LECTURE NOTES

ON

ELEMENTS OF MECHANICAL ENGINEERING

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DEPARTMENT OF MECHANICAL ENGINEERING

3RD SEMESTER

KIIT POLYTECHNIC, BHUBANESWAR

ODISHA-751024

SESSION: 2022-23

ELEMENTS OF MECHANICAL ENGINEERING

3RD SEMESTER – MECHANICAL

CONTENT

THERMODYNAMICS

Thermodynamics:

It may be defined as the science which deals with the conversion of heat into mechanical work or energy by using a suitable medium.

Thermodynamic System, Boundary and Surrounding:

System: A system is defined as any quantity of matter or a region in space having certain volume upon which our attention is concerned in analysis of problem.

Surrounding: Anything external to the system constitute as surrounding.

Boundary: System is separated from the surrounding by system boundary. This boundary may be fixed or movable.

Systems are classified into three types as follows.

Open System:

It is also known as *flow system.* Open system is one in which both mass and energy crosses the boundary. Open system is also called control volume. Ex- reciprocating air compressor, turbine, pump etc.

Closed System:

It is also known as *non-flow system*. In this system the mass within the boundary remains constant only energy interaction takes place with respect to the surrounding. Ex – Cylinder piston arrangement, Tea kettle.

Isolated System:

An isolated system is one in which there is no interaction between the system and surrounding. There is no mass and energy transfer across the system. Ex- Universe.

Thermodynamic Property:

Intensive property: The properties which are independent of mass of the system are known as intensive properties. Its value remains the same whether one considers the whole system or only a part of it. The intensive property includes pressure, temperature, specific volume, specific energy, specific density etc.

Extensive property: the property which depends upon mass of the system are known as extensive property. The extensive properties include volume, energy, enthalpy, entropy etc.

First law of thermodynamics:

This law may be stated as follow:

The heat and mechanical work are mutually convertible. According to this law, when a closed system undergoes a thermodynamic cycle, the net heat transfer is equal to the net work transfer. In other works, the cyclic integral of heat transfers is equal to the cyclic integral of work transfers.

Mathematically, $\oint \delta Q = \oint \delta W$

Where $\oint \delta Q$ and $\oint \delta W$ represent infinitesimal elements of heat and work transfers respectively.

The energy can neither be created nor destroyed though it can be transferred from one form to another. According to this law, when a system undergoes a change of state, then both heat transfer and work transfer takes place. The net energy transfer is stored within the system and is known as stored energy or total energy of the system.

Mathematically $dQ - dW = dU$

Whenever heat is absorbed by a system it goes to increases its internal energy plus to do some external work (PdV work) i.e. $Q = \Delta U + W$

Where Q is the energy entering a system, ΔU is the increase in internal energy, W is the external work.

$$Q = \Delta U + PdV$$

Heat:

- Heat is a transfer form of energy that flows between two systems or between system and surrounding due to temperature difference between them.
- Amount of heat transfer between state 1 and 2 is given by Q_{1-2}.
- The S.I unit of heat is Joule (J) or KiloJoule (kJ) and in M.K.S it is given by Calorie.
- Heat transfer to a system is considered as positive and heat transfer from a system is considered as negative.
- Heat is a form of energy in transit.
- It is a path function.
- It is low grade energy.
- It is a boundary phenomenon.
- It is associated in a process not in a state.

Work:

- Work is said to be done when the point of application of a force on a body results in its motion.
- Work is defined as the product of the force (F) and the distance moved (s) in the direction the force. Mathematically, work done, W= **F**× s,
- The mechanical work on a body is the amount of mechanical energy transferred to the body by a force.
- Amount of work transfer between two state 1 and 2 is given by W_{1-2}.
- The S.I unit of work is Joule (J) or kilojoule (kJ).
- Work transfer to a system is considered as negative and work transfer from a system is considered as positive.
- Work is form energy in transit.
- It is a path function.
- It is high grade energy.
- It is a boundary phenomenon.

- It is associated in a process not in a state.

Specific heat:

- It is the amount of heat energy required to change the temperature of unit mass of a substance by one degree.
- It is classified as specific heat at constant pressure (Cp) and specific heat at constant volume (Cv).
- Cp – Cv is equal to R.

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.

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.

Relation between Cp and Cv:

Consider a gas enclosed in a container and being heated, at a constant pressure, from the initial state 1 to the final state 2.

m= Mass of the gas

T_1= Initial temperature of the gas

T_2= Final temperature of the gas

V_1= Initial volume of the gas

V_2= Final volume of the gas

Cp= Specific heat at constant pressure

Cv= Specific heat at constant volume

P= Constant pressure

We know that heat supplied to the gas at constant pressure, $Q_{1\text{-}2} = m.Cp.\ (T_2 - T_1)$ ………(i)

A part of this heat is utilised in doing the external work, and the rest remains within the gas and is used in increasing the internal energy of the gas.

Heat utilised for external work $W_{1\text{-}2} = P(V_2 - V_1)$ .... (ii)

Increase in internal energy $dU = mC_v(T_2 - T_1)$ …....................... (iii)

We known that $Q_{1\text{-}2} = W_{1\text{-}2} + dU$ .... (iv)

Or $m.C_p\ (T_2 - T_1) = P(V_2 - V_1) + m.C_v\ (T_2 - T_1)$ .... (v)

Using characteristic gas equation (i.e. PV = mRT), we have

$PV_1 = mRT_1$ and $PV_2 = mRT_2$

Thus $P(V_2 - V_1) = m.R(T_2 - T_1)$

Now substituting the value of $P(V_2 - V_1)$ in equation (v), we get

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

or $C_p = R + C_v$

or $C_p - C_v = R$ ....(vi)

The equation (v) gives an important result as it proves that characteristic constant of a gas (R) is equal to the difference of its two specific heats i.e. $(C_p - C_v)$.

The above equation may be rewritten as

$C_p - C_v = R$, Dividing Cv in both sides we get

or $C_p/C_v - 1 = R/C_v$ where $C_p/C_v = \gamma$

or $\gamma - 1 = R/C_v$

or $C_v = R/(\gamma - 1)$

Law of Perfect gases:

1) Boyle's Law:

The volume of a given mass of gas is inversely proportional to its absolutely pressure at constant temperature.

i.e $V \alpha \frac{1}{P}$ (T =constant), PV = Constant.

2) Charles's Law:

The volume of a given mass of a gas is directly proportional to its absolute temp at constant pressure.

i.e $V \alpha\, T$ (P =constant), V/T = Constant.

3) Gay-Lussac Law:

The pressure of a given mass of a gas is directly proportional to its absolute temp at constant volume.

. i.e $P \alpha\, T$ (V =constant), P/T = Constant.

4) Ideal gas Law:

From Boyle's law PV = C

From Charles's law V/T = C

Combining both the laws: $\frac{PV}{T} = C,$ i.e $PV \alpha\ T$ i.e PV = RT

This equation is called characteristic gas equation or ideal gas equation.

Where R = characteristic gas constant = 0.287 KJ / Kg-k (for atm. air)

5) Avogadro's law:

It states that the equal volumes of different ideal gases are at the same temperature & pressure contains equal number of molecules.

PROPERTIES OF STEAM

Steam:

- Steam is the gaseous phase of water.

Saturated steam:

- The steam which is about to condense is called as saturated steam.

Wet steam:

- It is the mixture of dry steam and water particles as moisture.
- The enthalpy of wet steam is given by: $h = h_f + x.h_{fg}$ where 'x' is the dryness fraction of steam.

