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SCHOOL OF BIO AND CHEMICAL ENGINEERING

DEPARTMENT OF CHEMICAL ENGINEERING

UNIT – I – Conventional and non-conventional energy sources-Introduction – SCHA4002

Energy is the capacity for doing work.

Potential energy is energy deriving from position. E.g.: Water in an elevated reservoir has gravitational PE.

A lump of coal or petrol together with oxygen needed for their combustion have chemical energy.
Moving bodies possess kinetic energy (KE).

Other forms of energy are electrical and nuclear, light and sound.

Energy can be converted from one form to another, but the total quantity stays the same according to the law of conservation of energy.

For e.g. As an apple falls, it loses gravitational PE but gains KE.

Although energy is never lost, after a number of conversions, it tends to finish up as the KE of random motion of molecules (of the air for e.g.) at relatively low temperatures. This is degraded energy that is difficult to convert to other forms.

Energy Sources :

The energy sources are classified as

1) Primary energy sources
2) Secondary energy fuels and
3) Supplementary sources

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1) Primary Energy Sources

Primary Energy Sources provide a net supply of energy. For e.g. Coal, Oil, Uranium etc. Their energy yield is defined as the energy fed by the material to the energy received from the environment, is very high. It is very important to use these fuels sparingly because of its limited availability. Primary Fuels contribute a large amount of energy.

2) Secondary Fuels

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Secondary Fuels do not produce net energy. Intensive Agriculture is an example in which energy yield is less than the input.

3) Supplementary Sources:

Supplementary sources are those whose net energy yield is zero, requiring highest investment in terms of energy. Thermal insulation is an example for supplementary source.

Coal, natural gas, oil and nuclear energy using breeder reactor are net energy yielders and are primary sources of energy.

Secondary Sources are Solar Energy, Wind Energy, and Water Energy
Solar Energy can be used through Plants, Solar Cells, and Solar Heaters.
Solar Tower, Solar Drying and Solar Heating are other examples.
Wind, Tide, Wave, and Hydroelectric applications are better sources.

Other sources which may be useful in future are Geothermal, Ocean thermal, and Solar Wind etc.

Energy resources are stores of convertible energy.

Nonrenewable resource$_{235}$ s include the fossil fuels (coal, oil, and gas) and Nuclear-fission fuels- for example U ^{235}

Renewable sources such as wind, tidal, and geothermal power have so far been less exploited.

Hydroelectric projects are well established and wine turbines and tidal systems are being developed.

Alternate Energy: -

Alternate Energy is the energy from sources that are renewable and ecologically safe, as opposed to sources that are non-renewable with toxic by-products such as coal, oil or gas (fossil fuels) and Uranium (for nuclear power).

The most important alternate energy source is flowing water, harnessed as hydroelectric power. Other sources include the Ocean's tides and waves, wind power (harnessed by windmills and wind turbines) the Sun (Solar energy) and the heat trapped in the Earth's Crust (geothermal energy).

Renewable Resource: -

Renewable Resource is the natural resource that is replaced by natural process in a reasonable amount of time. Soil, Water, Forests, Plants and Animals are all renewable resources s long as they are properly conserved. Solar, Wind Wave and geothermal energies are based on renewable resources and have so far been less exploited.

Non-Renewable Resource: -

Non-Renewable Resource is the natural resource such as coal or oil, that takes thousands of millions of years to form naturally and can therefore not be replaced once it is consumed. The main energy sources used by human beings are non-renewable resources.

Nonrenewable resources have a high carbon content because their origin has in the photosynthetic activity of plants millions of years ago. The fuels release this carbon back into the atmosphere as CO_2. The rate at which such fuels are being burnt is thus resulting in rise in the concentration of CO_2 in the atmosphere.

Energy Resources:

There are different forms of energy. Fuels such as coal, oil (Petroleum), and wood contain Chemical energy. When these fuels are burnt, the Chemical energy changes to heat and light energy.

Electricity is the most important form of energy in the industrialized world, because it can be transported over long distances through cables and transmission lines. It is also a very convenient form of energy, since it can power a wide variety of household appliances and industrial machinery. It is produced by converting chemical energy from coal, oil or natural gas in power stations.

Energy resources fall into two broad groups.

Renewable and Non-Renewable

Renewable resources: are those which replenish themselves naturally and will either always be available (hydro-electric power, Solar energy, Wind energy, Wave power, tidal - energy, and geothermal energy) or will continue to be available provided supplies are given sufficient time to replenish themselves (peat and firewood).

Non-Renewable resources: are those which are in limited supplies, and which once used are gone forever. These include coal, oil, natural gas and U.

Fossil fuels: Coal, oil and natural gas are called Fossil fuels because they are the fossilized remains of plants and animals that lived hundreds of millions of years ago.

Burning fossil fuels releases chemicals that cause acid rain, and is gradually increasing the CO_2 in the atmosphere, causing global warnings.

Fossil fuels resources are not evenly distributed around the world.

Over half the world's known oil reserves are in the Middle East; about 40% of the reserves of natural gas are in the common wealth of Independent States (CIS) , 25% in the Middle East. About 2/3 of the worlds' coal is shared between North America, the CIS and China.

Uranium:

U is a radioactive metallic element and a very concentrated source of energy: large reserves are found in Australia, North America, and South Africa. U is used to produce electricity in a nuclear power station. A single ton of U can produce as much energy as 15,000 tons of coal, or 10,000 tons of oil.

U is used in the type of nuclear power station now in operation, the worlds' known U supplies have about the same energy content as the known oil reserves.

However, these power stations known as fast or breeder reactors, release virtually all of its energy. These reactors would increase the worlds' U energy reserves by 60 times.

However, although nuclear power stations do not produce CO_2 or cause acid rain, they do produce radioactive waste that is dangerous and difficult to process or store safely.

Solar Energy:

Many renewable resources take advantage of the energy in sunlight. The Sun's energy can be tapped directly by photo voltaic cells that convert light into electricity. Other Solar energy plants use mirrors to direct sunlight onto pipes containing a liquid. The liquid boils and is used to drive an electricity generator.

The Solar energy also drives the wind and waves, so energy produced by wind farms and Wave-driven generators is also derived from the Sun.

Gravitational Energy:

Hydroelectricity and tidal power stations make use of gravitational forces. The Earth's gravity pulls water downward through the turbines in a hydroelectric power station.

In a tidal power station, the Moon's gravity lifts the water as the tides rise, giving the Water potential energy (energy due to position) which is released as the water flows through the turbine.

Commercial sources of energy:

The major sources of

1) Fossil fuels: This comprises solid fuels such as Coal including Anthracite, Bituminous, Lignite and Peat; liquid fuels such as Petroleum and its derivatives: gaseous fuels such as Natural gas.
2) Waterpower (hydro) or energy stored in water.
3) Energy of nuclear fission.

The minor sources of energy are solar, wind, tidal (tides in the sea), geothermal, ocean thermal electric conversion, fuel cells, thermionic, thermo electric generators, etc.

Wood was the dominant source of energy in the pre-industrialization era. Coal later became the dominant source of energy in the early part of the 20^{th} century. Later, Oil became the major source of energy. Wood is no more regarded as a conventional source. Hydroelectricity has already grown to a stable level in developed countries. The % use of various sources for the total energy consumption in the world is given in the table 1.

Table:1 Sources of Energy

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Type of source	**Energy sources**	**Total Energy**
Commercial sources	Oil	38.3%
	Coal	32.5%
	Gas	19.0%
	Hydro	2.0%
	Nuclear (Uranium)	0.13%
Non-commercial sources	Wood	6.6%
	Dung	1.2%
	Waste	0.3%

Coal, oil, gas, Uranium and hydro are commonly known as commercial (or) conventional energy sources. World's energy supply comes mainly from fossil fuels (from above). Firewood, animal dung and agricultural waste represent 8% of total energy consumption in the world.

Gas:

It is economical to run long distance pipelines for the gas to be transported several hundred kilometers to the place where it can be used. This is a very significant improvement. Any organic waste can be used for the production of biogas

Nuclear Energy:

In a pressurized water nuclear power station, water at high pressure is circulated around the reactor vessel where it is heated. The hot water is pumped to the steam generator where it boils in a separate circuit; the steam drives the turbines coupled to the electricity generator. This is the most likely widely used type of reactor. More than 20 countries have pressurized water reactors.

Nuclear Reactors:

Nuclear Reactor is a device for producing nuclear energy in a controlled manner. There are various types of reactors in use, all using nuclear fission in a gas cooled reactor, a gas under pressure (such as CO_2) removes heat from the core of the reactor, which usually contains natural U. The efficiency of the fission process is increased by slowing neutrons in the core by using a moderator such as Carbon. The reaction is controlled with neutron-absorbing rods made of Boron. An advanced Gas-cooled reactor (AGR) generally has enriched U as its fuel. A water-cooled reactor such as the steam generating heavy water (deuterium oxide) reactor, has water circulating through the hot core. The water is converted to steam, which drives turbo-alternators for generating electricity. The most widely used reactor is the PWR (Pressurized Water Reactor) which contains a sealed system of pressurized water that is heated to form steam in the heat exchanger in an external circuit.

The fast reactor has no moderator and uses fast reactions to bring about fission. It uses a mixture of Plutonium (or) Uranium oxide as fuel. When operating U is converted to Plutonium which can be extracted and used later as fuel. It is also called the fast breeder reactor because it produces more Plutonium than it consumes. Heat is removed from the reactor by a coolant of liquid Sodium. The safest system allows for the emergency cooling of a reactor by automatically flooding an overheated core with water.

Nuclear fission:

Nuclear fission is the splitting of a heavy atomic nucleus into two or more major fragments. It is accompanied by the emission of 2 or 3 neutrons and the release of large amounts of large amounts of nuclear energy.

Fission occurs spontaneously in nuclei of U^{235}, the main fuel used in nuclear reactors. However, the process can also be induced by bombarding nuclei with neutrons because a neutron that has absorbed a neutron becomes unstable and soon splits. The neutrons released spontaneously by the fission of U nuclei may therefore be used in turn to induce further fissions, setting up a chain reaction that must be controlled if it is not to result in a nuclear explosion.

Chain Reaction:

In nuclear physics, a fission reaction that is maintained because of neutrons released by the splitting of some atomic nuclei themselves go on to split others, releasing even more neutrons. Such a reaction can be controlled (as in a nuclear reactor) by using moderators to absorb excess neutrons. Uncontrolled, a chain reaction produces a nuclear explosion (as in an atom bomb).

In nuclear reactions, the sum of the masses of all the products (on the atomic mass unit scale) is less than the sum of the masses of the reacting particles. The lost mass is converted to energy according to Einstein’s Equation.

Hydroelectric Power Generation:

Hydroelectric facilities can supply significant amounts of electricity for irrigation or water pumping, lighting, health or educational purposes. Hydro power is a renewable energy source. It is essentially non-polluting and releases no heat. With the development of compact efficient machines, the investment per KW is not very high. Compared to other conventional energy generation schemes, it has low gestation period ranging from 8-24 months. Operating costs are low, and the equipment does not need trained and skilled personnel. Most of the schemes in India can be constructed on existing canals and irrigation system with minor modification.

The basic components of a hydroelectric schemes are:

a) Diversion and Intake
b) Desilting Chamber
c) Water conductor System
d) Forebay/balancing reservoir
e) Penstock
f) Surge tank (if necessary)
g) Powerhouse including turbine, generator, protection & control equipment, dewatering, drainage system, auxiliary power system; emergency & standby power system, lighting & ventilation.
h) Tail race channel

Dams and barrages are employed to divert the required flow from the riverbed / streams to the intake structure (see figure)

Desilting Chamber is necessary where the water contains large quantities of course silt to minimize erosion to the turbine.

Penstocks can be made from steel pipes, Hume pipes and PVC pipes depending on the design pressure. Due to the variation in the load, the water entering into the turbine may be pushed back. This increases the pressure in the pipe called hammering. To prevent this, surge tank is used. A smooth entry of water is ensured from the forebay tank into the Penstocks.

Dam: is used to increase the level of water stored in the reservoir. The level of water surface is called the head race.

Turbine: Converts Kinetic Energy of water to Mechanical energy.

Generator: Converts Mechanical Energy to Electrical Energy.

Step - Up Transformer: increases the voltage so that the power produced can be transmitted to the load area.

Tail Race: is a simple water channel or cover conduit with a maximum water velocity of m/s transporting the water from the turbine outlet (or draft tube) to the river

Efforts must be taken to reduce the cost of equipment and civil works from a major part of the total cost of the project.

Fore bay: is usually constructed in reinforced concrete of stone masonry. It is provided so that a minimum lead over the penstock is always there.

Spill way: In the case of load rejection the water level may rise and flood the area. Therefore, a spillway is provided keeping its crest at the permissible water level so that water level may not rise above the maximum permissible level. Spillway can be provided in the form of channel or pipe.

Powerhouse building: accommodates turbine, generator, control panels, auxiliary equipment, etc., It must be a simple structure constructed either in RCC or stone masonry.

Conduit: carries water from head race to tail race. At the head race, the gravitational potential energy is converted into kinetic energy due to the head.

The turbine is essentially of Kaplan type or propeller type. The generator may be directly coupled to the turbine shaft or driven through a set of gear for increasing the speed to reduce the generator size. The generator is usually on the upstream side of the turbine. The turbine at the downstream end is connected to the generator by means of a sealed shaft. Water flows in the axial direction to the turbine runner with propeller type blades.

Conventionally hydroelectric A.C. synchronous generators are used. The generator (rotor) should withstand turbine runaway speed.

Advantages of hydroelectric power plant

1) The running expenditure is almost negligible.
2) The operation and maintenance of hydroelectric power plant is the simplest
3) These energy sources are free from pollution.

Introduction:

The energy sources are classified in following way:

1. Non-commercial fuel or natural fuels which include wood, animal waste and agricultural waste.
2. commercial fuel which includes the fossil fuels (coal, oil, natural gas)
3. Hydraulic energy (Energy obtained through the use of Potential energy water).
4.

Conventional energy sources:

Non-Commercial fuel: These fuels include woods, leaves, agro waste, dung of animal etc. Commercial fuel: Coal, Petroleum, Natural gas:

Commercial fuel

1. Fossil fuels Coal, Natural Gas, Petroleum

2. Atomic Fuel Uranium, Radium, Plutonium

Hydraulic Energy: Hydraulic energy is also known as waterpower. When river water falls from the mountain, its potential energy is converted into kinetic energy

The major **potentials and limitations** of the conventional sources of energy:

1 Major portion of the energy requirement in the world today is met by the conventional sources of energy like coal, petroleum, natural gas and atomic fuels.

2 The conventional source of energy exists in finite reserves in the world they are rapid ally depleting due to increase consumption of energy. they are likely to exhausted in future.

3 There are always danger of fire and accidents during use of conventional sources of fuel.

4 The conventional sources of fuel have great polluting effect on environments.

5 Transportation and distribution of conventional sources of fuel are very costly.

The Non-Conventional Sources of Energy are:

1. Tidal energy.

2. Energy from sea waves.

3. Geothermal energy or terrestrial heat energy.

4. Hydel energy using small size power plants.

5. Solar energy.

6. Wind energy

The formation of Natural Resources

Coal

Most coal was formed from plants which grew 300 million years ago.The time period is called CARBONIFEROUS ERA

