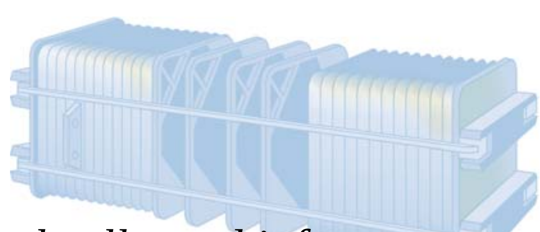
U.S. Department of Energy
Energy Efficiency and Renewable Energy

Module 1

Permitting Stationary Fuel Cell Installations



hydrogen, fuel cells, and infrastructure

Version 1.0
PNNL-14518 Released 1/12/2004

Contents

Module 1: Permitting Stationary Fuel Cell Installations

1.0 Introduction

1.1 Purpose

The purpose of this module is to facilitate the acceptance of stationary fuel cell technologies for buildings. To achieve this purpose, the module provides information on the building regulatory processes and provisions of relevant codes and standards that will have an impact on the design, deployment, approval, installation, operation, and maintenance of fuel cell technologies. The module covers fuel cell installations in buildings other than one- and two-family dwellings and for energy functions other than industrial processes. It is intended as a tool for determining the codes and standards applicable to stationary fuel cell installations that provide electricity for commercial buildings and that may also produce waste heat that can offset other energy-using features of such buildings.

1.2 Background

Widespread use of hydrogen as an energy source in this country could help address concerns about energy security, global climate change, and air quality. Fuel cells are an important enabling technology for the Hydrogen Future and have the potential to revolutionize the way we power our nation, offering cleaner, more efficient alternatives to the combustion of gasoline and other fossil fuels.

Hydrogen can be derived from a variety of domestically available primary sources, including fossil fuels, renewables, and nuclear power. This flexibility would make us less dependent upon oil from foreign countries.

Hydrogen can be produced from a wide variety of domestic resources using a number of different technologies. Hydrogen can also provide a storage medium for intermittent and seasonal renewable technologies. Hydrogen can be used in combustion processes and fuel cells to provide a broad range of energy services such as lighting, mobility, heating, cooling, and cooking.

1.3 Structure of This Module

Section 2 presents a description of how a fuel cell works and how it interacts with the building and its various energy systems.

Section 3 illustrates the installation requirements for fuel cells and summarizes the associated codes and standards (sometimes also referred to as building construction regulations) that regulate the installation.

Section 4 is designed for use by code enforcement personnel (building officials) who will be reviewing construction documents and project specifications for compliance with adopted codes and standards. This section also can be used by the installation designer as a guide to the types of documentation required to demonstrate compliance with the codes and standards listed in this module.

Section 5 presents a case study highlighting one of the existing fuel cell installations in the United States. Case studies can be used as examples for both code enforcement personnel and the design and engineering community to identify how the permitting and approval process proceeded with each installation.

2.0 Fuel Cell Basics

2.1 How Fuel Cells Work

A fuel cell is an electrochemical device that combines hydrogen and oxygen to produce electricity; heat, and water (see Figure 2.1). The hydrogen comes from any hydrocarbon fuel such as natural gas, gasoline, diesel, or methanol. The oxygen comes from air around the fuel cell. Because fuel cells are electrochemical devices that operate without combustion, they do not generate combustion emissions.

A fuel cell can operate at high efficiencies and provide an opportunity for the capture of heat that is given off by the process (cogeneration). The fuel cell itself has no moving parts, making it a quiet and reliable source of power, electricity, heat, and water.

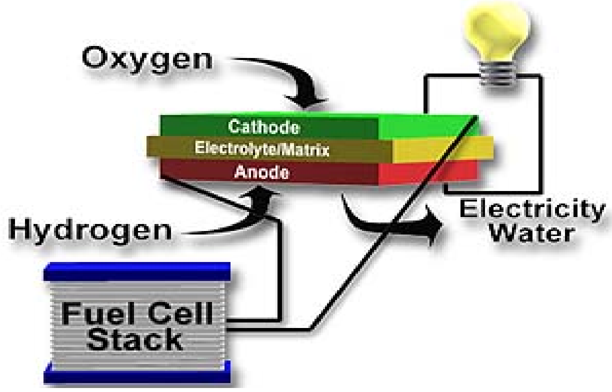


Figure 2.1. Fuel Cell Configuration

Fuel cell equipment comprises individual fuel cells "stacked" to make a fuel cell stack that is the heart of the fuel cell equipment or power plant. In addition, there may be a fuel processing section of the equipment that is separate from or integral to the cell stack. Where alternating current (ac) power is needed, there will be a power conditioning section to convert the direct current (dc) power produced by the fuel cell into ac power. Although all fuel cell power plants contain these components, the assembly of these components into the actual equipment is very important. Stationary fuel cell equipment can be categorized as either unitary, matched modular, modular, or site-built.

A typical fuel cell is composed of a fuel cell processor/reformer, electrodes, electrolyte, oxidant, fuel cell stack, and power-conditioning equipment. These components are described briefly in the following paragraphs.

- **Fuel Processor/Reformer**

The job of the fuel processor/reformer is to provide relatively pure hydrogen to the fuel cell, using a fuel that is readily available or easily transportable. The hydrogen comes from any hydrocarbon fuel such as natural gas, liquified petroleum gas, or even diesel fuel. The generic term generally applied to the process of converting liquid or gaseous light hydrocarbon fuels to hydrogen and carbon monoxide is *reforming*. A number of methods are used to reform fuel. The three most commercially developed and popular methods are steam reforming, partial-oxidation reforming, and autothermal reforming. These processes involve heating the hydrocarbon fuels to the point of vaporization and then injecting superheated steam to help force the reaction to completion. The heat source for the reaction is usually an immediately adjacent high-temperature furnace that combusts a small portion of the raw fuel or the fuel effluent from the fuel cell. Rejected heat from the fuel cell system also can be used for the heat source.

The reforming of hydrocarbon-rich fuels is often not complete, and gases including carbon monoxide pass through the reforming process. These gases are converted to water and carbon dioxide with a catalyst.

- **Electrodes**

A hydrogen-rich gas from the reformer (or hydrogen from storage on the site) is fed continuously to the electrodes where an electrochemical reaction takes place to produce an electric current. As with a battery, two electrodes—the anode and the cathode—are used to produce electricity.

Anode

The anode, the negative post of the fuel cell, has several jobs. It conducts the electrons freed from the hydrogen molecules so they can be used in an external circuit. The anode is etched with channels that disperse the hydrogen gas equally over the surface of the catalyst is used to split the hydrogen molecules into positively charged ions, giving up one electron each.

The positively charged ions then migrate through the electrolyte (see description of electrolyte below) to the positive post (cathode). The negatively charged electrons travel through the external circuit to produce electric energy.

Cathode

The cathode, the positive post of the fuel cell, also is etched with channels that distribute the continuous supply of oxygen from air (oxidant) to the surface of the catalyst. It also conducts the electrons back from the external circuit to the catalyst, where they can recombine with the hydrogen ions and oxygen to form water.

- **Electrolyte**

The electrolyte transports the positively charged hydrogen ions to the cathode and thereby completes the cell electric circuit. It also provides a physical barrier to prevent the fuel and oxidant gas streams from directly mixing.

- **Oxidant**

The most common oxidant is gaseous oxygen, which is available from air for stationary fuel cell applications. The oxidant is introduced into the system at the cathode (see cathode above).

Stationary fuel cell equipment can be categorized in a number of different ways:

- unitary – All the components (fuel processor, cell stack, and power-conditioning unit) are matched together and assembled in one complete piece of equipment.
- matched modular – One or more of the components are separate from the others but have been designed to work together and are provided by one manufacturer for assembly in the field.
- Modular – The components have not been designed specifically to work together and are not provided by one manufacturer but by separate manufacturers for assembly in the field.
- site-built – This field-erected fuel cell uses components and pieces from various sources to make up a fuel cell power plant.

Unitary equipment will typically provide a smaller output (up to ~500 kW) due to the limitation on the size of the equipment posed by the single package in which it would be provided. Matched modular or modular would have larger outputs. Site-built fuel cell power plants would provide large outputs, on the order of a few megawatts or more.

- **Fuel Cell Stack**

A single fuel cell produces only about 0.7 volt. To increase the voltage, many separate fuel cells must be combined to form a fuel cell stack. The fuel cell stack is integrated into a fuel cell system with other components, including a fuel reformer, power electronics, and controls. Simply stated, the more cells in the stack and the more stacks in the equipment, the greater the power output. The term *stack power density* describes how much power is produced for a given area of fuel cell.

