Unit III

ENERGY CONSERVATION

3.1 INTRODUCTION

- Energy is the most important requirement in human development, and acts as a key factor in determining the economic development of all countries.
- The Indian energy sector is rapidly growing to meet the demands of the nation. However the growth in energy supply have failed to meet the increasing demands because of rise in population, rapid urbanization and progressing economy.
- Therefore the gap between the demand and supply goes on increasing day by day. Hence there is serious energy shortages in India, forcing it to rely heavily on imports.
- It becomes an urgent need to conserve energy and reduce the demand of energy requirement by adopting more efficient energy technologies in all sectors.
- The human beings requirement of energy is largely depending on the commercial fuels. These fossil fuels reserve like coal, oil, natural gas will get depleted and the costs, are bound to go up. For this reason we must give up many wasteful practices in energy utilization which have grown up over the years.
- Therefore we must conserve energy by all possible means.

3.1.1 Scope of Energy Conservation

- Energy conservation is defined as the reduction in energy consumption but without sacrificing the quantity and quality of production. This means that for the same energy consumption there should be higher production. Therefore energy saved is the money earned which would be used in other productive means.
- For example the electricity which is mostly in shortage should be utilized efficiently and the areas where the energy is wastefully used are to be identified and the corrective action has to be taken. This could be achieved by "Energy Audit".
- The energy audit is a technical survey of a plant in which the machine wise, section wise, department wise pattern of energy consumption is to be studied and the attempts are to be made to balance the total energy input with the production.
- This energy audit will point out the areas where the energy is wastefully used and the improvements required are identified.
- For this improvements the corrective measures has to be recommended which can be adopted on short term or long term basis giving priorities so that the overall plant efficiency could be improved.
- For this improvement there should be a clear picture of financial involvement which is to be provided for each type of recommended measures which should be supported by payback period.
- Energy conservation can also be defined as the substitution of energy with capital, labour, material and time.

3.1.2 Energy Conservation Principle [Dec. 17, May 18]

- The two principle governing energy conservation policies are maximum thermodynamics efficiency and maximum cost effectiveness in energy use.
- Maximum thermodynamic efficiency in energy use is defined as the maximum possible work output by using a given amount of primary energy input.
- This can be given in the following form as

  Maximum work output

  = Energy input – Energy loss in transfer – Energy discharge
- Work is the energy transfer between system and surroundings. It is done by the system on the surroundings, if the sole effect of this interaction is to move the desired mass in the surroundings. For example in case of steam power plant the energy input as chemical energy in the form of fossil fuels is supplied to the boiler to produce steam and the work output is measured by the number and force of turn made by the turbine.
- The energy loss in transfer is the energy lost to the ambient environment through radiative and convective heat transfer.
- The energy discharge is the energy discharge to the atmosphere after producing the required amount of work. For example the flue gases (gas produced after

combustion of fuel) is expel to the atmosphere at high temperature after doing the work in case of gas turbine.

- Energy conservation is the energy demand management which aims at increasing the efficiency of use. An energy audit helps to identify the different ways of energy sources to be used in the industry. It also helps in quantifying the areas where waste can occur and where scope for improvement may be possible.

3.1.3 Energy Efficiency [Dec. 17, May 18]

- Energy efficiency involves using energy more effectively at the technological level. Energy efficient products aims to provide users with the same level of comfort and convenience while cutting costs and preserving the environment. For example the electrical appliances can be purchase with high energy star ratings.
- The energy efficiency can be defined as the low cost and readily available resource that offers variety of benefits to utility customers and to society as a whole. It is the utilization of energy in the most cost effective manner to carry out a manufacturing process or provide a service, whereby energy waste is minimized and the overall consumption of primary energy resources is reduced.

3.1.4 Maximum Cost Effectiveness

- To address the challenges of high energy prices, energy security, air pollution and global climate change it becomes important to improve the energy efficiency cost effectively.
- Industries ,hospitals consumes more than 70 percent of the natural gas and electricity used in the country. Therefore it is to be have the constructive cost effective ways to address the challenges of energy consumption.
- Evaluating the cost-effectiveness of energy efficiency is essential to identifying how much of our country's potential for energy efficiency resources will be captured.
- Energy efficiency cost-effectiveness is measured by comparing the benefits of an investment with the costs.
- The basic structure of cost-effectiveness involves a calculation of the total benefits and the total costs in rupees terms from a certain advantage point to determine whether or not the overall benefits exceed the costs.

3.2 ENERGY CONSERVATION IN VENTILATION AND AIR CONDITIONING

- Out of the total energy used in manufacturing industries heating, ventilation and air conditioning (HVAC) constitutes up to 35 percent.
- The design of good HVAC system consider the interrelationship of building systems while taking into consideration the energy consumption, indoor air quality and environmental benefit.
- HVAC refers to the equipment, distribution network and terminal used either individually or collectively to provide fresh filtered air, heating, cooling and humidity control in a building.
- To supply the HVAC system, the facilities can have any combination of heating and cooling sources. For heating a facility, a gas-fired heat pump, infrared radiation or electric heater could be employed.
- For cooling a facility rooftop units, chillers and air conditioner could be used.

