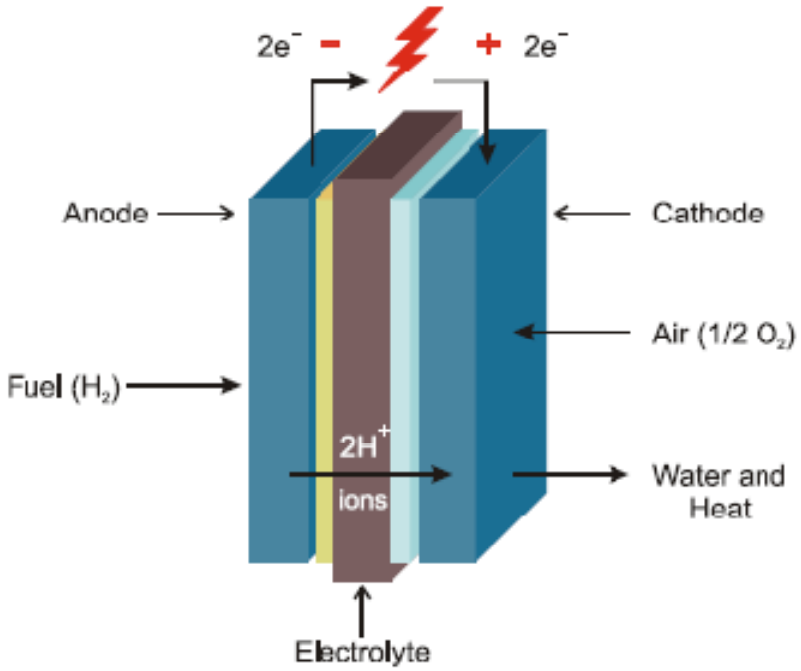
What is a Fuel Cell?

Quite simply, a fuel cell is a device that converts chemical energy into electrical energy, water, and heat through electrochemical reactions.



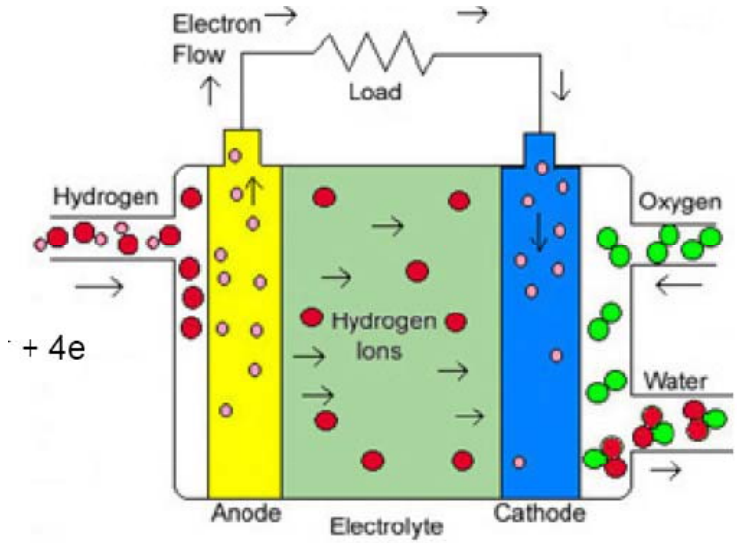
- Fuel and air react when they come into contact through a porous membrane (electrolyte) which separates them.
- This reaction results in a transfer of electrons and ions across the electrolyte from the anode to the cathode.
- If an external load is attached to this arrangement, a complete circuit is formed and a voltage is generated from the flow of electrical current.

The voltage generated by a single cell is typically rather small (< 1 volt), so many cells are connected in series to create a useful voltage.

Fuel Cell Vs. Battery

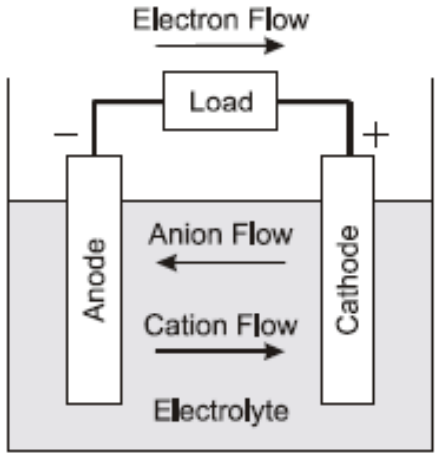
Basic operating principles of both are very similar, but there are several intrinsic differences.

Hydrogen fuel cell



- Open system
- Anode and cathode are gases in contact with a platinum catalyst.
- Reactants are externally supplied, no recharging required.

