

ACS COLLEGE OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

SUBJECT: ELEMENTS OF MECHANICAL ENGINEERING

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MODULE – 1

Topics Covered:

- *Sources of Energy (Page No : 02 – 19)*
- *Steam Formation and its Properties (Page No: 20-23)*

COMMON TO SECTION D, E, F,

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MODULE – 1

ENERGY RESOURCES

Energy Resources: Non-renewable and renewable energy resources, Petroleum based solid, liquid and gaseous fuels, Calorific values of fuels, Combustion and combustion products of fuels, **Solar Power:** Solar Radiation, Solar constant (definition only), Solar Thermal energy harvesting, ex: liquid flat plate collectors, solar ponds (principle of operation only), Solar photovoltaic principle. **Wind Power:** principle of operation of a typical windmill. **Hydro Power:** Principles of electric power generation from hydropower plants, **Nuclear Power:** Principles of Nuclear power plants, **Bio Fuels:** introduction to bio fuels, examples of various biofuels used in engineering applications, Comparison of biofuels with petroleum fuels in terms of calorific value and emission. **Steam Formation and Properties:** wet steam, saturated and superheated steam, specific volume, enthalpy and internal energy.

Resources and its Classification

All things that are useful to us are called resources. Air, water, land, soil, **forest** etc are all resources. Resources are useful raw materials that we get from nature. These are naturally occurring materials. They are useful for us in many ways, and we keep developing new ways to use them or convert them into useful things.

Energy Resources: energy is defined as the capacity to do work. it is primary requirement for day to day activities of human beings.

ENERGY- Capacity to do work.

- Most of the energy that we use is mainly derived from conventional energy sources.
- Due to the vast demand of energy, the rate of depletion of these resources has reached alarmingly low levels.
- This situation has directed us to seek alternate energy sources such as solar, wind, ocean, biomass, Hydel etc.

ENERGY SOURCES:

- The energy existing in the earth is known as CAPITAL energy.
- Energy that comes from outer space is called CELESTIAL energy.
- The CAPITAL energy sources are mainly, fossil fuels, nuclear fuels and heat traps.
- CELESTIAL ENERGY SOURCES ARE- Electromagnetic, gravitational and particle energy from stars, planets, moon etc.
- ELECTROMAGNETIC ENERGY of the earth's sun is called DIRECT SOLAR ENERGY. This results in WIND, HYDEL, GEOTHERMAL, BIOFUEL, etc.
- GRAVITATIONAL ENERGY of earth's moon produces TIDALENERGY.

RENEWABLE SOURCES OF ENERGY:

Energy sources which are continuously produced in nature and are essentially inexhaustible are called renewable energy sources.

- | | |
|-------------------------|-----------------|
| 1. Direct solar energy | 2. Wind energy |
| 3. Tidal energy | 4. Hydel energy |
| 5. Ocean thermal energy | 6. Bio energy |
| 7. Geo thermal energy | 8. Peat |
| 9. Fuel wood | 10. Fuel cells |
| 11. Solid wastes | 12. Hydrogen |

NONRENEWABLE ENERGY SOURCES:

Energy sources which have been accumulated over the ages and not quickly replenishable when they are exhausted.

1. Fossil fuels.
2. Nuclear fuels.
3. Heat traps.

ADVANTAGES OF RENEWABLE ENERGY SOURCES:

1. Non exhaustible.
2. Can be matched in scale to the need and can deliver quality energy.
3. Can be built near the load point.
4. Flexibility in the design of conversion systems.

5. Local self-sufficiency by harnessing locally available renewable energy.
6. Except biomass, all other sources are pollution free.

DISADVANTAGES OF RENEWABLE ENERGY SOURCES:

1. Intermittent nature of availability of energy such as solar, wind, tidal etc. is a major setback in the continuous supply of energy.
2. Solar energy received at the earth is dependent on local atmosphere conditions, time of the day, part of the year etc.
3. Sources such as wind, tidal etc. are concentrated only in certain regions.
4. Technology is not fully developed to meet the present energy requirements.
5. Systems such as solar cells require advanced technologies and hence costlier.
6. Application to transport sector has been found to be not viable as on today.

ADVANTAGES OF NON-RENEWABLE ENERGY SOURCES:

1. Initial cost are lower. Hence widely used.
2. Unit power costs are much lower and so are economical.
3. Sources are highly reliable.
4. Power generation technologies are well established.

DISADVANTAGES OF NON-RENEWABLE ENERGY SOURCES:

1. The sources are getting depleted and soon will be exhausted.
2. They pollute the atmosphere.
3. They are not freely available.

Difference between Renewable and Non-renewable Resources

Renewable Resources	Non-renewable Resources
It can be used again and again throughout its life.	It cannot be used again and again as it is limited which can be depleted one day.
They are the energy resources which cannot be exhausted.	They are the energy resources which can be exhausted one day.
It is environment-friendly as the amount of carbon emission is low.	It is not environment-friendly as the amount of carbon emission is high.
These resources are present in unlimited quantity.	These resources are present in a limited quantity only.
The total cost of these resources is low.	The total cost of these resources is comparatively high.

These resources are pollution free.	These resources are not pollution free.
The maintenance cost of the renewable resources is very high.	The maintenance cost of the renewable resources is low.
Requires large land area for the installation of the power plant.	Requires less land area for the installation of the power plant.
It is sustainable	It is exhaustible
The rate of renewal is greater than the rate of consumption.	The rate of renewal is lower than the rate of consumption.
Causes no harm to life existing on the planet earth.	Adversely affect the health of humans by emitting smoke, radiations, carcinogenic or cancer causing elements into the environment.
Sunlight, are the examples of renewable resources.	Coal, petroleum, natural gases, batteries, are the examples of non-renewable resources

Petroleum based Fuels:

Formed mainly from ancient microscopic plants and bacteria that lived in the ocean and salt water seas. These micro-organisms died and settled to the sea floor, they mixed with sand silt to form organic rich mud which was gradually heated and compressed chemically transforming into petroleum. The liquid petroleum gases which are less dense than water move upwards through earth's crust. It passes through an impermeable layer of rock which traps the petroleum creating a reservoir of petroleum and natural gas.

Types of Fuels: - The important fuels are as follows-

1) Solid fuels, 2) Liquid fuels & 3) Gaseous fuels

Solid fuels

- ✓ Coal is the major fuel used for thermal power plants to generate steam.
- ✓ Coal occurs in nature, which was formed by the decay of vegetable matters buried under the earth millions of years ago under pressure and heat.
- ✓ This phenomenon of transformation of vegetable matter into coal under earth's crust is known as Metamorphism.
- ✓ The type of coal available under the earth's surface depends upon the period of metamorphism and the type of vegetable matter buried, also the pressure and temperature conditions.
- ✓ The major constituents in coal moisture (5-40%), volatile matter (combustible & or incombustible substances about 50%) and ash (20-50%).
- ✓ The chemical substances in the coal are carbon, hydrogen, nitrogen, oxygen and sulphur.

