Noida Institute of Engineering and Technology, Greater Noida

Geothermal Energy, Magneto-hydrodynamics, Fuel Cells

Unit: 3

Renewable Energy Resources(KOE-074)

Course Details
(B.Tech ME 7th Sem)

Avdhesh kumar
Assistant Professor
ME Department

Brief introduction of faculty with photograph

Mr. Avdhesh Kumar

I, Avdhesh Kumar, Assistant Professor, MED, NIET is currently associated with NIET, Gr. Noida. I have vast experience in the field of Fluid mechanics, fluid machinery, Manufacturing science, Automobile Engineering, Total Quality Management. I have 13 years teaching experience. Here (NIET Gr. Noida) I m teaching from 4 Feb 2019 to till now. I m currently pursuing PhD from National Institute of Technology (NIT) Patna.

Evaluation Scheme

B. Tech Mechanical Engineering Evaluation Scheme
Effective in Session 2021-22

SEMESTER- VII													
Sl. No.	Code	Subject	Periods			Evaluation Scheme				End Semester		Total	Credit
			L	T	P	CT	TA	Total	PS	TE	PE		
1		HSMC-1/HSMC-2	3	0	0	30	20	50		100		150	3
2		Departmental Elective-IV	3	0	0	30	20	50		100		150	3
3		Departmental Elective-V	3	0	0	30	20	50		100		150	3
4		Open Elective-II	3	0	0	30	20	50		100		150	3
5	KME 751	Measurement & Metrology Lab	0	0	2				25		25	50	1
6	KME 752	Mini Project or Internship Assessment*	0	0	2				50			50	1
7	KME 753	Project	0	0	8				150			150	4
8		MOOCs (Essential for Hons. Degree)											
		Total	9	0	12	21						850	18

*The Mini Project or internship (5 - 6 weeks) conducted during summer break after VI semester and will be assessed during VII semester.

Evaluation Scheme

B. Tech Mechanical Engineering
OPEN ELECTIVE-II

KOE071	FILTER DESIGN
KOE072	BIOECONOMICS
KOE073	MACHINE LEARNING
KOE074	RENEWABLE ENERGY RESOURCES
KOE075	OPERATIONS RESEARCH
KOE076	VALUE RELATIONSHIP & ETHICAL HUMAN CONDUCT- FOR A HAPPY & HARMONIOUS SOCIETY
KOE077	DESIGN THINKING
KOE078	SOIL AND WATER CONSERVATION ENGINEERING
KOE078	INTRODUCTION TO WOMEN'S AND GENDER STUDIES

Syllabus

Unit 1: Introduction: Various non-conventional energy resources- Introduction, availability, classification, relative merits and demerits. Solar Cells: Theory of solar cells. Solar cell materials, solar cell array, solar cell power plant, limitations.

Unit 2: Solar Thermal Energy: Solar radiation, flat plate collectors and their materials, applications and performance, focusing of collectors and
their materials, applications and performance; solar thermal power plants, thermal energy storage for solar heating and cooling, limitations.

Unit 3: Geothermal Energy: Resources of geothermal energy, thermodynamics of geo- thermal energy conversion-electrical conversion, non-electrical conversion, environmental considerations. Magneto-hydrodynamics (MHD): Principle of working of MHD Power plant, performance and limitations. Cells: Principle of working of various types of fuel cells and their working,
performance and limitations.

Syllabus

Unit 4: Thermo-electrical and thermionic Conversions: Principle of working, performance and limitations. Wind Energy: Wind power and its sources, site selection, criterion, momentum theory, classification of rotors, concentrations and augments, wind characteristics. Performance and limitations of energy conversion systems.

Unit 5: Bio-mass: Availability of bio-mass and its conversion theory. Ocean Thermal Energy Conversion (OTEC): Availability, theory and working principle, performance and limitations. Wave and Tidal Wave: Principle of working, performance and limitations. Waste Recycling
Plants.

Branch wise Application

- The renewable energy industry has seen impressive, global growth over the last decade, and mechanical engineers have played a key role in enabling the world's transition to clean energy and more sustainable practices.

- mechanical engineers looked at ways of improving the design of wind turbines, and mechanical engineering has led to similar improvements in solar and geothermal power, as well as every stage of renewable energy development.

- Many of the key skills that mechanical engineers learn and develop in mechanical engineering graduate programs have a wide range of applications for renewable energy engineering. Knowledge of thermodynamics, fluid mechanics and heat transfer, for example, is essential for solving the wind power challenge outlined above, but the same expertise is also critical in designing hydropower infrastructure, optimizing cooling systems and developing new energy storage technology such as thermochemical batteries and solar fuel (pioneered at MSU) for long duration energy storage.

Course Objectives

1. To impart knowledge on various non-conventional energy resources so that the students can apply them in the domestic and engineering industry.
2. To gain understanding of applications and performance of solar thermal power plants, thermal energy storage for solar heating and cooling in the domestic and industry.
3. To develop the knowledge of geothermal energy, Magneto-hydrodynamics and principle of working of various types of fuel cells, performance, limitations and environmental considerations.
4. To acquire knowledge and to solve problems associated with Thermo-electrical and thermionic conversions and Wind Energy, wind characteristics, performance and limitations of energy conversion systems.
5. To impart knowledge on Bio-mass, Ocean Thermal Energy Conversion, Wave and Tidal Wave, conversion theory, performance and limitations.

Course Outcomes

After completion of this course students will be able to-

CO 1. Identify and understand the concepts of various non-conventional energy resources and their application in the domestic and engineering industry.

CO 2. Understand the applications and performance of solar thermal power plants, thermal energy storage for solar heating and cooling in the domestic and industry.

CO 3. Analyze and predict about geothermal energy, Magneto-hydrodynamics and various types of fuel cells, performance, limitations and environmental considerations.

CO 4. Solve the problems associated with Thermo-electrical and thermionic conversions and Wind Energy, wind characteristics, performance and limitations.

CO 5. Use appropriate knowledge on Bio-mass, Ocean Thermal Energy Conversion, Wave and Tidal Wave their performance and limitations.

Program Outcomes

1. **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization for the solution of complex engineering problems.
2. **Problem analysis:** Identify, formulate, research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health & safety, cultural, societal, & environmental considerations.
4. **Conduct investigations of complex problems:** Use research based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.

Program Outcomes

5. **Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modeling to complex engineering activities, with an understanding of the limitations.
6. **The engineer & society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal & cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

Program Outcomes

9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

10. Communication: Communicate effectively on complex engineering activities with engineering community & society at large, such as, being able to comprehend & write effective reports & design documentation, make effective presentations, & give & receive clear instructions.

11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

CO-PO Mapping

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	1	2	1	2	3	-	3	1	2	2
CO2	2	2	1	1	3	1	3	2	3	-	1	3
CO3	2	1	2	1	2	2	3	2	3	1	2	3
CO4	2	2	2	1	2	2	3	2	3	1	1	2
CO5	1	2	1	1	2	1	3	3	3	1	2	3

Program Specific Outcomes

- **PSO1.** To impart proper knowledge of science, mathematics and mechanical engineering related subjects to the students.

- **PSO2.**To enhance the skills of the students with the ability to implement the scientific concepts for betterment of the society in professional and ethical manner.

- **PSO3.** To prepare the students to understand physical system, mechanical components and processes to address social, technical and engineering challenges.

CO- PSO Mapping

Mapping of Program Specific Outcomes and Course Outcomes:

CO/PSO	PSO1	PSO2	PSO3
CO1	1	3	3
CO2	1	2	3
CO3	2	1	2
CO4	1	1	1
CO5	2	2	1

PEOs

- PEO1 - Graduates will demonstrate technical competency and leadership to become professional engineers leading to a successful career.
- PEO2 - Graduates will demonstrate commitment towards sustainable development for the betterment of society.
- PEO3 - Graduates will pursue lifelong learning in generating innovative engineering solutions using research and complex problem-solving skills.

Result Analysis

End Semester Question Paper

Section A

1. Attempt all questions in brief 2*10=20

(a) State Seebeck Effect and Peltier Effect.

(b) Write the chemical reaction takes place in Alkaline Fuel Cell.

(c) What is an aerobic digestion?

(d) Define solar constant. What is its standard value?

(e) Discuss the terms Energy conservation and Energy audit.

(f) What is the maximum energy conversion efficiency of a wind turbine for a given swept area?

(g) Define Fill Factor.

(h) On what factors does the collector efficiency of a solar flat plate collector depend?

(i) What is OTEC? Discuss in brief.

(j) Describe various Geothermal Energy Resources.

End Semester Question Paper

Section B

2. Attempt any five of the following 5*10=50

(a) Discuss the main features of various types of renewable and non-renewable energy sources. Also explain the importance of non-conventional energy sources in the context of global warming.

(b) Classify different types of solar thermal collector and show the constructional details of a flat plate collector. What are its main advantages?

(c) Explain the mechanism of photoconduction in a PV cell.

(d) Explain the process of gasification of solid biomass. What is the general composition of the gas produced and what is its heating value? What are its applications?

End Semester Question Paper

Section B

2. Attempt any five of the following 5*10=50

(e) Explain the 'Single Basin' and 'Two Basin' systems of tidal power harnessing. Discuss their advantages and limitations.

(f) Explain the essential features of a hydrogen-oxygen cell. Draw a suitable diagram of this cell and give the reactions took place at the electrodes.

(g) With the help of a schematic diagram, explain the operation of closed cycle MHD generating system.

(h) Explain the process of production of biogas from biomass. Describe Deen Bandhu Biogas plant.

End Semester Question Paper

Attempt any two of the following questions: **2 x 15 = 30**

3. What are the most favorable sites for installing wind turbines? Using Betz model of a wind turbine, derive the expression for power extracted from wind. Under what condition does the

maximum theoretical power can be extracted from the wind turbine?

4. Write short notes on: i) Practical problems associated with MHD power generation. ii) Solar Cell Arrays. iii) Vertical Axis Wind Mills.

5. Describe the principle of working and constructional details of basic thermionic generator.

What is the basic difference between thermoelectric and thermionic conversion systems? Also,

explain the working of thermoelectric generators.

Prerequisite and Recap

Students should have knowledge of

- Magnets and magnetic field
- Faraday law and working of conventional generator
- Different layers of earth
- **In previous unit** we have learned about solar thermal energy and solar thermal power plants.
- Students must have some concept of geothermal energy which originates from earths interior in the form of volcanoes, geysers, hot springs etc.

Introduction about the subject with videos

Energy **generated by using wind, solar, small hydro, tides, geothermal heat and biomass** is known a non-conventional energy. All these sources are renewable process of energy generation and do not cause environmental pollution. Our country has been endowed with adequate natural resources.

Figure -1: Types of non conventional energy sources

Introduction about the subject with videos

Links for videos:-

1.https://nptel.ac.in/content/storage2/courses/113106065/Week%208/Lesson19.pdf
2.https://www.youtube.com/watch?v=CPlsarZGBOo
3.https://www.youtube.com/watch?v=Fuyq6WrM1EA
4.https://ocw.mit.edu/courses/mechanical-engineering/2-997-direct-solar-thermal-to-electrical-energy-conversion-technologies-fall-2009/audio-lectures/MIT2_997F09_lec07.pdf
5.EnergyResources Conventional and Non-Conventional
6. https://www.youtube.com/watch?v=Zgp86PVXXuQ
7. https://www.youtube.com/watch?v=X0OZ6tpZ3Mc
8. https://www.youtube.com/watch?v=xKxrkht7CpY
9. https://www.youtube.com/watch?v=x3AfhSHAcqg
10. https://www.youtube.com/watch?v=VkTRcTyDSyk
11. https://www.youtube.com/watch?v=eyOXmqu4PS8
12. https://www.youtube.com/watch?v=e9LvM8EThyk
13. https://www.youtube.com/watch?v=9zgx-PlDEKA

Content

Geothermal Energy:

- Resources of geothermal energy,
- Thermodynamics of geothermal energy
- conversion-electrical conversion,
- non-electrical conversion,
- environmental considerations.

Magneto-hydrodynamics (MHD):

- Principle of working of MHD Power plant,
- Performance and limitations.

Fuel Cells:

- Principle of working of various types of fuel cells
- Performance and limitations.

Objective of Unit

The objectives this unit is as follows -

1. To know about various resources of geothermal energy. Thermodynamics of geothermal energy is done in 2 conversion ways
2. To know about Principle of working of MHD Power plant. It's performance and limitations.
3. To know about Principle of working of various types of fuel cells and their working.
4. It's performance and limitations.

Topic wise Objective (CO3)

Topic : Geothermal Energy

Objective : Objective is to know about various resources of geothermal energy. Thermodynamics of geothermal energy is done in 2 conversion ways –.electrical conversion and .non-electrical conversion,

Objective is to be clear with the environmental considerations

CO 3. Analyze and predict about geothermal energy, Magneto-hydrodynamics and various types of fuel cells, performance, limitations and environmental considerations.

Prerequisite and recap (CO3)

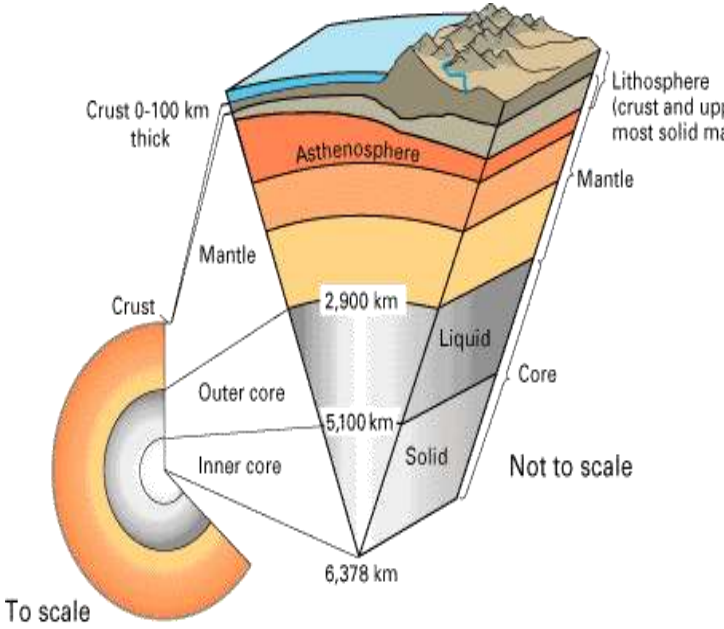
Topic : Geothermal Energy

Prerequisite :

- In previous unit we have learned about solar thermal energy and solar thermal power plants.
- Students must have some concept of geothermal energy which originates from earths interior in the form of volcanoes, geysers, hot springs etc.

Introduction to Geothermal Energy (CO3)

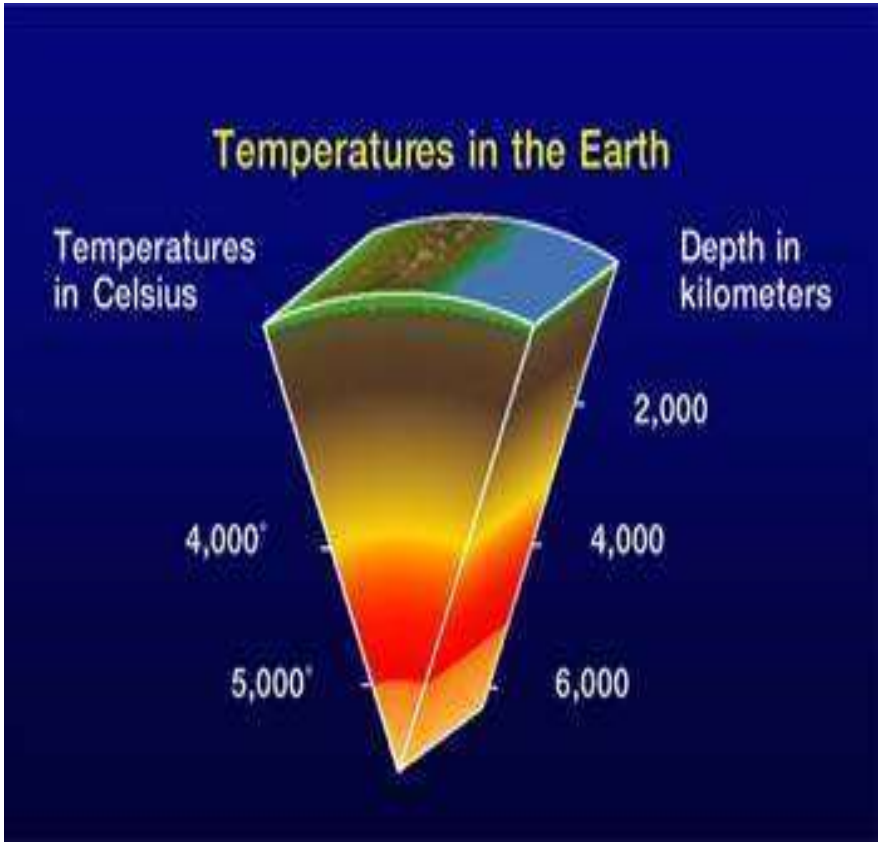
- Geothermal energy is the heat derived within the sub-surface of the Earth.
- Water and/or steam carry the geothermal energy to the Earth's surface.
- It is harnessed for cooking, bathing, space heating, electrical power generation, and other uses.
- The heat is produced mainly by the radioactive decay of potassium, thorium, and uranium in Earth's crust and mantle and also by friction generated along the margins of continental plates.