- **Power-Conditioning Equipment**

The fuel cell system can provide either dc or ac power. Power conditioning for a fuel cell power plant used to supply dc rated equipment includes current and voltage controls. Power conditioning for a fuel cell power plant used to supply ac-rated equipment includes dc to ac inversion and current, voltage and frequency control, stepping the voltage up or down through a transformer depending on final equipment utilization voltage, and maintaining harmonics output to an acceptable level. In addition, transient response of the power-conditioning equipment should be considered. For utility grid interconnection, synchronization, real power (watts) ramp rate, and reactive power (volt-amperes reactive, or VAR) control also must be addressed.

2.2 Types of Fuel Cells

Four primary fuel cell system types have been utilized in stationary fuel cell equipment installed in commercial buildings. The descriptions that follow provide specific detail on the following fuel cell system types:

- molten carbonate fuel cells (MCFCs)
- phosphoric acid fuel cell (PAFCs)
- proton exchange membrane fuel cell (PEMFCs)
- solid oxide fuel cells (SOFCs).

Alkaline fuel cells (AFCs) are not discussed in this document because they are not usually installed in commercial buildings. They are a type of fuel cell with low overall efficiencies and low operating temperatures.

Fuel cells are classified primarily by the kind of electrolyte they employ. This determines the kind of chemical reactions that take place in the cell, the kind of catalysts required, the temperature range in which the cell operates, the fuel required, and other factors. These characteristics, in turn, affect the applications for which these cells are most suitable. Table 2.1 provides a comparison of the four fuel cells discussed.

Table 2.1. Fuel Cell Comparison

	MCFC	PAFC	PEMFC	SOFC
Electrolyte	Molten carbonate salt	Liquid phosphoric acid	Ion exchange membrane	Solid metal oxide
Operating Temperature	1100–1830°F (600–1000°C)	300–390°F (150–200°C)	140–212°F (60–100°C)	1100–1830°F (600–1000°C)
Reforming	External/Internal	External	External	External/Internal
Oxidant	CO_2/O_2/Air	O_2/Air	O_2/Air	O_2/Air
Efficiency (without cogeneration)	45-60%	35-50%	35-50%	45-60%
Maximum Efficiency (with cogeneration)	85%	80%	60%	85%
Maximum Power Output Range (size)	2 MW	1 MW	250 kW	220 kW
Waste Heat Uses	Excess heat can produce high-pressure steam	Space heating or water heating	Space heating or water heating	Excess heat can be used to heat water or produce steam

2.2.1 Molten Carbonate Fuel Cells

The molten carbonate fuel cell (MCFC) uses a molten carbonate salt as the electrolyte. It may also be fueled with coal-derived fuel gases or natural gas.

MCFCs are high-temperature fuel cells that use an electrolyte composed of a molten carbonate salt mixture suspended in a porous, chemically inert ceramic lithium aluminum oxide ($LiAlO_2$) matrix. Because they operate at extremely high temperatures of 600ºC (roughly 1100ºF) and above, nonprecious metals can be used as catalysts at the anode and cathode, reducing costs.

Manufacturers claim that fuel efficiencies approach 60%, considerably higher than the 35%–50% efficiencies of a phosphoric acid fuel cell plant. When the waste heat is captured and used, overall fuel efficiencies can be as high as 85%.

Unlike alkaline, phosphoric acid, and polymer electrolyte membrane fuel cells, MCFCs do not require an external reformer to convert more energy-dense fuels to hydrogen. Due to the high temperatures at which they operate, these fuels are converted to hydrogen within the fuel cell itself by a process called internal reforming, which also reduces cost.

Molten Carbonate Fuel Cell

10-kW to 2-MW MCFC systems have been tested.

MCFC systems promise high fuel-to-electricity efficiencies, about 60% normally or 85% with cogeneration, as the excess heat generated can be harnessed and used in combined heat and power plants.

Electrochemical Reactions

Anode:
$H_2+CO_3^{2-} \Rightarrow H_2O + 2e^-$

Cathode:
$½O_2+CO_2+2e^- \Rightarrow CO_3^{2-}$

Cell:
$H_2+½O_2+CO_2 \Rightarrow H_2O+CO_2$

MCFCs are not prone to carbon monoxide or carbon dioxide "poisoning"—they even can use carbon oxides as fuel—making them more attractive for fueling with gases made from coal. Although they are more resistant to impurities than other fuel cell types, scientists are looking for ways to make MCFCs resistant enough to impurities from coal, such as sulfur and particulates.

The primary disadvantage of current MCFC technology is durability. The high temperatures at which these cells operate and the corrosive electrolyte used accelerate component breakdown and corrosion, decreasing cell life. Scientists currently are exploring corrosion-resistant materials for components as well as fuel cell designs that increase cell life without decreasing performance.

2.2.2 Phosphoric Acid Fuel Cells

A phosphoric acid fuel cell (PAFC) consists of an anode and a cathode made of a finely dispersed platinum catalyst on carbon paper, and a silicon carbide matrix that holds the phosphoric acid electrolyte.

PAFCs are more tolerant of impurities in the reformate than proton exchange membrane fuel cells, which are easily "poisoned" by carbon monoxide—carbon monoxide binds to the platinum catalyst at the anode, decreasing the fuel cell's efficiency. They are 85% efficient when used for the cogeneration of electricity and heat but less efficient at generating electricity alone (35% to 50%). This is only slightly more efficient than combustion-based power plants, which typically operate at 33% to 35% efficiency.

More than 200 PAFC systems have been installed all over the world including hospitals, nursing homes, hotels, office buildings, schools, utility power plants, military bases, an airport terminal, landfills, and waste water treatment plants. Most are the 200-kW PC25 fuel cell power plant manufactured by the ONSI Corporation, including one that powers a police station in New York City's Central Park and two that provide supplemental power to the Conde Nast Building at 4 Times Square in New York. The PC25 is a prepackaged tested and listed unit delivered on a skid to facilitate installation and interconnection with the building systems and fuel source. The largest PAFC system to be tested is an 11-MW power plant sited in Japan. Many of these installations have operated for more than 40,000 hours without interruption.

Phosphoric Acid Fuel Cell

International Fuel Cells has installed many of these 200-kW phosphoric acid fuel cells. This one is situated at a hospital and provides power and heat.

Photo courtesy of International Fuel Cells

More than 200 of the International Fuel Cells 200-kW ONSI units have been put into service all over the world.

Photo courtesy of International Fuel Cells

Electrochemical Reactions

Anode:
$H_2 \Rightarrow 2H^+ + 2e^-$

Cathode:
$\frac{1}{2} O_2 + 2H^+ + 2e^- \Rightarrow H_2O$

Cell:
$H_2 + \frac{1}{2}O_2 \Rightarrow H_2O$

2.2.3 Proton Exchange Membrane Fuel Cells

The proton exchange membrane fuel cell (PEMFC) uses a fluorocarbon ion exchange with a polymeric membrane as the electrolyte. These cells operate at relatively low temperatures and can vary their output to meet shifting power demands. These properties make PEMFCs the best candidates for light-duty vehicles, buildings, and much smaller applications.

PEMFCs operate at relatively low temperatures, around 80°C (176°F). Low-temperature operation allows them to start quickly (less warm-up time) and results in less thermal stress on system components. However, this low-temperature operation requires that a noble-metal catalyst (typically platinum) be used to separate the hydrogen electrons and protons. The platinum catalyst is extremely sensitive to carbon monoxide poisoning, making it necessary to employ an additional reactor to reduce carbon monoxide in the fuel gas if the hydrogen is derived from a carbon-containing fuel. Developers are exploring different catalyst formations that are more resistant to carbon monoxide.

Manufacturers claim that the PEMFC system efficiencies range from 35% to 50% and, with capture and use of waste heat, can have an overall efficiency approaching 60%.

Proton Exchange Membrane Fuel Cell

Avista Labs has developed a modular technology, allowing "hot swapping" of stack subcomponents and on-line maintenance.

Photo courtesy of Avista Labs

Ballard Generation Systems' first field trial of a 250-kW Natural Gas PEM Fuel Cell Power Generator is sited at the Crane Naval Surface Warfare Center for a two-year demonstration and testing program.

