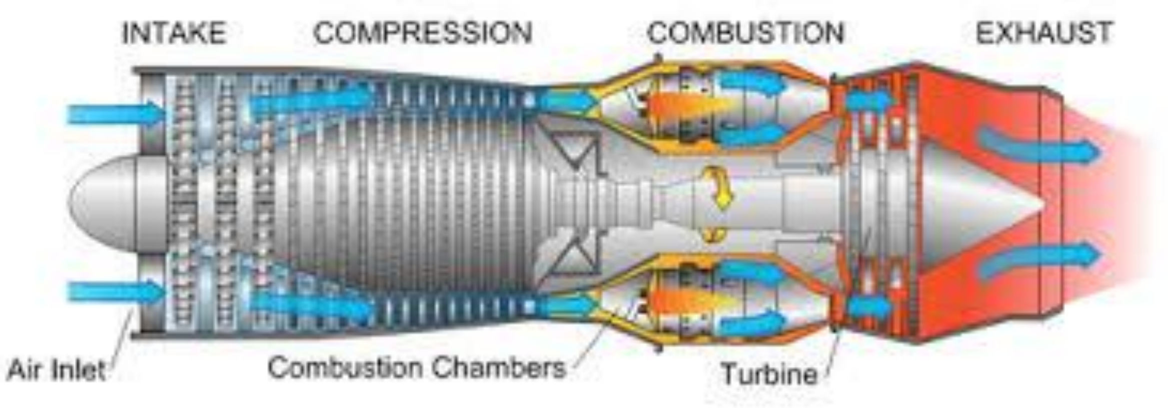
TIKRIT UNIVERSITY

COLLEGE OF ENGINEERING

MECHNICAL DEPARTMENT

INTERNAL COMBUSTION ENGINE



Lecture One

IC Engine Testing

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❑Why an engine needs a test?

✓ To find out performance before mass production and fitting it into a vehicle.

✓ To improve the design and configuration, to integrate new materials and technology.

❖ **Historically, the test basically was to find out the power and fuel consumption, also to test effectiveness of cooling, vibration and noise, lubrication, controllability, etc.**

❖ **Modern regulations force engines to reduce harmful emission and comply stringent regulations, therefore, test is getting more and more sophisticated.**