Geothermal Reservoirs (CO3)

What is Geothermal Energy ?

- It's simply the heat energy of the earth, generated by various natural processes, such as:
- heat from when the planet formed and accreted, which has not yet been lost
- decay of radioactive elements 3.friction etc
- The deeper you go, the hotter it is.



Phase Changing Material (PCM) (CO3)

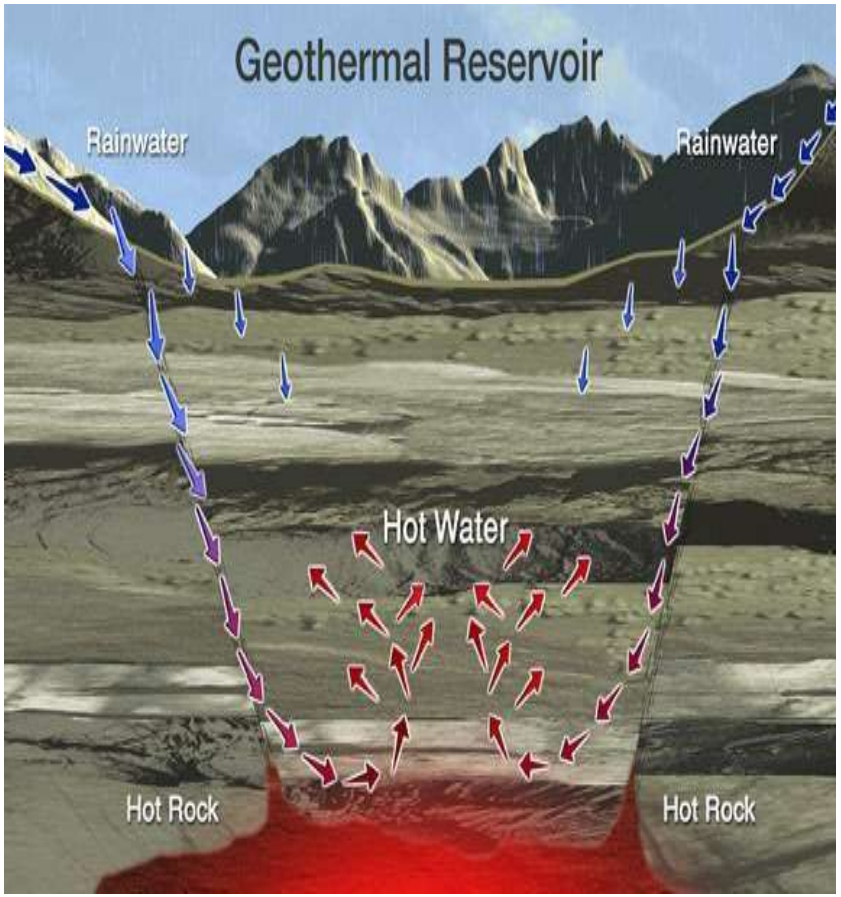
- Geyser
- Boiling mud pot
- Volcano
- Hot springs

Geothermal Reservoirs (CO3)

The rising hot water & steam is trapped in permeable & porous rocks to form a geothermal reservoir.

Reservoirs can be discovered by

- testing the soil
- Analyzing underground temperature



Extraction & uses (CO3)

The heat energy can be brought to earth surface by following ways..

- directly from hot springs/ geysers
- geothermal heat pump

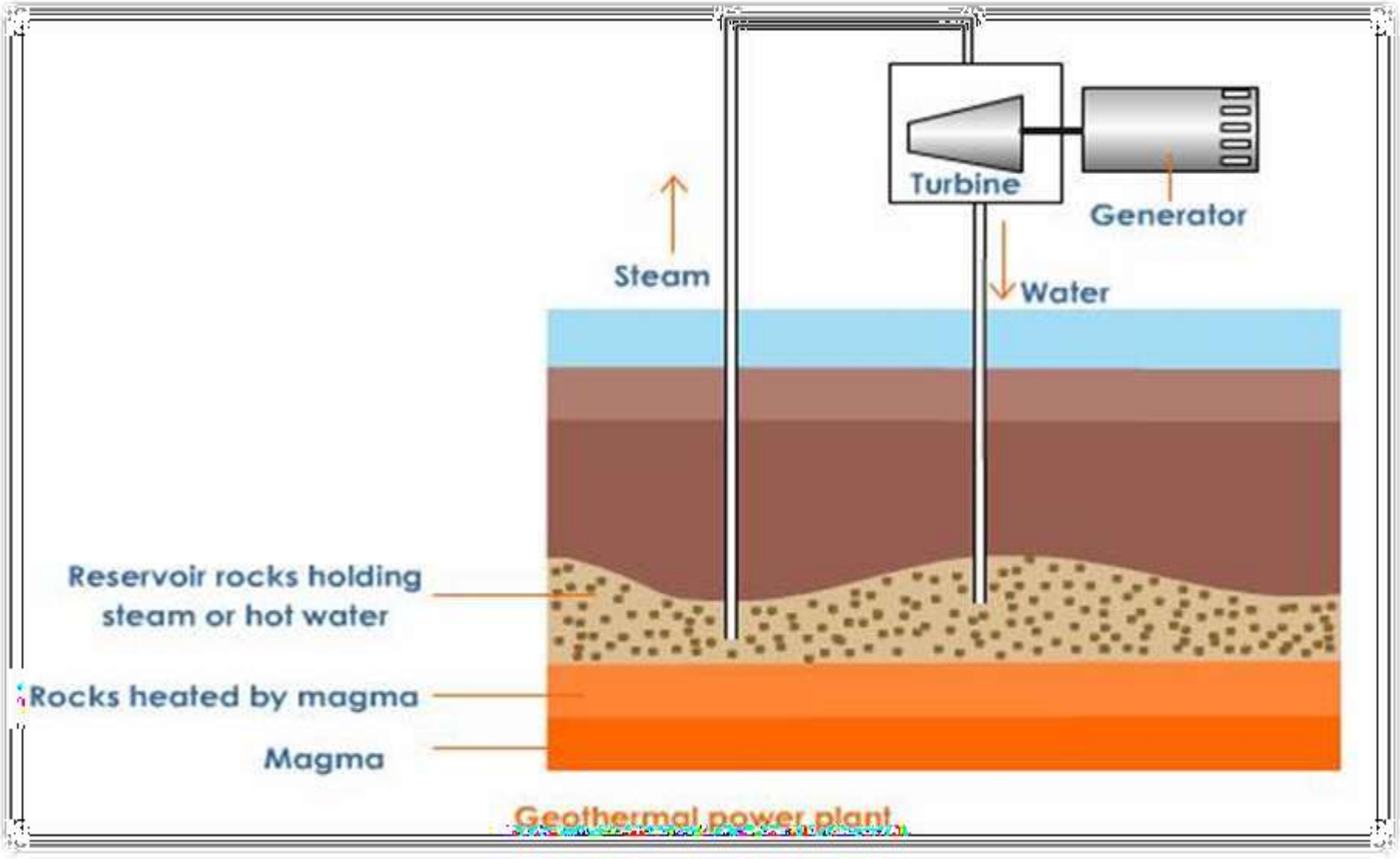
Uses are broadly classified as:-

- direct use
- indirect use

Direct use of Geothermal Energy (CO3)

- Heating water at fish farms.
- Provide heat for buildings.
- Raising plants in greenhouses,
- Drying crops.
- Provides heat to industrial processes

Indirect use of Geothermal Energy (CO3)

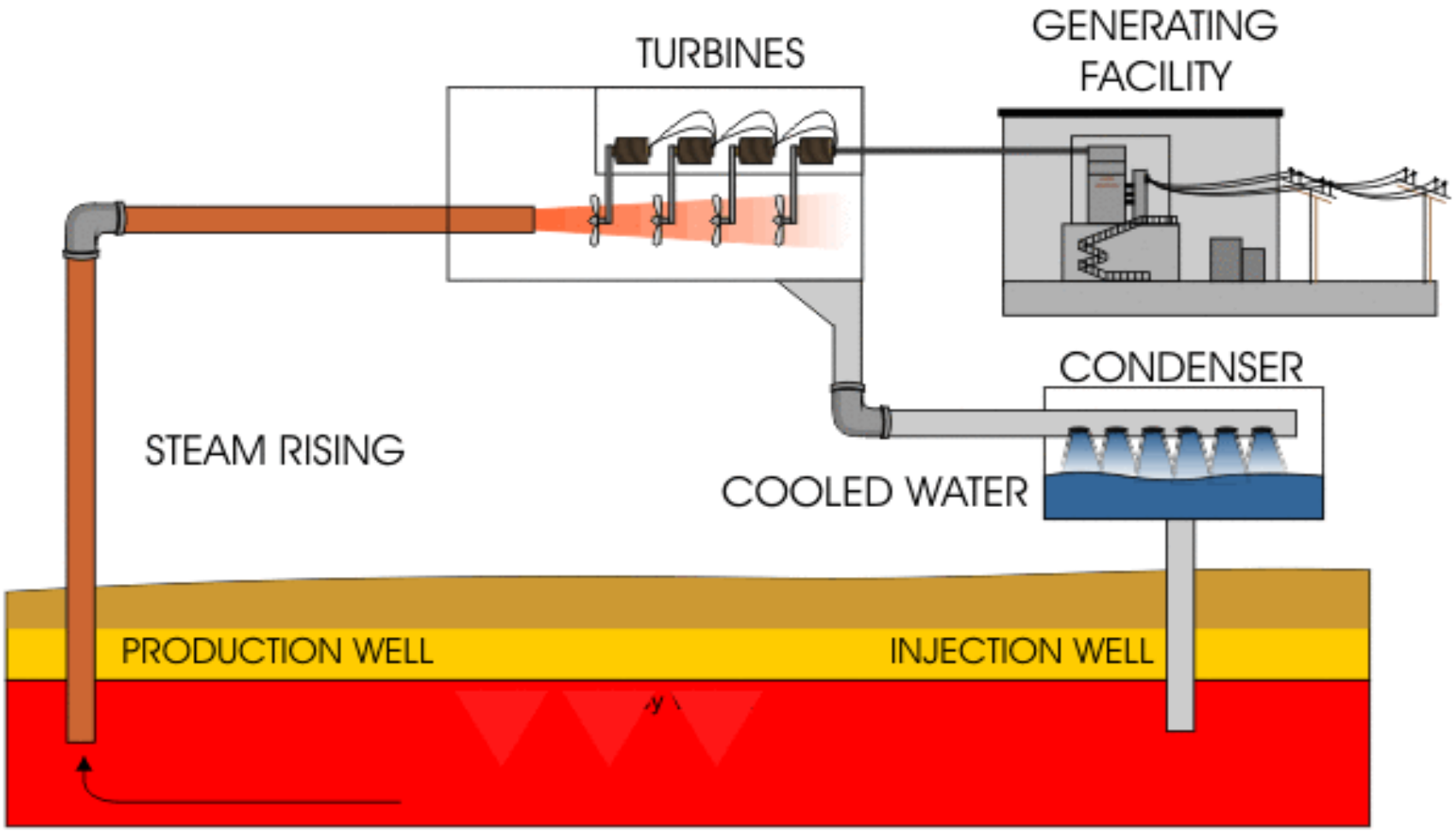


Electricity Generation (CO3)

There are 3 types of power plants:-

- Dry steam power plant
- Flash steam power plant
- Binary cycle power plant

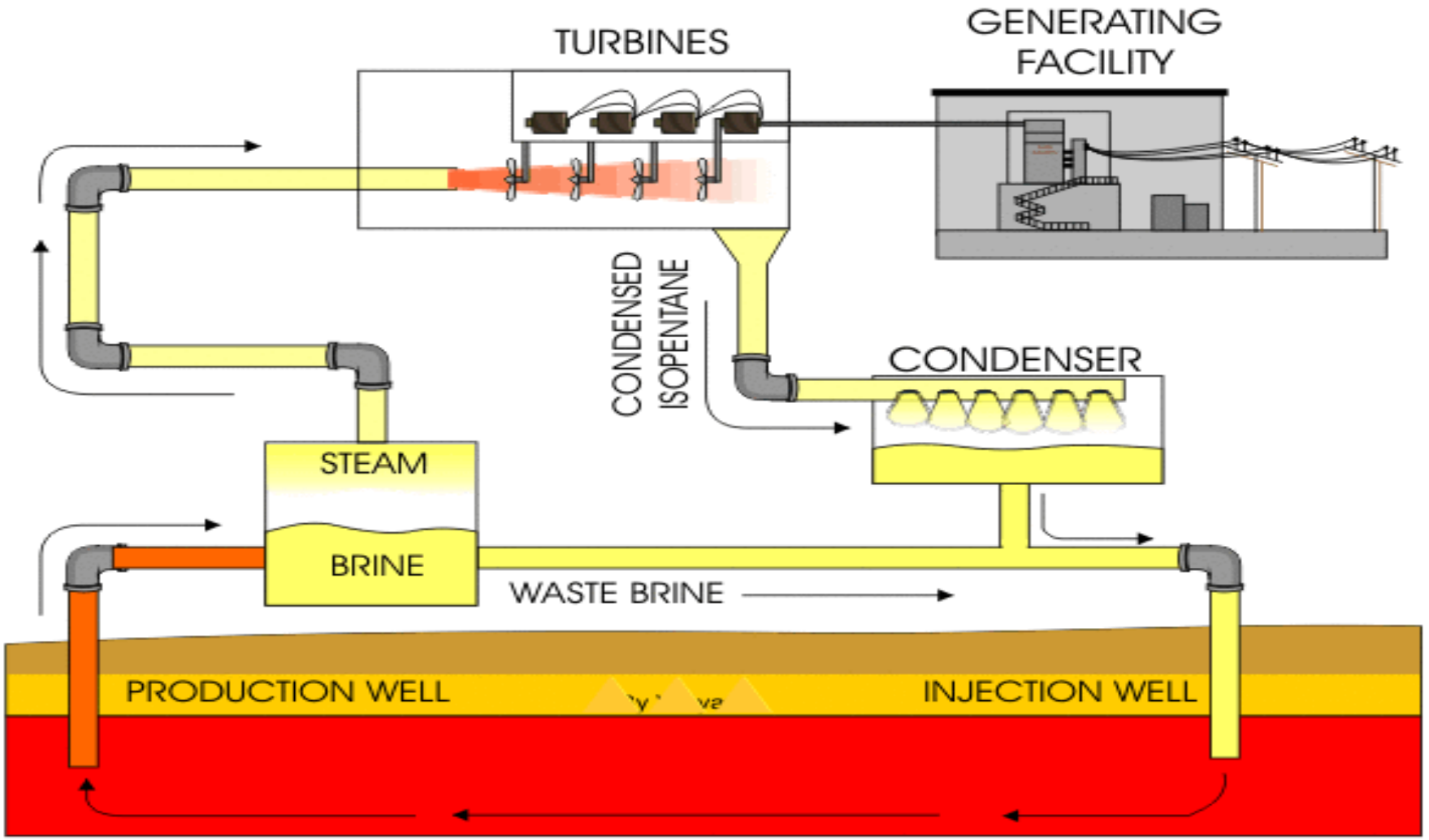
Dry Steam power plant (CO3)



Dry Steam power plant (CO3)

- The oldest type of Geothermal power plant used.
- Geothermal reservoir containing pure steam is required.
- Pure dry steam drives turbine.
- Very rare type of geothermal power plant.
- Operating at California, Italy, and Japan.