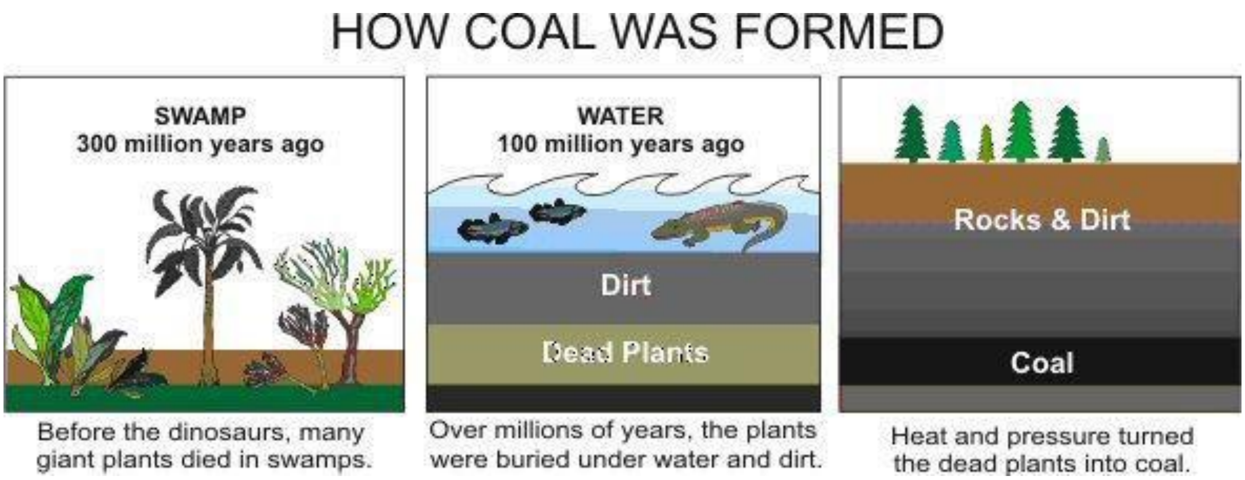

Figure:1 Coal formation

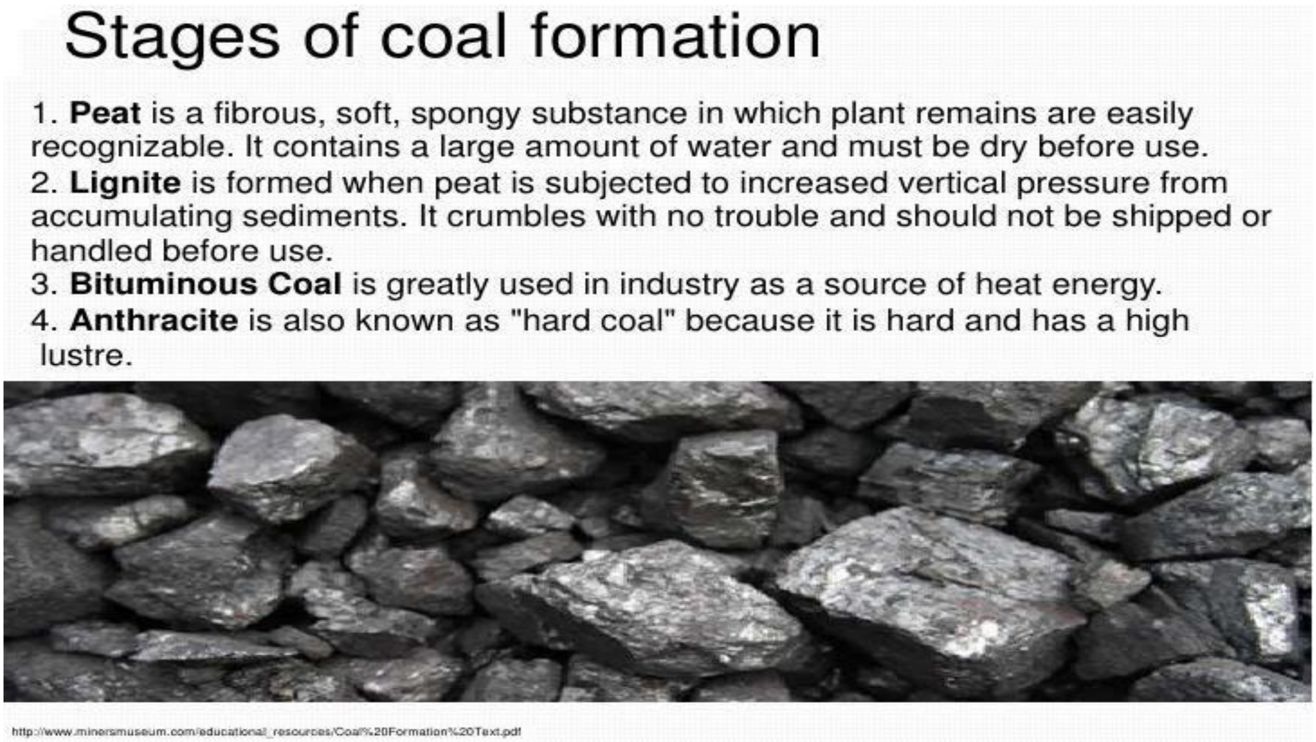

Figure:2 Stages of Coal formation

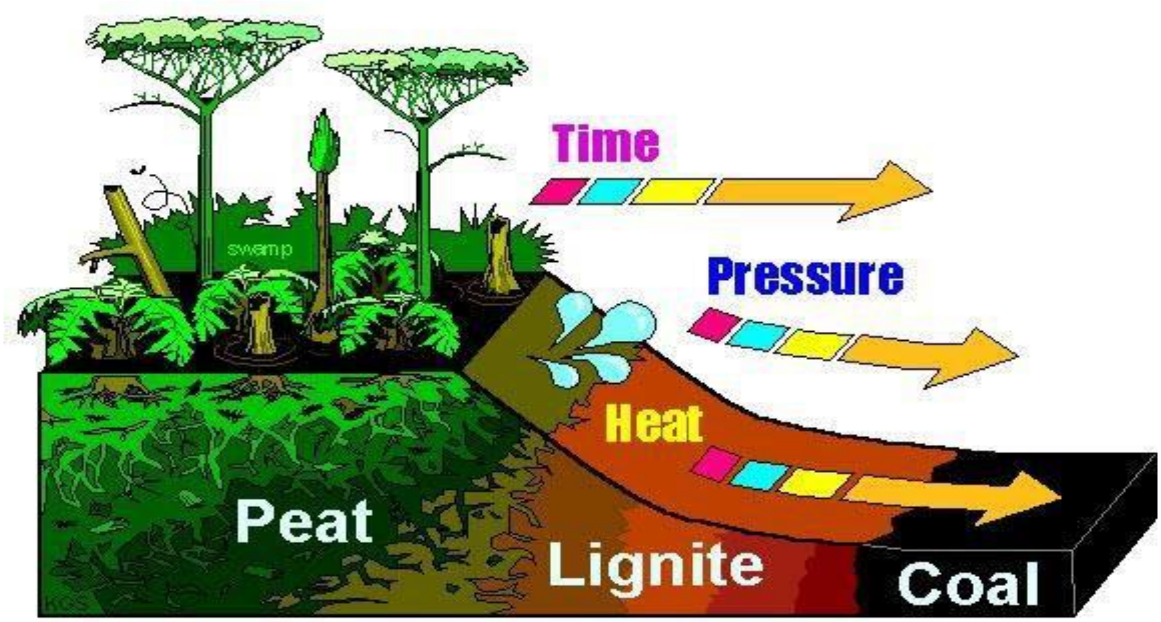

Figure:3 Ranking of coal

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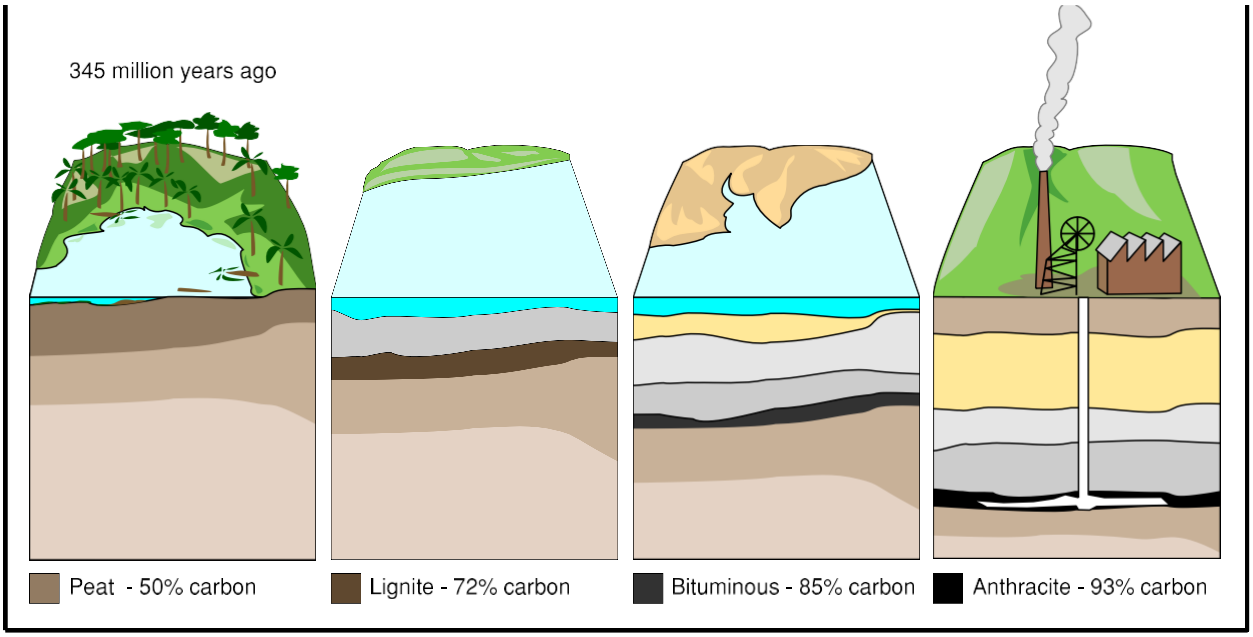


Figure: 4 ranking of coal

The ranking sequence is:

Wood

Peat

Lignite (brown coal)

Bituminous Coal

Anthracite

In general, deposits close to the surface which can be worked by strip mining produce a more economical fuel than deep mined coal.

OIL (PETROLEUM)

Buried organic matter rich in hydrocarbons

Figure:5 Petroleum

How oil and gas were formed

1. In the ocean - Plants use sun's energy to survive and animals get their energy by eating plants
2. Plants and animals in ocean die. The one's that are not eaten fall to the bottom of the sea.
3. A few millions of years later - layers of mud forms on top of the dead animals and plants
4. Another few millions of years later - layers of sand builds up on top of the mud
5. Pressure of all these layers of mud and sand squashes and turns in to mud stone
6. Pressure of all these layers of mud and sand squashes and turns plants and animals to oil and natural gas
7. Now, scientist burn oil and gas in power stations, but this releases harmful gases

OIL and NATURAL GAS (Methane)

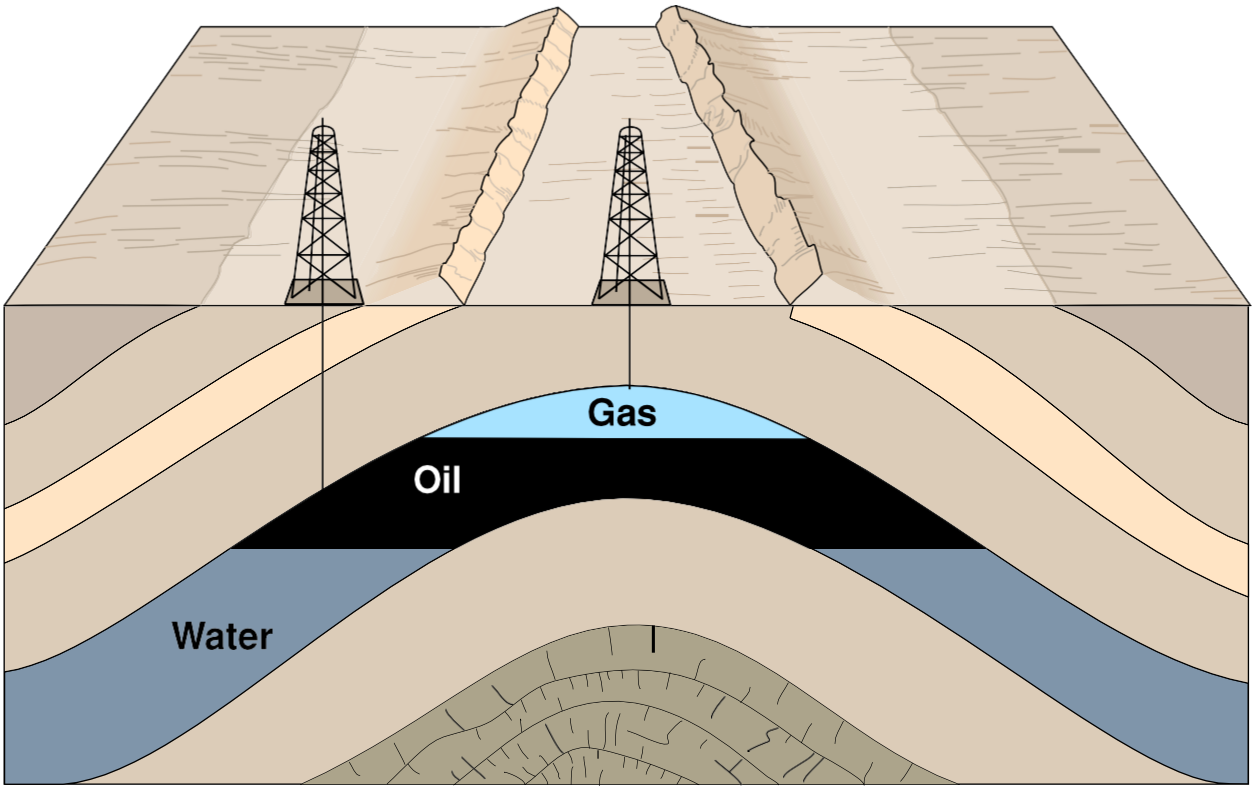


Figure:6 Natural Gas

Even though it was not made from dead plants or animals, nuclear fuel is a fossil fuel because it comes from the ground and is running out.

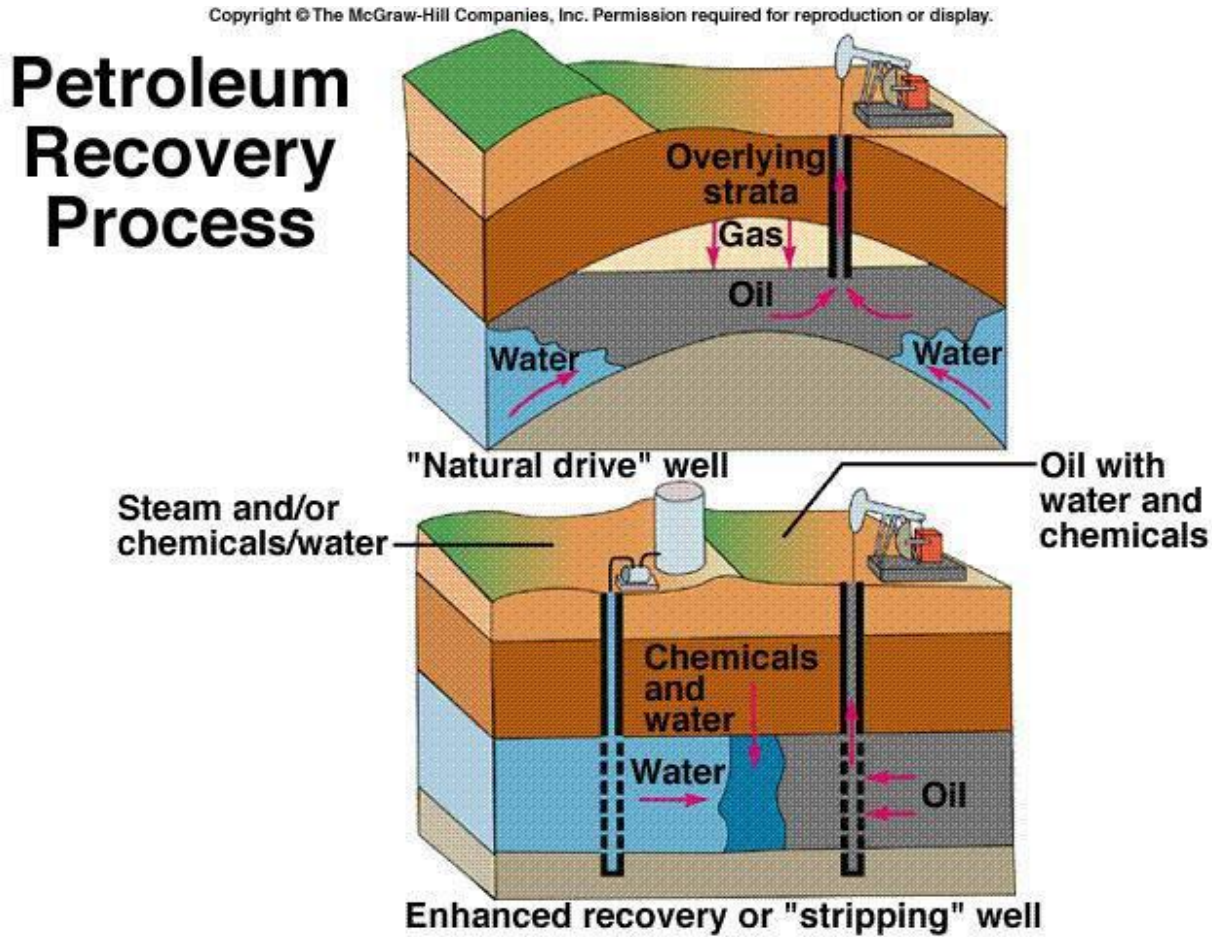


Figure:7 Petroleum Recovery process

<u>NATURAL GAS:</u>

Natural Gas is generally associated with petroleum deposits and is obtained from well dug in the oil-bearing regions. When Natural gas occurs along with petroleum in oil wells, it is called 'Wet Gas 'and contains gaseous hydrocarbons from C_1 to C_4. The Wet gas is then suitably treated to remove propane, propene, butene, butane, which is used as LPG. On the other hand , when the gas is associated with crude oil , it is called 'Dry Gas' and consists almost entirely of methane , ethane , with small concentration of impurities such as CO_2 , CO , H_2S , N_2 and inert gases . Before use, the natural gas is purified to remove objectionable ingredients such as water , dust , grit , H_2S, , CO_2 , N_2 and heavier liquefiable hydrocarbons . The approximate composition of natural gas is : CH_4 = 70-90% , C_2H_6 = 5-10% ,

H_2 = 3%, CO + CO_2 = rest . The calorific value varies from 12000 to 14000 kcal/m^3.

It is an excellent domestic fuel and is conveyed over very large distance in pipelines.

SOLAR ENERGY:

Introduction

The sun is the prime souce of all the forms of energy on the earth

Solar power: The Sun provides 1,366 watts/meter^2 at the distance of the Earth's orbit, but less at ground level.

Solar Constant: I_{sc} is defined as, the rate at which energy is received from the sun on a unit area perpendicular to the rays of the sun at average earth sun distance just out side the earth's atmosphere. Its value is **1353W/m^2.**

Due to the variation of in the earth sun distance , rate of **Extra-terrestrial incident solar radiation** perpendicular to the rays of the sun I_o varies. The value of I_o on any day can be closely approximated by the equation: $\mathbf{I_o = I_{sc}[1+0.033coss(360n/365)].}$

Solar Radiation measuring instruments

It is necessary to determine the amount of solar radiation received on the surface of the earth. This information is require for

1 Proper utilization of solar energy
2 Energy balance studies.

Principle of solar radiation.

1. **Principle of thermocouple.** When the junction of two dissimilar metal are formed and one of the it is heated, e.m.f. if generated on the ends of open junction. This is known as thermoelectric Phenomenon. This e.m.f. is produced is proportional to the difference of the temp. between two ends.

2. **Photovoltaic Principle:** When the solar radiation fall on the photovoltaic cell the electrons are released in such a way as to set up emf in the circuit. The electrical energy is proportional to intensity of solar radiation. This gives direct measurement of solar radiation. Measuring Instruments of Solar radiations: Two basic type of instruments are employed for solar radiation measuring.

Pyranometers: These may use a thermopile or a solar cell. most commonly used is the one with thermopiles. In this sensing element, there is a black metal surface. This is placed horizontally as under a single or double glass hemisphere which protects the surface and prevent the loss of heat. Glass is grand transparent to solar radiation. i.e. it permits solar radiation to enter inside. after reacting inside, it gets converted into low temp. radiation. Glass does not permit low temp. radiation to go out. thus it prevent to heat loss. A set of thermocouple is attached to underside of the black surface and working as hot junction. The cold junction of the thermopile are either connected to white surface adjacent to the black surface or to an electronic cold junction inside the instrument.

Pyrheliometer: This is used to measure only direct beam radiations.

It is consists of cylindrical collimating tube which can be adjusted , and kept in such a way that it remains parallel to in coming solar radiations. Hence, only direct beam radiation are received on sensor plate. Aperture of the collimating tube makes acceptance come of 5.8o. Black surface is mounted behind the collimating tube.

Sunshine Recorder: The duration of bright sunshine is measured by means of a sunshine recorder. The sunshine recorder is consisting of a glass provided with a bowl under it. The bowl of a hemispherical shape and provided with grooves in which specially treated paper is kept. The sunshine recorder is normally fixed on a concrete plat form out.

The sunshine recorder is kept in open where direct sun rays are falling on glass sphere. The solar rays after passing through the glass sphere are concentrated at a point and fall on the specially treated paper. The concentrated solar rays being power full enough to make burning marks on the paper kept in the groves of bowl When the sun moves east to west, the corresponding burn marks are left on the paper. The length of the mark indicates the period for which there was a clear sunshine.

Various Methods of solar energy utilization

Introduction:

Indirect Utilization of solar energy:

(1) wind energy (2) Tidal energy (3) Sea waves energy

(4) Geothermal energy (5) Biomass energy. (6) Hydrolic energy.

Solar Thermal Collector**.**

Introduction: Solar thermal collector is the direct method of solar energy utilization. There are two type:

1 Liquid flat plate collector.

2 Solar air heater.

Flat-plate Collectors: A flat-plate collector consists of an absorber, a transparent cover, a frame, and insulation. Usually an iron-poor solar safety glass is used as a transparent cover, as it transmits a great amount of the short-wave light spectrum.

Construction and working of solar liquid flat plate collector:

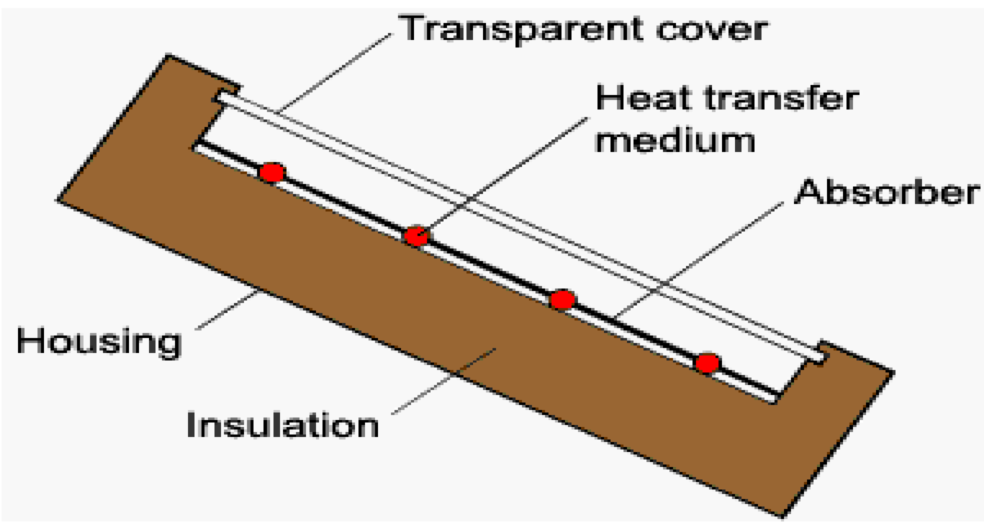


Figure:8 Liquid flat plate collector

Advantages and Disadvantages of LFPC:

Uses of flat plate collector:

Types of Absorber Plate:

Tubes bound on the surface of the absorber plate.

Tubes fitted in grooved absorber plate.

Tubes in absorber plate.

Roll Bend aluminum absorber plate.

1. Corrugated sheets fastened together.

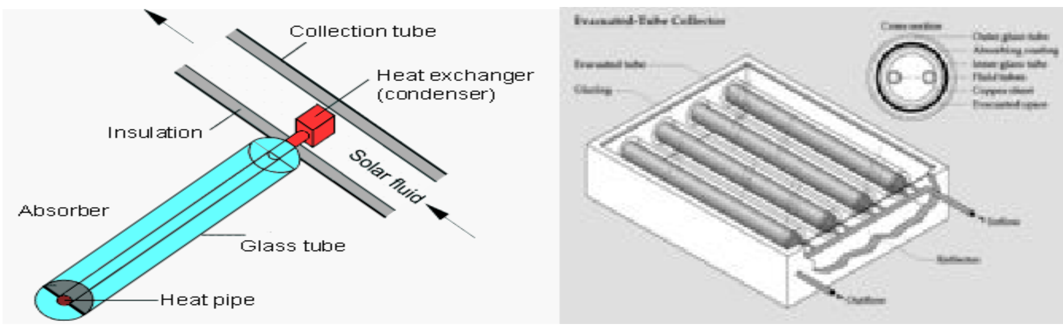


Figure:9 Arrangement of plates

Evacuated (or vacuum) tubes panel.

Evacuated tube collectors are made of a series of modular tubes, mounted in parallel, whose number can be added to or reduced as hot water delivery needs change. This type of collector consists of rows of parallel transparent glass tubes, each of which contains an absorber tube.

Solar Air heater:

Introduction: We have discussed in the previous lesson that flat plate liquid collectors are used fro heating water. Solar air heater are used for heating air. Heated air is used for many purposes such as space heating, air drying etc.

Construction and working of solar air heater:

The air heater are similar to liquid flat plate collector

(a) **Principle:** When the solar radiation falls on the black surface, they are absorbed by the absorber plate. The air passing close to it, is heated up.