Dry steam:

- It is the saturated vapor free from moisture.
- The dry saturated steam has absorbed its full latent heat. The enthalpy of dry saturated steam is given by: $h = h_g = h_f + h_{fg}$ where dryness fraction x = 1.

Superheated steam:

- It is the steam existing at higher temperature than its saturation temperature.
- 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.

Dryness fraction:

- It is the measure of quality of wet steam. It is the ratio of mass of dry steam (m_g) to the total mass of wet steam (m).

Enthalpy of steam or Total heat:

- It is the sum of enthalpy of saturated water (h_f) and enthalpy of vaporization (h_{fg}).

Sensible heat (enthalpy of saturated water-h_f):

- Sensible heat is defined as an amount of heat energy absorbed by 1 kg of water during its heating from 0^0C to the saturation temperature at a given pressure.

Latent heat of fusion:

- It is defined as the amount of heat required to convert one kg of ice into water at constant temperature of 0^0C.

Steam table and their uses:

- The properties of dry superheat steam like its temperature of formation (saturation temperature), sensible heat, latent heat of vaporization, enthalpy or total heat, specific volume, entropy etc., vary with pressure and can be found by experiments only. These properties have been carefully determined and made available in a tabular form known as steam tables.

(Solve Numerical to determine Total heat of Wet, Dry and Superheated Steam)

BOILER

Steam generator:

- A boiler is a steam generator which is used to convert steam from water by heating it.
- A steam generator or boiler, usually, a closed vessel made of steel. Its function is to transfer the heat produced by the combustion of fuel (solid, liquid or gas) to water, and ultimately to generate steam. The steam produced may be supplied:
    - To an external combustion engine, i.e. steam engines and turbines.
    - At low pressures for industrial process work in cotton mills, sugar factories, breweries etc.
    - For producing hot water.

Classification of steam boilers:

1. ***According to the contents in the tube***

    (a) Fire tube or smoke tube boiler

    (b) Water tube boiler.

2. ***According to the position of the furnace***

    (a) Internally fired boilers

    (b) Externally fired boilers

3. ***According to the axis of the shell***

    (a) Vertical boilers

    (b) Horizontal boilers

4. ***According to the number of tubes***

    (a) Single tube boilers

    (b) Multi tubular boilers

5. ***According to the method circulation of water and steam***

    (a) Natural circulation boilers

(b) Forced circulation boilers

6. ***According to the use***

(a) Stationary boilers

(b) Mobile boilers

Fire tube boiler:

- ♣ Fire tube boilers are those in which flue gas flows inside the tubes and the water that is to be heated remains outside the tube.
- ♣ Examples of fire tube boilers are: Simple vertical boiler, Cochran boiler, Lancashire boiler, Cornish boiler.

Water tube boiler:

- ♣ Water tube boilers are those in which water flows inside the tube and flue gas remains outside the tube to heat the water.
- ♣ Examples of water tube boilers are: Babcock and Wilcox boiler, Stirling boiler, La-Mont boiler, Benson boiler.

COCHRAN BOILER:

Cochran boiler is a vertical multi-tubular fire tube boiler. It produces steam at low pressure from the heat exchange between water and flue gas. It has the Steam capacity up to 3500 kg/hr.

Construction of Cochran boiler:

It consists of a cylindrical shell with a dome shaped top where the space is provided for steam. The furnace is one piece construction and is seamless. Its crown has a hemispherical shape and thus provides maximum volume of space. It has the following parts and mountings.

- ❖ Boiler shell (cylindrical, top is dome shaped, hemispherical crown)
- ❖ Grate and furnace (Internally fired boiler)
- ❖ Combustion chamber and fire tubes
- ❖ Smoke box and chimney

- *Mountings*: water gauge, pressure gauge, fusible plug, feed check valve, steam stop valve, safety valve and blow off cock.

Working of Cochran boiler:

When the fuel burns inside the fire box/furnace flue gas produces and flows into the combustion chamber after striking through the fire brick linings. Then the flue gas passes through the fire tubes to exchange heat with water surrounding to them. Then the flue gas is collected in a smoke box and escape to the atmosphere through chimney. In this way the steam produces at the top of the boiler shell and collected.

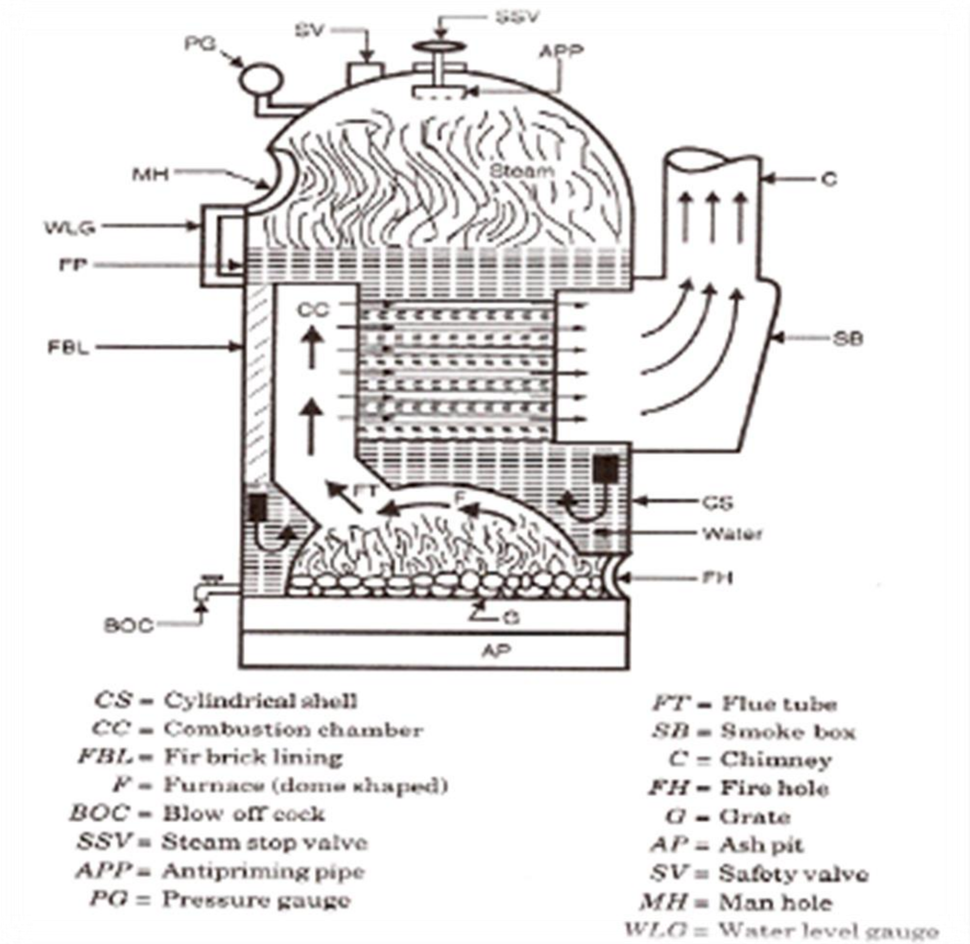
Mountings: These are the fitting and devices which are necessary for the operation and safety of a boiler.

