NON CONVENTIONAL ENERGY SOURCES 2

BY

Prof. P.W.Ingle

Sanjivani College of Engineering Kopargoan

*OTEC Plant***:** principal of working, Claude cycle, Anderson Cycle.

MHD Power Generation : Principal of working, Open Cycle MHD generator, closed cycle MHD generators

FUEL CELL

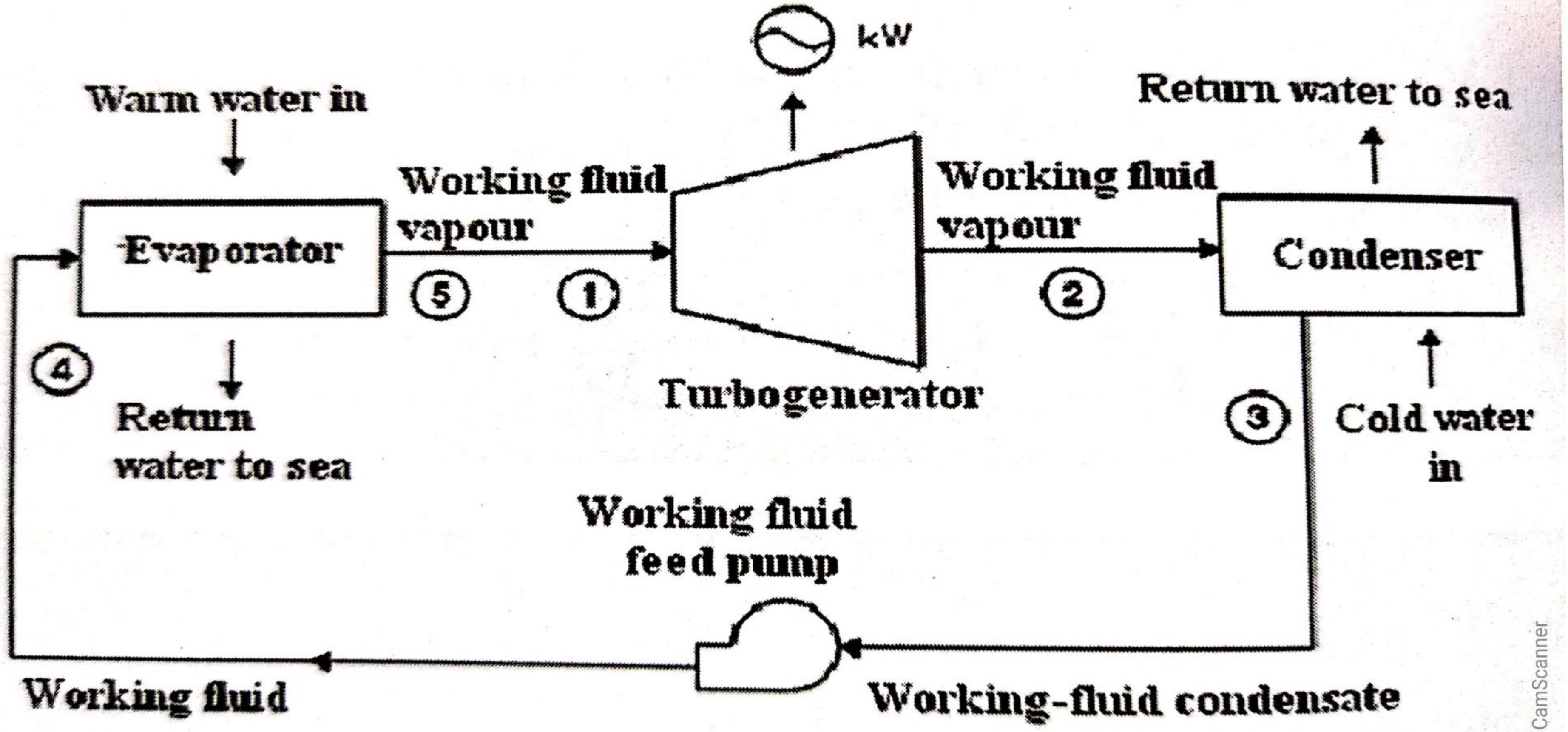
OCEAN THERMAL ENERGY CONVERSION (OTEC)

The ocean of the world constitute a natural reservoir for receiving and storing the energy of the Sun. These oceans consist of nearly three times the area of that of land, and they take the solar energy in proportion to their surface. Water near the surface of tropical and subtropical seas is maintained by this solar radiation at higher temperatures at greater depth or higher altitudes. Due to heat and mass transfer at the surface of ocean, the maximum temperatures occur just below the surface. The ocean is the largest solar collector. In ocean thermal energy transfer system, the temperature difference between the warm ocean surface water and cold deep ocean water can be utilized to generate electricity. The temperature difference needs to be 20 degree Celsius. This occurs at a depth of around 1000 m. This condition exist in tropical coastal area, between the Tropic of Capricorn and the Tropic of Cancer.

