Module-1

Introduction to Mechanical Engineering (Overview only):

Role of Mechanical Engineering in Industries and Society- Emerging Trends and Technologies in different sectors such as Energy, Manufacturing, Automotive, Aerospace, and Marine sectors and contribute to the GDP.

Steam Formation and Application:

Formation of steam and thermodynamic properties of steam (Simple Problems using Steam Tables), Applications of steam in industries namely, Sugar industry, Dairy industry, Paper industry, Food processing industry for Heating/Sterilization, Propulsion/Drive, Motive, Atomization, Cleaning, Moisturization, Humidification.

Energy Sources and Power Plants:

Review of energy sources; Construction and working of Hydel power plant, Thermal power plant, nuclear power plant, Solar power plant, Tidal power plant, Wind power plant.

Introduction to Mechanical Engineering

Mechanical Engineering is one of the oldest engineering professions. Mechanical Engineering can trace its roots back to the very beginning of the Industrial Revolution, from 1750 to 1800 in Europe and 1800 to 1850 in the United States. The invention of the steam engine by James Watt in 1802, propelled the growth in this field by leaps and bounds. After the invention of the automobile, both the need for precisely machined metal and a more formalized method of assembling the components.

Mechanical engineering is the study, design, development, construction, and testing of mechanical and thermal sensors and devices, including tools, engines, and machines. Mechanical engineering careers centre on creating technologies to meet a wide range of human needs.

Mechanical engineering subjects include automobile engineering, manufacturing engineering, power plant engineering, thermal engineering, and mechatronics engineering, which is a combination of electrical, computer, and mechanical engineering.

Role of Mechanical Engineering in Industries and Society:

Mechanical Engineer will play a vital role in the sustainable development of the industry and the society. Starting from the conceptualization of the product to the design, manufacturing, sales and service to the end of life of a product i.e, recycling mechanical engineer will play his role.

To start with, for a design a product mechanical engineer has to conceptualize the product, draw the preform of the product, then apply the mechanical design and will build the product for its strength.

Mechanical engineer role as a manufacturing Engineering is a huge. Studying the design, laying out the tooling for the production and optimize the raw material consumption in the manufacturing a component requires huge skills as a mechanical Engineering.

Mechanical Engineer also place a vital role in the logistics. Procuring the materials for the production, maintaining the adequate material in the stores, dispatching the finished products to the Consumer is the role of a Logistic Engineer.

Mechanical Engineer also works as a safety Engineer in an Industry. Taking care of the human resources, machineries, equipment’s and planning out the safer working conditions and ensuring the safety of the operations is the responsibility of the safety engineer.

Mechanical Engineer plays a vital role in the overall growth of the economy as well as the Society. Meeting the demand for a product to the optimum utilization of the resources taken care by the mechanical Engineer. Designing a product for longer product life cycle and reutilization/ recycling the product reduces the dependency of the materials by the industry. Also, developing newer equipment's, devices for harnessing the renewable sources energy reduces the dependencies on the fossil fuels. This in turn contribute the green energy, low or no emission of carbon and its compounds.

Following are few of the areas where in Mechanical Engineer play his role in an industry: Design Engineer, Production Manager, Safety Engineer, QA Engineer, Logistic Manager, Data analyst, Drafts man, Sales Executive, Customer Service etc.,

Emerging Trends and Technologies in Mechanical Engineering in different Sectors:

Energy: The energy sector is a category that relate to producing or supplying energy. The energy sector or industry includes companies involved in the exploration and development of oil or gas reserves, oil and gas drilling, and refining. The energy industry also includes integrated power utility companies such as renewable energy and coal.

Figure: Solar PV Panels and Wind Turbines

Advent of technology and raising concern on the use of fossil fuels gives an opportunity to think of the energy harnessing through renewable resources. Increased efficiency in the solar PV cells, ease in the manufacturing of complicated shapes of a wind turbine blades through various manufacturing process, newer innovations in the electric vehicles, newer materials compositions to produce parts used in devises etc., creating the opportunity to extract the energy at low cost through renewable sources and avoiding the dependency on fossil fuels.

Manufacturing: Manufacturing is the process of converting the raw material into a finished product. The technology had taken a great leap in the manufacturing sector. Along with side of conventional manufacturing methods other manufacturing methods are also practicing in the industry. Lean manufacturing, just in time manufacturing (JIT), Flexible manufacturing system (FMS), Computer Integrated manufacturing (CIM) are already in use. Along with this additive manufacturing is getting its importance in the new product development which reduces the material and time.

