Basis Concepts of Thermodynamics

Thermodynamics:

It is the field of thermal engineering that studies the properties of systems that have a temperature and involve the laws that govern the conversion of energy from one form to another, the direction in which heat will flow, and the availability of energy to do work.

System:

A thermodynamic system is defined as a quantity of matter or a region in space which is selected for the study.

Suroundings:

The mass or region outside the system is called surroundings.

Boundary:

The real or imaginary surfaces which separates the system and surroundings is called boundary. The real or imaginary surfaces which separates the system and surroundings is called boundary.

Define and write unit of heat and work ? ***

Work: Work in thermodynamics may be defined as any quantity of energy that flows across the boundary between the system and the surroundings which can be used to change the height of a mass in the surroundings.

unit = Joule or Kilo Joule

Heat: Heat is defined as the quantity of energy that flows across the boundary between the system and the surroundings because of a temperature difference between the system and the surroundings.

unit = Joule or Kilo Joule

Zeroth Law of Thermodynamics: The zeroth law of thermodynamics states that "if two thermodynamic systems are each in thermal equilibrium with a third, then they are in thermal equilibrium with each other."

First Law of Thermodynamics: 1.The First law of thermodynamics states that "when a small amount of work (dw) is supplied to a closed system undergoing a cycle, the work supplied will be equal to the heat transfer or heat produced (dQ) in the system." $\phi dw = J \phi dQ$

2.It state that energy can’t be created nor be destroyed, it can only transformed from one form to another form.

State Laws of perfect gas.

1. Boyle’s Law

This law was formulated by Robert Boyle in 1662.

It states, “ The absolute pressure of a given mass of a perfect gas varies inversely as its volume, when the temperature remains constant”.

Mathematically, **$P \alpha 1/V$**

$V\alpha 1/P$

PV=constant

2. Charles’s Law

This law was formulated by a Frenchman A.c. Charles in about 1787.

It states “The volume of a given mass of a perfect varies directly as its absolute temperature, when the absolute pressure remains constant”.

Mathematically, **$V \alpha T$**

V/T=constant

3.Avogrodo law

It’s state that equal volume of gas under similar condition of temp. & pressure contains equal no. of molecular mass.

$V \alpha n$

4. Gay-Lussac Law

This law states, “ The absolute pressure of a given mass of a perfect gas varies directly as its absolute temperature when the volume remains constant”.

Mathematically **$P \alpha T$**

P/T=constant

Combined with equation (1), (2), (3), we get

$V \alpha Tn/P$

$PV \alpha Tn$

PV/Tn= constant

PV/Tn=Ru (where Ru=universal real gas constant)

PV= nRuT

Combined with equation (1), (2),

$V \alpha T/P$

$PV \alpha T$

PV/T=constant

$P_1V_1 / T_1 = P_2V_2/T_2$ (General gas equation)

Specific heats of a gas

The specific heat of a substance may be broadly defined as the amount of heat required to raise the temperature of its unit mass through one degree. All the liquids and solids have one specific heat only. But a gas can have any number of specific heats (lying between zero and infinity) depending upon the conditions, under which it is heated. The following two types of specific heats of a gas are important from the subject point of view.

1. Specific heat at constant volume
2. Specific heat at constant pressure

Specific heat at constant volume

It is the amount of heat required one to raise the temperature of a unit mass of gas through one degree when it is heated at a constant volume. It is generally denoted by Cv.

Consider a gas contained in a container with a fixed lid as shown in the figure. Now, if this gas is heated, it will increase the temperature and pressure of the gas in the container. Since the lid of the container is fixed, therefore the volume of gas remains unchanged.

Let m= Mass of the gas

T_1= Initial temperature of the gas

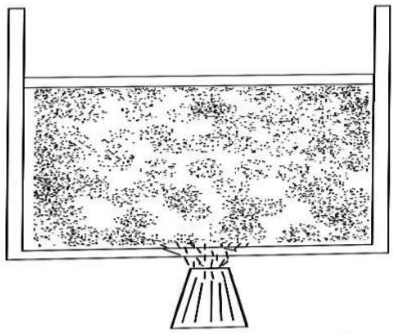
T_2= Final temperature of the gas

Total heat supplied to the gas at constant volume Q1-2= mass x supplied heat at constant volume x rise in temperature = $mC_v (T_2 – T_1)$.

It may be noted that whenever a gas is heated at constant volume, no work is done by the gas. The whole heat energy is utilised in increasing the temperature and pressure of the gas.

Specific heat at constant pressure

It is the amount of heat required to raise the temperature of a unit mass of a gas through one degree, when it is heated at constant pressure. It is generally denoted by Cp.



Consider a gas contained in a container with a movable lid as shown in figure. Now if this gas is heated, it will increase the temperature and pressure of the gas in container. Since the lid of the container is movable, therefore it will move upwards in order to counter balance the tendency for pressure to rise.

Let m= Mass of the gas

T_1= Initial temperature of the gas

V_1= Initial volume of the gas

T_2, V_2= Corresponding values for the final condition of the gas

Total heat supplied to the gas, at constant pressure.

Q1-2= Mass x Sp. heat at constant pressure x rise in temperature = $mC_p (T_2 – T_1)$.

Whenever a gas is heated at a constant pressure, the heat supplied to the gas is utilised for the following two purposes.

1. To raise the temperature of the gas. The heat remains within the body of the gas and represents the increase in initial energy. $dU= mC_v (T_2 – T_1)$.

2. To do some external work during expansion. Mathematically, work done by the gas W1-2= P(V2-V1) = mR (T_2 – T1).

<u>RELATIONSHIP BETWEEN C_P,C_V AND R</u>

Let m = mass of the gas

$P_1 = P_2$ = Pressure of gas (P= C)

V_1 = initial volume of gas

V_2 = final volume of gas

T_1 = initial temp. of gas

T_2 = final temp. of gas

dQ = Change of heat reply

du = change in internal energy

we know that 1st law of thermodynamics

dQ =dU + dW

$mc_pdT = mC_vdT + Pdv$

$mC_p (T_2 - T_1) = mC_v (T_2 - T_1) + P (V_2-V_1)$

~~m~~$C_p (T_2 - T_1) =$ ~~m~~$C_v (T_2 - T_1) +$ ~~m~~$R (T_2-T_1)$

$C_p = C_v + R$

$C_p - C_v = R$

$C_p/ C_v - C_v / C_v = R/ C_v$

$v-1= R/ C_v$ **(where $C_p/ C_v = v$)**

$C_v = R/v-1$

PROPERTIES OF STEAM

Define dryness fraction

It is define as the ratio of mass of the actual dry steam to the mass of same quality of

cued steam it is re-hated by ‘x’

$x = ms /(ms + m\omega)$

Let, ,x = mass of the dry steam in kg.

For dry steam $m\omega = 0$

$m\omega$ = mass of the water vapour its suspension

1.Wet steam

When the steam contains moisture or particles of water in suspension, it is said to be wet steam. It means that evaporation of water is not complete and the whole of the latent heat has not been absorbed. The enthalpy of wet steam is given by: h= hf + Xhfg where x is the dryness fraction of steam.

2. Dry saturated steam

When the wet steam is further heated and it does not contain any suspended particles of water, it is known as dry saturated steam. The dry saturated steam has absorbed its full latent heat. The enthalpy of dry saturated steam is given by: h=hg =hf +hfg where dryness fraction X= 1.