All OTEC technology namely, closed cycle, open cycle and hybrid system are as follows:

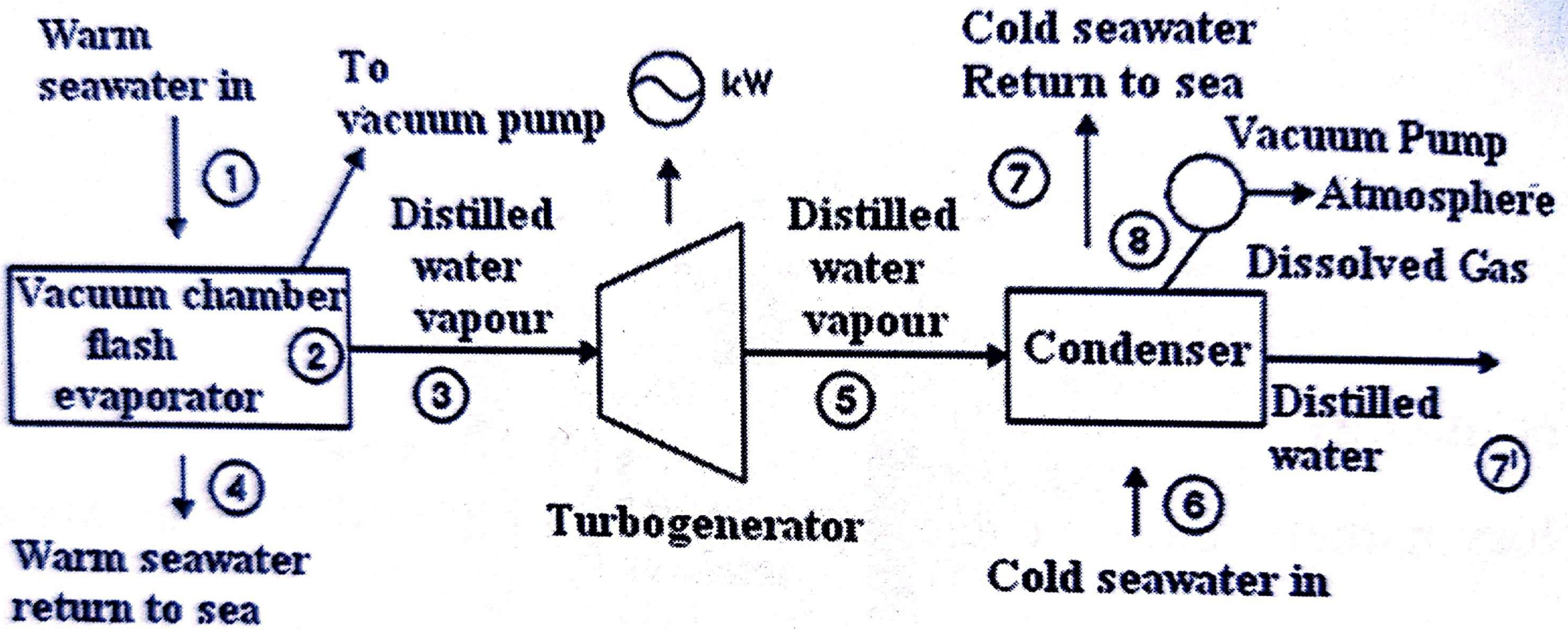
The closed cycle (Anderson) system:- In this case, a working fluid with a low boiling temperature (ammonia and Freon) is used. The fluid is heated and then vaporized in a heat exchanger by the warm sea water. The steam produced drives a steam turbine. After passing through the steam turbine, the working fluid vapor is condensed in another heat exchanger. It is cooled by water drawn from the deep ocean. The working fluid is then pumped back through the warm water heat exchanger. The cycle is repeated continuously.

The most advantage of this cycle is that warm seawater is flash evaporated. The need for having a surface heat exchanger is eliminated. Disadvantage is steam is generated at very low pressure 0.02 bar, volume to be handled is high leading to large sized steam turbine, 1 MW OTEC plant require a steam turbine of 12 m diameter. Again to maintain a vacuum in the flash evaporator, massive vacuum pumps are required



Schematic diagram of a closed-cycle OTEC system.

The open cycle system:- In this case, sea water is the working fluid. Warm water from near the surface of the sea is pumped into a flash evaporator. The pressure is lowered by a vacuum pump to the point where the warm seawater boils at ambient temperature. This process produces steam. It drives the low pressure turbogenerator to generate electricity. After leaving the turbine, the steam is condensed in a heat exchanger cooled by cold and deep ocean water. It also produces desalinated water. G. claude tried the first operational OTEC by using warm surface water as the working fluid. Hence open cycle is also known as Claude Cycle OTEC system. Closed system requires expensive working fluid like Freon or ammonia. For 1MW power only 1.1 M diameter turbine required whose fabrication is easier



Schematic diagram of an open-cycle OTEC system.

MHD Power generation: Magnetohydrodynamic power generation provides a way of generating electricity directly from a fast moving stream of ionized gases without the need for any moving mechanical parts - no turbines and no rotary generators. Several MHD projects were initiated in the 1960s but overcoming the technical challenges of making a practical system proved very expensive. Interest consequently waned in favor of nuclear power which since that time has seemed a more attractive option.

MHD power generation has also been studied as a method for extracting electrical power from nuclear reactors and also from more conventional fuel combustion systems