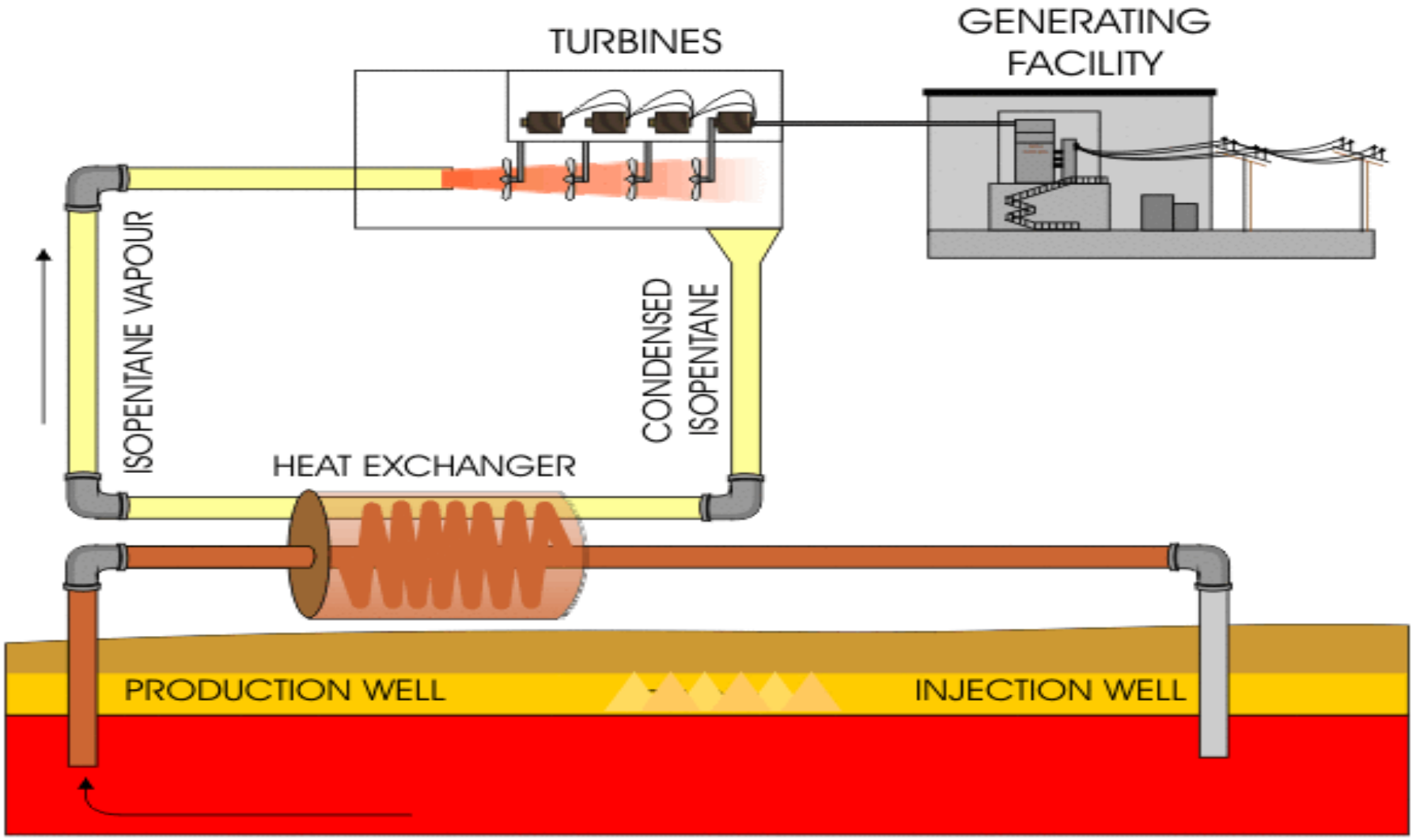
Flash steam power plant (CO3)



Flash steam power plant (CO3)

- Commonly used geothermal power plant.
- Geothermal reservoirs containing both hot water & steam is required.
- Pressure changing system is required

Binary cycle power plant (CO3)



Binary cycle power plant (CO3)

- Does not use steam directly to spin turbines.
- Only the heat of the underground water is used.
- Vaporized hydrocarbons are used to spin the turbine.
- Hydrocarbons having lower boiling point such as isopentane, isobutane and propane can be used.
- No harmful gas is emitted to the atmosphere because the underground water is never disclosed to outside.
- This's the worldwide accepted power plant.

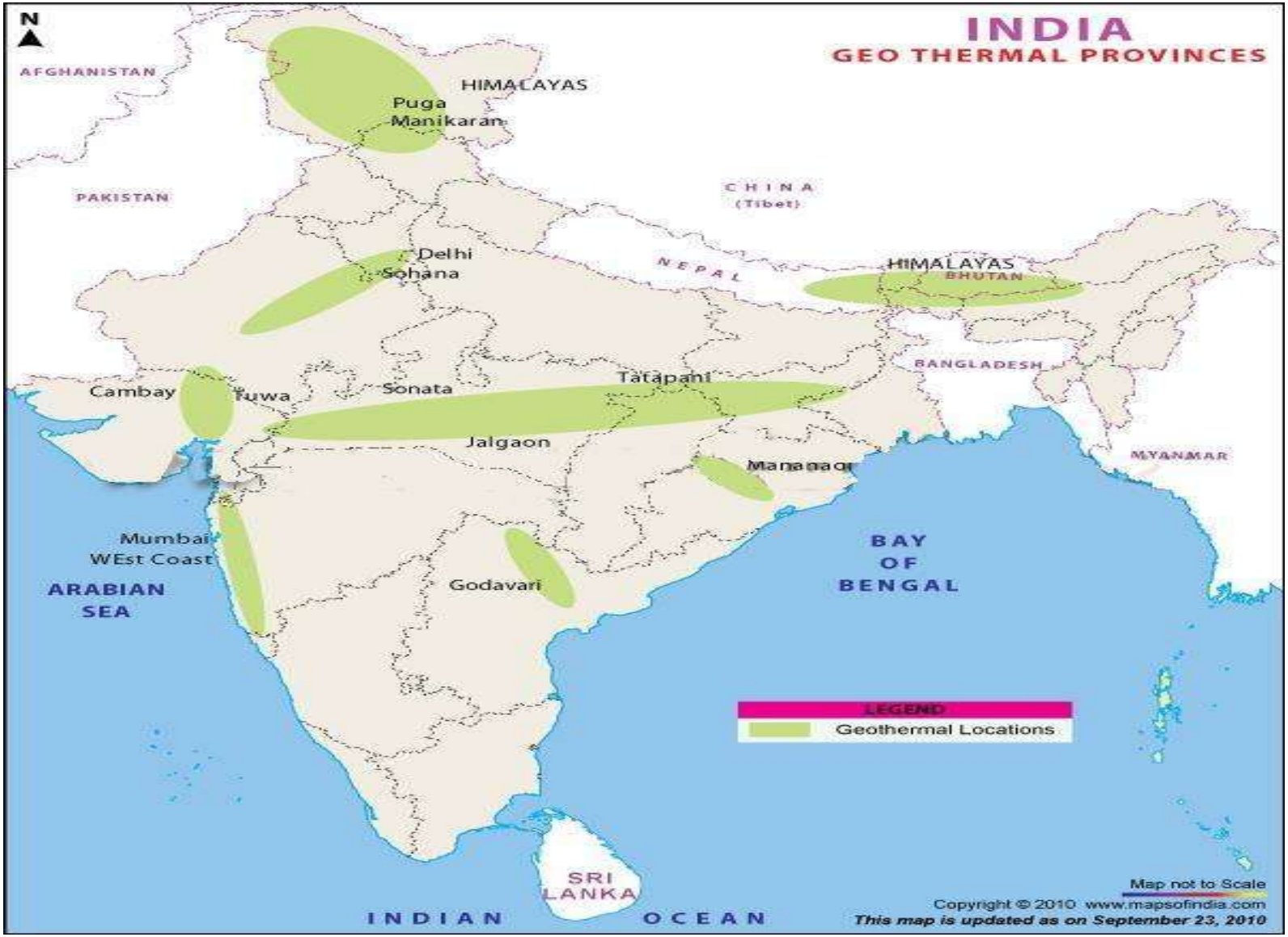
Cost (CO3)

Direct use of geothermal energy is absolutely cheaper than other energy sources.

Cost of electricity generation depends upon certain factors:

- Temperature and depth of resource
- Type of resource (steam, liquid, mix)
- Available volume of resource
- Size and technology of plant

Geothermal Energy in India (CO3)



Geothermal Energy in India (CO3)

- Geothermal provinces are estimated to produce 10,600 MW of power (experts are confident only to the extent of 100 MW)
- Geothermal provinces in India: the Himalayas, Sohana, West coast, Cambay, Son-Narmada-Tapi , Godavari, and Mahanadi
- Reykjavík Geothermal will assist Thermax to set up a pilot project in Puga Valley, Ladakh (Jammu & Kashmir)
- First operational commercial geothermal power plant is likely to come up in AP with a capacity of 25 MW by Geosyndicate Pvt Ltd.

Advantages (CO3)

- Available all the year around.
- Does not involve any combustion of fuel.
- Independent of weather
- Clean Resource – Very little emissions or overall environmental impact.
- Economically Sound Alternative – The fuel is free, rate / KWh likely to be competitive
- Overall, geothermal energy is a sustainable resource.

Disadvantages (CO3)

- Not widespread source of energy
- High installation costs
- Can run out of steam
- May release harmful gases
- Transportation
- Earthquakes

Environmental Impact of Geothermal Use (CO3)

Water Quality and Use:

- Impact water quality, in closed loop system, extracted water is pumped directly back into geothermal reservoir after use.
- Here water is contained within steel well casing, high levels of Sulphur and salt.
- Large quantum of water required for cooling and rejection. Typically geothermal plants using wet recirculating technology can require between 1700 and 4000 gallons of water per mega watt hour.

Environmental Impact of Geothermal Use (CO3)

Air Emission;

- Open loop system emit hydrogen sulphide carbon ammonia, methane and boron. Whilst in closed loop system gases removed from the well are not exposed to the atmosphere and are injected back into the ground after giving up the heat.

Land Use:

- Specifically, the geysers requires the largest geothermal plant in the world, Typically a capacity of approx. 1517 MW and the area of the plant is 78 Km square, which translate to approximately 13acres per MW.

Thermodynamics of Geothermal Energy conversion (CO3)

- Converting geothermal to electric power. The type of energy conversion system used to produce electrical power from a geothermal resource depends on the type and quality (temperature) of the resource. Vapor-dominated resources use conversion systems where the produced steam is expanded directly through a turbine.

Electrical and Non-electrical conversion (CO3)

The conversion basically can be done in 2 ways :

1) Electrical conversion

2) Non-electrical conversion

- **Link for more Understanding**

  https://www.youtube.com/watch?v=583-Oyq0l3Y

Daily Quiz(CO3)

When the water is ejected from earth's interior in the form of hot water, it is called

(A) Geyser (B) Hot springs

(C) Both (A) and (B) (D) None of the above

Water boils underground in a hydrothermal when it has pressure of about ____ atm and temperature of about ____ °C.

(A) 3, 100 (B) 5, 120

(C) 6, 140 (D) 7, 165

In dry steam hydrothermal plant, we use

(A) Carnot cycle (B) Brayton cycle

(C) Rankine Cycle (D) None of the above

Daily Quiz (CO3)

The molten rock within the earth is

(A) Igneous

(B) Magma

(C) Sedimentary

(D) Metamorphic

Water boils underground in a hydrothermal when it has pressure of about ____ atm and temperature of about ____ °C.

(A) 3, 100

(B) 5, 120

(C) 6, 140

(D) 7, 165

The molten rock within the earth is

(A) Igneous

(B) Magma

(C) Sedimentary

(D) Metamorphic

Topic wise Recap (CO3)

Topic : Geothermal Energy

Recap : In this topic we get know about various resources of geothermal energy. Thermodynamics of geothermal energy is done in 2 conversion ways –

1.electrical conversion and 2.non-electrical conversion and various environmental considerations

Topic wise Objective (CO3)

Topic : Magneto-hydrodynamics (MHD)

Objective : Objective is to know about Principle of working of MHD Power plant. It's performance and limitations.

CO 3. Analyze and predict about geothermal energy, Magneto-hydrodynamics and various types of fuel cells, performance, limitations and environmental considerations.

Prerequisite (CO3)

Topic : Magneto-hydrodynamics (MHD)

Prerequisite : Some concepts of physics related to magnets, Principle of Faraday's law must be required to understand Magneto hydrodynamics.

Magneto-hydrodynamics (MHD) (CO3)

- Magneto hydro dynamic (MHD) principle is applied for generating power from coal fired or reactor power plants.
- MHD generator plant does not require any turbine and does not have any generator shaft . In a MHD generator the thermal energy in plasma (hot ionized gas) is directly converted to electrical (without intermediate conversion to mechanical shaft energy).

Principle of working of MHD Power plant (CO3)

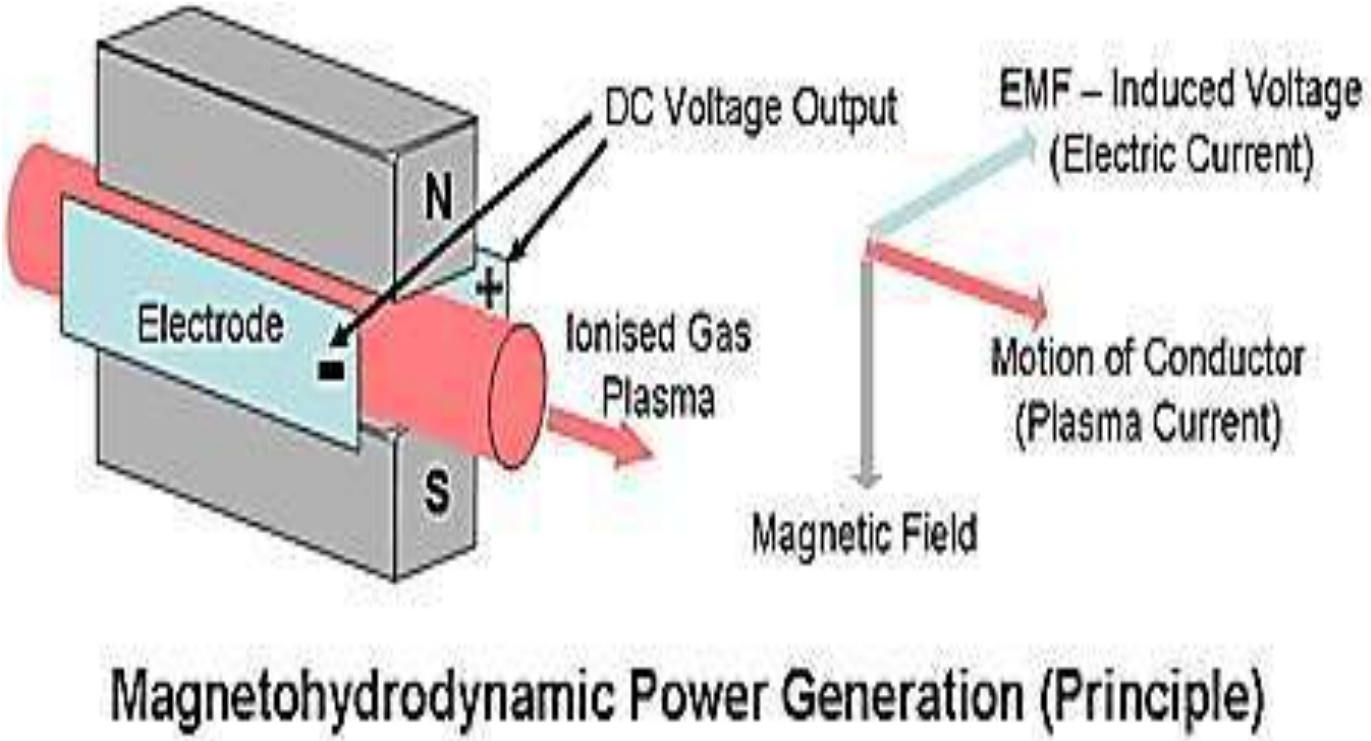
- When an conductor moves across a magnetic field, a voltage is induced in which produces an electric current . This is the principle of the conventional generator where the conductors consist of copper strips.

- In MHD generator, the solid conductors are replaced by a gaseous conductor, an ionized gas. If such a gas is passed at a high velocity through a powerful magnetic field, a current is generated and can be extracted by placing electrodes in suitable position in the stream.

- The principle can be explained as follows: An conductor moving through a magnetic field experiences a retarding force as well as an induced electric field and current The flow direction is right angles to the magnetic fields directions.