3. Superheated steam

When the dry steam is further heated at a constant pressure this rising its temperature, it is said to be superheated steam since the pressure is constant, therefore the volume of superheated steam increases.

The total heat required for the steam to be superheated is

h_{sup}=total heat for dry steam+ heat for superheated steam

$= h_f + h_{fg} + C_p(t_{Sup} - t)$

$= h_g + C_p(t_{Sup} - t)$

Where C_p= mean specific heat at constant pressure for superheated steam.

t_{sup}=temperature of the superheated steam.

t= saturation temperature at the given constant pressure.

The difference $(t_{Sup}-t)$ is known as degree of superheat.

PROBLEM

Steam enters an engine at a pressure 12 bar with a 67^{O}C of superheated. It is exhausted at a pressure 0.15 bar of 0.95 dry. Find the drop is enthalpy of the steam.

Given data,

P1 = 12 bar

P = 12 bar

$t_{sup} - t = 67^{O}C$

hf = 798.4 KJ/kg

P2 = 0.15 bar

h_{fg} = 1984.3 kJ/kg

Q = 0.95

For 1 kg superheated steam

$\mathbf{h_{sup} = h_f + h_{fg} + c_p (t_{sup} - t)}$

= 798.4 + 1984.3 + 2 × 67

= 2916.7 kJ/kg (Taking Cp = 2 kJ/kg k)

A pressure 0.15 bar,

H_f= 226 kJ/kkg.

H_{fg} = 2373.2 kJ/kg

For 1 kg of wet steam $h = h_f + x\, h_{fg}$

= 226 + 0.,95 × 1984.3 = 2111 kJ/kg

∴ Drop enthalpy of the steam = h_{sup} — h = 2916.7 – 2111 = 805.7 kJ/kg

BOILER

Boiler (Steam Generator)

A steam boiler or steam generator is a closed vessel in which water is heated, vaporized and converted into steam at a pressure higher than atmospheric pressure.

Classifications or Types of Boiler:

1.According to the circulation of gases/contents in the tube:

1. **Fire-tube boiler or smoke tube boiler od donkey tube boiler**
2. **Water-tube boiler or High pressure boiler**

Fire-tube boiler:

Fire tube boilers are those boilers in which hot gases produced by the combination of fuel in the boiler furnace while on their way to chimney pass through a number of tubes (called fuel tubes or smoke tubes) which are immersed in water.

Heat is transferred from the hot gasses to water through the walls of tubes.

Example of fire tube boilers are **Cochran boiler, locomotive boiler** etc.

Water-tube boiler:

Water-tube boilers are those boilers in which water flows through a number of tubes (called water tubes) and the hot gases produced by the combustion of fuel in the boiler furnace while on their way to chimney pass surrounding the tubes.

The heat from the hot gases is transferred to the water through the walls of the water tubes.

Examples of water tube boilers are **Bab-cock and Wilcox boiler, Benson boiler,** etc.

2.According to Circulation of water:

Free circulation(Natural circulation)

In any water heating vessel heat is transmitted from one place to another not by condition but by convection because water is a bad conductor of heat.

In boilers like **Lancashire, Babcock, and Wilcox,** etc. free circulation of water takes place.

Forced Circulation:

In Forced circulation, pumps are used to maintains the continuous flow of water in the boiler. In such a case, the circulation of water takes place due to pressure created by the pump.

3.According to the number of tubes :

Single tube boiler:

Cornish boiler may be termed as a single tumbler boiler because it has only **one flue tube.**

Multi-tube boiler:

Cochran boiler may be termed as multi-tube boiler because it has a **number of flue tubes**.

4.According to the nature of use:

According to nature use, boilers are classified as

1. **Stationary boilers**
2. **locomotive boilers**
3. **Marine boilers.**

Stationary boilers:

For the generation of thermal power and for process work (in chemical, sager and textile industries) boilers used are called stationary boiler.

Locomotive boilers:

Boilers used in locomotive steam engines are called locomotive boilers.

Marine boilers:

Boilers used in steamships are called marine boilers.

5.According to the nature of the fuels used:

Fuel-fired

Gas fired

Liquid fuel fired

Electrically fired

Nuclear fired

6.According to the pressure of the boiler:

1. **High-pressure boiler**
2. **Medium-pressure boiler**
3. **Low-pressure boiler**

High-pressure boiler: The pressure of the boiler **above 80 bar**.

Medium-pressure boiler:

It has a working pressure of steam **from 20 bar to 80 bar**. It is used for power generation or process heating.

Low-pressure boiler:

This type of boiler produces steam **at 15-20 bar** pressure. This is used for process heating.

7.According to the position of the axis of the boiler shell,

1. **Vertical boiler**
2. **Horizontal**

boiler Vertical boiler:

If the boiler axis is vertical, it is called a vertical boiler. For example, **Cochran boiler**.

Horizontal boiler:

If the boiler axis is horizontal, it is called a horizontal

boiler. For example, **Lancashire boiler**. **Applications of**

Boiler:

- *Operating steam engines.*
- *Operating steam turbines.*
- *Operating reciprocating pumps.*
- *Industrial process work in chemical engineering.*
- *For producing hot water required to be supplied to room in very cold areas.*
- *In thermal power stations.*

Cochran boiler

It is a multi-tubular vertical fire tube boiler having a number of horizontal fire tubes. it is the modification of a simple vertical boiler where the heating surface has been increased by means of a number of fire tubes. It consists of:

1.Shell

2. grate

3. Fire box

4.Flue pipe

5.Fire tubes

6. Combustion chamber

7.Chimney

8.Man-hole

Shell--It is hemispherical on the top, where space is provided for steam.

Grate-- It is placed at the bottom of the furnace where coal is burnt. A furnace grate is provided in a steam boiler furnace for supporting the solid fuel in the furnace. Grate is so designed that it can also allow air to admit air in the solid fuel for combustion

Fire box (furnace)-- It is also dome-shaped like the shell so that the gases can be deflected back till they are passed out through the flue pipe to the combustion chamber.

Flue pipe: It is a short passage connecting the fire box with the combustion chamber.

Fire tubes: A number of horizontal fire tubes are provided, thereby the heating surface is increased.

Combustion chamber: It is lined with fire bricks on the side of the shell to prevent overheating of the boiler. Hot gases enter the fire tubes from the flue pipe through the combustion chamber.

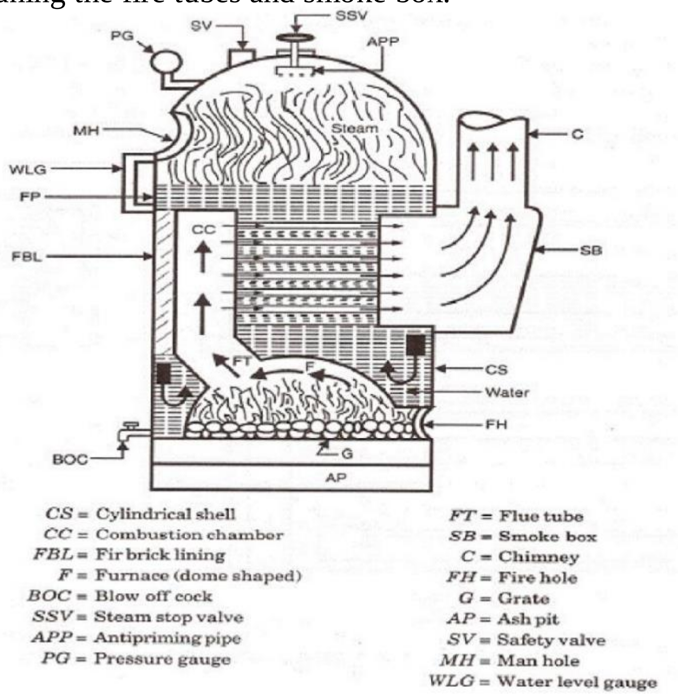
Chimney: It is provided for the exit of the flue gases to the atmosphere from the smoke box.

