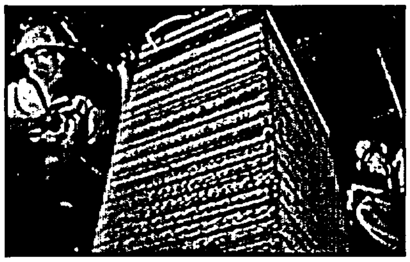
Future Fuel Cells R&D



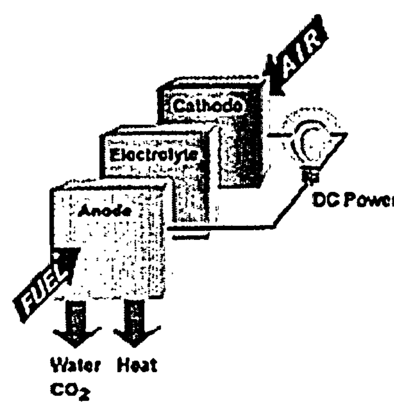
"So we're creating the National Climate Change Technology Initiative...to fund demonstration projects for cutting-edge technologies, such as fuel cells."
President George W. Bush
June 11, 2001

MORE INFO
- Phosphoric Acid Fuel Cells
- Molten Carbonate Fuel Cells
- Solid Oxide Fuel Cells
- Solid State Energy Conversion Alliance

Fuel cells are an energy user's dream: an efficient, combustion-less, virtually pollution-free power source, capable of being sited in downtown urban areas or in remote regions, that runs almost silently, and has few moving parts.

Using an electrochemical process discovered more than 150 years ago, fuel cells began supplying electric power for spacecraft in the 1960s. Today they are being used in more down-to-earth applications: to provide on-site power for banks, police stations, and office buildings. In the near future, fuel cells could be propelling automobiles and allowing homeowners to generate electricity in their basements or backyards.

Fuel cells operate much like a battery, turning oxygen and hydrogen into electricity in the presence of an electrically conductive material called an electrolyte. Unlike a battery, however, fuel cells never lose their charge. As long as there is a constant source of fuel – usually natural gas for the hydrogen and air for the oxygen – fuel cells will generate electricity.



DOE's Stationary Power Fuel Cell Program

The U.S. Department of Energy's Office of Fossil Energy is partnering with several fuel cell developers to develop the technology for the stationary power generation sector - that is, for power units that can be connected into the electricity grid primarily as distributed generation units. Industry participation is extensive, with more than 40 percent of the program funded by the private sector. If the joint government-industry fuel cell program is successful, the world's power industry will have a revolutionary new option for generating electricity with efficiencies, reliabilities, and environmental performance unmatched by conventional electricity generating approaches.

For most of the 1970s and early 1980s, the federal program included development of the phosphoric acid fuel cell system, considered the "first generation" of modern-day fuel cell technologies. Largely because of the federal program, United Technologies Corporation and its subsidiaries manufactured and sold phosphoric acid fuel cells around the world.

In the late 1980s, the department shifted its emphasis to advanced generations of fuel cell technologies, specifically the molten carbonate and solid oxide fuel cell systems. The goal is to ready these technologies for initial commercial entry by 2003. Federal funding for these technologies is concluding, and private commercial manufacturing facilities have been and continue to be built. Commercial entry is expected in the near future.

While the initial generations of fuel cells will continue to develop the market and spur interest in fuel cell technologies, the focus of the Department of Energy's fuel cell program is now to develop a much lower cost fuel cell - the target is $400 per kilowatt - that can significantly widen market acceptance of future fuel cells (see below).

Fuel Cell Benefits

Fuel cells are one of the cleanest and most efficient technologies for generating electricity. Since there is no combustion, there are none of the pollutants commonly produced by boilers and furnaces. For systems designed to consume hydrogen directly, the only products are electricity, water and heat.

News & Event
- New Fuel Cel Continue Pro Emissions En

More

Project Info
- Database of F Projects
- National Ener Laboratory W

Program Conta
- Samuel Bionc Office of Foss (FE-22) U.S Dept. of DC, Washingt 301-903-591C
- Mark Williams National Ener Laboratory PO Box 880 U.S. Dept. of WV, Morgant 304-285-4747

When natural gas or other hydrocarbons are used, fuel cells produce some carbon dioxide, though much less than would be created if the fuel was burned. Advanced fuel cells using natural gas, for example, could potentially reduce carbon dioxide emissions by 60% compared to a conventional coal plant and by 25% compared to today's natural gas plants. Moreover, the carbon dioxide is emitted in concentrated form which makes its capture and sequestration much easier.

