THE ACADEMY OF ELECTRICAL CONTRACTING

Paper Presented by
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FUEL CELL TECHNOLOGY
THE FUTURE IS NOW

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FOREWORD

About six months ago someone asked what I thought about fuel cells, and I realized my knowledge on the subject was fairly limited. Since the fuel cell industry is closely related to electrical contracting, I decided to find out more about its technology. This paper is the result of that research.

It is a brief overview of fuel cells but certainly does not pretend to present all the information available. The problem I faced was not what to include in the paper but what to leave out; there is a tremendous amount of information available on fuel cells. I have tried to present enough information to give a basic overview of the industry but not be too technical. The main body of the paper is designed to be easy to read. The Appendix is more technical and was designed to be used as a reference.

The fuel cell industry is in its infancy and I believe that it is vitally important for NECA contractors to become involved in this market. If we don't, just like the VDV market, we'll find that someone else is doing the work.

Milner Irvin
April 2002

I would like you to imagine that it is the year 2020. Now further imagine that in your house you have a power-cell that will develop most of the electric power needed to run your house. This power-cell is not a generator as we know generators now – but a hybrid unit. You will still be connected to the power company, but draw from the power grid only on peak loads. Under non-peak times you could sell power back into the grid. This power-cell will cost approximately what an equivalent size generator would cost today. It will produce power at about one third to one half the cost of electricity you pay now.

Further imagine that you have a similar, but smaller power-cell in your car. It will produce power for about one half the cost of your current gasoline engine. Statistics show that the average car is used only about 3% of its life. 97% of the time it could be parked and plugged into your house or business. Instead of drawing power from your house like an electric car, it would feed power back into the system and thus into the power grid providing income to offset its cost.

What you have just imagined is not science fiction or fantasy. It is a lot closer to reality than you may think. There are more than 250 fuel cell installations worldwide today. There are approximately 20 companies manufacturing fuel cells today and more companies are gearing up to start production. We also know that Ford, General Motors and Daimler Chrysler have fuel-cell cars in the testing stage right now.

Fuel Cell History

Contrary to popular belief, fuel cells are not new. The scientific community has been experimenting with and producing fuel cells for more than 150 years. In 1840 William Grove developed the first fuel cell. The "Grove Cell," as it was called, was actually an improvement on a wet-cell battery. He used a platinum electrode in nitric acid and a zinc electrode in zinc sulfate to produced 1.8 volts and about 12 amps. Grove labeled his device a gas battery.

In 1889 Ludwig Mond, an industrial chemist, and his assistant Carl Langer, developed a hydrogen-oxygen fuel cell that had an output of 6amps at .73 volts.

Friedrich Wilhelm Ostwald, a physical chemist, did not technically invent a fuel cell, but in 1893 he developed and published the theory explaining how electrical energy is produced from the chemical reactions in a fuel cell.

Some other early experimenters in fuel cells were William W. Jacques, in 1896, who used a carbon electrode and an alkali electrolyte to produce an electrochemical action. Emil Baur, in the early part of 20th century, worked with a high temperature device using molten silver as an electrolyte, and in 1939 Francis Thomas Bacon built a cell using nickel electrodes under pressure (3000 psi.)

In the 1930's Karl Kordesch, of Union Carbide, designed an alkali cell with carbon gas diffusion electrodes that the U.S. Army used to power a mobile radar set. In 1967 Union Carbide developed an experimental motorcycle that used an alkali fuel cell for propulsion.

In the early 1960's Pratt & Whitney won the National Aeronautics and Space Administration contract to provide alkali fuel cells for the Apollo spacecraft. NASA continues to use the alkali fuel cell for the Space Shuttle fleet primarily because of its nearly 70 percent efficiency and because the fuel cells provide water for the astronauts to drink.

Fuel Cell Description

A fuel cell is similar to a battery; however, unlike a battery, it does not need to be recharged. As long as fuel is supplied to the fuel cell, energy will be produced. In most cases the fuel used is hydrogen.

