UNIT – 5

Testing and Performance
Performance parameters, measurements of brake power, indicated power, friction power, fuel and air consumption,
exhaust gas calorimeter, calculation of various performance parameter, heat balance sheet.
Performance current for S.I. and C.I. Engine with load and speed.
Emission and Pollution
SI Engine and CI Engine emissions and its control and comparison. Effect of pollution on Human health and bio
sphere.

Engine Testing & Performance

Engine Performance:- It is an indication of the degree of success with which it is doing its assigned job.

The degree of success is compared on the following basis –

1. Specific fuel consumption.
2. Brake means effective pressure.
3. Specific power output.
4. Specific weight.
5. Exhaust smoke and other emissions.

The basic performance parameters –

(1) **Power –** Power is defined as the rate of doing work and it is equal to the product of force and linear velocity (or) the product of Torque and angular velocity.

a. **Brake Power:-** The power developed by an engine at the shaft output is called Brake Power (B.P.)

b. p. = 2πTNT where T = W x r

W = 9.81 x load in kg. and r = radius in meters

b. **Indicated Power:-** The total power available at the beginning of the expansion stroke is called Indicated Power (or) the power developed in the cylinder, forms on the basis of evaluation of combustion efficiency.

c. **Frictional Power:-** The power required to overcome the resistance offered by all moving parts of the engine.

i. p. = bp + fp => fp = ip – bp

(or) The difference between Indicated power and Brake power is called Frictional power.

(2) **Mechanical Efficiency –** The ratio of Brake Power of the Indicated Power is called mechanical efficiency.

$$\mu_{mech} = \frac{b.p}{i.p.} = \frac{b.p.}{bp+fp}$$

(3) **Mean Effective Pressure (MEP):-** It is the hypothetical pressure which is thought to be acting on the piston through out the power stroke.

$$Pm = \frac{\text{Net Area of indicator diagram in mm}^2}{\text{Length of indicator diagram in mm x Spring constant.}}$$

$i.p = \frac{P_{im} LAN}{n}$ Watts & $b.p = \frac{P_{bm} LAN}{n}$

Where P_{im} = indicated mean effective pressure (N/m^2)

L = Length of the stroke (m)

A = Area of the piston (m^2)

N = Speed of the engine in revolutions per second.

n = no. of revolutions required to complete the one engine cycle.

= 1 (for two – stroke Engine)

= 2 (for four – stroke Engine)

P_{bm} = brake mean effective pressure (N/m^2)

also $P_{im} = P_{bm} + P_{fm}$

Where P_{fm} = friction mean effective pressure

but $pb = 2\pi TNT$

hence $2\pi NT = P_{bm} \frac{LAN}{n}$

$\Rightarrow T = P_{bm} \frac{LAN}{n.2\pi N} \Rightarrow \frac{P_{bm} LA}{n} \cdot \frac{1}{2\pi}$

Note:-

- A larger engine produces more torque for the same mean effective pressure. Hence Torque is not the proper parameter to measure the ability of an engine.
- Higher the mean effective pressure, higher will be the power developed by an engine for a given displacement.
- Mean effective pressure is the true indication of the relative performance of different engines.

(4) Specific Output:- Specific output of an engine is defined as the brake output per unit of piston displacement.

= b.p / A.L

$\Rightarrow P_{bm} \frac{LAN}{n} \Rightarrow \frac{1}{n} \cdot P_{bm} \times N$

(5) Volumetric Efficiency:- It is defined as the ratio of the mass of air inducted into the engine cylinder during the section stroke to the mass of air corresponding to the swept volume of the engine.

$$\gamma_{vd} = \frac{\text{Mass of charge actually induced}}{\text{Mass of charge corresponding to the cylinder volume at intake pressure and temperature.}}$$

(6) Fuel – Air Ratio (F/A):- It is the ratio of the mss of fuel to the mass of air in the fuel mixture.

Relative fuel – air ratio (F_R):- $\frac{\text{Actual fuel – air ratio}}{\text{Stoichiometric fuel air ratio}}$

(7) Specific fuel consumption:- It is defined as the amount of fuel consumed per unit of power developed per hour.

$$Stc = \frac{\text{Fuel consumed in grams/hr.}}{\text{Horse Power Developed.}}$$

bstc = mt (gram/hr) / bp; istc = mt / Ep.

(8) Thermal Efficiency:- The ratio of the output to that of the chemical energy input in the form of fuel supply.

$$\gamma_{an} = \frac{bp}{m_f \times C.V.}$$ where C.V. = calorific value

(9) Specific Weight:- The weight of the engine in kg. for each brake power developed.

(10) Heat Balance:- The energy input to the engine goes out in various forms.

- A part is in the form of brake output
- A part goes into exhaust
- The rest is taken by cooling water and the lubricating oil.

The brake – up of the total energy input into these different parts is called heat balance.

Measurement of Exhaust Stroke:-

Generally there are three smoke meters namely BOSCH, HARTRIDGE and PHS used to measure soot density (g/m^3).

BOSCH SMOKE METER (Spot Filtering Type)

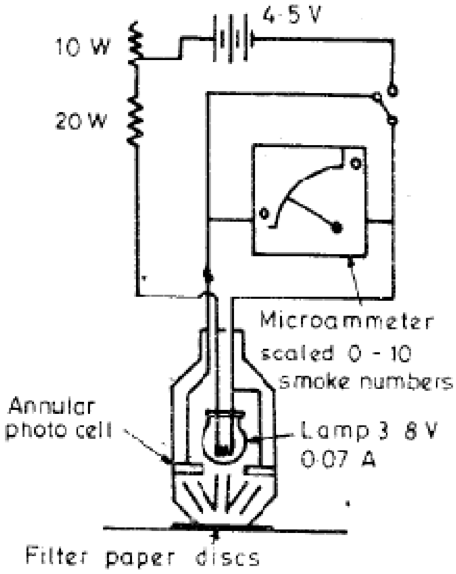


Figure – Boach smokemeter

A fixed quantity of exhaust gas is passed through a fixed filter paper. The density of smoke status on the paper are evaluated optically.

In a modified device, a pneumatically operated sampling pump and a photo – electric unit are used to measure the intensity of smoke stain on filter paper.

VON BRAND SMOKE METER (Continuous Filtering Type)

In this method, the measurement of smoke intensity is achieved by continuously passing exhaust gas through a moving strip of filter paper and collecting particles.

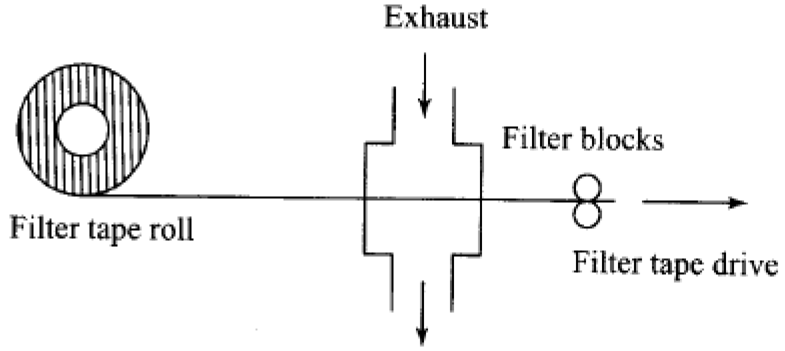


Figure – Continuous Filter Type Smoke meter

The exhaust sample is passed at a constant rate through a strip of filter paper moving at a preset speed. A stain is imparted to the paper.

The intensity of the stain is measured by the amount of light which passes through the filter and is indication of the smoke density of exhaust. It indicates the smoke level.

Measurement of Exhaust Emission:-

The substances which are emitted to the atmosphere from an engine are termed as exhaust emissions. The exhaust gas consists of a variety of components the important of them are carbon monoxide (CO), unburned hydrocarbons (UBHC) and oxides of Nitrogen (NO_x). Some other inert gases and a small amount of oxygen may also present.

The following devices are used to measure the various exhaust components.

(11) Flame ionization Detector Burner (FiD) –

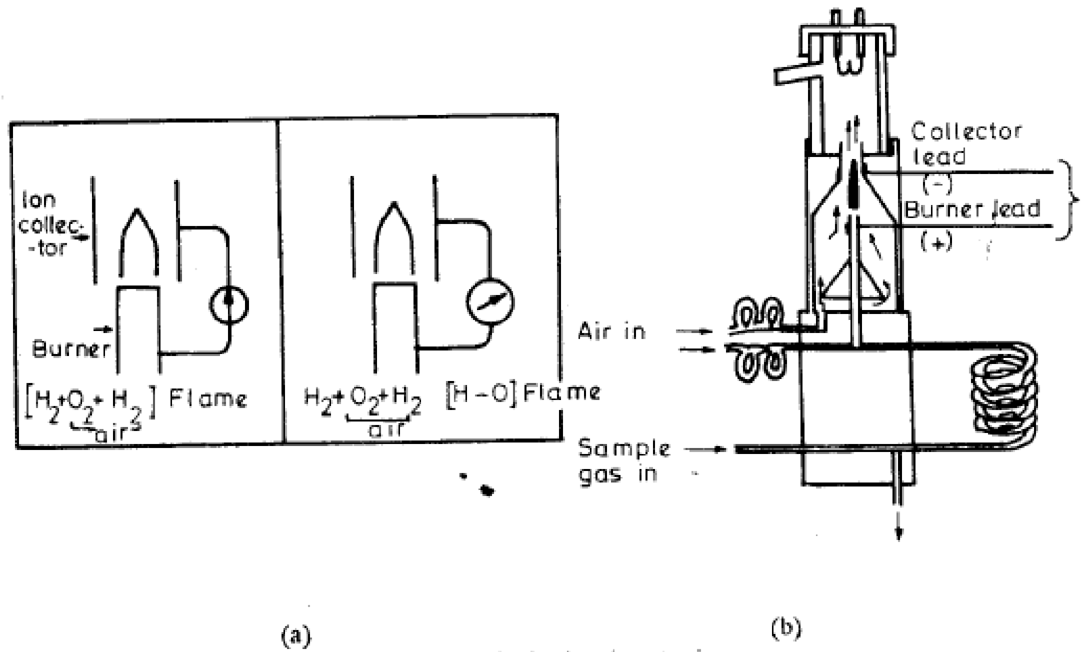


Figure – Flame ionization detector burner

(1) The working principle:- A hydrogen air flame contains a negligible amount of ions. If it traces amounts of any hydrocarbons of exhaust, a larger number of ions are produced.

