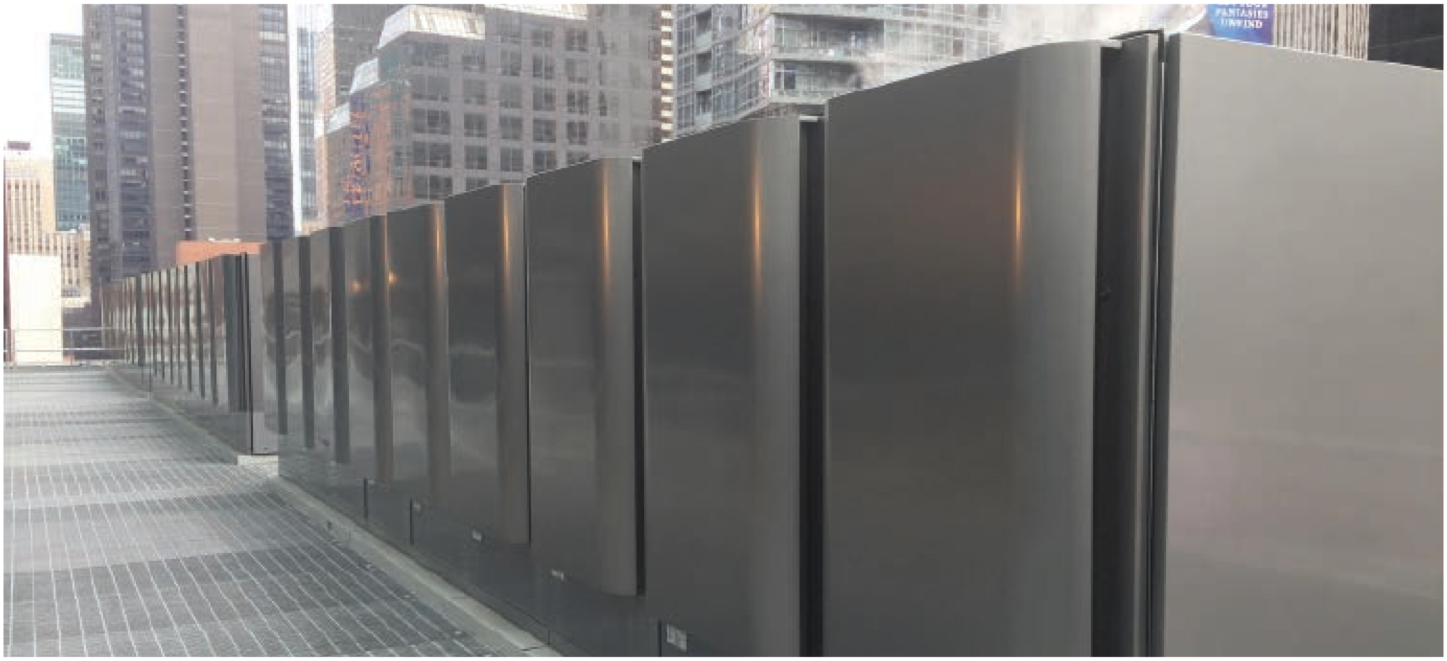
Fuel Cell Technology for Stationary Power Generation

By Assistant Chief Ronald R. Spadafora, Chief of Fire Prevention



Fuel cell installation using natural gas, located on setback roof at Morgan Stanley building in midtown Manhattan. Photo by author

Hydrogen Fuel Initiative (HFI)

The United States Department of Energy (DOE) supports the development of hydrogen and fuel cell technologies through research in order to lower our country's dependence on foreign oil and reduce the environmental impacts of fossil fuel combustion. The Hydrogen Fuel Initiative (HFI), a component of the Energy Policy Act of 2005, increased federal funding for hydrogen and fuel cell research and development to $1.2 billion over five years. The goal was to enable hydrogen and fuel cell technology to overcome obstacles facing the widespread use of hydrogen and fuel cell technologies for transportation and stationary power generation.

Fuel Cell Definition

A fuel cell is an electrochemical device that converts hydrogen from fuel and oxygen in the air into direct current (DC) voltage. Every fuel cell has two electrodes; one positive (anode) and one negative (cathode). The chemical reactions that produce electricity take place at the electrodes. Every fuel cell also has electrolyte; a substance (acid, polymer, ceramic) that carries electrically charged particles from one electrode to the other and a catalyst (platinum) that speeds the chemical reactions at the electrodes.

A single fuel cell produces a small amount of voltage. Therefore, to increase power generation, many individual fuel cells are combined to create a fuel cell stack. This stack is integrated into a fuel cell system with additional components, including a fuel reformer (separates hydrogen in alternate fuels), inverter (changes direct current to alternating current), power electronics and controls.