Fuel cells are so clean that, in the United States, 20 states have financial incentives. In fact, the South Coast Air Quality Management District in southern California and regulatory authorities in Massachusetts and Connecticut have exempted fuel cells from air quality permitting requirements. Some 14 states have portfolio standards or set asides for fuel cells and there are major fuel cell programs in New York (NYSERDA), Connecticut (Connecticut Clean Energy Fund), Ohio (Ohio Development Department), and California (California Energy Commission.) In addition, some states have favorable policies which improve the economics of fuel cell projects. For example, some 36 states have net metering, and 14 states have net metering for fuel cells.

Fuel cells are also inherently flexible. Like batteries in a flashlight, the cells in fuel cells can be stacked to produce voltage levels that match specific power needs, from a few watts for certain appliances to multiple megawatt power stations that can light a community.

Cost - the Major Hurdle

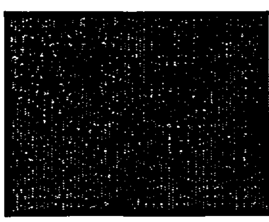
So why aren't fuel cells being installed everywhere there is a need for more power?

The primary reason is cost. Fuel cells developed for the space program in the 1960s and 1970s were extremely expensive and impractical for terrestrial power applications. During the past three decades, significant efforts have been made to develop more practical and affordable designs for stationary power applications. But progress has been slow. Today, the most widely marketed fuel cells cost about $4,500 per kilowatt; by contrast, a diesel generator costs $800 to $1,500 per kilowatt, and a natural gas turbine can be even less.

Recent technological advances, however, have significantly improved the economic outlook for fuel cells.

The U.S. Department of Energy has launched a major initiative - the Solid State Energy Conversion Alliance (www.seca.doe.gov) - to bring about dramatic reductions in fuel cell costs. The goal is to cut costs to as low as $400 per kilowatt by the end of this decade, which would make fuel cells competitive for virtually every type of power application. The initiative signifies the Department's objective of developing a modular, all-solid-state fuel cell that could be mass-produced for different uses much the way electronic components are manufactured and sold today.

Return to top of page >

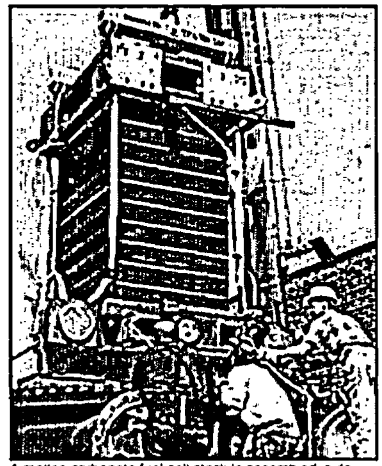


PageOwner: Office of Communications
Page updated on: August 02, 2004

Molten Carbonate Fuel Cell Technology

Molten carbonate fuel cells are designed to operate at higher temperatures than phosphoric acid or proton exchange membrane fuel cells and can achieve higher fuel-to-electricity and overall energy use efficiencies than these low temperature cells.

In a molten carbonate fuel cell, the electrolyte is made up of lithium-potassium carbonate salts heated to about 1,200 degrees F (650 degrees C). At these temperatures, the salts melt into a molten state that can conduct charged particles, called ions, between two porous electrodes.


A molten carbonate fuel cell stack is assembled in its housing prior to shipment.

Molten carbonate fuel cells eliminate the external fuel processors that other fuel cells need to extract hydrogen from the fuel. When natural gas is the fuel, methane (the main ingredient of natural gas) and steam are converted into a hydrogen-rich gas inside the fuel cell stack (a process called "internal reforming"). At the anode, hydrogen reacts with the carbonate ions (CO3) to produce water, carbon dioxide, and electrons. The electrons travel through an external circuit – creating electricity – and return to the cathode. There, oxygen from the air and carbon dioxide recycled from the anode react with the electrons to form CO3 ions that replenish the electrolyte and transfer current through the fuel cell, completing the circuit.

Molten carbonate fuel cells can reach fuel-to-electricity efficiencies approaching 60%, considerably higher than the 37-42% efficiencies of a phosphoric acid fuel cell plant. When the waste heat is captured and used, overall thermal efficiencies can be as high as 85%.

Improved efficiencies are one reason why molten carbonate fuel cells offer significant cost reductions over phosphoric acid technology. Another is that the electrodes of a molten carbonate fuel cell can be made of nickel catalysts rather than the more costly platinum of phosphoric acid systems. The elimination of the external fuel reformer also contributes to lower costs.