Manhole: It is provided for inspection and repair of the interior of the boiler shell.

Normal size of a Cochran boiler: Shell diameter – 2.75 meters: Height of the shell – 6 meters.

Working of the Cochran boiler:

Coal is fed into the grate through the fire hole and burnt. Ash formed during burning is collected in the ashpit provided just below the grate and then it is removed manually. The hot gases from the grate pass through the flue pipe to the combustion chamber. The hot gases from the combustion chamber flow through the horizontal fire tubes and transfer the heat to the water by convection. The flue gases coming out of fire tubes pass through the smoke box and are exhausted to the atmosphere through the chimney. Smoke box is provided with a door for cleaning the fire tubes and smoke box.



Boiler Mountings

The following **mountings** are fitted to the boiler:

Water Level Indicator: It is an main fitting in the boiler, Water level indicator indicates the water level inside the boiler. It is a safety device upon which safe working of the boiler depends.

Pressure gauge: this indicates the pressure of the steam inside the boiler.

Water gauge: this indicates the water level in the boiler.

Safety valve: the function of the safety valve is to prevent an increase of steam pressure in the boiler above its normal working pressure.

Steam stop valve: it regulates the flow of steam supply to requirements.

Blow-off cock: it is located at the bottom of the boiler. When the blow-off cock is opened during the running of the boiler, the high pressure steam pushes (drains) out the impurities like mud, sand, etc., in the water collected at the bottom.

Fusible plug: it protects the fire tubes from burning when the water level in the boiler falls abnormally low.

Boiler Accessories

The boiler accessories are required to improve the efficiency of the steam power plant and to enable for the proper working of the boiler. The boiler accessories aren't mounted directly on the boiler.

Babcock and Wilcox boiler

Babcock and Wilcox is a **water-tube boiler** is an example of **horizontal inclined tube** boiler it also a **High Pressure Boiler**.

Construction: Babcock and Wilcox boiler with longitudinal drum. It consists of a drum connected to a series of front end and rear end header by short riser tubes.

1. Economiser
2. Air pre-heater
3. Superheater
4. Feed pump
5. Steam Separator
6. Steam trap

Boiler Mountings	Boiler Accessories
They are mounted on the surface of the boiler.	The accessories are the integral parts of the boiler.
Inside the boiler, the fluid parameters are controlled by the boiler mountings.	Outside the boiler, the fluid parameters are controlled by the boiler Accessories.
They can ensure the safety of the boiler.	They can ensure the efficiency of the boiler.
Boiler mountings are essential for the operation to be carried out.	They are not at all essential for the operation to be carried out.
Some of the **examples of Boiler Mountings are** Water Level Indicator, Pressure Gauge, Blow off cock, Fusible Plug, Feed check valve, and Safety Valves.	Some of the **examples of Boiler Accessories** are Economizer, Steam Separator, Air Preheater, Superheater, and Feed Pu

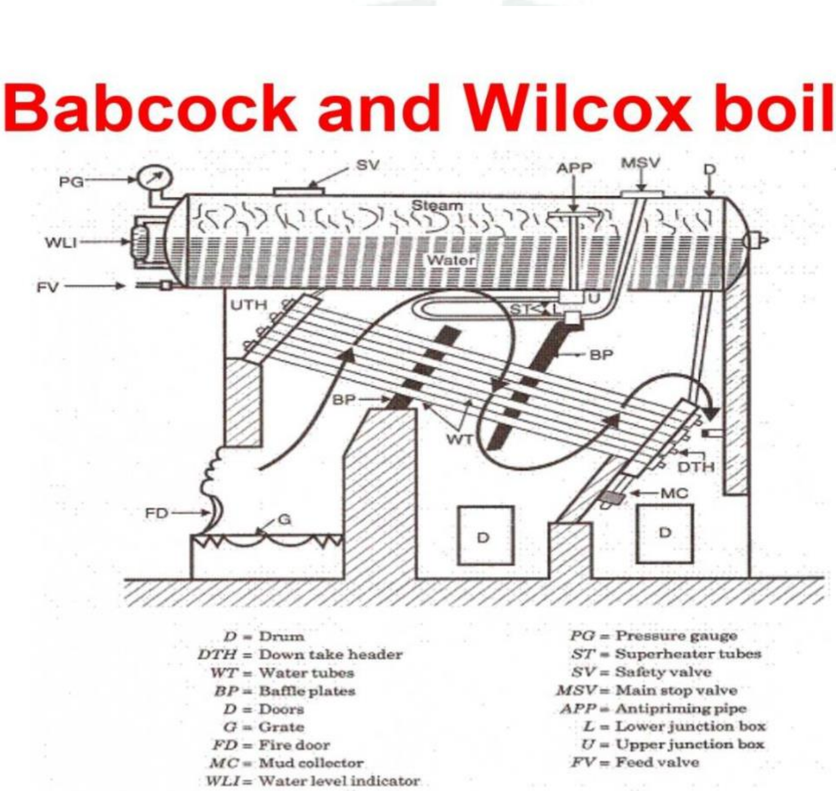
Working:

The fire door the fuel is supplied to grate where it is burnt.

The hot gases are forced to move upwards between the tubes by baffle plates provided.

The water from the drum flows through the inclined tubes via down take header and goes back into the shell in the form of water and steam via uptake header.

The steam gets collected in the steam space of the drum. The steam then enters through the anti priming pipe and flows in the super heater tubes where it is further heated and is finally taken out through the main stop valve and supplied to the Steam turbine or Steam engine when needed.



STEAM TURBINE

A **steam turbine** is one powerful turbomachine where **thermal energy** is utilized to produce **mechanical energy**.Steam turbine is a **prime mover** in which **pressure energy** of steam is transformed into **kinetic energy** & later in its turn into **mechanical energy** of rotation of turbine of shaft.

Types of Steam Turbine & Their

Classifications 1.Based On Principle of

Operation: (i) Impulse Turbine:

Here rotor blades are subjected only to kinetic energy. Since the drop in steam pressure took place across nozzles and not the rotor blades.

(ii) **Reaction Turbine:**

Here the blades are subjected to both pressure and kinetic energy. This is achieved by having a varying cross-section area for the blade passage.

2. Based On Number of Cylinders:

(i) Single Cylinder Turbine: Single cylinder steam turbine has all its stages housed within the same casing.

(ii) **Multi-Cylinder Turbines:**These are large output turbines with too many multiple stages to support all of them on one shaft.

3. Based On Means of Heat Supply

(i) **Single Pressure Turbine:** These are the typical turbines assembly used for generic use and have a single source of steam supply.

(ii) **Reheat Turbines:** For large multi-stage turbines there needs to be steam reheating before the steam exit the turbine.