Figure: CNC machine tool in Turning Operation

Automotive Industry:

Figure: Concept of electric vehicle during docking

Indian Automobile market is the 3rd Largest automobile market in the world. The automobile market seen a considerable changes in the advance of technology. Electric vehicles are the next alternative to the conventional fossil fueled vehicles. Providing the better customer ride experience electric vehicles are the future of automobile market. Also, Hybrid vehicles are already in market uses dual fuel technology like electric and gasoline. Automation is another aspect in the automobile industry. Use of mechatronics, internet, AI automobile manufacturers are striving for the better user interface and comfort in automobile experience.

Aerospace Industry: Invention of new materials like composites, shape memory alloys added the strength to weight ratio among the material used in the production of Aerospace vehicles. Also, use of sophisticated manufacturing techniques in the building of aircrafts make the cost of the air craft vehicles much economical.

Marine Sector: Marine engineering is the discipline that deals with matters related to the design, innovation, construction and maintenance of seagoing vessels and navigation equipment. Marine engineers focus primary on the development and production of internal systems of boats, ships, or submarines. They are engaged in designing propulsion systems, auxiliary power machinery and operation equipment. Their technical responsibilities also include working on-board to maintain these systems.

Figure: Jet turbine used in Aircrafts

STEAM

Steam, which is gaseous form of pure water, is an excellent working medium in various thermodynamic systems because of its following properties:

1) It can carry large quantities of heat
2) It is produced from water which is cheap and readily available
3) It can be used for heating purposes after its duty as working agent is completed.
4) It can be used purely as a heating medium in food processing Industries because of a fast, easily controllable and hygienic method of heating.

Formation of Steam

In general, steam can be formed by boiling water in a vessel. But to use it effectively as a working or heating medium, it has to produce in a closed vessel under pressure. Steam formed at a higher pressure has higher temperature and can be made to flow easily through insulated pipes from steam generator to point of use. A simple arrangement of formation of steam at constant pressure is shown in figure,

Figure 1: T-h diagram for Steam formation at constant pressure

A =
B =
C =
D =

h_w =
h_f =
h_{fg} =
h_g =
h_{sup} =

Consider 1 kg of water at temperature 0^0C in a cylinder as shown in fig 2. A weight w is placed on a piston to achieve constant pressure. Let it be heated at constant pressure P.

Fig 2 : Formation of Steam

On addition of heat, the temperature of water starts rising until it reaches the boiling temperature or saturation temperature corresponding to pressure P. This heat absorbed by water in sensible heat.

Note: Saturation temperature or boiling temperature increases with increase in pressure

After the boiling temperature is reached, it remains constant with further addition of heat and vaporization take place. The water absorbs its latent heat and converts into dry saturated steam remaining at same saturation temperature. The intermediate stage of water and dry saturated steam is wet steam, which is actually a mixture of steam and water.

If further the heat is added, the temperature of this dry saturated steam starts rising from saturation temperature and it converts into superheated steam. This heat absorbed is again the sensible heat. The total rise in temperature of superheated steam above the saturation temperature is called degree of superheat. We must know here that the saturation temperature, latent heat and other properties of steam remain same at constant pressure but varies with the variation of pressure.

Advantages of superheated steam

1) The superheated steam can be considerably cooled during expansion in an engine cylinder, before its temperature falls so low as to cause condensation on cylinder walls which is a direct heat loss.

2) The temperature of superheated steam being higher, it gives a high thermal efficiency in heat engine.

3) It has high heat content and so high capacity of doing work. Thus, it results in an economy in steam consumption.

Definitions:

Enthalpy of Steam: To find out the total heat content or enthalpy of any state of water/ steam we have to add all types of heat added i.e., sensible and latent to convert the water to that state starting from some initial state or datum which is assumed as a zero-enthalpy point or where the heat content is taken as zero. Generally, in engineering calculations the datum is water at 00C where it is considered as having zero heat content or zero enthalpy. Enthalpy of one kg of water or steam is called as specific enthalpy.

Specific enthalpy of un-saturated water (hw): It is simply the amount of heat required to raise the temperature of one kg of water from 0 °C to its actual temperature which is below its saturation temperature. It can be calculated by multiplying actual temperature of unsaturated water with its specific heat which is considered equal to 4.187 kJ/ kg/ K. It is denoted as hw.

$$\text{So,} \quad h_w = C_w . t$$

Where, t = is the temperature of water in ^oC

Specific enthalpy of saturated water (hf):

It is the quantity of heat required to raise the temperature of one kg of water at 00C to its boiling point or saturation temperature corresponding to the pressure applied. It is denoted as hf. It can be calculated by multiplying the specific heat of water to the total rise in temperature. The specific heat Cpw of water may be approximately taken as constant i.e., 4.187 kJ/kg K, but in actual it slightly increases with increase in saturation temperature or pressure. Thus

$$h_f = C_w (t_s - 0) = C_p t_s$$

Where, t_s = Saturation temperature

Latent heat of steam (h_{fg}):

Latent heat of steam at a particular pressure may be defined as the quantity of heat in kJ required to convert one kg of water at its boiling point (saturated water) into dry saturated steam at the same pressure. It is usually denoted by L or h_{fg}. It decreases with increase in pressure or saturation temperature.

