Fuel cells

Fuel cells are electrochemical cells consisting of two electrodes and an electrolyte which convert the chemical energy of chemical reaction between fuel and oxidant directly into electrical energy.

❖ Ordinary Combustion process of fuel is

❖ The process of fuel cell is

- The conventional process to produce electrical energy is as follows:

- But in fuel cell, it directly coverts chemical energy to electrical energy.
- The efficiency of energy conversion in fuel cell approaches 70%. It is only 15-20% in gasoline powered engines and 30 – 35% in diesel engines.

Principle of Fuel Cell:

- Fuel cell consists of electrodes, electrolyte & catalyst to facilitate the electrochemical redox reaction.
- The basic arrangement in a fuel cell can be represented as follows:

Fuel cell consist of

Anode

- A layer of anodic catalyst.

Electrolyte

- A layer of cathodic catalyst.

Cathode

Fuel cell consist of

Anode & Cathode

- Materials which have high electron conductivity & zero proton conductivity in the form of porous catalyst (porous catalyst or carbon).

Catalyst

- Platinum

Electrolyte

- High proton conductivity & zero electron conductivity.

➢ Fuel Cell System:

1. The fuel (direct H_2 or reformed H_2) undergoes oxidation at anode and releases electrons.

2. These electrons flow through the external circuit to the cathode.

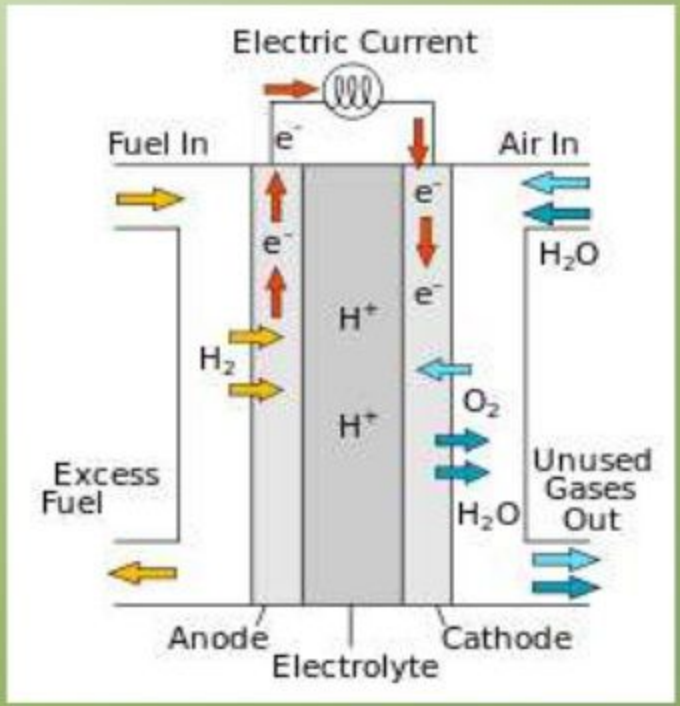
3. At cathode, oxidant (O_2 from air) gets reduced.

4. The electrons produce electricity while passing through the external circuit. Electricity is generated continuously as long as fuel and the oxidant are continuously and separately supplied to the electrodes of the cell from reservoirs outside the electrochemical cell.

➢ The Fuel cell can be represented as:

At anode	• $2H_2 \rightarrow 4H^+ + 4e^-$
At Cathode	• $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$
Overall Reaction	• $2H_2 + O_2 \rightarrow 2H_2O$

➢ Large number of these cells are stacked together in series to make a battery called as fuel cell battery or fuel battery.


Electric Current
Fuel In
Air In
e⁻
e⁻
e⁻
e⁻
H₂O
H⁺
H₂
H⁺
O₂
Excess Fuel
Unused Gases Out
H₂O
Anode
Electrolyte
Cathode

Advantages of Fuel Cells

1. High efficiency of energy conversion (approaching 70%) from chemical energy to electrical energy.
2. Low noise pollution & low thermal pollution.
3. Fuel cell power can reduce expensive transmission lines & minimize transmission loses for a disturbed system.
4. Fuel cells gives excellent method for efficient use of fossil fuels hence saves fossil fuels.
5. Fuel cells are less polluting. The chemical process involved in it is clean. It does not produce polluting exhaust. Mostly the byproducts are water & waste heat, which are environmentally acceptable when hydrogen & air are used as reactants.