- **Steam Stop Valve:** It is use to regulate the flow of steam from the boiler to the steam pipe.
- **Safety Valve:** It is use for releasing the excess steam when the pressure of steam inside the boiler exceeds the rated pressure. Types of safety valve are the following: · Dead weight safety valve, Lever safety valve, Spring loaded safety valve, Gravity safety valve
- **Water Level Indicator:** It is use to indicate the level of water in the boiler constantly.
- **Pressure Gauge:** It is use to measure the pressure exerted inside the vessel.
- **Fusible Plug:** It is use to protect the boiler against damage due to overheating for low water level.
- **Feed Check Valve:** It is use to control the supply the water to the boiler and to prevent the escaping of water from the boiler when the pump is stopped.
- **Blow Off Cock:** It is use to discharge a portion of water when the boiler is empty when necessary for cleaning, inspection, repair, mud, scale and sludge.
- **Man Hole:** It is used for inspection and maintenance purpose.

Accessories: These are auxiliary parts required for steam boilers for the proper operation and for the increase of their efficiency.

- **Super heater:** It is use to increase the temperature of steam above it saturation point.

- ❖ **Economizer:** It is a device in which the waste heat of flue gases is utilized for heating the feed water before supplying into the boiler.
- ❖ **Air pre heater:** It is use to increase the temperature of air before it enters the furnace.
- ❖ **ESP:** It is used to collect dust or harmful particle from flue gas before escape into the atmosphere.
- ❖ **Boiler feed pump:** It is used to deliver feed water to the boiler.\



BABCOCK WILCOX BOILER:

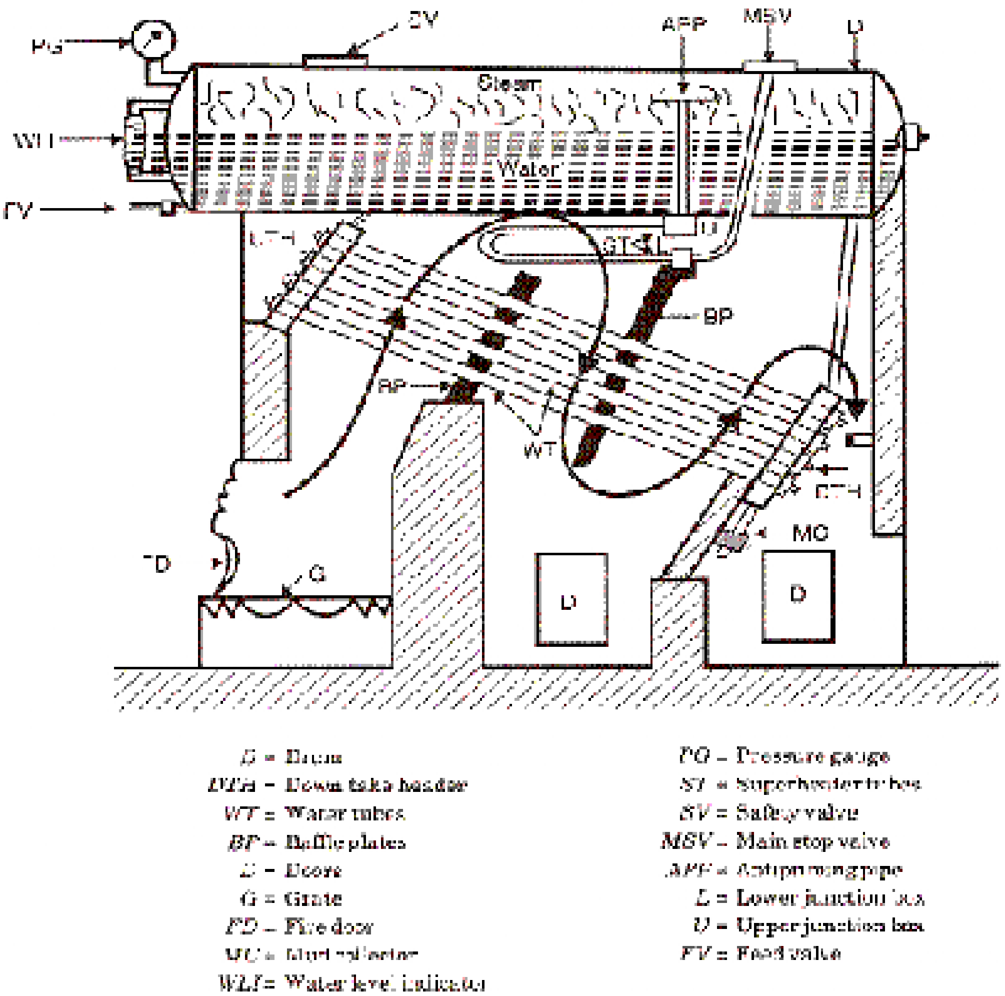
It is a horizontal inclined tube, water tube boiler. In this boiler high pressure steam produces from the heat exchange between water and hot flue gas.

Construction:

It consists of a longitudinal drum connected to a series of front end and rear end header by short riser tubes. These headers are connected by a series of inclined water tubes. The angle of inclination of the water tubes to the horizontal is about 15° or more. Mountings are mounted over the boiler shell for safe operation such as: steam stop valve, safety valve, water level indicator, pressure gauge, thermometer, fusible plug, feed check valve, blow- off cock, man hole etc.

Working:

Fuel is supplied to grate through fire door 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.



Difference between Water tube and Fire tube boiler:

Water tube boiler	Fire tube boiler
1. The water circulates inside the tubes which are surrounded by hot gases from the furnace.	1. The hot gases from the furnace the furnace pass through the tubes which are surrounded by water.
2. The rate of generation of steam is high.	2. The rate of generation of steam is low.
3. It generates steam at a higher pressure up to 165 bar.	3. It generates steam at up to 24.5 bar.

4. For a given power, the floor area required for the generation is less.	**4.** For a given power, the floor area required for the generation is more.
5. The operating cost is high.	**5.** The operating cost is less.
6. The bursting chance is more.	**6.** The bursting chance is less.
7. It is used for large power plants.	**7.** It is not suitable for large power plants.

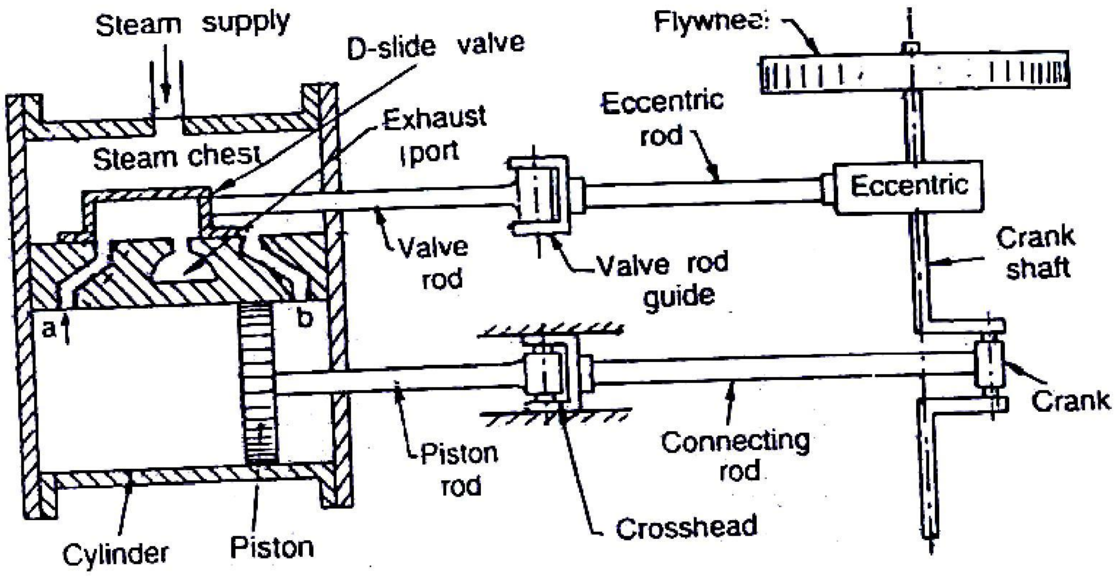
STEAM ENGINE

Steam Engine:

In all steam engines, the steam is used as the working substance. These engines operate on the principle of first law of thermodynamics, i.e. heat and work are mutually convertible. In a reciprocating steam engine, as the heat energy in the steam is converted into mechanical work by the reciprocating (to and fro) motion of the piston, it is also called reciprocating steam engine.

