in the marine market. For example, the near-term use of fuel cells in the marine industry could be stimulated by developing technology capable of reforming diesel oil. Other research that could be undertaken includes: laboratory testing, followed by shipboard analysis and testing, of fuel cell components to determine their suitability and/or vulnerability to the marine environment; basic electrochemical studies to improve catalysts and electrolytes that would not be contaminated by fuel processed from fuel oil; and accelerated investigation of molten carbonate fuel cells and of the vulnerability of this type of fuel cell to the marine environment. The Federal Government's investment in molten carbonate technology could concentrate on those developments needed to support a demonstration of this fuel cell's higher efficiency and fuel flexibility. The private sector could focus on the technology and processes needed to manufacture these fuel cells at a cost competitive with conventional power generators.

The Maritime Administration, and perhaps other agencies within the Department of Transportation, and DOE might be able to offer some assistance for applications more directly relevant for the commercial transportation sector. For instance, funding could be provided to demonstrate and evaluate use of a fuel cell system on a commercial ship or locomotive. One suggestion is that future fuel cell research for heavy-duty transportation applications focus on developing the more efficient molten carbonate fuel cells. Once a small (i.e., 50 kilowatts (kW)) molten carbonate system has been demonstrated, these agencies could coordinate a demonstration of a 2 to 4 megawatt (MW) powerplant for the heavy-duty transportation sector. Different types of incentives to private industry might also be used, such as tax benefits for those who use non-petroleum-based fuels or accelerated depreciation.

The Federal Government may also wish to encourage the Navy, Army, Air Force, and Coast Guard to become more involved in developing fuel cells for their mission requirements, OTA's analysis indicates potential benefits of marine fuel cell use in naval applications, and suggests that more in-depth analysis of the potential applicability of fuel cell technologies for Navy missions is needed.

The Navy is currently monitoring fuel cell developments, but it may be useful for the Navy to consider supporting specialized research into marine fuel cell development as well. At present, for example, very little work has been done on developing fuel cells for "quiet" ship operation aboard certain vessels where noise emissions from conventional engines are a major problem. If fuel cells could match these and other unique Navy missions, then naval fuel cell research, independent of private sector efforts, may be justified.

Recognizing that research funds are limited and must be carefully targeted to the most productive avenues of research, it may be best to begin by encouraging the military to develop small fuel cell systems for auxiliary power on naval surface ships, As experience is gained, larger fuel cells (on the order of a megawatt) might be used for naval and Coast Guard auxiliary power. Finally, beyond 2000, the Navy or Coast Guard could be encouraged to focus on developing larger fuel cell powerplants for primary propulsion power. The Navy and Coast Guard have different missions than the civilian sector and some applications developed by them may not be directly useful for the private sector. On the other hand, some applications first developed for military purposes might stimulate development of applications for commercial use.