Galvanic cell (battery)

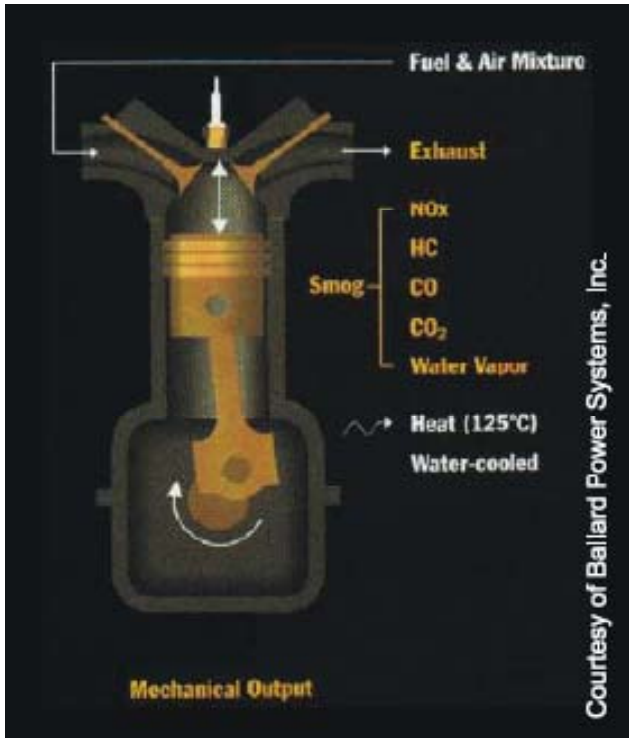


- Closed system
- Anode and cathode are metals.
- Reactants are internally consumed, need periodic recharging.

Fuel Cell Vs. Internal Combustion Engine

Similarities:

- Both use hydrogen-rich fuel.
- Both use compressed air as the oxidant.
- Both require cooling.



Differences:

Fuel cell:

- Output is electrical work.
- Fuel and oxidant react electrochemically.
- Little to no pollution produced.

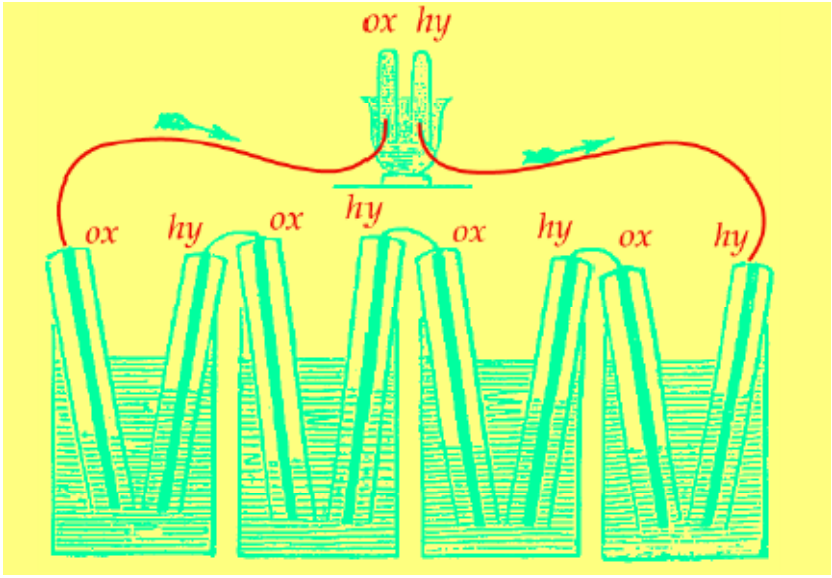
I.C. Engine:

- Output is mechanical work.
- Fuel and oxidant react combustively.
- Use of fossil fuels can produce significant pollution.

Some History…

Fuel cell principle first discovered by William Grove in 1839.

Grove used four large cells, each containing hydrogen and oxygen, to produce electric power which was then used to split the water in the smaller upper cell.

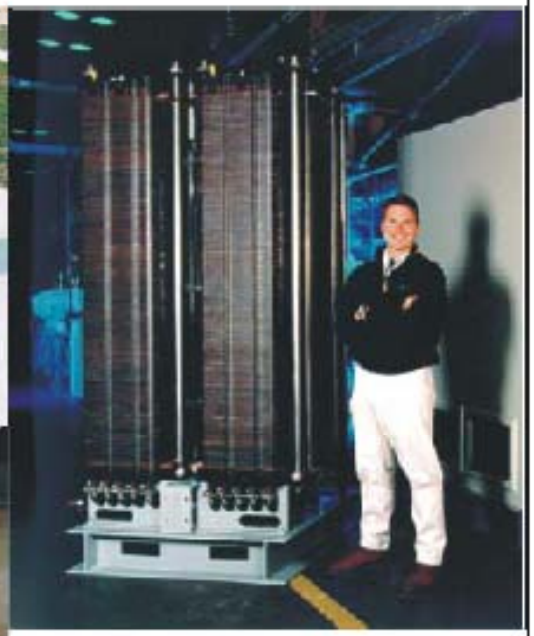


Commercial potential first demonstrated by NASA in the 1960's with the usage of fuel cells on the Gemini and Apollo space flights. However, these fuel cells were very expensive.

