LECTURE NOTE

ELEMENTS OF MECHANICAL ENGINEERING

TH3.

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1 .Thermodynamics

1.1 State Heat;

Heat is a form of energy which flows. It is the energy of motion of molecules constituting the body. The unit of heat is same as that of the energy, the S.I. unit of **heat is Joule (abbreviated** as J)

State work;

Work can be defined as the product of the force used to move an object times the distance the object is moved.

i.e $w = F \times d$

The SI unit of work is Joule which is denoted by the abbreviation "J."

First law of thermodynamics;

The first law of thermodynamics states that e*nergy can neither be created nor destroyed, only altered in form*. For any system, energy transfer is associated with mass crossing the control boundary, external work, or heat transfer across the boundary. These produce a change of stored energy within the control volume.

1.2 Perfect gases laws;

Boyle's law, also referred to as the **Boyle–Mariotte law**, or **Mariotte's law** (especially in France), is an experimental gas law that describes how the pressure of a gas tends to decrease as the volume of the container increases. A modern statement of Boyle's law is:

The absolute pressure exerted by a given mass of an ideal gas is inversely proportional to the volume it occupies if the temperature and amount of gas remain unchanged within a closed system.[1][2]

Mathematically, Boyle's law can be stated as:

Pressure is inversely proportional to the volume

or

$PV = k$ Pressure multiplied by volume equals some constant k

where P is the pressure of the gas, V is the volume of the gas, and k is a constant.

Charle's Law

Jacques Charles in 1787 analyzed the effect of temperature on the volume of a gaseous substance at a constant pressure. He did this analysis to understand the technology behind the hot air balloon flight. According to his findings, at constant pressure and for constant mass, the volume of a gas is directly proportional to the temperature.

This means that with the increase in temperature the volume shall increase while with decreasing temperature the volume decreases. In his experiment, he calculated that the increase in volume with every degree equals 1/273.15 times of the original volume. Therefore, if the volume is V_0 at 0° C and V_t is the volume at t° C then,

$$V_t = V_0 + t/273.15\ V_0 \Rightarrow V_t = V_0 (1 + t/273.15)$$

$$\Rightarrow V_t = V_0 (273.15 + t/273.15)$$

For the purpose of measuring the observations of gaseous substance at temperature 273.15 K, we use a special scale called the Kelvin Temperature Scale. The observations of temperature (T) on this scale is 273.15 greater than the temperature (t) of the normal scale.

$$T = 273.15 + t$$

while, when T = 0° c then the reading on the Celsius scale is 273.15. The Kelvin Scale is also called Absolute Temperature Scale or Thermodynamic Scale. This scale is used in all scientific experiments and works. In the equation [$V_t = V_0 (273.15 + t/273.15)$] if we take the values T_t = 273.15+t and T_0 = 273.15 then:

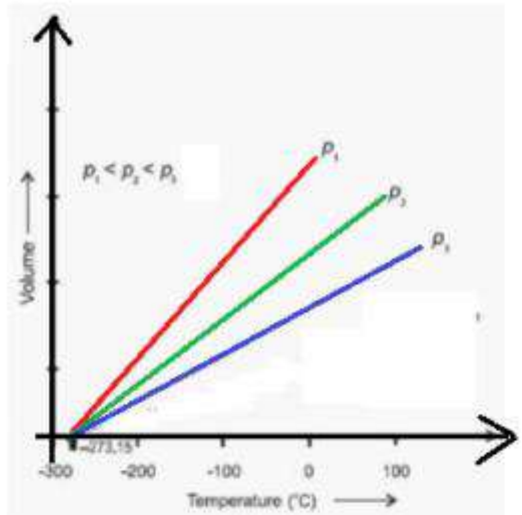
$$V_t = V_0 (T_t / T_0)$$

which implies $V_t/V_0 = (T_t / T_0)$, which can also be written as:

$$V_2/V_1 = T2/ T_1$$

$$\text{or } V_1 / T_1 = V_2 / T_2$$

$$V/T = \text{constant} = k_2$$



Therefore, $V = k_2 T$

The graphical representation of Charles law is shown in the figure above. Its an isobar graph as the pressure is constant with volume and temperature changes under observation.

Gay-Lussac's law

Also referred to as Pressure-Temperature Law, Gay Lussac's Law was discovered in 1802 by a French scientist Joseph Louis Gay Lussac. While building an air thermometer, Gay-Lussac accidentally discovered that at fixed volume and mass of a gas, the pressure of that gas is directly proportional to the temperature. This mathematically can be written as: $p \propto T$

$$\Rightarrow \; p/T = \text{constant} = k_3$$

The temperature here is measured on the Kelvin scale. The graph for the Gay- Lussac's Law is called as an isochore because the volume here is constant.

1.3 Specific heat at constant pressure;

The specific heat of a gas at constant pressure is defined as **the quantity of heat required to raise the temperature of unit mass of the gas by 1 degree**, the pressure remaining constant during heating. It is given the symbol c_p.
Specific

Specific heat at constant volume;

Specific heat at constant volume means **the amount of that is required to raise the temperature of unit mass of gas by 1 degree at constant volume**. **$Q=nC_V\Delta T$(1)** For an ideal gas, from 1st law of thermodynamics.

Relationship Between Cp and Cv

According to the first law of thermodynamics:

$\Delta Q = \Delta U + \Delta W$ where, ΔQ is the amount of heat that is given to the system, ΔU is the change in internal energy and ΔW is the work done.

We can write –

$\Delta Q = \Delta U + P\Delta V$, as $\Delta W = P\Delta V$

Since ΔQ = nC

pp

ΔT and ΔU = n

vv

$C\Delta T$

Therefore, nC

pp

ΔT = nC

vv

$\Delta T + P\Delta V$ ------------------(3)

We know that $PV = nRT$

At T1 Kelvin: $PV_1 = nRT_1$ ------------(a)

At T2 Kelvin: $PV_2 = nRT_2$ ------------(b)

Subtracting (a) from (b):

$PV_2 - PV_1 = nRT_2 - nRT_1$

$P(V_2 - V_1) = nR(T_2 - T_1)$

Where $V_2 - V_1 = \Delta V$ and $T_2 - T_1 = \Delta T$

Therefore, $P\Delta V = nR\Delta T$

Putting the value of $P\Delta V$ in equation (3):

nC

pp

ΔT = nC

vv

$\Delta T + nR\Delta T$

nC

pp

$\Delta T = n\Delta T(C$

vv

$+ R)$

C

pp

$= C$

vv

$+ R$

or C

pp

$- C$

vv

$= R$

The following relationship can be given considering the ideal gas behaviour of a gas.

C

pp

$- C$

vv

$= R$

where R has been called universal gas constant.

2. Properties of steam

2.1 Steam Table;

Steam tables are defined as the thermodynamic data that contain the properties of water or steam. These data are commonly used by engineers. It is normally used to obtain the following properties using **steam pressure for saturated steam temperature and saturated temperature for saturated steam pressure**.

Saturated Steam Tables

A saturated steam table is an indispensable tool for any engineer working with steam. It's typically used to determine saturated steam temperature from steam pressure, or the opposite: pressure from saturated steam temperature. In addition to pressure and temperature, these tables usually include other related values such as specific enthalpy (h) and specific volume (v).

The data found in a saturated steam table always refers to steam at a particular saturation point, also known as the boiling point. This is the point where water (liquid) and steam (gas) can coexist at the same temperature and pressure. Because H_2O can be either liquid or gas at its saturation point, two sets of data are required: data for saturated water (liquid), which is typically marked with an "f" in subscript, and data for saturated steam (gas), which is typically marked using a "g" in subscript.

Saturation Properties for Steam - Pressure Table (1 kPa - 1 MPa)

Pressure	Temp	volume (m^3/kg)		energy (kJ/kg)		enthalpy (kJ/kg)			entropy (kJ/kg.K)		
MPa	°C	vf	vg	uf	ug	hf	hfg	hg	sf	sfg	sg
0.001	6.97	0.00100	129.18	29.3	2384.5	29.3	2484.4	2513.7	0.1059	8.8690	8.9749
0.0012	9.65	0.00100	108.67	40.6	2388.2	40.6	2478.0	2518.6	0.1460	8.7622	8.9082
0.0014	11.97	0.00100	93.90	50.3	2391.3	50.3	2472.5	2522.8	0.1802	8.6720	8.8522
0.0016	14.01	0.00100	82.74	58.8	2394.1	58.8	2467.7	2526.5	0.2100	8.5935	8.8035
0.0018	15.84	0.00100	74.01	66.5	2396.6	66.5	2463.4	2529.9	0.2366	8.5242	8.7608
0.002	17.50	0.00100	66.99	73.4	2398.9	73.4	2459.5	2532.9	0.2606	8.4620	8.7226
0.003	24.08	0.00100	45.65	101.0	2407.9	101.0	2443.8	2544.8	0.3543	8.2221	8.5764
0.004	28.96	0.00100	34.79	121.4	2414.5	121.4	2432.3	2553.7	0.4224	8.0510	8.4734
0.006	36.16	0.00101	23.73	151.5	2424.2	151.5	2415.1	2566.6	0.5208	7.8082	8.3290
0.008	41.51	0.00101	18.10	173.8	2431.4	173.8	2402.4	2576.2	0.5925	7.6348	8.2273
0.01	45.81	0.00101	14.67	191.8	2437.2	191.8	2392.1	2583.9	0.6492	7.4996	8.1488
0.012	49.42	0.00101	12.36	206.9	2442.0	206.9	2383.4	2590.3	0.6963	7.3886	8.0849
0.014	52.55	0.00101	10.69	220.0	2446.1	220.0	2375.8	2595.8	0.7366	7.2945	8.0311
0.016	55.31	0.00102	9.431	231.6	2449.8	231.6	2369.0	2600.6	0.7720	7.2126	7.9846
0.018	57.80	0.00102	8.443	242.0	2453.0	242.0	2363.0	2605.0	0.8036	7.1401	7.9437

0.02	60.06	0.00102	7.648	251.4	2456.0	251.4	2357.5	2608.9	0.8320	7.0752	7.9072
0.03	69.10	0.00102	5.228	289.2	2467.7	289.3	2335.2	2624.5	0.9441	6.8234	7.7675
0.04	75.86	0.00103	3.993	317.6	2476.3	317.6	2318.5	2636.1	1.0261	6.6429	7.6690
0.06	85.93	0.00103	2.732	360.0	2489.0	359.9	2293.0	2652.9	1.1454	6.3857	7.5311
0.08	93.49	0.00104	2.087	391.6	2498.2	391.7	2273.5	2665.2	1.2330	6.2009	7.4339
0.1	99.61	0.00104	1.694	417.4	2505.6	417.5	2257.4	2674.9	1.3028	6.0560	7.3588
0.12	104.78	0.00105	1.428	439.2	2511.7	439.4	2243.7	2683.1	1.3609	5.9368	7.2977
0.14	109.29	0.00105	1.2366	458.3	2516.9	458.4	2231.6	2690.0	1.4110	5.8351	7.2461
0.16	113.30	0.00105	1.0914	475.2	2521.4	475.4	2220.6	2696.0	1.4551	5.7463	7.2014
0.18	116.91	0.00106	0.9775	490.5	2525.5	490.7	2210.7	2701.4	1.4945	5.6676	7.1621
0.2	120.21	0.00106	0.8857	504.5	2529.1	504.7	2201.5	2706.2	1.5302	5.5967	7.1269
0.3	133.52	0.00107	0.6058	561.1	2543.2	561.4	2163.5	2724.9	1.6717	5.3199	6.9916
0.4	143.61	0.00108	0.4624	604.2	2553.1	604.7	2133.4	2738.1	1.7765	5.1190	6.8955
0.6	158.83	0.00110	0.3156	669.7	2566.8	670.4	2085.7	2756.1	1.9308	4.8284	6.7592
0.8	170.41	0.00112	0.2403	720.0	2576.0	720.9	2047.4	2768.3	2.0457	4.6159	6.6616
1	179.88	0.00113	0.1944	761.4	2582.7	762.5	2014.6	2777.1	2.1381	4.4469	6.5850

Simple problems using steam table.

2.1.1 Calculate the total heat of 5 kg of steam at an absolute pressure of 8 bar having dryness fraction of 0.8. Also calculate heat in kJ required to convert the steam into dry and saturated steam.

Solution

From steam tables

At pressure 8 bar, h_f = 720.9 kJ/kg

h_{fg} = 2046.5 kJ/kg

h_g = 2767.4 kJ/Kg

Sp. enthalpy of wet steam

$h_w = h_f + x.h_{fg}$

= 720.9 + 0.8 x 2046.5

= 2358.1 kJ/kg

Total heat of 5 kg steam = weight of steam x Sp. Enthalpy = 5x2358.1 = 11790.5 kJ (**Ans**)

Now total heat of 5kg dry saturated steam = 5x h_g = 5x 2767.4 = 13830 kJ

Net heat required to be supplied for conversion of wet steam into dry saturated steam = 13830 11790.5 = 2039.5 kJ (**Ans**)

2.1.2 4 Kg of 0.5 dry steam at 6.0 bar pressure is heated, so that it becomes

(a) 0.95 dry at 6.0 bar pressure or

(b) Dry & saturated at 6.0 bar or

(c) Superheated to 300^oC at 6.0 bar or

(d) Superheated to 250^oC at 8.0 bar

Using steam tables determine in each case the quantity of heat required to be supplied. Take C_{sup} for superheated steam as 2.3 kJ/ kg K.