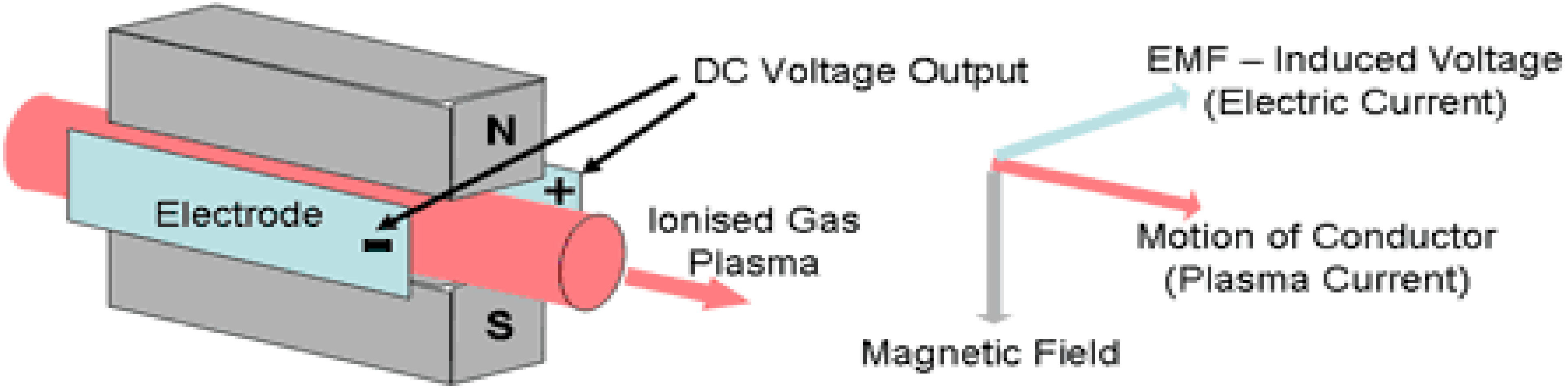
Working Principle

The MHD generator can be considered to be a fluid dynamo. This is similar to a mechanical dynamo in which the motion of a metal conductor through a magnetic field creates a current in the conductor except that in the MHD generator the metal conductor is replaced by a conducting gas plasma.

When a conductor moves through a magnetic field it creates an electrical field perpendicular to the magnetic field and the direction of movement of the conductor. This is the principle, discovered by Michael Faraday, behind the conventional rotary electricity generator. Dutch physicist Antoon Lorentz provided the mathematical theory to quantify its effects.

The flow (motion) of the conducting plasma through a magnetic field causes a voltage to be generated (and an associated current to flow) across the plasma , perpendicular to both the plasma flow and the magnetic field according to Fleming's Right Hand Rule

A MHD generator like a turbo generator is an energy conversion device. It can use any high temperature heat source like chemical, nuclear, solar energy etc. In a MHD system, hot gases act as the conductor. When gases are heated to sufficiently high temperature, one or more of the valence electrons are expelled from their orbit in which they are revolving. This ionizes the gas i.e. the neutral atoms are split into positive and negative ions. These ions are the electrical conductors. The gases are moved in a duct called MHD duct at a very high velocity. The movement of these ions in the MHD duct in which a strong magnetic field is applied leads to the electromagnetic induction of an e.m.f in a pair of electrodes which are placed in a direction perpendicular to both the direction of flow of the ionized gases and that of magnetic field. The electrodes are connected to the external circuit which drive a current in the external load



Magnetohydrodynamic Power Generation (Principle)

Lorentz Law describing the effects of a charged particle moving in a constant magnetic field can be stated as

$$\mathbf{F = QvB}$$

where

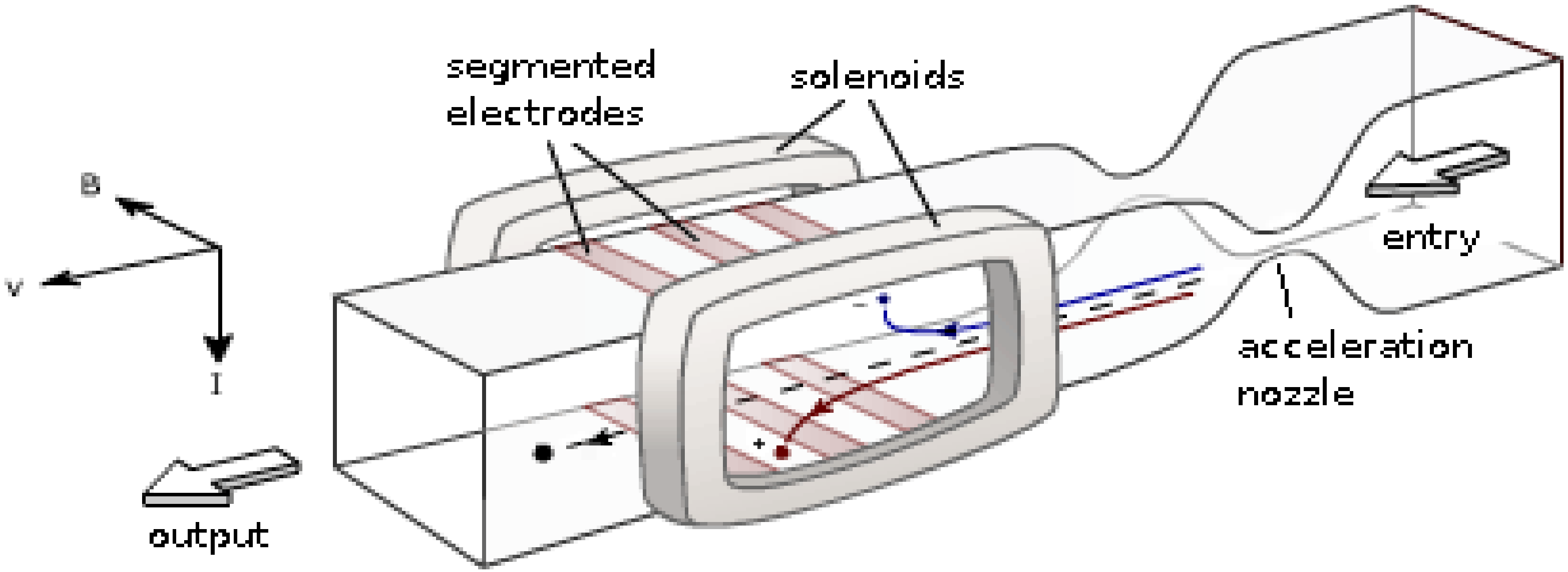
F is the force acting on the charged particle

Q is charge of particle

v is velocity of particle

B is magnetic field

An MHD generator, like a conventional generator, relies on moving a conductor through a magnetic field to generate electric current. The MHD generator uses hot conductive ionized gas (a plasma) as the moving conductor. The mechanical dynamo, in contrast, uses the motion of mechanical devices to accomplish this.