3.2.1 Ventilation

- The process of supplying or removing air from a space by natural or mechanical means is called as ventilation.
- The air which is exhausted from the building must be replaced by outside air. By using a makeup air units the outside air must be brought to a certain temperature to supply throughout the building.
- The conditioned air is distributed through duct. Window air conditioner is used to distribute air directly from the unit.

3.2.2 Air Conditioning

- Air conditioning is nothing but controlling the temperature, humidity, velocity and purity of air, which is further used for different applications.
- Air conditioning is required to meet the human comfort conditions as well as industrial applications.
- There are various categories of industrial air conditioning depending upon the inside design conditions.

Examples :

- In metrology laboratories, computer centres, etc., maintaining a constant temperature is very important compared with relative humidity. 10 % to 20% variation in relative humidity does not affect much.

- The paper and textile industries require relative humidity of the order of 70 % to 75 %. The temperature requirements in such spaces are not severe.
- There is still another category of applications where strict control of both temperature and humidity are required (in chemical and biological applications).

The above applications indicate that air conditioning means controlling all the parameters (temperature, humidity, velocity, purity) simultaneously or controlling any one of these variables to meet a particular application.

Let us discuss the parameters of human comfort conditions.

Actually, it is very difficult to decide the numerical values of variables of comfort conditions. Comfort ability of a human being depends upon the metabolic rate of heat generation. A person will feel comfortable when the metabolic rate of heat generation equals the rate of heat dissipation to the environment.

The metabolic rate varies from a person sleeping (60 W) to a person engaged in sustained hard work (600 W). (The rate at which body produces heat is called as metabolic rate).

The metabolic rate depends upon age, sex, type of activity being carried out, etc. Therefore, it is very difficult to say that for a particular set of conditions, all the people shall feel comfortable. But it is surveyed that majority of the people feel comfortable for the following conditions.

3.2.3 Comfort Conditions

- **Temperature of Surrounding :** Air at 21°C with 50 % relative humidity.
- **Purity of Air :** For health and comfort :
  - Air must be free from dust or other particle impurities.
  - Air must contain its constituents in proper proportions.
  - It should not have unpleasant odour.
- **Velocity of Air :** The velocity of air is about 0.4 m/s, it should be from front side of the people.

The comfort conditions will vary according to the season.

The atmospheric air and air in the conditioned space always contains water vapour in superheated state. The level of water vapour in the air plays an important role in designing the air conditioning equipments.

Therefore, it is very important to study the properties of moist air called psychromatic properties and the subject which deals with the behavior of moist air is known as psychrometry.

Moist air is the homogeneous mixture of dry air and water vapour.

In air conditioning practice, all the calculations are based on the dry air part, since the water vapour part is continuously changing. For defining psychrometric properties, consider V is the volume of moist air at pressure P and temperature T. This air contains m_a kg of dry air and m_v kg of water vapour (See Fig. 3.1).

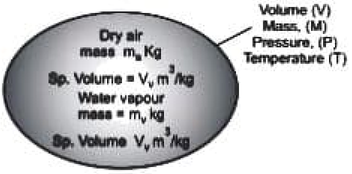


Fig. 3.1 : Mixture of dry air of water vapour

1. **Dry Bulb Temperature (DBT) :**

   The actual temperature 'T' of moist air is known as dry bulb temperature.

2. **Specific or Absolute Humidity or Humidity Ratio :**

   It is denoted by w. It is the ratio of mass of water vapour to the mass of dry air in a volume 'V' of mixture.

$$w = \frac{m_v}{m_a} = \frac{V/v_v}{V/v_a} = \frac{v_a}{v_v}$$

3. **Relative Humidity (RH) :**

   It is the ratio of mass of water vapour in a certain volume of moist air at a given temperature to the mass of water vapour in the same volume of saturated air at the same DBT.

4. **Saturated Air (w_s) :**

   It is the mixture of dry air and water vapour; such that air holds maximum amount of water vapour, at the given DBT.

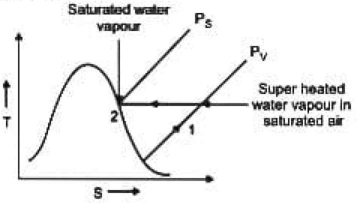


Fig. 3.2 : Saturated air

5. Degree of Saturation (Fig. 3.2) :

It is the ratio of the actual specific humidity (w) to the specific humidity (w_s) of saturated air at same DBT. It is denoted by μ.

$$\mu = \frac{w}{w_s}$$

6. Wet Bulb Temperature (WBT) (Fig. 3.3) :

It is the temperature of air recorded by a thermometer, when its bulb is covered by a wet cloth, exposed to the air.