If a polarized voltage is applied across the burner jet; a current is produced which is proportional to the number of ions and thus to the HC present. The output depends on the number of carbons atoms passing through it in a unit time.

The presence of CO, CO_2, NO_x, water and N_2 in the exhaust have no effect the FID reading.

FID is a rapid, continuous and accurate method to measure HC in the exhaust.

(2) Spectroscopic Analyzers:-

All the spectroscopic analyzers works on the principle that the quantity of energy absorbed by a compound in a sample cell is proportional to the concentration of the compound in the cell.

There are two types of analyzers –

1. ***Dispersive Analyzers:-*** There analyzers use only a narrow dispersed frequency of light spectrum to analyze a compound. These are generally not used.
2. ***Non – Dispersive Infrared (NDIR) Analyzers:-***

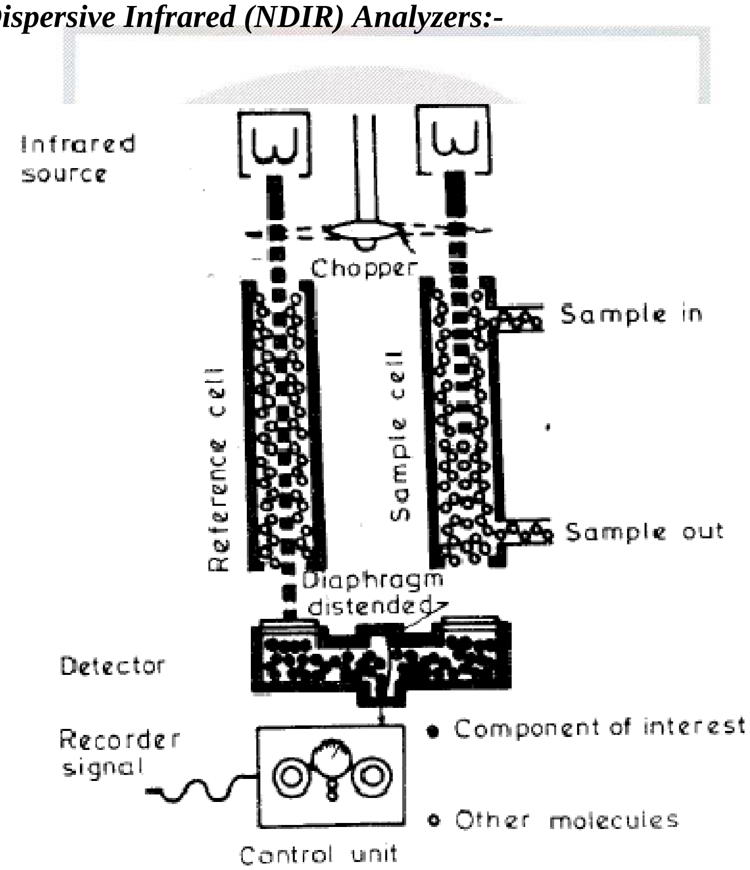


Figure – Schematic of non – dispersive infrared analyzer (NDIR)

It consists of two infrared sources, interrupted simultaneously by an optical chopper. Radiation from these sources pass in parallel paths through a reference and a sample cell to opposite side of a common detector. The sample cell contains the sample to be analyzed and reference cell filled with an inert gas (N2). The inert gas do not absorb the infrared energy which was corresponded to the sample. A closed container filled with the sample works as detector. The detector is divided into two equal volumes by a thin metallic diaphragm.

When the chopper blocks the radiation, the pressure in both parts of the detector is same and the diaphragm remains in the neutral position. As the chopper blocks and unblocks the radiation, the radiant energy from one source passes through the reference cell unchanged; where as the sample cell absorbs the infrared energy. The absorption is proportional to the concentration of the sample to be measured. Thus unequal amounts of energy are transmitted to the volumes of the detector and pressure difference causes the movement of the detector by this concentration of the sample to be measured.

This analyzer can accurately measure CO, CO_2 and those HCs which have clear absorption peaks.

Gas Chromato Graphy –

In this method individual constituents of mixture are separated and their concentrations will be analyzed and measured.

This is the only method by which each component of an exhaust sample can be identified and analyzed. But it is very time – consuming method.

Measurement of Brake Power:-

It involves the determination of the torque and the angular speed of the engine output shaft. The torque measuring device is called a "Dynamometers".

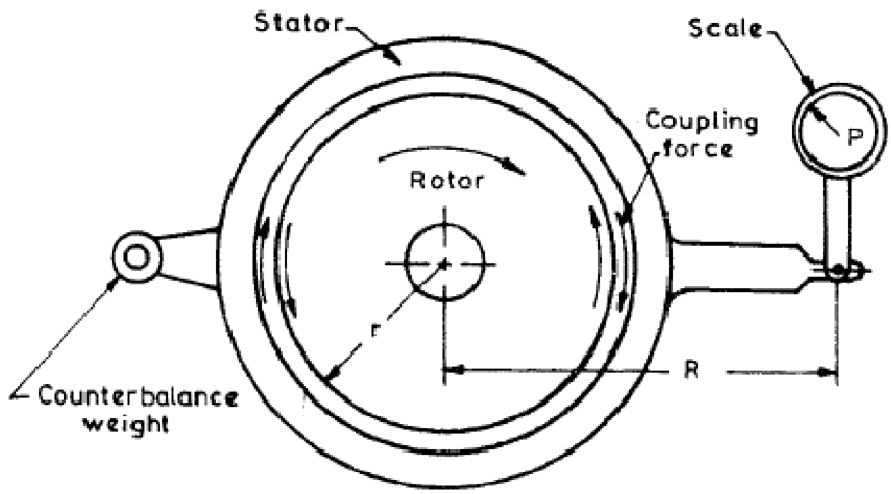


Figure – The dynamometer principle

Principle:- A rotor driven by the engine under test is electrically hydraulically of magnetically coupled to a stator. For every revolution of the shaft, the rotor periphery moves through a distance ($2\pi r$), against the coupling force (F).

The work done per revolution (W) = $2\pi rF$

The external torque is equal to P x R where P = Scale reading

And R is the 'arm'. This moment balances the turning moment r x f => P x R = T

Work done / rev. = $2\pi T$

Work done / sec. = $2\pi NT$ where N is rev/sec.

⇨ Power = $2\pi PRN$

The dynamometers are classified into two main groups

1. **Absorption Dynamometers:-** These dynamometer measure and absorb the power output of the engine to which they are coupled. The power absorbed is usually dissipated as heat. The following are the example.

A. Prony Brake:- It is the simplest method to measure Horsepower.

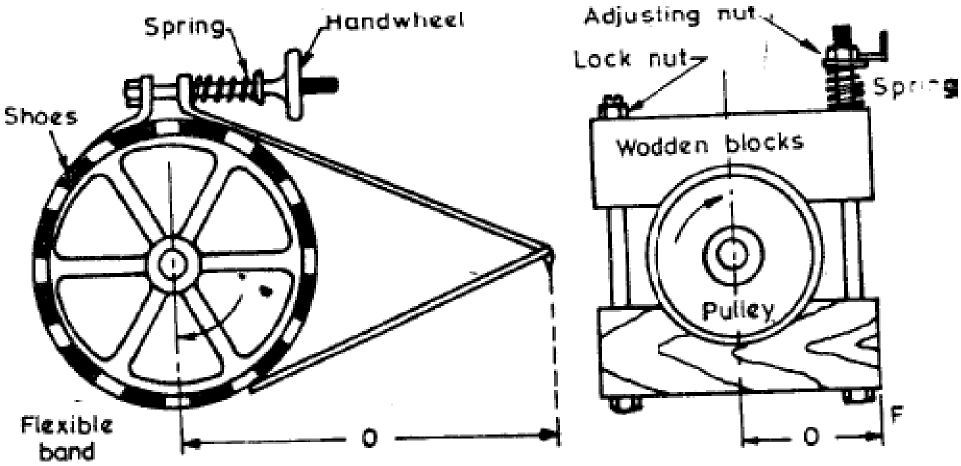


Figure – Prony Brake

Principle:- It works on principle of converting power into heat by dry friction. It consists of a wooden block mounted on a flexible rope. The wooden block when pressed into contact with the rotating drum takes the engine torque and power is dissipated in frictional resistance. Spring loaded bolts are provided to tighten the wooden block and hence increase the friction. The whole power absorbed is converted into heat and hence this type of dynamometer must be cooled.