(iii) **Dual Pressure Turbine:** A mixed or dual pressure turbine use two separate source of steam at different pressure.

4. **Based On Direction of Steam Flow**

(i) **Axial Flow Turbine:** The most suitable turbine design for large turbo-generators; here the direction of flow is parallel to the axis of the shaft.

(ii) **Radial Flow Turbine:** As the name suggests here the steam flows in a radial direction to the rotor shaft axis.

(iii) **Tangential Flow Turbine:** These are types of turbines where the steam flows tangentially to the rotor shaft axis.

5.Based On Exhaust Condition

(i) Condensing Turbine

(ii) **Non Condensing Turbine**

6.Based on method of governing

- **Throttle governing**

- Nozzle governing
- Pass governing

7.Based on steam condition at inlet of turbine

- Low pressure
- Medium pressure
- High pressure

	IMPULSE TURBINE	REACTION TURBINE
1	All hydraulic energy is converted into kinetic energy by a nozzle. Steam strikes only kinetic energy.	Only some amount of the available energy is converted into kinetic energy. Steam glides over the blades both preesure and kinetic energy.
2	Required less maintenance.	Required more maintenance.
3	The degree of reaction is zero.	The degree of reaction is between '0' to '1'
4	It needs a low discharge of water.	It needs medium and high discharge of water.
5	Water flow is a tangential direction to the turbine wheel.	Water flow is a radial and axial direction to the turbine wheel.
6	Blades are symmetrical. e.g pelton wheel	Blades are not symmetrical e.g Francis turbine and Kaplan turbine
7	Impulse turbine operates at high water heads.	It operates at medium and low heads.

CONDENSER

What is Condenser?

The condenser is a type of heat exchanger device, where gaseous substances are compressed into a liquid state using a cooling agent and, then latent heat is released in the environment, known as a condenser.

In general, A Heat Exchanging device used in condensing **gaseous or vapour state** substances into a **liquid state**, Known as a **condenser.**

Types of Steam Condenser

Following are the two main types of steam condenser:

1. **Jet condensers (mixing type condensers)**

In jet condensers, there is **direct contact** between the **cooling water and the steam** that is to be condensed. Steam escapes with the cooling water and the recovery of the condensate for re-use, as boiler **feed water is not possible**.

   1. Parallel flow jet condenser
   2. Counterflow or Low-level jet condenser
   3. Barometric or High-level jet condenser
   4. Ejector Condenser

2. **Surface condensers (non-mixing type condensers)**

In surface condensers, there is **no direct contact** between the **cooling water and the steam** that is to be condensed. The heat transfer between steam and cooling water is by conduction and convection. The condensate can be recovered **for re-use as feed water**.

   1. Downflow surface condenser
   2. Central flow condenser
   3. Invertive flow condenser
   4. Regenerative condenser
   5. Evaporative condenser

1. JET CONDENSER

(a) Parallel Flow Jet Condenser

In parallel flow jet condensers, both the steam and water enter at the top and the mixture is removed from the bottom.

(b) Counter flow jet condenser

The steam and cooling water enter the condenser from opposite directions. Generally, the exhaust steam travels in upward direction and meets the cooling water which flows downwards.

(c)Barometric jet condenser

In high level jet condensers, exhaust steam enters at the bottom, flows upwards and meets the downcoming cooling water in the same way as that of low level jet condenser. vacuum is created by the air pump, placed at the top of the condenser shell. The condensate and cooling water descends through a vertical pipe to the hot well without the aid of any pump. The surplus water from the hot well flows to the cooling water tank through an overflow pipe.

(d)Ejector Condensers

In ejector condensers, the steam and water mix up while passing through a series of metal cones. Water enters at the top through a number of guide cones.

2.SURFACE CONDENSER

(a)Down Flow Surface Condenser

In down flow surface condensers, the exhaust steam enters at the top and flow downwards over the tubes due to force of gravity as well as suction of the extraction pump fitted at the bottom. The condensate is collected at the bottom and then pumped by the extraction pump.

(b)Central Flow Surface Condenser

In this type of condenser, the suction pipe of the air extraction pump is located in the centre of the tubes which results in radial flow of the steam. The better contact between the outer surface of the tubes and steam is ensured, due to large passages the pressure drop of steam is reduced.

©Invertive Flow Surface Condenser:

This type of condenser has the air suction at the top, the steam after entering at the bottom rises up and then again flows down to the bottom of the condenser, by following a path near the outer surface of the condenser. The condensate extraction pump is at the bottom.

(d)Regenerative Condenser:

This type is applied to condensers adopting a regenerative method of heating of the condensate. After leaving the tube nest, the condensate is passed through the entering exhaust steam from the steam engine or turbine thus raising the temperature of the condensate, for use as feed water for the boiler.

(e)Evaporative Condenser:

The principle of this condenser is that when a limited quantity of water is available, its quantity needed to condense the steam can be reduced by causing the circulating water to evaporate under a small partial pressure. The exhaust steam enters at the top through gilled pipes. The water pump sprays water on the pipes and descending water condenses the steam.

Function of Condenser:

A steam condenser has the following two objects

(i) The primary object is to maintain a law pressure (below atmospheric pressure) so as to obtain the maximum possible energy from steam and thus to secure a high efficiency.

(ii) The secondary object is to supply pure feed water to the hot well, from where it is pumped back to the boiler. This reduces feed water treatment considerably. Thus, the thermal efficiency and capacity of the steam plant are greatly increased by fitting a condenser.

DIFFERENCE BETWEEN JET CONDENSER AND SURFACE CONDENSER

JET CONDENSER

i) Cooling water & steam are mixed up

ii) Low manufacturing cost

iii) It require small floor area

iv) Less suitable for high capacity plant

v) Condensate is wasted

vi) It's maintenance cost is low.

SURFACE CONDENSER

i) Cooling water & steam are not mixed up

ii) High manufacturing cost

iii) It require large floor area

iv) more suitable for high capacity plant

v) condensate is reused

vi) It's maintenance cost is high.

I.C ENGINE

Difference between internal combustion engine and external combustion engine ?

E.C ENGINE

i) The combustion of fuel takes place out side the engine cylinder.

ii) The working pressure and temp. inside the engine cylinder is low.

iii) It can not be started instantaneously.

I.C ENGINE

i) The combustion of fuel takes place inside the engine cylinder

ii) The working pressure and temp. inside the engine cylinder is very high.

iii) It can be started instantaneously.

Classification:

i) According to type of fuel used

(a) petrol engine (b) Diesel engine (c) Gas engine

ii) According to method of ignition

(a) Spark ignition (b) Compression ignition

iii) According to number of stroke

(a) Two stroke (b) Four stroke

Difference between Two stroke Engine & Four stroke Engine.

TWO STROKE ENGINE

a) There are ore working stroke for each revolution of the crank shaft.

b) It is mostly single cylinder engine.

c) Engine is lighter

d) Engine designer is simple

e) It is air cooled

f) Fuel consumption per KW power develop is more

g) It consume more lubricating oil.