Molten carbonate fuel cell development can be traced back to the late 1950s when Dutch scientists G.H.J. Broers and J.A.A. Ketelaar began experimenting with laboratory-scale fuel cells using electrolytes of fused (molten) carbonate salts. In the 1960s, engineer Francis T. Bacon – a direct descendent of the 17th century literary giant – began working on a "free molten" electrolyte fuel cell. In the mid-1960s, the U.S. Army tested several small molten carbonate fuel cells – 100 watts to 1,000 watts – made by Texas Instruments that were designed to run on "combat gasoline" using an external reformer.

The U.S. Department of Energy began its cooperative molten carbonate fuel cell research program with industry in the 1970s, focusing on scaling up the concept to utility-size stationary power units. By 2003, FuelCell Energy, a molten carbonate developer, had progressed to the threshold of commercializing its technology, and the Energy Department began concluding its R&D program on molten carbonate fuel cell technology.

FuelCell Energy has signed agreements to build and site nearly a dozen molten carbonate fuel cell systems in the United States, Asia, and Japan. These include:

- Renton, Washington, where a 1-megawatt power plant will be located at the King County wastewater treatment facility and fueled by wastewater digester gas. Scheduled to begin operations in the fall of 2002, the project is co-funded by a grant from the U.S. Environmental Protection Agency.
- Los Angeles, California, where the city's Department of Water and Power has ordered three 250-kilowatt plants, the first of which was shipped to the utility's downtown headquarters in July, 2001.
- Cadiz, Ohio, where Northwest Fuel Development Inc., based on Lake Oswego, Oregon, will operate a 250-kilowatt fuel cell on coal-mine methane gas from the Harrison Mining Corporation and supply electricity back to the mining operation.

One of the first key tests of a coal gas-fueled molten carbonate fuel cell could take place in the Energy Department's Clean Coal Technology Program. FuelCell Energy Inc., will supply a 2-megawatt Direct FuelCellTM power plant to Kentucky Pioneer Energy L.L.C., a subsidiary of Global Energy Inc., which plans to construct a $432 million, 400-megawatt coal gasification power plant in Clark County, Kentucky. The fuel cell portion, estimated at $34 million, will be 50 percent funded by the Energy Department.

News & Events
New Fuel Cel
Continue Pro
Emissions En
More

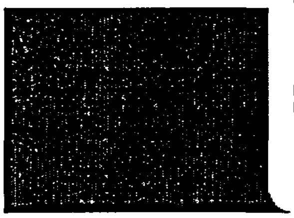
Project Info
Database of F
Projects
National Ener
Laboratory W

Meeting Fuel Cell and Distributed Generation Standards

The molten carbonate fuel cell is the latest of eight distributed generation technologies to receive approval under California's Rule 21 since it became effective in 2001. Rule 21 aims to significantly reduce the time, cost, and complexity of utility approval with prescriptive requirements jointly developed and accepted by the state's utilities. This Rule 21 standard could serve as a model for utilities and utility commissions in other states seeking to streamline their distributed generation application process.

In May 2003, FuelCell Energy announced that its Direct FuelCell® (DFC) power plant is now state-certified to meet the California Air Resources Board's (CARB) stringent new distributed generation emissions standards for 2007. By meeting this standard, the Company's sub-megawatt DFC power plant is categorized as an 'ultra-clean' technology, exempting it from air pollution control or air quality district permitting requirements by CARB. In addition, this certification qualifies the Company's products for preferential rate treatment by the California Public Utilities Commission (CPUC) such as the elimination of 'exit fees' and 'standby charges' for customer electric generation.

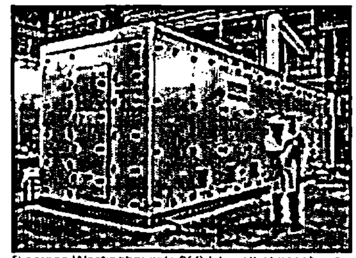
In May 2003, the company's DFC300A power plant was certified to meet the American National Standards Institute (ANSI) products safety standard for stationary fuel cell systems, ANSIZ21.83. Collectively, these three certifications will reduce the time and cost for installation of Fuel Cell Energy's DFC power plants and enhance the products' acceptance throughout the United States.



Return to top of page >

PageOwner: Office of Communications
Page updated on: August 02, 2004

Solid Oxide Fuel Cell Technology


Siemens Westinghouse's 250-kilowatt atmospheric pressure combined heat and power fuel cell system.