Advantages of Fuel Cells

6. In case of fossil fuels, when used as reactants, environmentally undesirable NO_x are not produced since there is no combustion in the process.
7. Hydrogen-Oxygen fuel cells produce drinking water of potable quality.
8. Designing is modular, therefore the parts are exchangeable.
9. Low maintenance cost.
10. Fuel cell performance is independent of power plant size. The efficiency does not depend on the size of power plant. It remains same for the plants of MW or kW or W size.

Advantages of Fuel Cells

11. Fast start up time for low temperature system.
12. The heat is cogenerated hence increases efficiency of high temperature system.
13. The demand for variations in power & energy densities is easily met as required. e.g. Laptop, computers requires low power density & high energy density where as automobile requires high power density, high energy density. Both can be powered by fuel cells.
14. Fuel cells automotive batteries can render electric vehicles, efficient & refillable.

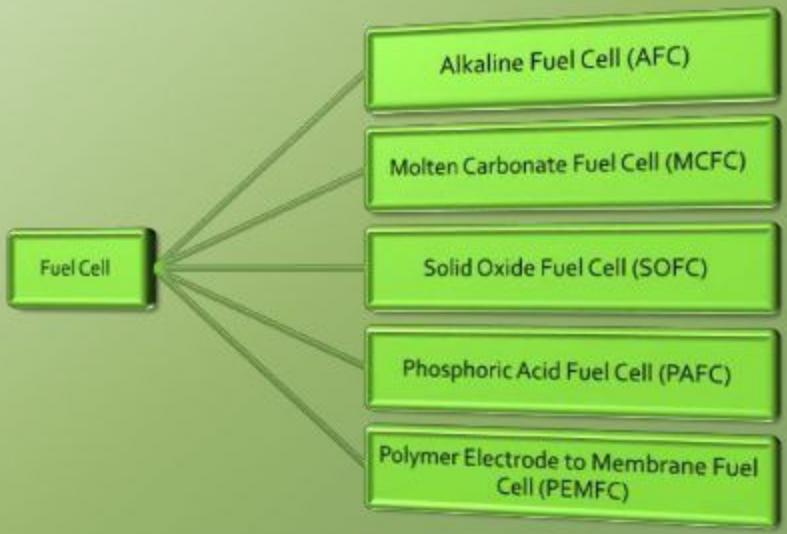
Disadvantages of Fuel Cells

- High initial cost.
- Life times of the cells are not accurately known.
- Large weight and volume of gas fuel storage system.
- High cost of pure hydrogen.
- Hydrogen can be stored in lesser volume by liquefaction but liquefaction itself require 30% of the stored energy.
- Lack of infrastructure for distributing hydrogen.

Applications of Fuel Cells

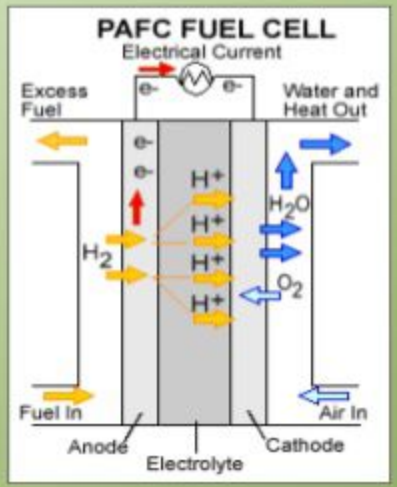
- The first commercial use of fuel cell was in NASA space program to generate power for satellites and space capsules.
- Fuels are used for primary and backup power for commercial, industrial and residential buildings in remote and inaccessible area.
- They are used to power fuel cell vehicles including automobiles, aeroplanes, boats and submarines.