Fuel cells differ, however, from batteries in that they require a *continuous source* of

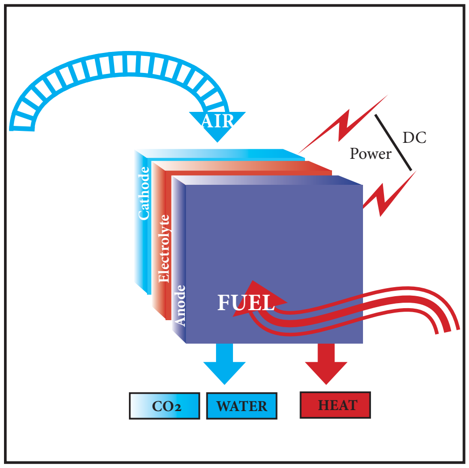
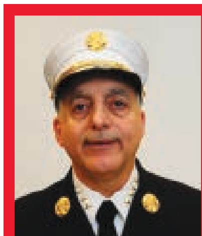


Illustration above denotes fuel and air (oxygen) flowing into fuel cell with the creation of direct current (DC) power. By-products of the reaction include water, heat and carbon dioxide. Ethanol Fuel Cell Technology http://running_on_alcohol.tripod.com/id30.html



About the Author

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Fixed Fuel Cell Installation Benefits

- Primary or backup electrical power generation
- Unlimited power generation
- Grid-tied or independent
- Fuel flexible
- Space and water heat generation
- High-pressure steam generation
- Environmentally friendly (few to no emissions)
- Modular (scalable)
- Easy installation
- Remote system monitoring
- Quiet
- Low maintenance

fuel and oxygen or air to sustain the chemical reaction. A battery *stores* electricity and needs regular recharging or replacement. They are used to produce both primary and backup electrical power, as well as heat (co-generation) cleanly and efficiently in commercial, industrial and residential buildings. Fuel cells can be co-located with other energy resources (wind, solar, energy storage batteries and turbines) directly at a facility or as part of the grid system. They also are being installed as replacements for battery backup systems (UPS). The cells are installed close to the source that uses the power, so less energy is lost over transmission lines. They also are employed to power vehicles, machinery (forklifts), boats and submarines.

Hydrogen Hazards

Hydrogen is an extremely flammable gas that is much lighter than air, with a wide explosive range. Explosive mixtures in air that can ignite spontaneously are created from as little as four percent hydrogen (lower explosive limit or LEL), to as much as 75 percent hydrogen (upper explosive limit or UEL). This characteristic is of utmost concern in an enclosed space. At the optimal range (29 percent hydrogen-to-air volume ratio), the energy required to initiate combustion is much lower than that required for other common fuels. Hydrogen vapors can be ignited by pilot lights, cigarettes, sparks, heaters, electrical equipment and static discharge. It produces a flame that is nearly invisible in the daylight. Additionally, heat from a hydrogen flame may be difficult to feel until Firefighters get too close. It is colorless, odorless, tasteless, non-toxic and non-corrosive.

The majority of hydrogen used to supply fuel cell sites currently is stored in high-pressure cylinders. Very large systems may store hydrogen in liquid (cryogenic) form. The danger from the very low storage temperatures used for liquid hydrogen (approximately minus 418 degrees Fahrenheit), include severe cold-burns. Contaminated clothing must be removed immediately and the underlying skin must be washed with soap and water.

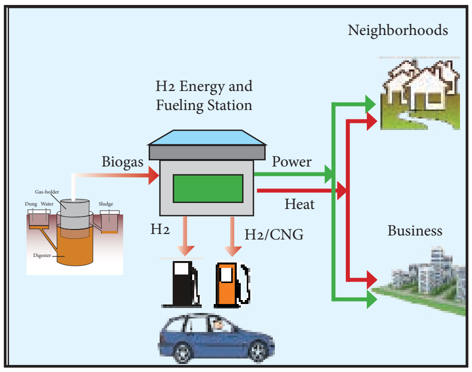
Victims of hydrogen inhalation may experience symptoms that include headaches, ringing in ears, dizziness, drowsiness, unconsciousness, nausea, vomiting and sensory depression. High concentrations can create an oxygen-deficient environment with the risk of death. Firefighters should check the oxygen content of the space before entering a hydrogen storage or fuel cell area. First aid includes moving victims to fresh air, administering supplemental oxygen and artificial respiration, where required.