Fuel cell research and development has been actively taking place since the 1970's, resulting in many commercial applications ranging from low cost portable systems for cell phones and laptops to large power systems for buildings.

Fuel Cells in Use: Stationary Systems

Ballard Generation Systems' 250 kW Natural-Gas Fueled Fuel Cell Powerplant



These massive proton exchange membrane fuel cell stacks are the most powerful in the world

Courtesy of Ballard Power Systems, Inc.

Fuel Cells in Use: Stationary Systems

Fuel cell system for submarine

This 80 kW powerplant was built by Ballard Power Systems for German submarine manufacturer Howaldtswerke-Deutsche Werft AD and operates using pure hydrogen and oxygen.

Fuel Cells in Use: Transportation Systems

XCELLSiS fuel cell bus prototypes

Buses are most commercially advanced applications of fuel cells to date.

Are currently being used by many American and European cities.

Fuel Cells in Use: Transportation Systems

Many of the major car companies are developing fuel cell car prototypes which should come to market during the next decade. The cars use either pure hydrogen or methanol with an on board reformer.

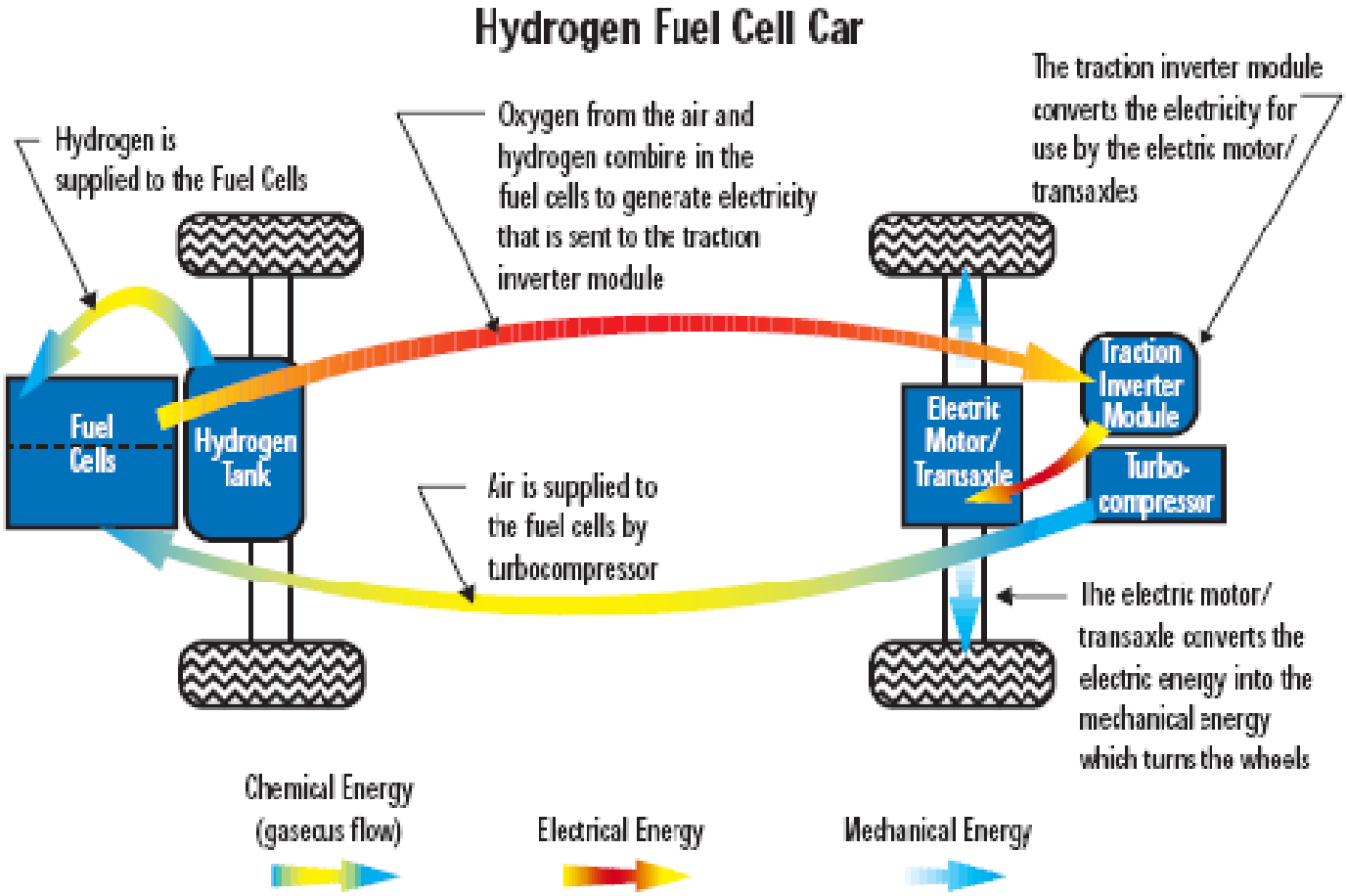
Gaseous hydrogen fueled Necar 1 (1994) and Necar 2 (1996), and liquid methanol fueled Necar 3 (1997).