The brake horse is given by

b.p = $2\pi NT$ Where $T = W r$

where W; weight applied at a radius 'r'.

B**.** **Rope brake Dynamometer:-** It is a simple device for measuring b.p. of an engine.

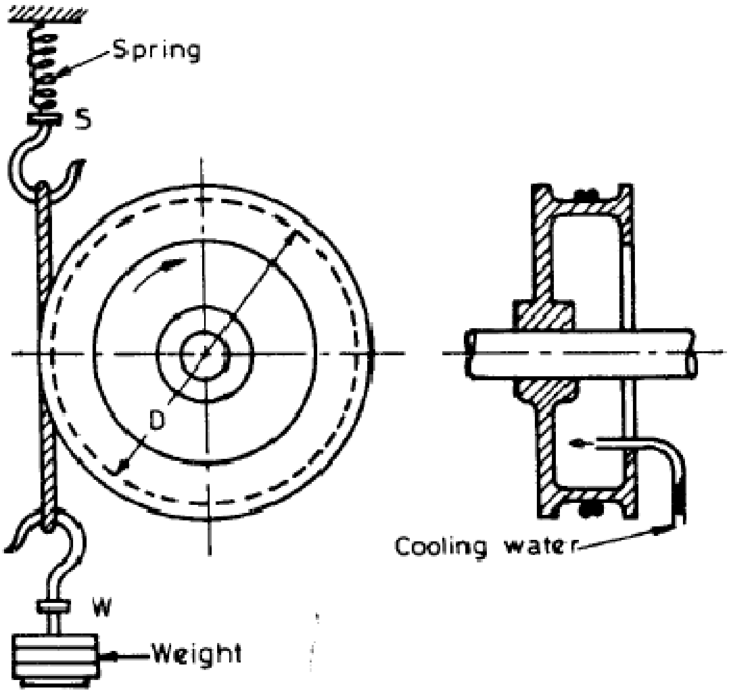


Figure – Rope brake

It consists of a number of turns of rope wound around the rotating drum attached to the output shaft. One side of the rope is connected to a spring balance and other to a loading device. The power is absorbed in friction between the rope and the drum. Hence the drum requires cooling. It is cheap and easily constructed but it is not accurate.

b.p = πDN(W-S)

Where; D = brake drum diameter

W = Weight

S = Spring scale Reading

C. Hydraulic Dynamometer:-

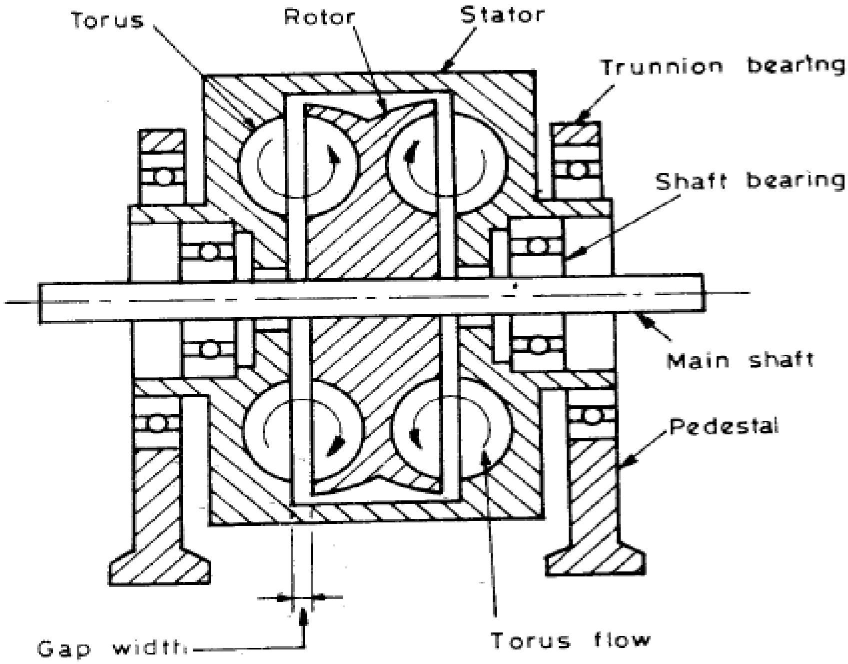


Figure - Hydraulic Dynamometer

It works on the principle of dissipating the power in fluid friction rather than in dry friction. It consists of an impeller coupled to the output shaft of the engine which rotates in a casing filled with fluid. The outer casing due to the centrifugal force developed, tends to revolve with the impeller, but is resisted by a torque arm supporting the balance weight.

The frictional forces between the impeller and the fluid are measured by the spring balance fitted on the casing.

D. Eddy Current Dynamometer:-

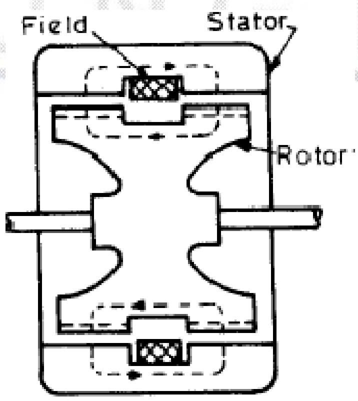


Figure – Eddy current dynamometer

It consists of a stator on which a number of electromagnets are fitted. A rotor disc made of copper (or) steel coupled to the output shaft of the engine. When the rotor rotates, eddy currents are produced in the stator due to magnetic flux. These currents oppose the rotor motion, thus loading the engine. It requires a cooling system to carry the heat dissipated.

Advantages –

1. High horse power per unit weight of dynamometer.
2. Development of eddy current is smooth and hence the torque is also smooth.
3. No limit to size.

E. Swinging field D.C. Dynamometers:-

It is a D.C. shunt motor so supported on trunnion bearings to measure the reaction torque. The outer case and field coils tend to rotate with the magnetic drag. Hence the name is "swinging field". The torque is measured with an arm and weight in the usual manner.

It is reversible, i.e. works as an absorption dynamometer as well as motoring device.

The load is controlled by changing the fields current.

F. Fan Dynamometer:-

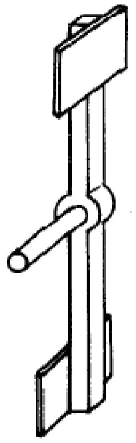


Figure – Fan Dynamometer

This is an absorption type of dynamometer. When it is driven by the engine, absorbs the power. It is mainly for rough testing. The accuracy is very poor. It is quite difficult to adjust the load. The power is measured is normal manner.

2. Transmission Dynamometers:-

The power is transmitted to the load, coupled to the engine after it is indicated on some type of scale. These are also called "Torque – meters".

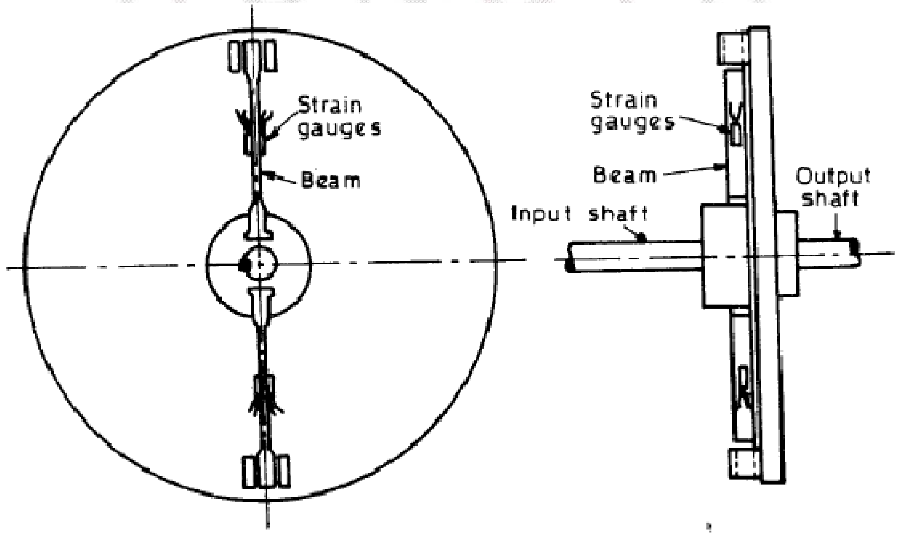


Figure – Transmission Dynamometer

It consists of a set of strain gauges fixed on the rotating shaft and the torque is measured by the angular deformation of the shaft which is indicated by strain gauge.

These are very accurate and are used where continuous transmission of load is necessary. They are used mainly in automatic units.

**Measurement of Friction Power –

The power required to overcome the resistance offered by all the moving parts of an engine is called Friction Power.

Friction has a dominating effect on the performance of an engine. The difference between a good engine and a bad engine is due to difference between their frictional losses. These losses are finally dissipated to the cooling system (and exhaust). Lower the friction power higher the brake power, hence brake specific fuel consumption is lower. The bsfc rises with an increase is speed. Hence it decides the maximum output of the engine which can be obtained economically.

The friction power of an engine is determined by the following method.

(1) Willan's Line Method:- (CSVTU)

In this method 'gross fuel consumption' Vs 'brake power' at a constant speed is plotted. The graph is extrapolated back to zero fuel consumption.