Solution: Initial Condition of steam are mass, m = 4 kg; x_1= 0.5 and P = 6.0 bar

So initial enthalpy (total heat content) of 4kg steam is

$$H_1 = 4[h_f + 0.5h_{fg}]$$

From steam table, at 6.0 bar pressure value of specific enthalpy of saturated water, h_f and latent heat of steam, h_{fg} are given as

$$h_f = 670.4 \text{ kJ/kg}$$

$$h_{fg} = 2085.1 \text{ kJ/kg}$$

Putting these values in equation (i)

$$H_1 = 4[670.4+0.5X2085.1] = 6851.8 \text{ kJ} \approx 6852 \text{ kJ}$$

Heat Supplied

<u>Case I</u> Final Conditions of Steam are x_2=0.95 and pressure, p=6.0 bar. So final enthalpy of steam is

$$H_2 = 4[h_f + x.h_{fg}] = 4[670.4 + 0.95 X2085.1] = 10605 \text{ kJ}$$

Net heat supplied = Final Enthalpy X Initial Enthalpy

= H_2 XH_1 = 10605 X 6852 = 3753 kJ **(Ans)**

<u>Case II</u> Final Conditions of Steam are pressure, p=6.0 bar. Condition is dry saturated i.e.,

x_2 = 1. So final enthalpy of steam is

$H_2 = m.h_g = 4X2755.5$ kJ/kg [From Steam Table]

=11022 kJ

Net heat supplied = Final Enthalpy Initial Enthalpy

= H_2 XH_1 = 11022 X6852 = 4170 kJ   (**Ans**)

Case III Final Conditions of Steam are pressure, p=6.0 bar, Superheated to 300^0C. Form steam tables, saturation temperature, t_S at given pressure 6.0bar is $t_s = 158.8^0$C. So final enthalpy of superheated steam is $H_2 = m\,[h_g + C_{Ps}\,(t_{sup} - t_s)] = 4[2755.5 + 2.3(300-158.8)] = 12321$ kJ

So Net heat supplied = Final Enthalpy -Initial Enthalpy

= $H_2 - H_1 = 12321 - 6852 = 5469$ kJ (**Ans)**

Case IV Final Conditions of Steam are pressure, p=8.0 bar, Superheated to temperature, $t_{sup} = 250^0$C.

From steam tables

At 8.0 bar pressure $t_s = 170.4^0$C, $h_g = 2767.4$ kJ/kg

So $H_2 = m\,[h_g + C_{Ps}\,(t_{sup} - t_s)] = 4[2767.4 + 2.3(250-170.4)] = 11801.92 \approx 11802$ kJ

Heat Supplied = $H_2 - H_1 = 11802 - 6852 = 4950$ kJ [Ans]

2.1.3 Calculate the entropy and volume of 4.73 kg of superheated steam at pressure 7.8 bar and temperature 240°C. Take C_p for superheated steam = 2.32 kJ/kg. K

Solution

At 7.8 bar   Saturation temperature $t_s = 169.4^oC$

or $T_s = 169.4+273 = 442.4$ K

$v_g = 0.2461\ m^3/kg$

$s_g = 6.668$ kJ/kg K

$t_{sup} = 240^oC$

so, $T_{sup} = 240 + 273 = 513$ K

∴ Sp.vol. of superheated Steam

$= V_g \times \frac{T_{sup}}{T_s} = 0.2461 \times \frac{513}{442.4}$

$= 0.2854\ m^3/kg$

Total volume of 4.73 kg of steam = 4.730.2854 = 1.3498 m^3

Sp. entropy of superheated steam = $S_g + C_{sup} \log_e \frac{T_{sup}}{T_s}$

$= 6.668 + 2.32 \times \log_e \frac{513}{442.4}$

= 7.0115 kJ/ kg K

Total entropy of steam = 4.73x 7.0115 = 33.16 kJ/ K (**Ans**)

2.2 Total Heat or Specific enthalpy of the steam:

Total heat is the sum of the enthalpy of the various states, liquid (water) and gas (vapour) and also total heat can defined as **the total amount of heat received by 1 kg of water from O°C at constant pressure to convert it to desired form of steam**.

1. Sensible heat of water (hf). It is defined as the quantity of heat absorbed by 1 kg of water when it is heated from 0°C (freezing point) to boiling point. It is also called total heat (or enthalpy) of water or liquid heat invariably. It is reckoned from 0°C where sensible heat is taken as zero. If 1 kg of water is heated from 0°C to 100°C the sensible heat added to it will be 4.18 × 100 = 418 kJ but if water is at say 20°C initially then sensible heat added will be 4.18 × (100 – 20) = 334.4 kJ. This type of heat is denoted by letter hf and its value can be directly read from the steam tables. Note. The value of specific heat of water may be taken as 4.18 kJ/kg K at low pressures but at high pressures it is different from this value.

2. Latent heat or hidden heat (hfg). It is the amount of heat required to convert water at a given temperature and pressure into steam at the same temperature and pressure. It is expressed by the symbol hfg and its value is available from steam tables. The value of latent heat is not constant and varies according to pressure variation.

3. Dryness fraction (x). The term dryness fraction is related with wet steam. It is defined as the ratio of the mass of actual dry steam to the mass of steam containing it. It is usually expressed by the symbol 'x' or 'q'. If ms = Mass of dry steam contained in steam considered, and mw = Weight of water particles in suspension in the steam considered, Then, x m m ms s w = + ...(3.2) PROPERTIES OF PURE SUBSTANCES 71 Dharm \M-therm/th3-1.p65 Thus if in 1 kg of wet steam 0.9 kg is the dry steam and 0.1 kg water particles then x = 0.9. Note. No steam can be

completely dry and saturated, so long as it is in contact with the water from which it is being formed.

4. Total heat or enthalpy of wet steam (h). It is defined as the quantity of heat required to convert 1 kg of water at 0°C into wet steam at constant pressure. It is the sum of total heat of water and the latent heat and this sum is also called enthalpy. In other words, $h = h_f + x h_{fg}$ ...(3.3) If steam is dry and saturated, then $x = 1$ and $h_g = h_f + h_{fg}$.

5. Superheated steam. When steam is heated after it has become dry and saturated, it is called superheated steam and the process of heating is called superheating. Superheating is always carried out at constant pressure. The additional amount of heat supplied to the steam during superheating is called as 'Heat of superheat' and can be calculated by using the specific heat of superheated steam at constant pressure (c_{ps}), the value of which varies from 2.0 to 2.1 kJ/ kg K depending upon pressure and temperature. If $T_{sup.}$, T_s are the temperatures of superheated steam in K and wet or dry steam, then ($T_{sup} – T_s$) is called 'degree of superheat'. The total heat of superheated steam is given by $h_{sup} = h_f + h_{fg} + c_{ps} (T_{sup} – T_s)$ ...(3.4) Superheated steam behaves like a gas and therefore it follows the gas laws. The value of n for this type of steam is 1.3 and the law for the adiabatic expansion is $pv^{1.3}$ = constant. The advantages obtained by using 'superheated' steam are as follows : (i) By superheating steam, its heat content and hence its capacity to do work is increased without having to increase its pressure. (ii) Superheating is done in a superheater which obtains its heat from waste furnace gases which would have otherwise passed uselessly up the chimney. (iii) High temperature of superheated steam results in an increase in thermal efficiency. (iv) Since the superheated steam is at a temperature above that corresponding to its pressure, it can be considerably cooled during expansion in an engine before its temperature falls below that at which it will condense and thereby become wet. Hence, heat losses due to condensation of steam on cylinder walls etc. are avoided to a great extent.

3.BOILERS

3.1 Steam Generator Boiler is an apparatus to produce steam. Thermal energy released by combustion of fuel is transferred to water, which vaporizes and gets converted into steam at the desired temperature and pressure. The steam produced is used for: (i) Producing mechanical work by expanding it in steam engine or steam turbine. (ii) Heating the residential and industrial buildings (iii) Performing certain processes in the sugar mills, chemical and textile industries. Boiler is a closed vessel in which water is converted into steam by the application of heat. Usually boilers are coal or oil fired.

TYPES OF BOILERS The boilers can be classified according to the following criteria. According to flow of water and hot gases. 1. Water tube.

2. Fire tube. In water tube boilers, water circulates through the tubes and hot products of combustion flow over these tubes.

In fire tube boiler the hot products of combustion pass through the tubes, which are surrounded, by water. Fire tube boilers have low initial cost, and are more compacts. But they are more likely to explosion, water volume is large and due to poor circulation they cannot meet quickly the change in steam demand. For the same output the outer shell of fire tube boilers is much larger than the shell of water-tube boiler. Water tube boilers require less weight of metal for a given size, are less liable to explosion, produce higher pressure, are accessible and can response quickly to change in steam demand. Tubes and drums of water-tube boilers are smaller than that of fire-tube boilers and due to smaller size of drum higher pressure can be used easily. Water-tube boilers require lesser floor space. The efficiency of water-tube boilers is more.

Water tube boilers are classified as follows. 1. Horizontal straight tube boilers

(a) Longitudinal drum (b) Cross-drum.

2. Bent tube boilers

(a) Two drum (b) Three drum (c) Low head three drum (d) Four drum.

3. Cyclone fired boilers

Various advantages of water tube boilers are as follows.

(i) High pressure of the order of 140 kg/cm2 can be obtained.
(ii) Heating surface is large. Therefore steam can be generated easily.
(iii) Large heating surface can be obtained by use of large number of tubes.
(iv) Because of high movement of water in the tubes the rate of heat transfer becomes large resulting into a greater efficiency.

Fire tube boilers are classified as follows. l. External furnace:

(i) Horizontal return tubular
(ii) Short fire box

(iii) Compact.

2. Internal furnace:

(i) Horizontal tubular

(a) Short firebox (b) Locomotive (c) Compact (d) Scotch

(ii) Vertical tubular.

(a) Straight vertical shell, vertical tube (b) Cochran (vertical shell) horizontal tube.

Various advantages of fire tube boilers are as follows. (i) Low cost

(ii)Fluctuations of steam demand can be met easily

(iii) It is compact in size.

According to position of furnace.

(i) Internally fired (ii) Externally fired

In internally fired boilers the grate combustion chamber are enclosed within the boiler shell whereas in case of extremely fired boilers and furnace and grate are separated from the boiler shell.

3.2 Cochran Boiler

Cochran Boiler 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. The efficiency of this boiler is much better than the simple vertical boiler.

Parts of Cochran Boiler:

A Cochran Boiler is consisted of following parts:

1. Shell
2. Grate
3. Combustion Chamber
4. Fire tubes
5. Fire hole
6. Firebox (Furnace)
7. Chimney
8. Man Hole
9. Flue pipe
10. Fire Brick Lining
11. Feed Check Valve
12. Blow Off Valve
13. Ash Pit
14. Smoke Box Door
15. Anti Priming Pipe
16. Crown
17. Pressure Gauge
18. Safety Valve
19. Water Level Indicator
20. Water Level Gauge
21. Fusible Plug
22. Stop Valve

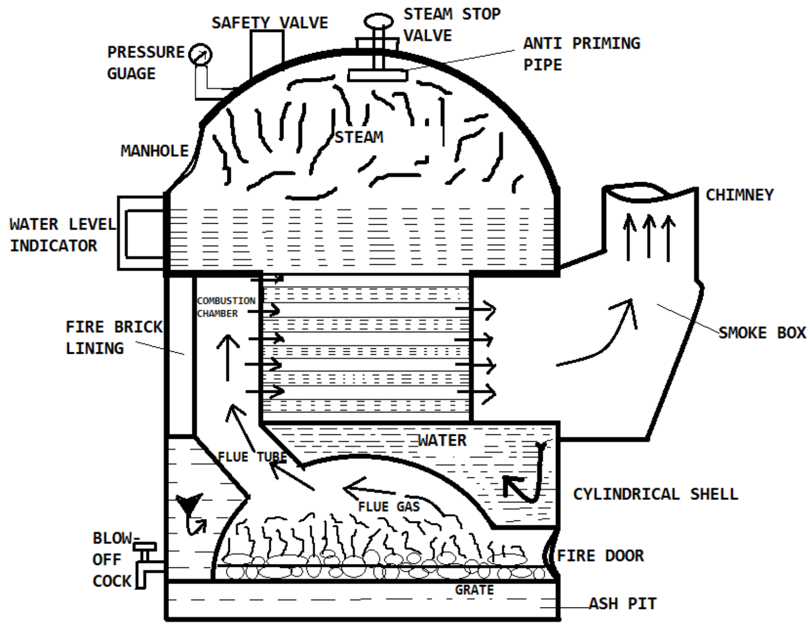


FIG: COCHRAN BOILER

1 Shell:

The main body of the boiler is known as a shell. It is hemispherical on the top, where space is provided for steam.

This hemispherical top gives a higher volume to area ratio which increases the steam capacity.

#2 Grate:

In the grate section, solid fuel is stored, it is designed so well that air can easily flow through it, and also the ashes fall from the grate quite easily. In this section, the fire is placed.

#3 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. The combustion chamber is connected to the furnace.

#4 Fire Tubes:

There are various fire tubes whose one end is connected to the furnace and other to the chimney. Sevaral horizontal fire tubes are provided to increased the heating surface.

#5 Fire Hole:

The small hole is provided at the bottom of the combustion chamber to place fuel is known as a fire hole.

#6 Fire Box (Furnace):

It works as a mediator of fire tubes and combustion chamber.

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.

#7 Chimney:

It is provided for the exit of flue gases to the atmosphere from the smokebox.

#8 Man Hole:

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

#9 Flue Pipe:

It is a short passage connecting the firebox with the combustion chamber.

#10 Fire Brick Lining:

It is a special type of brick ling use in Cochran Boiler to reduce the convection of heat from the outer surface of the boiler. Fire Brick is generally made of fire clay.

#11 Feed Check Valve:

It is used to control the flow of water inside the boiler, it also helps to restrict the backflow of water.

#12 Blow Off Valve:

It is used to blow off the settle down impurities, mud, and sediments present in the boiler water.

#13 Ash Pit:

It is a chamber inside a boiler where ashes are stored.

#14 Smoke Box Door:

It is used to clean the smoke box deposits materials.

#15 Anti Priming Pipe:

Sometimes water droplets come out with the steam, so to prevent the droplets from carried out by the steam the Anti Priming Pipe is used.

#16 Crown:

It is hemispherical dome-shaped section of a boiler, where burning of fuel happens.

#17 Pressure Gauge:

It measures the pressure of steam inside the boiler.

#18 Safety Valve:

It blows off the extra steam when the steam pressure inside the boiler reaches above safety level.

#19 Water Level Indicator:

The position of the water level in the Cochran boiler is indicated by the water level indicator.

#20 Water Level Gauge:

It glass tube fitted out side of the boiler to check the water level inside the boiler.

#21 Fusible Plug:

It is one type of safety measure. If the inside temperature of the boiler cross the limit, then for safety purpose this Fusible Plug melts and the water comes into the boiler furnace and extinguish the fire.

#22 Stop Valve:

Stop valve is used to transfer steam to the desired location when it is required. Otherwise, it stops the steam in the boiler.

Working Principle of Cochran Boiler:

The Cochran boiler works as same as other fire tube boiler.

First, The coal is placed at the grate through the fire hole.

Then the air is entering into the combustion chamber through the atmosphere and fuel is sparked through fire hole.