(b) **Construction:** the air heater has following important parts

(c) Absorber Plate:air passage:

1. Transparent cover:

2. Insulation:
3. Casing:

Working:

Non-porous absorber
collector Porous
absorber plate

Types of solar Air heater

a. Simple Flat plate collector:
b. Finned Plate Absorber air Heater:
c. Corrugated Plate air heater :
d. Overlapped Glass Plate Air Heater:

Porous air heaters

1 Matrix Air heater:
2 Honeycomb porous Air Heater:

Table:2 Comparison between Liquid flat plate collector and Air heater:

Liquid collector	Air Heater
• Water to be heated up is passing through the water tubes.	• There are no tubes . Usually air passages through space between absorber plate and insulation.
• Leakage of water stops the functioning of collector.	• Leakage of air does not stop the working of collector. It reduces the its efficiency.
• Absorber plates and cooling water tubes are integral to each other. No fins are provided.	• Usually an air passage around matrix of honey comb or fins are provided to increase heat transfer.
• There is a problem of corrosion.	• There is usually no problem of corrosion.
• Due to smaller dia. of cooling water tubes there is large increase in temp.	• The space through which the air is circulated is large hence it is difficult to obtain higher temp.
• In cold countries water in the collector may get frozen and damage the tubes.	• No such problem in this type of collector.
• Heat transfer value for a surface and liquid is much higher than for air. This results in higher collector efficiency.	• Heat transfer rate for a surface and air is much lower than for liquid. This results in lower collector efficiency. Special arrangements to increase heat transfer coefficient are required.

Solar Concentrating type collectoWorking principles of solar concentration: Two types of optical principle are used in solar concentrators:

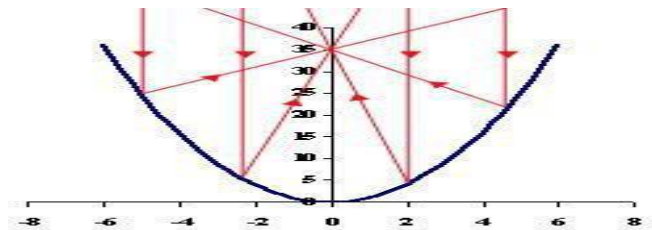


Figure:10 Solar collector

1. **Reflection principle:** The incident solar radiation is reflected from the concave surface of mirrors and collected at its focus. The working fluid or any material to be heated is kept at focus, it can be heated to very high temp.
2. **Refraction Principle:** The incident solar radiation is directed by an arrangement of lenses at the focus after refraction. This also gives very high temp. of working fluids.

Tracking and Non tracking Collectors:

Types of Concentrating collectors:

1 Fresnel lens collector:

2 Flat Plate collector augmented with mirrors:

3 Compound parabolic collector (CPC) or Wiston Collector:

4 Parabolic Collector:

5. Cylindrical Parabolic Collector:

6. Heliostat Collector:

Energy can be stored in mechanical or electrical devices, or in containers of chemicals called eutectic or phase changing salts.

Utilization of solar energy is of great importance to India since sunlight is abundanty for a major part of the year.

The applications of solar energy are:

1) Heating and cooling of residential buildings.
2) Solar water heating.
3) Solar distillation.
4) Solar cooking.
5) Solar engines for pumping water.
6) Solar furnaces.
7) Solar drying of agricultural and animal products.
8) Solar electric power generation is by
    (a) Solar ponds
    (b) Reflectors with lenses and pipes for fluid circulation.
    (c) Steam generators heated by rotating reflectors (heliostat mirrors).
9) Solar photovoltaic cells for directly converting solar energy nito electricity or for water pumping.
10) Salt production by evaporation of sea water.
11) Food refrigeration.
12) Bioconversion and wind energy, which are indirect sources of solar energy.

How Does Solar Cooking Work?

Solar cooking is done by means of the suns **UV rays.**

A solar cooker lets the UV light rays in and then converts them to longer **infrared light rays** that cannot escape. Infrared radiation has the right energy to make the water, fat and protein molecules in food vibrate vigorously and heat up.

It is not the sun's heat that cooks the food, nor is it the outside ambient temperature, though this can somewhat affect the rate or time required to cook, **but rather it is the sun's rays that are converted to heat energy that cook the food;** and this heat energy is then retained by the pot and the food by the means of a covering or lid.

This occurs in much the same way that a greenhouse retains heat or a car with its windows rolled up. An effective solar cooker will use the energy of the sun to heat a cooking vessel and efficiently retain the energy (heat) for maximum cooking effectiveness.

For maximum efficiency it is necessary to "track" the sun, or in other words adjust your solar cooker so that it is directly towards the sun in order to be able to better concentrate and absorb the suns rays.

This does not mean that you must continually stand beside the solar cooker the whole cooking period.But it can mean adjusting the angle and direction every so often or every set period, such as every one to two hours.

The more direct that the sun's rays are towards the food and cooking pot the greater the energy (heat) capacity will be from the sun's converted rays.

Ideal cooking results when using a solar oven occur when the sun is bright and uninhibited or unimpeded by clouds, shadows etc.

Cooking can be accomplished as well on days when the clouds are high and thin, but it may slow things down a bit, and one would be wise to start a little earlier than usual.

Long, slow moderate solar cooking, such as with stew, chili, veggies etc. will do fine under less than bright skies if you allow more time.

Baking on the other hand will take longer and the temperatures will not be as optimum as could be, thus resulting in mixed outcomes with your baked goods.

There are three main components to most solar cookers, or you could say three main principles to effective solar cooking: these being:

- Concentration (reflection, or reflectance)
- Absorption (ability to attract or hold heat.

Retention (means or capacity to retain heat) ***Concentration*** of the sun's rays is performed most often by reflecting panels, petals and such surfaces that can "focus" or concentrate the rays of light (UV) to a point or concentration. These reflecting panels are usually made of materials that are shiny and reflective due to the substance used in their manufacture, such as silver, chromium and aluminum. Without a means to concentrate the sun's rays it can take longer to heat objects or surfaces, thus most solar cookers are constructed with reflector panels to speed up the process of heat accumulation

Absorption of the sun's energy (heat)in solar cooking is best achieved when a surface is dark in color, thus the most common solar oven interiors are usually black in color as well as the color of the cookware used for cooking the food.

Dark colors absorb the heat, whereas light colors do not absorb heat well. And some colors can reflect the sun's energy away, such as silver for example. Generally, the best cookware for solar cooking is the dark, thin variety because it absorbs the heat (energy) well; and because it is thin, it can then transfer the heat more quickly and evenly to the food.

Retention is the final principle in solar cooking. If a solar cooker is not well insulated and if it does not have a cover, or lid, then all of the *concentrated* heat (energy) and all of the *absorbed* heat would quickly dissipate into the air and be lost to the surrounding environment. A solar cooker must have the means to "trap" or hold the concentrated heat allowing it to accumulate and to "build up" to sufficiently high enough levels to be able to effectively cook.

A fourth principle, though not vital in all forms of solar cooking (parabolic cooking is one)is: **transparency** of your retentive materials, or in other words, your lid on a solar oven or your enclosure around your pot/pan on a solar panel cooker needs to be able to allow the sun's rays to penetrate inside to where the food/cooking vessels are located.

This ability of the sun to penetrate is usually achieved by using clear glass, or plastic coverings on a solar cooker lid/door/enclosure which then in turn acts as an inhibitor, trapping the heat as well.

SOLAR POWERED PUMP

A **solar-powered pump** is a pump running on electricity generated by photovoltaic panels or the radiated thermal energy available from collected sunlight as opposed to grid electricity or diesel run water pumps. The operation of solar powered pumps is more economical mainly due to the lower operation and maintenance costs and has less environmental impact than pumps powered by an internal combustion engine (ICE). Solar pumps are useful where grid electricity is unavailable and alternative sources (in particular wind) do not provide sufficient energy.

Components

A photovoltaic solar powered pump system has four parts:

- the pump
- the controller
- solar panels.

The solar panels make up most (up to 80%) of the systems cost. The size of the PV- system is directly dependent on the size of the pump, the amount of water that is required (m^3/d) and the solar irradiance available. The purpose of the controller is twofold. Firstly, it matches the output power that the pump receives with the input power available from the solar panels. Secondly, a controller usually provides a low voltage protection, whereby the system is switched off, if the voltage is too low or too high for the operating voltage range of the pump. This increases the lifetime of the pump thus reducing the need for maintenance.

Voltage of the solar pump motors can be AC (alternating current) or DC (direct current). Direct current motors are used for small to medium applications up to about 3 kW rating, and are suitable for applications such as garden fountains, landscaping, drinking water for livestock, or small irrigation projects. Since DC systems tend to have overall higher efficiency levels than AC pumps of a similar size, the costs are reduced as smaller solar panels can be used.

Finally, if an alternating current solar pump is used, an inverter is necessary that changes the direct current from the solar panels into alternating current for the pump. The supported power range of inverters extends from 0.15 to 55 kW and can be used for larger irrigation systems. However, the panel and inverters must be sized accordingly to accommodate the inrush characteristic of an AC motor.

Water pumping

Solar powered water pumps can deliver drinking water as well as water for livestock or irrigation purposes.[1] Solar water pumps may be especially useful in small scale or community based irrigation, as large scale irrigation requires large volumes of water that in turn require a large solar PV array.[2] As the water may only be required during some parts of the year, a large PV array would provide excess energy that is not necessarily required, thus making the system inefficient.

Solar distillation

Solar distillation is the use of solar energy to evaporate water and collect its condensate within the same closed system. Unlike other forms of water purification it can turn salt or brackish water into fresh drinking water (i.e. desalination). The structure that houses the process is known as a solar still and although the size, dimensions, materials, and configuration are varied, all rely on the simple procedure wherein an influent solution enters the system and the more volatile solvents leave in the effluent leaving behind the salty solute behind.

Solar distillation differs from other forms of desalination that are more energy-intensive, such as methods such as reverse osmosis, or simply boiling water due to its use of free energy. A very common and, by far, the largest example of solar distillation is the natural water cycle that the Earth experiences.

UNIT – II– ENERGY FROM BIOMASS– SCHA4002

2. ENERGY FROM BIOMASS

Bioenergy conversion technologies

Direct combustion processes.
Thermochemical processes.
Biochemical processes.

There are five fundamental forms of biomass energy use.

(1) the "traditional domestic" use in developing countries (fuelwood, charcoal and agricultural residues) for household cooking (e.g. the "three stone fire"), lighting and space-heating. In this role-the efficiency of conversion of the biomass to useful energy generally lies between 5% and 15%.

(2) the "traditional industrial" use of biomass for the processing of tobacco, tea, pig iron, bricks & tiles, etc, where the biomass feedstock is often regarded as a "free" energy source. There is generally little incentive to use the biomass efficiently so conversion of the feedstock to useful energy commonly occurs at an efficiency of 15% or less.

(3) "Modern industrial." Industries are experimenting with technologically advanced thermal conversion technologies which are itemised below. Expected conversion efficiencies are between 30 and 55%.

(4) newer "chemical conversion" technologies ("fuel cell") which are capable of by-passing the entropy-dictated Carnot limit which describes the maximum theoretical conversion efficiencies of thermal units.

(5) "Biological conversion" techniques, including anaerobic digestion for biogas production and fermentation for alcohol.

In general, biomass-to-energy conversion technologies have to deal with a feedstock which can be highly variable in mass and energy density, size, moisture content, and intermittent supply.

Therefore, modern industrial technologies are often hybrid fossil-fuel/biomass technologies which use the fossil fuel for drying, preheating and maintaining fuel supply when the biomass supply is interrupted.

Direct combustion processes.

<u>Co-firing.</u>

Feedstocks used are often residues such as woodchips, sawdust, bark, hog fuel, black liquor, bagasse, straw, municipal solid waste (MSW), and wastes from the food industry.

Direct combustion furnaces can be divided into two broad categories and are used for producing either direct heat or steam. Dutch ovens, spreader-stoker and fuel cell furnaces employ two-stages. The first stage is for drying and possible partial gasification, and the second for complete combustion. More advanced versions of these systems use rotating or vibrating grates to facilitate ash removal, with some requiring water cooling.

The second group, include suspension and fluidised bed furnaces which are generally used with fine particle biomass feedstocks and liquids. In suspension furnaces the particles are burnt whilst being kept in suspension by the injection of turbulent preheated air which may already have the biomass particles mixed in it. In fluidised bed combustors, a boiling bed of pre-heated sand (at temperatures of 500 to 900°C) provides the combustion medium, into which the biomass fuel is either dropped (if it is dense enough to sink into the boiling sand) or injected if particulate or fluid. These systems obviate the need for grates, but require methods of preheating the air or sand, and may require water cooled injection systems for less bulky biomass feedstocks and liquids.

Co-firing.

A modern practice which has allowed biomass feedstocks an early and cheap entry point into the energy market is the practice of co-firing a fossil-fuel (usually coal) with a biomass feedstock. Co-firing has a number of advantages, especially where electricity production is an output.

Firstly, where the conversion facility is situated near an agro-industrial or forestry product processing plant, large quantities of low-cost biomass residues are available. These residues can represent a low-cost fuel feedstock although there may be other opportunity costs. Secondly, it is now widely accepted that fossil-fuel power plants are usually highly polluting in terms of sulphur, CO_2 and other GHGs. Using the existing equipment, perhaps with some modifications, and co-firing with biomass may represent a cost-effective means for meeting more stringent emissions targets. Biomass fuel's low sulphur and nitrogen (relative to coal) content and nearly zero net CO_2emission levels allows biomass to offset the higher sulphur and carbon contents of the fossil fuel. Thirdly, if an agro-industrial or forestry processing plant wishes to make more efficient use of the residues generated by co-producing electricity but has a highly seasonal component to its operating schedule, co-firing with a fossil fuel may allow the economic generation of electricity all year round.

Agro-industrial processors such as the sugarcane sugar industry can produce large amounts of electricity during the harvesting and processing season, however, during the off-season the plant will remain idle. This has two drawbacks, firstly, it is an inefficient use of equipment which has a limited lifetime, and secondly, electrical distribution utilities will not pay the full premium for electrical supplies which can't be relied on for year round production. In other words the distribution utility needs to guarantee year round supply and may therefore, have to invest in its own production capacity to cover the off-season gap in supply with associated costs in equipment and fuel. If however, the agro-processor can guarantee electrical supply year-round through the burning of alternative fuel supplies (i.e. coal and bagasse in Mauritius, see section 3) then it will make efficient use of its equipment and will receive premium payments for its electricity by the distribution facility

Thermochemical processes.

Pyrolysis.
Carbonisation.
Gasification.
Catalytic Liquefaction.

These processes do not necessarily produce useful energy directly, but under controlled temperature and oxygen conditions are used to convert the original biomass feedstock into more convenient forms of energy carriers, such as producer gas, oils or methanol. These carriers are either more energy dense and therefore reduce transport costs, or have more predictable and convenient combustion characteristics allowing them to be used in internal combustion engines and gas turbines.

Pyrolysis.

The biomass feedstock is subjected to high temperatures at low oxygen levels, thus inhibiting complete combustion, and may be carried out under pressure. Biomass is degraded to single carbon molecules (CH_4 and CO) and H_2 producing a gaseous mixture called "producer gas." Carbon dioxide may be produced as well, but under the pyrolytic conditions of the reactor it is reduced back to CO and H_2O; this water further aids the reaction. Liquid phase products result from temperatures which are too low to crack all the long chain carbon molecules so resulting in the production of tars, oils, methanol, acetone, etc. Once all the volatiles have been driven off, the residual biomass is in the form of char which is virtually pure carbon.

Pyrolysis has received attention recently to produce liquid fuels from cellulosic feedstocks by "fast" and "flash" pyrolysis in which the biomass has a short residence time in the reactor. A more detailed understanding of the physical and chemical properties governing the pyrolytic reactions has allowed the optimization of reactor conditions necessary for these types of pyrolysis. Further work is now concentrating on the use of high-pressure reactor conditions to produce hydrogen and on low pressure catalytic techniques (requiring zeolites) for alcohol production from the pyrolytic oil.

Carbonisation.

This is an age-old pyrolytic process optimized for the production of charcoal. Traditional methods of charcoal production have centred on the use of earth mounds or covered pits into which the wood is piled. Control of the reaction conditions is often crude and relies heavily on experience. The conversion efficiency using these traditional techniques is believed to be very low; on a weight basis Openshaw estimates that the wood to charcoal conversion rate for such techniques ranges from 6 to 12 tonnes of wood per tonne of charcoal. {Openshaw, 1980}.

During carbonisation most of the volatile components of the wood are eliminated; this process is also called "dry wood distillation." Carbon accumulates mainly due to a reduction in the levels of hydrogen and oxygen in the wood.

The wood undergoes a number of physico-chemical changes as the temperature rises. Between 100 and 170°C most of the water is evaporated; between 170°C and 270°C gases develop containing condensible vapours, CO and CO_2. These condensible vapours (long chain carbon molecules) form pyrolysis oil, which can then be used for the production of chemicals or as a fuel after cooling and scrubbing. Between 270°C and 280°C an exothermic reaction develops which can be detected by the spontaneous generation of heat.

The modernisation of charcoal production has lead to large increases in production efficiencies with large-scale industrial production in Brazil now achieving efficiencies of over 30% (by weight).

There are three basic types of charcoal-making: a) internally heated (by controlled combustion of the raw material), b) externally heated (using fuelwood or fossil fuels), and c) hot circulating gas (retort or converter gas, used for the production of chemicals).

Internally heated charcoal kilns are the most common form of charcoal kiln. It is estimated that 10 to 20% of the wood (by weight) is sacrificed, a further 60% (by weight) is lost through the conversion to, and release of, gases to the atmosphere from these kilns. Externally heated reactors allow oxygen to be completely excluded, and thus provide better quality charcoal on a larger scale. They do, however, require the use of an external fuel source, which may be provided from the "producer gas" once pyrolysis is initiated.

Gasification.

High temperatures and a controlled environment leads to virtually all the raw material being converted to gas. This takes place in two stages. In the first stage, the biomass is partially combusted to form producer gas and charcoal. In the second stage, the $C0_2$ and H_2O produced in the first stage is chemically reduced by the charcoal, forming CO and H_2. The composition of the gas is 18 to 20% H_2, an equal portion of CO, 2 to 3% CH_4, 8 to 10% CO_2, and the rest nitrogen. {Makunda, 1992}. These stages are spatially separated in the gasifier, with gasifier design very much dependant on the feedstock characteristics.

Gasification technology has existed since the turn of the century when coal was extensively gasified in the UK and elsewhere for use in power generation and in houses for cooking and lighting. Gasifiers were used extensively for transport in Europe during World War II due to shortages of oil, with a closed top design predominating.

Catalytic Liquefaction.

This technology has the potential to produce higher quality products of greater energy density. These products should also require less processing to produce marketable products.

Catalytic liquefaction is a low temperature, high pressure thermochemical conversion process carried out in the liquid phase. It requires either a catalyst or a high hydrogen partial pressure. Technical problems have so far limited the opportunities of this technology.

Biochemical processes.

<u>Anaerobic Fermentation.</u>
<u>Methane Production in Landfills.</u>
<u>Ethanol Fermentation.</u>
<u>Biodiesel.</u>

The use of micro-organisms for the production of ethanol is an ancient art. However, in more recent times such organisms have become regarded as biochemical "factories" for the treatment and conversion of most forms of human generated organic waste. Microbial engineering has encouraged the use of fermentation technologies (aerobic and anaerobic) for use in the production of energy (biogas) and fertiliser, and for the use in the removal of unwanted products from water and waste streams.

Anaerobic Fermentation.

Anaerobic reactors are generally used for the production of methane rich biogas from manure (human and animal) and crop residues. They utilise mixed methanogenic bacterial cultures which are characterised by defined optimal temperature ranges for growth. These mixed cultures allow digesters to be operated over a wide temperature range i.e. above 0°C up to 60°C.

When functioning well, the bacteria convert about 90% of the feedstock energy content into biogas (containing about 55% methane), which is a readily useable energy source for cooking and lighting. The sludge produced after the manure has passed through the digester is non-toxic and odourless. Also, it has lost relatively little of its nitrogen or other nutrients during the digestion process thus, making a good fertiliser. In fact, compared to cattle manure left to dry in the field the digester sludge has a higher nitrogen content; many of the nitrogen compounds in fresh manure become volatised whilst drying in the sun. On the other hand, in the digested sludge little of the nitrogen is volatised, and some of the nitrogen is converted into urea. Urea is more readily accessible by plants than many of the nitrogen compounds found in dung, and thus the fertiliser value of the sludge may actually be higher than that of fresh dung.

Anaerobic digesters of various types were widely distributed throughout India and China. Extension programmes promote biogas plants as ideal candidates for rural village use due to their energy and fertiliser production potential along with their improved health benefits. Health benefits primarily arise from the cleaner combustion products of biogas as opposed to other biomass or fossil fuels which may be used in the domestic environment, These two countries now have an estimated 5 to 6 million units in use.

Reliability problems have arisen from a number of problems i.e. construction defects, the mixed nature of the bacterial population, the digesters requirements for water and the maintenance of the optimum nitrogen ratio of the medium. Another problem is the digester's demand for dung, which may have alternative uses.

Modern designs have answered many of these problems and digesters are again becoming useful, especially with regard to the potential of digesters to remove toxic nutrients such as nitrates from water supplies; levels of which are now much more stringently controlled in many industrialised countries. The combination of energy production with the ability to enhance crop yields makes biogas technology a good candidate for more widespread use now that reliable operation can be demonstrated. Recent Danish commercial experience with large scale digesters provides a useful example.