Wet and dry steam

Wet steam is that steam in which the whole of water has not vaporized but the un-vapourised water is present in the form of mist/fog suspended in completely vaporized water or steam. Due to this mist the wet steam is visible. However, the dry steam i.e., in which the vaporization is complete is invisible or colourless. Any steam which is completely dry and present at saturation temperature is called dry saturated steam.

Dryness fraction

This term refers to quality of wet steam. It is defined as the ratio of the weight of dry steam actually presents to the weight of total wet steam which contains it. It is denoted by x. Thus

$$x = \frac{W_d}{W_d + W}$$

Where W_d = Weight of dry steam in 1 kg of wet steam,

W = Weight of water in suspension in 1 kg of wet steam

Dryness fraction is zero for saturated water and one for dry saturated steam.

Enthalpy of Steam:

Specific enthalpy of wet steam (hws):

It may be defined as the quantity of heat required to convert 1 kg of water at 0^0C into wet steam of a given quality and at constant pressure. It may be denoted by h_{ws}. It is equal to the sum of specific enthalpy of saturated water and latent heat of dry fraction of steam. So

$$h_{ws} = h_f + x.\,h_{fg}$$

Specific enthalpy of dry saturated steam (hg):

It may be defined as the quantity of heat required to convert 1kg of water at 0^0C into dry saturated steam at given constant pressure. It may be denoted by h_g. It is equal to the sum of specific enthalpy of saturated water and latent heat corresponding to given saturation pressure and temperature. Thus

$$h_g = h_f + h_{fg}$$

Specific enthalpy of superheated steam (h_{sup}):

It is defined as the quantity of heat required to convert 1kg of water at 0^0C into the superheated steam at given temperature and pressure. It may be denoted as h_{sup} and is equal to the sum of specific enthalpy of dry saturated steam and product of specific heat of superheated steam (C_s) to degree of superheat.

$$h_{sup} = h_g + C_s(t_{sup} - t_s)$$

Where, h_g and t_s are the specific enthalpy of dry steam and saturation temperature at corresponding pressure and C_S & t_{sup} are specific heat of superheated steam and temperature of superheated steam at the same pressure.

Specific Volume of Water/Steam:

The volume of a unit mass of water/steam is known as its specific volume

Specific volume of saturated water (v_f):

It is defined as volume of 1kg of water at saturation temperature corresponding to the given pressure. It is denoted by v_f. It can be calculated experimentally. It slightly increases with increase in saturation temperature and hence the pressure. The reciprocal of sp-volume is equal to density.

22.4.2 Specific volume of dry saturated steam (v_g)

It is defined as volume of 1kg of dry saturated steam corresponding to the given pressure. It is denoted by v_g and can be calculated experimentally. As dry saturated steam is a gas, its specific volume decreases with increase in pressure or the saturation temperature.

22.4.3 Specific volume of wet steam of quantity x

It is the volume of 1kg of wet steam and is denoted as

$$v_{ws} = x.v_g + (1-x)\, v_f$$

At low pressure the value of vf is very small as compared to vg; so the term (1-x) vf may be neglected. Then volume of 1kg of wet steam = $x.v_g$

Specific volume of Superheated Steam (Vsup)

It is the volume of 1kg of superheated steam and can be determined by assuming that the steam behaves as a perfect gas i.e., obeys the gas laws. It is denoted by v_{sup}

Let P = pressure under which steam is superheated.

t_{sup} =temperature of superheated steam

v_g = Specific volume of dry saturated steam

t_s = saturation temperature at pressure P.

Since, P = constant, so

$$\frac{v_g}{t_s} = \frac{v_{sup}}{t_{sup}} \text{ or } v_{sup} = v_g . \frac{t_{sup}}{t_s}$$

Simple Numerical:

Problems will be discussed in the class

Application of Steam in Sugar Industry:

Steam boilers are very important in the processing operations of crystallization and drying in sugar mills. Additionally, boilers in sugar industry also generate electricity through cogeneration plants.

Stages of Sugar extraction from Sugarcane:

1. Washing
2. Extraction
3. Purifying juice
4. Crystallization
5. Centrifugation
6. Drying

Crystallization:

Crystallization is a major process stage that relies on a steam boiler. In the crystallization process, a vacuum pan evaporates the syrup to saturate with sugar crystals through a process, termed seeding. This seed is pure sucrose suspended in alcohol and glycerine that is added to the syrup. The minute grains of sugar in the solution helps in extracting the sugar in the solution and forming it into crystals. With the boiling of the mixture in the vacuum pan, the crystals convert into a paste known as ‘massecuite’ that is a mixture of sugar crystal and syrup. The mixture is further processed in a large container named ‘crystallizer’ to continue crystallization by stirring and cooling the massecuite.