Principle of working of MHD Power plant (CO3)

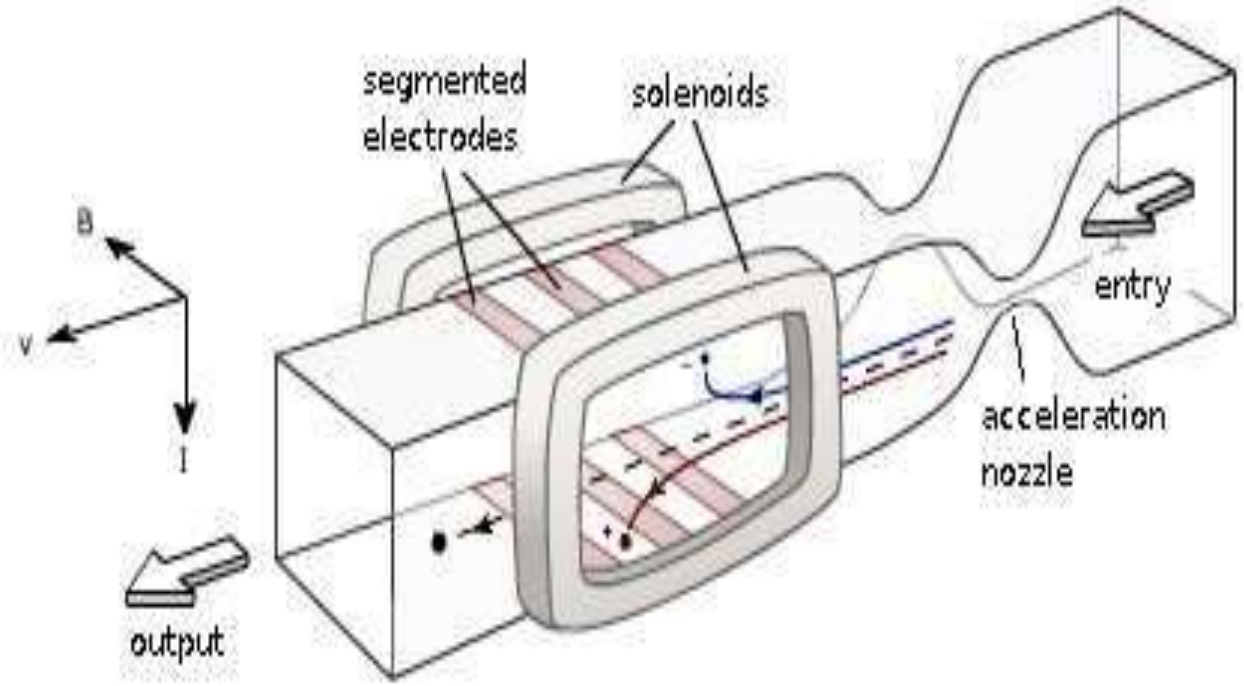
An electromotive force (or electric voltage) is induced in the direction at right angles to both flow and field directions.



Magnetohydrodynamic Power Generation (Principle)

Principles of MHD power generation (CO3)

Faraday's law of electromagnetic induction when an electric conductor moves across a magnetic field, an emf is induced in it, which produces an electric current .



MHD Generator

Faraday linear nozzle with segmented electrodes

Principles of MHD power generation (CO3)

- According to the principle of conventional generator the conductors are made of copper strips.
- In MHD generator, the solid conductors are replaced by the gaseous conductor, an ionized gas. If such a gas is passed at a high velocity through a powerful magnetic field, a current is generated and can be extracted by placing electrodes in suitable position in the stream. Moving through a magnetic field experiences a retarding force as well as an induced electric field and current.

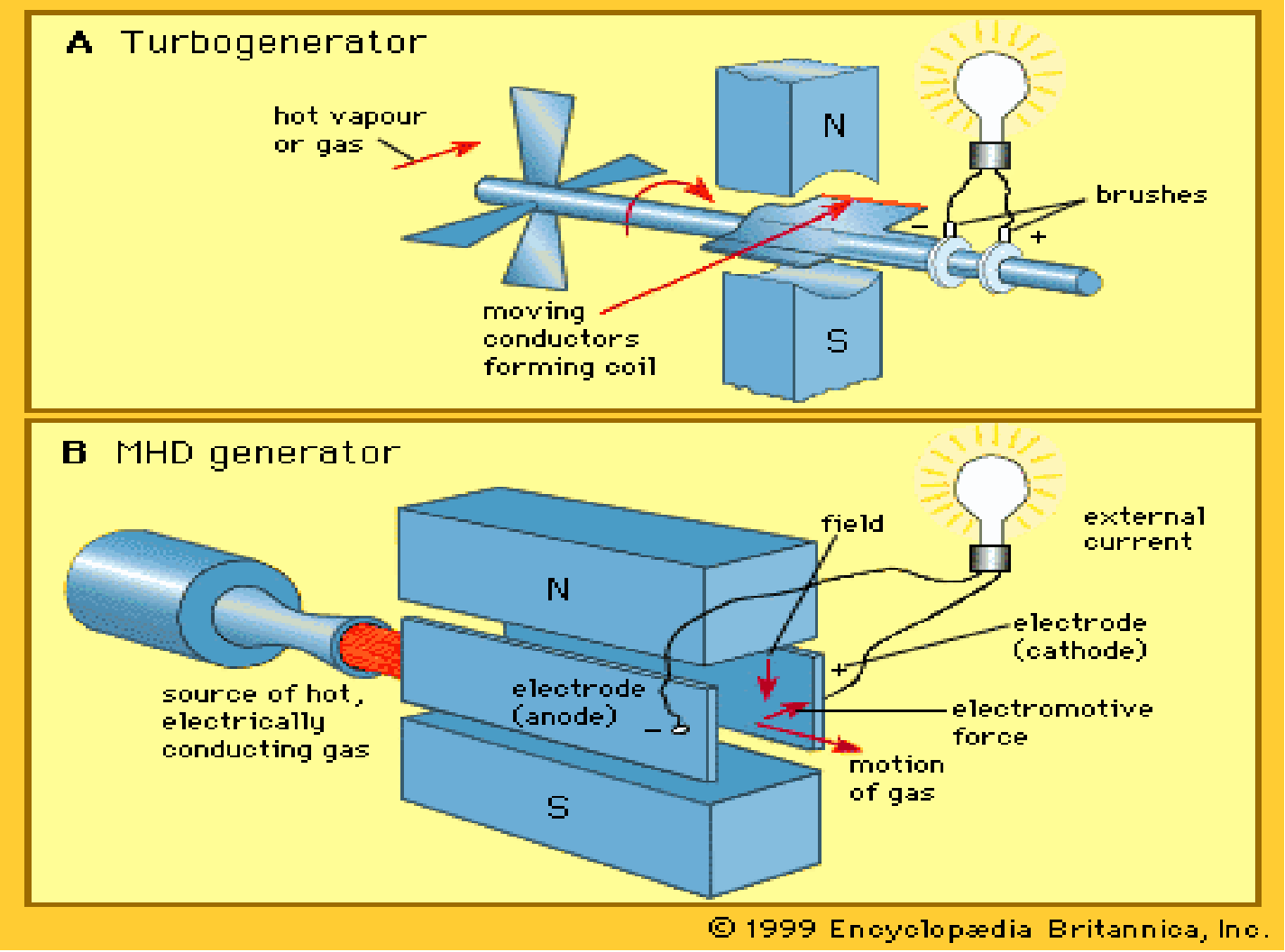
Principle of working of MHD Power plant (CO3)

- **Link for more Understanding**

Magnetohydrodynamic Generator (Open Cycle And Closed Cycle)

https://www.youtube.com/watch?v=e9LvM8EThyk

Comparission between Turbo Genrator and MHD Generator (CO3)



TYPES OF MHD (CO3)

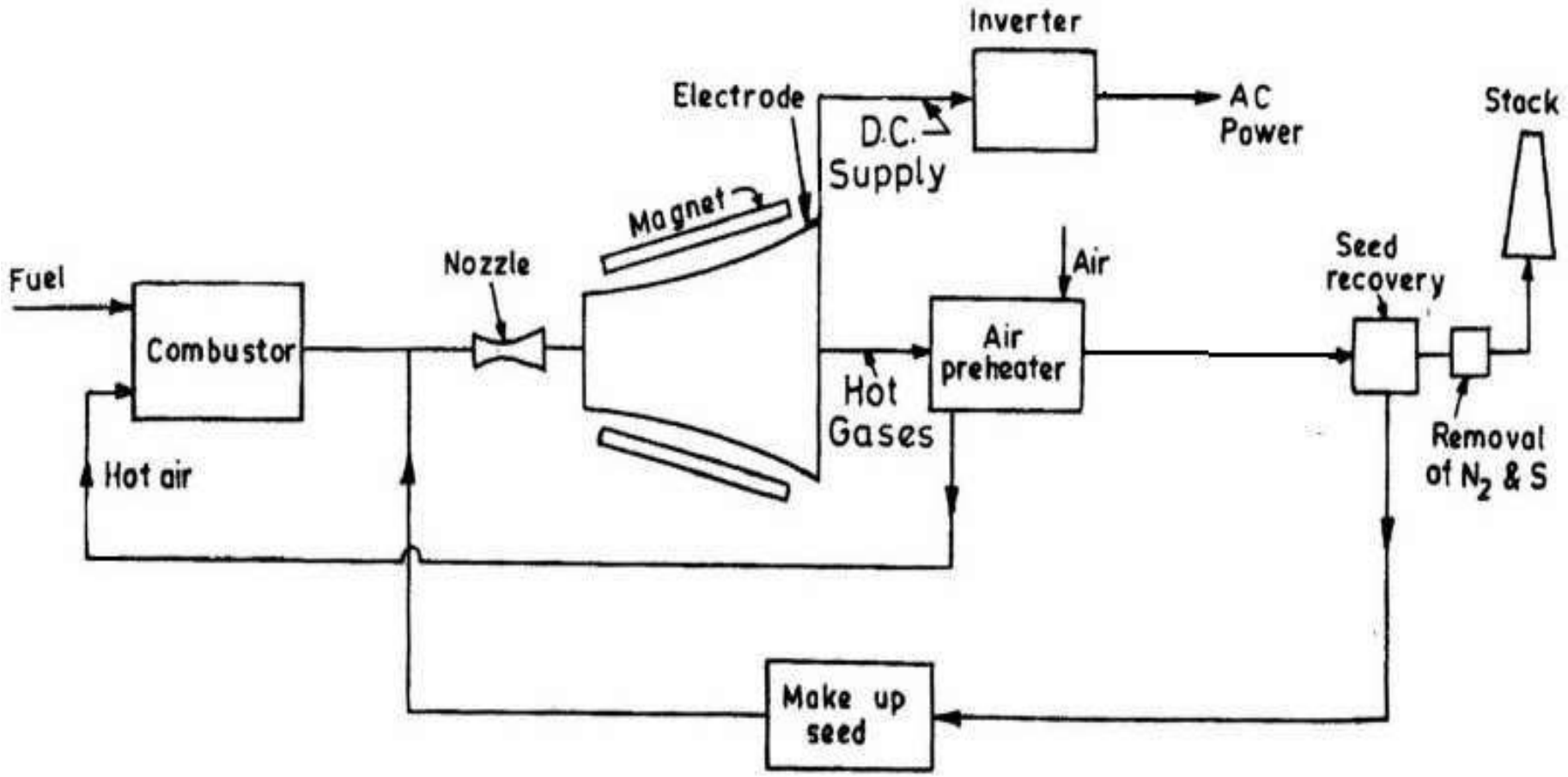
- Open Loop System
- Closed Loop System

1. Seeded inert gas system
2. Liquid metal system

Open loop System (CO3)

- In an open cycle MHD system ,atmospheric air at very high temperature and pressure is passed trough a strong magnetic field.
- Coal is first processed and burnt in the combustor at high temperature and pressure.
- Then a seeding material is injected(Potassium Carbonate) to increase the conductivity. It’s then expanded through a nozzle and passed through the magnetic field.
- During the expansion the positive and negative ions at high temperature move to the electrodes and constitute current. In this cycle same air can’t be reused, that's why this is called open cycle MHD.

Open loop System (CO3)



Open cycle MHD System

Open Loop System (CO1)

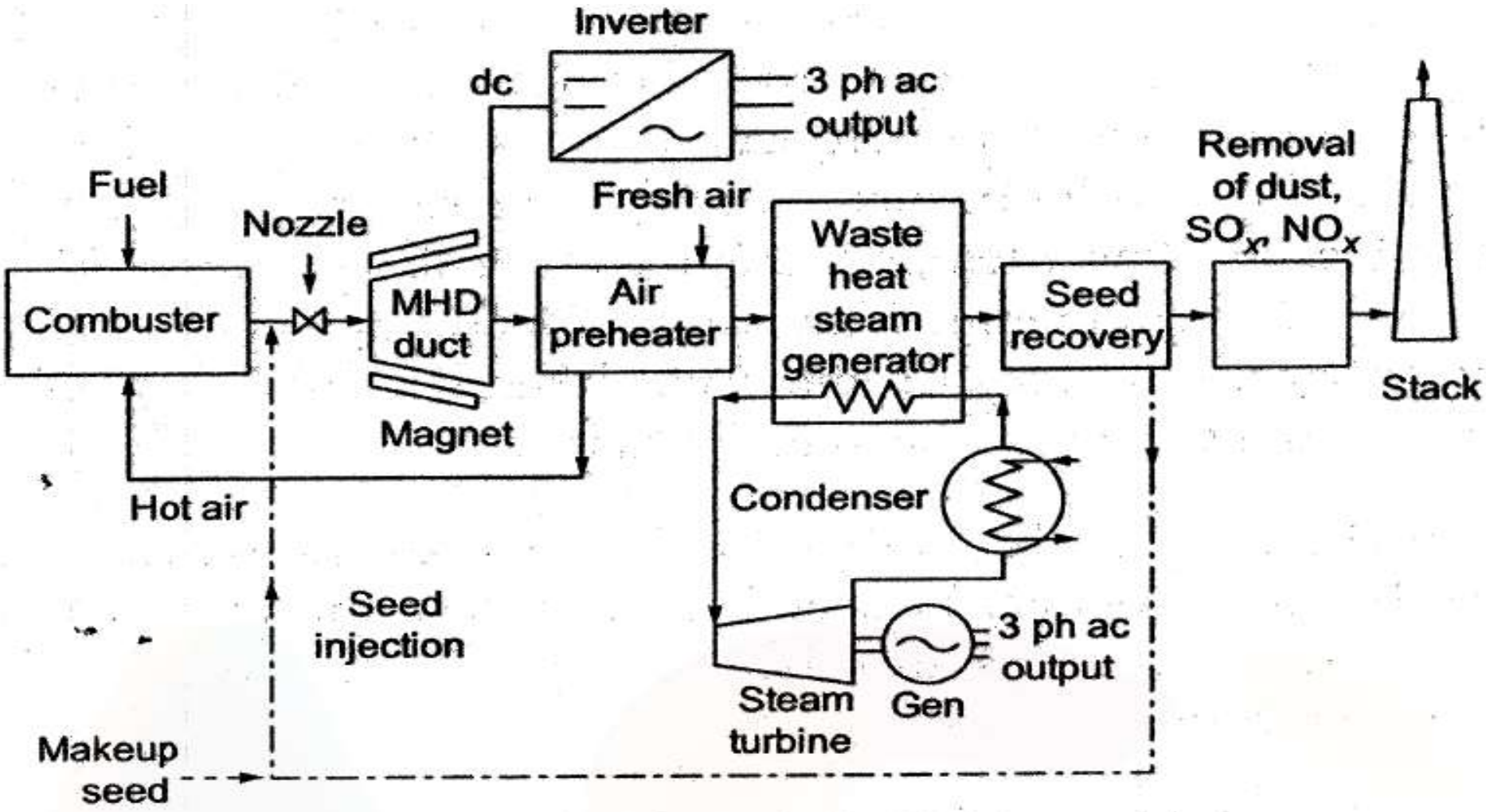


Fig. 13.3 *Open-cycle MHD generating system*

CLOSED LOOP SYSTEM (CO3)

As the name suggests the working fluid in a closed cycle MHD is circulated in closed cycle. Here inert gas or liquid metal is used as working fluid. Liquid metal has high electrical conductivity, so the temperature of combustion material need not to be high. Hence there is no inlet and outlet as open loop for atmospheric air. The process is simplified to great extent.