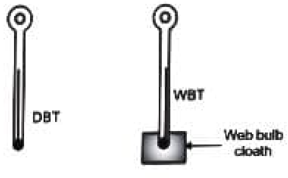


Fig. 3.3 : DBT and WBT measurement

7. Wet Bulb Depression :

It is the difference between dry bulb temperature and wet bulb temperature at any point. The wet bulb depression indicates relative humidity.

8. Dew Point Temperature (Fig. 3.4) :

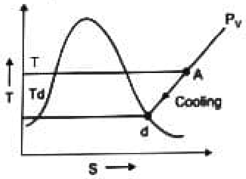


Fig. 3.4 : Dew Point Temperature

The water vapour existing at temperature T and partial water vapour pressure P_w of the mixture is in superheated state. Moist air containing moisture in such a state is an unsaturated air.

If unsaturated air is cooled at constant pressure, the mixture will reach the saturation temperature t_d of water vapour, at which point, the first drop of dew point will be formed. This temperature t_d is called the dew point temperature (DPT).

All data essential for the complete thermodynamic and psychrometric analysis of air conditioning processes can be summarized in a psychrometric chart (Fig. 3.5)

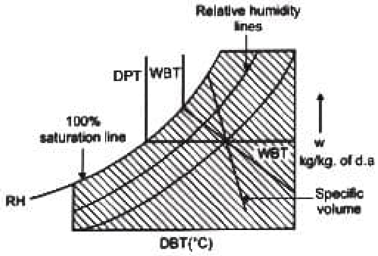


Fig. 3.5 : Psychrometric Chart

Psychrometric chart is a graph of specific humidity (w) against DBT

3.2.4 Air Conditioning System

Practically, it is difficult to select a proper air conditioning system to meet the space requirement. A suitable system should maintain correct temperature, humidity, air purity, air - movement and noise level.

Always it is not possible to maintain all the above factors mentioned and a compromise should be made so that the system becomes economical.

Air conditioning system consists of many different components to control the variables. The air conditioning systems are classified as :

- Central air conditioning system
- Unitary air conditioning system
- District air conditioning system
- Self-contained air conditioning system.

It is not possible to discuss all these systems. Only a window air conditioner is discussed here.

3.2.5 Room Air Conditioner or Window Air Conditioner

- It is a packaged air conditioner. In this unit, cooling, filtering and air distribution units are combined in a compact size. Therefore, it is easy for its installation, servicing and also cheaply available.

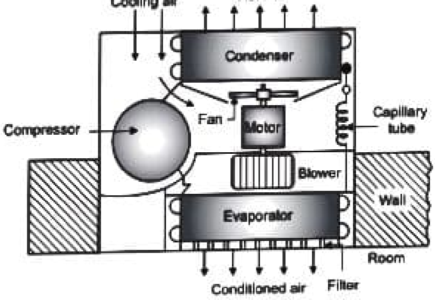


Fig. 3.6 : Room air conditioner

- The components of the unit are illustrated in Fig. 3.6
- The basic components are compressor, condenser, capillary and evaporator. In addition to there are filters, accumulators, motors, fans and various controls.
- High pressure and high temperature refrigerant gas (usually R-23) coming from the compressor is cooled in the condensing unit by using outside air as coolant. For this, an air circulating fan is provided.
- The refrigerant in its liquid state at outlet of condenser further passes through a capillary tube where its pressure and temperature are further reduced.
- This liquid refrigerant flowing through the evaporator extracts heat from the air which is flowing over the evaporator. Thus air is cooled and is supplied to the room. The liquid refrigerant vaporises and enters the hermetic compressor. In this way, cycle repeats.

3.2.6 Advantages of Window Air Conditioner

- Window air conditioners are available in wide ranging capacities (1.5 TR to 5 TR). Hence can be easily installed to meet the requirement.
- Size is very small, therefore, installation is simple.
- They are assembled in the factory itself. Therefore, manufacturing cost is very less.
- Individual room temperature control is a specific feature.
- Zoning or extensive duct work is eliminated.