- ✓ In the metamorphism phenomenon, the vegetable matters undergo the transformation from peat to anthracite coal, with intermediate forms of lignite and bituminous coal.

Liquid Fuels

- All types of liquid fuels used are derived from crude petroleum and its by-products.
- The petroleum or crude oil consists of 80-85% C, 10-15% hydrogen, and varying percentages of sulphur, nitrogen, oxygen and compounds of vanadium.
- The crude oil is refined by fractional distillation process to obtain fuel oils, for industrial as well as for domestic purposes.
- The fractions from light oil to heavy oil are naphtha, gasoline, kerosene, diesel and finally heavy fuel oil.
- The heavy fuel oil is used for generation of steam. The use of liquid fuels in thermal power plants has many advantages over the use of solid fuels.

Some important advantages are as follows:

- 1) The storage and handling of liquid fuels is much easier than solid and gaseous fuels.
- 2) Excess air required for the complete combustion of liquid fuels is less, as compared to the solid fuels.
- 3) Fire control is easy and hence changes in load can be met easily and quickly.
- 4) There are no requirements of ash handling and disposal.
- 5) The system is very clean, and hence the labour required is relatively less compared to the operation with solid fuels.

Gaseous Fuels

- For the generation of steam in gas fired thermal plants, either natural gas or manufactured gaseous fuels are used. However, manufactured gases are costlier than the natural gas.
- Generally, natural gas is used for power plants as it is available in abundance. The natural gas is generally obtained from gas wells and petroleum wells.
- The major constituent in natural gas is methane, about 60-65%, and also contains small amounts of other hydrocarbons such as ethane, naphthenic and aromatics, carbon dioxide and nitrogen.
- The natural gas is transported from the source to the place of use through pipes, for distances to several hundred kilometres.
- The natural gas is colourless, odourless and non-toxic.
- Its calorific value ranges from 25,000 to 50,000 kJ/m³, in accordance with the percentage of methane in the gas.
- The artificial gases are producer gas, water gas coke-oven gas; and the Blast furnace gas.
- Generally, power plants fired with artificial gases are not found.

- The gaseous fuels have advantages similar to those of liquid fuels, except for the storage problems.
- The major disadvantage of power plant using natural gas is that it should be setup near the source; otherwise the transportation losses are too high.

Calorific values of fuels:

The calorific value or heat of combustion or heating value of a sample of fuel is defined as the amount of heat evolved when a unit weight (or volume in the case of a sample of gaseous fuels) of the fuel is completely burnt.

It is usually expressed in Gross Calorific Value (GCV) or Higher Heating Value (HHV) and Net Calorific Value (NCV) or Lower Heating Value (LHV).

Higher Calorific Value (or Gross Calorific Value - GCV, or Higher Heating Value - HHV) - the water of combustion is entirely condensed and that the heat contained in the water vapor is recovered
Lower Calorific Value (or Net Calorific Value - NCV, or Lower Heating Value - LHV) - the products of combustion contains the water vapor and that the heat in the water vapor is not recovered

Combustion and Combustion Products:

Combustion or burning is the sequence of exothermic chemical reactions between a fuel and an oxidant accompanied by the production of heat and conversion of chemical species. The release of heat can produce light in the form of either glowing or a flame. Complete combustion of fuel is possible only in the presence of an adequate supply of oxygen.

Oxygen (O_2) is one of the most common elements on earth making up 20.9% of our air. Rapid fuel oxidation results in large amount of heat. Solid or liquid fuels must be changed to a gas before they will burn in their normal state if enough air is present.

Most of the 79% of air (that is not oxygen) is nitrogen, with the traces of other elements. Nitrogen is considered to be a temperature reducing diluter that must be present to obtain the oxygen required combustion.

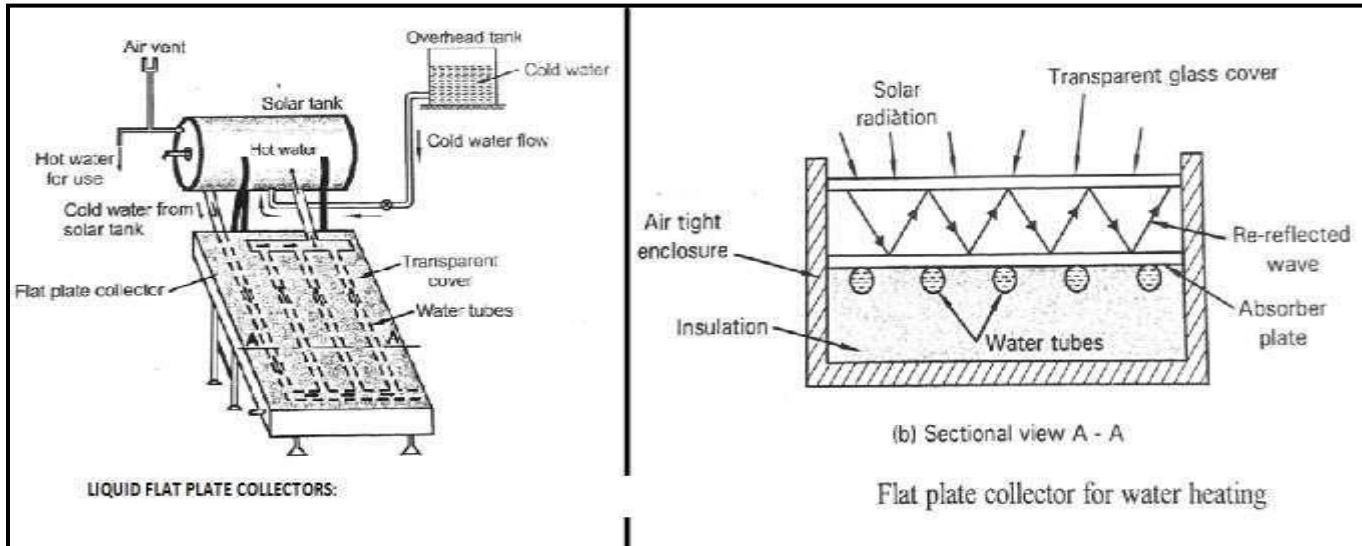
Nitrogen reduces combustion efficiency by absorbing heat from the combustion of fuels and diluting the flue gases. This reduces the heat available for transfer through the heat exchange surfaces. It also increases the volume of combustion by products. Which then have to travel through the heat exchanger and up the stack faster to allow the introduction of additional fuel-air mixture.

This nitrogen also can combine with oxygen (particularly flame temperatures) to produce oxides of nitrogen (NO_x) which are toxic pollutants. Carbon, hydrogen and sulphur in the fuel combine with oxygen in the air to form carbon dioxide, water vapour and sulphur dioxide, releasing 8084 kJ, 28922 kJ and 2224 kJ of heat respectively. Under certain conditions, carbon may also combine with the oxygen to form carbon monoxide, which results in the release of smaller quantity of heat (2430 kJ/kg of carbon). Carbon burned to CO_2 will produce more heat per unit of fuel than CO or smokes are produced.