Biodiesel.

The use of vegetable oils for combustion in diesel engines has occurred for over 100 years. In fact, Rudolf Diesel tested his first prototype on vegetable oils, which can be used, "raw", in an emergency. Whilst it is feasible to run diesel engines on raw vegetable oils, in general the oils must first be chemically transformed to resemble petroleum-based diesel more closely.

The raw oil can be obtained from a variety of annual and perennial plant species. Perennials include, oil palms, coconut palms, physica nut and Chinese Tallow Tree. Annuals include, sunflower, groundnut, soybean and rapeseed. Many of these plants can produce high yields of oil, with positive energy and carbon balances.

Transformation of the raw oil is necessary to avoid problems associated with variations in feedstock. The oil can undergo thermal or catalytic cracking, Kolbe electrolysis, or transesterification processes in order to obtain better characteristics. Untreated oil causes problems through incomplete combustion, resulting in the build up of sooty residues, waxes, gums etc. Also, incorrect viscosities can result in poor atomization of the oil also resulting in poor combustion. Oil polymerisation can lead to deposition on the cylinder walls.

Generally, the chemical processing required to avoid these problems is simple, and in the case of soybean oil may be carried out in existing petroleum refineries. The use of diesel powered vehicles is widespread throughout agriculture, and biodiesel provides an environmentally friendly, CO_2-neutral alternative. It is now being widely promoted in the EC and elsewhere, as its use does not require major modification to existing diesel engines.

ENERGY FROM BIO-MASS AND BIO-GAS:

The potential for bio-mass as an alternate source of energy in India is very great since plenty of agricultural and forest resources are available for production of bio-mass. Bio-mass is produced through photosynthesis achieved by solar energy conversion. Bio-mass means organic matter. The reaction is the process of photosynthesis in the presence of solar radiation given by

$$H_2O + CO_2 \xrightarrow{\text{Solar Energy}} CH_2O + O_2$$

Water and CO_2 are converted into organic material, i.e., CH_2O, which is the basic molecule of forming carbohydrates stable at low temp., it breaks at high temp., releasing an amount of heat = 112,000 cal/mole or 469 kJ /mole.

$$CH_2O + O_2 \longrightarrow CO_2 + H_2O + 112 \text{ K cal /mole}$$

It is possible to produce large amount of Carbohydrate by growing, For example: algae under optimum conditions in plastic tubes or in ponds. The algae could be harvested, dried and burnt for production of heat that could be converted into electricity by conventional methods. The bio-mass is used directly by burning or is further processed to produce more convenient liquid and gaseous fuels.

Bio-mass resources fall into 3 categories :

1.) Bio-mass in its traditional solid mass (wood and agricultural residue) when burnt gives the energy directly.
2.) Bio-mass in non-traditional form (converted into liquid fuels) which is converted into ethanol and methanol to be used as liquid fuels in engines.

The third category is to ferment the bio-mass anaerobically to obtain a gaseous fuel called bio-gas containing 55 --- 65% methane, 30 – 40% CO_2 and the rest impurities such as H_2, H_2S and N_2.

Bio-mass resources include :

a.) Concentrated waste – municipal solids, sewage wood products, industrial waste, manure of large lots.

b.) Dispersed waste residue – crop residue, disposed manure.

Harvested bio-mass, standby bio-mass, bio-mass energy plantation.

Energy Plantation :

For large scale production of selected power, fire wood is used as a fuel for the bodies of a conventional power plant. In energy plantation scheme, selected species of trees would be planted and harvested over regular time period on a large area of land near the power plant. In India, eucalyptus, casuarina and babool are the selected trees planted.

Bio-gas :

The main source for production of bio-gas is wet cow dung or wet livestock and human waste, to produce bio-gas. The production of bio-gas is important in India because of its large cattle population of about 250 million.

Other sources of bio-gas are :

i) Sewage

ii) Crop residue

iii) Vegetable waste

iv) Algae

v) Poultry droppings

vi) Pig manures etc.,

In cities, sewage is the main source for production of bio-gas. Bio-gas thus obtained can be used to run pumps to pump out the sewage water itself. Pilot plants have already been developed for handling sewage. The sewage bio-gas is high quality fuel containing 84% CH_4. CH_4 could be economically used to run engines to drive electric generators.

In the rural areas, bio-gas finds great applications in cooking, lighting, mechanical power and generation of small electricity. The gas can be used with advantage to improve sanitary conditions and also to control environmental pollution. Bio-gas can be used independently or with diesel in I.C. engines for production of power. For converting I.C. engines of diesel, or petrol/kerosene type to gas engines, a special attachment is required. Ruston and Hornsby have developed 5 HP engine to work on bio-gas. Remarkable progress has been made in India in respect of bio-gas plants. Many bio-gas plants were installed during the Seventh Plan Period. Some successful bio-gas plants commissioned by DNES during 1985-86 are at Muradnagar (U.P.), Rishikesh (U.P.) , Sanganer and Sihar (Rajasthan), Pondicherry, Bhopal (M.P.), etc. About 70 community / institutional type bio-gas plants are set during the year 1985- 86.

BIOGAS

A combustible gas (composed primarily of methane) produced when Organic waste, sewage or manure is fermented in the absence of oxygen. The solid material that remains in the digester after fermentation can be used as an organic fertilizer.

Biofuels: how Bio Gas is Generated.

Floating gas holder type of plant: The diagram below shows the details of a floating gas holder type of bio gas plant.

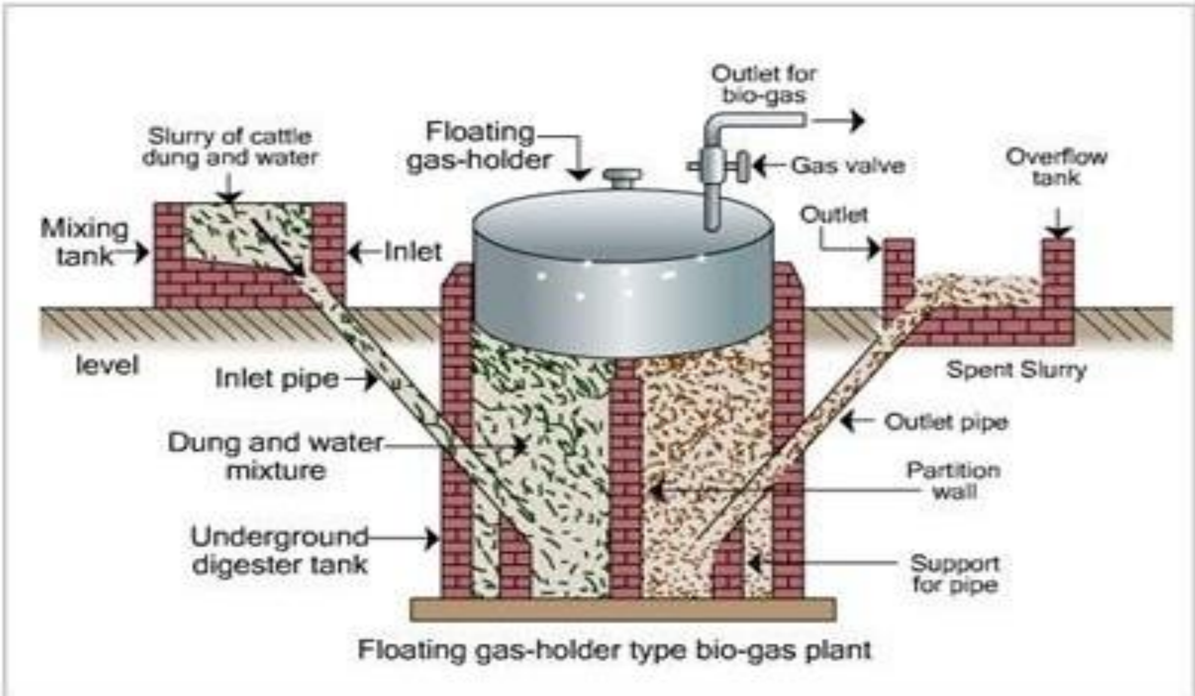


Figure:11 Floating gas-holder bio-gas plant

Biogas - a gas mixture of methane, carbon dioxide and small quantities of hydrogen and hydrogen sulphide - is created under air exclusion through the fermentation of organic substances with microorganism assistance. Biogas is a gas mixture, consisting of approximately 40 to 75 % methane (CH4), 25 to 60 % carbon dioxide (CO2), and approx. 2 % of other gases (hydrogen, hydrogen sulphide and carbon monoxide).

Benefits Of Biogas

- Availability of power at affordable rates
- Reduces pollution
- Reduces time wastage while collecting firewood
- Reduces reliance on fossil fuels
- Saves on the environment (Reduces deforestation)
- Improves living standards in rural areas
- Reduces global warming

- Produces good quality enriched manure to improve soil fertility.
- Effective and convenient way for sanitary disposal of organinc wastes, improving the hygienic conditions.
- As a smokeless domestic fuel it reduces the incidence of eye and lung diseases.

Types of Biogas Plants

A total of seven different types of biogas plant have been officially recognised by the MNES.

1. the floating-drum plant with a cylindrical digester (KVIC model),
2. the fixed-dome plant with a brick reinforced, moulded dome (Janata model)
3. the floating-drum plant with a hemisphere digester (Pragati model)
4. the fixed-dome plant with a hemisphere digester (Deenbandhu model)
5. the floating-drum plant made of angular steel and plastic foil (Ganesh model)
6. the floating-drum plant made of pre-fabricated reinforced concrete compound units
7. the floating-drum plant made of fibre-glass reinforced polyester.

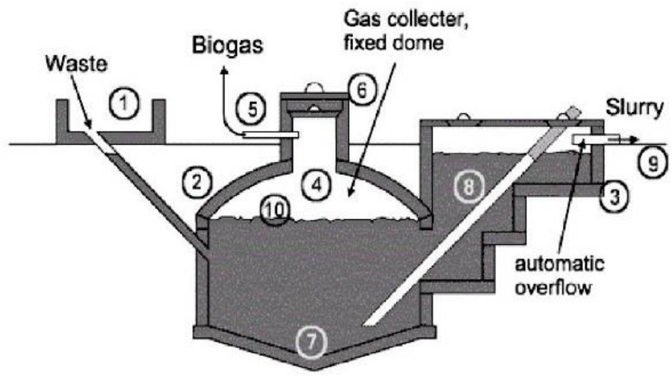
Small Scale Biogas Digester

1. Fixed-dome Plants

A fixed-dome plant consists of a digester with a fixed, non-movable gas holder, which sits on top of the digester. When gas production starts, the slurry is displaced into the compensation tank. Gas pressure increases with the volume of gas stored and the height difference between the slurry level in the digester and the slurry level in the compensation tank. The costs of a fixed-dome biogas plant are relatively low. It is simple as no moving parts exist. There are also no rusting steel parts and hence a long life of the plant (20 years or more) can be expected.

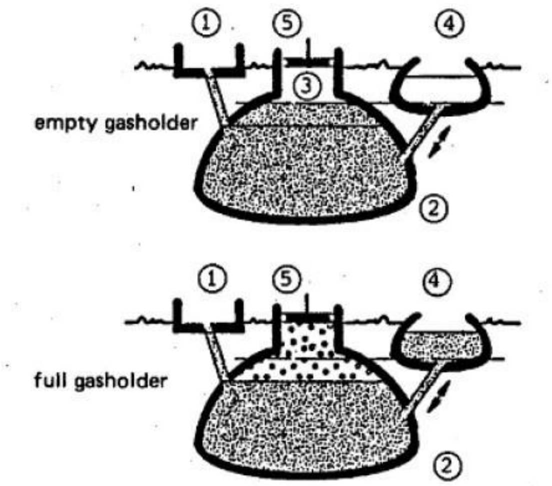
The plant is constructed underground, protecting it from physical damage and saving space. While the underground digester is protected from low temperatures at night and during cold seasons, sunshine and warm seasons take longer to heat up the digester. No day/night fluctuations of temperature in the digester positively influence the bacteriological processes. The construction of fixed dome plants is labor-intensive, thus creating local employment. Fixed-dome plants are not easy to build. They should only be built where construction can be supervised by experienced biogas technicians. Otherwise plants may not be gas-tight (porosity and cracks).

The basic elements of a fixed dome plant (here the Nicarao Design) are shown in the figure below.



Fixed dome plant Nicarao design:
1. Mixing tank with inlet pipe and sand trap. 2. Digester. 3. Compensation and removal tank. 4. Gasholder. 5. Gaspipe. 6. Entry hatch, with gastight seal. 7. Accumulation of thick sludge. 8. Outlet pipe. 9. Reference level. 10. Supernatant scum, broken up by varying level.

Figure:12 Fixed Dome plant



Basic function of a fixed-dome biogas plant, 1 Mixing pit, 2 Digester, 3 Gasholder, 4 Displacement pit, 5 Gas pipe

Figure :13 Fixed Dome Mixing pit

Function - A fixed-dome plant comprises of a closed, dome-shaped digester with an immovable, rigid gasholder and a displacement pit, also named 'compensation tank'. The gas is stored in the upper part of the digester. When gas production commences, the slurry is displaced into the compensating tank. Gas pressure increases with the volume of gas stored, i.e. with the height difference between the two slurry levels. If there is little gas in the gasholder, the gas pressure is low.

Digester - The digesters of fixed-dome plants are usually masonry structures, structures of cement and ferro-cementexist. Main parameters for the choice of material are:

Technical suitability (stability, gas- and liquid tightness);□ cost-effectiveness;□ availability in the region and transport costs;□ availability of local skills for working with the particular building material.□ Fixed dome plants produce just as much gas as floating-drum plants, if they are gas-tight. However, utilization of the gas is less effective as the gas pressure fluctuates substantially. Burners and other simple appliances cannot be set in an optimal way. If the gas is required at constant pressure (e.g., for engines), a gas pressure regulator or a floating gas-holder is necessary.

Gas Holder - The top part of a fixed-dome plant (the gas space) must be gas-tight. Concrete, masonry and cement rendering are not gas-tight. The gas space must therefore be painted with a gas-tight layer (e.g. 'Water-proofer', Latex or synthetic paints). A possibility to reduce the risk of cracking of the gas-holder consists in the construction of a weak-ring in the masonry of the digester. This "ring" is a flexible joint between the lower (water-proof) and the upper (gas-proof) part of the hemispherical structure. It prevents cracks that develop due to the hydrostatic pressure in the lower parts to move into the upper parts of the gas-holder.

Types of Fixed Dome Plants Chinese fixed-dome plant is the archetype of all fixed dome plants. Several million have been□ constructed in China. The digester consists of a cylinder with round bottom and top.

Janata model was the first fixed-dome design in India, as a response to the Chinese fixed dome□ plant. It is not constructed anymore. The mode of construction lead to cracks in the gasholder - very few of these plant had been gas-tight.

Deenbandhu, the successor of the Janata plant in India, with improved design, was more crackproof and consumed less building material than the Janata plant. with a hemisphere digester

Floating Drum Plants Floating-drum plants consist of an underground digester and a moving gas-holder. The gas-holder floats either directly on the fermentation slurry or in a water jacket of its own. The gas is collected in the gas drum, which rises or moves down, according to the amount of gas stored. The gas drum is prevented from tilting by a guiding frame. If the drum floats in a water jacket, it cannot get stuck, even in substrate with high solid content.

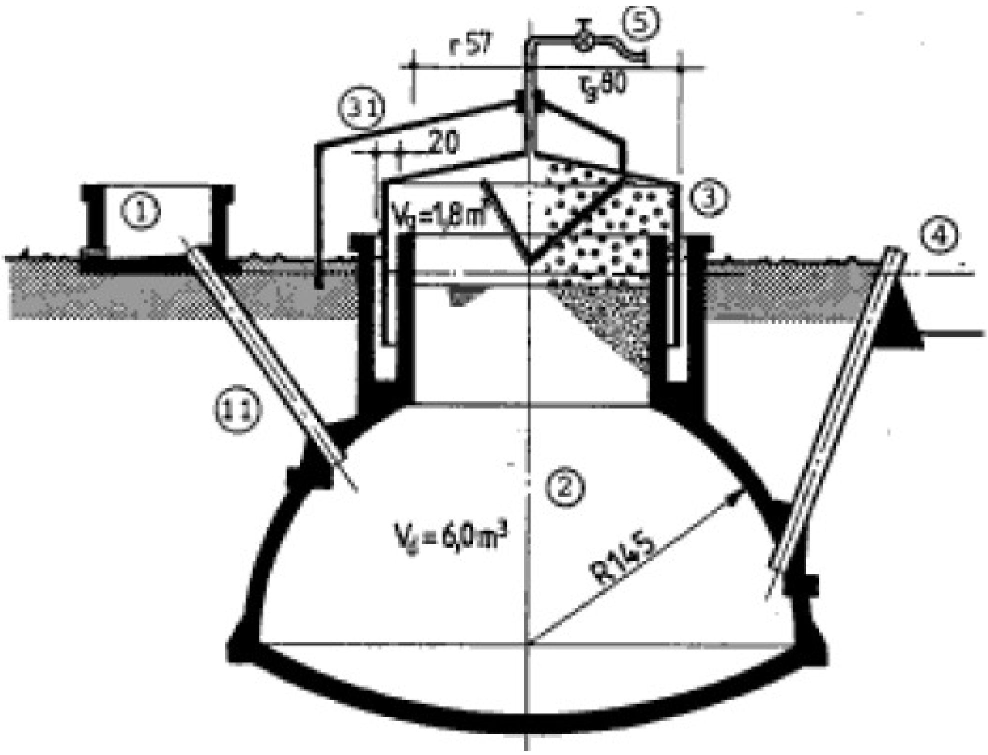


Figure:14Floating Drum plants

Drum - In the past, floating-drum plants were mainly built in India. A floating-drum plant consists of a cylindrical or dome-shaped digester and a moving, floating gas-holder, or drum. The gas-holder floats either directly in the fermenting slurry or in a separate water jacket. The drum in which the biogascollects has an internal and/or external guide frame that provides stability and keeps the drum upright. If biogas is produced, the drum moves up, if gas is consumed, the gas-holder sinks back. Size - Floating-drum plants are used chiefly for digesting animal and human feces on a continuous feed mode of operation, i.e. with daily input. They are used most frequently by small- to middle-sized farms (digester size: 5-15m3) or in institutions and larger agro-industrial estates (digester size: 20- 100m3). Disadvantages: The steel drum is relatively expensive and maintenance intensive. Removing rust and painting has to be carried out regularly. The life-time of the drum is short (up to 15 years; in tropical coastal regions about five years). If fibrous substrates are used, the gas-holder shows a tendency to get "stuck" in the resultant floating scum.

Types of Floating Drum Plants

KVIC model with a cylindrical digester, the oldest and most widespread floating

Drum biogas plant from India.

Pragati model with a hemisphere digester

Ganesh model made of angular steel and plastic

floating-drum plant made of pre-fabricated reinforced concrete compound

unit - floating-drum plant made of fibre-glass reinforced polyester

low-cost floating-drum plants made of plastic water containers or fiberglass drums:

2. **Low Cost Polyethylene Tube Digester** - In the case of the Low-Cost Polyethylene Tube Digester model which is applied in Bolivia (Peru, Ecuador, Colombia, Centro America and Mexico), the tubular polyethylene film (two coats of 300 microns) is bended at each end around a 6 inch PVC drainpipe and is wound with rubber strap of recycled tire-tubes. With this system a hermetic isolated tank is obtained.

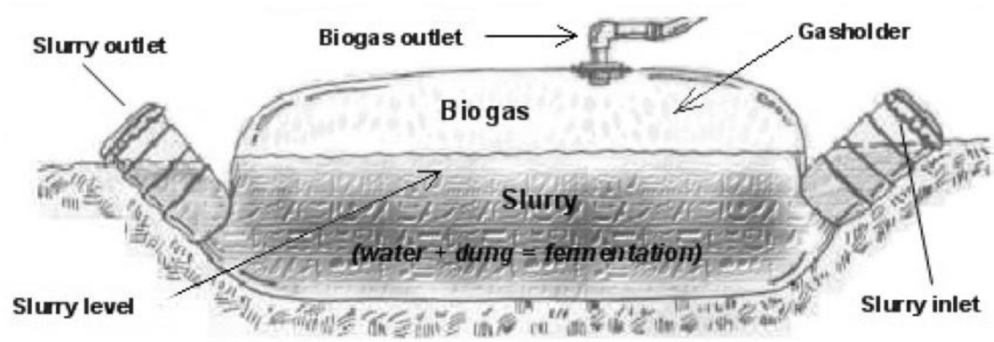


Figure :15 Polyethylene Tube Digester

UNIT – III– Bio Energy and MHD – SCHA4002

ENERGY FROM BIO-MASS AND BIO-GAS:

The potential for bio-mass as an alternate source of energy in India is very great since plenty of agricultural and forest resources are available for production of bio-mass. Bio-mass is produced through photosynthesis achieved by solar energy conversion. Bio-mass means organic matter. The reaction is the process of photosynthesis in the presence of solar radiation given by

$$H_2O + CO_2 \xrightarrow{\text{Solar Energy}} CH_2O + O_2$$

Water and CO_2 are converted into organic material, i.e., CH_2O, which is the basic molecule of forming carbohydrates stable at low temp., it breaks at high temp., releasing an amount of heat = 112,000 cal/mole or 469 kJ /mole.

$$CH_2O + O_2 \longrightarrow CO_2 + H_2O + 112 \text{ K cal /mole}$$

It is possible to produce large amount of Carbohydrate by growing, For example: algae under optimum conditions in plastic tubes or in ponds. The algae could be harvested, dried and burnt for production of heat that could be converted into electricity by conventional methods. The bio-mass is used directly by burning or is further processed to produce more convenient liquid and gaseous fuels.