Working of a Single Cylinder Double Acting Horizontal Reciprocating Steam Engine:

The principal parts of a single cylinder, double acting horizontal reciprocating steam engine are shown in Fig.



(Single cylinder, double acting horizontal reciprocating steam engine)

The superheated steam at a high pressure (about 20 atmospheres) from the boiler is led into the steam chest. After that the steam makes its way into the cylinder through any of the ports ‘a’ or ‘b’ depending upon the position of the D-slide valve. When port ‘a’ is open, the steam rushes to the left side of the piston and forces it to the right. At this stage, the slide valve covers the exhaust port and the other steam port ‘b’ as shown in Fig. Since the pressure of steam is greater on the left side than that on right side, the piston moves to the right.

When the piston reaches near the end of the cylinder, it closes the steam port 'a' and exhausts port. The steam port 'b' is now open, and the steam rushes to the right side of the piston. This forces the piston to the left and at the same time the exhaust steam goes out through the exhaust pipe, and thus completes the cycle of operation. The same process is repeated in other cycles of operation, and as such the engine works.

Important Terms used in Steam Engines:

1. **Bore:-** The internal diameter of the cylinder of the engine is known as bore.

2. **Dead centre's:-** The extreme positions of the piston inside the cylinder during its motion are known as dead centre's. There are two dead centres, i.e. Inner dead centre (I.D.C.) and Outer dead centre (O.D.C.).

3. **Clearance volume**- The volume of space between the cylinder cover and the piston, when the piston is at I.D.C. position is called clearance volume It is usually represented as a percentage of stroke volume.

4. Stroke volume or swept volume- The volume swept by the piston when it moves from I.D.C. to O.D.C., is known as stroke volume or swept volume v**5**. It is also known as piston displacement. Mathematically, stroke volume or swept volume

$$V_S = \frac{\pi}{4} D^2 L$$

Where D = Bore or internal diameter of the cylinder, and

L = Length of the stroke.

5. Cut-off volume:- Theoretically, the steam from the boiler enters the clearance space and pushes the piston outward doing external work. At some point during outward movement of the piston, the supply of steam is stopped. The point or the volume where the cut-off of steam takes place is called the point of cut-off or cut-off volume.

6. **Average piston speed-** The distance travelled by the piston per unit time is known as average piston speed. Mathematically,

Average piston speed = LN m/min, for single acting steam engine

= 2 LN m /min, for double acting steam engine

where L = Length of the stroke in metres, and N = Speed in R.P.M.

7. Mean effective pressure- The average pressure on the piston during the working stroke is called mean effective pressure. It is given by the mean depth of the p-v diagram.

Mathematically, mean effective pressure P_m = Work done per cycle/ Stroke volume.

Indicator Diagram of a Simple Steam Engine:

It is a graphical representation of the variation in pressure and volume of steam inside the cylinder or p-v diagram. As a matter of fact, the theoretical or hypothetical indicator diagram of a simple steam engine has been developed from that of a modified Rankine cycle.

Theoretical or Hypothetical Indicator Diagram:

The theoretical or hypothetical indicator diagram without clearance and with clearance is shown in Fig. 4.3. In other words, if there is no steam in the cylinder (or there is zero volume of steam at point 1).

The sequence of processes is given below:

1. **Process 1-2 -** At point 1, the steam is admitted into the cylinder through the inlet port. As the piston moves towards right, therefore the steam is admitted at constant pressure. Since the supply of steam is cut off at point 2, therefore this point is known as cut-off point.

2. **Process 2-3-** At point 2, expansion of steam, in the cylinder, starts with movement of the piston till it reaches the dead end. This expansion takes place hyperbolically (i.e. pv=C) and pressure falls considerably as-shown in Fig. 4.4.

3. **Process 3-4-** At point 3, the exhaust port opens and steam is released from the cylinder to the exhaust. As a result of steam exhaust, pressure in the cylinder falls suddenly (without change in volume) as shown in Fig. 4.4. The point 3 is known as release point.

4. **Process 4-5-** At point 4, return journey of the piston starts. Now the used steam is exhausted at constant pressure, till the exhaust port is closed, and the inlet port is open. The steam pressure at point 4 is called back pressure.

5. **Process 5-1-** At point 5, the inlet port is opened and some steam suddenly enters into the cylinder, which increases the pressure of steam (without change in volume). This process continues till the original position is restored.

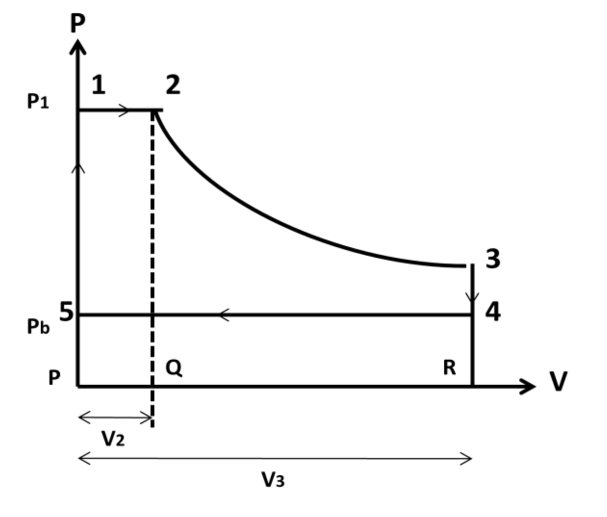


Figure-(a)

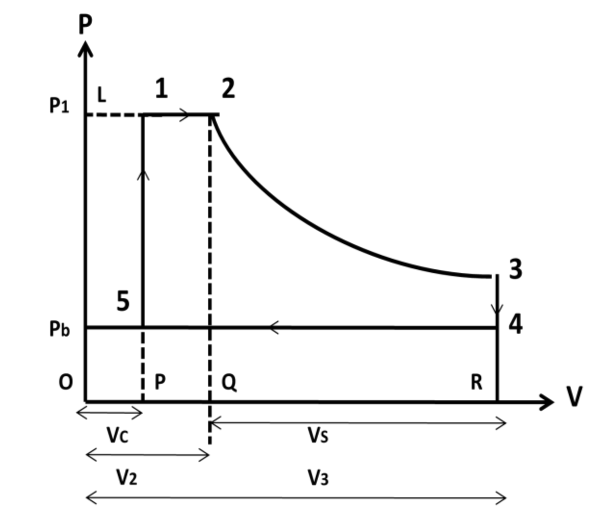


Figure-(b)

Theoretical or Hypothetical Mean Effective Pressure:

Theoretical or hypothetical mean effective pressure is given by:

$$\boldsymbol{P_m = \frac{Work\ done\ per\ cycle}{Stroke\ Volume} = \frac{P_1V_2 + 2.3P_1V_2\log\left(\frac{V_3}{V_2}\right) - P_bV_3}{V_3} = P_1\frac{V_2}{V_3} + 2.3P_1\frac{V_2}{V_3}\log\frac{V_2}{V_3} - P_b}$$

$$= \frac{P_1}{r}(1 + 2.3\ log r) - P_b \qquad \text{Where, } r = \frac{V_3}{V_2} = Expansion\ ratio$$

Numerical

1) A steam engine cylinder receives steam at a pressure of 11.5 bar and cut-off takes place at half of the stroke. Find the theoretical mean effective pressure, if the back pressure of the steam is 0.15 bar. Neglect clearance.

