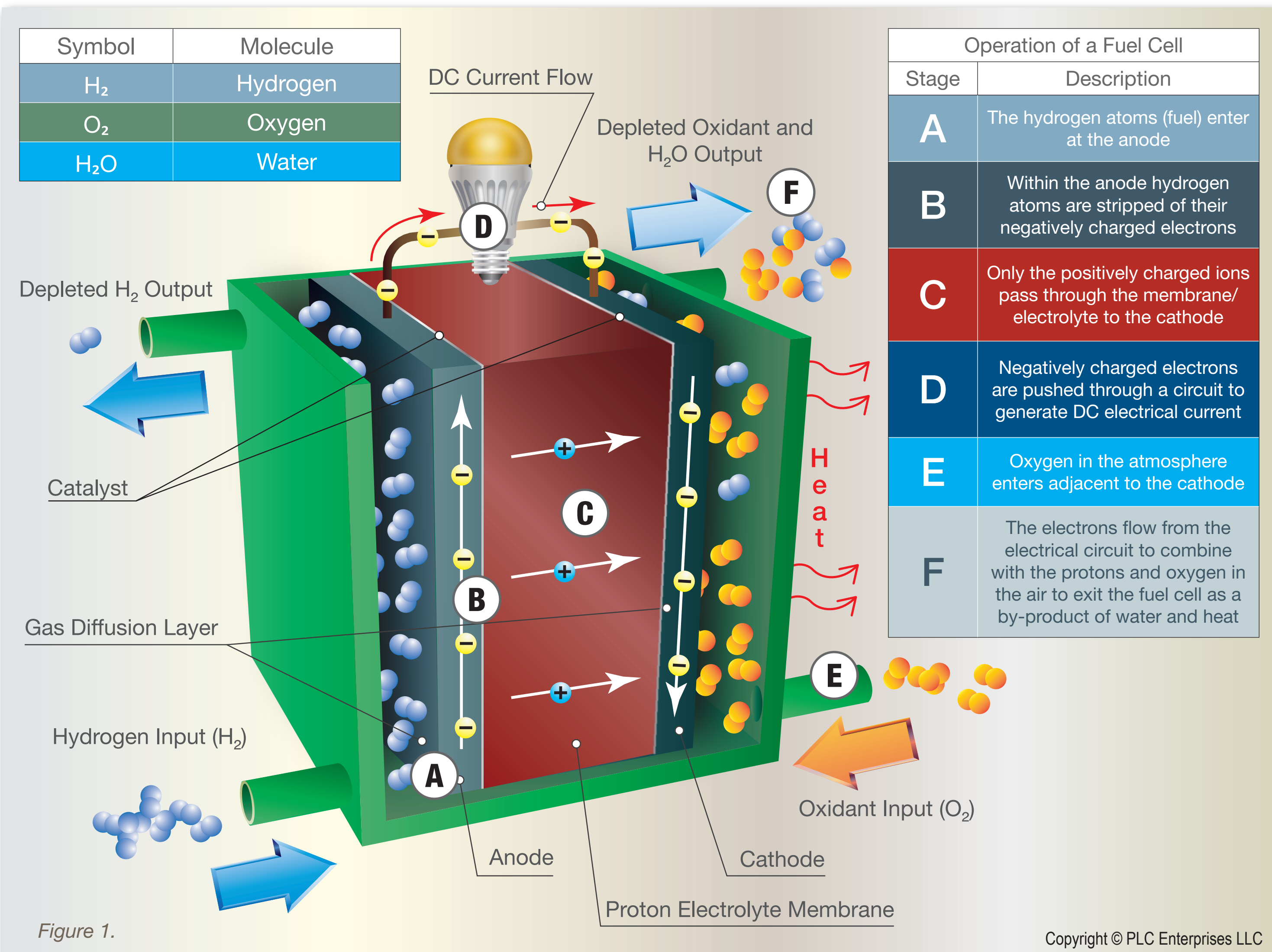
Buckeye Power Sales
Reliable Power Professionals Since 1947

As regulators, users, and manufacturers of generator systems look to lower levels of exhaust emission components; particularly carbon dioxide as contributor to global warming and nitrous oxides known to cause breathing problems. The quest for zero harmful emissions is moving towards alternative technologies to replace the internal combustion engine, the primary power source for engine-driven generator systems. Two technologies under consideration, are batteries and fuel cells. To date, batteries are the primary candidate for zero emissions. But batteries have to be recharged by another source of electricity, whereas fuel cells, as long as they have a source of fuel, will generate electricity continuously. This information sheet discuses how hydrogen-fueled fuel cells operate, the advantages they have over the internal combustion engine, and the technological and costs issues that have to be addressed before they are widely accepted.

1.0 WHAT IS A FUEL CELL:

A fuel cell is an electrochemical cell that generates electrical energy through a process called electrochemical reaction, not combustion. They were first invented by a Welsh scientist, William Robert Grove, in 1839. However, it wasn't until the 1960s, when NASA adopted them for the Project Gemini, and then used them for probes, satellites and space capsules, they became commercially available and considered for other applications.

Illustration Depicting Hydrogen Powered Fuel Cell Operation



Symbol	Molecule
H_2	Hydrogen
O_2	Oxygen
H_2O	Water

Operation of a Fuel Cell	
Stage	Description
A	The hydrogen atoms (fuel) enter at the anode
B	Within the anode hydrogen atoms are stripped of their negatively charged electrons
C	Only the positively charged ions pass through the membrane/ electrolyte to the cathode
D	Negatively charged electrons are pushed through a circuit to generate DC electrical current
E	Oxygen in the atmosphere enters adjacent to the cathode
F	The electrons flow from the electrical circuit to combine with the protons and oxygen in the air to exit the fuel cell as a by-product of water and heat

Figure 1.