$$Q_{in} = \dot{m}_f \times LHV \times \eta_c$$

$$Q_{cool} = \dot{m}_w \times Cp_w \times (T_{w,out,eng} - T_{w,in,eng})$$

$$\dot{m}_{exh} = \dot{m}_f + \dot{m}_{air}$$

$$Q_{exh} = \dot{m}_{exh} \times c_{p,exh} \times (T_{exh} - T_{amp})$$

$$Q_{uncont.} = Q_{in} - (\dot{W}_b + Q_{cool} + Q_{exh})$$

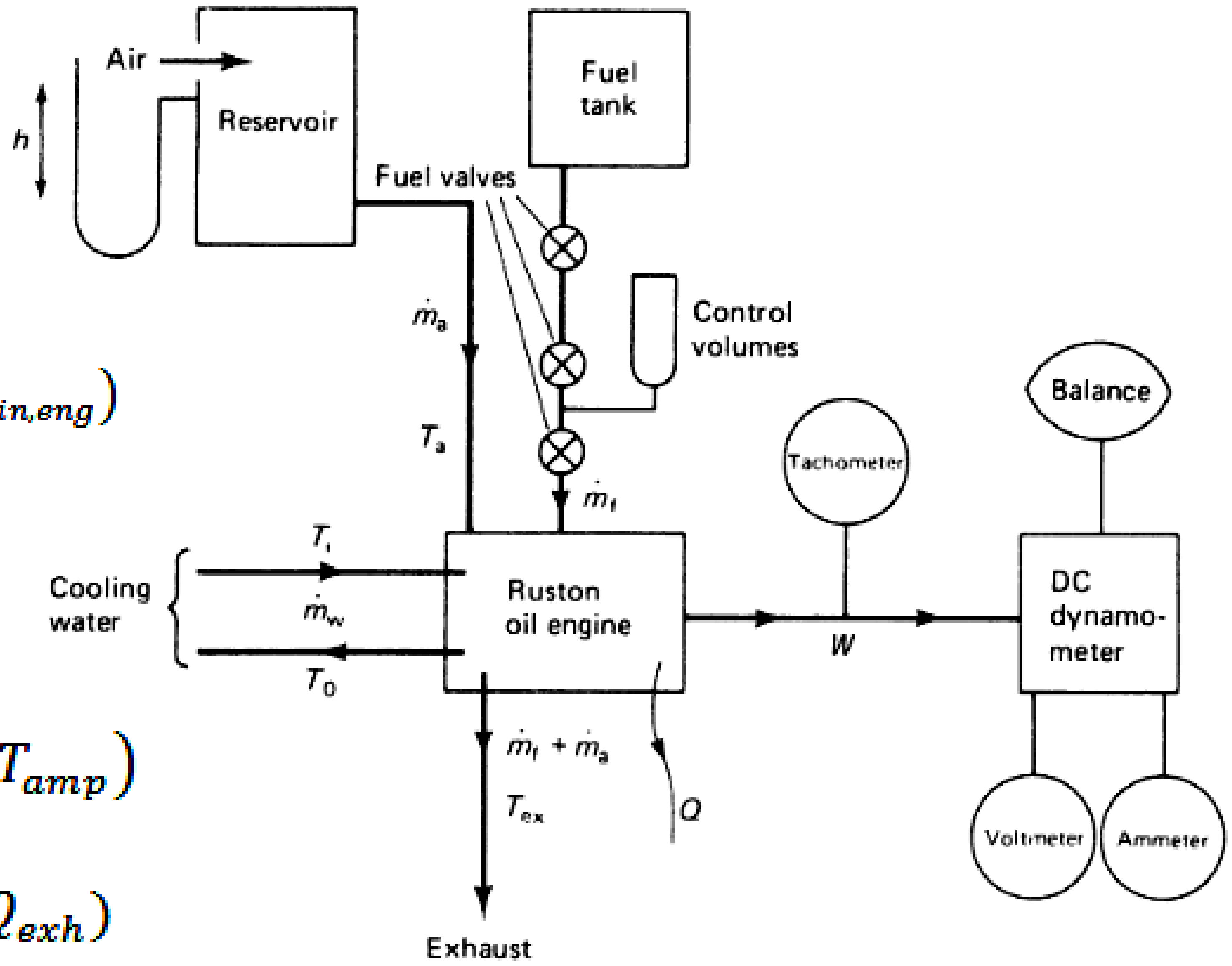


Figure: Schematic test arrangement for a Ruston Oil Engine.

Review of Performance IC Engine Parameters

Basic measuremen

Basic measurements to be undertaken to evaluate the performance of an engine are as follows:

- ❑ Speed