2) The steam is supplied at a pressure of 8.4 bar and cut-off occurs at 0.35 of the stroke. The back pressure is 1.25 bar. If the diagram factor is 0.75, determine the actual mean effective pressure. Neglect clearance.

3) A double acting single cylinder has 200mm stroke, 160mm diameter. It runs at 250 r.p.m and the cut-off is 25% of the stroke. The pressure at cut-off is 15 bar and exhaust is at 0.3 bar for a diagram factor of 0.75. Estimate the indicated power in kW.

4) Calculate the indicated power and steam consumption in kg/h of a double acting steam engine from the following data :
Diameter of cylinder=300 mm; stroke=450mm; R.P.M=120; Steam pressure=7 bar, and 0.9 dry; Back pressure = 1.2bar; Cut-off takes place at 32% of stroke for both ends.

5) During a test on a single acting non-condensing, single cylinder steam engine, the following observations were recorded:
Bore - 225 mm ; Stroke - 600 mm ; Speed = 100 r.p.m.; Effective brake diameter = 2.75 m ; Net load on the brake = 1650 N ; Area of indicator diagram = 2500 mm^2 ; Length of indicator diagram = 100 mm ; Spring strength = 530 bar/m.
Determine: 1. Indicated power ; 2. Brake power; and 3. Mechanical efficiency.

6) Estimate the brake power of simple steam engine having 250 mm piston diameter, and 40 mm piston rod diameter with 250mm stroke length operating at 300 r.p.m. The initial and back pressure of steam is 8.5 bar and 1.2 bar respectively. Assume 90% mechanical efficiency, cut-off at 25% of the forward stroke and 0.73 diagram factor. Neglect clearance and compression.

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Power developed by a Simple Steam Engine:

Power may be defined as the rate of doing work. It is thus the measure of performance of a steam engine.

Mathematically: Power (P) = (Work done) / (time taken)

In case of steam engines, the following two terms are commonly used for the power developed.

1. Indicated power, and 2. Brake power

Indicated power:

Actual power generated in the engine cylinder is called power input or indicated power.

For single acting steam engine: $I.P = \frac{P_m LAN}{60}\ Watt$

For double acting steam engine: $I.P = \frac{2P_m LAN}{60}\ Watt$

STEAM TURBINE

TURBINE:

A steam turbine is a machine which converts the available thermal energy into mechanical energy. These are classified as Impulse and Reaction turbine.

Types of turbine (Classification):

The steam turbines may be classified into the following types:

1. According to the mode of steam action
   (i) Impulse turbine, and (ii) Reaction turbine
2. According to the direction of steam flow
   (i) Axial flow turbine, and (ii) Radial flow turbine.
3. According to the exhaust condition of steam
   (i) Condensing turbine, and (ii) Non-considering turbine
4. According to the pressure of steam
   (i) High pressure turbine, (ii) Medium pressure turbine, and
   (iii) Low pressure turbine
5. According to the number of stages
   (i) Single stage turbine, and (ii) Multi stage turbine

Difference between Impulse and reaction turbine:

Impulse turbine	Reaction turbine
1. The steam flows through the nozzles and impinges on the moving blades.	**1.** The steam flows first through guide mechanism and then through the moving blades.
2. The steam impinges on the buckets with kinetic energy.	**2.** The steam glides over the moving vanes with pressure and kinetic energy.
3. The steam may or may not be admitted over the whole circumference.	**3.** The steam must be admitted over the whole circumference.

4. The steam pressure remains constant during its flow through the moving blades.	**4.** The steam pressure is reduced during its flow through the moving blades.
5. The negative velocity of steam while gliding over the blades remains constant.	**5.** The relative velocity of steam while gliding over the moving blades increase
6. The blades are symmetrical.	**6.** The blades are not symmetrical
7. The number of stages required is less for the same power developed.	**7.** The number of stages required is more for the same power developed.

STEAM CONDENSER

CONDENSER:

A steam condenser is a closed vessel into which the steam is exhausted, and condensed after doing work in an engine cylinder or turbine. A steam condenser has the following two objects.

1. The primary object is to maintain a low pressure (below atmospheric pressure) so as to obtain the maximum possible energy from steam and thus to secure a high efficiency.
2. The second object is to supply pure feed water to the hot well, from where it is pumped back to the boiler.

Classification of Condensers:

The steam condensers may be broadly classified into the following two types: (1) Jet condensers or mixing type condensers; (2) Surface condensers or non-mixing type condensers.

Types of Jet Condensers:

1. Parallel flow jet condenser
2. Counterflow or low level jet condenser
3. Barometric or high level jet condenser, and
4. Ejector condenser.

Types of Surface Condensers:

1. Down flow surface condenser
2. Central flow surface condenser
3. Regenerative surface condenser and
4. Evaporative condenser.

INTERNAL COMBUSTION ENGINE

Internal Combustion (I.C) engine:

- When the combustion of fuel supplied to the engine takes place inside the engine cylinder, the engine is called as an internal combustion engine.
- *Examples* – 2-stroke and 4-stroke petrol and diesel engines.

Terminology:

- ***Bore***: It is the diameter of the engine cylinder or piston.
- ***Stroke***: It is the distance moved by piston between two dead centres.
- ***Swept volume***: It is the maximum volume swept by the piston when it moves from one dead centre to another.
- ***Compression ratio***: It is the minimum volume between the cylinder head and top of the piston when the piston is at the top dead centre.
- ***Air standard efficiency***: It is ratio between work done and heat supplied for air standard cycle.

Main Components of I.C engine:

The main components of an I.C engine are cylinder, cylinder head, piston, piston rings, connecting rod, crank, crank shaft and flywheel.

Classification of I.C engine:

The classification of I.C engine is as follows:

- According to number of strokes:
  - Four stroke engine
  - Two stroke engine
- According to fuel used
  - Petrol engine
  - Diesel engine
  - Gas engine
- According to method of ignition
  - Spark ignition engine

- Compression ignition engine
- ♣ According to cooling system
  - Air cooled engine
  - Water cooled engine
- ♣ According to number of cylinder
  - Single cylinder engine
  - Multi cylinder engine
- ♣ According to speed of engine
  - Low speed engine
  - Medium speed engine
  - High speed engine

Difference between Petrol engine and Diesel engine:

Petrol engine	Diesel engine
1. Air fuel mixture is drawn into the engine cylinder in suction stroke.	1. Only Air mixture is drawn into the engine cylinder in suction stroke.
2. The carburetor is used to mix air and petrol in a proper ratio.	2. Fuel injector is used to inject fuel.
3. Pressure at the end of compression is about 10 bar.	3. Pressure at the end of compression is about 35 bar.
4. The air fuel mixture is ignited by using the spark plug.	4. Mixture is self ignited at high compression ratio.
5. Combustion of fuel takes place at constant volume.	5. Combustion of fuel takes place at constant pressure.
6. It has compression ratio approximately 6 to 10.	6. It has compression ratio approximately 15 to 25.