A typical fuel cell has two electrodes, an anode and a cathode, immersed in an electrolyte or catalyst. The anode receives the hydrogen fuel and the cathode is fed oxygen (or air). Through the catalyst the hydrogen atom splits into a proton and an electron. Each takes a different path to the cathode. The proton passes through the electrolyte while the electron takes a path through a circuit providing the electrical current and voltage. Once the proton and electron reach the cathode they reunite with the hydrogen and oxygen in a molecule of water. I've included a drawing of a simple fuel cell in the Appendix.

There are eight different types of fuel cells. Listed in order of popularity and availability they are:

- Phosphoric Acid (PAFC)
- Proton Exchange Membrane (PEM)
- Molten Carbonate (MCFC)
- Solid Oxide (SOFC)
- Alkaline
- Zinc Air (ZAFC)
- Protonic Ceramic (PCFC)
- Regenerative

One other type of fuel cell – Direct Methanol is not listed above since it is actually based on the Proton Exchange Membrane Fuel Cell (PEM.) For those interested in the technology, I've included a complete description of the operational methods of each type of fuel cell in the Appendix.

Perhaps the greatest hope for a practical fuel cell in the automobile lies with the direct type of fuel cell. The direct fuel cell has a fuel reformer built in and extracts hydrogen directly from a fuel such as methane or methanol without first having the fuel go through a reformer. The importance of this becomes apparent when considering the refueling problems associated with the automobile. Using hydrocarbon fuels like methane or natural gas would avoid the problems of providing hydrogen-refueling stations.

Fuel Cell Applications

Fuel cells are being used to power practically every form of transportation imaginable. They are presently installed in cars, boats buses, airplanes, motorcycles and scooters. Most all of these installations are in the trial stage and not for sale yet.

Some of the fuel cells that are currently being used in permanent applications are in vending machines, highway road signs, and various building as supplemental or backup power. In fact there are fuel cells installed in hospitals, hotels, office buildings, schools, utility power plants, airport terminals and nursing homes. There are approximately 40 landfill/wastewater treatment plants in the country that currently operate fuel cells using methane gas as the fuel. Since the methane gas is a by-product of the landfill, the power produced is very cost effective - practically free energy. In fact the savings in power cost for an average landfill site when using power cells is more than $100,000.00 per year.

Yan Kishinevsky of the New York Power Authority states that the fuel cell at the Yonkers wastewater treatment facility generates 1.6 million kilowatts of electricity a year from its 200kw unit. The total emissions released from the plant for the entire year is about 72 pounds. An average fossil fuel plant producing the same amount of power would produce more than 41,000 pounds of air pollutants.

For fuel cell vehicle application (FCV), direct fuel cells are the choice. Among these types of fuel cells the direct methanol fuel cell (DMFC) seems to be the best fit. The DMFC is similar to the PEM cell in that they both use a polymer membrane as the electrolyte. The difference is that in the DMFC the anode catalyst itself draws the hydrogen from the liquid methanol eliminating the need for a reformer. This type of cell has at least 40% efficiency and also has a fairly low operating temperature of 120-190 degrees F. Because the fuel cell operates on chemical reaction instead of combustion, the emissions are much less than the cleanest burning internal combustion engine.

In March 2002 Ford Motor Company announced that it would offer a zero-emissions Ford Focus in 2004. John Wallace, executive director of Ford's environmental THINK group says, "This is the prototype of the groundbreaking fuel cell vehicle that we will begin building in 2004. This latest technology brings us one step closer to making fuel cell vehicles viable for consumers." The Ford Focus Fuel Cell Vehicle (FVC) is a hybrid vehicle with the addition of a 300-volt Sanyo battery pack and a brake-by-wire electrohydraulic series regenerative braking system.

In the beta testing stage right now are miniature fuel cells small enough for laptops and palm pilots. These fuel cells generally use methanol or wood alcohol for fuel. About 1.5 ml of alcohol will run a laptop for eight hours. It's not hard to imagine one day carrying a small bottle of alcohol to refuel your laptop battery using an eyedropper. Micro fuel cells are being developed to power cell phones, pagers, portable power tools, smoke detectors and hearing aids. Casio Computer Company, Ltd. has announced that it has succeeded in developing a small-scale, high performance fuel cell to be used in portable devices. It will be out in 2004 and will use methanol for fuel.