- ❑ Fuel consumption
- ❑ Air consumption
- ❑ Brake horse-power
- ❑ friction horse power
- ❑ Indicated horse power and
- ❑ Heat balance sheet or performance of SI and CI engine
- ❑ Smoke density
- ❑ Exhaust gas analysis

1. Measurement of speed:

The best method of speed measurement is to count the number of revolution in a given time. A mechanical tachometer, digital tachometer and an electrical tachometer is used for measuring the speed.

Fig: Analog Tachometer

Fig: LED digital Tachometer

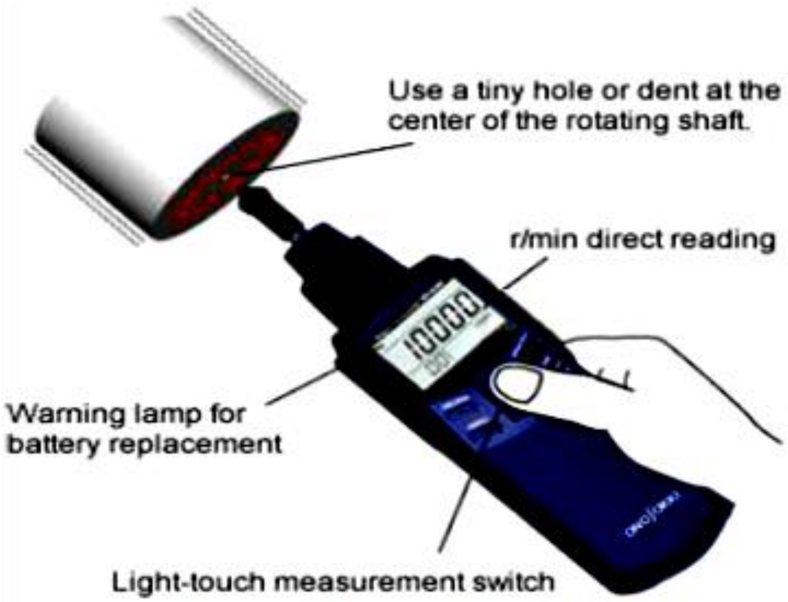
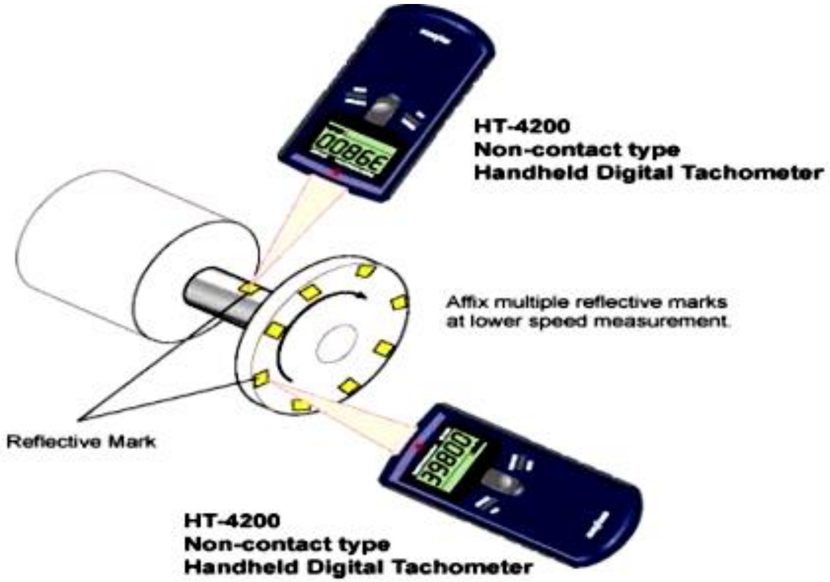