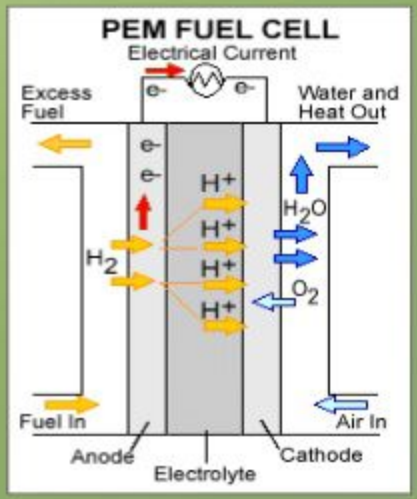
Types of Fuel Cells



Two Commercially important Fuel Cells as:

- Phosphoric Acid Fuel Cell
- Polymer Electrode to Membrane Fuel Cell


PAFC FUEL CELL
Electrical Current
e-
e-
Excess Fuel
Water and Heat Out
e-
e-
H+
H+
H+
H+
H2O
H2
O2
Fuel In
Air In
Anode
Electrolyte
Cathode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Characteristic features	PEMFC	PAFC
Primary fuel	H_2	H_2
Electrodes	Graphite	Carbon
Electrolyte	Polymer membrane(Per fluoro sulphonic acid)	Phosphoric acid soaked in silicon matrix
Catalyst	Pt	Pt
Operating temperature	50 – 100°C (typically 80°C)	150 – 200°C
Major applications	Stationary and automotive power	Stationary power
Advantages	•Solid electrolyte reduce corrosion & electrolyte management problems •Operates at low temperature •Quick start up	•Higher temperature combines heat power •Increases tolerance to fuel impurities
Disadvantages	•Expensive catalyst •Sensitive to fuel impurities	•Expensive catalyst •Long start time •Low current & power

Comparison of PAFC & PEMFC

- It has H_2 as a primary fuel.
- It requires carbon as an electrode.
- Phosphoric acid is used as an electrolyte.
- Platinum acts as catalyst.
- It's operating temperature is 150 to 200°C.
- It has major applications in stationary & automotive power.

- It has H_2 as a primary fuel.
- It requires graphite as an electrode.
- Polymer membrane is used as an electrolyte.
- Platinum acts as catalyst.
- It's operating temperature is 50 to 100°C (typically 80°C).
- It has major applications in stationary power.

PAFC

PAFC were the first fuel cells to cross commercial threshold in the electric power industry.

- PAFC is considered the "First generation" of modern fuel cell.
- These are considered as the most advanced fuel cells after alkaline fuel cells.
- They operate at around 150 to 200°C.

Set up of PAFC

- These fuel cell use liquid phosphoric acid as electrolyte contained in a silicon carbide matrix placed between electrodes.
- The electrodes are made of carbon paper coated with a finely dispersed platinum catalyst bonded with teflon.
- Hydrogen or reformate gas (mixture of H_2 + CO) generated from alcohols or hydrocarbons is used as the fuel whereas air is used as oxidant.

Working of PAFC

- The catalyst strips electron off the hydrogen rich fuel at the anode.
- Positively charged hydrogen ions then migrate through the electrolyte from anode to the cathode.
- Electrons generated at the anode travel through an external circuit providing electric power & reach to the cathode.
- At cathode, the electrons, hydrogen ions & oxygen form water which is discharged from the fuel cell.

➢The cell reaction can be represented as:

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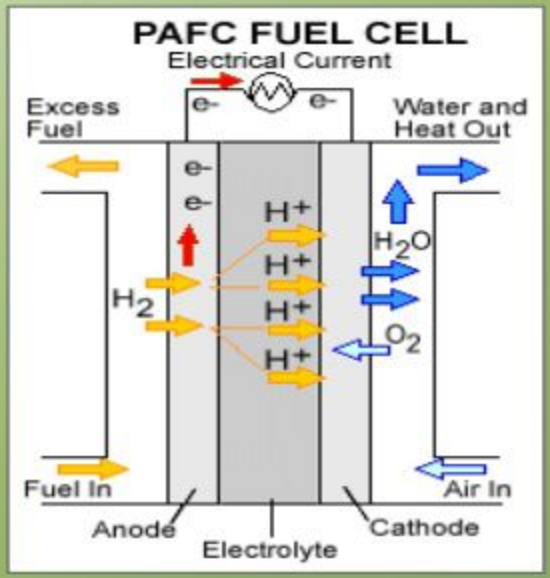
Diagram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