FOUR STROKE ENGINE

a) There are one working stroke for each two revolution of the crank shaft.

b) It is mostly multi cylinder engine

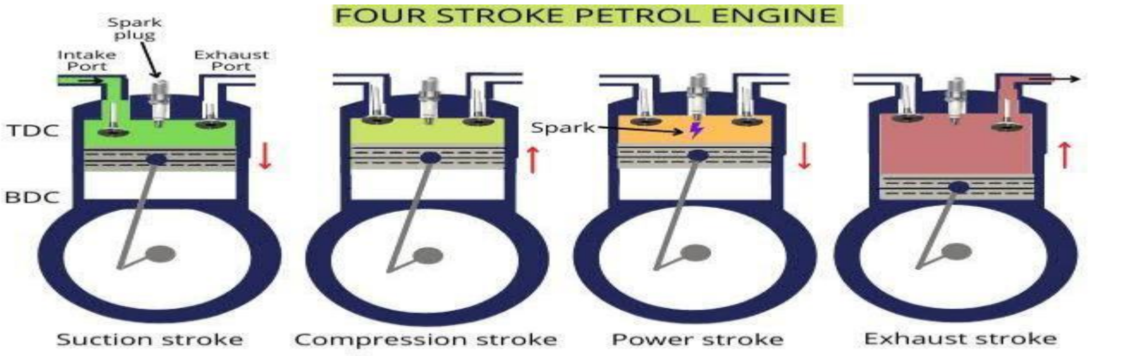
c) Engine is heavier

d) Engine design is complicate

f) Fuel consumption per KW power develop is less. g) It consume less lubricating oil.

Que:With neat sketch of four stroke cycle petrol Engine. Explain

Ans: It is also knows as Otto cycle. It requires four strokes of the piston to complete one cycle of operation in the engine cylinder. The four strokes of a petrol engine sucking fuel air mixture (petrol mixed with proportionate quantity of air in the carburetor known as charge) are described below.



a) Suction or charging stroke

In this stroke, this inlet valve opens and charge is sucked into the cylinder as the piston moves downward from top dead centre (T.D.C) It continuously the piston reaches its bottom dead centre (B.D.C).

b) Compression stroke

In this stroke, both the inlet and exhaust valves are closed and the charge is compressed as the piston moves upwards from B.D.C to T.D.C. As a result of compression, the pressure and temperature of the charge increase considerably (the actual valves depend upon the compression ratio). This completes one revolution of the crank shaft.

c) Expansion or working stroke

Shortly before the piston reaches T.D.C. (during compression stroke), the change is ignited with the help of spark plug. It suddenly increases the pressure and temperature of the products of combustion but the volume, practically remains constant. Due to the rise in pressure , the piston is pushed down with a great force. The hot burnt gases expand due to high speed of the piston. During this expansion, some of the heat energy produced is transformed into mechanical work.; It may be noted that during this working stroke, as both the valves are closed and piston moves from T.D.C. to B.D.C.

d) Exhaust Stroke

In this stroke the exhaust valve is open as piston moves from B.D.C. to T.D.C. This movement of the piston pushes out the products of combustion, from the engine cylinder and are exhausted through the exhaust valve into the atmosphere, as figure. This completes the cycle and the engine cylinder is ready to suck the charge again petrol engine are usually employed in light vehicles such as Cars, Jeeps and Aeroplanes.

<u>Explain with help of suitable sketched the working a 4-stroke cycle diesel engine.</u>

<u>4 – stroke diesel engine</u>

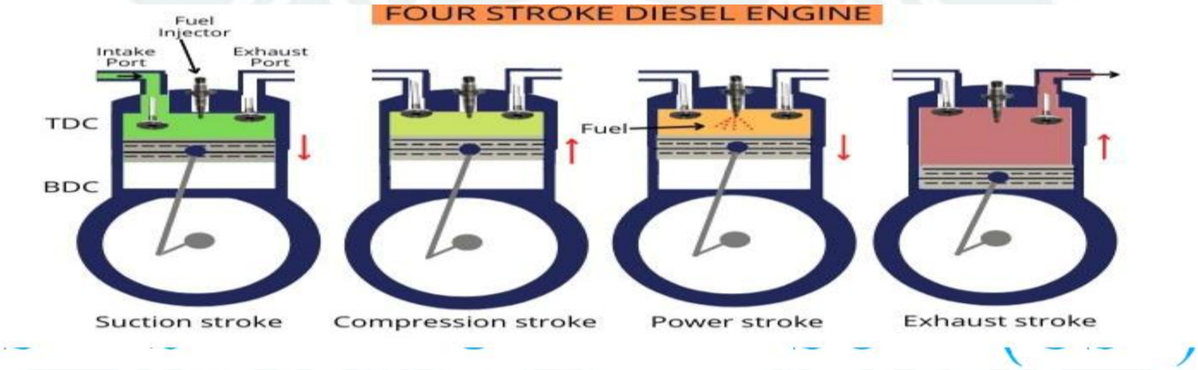
It is also known as compression ignition engine because the ignition takes place due to the heat produced in the engine cylinder at the end of compression strokes.

i) Suction Stroke

In this stroke, the inlet valve opens and pure air is sucked into the cylinder as the piston masses down wards from the top dead centre (TDC). It continues till the piston reaches its bottom dead centre.

ii) Compression stroke

In this stroke, both the valves are closed and the air is compressed as the piston moves upwards from BDC to TDC. As a result of compression, pressure and temp. of the air increases considerably. This complete are revolution of the crank- shaft.



iii) Working stroke

Before the piston reached the TDC, fuel oil is injected in the form of very fine spray into the engine cylinder through the nozzle, known as fuel injection valve. At this moment, temp. of the compressed air is sufficiently high to light the fuel. It suddenly increase the pressure & temp. of the products of combustion. The fuel oil is continuously injected for a friction of the revolution. The fuel oil is assumed to be burnt of constant pressure due to one pressure, the piston is pushed down with a great force. Both the valves and closed and the piston moves from TDC to BDC

Exhaust Stroke

In this stroke, the exhaust valve is open as the piston moves from BDC to TDC. This movement of the piston pushes out the products of combustion from the engine cylinder through the exhaust valve into the atmosphere. This complete the cycle and the engine cylinder is ready to break the fresh air again.

<u>TWO STROKE CYCLE DIESEL ENGINE</u>

i) Suction Stage : -

In this stage, the piston while moving down downwards BDC uncovers the transfer part and then exhaust point. The fresh air flows into the engine cylinder from the Crank case.

ii) Compression Stage.

In this stage, the piston while moving up, 1st covers the transfer point and then exhaust point. After that the air is compressed as the piston moves upwards . In this stage the inlet point opens and the fresh air enters in the crank case.

iii) Expansion stage

Before the piston reaches the TDC, the fuel oil is injected min the form of very fine spray into the engine cylinder through the nozzle. At this moment the temp. of the compressed air is sufficiently high to ignite the fuel. It suddenly increases the prime and temp of the product of combustion. During the expansion, some of the heat engine produced is transformed in to mechanical work.

iv) Exhaust stage.

In this stage, the exhaust point is opened and the piston moves down words. The products of combust from the engine cylinder are exhausted through the exhaust point into the atmosphere.