The manufacturers of computer chips have shown interest in the production of these micro fuel cells. In June 2000, the Department of Energy established a new program – The Solid-State Energy Conversion Alliance – to provide partial funding for the commercializing of the micro fuel cell. This Alliance will provide $35 million a year to entice the chip manufacturers to blend recent advances in the solid oxide fuel cell (SOFC) materials with low-cost manufacturing techniques developed in the semi-conductor industry.

In fact, the U.S. Government has the world's largest fleet of fuel cells. In conjunction with the U.S. Army Engineer Research and Development Center/Construction Engineering Research Laboratory, the U.S. owns and operates 30 fuel cell cogeneration units. The Environmental Protection Agency has also established a program to promote fuel cell usage at wastewater treatment plants and landfills and the Climate Change Fuel Cell Program established in 1996 by the Department of Defense provides grants of $1,000/kilowatt to purchasers of fuel cell power plants. Since its formation, the DOD program has awarded more than $20 million toward the purchase of approximately 100 fuel cell units.

The Fuel Cell Market

The current fuel cell market is estimated to have sales of about $225 million. Some studies suggest that by 2004 the market will be $2.4 billion and grow to $7 billion by 2009. The stationary fuel cell market, units connected to the power grid or used as standby or supplemental power, is currently $40 million. A study done by Allied Business Intelligence, Inc. suggests that this market will be $10 billion by 2010.

The $2.4 billion market estimated for 2004 is broken down in Table I below.

Table I: Fuel Cell Market

Electric power generation (stationary power)	$850 million
Motor vehicles	$750 million
Portable electronic equipment	$200 million
Military/aerospace	$200 million
Other	$400 million

According to K. Atakan Ozbek, Allied Business Intelligence, Inc. Senior Energy Analyst, "By the second decade of this century, mass production of the automotive fuel cells will result first in a glut in the world oil supply and then in a total rejection of oil as a vehicle fuel."

The stationary fuel cell market is already in full swing. In April 2002, Starwood Hotels & Resorts Worldwide Inc signed an agreement with PPL Energy Plus for installation of one 250KW fuel cell system at its Sheraton Parsippany Hotel and another at the Sheraton Edison Hotel Raritan Center. Since both properties are in New Jersey, the New Jersey Clean Energy Program will provide approximately $1.7 million in funding to PPL as part of its incentive program to encourage the use of clean energy technology. PPL will own and operate each of the units.

Starwood is one of the leading hotel and leisure companies in the world, with more than 740 properties in 80 countries, and 110,000 employees. These two projects are part of a master agreement between PPL and Starwood that may eventually lead to installation of fuel cells in other properties. Natural gas will be supplied from local distributors for each installation.

Siemens Power Generation Group has signed an agreement to build a 250kw solid oxide fuel cell at the Herrenhausen power plant in Hanover, Germany by 2003. There are many more projects already awarded or in the planning stage and new projects are being announced daily.

The energy and power companies are very interested in and are currently testing fuel cells. A phrase heard more and more in recent months is "distributed generation" (DG). Instead of one central generating facility with its corresponding grid of high-voltage distribution lines and substations, fuel cells will allow the production of electrical power much closer to the end user. By placing fuel cells in a neighborhood substation, the high-voltage distribution lines can almost be eliminated. Producing power closer to the end user is possible because of the fuel cell's low pollution and almost silent operation.

A study done by Chartwell, the energy information publisher, found that approximately 56 power or energy companies were already conducting DG testing and half of those had signed agreements with manufacturers of alternate forms of power production. According to the Department of Energy, distributed generation accounted for approximately 5% of the total energy used in 2000-2001. It predicts that DG will represent nearly 20% by the year 2010.

As electrical contractors looking at the fuel cell and its market, we don't want to overlook the energy companies as potential customers; however, there may be an even larger customer base available to us. Another survey showed approximately 40,000 industrial and commercial companies in the U.S. and Canada indicating that they are ready to consider some form of alternate energy. A large number of these expressed an interest in the fuel cell as a method of peak load shaving. These companies are the ones I believe we should be looking at for our market.