MHD Generator

Faraday linear nozzle with segmented electrodes

Open-Cycle MHD Systems: Construction and Working:

i. The fuel (e.g. Oil, coal, natural gas) is burnt in ‘combustion chamber’, air required for combustion is supplied from ‘air preheater’.

ii. The hot gas produced by the combustion chamber are then seeded with a small amount of an ionized alkali metal (cesium or potassium) to increase the electrical conductivity of the gas.

iii. The ionization of potassium (generally potassium carbonate is used as seed material) takes place due to gases produced at temperature of about 2300-2700°C by combustion.

v. The hot pressurized working fluid so produced leaves the combustion chamber and passes through a convergent-divergent ‘nozzle’.

v. The gases coming out the nozzle at high velocity then enter the ‘MHD generator’.

vi. The MHD generator produces direct current (D.C.). By using an ‘inverter’ this direct current can be converted into alternating current (A.C.)

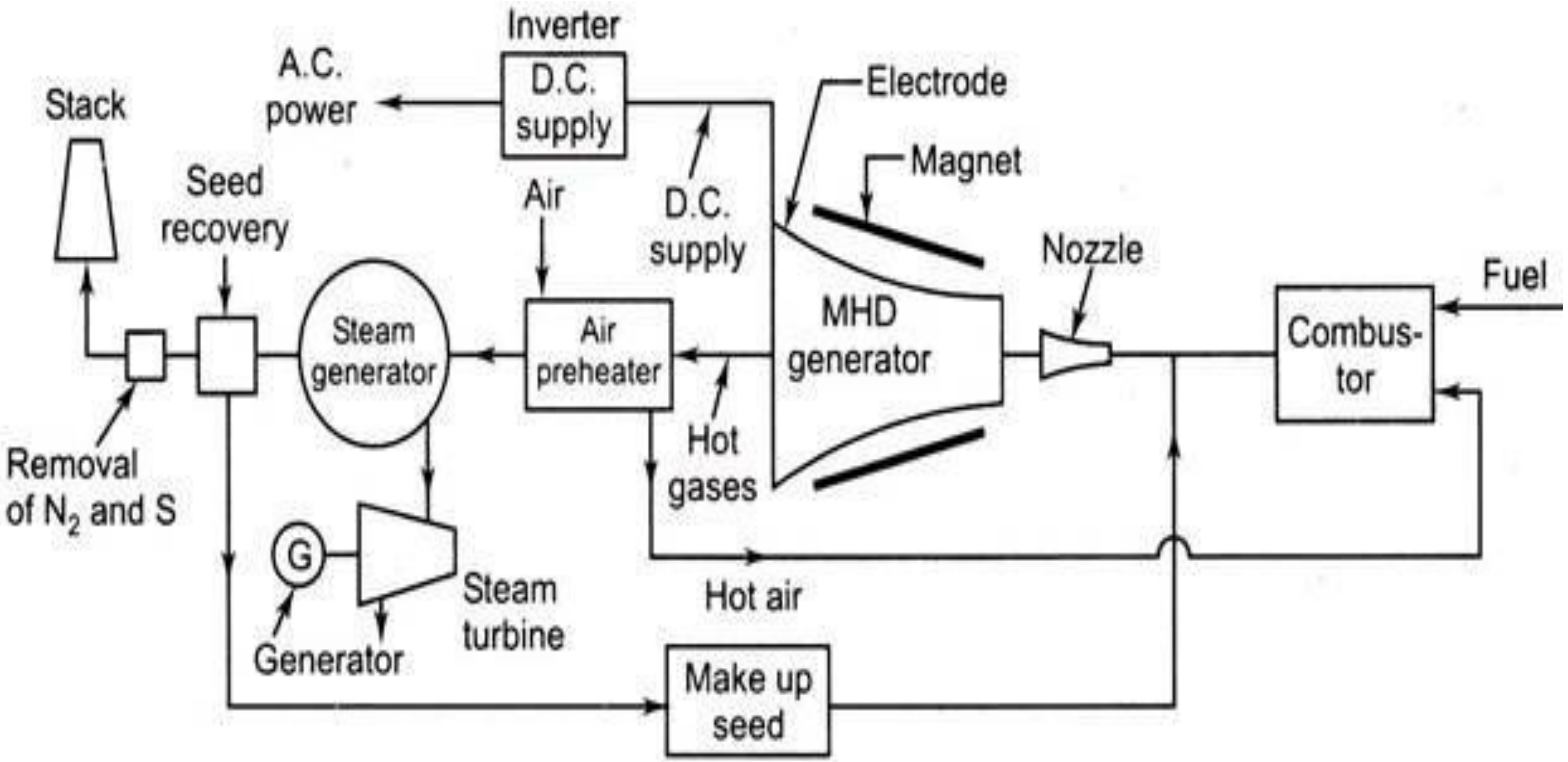


Fig. 9.10. Open-cycle MHD system

Closed-Cycle MHD Systems:

1. Seeded Inert Gas Closed-Cycle MHD System:

This MHD system works on Brayton cycle with inert carrier gas (Argon/helium). Refer to Fig. 9.11. In seeded inert gas system, electrical conductivity is maintained in the working fluid by ionization of a seed material. The inert gas is compressed and heated in primary heat exchanger.