Bio-mass resources fall into 3 categories :

1.) Bio-mass in its traditional solid mass (wood and agricultural residue) when burnt gives the energy directly.

2.) Bio-mass in non-traditional form (converted into liquid fuels) which is converted into ethanol and methanol to be used as liquid fuels in engines.

The third category is to ferment the bio-mass anaerobically to obtain a gaseous fuel called bio-gas containing 55 --- 65% methane, 30 – 40% CO_2 and the rest impurities such as H_2, H_2S and N_2.

Bio-mass resources include :

a.) Concentrated waste – municipal solids, sewage wood products, industrial waste, manure of large lots.

b.) Dispersed waste residue – crop residue, disposed manure.

Harvested bio-mass, standby bio-mass, bio-mass energy plantation.

Thermal Gasification of Biomass

Renewable biomass and biomass derived fuels could readily replace fossil fuels in many of the present energy utilization applications with concomitant environmental benefits. Gasification is a form of biomass energy conversion producing a fuel that could substitute for fossil fuels in high efficiency power generation and CHP applications. While fossil fuel resources are heavily concentrated in coal mines and oil and gas wells, biomass resources are dispersed and hence the fuels they produce are more expensive than fossil fuels.

However, biomass is a renewable resource and may become a significant component in the global sustainable energy mix as fossil fuel resources begin to be depleted. For example, short rotation poplar crops as shown below. In addition, biomass utilization can expedite mitigation of greenhouse gas emissions and carbon sequestration cycles and promote 'green' industries with associated growth in rural economies. Biomass gasification fuels may be able to use the existing natural gas distribution network and, with minor equipment modifications, biomass fuel gases could be readily used in most of the present natural gas energy conversion devices.

TYPES OF GASIFIERS

Updraught or counter current gasifier

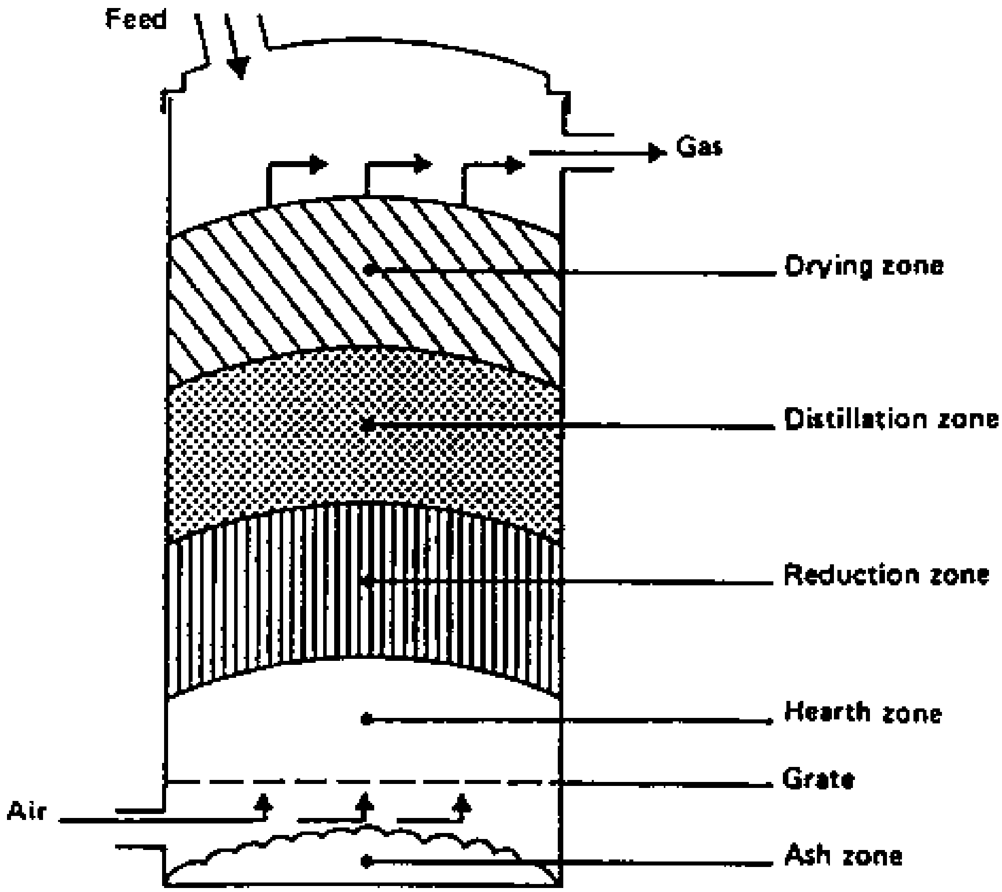


Figure:16 Updraught or counter current gasifier

The air intake is at the bottom and the gas leaves at the top. Near the grate at the bottom the combustion reactions occur, which are followed by reduction reactions somewhat higher up in the gasifier. In the upper part of the gasifier, heating and pyrolysis of the feedstock occur as a result of heat transfer by forced convection and radiation from the lower zones. The tars and volatiles produced during this process will be carried in the gas stream. Ashes are removed from the bottom of the gasifier.

The major advantages of this type of gasifier are its simplicity, high charcoal burn-out and internal heat exchange leading to low gas exit temperatures and high equipment efficiency, as well as the possibility of operation with many types of feedstock (sawdust, cereal hulls, etc.) .

Major drawbacks result from the possibility of "channelling" in the equipment, which can lead to oxygen break-through and dangerous, explosive situations and the necessity to install automatic moving grates, as well as from the problems associated with disposal of the tar-containing condensates that result from the gas cleaning operations. The latter is of minor importance if the gas is used for direct heat applications, in which case the tars are simply burnt.

Downdraught or co-current gasifiers

A solution to the problem of tar entrainment in the gas stream has been found by designing co-current or downdraught gasifiers, in which primary gasification air is introduced at or above the oxidation zone in the gasifier. The producer gas is removed at the bottom of the apparatus, so that fuel and gas move in the same direction, as schematically shown in Fig

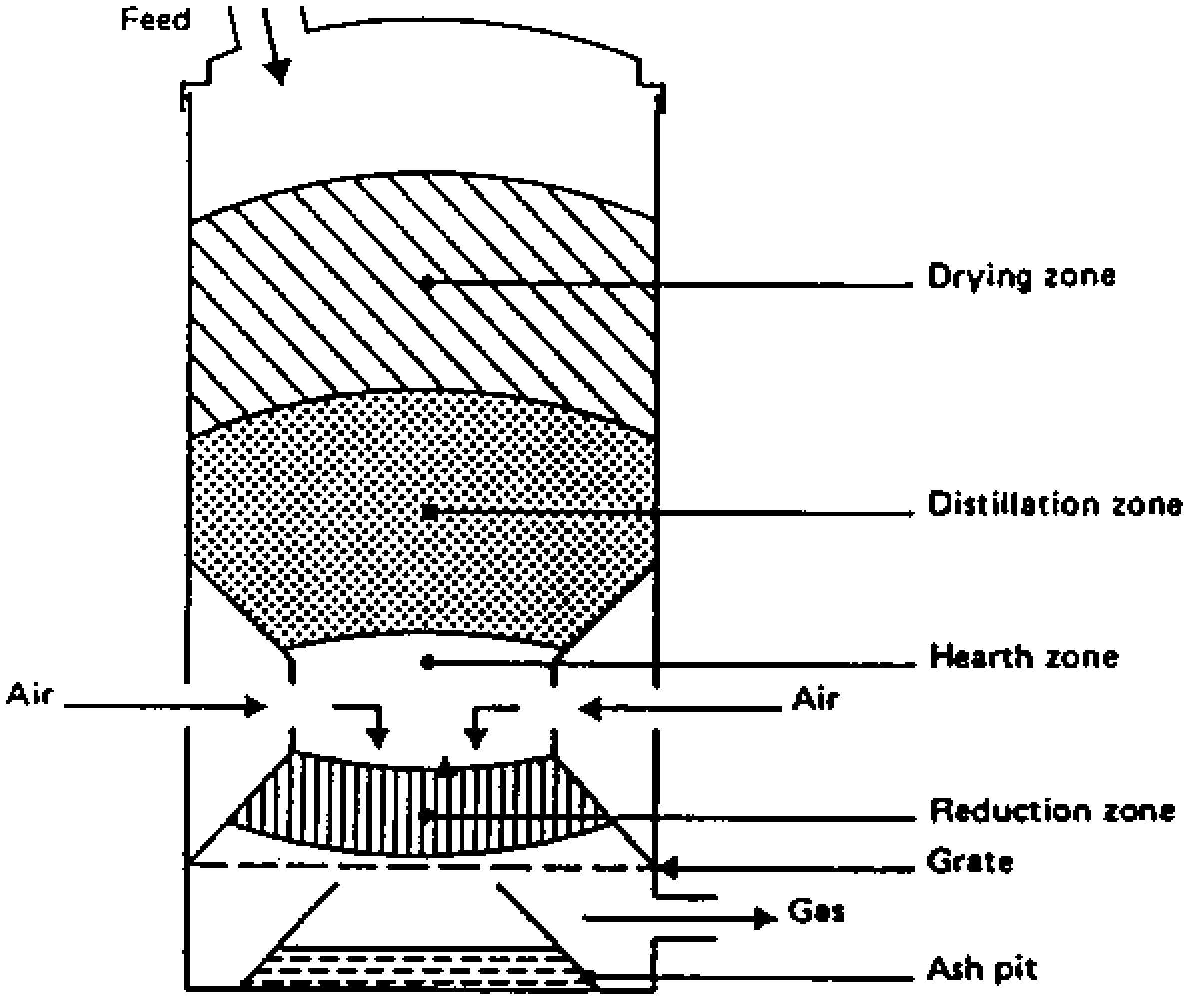


Figure :17 Downdraught or co-current gasifier

On their way down the acid and tarry distillation products from the fuel must pass through a glowing bed of charcoal and therefore are converted into permanent gases hydrogen, carbon dioxide, carbon monoxide and methane.

Depending on the temperature of the hot zone and the residence time of the tarry vapours, a more or less complete breakdown of the tars is achieved.

The main advantage of downdraught gasifiers lies in the possibility of producing a tar-free gas suitable for engine applications.

In practice, however, a tar-free gas is seldom if ever achieved over the whole operating range of the equipment: tar-free operating turn-down ratios of a factor 3 are considered standard; a factor 5-6 is considered excellent.

Because of the lower level of organic components in the condensate, downdraught gasifiers suffer less from environmental objections than updraught gasifiers.

A major drawback of downdraught equipment lies in its inability to operate on a number of unprocessed fuels. In particular, fluffy, low density materials give rise to flow problems and excessive pressure drop, and the solid fuel must be pelletized or briquetted before use. Downdraught gasifiers also suffer from the problems associated with high ash content fuels (slagging) to a larger extent than updraught gasifiers.

Minor drawbacks of the downdraught system, as compared to updraught, are somewhat lower efficiency resulting from the lack of internal heat exchange as well as the lower heating value of the gas. Besides this, the necessity to maintain uniform high temperatures over a given cross-sectional area makes impractical the use of downdraught gasifiers in a power range above about 350 kW (shaft power).

Cross-draught gasifier

Cross-draught gasifiers, schematically illustrated in Figure are an adaptation for the use of charcoal. Charcoal gasification results in very high temperatures (1500 °C and higher) in the oxidation zone which can lead to material problems. In cross draught gasifiers insulation against these high temperatures is provided by the fuel (charcoal) itself.

Advantages of the system lie in the very small scale at which it can be operated. Installations below 10 kW (shaft power) can under certain conditions be economically feasible. The reason is the very simple gas-cleaning train (only a cyclone and a hot filter) which can be employed when using this type of gasifier in conjunction with small engines.

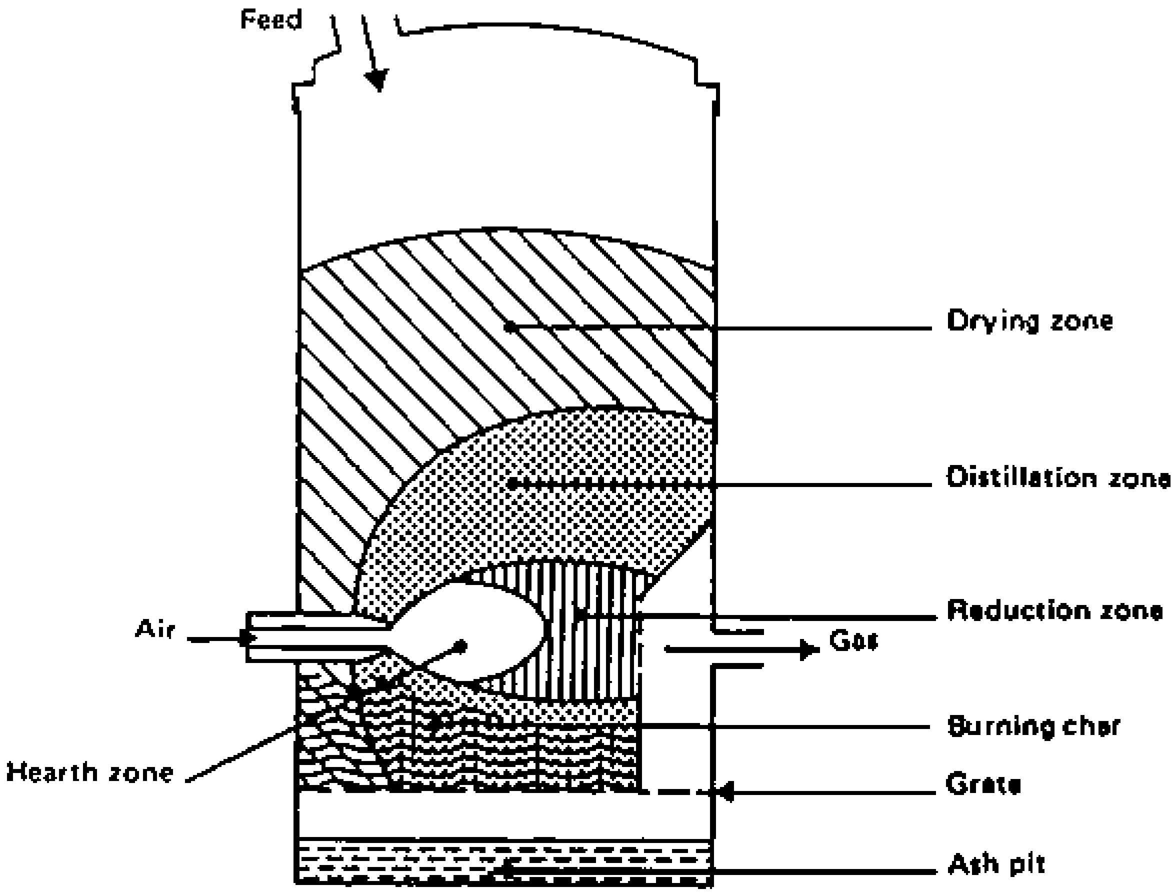


Figure:18: Cross -draught gasifiers

A disadvantage of cross-draught gasifiers is their minimal tar-converting capabilities and the consequent need for high quality (low volatile content) charcoal.

It is because of the uncertainty of charcoal quality that a number of charcoal gasifiers employ the downdraught principle, in order to maintain at least a minimal tar-cracking capability.

Fluidized bed gasifier

The operation of both up and downdraught gasifiers is influenced by the morphological, physical and chemical properties of the fuel. Problems commonly encountered are: lack of bunkerflow, slagging and extreme pressure drop over the gasifier.

A design approach aiming at the removal of the above difficulties is the fluidized bed gasifier illustrated schematically in Fig.

Air is blown through a bed of solid particles at a sufficient velocity to keep these in a state of suspension. The bed is originally externally heated, and the feedstock is introduced as soon as a sufficiently high temperature is reached. The fuel particles are introduced at the bottom of the reactor, very quickly mixed with the bed material and almost instantaneously heated up to the bed temperature. As a result of this treatment the fuel is pyrolysed very fast, resulting in a component mix with a relatively large number of gaseous materials. Further gasification and tar- conversion reactions occur in the gas phase. Most systems are equipped with an internal cyclone in order to minimize char blow-out as much as possible. Ash particles are also carried over the top of the reactor and have to be removed from the gas stream if the gas is used in engine applications.

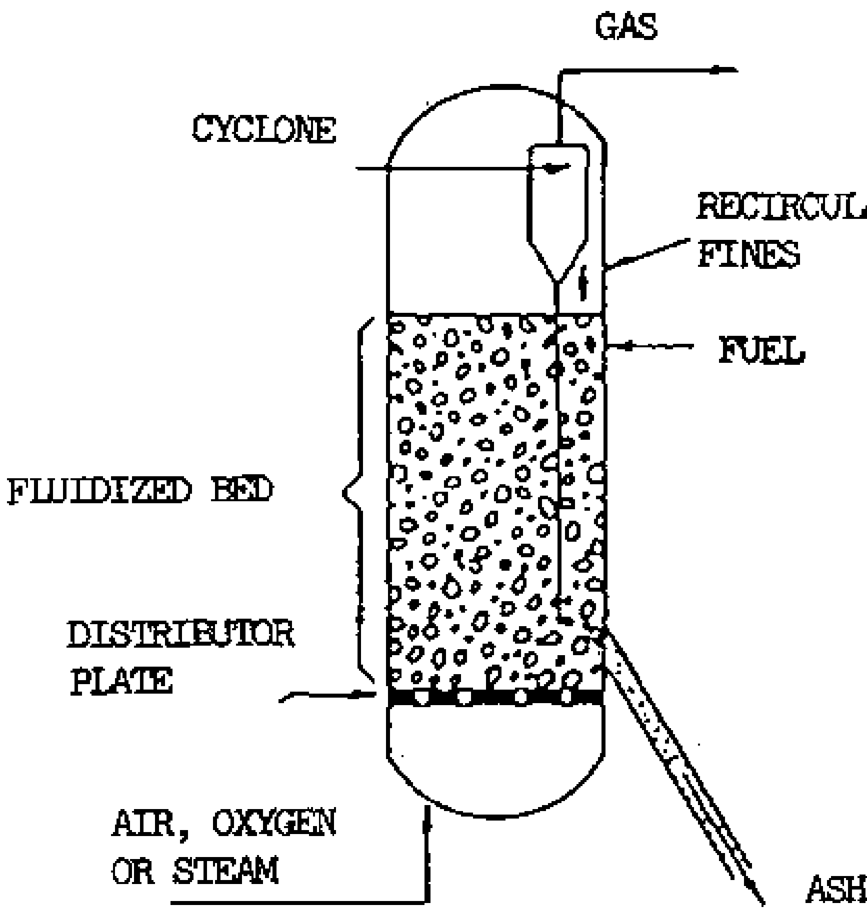


Figure :19 Fluidized bed gasifier

The major advantages of fluidized bed gasifiers, as reported by Van der Aarsen (44) and others, stem from their feedstock flexibility resulting from easy control of temperature, which can be kept below the melting or fusion point of the ash (rice husks), and their ability to deal with fluffy and fine-grained materials (sawdust etc.) without the need of pre- processing. Problems with feeding, instability of the bed and fly-ash sintering in the gas channels can occur with some biomass fuels.

Other drawbacks of the fluidized bed gasifier lie in the rather high tar content of the product gas (up to 500 mg/m^3 gas), the incomplete carbon burn-out, and poor response to load changes.

MAGNETO HYDRO DYNAMIC [MHD] POWER GENERATION

Magneto Hydro-Dynamics Generator:

The principle of Magneto Hydrodynamics (MHD) power generation enables direct conversion of thermal energy to electrical supply. MHD power generation works on Faraday's principle: When electric conductor moves across a magnetic field, a voltage is induced in it which produces an electric current. In MHD generators, the solid conductors are replaced by a fluid which is electrically conducting. The working fluid may be either an ionized gas or a liquid metal. The hot, partially ionized and compressed gas is expanded in a duct, and forced through a strong magnetic field. Electric potential is generated in the gas. Fig. Shows the principle of MHD power generations. Electrodes placed on the side of the duct pick up potential generated in the gas. In this manner, direct current is obtained which can be converted into A.C with the aid of an inverter.