HYDROSTATICS

Properties of a Fluid

The basic properties of a Fluid are

i) Density

ii) Specific weight

iii) Specific volume

iv) Specific gravity

v) Incompressibility

vi) Viscosity

vii) Cohesion

viii) Adhesion

ix) Surface tension

x) Capillarity

xi) Vapour pressure

Density:

Density of a liquid is the mass per unit volume of the liquid

So, density of a liquid is given by **$\rho = M/V$**

Where M = mass of the liquid

V = volume of the liquid

In M.K.S. and S.I. unit both density is expressed in **Kg/M^3**

Specific weight

Specific weight of a liquid is the weight per unit volume of the liquid So specific weight of a liquid is given by

$W = w/v$

Where w = weight of the liquid

V= volume of the liquid

In M. K.S units, specific weight is expressed in **kgf/m^3** and S.I. units specific weight is expressed in **N/M^3**

or **kw/m^3**

Specific Volume :

Specific volume of a liquid is the volume occupied by unit mass of the liquid So specific volume = **v/m**

Where v = volume of the liquid

M= mass of the liquid

In M.K.S. and S.I. unit both specific volume is expressed in **M^3/Kg**

Specific Gravity

Specific gravity of a liquid is defined as the ratio of weight of any volume of the liquid to the weight of same volume of water.

So specific gravity is given by

Weight of any volume of the liquid /weight of the same volume of water

Viscosity

Viscosity is defined as the property of a fluid by virtue of which the fluid offers resistance shear or to angular deformation greater this resistance greater is the viscosity and point.

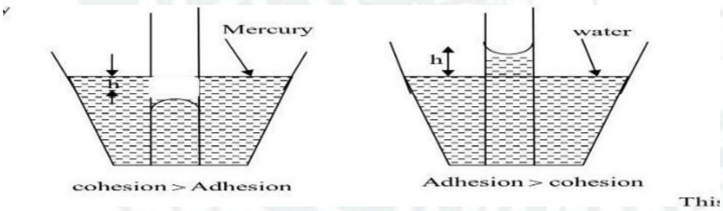
Surface Tension:

Due to cohesion tensile force occurs on the free surface of a liquid. This tensile force on the surface of a liquid is called surface tension.

Surface tension may also occur in the common contact surface between two immiscible liquids such that the contact surface acts like as membrane under tension.

Capillarity

The phenomenon by which a liquid rises up or drops down in a tube of smaller cross sectional area relative to the general liquid level in the vessel into the liquid is called capillarity.



Define pressure.

The force applied perpendicular to the surface of an object per unit area over which that force is distributed is known as pressure.

P=F/A

Pascal is the SI unit of pressure.

Define pascal.

A pascal can be defined as a force of one newton applied over a surface area of a one-meter square.

- **1 Pascal = 1 N/m^2**

Define Bar

The **bar** is a metric unit of **pressure**. It is not part of the International System of Units (SI). The **bar** is commonly used in the **industry** and in the **meteorology**, and an instrument used in meteorology to measure atmospheric pressure is called barometer.

Pressure measuring instrument

Many techniques have been developed for the measurement of pressure and vacuum. Instruments used to measure pressure are called pressure gauges or vacuum gauges.

A 'manometer' is an instrument that uses a column of liquid to measure pressure, although the term is often used nowadays to mean any pressure measuring instrument.

Absolute pressure is zero-referenced against a perfect vacuum, so it is equal to gauge pressure plus atmospheric pressure.

Gauge pressure is zero-referenced against ambient air pressure, so it is equal to absolute pressure minus atmospheric pressure. Negative signs are usually omitted. To distinguish a negative pressure, the value may be appended with the word "vacuum" or the gauge may be labeled a "vacuum gauge."

Differential pressure is the difference in pressure between two points.

Types of manometer:

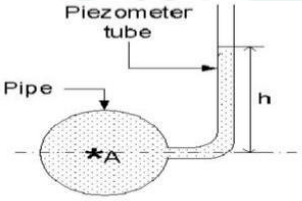
1.simple manometer

2.U-tube manometer

3.Differential manometer

1.simple manometer: A simple manometer is one which consists of a glass tube, whose one end is connected to a point where pressure is to be measured and the other end is open to atmosphere.

Piezometer is one of the simplest forms of manometers. It can be used for measuring moderate pressures of liquids. The setup of piezometer consists of a glass tube, inserted in the wall of a vessel or of a pipe. The tube extends vertically upward to such a height that liquid can freely rise in it without overflowing. The pressure at any point in the liquid is indicated by the height of the liquid in the tube above that point.



Pressure at point A can be computed by measuring the height to which the liquid rises in the glass tube. The pressure at point A is given by **p = wh**, where w is the specific weight of the liquid.

U-tubemanometer consists of a glass tube bent in U-shape, one end of which is connected to a point at which pressure is to be measured and other end remains open to the atmosphere.

Pressure in a continuous static fluid is the same at any horizontal level so,

Pressure at B=Pressure at C

$P_B = P_C$

$P_B = P_{ATMOSPHERIC} + \rho g h_1$

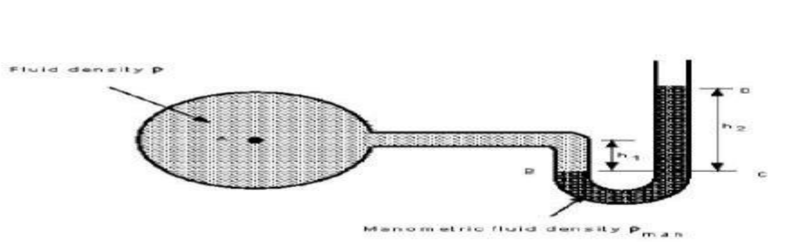
$P_C = P_{ATMOSPHERIC} + \rho_{MANOMETRIC} g h_2$

we are measuring gauge pressure we can subtract giving

$P_A = \rho_{MANOMETRIC} g h_2 - \rho g h_1$

If the fluid being measured is a gas, the density will probably be very low in comparison to the density of the manometric fluid i.e. rman >> r. In this case the term can be neglected, and the gauge pressure give by

$P_A = \rho_{MANOMETRIC} g h_2$



Differential U – tube manometer

It is used when difference between two pressures needed and consists of a transparent U-tube containing the fluid of density (ρ) whose pressure is to be measured and an immiscible fluid (m) of higher density (ρm).

The limbs are connected to the two points between which the pressure difference (P2 - P1) is required.

The pressure at level x will be: $P_x = P_1 + \rho g (a+h)$

The pressure at level x' will be: $P_{x'} = P_2 + \rho_m g h + \rho g a$

Since Px= Px' (at same level) Then $P_1 - P_2 = (\rho_m - \rho) g h$

Bourdon's tube pressure gauge.

Bourdon tube pressure gauge is used for measuring high as well as low pressure. It consists of an elliptical tube ABC, bent into an arc of a circle. This bent-up tube is called Bourdon's tube. When the gauge tube is connected to the fluid (whose pressure is required to be found out) at C, the fluid under pressure flows into the tube. The Bourdon's tube as a result of the increased pressure, tends to straighten itself. Since the tube is encased in a circular cover, therefore it tends to become circular instead of straight. With the help of a simple pinion and sector arrangement, the elastic deformation of the €Bourdon's tube rotates the pointer. This pointer moves over a calibrated scale, which directly gives the pressure.

HYDROKINETICS

steam line and streak line motion of fluid.

The **steam line motion** of the fluid in the pipe without overlap of the particle with not to be diverse each other continuously.

A streamline is a line that is tangential to the instantaneous velocity direction (velocity is a vector, and it has a magnitude and a direction).

For example, we could mark a drop of water with fluorescent dye and illuminate it using a laser so that it fluoresces.

In case of **streak line motion** of fluid, the particle of the fluid not to be overlap with each other but diverse in that way.