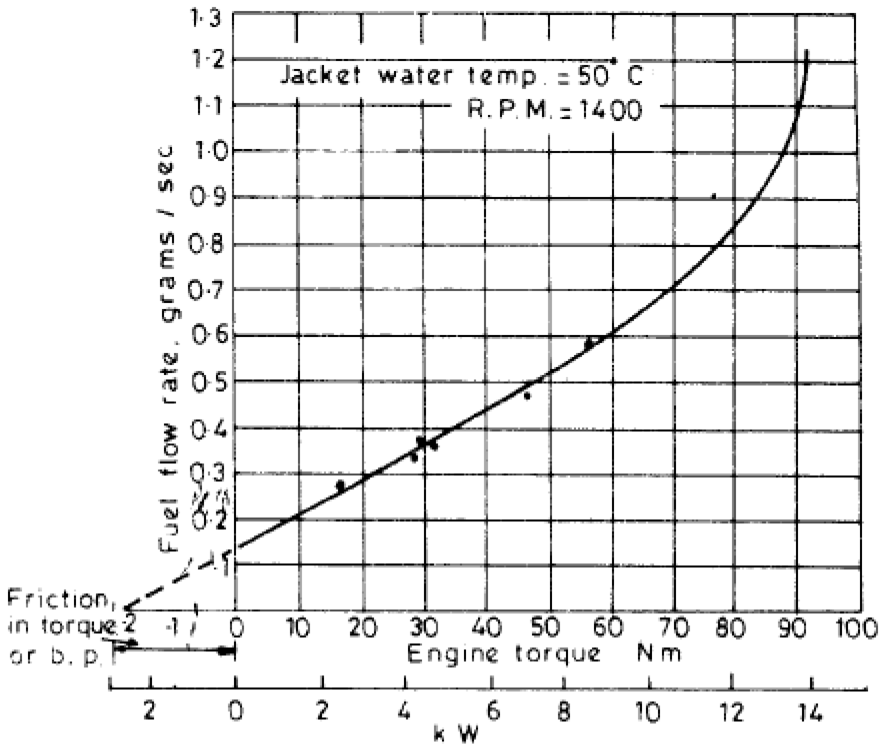


Figure – Willan's line method

The point where this graph cuts the b.p. axis is an indication of the friction power of the engine at that speed. This negative work represents the combined loss due to mechanical friction, pumping and blow by.

The test is applicable only to **compression ignition engines**. The accuracy obtained in this method is good, if extrapolation is carefully done.

The main drawback of this method is the long distance to be extrapolated.

(2) Morse Test:- (CSVTU)

It is applicable only to multi cylinder engines. The engine is first run at the required speed and the output is measured. Consider, a four cylinder engine, and then the total brake power is given –

$$BP = BP_1+BP_2+BP_3+BP_4$$

$$BP_{1234} = (IP_1 - FP_1) + (IP_2 - FP_2) + (IP_3 - FP_3) + (IP_4 - FP_4) \quad \Rightarrow \quad (1)$$

Then one cylinder is cut out by disconnecting the spark plug in case of S.I. Engines or by disconnecting the injector in case of C.I. Engine. Let the cylinder is 1 then IP of cylinder one is '0'. But frictional power of cylinder one remains same. Then

$$BP_{234} = (0 - FP_1) + (IP_2 - FP_2) + (IP_3 - FP_3) + (IP_4 - FP_4) \quad \Rightarrow \quad (2)$$

(1) – (2)

$$BP_{1234} - BP_{234} = IP_1$$

If cylinder No. – 2 is cut off; then

$$BP_{134} = (IP_1 - FP_1) + (0 - FP_2) + (IP_3 - FP_3) + (IP_4 - FP_4)$$

Then $BP_{1234} - BP_{134} = IP_2$

If cylinder No. – 3 is cut off; then

$$BP_{124} = (IP_1 - FP_1) + (IP_2 - FP_2) + (0 - FP_3) + (IP_4 - FP_4)$$

Then $BP_{1234} - BP_{124} = IP_3$

If cylinder No. – 4 is cut off; then

$$BP_{123} = (IP_1 - FP_1) + (IP_2 - FP_2) + (IP_3 - FP_3) + (0 - FP_4)$$

Then $BP_{1234} - BP_{123} = IP_4$

Hence $IP_{1234} = IP_1 + IP_2 + IP_3 + IP_4$

Then $(FP)_{Total} = IP_{1234} - BP_{1234}$

It gives reasonable accurate results if there are no changes in mixture and other conditions.

Assumptions made in this test: 1) It is assumed that pumping power and friction losses are the same when the cylinder is inoperative as well as during firing. 2) The mixture distribution is uniform and remains same when cylinder is inoperative. iii) The combustion is complete during the trials of an engine during conducting Morse test.

Precautions: i) The speed of the engine should be maintained constant during the test. ii) It is to be ckecked that spark plug is properly removed (disconnected) in case of SI engine and fuel cut of for the injector of that particular inoperative cylinder.

(3) Motoring Test –

In this test, the engine is first run up to the desired speed by its own power and allowed to remain for some time so that oil, water and engine components reach stable conditions. The power of the engine is absorbed by a "Swinging field D.C. dynamometer".

The fuel supply is then cut off and by electric switching devices the dynamometer is converted to run as a motor to drive the engine at the same speed at which it was previously running. The power required for the above is measure of the frictional power of the engine.

This method gives reasonably good results and is very suitable for finding the losses of friction.

(4) Difference between i.p. and b.p. –

The method of finding the frictional power by finding the difference between indicated power (i.p.) [which is obtained from an indicator diagram] and brake power (bp) [which measured by a dynamometer] is ideal one.

This is mainly used in research laboratories.

F.p. = i.p. – b.p.

Measurement of Indicated Power (i. p.):–

The following methods are used to find I. P.

(1) By taking an indicator diagram with the help of a suitable Engine indicator.

Indicator Diagram :- The devices which measures the variation of pressure in the cylinder over a part of full cycle is called "indicator" and the plot of such information obtained is called an "indicator diagram".

It is the only intermediate record available in the account of total energy liberated before it is measured at the output shaft. Hence it gives a very good indication of the process converting heat into mechanical work. A great insight can be obtained into combustion phenomenon and its associated factors such as rate of pressure rise, ignition lag etc. by its analysis. It is also used to study engine combustion, detonation, tuning of inlet and exhaust manifolds, etc.

There are two types of indicator diagrams –

(a) Pressure – Volume (P – V) plot
(b) Pressure – Crank angle (P – Ø) plot

Performance of S.I. Engine

The performance of an engine is generally given by **heat balance sheet**. The main components of the heat balance are (i) heat equivalent to the effective **(brake) power** of the engine (ii) heat rejected to the cooling medium (iii) Heat carried away from the engine by the exhaust gases and (iv) unaccounted losses. Radiation losses from the various parts and heat loss due to incomplete combustion.

Note: The **friction losses** are not shown as a separate item in the heat balance sheet because these losses finally reappear as heat **in cooling water.**

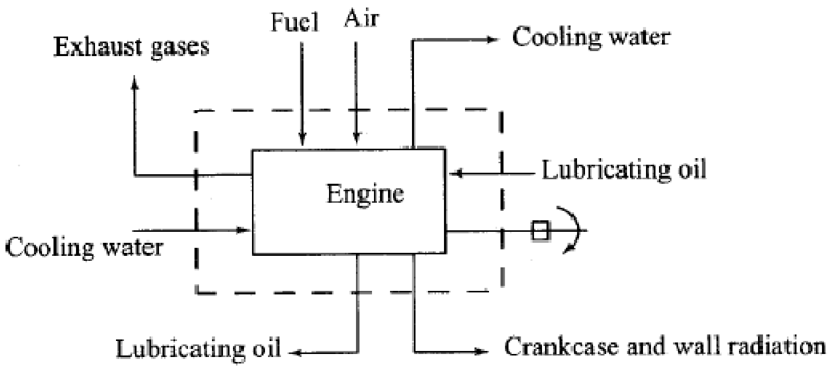


Fig. External Heat Balance

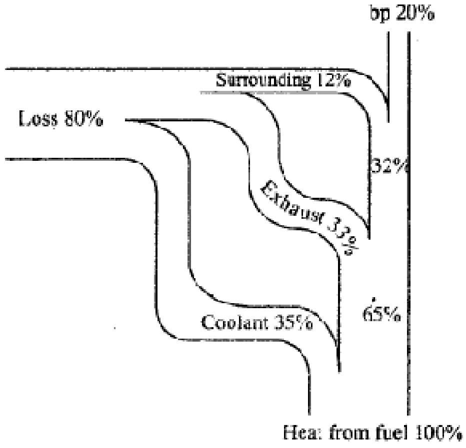


Fig. Energy Balance Diagram

Heat Balance Vs Speed

In S.I. Engines, the **loss due to incomplete combustion** is included in unaccounted losses, can be rather high.

For a rich mixture (A/F =12.5 to 13) it (losses due to incomplete combustion) could be 20%.