I think it is important as electrical contractors to get involved in the fuel cell industry now. Two or three years from now may be too late. There are several ways to become involved. For example, our company has formed an alliance with a local generator distributor to market and install fuel cells in our area; we already install generators for this company now.

The high costs of fuel cells have been a hindrance to their marketability. Until recently a cost of $2500 per kw had been the average. Now units are coming on the market in the $1500 per kw range. In fact one manufacturer will have an alkaline unit available by the end of the year for under $800/kw. This price includes almost all of the ancillary equipment needed, making the unit very attractive and marketable. When the DOD grant money of $1000 per kw, mentioned above, is factored in, this unit should be easy to sell if marketed properly.

Since the fuel cell industry is so new, marketing becomes particularly important. We have identified prospective customers in our area where the fuel cell installation seems to be a natural fit. One of the manufacturers we're talking to has provided us with brochures. By combining this information with our own company literature, we have a package to use for marketing.

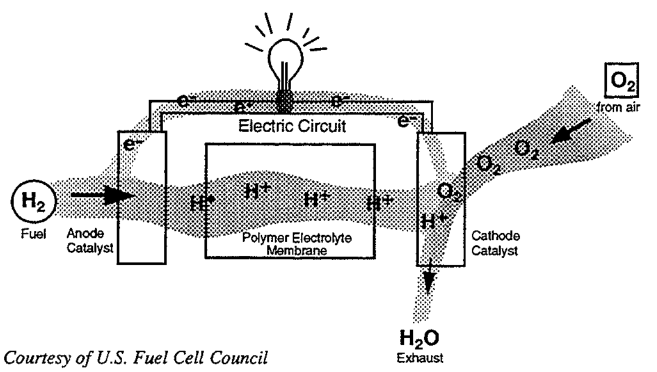
Like most other endeavors in electrical contracting, the fuel cell market is there for us to pursue. And like other markets, it won't come to us. If we do the research, understand the pitfalls and do the marketing, I believe that the fuel cell industry offers a tremendous opportunity for growth in an unexplored market.

APPENDIX

Basic Fuel Cell

The fuel cell operates using a chemical reaction, which is the exact reverse of electrolysis. In the fuel cell, hydrogen and oxygen combine to produce electricity and water.

There are two electrodes sandwiched around an electrolyte. Oxygen (or air) passes over one electrode and hydrogen over the other, generating electricity, water and heat.



Courtesy of U.S. Fuel Cell Council

The anode side of the fuel cell receives the hydrogen and oxygen (from air) enters the fuel cell through the cathode. The catalyst splits the hydrogen atom into a proton and an electron, with each taking a different path to the cathode. The electrons create a separate current that can be utilized and the proton passes through the electrolyte. At the cathode both are reunited with the hydrogen and oxygen in a molecule of water.

When pure hydrogen is not available, a "fuel reformer" can extract the hydrogen from any hydrocarbon fuel – for example, natural gas, methanol, and even gasoline. Since the fuel cell relies on chemistry and not combustion, emissions from this type of system would still be much smaller than emissions from the cleanest fuel combustion processes.

Fuel Cell Types

All fuel cells use an electrolyte, of which there are five primary types. Each has specific characteristics that may make it better for some applications than for others. The following fuel cell descriptions list the type of electrolyte, the fuel cell operating temperature and the fuel cell efficiency. In general, higher operating temperatures result in more efficient fuel cells.

Phosphoric Acid (PAFC)

The electrolyte, as the name suggests, is phosphoric acid at a concentration of 100%. PAFCs use liquid phosphoric acid soaked in a matrix. Operating temperatures range from 300 to 400 degrees F (150 – 200 degrees C). At lower temperatures, phosphoric acid is a poor ionic conductor. Positively charged hydrogen ions pass through the electrolyte from the anode to the cathode. Electrons generated at the anode move through an external circuit, providing electrical power, and return to the cathode. At the cathode the electrons, hydrogen ions, and oxygen recombine to form water. A platinum catalyst at the electrodes helps to speed the reactions. An external fuel reformer is required to extract hydrogen from a hydrocarbon fuel.