Derivation of Continuity equation

Assume that short interval of time as Δt. In this time, the fluid will cover a distance of Δx_1 with a velocity v_1 at the lower end of the pipe.

At this time, the distance covered by the fluid will be:

$\Delta x_1 = v_1 \Delta t$

Now, at the lower end of the pipe, the volume of the fluid that will flow into the pipe will be:

$V = A_1\, \Delta x_1 = A_1\, v_1\, \Delta t$

It is known that ***mass (m) = Density (ρ)*** × ***Volume (V).*** So, the mass of the fluid in Δx_1 region will be:

$\Delta m_1 = \text{Density} \times \text{Volume}$

$\Rightarrow \Delta m_1 = \rho_1 A_1 v_1 \Delta t$ ———***(Equation 1)***

$\Delta m_{1/\Delta t} = \rho_1 A_1 v_1$ ———***(Equation 2)***

Similarly, the mass flux at the upper end will be:

$\Delta m_{2/\Delta t} = \rho_2 A_2 v_2$ ———***(Equation 3)***

Here, v_2 is the velocity of the fluid through the upper end of the pipe i.e. through Δx_2 , in Δt time and A_2, is the cross-sectional area of the upper end.

In this, the density of the fluid between the lower end of the pipe and the upper end of the pipe remains the same with time as the flow is steady. So, the mass flux at the lower end of the pipe is equal to the mass flux at the upper end of the pipe i.e. ***Equation 2 = Equation 3.***

Thus,

$\rho_1 A_1 v_1 = \rho_2 A_2 v_2$ ———*(Equation 4)*

This can be written in a more general form as:

$\rho\ A\ v = constant$

The equation proves the **law of conservation of mass** in fluid dynamics. Also, if the fluid is incompressible, the density will remain constant for steady flow**.** So, $\rho_1 = \rho_2$**.**

Thus, ***Equation 4*** can be now written as:

$A_1\ v_1 = A_2\ v_2$

This equation can be written in general form as:

$A\ v = constant$

Now, if R is the volume flow rate, the above equation can be expressed as:

R = A v = constant

This was the derivation of continuity equation.

VARIOUS ENERGIES OF FLUID;

There are three types of energies or head as follows

1. **Pressure energy or pressure head**- is the energy possessed by a liquid particle by virtue of its existing pressure. Pressure energy or pressure head is denoted by $p/\rho g$**.**

2. Kinetic energy- It is the energy possessed by a liquid particle by virtue of its motion or velocity.K.E is also known as kinetic head or velocity head. Kinetic energy or kinetic head is measured as $v^2/2g$

3. Potential energy- It is the energy possessed by a liquid particle by virtue of its position with respect to a datum. Potential energy or potential head is denoted by **z.**

TOTAL ENERGY- Total energy of a liquid particle in motion is the sum of its pressure energy , kinetic energy and potential energy.

Total energy head $H = p/\rho g + v^2/2g + z$

STATE AND PROVE BERNOULLI'S EQUATION:-

Bernoulli's equation states that ,"In an ideal incompressible fluid when the flow is steady and continuous the sum of pressure energy, kinetic energy and potential energy is constant along a stream line.

Mathematically $p/\rho g + v^2/2g + z$ is constant.

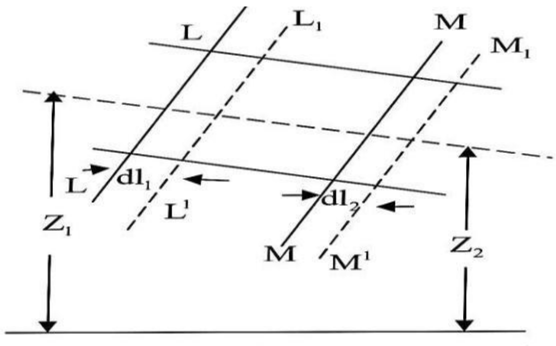
Where $p/\rho g$=pressure energy

$v^2/2g$=kinetic energy

z=datum energy

Proof:-

Consider an ideal incompressible liquid flowing through a non-uniform pipe as shown in the figure.



Let us consider two sections 1-1 & 2-2 and assume that the pipe is running full and there is continuity of flow between the two sections.

Let p_1=pressure at 1-1

V_1=velocity of liquid at 1-1

Z_1=height of 1-1 above the datum

A_1=area of pipe at 1-1

And p_2, v_2, z_2, a_2 are corresponding values at 2-2.

Let the liquid between two sections 1-1 & 2-2 move to 1'-1' & 2'-2' through very small length dl_1& dl_2 as shown in the figure.

This movement of liquid between 1-1 & 2-2 is equivalent to the movement of the liquid between 1-1

and between 1'-1' and between 2-2 & between 2'-2'.

Let W=weight of the liquid between 1-1 & 1'-1'

As the flow is continuous $W= \rho g A_1 \times dl_1 = \rho g A_2 \times dl_2$

Or $A_1 \times dl_1 = W/\rho g$

Or $A_2 \times dl_2 = W/\rho g$

Or $A_1 \times dl_1 = A_2 \times dl_2$

Workdone by pressure force at 1-1 moving the liquid to 1'-1' =force×distance=$\rho_1 A_1 \times dl_1$

Similarly workdone by the pressure force at 2-2 in moving the liquid to 2'-2'=$\rho_2 A_2 \times dl_2$

Total work done by the pressure =$\rho_1 A_1 \times dl_1 - \rho_2 A_2 \times dl_2$ ($A_1 \times dl_1 = A_2 \times dl_2$)

$=A_1 \times dl_1 (p_1 - p_2)$

$=w/\rho g (p_1 - p_2)$

Total work done by the pressure =$\rho_1 A_1 \times dl_1 - \rho_2 A_2 \times dl_2$ ($A_1 \times dl_1 = A_2 \times dl_2$)

$=A_1 \times dl_1 (p_1 - p_2)$

$=w/\rho g (p_1 - p_2)$

Loss of potential energy $=w(z_1-z_2)$

Gain in kinetic energy$=w(v_2^2/2g-v_1^2/2g)$

$=w/2g(v_2^2-v_1^2)$

Also loss of potential energy +work done by pressure = gain in kinetic energy

Since $w(z_1-z_2)+w/\rho g(p_1-p_2)=W/2g(v_2^2-v_1^2)$

Or $z_1-z_2+(p_1/\rho g-p_2/\rho g)=(v_2^2/2g-v_1^2/2g)$

Or $\mathbf{p_1/\rho g + v_1^2/2g+ z_1=p_2/\rho g +v_2^2/2g +z_2}$

HYDRAULIC DEVICES AND PNEUMATICS

There are many types of hydraulic devices in which force and energy are transmitted through an incompressible fluid, oil etc. These devices based on the principles of hydro-static and hydro-kinetics.

Classification of Hydraulic Devices

a) Hydraulic lift

b) Hydraulic jack

c) Hydraulic accumulator

d) Hydraulic crane

e) Hydraulic ram

f) Hydraulic intensifier

HYDRAULIC LIFT

The hydraulic lift is a device used to lift or bring down passengers and loads from one floor to another in multi storeyed buildings.