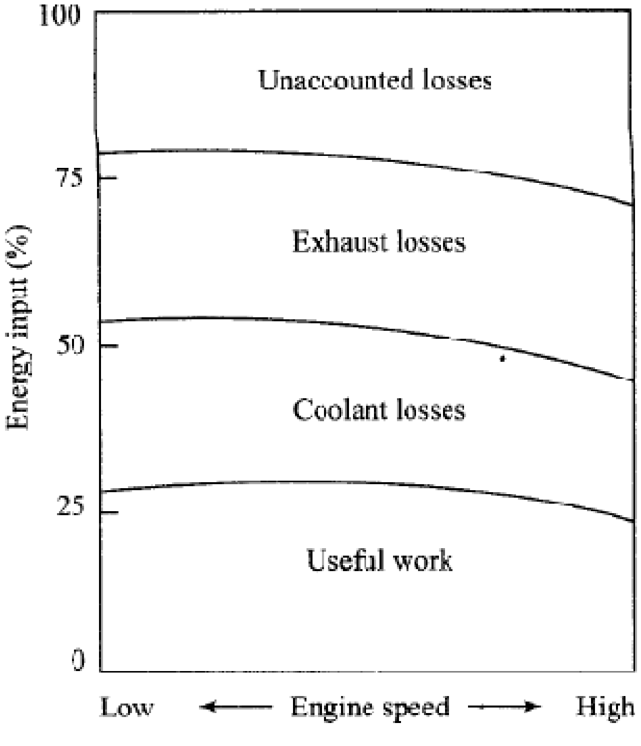


Fig. Heat Balance Diagram for a Typical SI Engine

Torque, ip, bp and F.p. Vs speed. (Full throttle and variable load & variable speed:

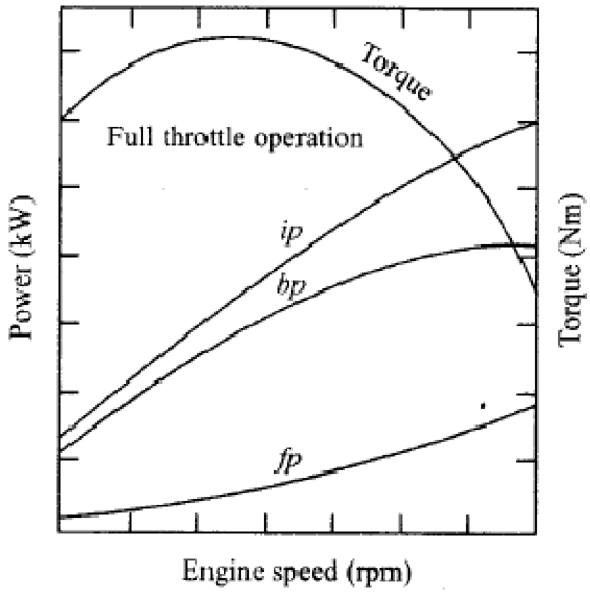


Fig. Typical SI Engine Performance Curves

At low engine speeds the f.p. is relatively low and b.p. is nearly as large as ip. As speed increases, f.p. increases at a greater rate.

At engine speeds above the usual operating range f.p. increases vary rapidly. Also at these higher speeds i.p. will reach a maximum and then fall off.

At some point, i.p. and f.p. will be equal and b.p. will then drop to zero.

The Torque reaches a maximum at approximately 80% of the rated rpm of the engine, while the i.p. has not reached maximum even at the rated speed.

Fuel consumption and b.s.f.c.(Vs) Engine Speed. [Same engine operating at same conditions:

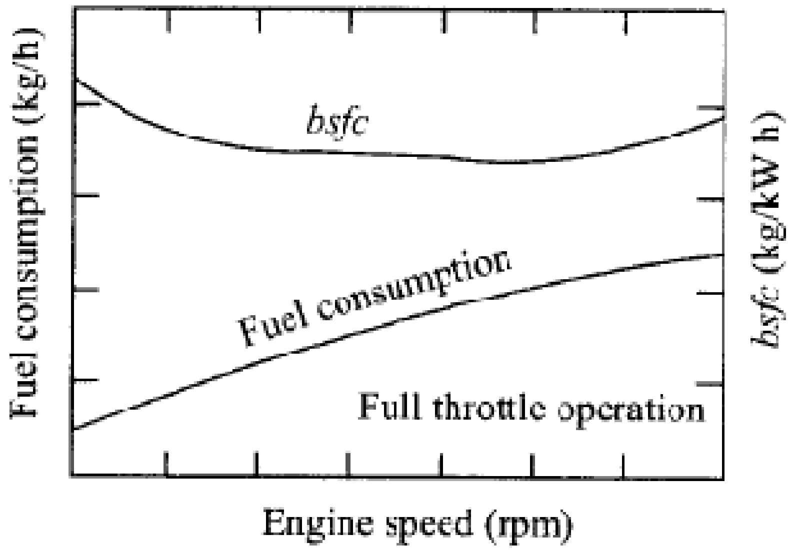


Fig. Typical Fuel Consumption Curves for an SI Engine

[Full throttle, variable speed]

The quantity of fuel consumed increases with engine speed. The bsfc on the other hand drops as speed increased in low speed range, nearly level off at medium speeds and increases in the high speed range.

At low speeds, the heat losses are greater and combustion efficiency is poorer, resulting in higher fuel consumption for the power produced.

At high speeds, the f.p. is increasing at a rapid rate resulting in a slower increase in b.p. than in fuel consumption with a consequent increase in bsfc.

Bsfc Curve at Constant Speed and Variable Load:

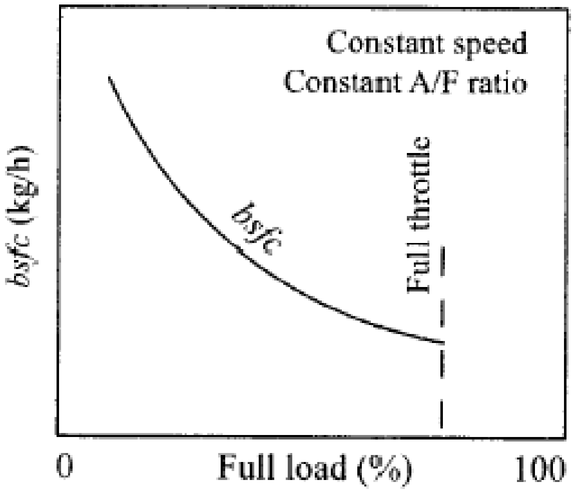


Fig. bsfc Curve at Constant Speed and Variable Load

At the constant speed and variable load and at a constant air fuel ratio, the bsfc will rise consistently and rapidly as the load is decreased. [Reduction in throttle opening]

The reason is that the f.p. remains essentially constant, while the i.p. is being reduced. The b.p. drops more rapidly than fuel consumption and thereby the bsfc rises.

Efficiencies and Specific Fuel Consumption (Vs) Speed [Full Throttle]

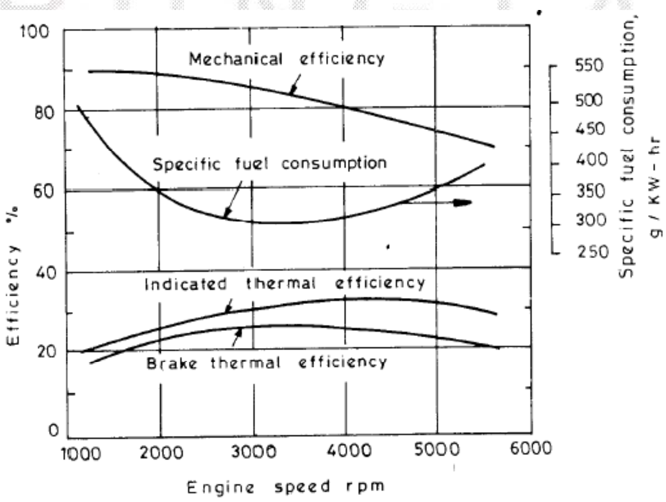


Fig. Efficiency and specific fuel consumption vs. speed for a petrol engine at full throttle

i. As the speed increases, the brake thermal efficiency increases to a maximum value and then decreases with speed.

ii. As the speed increases, the indicated thermal efficiency increases to a maximum value and then decreases.

iii. As the speed increases, the mechanical efficiency decreases.

iv. As the speed increases; the bsfc decreases to a minimum value and then increases.

Isfc, bsfc and mechanical efficiency (Vs) Variable Speed

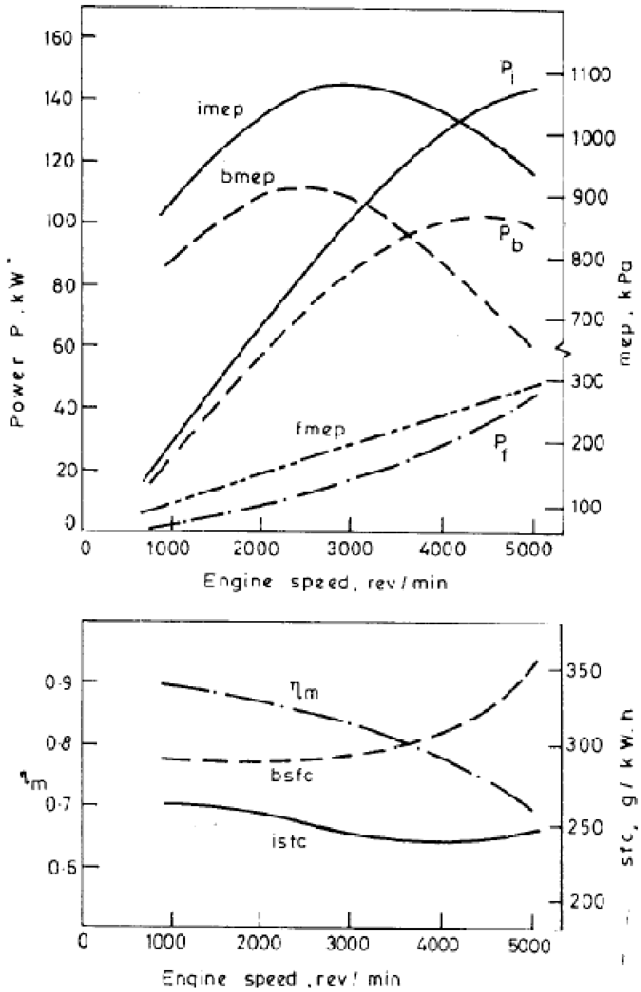


Fig. Variable speed test of automotive SI engine at full throttle (CR = 9)

i. As the speed increases, the mechanical efficiency decreases.
ii. As the speed increases; the isfc reaches to a minimum value and then increases.