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2.0 OPERATION OF A HYDROGEN FUEL CELL:

As detailed in ***figure 1***, the individual fuel cell is a static item with an electrolyte separated by a catalyst located located between an anode and cathode, all enclosed with a container. As follows the process to generate electrical energy:

- Hydrogen (H_2) atoms enter the fuel cell adjacent to the anode.
- Within the anode the atoms are stripped of their negatively charged electrons.
- Positively atoms charged ions pass from the anode via a catalyst though the porous electrolyte/membrane to the cathode.
- The negatively charged electrons are draw through a circuit to generate an electrical current and excess heat.
- Passing through the electrical circuit (from which power is drawn) the negative electrons combine with the positively charged protons in the cathode and the oxygen (O_2) (the O_2 in the atmosphere is fed to the cathode). The combining of the O_2 and the H_2 electrons and protons, generates the fuel cell byproducts of water and heat.

3.0 CONSTRUCTION OF A FUEL CELL:

A fuel cell generates direct current (DC) power, but each cell barely produces one volt, far below the voltage most generator systems are designed to produce. To reach the required voltage output, individual fuel cells are stacked in series. Each cell in the stack is sandwiched between two bipolar plates to separate it from neighboring cells. The DC output will go through a power conditioner, typically an inverter, to produce the required Alternating current (AC).

The fuel cell stack can consist of hundreds of fuel cells. The power produced will depend on the fuel cell size, operating temperature, and the pressure of the gases supplied to the cell.

Within a hydrogen fuel cell is a proton electrolyte membrane (PEM). The PEM is central to fuel cell technology and it must only allow the necessary ions to pass between the anode and cathode. At the center of the PEM fuel cell, ***see figure 1***, is the membrane electrode assembly (MEA). Either side of the membrane between the anode and the cathode is a conventional catalyst layer including nanometer-sized particles of platinum to purify the gases. On the anode side, the platinum catalyst enables hydrogen molecules to be split into protons and electrons. On the cathode side, the platinum catalyst enables oxygen reduction by reacting with the protons generated by the anode to produce water molecules.

Gas Diffusion Layers (GDLs) sit outside the catalyst layers, and facilitate transport of reactants into the catalyst layer, as well as removal of water produced during the generation process.

In addition to the fuel cell stack and power conditioner, depending on the type of fuel, could also be included a fuel processor, air compressor and humidifier.

4.0 ADVANTAGES OF HYDROGEN FUELED FUEL CELLS:

Outside of hydroelectric power, nuclear power, and renewable power, fossil fuels are the principal power source for power generation. Fuel cell technology offers several advantages over fossil fueled generation systems including:

4.1 ZERO HARMFUL EMISSIONS - The principal byproduct of a hydrogen fuel cell is water and heat.

4.2 NO RECHARGING - Power is generated as long as fuel and oxygen are available. Unlike batteries, no recharging is required.

4.3 QUIET OPERATION - The electrochemical reaction process is very quite, unlike the internal engine combustion process.

4.4 EFFICIENCY - Fuel cells generate electricity through chemistry, not internal combustion, which enables much higher efficiencies than steam turbines and internal combustion engines. While the additions of a power conditioner, humidifier and air compressor can lower efficiency, the overall efficiency of a fuel cell is still up to three times that of an internal combustion engine.

4.5 RELIABILITY/DURABILITY - Fuel cells operate as a static electrochemical reaction; there are no electro-mechanical rotating pieces of machinery with consumable parts and wear, resulting in minimal maintenance.

5.0 CURRENT DISADVANTAGES OF FUEL CELLS:

Considering all the advantages hydrogen fuel cells have over steam generation and the internal combustion engine, there has to be a reason they have not become a bigger contributor to power generation. This can be summarized in two words, cost, and fuel.

When wide spread electrification came about, little consideration was given to emissions from fossil fuels, and there was an abundant supply of oil, gas and coal. However, if fuel cells are to become a larger player, the following issues have to be addressed:

5.1 COST OF MANUFACTURE - While a fuel cell has less moving parts than electro-mechanical power generation, they rely on expensive materials to operate effectively, particularly platinum for the catalyst. Platinum is the only metal that can withstand the acidic conditions inside such a cell, but it is expensive, and this has limited the broad, large-scale applications of fuel cells.

5.2 ALTERNATIVES TO PLATINUM - Several alternatives are being explored, such as an "Iron Boost". By embedding iron-nitrogen complexes into graphene, experiments have shown an excellent catalytic efficiency approaching platinum.

5.3 HYDROGEN SUPPLY/STORAGE - There is not in place the infrastructure to distribute hydrogen in the quantities such as for natural gas, goal and gasoline. Hydrogen for storage and transportation has to be pressurized to high pressures and/or cooled to very low temperatures. The need for zero emission fuel is creating research into more effective hydrogen distribution.

5.4 TYPE OF HYDROGEN - Currently 98% of hydrogen produced is called Gray Hydrogen. Gray because it is made from methane using steam methane reforming (SMR) which releases a large amount of carbon dioxide (CO_2) into the atmosphere. Blue hydrogen uses the same process, but the CO2 is piped to disused salt mines or oil wells. The longer term solution is to use Green Hydrogen manufactured by the electrolysis of water using renewable power such as wind and solar.

To fulfill our commitment to be the leading supplier in the power generation industry, the Buckeye Power Sales team ensures they are always up-to-date with the current power industry standards as well as industry trends. As a service, our Information Sheets are circulated on a regular basis to existing and potential power customers to maintain their awareness of changes and developments in standards, codes and technology within the power industry.

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