Photo courtesy of Ballard

Electrochemical Reactions

Anode:
$H_2 \Rightarrow 2H^+ + 2e^-$

Cathode:
$\frac{1}{2}O_2 + 2H^+ + 2e^- \Rightarrow H_2O$

Cell:
$H_2 + \frac{1}{2}O_2 \Rightarrow H_2O$

2.2.4 Solid Oxide Fuel Cells

Solid oxide fuel cells (SOFC) currently under development use a thin layer of zirconium oxide as a solid ceramic electrolyte and include a lanthanum manganate cathode and a nickel-zirconia anode. This is a promising option for high-powered applications such as industrial uses or central electricity generating stations.

SOFCs operate at very high temperatures—around 1000ºC (~1800ºF). High-temperature operation removes the need for a precious-metal catalyst. It also allows SOFCs to reform fuels internally, which enables the use of a variety of fuels and reduces the cost associated with adding a reformer to the system.

SOFCs are the most sulfur-resistant fuel cell type. In addition, they are not poisoned by carbon monoxide, which is actually used as fuel. As a result, SOFCs can use gases made from coal or other gas-fired fossil fuels.

High-temperature operation has disadvantages. It results in a slow start-up and requires significant thermal shielding to retain heat and protect personnel, which may be acceptable for utility applications but not for transportation and small portable applications. The high operating temperatures also place stringent durability requirements on materials. The development of low-cost materials with high durability at cell operating temperatures is the key technical challenge facing this technology.

Currently available unpressurized SOFCs provide electric efficiencies in the range of 45%. Argonne National Laboratory suggests that pressurized systems could yield fuel efficiencies of 60%. Power generating efficiencies could reach 60% to 85% with use of waste heat to facilitate cogeneration.

Solid Oxide Fuel Cell

This system, developed by SiemensWestinghouse, is the world's first fuel cell/gas turbine hybrid., It began operation at the University of California–Irvine in May 2000. It integrates a microturbine generator with a solid oxide fuel cell and produces 220 kW at a system electrical efficiency of 58%. Future SOFC/gas-turbine hybrid plants are expected to have electrical efficiencies of 60%–70%.

Photo courtesy of SiemensWestinghouse

Electrochemical Reactions

Anode:
$H_2+O^{2-} \Rightarrow H_2O + 2e^-$

Cathode:
$\frac{1}{2}O_2+2e^- \Rightarrow O^{2-}$

Cell:
$H_2+\frac{1}{2}O_2 \Rightarrow H_2O$

2.3 Bibliography

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, "Types of Fuel Cells," http://www.eere.energy.gov/hydrogenandfuelcells/fuelcells/types.html#sofc (December 8, 2003).

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, "Hydrogen: Fuel Cells", http://www.eere.energy.gov/RE/hydrogen_fuel_cells.html (December 19, 2003).

U.S. Department of Energy, Fossil Energy.Gov, "Future Fuel Cells", http://www.fossil.energy.gov/programs/powersystems/fuelcells/ (December 19, 2003).

2.4 Glossary

A comprehensive on-line glossary with general fuel cell terms provided by the U.S. Department of Energy is available at http://www.eere.energy.gov/hydrogenandfuelcells/glossary.html. Many fuel cell and hydrogen terms are also defined in the glossary of this document (Overview, Section 3).

3.0 Requirements Overview

Several issues related to fuel cells may attract the attention of code officials, including fuel supply and storage, electrical interconnection to the power grid, ventilation, fire protection, and intervention. Figure 3.1 shows the most common installation requirements for a fuel cell in a commercial building.

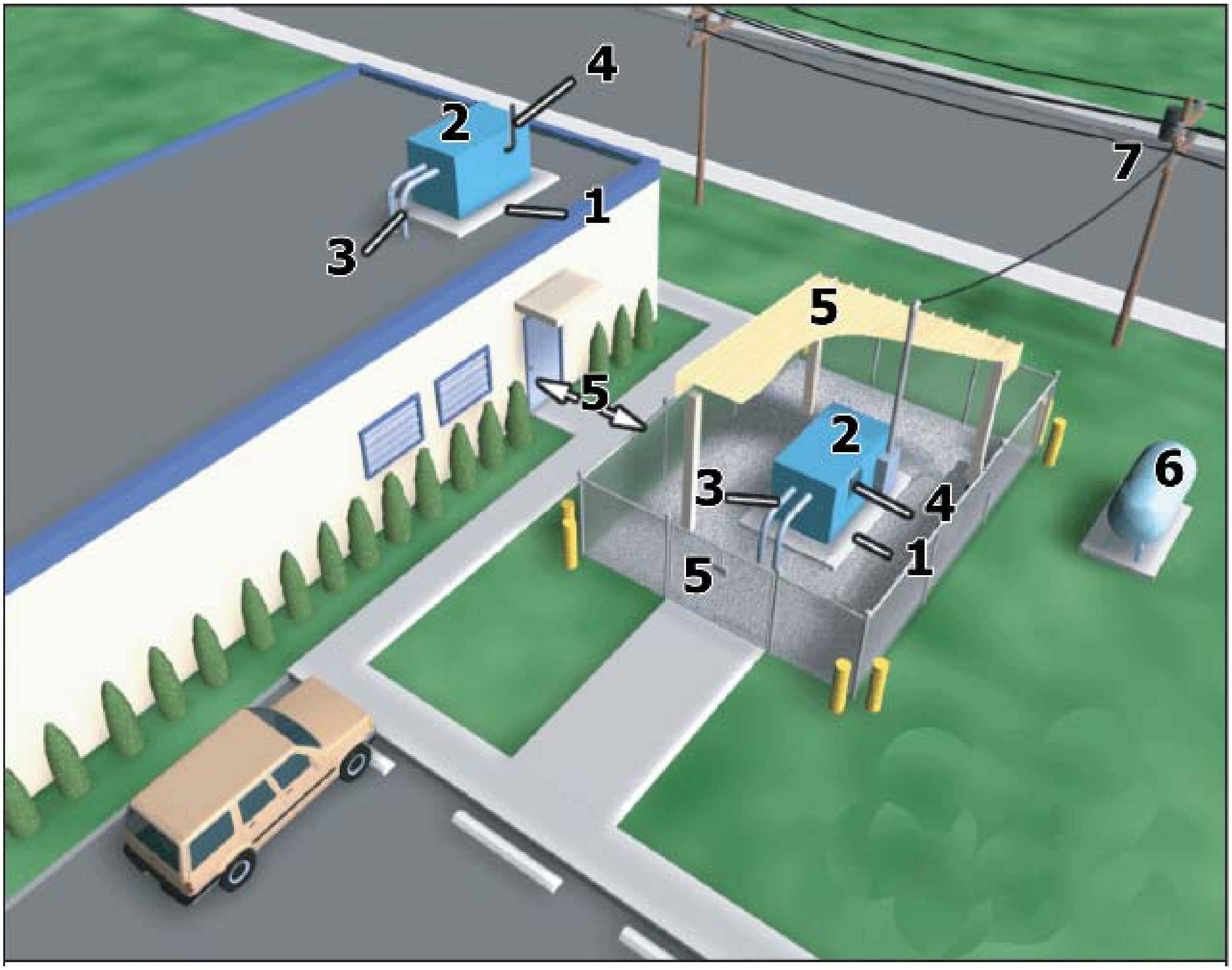


Figure 3.1. Typical Installation Requirements for a Fuel Cell in a Commercial Building

1 **Foundation and Protection** (see Table 4.2, Section 2.0)
2 **Fire Protection Systems** (see Table 4.2, Section 4.0)
3 **Piping Components and Connections** (see Table 4.2, Section 3.0)
4 **Ventilation, Exhaust, and Makeup Air** (see Table 4.2, Section 2.2)
5 **Siting, Installation, and Protection** (see Table 4.2, Section 2.0)
6 **Fuel Supply and Storage** (see Table 4.2, Section 1.0)
7 **Interconnections** (see Table 4.2, Section 5.0)

4.0 Codes and Standards for Stationary Fuel Cell Installations

4.1 Overview

This section focuses on codes and standards (building regulations) that affect the design, installation, and operation of a fuel cell (and, hence, its acceptability). Guidance is provided for each of the codes and standards available and applicable to a stationary fuel cell installation. The guidance briefly describes the documentation and information that should be provided by the designer and reviewed by the building official.

4.2 Codes and Standards Tables

The codes and standards listed in Table 4.1 provide a general guide to the regulations associated with fuel cell installation. More detail on the exact provisions for specific issues is provided in Table 4.2.