3.2.7 General Opportunities for Energy Conservation HVAC

1. Reduce HVAC system operation when building or space is unoccupied.
   - To reduce electrical, heating and cooling requirements reduce the operating hours.
   - Eliminate usage in un-occupied space.
   - The direct cooling of un-occupied areas can be minimize by turning off fan coil units and unit heaters or by closing the vent or supply air diffuser.
   - Close outdoor air dampers.
2. Reduce HVAC operating hours
   - Install HVAC hight-set back controls.
   - Adjust thermostat setting for change in seasons.
   - Install separate controls for zones.
   - Use variable speed drives.
3. Adjust areas that are too hot or too cold
   - Adjust air duct registers
   - Use operate windows for ventilation during mild weather.
   - Create zones with separate controls.
4. Reduces unnecessary heating or cooling
   - The thermostat should be set to higher in the cooling season and lower in the heating season.
   - Allow the fluctuation of temperature.
   - Adjust the air supply from the air handling unit to match the required space conditioning.
5. Install an economizer cycle the HVAC systems are normally designed for a fixed minimum air flow, if the economizer is incorporated in HVAC system it will allows the HVAC system to utilize outdoor air by varying the supply air conditions, usually using an outdoor dry bulb temperature sensors.
6. Heat recovery ventilators : Employ heat recovery ventilators that exchange between 50 and 70 percent of the energy between the incoming fresh air and the outgoing return (conditioned) air.
7. Minimum make up and exhaust air
   - Keep door closed when air conditioning is running.
   - Properly insulate walls and ceilings.
   - Insulate air ducts, chilled water, hot water and steam pipes.
8. Implement a regular maintenance plan
   - Inspect to ensure the dampers are sealed tightly.
   - Ensure doors and windows have tight seals.
   - Check fans for lint, dirt or other causes of reduced flow.
   - Replace air filters regularly.
   - Inspect ductwork.
   - Repair leaks.

3.3 COMPRESSOR

It is a machine which increases the pressure of air. For this work, it requires external power. The general arrangement of air compressor is shown in Fig. 3.7.

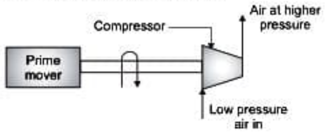


Fig. 3.7 : General arrangement of a compressor

Prime mover may be engine, electric motor which supplies power to the compressor shaft.

Question arises, why we should compress air or gas at all ? This can be answered with the applications of compressed air.

(A) Low pressure compressed air (Pressure < 1 MPa) is used
- To supply the compressed air (higher density air) to the I.C. engine to increase its power output.
- To paint by spraying.
- To convey the materials like sand, powered fuel, etc. through a pipeline.
- To maintain required air flow for the furnace.

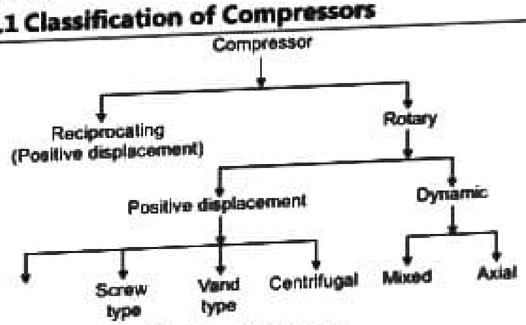
(B) The compressed air having its pressure 1 MPa to 8 MPa is known as medium pressure, is used in gas turbine applications.

(C) The compressed air having its pressure greater than 8 MPa is known as high pressure air.

Such a high pressure is used
- To drive air motors.
- To operate brakes of locomotives.
- To operate pneumatic drills, screw drivers, etc.

At many places, one has to take care of fire (to protect from fire). For example, while digging the coal mines few kilometers below the earth crust, conventional engines cannot be used to avoid any fire accidents. Therefore, all the machines are operated by compressed air for safety purpose.

3.3.1 Classification of Compressors



3.3.2 Reciprocating Compressor

These are again classified as single (or double) acting single stage reciprocating compressors and (double) or single acting multistage reciprocating compressors, etc.

To explain the working of a reciprocating compressor, single acting type is discussed as follows :

It consists of a cylinder having water jackets, piston, suction and delivery valves, connecting rod etc. as shown in

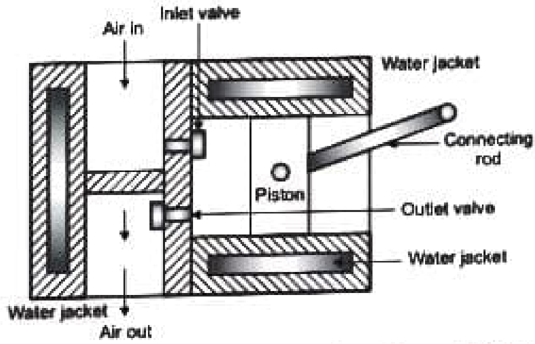


Fig. 3.8 : Parts of a single acting reciprocating compressor

The leftmost position of piston is known as Inner Dead Centre (IDC) position and right- most position as Outer Dead Centre (ODC) position.

1. When piston moves from IDC position towards right, the pressure inside the cylinder falls below atmospheric pressure. Therefore, suction valve opens, so air enters the cylinder until the piston reaches ODC position. This is known as suction stroke.
2. When the piston starts moving from its ODC position towards left, the pressure inside the cylinder increases, and the suction valve closes. As the pressure inside the cylinder is higher than the pressure on delivery side, then the discharge valve opens. Thus a quantity of air is pushed into the delivery side. This is known as delivery stroke.

This completes one cycle of operation. Similarly, steps (1) and (2) above will be repeated during the operation. In order to cool the cylinder walls, cooling water is circulated through the space (jackets) provided around the cylinder.