There are two types of collectors:

(a) Flat plate collectors (b) Focusing collectors.

LIQUID FLAT PLATE COLLECTORS:



It has the following components:

(a) Absorbing plate –

- ☐ Made of Copper, Aluminium or steel.
- ☐ It is coated with material to enhance the absorption of solar radiation.
- ☐ From the absorbing plates heat is transferred to tubes which carry either water or air.

(b) Water tubes –

- ☐ These are metallic tubes through which water circulates. Which are attached to the absorber plate.

(c) Transparent covers –

- Sheets of solar radiation transmitting materials placed above the absorbing plate.
- They allow solar energy to reach the absorbing plate while reducing convection, conduction and re-radiation heat losses.
- Made of a toughened glass, usually 4mm thick. Which helps in reflecting the incident solar energy back to the absorber plate.
- Glass cover permits the entry of solar radiation as it is transparent for incoming short wave lengths.

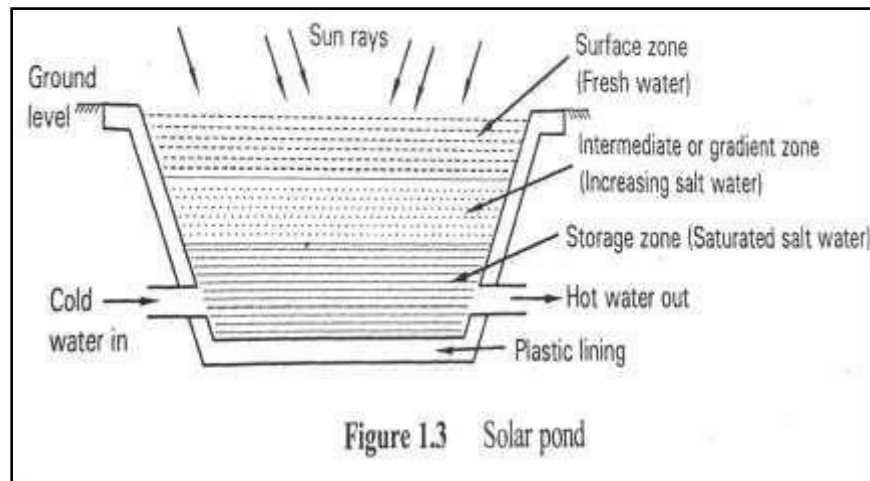
(d) Insulation –

- It minimizes and protects the absorbing plate from heat losses.

Working – Sun's rays falling on the transparent covers are transmitted to the absorbing plate. The absorbing plate usually of Cu, Al or galvanized iron is painted dead black for maximum absorption. The collector (plate) will absorb the sun energy and transfer it to the fluid in the pipe beneath the collector plate.

Use of flat mirrors on the sides improves the output. Water from the overhead tank is made to flow through the water tubes. Solar rays pass through the transparent cover and fall on the absorber plate. Heat energy from the absorber plate is transferred to the cold water flowing through the tubes. Warm water rises above the cold water because of low density and flows into the heater tank.

SOLAR POND:



- A salinity gradient solar pond is an integral collection and storage device of solar energy.
- By virtue of having built-in thermal energy storage, it can be used irrespective of time and season.
- In an ordinary pond or lake, when the sun's rays heat up the water this heated water, being lighter, rises to the surface and loses its heat to the atmosphere.
- The net result is that the pond water remains at nearly atmospheric temperature.
- The solar pond technology inhibits these phenomena by dissolving salt into the bottom layer of this pond, making it too heavy to rise to the surface, even when hot.
- The salt concentration increases with depth, thereby forming a salinity gradient.
- The sunlight which reaches the bottom of the pond remains entrapped there.
- The useful thermal energy is then withdrawn from the solar pond in the form of hot brine.

The pre-requisites for establishing solar ponds are: a large tract of land (it could be barren), a lot of sun shine, and cheaply available salt (such as Sodium Chloride) or bittern.

- Generally, there are three main layers. The top layer is cold and has relatively little salt content.

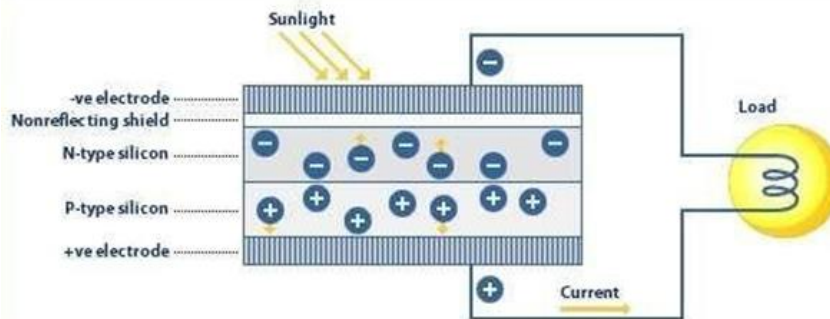
- The bottom layer is hot -- up to 100°C (212°F) -- and is very salty.
- Separating these two layers is the important gradient zone.

PHOTOVOLTAIC CELL:

Solar energy can be directly converted to electrical energy by means of photovoltaic effect. Photovoltaic effect is defined as the generation of an electromotive force (EMF) as a result of the absorption of ionizing radiation. Devices which convert sunlight to electricity are known as solar cells or photovoltaic cells. Solar cells are semiconductors, commonly used are barrier type iron-selenium cells.

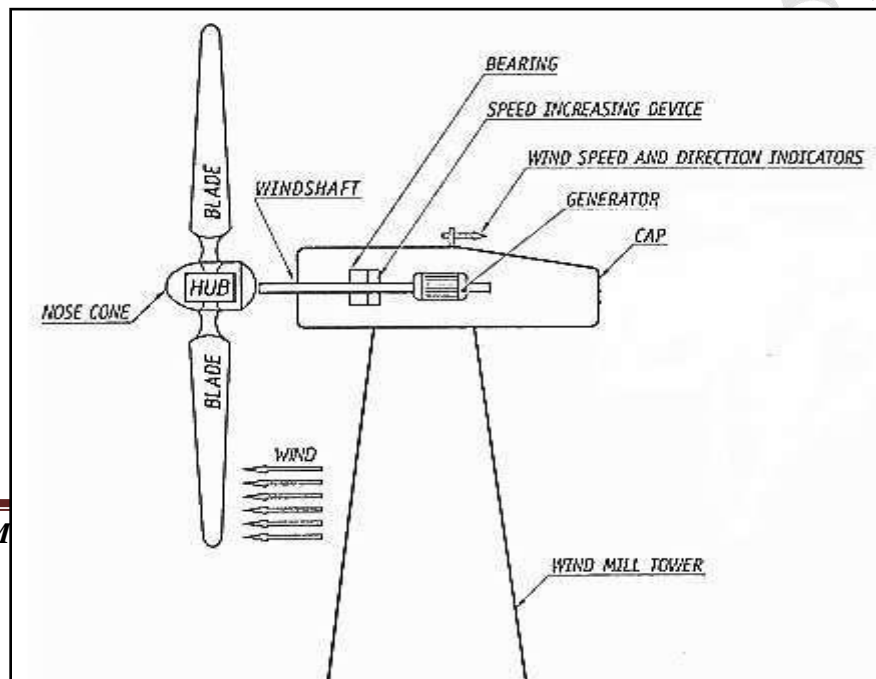
Iron-selenium cells consist of a metal electrode on which a layer of selenium is deposited.