Fig: Contact type digital tachometer

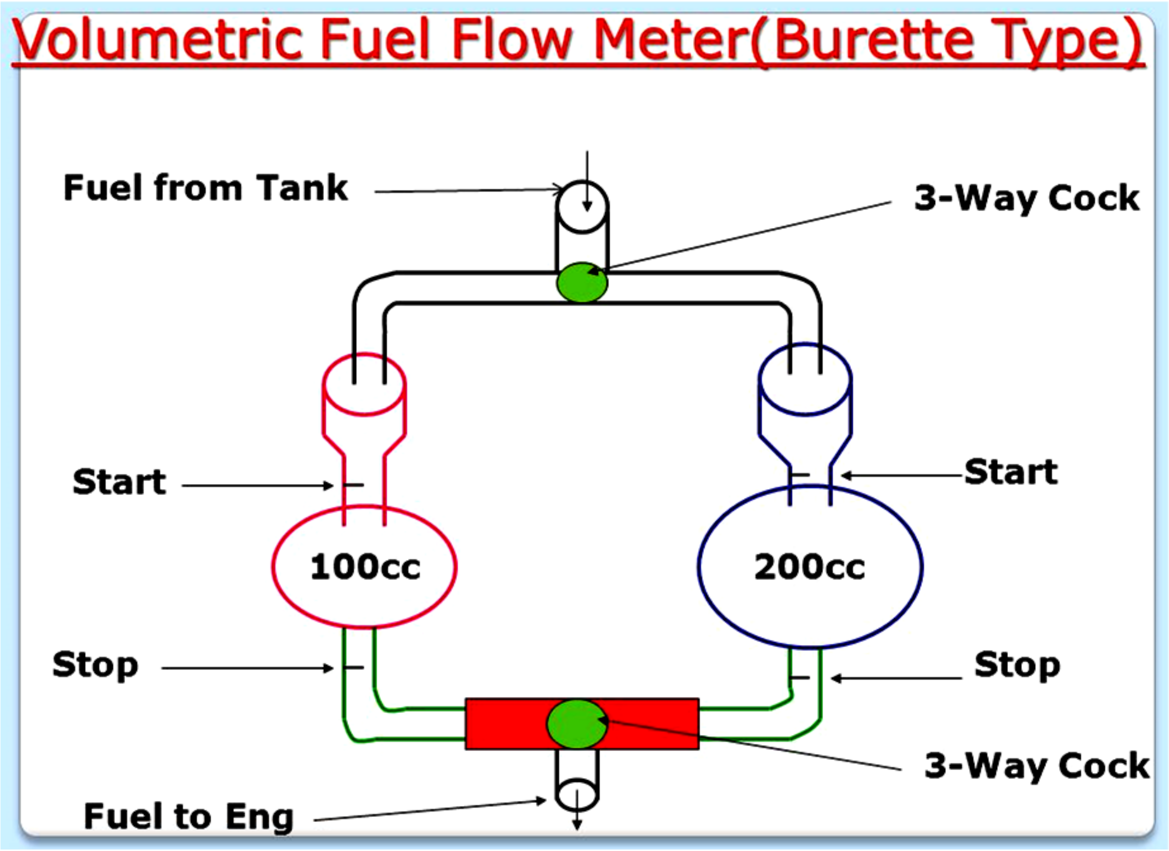


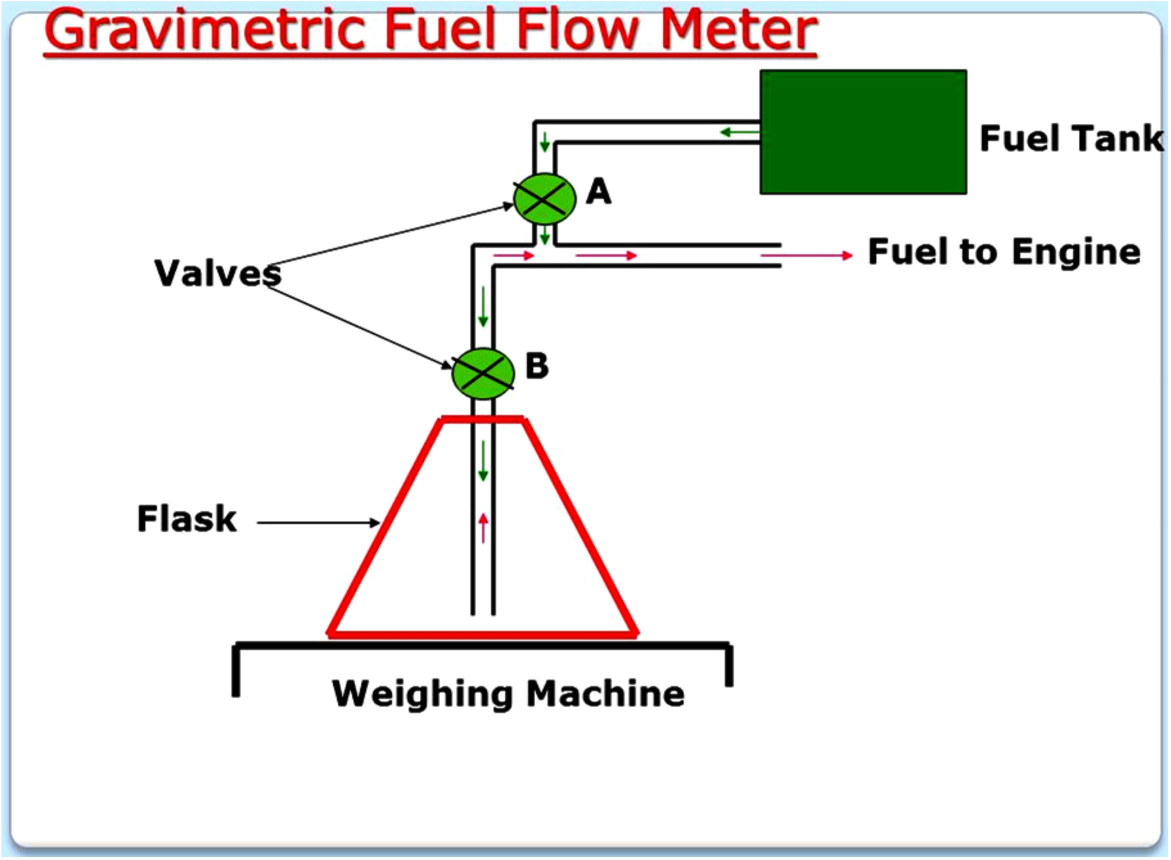
2. Fuel Consumption Measurement

Fuel consumption is measured in two ways :

(a) Volumetric type: The fuel consumption of an engine is measured by determining the volume flow in a given time interval and multiplying it by the specific gravity of the fuel which should be measured occasionally to get an accurate value.

(b) Gravimetric type: Another method is to measure the time required for consumption of a given mass of fuel.





3. Measurement of Air Consumption

The methods and meters used for air flow measurement include

$$\dot{m}_{air} = C_d \times \rho_{air} \times V_{air} \times A_o$$

(a) Air box method

(b) Viscous-flow air meter.

(a) Air box method

An air flow meter is a device that measures air flow, i.e. how much air is flowing through engine. In this method, the intake air is drawn from large tank and measurement of air flow into the intake is perfumed using a calibrated orifice or a flow nozzle. The flow is proportional to the square root of the pressure difference.

$$\dot{m}_{air} = C_d \times \rho_{air} \sqrt{\frac{2 \times \rho_m \times g \times \Delta h_m}{\rho_{air}}} \times \frac{\pi}{4} d_o^2$$