3.3.3 Centrifugal Compressor

It is a device to increase the pressure of air or gas by centrifugal action. It handles large quantity of air and increases its pressure to smaller extent.

It consists of a rotating impeller surrounded by diffuser and casing (See Fig. 3.9).

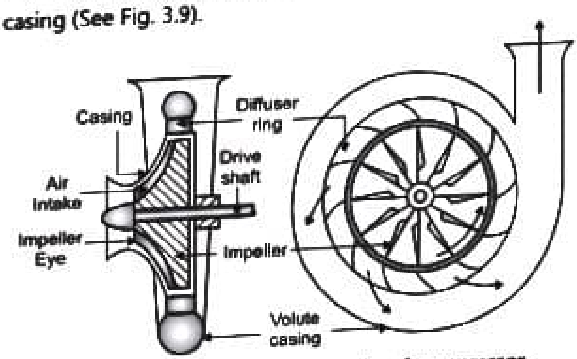


Fig. 3.9 : Construction of centrifugal compressor

1. **Impeller :** It is a disc with radial vanes. It is mounted on a shaft which is driven by an electric motor. Air is made to rotate by these vanes or impeller, because of which the pressure and velocity of air increases.
2. **Diffuser :** It is a fixed wheel surrounding the impeller. This unit helps to convert kinetic energy of air into pressure energy thereby increasing the air pressure.
3. **Casing :** It surrounds the impeller. The cross-section of this increases towards the delivery. Therefore, it also helps to convert kinetic energy of air to pressure energy by reducing its velocity.

Working :

Air enters the eye of impeller with low velocity V_1 and atmospheric pressure P_1. Based on centrifugal action of impeller, air flows radially outwards during which it is guided by the impeller vanes. The pressure and temperature of air increases as it receives energy from the impeller. Therefore, its velocity also increases. Suppose P_2 and V_2 are the increased pressure and velocity of air. This air now enters the diffuser (a diverging passage) where the velocity of air is reduced; thereby increasing pressure to P_3. The reduced velocity is say V_3. This is illustrated in Fig. 3.10.

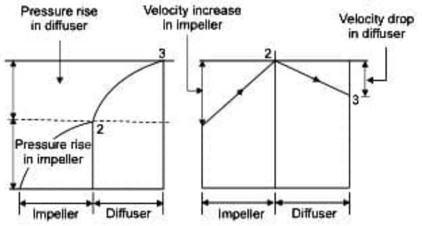


Fig. 3.10 : Pressure and velocity variation across the impeller and diffuser

3.3.4 Energy Conservation in Compressor

For the efficient operation of compressor, the number of issues must be considered right at the project planning stage and also during operation.

- Intake air temperature of air : The air supplied at the intake of air compressor should be at lower temperature. It is seen than if the temperature of intake air increase the power consumption of compressor increases. The compressor is power consuming device so our aim should be that the compressor should consume less power, hence less electrical power required. Therefore the compressor should be placed away from heat source like kiln, furnace etc.
- The air supplied to the compressor should be dust free. The dust accumulated in the filter should be removed regularly and eventually the filters must be replaced.
- Dry air free of moisture should be supplied to the compressor. The moisture present in the air gets converted in to water during compressor operation and will damage the parts.
- In multistage compressors there is rise in temperature of air as the air passes from one stage to another which will result in rise in power consumption. To avoid the rise in power consumption intercoolers are provided which will cool the air of intermediate stages.
- The intercooler are either air cooled or water cooled. The intercoolers need to be maintained well.

3.4 FANS AND BLOWERS

- A centrifugal fan is a mechanical device for moving air or other gases for ventilation and industrial process requirements. The term blower are frequently used as synonyms. The fans and blowers increase the speed and volume of an air stream with the rotating impellers.
- It increases the pressure of air to move it against a resistance caused by ducts, dampers or other components in the system.
- There are two categories of the fan centrifugal flow and axial flow.
- In centrifugal flow fan the air enters around centre of the fan and exists around the outside, in which airflow changes direction twice.
- The typical impeller blade construction types includes paddle, Radial, Backward curved and forward curve. The characteristics are low flow rates and high pressures.
- Typical applications for centrifugal fans are air handling units, process heating and cooling, electronic cooling and in supplying air in boiler combustion.
- In axial flow fans the air enters parallel to the axis of fan, in which airflow does not change its direction.
- The blade shapes for axial flow fans are aerofoil, paddle and variable pitch. These fans are used where high flow rates and low pressure flow is required. The applications for this fans includes simple extraction or cooling applications, desk fans and condenser cooling in refrigeration.