- Two types of closed loop system are
- Seeded inert gas system
- Liquid metal system

Seeded Inert Gas System (CO3)

- In a closed cycle system the gas is compressed and heat is supplied by the source at constant pressure, the compressed gas then expand in the MHD generator. Then it's pressure and temperature falls.
- After leaving the generator heat is removed from the gas by cooler, this is the heat rejection stage of the cycle. Finally the gas is recompressed.

SEEDED INERT GAS SYSTEM (CO3)

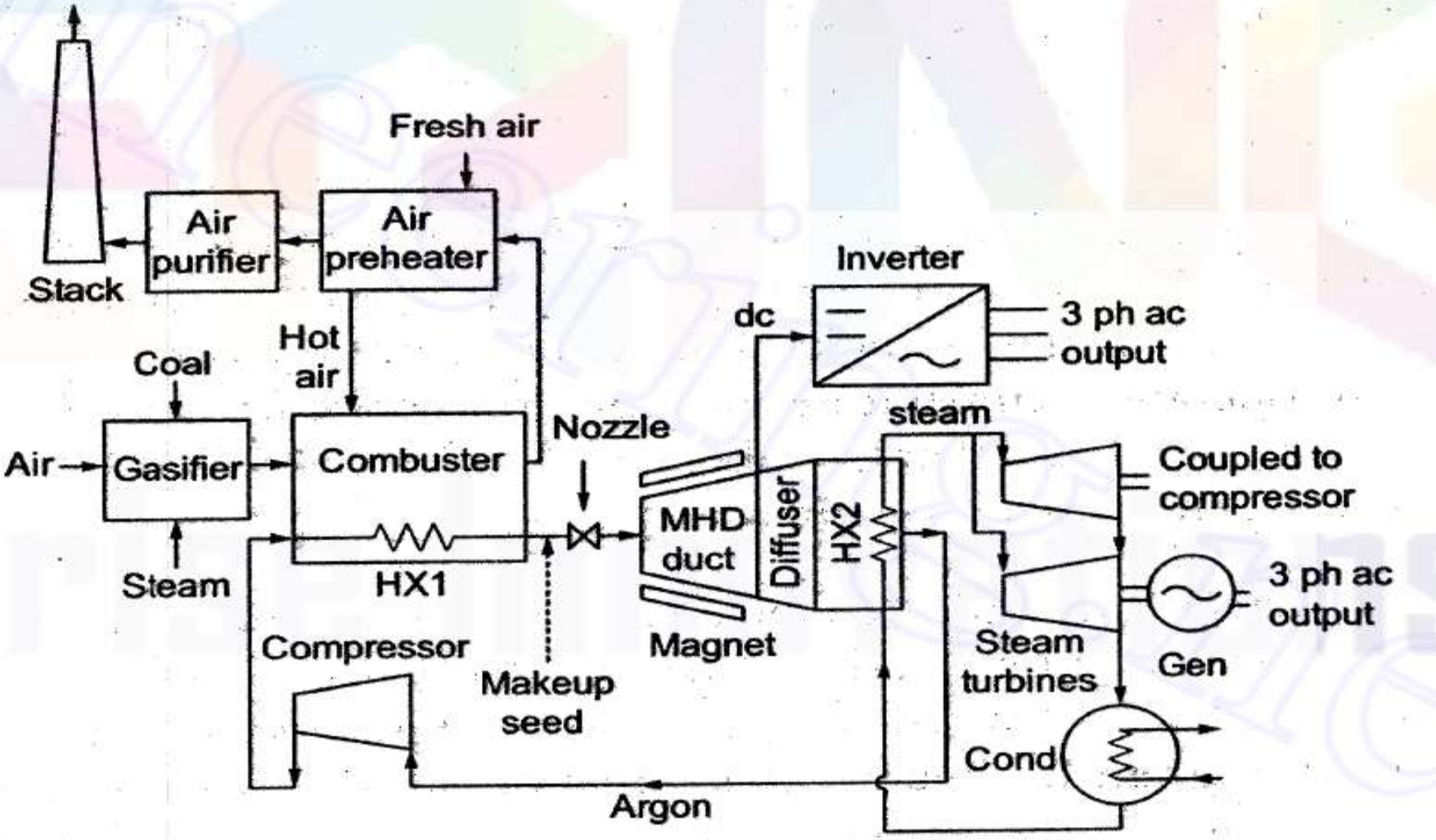


Fig. 13.4 *Seeded inert gas carrier, closed cycle MHD generating system*

Liquid Metal System (CO3)

- When a liquid metal provides the electrical conductivity, it is called a liquid metal MHD system.
- the carrier gas is pressurized and heated by passage through a heat exchanger within combustion chamber. The hot gas Is then incorporated into the liquid metal usually hot sodium or lithium to form the working fluid.
- The working fluid is introduced into the MHD generator through a nozzle in the usual ways. The carrier gas then provides the required high direct velocity of the electrical conductor.

Liquid Metal System (CO3)

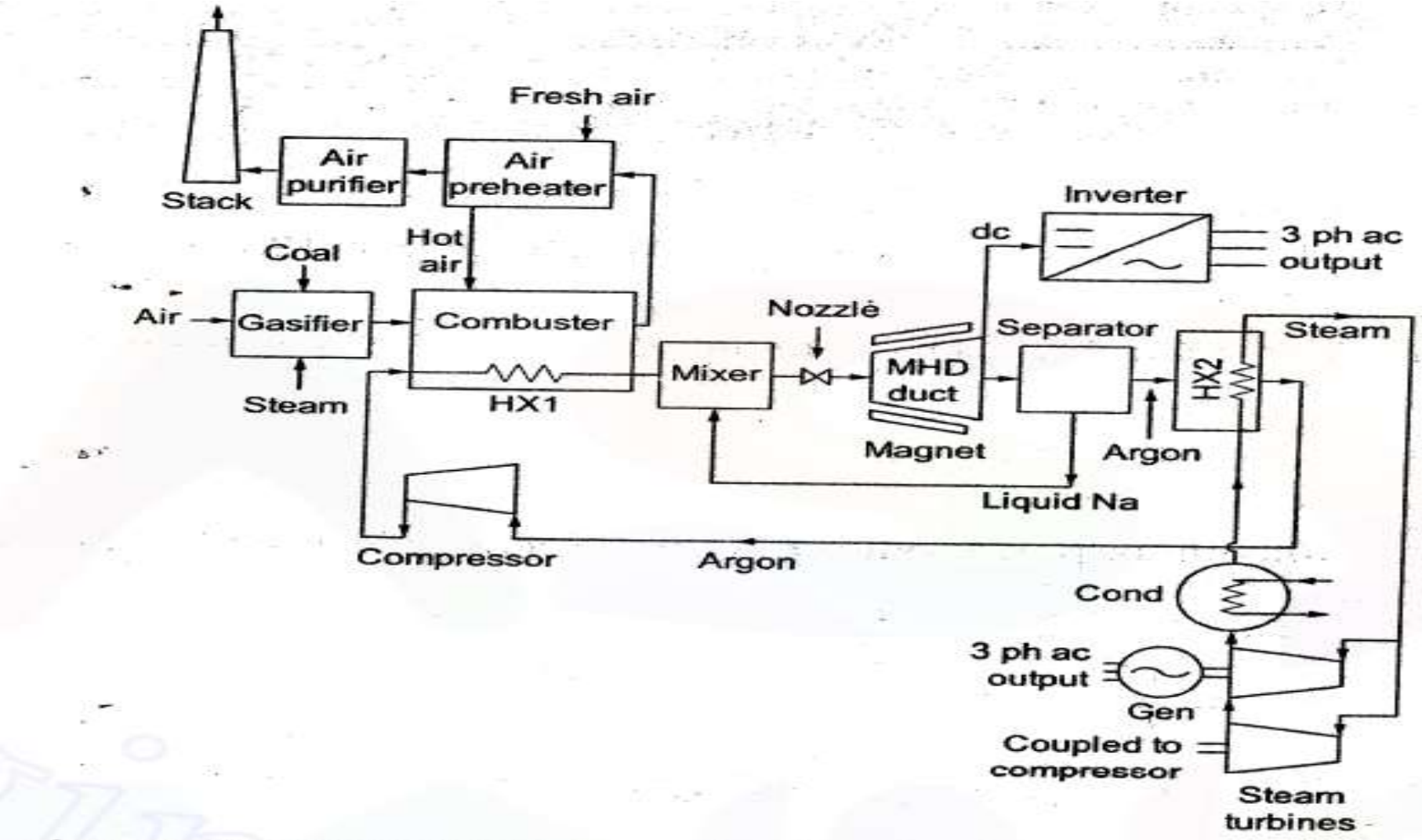


Fig. 13.5 *Liquid metal-inert gas carrier, closed cycle MHD generating system*

Liquid Metal System (CO3)

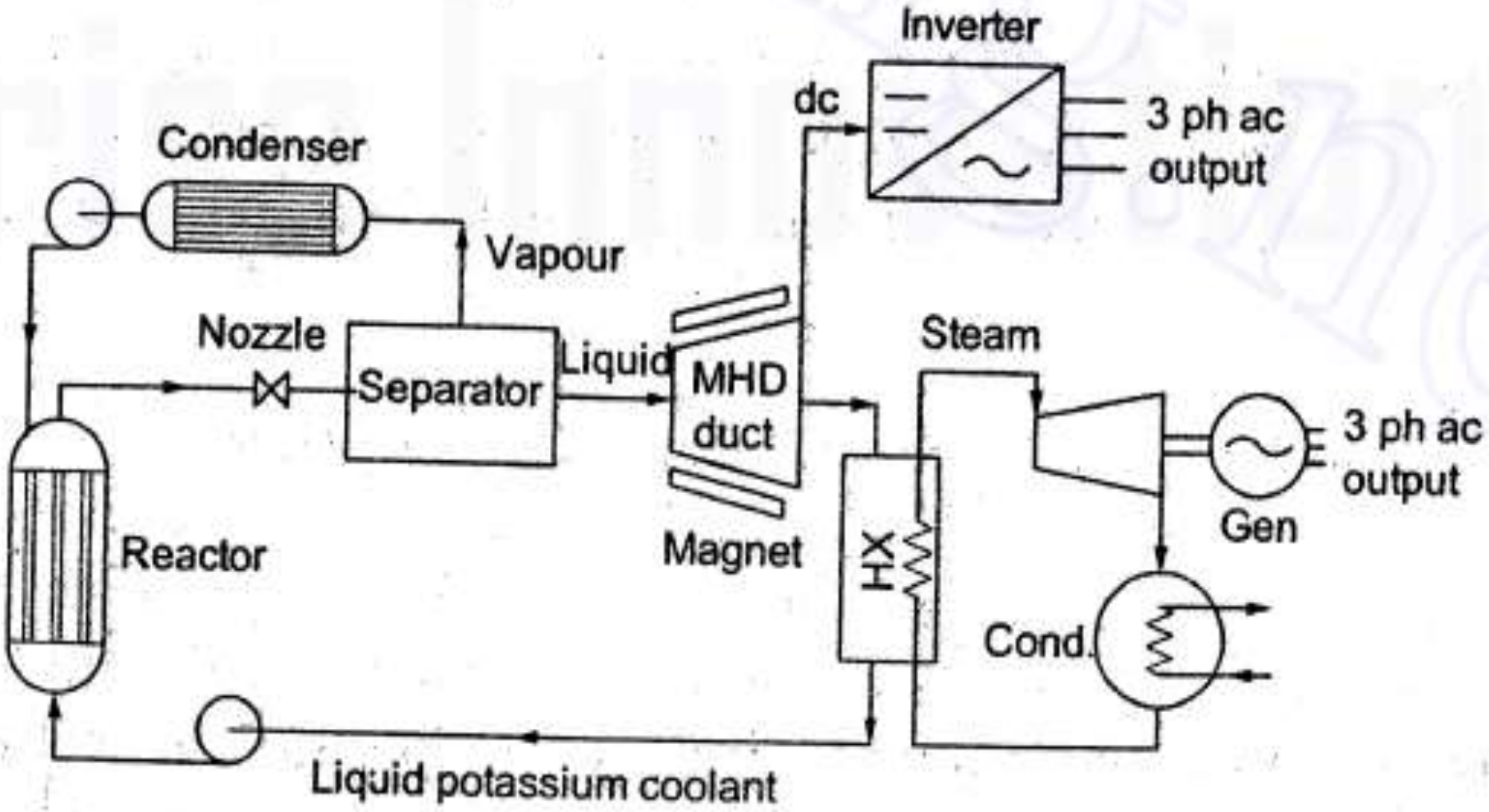


Fig. 13.6 *FBR coupled, closed cycle MHD generating system*

Difference between Open and Closed cycle (CO3)

Open Cycle System

- Working fluid after generating electrical energy is discharged to the atmosphere through a stack
- Operation of MHD generator is done directly on combustion products
- Temperature requirement : 2300˚C to 2700˚C.
- More developed.

Difference between Open and Closed cycle (CO3)

Closed Cycle System

- Working fluid is recycled to the heat sources and thus is used again.
- Helium or argon(with cesium seeding) is used as the working fluid.
- Temperature requirement : about 530˚C.
- Less developed.

Need of MHD (CO3)

At present a plenty of energy is needed to sustain industrial and agricultural production, and the existing conventional energy sources like coal, oil, uranium etc. are not adequate to meet the ever increasing energy demands. Consequently, efforts have been made for harnessing energy from several non-conventional energy sources like **Magneto Hydro Dynamics(MHD) System.**

Advantages of MHD (CO3)

- The conversion efficiency of a MHD system can be around 50% much higher compared to the most efficient steam plants. Still higher efficiencies are expected in future, around 60 – 65 %, with the improvements in experience and technology.
- Large amount of power is generated.
- It has no moving parts, so more reliable.
- The closed cycle system produces power, free of pollution.
- It has ability to reach the full power level as soon as started.
- The size if the plant is considerably smaller than conventional fossil fuel plants.

Disadvantages (CO3..)

- Suffers from reverse flow (short circuits) of electrons through the conducting fluids around the ends of the magnetic field.
- Needs very large magnets and this is a major expense.
- High friction and heat transfer losses.
- High operating temperature.
- Coal used as fuel poses problem of molten ash which may short circuit the electrodes. Hence, oil or natural gas are much better fuels for MHDs. Restriction on use of fuel makes the operation more expensive.

Future Prospect of MHD (CO3)

- It is estimated that by 2020, almost 70 % of the total electricity generated in the world will be from MHD generators.
- Research and development is widely being done on MHD by different countries of the world.

Nations involved:

- USA, Former USSR, Japan, India, China, Yugoslavia, Australia, Italy, Poland

Performance (CO3)

- MHD power generator system involves several subjects such as magneto hydrodynamics, plasma physics, material science, and structure mechanics. Therefore, the performance of the MHD power generator is affected by many factors, among which the load coefficient k is of great importance.

- The effect of some system parameters on the performance by three-dimensional (3D) numerical simulation for a Faraday type MHD power generator using He/Xe as working plasma. The results show that average electrical conductivity increases first and then decreases with the addition of magnetic field intensity. Electrical conductivity reaches the maximum value of 11.05 S/m, while the applied magnetic field strength is B = 1.75 T.

Performance (CO3)

- The ionization rate along the midline well keeps stable, which indicates that the ionization rate and three-body recombination rate (three kinds of particles combining to two kinds of particles) are approximately equal, and the relatively stable plasma structure of the mainstream is preserved.
- Efficiency of power generation of the Faraday type channel increases with an increment of the load factor.
- However, enthalpy extraction first increases to a certain value, and then decreases with the load factor.
- The enthalpy extraction rate reaches the maximum when the load coefficient *k* equals 0.625, which is the best performance of the power generator channel with the maximum electricity production.

Limitations (CO3)

- Superconductor technology challenges prevents wider use.
- Reverse flow at end of magnetic field
- Large magnets is a major expense
- Lack of accurate analytical models
- Non-homogenous distribution of the fluid velocity profile and instability of the flow under certain operating condition

Daily Quiz (CO1)

In an open cycle MHD-steam power plant, the temperature at the entrance of MHD duct is (in K)

a) 2500-3000

b) 2000-2500

c) 1500-2000

d) 2250

In closed cycle MHD-steam power plant, which of the following gas is seeded in the MHD duct?

a) helium

b) xenon

c) sodium vapour

d) chlorine

Daily Quiz (CO1)

Coal is processed and burnt in the combustor of a hybrid MHD at a high temperature and pressure with the preheated air to form which among the following element?

a) Steam

b) Plasma

c) Coke

d) None of these

The nature of the current developed in MHD generator is

a) AC

b) DC

c) Both ac and dc

d) None of these

Topic wise Recap (CO3)

Topic : Magneto-hydrodynamics (MHD)

Recap : In this topic we get to know about Principle of working of MHD Power plant. It's performance and limitations.