7. It has easy starting.	**7.** Its starting is difficult.
8. It is lighter and cheaper.	**8.** It is heavier and costlier.
9. Its running cost is high.	**9.** Its running cost is low.
10. Its maintenance cost is less.	**10.** Its maintenance cost is high.
11. It has thermal efficiency up to 26%.	**11.** It has thermal efficiency up to 40%.
12. It is used in light vehicles.	**12.** It is used in heavy vehicles.

Difference between 2-stroke and 4-stroke engine:

2-Stroke engine	4-Stroke engine
1. Two stroke engines give one power stroke for each revolution of crank.	**1.** Four stroke engines give one power stroke for every two revolutions of crank.
2. Power produced by this engine is almost double than four stroke cycle engine.	**2.** Power produced by this engine is almost half than two stroke cycle engine.
3. To produce same power it requires less space.	**3.** To produce same power it requires more space.
4. It has inlet, exhaust and transfer ports.	**4.** It has inlet and outlet valves.
5. Its thermal efficiency is low.	**5.** Its thermal efficiency is high.
6. It requires lighter fly wheels.	**6.** It requires larger flywheels.
7. It is used in light vehicles.	**7.** It is used in light, medium and heavy vehicles.
8. Its initial cost is less.	**8.** Its initial cost is high.

Indicated horse Power of I.C engine:

Indicated power is defined as the rate of work done on the piston by the combustion of charge inside the engine cylinder. Indicated power in terms of horse power is called as *Indicated horse power*.

Mathematically: $I.P = \dfrac{P_m LAnk}{60}$

Brake horse power of I.C engine:

It is the net power available at the engine shaft. Brake power in terms of horse power is called as *Brake horse power*.

Mathematically: $B.P = \dfrac{2\pi RNF}{60} = \dfrac{2\pi NT}{60}$

Mechanical efficiency of I.C engine:

It is defined as the ratio of brake power to the indicated power or I.H.P to B.H.P.

Four stroke Cycle Petrol Engine:

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

1. Suction or charging stroke

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

2. Compression stroke

In this stroke, both the inlet and exhaust valves are closed and 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 increases considerably (the actual values depend upon compression ratio). This completes one revolution of the crankshaft.

3. Expansion or working stroke

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

4. 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.

Now the cycle completes and the engine cylinder is ready to suck the charge again

Four stroke Cycle Diesel Engine

It is also known as compression ignition engine because the ignition takes place due to the compression produced in the engine cylinder at the end of compression stroke. The four strokes of a diesel engine sucking pure air are described below :

1. Suction or charging stroke

In this stroke, the inlet valve opens and pure air is sucked into the cylinder as the piston moves downwards from the top dead centre {TDC). It continues till the piston reaches its bottom dead centre {BDC).

2. 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 temperature of the air increases considerably (the actual value depends upon the compression ratio). This completes one revolution of the crank shaft.

3. Expansion or working stroke

Shortly before the piston reaches the TDC (during the compression stroke), 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, temperature of the compressed air sufficiently high to ignite the fuel. It suddenly increases the pressure and temperature of the producer of combustion. The fuel oil is continuously injected for a fraction of the revolution. The fuel oil assumed to be burnt at constant pressure. Due to increased 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 is transformed into mechanical work. It may be noted that during this working stroke, both the valves are closed and the piston moves from TDC to BDC.

5. 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 completes the cycle and the engine cylinder ready to suck the fresh air again.

HYDROSTATICS

Fluid:

Fluid is a substance having particles which readily change their relative motion and they have the capability of flowing. Example: air and liquid. The standard liquid is taken as water and standard gas is taken as air.

Properties of Fluid:

1. **Density or mass density:** It is the ratio of mass per unit volume of a fluid. It is denoted the symbol ρ (rho).

   Unit: The unit of mass density is kg/m^3 in S.I and gm/cm^3 in C.G.S

   mathematically: $\rho = \frac{mass\ of\ fluid}{volume\ of\ fluid}$

   The value of density of water is 1 gm/cm^3 or 1000 kg/m^3

2. **Specific weight or weight density:**

   Specific weight or weight density of a fluid is the ratio between the weights of a fluid to its volume. Thus weight per unit volume of a fluid is called weight density and it is denoted by the symbol w.

   Mathematically: $w = \frac{weight\ of\ fluid}{volume\ \ of\ fluid} = \frac{m \times g}{V} = \rho \times g$

   Unit: The unit of weight density is N/m^3 in S.I and $dyne/cm^3$ in C.G.S

   We know that: 1 liter = $\frac{1}{1000}$ m^3, 1liter = 1000cm^3

   The value of specific weight or weight density (w) for water is 9810 N/m^3 in S.I. units.

3. **Specific gravity or relative density (S):**

   Specific gravity is defined as the ratio of the mass density or weight density of a given liquid to the mass density or weight density of standard liquid (water at 4^0c).

   Mathematically: S (for liquids) = $\frac{\text{weight density (density) of liquid}}{\text{weight density (density) of water}}$

   It is unit less. Specific gravity of water = 1 and specific gravity of mercury = 13.6

4. **Viscosity (μ):**

Viscosity is defined as the property of a fluid which offers resistance to the movement of one layer of fluid over another adjacent layer of the fluid.

Mathematically: $\mu = \frac{\text{shear stress}}{\text{velocity gradient}}$

Units of viscosity: - $N\text{-}s/m^2$ in S.I, $kgf\text{-}sec/m^2$ in M.K.S, dyne- sec/cm^2 in C.G.S

it is also known as dynamic viscosity. 1 poise = dyne- sec/cm^2

Kinematic viscosity:

It is defined as the ratio between the dynamic viscosity and density of fluid.

It is denoted by ν (nu).

$$\nu = \frac{viscosity}{density} = \frac{\mu}{\rho}$$

Unit of kinematic viscosity: m^2/sec in S.I and cm^2/sec in C.G.S

1 stoke = $cm^2/sec = \left(\frac{1}{100}\right)^2 m^2/sec$

Types of Fluid:

Ideal fluid & Real fluid.

Ideal fluid of two types - (I) Newtonian fluid (ii) Non- Newtonian fluid.

Ideal Fluid or Perfect Fluid:

Ideal fluids are only imaginary fluids which are incompressible, non-viscous, no surface tension.

In nature ideal fluid does not exist.

Real fluid:

The fluid's actually available in nature causing property such as viscosity, surface tension and compressibility.

Pressure:

Pressure is force per unit area applied in a direction perpendicular to the surface of an object.

The SI unit of pressure is the newton per meter square, which is called the Pascal (Pa).

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.

Vacuum pressure is zero-referenced against ambient air pressure, so it is equal to atmospheric pressure minus absolute Pressure.

Differential pressure is the difference in pressure between two points.

Pressure Measuring Instruments:

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. A **vacuum gauge** is used to measure the pressure in a vacuum.

Types of manometer:

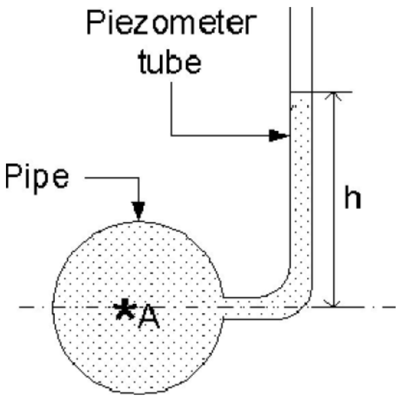
1.Simple manometer

2.U-tube manometer

3.Differential manometer

Piezometer:

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 = w.h**, where w is the specific weight of the liquid.