Ionized gas can be produced by heating it to a high temp. As the gas is heated, the outer electrons escape from its atoms or molecules. The gas particles acquire an electric charge and the gas passes into the plasma state. High temps. in excess of 2800^0 C are needed to produce necessary ionization of the gas. However, to achieve thermal ionization of products of combustion of fossil fuels or inert gases, extremely high temps. are needed. Seeding the gas with potassium or cesium helps in ionization and reduces temp. requirement.

MHD generator is at a temp. of about 2500 K and can be used as the heating medium for raising steam in a conventional boiler. This system of power generation is simple and has moving parts, it has high reliability. It can be brought to full power from standby conditions in 45 seconds. The output can be changed from no load to full load in fraction of a second. An experimental power plant of 5 MW of thermal input has been commissioned at Tiruchirapalli.

MHD is concerned with the flow of conducting fluid in the presence of magnetic and electric field. The fluid may be gas at elevated temperature or liquid metal like Sodium or potassium. An MHD generator is A device for converting heat energy of a fuel directly into electrical energy without a conventional electric generator. An MHD converter system is a heat engine in which heat is taken up at a higher temperature and partly converted into useful [electrical] work and the remainder ids rejected at a lower temperature.

The thermal efficiency of an MHD converter is increased by supplying the heat at the highest practical temperature and rejecting it at the lowest practical temperature.

MHD generation is the most promising of the direct conversion techniques for the large-scale production of electric power.

PRINCIPLE OF MHD POWER GENERATION:

The principle of MHD power generation is simply that of Faraday’s law according to which when an electric conductor moves across a magnetic field, a voltage is induced in it which produces an electric current. It is Faraday’s law of electromagnetic induction.

In MHD generator , a gaseous conductor is ionized and passed through a powerful magnetic field at a high velocity , a current is generated and can be extracted by placing electrodes in a suitable position in the stream. This arrangement as shown in figure provides DC power directly.

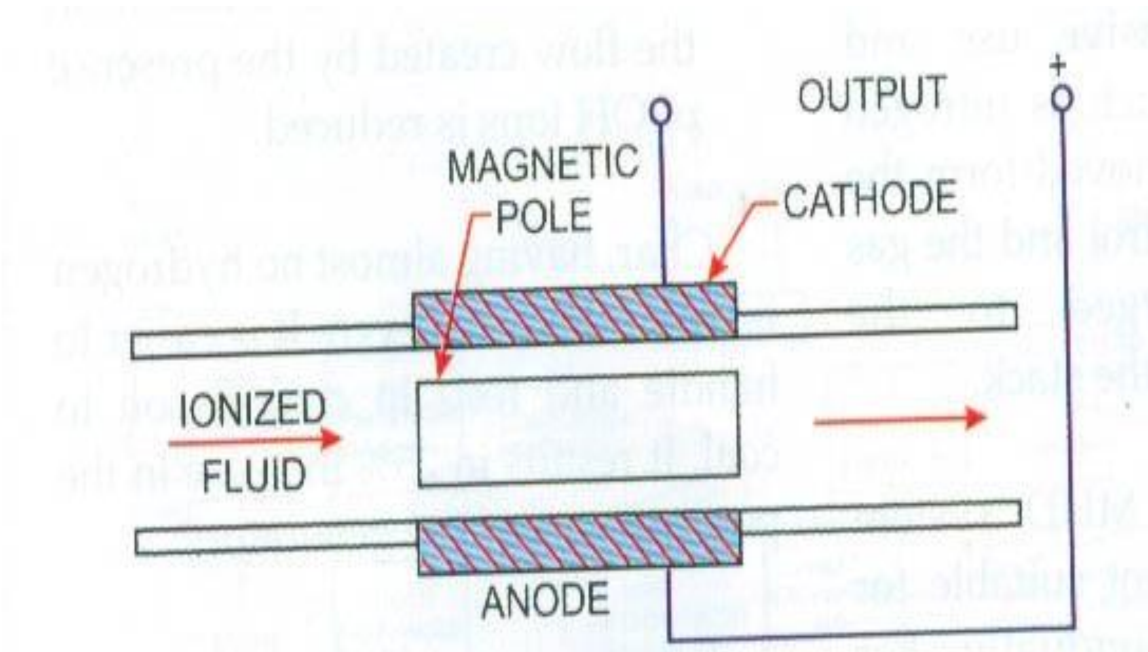


Figure:20 Principle of MHD Power Generation

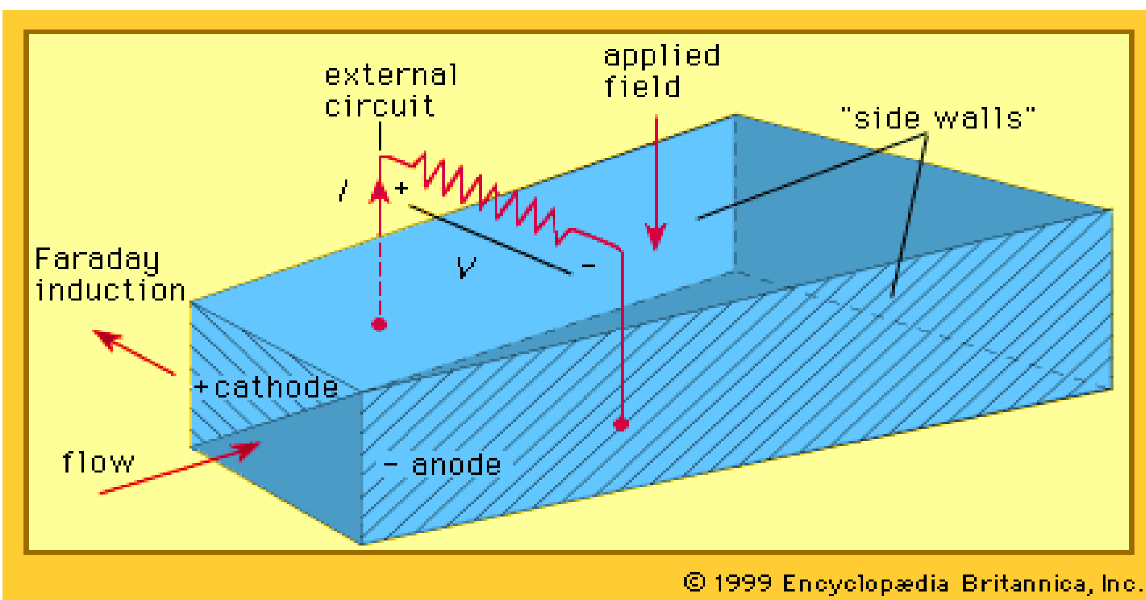


Figure:21 Principle of MHD Power Generation

Thus , kinetic energy is directly converted into electrical energy by the flow of an electrically conducting fluid, usually a gas or a gas-liquid combination , through a stationary magnetic field. If the flow direction is at right angles to the magnetic field direction, an emf is induced in the direction at right angles to both flow and field directions,

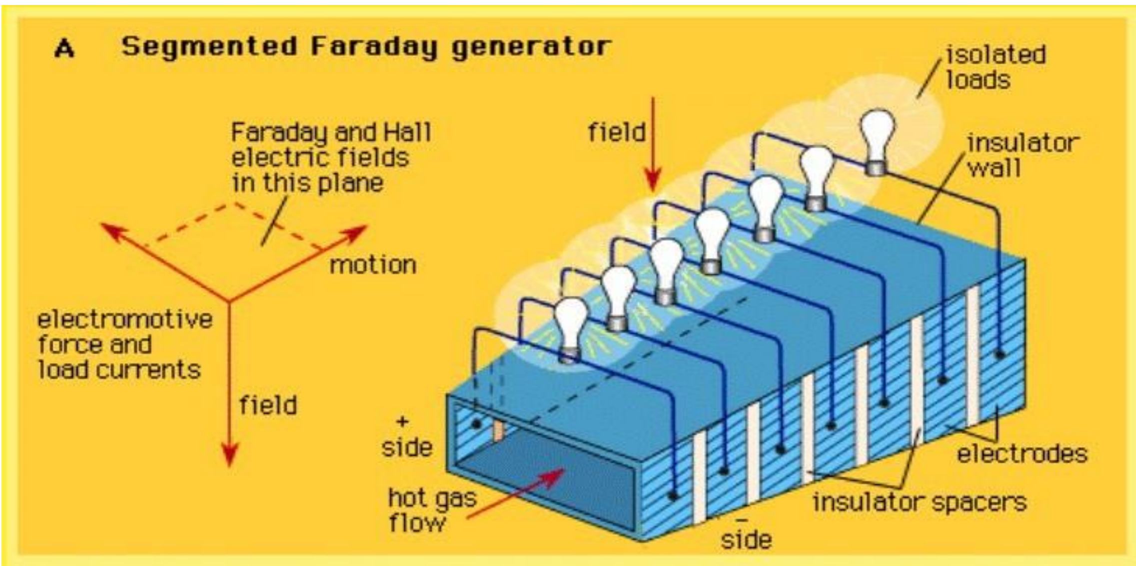


Figure:22 Faradays Law

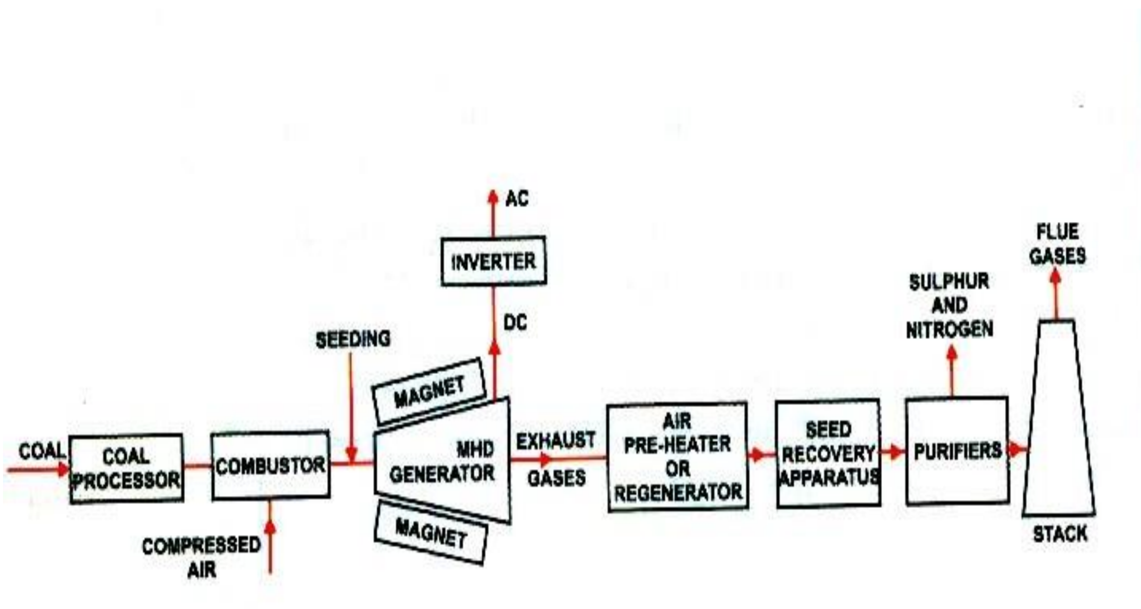


Figure:23 Schematic of an open cycle MHD Generators

Ionization is produced either by thermal means at elevated temperature or by sending with substance like cesium or potassium vapors which ionize at relatively low temperatures. The atoms of the seed element split off electrons . The presence of the negatively charged electrons makes the carrier gas an electrical conductor.

Thermal efficiency= Work output / Heat input

Factors which reduce the efficiency of the converter :

1. Dissipation of energy in the internal resistance of the ionized gas
2. A space charge barrier at the electrode surface
3. Heat transfer through the electrode and insulator walls.
4. Various losses due to fluid friction, etc .
5. Hall effect losses resulting in current induction in the direction of the flow.

To achieve a large power output, the gas must have a high velocity of 1000 m/s and the applied magnetic field density must be as large as possible. One of the major problems is to achieve adequate conductivity in the gas (> 10 mho/ m). To achieve equilibrium conductivities in the pure gas , thermal ionization temperature of tens of thousands of degrees are required. By seeding the gas with elements which have low ionization potentials , such as caesium and potassium , it is possible to achieve reasonable conductivities at gas temperatures in the region of 2000 ^{o} C.

An MHD generator is a device for converting heat energy directly into electrical energy without a conventional electrical energy without a conventional electric generator . High thermal efficiencies is possible . MHD conversion systems can operate as either open or closed cycle system.

In an open cycle system , the working fluid is used on the once through basis. The working fluid is discharged to the atmosphere through a stack after generating electrical energy.
In the closed cycle system , the working fluid is continuously re-circulated ; the discharged working fluid is reheated and recycled to the converter. In an open cycle system , the working

fluid is air . In closed cycle system , helium or argon is used as the working fluid.

OPEN CYCLE MHD POWER GENERATION:

The arrangement of open cycle system , is shown schematically in FIG. Fuel used may be oil through an oil tank or gasified coal through a coal gasification plant. The fuel (coal, oil, or natural gas) is burnt in the combustor. The hot gases from combustor are then seeded with a small amount of an ionized alkali metal (cesium or potassium) to increase the electrical conductivity of the gas. The seed material, generally potassium carbonate, is injected into the combustor , the potassium is then ionized by the hot combustion gases at temperatures of 2300-2700 ^{o} C.

To attain such high temperatures. the compressed air must be preheated to atleast 1100oC . A lower preheat temperature would be adequate if oxygen is used. An alternative is to use compressed oxygen alone for combustion of the fuel so that little or no preheating is required . The hot , pressurized working fluid leaving the combustor flows through a convergent divergent nozzle and the random motion energy of the molecules in the hot gas is largely converted into directed , mass motion energy . Thus , the gas emerges from the nozzle and enters the MHD generator unit at a high velocity.

The MHD generator is a divergent channel made of a heat – resistant alloy (e.g . Inconel) with external water cooling . The hot gas expands through the generator surrounded by powerful magnet. During the motion of the gas , the positive and negative ions move to the electrodes and constitute an electric current. The magnetic field direction is at right angle to the fluid flow. A number of oppositely located electrode pairs are current generated to an external load. An MHD generator produced DC . which can be converted to AC . by means of an inverter.

The seed material is recovered for successive use in seed recovery apparatus. Prior to the discharge of the working gas as flue gas from the steam boils to the atmosphere ,

The fly ash must be removed. It may be treated for recovery of the seed material which is mixed with ash . If sulphur is not removed from the coal , the original K_2CO_3 will have been converted into K_2SO_4 . This must be extracted from the fly ash and reconverted by chemical reactions into K_2CO_3. When oxygen alone is used for combustion of coal or other fossil fuel , nitrogen oxide formation does not arise

FACTORS FAVOURABLE FOR EFFICIENT OPERATION OF AN MHD SYSTEM

1. Air super heating arrangement to heat the gas to around 2500 ^{o} C so that the electrical conductivity of the gas is increased.
2. The combustion chamber must have low heat losses.
3. Arrangement to add a low ionization potential seed material to the gas to increase its conductivity.
4. A water cooled but electrically insulating expanding duct with long life electrodes.
5. Seed recovery apparatus – necessary for both environmental and economic reasons.

ADVANTAGES OF MHD SYSTEMS

1. The conversion efficiency of an MHD system is around 50 % when compared to 40 % for the most efficient steam plants.
2. Large amount of power is generated.
3. It has no moving parts and therefore high reliability.
4. Pollution –free-power.
5. It has the ability to reach full power as soon as its started.
6. The size of the plant (m2/kw) is considerably small than conventional fossil fuel plants
7. Capital costs of MHD plants will be competitive
8. Less operational costs
9. Elimination of boiler & gas turbine reduces the losses of energy
10. Better fuel utilization leading to conservation of energy sources

It is possible to use MHD for peak power generation with rapid start to full load.

CLOSED CYCLE SYSTEM

- Two general types of closed cycle MHD generators are being investigated.
- Electrical conductivity is maintained in the working fluid by ionization of a seed material, as in open cycle system.
- A liquid metal provides the conductivity.
- The carrier is usually a chemical inert gas, all through a liquid carrier is been used with a liquid metal conductor. The working fluid is circulated in a closed loop and is heated by the combustion gases using a heat exchanger. Hence the heat sources and the working fluid are independent. The working fluid is helium or argon with cesium seeding.

SEEDED INERT GAS SYSTEM

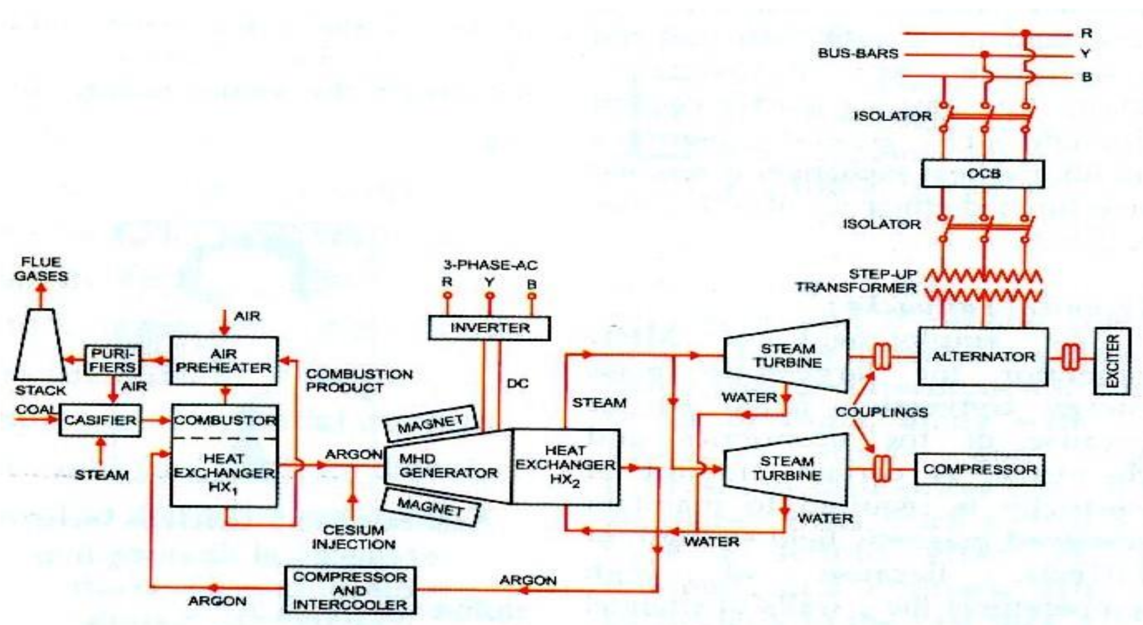


Figure:24 Closed system

In a closed cycle system the carrier gas operates in the form of Brayton cycle. In a closed cycle system the gas is compressed and heat is supplied by the source, at essentially constant pressure, the compressed gas then expands in the MHD generator, and its pressure and temperature fall. After leaving this generator heat is removed from the gas by a cooler, this is the heat rejection stage of the cycle. Finally the gas is recompressed and returned for reheating.

The complete system has three distinct but interlocking loops. On the left is the external

heating loop. Coal is gasified and the gas is burnt in the combustor to provide heat. In the primary heat exchanger, this heat is transferred to a carrier gas argon or helium of the MHD cycle. The combustion products after passing through the air preheated and purifier are discharged to atmosphere.

- Because the combustion system is separate from the working fluid, so also are the a and flue gases. Hence the problem of extracting the seed material from fly ash does not arise. The fuel gases are used to preheat the incoming combustion air and then treated for fly ash and sulfur dioxide removal, if necessary prior to discharge through a stack to the atmosphere.
- The loop in the center is the MHD loop. The hot argon gas is seeding with cesium

  resulting working fluid is passed through the MHD generator at high speed. The dc power out of MHD generator is converted in ac by the inverter and is then fed to the grid.

LIQUID METAL SYSTEM

- When a liquid metal provides the electrical conductivity, it is called a liquid metal MHD system.
- An inert gas is a convenient carrier
- 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 to form the working fluid. The latter then consists of gas bubbles uniformly dispersed in an approximately equal volume of liquid sodium.

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.

UNIT – IV– WIND ENERGY AND OTEC – SCHA4002

WIND ENERGY CONVERSION SYSTEM (WECS)

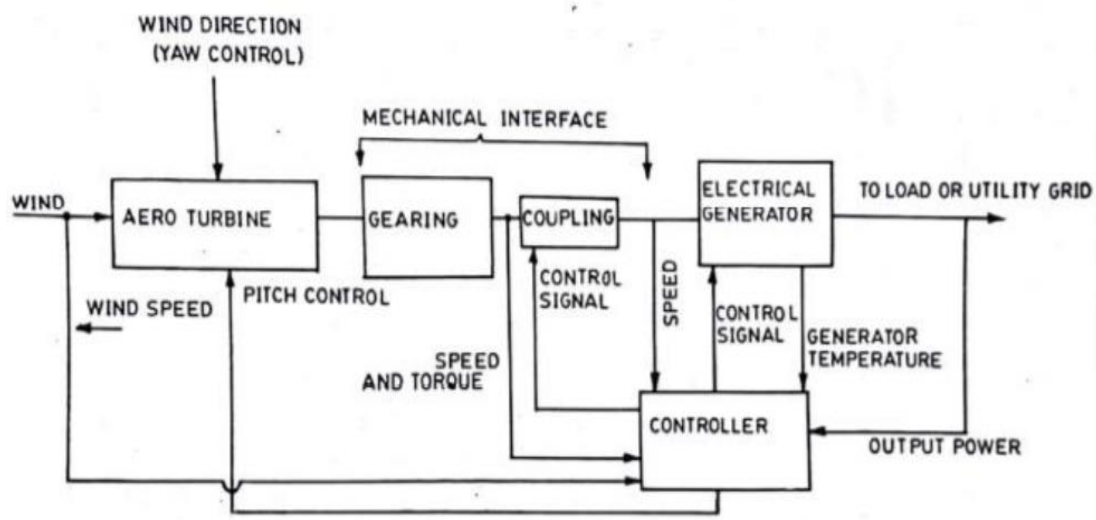


Fig. 6.5.1. Basic components of a Wind Electric System.