Then flue gases start flowing into the hemispherical dome-shaped combustion chamber. This flue gases further moves into the fire pipes.

Heat is exchanged from flue gases to the water into the fire tubes.

The steam produce collected into the upper side of the shell and taken out by when the required pressure generated.

The flue gases now send to the chimney through a firebox where it leaves into the atmosphere.

Now, this process repeats and runs continuously. The steam generates used into the small industrial processed.

Applications of Cochran Boiler:

The application of Cochran boiler are:

- Variety of process applications industries.
- Chemical processing divisions.
- Pulp and Paper manufacturing plants.
- Refining units.

Besides, they are frequently employed in power generation plants where large quantities of steam (ranging up to 500 kg/s) having high pressures i.e. approximately 16 megapascals (160 bar) and high temperatures reaching up to 550 °C are generally required.

Features of Cochran boiler:

These are some features of Cochran Boiler:

- In the Cochran boiler, any type of fuel can be used.
- It is best suitable for small capacity requirements.
- It gives about 70% thermal efficiency with coal firing and about 75% thermal efficiency with oil firing.
- The ratio of the grate area to the heating surface area varies from 10: 1 to 25:1.

Advantages of Cochran Boiler:

The advantages of Cochran Boiler are following:

- Low floor area required.
- Low initialization cost.
- It is easy to operate.
- Transport from one place to another is very easy.
- It has a higher volume to area ratio.

Disadvantages of Cochran Boiler:

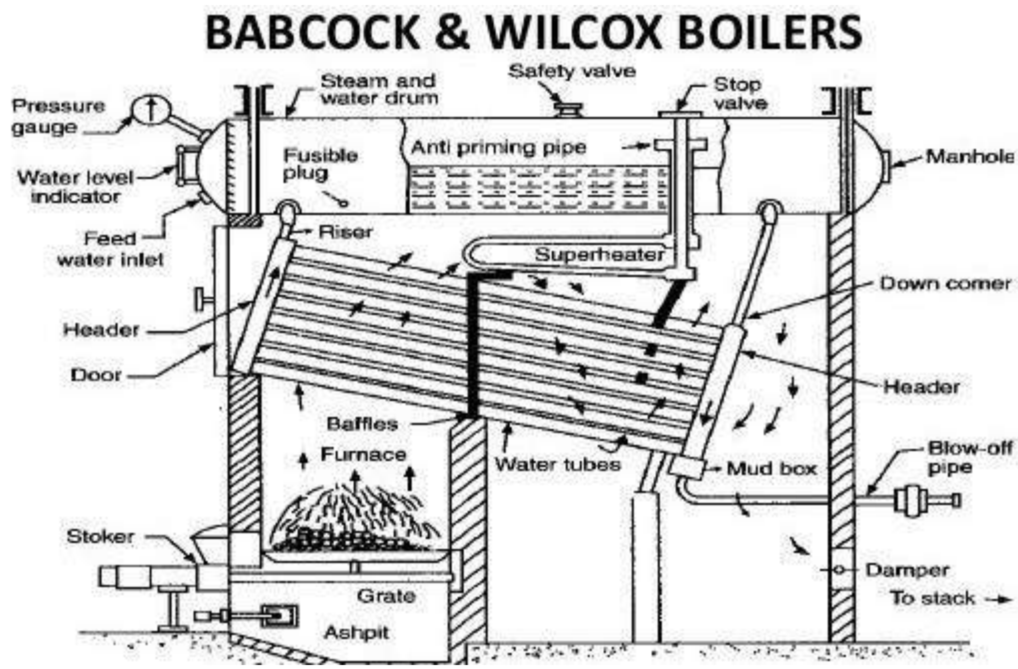
There are some disadvantages of Cochran Boiler and those are:

- Low steam generation rate.
- Limited pressure handles capacity.
- It is difficult to inspect and maintain.

Babcock and Wilcox Boiler Parts:

A Babcock and Willcox Boiler Parts or Construction consists of:

- *Drum*
- *Water Tubes*
- *Uptake and Downtake header*
- *Grate*
- *furnace*
- *Baffles*
- *Superheater*
- *Mud box*
- *Inspection Door*
- *Water Level Indicator*
- *Pressure Gauge*



Drum:

This is a horizontal axis drum which contains water and steam.

Water tubes:

Water tubes are placed between the drum and furnace in an inclined position (at an angle of 10 to 15 degrees) to promote water circulation.

Uptake and Downtake Header:

This is present at the front end of the boiler and connected to the front end of the drum. It transports the steam from the water tubes to the drum. and

This is present at the rear end of the boiler and connects the water tubes to the rear end of the drum.

It receives water from the drum.

Grate:

Coal is fed to the grate through the fire door.

Furnace:

The furnace is kept below the uptake-header.

Baffles:

The fire-brick baffles, two in number, are provided to deflect the hot flue gases.

Superheater:

It increases the temperature of saturated steam to the required temperature before discharging it from the steam stop valve.

Mud Box:

This is used to collect the mud present in the water.

Mud box is provided at the bottom end of the down-take header.

Inspection Door:

Inspection doors are provided for cleaning and inspection of the boiler.

Water Level Indicator:

The water level indicator shows the level of water within the drum.

Pressure Gauge:

The pressure gauge is used to check the pressure of steam within the boiler drum.

Working Principle of Babcock and Wilcox Boiler:

The working of Babcock and Wilcox boiler is first the water starts to come in the water tubes from the drum through down take header with the help of a boiler feed pump which continues to feed the water against the drum pressure.

The water present in the inclined water tubes gets heated up by the hot flue gases produced by the burning of coal on the fire grate.

These fuel gases are uniformly heated the water tube with the help of a baffle plate which works deflect the flues gas uniform throughout the tubes which absorbed the heating maximum from the flue gases.

As the hot flue gases come in contact with water tubes, It exchanges the heat with heater and converts into the steam.

Continuous circulation of water from the drum to the water tubes and water tubes to the drum is thus maintained.

The circulation of water is maintained by convective current and it’s known as Natural Circulation.

The Steam generated is moved upward, due to density difference and through the up-take header, it gets collected at the upper side in the boiler drum.

Anti-priming pipe inside the drum which works separates the moisture from the steam and sends it’s to the superheater.

The superheater receives the water-free steam from an anti-priming pipe. It increases the temperature of the steam to the desired level and transfers it to the main steam stop valve of the boiler.

The superheated steam stop valve is either collected in a steam drum or send it’s inside the steam turbine for electricity generation.

Applications Babcock and Wilcox Boiler:

The main application Babcock and Wilcox boiler to produce **high-pressure steam in power generation industries**.

Advantages of Babcock and Wilcox:

The advantages of Babcock and Wilcox boiler are:

- *The overall efficiency of this boiler is high.*

- *The steam generation rate is higher about 20 ton per hour at pressure 10 to 20 bars.*
- *The tubes can be replaced easily.*
- *The boiler can expand and contract freely.*
- *It is easy to repair maintenance and cleaning.*

Disadvantages of Babcock and Wilcox Boiler:

These are some disadvantages of Babcock and Wilcox Boiler:

- *It is less suitable for impure and sedimentary water, as a small deposit of scale may cause the overheating and bursting of tubes. Hence, water treatment is very essential for water tube boilers.*
- *Failure in feed water supply even for a short period is liable to make the boiler overheated. Hence the water level must be watched very carefully during the operation of a water tube boiler.*
- *The maintenance cost is high.*

3.3Boiler Mountings

These are the fittings, which are necessarily mounted on the boiler itself and mandatorily required for the safe and proper operation of boiler. Various boiler mountings are being discussed here one by one.

1 Water level indicator

Function

Water level indicator is fitted outside the boiler shell to indicate the water level in the boiler through a glass tube. In any type of boiler, water should remain at the designed level. If the water falls below the level due to change of phase into steam and simultaneously fresh water does not fill in by some reason, the hot surface may expose to steam only and overheat. This is because the heat transfers co-efficient of steam is very less as compared to water. Due to overheat, damage of tube surface may occur. To avoid this situation, level of water in the boiler needs to be constantly monitored & maintained by boiler operator by keeping watch on water level indicator.

Construction

As shown in the , two horizontal tubes made of gun metal extend from the boiler shell in such a way that top one is connected to steam space and bottom one is connected to water space of the boiler. These are connected at the other end by a vertical glass tube contained in a hollow casting in such a way that water and steam come out in the glass tube and their interface is visible through it. Each gun metal tube is also provided with a cock to control the flow of water/steam to the glass tube. One drain cock is fitted at the bottom for cleaning purpose. The horizontal metal tubes also contain one metal ball each which normally rests on a hemispherical groove in the tubes. In case the water/steam rush with high speed as may be if glass tube breaks by accident, this ball lifts up from its normal position and block a hole which connects the metal tube with glass tube and stops the flow.

Working

Working of water level indicator or water gauge is very simple. When the cocks are opened, boiling water and steam from the boiler shell flow into the hard glass tube and maintain the same level as in the boiler which is visible to operator. When the water level falls down beyond a safe limit, operator may switch on the feed pump to fill more water in the boiler shell. In the water and steam passages in the gun metal tubes, a metal ball rest in the cavity made in the passage. In case of breakage of glass tubes by accident, water and steam contained at high pressure in the boiler rush with high speed towards broken glass tube due to large pressure difference between inside and outside of boiler. Due to this, the ball resting in the cavity made in the passage lifts and rushes towards the end of gun metal tube and blocks the passage of steam or water flow. Then immediately the cock can be closed and glass tube can be replaced safely.

2 Pressure Gauge

Function

A pressure gauge is used to indicate the pressure of steam in the boiler. It is generally mounted on the front top of the boiler. Pressure gauge is of two types as (i) Bourdon Tube Pressure Gauge (ii) Diaphragm type pressure gauge. Both these gauges have a dial in which a needle moves over a circular scale under the influence of pressure. At atmospheric pressure it gives zero reading. Some gauges indicate only the positive pressure but some are compound and indicate negative pressure or vacuum also. Looking at the gauge, boiler operator can check the safe working pressure of the boiler and can take necessary steps to keep the pressure within safe limits. If pressure increases and crosses the safe limit due to any reason, the boiler shell material may fail and it can burst causing damage to life and property. Thus it is very important to constantly monitor pressure in a boiler with the help of pressure gauge.

Construction & working

A bourdon tube pressure gauge is normally used, the construction of which is shown in the

The bourdon tube is an elliptical spring material tube made with special quality bronze. One end of tube is connected to gauge connector and other end is closed and free to move. A needle is attached to the free end of tube through a small gear mechanism. With the movement of tube under pressure, needle rotates on the circular scale. The movement of tube & hence needle is proportionate to the rise in pressure and so calibrated with scale.

The pressure gauge connector is attached to the boiler shell through a U-tube siphon and three way cocks. In the U-tube, condensate remains filled and so live steam does not come in direct content of bourdon tube but it push or exert pressure on the condensate which further stretch bourdon tube. Steam is not allowed a direct contact with the gauge due to high temperature effect on the pressure recording. The three way cock is used to give an entire connection for inspector�s pressure gauge.

3 Spring loaded safety valve

Function

Spring loaded safety valve is a safely mounting fitted on the boiler shell and is essentially required on the boiler shell to safeguard the boiler against high pressure. It is a vital part of boiler and always be in good working condition to protect the boiler from bursting under high pressure and so to save life and property.

Construction

As shown in fig it consists of two openings or valve seats which are closed by two valves attached to a single lever. The lever is pivoted at one end and attached to a spring at the middle. The spring is fixed at the bottom end with the overall body of valve. Due to spring force, the liver and hence valves remain seated on the valve seats and do not allow the steam to escape. When the pressure force of steam exceeds the spring pulling force, valve & lever are lifted and steam escape thus decreasing the pressure below the safe limit. On decreasing the pressure valves sit again on their seats and thus stop the steam flow from the boiler. Sometimes, the lever may also be lifted manually to release steam if required.

4 Fusible plug

Function

The function of fusible plug is to protect the boiler from damage due to overheating of boiler tubes by low water level.

Construction

As shown in Fig., it is simply a hollow gun metal plug screwed into the fire box crown. This hollow gun metal plug is separated from the main metal plug by an annulus fusible material. This material is protected from fire side by means of a flange.

Working

When the water in the boiler is at its normal level, fusible plug remains submerged in water and its temperature does not exceed its melting temperature, because its heat is transferred to water easily. If under some unwanted condition, water level comes down to unsafe limit; fusible plug is exposed to steam in place of water. On the other side it is exposed to fire. So its temperature exceeds its melting point due to very low heat transfer to steam and it melts down. Immediately steam and water under high pressure rush to the fire box and extinguish the fire.

5 Blow-off-cock

Function

It is a controllable valve opening at the bottom of water space in the boiler and is used to blow off some water from the bottom which carries mud or other sediments settled during the operation of boiler. It is also used to completely empty the water when the boiler is shut off for cleaning purpose or for inspection and repair.

Construction and working

The construction is as shown in **fig.** It has a casing having a passage with one side flange to connect with boiler shell. The passage is blocked by a cone shape plug having a cross rectangular hole. Sealing is made with a top and bottom asbestos packing filled in grooves on plug. The shank of the plug passes through a gland and stuffing box in the cover. On the top portion of the shank a box spanner can be fitted to rotate the shank and plug by 90^0 to either open or close the blow-off-cock. The working is also clearly visible on playing the animation.

6 Feed-check-valve

Function

The feed check valve is fitted in the feed water line of the boiler after the feed pump. Its function is to allow the water to flow in the boiler when the discharge pressure of feed pump is more than the inside steam pressure of boiler and prevent the back flow in case the feed pump pressure is less than boiler pressure. Feed check valve is fitted slightly below the normal water level in the boiler.

Construction

The construction of feed check valve is as shown in fig 25.6 In the casing of valve there is a check valve which can move up or down on its seat under the pressure of water. When supply pressure of feed water acting at the bottom of check valve is more, valve lifts up and allows the water to fill in the boiler. When supply pressure drops by stopping of feed pump, the boiler pressure acts on the top of valve and it sits on its gun metal seat and stops back flow of the boiler water out of the boiler shell.