"U"-Tube Manometer:

Using a "U"-Tube enables the pressure of both liquids and gases to be measured with the same instrument. The "U" is connected as in the figure below and filled with a fluid called the *monomeric fluid*. The fluid whose pressure is being measured should have a mass density less than that of the manometric fluid and the two fluids should not be able to mix readily – that is, they must be immiscible.

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

$$\text{pressure at B} = \text{pressure at C}$$
$$p_B = p_C$$

For the left hand arm:

$$\text{pressure at B} = \text{pressure at A} + \text{pressure due to height } h_1 \text{ of fluid being measured}$$
$$p_B = p_A + \rho g h_1$$

For the right hand arm

$$\text{pressure at C} = \text{pressure at D} + \text{pressure due to height } h_2 \text{ of manometric fluid}$$
$$p_C = p_{\text{Amospheric}} + \rho_{\text{man}} g h_2$$

Gauge Pressure: $p_A = \rho_{\text{man}} g h_2 - \rho g h_1$

HYDROKINETICS

Total Head of a Liquid Particle in Motion:

The total head of a liquid particle, in motion, is the sum of potential head, kinetic head and pressure head.

Mathematically: **Total Head, $H = Z + V^2/2g + P/W$** m of liquid.

Continuity Equation:

The equation based on the principle of conservation of mass is called continuity equation. Thus for a fluid flowing through the pipe at all the cross-section, the quantity of fluid per section is constant.

Consider two cross-section of a pipe as shown in figure.

Let V_1 = Average velocity at cross-section1-1

ρ_1= Density at section 1-1

A_1 = Area of pipe at section 1-1

And V_2, ρ_2, A_2 are corresponding values at section, 2-2

Then, rate of flow at section 1-1 = $\rho_1 A_1 V_1$

Rate of flow at section 2-2 = $\rho_2 A_2 V_2$

According to law of conservation of mass,

Rate of flow at section 1-1 = Rate of flow at section 2-2

$$\rho_1 A_1 V_1 = \rho_2 A_2 V_2$$

This equation is applicable to the compressible as well as incompressible fluids and is called continuity equation. If the fluid is incompressible, then $\rho_1 = \rho_2$ and
continuity equation $A_1 V_1 = A_2 V_2$

Bernoulli's Equation:

It states that, "*for a perfect incompressible liquid, flowing in a continuous stream, the total energy of a particle moves from one point to another.*"

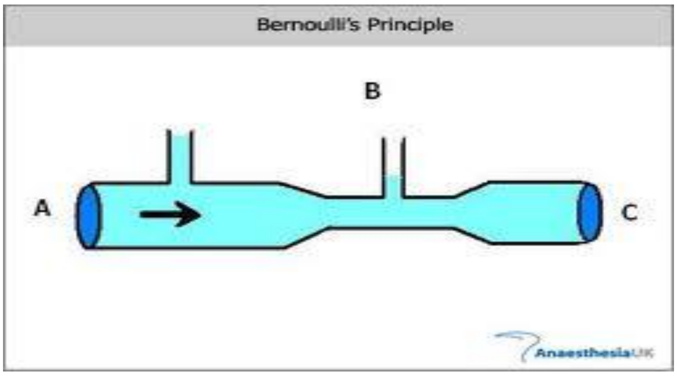
This statement is based on the assumption that there are no losses due to friction in the pipe.

Mathematically, $Z + V^2/2g + p/w = \text{constant}$.

Where, Z = potential energy, $V^2/2g$ =Kinetic energy, P/W= pressure energy

Proof:

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



Let us consider two sections AA & BB of the pipe. Now let us assume that the pipe is running full and there is a continuity of flow between the two sections.

Let Z_1 = Height of AA above the datum.

P_1 = Pressure at AA.

V_1 = Velocity of liquid at AA,

a_1= cross-sectional area of the pipe at AA, and

Z_2, P_2 , V_2, a_2 = corresponding values at BB.

Let the liquid between the two sections AA and BB moves to A^1A^1 and B^1B^1 through very small lengths dl_1 and dl_2 as shown in fig. This movement of the liquid between AA & BB is equivalent to the movement of the liquid between AA and A^1A^1 to BB and B^1B^1 the remaining liquid between A^1A^1 and BB being unaffected.

Let W be the weight of the liquid between AA and A^1A^1. Since the flow is continuous.

Therefore $W = w.a1.dl_1 = w.a_2.dl_2$

$\Rightarrow a_1.dl_1 = a_2.dl_2 = W/w$ -------- (1)

or $a_1.dl_1 = a_2.dl_2$ ---------------- (ii).

We know that work done by pressure at AA in moving the liquid to A^1A^1 = force× distance

$= p_1 a_1.dl_1$

Similarly, work done by pressure at BB, in moving the liquid to $B^1B^1 = - P_2.a_2dl_2$

(minus sign is taken as the direction of p_2 is opposite to that of p_1)

Total work done by the pressure $= P_1.a_1dl_1 – P_2.a_2.dl_2$

$= P_1.a_1dl_1 – P_2.a_1dl_1$ $(a_1.dl_1 = a_2.dl_2)$

$= a_1dl_1 (P_1 - P_2) = W/w (P_1 - P_2)$ $(\because a_1dl_1 = W/w)$

Loss of potential energy $= w (z_1 - z_2)$ & gain in kinetic energy $= w (V_2^2/2g - V_1^2/2g)$

$= w/2g(V_2^2 - V_1^2)$

We know that: loss of potential energy + work done by pressure = gain in kinetic energy

$W (Z_1 - Z_2) + W/w (P_1 - P_2) = W/2g (V_2^2 – V^2_1)$

$(Z_1 – Z_2) + P_1/w - P_2/w = V_2^2/2g – V_1^2/2g$

Or $\mathbf{Z_1 + V_1^2/2g + P_1/w = Z_2 + V_2^2/2g + P_2/w}$

This proves the Bernoulli’s equation.

Assumptions:

The following are the assumptions made in the derivation of Bernoulli’s equation.

(i)The fluid is ideal, i.e. viscosity is zero.

(ii) The flow is steady

(iii)The flow is incompressible (iv)The flow is rotational.

Limitations of Bernoulli’s equation:

The Bernoulli’s theorem or Bernoulli’s equation has been derived on certain assumptions, which are rarely possible. Thus the Bernoulli’s theorem has the following limitations.

(1)The Bernoulli’s equation has been derived under the assumption that the velocity of every liquid particle across any cross-section of a pipe is uniform. But in actual practice, It is not so. The velocity of liquid particle in the centre of a pipe is maximum & gradually decreases towards the walls of the pipe due to the pipe friction. Thus, while using the Bernoulli’s equation, only the mean velocity of the liquid should be taken into account.

(2)The Bernoulli’s equation has been derived under the assumption that no external force, except the gravity force is acting on the liquid. But in actual practice, it is not so. There is always some external force such as pipe friction etc acting the liquid, which affect the flow of the liquid.

Thus, while using the Bernoulli’s equation, all such external force should be neglected. But if some energy is supplied to, or, extracted from the flow the same should also be taken into account.