The main advantage of the PAFC is that it can use impure hydrogen as a fuel and it can tolerate CO concentration of up to 1.5 percent. Its disadvantages include: use of expensive platinum as a catalyst, a large size and weight, and generation of a relatively low current and power compared to other types of fuel cells. The PAFC has an electrical efficiently of 37 – 42%.

The Phosphoric Acid fuel cell is commercially available today and is being used in hospitals, hotels, office building, schools, utility power plants and nursing homes. Some municipal buses are also using PAFCs. Outputs of up to 200 KW are available with existing PAFCs.

Proton Exchange Membrane or Solid Polymer (PEM)

The PEM uses a solid organic polymer (polyperflourosulfonic acid) as an electrolyte. The proton exchange membrane is a thin plastic sheet coated on both sides with highly dispersed metal alloy particles (usually platinum) that allow the hydrogen ions to pass through. Operating temperatures are relatively low (about 175 degrees F or 80 degrees C). Hydrogen atoms are stripped of their electrons at the anode and the positively charged protons pass through one side of the porous membrane and move toward the cathode.

The electrons travel from the anode to the cathode through an external circuit providing electrical power. At the cathode, the hydrogen protons, oxygen from the air and the electrons recombine to form water. An external reformer is required to extract hydrogen from hydrocarbon fuels.

Advantages include high power density, the ability to vary its output quickly to meet power demands, and the solid electrolyte, which reduces corrosion and management problems. Disadvantages include its sensitivity to fuel impurities. The PEM has an electrical efficiency of about 45%.

A General Electric Company PEM fuel cell was used on the NASA Gemini flights. Some of these fuel cells are being tested today in automobiles, and they are primary candidates for residential standby power supplies. In a small size, they could be used as replacements for rechargeable batteries. Proton Exchange Membrane Fuel Cells generally range in size from 5kw up to 250kw.

Molten Carbonate (MCFC)

The electrolyte used for these fuel cells is a liquid solution of lithium, sodium and/or potassium carbonate soaked in a ceramic matrix. Operating temperatures of 1200 degrees F (650 degrees C) are normal for MCFC fuel cells. The high temperature is needed to obtain sufficient conductivity of the electrolyte. Noble metal catalysts are not required for the cell's electrochemical oxidation and reduction process because of this high operating temperature. At these high temperatures the carbonate salts in the electrolyte melt and conduct carbonate ions (CO3) from the cathode to the anode. At the anode, hydrogen reacts with the ions to produce water, electrons and carbon dioxide. Traveling through an external circuit, the electrons provide electrical power and then return to the cathode. At the cathode the electrons, oxygen from the air and carbon dioxide recycled from the anode combine to replenish the electrolyte and transfer current through the fuel cell.

Advantages include high efficiency, flexibility in using different types of fuels, and inexpensive catalysts. A disadvantage is that the high temperatures will accelerate corrosion and breakdown of cell components. The MCFC has an electrical efficiency of 60% or can be as high as 85% when the heat is used for cogeneration.

The MCFC is currently targeted for larger standby applications such as landfills, large office buildings and electrical utilities. They generally range in size from 10kw to 2mw.

Solid Oxide (SOFC)

Instead of a liquid electrolyte the SOFC uses a hard ceramic material of solid zirconium oxide and calcium oxide to form a crystal lattice. This solid electrolyte is coated on both sides with specialized porous electrode material. Because of the solid electrolyte, operating temperatures can be up to 1800 degrees F (1000 degrees C). At high temperatures, the oxygen ions (with a negative charge) travel through the crystal lattice. At the anode hydrogen is introduced and a flow of negatively charged oxygen ions moves across the electrolyte to oxidize the fuel. Oxygen from the air is supplied to the cathode. The electrons generated at the anode flow through an external circuit providing electrical power completing the circuit.

Advantages are high efficiency, flexibility of fuel use (practically any hydrocarbon fuel can be used without reforming), relatively small size and production of very little pollution. The SOFC has an electrical efficiency up to 60%. Higher efficiencies are possible if the heat is used for cogeneration.

Because of their compact size and low pollution these power cells offer an attractive unit for residential use. Two 25kw units have been on line in Tokyo for several years. Siemens Westinghouse will have a 250kw unit on line in Hanover, Germany by early 2003.