- On the top of this a barrier layer is formed which is coated with a very thin layer of gold.
- The layer of gold serves as a translucent electrode through which light can impinge on the layer below.
- Under the influence of sunlight, a negative charge will build up on the gold electrode and a positive charge on the bottom electrode.
- This difference in charge will produce voltage in proportion to the sun's radiant energy incident on it.



WIND ENERGY:

Wind energy is the energy contained in the force of the winds blowing across the earth surface. Wind energy is defined as the kinetic energy associated with the movement of large masses of air over the earth's surface.



The circulation of the air in the atmosphere is caused by the non-uniform heating of the earth's surface by the sun. The air immediately above warm area expands and becomes less dense. It is then forced upwards by a cool denser air which flows in from the surrounding areas causing wind.

Power in the wind:

Wind possesses kinetic energy by virtue of its motion. Any device capable of slowing down the mass of moving air, like a sail or propeller, can extract part of this energy and convert into useful work.

The kinetic energy of one cubic meter of air blowing at a velocity V is given by,

A windmill is the oldest device built to convert the wind energy into mechanical energy used for grinding, milling and pumping applications. It consists of a rotor fitted with large sized blades.

Merits:

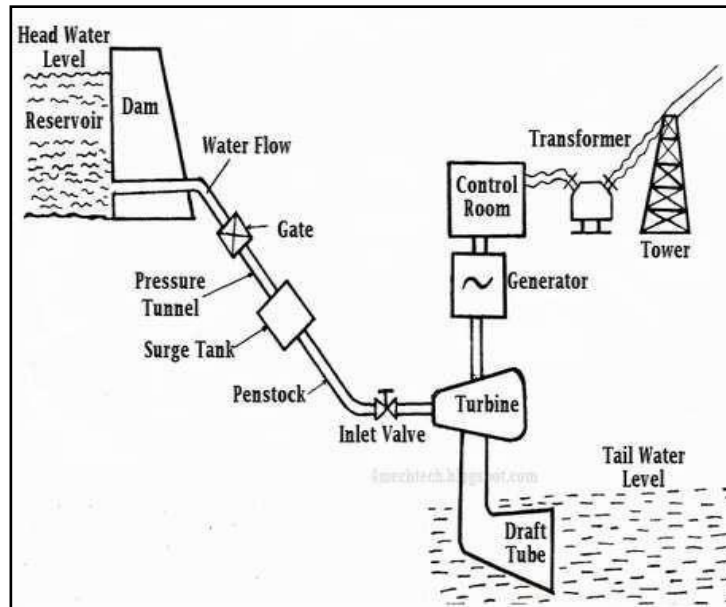
1. The wind is free and with modern technology it can be captured efficiently.
2. Once the wind turbine is built the energy it produces does not cause greenhouse gases or other pollutants.
3. Many people find wind farms an interesting feature of the landscape
4. Remote areas that are not connected to the electricity power grid can use wind turbines to produce their own supply.
5. Wind turbines have a role to play in both the developed and third world.
6. Wind turbines are available in a range of sizes which means a vast range of people and businesses can use

De-merits:

1. Wind turbines are noisy.
2. The strength of the wind is not constant and it varies from zero to storm force.
3. Only selected places it can be harnessed.

Hydro Power Plants/ Hydel Energy:

In hydroelectric power plants the potential energy of water due to its high location is converted into electrical energy. The total power generation capacity of the hydroelectric power plants depends on the head of water and volume of water flowing towards the water turbine.



The hydroelectric power plant, also called as dam or hydro power plant, is used for generation of electricity from water on large scale basis. The dam is built across the large river that has sufficient quantity of water throughout the river. In certain cases where the river is very large, more than one dam can be built across the river at different locations. The rain water flowing as river can be stored behind dams and released in a regulated way to generate hydro power.

Working Principle of Hydroelectric power plant

The water flowing in the river possesses two types of energy:

- (1) Gravitational Potential energy due to the height of water and
- (2) The kinetic energy due to flow of water

In hydroelectric power plant, potential energy of water is utilized to generate electricity. The potential energy of water stored at a height is converted into mechanical energy in water turbine. The mechanical energy produced by the water turbine is converted into electrical energy. After doing useful work water is discharged from the turbine to the river through a draft tube.

Merits: - environmental friendly source, large scale power generation, energy at free of cost.

Demerits: - expensive to build the dam, in summer water may not be sufficient to produce electricity.

NUCLEAR ENERGY :

Nuclear energy is the energy that holds the nucleus of an atom. The energy released during nuclear fission or fusion, especially when used to generate electricity.

“The most common nuclear fuels are ^{235}U and Plutonium ^{239}Pu .

NUCLEAR FUELS

- ☐ Alternative source of energy.
- ☐ Uranium is the main element required to run a nuclear reactor.
- ☐ Nuclear fission or fusion will produce tremendous amount of heat energy.

Nuclear fusion: Fusion energy is a form of nuclear energy released by the fusion (combustion) of two light nuclei (i.e. nuclei of low mass) to produce heavier mass.



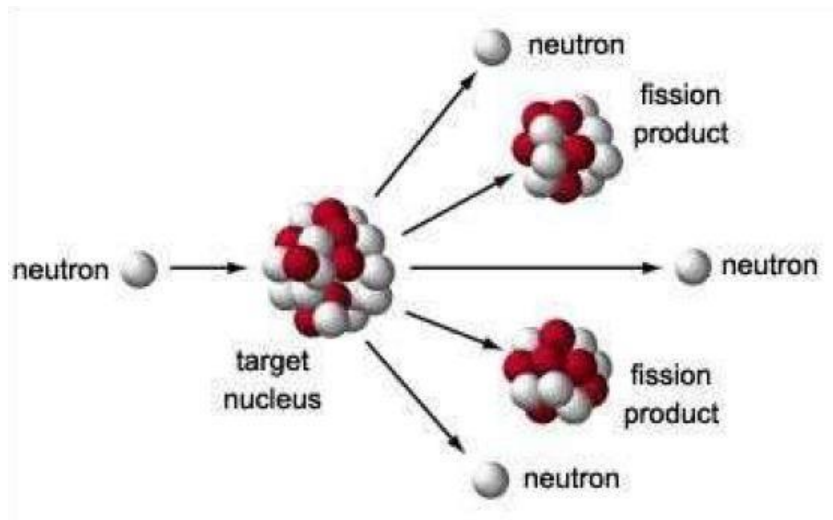
Nuclear fission:

Nuclear fission is the process, where a heavy nucleus splits into two fragments of more or less of equal mass. ☐