Low-Tech Firefighting Procedures

In earlier times without advanced technology, Firefighters operating at hydrogen, as well as alcohol fires, watched for thermal waves that can indicate the presence of flame. They probed the suspected area, slowly advancing with corn straw brooms. The broom was held forward at arm's length and ignited when it came in contact with the invisible flame. Simultaneously, the Firefighters would throw dirt ahead, in anticipation of the combustible particles in the soil flaring up in the fire. These techniques have their drawbacks, however, since flame can change direction during windy conditions.

Alternate Fuels

Fuel cells operate most efficiently on pure hydrogen in pressurized gas or liquid form. Due to hydrogen's potential risks listed above, however, other fuels, such as natural gas, liquefied petroleum gas, methanol, ethanol, biogas and gasoline, can be *reformed* into a mixture containing hydrogen to serve as a reactant for the fuel cell. Many of the current applications for fuel cells use natural gas. Fuel cells also have operated well on renewable biogas produced at wastewater treatment plants, as well as landfill gas.



Fuel cell technology, reforming biogas to generate hydrogen for electrical power and heat, as well as vehicle fueling.
http://www.sustainableplant.com/2012/03/fuel-cell-tri-generation-plants-to-produce-hydrogen-electricity-and-heat/

Firefighting Procedures at Fuel Cell Installations (All Fuels)

Fixed gas and flame detectors com-

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General Fuel Cell Installation Fire Protection Requirements

- Sites to have adequate fire hydrant water supply
- Automatic fire and combustible gas alarm detection system
- Indoor liquid fuel pumps to be protected by an automatic fire suppression system
- Combustible gas detector to be installed in the fuel cell power system enclosure
- Combustible gas detection system arranged to alarm at 25 percent of the LEL and interlocked to shut down the power system fuel supply at 60 percent LEL
- Automatic fire suppression system interconnected to shut off the fuel supply when activated
- Fuel cell enclosure separated from the rest of the building by one-hour, fire-rated construction
- All penetrations (electrical, plumbing) through walls to have a one-hour, fire-resistive rating
- Fire doors to have a rating equivalent to the barrier
- Piping, valves and other fuel system components located in an area not easily subject to physical damage
- Fuel piping to be marked according to current labeling standards
- Nearby and accessible Emergency Power Off (EPO) button that shuts off electrical power, as well as gas flow within the system
- Electrical equipment associated with the fuel cell installation should be designed to an appropriate standard
- Warning signs denoting the risk of electric shock
- Provide adequate high and low ventilation in the fuel cell enclosure to alleviate buildup of flammable gases
- Ventilation and exhaust system to provide a negative or neutral pressure in the room containing the fuel cell installation with respect to the building
- Combustible materials, high-piled storage and hazardous chemicals should be excluded from fuel cell room.
- Access to the fuel cell and fuel storage area limited to competent personnel who are trained in this technology
- Fire department access must be provided through an approved location.

Note: More specific requirements can be found in NFPA 853: *Standard for the Installation of Stationary Fuel Cell Power Systems*.

Photo #2—The interior of the City Ice Pavilion, which is built on a rooftop. Note the high glass along the boards, which could cause damage to the fabric during high winds if not maintained properly. It will be difficult for people wearing ice skates to evacuate.

Photo #3—*An exhaust fan in an air-supported structure. This permanent fan exhaust system is located at North Shore Indoor Sports, Bayside, Queens.*

Photo #4—*Natural gas-powered generator. This is the primary fan unit of North Shore Indoor Sports, Bayside, Queens. There will be a knife switch located on the unit.*

the structure, the engineer may throw ropes over the top and attempt to break up the snow, forcing it to slide down the structure in a pre-determined route. If too much snow accumulates on the top of the structure, there is a risk of uncontrolled snow slides. These slides have been known to slice into the seam of a door, causing it to tear open and expel the air, thus causing the structure to fail within minutes.

New York City code requires these air-supported structures to withstand a wind load of 98 miles per hour for a three-second gust. When positive pressure from wind exceeds the internal pressure, the structure will begin to dimple on the windward side. This dimple may come in close contact with items within the structure, such as hanging lights or boards surrounding an ice rink, causing a puncture. With a weather advisory of strong winds, the on-site engineer will increase the pressure inside the structure.

A University of Maryland study demonstrated that a fire in an air-supported structure eventually would create a small tear directly over the heat source. The study also showed that this small tear expanded very quickly, thus diminishing the internal pressure and causing a complete failure of the structure. In the study, the tear occurred 10 minutes after igniting the controlled fire, which may allow a significant number of occupants to escape the complex before failure. The secondary fans installed in this study were not large enough to keep the configuration, causing it to become deflated.