Drying:

Large hot air dryers are used to dry damp sugar crystals and reduce their moisture content to as low as 0.02% and then pass it through hot air in a granulator. The dried crystals are later segregated as per their sizes and packed to transfer to the market.

Application of Steam in Dairy Industry:

Steam is quite commonly used for heating and sterilizing dairy equipment, both on the farm and in the dairy manufacturing plant. It is used in the small self-contained oil or electric sterilizers and in large continuous can washers. Boilers in the dairy industries mainly perform the processes of milk pasteurization and Ultra Heat Temperature (UHT) to ensure that the milk is safe for consumption and free from harmful bacteria for optimal shelf life. The milk processing plants utilize steam for processing and pasteurizing raw milk and dairy products under heat treatment. It leads to the process and production of various dairy products such as milk powder, yogurt, cheese, condensed milk, skimmed milk, butter, ghee, and cream.

Application of Steam in Paper Industry:

Steam is pivotal in the paper industry for the process of drying the paper, energy requirement, and the cooking of wood chips in the digester. Some of the essential requirements of steam in paper processing are,

Uniform Heating:

The utilization of rolls in paper processing requires it to be heated internally with steam. Therefore, it is essential to maintain an even temperature across the surface of the rolls for uniformity and high-quality products. Steam is an ideal choice as it condenses and distributes heat evenly.

Precision in Steam Temperature:

As temperature demand increases or the higher-grade papers are manufactured, higher pressure and temperature are needed. The plant operators can control the pressure and set the steam temperature inside the roll. The saturated steam maintaining the same temperature at a given pressure allows the operators to control the pressure and steam temperature as required.

Application of Steam in Food Processing Industry:

The food industry needs heat at every stage of the process. Direct heat or heat in the form of steam is an essential factor of food processing industry. Inside the beverage business, steam is used for cooking, drying, and warming, and for general utilize-cleaning. Steam is also used to eliminate microbiological risk in food.

Direct Heating: In direct heating, the steam is directly subjected to the product that needs to be heated. Precision is required to ensure uniform heating and that the steam does not exit the steam boiler without heating the products. Pharmaceuticals and food processing are prime examples that utilize steam for direct heating.

Indirect Heating: Indirect heating, as the name suggests, uses steam to heat the products without any direct contact. Indirect heating takes place with the help of various heating equipment such as heat exchangers, cookers, jacketed vessels, etc.

Application of Steam in Power Generation:

Since from centuries, Steam is used to drive the locomotive and also in the production of electrical energy. A steam/thermal power station uses heat energy (Steam) generated from burning coal to produce electrical energy.

Thermal powerplant works under the Rankine cycle. This is the cycle of the steam produced in the boiler, then taken to the Steam turbine (prime mover). From the turbine the steam is cooled back to water in the Condenser, the resulting water is fed back into the boiler to repeat the cycle.

Steam as motive fluid:

Steam can also be used as a direct "motive" force to move liquid and gas streams in piping. Steam jet ejectors are used to pull vacuum on process equipment such as distillation towers to separate and purify process vapor streams. They are also used for continuous removal of air from surface condensers, in order to maintain desired vacuum pressure on condensing (vacuum) turbines.

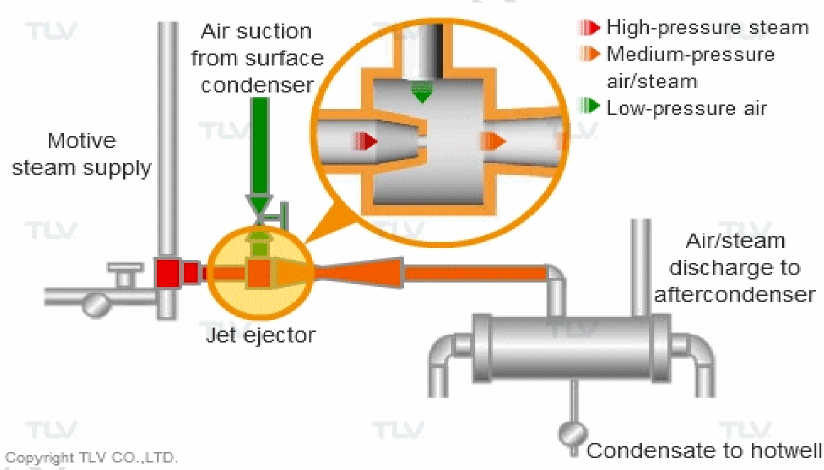


Figure: Ejector for Surface Condenser

High pressure motive steam enters the jet ejector through the inlet nozzle and is then diffused. This creates a low-pressure zone which entrains air from the surface condenser.