Neutron + Heavy nucleus \rightarrow Fission fragments + Neutrons (2 to 3) + energy ☐

- ☐ The energy released by fission of 1 gram of U-235 is equal to that due to combustion of 50 million tons of coal ; it is about $8.5 \times 10^{10}\text{J}$. ☐



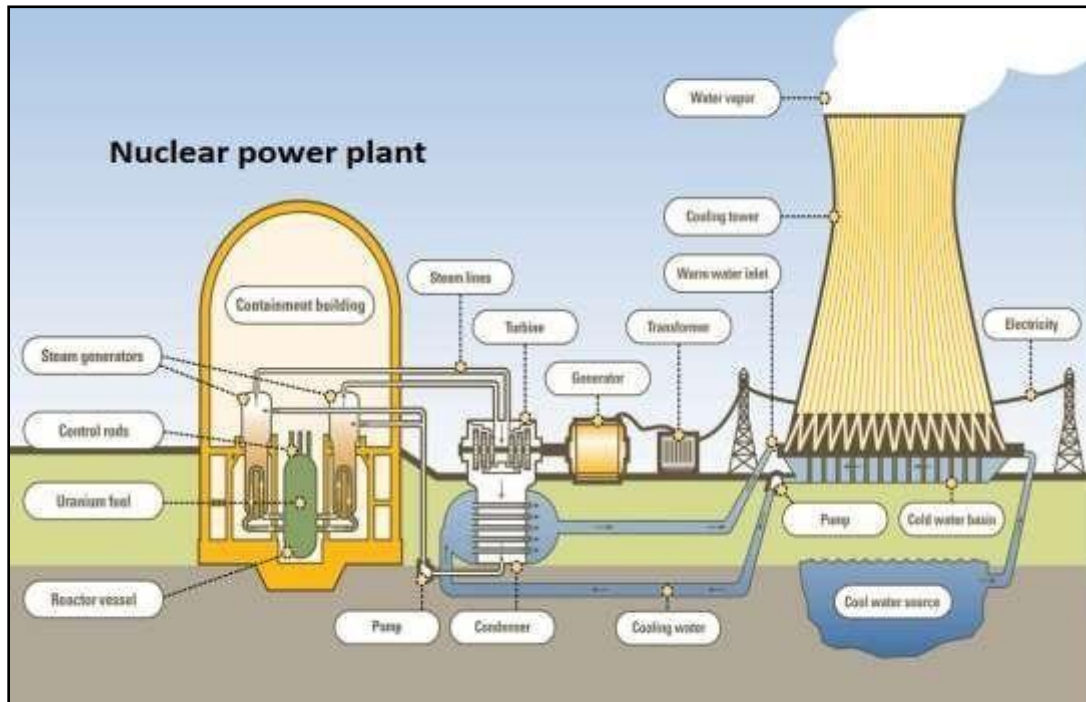
Chain Reaction: - A chain reaction is an ongoing series of fission reactions. Billions of reactions occur each second in a chain reaction.

- ☐ On earth, nuclear fission reactions take place in nuclear reactors, which use controlled

chain reactions to generate electricity.

- Uncontrolled chain reactions take place during the explosion of an atomic bomb.

Nuclear Fusion: - Nuclear fusion is the combining of two nuclei with low masses to form one nucleus of larger mass. Nuclear fusion reactions are also called thermonuclear reactions.



Working principle of a nuclear power station

The schematic diagram of nuclear power station is shown in fig.

A generating station in which nuclear energy is converted into electrical energy is known as nuclear power station.

The main components of this station are nuclear reactor, control rods, steam generators, steam turbine, coolant pump, feed pump, condenser, cooling tower.

NUCLEAR REACTOR:- A **Nuclear reactor** is a device in which nuclear chain reactions are initiated, controlled, and sustained at a steady rate, as opposed to a nuclear bomb, in which the chain reaction occurs in a fraction of a second and is uncontrolled causing an explosion.

CONTROL RODS: - Control rods made of a material that absorbs neutrons are inserted into the bundle using a mechanism that can rise or lower the control rods. The control rods essentially contain neutron absorbers like, boron, cadmium or indium.

STEAM GENERATORS: - Steam generators are heat exchangers used to convert water into steam from heat produced in a nuclear reactor core. Either ordinary water or heavy water is used as the coolant.

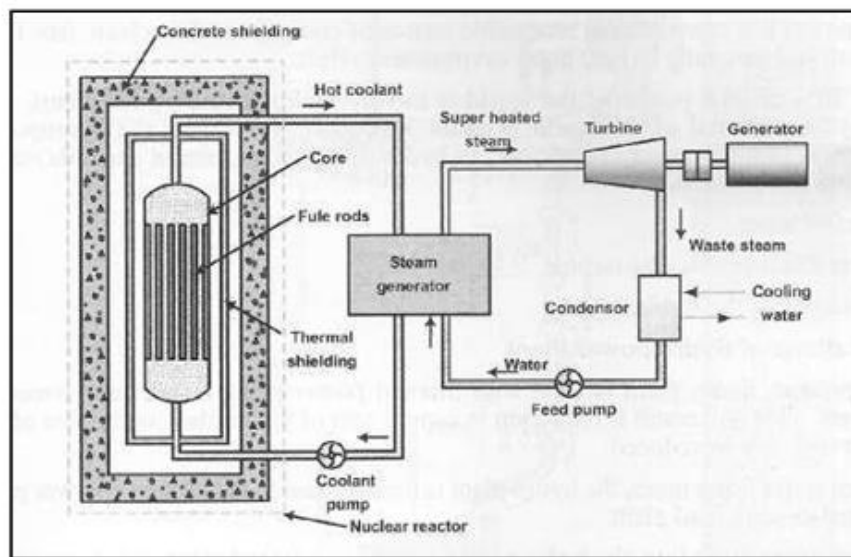
STEAM TURBINE: - A steam turbine is a mechanical device that extracts thermal energy from pressurized steam, and converts it into useful mechanical. Various high-performance alloys and super alloys have been used for steam generator tubing.

COOLANT PUMP: - The coolant pump pressurizes the coolant to pressures of the order of 155bar. The pressure of the coolant loop is maintained almost constant with the help of the pump and a pressurizer unit.

FEED PUMP: - Steam coming out of the turbine, flows through the condenser for condensation and recirculated for the next cycle of operation. The feed pump circulates the condensed water in the working fluid loop.

CONDENSER: - Condenser is a device or unit which is used to condense vapor into liquid. The objective of the condenser are to reduce the turbine exhaust pressure to increase the efficiency and to recover high quality feed water in the form of condensate & feedback it to the steam generator without any further treatment.

COOLING TOWER: - Cooling towers are heat removal devices used to transfer process waste heat to the atmosphere. Water circulating through the condenser is taken to the cooling tower for cooling and reuse. The reactor of a nuclear power plant is similar to the furnace in a steam power plant. The heat liberated in the reactor due to the nuclear fission of the fuel is taken up by the coolant circulating in the reactor. A hot coolant leaves the reactor at top and then flows through the tubes of heat exchanger and transfers its heat to the feed water on its way. The steam produced in the heat exchanger is passed through the turbine and after the work has done by the expansion of steam in the turbine, steam leaves the turbine and flows to the condenser. The mechanical or rotating energy developed by the turbine is transferred to the generator which in turn generates the electrical energy and supplies to the bus through a step-up transformer, a circuit breaker, and an isolator. Pumps are provided to maintain the flow of coolant, condensate, and feed water.