Topic wise Objective (CO3)

Topic : Fuel Cells

Objective : Objective is to know about Principle of working of various types of fuel cells and their working. It's performance and limitations.

CO 3. Analyze and predict about geothermal energy, Magneto-hydrodynamics and various types of fuel cells, performance, limitations and environmental considerations.

Topic wise Objective (CO3)

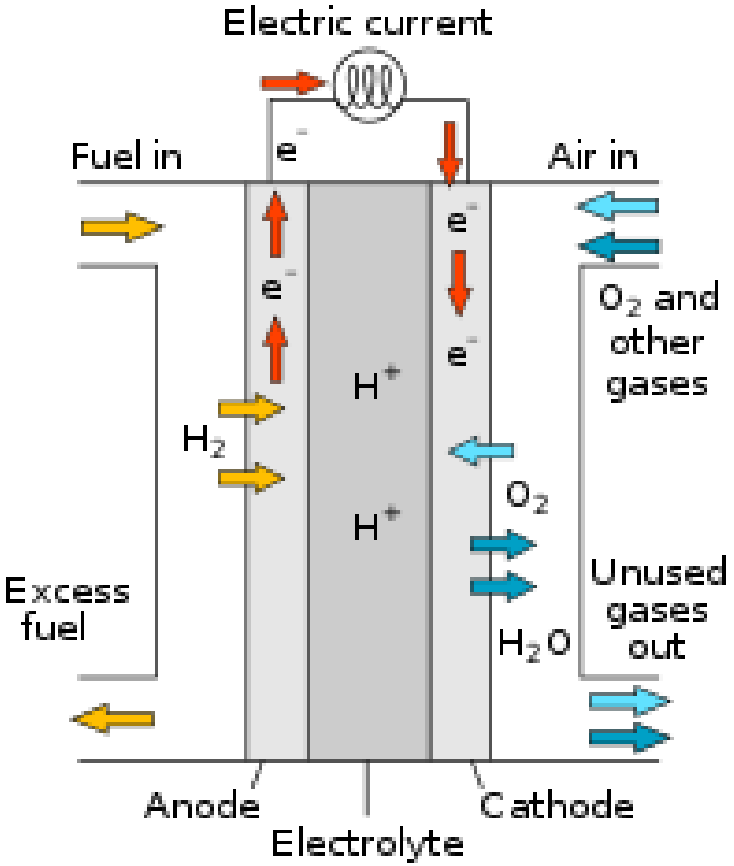
Topic : Fuel Cells

Prerequisite : basic concepts of electrode, electrolyte and primary cells must required for understanding the working of fuel cells.

Introduction to Fuel cells (CO3)

Basics of Fuel Cells

Fuel Cell is an electrochemical device that is used to convert an open source fuel into electricity.



Introduction to Fuel cells (CO3)

- An electrolytic process has to take place inside a cell in which there is an open source fuel [hydrogen] and an oxidant [oxygen].
- Both the fuel and oxidant reacts in the presence of an electrolyte.
- Both the fuel and oxidant are introduced into the cell, where they react and the output product is carried out of the cell and stored.
- The electrolyte is left as it is inside the cell.
- This process can take place non-stop for a long time as long as the flow of resources are maintained.

Principle of working of various types of fuel cells and their working (CO3)

- Polymer Electrolyte Membrane Fuel Cell (PEMFC)
- Alkaline fuel cell (AFC)
- Direct Methanol Fuel Cell (DMFC)
- Molten-Carbonate Fuel Cell (MCFC)
- Phosphoric Acid Fuel Cell (PAFC)
- Solid oxide Fuel Cell (SOFC)

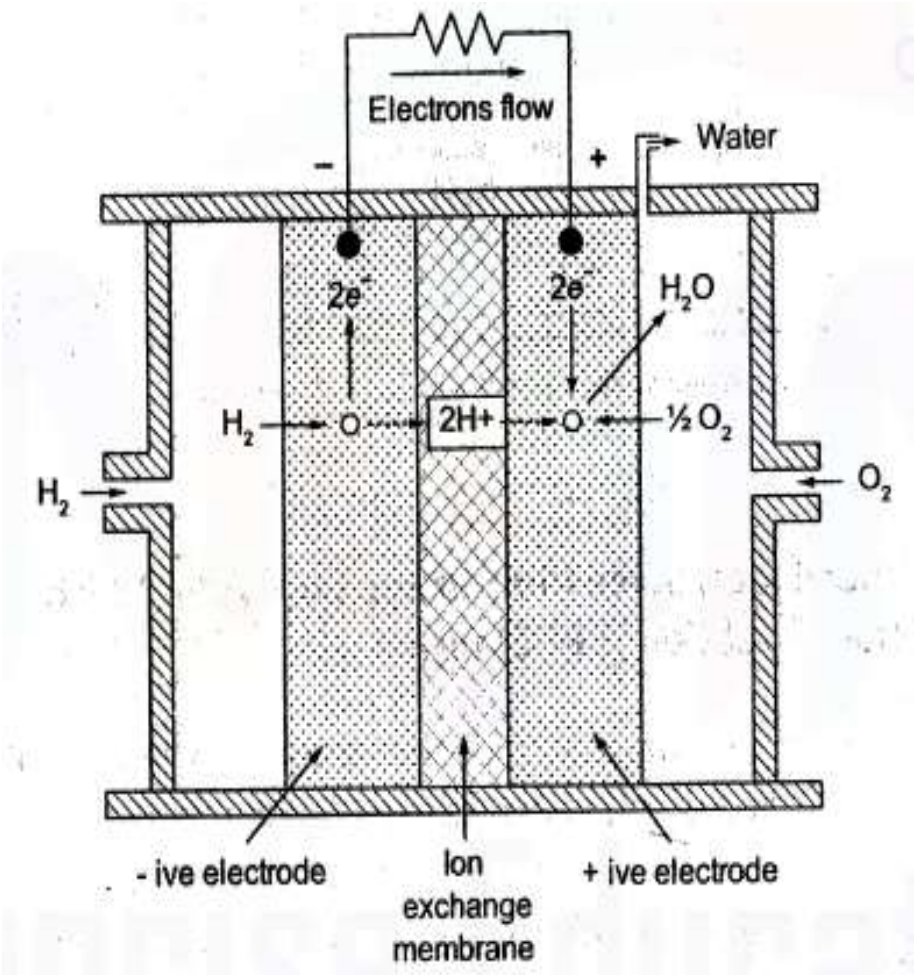
Principle of working of various types of fuel cells and their working (CO3)

Polymer Electrolyte Membrane Fuel Cell (PEMFC)

- Polymer Electrolyte Membrane Fuel Cell (PEMFC) uses electro-chemical reaction to react both hydrogen and oxygen to form water as a by-product and also electricity.
- The device is said to be completely pollution free and with an efficiency of more than 50%.
- As the name suggests, in between the anode and cathode terminals is a sandwiched membrane called the proton-exchange polymer membrane.

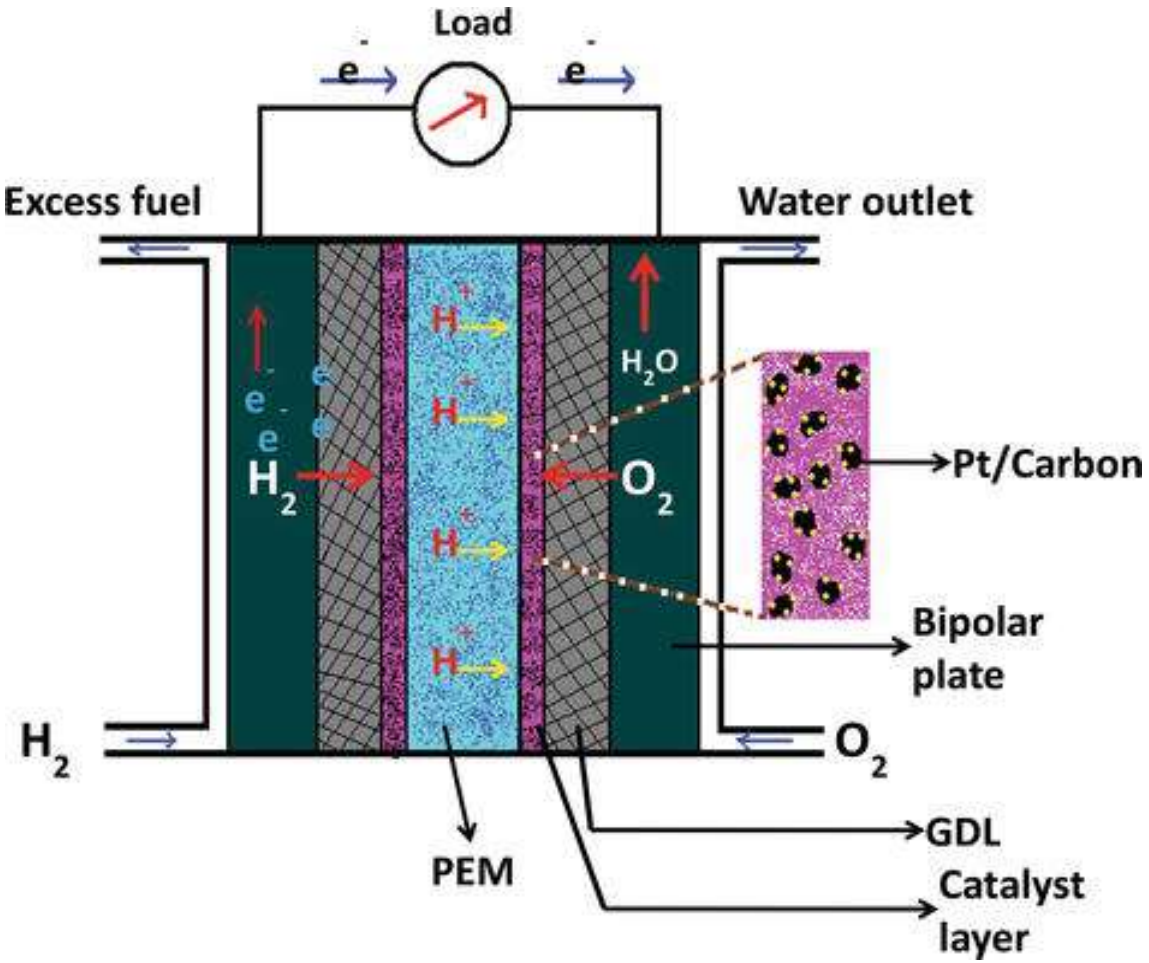
Principle of working of various types of fuel cells and their working (CO3)

Polymer Electrolyte Membrane Fuel Cell (PEMFC)



Principle of working of various types of fuel cells and their working (CO3)

Polymer Electrolyte Membrane Fuel Cell (PEMFC)



Principle of working of various types of fuel cells and their working (CO3)

Alkaline fuel cell (AFC)

- This type of fuel cell was been introduced since the early 1960's.
- As the electrolyte used for this device is aqueous alkaline solution like potassium hydroxide, the procedure for electricity consumption is rather expensive.

Principle of working of various types of fuel cells and their working (CO3)

Alkaline fuel cell (AFC)

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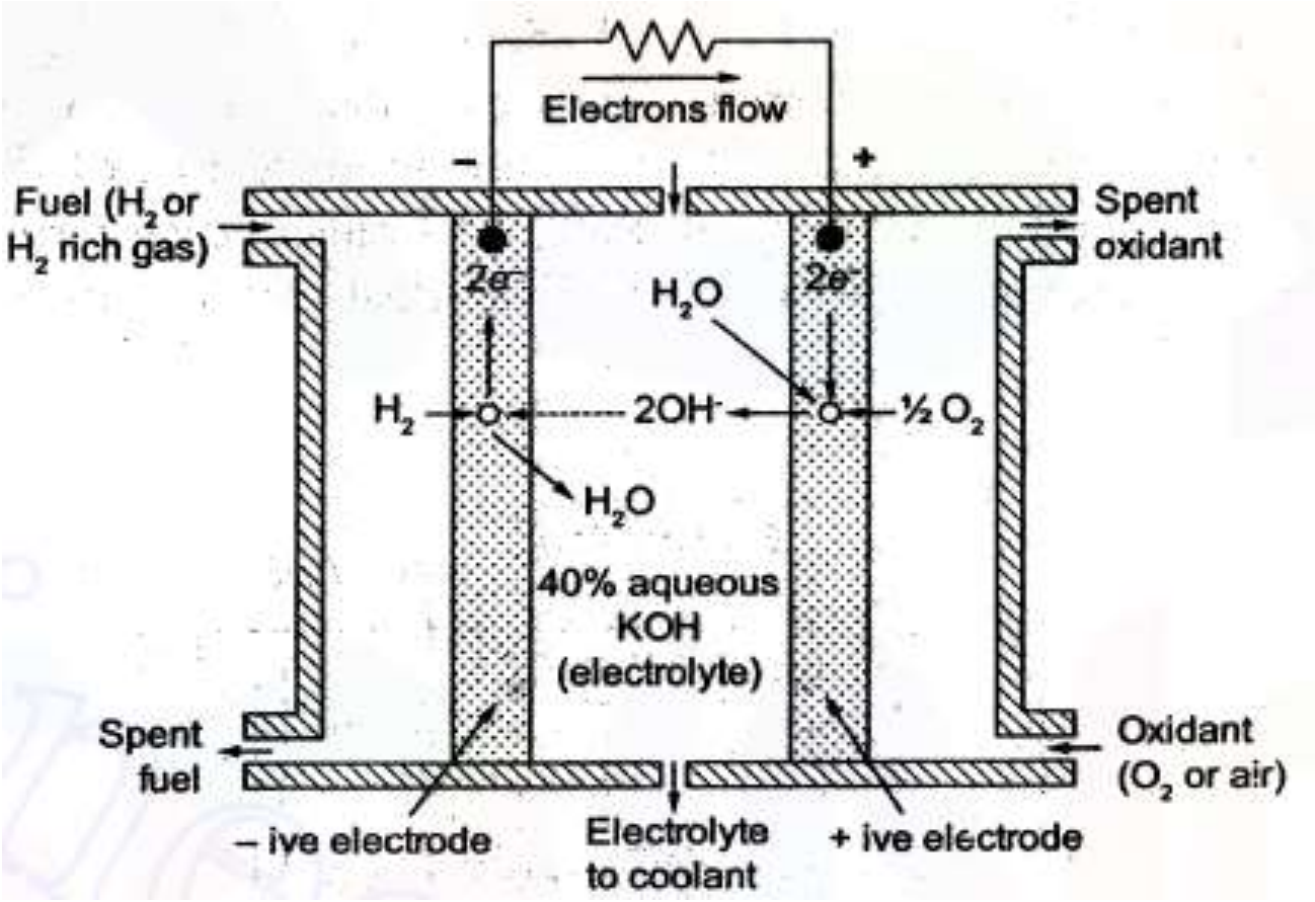

Principle of working of various types of fuel cells and their working (CO3)

Alkaline fuel cell (AFC)