Table 4.1. Codes and Standards Applicable to Stationary Fuel Cell Installations

Title of Code/Standard	Contact
2000 International Mechanical Code (IMC) Regulates and controls the design, construction, installation, quality of materials, location, operation and maintenance of use of mechanical systems.	ICC
2000 International Fuel Gas Code (IFGC) Regulates and controls the design, construction, installation, quality of materials, location, operation and maintenance or use of fuel gas systems.	ICC
2000 International Fire Code (IFC) The purpose of the IFC is to establish the minimum requirements consistent with nationally recognized good practice for providing a reasonable level of like safety and property protection from the hazards of fire, explosion or dangerous conditions in new and existing buildings, structures and premises.	ICC
2000 International Residential Code (IRC) Provides minimum requirements to safeguard life or limb, health and public welfare for one and two family occupancies and townhouses.	ICC
2000 International Building Code (IBC) Establishes the minimum requirements to safeguard the public health, safety and general welfare through structural strength, means of egress facilities, stability, sanitation, adequate light and ventilation, energy conservation, and safety to life and property from fire and other hazards attributed to the built environment.	ICC
2000 International Plumbing Code (IPC) Regulates and controls the design, construction, installation, quality of materials, location, operation and maintenance or use of plumbing equipment and systems.	ICC

Table 4.1. Codes and Standards Applicable to Stationary Fuel Cell Installations (contd)

Title of Code/Standard	Contact
NFPA 70 (NFPA 70) **2002 National Electric Code** §692, Fuel Cell Systems—Requirements for the installation of fuel cell power systems, which may be stand-alone or interactive with other electrical power production sources and may be with or without electrical energy storage such as batteries.	NFPA
NFPA 50A / 50B **NFPA 50A – Standard for Gaseous Hydrogen Systems at Consumer Sites** Covers the general principles recommended for the installation of gaseous hydrogen systems on consumer premises where the hydrogen supply to the consumer premises originates outside the consumer premises and is delivered by mobile equipment. **NFPA 50B – Standard for Liquefied Hydrogen Systems at Consumer Sites** Covers the general principles recommended for the installation of liquefied hydrogen systems on consumer premises where the liquid hydrogen supply to the consumer premises originates outside the consumer premises and is delivered by mobile equipment.	NFPA
NFPA 54 - National Fuel Gas Code **Natural Gas Systems** Applies to the installation of fuel gas piping systems, fuel gas utilization equipment, and related accessories.	NFPA
NFPA 58 -Liquefied Petroleum Gas Code **LPG** Applies to the highway transportation of liquefied petroleum gas and to the design, construction, installation and operation of all liquefied petroleum gas systems.	NFPA
NFPA 853-2000 (NFPA 853) **Standard for the Installation of Stationary Fuel Cell Power Plants** Applies to the design and installation of 1) a singular prepackaged self-contained power plant unit; 2) combination of prepackaged self-contained units; 3) power plant units comprised of two or more factory matched modular components intended to be assembled in the field.	NFPA
AMSE Boiler and Pressure Vessel Code The International Boiler and Pressure Vessel Code establishes rules of safety governing the design, fabrication, and inspection of boilers and pressure vessels and nuclear power plant components during construction.	ASME
UL 1741 (UL 1741) **Standards for Inverters Converters and Controllers for Use in Independent Power Systems, January 2001** Covers inverters, converters, charge controllers, and output controllers intended for use in stand-alone (not grid-connected) or utility-interactive (grid-connected) power systems. Utility-interactive inverters and converters are inteded to be installed in parallel with the electric supply system or an electric utility to supply common loads.	UL

Table 4.1. Codes and Standards Applicable to Stationary Fuel Cell Installations (contd)

Title of Code/Standard	Contact
ANSI Z 21.83-1998 (ANSI Z 21.83) **Standard on Stationary Fuel Cell Power Plants** Provides fire prevention and fire protection requirements for safeguarding life and physical property associated with buildings or facilities that employ stationary fuel cells or all sizes.	CSA
ICC — International Code Council, 5203 Leesburg Pike, Suite 600, Falls Church, VA 22041, (703) 931-4533, www.iccsafe.org **NFPA** — National Fire Protection Association, 1 Batterymarch Park. Quincy, MA 02269-9101, (800) 344-3555, www.nfpa.org **ASME** — ASME International, Three Park Avenue, New York, NY 10016, 1-800-843-2763, or 1-973-882-1167, Fax: 1-973-882-1717 **UL** — Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096, Tim Zgonena, (847) 272-8800 Ext. 43051, timothy.p.zgonena@us.ul.com **CSA** — CSA International, Steven E Kazubski, Project Manager, Standards, 8501 E. Pleasant Valley Road, Cleveland, OH 441310-5575, (216) 524-4990 Ext. 8303, http://www.cas-international.org	

Table 4.2 is subdivided into five key sections that correspond to different aspects of a hydrogen storage and fueling station:

1. **Fuel Supply and Storage**
   1.1. Fuel Supply and Storage-Outside the Fuel Cell

2. **General Fuel Cell Siting**
   2.1. General
   2.2. Outdoor Installations (not located within a building or structure; not enclosed by surrounding wall or roof construction; open to the outside environment)
   2.3. Indoor Installations (within a building or structure; enclosed by surrounding wall or roof construction; not open to the outside atmosphere)

3. **Fuel Cell Equipment**

4. **Fire Protection**

5. **Interconnections**
   5.1. Disconnecting Means
   5.2. Wiring Methods
   5.3. Grounding
   5.4. Marking
   5.5. Connection to Other Circuits
   5.6. Output Over 600 Volts
      5.6.1. Equipment – Metal-Enclosed Power Switchgear and Industrial Control Assemblies

Enforcement personnel can use Table 4.2 during preliminary review of a hydrogen fuel cell installation to verify that each of the applicable provisions has been met. The number designated within Table 4.2 represents a major section heading within a code/standard or group of related codes/standards that covers a topic (e.g., Section 2.1, General). Please be aware that further subsections may be associated with each major section (e.g., Section 2.1.1) and further review by the user will be necessary.

The following information is included in Table 4.2:

- Issue – The provision title used in the code/standard.
- Requirements – A brief description of each of the code provisions is provided to give the user an overview of the code text.
- What To Look For – Guidance is provided to enforcement personnel on what to review for a hydrogen fuel cell installation submittal. The description includes the documentation that should be submitted (e.g., a label or listing) and where the information should be included in the plans or specifications.
- Code/Standard – The requisite code or standard that affects the design, installation, equipment specification, or operation of the hydrogen fuel cell installation is listed in abbreviated form.

As technology evolves, so do codes and standards. This module was written based on information available at a specific point in time, so readers should be aware that codes and standards covered herein may have been revised and/or a new version of this document created. It is highly recommended that the user verify that the latest editions of this document and, more importantly, that the relevant codes and standards are being used. In terms of systems design, it is suggested that manufacturers become involved in the codes and standards development process and, to the degree possible, remain aware not only of currently published documents but also of ongoing revisions and new documents under development.

Table 4.2. Codes and Standards for Fuel Cell Installations

Issue	Requirement Description	What To Look For	Code/Standard
1.0 Fuel Supply and Storage			
1.1 Fuel Supply and Storage-Outside the Fuel Cell			
Natural Gas Fuel Supplies	Covers piping, components, and connections from point of delivery to fuel feedstock inlet of the fuel cell.	Natural gas in accordance with NFPA 54 or IFGC as applicable. Compressed natural gas in accordance with NFPA 52 and IFC.	NFPA 853 – §4-2
Liquefied Petroleum Gas (LP-Gas) Systems	Covers piping components and connections from LP-Gas storage or piping system to fuel feedstock inlet of the fuel cell.	LP gas in accordance with NFPA 58 or IFGC as applicable.	NFPA 853-§4-3
Hydrogen Fuel Systems	Covers piping components and connections from gaseous or liquefied storage or piping system to fuel feedstock inlet of the fuel cell.	IBC and NFPA 50A (gaseous) or 50B (liquefied), where the H2 supply to the premises originates off-site, and the H2 is delivered by mobile equipment (i.e., a truck). Requires piping valves and fittings in accordance with ASTM/ANSI B31.3; or IBC and 2003 IFGC for the installation of all gaseous or liquefied hydrogen system	NFPA 853 – §4-4
Biogas Fuel Systems* *Includes landfill gases, anaerobic digester gases,and other gases derived from the decomposition of organic materials.	Covers piping components and connections from biogas storage or piping system to fuel feedstock inlet of the fuel cell.	Biogas fuel storage tanks and associated equipment in accordance with NFPA 54 or IFGC as applicable.	NFPA 853-§4-5