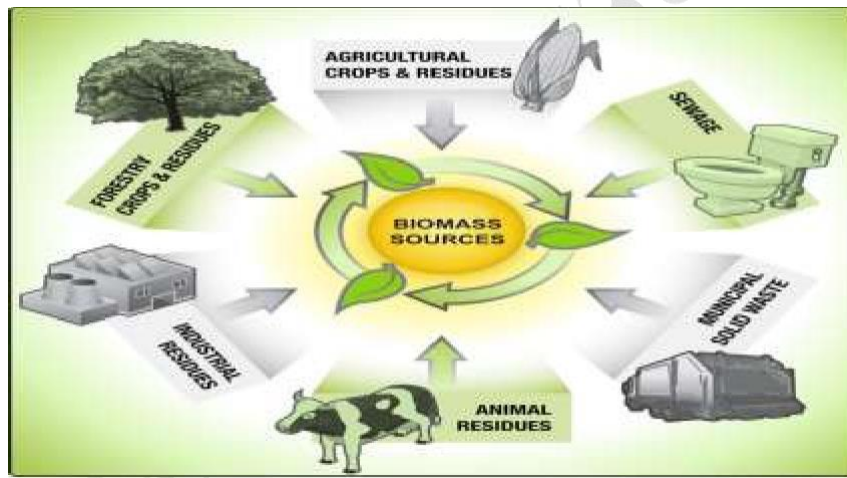


Bio fuels are a liquid fuels produced from biological materials for biomass such as sugarcane fiber, corn, cellulose or vegetable oils, Agricultural residues, sewage and other waste it is a renewable source of energy emitting less than fossil fuels and asset considered as an alternative to the constantly and rapidly diminishing fossil fuels.

A variety of fuels can be produced from biomass resources including liquid fuels, such as ethanol, methanol, biodiesel, and gaseous fuels, such as hydrogen and methane. The biomass resource base for biofuel production is composed of a wide variety of forestry and agricultural resources, industrial processing residues, and municipal solid and urban wood residues.

- A. Renewable energy source and Stored in the form of complex organic compounds of Carbon, Hydrogen, Oxygen and Nitrogen etc.
- B. It is a source of '5F': food, fodder, fuel, fibre and fertilizer.
- C. It can be converted into useful forms of energy through different conversion routes.
- D. Gets converted into fossil fuels after several million years under certain conditions of pressure, temperature, air etc. fossil fuels are not renewable, hence, are not biomass.

Source of biomass: - sources of biomass/biofuels are:-



Examples of various biofuels used in engineering applications: - The various bio-fuels are bio-methanol, bio-ethanol, bio-diesel, bio-gas and producer gas.

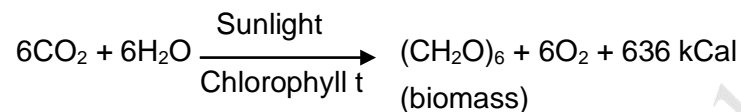
First-generation biofuels are made from sugar, starch, vegetable oil, or animal fats using conventional technology. The basic feedstock for the production of first-generation biofuels come from agriculture and food processing.

The most common first-generation biofuels are:

- **Biodiesel:** Extraction with or without esterification of vegetable oils from seeds of plants like soyabean, oil palm, oilseed rape and sunflower or residues including animal fats.

- **Bioethanol:** Fermentation of simple sugars from sugar crops like sugarcane or from starch crops like maize and wheat applied as fuel in petrol engines.
- **Bio-oil:** Thermo-chemical conversion of biomass. A process still in the development phase.
- **Biogas:** Anaerobic fermentation of organic waste, animal manures, crop residues and energy crops applied as fuel in engines suitable for compressed natural gas.

Second-generation biofuels are derived from non-food feedstock including lignocellulose biomass like crop residues or wood. Two transformative technologies are under development.



- **Biochemical:** Modification of the bio-ethanol fermentation process including a pre-treatment procedure
- **Thermo chemical:** Modification of the bio-oil process to produce syngas and methanol, Fisher-Tropsch diesel or dimethyl ether (DME).

Emission of bio-fuels: - Biodiesel plays a vital role in reducing emission of many air pollutants. The emission of carbon monoxide (CO), sulphur oxides (SO_x), nitrogen oxides (NO_x) etc., is lesser than those of petroleum fuels and thus these are eco-friendly.

Calorific value of bio-fuels: - Calorific values of biofuels will be considerably lesser than that of petroleum fuels.

Advantages of biomass energy:-

- Renewable and inexhaustible (theoretically) source of energy.
- Biomass is very abundant.
- It is easy to convert to a high energy portable fuel such as alcohol or gas which are efficient, viable and relatively clean-burning.
- It is cheap in contrast to the other energy sources.
- Biomass production can often mean the restoration of waste land (e.g. deforested areas).
- Commercial use of biomass may reduce the problem of waste disposal.
- It may also use areas of unused agricultural land and provide jobs in rural communities.
- When direct combustion of plant mass is not used to generate energy (i.e. fermentation, pyrolysis, etc. are used instead), there is minimal environmental impact.

Disadvantages of biomass energy:-

- A dispersed and land-intensive source.
- Low energy density.
- Could contribute a great deal too global warming and particulate pollution if directly burned.
- Still an expensive source, both in terms of producing the biomass and converting it to alcohols.
- On a small scale there is most likely a net loss of energy- energy must be put in to grow the plant mass.

Comparison of biofuels with petroleum fuels in terms of calorific value and emission:

It is well known that petroleum diesels are the major source of air pollutions that create an adverse impact on human health and overall greenhouse gases. Biodiesel has some great benefits over petroleum diesel, such as it produces 4.5 units of energy against every unit of fossil energy and also it has some environment-friendly properties such as it is non-toxic, biodegradable and safer to breathe. Biodiesel is also a clean-burning and stable fuel. Properties of biodiesel such as oxygen content, cetane number, viscosity, density and heat value are greatly dependent on the sources (soybean, rapeseed or animal fats) of biodiesel. Engine performance and emissions depend on the properties of biodiesels. Biodiesel is a highly oxygenated fuel that can improve combustion efficiency and can reduce unburnt hydrocarbons (HCs), carbon dioxide (CO₂), carbon monoxide (CO), sulphur dioxides (SO₂), nitric oxide (NO_x) and polycyclic aromatic HC emissions.

However, brake-specific fuel consumption slightly increases. Popularity of biodiesel as renewable sources of alternative fuel of petroleum diesel is growing quickly due to increased environmental awareness and the rising price of diesel. It is an earth-friendly choice of consumers that already occupies a great volume of the world's fuel sector due to its clean emission characteristics.