3.4.1 Energy Conservation in Fans and Blowers

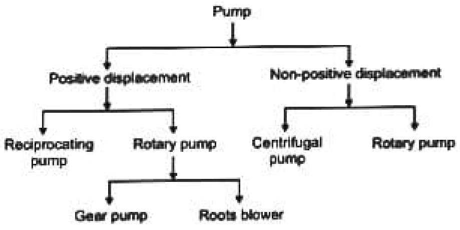
- **Pressure Minimization :** To reduce energy costs pressure offers greater opportunities. To manage the system pressure and to have good airflow characteristics the proper control device or pressure monitors should be used. Thousands of rupees can be saved by suing a good pressure monitoring system.
- **Density Control :** The density of transporting gas gets affected by temperature, moisture, molecular weight, elevation and the absolute pressure in the duct. For example cooling of the gas reduces the density but may required more power.
- **Fan Efficiency :** The selection of proper fan is important. The design of the fan and its blade type can affect efficiency and power requirement significantly.
- **Sizing of the Fan :** The fan may be oversized for the particular application which can result in efficiency losses of 1 to 5%.
- **Adjustable Spaced Drives :** By selecting the adjustable speed drives there is significant energy savings can be achieved. The savings may vary between 14 to 40%.
- **High Efficiency Belts :** The belts are significant position of the fan system in many plants. The V-belts tends to stretch slip, bend and compress which lead to a loss of efficiency. Replacing standard v-belts by cogged belts can save energy and money.

3.5 PUMPS

Pump is a device which converts mechanical energy into hydraulic energy. Mechanical energy is supplied to the pump from external source.

When a pump is placed in a pipe line, it imparts pressure energy to the liquid. Therefore, pressure energy of fluid increases, due to which it is lifted to a greater height.

The pumps are classified as follows :



Let us discuss these pumps one by one.

3.5.1 Centrifugal Pump

Centrifugal pump is known as dynamic pressure generator.

Water enters the pump through its centre. It is rotated by the impeller which throws it outwards with a pressure energy to the fluid. The fluid flow depends upon the resistance offered by pipe line.

Centrifugal Force : It means impeller gives pressure energy to the liquid. Therefore, liquid can be lifted from low level to high.

3.5.2 Construction of a Centrifugal Pump

Following are the main parts :

(1) Impeller, (2) Casing, (3) Suction pipe with a foot valve and a strainer, (4) Delivery pipe, (5) Shaft with bearings, (6) Prime mover.

All these parts are shown in Fig. 3.11.

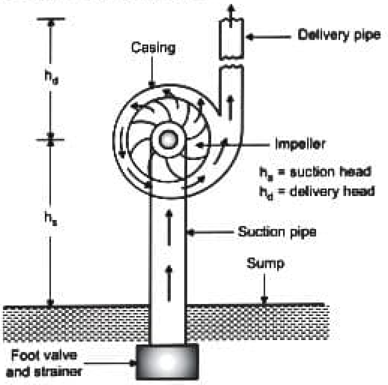


Fig. 3.11 : Main parts of a centrifugal pump

1. **Impeller :** The rotating part of a centrifugal pump is called as "impeller". The impeller consists of backward vanes, which will rotate the water. The shaft on which impeller is mounted is coupled to electric motor.
2. **Casing :** It surrounds the impeller. It is of spiral shape in which area of flow increases gradually. The increase in area of flow decreases the velocity of flow thereby increasing the pressure of water flowing through the casing.

   The various types of casing are (a) Volute casing, (b) Vortex casing, (c) Casing with guide blades.

3. **Suction Pipe, Foot Valve and Strainer :** The pipe which is connected to inlet of pump and other end dips in sump. A foot valve is a non-return valve which allows the water in one direction. Strainer is provided to avoid the entry of debris.

4. **Delivery Pipe :** A pipe connecting the pump and tank.

3.5.3 Starting of Centrifugal Pump

The suction pipe, casing and a portion of delivery pipe upto delivery valve is filled with water removing the air. This process of replacing air by water is known as priming.

The pressure generated by the impeller is dependent on the density of fluid which is in contact with it. The density of air is very less as compared to water. Therefore, if impeller is rotated with air in contact, sufficient pressure will not be generated to lift the water. Therefore, priming is essential.

After priming of the pump, delivery valve is closed and the impeller is rotated by starting the electric motor coupled to it. Due to the rotation of impeller, a suction (vacuum) is created at the eye of impeller. Therefore, water from suction pipe continuously flows to the impeller.

When the impeller attains its normal speed, then delivery valve will be opened, thereby getting the continuous discharge through the delivery pipe.

Depending upon the centrifugal head imparted to the water by impeller, water will be lifted to a certain height.

Applications of a Centrifugal Pump :

- It is used to lift large quantity of liquid through a smaller height.
- Dirty liquid may also be lifted by this pump, which is not possible with reciprocating pumps. Hence, it is used for lifting dirty water, sugar cane juice in sugar factory, etc.
- To get high pressures, the centrifugal pumps may be connected in series (multi-staging). Therefore, high discharge at higher head is also possible, hence used in water supply schemes. Multistage centrifugal pumps are used to supply water through the water-tube boilers of large steam generating capacity.