Alkaline (AFC)

The electrolyte used is an aqueous solution of alkaline potassium hydroxide soaked in a matrix. The operating temperatures are 300 to 400 degrees F (150 – 200 degrees C). Hydroxyl ions (OH-) migrate from the cathode to the anode. Hydrogen gas at the anode reacts with the OH- ions producing water and releasing the electrons. The electrons generated at the anode travel through an external circuit producing electrical power and return to the cathode. At the cathode the electrons combine with oxygen and water to produce more hydroxyl ions to return to the electrolyte.

Advantages include high efficiency, low pollution, low temperature, and production of potable water. Disadvantages are that they require very pure hydrogen and oxygen as fuel and require large amounts of platinum catalyst to speed up the reaction. The AFC can have electrical power efficiency as high as 70%.

Among modern fuel cells, the alkaline cell was the first to be developed. Experimenting with alkaline electrolytes began in the late 1930s, and Union Carbide developed an alkali cell in the 1950s. NASA used the alkaline fuel cell for the Apollo program and the Space Shuttle fleet. Because of the pure water byproduct, the alkaline cell also provided drinking water for the astronauts.

Direct Methanol (DMFC)

The electrolyte used in the DMFC is similar to the PEM cell (polymer membrane). The operation is also the same as the polymer electrolyte fuel cell. However, in the DMFC, the anode catalyst has the ability to extract the hydrogen from liquid methanol, thus eliminating the need for a fuel reformer. Operating temperatures are from 120 – 200 degrees F (50 – 100 degrees C).

An advantage is the low temperature, making the DMFC suitable for small to mid-size applications. Disadvantages include low efficiency and problems with the fuel crossing over from the anode to the cathode without producing electricity. This power cell has an efficiency of about 40%.

The small size and low heat make the DMFC attractive for replacing rechargeable batteries in cell phones and notebook computers.

Protonic Ceramic (PCFC)

The PCFC is relatively new and is based on a ceramic electrolyte similar to the solid oxide or the molten carbonate. Operating temperatures are up to 1200 degrees F (650 degrees C) allowing high electrical efficiency. The high temperature allows practically any hydrocarbon fuel to be used without reforming. Gaseous molecules of the fuel are absorbed on the surface of the anode in the presence of water vapor, and the hydrogen atoms are stripped off to be absorbed into the electrolyte. The complete operation is very similar to the Molten Carbonate. Efficiencies of 70% are expected.

Regenerative Fuel Cell

As of early 2002 the regenerative fuel cell is not totally developed. It is a closed-loop form of power generation. Water is separated into hydrogen and oxygen by a solar-powered electrolyzer and then fed into the fuel cell generating electricity. The byproducts are heat and water. The water is then recirculated back to the solar-powered electrolyzer and the process begins again. This fuel cell comes as close to perpetual motion as any unit we know of. Theoretically this fuel cell could have close to 100% efficiency. Currently NASA is doing research on regenerative fuel cells.

Zinc-Air Fuel Cell (ZAFC)

The ZAFC uses a gas diffusion electrode (GDE) and a zinc anode. The anode and electrode (GDE) are separated by an electrolyte (similar to a PEM) and mechanical insulators. The GDE is a permeable membrane allowing atmospheric oxygen to pass through and be converted to hydroxyl ions and water. The hydroxyl ions travel through the electrolyte and reach the zinc anode where they react with the zinc and form zinc oxide. This process results in an electrical potential. The electrochemical process is similar to the PEM. However since the zinc is continuously being transferred from the anode, it needs to be replaced. This cell is really more like a battery than a typical fuel cell. It requires a short duration recharge (about 5 minutes) from an electrical power source.

Metallic Power Corporation has designed a ZAFC that incorporates a zinc fuel tank and zinc "refrigerator" that regenerates the zinc fuel by using a small amount of electrical power (from the ZAFC). It is a closed loop system; however, it still requires a very short connection to an external power source.

The ZAFCs seem to offer the best technology for hybrid electric vehicles (EV). The main advantage it has over other types of batteries is its high specific energy (running duration relative to its weight). With zinc being one of the most abundant elements on earth, the material costs for ZAFCs are very low.