Small quantity of seed material (e.g., cesium) is then added to make up for the loss of seed through leakage etc. At lower temperature, low cost seed material can also be a used but at low temperature, efficiency of the system reduces. The D.C. output from MHD generator is converted to A.C. in inverter.

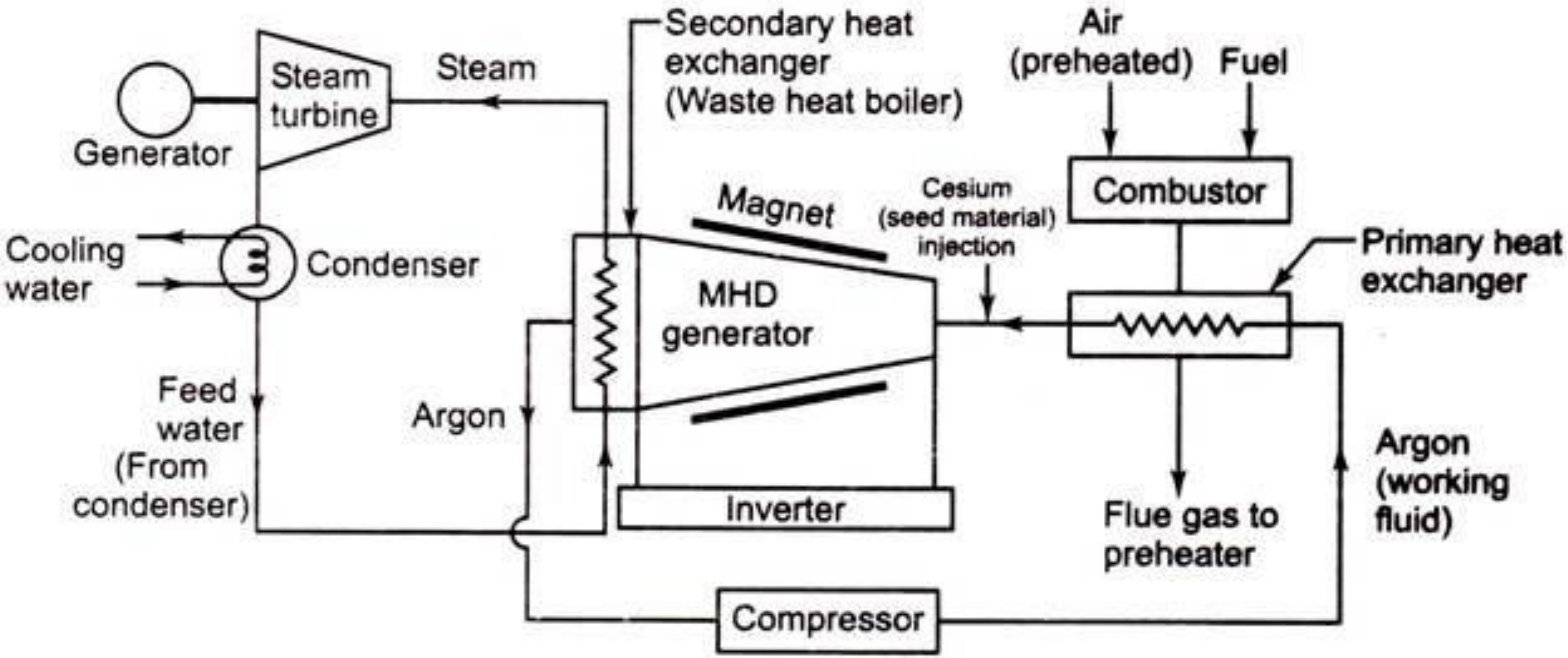


Fig. 9.11. Seeded inert gas closed-cycle MHD generator.

2. Close-Cycle Liquid Metal MHD System: Fig. 9.12 shows the schematic of a closed-cycle liquid metal system. In this system, a liquid metal (Potassium) is used as a working fluid.

Construction and Working:

i. The liquid potassium after being heated in the ‘breeder reactor’ is passed through the ‘nozzle’ where its velocity is increased.

ii. The small amount of vapors formed due to nozzle action are separated in the separator and condensed and them pumped back to the reactor.

iii. Then the liquid metal with high velocity is passed through ‘MHD generator’ to produce D.C. power.

iv. The liquid potassium coming out of MHD generator is passed through the heat exchanger’ (boiler) to use its remaining heat to run a turbine-generator set and then pumped back to the reactor.