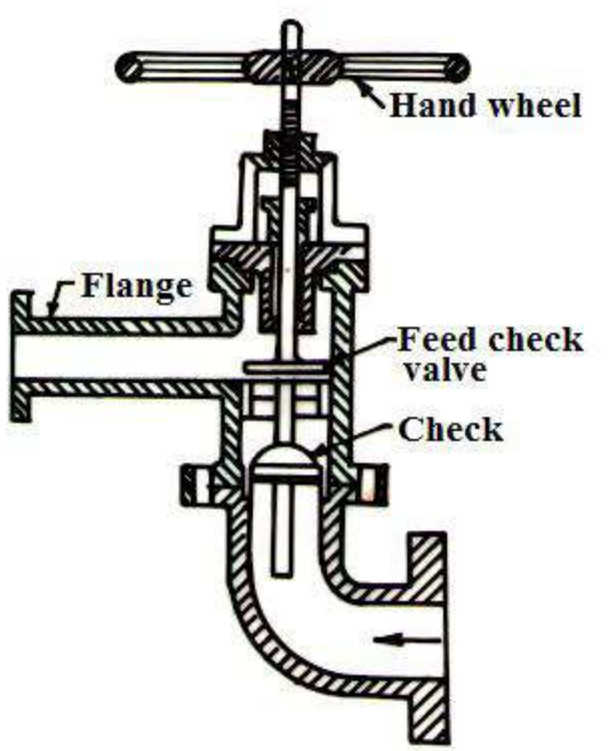


Fig.6 Feed check valve

7 Steam stop valve

Function

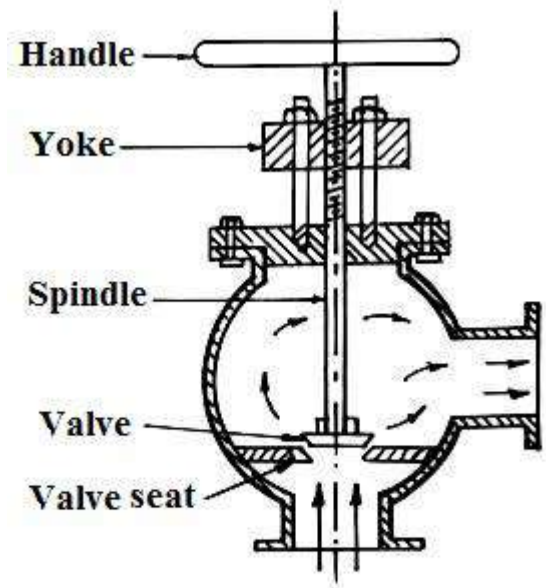
It is fitted over the boiler in between the steam space and steam supply line. Its function is to regulate the steam supply from boiler to the steam line.

Construction and working

The construction of steam stop valve is as shown in fig 25.7. Its casing has a L-shaped steam flow passage. It consists of a valve and valve seat to stop or allow

the steam flow.

The valve is attached to a spindle and handle. Spindle passes through packing in the stuffing box to prevent leakage. The spindle has external threads in the top portion and moves in the internal threats of a fix nut. By rotating clockwise and anticlockwise the spindle and valve moves down and up thus closing or opening the valves.



Steam stop valve

Boiler Accessories

Boiler accessories are the components which are attached to the boiler (Not mounted on it) and are essentially for working of boiler and for increasing its efficiency. Various boiler accessories are discussed as below

1 Feed pump

Feed pump is placed nearby the boiler and is used to feed water to boiler working at a high pressure. The job of feed pump is not just put the water in the boiler but as boiler is working at high pressure, discharge pressure of feed pump must be sufficiently higher than this to push the water inside the boiler.

Construction & working

The feed pump used in boiler is of two types (i) Reciprocating type (ii) Rotary type. Both these types are positive displacement type to discharge against high pressure. The discharge pressure of a single stage centrifugal pump is not high enough to overcome the high pressure of boiler so multistage centrifugal pump is used as a boiler feed pump.

In stationary low pressure boiler used in processing industries, a multistage centrifugal pump run by an electrical motor is more suitable. In multistage centrifugal pump, a number of centrifugal casing are so attached to each other that the **impeller** of each is mounted on the same shaft run by an electrical motor and discharge of 1^{st} stage goes to 2^{nd} stage and of 2^{nd} to 3^{rd} stage and so on. As shown in fig , in each stage the pressure of water goes on increasing and discharge pressure of final stage is so high as to overcome the internal pressure of boiler. Theses pumps have independent working and have smooth operation.

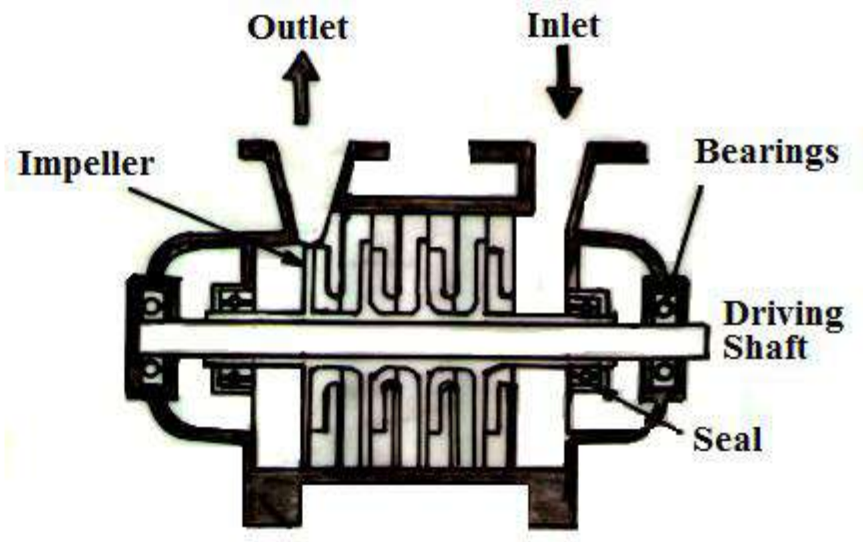


Fig. Multistage centrifugal pumps

2. Economizer

Function

An economizer is a specially constructed heat exchanger for harnessing the heat energy of outgoing flue gases and utilizing it in preheating of boiler feed water. It saves the heat energy and so the fuel and decreases the operating cost of boiler by increasing its thermal efficiency.

Construction & working

Economizers are of two types as (i) External type (ii) Internal type. The external type economizer is constructed and installed apart from the boiler and the flue gases from the boiler are directed to flow through it before escaping through chimney. A vertical tube external economizer is shown in fig .

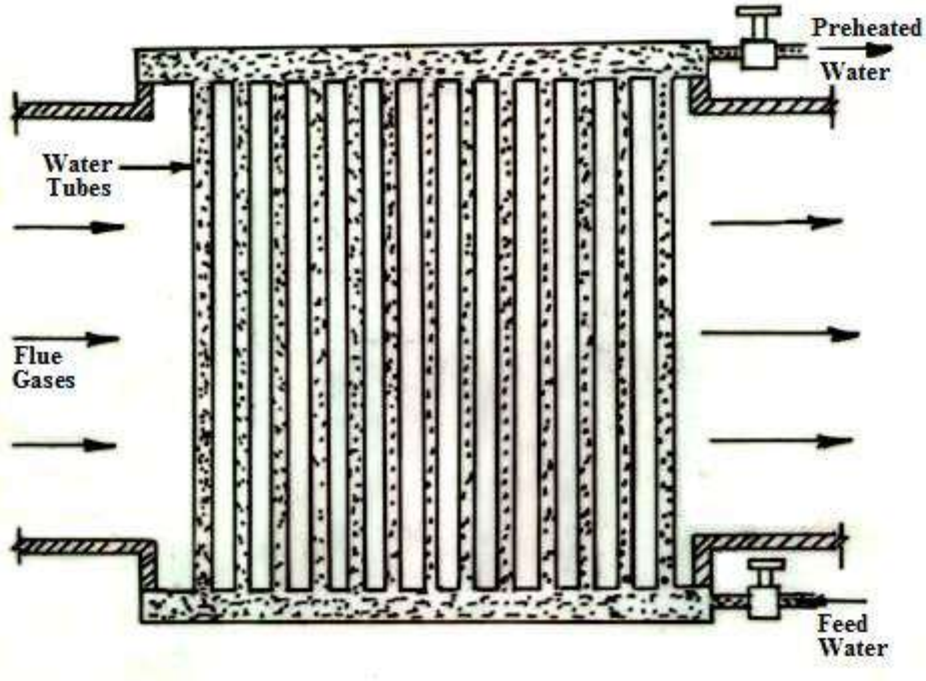


Fig. External economizer

It is employed for boilers of medium pressure range. Here a number of vertical tubes made of cast iron are connected to common headers at the bottom and top. Feed water flow into the bottom header and then through the vertical tubes flow out from the top header. Hot flue gases escaping from the boiler are directed to flow across the outside surface of tubes thus indirectly heating the feed water flowing inside. To avoid deposit of soot over the tube surface, tubular scrapers are fitted over the tubes. These are operated by chain and pulley system and while moving up and down slowly scrap the soot over the wall of tubes and so increase the heat transfer rate. An internal tube economizer is fitted inside the boiler and is an integral part of it.

Advantages of Economizer

1. Stresses produced in the boiler material due to temperature difference of boiler material and feed water are reduced because of increase in feed water temperature.
2. Evaporative capacity of boiler increases as less heat will be required to generate steam if feed water temperature is already high due to preheating.
3. Overall efficiency of boiler increases because of more steam produced per kg of fuel burnt.

3. Air Pre-heater

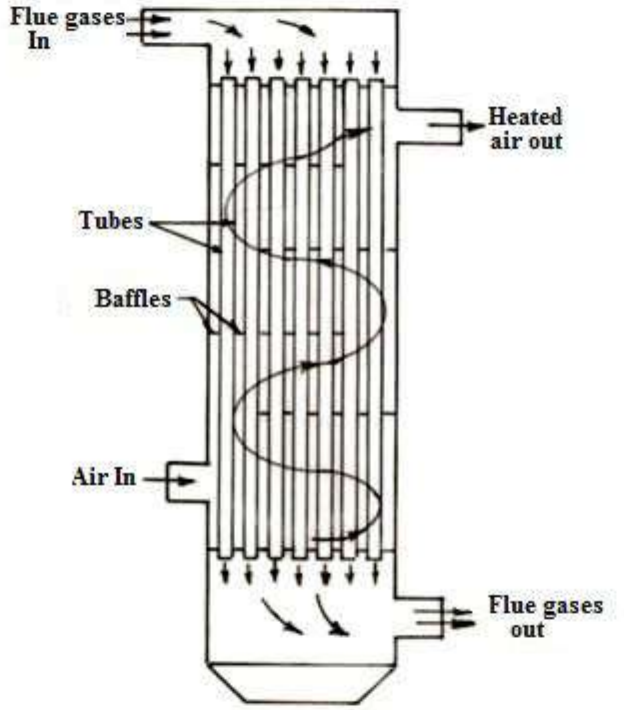


Fig. Air Pre-heater (Tubular Type)

Function

The function of air pre-heater is to further utilize the heat of flue gases after coming out of economizer to preheat the air used in furnace or oil burner.

Construction

It is a plate type or tubular type or storage heat exchanger, in which flue gases pass through the tubes on one side of plate and air pass on other side. In storage type a rotor fitted with mesh or matrix alternatively come in the passage of flue gases and air thus exchanging heat. A tubular type air-heater is as shown in fig 25.10

4 Super heater

The function of super heater is to increase the temperature of steam beyond its saturation temperature. It is a type of heat exchanger. Hot flue gases coming out of burner are first directed through super heater before the boiler. The main advantage of superheating of steam comes in power plants, where steam is expanded through a turbine. But in a processing industry superheating is required only to avoid condensation in pipes. Thus super heater has less advantage or use in a processing industry and many times not used but not always.

4 STEAM ENGINES

4.1. Introduction 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. Moreover, as the combustion of the fel takes place outside the engine cylinder, it is also called an external combustion engine.

Classification of Steam Engines;

T he steam engines have been classified by various scientists on different basis. But the following classifications are impohant from the subject point of view.

1.

(a) Single acting steam engine, and (b) Double acting steam engine.

When steam is admitted on one side of the piston, and one working stroke is produced during each revolution of the crankshaft, it is said to be a single acting steam engine. But when the steam is admitted, in turn, on both sides of the piston and two working strokes are produced during each revolution of the crankshaft, it is said to be a double acting steam engine. A double acting steam engine produces double the power than that produced by a single acting steam engine.

2.

(a) Horizontal steam engine, and (b) Vertical steam engine.

When the axis of the cylinder is horizontal, it is said to be a horizontal St earn engine. But when the axis of the cylinder is vertical, it is called a vertical steam engine. A vertical steam engine requires less floor area than the horizontal steam engine.

3. A.:.idi' i 10 t.e .pec: th' cr;kvio(t (a) Slow speed steam engine, (h) Medium speed steam engine, and (c) High speed steam engine. When the speed of the crankshaft is less than 100 revolutions per minute (r.p.m.), it is called a slaw speed steam engine. But when the speed of the crankshaft is between 100 r.p.m. and 250rpm., 374 Simple Steam Engines 37ç, it is called a medium speed steam engine. Similarly, when the speed of the crankshaft is above 250 r.p.m., it is known as a high speed steam engine.

4. Areord'it.t to the type of exhaust (a) Condensing steam engine, and (b) Non-condensing steam engine. When steam after doing work in the cylinder passes into a condenser, which condenses the steam into water at a pressure less than the atmospheric pressure, it is said to be a condensing steam engine. But when the steam after doing work in the cylinder is exhausted into the atmosphere, it is said to be a non-condensing steam engine. Th steam pressure in the cylinder is, therefore, not allowed to fall below

the atmospheric pressure. . Act onisnc' to the expansion oj the steam in the ençi,ic cylrider

5. (a) Simple steam engine, and (b) Compound steam engine. When the expansion of the steam is carried Out in a single cylinder and then exhausted into the atmosphere or a condenser, it is said to be a simple steam engine. But when the expansion of the Steam is completed in two or more cylinders, the'engine is called a compound steam engine. The compound steam engines are generally condensing engines. But some of them may be non-condensing also.

6. According to the method ofoveniing employed (a) Throttling Steam engine, and (b) Automatic cut-off steam engine. When the engine speed is controlled by means of a throttle valve in the steam pipe, which regulates the pressure of steam to the engine, it is called a throttling steam engine. But when the.spced is controlled by controlling the steam pressure with an automatic cut-off governor, it is called an automatic cut-off steam engine.