Liquid hydrogen fueled Necar 4 (1999).

Liquid methanol fueled Necar 5 (2000).

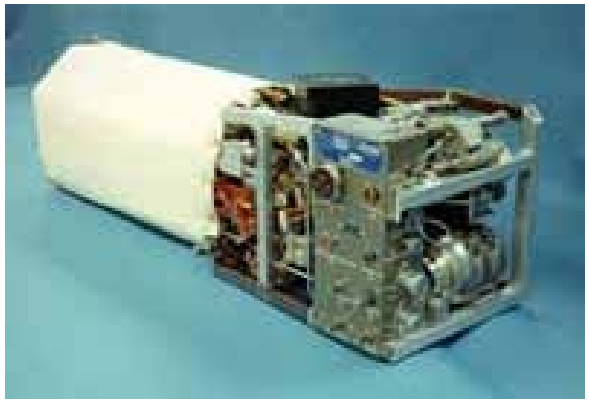
Each successive vehicle has a considerably more compact fuel cell engine and fuel storage system. The Necar 5 has uses an on-board methanol reformer but still has space for five passengers and their luggage. It is capable of a top speed of 90 mph (150 km/h) with nearly zero emissions.

Fuel Cells in Use: Hydrogen Fuel Cell System



The P2000, from Ford Motor Company, is a zero-emission vehicle that utilizes a direct hydrogen polymer electrolyte fuel cell. (Courtesy of Ford Motor Co.)

Fuel Cells in Use: Space Systems



12 kW Space shuttle fuel cell
Weight: 120 kg
Size: 36x38x114 cm
Contains 32 cells in series

1.5 kW Apollo fuel cell
Apollo used two of these units.

Fuel Cells in Use: Portable Systems

A laptop using a fuel cell power source can operate for up to 20 hours on a single charge of fuel (Courtesy: Ballard Power Systems)

But Isn't Hydrogen Explosive?

The New York Times.

HINDENBURG BURNS IN LAKEHURST CRASH; 21 KNOWN DEAD, 12 MISSING; 64 ESCAPE

Airship Like a Giant Torch On Darkening Jersey Field

Many have blamed this disaster on a hydrogen explosion. However, hydrogen burns invisibly, and no evidence of leaks were ever found (garlic scent added to hydrogen gas).

Using infrared spectrographs, NASA scientists found that the skin of the Hindenburg was treated with compounds which are found in gunpowder and rocket fuel (nitrates and aluminum powder). This, combined with a wooden frame coated with lacquer resulted in a highly flammable ship.

Glossary of Terms Used in Describing Fuel Cell Technology

Electrochemical reaction: A reaction involving the transfer of electrons from one chemical substance to another.

Electrode: An electrical terminal that conducts an electric current into or out of a fuel cell (where the electrochemical reaction occurs).

Anode: Electrode where oxidation reaction happens (electrons are released).

Cathode: Electrode where reduction reaction occurs (electrons are acquired).

In a fuel cell, hydrogen is oxidized at the anode and oxygen reduction occurs at the cathode.

Electrolyte: A chemical compound that conducts ions from one electrode to the other.

Ion: An atom that carries a positive or negative charge due to the loss or gain of an electron. Anion is a negative ion, cation is a positive ion.

An electrochemical cell consists of 2 electrodes + 1 electrolyte

Terminology (cont.)

Catalyst: A substance that participates in a reaction, increasing its rate, but is not consumed in the reaction.

Polymer: A natural or synthetic compound made of giant molecules which are composed of repeated links of simple molecules (monomers).

Inverter: A device used to convert direct current electricity produced by a fuel cell to alternating current.

Reformer: A device that extracts pure hydrogen from hydrocarbons.

Stack: Individual fuel cells connected in series within a generating assembly.

Overview of Operating Principles

(modify as necessary)

Will now look at in more detail:

-Thermodynamic principles of fuel cells.

- Fuel cell components.

- Fuel cell support systems.

- Current research issues.