C.I. Engines – Performance Curves:

i) Heat Balance (Vs) Speed –

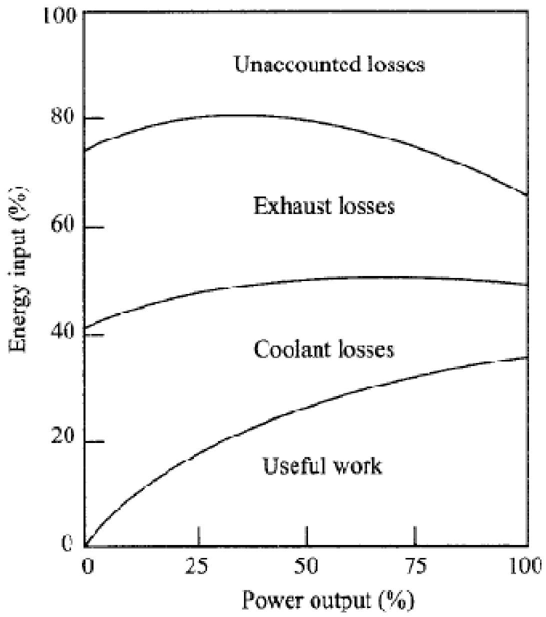


Fig. Heat Balance Diagram for a Typical CI Engine

ii) Indicated Pressure (Pi), Brake pressure (Pb), imep, bmep, istc, bsfc Vs Speed. (Variable Speed)

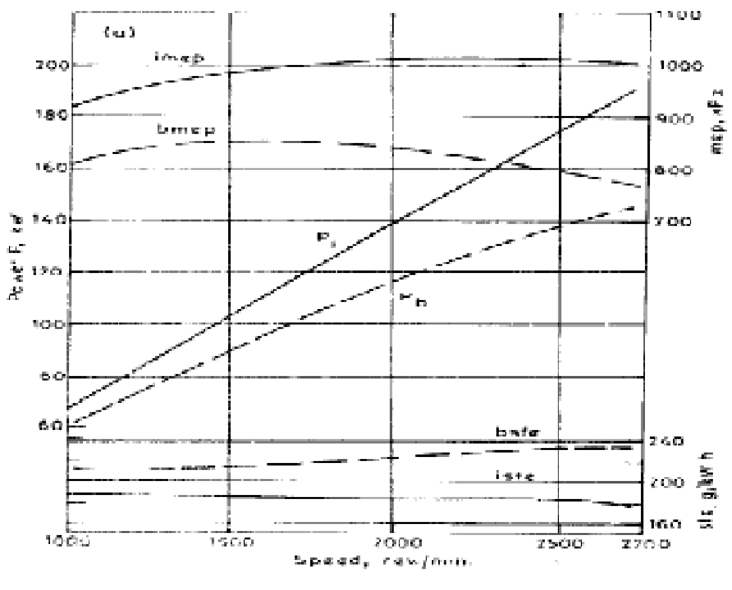


Fig. Gross indicated and brake power (P_i,P_b), mean effective pressure (imep, bmep), and specific fuel consumption (isfc,bsfc) for : 8.4-dm six-cylinder naturally aspirated direct-injection diesel engine : bore = 11.5 mm, stroke = 135 mm, r_c = 16[3]

(a) As the speed increases, the i.p. (Pi) increases.
(b) As the speed increases, the bp (Pb) increases.
(c) As the speed increases, the imcp increases and then decreases.
(d) As the speed increases, the bmcp increases to a maximum value and then decreases.
(e) The bsfc is low through most of speed range.

iii) Torque; bsfc; bmep; bhp (Vs) Speed (Variable Speed) –

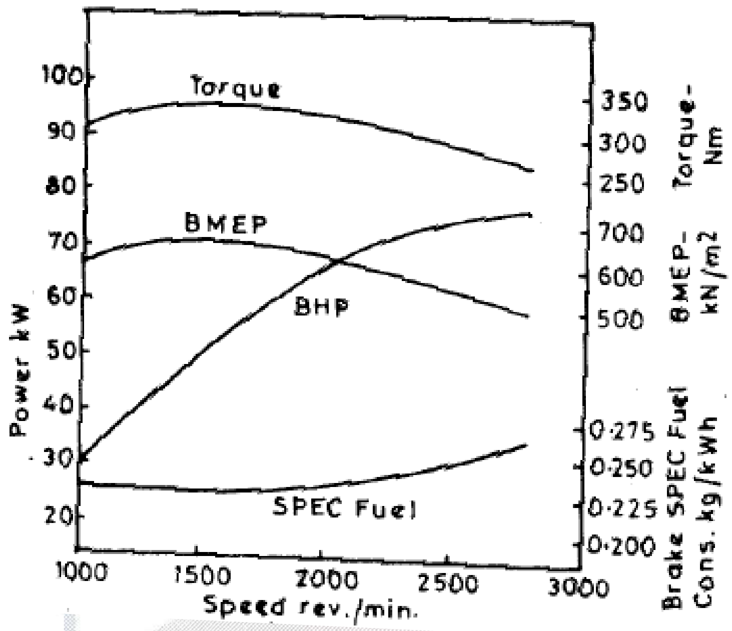


Fig. Performance curves of a diesel engine.

i. The Torque is maximum at about 70% of maximum rated speed.
ii. The bsfc is Low Through most of speed range.

iv) Torque, bp, bsfc, bmep (Vs) Load [at counst. Speed] –

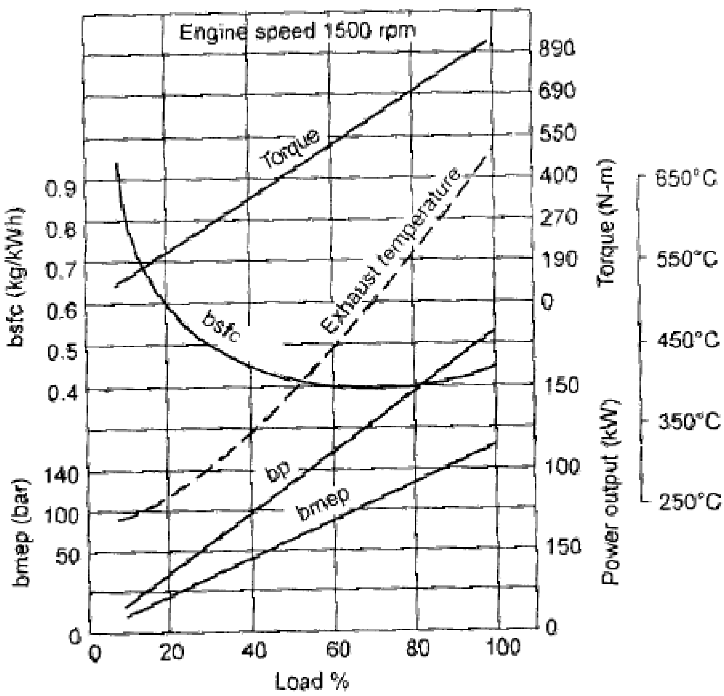


Fig. Constant Speed Test of 4-stroke CI Engine

Performance Maps –

For critical analysis the performance of an IC Engine under all conditions of load and speed is shown by a performance map.

Generally, all the engines show a region of lowest specific fuel consumption (highest efficiency0 at a relatively low piston speed with a relatively high bmcp.

S.I. Engine –

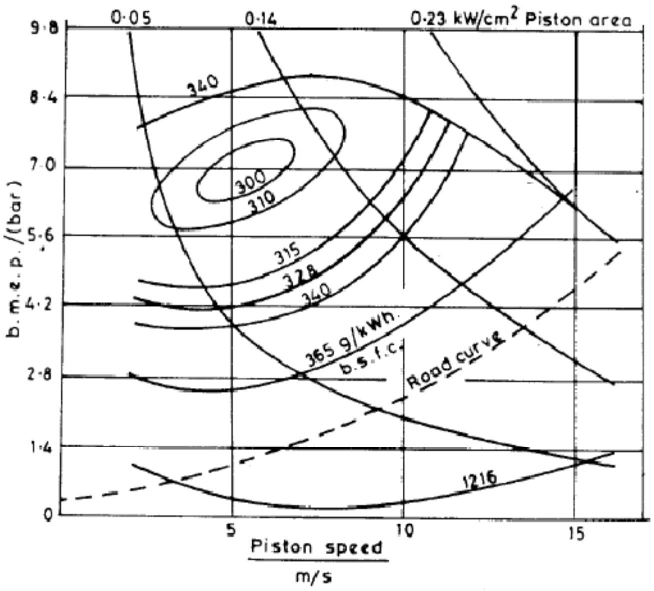


Fig. Form of performance map for a petrol engine.

Constant Speed Line – Increased bsfc is obtained by moving upward along constant speed line, because of mixture enrichment at high load which more than offsets increase in mechanical efficiency.