ENVIRONMENTAL ISSUES

Environmental issues refer to the harmful effects created by human beings on the living environment. The issues mainly relate to the climatic changes taking place in the living atmosphere. Increased human activity, urbanization and industrialization have led to rapid deterioration of the environment.

Two important global environmental issues, viz., Depletion of the Ozone Layer and Global warming

Depletion of the Ozone Layer

An ozone molecule (O₃) is composed of three atoms of oxygen. Ozone in the upper atmosphere (the stratosphere) is referred to as the “ozone layer” and protects life on Earth by absorbing most of the ultraviolet (UV) radiation emitted by the sun. Exposure to too much UV radiation is linked to skin cancer, cataracts, and depression of the immune system, and may reduce the productivity of certain crops.

Accordingly, stratospheric ozone is known as “good ozone.” In contrast, human industry creates “ozone pollution” at the ground level. This “bad ozone” is a principal component of smog. The ozone layer is reduced when man-made CFC molecules (comprised of chlorine, fluorine, and carbon) reach the stratosphere and are broken apart by short-wave energy from the sun. Free chlorine atoms then break apart molecules of ozone, creating a hole in the ozone layer. The hole in the ozone layer over the Antarctic in 1998 was “the largest observed since annual holes first appeared in the late 1970s.”¹⁰

CFCs were once used in aerosol sprays and as foam blowing agents. Their manufacture is now banned by an international treaty, the Montreal Protocol, signed by 160 nations. But because CFCs have a long atmospheric lifetime (about 50 years), those manufactured in the 1970s continue to damage the ozone layer today. The amount of CFCs in the stratosphere is now peaking. The good news is that scientists forecast that the ozone layer will return to its earlier, stable size by the middle of the 21st century—assuming that nations continue to comply with the treaty.

GLOBAL WARMING

Global warming is caused by the “greenhouse effect,” which is essential to life as we know it on planet Earth. Electromagnetic energy coming from the sun is absorbed by the Earth, which radiates some of this energy outward as infrared energy (heat). Some of this infrared energy escapes into space, but much of it is absorbed by “greenhouse gases” in the lower atmosphere (the troposphere) and is radiated back to the Earth as heat energy.

The greenhouse effect, then, is a warming of the Earth’s surface that makes it hospitable to life. The climate change is due to the increased volumes of carbon dioxide and green house gases (Toxic gases) released by the burning of fossil fuels, land clearing, agriculture and other emissions created by human activities that have occurred over the past 50 years. The gases form a layer in the atmosphere and trap the sun’s radiation which in turn makes the planet warmer. The changes resulting global warming may include rising sea levels due to the melting of the polar ice caps, as well as an increase in occurrence of storms, droughts, and other severe weather events.

Steam Formation and Properties:

Introduction: - All the substance under suitable conditions of temperature and pressure can exist in one of the three states via solid, liquid or gas. But water is one of the pure substance that exists in all the three phases namely in solid phase as ice, liquid phase as water and gaseous phases as vapour (steam).

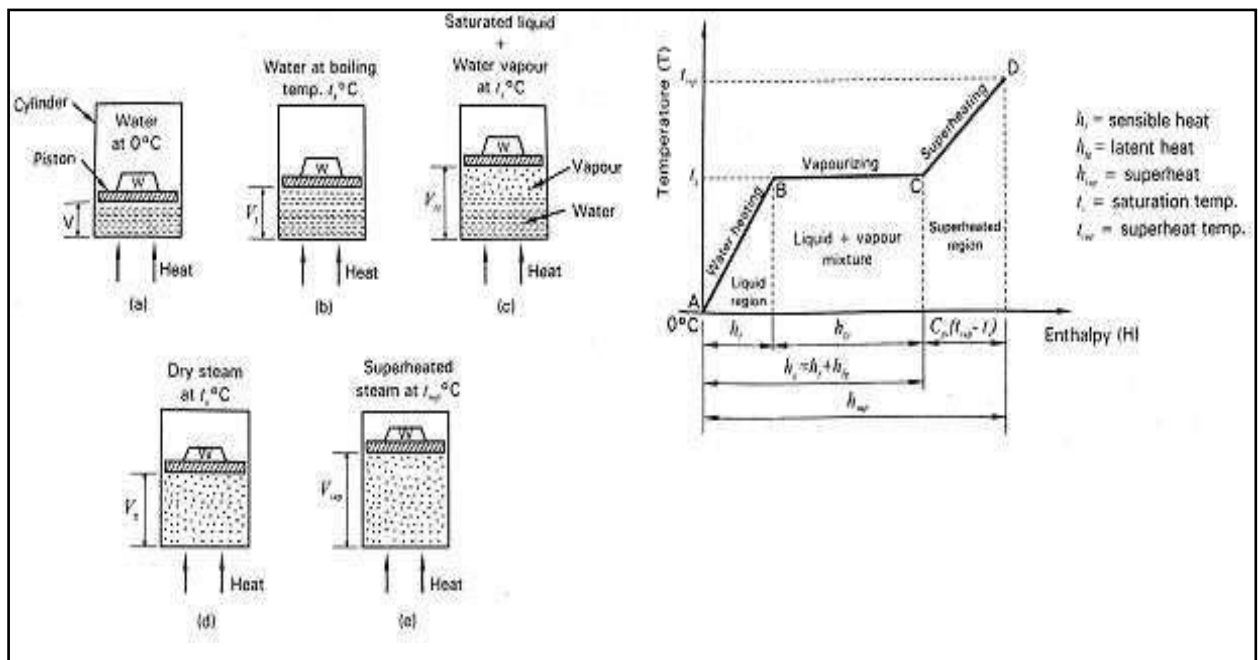
Most of the practical problems in thermal engineering are concerned with liquid and gaseous phase rather than the solid phase. Water, which is liquid at normal

temperature begins to boil to form steam when heat sufficiently. In practice, steam is generated in steam generators or popularly known as BOILERS.

Definition of Steam: Steam can be defined as it is a mixture of water and air or it can also be defined as vapour of water.

Formation of steam at constant pressure:

- Consider 1 kg of water at 0°C taken in a cylinder, on which a constant pressure P is exerted. Point A on the temperature-enthalpy graph.
- When this water is heated its temperature rises till the boiling point is reached. This temperature is called saturation temperature (T_s). Point B on the graph.
- Further addition of heat, initiates the evaporation of water while the temperature remains at saturation temperature until all of water is converted into steam. Point C on the graph.
- On heating the steam further, it increases the temperature of steam above the saturated temperature to superheated steam.



1. **Saturation temperature (T_s):** It is defined as the temperature at which the water begins to boil at constant pressure.
2. **Sensible heat (h_f):** It is the amount of heat required to raise the temperature of 1 kg of water from 0°C to the saturation temperature (boiling point) at constant pressure. It is also known as enthalpy of the liquid.
3. **Latent heat of evaporation (h_{fg}):** It is the amount of heat required to evaporate 1 kg of water at saturation temperature to 1 kg of dry steam at the same saturation temperature at constant pressure. Also known as enthalpy of evaporation.
4. **Enthalpy of superheat:** The amount of heat required to increase the temperature of dry steam from its saturation temperature to any desired higher temperature at constant pressure is called enthalpy of superheat.