In a similar type of application, steam is also the primary motive fluid for secondary pressure drainers, which are used for pumping condensate from vented receiver tanks, flash vessels, or steam equipment that experiences stall conditions.

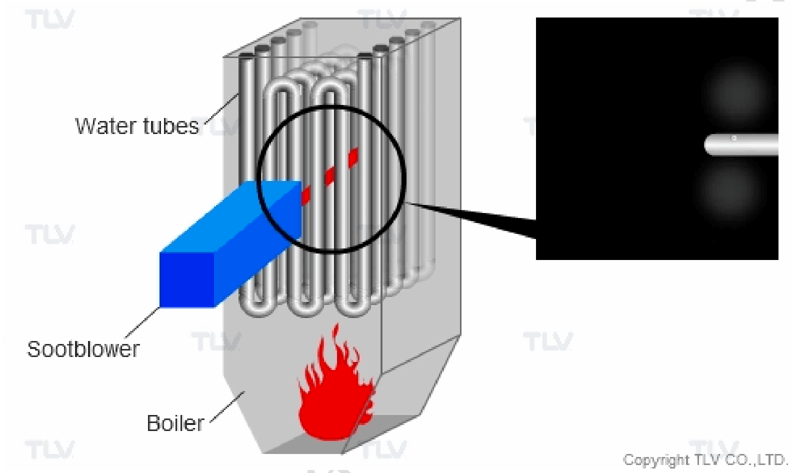
Steam for Atomization

Atomization refers to breaking the fuels into tiny particles. In a steam boiler, atomization takes place in burners. Steam is utilized for atomizing the fuel to ensure a larger surface area that results in effective combustion. Atomization also leads to minimal soot formation and acceleration in overall efficiency.

Steam atomization is a process where steam is used to mechanically separate a fluid. In some burners, for example, steam is injected into the fuel in order to maximize combustion efficiency and minimize the production of hydrocarbons (soot). Steam boilers and generators that use fuel oil will use this method to break up the viscous oil into smaller droplets to allow for more efficient combustion.

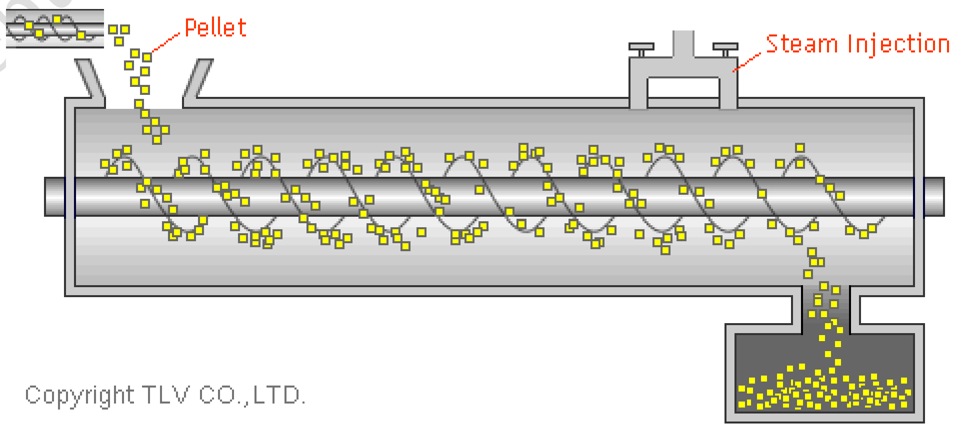
Steam for Cleaning:

Steam is used to clean a wide range of surfaces. One such example from industry is the use of steam in soot blowers. Boilers that use oil or coal as the fuel source must be equipped with soot blowers for cyclic cleaning of the furnace walls and removing combusted deposits from convection surfaces to maintain boiler capacity, efficiency, and reliability. Steam released out of the soot blower nozzle dislodges the dry or sintered ash and slag, which then fall into hoppers or are carried out with the combusted gasses.