A different study conducted by the Fire Research Station showed that when a fire tears a hole directly above the source, all of the smoke and heat would travel up and through that opening. However, when the doors open to allow occupants to escape, the larger door openings will force the heat and smoke to expel in that direction, hindering the evacuation of occupants.

In the event of a small fire within the structure, the technique of chocking any openings may prove detrimental to the operation. It is advised that leaving the door slightly ajar, possibly allowing the door to close on a charged hose-line, will assist in maintaining the air pressure within the facility. Another option will be to contact the on-site building engineer and have him/her increase the pressure in the fans. Larger fires are best fought from the outside when deflation of the structure has caused the fabric to lie on the ground.

However, items within this deflated structure preventing the material to lie directly on the ground may result in more complicated issues. Air-supported material is classified as "not easily ignitable." Because of this, there should be no difficulty walking over the deflated structure to reach the seat of the fire. The material is cut easily with a utility knife when fully inflated. However, when the structure has lost its form, Firefighters may be forced to use more strength to cut the material.

While walking on top of a deflated structure, Firefighters must be aware of objects or victims that/who may be underneath the fabric. Be mindful of the large hanging lights and electrical wires,

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Fixed gas monitor with red warning light outside enclosure, harboring natural gas distribution piping for fuel cell installation. Photo by author

Emergency Power Off (EPO) button shuts off electrical power, as well as gas flow within a fuel cell system. Photo by author

Fuel cell system being installed in the basement of the Madagascar building at the Bronx Zoo. New York Power Authority, Energy Technologies https://www.nypa.gov/services/profiles/Bronxzoofuelcell.htm

monly are installed in facilities that have fuel cell installations. Listen and watch for audible/visual alarm signals. Escaping gas may ignite explosively. If leaking gas is not burning, eliminate ignition sources and monitor gas concentrations. Shut down power to the fuel cell installation. Ventilate the area and use water spray to dissipate vapors. Except to save lives, let the fire burn until you can safely shut off the fuel supply. Use fog streams to cool adjacent areas and equipment. For cryogenic fuels, avoid putting water on pressure-relief valves, since ice formation can make them inoperable. Self-contained breathing apparatus (SCBA) and personal protective equipment (PPE) are essential. Additionally, Firefighters should employ thermal imaging cameras and portable gas detectors to facilitate operations and enhance personal safety. Carbon dioxide, multi-purpose dry chemical and clean agents are acceptable portable fire extinguishers for Firefighters to carry.

Emergency Planning Requirements/Recommendations

An emergency plan for a fuel cell installation will address potential hazards, threats and vulnerabilities that can harm building personnel and Firefighters. It should be formulated with the assistance of local first responders, drawing on their experience in extinguishing/mitigating fires and emergencies. The list below is not exhaustive, but can provide the reader with an understanding of critical plan items.

- Written fire/emergency plan that includes response to alarms and key personnel notifications
- Written information on fire prevention, fire extinguishment activities and evacuation procedures
- Posting of the location of equipment, operating instructions and emergency controls
- Availability of portable flammable gas detectors at the service entrance to the fuel cell installation
- Coordination with internal security personnel and incoming first responders
- Periodic drills on the fire/emergency plan
- Documented inspections
- Written description of general housekeeping procedures
- Written procedures that address impairments to fire protection systems
- Listing of frequency for periodic inspection, testing and maintenance of the fuel cell system
- Standard markings on fuel piping and components
- First responder access should be provided through an approved location.

Conclusion

In December 2016, a 750-kW fuel cell project using natural gas was completed at Morgan Stanley's global headquarters in midtown Manhattan. It will provide approximately six million kWh of clean electrical energy every year. Support for this project was provided by the New York State Energy Research and Development Authority (NYSERDA) through a long-term renewable energy credit contract. NYSERDA also funded the 400-kW fuel cell project (natural gas) completed in 2011 at the 500-unit apartment complex known as the Octagon, located on Roosevelt Island, becoming the first residential building in New York State to be powered and heated by a fuel cell system.

In 2001, the New York Power Authority (NYPA) installed a fuel cell system that produces electricity for the New York Aquarium, located in Coney Island, Brooklyn. It generates 200 kilowatts of electricity, along with 700,000 Btu of heat. Fueled by natural gas, the system supplies approximately 20 percent of the aquarium's daily requirements. The NYPA also installed a similar fuel cell system at the Bronx Zoo in 2010, located in the basement of the Madagascar building. Other notable stationary cell sites that are fueled by biogas include Hunt's Point (Bronx), Red Hook (Brooklyn) and Oakwood Beach (Staten Island) water pollution/treatment plants.

Stationary fuel cell sites can be found throughout New York City. FDNY Fire companies should visit these locations to familiarize themselves with this growing technology.

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