Table 4.2. Codes and Standards for Fuel Cell Installations (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Liquid Fuels (Diesel, JP-4, JP-5, Ethanol, Naphtha, Methanol)	Covers piping components and connections from flammable or combustible liquid storage or piping to the fuel feedstock inlet of the fuel cell.	Flammable liquid fuels in accordance with IFC and NFPA 30, Flammable and Combustible Liquids Code.	NFPA 853-§4-6
Hazardous Materials, General Provisions* *(Inclusive of liquefied petroleum gas, hydrogen gas, natural gas, biogas and flammable & combustible liquefied fuel systems)	Regulate the storage, dispensing and use of all hazardous materials classified as either physical or health hazards.	Evaluate the requirements of these Sections and the IFC Chapter concurrently as they both address the use of control areas, requirements for cabinets, signage and labeling, handling and transport, on-site emergency response personnel, design requirements for containers tanks and piping, general storage requirements for hazardous materials exceeding exempt amounts per control area, spill control and monitor control equipment to name a few. Not all occupancies utilizing hazardous materials are classified as high hazard. Only buildings containing more than the exempt amounts of a given material per control areas would be classified as such.	IBC §307.1, IFC Chapter 27
Condensate Disposal Gray Water Recycling Systems	Provides detailed requirements for the disposal of condensate from appliances and equipment. Establishes provisions for gray water recycling systems.	Evaluate compliance based on most appropriate classification of liquid by-products.	IMC §307 IPC §301.3 (as modified by Appendix C), Appendix C
Boiler and Pressure Vessel Code, Section VIII, Pressure Vessels	Establishes rules of safety governing the design, fabrication, and inspection of boilers and pressure vessels and nuclear power plant components during construction.	Evaluate compliance assessment for fuel cell installations (not tested to ANSI Z21.83) employing pressure vessels or power piping.	ASME BPVC IMC §1001, §1003 IFC Chapter 32

Table 4.2. Codes and Standards for Fuel Cell Installations (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Process Piping	Requirements for materials and components, design, fabrication, assembly, erection, examination, inspection, and testing of piping.	For fuel cell installations not tested to ANSI Z21.83, assess compliance as this code applies to piping for all fluids including: raw intermediate, and finished chemicals; petroleum products; gas, steam, air, and water; fluidized solids; refrigerants; and cryogenic fluids.	ASME B31.3
Flammable Gases	Addresses provisions for storage and use of flammable compressed gases such as ethane, ethylene, methane, and others; but as pertains to Fuel Cells, primarily hydrogen.	Fuel cells utilize hydrogen-rich gaseous mixture (reformate) reformed from either LPG or natural gas. This reformate is delivered directly to the power section of the fuel cell. Piping conveying hydrogen or reformate is generally considered a closed system in accordance with IBC §307.9, Exception 5 and the definition, CLOSED SYSTEM. Gaseous hydrogen systems must also comply with NFPA 50A.	IFC Chapter 35
Hazardous Exhaust Systems	Governs the design and construction of duct systems for hazardous exhaust and determines where such systems are required.	Hazardous exhaust systems are generally not required for fuel cells having sealed direct vented/exhausted fuel-carrying compartments or fuel cells designed and installed in accordance with manufacturer's instructions or NFPA 853. Fuel cells installed inside of buildings and not meeting the above criteria must be designed in accordance with §510 and be provided with ventilation (dilution), exhaust and make-up air in sufficient quantities supplied directly to the fuel cell compartment or to the room or space in which the fuel cell is located.	IMC §510

Table 4.2. Codes and Standards for Fuel Cell Installations (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Liquefied Petroleum Gases (LPG)	Establishes requirements for storing, handling and using LPG.	Evaluate the requirements of this chapter as they address hazards associated with the storage and general use of LPG. The IFC also references NFPA 58, for the use of LPG. This standard is supplemented by NFPA 59, which specifically addresses the use of LPG at utility gas plants.	IFC Chapter 38
2.0 General Fuel Cell Siting			
General Siting	Covers the siting and installation of fuel cells and associated equipment for structure stability, protection, proximity to potentially hazardous atmospheres, maintenance, physical damage from impact or vandalism.	Evaluate the requirements of these Sections such that: 1. The fuel cell is provided with a firm foundation capable of supporting the equipment or otherwise suspended above exposed surrounding earth. The fuel cell is anchored, located and protected from the elements and from gravity (e.g., dead load, live load, snow, etc.), seismic, hydrodynamic (e.g., flood) and wind loads; lightning and physical damage. The fuel cell is protected against unauthorized access. The fuel cell is located outside of potentially hazardous atmospheres (NFPA 70 and 496). Locations in which fuel cells are installed are considered Class I, Division 2, hazardous locations. The proximity of ignition sources with respect to the power plant shall be located in accordance with the applicable Electric and Fire Codes of reference. In general, this is not an issue for fuel cells having sealed direct vented/ exhausted fuel-carrying compartments or fuel cells designed and installed in accordance with manufacturer's instructions or NFPA 853. Sited so as not to affect required exits.	NFPA 853 – §3-1 IBC §1609, §1612, §1621, §1805 IFC §304, §305, §312, §2704 IMC §102.3, §303.4, §303.6, §306, §401.5, §501.3

Table 4.2. Codes and Standards for Fuel Cell Installations (contd)

Issue	Requirement Description	What To Look For	Code/Standard
General Siting (contd)		Associated exhaust vents/terminations separated from doors, windows, outdoor air intakes or other openings from which exhaust cannot be readily drawn into the building. Access for service and maintenance shall be provided. The fuel cell must be located away from hazardous or combustible materials. Multiple power plants must be sited so that a fire or failure of one plant does not affect the other plant.	
2.1 Outdoor Installations			
Outdoor Installations	Provides provisions for outdoor fuel cell installations including requirements for associated exhaust systems.	Evaluate the requirements of these Sections as follows: 1. Confirm that the power plant is designed and listed for outdoor installation. 2. Evaluate proximity of exhaust and intake openings serving the fuel cell that they are located at least 15 feet from intakes, windows, doors or other openings from which exhaust cannot be readily drawn into the building and at least 10 feet from lot lines or other buildings. 3. Verify that the provisions of Article 500 of NFPA 70 are met for electrical, electrical equipment and wiring installed in locations with potential fire or explosion risk. 4. Confirm that air flow to the fuel cell is not likely to be affected as a result of its proximity to fences, enclosures, etc. if the fuel cell shall be located away from ignition sources, hot work; and combustible, flammable or hazardous material storage.	NFPA 853 – §3-2 NFPA 70-2002– §500 IBC §307.1, T307.7(1); IFC §304, §305, Chapter 27, §2704 IMC §303.6, §401.5 §401.6, §501.3, §701.5, §710

Table 4.2. Codes and Standards for Fuel Cell Installations (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Rooftop Installations	Provides requirements for rooftop installation	Assess compliance with NFPA 853 – §3-2 Evaluate roofing materials such that they are either noncombustible or otherwise confirmed as having a Class A fire classification.	NFPA 853 – §3-4 IBC §703.4, §1505
2.2 Indoor Installations			
Indoor Installations Stationary Fuel Cell Power Plants	Provides requirements for indoor fuel cell installations. General appliance installation provisions for testing and installation of stationary fuel cells having a power output not exceeding 1,000kW.	Evaluate the requirements of these Sections as follows: 1. Confirm that the fuel cell has been tested in accordance with ANSI Z21.83 and installed in accordance with the manufacturer's installation instruction; -OR- where it cannot be demonstrated that the fuel cell has been tested or installed as required (above), the code official must require the submission of any appropriate information and data to assist in the determination of equivalency. 2. With the exception of incidental use areas within dwelling units, rooms or spaces that enclose the fuel cell installation shall be separated from other building areas by 1-hour fire barriers with equivalent opening protectives.	NFPA 853 – §3-3 IMC §105, §924 IBC §302.1.1, §706, §714
Ventilation and Exhaust	Establishes requirements for providing ventilation, exhaust and makeup air to fuel cell installations. States requirements for equalized and negative pressures and the conditions requiring the installation of a hazardous exhaust system as applicable.	With the exception of unvented power plants tested with ANSI Z21.83, fuel cells shall either have sealed, direct-vented/exhausted fuel-carrying compartments or otherwise be equipped with controls such that it is not possible for a flammable mixture to be achieved. (see IMC §510.2 for stating conditions requiring the installation of a hazardous exhaust system).	NFPA 853 – Chapter 5 IMC §401.3, §501.4, §510

Table 4.2. Codes and Standards for Fuel Cell Installations (contd)