3.5.4 Reciprocating Pump

It is a positive displacement pump. In such pumps, the liquid is sucked and then actually pushed or displaced by exerting a pressure on it due to a moving member (piston).

3.5.5 Main Parts of Reciprocating Pump

Following are the main parts of a reciprocating pump :

1. A cylinder with a piston, piston rod, connecting rod and a crank,
2. Suction pipe,
3. Delivery pipe,
4. Suction valve,
5. Delivery valve,
6. Prime mover with a speed reducing device.

All these parts are shown in Fig. 3.12

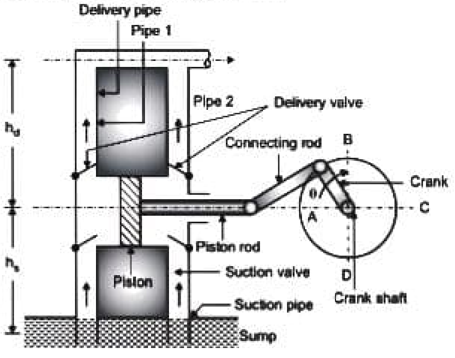


Fig. 3.12 : Main parts of a double acting reciprocating pump

3.5.6 Working of a Reciprocating Pump

Fig. 3.12 shows a double acting pump

It consists of a piston which reciprocates in the cylinder. The reciprocating motion of piston is obtained through crank and connecting rod arrangement. The crank is rotated by means of an electric motor.

When crank starts rotating, the piston moves forward and backward in the cylinder. When the crank is at 'A', the piston is at extreme left position in the cylinder. As the crank starts rotating ($\theta = 0$ to $\theta = 180°$) from A to C, piston moves from left to right. During this motion, vacuum is created on left side, so there is a suction on left side of piston but on the other side of piston (rod side), water is pushed into the delivery pipe. Therefore there is a discharge from pipe 2.

As the crank rotates from C to A (i.e. from $\theta = 180°$ to $\theta = 360°$), the piston moves from its right position and starts moving towards left in the cylinder. The movement of piston towards left increases the pressure of the liquid on the left side of piston but on the other side (rod side), there is a vacuum. It means, there is a discharge from one side of piston into pipe 1 but at the same time, water enters into the cylinder on rod side (suction on rod side).

In this way, for every stroke, a definite quantity of water is pushed into the delivery pipe. Therefore, discharge is more uniform compared with single acting reciprocating pump.

Applications of a Reciprocating Pump :

- These are suitable for high head and small discharge. So these are used as a feed pump for small capacity boilers.
- Speed of reciprocating pump is limited due to separation phenomenon inside the cylinder. Therefore, it is not used where high discharge is required.
- Only pure liquid can be lifted.

3.5.7 Difference Between Centrifugal Pump and Reciprocating Pump

Sr. No.	Centrifugal Pump	Reciprocating Pump
1.	It is a non-positive displacement pump.	It is a positive displacement pump.
2.	Useful for high discharge and low head.	It is suitable for high head and low discharge.
4.	The discharge is continuous and uniform.	Discharge is fluctuating. To make discharge uniform, air vessels are to be used for single acting pump.
5.	Operate at higher speed.	Speed of reciprocating pump is limited due to cavitation and flow separation phenomenon (120 rpm).
6.	Useful for lifting dirty water. It can be used in dredging operations.	Not suitable for lifting dirty liquids on account of clogging the valves.
7.	Priming is essential.	Priming is not required.
8.	Easy control of discharge by varying the speed of drive.	Bypass valves have to be fitted to deal with varying discharge.
9.	It has no suction and delivery valves.	It has suction and delivery valves, maintenance of these will be a problem.
10.	Weight to capacity ratio is smaller.	Weight of the unit to capacity (discharge) is higher.
11.	Variation of efficiency with head is not so drastic.	Efficiency falls drastically for low heads than normal.

3.5.8 Energy Conservation in Pumps

- The pump should be operated near best efficiency point.
- The old pump should be replaced by energy efficient pump.
- The resistance of the system can be reduce by pressure drop assessment and pipe size optimization.
- For higher heads the booster pump should be provided.
- To minimize the fluid losses repair the seals and packing.
- As far as possible avoid the valves in discharge side.

3.6 ENERGY CONSERVATION IN ELECTRIC FURNACE

The electric furnance are the type of heat producing equipment using electric power.

An electric arc furnace used for steel making and in foundries for producing cast iron products.

- An industrial heat treating furnace.
- An electrically heating kiln.
- An induction furnace used for preparation of special alloys.

1. The furnaces are provided with a number of inspection doors, check against infiltration of air, and provide insulation over the doors.
2. It is to be ensure that the furnace chamber should be under slight positive pressure.
3. Match the load to the furnace capacity.
4. Retrofit with heat recovery capacity.
5. Investigate the total cycle time and optimize it.
6. The furnace should be provided with temperature controllers.