Manufacturers/Developers

The following is a list of corporations and organizations involved in fuel cell manufacture and research. I've listed the name and, where the information is known, I've listed the type of fuel cell they're involved with.

AlliedSignal – Solid Oxide
Analytic Power Corporation – Primarily fuel reforming
Apollo Energy Systems - Alkaline
Avista Laboratories – PEM
Ballard Power Systems – PEM
DCH Technology – PEM
Energy Partners – PEM
FuelCell Energy – Direct Fuel cell
Ford Motor Company – Solid Oxide
Global Thermoelectric – Solid Oxide
H Power Corporation – PEM
UTC Fuel Cells – Division of United Technologies Corp. – Alkali
Manhattan Scientifics, Inc. – Micro Fuel Cell
Metallic Power, Inc. – Zinc/Air
M-C Power – Molten Carbonate
National Renewable Energy Lab, Colorado – PEM
Netherlands Energy Research Foundation – MCFC, SOFC, SPFC
Oak Ridge National Laboratory – Solid Oxide
Pacific Northwest National Laboratory – PAFC, MCFC, SOFC
Plug Power, L.L.C. – PEM
Princeton University – Various
Proton Energy Systems – PEM
Rock Mountain Institute – Various
Sandia National Labs – Various
Siemens AG – Various
Small-Scale Fuel Cell Commercialization Group
Southern California Gas
Toyota Motor Corporation – Various
University of California, Davis – Various
University of California, Riverside – Various
Warsitz Enterprises
Siemens Westinghouse Power Corporation – Solid Oxide

Current Standards Applicable to Fuel Cells

UL

UL 674, *Electric Motors and Generators for Hazardous Locations*
UL 795, *Commercial-Industrial Gas Heating Equipment*
UL 991, *Standard for Safety for Test For Safety Related Controls Employing Solid-State* Devices
UL 1741, *Inverters Converters, and Controllers for Use in Independent Power Systems*
UL 1778, *Uninterruptible Power Supply Equipment*
UL 1998, *UL Standard for Safety for Software in Programmable Components*
UL 2200, *Stationary Engine Generator Assemblies*

NFPA

NFPA 853, *Standard for the Installation of Stationary Fuel Cell Power Plants* (Currently applies for fuel cells > 50kW)
NFPA 70, *National Electrical Code®*, Article 692, Fuel Cell Systems will be in the 2002 edition
NFPA 54, *National Fuel Gas Code*
NFPA 110, *Emergency Generators*
NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*
NFPA 497, *Recommended Practice for Classification of Class I Hazardous Locations for Electrical Installations in Chemical Plants*

IEEE

IEEE 929, *Recommended Practice for Utility Interface of Photovoltaic (P P9 Systems*
IEEE P1547, *Standards for Distributed Generation Interconnection with Electric Power Systems*
IEEE C2, *National Electrical Safety Code*

Various State Interconnection Requirements (NY, Texas, California, etc.) – USFCC position is to support IEEE interconnection standard development and adoption in lieu of individual state requirements

Other

ANSI Z21.83, *Fuel Cell Power Plants*

ASME Performance Test Code (PTC) 50, *Fuel Cell Power Systems*

Code of Federal Regulations (CFR) 47 - *Telecommunication* (Part 15)

IEC TC 105, *International Fuel Cell Standard*

All applicable Building Codes (including Plumbing Codes)

Fuel Cell Fuels

Current Fuels

Hydrogen
Natural Gas – CH_4
Direct Methanol – CH_3OH
Propane – C_3H_8
Reformed Methanol
Ammonia
Landfill Gas
Digester Gas

Future Fuels

Diesel / Jet Fuel
Gasoline
Naphtha
Sulfur Free Distillate
Ethanol
Biomass Gas
Coal Gas

E. Milner Irvin, III, President of Riverside Electric Company, Miami, Florida, first became involved with NECA in 1972. The Company was founded in 1922 by his grandfather and became a NECA member in May 1949. He has served on the Board of Directors of the South Florida Chapter since 1979: 13 years as Treasurer, 2 years as President and 9 years as Governor. He served on the Council of Industrial Relations from 1999 to 2000. He is the current District III Vice President and is chairman of the Manpower Development Committee.