Issue	Requirement Description	What To Look For	Code/Standard
General	General requirements for providing ventilation, exhaust and makeup air to fuel cell installations.	Rooms or spaces enclosing fuel cells and served by exhaust systems must be provided with makeup air to replace the air exhausted. Such spaces shall be maintained with a negative or neutral pressure. Electro-mechanical controls are required to supervise and automatically coordinate the simultaneous operation of mechanical ventilation, exhaust and makeup air systems such that the fuel cell is shut down if any of these systems fail. Confirm that these systems, where serving a grid-isolated power plant, are capable of operating under standby power for the duration necessary to complete system shutdown and purge.	NFPA 853 – §5-1 IMC §501.4, §510.3, IFC §2210.7.1
Fire Protection	Establishes active fire safety provisions for fuel cell installations. They are provisions directed at containing and abating the fire once it has erupted.	Confirm installation as required	NFPA 853 – Chapter 6

Table 4.2. Codes and Standards for Fuel Cell Installations (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Indoor Locations	Establishes active fire safety provisions for fuel cell installations. They are provisions directed at containing and abating a fire once it has erupted.	Verify that an automatic fire suppression system has been specified for the room or space in which the fuel cell and associated components are located. Confirm the installation of a flammable gas detection system for all indoor gas compressors and in the power plant enclosure, exhaust system or room that encloses the fuel cell. The detection system must meet the following criteria. 1. It shall be arranged to alarm at 25 percent of the lower flammable limit (LFL) 2. It shall shut down the power plant fuel supply at 60 percent LFL The LFL used shall be the lower flammability limit of the gas or gas mixture. Where gaseous or liquefied hydrogen is piped directly to an indoor PC, confirm the installation of an approved continuous monitoring flammable gas detection system in rooms or spaces where the fuel cell is installed. The detection system must meet the following criteria: 1. Arranged to alarm at 25 percent of the lower flammable limit (LFL) 2. Interlocked to initiate safety shut down of the fuel cell supply at 60 percent LFL	NFPA 853 – §6-1.6 IMC §502.4.1 IFC §2210.7.1
Fire Protection	Establishes active fire safety provisions for fuel cell installations. They are provisions directed at containing and abating the fire once it has erupted.	Confirm installation as required	NFPA 853 – Chapter 6

Table 4.2. Codes and Standards for Fuel Cell Installations (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Process purging and venting	Provides requirements for system purging venting during system start and shutdown as applicable.	Pressure tanks and piping intended to be purged of combustible gas shall be vented outdoors at a point where it will not cause a nuisance and from which it cannot again be readily drawn in by a ventilation system. Verify that the vent is protected from the entry of water or foreign objects.	NFPA 853 – §5-4 IMC §501.4 (see also 2003 IFGC, Chapter 7, and 2003 IFC § 2210.8)
3.0 Fuel Cell Equipment			
Stationary Fuel Cell Power Plants Prepackaged, Self-contained Fuel Cell Power Plants Installation and Listing Requirements	General appliance installation provisions for testing and installation of stationary fuel cells having a power output not exceeding 1,000kW. Allows the use of a fuel cell system to supply electricity to a building. Requires a fuel cell to be evaluated and listed for its intended application.	Confirm that the fuel cell has been tested in accordance with ANSI Z21.83 and installed in accordance with the manufacturer's installation instructions; -OR- where it cannot be demonstrated that the fuel cell has been tested or installed as required (above), the code official must require the submission of any appropriate information and data to assist in the determination of equivalency.	IMC §105, §924 NFPA 853 – §2.1 NFPA 70 – §692.4, §692.6
Stationary Fuel Cell Power Plants Pre-Engineered Fuel Cell Power Plants	General appliance installation provisions for testing and installation of stationary fuel cells having a power output not exceeding 1,000kW References ANSI Z21.83 for design of pre-engineered fuel cell systems and matched modular components.	Confirm that the fuel cell has been tested "to meet the intent" of ANSI Z21.83 and installed in accordance with the manufacturer's installation instructions; -OR- where it cannot be demonstrated that the fuel cell has been tested or installed as required (above), the code official must require the submission of any appropriate information and data to assist in the determination of equivalency.	IMC §105, §924 NFPA 853 – §2.2
Engineered and Field-Constructed Fuel Cell Power Plants	Requires documentation for engineered and field-constructed fuel cell power systems	The code official must require the submission of any appropriate information and data to assist with compliance assessment. Documentation shall include a Fire Risk Evaluation prepared by a registered design professional.	NFPA 853 – §2.3

Table 4.2. Codes and Standards for Fuel Cell Installations (contd)

Issue	Requirement Description	What To Look For	Code/Standard
4.0 Fire Protection			
Fire Protection and Detection	Provides requirements for siting fire hydrants in addition to general fire detection and alarm systems for fuel cell installations.	For outdoor fuel cells that do not have flammable or combustible liquid feedstock-fuel storage, confirm that yard or city hydrant protection is provided. A Fire Risk Evaluation is required for all other fuel cell power plants. Confirm that rooms or spaces enclosing fuel cells are provided with an automatic fire detection system.	NFPA 853 – §6-1 IBC §907
Fire-Prevention and Emergency Planning	Requires a written fire prevention and emergency plan based on the size and location of the fuel cell plant	Reporting of emergencies, coordination with emergency response forces, emergency plans, and procedures for managing or responding to emergencies shall comply with the provisions of this Chapter.	NFPA 853 – §6-2 IFC Chapter 4
5.0 Interconnections			
Stationary Fuel Cell Power Plants	Requires stationary fuel cells having a power output not exceeding 1,000kW to be installed in accordance with the manufacturers' installation instructions	Verify that the stationary fuel cell is listed. Require the submittal of manufacturers' installation instructions and verify that the installation is in accordance with these instructions.	IMC §924
Interconnections with Other Building Systems	Provides requirements for fuel cell connection with other building systems.	For electrical connections and wiring, compliance assessment shall be in accordance with NFPA 70. For fuel gas piping systems and connections compliance assessment shall be in accordance with NFPA 54 or IFGC as applicable	NFPA 853 – §3-5 NFPA 70 – §692 IFGC
Inverters, Converters and Controllers for Use in Independent Power Systems	Provides requirements for inverters, converters, charge controllers and output controllers intended for use in stand-alone or utility-interactive power systems.	Verify that the inverter, converter, charge controllers and output controllers are tested, certified and labeled in compliance with UL 1741.	UL 1741

Table 4.2. Codes and Standards for Fuel Cell Installations (contd)

Issue	**Requirement Description**	**What To Look For**	**Code/Standard**
Draft Standard for Interconnecting Distributed Resources with Electric Power Systems—Establishes criteria and requirements for interconnection of distributed resources (DR) with electric power systems (EPS).	Provides a uniform standard for interconnection of distributed resources with electric power systems. It provides requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection.	Grid interconnection for fuel cells should be in accordance with this “draft” standard currently under development by IEEE Standards Coordinating Committee (SCC) 21.	IEEE P1547
Circuit Sizing and Current	Provides requirements for circuit, current and ampacity sizing for a fuel cell system.	Assess whether circuit conductors have been protected against overcurrent in accordance with their ampacity. The fuel cell’s output rating plus the maximum unbalanced neutral load current must not exceed the ampacity of grounded or neutral conductors.	NFPA 70 – §692.8
Overcurrent Protection	Exempts fuel cell systems from additional circuit overcurrent protection if the fuel cell system is provided with sufficient overcurrent protection.	If connected to multiple electrical sources, the fuel cell and ancillary equipment require such protection.	NFPA 70 –§ 692.9
Stand-Alone Systems	Allows stand-alone fuel cell systems to provide AC power to the building’s disconnecting means and regulates sizing, protection and supply of 120 volt power to the service equipment or distribution panels.	Confirm the presence or absence of characteristics representative of stand-alone fuel cell system.	NFPA 70 – §692.10
5.1 Disconnecting Means			
All Conductors	Requires a means to disconnect all current-carrying conductors of a fuel cell system from the building or structure.	Verify an approved means to disconnect is provided.	NFPA 70 – §692.13

Table 4.2. Codes and Standards for Fuel Cell Installations (contd)