3.7 ELECTRIC OVENS

Energy savings in ovens. The electric ovens are used for curing, drying, annealing, baking.

The electric ovens are used for curing, drying, annealing and baking etc. Energy efficient features on industrial oven can drastically reduce energy use and operating costs.

Energy conservation in oven

1. **Exhaust Rate Adjustment:** The exhaust fans used in ovens removes solvent vapors, moisture, or combustion byproducts. The exhaust fans should be adjusted with a manual damper or variable frequency drive. Set them to the minimum necessary.
2. **Heat Recovery System:** Exhaust air from the oven carries heat energy. A heat recovery system or heat exchanger recovers that energy from exhaust air and returns it to the oven.
3. **Humidity Control System:** A humidity control system senses oven humidity and varies the exhaust rate of the oven or dryer to the absolute minimum necessary to dry your product. This is especially needed when many different materials and moisture levels are loaded.
4. **Use of Insulation:** By using thicker insulation reduce oven heat lost through the walls. Just addition of 2" of insulation can save thousands of dollars in energy costs over the life of the equipment. Older ovens often have areas where insulation has settled or broken down. Feel that spaces of the oven.
5. **Openings of seal Oven:** Seal of the oven is the area where the parts enter and exit the heating chamber. High temperature curtains, powered air seals, or unheated parts help retain heat. Even a small leak wastes a lot of energy.
6. **Variable Speed Recirculation Fan**: Use a variable frequency drive to power the recirculation fan. Ramp up the fan's RPM as the oven heats up. Once heated, the fan can move the lighter air easier. By matching the motor horsepower with the fan speed, the motor can operate at its optimum energy consumption mode and achieve maximum efficiency.
7. **Idle Mode:** Use idle mode for pauses in production, for tooling changes, or for operator rest breaks. During idle mode, the temperature is temporarily reduced so it uses less energy. If the oven does not have idle mode, it can be added to an existing unit.
8. **Maintain Your Equipment:** Proper maintenance will significantly impact your energy costs. Keep filters and blowers clean.

3.8 ENERGY EFFICIENCY IN BOILERS

- Preheat the air supplied to the combustion chamber with waste heat of flue gases.
- The burners, nozzles, strainers should be clean periodically.
- For proper oil temperature the oil heater should be inspected.
- To minimize the heat loss up the stack, close the burner air and/or stack, dampers when the burner is off.
- Use boiler blow down to supply warm back-up water to the boiler.
- The deaerator venting should be optimized.
- Inspect the door gasket regularly.
- The scale and sediment which is formed on the water side must be inspect and clean.
- The economizer is to be added to preheat boiler feed water using exhaust heat.
- Recycle the steam condensate from the condenser.
- Inspect for root, flyash and slag on the fire side.

3.9 ENERGY CONSERVATION IN LIGHTENING SYSTEM

Electric lighting is a major energy consumer. Using energy efficiency equipments, effective controls and careful design, it is possible to save large amount of energy.

Following are the few examples of energy saving opportunities with efficient lightening.

- Installation of compact fluorescent lamps (CFLs) in place of incandescent lamps.
- Whenever possible install the occupancy or motion sensors to turn lights ON and OFF.
- To regulate the electric power in room employ an automated device, such as a key tag system,
- Installation of LED panel indicator lamps in place of filament lamps.
- Installation of high frequency (HF) electronics ballasts in place of conventional magnetic ballasts.
- Use of high efficiency light sources for reducing the energy consumption for lightening.

EXERCISE

1. Discuss the scope of energy conservation and principle of energy conservation.
2. Explain the methods of energy conservation in ventilations.
3. Discuss the general opportunities of energy conservation in HVAC.
4. What are the different parts of centrifugal compressor and explain the energy conservation in compressor
5. Discuss the opportunities in fans, blowers and pump.
6. Write short notes on
7. Energy conservation in electric furnace
8. Electric ovens
9. Energy efficiency in boilers
10. Energy conservation in lightning system

UNIVERSITY QUESTIONS

December 2017

1. What do you mean by energy conservation? Explain the measures to be taken to reduce the energy conservation in domestic refrigerator. List any four measures. **[6]**
2. What do you mean by energy conservation? Explain the measures to be taken to reduce the energy conservation in domestic refrigerator. List any four measures. **[6]**

May 2018

1. Define energy conservation and energy efficiency. How these two terms are different? Discuss the various benefits derived from energy conservation. **[6]**
2. What are the energy conservation opportunities available in industry? Briefly explain how the energy is saved while using electric motor? **[6]**

June 2019

1. What do you mean by energy efficiency? Explain the measures to be taken to reduce the energy conservation in air conditioners. List any four measures. **[6]**
2. Explain the energy pyramid? Write at least six practices that lead to increase in energy conservation in industries. **[6]**

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