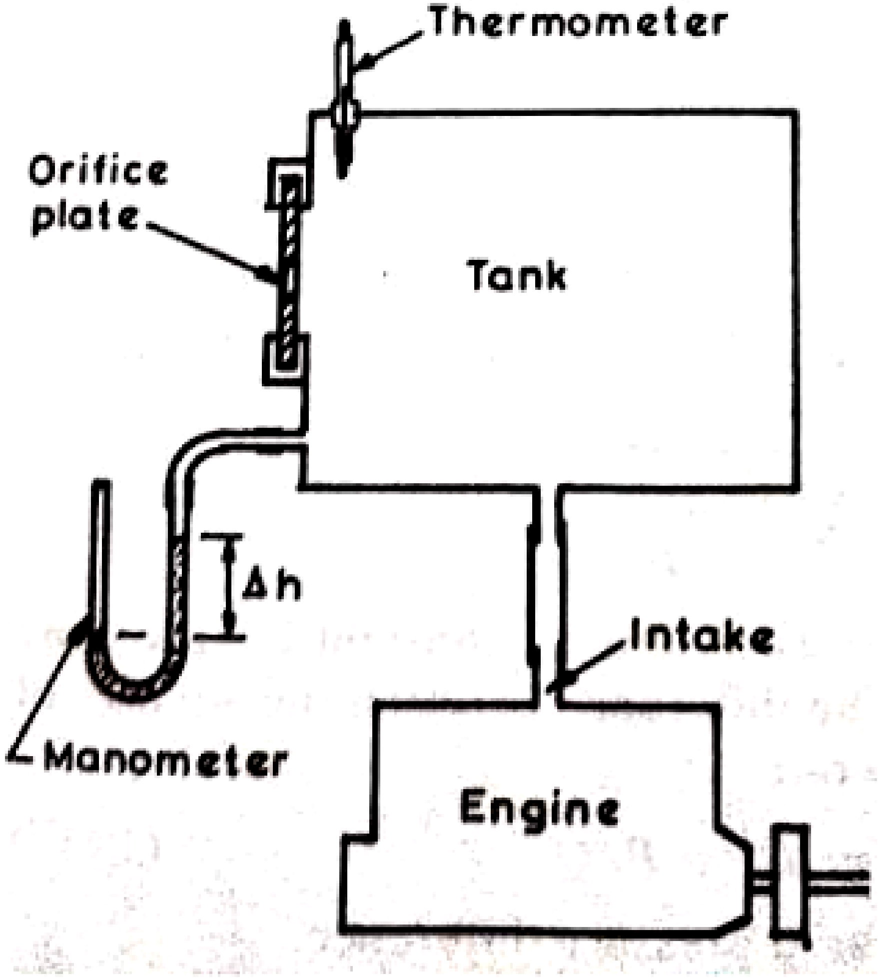


Fig: air box method

(b) Viscous-flow air meter

This meter is used where viscous resistance is the principal sources of pressure loss and kinetic effects are small.

Advantage: large range of flow can be measure without pressure head being too small.

The viscous resistance directly gives a linear relationship between pressure difference and flow and is measured by manometer.