Issue	**Requirement Description**	**What To Look For**	**Code/Standard**
Provisions	References NFPA 70 – 225.31 and 225.33 through 225.40 for fuel cell disconnection.	These provisions are applicable where more than one building or other structure is on the same property, under common management and additional buildings are served on the load side of the service disconnection. Utilize to evaluate the means, maximum number, grouping, access, identification, rating and access to overcurrent protection for disconnection.	NFPA 70 – §692.14
Switch or Circuit Breaker	Affords provisions that regulate the type of switches to be used for disconnecting ungrounded conductors.	Assess the presence or absence of switch or circuit breaker characteristics.	NFPA 70 – §692.17
5.2 Wiring Methods			
Wiring Systems	References NFPA 70, Chapter 3 for raceway and cable wiring methods.	Evaluate wiring methods and materials in accordance with Chapter 3.	NFPA 70 – §692.31
5.3 Grounding			
System Grounding	Provides grounding requirements for fuel cell systems.	Assess the grounding methods for the fuel cell system.	NFPA 70 – §692.41
Equipment Ground	Requires a separate equipment grounding conductor to be installed.	Verify that a separate grounding conductor is installed.	NFPA 70 – §692.44
Size of Equipment Grounding Conductor	References NFPA 70 – 250.122 for grounding conductor sizing.	Evaluate size of wire-type grounding conductors such that they are not smaller than Table 250.122 but not larger than the circuit conductors to the fuel cell. Other rules apply.	NFPA 70 – §692.45
Grounding Electrode System	References NFPA 70 – 250.118 for the connection of any supplementary grounding electrode.	The particular grounding electrode system of choice (i.e., metal underground water pipe, metal underground gas piping system, metal frame of the building, or others) shall be confirmed and evaluated.	NFPA 70 – §692.47
5.4 Marking			
Fuel Cell Power Services	Requires specific marking for the fuel cell power source.	Evaluate the markings for the fuel cell power source.	NFPA 70 – §692.53

Table 4.2. Codes and Standards for Fuel Cell Installations (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Fuel Shutoff Fuel Oil Valves Shutoff Valves	Requires a specific location for the manual fuel-feedstock shutoff valve to the fuel cell.	Verify manual shut off location is provided at the primary disconnecting means for the building.	NFPA 70 – §692.54 IMC §301.3, §1307 IFGC §409
Stored Energy	Requires signage for fuel cell systems that store electrical energy.	Evaluate the conspicuous location of required signage.	NFPA 70 - §692.56
5.5 Connection to Other Circuits			
Transfer Switch	Requires a transfer switch in non-grid interactive systems that use utility grid back-up.	For these fuel cells, confirm the installation of an approved transfer switch that may be mounted internal or external to the fuel cell. Also consult NFPA 70 – §230, Part V.	NFPA 70 – §692.59
Identified Interactive Equipment	Requires fuel cell systems to be listed and identified as interactive to be permitted in interactive systems.	Verify the limitations of use as specified by the manufacturer or otherwise confirm the listing conditions of the fuel cell. It is likely that grid interconnection for fuel cells in accordance with IEEE P1547 will provide a means to test and certify to such a listing.	NFPA 70 – §692.60 IEEE P1547
Output Characteristics	Requires the output of fuel cell systems operating in parallel to be compatible with the parallel electrical system.	Verify the output is compatible.	NFPA 70 – §692.61 IEEE P1547
Loss of Interactive System Power	Requires the fuel cell system to be provided with a means to detect when the electrical production and distribution network has become de-energized.	Verify that a detection system is present.	NFPA 70 – §692.62 IEEE P1547
Unbalanced Interconnections	Provides requirements for connecting single-phase systems with 3-phase power.	Assess the interconnection system.	NFPA 70 – §692.64 IEEE P1547

Table 4.2. Codes and Standards for Fuel Cell Installations (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Point of Connection	Provides requirements for the output connection for the fuel cell.	The means for connection is at the discretion of the designer/manufacturer. Both supply-side and load-side connection details are specified. Assess compliance accordingly.	NFPA 70 – §692.65
5.6 Output Over 600 Volts			
General	References provisions within NFPA 70 for fuel cell systems with an output of over 600 volts ac.	Use other NFPA 70 Sections germane to outputs over 600 volts to evaluate compliance.	NFPA 70 – §692.80
Circuit-Interrupting Devices	Provides requirements for circuit-interrupting devices for fuel cell systems.	Confirm access to, and operational characteristics of circuit breakers and power fuses, including maximum voltage and continuous, interrupting, closing and momentary current ratings.	NFPA 70 –§ 490.21
Isolating Means	Provides for the isolation of equipment.	Verify that a means to isolate fuel cell power conditioner is provided. Evaluate the suitability of the isolating switches, as required.	NFPA 70 – §490.22
Voltage Regulators	Requires proper switching sequences for regulators.	Confirm the use of mechanically sequenced bypass switches, mechanical interlocks or the conspicuous annotation of proper switching procedure.	NFPA 70 – §490.23
Minimum Space Separation	Provides requirements for the minimum air separation between bare live conductors and adjacent grounded surfaces.	Use this section and associated table to evaluate the minimum clearance between live parts.	NFPA 70 – §490.24
5.6.1 – Equipment – Metal-Enclosed Power Switchgear and Industrial Control Assemblies			
General	Provides requirements for metal-enclosed power switchgear and industrial control assemblies for fuel cell systems.	Evaluate assemblies for power switchgear, the use of barriers, and guards to prevent contact with energized parts and unobstructed clearance for entrance conductors.	NFPA 70 – §490.30 to §490.34
Accessibility of Energized Parts	Provides requirements for installing energized parts in compartments.	Verify that a means for locking access doors to high-voltage energized parts is present.	NFPA 70 –§ 490.35

Table 4.2. Codes and Standards for Fuel Cell Installations (contd)

Issue	Requirement Description	What To Look For	Code/Standard
Grounding	Requires frames of switchgear and control assemblies to be grounded.	Assess the power conditioning compartment(s), frame(s) and overall fuel cell enclosure for the presence or absence of ground .	NFPA 70 – §490.36
Grounding of Devices	Provides grounding requirements for metal cases or frames.	Assess the conditions of the power conditioning switchgear or control(s) such that the frame or case-work of devices located therein are grounded.	NFPA 70 – §490.37
Door Stops and Cover Plates	Provides requirement for metal hinged doors and cover plates that house energized parts.	Confirm the presence of stops for doors and lifting handles for inspection cover plates.	NFPA 70 – §490.38
Gas Discharge from Interrupting Devices	Requires gas discharged from interrupting devices to be exhausted so that it does not endanger personnel.	Assess the likelihood that such discharges would endanger personnel.	NFPA 70 – §490.39
Inspection Windows	Provides requirements for inspection windows.	Inspection windows shall be transparent.	NFPA 70 – §490.40
Location of Devices	Provides requirements for the location of control devices.	Switches, handles, and push buttons shall be readily accessible. Evaluate.	NFPA 70 – §490.41
Interlocks – Interrupter Switches	Requires mechanical interlocks for interrupter switches equipped with stored energy mechanisms.	Confirm the ‘blocking’ capability of interrupter switches equipped with stored energy mechanisms, as applicable.	NFPA 70 – §490.42
Stored Energy for Opening	Allows the stored energy operator to be left in the uncharged position after the switch has been closed.	Where applicable, confirm the installation and operation of “single movement operator(s).”	NFPA 70 – §490.43
Fused Interrupter Switches	Provides provisions for the installation of fused interrupter switches.	Confirm the operational characteristics and arrangement of supply terminals and witching means for fused interrupter switches. The presence of any requisite barriers shall also be evaluated.	NFPA 70 – §490.44
Circuit Breakers - Interlocks	Provides requirements for circuit breaker interlocks for fuel cell systems.	Confirm the presence of mechanical interlocks or alternatively, the ‘blocking’ capability of circuit breakers equipped with stored energy mechanisms, as applicable.	NFPA 70 – §490.45

5.0 Case Study

5.1 Overview

The purpose of the following case study is to provide a real-world example of a stationary fuel cell installation and insight into how it addressed the issue of approval and compliance with applicable codes and standards. The primary objective is to demonstrate to those who would specify, install, or approve such installations that fuel cells can be implemented safely and with a minimum of hassle through compliance with codes and standards already developed and available for adoption. A secondary objective is to provide an example that can be emulated in the future to facilitate the preparation of acceptable designs and specifications and the timely approval of new stationary fuel cell power plant installations.

5.2 Project Description

The following case study describes the experience of UTC Fuel Cells (UTCFC) with a turnkey power plant installation, including insight into how the firm addressed approval and compliance issues with local and state governments as well as met applicable codes and standards.

This case study details the installation of a PC-25C Power Plant at South Windsor High School in the Town of South Windsor (TOSW), Connecticut. The project was funded by the Connecticut Clean Energy Fund (CCEF) and installed by UTCFC as a turnkey project, where UTCFC handled the site design, construction, and startup of the fuel cell. The fuel cell was added to displace electricity purchased by the school, supplement the school's heating system, and provide emergency power when the grid is not available.