Moving to lower bmcp's the bsfc increases because of the reduced mechanical efficiency (imcp decreases while fmcp remains constant).

Constant bmcp line:- Moving from the region of highest efficiency along a line of constant bmcp, the bsfc increases due to increased friction at higher piston speeds.

Moving to the left towards lower piston speed, although friction mep decreases, indicated efficiency falls off owing to poor fuel distribution and increased relative heat losses.

C.I. Engine :-

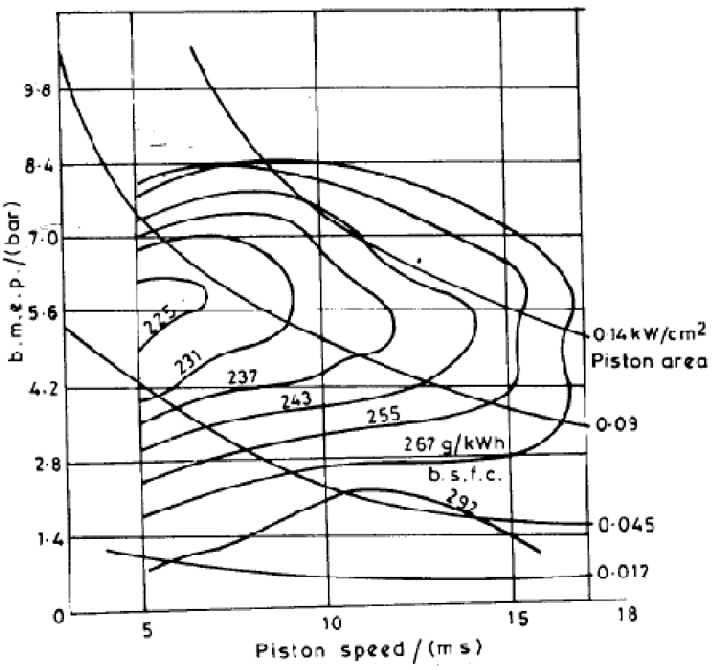


Fig. Form of Performance map for a diesel engine.

In the C.I. Engine the bsfc increases at high loads owing to the increased fuel waste (smoke) associated with high fuel air ratios.

At lower load bsfc increases due to decrease in mechanical efficiency.

UNIT – 5 (Part – 2)

Emission and Pollution

I. Exhaust Emission–

Air Pollution:- It is defined as the unwanted addition to our atmosphere, of any material which will have a harmful effect on life upon our planet.

The main pollutants by automobiles are:-

1. Carbon monoxide
2. Un-burn Hydrocarbon
3. Oxides of Nitrogen
4. Lead

The contribution of pollutants from an I.C.E. is as follows :-

(1) **Evaporative Losses:-** Tank and Carburettor. (These occurs 15 – 25% of total automobile pollution).

(2) **Crank-case Blow-by:-** 20 – 35% Hydro-Carbon.

(3) **Through Exhaust manifold:-** 50 – 60% Hydro-Carbon. If also includes carbon-Monoxide and Nitrogen Oxide.

Evaporative Losses:– It includes fuel tank losses and carburetor losses.

Exhaust Emission:- Carbon Monoxide, Hydro-Carbon, Partial Oxidation products and oxides of Nitrogen.

How to control Emission in Petrol Engine (Gasoline Engine Emission Control):-

An Emission control program aims at reducing concentration of CO, Hydro-Carbon and Nitrogen Oxide in the exhaust. The main approaches which have been made are:-

1. Engine design modification.
2. Treatment of Exhaust Gas.
3. Fuel modification.

Engine Design Modification:-

(1) **Use of Lean Air-Fuel Ratio -** The carburettor may be modified to provide relatively lean and stable air-fuel Mixture during no load condition by which it reduces exhaust Emission.

It can be done by better manifold design, inlet air heating, and rising of coolant temperature and use of electronic fuel injection system.

(2) **Retarding Ignition Time –** Retarding ignition timing allows increase in time for fuel burning. Retarding the spark reduces Nitrogen Oxides emissions by decreasing the maximum temperature. It also reduces Hydro-Carbon emission.

(3) **Modification of Combustion Chamber Configuration to reduce drenched (wetted, soaked or saturated) Area –** Modification of combustion chamber using attempts to avoids flame drenching zones where combustion might be incomplete and resulting in high Hydro-carbon emission. This includes reduced surface-volume ratio and reduced distance of top piston ring from the top of the piston.

(4) **Lower Compression Ratio –** Lower the compression ratio reduces the drenching effect by reducing drenching area thus reducing Hydro-Carbon emission and reduces NO_x emission.

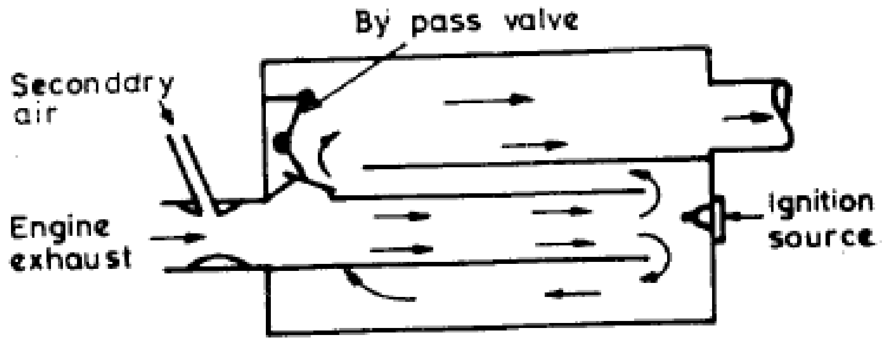
(5) **Reduced Valve Overlap –** Reducing valve overlap reduces the emission level.

(6) **Alternation in induction System –** By making proper alternation in induction system reduces the emission.

Treatment of Exhaust Gases:-

Exhaust Gases treated to reduce Hydro-Carbon, CO and NO_x.

(1) After Burner:-



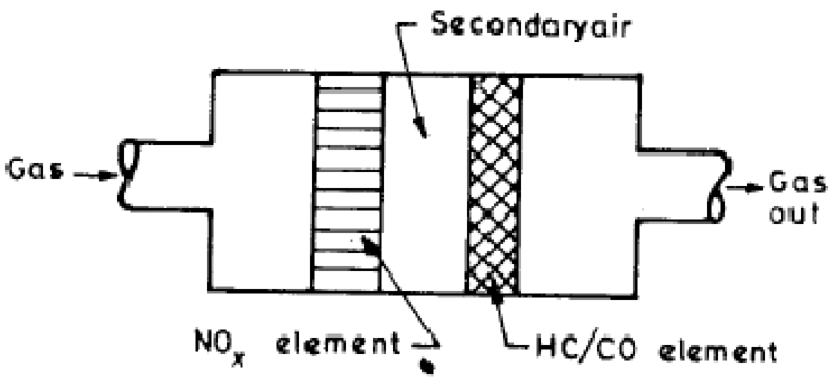
Placing on after burners is exhaust gas system while burn the practically un-burn Hydro – carbon in the emission. The Hydro – carbon and carbon – Monoxide in emission are because of insufficient Oxygen and time to burn and these are further burn by providing air in a separate box called as after burner.

It is placed very nearer to the exhaust manifold. The burning depends upon the exhaust temperature and mixing with air in the after burner.

Disadvantages:-

1. It does not have any effect on NO_x.
2. They are not successful due to high heat losses.

(2) Catalytic convertor:-



It was developed by Ford Motor. A catalytic convertor is a device which is placed in the vehicle exhaust system to reduce hydro-carbon and carbon-monoxide by **oxidizing-catalyst** and NO_x by **reducing-catalyst**. It consists of two separate elements one is for NO_x, other one is for HC/CO emission.

Oxidation Catalystic SK^n:- Carbon monoxide and Hydro–carbon in emission and Oxygen from air are catalytically converted to CO_2 and H_2O. The catalyst are platinum, Plutonium, Copper, Vanadium, Iron, Cobalt and Cronium.

Reduction Catalystic SK^n:- The primary concept is to reduce NO_x in the presence of Nickel or Copper prior to form N_2 and CO_2.

Draw backs:-

1. The SK^n are exogamic and exhaust system is hotter than the normal one.
2. If lead is present is emission, it will spoil all the catalystic SK^n. Thus the fuel must be un leaded.

Exhaust Emission Control by Fuel Variation:-

It is a well known fact that fuel – air ratios leaner than stoichiometric gives almost in-significant amount of CO and reduce HC with reduced specific fuel consumption.

Both methane and propane could burn at leaner than the gasoline at a given throttle and produce much lower CO than the gasoline.

By using propane as an engine fuel, instead of gasoline, CO emission can be reduced and also reduction in HC and NO_x. If Methane is used in place of propane then the emissions HC and CO touch zero level and only the NO_x remains as a significant factor.

Total Emission Control Packages:

These packages are used to reduce emissions of NO_x, HC and CO. They are

(1) Thermal Reactor Package [Developed by Ford] :-

A Thermal reactor is a chamber which is designed to provide sufficient residence time for appreciable homogeneous oxidation of CO and HC. The formation of CO_2 from CO can be increased by increasing the exhaust temperature.