STATES OF STEAM: - The steam as it is being generated can exist in 3 states as wet steam, dry saturated steam and superheated steam.

- **Wet Steam:** It is defined as a two-phase mixture of entrained water molecules and steam at saturation temperature.
- **Dry Steam (dry saturated steam):** As wet steam is heated further, the water molecules in the steam get converted into vapour. Dry steam is the steam at saturation temperature having no water molecules in it. Point C.
- **Superheated Steam:** It is defined as the steam which is heated beyond its dry state to temperatures higher than its saturated temperature at the given pressure.

Dryness fraction of steam: A wet steam has different proportions of water molecules and dry steam. Hence, the quality of wet steam is specified by the dryness fraction which indicates the amount of dry steam in the given quantity of wet steam and is denoted by x . It is defined as the ratio of mass of dry steam in a given quantity of wet steam to the total mass of wet steam.

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Let m_g = mass of dry steam
 m_f = mass of water molecules

Dryness fraction, $x = m_g / (m_g + m_f)$

- The dryness fraction of wet steam is less than 1.
- The dryness fraction of dry steam is 1

ENTHALPY (h), kJ/kg: It is the amount of heat required to raise the temperature of 1 kg of water from 0°C to the desired form of steam at constant pressure. It is the sum of the internal energy and work done at constant pressure.

Enthalpy of Dry Saturated Steam (h_g): It is the amount of heat required to raise the temperature of 1 kg of water from 0°C to 1 kg of dry saturated steam at constant pressure.

$$h_g = h_f + h_{fg} \text{ KJ/Kg}$$

Enthalpy of Wet Steam (h): It is the amount of heat required to raise the temperature of 1 kg of water from 0°C to 1 kg of wet steam to the specified dryness fraction, at constant pressure.

$$h = h_f + x h_{fg} \text{ KJ/Kg}$$

Enthalpy of Superheated Steam (h_{sup}): It is the amount of heat required to raise the temperature of 1 kg of water from 0°C to 1 kg of superheated steam to the stated saturated steam temperature, at constant pressure. It is the sum of enthalpy of dry steam and the amount of superheat.

$$h_{sup} = h_g + C_{ps}(T_{sup} - T_s) \text{ KJ/Kg}$$

$$h_{sup} = h_f + h_{fg} + C_{ps}(T_{sup} - T_s) \text{ KJ/Kg}$$

Where C_{ps} is the specific heat of superheated steam.

Steam Properties:

- Ice melts.
- Water is heated beyond boiling point.
- Steam is defined as vapour of water.
- Vaporization. Gaseous phase.
- Steam is two phase mixture of water and steam.

The important properties of steam are

- | | |
|--------------------|--------------------|
| 1. Pressure | 4. Enthalpy |
| 2. Temperature | 5. Internal energy |
| 3. Specific volume | 6. Entropy |

Specific volume (m^3/kg): It is the volume occupied by the unit mass of a substance.

Specific Volume of Dry Saturated Steam (V_g): It is the volume occupied by 1 kg of dry saturated steam at a given pressure.

Specific Volume of Wet Steam (v): It is the volume occupied by 1 kg of wet steam to the specified dryness fraction at a given pressure. $v = x v_g$

Internal Energy of Steam: The total heat energy of a dry saturated steam at a constant pressure is the sum of the sensible heat and latent heat. But in latent heat a portion is used for external work. Therefore, the actual energy stored in the steam is the sensible heat and the internal latent heat. This actual energy stored in the steam is called internal energy of steam. It is defined as the difference between the enthalpy of the steam and the external work of evaporation.

THERMODYNAMICS:

It is the science of the relations between heat, Work and the properties of the systems.

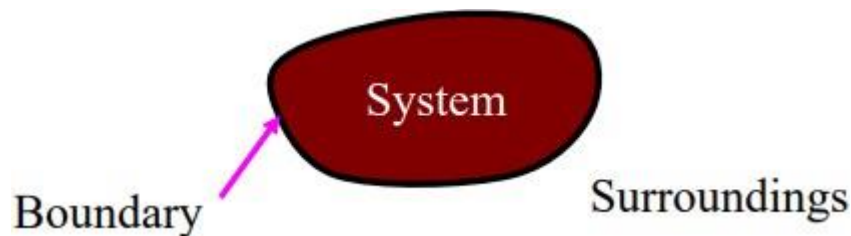
In our study of thermodynamics, we will choose a small part of the universe to which we will apply the laws of thermodynamics. We call this subset a **SYSTEM**.

The thermodynamic system is analogous to the free body diagram to which we apply the laws of mechanics, (i.e. Newton's Laws of Motion).

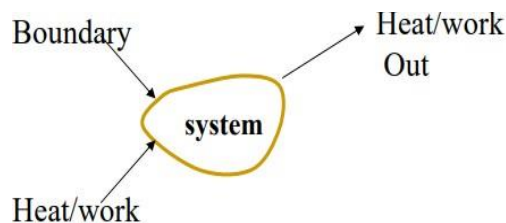
The system is a macroscopically identifiable collection of matter on which we focus our attention (eg: the water kettle or the aircraft engine).

The rest of the universe outside the system close enough to the system to have some perceptible effect on the system is called the **surroundings**.

The surfaces which separates the system from the surroundings are called the **boundaries** as shown in fig below (eg: walls of the kettle, the housing of the engine).



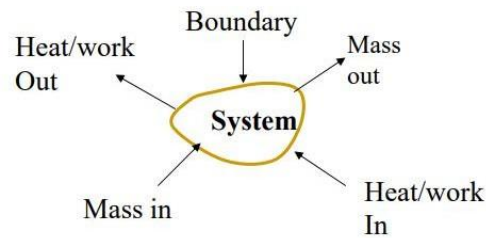
TYPES OF SYSTEM



CLOSED SYSTEM - in which no mass is permitted to cross the system boundary i.e. we would always consider a system of constant mass. We do permit heat and work to enter or leave but not mass.

OPEN SYSTEM- in which we permit mass to cross the system boundary in either direction (from the system to surroundings or vice versa). In analysing open systems, we typically look at a specified region of space, and observe what happens at the boundaries of that region. Most of the engineering devices are open system.\

ISOLATED SYSTEM - in which there is no interaction between system and the surroundings. It is of fixed mass and energy, and hence there is no mass and energy transfer across the system boundary



The **boundaries** may be real physical surfaces or they may be imaginary for the convenience of analysis. eg: If the air in this room is the system, the floor, ceiling and walls constitute real boundaries. The plane at the open doorway constitutes an imaginary boundary.

The boundaries may be at rest or in motion. eg: If we choose a system that has a certain defined quantity of mass (such as gas contained in a piston cylinder device) the boundaries must move in such way that they always enclose that particular quantity of mass if it changes shape or moves from one place to another.