South Windsor High School (SWHS) is a 300,000-ft^2 facility serving approximately 1400 students. With the addition of the fuel cell power plant, SWHS also can be used as an emergency shelter that can house up to 3000 people during an emergency.

5.3 Fuel Cell Type

The PC-25C Fuel Cell Power Plant, manufactured by UTC Fuel Cells, is a factory-assembled, self-contained power plant with an electrical rating of 200 kW/235kVa. At rated power, the PC25 also can provide up to 900,000 Btu/hr for customer hot water requirements through two heat recovery systems. The fuel cell's overall efficiency can exceed 80% when full heat recovery is utilized.

The fuel cell is an atmospheric pressure phosphoric acid electrolyte fuel cell that utilizes low-pressure natural gas (0.14 to 0.51 psi). The maximum total natural gas usage expected in this application is nominally 12 millionscf/yr. The installed fuel cell is capable of both grid-parallel and grid-independent operation and is equipped with low-grade and high-grade heat recovery systems that provide customer hot water needs at up to 140^{o}F and 250^{o}F, respectively.

Case Study Location

UTC Fuel Cell in South Windsor, Connecticut

Project Partners

- Connecticut Clean Energy Fund (CCEF)
- South Windsor High School
- Town of South Windsor, Connecticut
- UTC Fuel Cells (UTCFC)

Facilities and Equipment

- South Windsor High School facility
- PC-25C Fuel Cell Power Plant

Safety Features

- 8-foot fence around site
- Nitrogen rack located to prevent tampering
- Safety meetings with town fire marshall, contractors, UTCFC specialists
- Barrier fencing during construction

The South Windsor High School Fuel Cell includes the power module, cooling module, nitrogen rack, and electrical transfer switch installed at the site.

The fuel cell is interconnected to the school's electrical, heating boiler, make-up air, and potable water systems. Before the installation of the fuel cell, natural gas was not available on site. Consequently, natural gas service had to be added as part of the installation.

Equipment Specifications

Fuel Cell Type

- Phosphoric Acid (PAFC)

Fuel Cell Rating

- 200 kW/235 kVa

Fuel Cell Efficiency

- 80% (overall)

Fuel Cell Fuel

- Natural Gas
- 12 million scf/yr consumption expected

Cogeneration

- Low-grade (140°F) and high-grade (250°F) heat recovery for hot water
- Up to 900,000 Btu/hr heat recovery

Grid Connection

- Capable of grid-parallel or grid-independent operation

5.4 Installation Operation

The fuel cell installation provides multiple services to SWHS through its electrical and thermal output. The school load profile peaks at 600 kW and can go as low as 120 kW during nights and weekends. The fuel cell provides up to 200 kWe to the school but can vary its electrical output to ensure the school does not back-feed the grid when the total load at the school is less than 200 kWe. This feature, called Zero Power Export, adjusts the fuel cell power level to match the school load profile and prevents the power plant from back-feeding the grid. Without this option, the fuel cell would periodically generate more power than the school needed and trip the Beckwith relay. The Beckwith relay, a device that will trip the fuel cell off-line if electrical back feed is detected, was installed to satisfy Connecticut Light and Power requirements for interconnecting to its grid.

During a grid outage, when the school may be used as an emergency shelter, the fuel cell can be operated in the grid-independent mode and supply up to 200 kW of power to provide lighting, heat, hot water, and kitchen service for the emergency shelter. Before the fuel cell was installed, the school did not have an emergency power supply to the school. Therefore, the fuel cell has greatly increased the town's emergency preparedness.

The fuel cell can provide up to 900,000 Btu/hr of heat recovery to the school through the low-grade heat and high-grade heat systems. At SWHS, the low-grade heat system is used to preheat makeup air to the school through a glycol/water-to-air heating coil. The high-grade system preheats boiler system return water. Both uses are designed to reduce the amount of heat supplied by the oil-fired furnaces while remaining transparent to the customer. By supplanting oil consumption in the furnaces with residual heat from the fuel cell, the environmental benefits of the fuel cell are increased. Heat recovery is available also during emergency shelter operation, and any heat not used by the heat recovery systems is rejected to the cooling module.

The fuel cell is installed approximately 120 feet from the school's electrical and boiler rooms, which was a major factor driving the location of the fuel cell. A pad was poured for the power module, cooling module, and nitrogen rack, and an asphalt walkway was installed around the perimeter of the fuel cell for ease of maintenance.

Because the site is close to the property boundary, the potential impact upon area residents needed to be addressed. The town worked with adjacent property owners to answer any questions or concerns they had. Documenting low noise and emission levels from the fuel cell facilitated local/town approval and helped to resolve any concerns held by area residents.

When the site was being designed, consideration was given to minimize the site footprint. A secondary consideration was to ensure that people passing by the unit could not accidentally affect operation. An 8-foot fence was installed around the site, and the nitrogen rack was placed perpendicular to the nearest fence so that nitrogen control valves were not accessible from the fence boundary.

During the site construction phase, the access road adjacent to the fuel cell had to be closed temporarily. This required school buses normally using the road to be rerouted until the road could be reopened. The school and the town fire marshall were notified well in advance of this change to ensure school operation and safety were not affected.

Site safety was emphasized during all phases of construction. Prior to the start of work, a safety meeting was held with town representatives, the fire marshall, UTCFC environmental health and safety representatives, and the contractors involved with the project to stress the importance of site safety. Barrier fencing was required at the end of each day, and the area was left clean and secure. It was also imperative that school operation not be affected in any way. The construction schedule had to be revised to work around final exams, and noise and dust had to be kept to a minimum to avoid school disruptions.

5.5 Codes and Standards

The PC25 fuel cell power plants were certified originally to the American Gas Association standard, *Requirements for Fuel Cell Power Plants 8-90*. The American National Standards Institute Standard ANSI Z21.83, *Fuel Cell Power Plants*, has superceded this standard. ANSI Z21.83 is a product standard and, as such, addresses both fuel and electrical safety within the product. This standard is recognized by ICC model building codes and NFPA 853 for the installation of fuel cell power plants. Certification to this standard by an OSHA-approved testing laboratory facilitates building inspector acceptance of the product.

Canadian Standards Association (CSA) International acquired the AGA Test Laboratories and is the ANSI-approved secretariat for the fuel cell standard. Therefore, the ANSI/CSA Certification validates the product safety of the PC-25C design and proves that the PC-25C meets current recognized standards for fuel cell installations. Therefore, additional product inspection and certification are not necessary to site a PC-25C.

5.5.1 State Requirements

Per previous applications, the Connecticut Department of Environmental Protection (DEP) Bureau of Air Management exempted the PC-25 from permitting requirements. Therefore, no DEP application was necessary to site the fuel cell.

The only state application required for the installation was to the Connecticut Siting Council. This application described the proposed fuel cell site, the benefits of the installation to the Town of South Windsor, the State of Connecticut, local ratepayers, and the environment. The application was approved through the council's expedited review process for fuel cell projects.

5.5.2 Town of South Windsor Requirements

Before any work could begin, the project needed to be presented to the South Windsor Town Council and approved by vote. Because the project was fully funded by CCEF, town resources expended for the project would be limited. This fact, coupled with the benefits of the fuel cell for this application, helped the project easily win approval.

The town's permitting process was similar to that for most other towns. The contractor was required to submit a set of "For Construction" drawings for review and approval by the town's department of public works, fire marshall, and building department. Following the town's approval of the drawings, the contractor took out the normal permits and began construction.

These are standard codes and did not present any issues specific to fuel cell installations.

5.5.3 Utility Requirements

The local utility, Connecticut Light and Power (CL&P), required that a grid protection relay be installed and tested at the school/grid interface. This relay is redundant to the internal grid protection equipment included within the power plant and is a standard requirement that many distributed generation sites must satisfy. At SWHS, UTCFC installed a Beckwith

3410 relay that satisfied this requirement. CL&P also required a demonstration test of the relay, which the utility mandated its representatives witness, to ensure the Beckwith was functioning properly before the fuel cell could be connected to the grid.

Regulatory compliance for the SWHS installation was completed with a minimum of effort due in large part to lessons learned at previous sites and years of PC-25C product development. UTCFC anticipates additional streamlining and simplification of the siting process as fuel cell technology and distributed generation regulations continue to grow and develop.

5.6 Additional Resources

Other examples of stationary hydrogen fuel cell installations may be found at http://www.eere.energy.gov/hydrogenandfuelcells/fuelcells/stationary_power.html.