V7,4 'important Parts of a Steam Engine All the parts of a steam engine may be broadly divided into two groups i.e. stationary parts and moving parts. Though a steam engine Consists of innumerable parts, both stationary and moving, yet the following are important from the subject point of view

1.Frame. t is a heavy cast iron part, which supports all the stationary as well as moving parts and holds them in proper position. It generally, rests on engine foundations.

2.Cylinder. It is also a Cast iron cylindrical hollow vessel, in which the piston moves to and fro under the steam pressure. Both ends of the cylinder are closed and made steam tight. in small steam engines, the cylinder is made an integral part of the frame.

3. Steam chest. It is casted as an integral part of the cylinder. It supplies steam to the cylinder with the movement of D-slide valve.

4. D-slide valve. It moves in the steam chest with simple harmonic motion. Its function is to exhaust steam from the cylinder at proper movement.

5. Inlet and exhaust ports. These are holes provided in the body of the cylinder for the movement of steam. The steam is admitted from the Steam chest alternately to either sides of the cylinder through the inlet ports. The steam, after doing its work in the cylinder, is exhausted through the exhaust port.

6. Piston. It is a cylindrical disc, moving to and fro, in the cylinder because of the steam pressure. :ts function is to Convert heat energy of the steam into mechanical work. .Piston .rings, made from cast iron, are fitted in the grooves in the piston. Their purpose is to prevent the leakage of sçeam.

7 Piston rod It is circular rod, which is connected to the piston on one side and cross head to the other. Its main function is to transfer motion from the piston to the cross-head.

8., Cross-head. It is a link between the piston rod and connecting rod. Its function is to guide motion of the piston rod and to prevent it front

9. Connecting Rod. It is made of forged steel, whose one end is connected to the cross head and the other to the crank. Its function is to convert reciprocating motion of the piston (or cross head) into rotary motion of the crank.

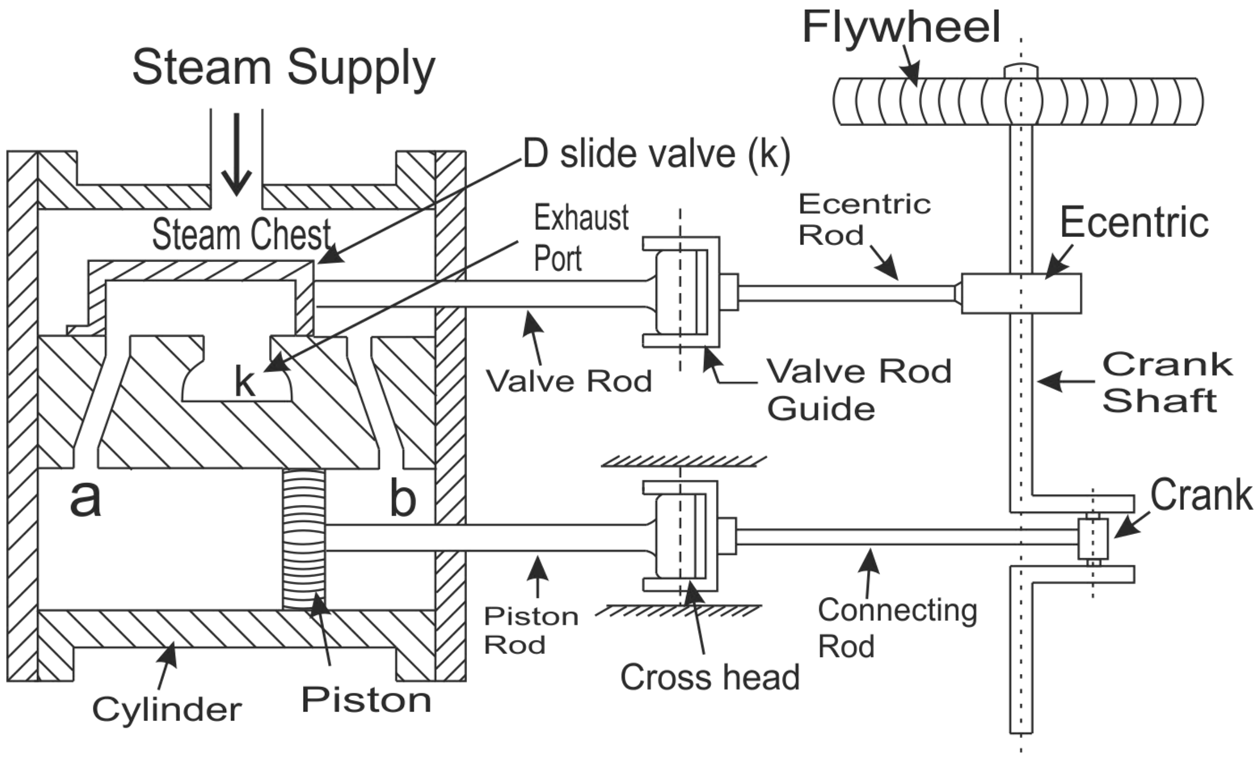
10.Crank Shaft. It is the main shaft of the engine having a ,rank. The crank works on the lever principle and produces rotary motion of the shaft. The crank .hafl is supported on main bearing or the engine.

11. Eicentric. i t is generally made of cast iron, and is fitted to the crank shaft. Its function is to provide reciprocating motion to the slide valve.

12.Eccentric rod and valve rod. The eccentric rod is made of forged steel, whose One end is fixed to the eccentric and other to the valve. rod. Its function is to convert rotary motion of the crankshaft into to and fro motion of the valve rod. Thg valve rod connects the eccentric and the D-slide valve. Its function is to provide simple harmonic motion to the D-slide valve.

13.FIywheel.it is a heavycast iron wheel, mounted on thecrank shaft. Its function is to prevent the fluctuation of engine. It also prevents the jerks to the crankshaft.
14.Governer. It is a device to keep the engine speed, more or less, uniform at all load conditions. It is (lone either by controlling the quantity or pressure of the steam supplied to the 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. 17.1. 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'.



Steam Supply
Flywheel
D slide valve (k)
Steam Chest
Exhaust
Port
Ecentric
Rod
Ecentric
k
Valve Rod
Valve Rod
Guide
Crank
Shaft
a
b
Crank
Piston
Rod
Connecting
Rod
Cross head
Cylinder
Piston

Since the pressure of steam is greater on the left side than that on right side, the piston moves to the right. Steam supply 1 • D-slide valve Flywhec' •.:J L',xs' ,s "_ E)thauSt Eccentric Steam che.— W port ,, rod\ Ecmeentric alve Crank rod Vallve shaft guide II istcn 'T Connecting Crank rod rod Cylinder Piston '- Crosshead Fig. 17A Si ng le cy lirdcr double acting horizontal reciprocating steam engine. When the piston reaches near the end of the cylinder, it closes the steam port 'a' and exhaust port. The steam port 'b' is now open, and the steam rushes to the right ske 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. Simple Steam engine

. Note At the end of each stroke, the piston changes its direction of moton and is momentarily stopped. The crank comes in line with the piston rod. The extreme left and right positions of the.çrank, where the piston rod exerts no turning tendency on the main shaft, are called dead centres of the crank.

Important Terms used in SteaM Engines The *theoretical indicator diagram for a simple steam engine .

The following are some importantcrms used in steam engines.

1 Bore. The internal diameter of the cylinder.

2 Cut-cU point inder of the engine is known as bore. t 2.Dead centre-T. The extreme positions of the piston inside the cylinder during its motion are Release point known as dead centres. There are two dead centres, i p------------ i.e. o 5, v_41l..___v. - Volume - Cylinder pc ^ a_ Crank end cover Of piston. iTi .O.D.0 Cover or back Cylinder end of piston length

3. Clearance so/tone. Fig. 17.2. Important terms used in steam 'fl volume of space between the cylinder cover and the piston, engines. when the piston is at LD.C. position is called clearance volume (t,). It is usually represented as a percentage of stroke volume.

4.Stroke va/ante 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). It is also known as prrfon displacement. Mathematically, stroke volume or swept volume, Va = x D2 x 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 thih and pushes the piston outward doing external work. At some point during outward rnivementof 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.A verae piston speed. The distance travelled by the piston per unit time is known as average piston speed. Mathematically, Average piston speed = LW ni/mm, for single acting steam engine = 2 LNrnumin, for double acting steam engine where L = Length of the stroke in metres, and N = Speed in R.P.M. • For further derails. 5cc Art. 17.7. ** Ina vertical eng ine. these centres are known as bottom dead centre (B.D.C.) and lop dead centre (T.D.C.). **(a) Inner dead centre (1.D.C.), and (b) Outer dead centre (O.D.C.). In a horizontal engine, the inner most position of the piston (towards the cylinder cover end) is known as inner dead centre, whereas the outer most position of the piston towards the crank end is called outer dead centre, as shown in Fig. 17.2. 51 - Volume - 378 A Text Book of Thermal Engineering

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, - Workdone 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. It is based on the following assumptions: !. The opening and closing of steam ports is instantaneous.

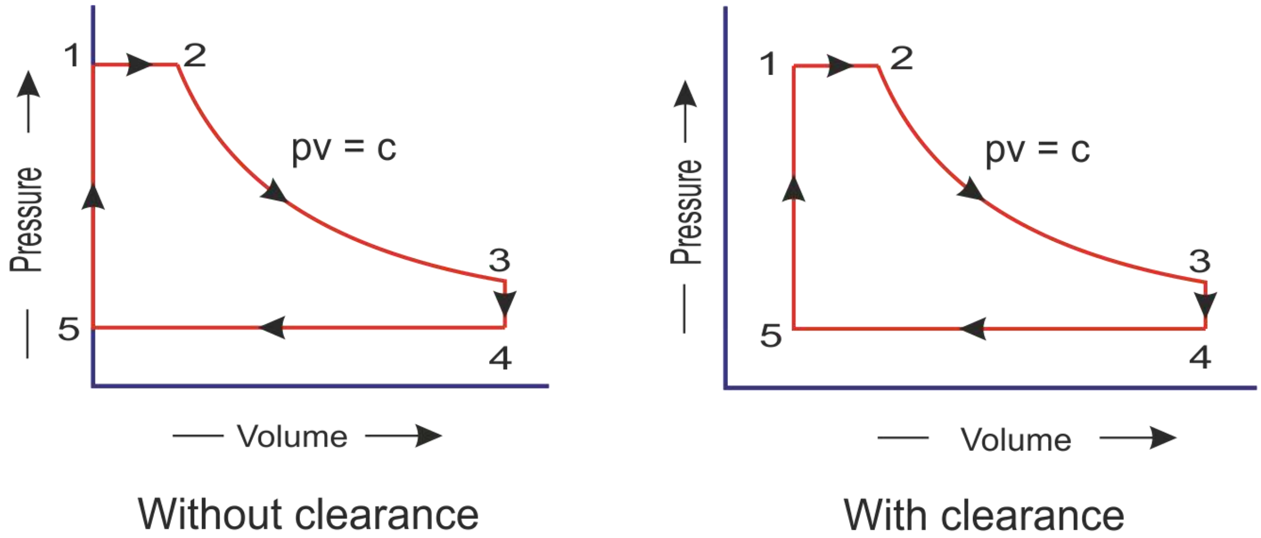
2. There is no pressure drop due to condensation.

3. T1ère is no wire drawing due to restricted valVe opening.

4. The steam is admitted at boiler pressure and exhausted at condenser pressure.

5. The expansion (or compression) of the steam is hyperbolic (i.e. p v = C) it may be noted that the above assumptions are not correct from the practical point of view. As a result of this, it has lead to the change in the indicator diagram from the basic modified Rankine cycle. Note In the succeedingaiticles, we shall discuss work done and mean effective pressure (also knows as theoretical work done and theoretical mean effective pressure) from the theoretical indicator diagrams.

4.2. Theoretical or Hypothetical Indicator Diagram The theoretical or hypothetical indicator diagram without clearance and with clearance is shown in Fig. 17.3. In other words, if there is no steam in the cylinder (Or there is zero volume of steam at point I), the indicator diagram will be as shown in Fig. 17.3 (a). Similarly, if there is some steam in the cylinder at point 1, the indicator diagram will be as shown in Fig. 17.3 (b).



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. l',oces, 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. pu = C) and pressure falls considerably as-shown in Fig. 17.3. P,rsie.ix 34. At point 3, the exhaust port opens and steam is released from the cylinder to I Simple Steam Engines the exhaust. As a result of steam exhaust, pressure in the cylinder falls suddenly (without change in volume) as shown in Fig. 173. The point 3 is known as release pokit. 4.Pox ess 4-5. At point 4, returnjoumey of the piston starts. Now the used steam is exhauted 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. 17.8. Theoretical or Hypothetical

Mean Effective Pressure The theoretical or hypothetical mean effective pressure may be determined as discussed below, by considering the theoretical indicator diagram without clearance and with clearance as shown in Fig. 17.4 (a) and (b) respectively. Volumeof steam at the point of cut-off Notes: 1. The volume of steam in the cylinder at the end of stroke, neglecting clearance, is equal to stroke volue 2. The ratio 01 / is3 (i.e. reciprocal of expansion ratio)is termed as cut-off ratio. It is defined as the ratio of volume between the points of admission and cut-off of steam and the stroke volume. 3. The steam consumption in kg per cycle maybe obtained as follows: Steam consumption per cycle = Volume of steam supplied per cycle in m3 Specific volume of thy steamat admissionpressure.

5. Steam Turbine

5.1 A Steam Turbine is a mechanical device that extracts thermal energy from pressurized steam and transforms it into mechanical work. Because the turbine generates rotary motion, it is particularly suited to driving electrical generators – about 90% of all electricity generation in the United States (1996) is by use of steam turbines.

Types of steam turbine:

Depending on their working pressures, size, construction and many other parameters, there are two basic types of steam turbines.

1) Impulse Turbine

2) Reaction Steam Turbine.