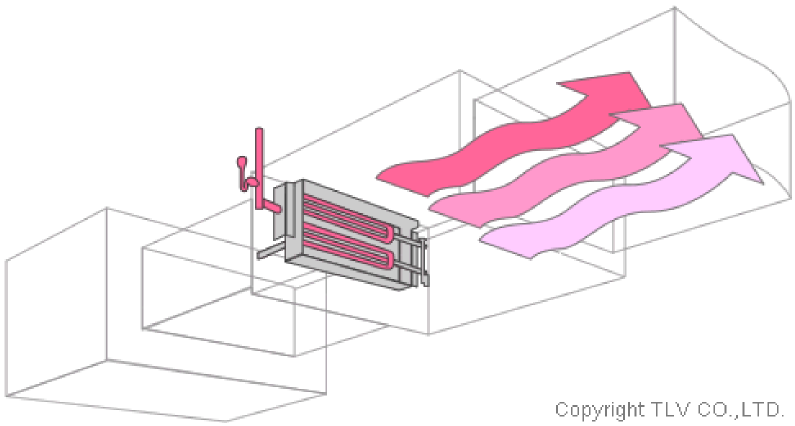
Steam for Moisturization:

Steam is sometimes used to add moisture to a process while at the same time supplying heat. For example, steam is used for moisturization in the production of paper, so that paper moving over rolls at high speed does not suffer microscopic breaks or tears. Another example is pellet mills. Often mills that produce animal feed in pellet form use direct-injected steam to both heat and provide additional water content to the feed material in the conditioner section of the mill. The moisturizing of the feed softens the feed and partially gelatinizes the starch content of the ingredients, resulting in firmer pellets.



Steam for Humidification

Many large commercial and industrial facilities, especially in colder climates, use low pressure saturated steam as the predominant heat source for indoor seasonal heating. HVAC coils, often combined with steam humidifiers, are the equipment used for conditioning the air for indoor comfort, preservation of books and records, and infection control. When the cold air is heated by the steam coils, the relative humidity of the air drops, and it must then be adjusted to normal levels with addition of a controlled injection of dry saturated steam into the downstream air flow. Steam is used to humidify air within an air duct before the air is distributed to other regions of a building.



Steam for Sterilization and Disinfection:

Processing and Manufacturing industries follow standard guidelines to ensure a clean and safe work environment. Sterilization and Disinfection are crucial to ensure that the products, equipment, and the process plants.

Industries such as pharmaceutical, food processing, chemicals, distilleries, etc. ensure proper sterilization with high-temperature steam for process plants and equipment to maintain the quality of the products.

Energy Sources and Power Plants

Review of energy sources:

- *"Energy"* is a word derived from the Greek word *Energia"*, meaning capacity to do work. Energy exists in various forms.
- The form of energy that bodies in motion possess is called *kinetic energy*.
- The energy related to the position of a body is called *potential energy*.
- The energy contained in a chemical system by virtue of the motion of and forces between the individual atoms and molecules of the system is called *internal energy*. There are different other forms of energy namely, kinetic energy, potential energy, internal energy, mechanical energy, thermal energy, chemical energy etc. All forms of energy are inter-convertible by appropriate processes.

ENERGY SOURCES:

Energy exists in the earth or comes from the outer space. The energy existing in the earth is called *capital energy* and that which comes from the outer space is called *celestial or income energy*. E.g. of capital energy: fossil fuels, nuclear fuels and heat traps. E.g. of celestial or income energy: Electromagnetic energy, gravitational energy, particle energy and potential energy of meteorites. The useful celestial energy sources are the electromagnetic energy of the Sun, called *direct solar energy*. The gravitational energy of the Moon produces tidal energy. The other sources such as wind energy, hydel energy, geothermal energy, biofuels etc. are derived from the direct solar energy.

Renewable and non-renewable sources of energy

The conventional and non-conventional energy sources have been classified as **renewable** and **non-renewable energy sources**, depending on whether these sources are continuously available or will be exhausted.

The renewable sources of energy are defined as the energy sources which are continuously produced in nature and are essentially inexhaustible at least in the time frame of human societies. These energy sources replenish themselves naturally in a relatively short time and therefore will always be available. E.g. of renewable energy sources: direct solar energy, wind energy, tidal energy, hydel energy, ocean thermal energy, bio energy, geothermal energy, peat, fuel wood, fuel cells, solid wastes, hydrogen energy etc. Of the above renewable energy sources, geothermal energy, peat and fuel wood must be used at a rate less than their renewal rate in the nature, to allow them to build up again in nature.

The non-renewable energy sources are defined as the energy sources which have been accumulated over the ages and not quickly replenishable when they are exhausted. E.g. Fossil fuels (coal, petroleum and petroleum products), nuclear fuels and heat traps.

Advantages of renewable energy sources

1. The renewable energy sources are non-exhaustible.

2. Renewable energy sources can be matched in scale to the need and also can deliver the energy required for a specific task.

3. Some of the renewable energy conversion systems can be built on or close to the site where energy is required.

4. The diversity and technologies of renewable energy conversion systems offer more flexibility in designing the conversion systems compared to the conventional energy conversion systems.

5. The local or regional self-sufficiency can be achieved by harnessing locally available renewable energy, which otherwise would be left unutilized.

6. Except biomass energy, all other renewable energy sources offer pollution-free environment and maintain ecological balance.