$$\dot{\forall}_{air} = k \times \Delta h_m$$

k *is* a constant for the flow meter

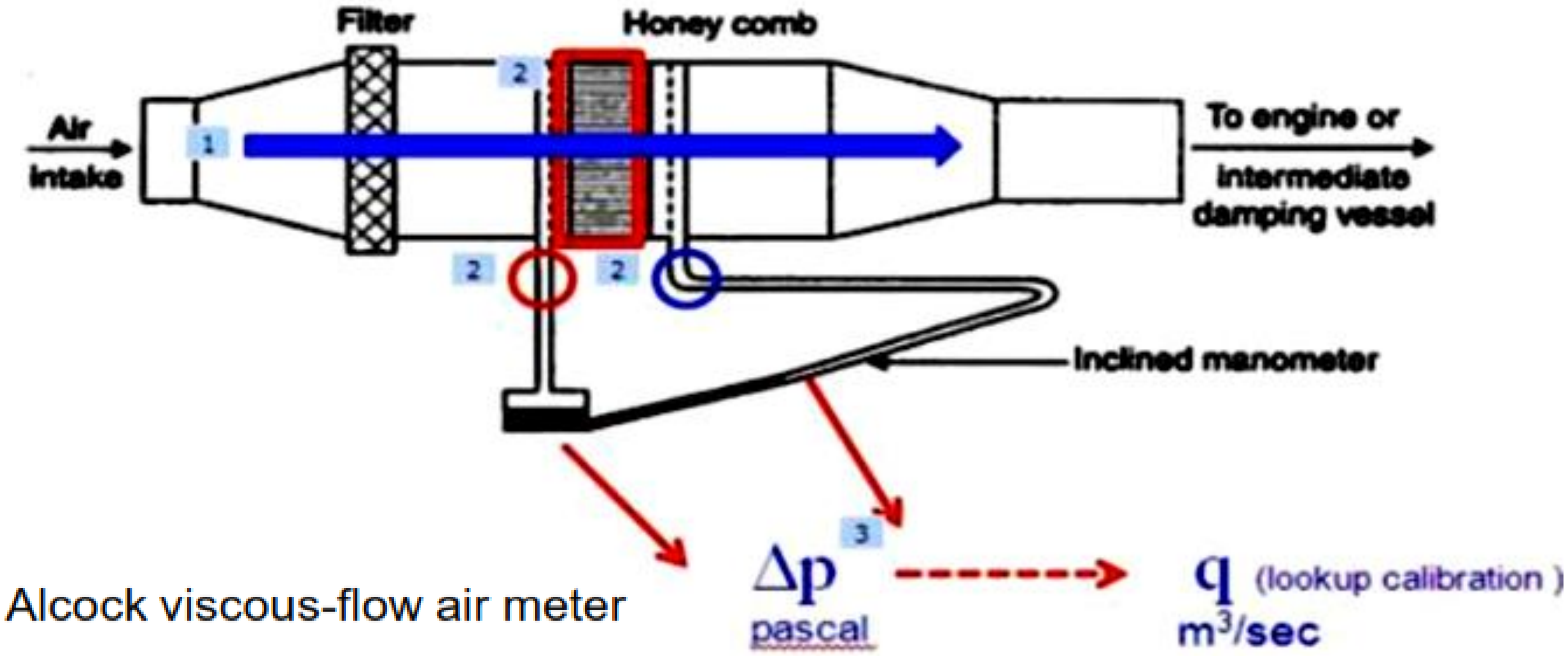


Fig: Alcock viscous-flow air meter

4. Measurement of brake power:

Brake power measurement involves the determination of the torque and the angular speed of the engine output shaft

✓ **Dynamometer**

1) **Power absorption dynamometers:** measure and absorb the power output of the engine to which they are coupled. power absorbed is usually dissipated as heat by some means. Example of such dynamometers is prony brake, rope brake, hydraulic dynamometer, etc.

2) **Transmission dynamometer:** 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.

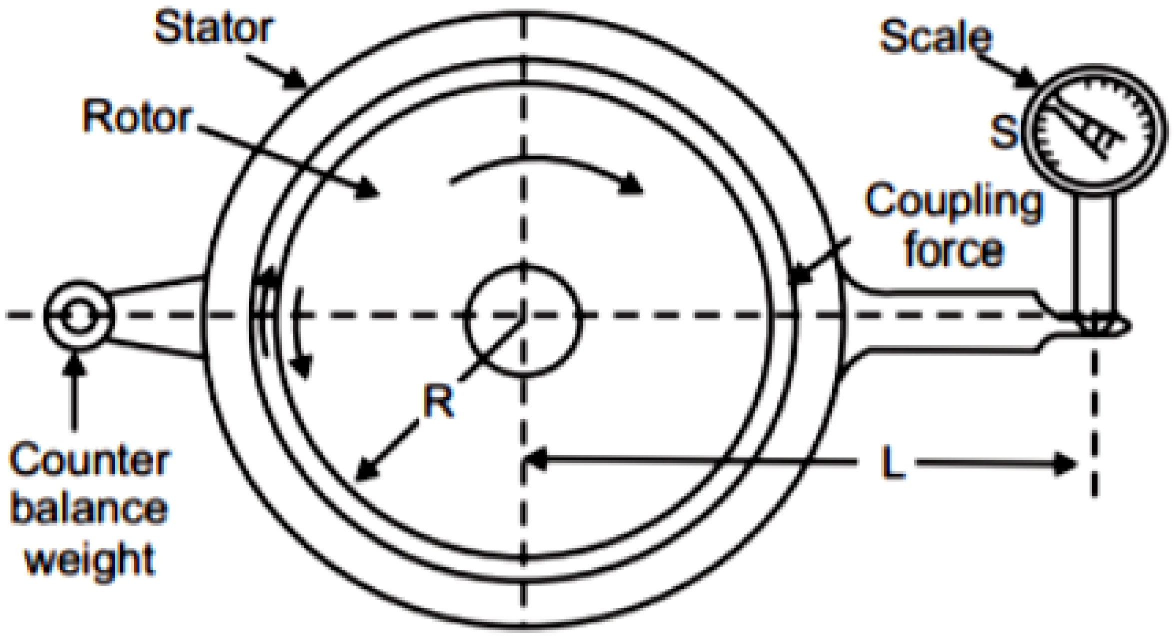
Most commonly types in the market

a) Fluid Dynamometers
b) The eddy – current Dynamometer
c) The electric dynamometer

Principle of Dynamometer Work

Figure shows the basic principle of a dynamometer. A rotor driven by the engine under test is electrically, hydraulically or 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. Hence, the work done per revolution is .

$$W = 2\pi RF$$



The external moment or torque is equal to $S \times L$ where, S is the scale reading and L is the arm. This moment balances the turning moment $R \times F$, i.e.