5.2 Differentiate between Impulse AND Reaction Turbine

Impulse Turbine	Reaction Turbine
At the inlet only kinetic energy is available. I.e. only momentum transfer.	At the inlet, both kinetic and pressure energy are available.
Steam expands in the fixed blade (which act as a nozzle) itself. The entire pressure drop occurs at nozzles. Therefore, pressure remains constant while it passes over the blades.	The steam expands continuously in both fixed and the moving blades as it passed above them. Thus, the pressure drop occurs in a gradual way during flow over both blades.
Water casing is not necessary.	Air-tight casing is necessary.
Pressure is same at both end of moving blade and is equal to atmospheric pressure.	Inlet pressure is higher than outlet pressure.
In impulse turbine, flow area of moving blade is constant, since there is no expansion of steam.	In reaction turbine, the moving blade do have change in flow area (convergent type).They are shaped like nozzle and accelerate the steam.
Blades are symmetrical about plane of turbine shaft. Therefore, the manufacturing of blade is simple	Blades are asymmetrical.
In impulse turbine, due to great pressure drop, the operating speed is very high.	In the reaction, small pressure drop due to turbine, the operating is low.
Due to high pressure drop on the nozzles, the number of stages are less. The size of an impulse for the power output turbine is comparatively small.	Due to the small pressure drop at each stage, the number of stages are more for the same pressure drop as in impulse turbine. Therefore the size of the reaction for the same output power turbine is large. Reaction turbines are only multi-stage turbines.
Operate at high water head.	Operate at low water head.
Less space per unit power	More space takes per unit power
Turbine Impulse is suitable for small powers generation. More hydraulic efficiency	Reaction turbine is suitable for medium and higher powers generation.
Examples: Pelton wheel, Banki turbine	Examples: Kaplan turbine, Francis turbine, Fourneyron turbine.

6. CONDENSER

6.1 The function of the condenser in a refrigeration system is **to transfer heat from the refrigerant to another medium, such as air and/or water**. By rejecting heat, the gaseous refrigerant condenses to liquid inside the condenser.

.6.2 1.The **steam condensers** are broadly classified into two types:

- **Surface condensers** (or non-mixing type condensers). In surface condensers, there is no direct contact between the exhaust steam and the cooling water.
- **Jet condensers** (or mixing type condensers). In jet condensers there is direct contact between the exhaust steam and cooling water.

2. Jet Condenser

1. Low-level Jet Condenser
- Parallel Flow Jet Condenser
- Counterflow Jet Condenser
2. Barometric Jet Condenser or High-level Jet Condenser
3. Ejector Condenser

7. I.C ENGINE

I.C Engine

Internal combustion engine: In this engine, the combustion of air and fuels take place inside the cylinder.

The working principle of 2-Stroke Petrol engine:

It consists of three parts namely inlet, exhaust, and transport instead of the valve.

It worked in the following ways:

- **Upstroke:**

The Piston moves upward and first cover the inlet port. So the charge enters into the casing through the inlet port, for the movement of the piston, It covers transfer port and then exhausts port. So the charge above the piston compressed adiabatically. Thus in this stroke suction and compression are completed in single Piston movement. After compression ignition of charge starts by means of the spark plug.

Working principle of four stroke Diesel engine.

There are four strokes as:

1. Suction Stroke
2. Compression stroke
3. Expansion stroke
4. Exhaust stroke

1. Suction stroke: This stroke starts with the piston at top dead centre position. The inlet value is opened and the exhaust value is closed. The downward movement of the piston creates vacuum in the cylinder due to which air is drawn into the cylinder. The movement of the piston is obtained either by the starter motor or by the momentum of the fly wheel.

2. Compression stroke: This stroke starts with the piston at B.D.C. position. Both the inlet and exhaust values are closed.

The air sucked during the suction stroke is compressed as the piston moves in the upward direction. A few degree before the completion of compression stroke, a very fine spray of diesel is injected into the compressed air. The fuel ignites spontaneously.

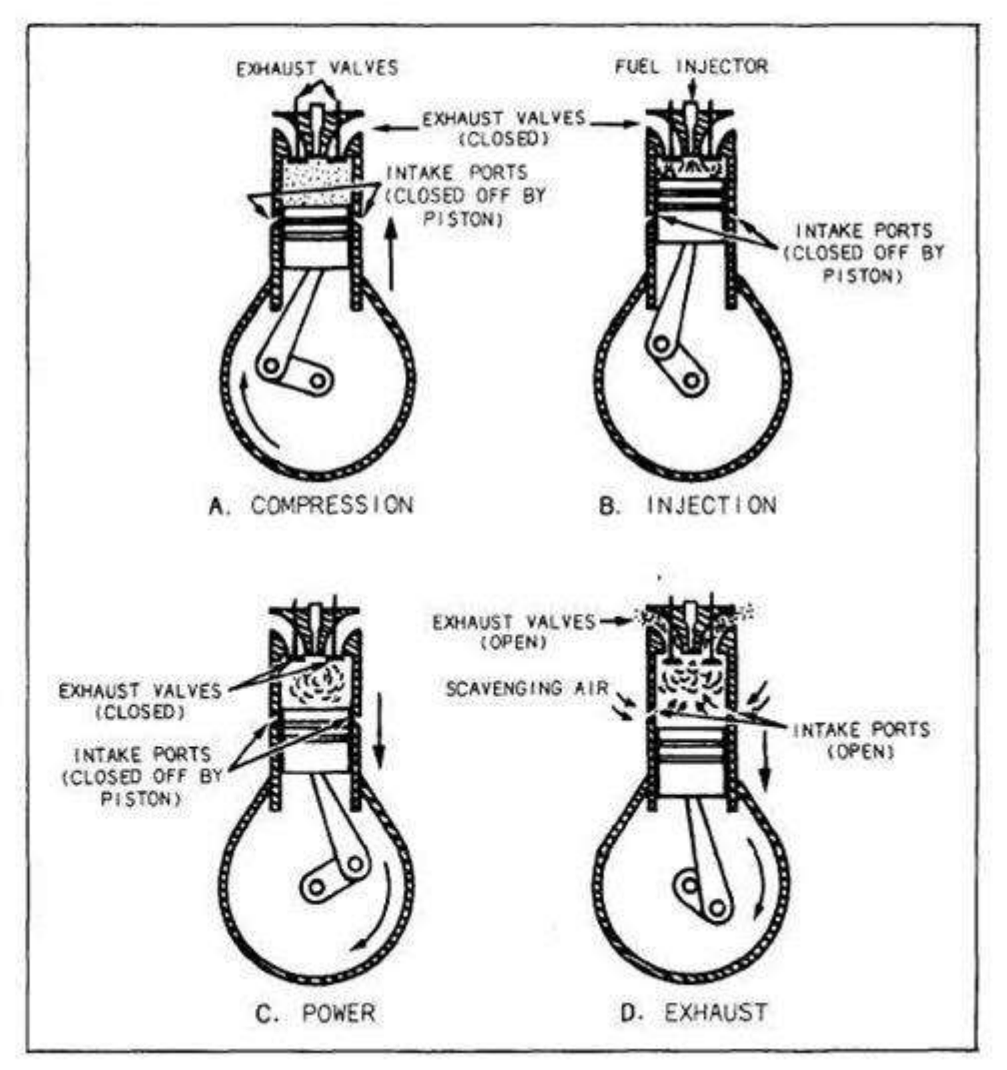


Figure of CI Engine Cycle

3. Expansion stroke: Both the inlet and exhaust valves remain closed. The heat energy released by the combustion of the fuel, results in the rise in pressure of the gases. This high pressure rise drives the piston in the downward direction, thereby producing some useful work. This stroke is called as power stroke.

4. Exhaust stroke: This stroke starts with the piston at the B.D.C. position. The inlet value remains closed whereas the exhaust value is opened. The upward movement of the piston pushes the burnt gases out of the cylinder through the exhaust valve. At the end of exhaust stroke, the exhaust valve is also closed.

The four-strokes complete one cycle which may repeat again to produce power.

WORKING PRINCIPLE OF 2 STROKE DIESEL ENGINE

1. 1st Stroke – As the piston starts rising from its B.D.C. position, it closes the transfer and the exhaust port. The air which is already there in the cylinder is compressed. At the same time with the upward movement of the piston, vacuum is created in the crank case. As soon as the inlet port is uncovered the fresh air is sucked in the crank case. The charging is continued until the crank case and the space in the cylinder beneath the piston in filled with the air.

2. 2nd Stroke – Slightly before the completion of the compression stroke a very fine spray of diesel is injected into the compressed air (which is at a very high temperature). The fuel ignites spontaneously.

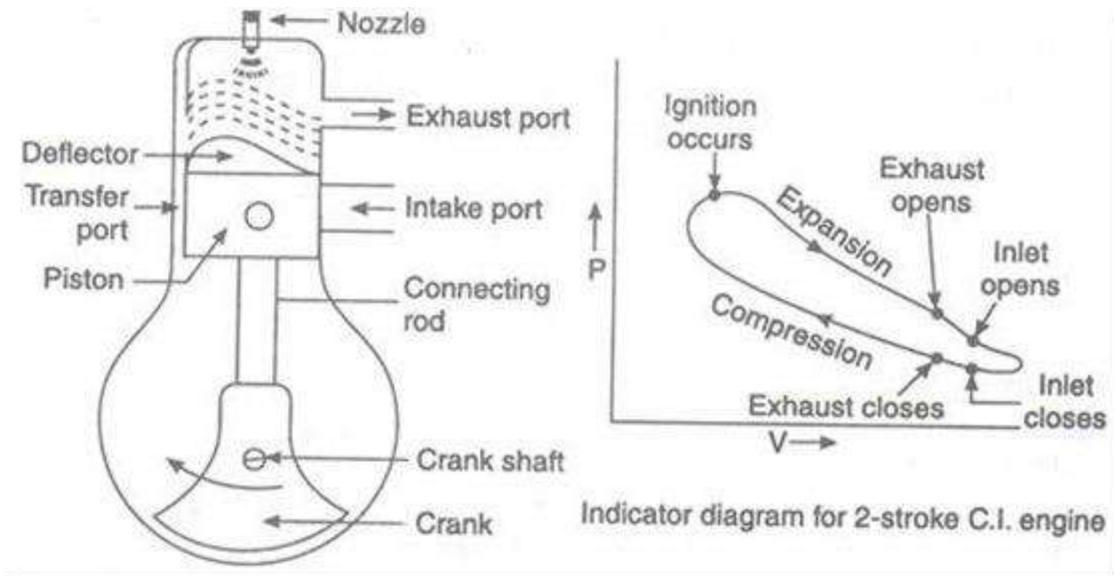


Figure of Two stroke CI Engine

Pressure is exerted on the crown of the piston due to the combustion of the air and the piston is pushed in the downward direction producing some useful power. The downward movement of the piston will first close the inlet port and then it will compress the air already sucked in the crank case.

Just at the end of power stroke, the piston uncovers the exhaust port and the transfer port simultaneously. The expanded gases start escaping through the exhaust port and at the same time the fresh air which is alredy compressed in the crank case, rushes into the cylinder through the transfer port and thus the cycle is repeated again.

1. WORKING PRINCIPLE OF FOUR STROKE PETROL ENGINES

There are four strokes which are as follows:

i) Suction stroke

ii) Compression stroke

iii) Expansion or working or power stroke

iv) Exhaust stroke

i) SUCTION STROKE: The suction stroke starts with the piston at top dead centre position. During this stroke, the piston moves downwards by means of crank shaft. The inlet valve is opened and the exhaust valve is closed. The partial vacuum created by the downward movement of the piston sucks in the fresh charge (mixture of air and petrol) from the carburetor through the inlet value. The stroke is completed during the half revolution (180°) of the crank shaft, which means at the end of the suction stroke, piston reaches the bottom head centre position.

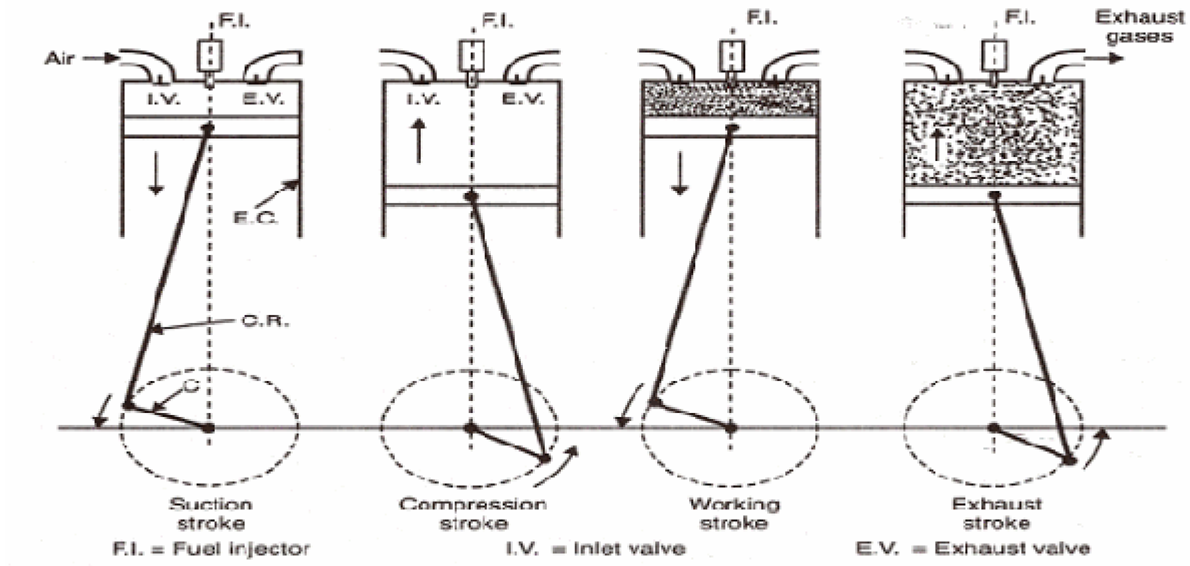


Figure of Four Stroke SI Engine Cycle

ii) COMPRESSION STROKE: During this stroke the inlet and exhaust valves are closed and the piston returns from bottom dead centre position. As the piston moves up, the charge is compressed. During compression the pressure and temperature rises. This rise in temperature and pressure depends upon the compression ratio (in petrol engines the compression ratio generally varies between 6:1 and 9:1). Just before the completion of the compression stroke, the charge is ignited by means of an electric spark, produced at the spark plug.

iii) WORKING OR EXPANSION STROKE: The ignition of the compressed charge. Just before the completion of compression stroke, causes a rapid rise of temperature and pressure in the cylinder. During this stroke the inlet and exhaust values remain closed. The expansion of gases due to the heat of combustion exerts pressure on the piston due to which the piston moves downward, doing some useful work.

iv) EXHAUST STROKE: The exhaust value is opened and the inlet valve remain closed. The piston moves upward (from its BDC position) with the help of energy stored in the flywheel during the working stroke. The upward movement of the piston discharges the burnt gases through the exhaust value.