Disadvantages of renewable energy sources

1. Some of the energy sources are intermittently available (i.e. not continuously available). E.g. solar energy, tidal energy, wind energy etc.

2. There is a limit to the rate at which solar energy is received at the Earth.

3. Renewable energy sources like wind energy, tidal energy etc. are concentrated only in certain regions.

4. State-of-the-art technology in harnessing the renewable sources is yet to be developed to meet the present day energy requirements.

5. Application of renewable energy sources in transportation sector is not viable as of today.

Differences between renewable and non-renewable sources of energy

Sl. No.	Renewable energy sources	Non-renewable energy sources
1	Inexhaustible in nature.	Exhaustible in nature.
2	Most of the renewable energy sources are freely and readily available in nature.	Most of the non-renewable energy sources are not readily available in nature.
3	Non-reliable since energy concentration varies from region to region and time to time.	Reliable, since energy concentration is almost constant in all regions.

4	Initial costs of extracting energy are high.	Initial costs are comparatively less.
5	Rarely used due to limitations in their equipment's.	Widely used due to maximum availability of their equipment's.
6	Energy transmission cost is less.	Energy transmission cost is relatively more.
7	Eco-friendly in nature.	Not eco-friendly in nature.
8	Maintenance cost is low.	Maintenance cost is high.
9	Energy conversion equipment's are not well developed.	Energy conversion equipment's are well developed.
10	Energy conversion equipments are of low efficiency.	Energy conversion equipments are of relatively high efficiency.
11	E.g. direct solar energy, wind energy, tidal energy, hydel energy, ocean thermal energy, bio energy, geothermal energy, peat, fuel wood, fuel cells, solid wastes, hydrogen energy etc.	E.g. Fossil fuels (coal, petroleum and petroleum products), nuclear fuels and heat traps.

Construction and working of Hydel power plant

A power plant that utilizes the potential energy of water for the generation of electrical energy is known as a hydroelectric power plant.

Hydroelectric power plants are generally located in hilly areas where dams can be built easily, and large water reservoirs can be made. In a hydropower plant, a water head is created by building a dam across a river or lake. From the dam, water is fed to a water turbine.

Working Principle of Hydroelectric Power Plant

The water turbine changes the kinetic energy of the falling water into mechanical energy at the turbine shaft. In simple words, falling water spins the water turbine. The turbine drives the alternator coupled with it and converts mechanical energy into electrical energy. This is the basic "working principle of hydroelectric power plant."

Figure: Schematic representation of Hydroelectric power plant

Construction & Working of Thermal Power Plant:

It is the power plant which is used to generate electricity by the use of steam turbine. The major components of these power plants are boiler, steam turbine, condenser, and water feed pump.

Figure: Layout of Thermal Power Plant

Working of Thermal Power Plant:

- In the steam power plant, the pulverized coal is fed into the boiler and it is burnt in the furnace. The water present in the boiler drum changes to high pressure steam.
- From the boiler the high-pressure steam passed to the superheater where it is again heated up to its dryness.
- This superheated steam strikes the turbine blades with high speed and the turbine starts rotating at high speed.
- A generator is attached to the rotor of the turbine and as the turbine rotates it also rotates with the speed of the turbine. The generator converts the mechanical energy of the turbine into electrical energy.
- After striking on the turbine the steam leaves the turbine and enters into the condenser. The steam gets condensed with the help of cold water from the cooling tower. The condensed water with the feed water enters into the economizer.
- In the economizer the feed water gets heated up before entering into the boiler. This heating of water increases the efficiency of the boiler.
- The exhaust gases from the furnace pass through the superheater, economizer and air pre-heater. The heat of this exhaust gases is utilized in the heating of steam in the superheater, feed water in the economizer and air in the air pre-heater.
- After burning of the coal into the furnace, it is transported to ash handling plant and finally to the ash storage.

Advantages:

- Less initial cost as compared to other generating stations.
- It requires less land as compared to hydro power plant.
- The fuel (i.e., coal) is cheaper.
- The cost of generation is lesser than that of diesel power plants.

Disadvantages:

- It pollutes the atmosphere due to the production of large amount of smoke. This is one of the causes of global warming.
- The overall efficiency of a thermal power station is low (less than 30%).

Construction & Working of Nuclear Power Plant:

The schematic diagram of nuclear power station is shown in figure. 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, heat exchanger or steam generator, steam or gas turbine, AC generator and condenser.

Figure: Schematic Arrangement of Nuclear Power Plant

The reactor of a nuclear power plant is similar to 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. Pumps are provided to maintain the flow of coolant, condensate, and feed water.

Solar Energy:

Solar energy is the energy obtained by capturing heat and light from the Sun. Energy from the Sun is referred to as solar energy. Technology has provided a number of ways to utilize this abundant resource. It is considered a green technology because it does not emit greenhouse gases. Solar energy is abundantly available and has been utilized since long both as electricity and as a source of heat.