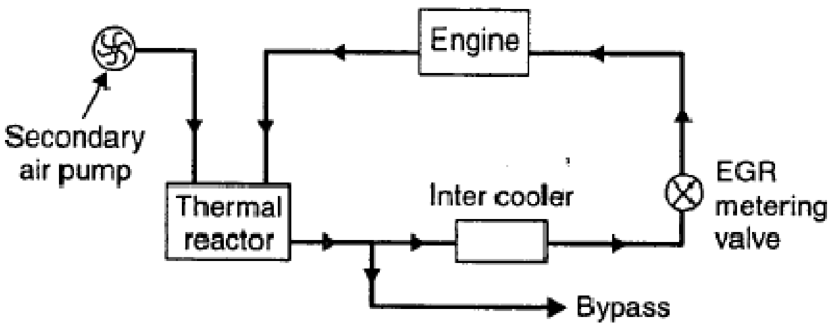


Figure - Thermal reactor package (Ford)

A Thermal reactor made of high Nickel Steel used in Car. It consists of two enlarged exhaust manifolds which allow sufficient time for burning HC and CO with Oxygen. For keeping a flame constantly burning a secondary air pump injects fresh air into the reactor this reduces HC and CO. About 10 to 75% of the gas is re-circulated after cooling in the intercooler to reduce NO_x.

* In this package emission of No_x, HC and CO are reduced to a required level but 10% more fuel consumption.

(2) Catalytic Converter Package:– This package is used to control the emission levels of various pollutants by changing the chemical characteristics of the exhaust gases. The major advantage of this is that it allows a partial decoupling of emission control from the engine operation in that the conversion efficiencies for HC and CO are very high. [EGR: Exhause gas recovery]

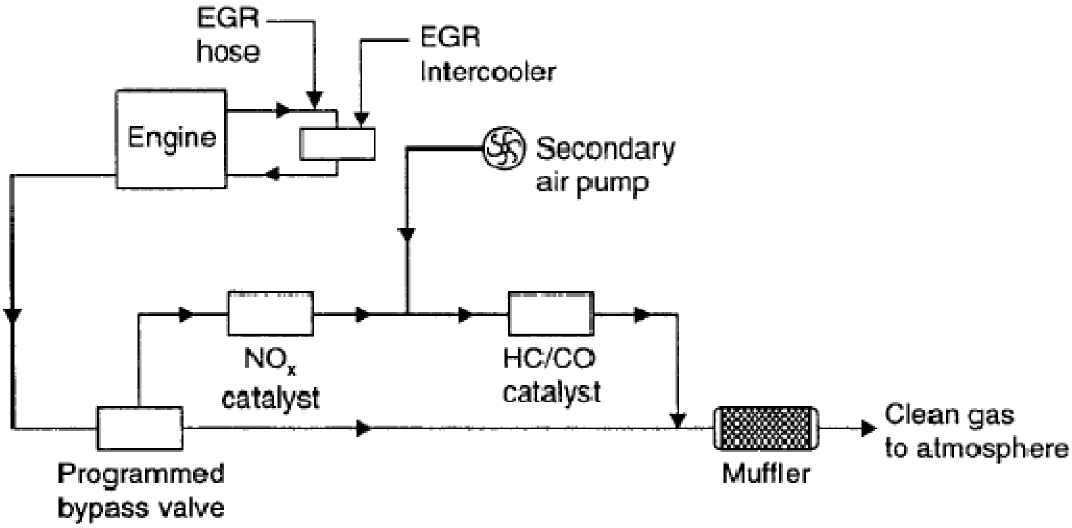


Figure – Catalytic converter package

The NO_x catalyst is the first element in the gas flow path, does not cause release of any heat. The next is HC/CO catalyst which releases heat to such a great extent that may cause overheating and burning of the element. This is taken care of by injecting air through secondary air pump.

A bypass valve ahead of converter is used to increase the converter life.

For better control of NO_x, exhaust gas is circulated via an intercooler back to air cleaner.

For this system the power loss is 30% and the fuel consumption is about 10% more than Normal.

The limitation is it requires un leaded fuel only. Leaded fuel reduces the catalytic action.

Diesel Engine Emissions and Control:-

In C.I. Engines, the fuel burnt at a relatively Fuel air ratio greater than 1.5 which produces soot. The quantity of soot formed depends on the following factors –

i. The local Fuel – Air ratio
ii. The type of fuel
iii. The pressure.

If the soot is able to find sufficient Oxygen, it will burn completely. If is there is no Oxygen, it pass as exhaust. And if the quantity is sufficient, it will be visible and that is called smoke. The colour of the smoke depends on the size of soot particles.

- Formation of smoke is basically a process of conversion of molecules of hydrocarbon fuels into particles of soot.
- Phrolysis of fuel molecules them selves is thought to be responsible for soot formation.

The smoke of a diesel engine of two types.

(1) Blue – White Smoke:- It is caused by liquid droplets of lubricating oil or fuel oil while starting from cold. At lower surrounding temperatures the combustion products are at a relative by low temperature and intermediate products of combustion do not burn. This results in bluish white smoke when exhausted.

(2) Black Smoke –

- It consists of carbon particles suspended in the exhaust gas depends upon Air – Fuel ratio.

- It increases rapidly with the increase in load.

Causes of Smoke:-

It is known that the cause of smoke is incomplete burning of fuel inside the combustion chamber. The two major reasons for incomplete combustion are –

(i) Incorrect Air – Fuel ratio
(ii) Improper mixing

These might result due to the following design factors.

(a) **Injection System:-** Unsuitable droplet size, inadequate penetration, excessive duration of injection of fuel may leads to smoke.
(b) **Rating:-** It has been observed that smoke limited power is reached much before the thermal load limited power. Thus, the smoke is unavoidable in C.I. Engine, only its level can be kept as low as possible.
(c) **Load:-** The smoke level rises from no-load to full load.
(d) **Fuel:-** More volatile fuels give less smoke.
(e) **Fuel:–** Air Ratio:- The smoke increases with the increasing fuel ration.
(f) **Engine Type and Speed:-** The smoke is very more at low and high speeds.
(g) **Maintenance:-** A good maintenance lowers the smoke level.

Control of Smoke –

Running the engine at lower loads and a good maintenance reduces the smoke level.

The Other methods used to control of smoke.

i. Smoke Suppress out Additives:- Addition of some barium compounds in fuel reduces the soot.
ii. Fumigation:- It is a method of introducing small amount of fuel with the intake manifold. This reduces the chemical delay which reduces the soot formation.
iii. Catalytic Mufflers:- The use of catalytic mufflers are not effective.

Diesel odour and control –

The partial oxidation of products are the main cause of odour in diesel exhaust.

The following factors affect odour production –

1. Fuel - Air ratio
2. Engine operation mode.
3. Engine type
4. Fuel consumption
5. Odour suppressant additives

Control of Odour –

1. Use of additives [but having less effect on control of odour]
2. Use of catalysts reduces the intensity of odour.

Comparison of Gasoline and Diesel Emissions –

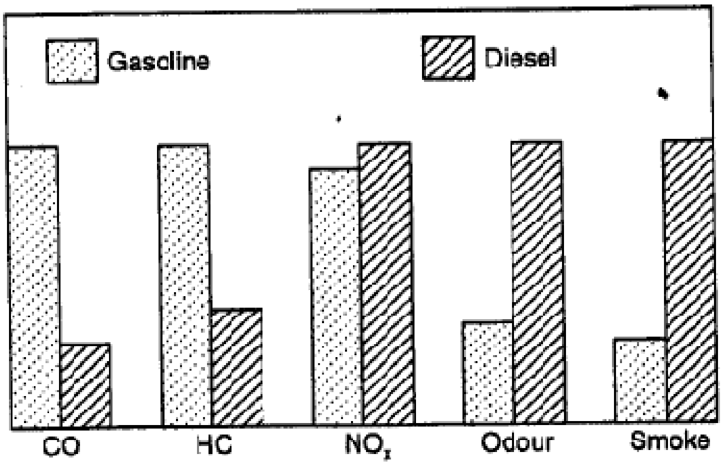


Figure - Comparison of emissions and odour from gasoline and diesel engines.

The petrol Engines have a similar emission pattern. All the diesel engines have different emission characteristics. In order to account for various difference in the design operation principles of petrol and diesel, the following correction factors is applied for comparison.

Correction factor = 15(% CO_2 + % CO + %C)

If the diesel engines are maintained properly, they have very little CO in their exhaust and a small quantity of smoke.

S.I. Engine exhaust have significant amount of CO and un-burnt Hydro Carbon (UBHC).

Effects of Engine Emissions on Human Health –

1. **Sulphur Dioxide (SO_2):-** It is an irritant gas. In the presence of water vapour it forms Sulphurrus and Sulphuric acids. These acids cause severe broncho sparma at very low levels of concentration. Diseases like bronchitis and asthma may prone at higher levels of concentration.
2. **Carbon – Monoxide (CO):-** It has a strong affinity for combining with the hemoglobin of the blood to form carboxy-hemoglobin. This reduces the ability of hemoglobin to carry oxygen to the blood.

   It affects the central nervous system.

   It is also responsible for heart attacks.
3. **Oxides of nitrogen (NOx):-** It may cause eye and Nasal irritation. It also aggravates dieses like bronchitis & Asthma.
4. **Hydro carbon Vapours:-** They are primarily irritating. They may also cause eye and respiratory irritation.
5. **Compounds of Incomplete Combustion:-** These compounds acts as carcinogenic agents and are responsible for lung cancer.
6. **Load:-** It may cause a variety of health disorder. It may cause liver, kidney damage and also leads to abnormality is pregnancy etc.
7. **Smoke:-** It causes irritation of eyes and lungs. It also causes other respiratory diseases.