At the end of exhaust stroke, piston reaches its TDC position and the next cycle starts

Working Principles of 2-Stroke petrol engine

The working principle of 2-Stroke petrol engine is discussed below:-

1) 1st Stroke: To start with let us assume the piston to be at its B.D.C. position. The arrangement of the ports is such that the piston performs two jobs simultaneously.

As the piston starts rising from its B.D.C. position it closes the transfer port and the exhaust port. The charge (mixture, of the air and petrol) which is already there in the cylinder, as the result of the previous running of the engine is compressed at the same time with the upward movement of the piston vacuum is created in the crank case (which is gas tight). As son as the inlet port is uncovered; the fresh change in sucked in the crank case. The charging is continued until the crank case and the space in the cylinder beneath the piston is filled with the charge. As the end of third stroke, the piston reached the T.D.C. position.

2) 2nd Stroke: Slightly before the completion of the compression stroke, the compressed charge is ignited by means of a spark produced at the spark plug.

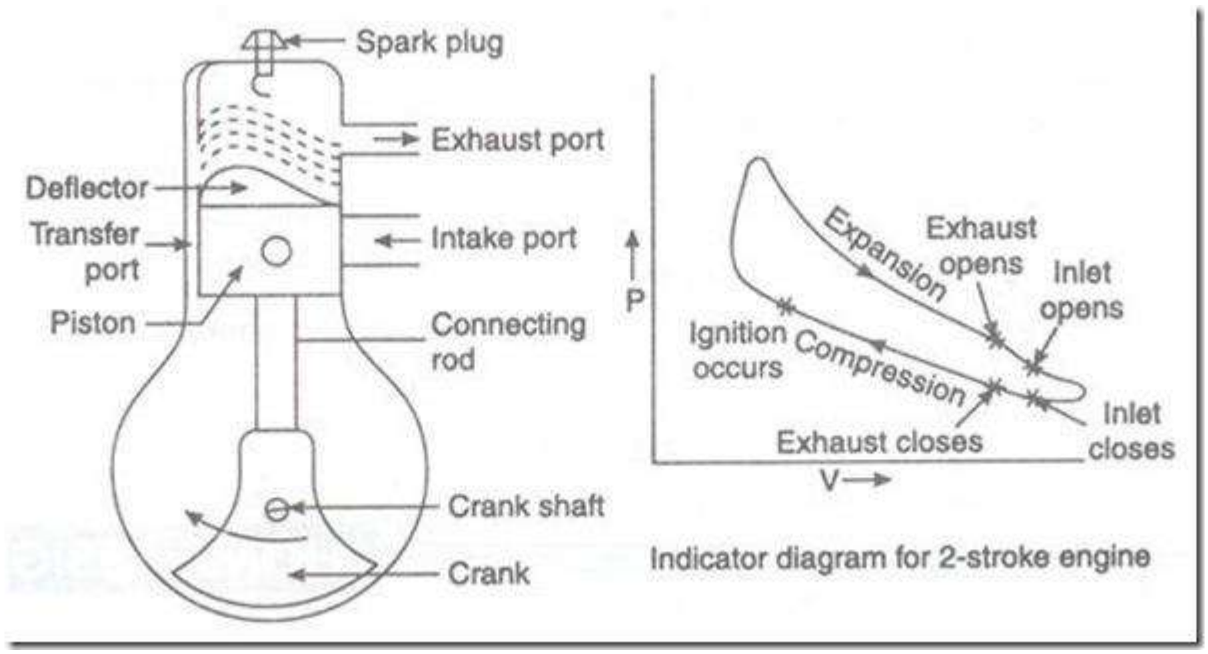


Figure of Two stroke SI Engine

Pressure is exerted on the crank of the piston due to the combustion of the piston is pushed in the downward direction producing some useful power. The downward movement of the will first close the inlet port and then it will compress the charge already sucked in the crank case.

Just the end of power stroke, the piston uncovered the exhaust port and the transfer port simultaneously the expanded gases start escaping through the exhaust port and the same time the fresh charge which is already compressed in the crank case, rushed into the cylinder through the transfer port and thus the cycle is repeated again.

The fresh charge coming into the cylinder also helps in exhausting the burnt gases out of the cylinder through the exhaust port. This is known as scavenging.

Difference Between 2 Stroke and 4 Stroke Engines

S.No.	Four stroke engine	Two stroke engine
1.	It has one power stroke for every two revolutions of the crankshaft.	It has one power stroke for each revolution of the crankshaft.
2.	A heavy flywheel is required and the engine runs unbalanced because turning moment on the crankshaft is not even due to one power stroke for every two revolutions of the crankshaft.	A lighter flywheel is required and the engine runs balanced because turning moment is more even due to one power stroke for each revolution of the crankshaft.
3.	Engine is heavy in Weight.	Engine is lighter in weight.
4.	Engine design is complicated due to the valve mechanism.	Engine design is simple due to the absence of valve mechanism.
5.	It is costlier.	Less cost than 4 stroke engine.

8. HYDROSTATICS

8.1 Fluid Properties;

Density[

The density of a fluid, is generally designated by the Greek symbol (rho) is defined as the mass of the fluid over an infinitesimal volume and in the SI system kg/m^3.

If the fluid is assumed to be uniformly dense the formula may be simplified as:

$\rho=m/v$

Specific Weight (Weight Density)

The specific weight of a fluid is designated by the Greek symbol

γ (gamma), and is generally defined as the weight per unit volume. The units is N/m^3 in the SI systems, .

Relative Density (Specific Gravity)

The relative density of any fluid is defined as the ratio of the density of that fluid to the density of the standard fluid. For liquids we take water as a standard fluid with density ρ=1000 kg/m^3. For gases we take air or O_2 as a standard fluid with density, ρ=1.293 kg/m^3.

Dynamic Viscosity

Viscosity is the property of fluid which defines the interaction between the moving particles of the fluid. It is the measure of resistance to the flow of fluids. The viscous force is due to the intermolecular forces acting in the fluid. The flow or rate of deformation of fluids under shear stress is different for different fluids due to the difference in viscosity. Fluids with high viscosity deform slowly.

Viscosity (represented by μ, Greek letter mu) is a material property, unique to fluids, that measures the fluid's resistance to flow. Though a property of the fluid, its effect is understood only when the fluid is in motion. When different elements move with different velocities, each element tries to drag its neighbouring elements along with it. Thus, shear stress occurs between fluid elements of different velocities.

Surface Tension

Surface tension is the tension of the surface film of a liquid caused by the attraction of the particles in the surface layer by the bulk of the liquid, which tends to minimise surface area”.

9. HYDROKINETICS

Equation of continuity of flow

The continuity equation is defined as the product of cross-sectional area of the pipe and the velocity of the fluid at any given point along the pipe is constant.

Continuity Equation Derivation

Continuity equation represents that the product of cross-sectional area of the pipe and the fluid speed at any point along the pipe is always constant. This product is equal to the volume flow per second or simply the flow rate. The continuity equation is given as:

R = A v = constant

Where,

- R is the volume flow rate
- A is the flow area
- v is the flow velocity

Assumption of Continuity Equation

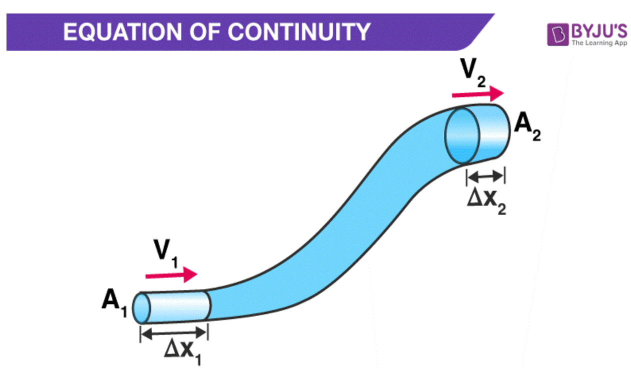
Following are the assumptions of continuity equation:

- The tube is having a single entry and single exit
- The fluid flowing in the tube is non-viscous
- The flow is incompressible
- The fluid flow is steady

Related Article:
Bernoulli's Principle

Derivation

Consider the following diagram:



Now, consider the fluid flows for a short interval of time in the tube. So, 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)***

Now, the mass flux has to be calculated at the lower end. Mass flux is simply defined as the mass of the fluid per unit time passing through any cross-sectional area. For the lower end with cross-sectional area A_1, mass flux will be:

$\Delta m_1/\Delta t = \rho_1 A_1 v_1$ ***———(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:

$\rho A v = \text{constant}$

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:

$A v = \text{constant}$

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.

Explain energy of flowing liquid

Total energy of a liquid: Pressure, Kineti, Potential energy

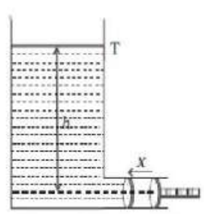


Fig. Pressure energy

Total energy of a liquid

A liquid in motion possesses pressure energy, kinetic energy and potential energy.

(i) Pressure energy

It is the energy possessed by a liquid by virtue of its pressure.

Consider a liquid of density ρ contained in a wide tank T having a side tube near the bottom of the tank as shown in Fig. . A frictionless piston of cross sectional area 'a' is fitted to the side tube. Pressure exerted by the liquid on the piston is P = h ρ g where h is the height of liquid column above the axis of the side tube.

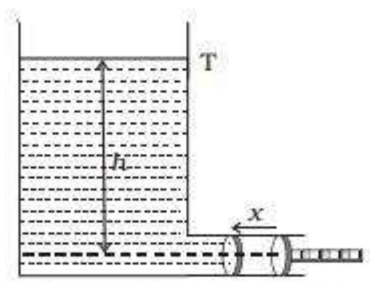


Fig. Pressure energy

If x is the distance through which the piston is pushed inwards, then

Volume of liquid pushed into the tank = ax

∴ Mass of the liquid pushed into the tank = ax ρ

As the tank is wide enough and a very small amount of liquid is pushed inside the tank, the height h and hence the pressure P may be considered as constant.

Work done in pushing the piston through the distance x = Force on the piston � distance moved

(i.e) W = Pax

This work done is the pressure energy of the liquid of mass axρ.

∴ Pressure energy per unit mass of the liquid = Pax /axp = P/p

(ii) Kinetic energy

It is the energy possessed by a liquid by virtue of its motion.

If m is the mass of the liquid moving with a velocity v, the kinetic energy of the liquid = � mv^2

Kinetic energy per unit mass = $1/2mv^2$ / m = v^2 / 2

(iii) Potential energy

It is the energy possessed by a liquid by virtue of its height above the ground level.

If *m* is the mass of the liquid at a height *h* from the ground level, the potential energy of the liquid = *mgh*

Potential energy per unit mass = mgh/ m = gh

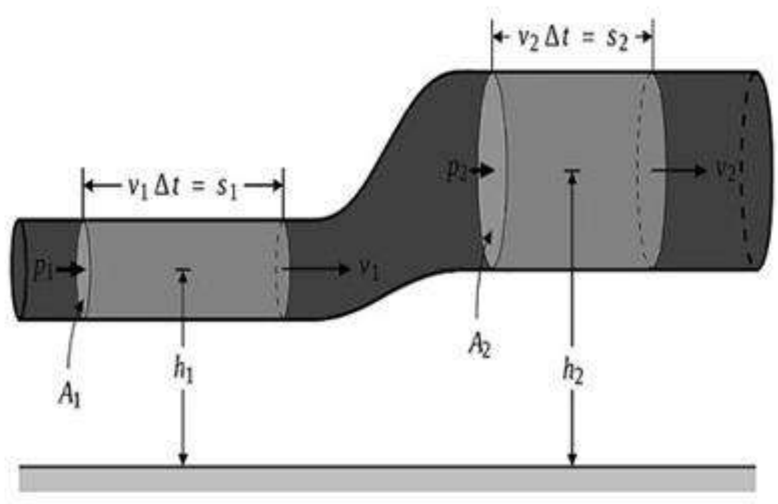
Total energy of the liquid in motion = pressure energy + kinetic energy + potential energy.

Total energy per unit mass of the flowing liquid = P/p + v^2/2 + gh

State and explain Bernoulli's theorem

Bernoulli's theorem states that the whole mechanical energy of the flowing liquid includes the gravitational potential energy of altitude, then the energy-related with the liquid force & the kinetic energy of the liquid movement, remains stable. From the energy conservation principle, this theorem can be derived.

Bernoulli's equation is also known as Bernoulli's principle. When we apply this principle to fluids in a perfect state, then both the density & pressure are inversely proportional. So the fluid with less speed will use more force compare with a fluid that is flowing very fast.



Bernoulli’s Theorem Equation

The formula of Bernoulli’s equation is the main relationships among force, kinetic energy as well as the gravitational potential energy of a liquid within a container. The formula of this theorem can be given as:

p + 12 ρ v2 + ρgh = stable

From the above formula,

‘p’ is the force applied by the liquid

‘v’ is the liquid’s velocity

‘ρ’ is the liquid’s density

‘h’ is the container’s height

This equation provides huge insight into the stability among force, velocity, and height.

State and Prove Bernoulli’s Theorem

Consider a slight viscosity liquid flowing with laminar flow, then the whole potential, kinetic, and pressure energy will be constant. The diagram of Bernoulli’s theorem is shown below.

Consider the ideal fluid of density ‘ρ’ moving throughout the pipe LM by changing cross-section.

Let the pressures at the ends of L&M are P1, P2 & the cross-section areas at L&M ends are A1, A2.

Allow the liquid to enter with V1 velocity & leaves with V2 velocity.

Let **A_1>A_2**
From the continuity equation

$A_1V_1=A_2V_2$
Let A1 is above A2 (A1>A2), then V2>V1 and P2>P1

The mass of liquid entering at the end of 'L' in 't' time, then the distance covered by the fluid is v1t.

Thus, the work done through force over the fluid end 'L' end within' time can be derived as

W1= force x displacement = **$P_1A_1v_1t$**
When same mass 'm' goes away from the end of 'M' in time 't', then the fluid covers the distance through v2t

Thus, work done through fluid against the pressure because of 'P1' pressure can be derived by

$W_2=P_2A_2v_2t$
Network done through force over the fluid in 't' time is given as

$$W = W_1-W_2$$
$$= P_1A_1v_1t- P_2A_2v_2t$$

This work can be done on the fluid by force then it increases its potential & kinetic energy.