$$S \times L = R \times F$$

$\therefore$ Work done/revolution = $2\pi SL$

Work done/minute = $2\pi SLN$

where, N is rpm. Hence, power is given by

Brake power $P = 2\pi NT$

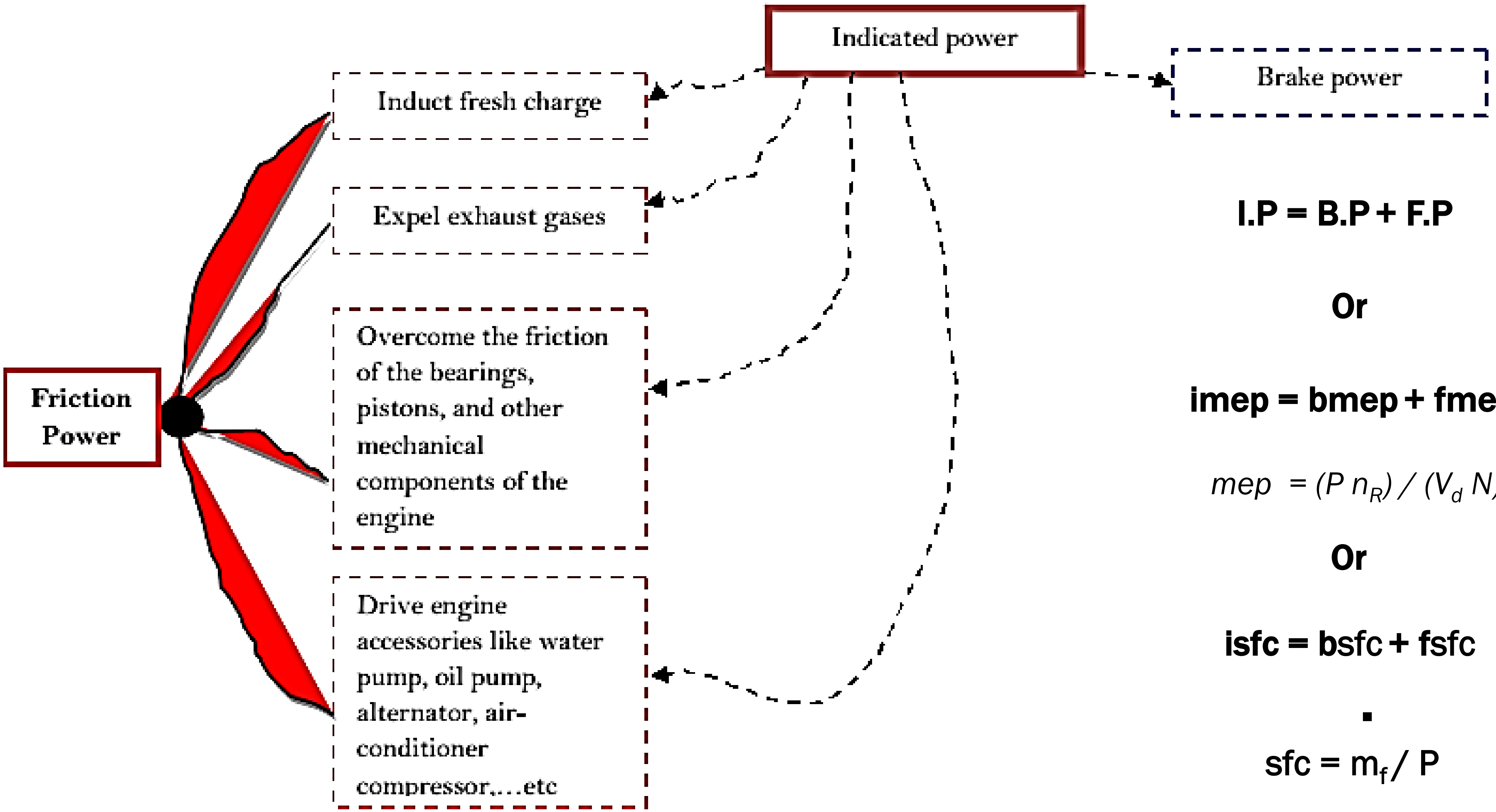
5-Measurement of engine indicated power:

There are two methods of finding the indicated power of an engine:
i-By taking the indicator diagram with the help of an indicator.
ii-By measuring b.p and f.p separately and adding the two.

i- Indicator Diagram:

The device which measures the variation of the pressure in the cylinder over the cycle is called an ***indicator*** and the plot (diagram) of such information obtained is called ***indicator diagram***. There are two types of indicator diagrams which can be taken from various indicators, these are:
1- Pressure – volume (p–v) plot.
2- Pressure – crank angle (p–θ) plot.

ii- Measuring B.P and F.P separately:



I.P = B.P + F.P

Or

imep = bmep + fmep

$$mep = (P\, n_R) / (V_d\, N)$$

Or

isfc = bsfc + fsfc

$$sfc = \dot{m}_f / P$$

6-Measurement of engine friction power:

The difference between indicated power and the brake power output of an engine is the **friction power**. The friction power is nearly constant at a given engine speed. Frictional losses are dissipated to the cooling system as they appear in the form of heat.