CLASSIFICATION OF HYDRAULIC LIFT

1.Direct Acting Hydraulic Lift

2.Suspended Hydraulic Lift

DIRECT ACTING HYDRAULIC LIFT

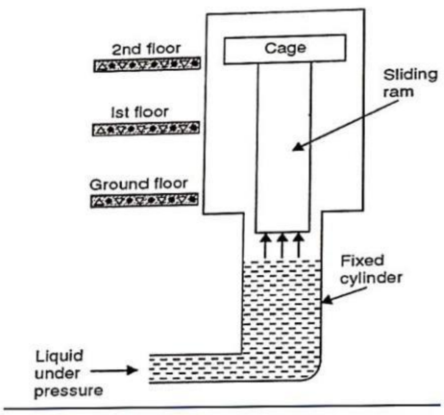
CONSTRUCTION DETAILS:

Components of direct acting hydraulic lift:

1.Fixed cylinder: It is fixed with the wall of the floor, where the sliding ram reciprocate when we apply the pressure.

2.Cage: It is fitted on the top of the sliding ram where the load is placed (i.e. lifted load).

3.Sliding ram: It is fitted in the fixed cylinder which is reciprocate (upward or downward direction) when we applied the pressure (i.e. reaches the floor wise.)



WORKING OF DIRECT ACTING HYDRAULIC LIFT

When fluid under pressure is forced into the cylinder, the ram gets a push upward. The platform carries loads or passengers and moves between the guides. At required height, it can be made to stay in level with each floor so that the good or passengers can be transferred.

In direct acting hydraulic lift, stroke of the ram is equal to the lift of the cage.

SUSPENDED HYDRAULIC LIFT

CONSTRUCTION DETAILS:

1.Cage: It is fitted on the top of the sliding ram where the load is placed (i.e. lifted load).

Wire rope: It connects the cage to pulley.

2.Sliding ram: It is fitted in the fixed cylinder which is reciprocate (upward or downward direction) when we applied the pressure (i.e. reaches the floor wise)

3.Pulleys: pulleys are connected to the sliding ram and fixed cylinder; where one pulley is fixed and other pulley is movable.

4.Hydraulic jigger: It consists of a moving ram which slides inside a fixed hydraulic cylinder.

5.Fixed cylinder-: It is fixed with the wall of the floor, where the sliding ram reciprocate when we apply the pressure.

WORKING OF SUSPENDED HYDRAULIC LIFT

When fluid under pressure is forced into the cylinder, the ram gets reciprocate to the movable

pulleys. With the help of arrangement of hydraulic jigger; pulley can rotates; with the help of wire rope the cage is maintain there pressure force with there floor. At required height, it can be made to stay in level with each floor so that the good or passengers can be transferred. Working period of the lift is ratio of the height of lift to the velocity of lift. Idle period of lift is the difference of the total time for one operation and the working period of the lift.

Hydraulic intensifier

A hydraulic intensifier is a hydraulic machine for transforming hydraulic power at low pressure into a reduced volume at higher pressure. Operation Such a machine may be constructed by mechanically connecting two pistons, each working in a separate cylinder of a different diameter. As the pistons are mechanically linked, their force and stroke length are the same. If the diameters are different, the hydraulic pressure in each cylinder will vary in the same ratio as their areas: the smaller piston giving rise to a higher pressure. As the pressure is inversely proportional to the area, it will be inversely proportional to the square of the diameter.

The working volume of the intensifier is limited by the stroke of the piston. This in turn limits the amount of work that may be done by one stroke of the intensifier. These are not reciprocating machines (i.e. continually running multi-stroke machines) and so their entire work must be carried out by a single stroke. This limits their usefulness somewhat, to machines that can accomplish their task within a single stroke. They are often used where a powerful hydraulic jack is required, but there is insufficient space to fit the cylinder size that would normally be required, for the lifting force necessary and with the available system pressure. Using an intensifier, mounted outside the jack, allows a higher pressure to be obtained and thus a smaller cylinder used for the same lift force. Intensifiers are also used as part of machines such as hydraulic presses, where a higher pressure is required and a suitable supply is already available.

Some small intensifiers have been constructed with a stepped piston. This is a double-ended piston, of two different diameters, each end working in a different cylinder. This construction is simple and compact, requiring an overall length little more than twice the stroke. It is also still necessary to provide two seals, one for each piston, and to vent the area between them. A leak of pressure into the volume between the pistons would transform the machine into an effective single piston with equal area on each side, thus defeating the intensifier effect.

Hydraulic accumulator

A hydraulic accumulator is a pressure storage reservoir in which a non-compressible hydraulic fluid is held under pressure by an external source. The external source can be aspring, a raised weight, or a compressed gas. An accumulator enables a hydraulic system to cope with extremes of demand using a less powerful pump, to respond more quickly to a temporary demand, and to smooth out pulsations. It is a type of energy storage device. Compressed gas accumulators, also called hydro-pneumatic accumulators, are by far the most common type.

Functioning of an accumulator

In modern, often mobile, hydraulic systems the preferred item is a gas charged accumulator, but simple systems may be spring-loaded. There may be more than one accumulator in a system. The exact type and placement of each may be a compromise due to its effects and the costs of manufacture.

An accumulator is placed close to the pump with a non-return valve preventing flow back to the pump. In the case of piston-type pumps this accumulator is placed in the ideal location to absorb pulsations of energy from the multi-piston pump. It also helps protect the system from fluid hammer. This protects system components, particularly pipework, from both potentially destructive forces.

An additional benefit is the additional energy that can be stored while the pump is subject to low demand. The designer can use a smaller-capacity pump. The large excursions of system components, such as landing gear on a large aircraft, that require a considerable volume of fluid can also benefit from one or more accumulators. These are often placed close to the demand to help overcome restrictions and drag from long pipework runs. The outflow of energy from a discharging accumulator is much greater, for a short time, than even large pumps could generate.

An accumulator can maintain the pressure in a system for periods when there are slight leaks without the pump being cycled on and off constantly. When temperature changes cause pressure excursions the accumulator helps absorb them. Its size helps absorb fluid that might otherwise be locked in a small fixed system with no room for expansion due to valve arrangement.

Hydraulic ram

A hydraulic ram, or hydram, is a cyclic water pump powered by hydropower. It takes in water at one "hydraulic head" (pressure) and flow rate, and outputs water at a higher hydraulic head and lower flow rate. The device uses the water hammer effect to develop pressure that allows a portion of the input water that powers the pump to be lifted to a point higher than where the water originally started. The hydraulic ram is sometimes used in remote areas, where there is both a source of low-head hydropower and a need for pumping water to a destination higher in elevation than the source. In this situation, the ram is often useful, since it requires no outside source of power other than the kinetic energy of flowing water.

The working principle of hydraulic ram is to use surge pressure which is produced after flow blocked and ten times higher than normal to lift water. Before working, waste valve stays open under the action of magnet spring while delivery valve keep closed under the action of magnet spring and its gravity.

It can work automatically when we control the waste valve to repeat the operation procedures of open and close. After that, water with different levels will flow out through water drive pipe and opened waste valve, and running water will drive the waste valve to close when the pressure inside the waste valve surpass that in magnet spring, and that is the water hammer. At the moment, water pressure rapidly increases and enforces the delivery valve to open, and some water flows into air chamber. Pressure inside the waste valve drops promptly and the waste valve reopens under the action of magnet spring and negative pressure. While delivery valve closes again by the action of self gravity and the pressure in magnet spring and air chamber. By the action of water flow, movements foregoing repeat automatically. And water will flow out through the delivery pipe when the pressure in air chamber exceeds that in lifting pipes.