Solid oxide fuel cells differ in many respects from other fuel cell technologies. First, they are composed of all-solid-state materials – the anode, cathode and electrolyte are all made from ceramic substances. Second, because of the all-ceramic make-up, the cells can operate at temperatures as high as 1800 degrees F (1000 degrees C), significantly hotter than any other major category of fuel cell.

This produces exhaust gases at temperatures ideal for cogeneration applications for use in combined-cycle electric power plants. Third, the cells can be configured either as rolled tubes or as flat plates and manufactured using many of the techniques now employed today by the electronics industry.

Although a variety of oxide combinations have been used for solid oxide electrolytes, the most common to date has been a mixture of zirconium oxide and calcium oxide. Formed as a crystal lattice, the hard ceramic electrolyte is coated on both sides with specialized porous electrode materials.

At the high operating temperatures, oxygen ions are formed at the "air electrode" (the cathode). When a fuel gas containing hydrogen is passed over the "fuel electrode" (the anode), the oxygen ions migrate through the crystal lattice to oxidize the fuel. Electrons generated at the anode move out through an external circuit, creating electricity. Reforming natural gas or other hydrocarbon fuels to extract the necessary hydrogen can be accomplished within the fuel cell, eliminating the need for an external reformer.

The fuel-to-electricity efficiencies of solid oxide fuel cells are expected to be around 50 percent. If the hot exhaust of the cells is used in a hybrid combination with gas turbines, the electrical generating efficiency is likely to approach 60%. In applications designed to capture and utilize the system's waste heat, overall fuel use efficiencies could top 80-85%.

The technical roots of solid oxide technology extend as far back as the late 1930s when Swiss scientist Emil Bauer and his colleague H. Preis experimented with zirconium, yttrium, cerium, lanthanum, and tungsten as electrolytes – although the early research showed little success. By the late 1950s, small-scale research into solid oxide fuel cells was being carried out by researchers in the Netherlands and by Consolidation Coal Company in Pennsylvania and General Electric in New York. Much of the research, however, was short-lived as melting, short-circuiting, and high electrical resistance inside the cell materials created numerous technical hurdles.

One company, Westinghouse Electric Corporation, however, continued to study solid oxide fuel cells, and in 1962, one of the first federal research contracts by the then newly-formed Office of Coal Research in the Department of the Interior was granted to Westinghouse to study a fuel cell using zirconium oxide and calcium oxide.

Today Westinghouse – now Siemens Westinghouse Power Corporation – is in the final stages of a joint government-industry development effort to produce a tubular configuration of a solid oxide fuel cell. Multiple ceramic layers are bonded together as a tube. Multiple tubes link to form bundles; bundles link to form sub-modules for small power systems; and submodules link to form a generator for larger power plants.

In September 2001, Siemens Westinghouse announced that it would site its commercial solid oxide fuel cell manufacturing facility in the Pittsburgh area. The company selected a 22-acre site for its 430,000-square-foot facility about four miles from its R&D facility near Churchill, Pennsylvania. An initial section of the plant is expected to begin fabricating commercial-scale solid oxide fuel cells by the end of 2004.

Fuel Cell/Turbine Hybrids

The high-temperature operation of a solid oxide fuel cell and its capability to operate at elevated pressures makes it an attractive candidate for linking with a gas turbine in a "hybrid" configuration. The hot, high pressure exhaust of the fuel cell can be used to spin a gas turbine, generating a second source of electricity.

The world's first solid oxide fuel cell/gas turbine hybrid system is at Southern California Edison for operation at the National Fuel Cell Research Center in Irvine, California. The hybrid system includes a pressurized solid oxide fuel cell module integrated with a microturbine/generator supplied by Ingersoll-Rand Energy Systems (formerly Northern Research and Engineering Corp.). The system has a total output of 220 kW, with 200 kW from the fuel cell and 20 from the microturbine generator. This proof of concept demonstration is expected to demonstrate an electrical efficiency of around 55%. Eventually, such hybrids should be capable of electrical efficiencies of 60-70%.

Return to top of page >

News & Events
New Fuel Cel Continue Pro Emissions En
More

Project Info
Database of F Projects
National Ener Laboratory W

Program Conta
Samuel Bionc Office of Foss (FE-22) U.S Dept. of DC, Washingt 301-903-591(
Mark Williams National Ener Laboratory PO Box 880 U.S. Dept. of WV, Morgant 304-285-4747

PageOwner: Office of Communications
Page updated on: August 02, 2004