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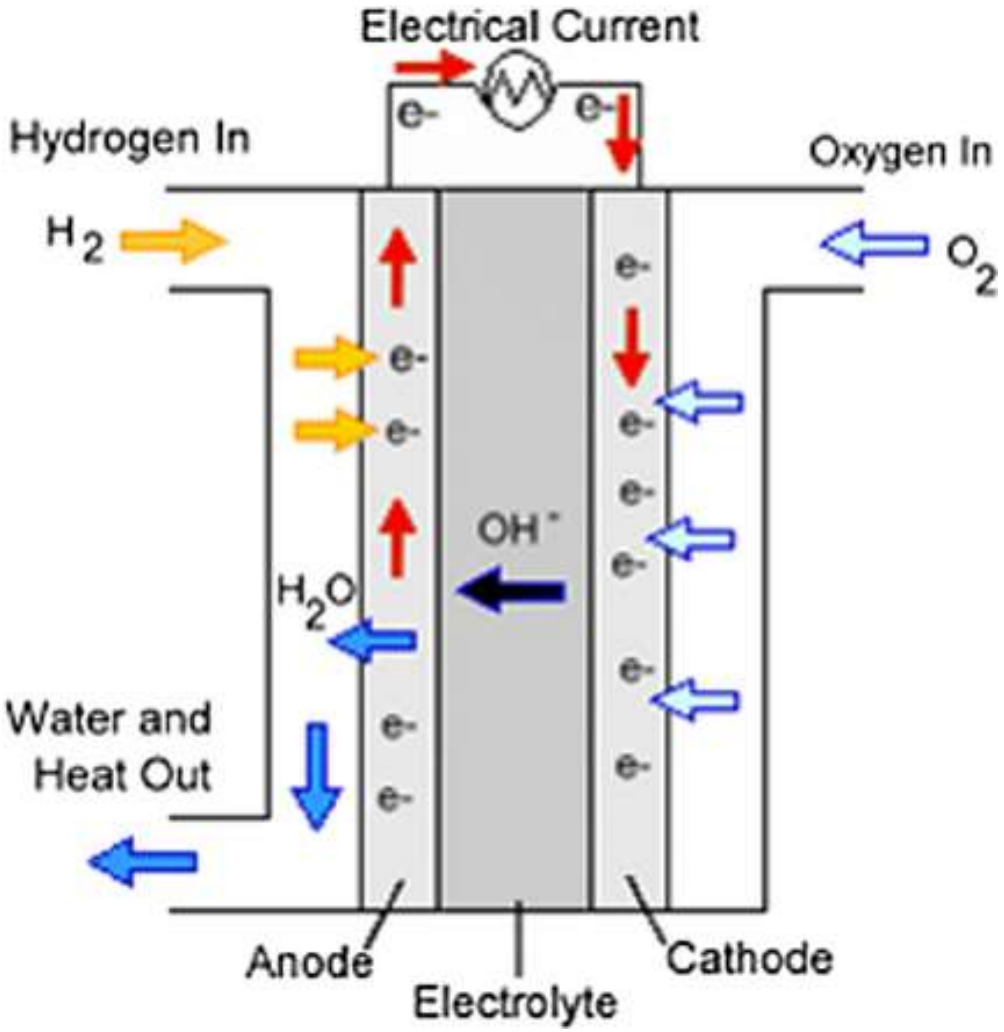


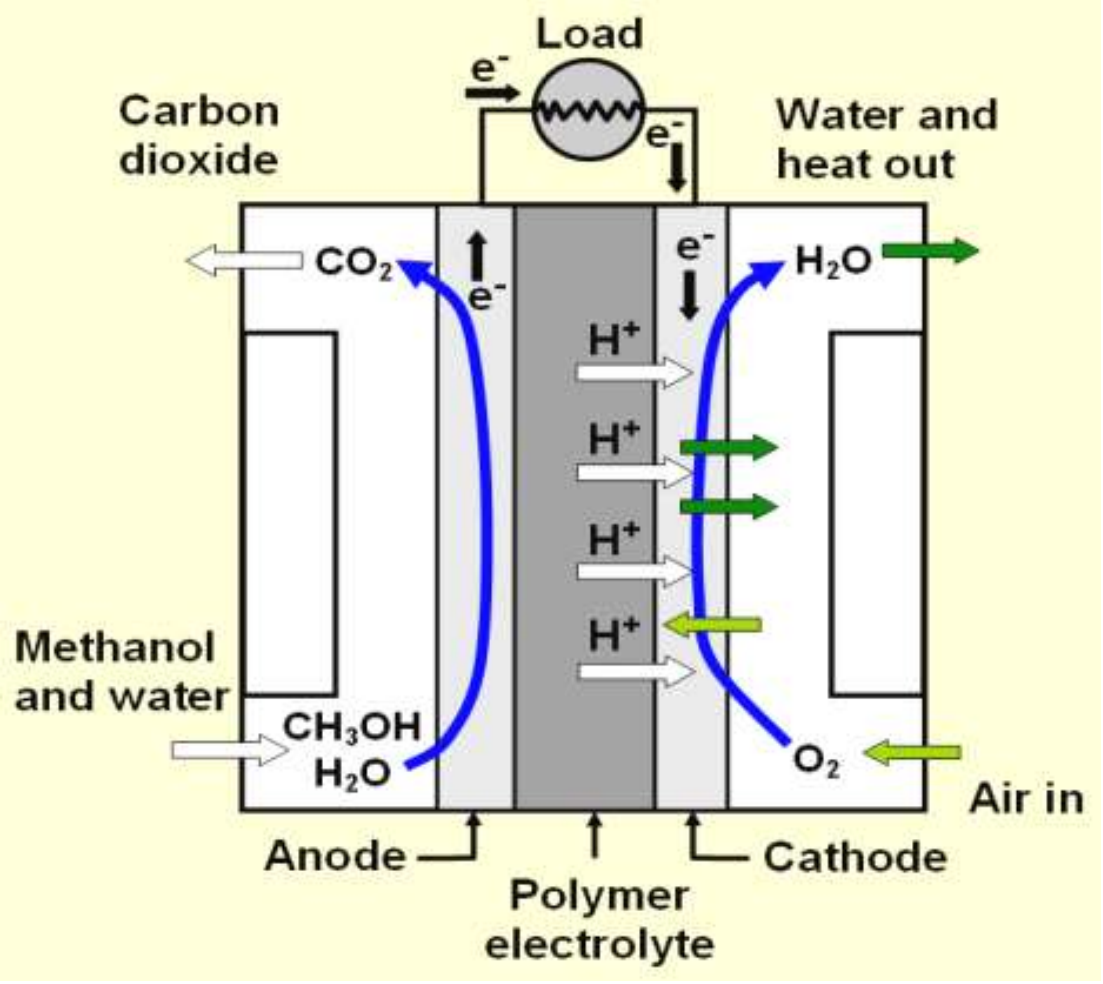
Principle of working of various types of fuel cells and their working (CO3)

Direct Methanol Fuel Cell (DMFC)

- This device has somewhat the same characteristics as that of a Polymer Electrolyte Membrane Fuel Cell (PEMFC). But the only difference is in the percentage of efficiency. It has lesser efficiency [<30%] and also needs a huge amount of anode catalyst and thus highly expensive. The device uses Polymer membrane.

Principle of working of various types of fuel cells and their working (CO3)

Direct Methanol Fuel Cell (DMFC)



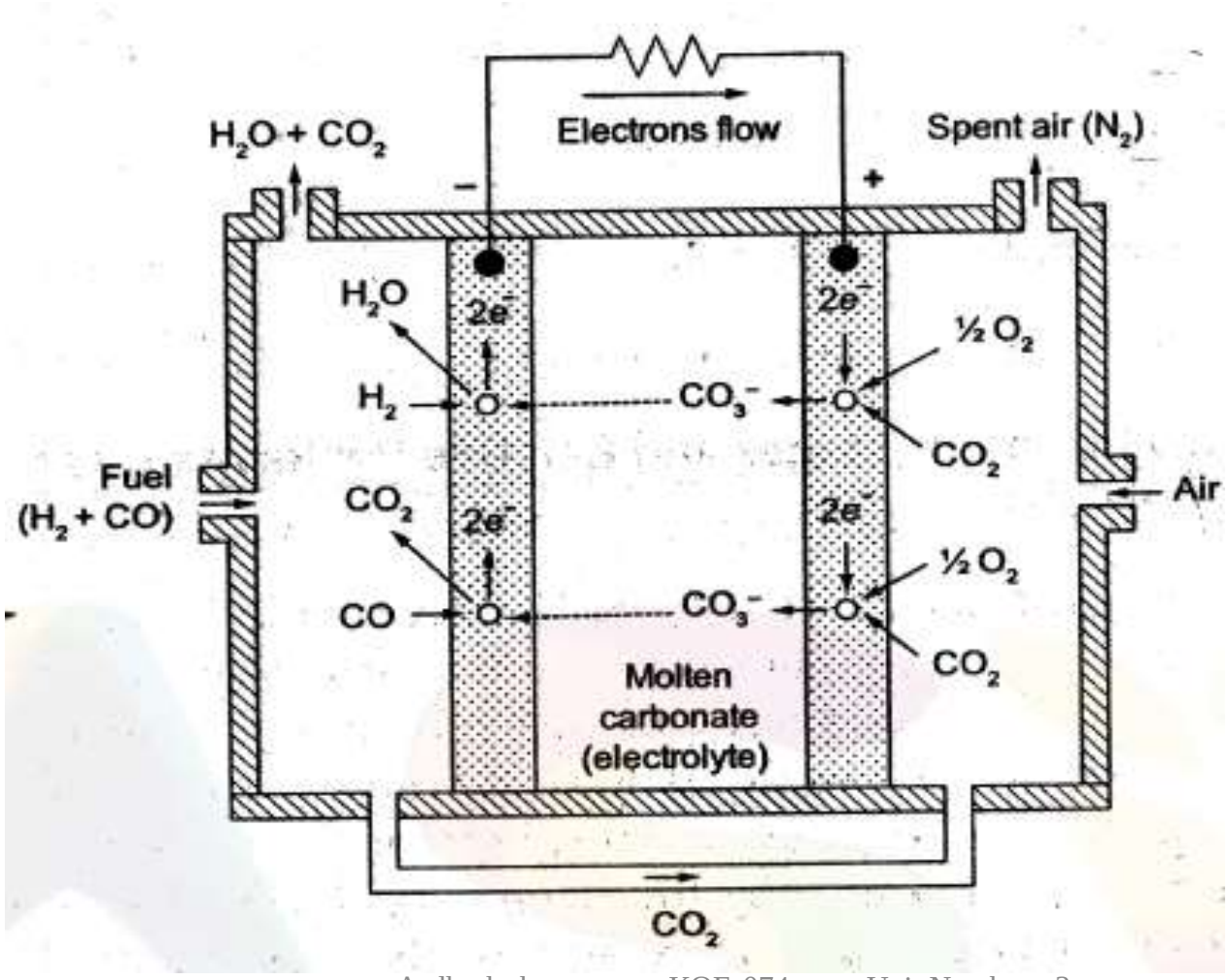
Principle of working of various types of fuel cells and their working (CO3)

Molten-Carbonate Fuel Cell (MCFC) :

Molten alkaline carbonate like sodium bicarbonate is used as the electrolyte. They can produce high powers up to 100 Mega Watts. Thus they can be used as high power generators. They can also be operated at high temperatures up to 650 degree Celsius. They are not so expensive in production and hence can be used for commercial uses. It has an efficiency of almost 55%.

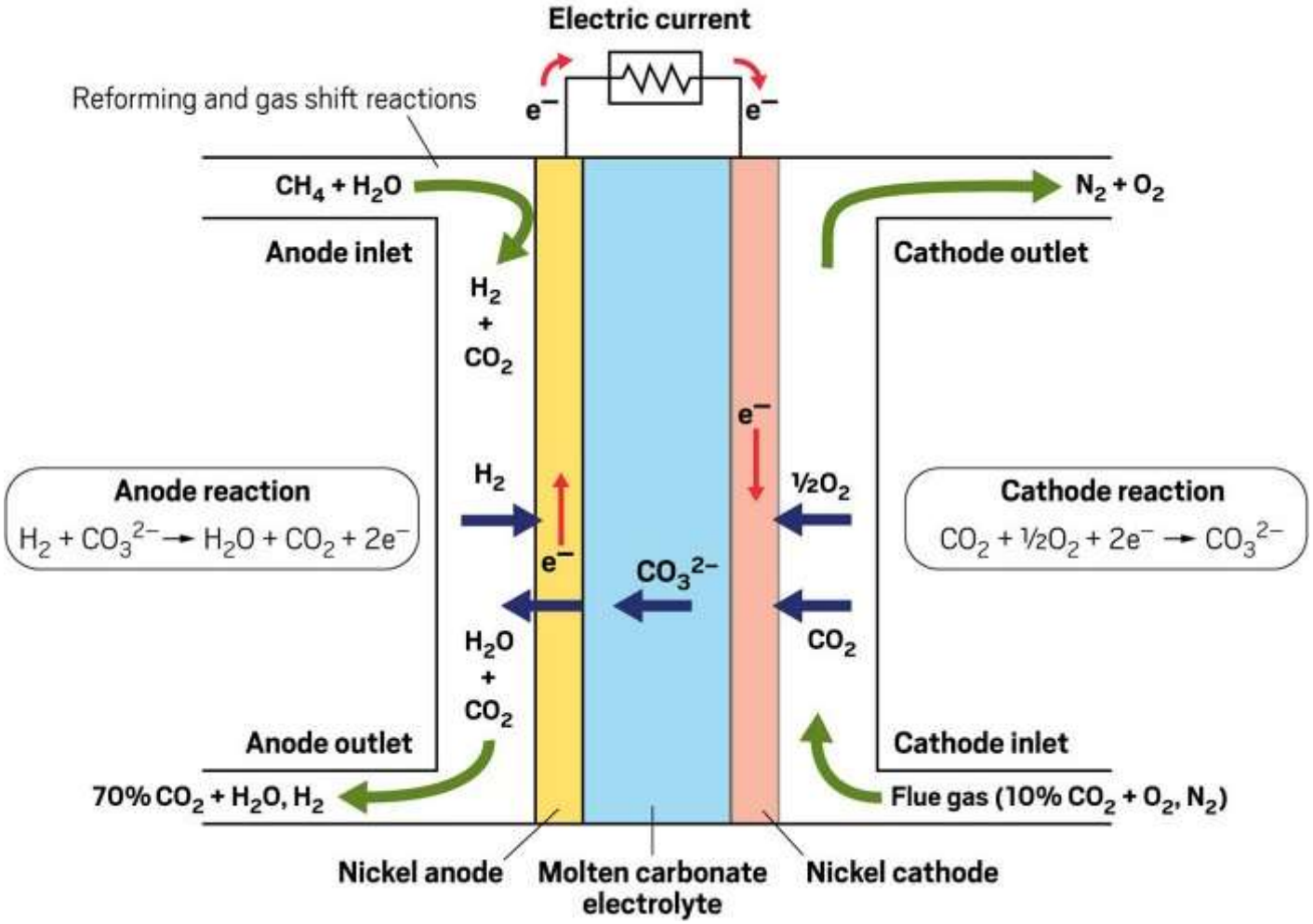
Principle of working of various types of fuel cells and their working (CO3)

Molten-Carbonate Fuel Cell (MCFC) :



Principle of working of various types of fuel cells and their working (CO3)

Molten-Carbonate Fuel Cell (MCFC) :



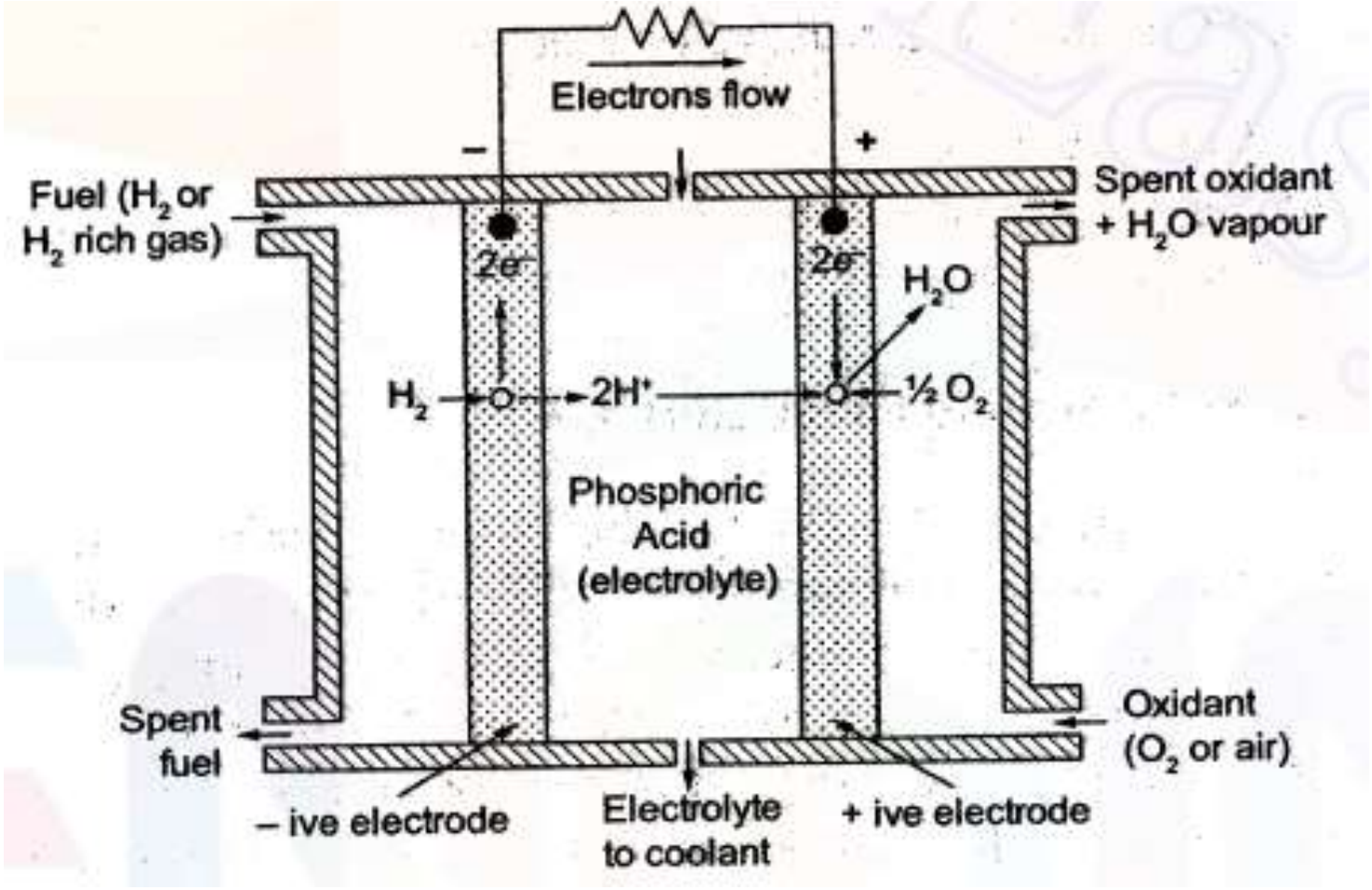
Principle of working of various types of fuel cells and their working (CO3)

Phosphoric Acid Fuel Cell :

Molten phosphoric acid is the electrolyte used in this type of fuel cell. It operates at high temperature up to 200 degree Celsius. It has an efficiency of up to 55%. This type of fuel cell is most commonly used in commercial cars.