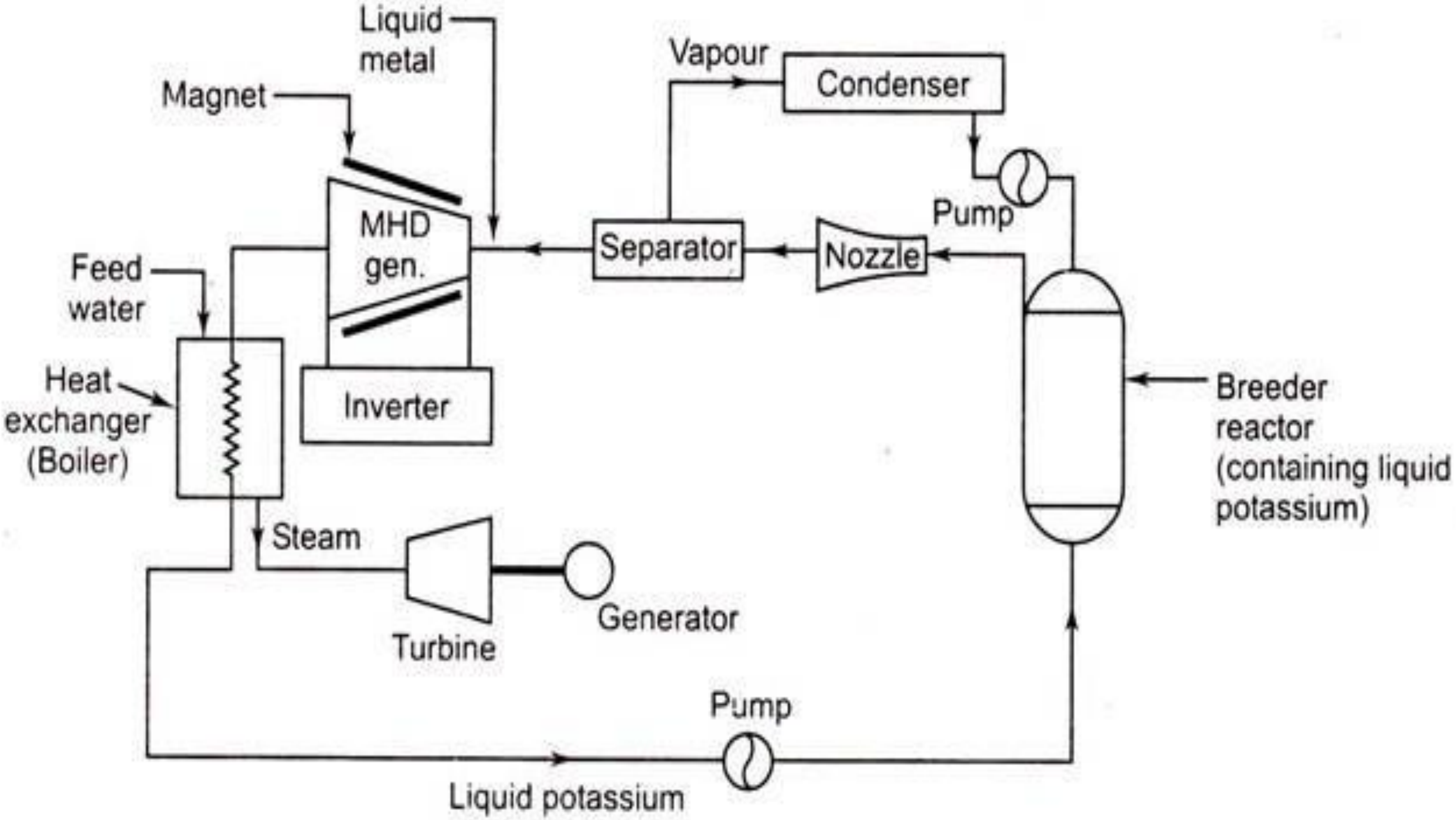


Fig. 9.12. Closed-cycle (liquid metal) system.

Fuel cell:- fuel cells are electromechanical devices that converts fuels chemical energy directly to electrical energy without an intermediate combustion or thermal cycle. With no internal moving parts, fuel cells operate similar to batteries. An important difference is that batteries store energy, while fuel cell produce electricity continuously as long as fuel (usually natural gas or hydrogen) and air are supplied.

Although fuel cell is not a renewable energy technology, it is certainly a core element in a renewable energy system, particularly if hydrogen comes from a renewable fuel or process, such as biofuel or electrolysis via solar generated electricity. Fossil fuel like natural gas can also be reformed for use in fuel cell. Gases from coal and diesel fuel are poor choices of fuel since they cause an overall increase in CO2 emission

Working of fuel cell:- the operation of fuel cell is illustrated in the figure. The fuel cell consist of two gas permeable electrodes separated by an electrolyte, which is a transport medium for electrically charged ions. Hydrogen gas, the ultimate fuel in all current design of fuel cells, enters the fuel cell through the anode, while oxygen is admitted through the cathode. Hydrogen is generated from biofuels and oxygen is supplied from air. Depending on the fuel cell design, either positively charged hydrogen ion form at anode or negatively charged ions containing oxygen form at cathode. In either case the resulting ions migrate through the electrolyte to the opposite electrode from which they are formed. Hydrogen ions migrate to cathode where they react with oxygen to form water. Oxygen bearing ions migrate to anode where they react with hydrogen to form water. Both ionic processes release chemical energy in the form of electrons at the anode, which flow to the cathode through an external circuit. The flow of electrons from anode to cathode represent the direct generation of electrical power from flameless oxidation of fuel

A fuel cell is an electrochemical device that combines hydrogen and oxygen to produce electricity, with water and heat as by-products. In its simplest form, a single fuel cell consists of two electrodes - an anode and a cathode - with an electrolyte between them. At the anode, hydrogen reacts with a catalyst, creating a positively charged ion and a negatively charged electron. The proton then passes through the electrolyte, while the electron travels through a circuit, creating a current. At the cathode, oxygen reacts with the ion and electron, forming water and useful heat.