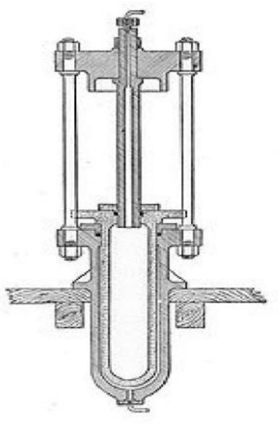
(3)The Bernoulli’s equation has been derived, under the assumption that there is no loss of energy of the liquid particle while flowing. But in actual practice, it is rarely so. In a turbulent flow, some kinetic energy is converted into heat energy. And in a viscous flow, some energy is lost due to shear forces. Thus, while using Bernoulli’s equation, all such losses should be neglected.

(4)If the liquid is flowing in a curved path, the energy due to centrifugal force should also be taken into account.

Practical Applications of Bernoull's Equation:

There are three types: (1) Venturimeter (2) Orifice meter (3) Pitot tube.

Hydraulic intensifier



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. A mechanically compact and popular form of intensifier is the concentric cylinder form, as illustrated. In this design, one piston and cylinder are reversed: instead of the large diameter piston driving a smaller piston, it instead drives a smaller moving cylinder that fits over a fixed piston. This design is compact, and again may be made in little over twice the stroke. It has the great advantage though that there is no "piston rod" and the effective distance between the two pistons is short, thus permitting a much lighter construction without risk of bending or jamming.

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.

Hydraulic accumulator

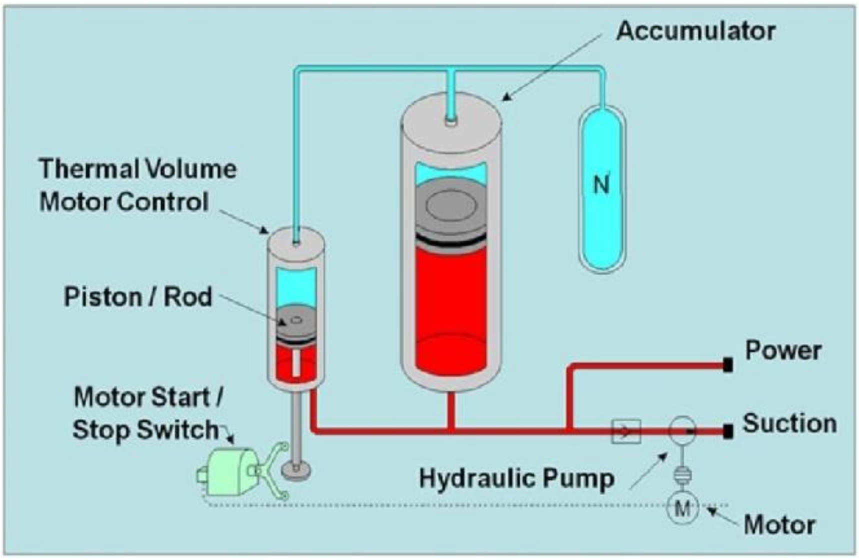
Functioning of an accumulator

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 pipe work, 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 pipe work runs. The outflow of energy from a discharging accumulator is much greater, for a short time, than even large pumps could generate.

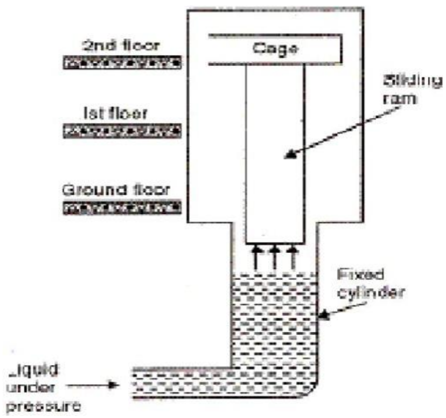
An accumulator can maintain the pressure in a system for periods when there are slight leaks without the pump being cycled on and off constantly. When temperature changes cause pressure excursions the accumulator helps absorb them. Its size helps absorb fluid that might otherwise be locked in a small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



Direct Acting Hydraulic Lift:

CONSTRUCTION DETAILS:

- fixed cylinder: It is fixed with the wall of the floor, where the sliding ram reciprocate when weapply the pressure.
- Cage: It is fitted on the top of the sliding ram where the load is placed (i.e. lifted load).
- 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.)



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:

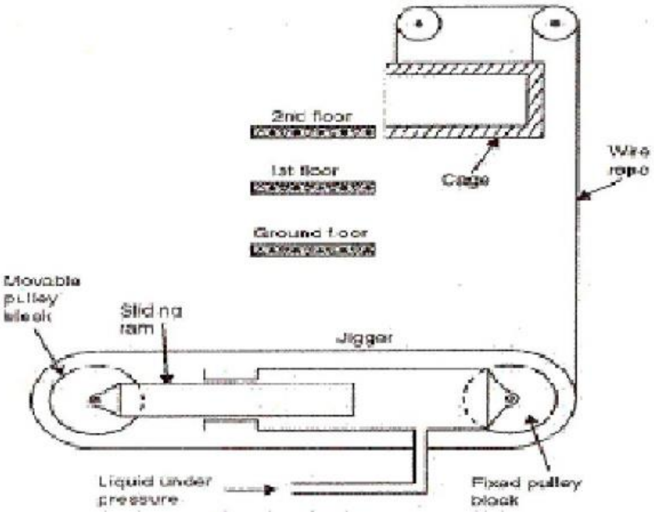
Cage: It is fitted on the top of the sliding ram where the load is placed (i.e. lifted load).Wire rope: It connects the cage to pulley.

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)

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

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

Fixed cylinder-: It is fixed with the wall of the floor, where the sliding ram reciprocate when weapply 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 the pressure force with their 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 thelift.

Hydraulic ram

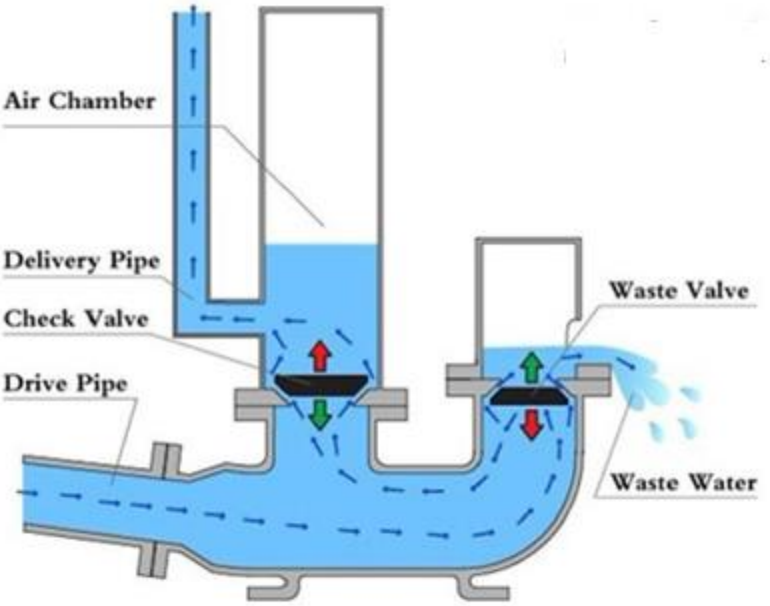
This article is about the water pump. For the vehicle extraction tool, see Hydraulic rescue tools. Forthe piston-based actuator, see hydraulic cylinder.

A hydraulic ram, 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.



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