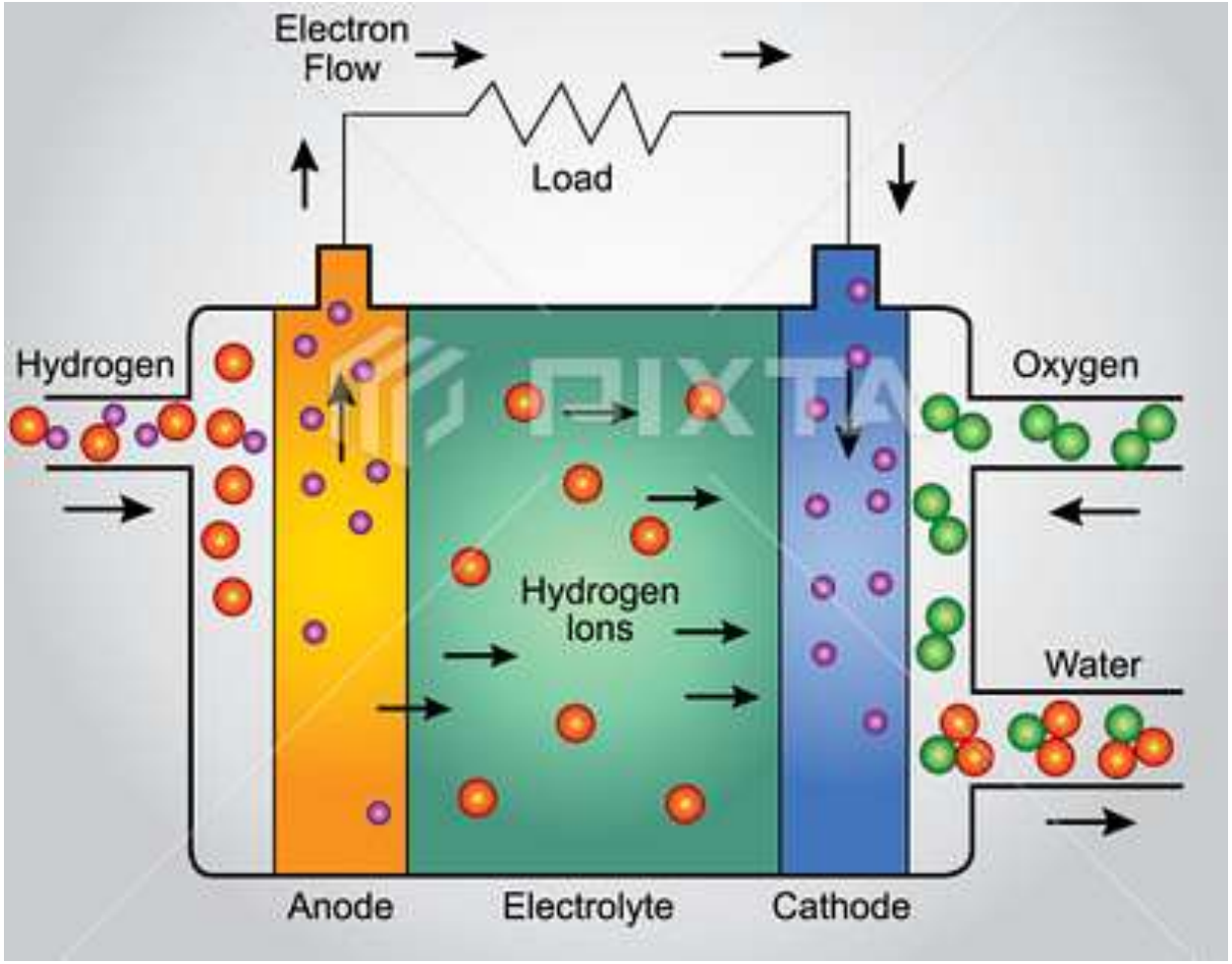
Principle of working of various types of fuel cells and their working (CO3)

Phosphoric Acid Fuel Cell :



Principle of working of various types of fuel cells and their working (CO3)

Phosphoric Acid Fuel Cell :



Principle of working of various types of fuel cells and their working (CO3)

Solid oxide Fuel Cell (SOFC)

- This is one of the most commercially used fuel cell as they have the highest operating life. It has a very high operating temperature of 1,000 degrees Celsius. But other parts of the fuel cell may not be able to withstand at this temperature making it highly unstable.
- But, when used in a continuous state they can be highly reliable.

Principle of working of various types of fuel cells and their working (CO3)

- At high temperatures the device can produce water in the form of steam which can be easily transported through steam turbines to produce more electricity, thus increasing the efficiency of the system.
- This device is also special in the case where a wide variety of fuels can be used. Most of the petroleum products can be used as the fuel. The electrolyte used in the cell is called yttria stabilized zirconia (YSZ).
- This electrolyte is good for large scale power generation and has the same characteristics as all the other electrolytes.

Fuel Cells – Advantages (CO3)

Advantages

- It is compact, light weight and has no moving parts. Thus it is 99.9% reliable.
- Pollution is reduced by 99%. This is the lowest pollution rate when compared to batteries as well as gasoline powered devices.
- The overall efficiency of a battery is considered to be 60% and that of a gasoline powered vehicle is 40%.

Fuel Cells – Applications (CO3)

Applications

- Can be used as power sources in remote areas.
- Can be used to provide off-grid power supplies.
- Can be applicable in both hybrid and electric vehicles.

Performance and Limitations of Fuel cells (CO3)

Cost

- The overall production cost of a fuel cell is very costly.
- The anode catalysts like platinum and also gas diffusion layers almost hold up to 75% of the total cost.
- When compared to batteries and gasoline powered vehicles, they tend to be the costliest.
- If a kilowatt of power produced by the fuel cell comes around $35 to $40, it can be used. Currently, it costs up to $75. This can be done only by extensive research in replacing platinum with some other cheaper substance.

Performance and Limitations of Fuel cells (CO3)

Durability

- Most of the fuel cells that are used in cars, like PEMFC does not operate well enough in higher temperatures.
- As a result they have less tolerance level and less stability under running conditions.

Bad infrastructure

- In order to make vehicles with fuel cells enough amount of hydrogen has to be generated.
- After generation process, they must also be carefully transported from the generating plants. This can be done only by transportation or pipelines. For this a proper infrastructure has not yet been developed.

Daily Quiz (CO3)

Batteries are energy storage devices

A)True B)False

Cycle life is important for primary batteries

A)True B)False

Electrolyte is expected to have good electronic conductivity

A)True B)False

The electrode where oxidation occurs is called the Anode

A)True B)False

A battery is a collection of cells connected in series or parallel

A)True B)False

Topic wise Recap (CO3)

Topic : Fuel Cells

Recap : In this topic we get to know about Principle of working of various types of fuel cells and their working. It's performance and limitations.

Summary

- In this unit we get to know about what is Geothermal Energy. Also about the various Resources of geothermal energy, thermodynamics of geothermal energy conversion-electrical conversion and non-electrical conversion, environmental considerations to be considered while harvesting Geothermal Energy.
- In this unit we get to know about what is Magneto-hydrodynamics (MHD). The Principle of working of MHD Power plant, performance and limitations.
- We get understanding of Fuel Cells: Principle of working of various types of fuel cells and their working, performance and limitations.

Faculty Video Links, Youtube & NPTEL Video Links and Online Courses Details

Youtube/other Video Links

1.Geothermal Energy

https://www.youtube.com/watch?v=JJoMobProrY

https://www.youtube.com/watch?v=GChB1Lkd-zA

https://www.youtube.com/watch?v=mCRDf7QxjDk

https://www.youtube.com/watch?v=aRpiqs5yX5s

https://www.youtube.com/watch?v=ttpBJKhiU34

Faculty Video Links, Youtube & NPTEL Video Links and Online Courses Details

Youtube/other Video Links

2.Magnetohydrodynamic Generator (Open Cycle And Closed Cycle)

https://www.youtube.com/watch?v=e9LvM8EThyk

https://www.youtube.com/watch?v=e9LvM8EThyk&t=265s

https://www.youtube.com/watch?v=308AUn2CGac

https://www.youtube.com/watch?v=q0G7aI3FL3A

https://www.youtube.com/watch?v=G9NgoxHMPwk

Faculty Video Links, Youtube & NPTEL Video Links and Online Courses Details

Youtube/other Video Links

3.Fuel cells

https://www.youtube.com/watch?v=gcvs1QzrxrE

https://www.youtube.com/watch?v=a4pXAmljdUA

https://www.youtube.com/watch?v=VIFuB0WPkCw

https://www.youtube.com/watch?v=qwsmQ5DyEhk

https://www.youtube.com/watch?v=XRxnNWVqgz8

Quiz (CO3)

The process of producing energy by utilizing heat trapped inside the earth surface is called _____

a) Hydrothermal energy

b) Geo-Thermal energy

c) Solar energy

d) Wave energy

What is hot molten rock called?

a) Lava

b) Magma

c) Igneous rocks

d) Volcano

Quiz (CO3)

3. **In an open cycle MHD-steam power plant, the temperature at the entrance of MHD duct is (in K)**

a) 2500-3000

b) 2000-2500

c) 1500-2000

d) 2250

4. **In closed cycle MHD-steam power plant, which of the following gas is seeded in the MHD duct?**

a) helium

b) xenon

c) sodium vapour

d) chlorine

Quiz (CO3)

5. **What do Fuel cells emit?**

a) water
b) nothing
c) hydrogen
d) oxygen

6. **The centre of earth is estimated to have a high temperature of about**

(A) 1,000 K

(B) 4,000 K

(C) 6,000 K

(D) 10,000 K

Quiz (CO3)

7. **The following is (are) the visible sign(s) of the large amount of heat lying in the earth's interior.**

(A) Volcanoes

(B) Geysers

(C) Hot springs

(D) All of the above

8. **When the water is ejected from earth's interior in the form of hot water, it is called**

(A) Geyser

(B) Hot springs

(C) Both (A) and (B)

(D) None of the above

Quiz (CO3)

9. **The efficiency of geothermal plant is about**

(A) 5%

(B) 15%

(C) 25%

(D) 35%

10. **Hydrothermal fluids are _____ in nature.**

(A) Corrosive

(B) Abrasive

(C) Both (A) and (B)

(D) None of the above

Weekly Assignment

Q1. Describe Geothermal Energy in detail.

Q2. Explain resources of Geothermal Energy.

Q3. Define fuel cells.

Q4. Describe principle of working of MHD power plant.

Q5. Explain performance of MHD power plant.

Q6. Explain non-electrical conversion.

Q7. Explain performance and limitations of fuel cells.

Q8. Describe the working of AFC. Draw the diagram also.

Q9. Differentiate between polymer Electrolyte fuel cell and DMFC.

Q10. Explain the working of PAFC with help of diagram.

MCQ s

Geothermal energy is the thermal energy present
(A) On the surface of the earth
(B) In the interior of the earth
(C) On the surface of the ocean
(D) None of the above

The centre of earth is estimated to have a high temperature of about
(A) 1,000 K
(B) 4,000 K
(C) 6,000 K
(D) 10,000 K

The molten rock within the earth is
(A) Igneous
(B) Magma
(C) Sedimentary
(D) Metamorphic

MCQ s

When the water is ejected from earth's interior in the form of hot water, it is called
(A) Geyser
(B) Hot springs
(C) Both (A) and (B)
(D) None of the above

Water boils underground in a hydrothermal when it has pressure of about ____ atm and temperature of about ____ °C.
(A) 3, 100
(B) 5, 120
(C) 6, 140
(D) 7, 165

In dry steam hydrothermal plant, we use
(A) Carnot cycle
(B) Brayton cycle
(C) Rankine Cycle
(D) None of the above

MCQ s

In which of the following type(s) of plant(s) refrigerant is used as working medium

(A) Vapour dominated plant
(B) Liquid dominated high temperature plant
(C) Liquid dominated low temperature plant
(D) All of the above

The efficiency of geothermal plant is about

(A) 5%
(B) 15%
(C) 25%
(D) 35%

Which of the following liquid metal is not used as a magneto hydrodynamic generation (MHD) working fluid?

a. Potassium
b. Sodium
c. Lithium
d. All of these.

Old Question Papers

1. Attempt any two out of the following **2*10=20**

(a) What do you mean by conventional energy resources? Discuss briefly.

(b) What is meant by dry steam, wet steam and hot water geothermal system.

(c) Discuss the difference between a geothermal power plant and thermal power plant. Categories resources of geothermal energy.

2. Attempt any two out of the following **2*10=20**

(a) Classify solar cells. Derive an expression for maximum power output and efficiency of a solar cell.

(b) Distinguish between global radiation and diffuse radiation, describe the procedure for evaluating the performance of a solar collector.

(c) Describe schematic diagram of a MHD power generating system with a heat recovery system. Explain the working of the system.

Old Question Papers

3. **Attempt any two out of the following** **2*10=20**

(a) Describe the features and main applications of solar photovoltaic system.

(b) Explain the difference between a fuel cell and battery. What are the uses and advantages of fuel cells?

(c) Sketch and explain the functioning solid oxide fuel cells.

4. **Attempt any two out of the following** **2*10=20**

(a) Explain the working of thermoelectric generator. Differentiate between thermoelectric and thermionic conversion system.

(b) Describe the basic principle of wind energy conversion and derive the expression for power developed due to wind.

(c) Classify the rotors employed for wind generation. Prove that for a propeller type horizontal axis turbine.

Old Question Papers

5. Attempt any two out of the following **2*10=20**

(a) Describe the bioconversion process for obtaining biofuels.

(b) Draw the schematic diagram of open cycle OTEC system. Also draw the temperature-entropy diagram for it and explain the principle of operation.

(c) State the present status of tidal power plants in India. Why is the tidal energy not being utilized?

Expected Questions for University Exam

1. Explain Geothermal energy in details and its location constraints.
2. Explain in detail thermodynamics of Geothermal energy.
3. What are the environmental considerations for Geothermal energy.
4. Explain the Principle of working of MHD Power plant, its performance and limitations in detail.
5. What are various types of Fuel cells. Explain in detail. Also mention what is the by product of hydrogen fuel cell.
6. With the help of a schematic diagram, explain the operation of closed cycle MHD generating system.
7. Describe various Geothermal Energy Resources
8. Discuss the difference between a geothermal power plant and thermal power plant. Categories resources of geothermal energy.
9. Explain the working of DMFC with suitable diagram.
10. Differentiate between PAFC and AFC.

References

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- John Twideu and Tony Weir, “Renewal Energy Resources” BSP Publications, 2006.
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- D.S. Chauhan,”Non-conventional Energy Resources” New Age International.
- C.S. Solanki, “Renewal Energy Technologies: A Practical Guide for Beginners” PHI Learning.

Thank You