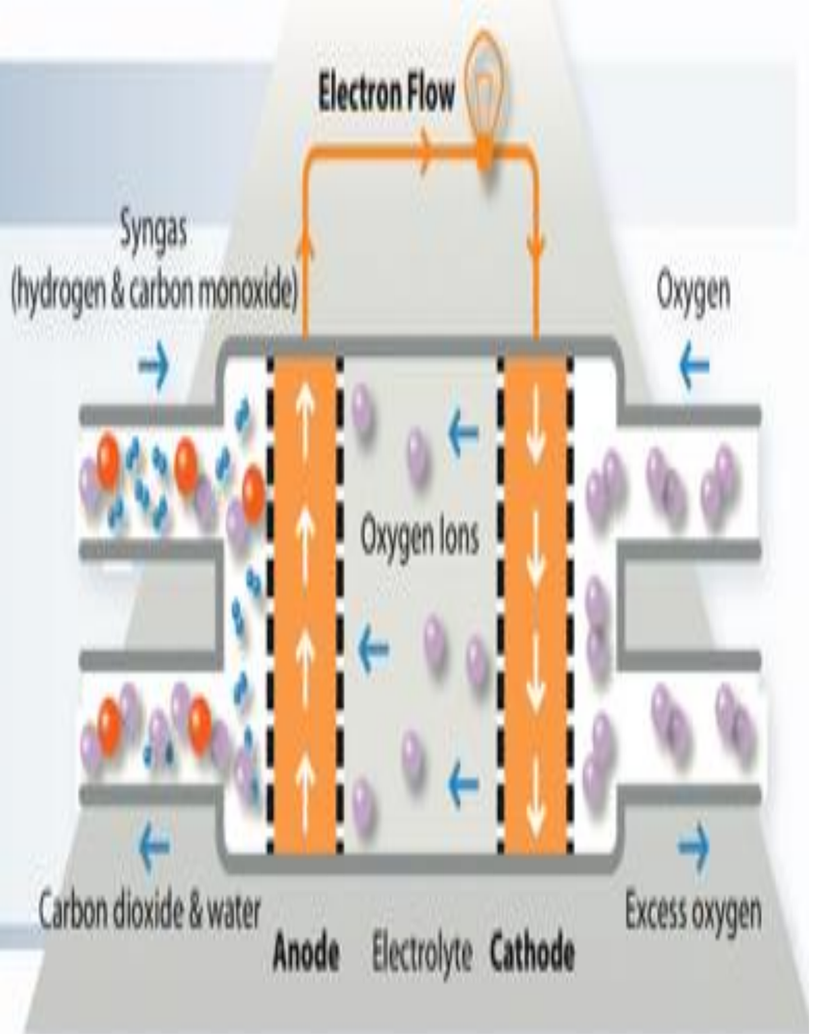
SOFCs use a hard, non-porous ceramic compound as the electrolyte. Since the electrolyte is solid, the cells do not have to be constructed in the plate like configuration typical of other fuel cell types. SOFCs are expected to be around 50%–60% efficient at converting fuel to electricity

They operate at very high temperatures, typically between 500 and 1 000 °C. At these temperatures, SOFCs do not require expensive platinum catalyst material, as is currently necessary for lower-temperature fuel cells such as PEMFCs, and are not vulnerable to carbon monoxide catalyst poisoning (deactivation by impurities). However, vulnerability to sulfur has been widely observed and the sulfur must be removed before entering the cell through the use of adsorbent beds or other means.

SOFCs have a wide variety of applications ranging from auxiliary power units in vehicles to stationary power generation, with outputs from 100 W to 2 MW.

SOFC – Solid Oxide Fuel Cells

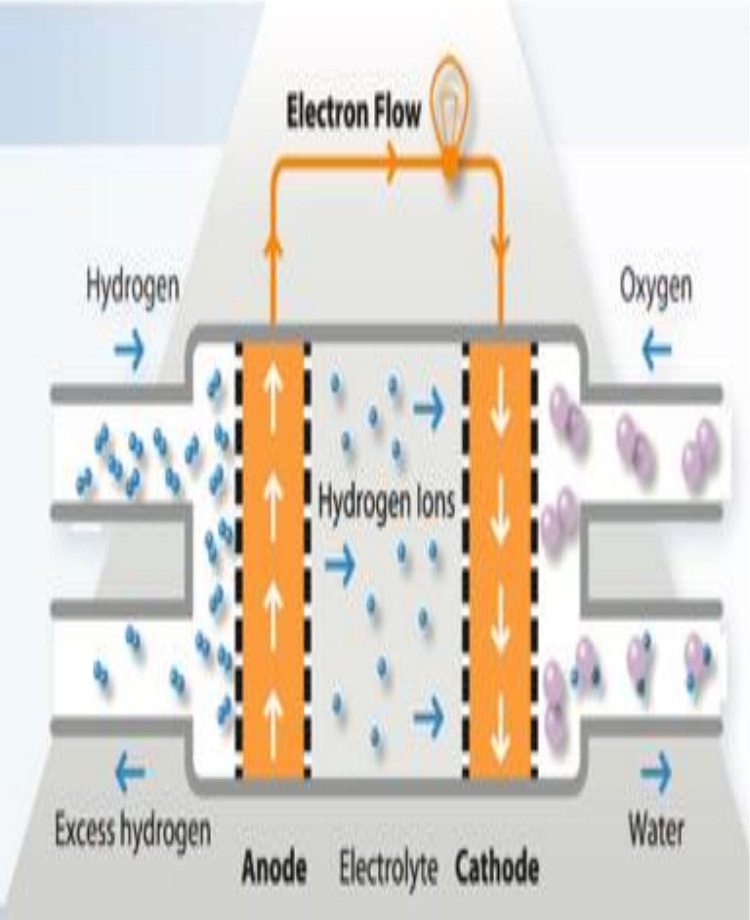
- Electrolyte: solid ceramic, such as stabilised zirconium oxide
- A precious metal catalyst is not necessary
- Can run on hydrocarbon fuels such as methane
- Operate at very high temperatures, around 800°C to 1,000°C
- Best run continuously due to the high operating temperature
- Popular in stationary power generation