There are several ways the solar energy can be harnessed. Such as;

a) Solar Photovoltaic Conversion (Helio- Electrical Process)
b) Solar Thermal Conversion (Helio-Thermal Process)

For, electricity generation Solar P-V cells are used at a larger extent.

Solar Power Plant (PV Cells):

The major components of the Solar power are plants are: Solar Panels, Solar cells, Battery and Invertor.

Figure: Working Principle of Solar Power Generation / PV Cell

As sunlight falls over a solar cell, a large number of photons strike the p-type region of silicon. Electron and hole pair will get separated after absorbing the energy of photon. The electron travels from p-type region to n-type region due to the action of electric field at p-n junction. Further the diode is reversed biased to increase this electric field. So, these current starts flowing in the circuit for individual solar cell and combining the current of all the solar cells of a solar panel, to get a significant output.

Solar power plant has a large number of solar panels connected to each other to get a large voltage output. The electrical energy coming from the combined effort of solar panels is stored in the Lithium-ion batteries to be supplied at night time, when there is no sunlight.

<u>Solar Thermal Conversion (Helio-Thermal Process): Flat Plate Collector</u>

The heating property of solar radiation is used in the devices to meet the thermal energy needs. It is necessary to collect and concentrate the solar radiation in an efficient manner to arrive a reasonably high-temperature heat source. The collectors gather the sun's energy and direct it onto receivers that contain the working fluid.

The flat plate collector is a device used to absorb and store solar energy. The stored energy is used for domestic, agriculture or industrial applications. The construction of flat plate collector is very simple.

The flat plate collector consists of a metal sheet (absorber surface) exposed to the solar radiation. This sheet absorbs both beam and diffused solar radiation. The sheet is coated with black paint. Fluid carrying pipes are connected to back side of the metal sheet. The liquid most commonly used is water. The lower side of metal sheet is covered with insulating material. The transparent cover (glass) is fixed above the metal sheet, which reduces the heat loss due to convection & radiation. The flat plate collector efficiency is good at medium and maximum temperatures, but at low temperature the efficiency is very low. The flat plate collectors are designed for output temperatures ranging from 60º C to 100º C.

Figure : Solar Flat Plate Collector

Cold water from overhead tank enters the flat plate collector from bottom and flows over the copper tubing which is having more temperature because of solar radiation. Because of the natural phenomenon of heat flow from hot to cold regions, because of this water observes the temperature in the tube and becomes hot water. This hot water will reach the tank from top of the system as shown in the figure.

Tidal power plant:

Tide is a periodic rise and fall of the water level of the sea which are carried by the action of the sun and moon on the water of the earth. The highest level of the tidal water is known as the high tide. The lower level of the water is known as low tide. The level difference between the high tide and the low tide is known as tidal range. To set up a tidal power plant, the range should be between 5 meters or more.

Two tidal cycles occur during a lunar of 24 hours & 50 minutes. That is to say, the time between high tide and low tide (ebb tide) at any position is little over six hours.

Construction & Working of Tidal power Plant:

Figure: Schematic arrangement of harnessing Tidal Energy

In this system, A barrage or dam is constructed on the sea. This provides the reservoir on the other end. As the head is created between sea and reservoir water, water made to flow through turbines to generate power.

Working: During the beginning of the high tide the water is allowed inside the barrage through the turbine. During this process the rotational mechanical energy is used to generate the electric power. At the end of the high tide, the water level in the sea side stop dropping continuously and when sufficient head is reached between the Sea and tidal basin, the water is released back to sea through turbine, thus generating power.

Wind Power:

Wind energy is defined as the kinetic energy associated with the moment of large mass of air over the earth surface. The circulation of air is caused by the uneven heating and cooling of the earth surface. In general, during the daytime the land masses heated up faster than sea hence air moving over the land masses heated up and becomes less dense. This makes the cold denser air from the sea blow towards the land masses.

But during the night, the land cools faster than the sea and hence, the denser air from the landmasses starts moving towards the sea. That is offshore.

Figure: Schematic Arrangement of a wind turbine parts

Above figure shows the schematic arrangement of windmill. The major parts of a windmill are hub, blades, nasal, tail, yawing mechanism and tower.

Working principle:

As the wind flows over the windmill, the blades of the mill start rotating slowly. Blade starts rotated because of their aerodynamic profile. The wings are connected to hub, which is in turn connected to main driving shaft, which is intern connected to gearbox. The function of the gearbox is to increase the speed of the shaft which is connected to the generator. The generator, generates the power and transmitted to grid. The minimum velocity in air required to run the windmill is more than five meter per second.