Figure:25 Wind Electric System

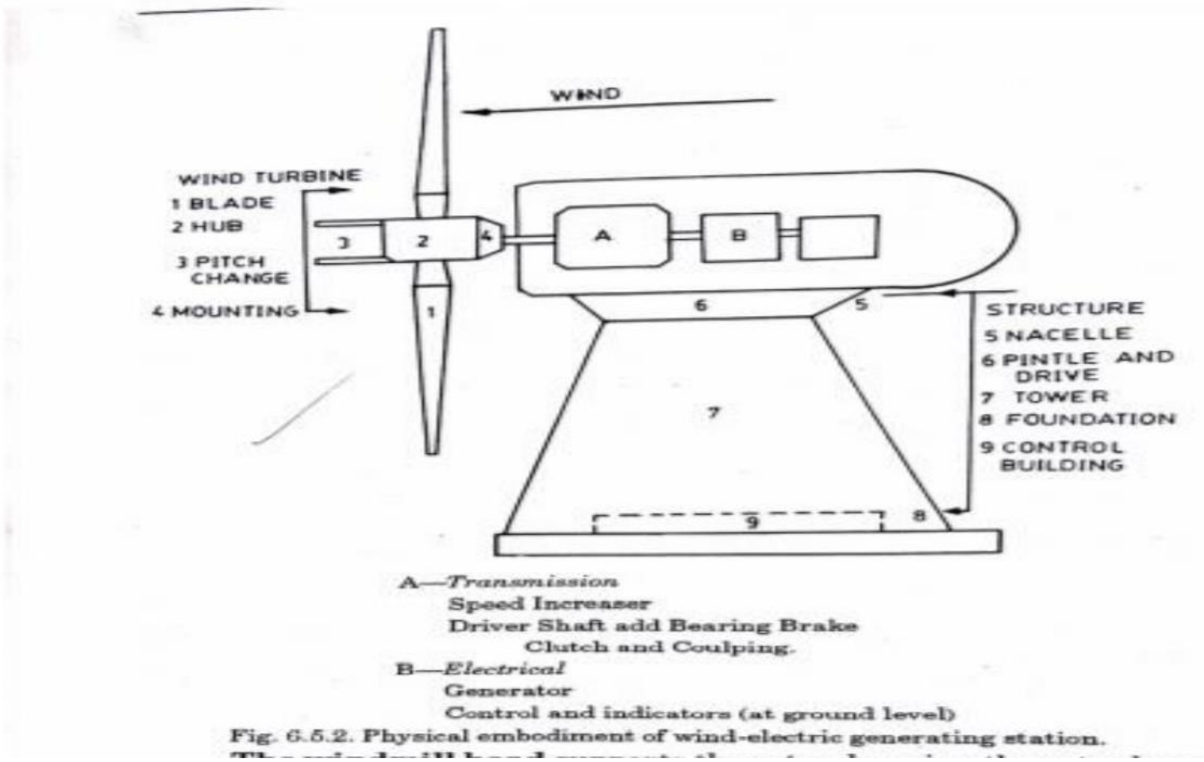


Figure:26 Embodiment of WECS

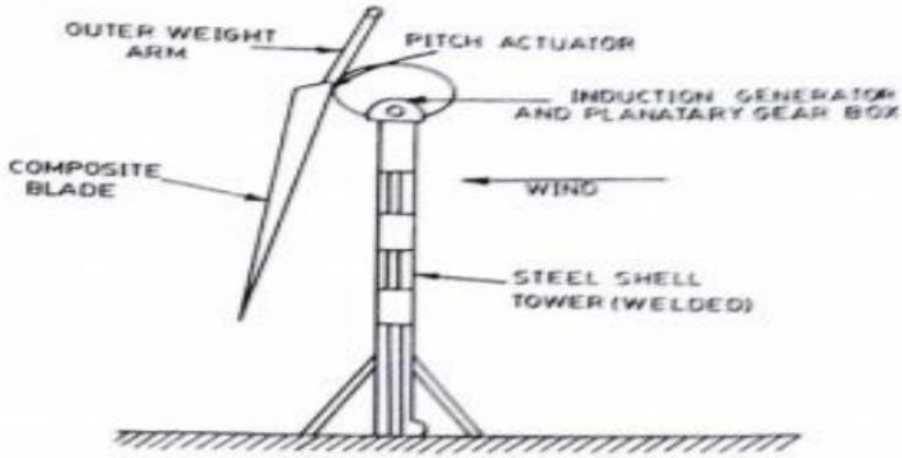


Fig. 6.8.2. Horizontal axis single blade wind mill.

Disadvantages :

(*i*) Vibration produced, due to aerodynamic torque.

(*ii*) Unconventional appearance.

(*iii*) Large blade root bending moment.

(*iv*) Starting-torque reduced by ground boundary layer.

(*v*) One-per-rev coriolis torque produced, due to flapping.

3. *Horizontal axis multibladed type.* This type of design for multiblades as shown in Fig. (6.8.3), made from sheet metal or

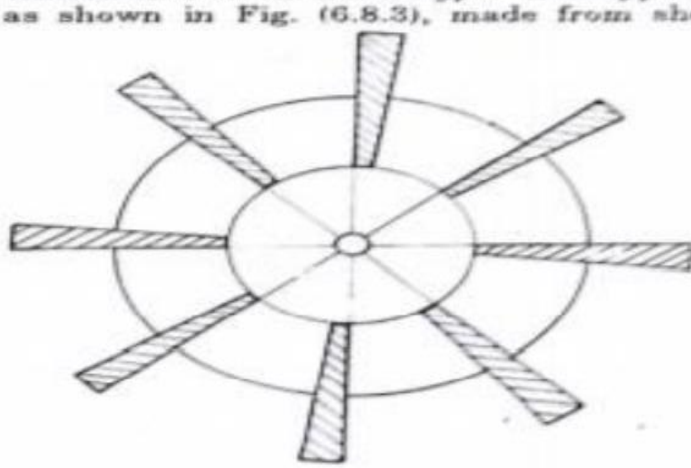


Fig. 6.8.3. Multiblade propeller.

Figure: 27 Multiblade propeller

advantage of simplicity and low cost.

4. *Horizontal axis wind mill-Dutch type*. It is shown in Fig. (6.8.4), is one of the oldest designs. The blade surfaces are made from an array of wooden slats which 'feather' at high wind speeds.

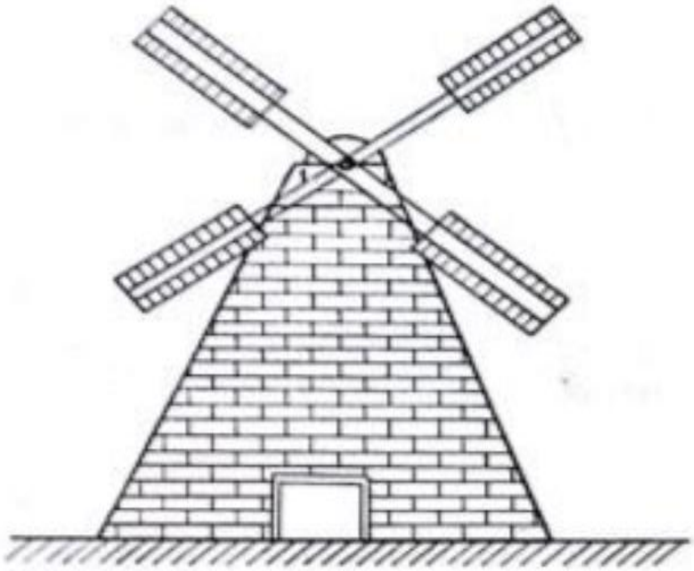


Fig. 6.8.4. Horizontal axis, Dutch type wind mill.

5. *Sail type*. It's blade are shown in Fig. (6.8.5). It is of recent origin. The blade surfaces is made from cloth, nylon or plastics arranged as mast and pole or sailwings. There is also variation in the number of sails used.

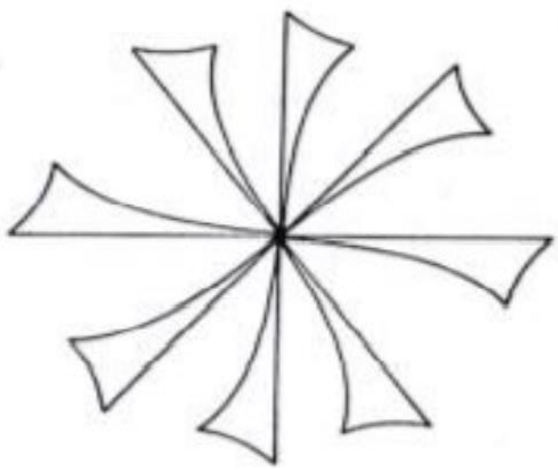
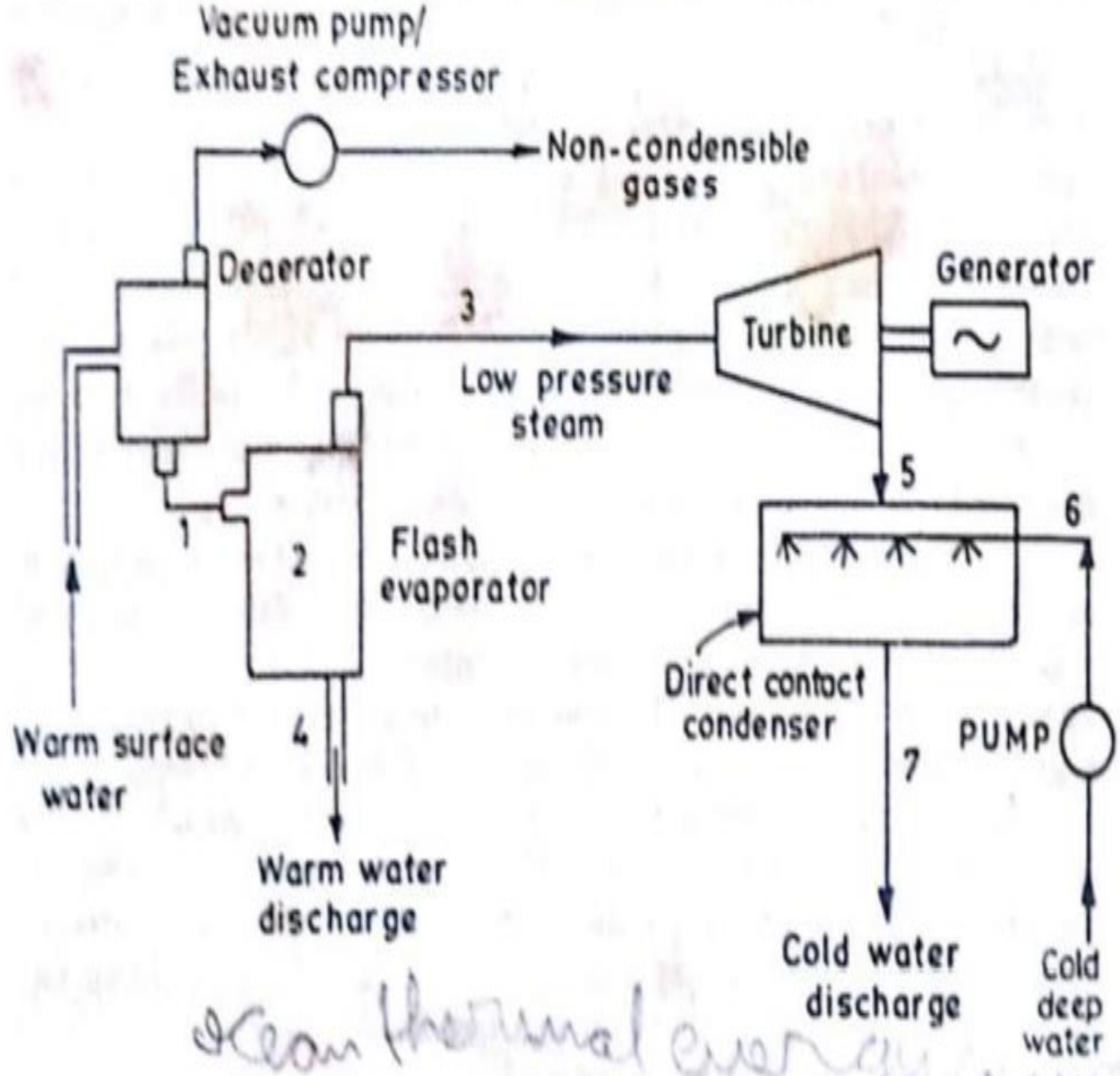


Fig. 6.8.5. Blades of sail type wind mill.

Figure:28 Types of Windmills

system is shown in Fig. (9.2.3.1). Its corresponding T-S diagram is also



Ocean thermal energy conversion

Fig. 9.2.3.1. Schematic of the OTEC open cycle.

Figure:30 OTEC Cycle

9.2.4. The Closed or Anderson, OTEC Cycle

A schematic of a closed-cycle OTEC power plant is shown in Fig. 9.2.4.1. Heat exchanger known as evaporators and condensers are a key ingredient, since extensive areas of material are needed to transfer significant amounts of low quality heat of the low temperature differences being exploited. In other words, large volumes of water must

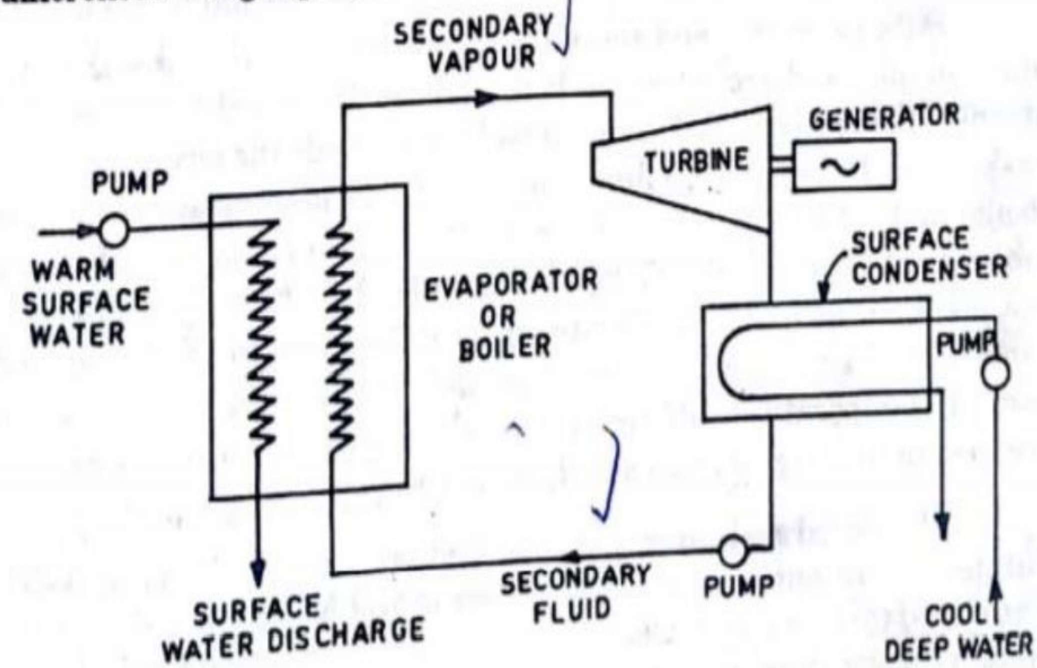


Fig. 9.2.4.1. Schematic of an OTEC closed cycle system.

Figure :31 OTEC Closed cycle system

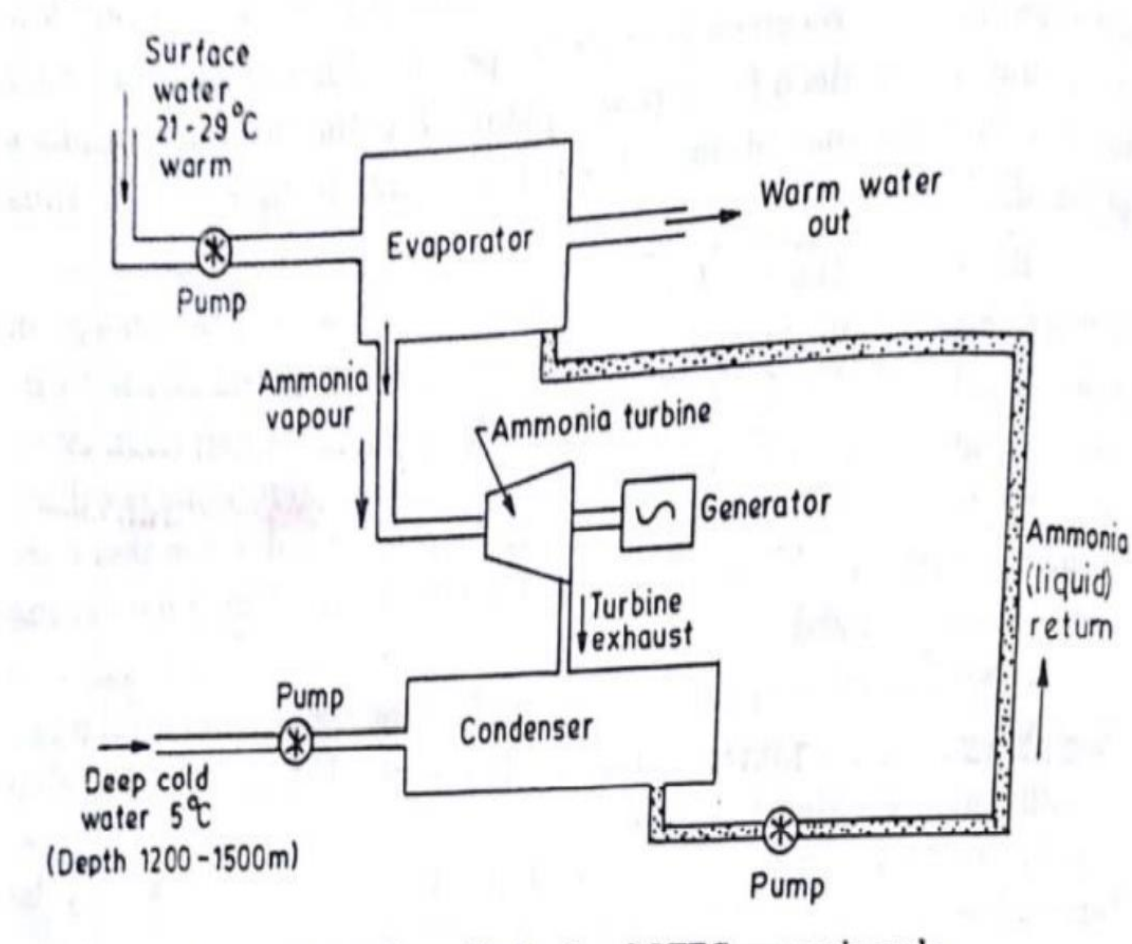


Fig. 9.2.4.2. Schematic of a closed OTEC ammonia cycle.

Figure:32 OTEC ammonia cycle

UNIT – V– FUEL CELLS AND WASTE HEAT RECOVERY-SCHA4002

FUEL CELLS:

Fuel cells are electrochemical devices for the continuous conversion of the portion of the free energy change in a chemical reaction to electrical energy. It differs from a battery in that it operates with continuous replenishment of the fuel and the oxidant at active electrode area and does not require recharging. The main components of a fuel cell are (i) a fuel electrode, (ii) an oxidant or air electrode and (iii) an electrolyte.

Hydrogen as a fuel gives the most promising results but cells consuming coal, oil or natural gas would be economically much more useful for large scale applications. Some of the fuel cells are hydrogen-oxygen, (H_2, O_2), Hydrazine-oxygen (N_2H_4, O_2), Carbon or coal-oxygen (C, O_2), methane-oxygen (CH_4, O_2), etc. Hydrogen-oxygen fuel cells (Hydrox) are efficient and the most highly developed cells. A low-pressure hydrogen-oxygen cell is shown in Fig.6. Two porous carbon or nickel electrodes are immersed in an electrolyte. Catalyst is embedded in nickel electrodes. The electrolyte is typically 30% KOH because of its high electrical conductivity, and it is less corrosive than acids.