Proton Exchange Membrane Fuel Cells, also known as Polymer Electrolyte Fuel Cells or PEMFC, provide high-power density and have several advantages related to its low weight and volume, compared to other FCs
PEMFCs use a polymeric membrane as an electrolyte, and porous carbon electrodes containing a platinum catalyst. These type of FCs only need hydrogen, oxygen from the air, and water to operate, and their operation do not involve corrosive fluids like some other FCs. They are typically fueled with pure hydrogen supplied from storage tanks.
They operate at low temperatures, about 80°C, and they are suitable for mobility applications and other uses that require an initial high demand of power, which is of high density.

PEMFC – Proton Exchange Membrane Fuel Cells

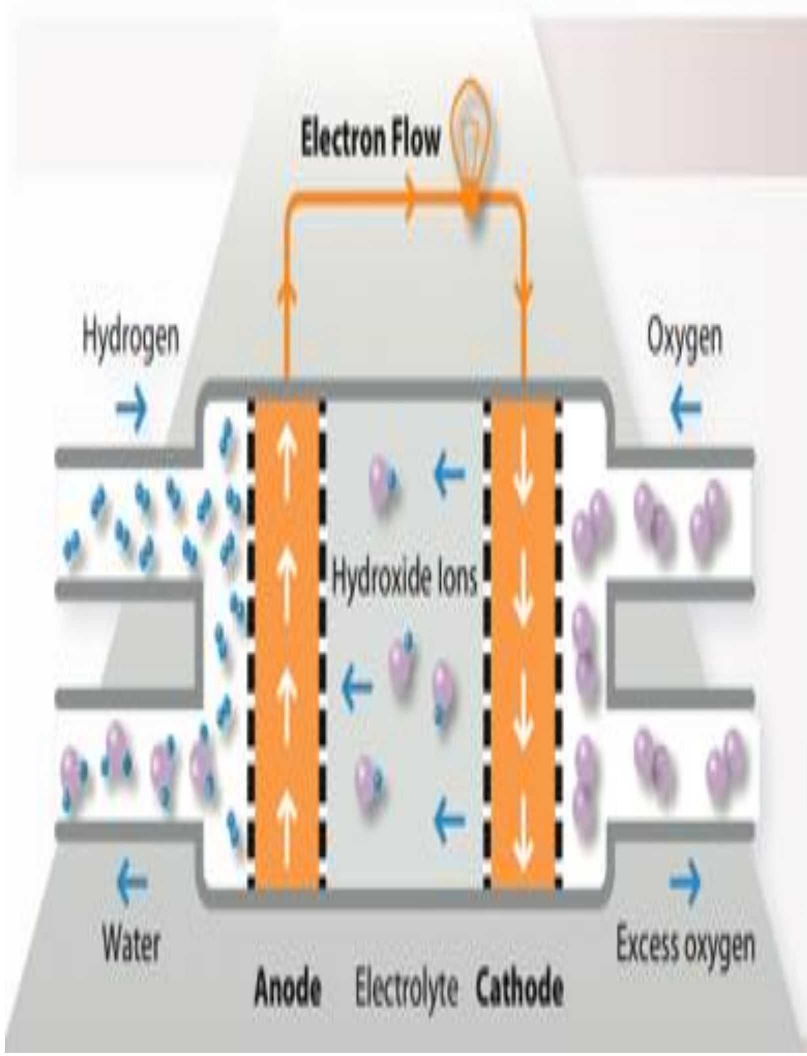
- Electrolyte: water-based, acidic polymer membrane
- Also called polymer electrolyte membrane fuel cells
- Use a platinum-based catalyst on both electrodes
- Generally hydrogen fuelled
- Operate at relatively low temperatures (below 100°C)
- High-temperature variants use a mineral acid-based electrolyte and can operate up to 200°C.
- Electrical output can be varied, ideal for vehicles



Alkaline Fuel Cells (AFCs) were one of the first developed FC technologies, and they were the first type widely used in the U.S. space program to produce electrical energy and water on-board spacecraft 13 . These FCs use a solution of potassium hydroxide in water as the electrolyte, and can use a variety of non-precious metals as a catalyst at the anode and cathode. High-temperature AFCs operate at temperatures between 100°C and 250°C. However, newer AFC designs operate at lower temperatures of roughly 23°C to 70°C. The efficiency of an alkaline FC operating on pure hydrogen is 60%. One of their advantages is that the water produced is drinkable and currently are the cheapest fuel cells to manufacture

The reason lies in the relatively inexpensive materials used as catalyst on their electrodes, compared to the catalysts such as platinum required for other types of FCs.

One of the limitations of AFCs, is that they are sensitive to carbon dioxide (CO2) which may be present in the fuel or air. The CO 2 reacts with the electrolyte to form a carbonate which can decrease the conductivity. Currently, this type of FC is being tested for stationary power applications.



Alkaline Fuel Cells – AFC

- Electrolyte: alkaline solution such as potassium hydroxide in water
- Commonly use a nickel catalyst
- Generally fuelled with pure hydrogen and oxygen as they are very sensitive to poisoning
- Typical operating temperatures are around 70°C
- Can offer high electrical efficiencies
- Tend to have relatively large footprints
- Used on NASA shuttles throughout the space programme