When kinetic energy increase in fluid is

$$\Delta k = 1/2m(v_2^2-v_1^2)$$

Similarly, when potential energy increases in the fluid is

$$\Delta p = mg (h_2-h_1)$$

Based on the relation of work-energy

$$P_1A_1v_1t- P_2A_2v_2t$$
$$= 1/2m(v_2^2-v_1^2) – mg (h_2-h_1)$$

If there is no liquid sink and source, then the fluid mass entering at 'L' end is equivalent to the fluid mass leaving from the pipe at the end of 'M' can be derived like the following.

$$A_1v_1 \rho t = A_2v_2 \rho t = m$$
$$A_1v_1t = A_2v_2t = m/\rho$$

Substitute this value in the above equation like P1A1v1t- P2A2v2t

$$P_1 m/ \rho – P_2 m/ \rho$$
$$1/2m(v_2^2-v_1^2) – mg (h_2-h_1)$$
$$\text{i.e, } P/ \rho + gh + 1/2v^2 = \text{constant}$$

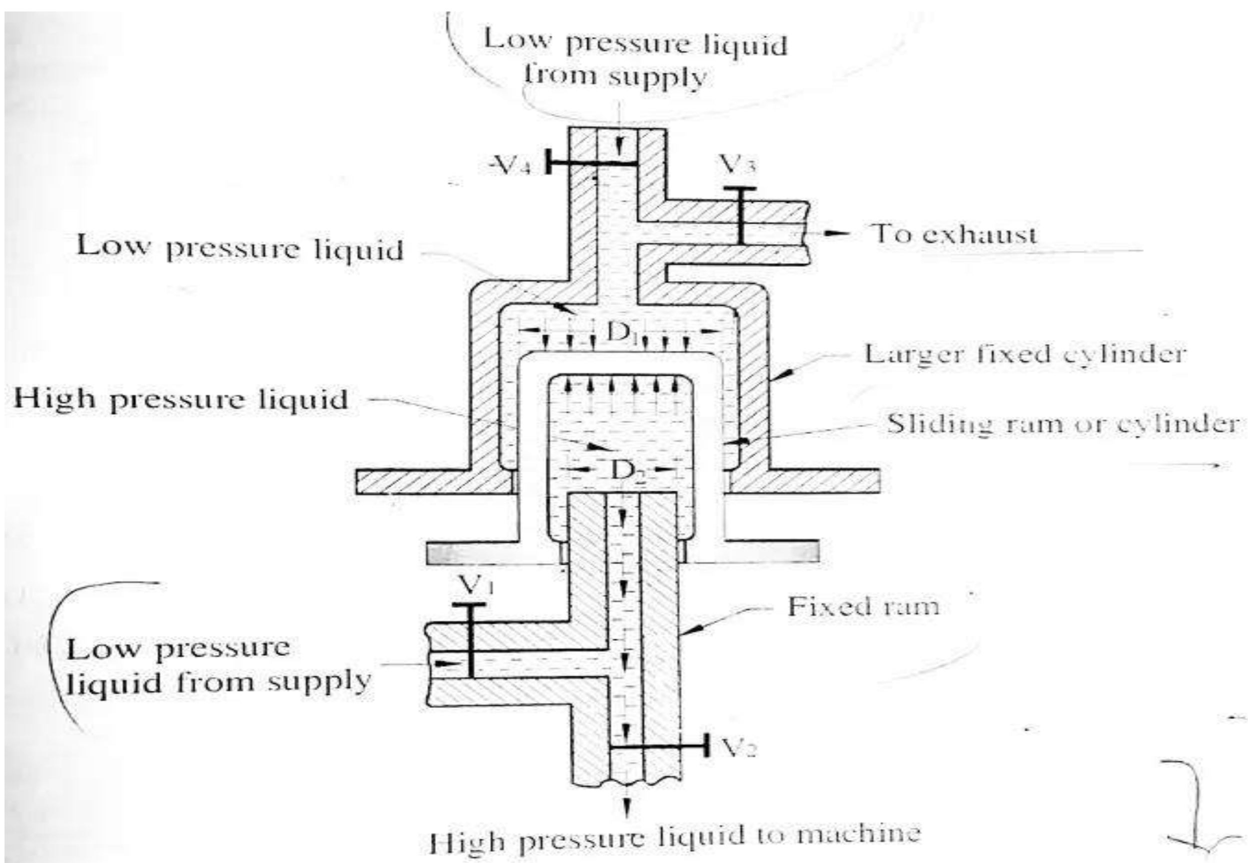
10.HYDRAULIC DEVICES AND PNEUMATICS

Intensifier

The hydraulic intensifier is a mechanical device which is used to increase the intensity of pressure of the fluid. It utilizes the energy of large quantity of liquid at low pressure. Some hydraulic machines require high pressure for working but this high pressure can't be obtained by using pump. Some of these hydraulic machines are hydraulic press, hydraulic ram and hydraulic lift etc. These machines require high pressure for this operation to obtain the required amount of pressure. A hydraulic intensifier is mounted in between the pump and the working machine. It has two types one is single acting and other is double acting. Here we will discuss the only single acting hydraulic intensifier i.e. it supplies high pressure liquid during the downward stroke only. The double acting hydraulic intensifier supplies high pressure in both strokes i.e. in continuous manner. Generally a normal intensifier can raise the pressure intensity of liquid at 150-160 MN/.

CONSTRUCTION:

A hydraulic intensifier is very simple in construction; it has only three main parts, these parts are attached in a proper sequence for increasing the pressure of input fluid. These three main parts are fixed ram, sliding cylinder or ram and a fixed cylinder.



1. **FIXED CYLINDER:** It is the outermost body part of the hydraulic intensifier. The low pressure liquid comes into the fixed cylinder from the main supply. The sliding cylinder or ram is slides inside the fixed cylinder.
2. **SLIDING CYLINDER OR RAM:** It is the middle part of hydraulic intensifier i.e. it slides in between the fixed ram and fixed cylinder. This is the only moving part of this device. It slides under the action of hydraulic force. Sliding cylinder contains high pressure liquid which is supplied to it through the fixed ram.

3. **FIXED RAM:** It is the inner most and smallest part of the hydraulic intensifier. It is surrounded by a sliding cylinder. The high pressure liquid is supplied to the machine through this fixed ram.
4. **VALVES:** Hydraulic intensifier consists of four valves for easy understanding we can name them A, B, C and D. ‘A’ and ‘D’ allows low pressure liquid from the supply into the device. The liquid comes in from valve ‘D’ goes into the fixed cylinder and the liquid goes in through the valve ‘A’ goes into the sliding cylinder. Valve is for exhaust purpose i.e. it permits the low pressure liquid from the fixed cylinder to be discharged to exhaust. The valve ‘B’ is used to supply high pressure liquid to the outlet of intensifier which is attached with hydraulic machines.

WORKING:

As discussed above hydraulic intensifier is used to increase the intensity of fluid pressure. Its working based upon the fluid movement in it. The liquid from low pressure comes in and at high pressure goes out to the machine or outlet. In the starting movement the sliding cylinder is at its rest position i.e. at bottom most position. Now the liquid of low pressure comes into the fixed cylinder through valve ‘D’ and fill it properly. Now the valve C, B and D are closed. The only valve ‘A’ is opened which permits the low pressure liquid into the sliding cylinder or ram. After that the valve ‘C’ is opened which permits the low pressure liquid from the fixed cylinder to be discharged to exhaust. When the low pressure comes out from the fixed cylinder then the sliding cylinder starts moving upwards due to the supply from valve ‘A’. When the sliding cylinder reaches the topmost position then this sliding cylinder is filled with low pressure liquid. The valves ‘A’ and ‘C’ are closed when the sliding cylinder completely filled with low pressure liquid. Now the valves ‘B’ and ‘D’ are opened, the low pressure liquid from the supply i.e. through valve ‘D’ enters into the fixed cylinder which pushes the sliding cylinder to move downwards which results high pressure liquid is produced in the sliding cylinder. This high pressure liquid is supplied to the required output or to the some hydraulic machinery. High pressure liquid is comes out from the valve ‘B’. This cycle is repeated continuously and low pressure liquid comes out with high pressure intensity.

APPLICATIONS:

- Hydraulic intensifier is used to supply high intensity pressure where ever need.
- It used where pump is not sufficient to provide high intensity of pressure as per the requirement.
- It is most commonly used in hydraulic press, hydraulic ram, hydraulic cranes and hydraulic lifts etc where high intensity of pressure is required for lift the loads.

ADVANTAGES:

- Hydraulic intensifier is a compact device and very easy to operate and control.
- It can be directly attached with the hydraulic machinery, where ever it is needed.
- It is compact as well as energy saving device.
- It is cheaper device if we looks about its working, it save lot of money by their easy and economical operation. We can say that it is simple in working, safe and economical in operations.
- It has high speed operation due to this it can be easily starts and stop as per our requirements.
- It can easily works with the pump, that’s why it may be attached in between the pump and the hydraulic machinery.
- It is very easy to operate and control.
- It provides constant force and pressure in whole working process.

DISADVANTAGES:

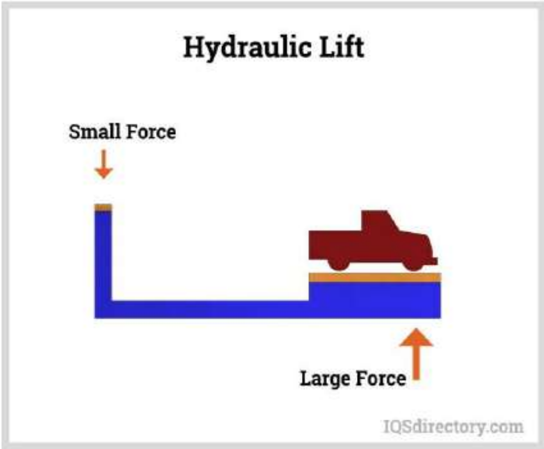
- The main disadvantage of the hydraulic intensifier is same which mostly occurs in case of the all other hydraulic systems i.e. leakage of the fluid.
- Sometimes the hydraulic fluid used is may be corrosive which damage the out machinery.
- The other main disadvantage is of leakage fluid can catch fire so the working should be done in proper manner and try to avoid the any small leakage of the fluids.
- This system requires high maintenance.

Hydraulic lift

A hydraulic lift is a device for moving objects using force created by pressure on a liquid inside a cylinder that moves a piston upward. Incompressible oil is pumped into the cylinder, which forces the piston upward. When a valve opens to release the oil, the piston lowers by gravitational force.

The principle for hydraulic lifts is based on Pascal's law for generating force or motion, which states that pressure change on an incompressible liquid in a confined space is passed equally throughout the liquid in all directions.

The concept of Pascal's law and its application to hydraulics can be seen in the example below, where a small amount of force is applied to an incompressible liquid on the left to create a large amount of force on the right. Hydraulic systems are used for precision control of large force applications, are economical, and make excellent use of energy resources.



A hydraulic system works by applying force at one point to an incompressible liquid, which sends force to a second point. The process involves two pistons that are connected by an oil filled pipe.

The image below is a representation of the two pistons and how they are connected by a pipe.

The diagram below represents a simple version of the working mechanism of a hydraulic device. The handle on the right moves the incompressible oil, under pressure, from the reservoir to the high pressure chamber in the middle of the diagram. The ram moves up as the oil is pumped in.

The force generated in a hydraulic system depends on the size of the pistons. If the smaller of the two pistons is two inches and the larger piston is six inches, or three times as large, the amount of force created will be nine times greater than the amount of force from the smaller piston. One hundred pounds of force by a small piston will be able to lift 900 pounds.

In this diagram, the piston on the left has a one pound load and an area of one inch. When it moves down ten inches, it is able to move the ten pound load on the piston on the right.

Parts of a Hydraulic System

The purposes of hydraulic systems widely vary, but the principles of how hydraulic systems work and their components remain the same for all applications. The most significant part of a hydraulic system is the fluid or liquid. The laws of physics dictate that the pressure on the fluid will remain unchanged as it is transmitted across a hydraulic system. Below is an explanation of each part of a hydraulic system.

Hydraulic Circuits:

Hydraulic Circuits control the flow and pressure of the liquid in the system. The image below shows all of the different parts of a hydraulic circuit.

Hydraulic Pump:

Hydraulic Pump converts mechanical power into hydraulic energy. Hydraulic pumps create a vacuum at the pump inlet, which forces liquid from the reservoir into the inlet line and out to the outlet to the hydraulic system

Hydraulic Motor:

Hydraulic Motor is an actuator to convert hydraulic pressure into torque and rotation. It takes the pressure and flow of the hydraulic energy and changes it into rotational mechanical energy, similar to a linear actuator. The pump sends hydraulic energy into the system, where it pushes the hydraulic motor.

Hydraulic Cylinder:

Hydraulic Cylinder converts the energy in the hydraulic fluid into force and initiates the pressure in the fluid that is controlled by the hydraulic motor.

Hydraulic Pistons:

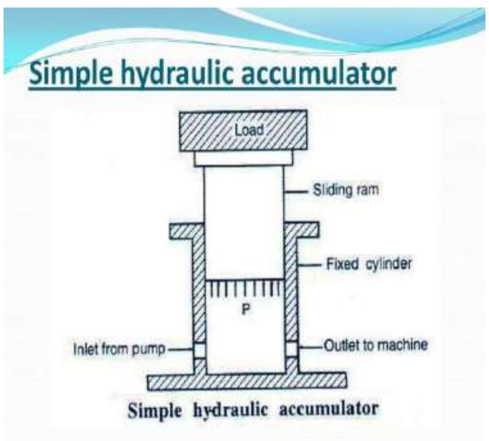
Hydraulic Pistons are moved linearly by fluid pressure. Axial designs have a number of pistons arranged in a circular pattern in a rotating housing.

Hydraulic Fluids:

Hydraulic Fluids transfer power in a hydraulic system. Most hydraulic fluids are mineral oil or water. The first hydraulic fluid was water before mineral oil was introduced in the twentieth century. Glycol ether, organophosphate ester, polyalphaolefin, propylene glycol, and silicone oil are used for high temperature applications and fire resistance.

Accumulator

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

Hydraulic ram This article is about the water pump. For the vehicle extraction tool, see Hydraulic rescue tools. For the piston-based actuator, see hydraulic cylinder. 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 Edited with the trial version of Foxit Advanced PDF Editor To remove this notice, visit: www.foxitsoftware.com/shopping [61] 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.