A single hydrogen-oxygen cell can produce an emf of 1.23 Volt at atmospheric pressure and 25^0 C. By connecting a number of cells, it is possible to create useful potential of 100 to 1000 Volts and power levels of 1 kW to nearly 100 MW.

Advantages of fuel cells

1.) It is a direct conversion process and does not involve a thermal process, so it has high operating efficiency.

Currently, fuel cell efficiency is 38% and it is expected to reach 60%.

2.) The unit is lighter, smaller and needs less maintenance.

3.) Fuel power plants may further cut generation costs by reducing transmission losses.

4.) Little pollution and little noise so that it can be readily accepted in residential areas.

Other Types of Fuel Cells

- Alkaline fuel cell (AFC)
    - This is one of the oldest designs. It has been used in the U.S. space program since the 1960s. The AFC is very susceptible to contamination, so it requires pure hydrogen and oxygen. It is also very expensive, so this type of fuel cell is unlikely to be commercialized.
- Phosphoric-acid fuel cell (PAFC)
    - The phosphoric-acid fuel cell has potential for use in small stationary power-generation systems. It operates at a higher temperature than PEM fuel cells, so it has a longer warm-up time. This makes it unsuitable for use in cars.
- Solid oxide fuel cell (SOFC)
    - These fuel cells are best suited for large-scale stationary power generators that could provide electricity for factories or towns. This type of fuel cell operates at very high temperatures (around

      1,832 F, 1,000 C). This high temperature makes reliability a problem, but it also has an advantage: The steam produced by the fuel cell can be channeled into turbines to generate more electricity. This improves the overall efficiency of the system.
- Molten carbonate fuel cell (MCFC)
    - These fuel cells are also best suited for large stationary power generators. They operate at 1,112 F (600 C), so they also generate steam that can be used to generate more power. They have a lower operating temperature than the SOFC, which means they don't need such exotic materials. This makes the design a little less expensive**.**

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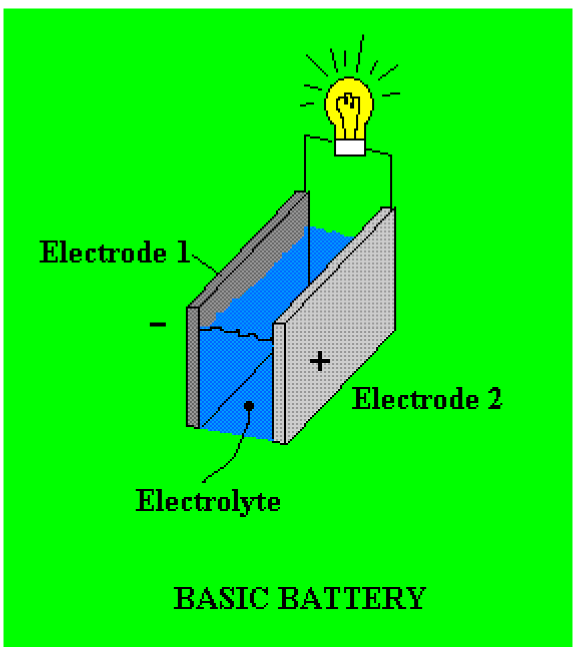
Advantages/Disadvantages of Fuel Cells

- Advantages
    - Water is the only discharge (pure H_2)

- Disadvantages
  - CO_2 discharged with methanol reform
  - Little more efficient than alternatives
  - Technology currently expensive
    - Many design issues still in progress
  - Hydrogen often created using “dirty” energy (*e.g.*, coal)
  - Pure hydrogen is difficult to

handle Refilling stations, storage tanks.



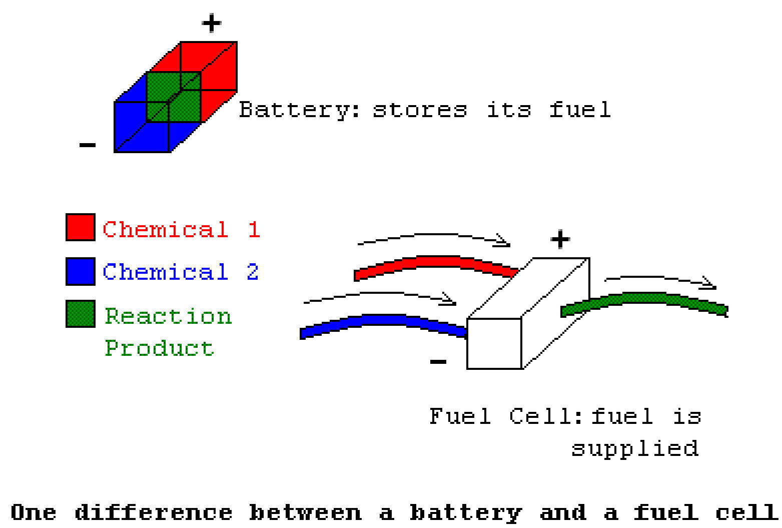


Figure:33 Basic Battery functions

For a Fuel Cell:

1. The electrodes are not consumed: As long as fuel is supplied, the cell will generate a voltage: it won't 'run down'.
2. The amount of energy is determined by the amount of gas reactants.
3. It can supply energy continuously.

Alkaline Fuel Cell

What's so interesting about Alkaline Fuel Cells?
They were used by NASA on Apollo and the Space Shuttle. They are less expensive than PEM cells (which are popular with the automotive industry), but very reliable. However, their use is limited for several reasons. One is they need clean, pure oxygen, not air. On Apollo and the Shuttle this was OK because it was available from the rocket fuel (liquid Oxygen). For automotive uses this is a problem. PEM cells, on the otherhand, can use straight air. Here's how the Alkaline Fuel Cell works.
In any fuel cell, hydrogen (H_2) and oxygen (O_2) are combined to form water (H_2O). The reaction is spontaneous and exothermic. The energy released from that reaction is harnessed in the form of electrical energy.
How?
When water is formed from two Hydrogens and an Oxygen, the Hydrogen gives up its electron. But instead of allowing the two electrons (one from each Hydrogen atom) to reach the Oxygen immediately, we
When electrons are officially exchanged between atoms, we have what's called an "Oxidation-Reduction.

PEM Fuel Cell

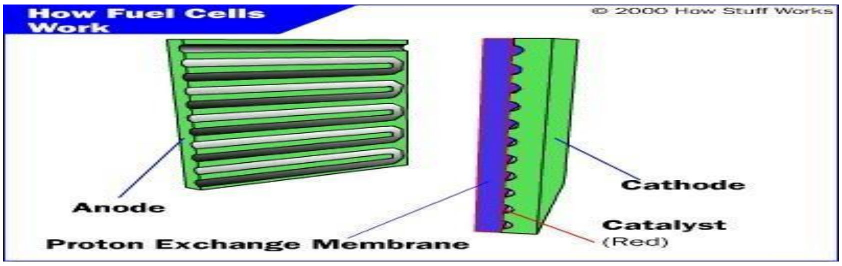


Figure:34 PEM fuel cell

Electrolyte

Proton exchange membrane.

Specially treated material only conducts positively charged ions.

Membrane blocks electrons.

Catalyst

Special material that facilitates reaction of oxygen and hydrogen Usually platinum powder very thinly coated onto carbon paper or cloth.

Rough & porous maximizes surface area exposed to hydrogen or oxygen

The platinum-coated side of the catalyst faces the PEM.

Fuel Cell Operation

- Pressurized hydrogen gas (H_2) enters cell on anode side.
- Gas is forced through catalyst by pressure.

When H_2 molecule comes contacts platinum catalyst, it splits into two H^+ ions and two electrons (e^-).

- Electrons are conducted through the anode
  - Make their way through the external circuit (doing useful work such as turning a motor) and return to the cathode side of the fuel cell.
- On the cathode side, oxygen gas (O_2) is forced through the catalyst
  - Forms two oxygen atoms, each with a strong negative charge.
  - Negative charge attracts the two H^+ ions through the membrane,
- Combine with an oxygen atom and two electrons from the external circuit to form a water molecule (H_2O).Proton-Exchange Membrane Cell

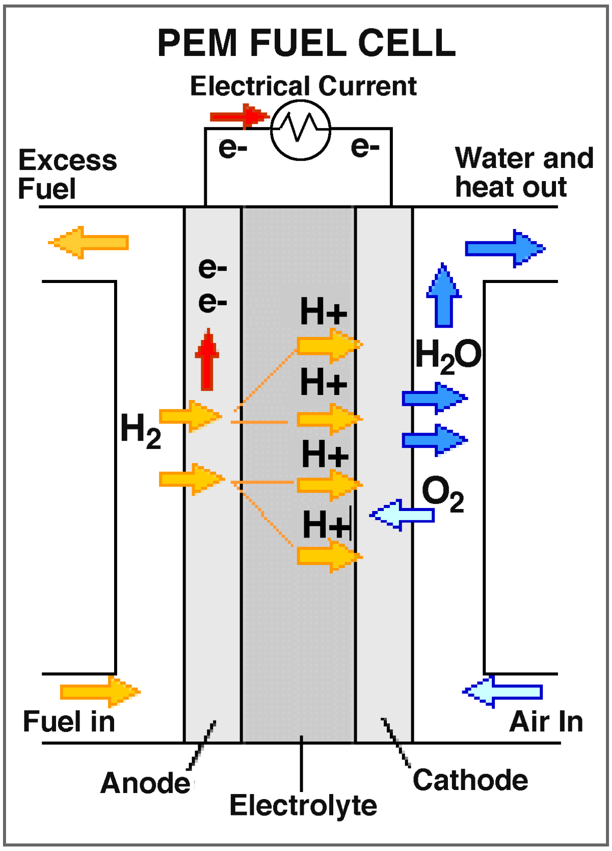


Figure:35 PEM Fuel cell

Other Types of Fuel Cells

Alkaline fuel cell (AFC)

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Solid oxide fuel cell (SOFC)

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The steam produced by the fuel cell can be channeled into turbines to generate more electricity. This improves the overall efficiency of the system.

Molten carbonate fuel cell (MCFC)

These fuel cells are also best suited for large stationary power generators. They operate at 1,112 F (600 C), so they also generate steam that can be used to generate more power. They have a lower operating temperature than the SOFC, which means they don't need such exotic materials. This makes the design a little less expensive.

Principle of Cogeneration

Cogeneration or Combined Heat and Power (CHP) is defined as the sequential generation of two different forms of useful energy from a single primary energy source, typically mechanical energy and thermal energy. Mechanical energy may be used either to drive an alternator for producing electricity, or rotating equipment such as motor, compressor, pump or fan for delivering various services. Thermal energy can be used either for direct process applications or for indirectly producing steam, hot water, hot air for dryer or chilled water for process cooling. Cogeneration provides a wide range of technologies for application in various domains of economic activities.

Overall efficiency of energy use in cogeneration mode can be up to 85 per cent and above in some

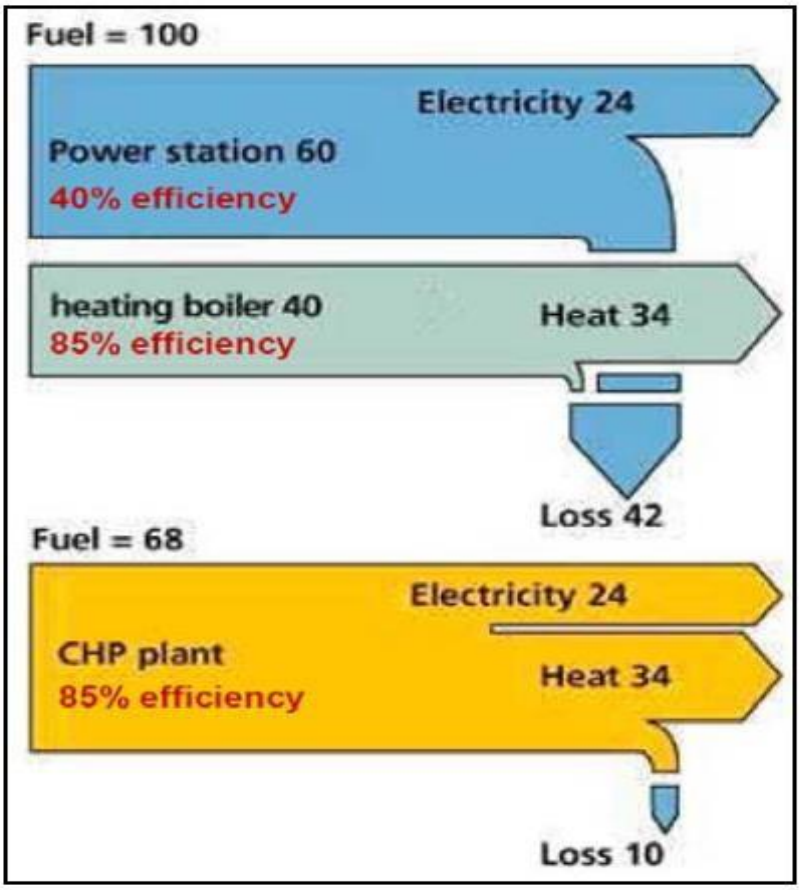
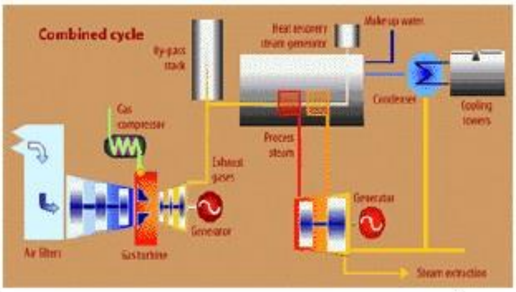
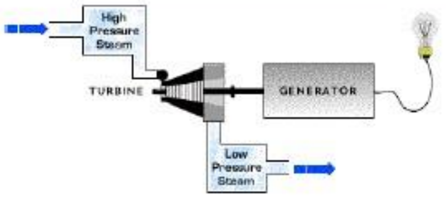
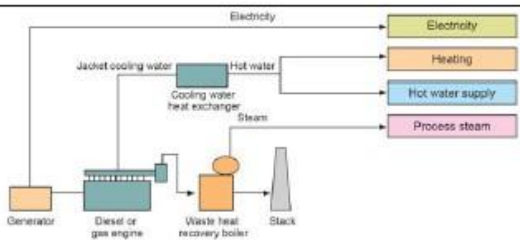
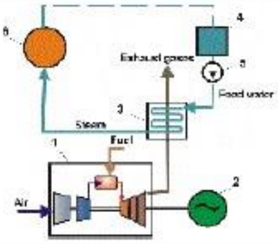


Figure 7.2 Cogeneration advantage

Figure:36 COGENERATION

Classification of Cogeneration Systems Cogeneration systems are normally classified according to the sequence of energy use and the operating schemes adopted. A cogeneration system can be classified as either a topping or a bottoming cycle on the basis of the sequence of energy use. In a topping cycle, the fuel supplied is used to first produce power and then thermal energy, which is the by-product of the cycle and is used to satisfy process heat or other thermal requirements. Topping cycle cogeneration is widely used and is the most popular method of cogeneration.

Table 7.1 Types of topping Cycles	
A gas turbine or diesel engine producing electrical or mechanical power followed by a heat recovery boiler to create steam to drive a secondary steam turbine. This is called a combined-cycle topping system.	
The second type of system burns fuel (any type) to produce high-pressure steam that then passes through a steam turbine to produce power with the exhaust provides low-pressure process steam. This is a steam-turbine topping system.	
A third type employs heat recovery from an engine exhaust and/or jacket cooling system flowing to a heat recovery boiler, where it is converted to process steam / hot water for further use.	
The fourth type is a gas-turbine topping system. A natural gas turbine drives a generator. The exhaust gas goes to a heat recovery boiler that makes process steam and process heat	

Bottoming Cycle In a bottoming cycle, the primary fuel produces high temperature thermal energy and the heat rejected from the process is used to generate power through a recovery boiler and a turbine generator. Bottoming cycles are suitable for manufacturing processes that require heat at high temperature in furnaces and kilns and reject heat at significantly high temperatures. Typical areas of application include cement, steel, ceramic, gas and petrochemical industries. Bottoming cycle plants are much less common than topping cycle plants. The Figure 7.6

illustrates the bottoming cycle where fuel is burnt in a furnace to produce synthetic rutile. The waste gases coming out of the furnace is utilized in a boiler to generate steam, which drives the turbine to produce electricity.

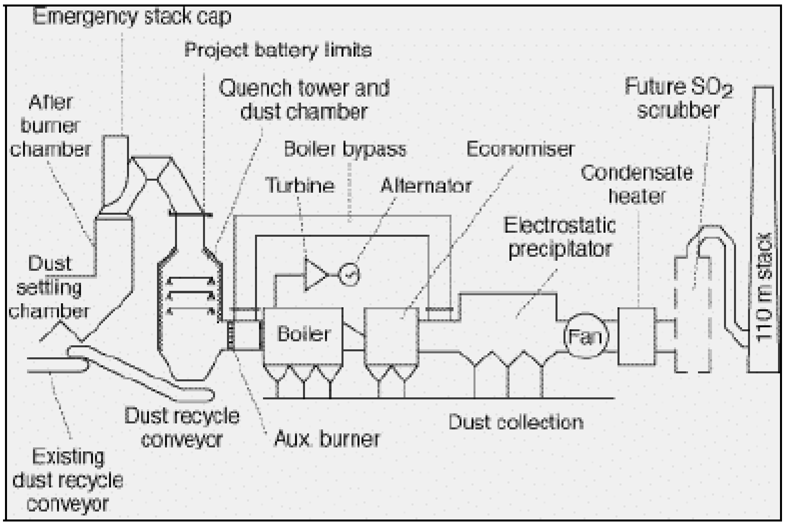


Figure 7.6 Bottoming Cycle

Figure:37 Bottoming Cycle

WASTE HEAT RECOVERY

Waste heat is heat, which is generated in a process by way of fuel combustion or chemical reaction, and then "dumped" into the environment even though it could still be reused for some useful and economic purpose. The essential quality of heat is not the amount but rather its "value". The strategy of how to recover this heat depends in part on the temperature of the waste heat gases and the economics involved. Large quantity of hot flue gases is generated from Boilers, Kilns, Ovens and Furnaces. If some of this waste heat could be recovered, a considerable amount of primary fuel could be saved. The energy lost in waste gases cannot be fully recovered. However, much of the heat could be recovered and loss minimized by adopting following measures as outlined in this chapter.

Benefits of Waste Heat Recovery Benefits of 'waste heat recovery' can be broadly classified in two categories:

Direct Benefits: Recovery of waste heat has a direct effect on the efficiency of the process. This is reflected by reduction in the utility consumption & costs, and process cost.

Indirect Benefits: a) Reduction in pollution: A number of toxic combustible wastes such as carbon monoxide gas, sour gas, carbon black off gases, oil sludge, Acrylonitrile and other plastic chemicals etc, releasing to atmosphere if/when burnt in the incinerators serves dual purpose i.e. recovers heat and reduces the environmental pollution levels. b) Reduction in equipment sizes: Waste heat recovery reduces the fuel consumption, which leads to reduction in the flue gas produced. This results in reduction in equipment sizes of all flue gas handling equipments such as fans, stacks, ducts, burners, etc. c) Reduction in auxiliary energy consumption: Reduction in equipment sizes gives additional benefits in the form of reduction in auxiliary energy consumption like electricity for fans, pumps etc.

Recuperators

In a recuperator, heat exchange takes place between the flue gases and the air through metallic or ceramic walls. Duct or tubes carry the air for combustion to be preheated; the other side contains the waste heat stream. A recuperator for recovering waste heat from flue gases is shown in Figure 8.1. The simplest configuration for a recuperator is the metallic radiation recuperator, which consists of two concentric lengths of metal tubing as shown in Figure 8.2. The inner tube carries the hot exhaust gases while the external annulus carries the combustion air from the atmosphere to the air inlets of the furnace burners. The hot gases are cooled by the incoming combustion air which now carries additional energy into the combustion chamber. This is energy which does not have to be supplied by the fuel;

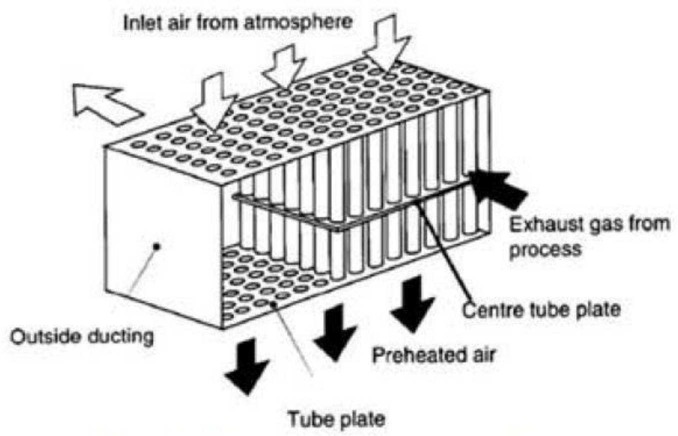


Figure 8.1 Waste Heat Recovery using Recuperator

Figure:38 Waste heat recovery using Recuperator

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