Methods of measuring the friction power are as follows:

i-Measurement of the i.p. and b.p. by the methods described previously for the engine at identical working conditions.

ii-Motoring test:

In this test; the engine is first run to measure the b.p at a given speed, then the fuel supply is cut-off and the dynamometer is converted to run as motor to drive the engine (motoring) at the same speed and keeping other parameters the same. The power supplied to the motor is measured which is a measure of the friction power (f.p).

The main objection to this method is that the engine is not firing, which leads to make running conditions are not similar. The pressure and temperature of cylinder contents, cylinder and piston surfaces are not the same.

iii-Morse test:

This test is only applicable to multi-cylinder engines. The engine is run at the required speed and the torque is measured. One cylinder is cut out, the speed falls because of the loss of power with one cylinder cut out, but is restored by reducing the load. The torque is measured again when the speed has reached its original value. If the values of i.p. of cylinders are denoted by I_1, I_2, I_3, and I_4(considering a four – cylinder engine), and the power losses in each cylinder are denoted by L_1, L_2, L_3 and L_4, then the value of b.p, B, at the test speed with all cylinders firing is given by:

$$B=(I_1-L_1)+(I_2-L_2)+(I_3-L_3)+(I_4-L_4)$$

If number 1 cylinder is cut out, then the contribution I_1 is lost; and if the losses due to that cylinder remain the same as when it is firing, then the b.p B_1 now obtained at the same speed is:

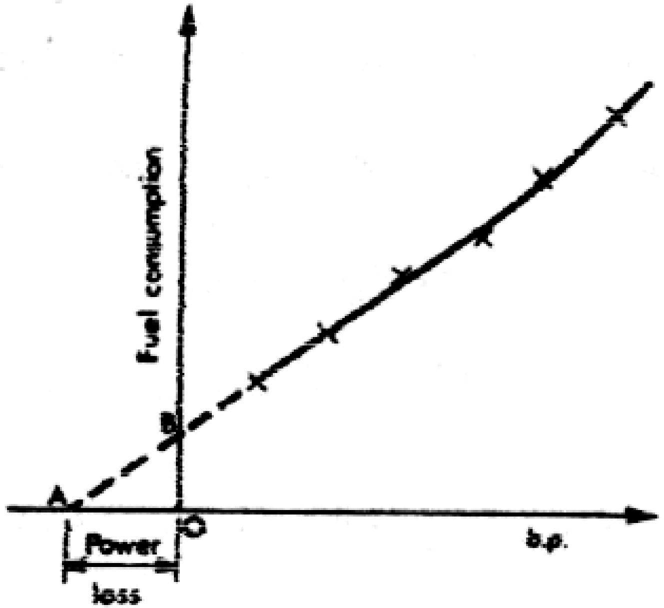
$$B_1= (0 -L_1)+(I_2-L_2)+(I_3-L_3)+(I_4-L_4)$$

Subtracting the second equation from the first given $B - B_1 = I_1$

By cutting out each cylinder in turn the values I_2, I_3 and I_4 can be obtained, then: $I = I_1 + I_2 + I_3 + I_4$

iv- Willan's line:

In this method gross fuel consumption versus b.p at a constant speed is plotted. The graph drawn is called the "Willan's line" and extrapolated back to cut the b.p axis at the point A. OA represent the power loss of the engine at this speed. The fuel consumption at zero b.p is given by OB; this would be equivalent to the power loss OA. This test is applicable to C.I. engines only.



Comments on Methods of Measuring *fp*

- The Willan' line method and Morse tests are very cheap and easy to conduct.
- However, both these tests give only an overall idea of the losses whereas motoring test gives a very good insight into the various causes of losses and is a much more powerful tool.

The total engine friction can be divided into five main components:

1. Crankcase mechanical friction.
2. Blow-by losses.
3. Exhaust and inlet system throttling losses.
4. Combustion chamber pumping loop losses.
5. Piston mechanical friction.

- As far as accuracy is concerned the *ip* – *bp* method is the most accurate if carefully done.
- Motoring method usually gives a higher value for *fhp* as compared to that given by the Willian's line method.

7 – Heat balance of Engine:

The main components of the heat balance are:

1- Heat equivalent to the b.p of the engine.

2- Heat rejected to the cooling medium.

3- Heat carried away from the engine with the exhaust gases.

4- Unaccounted losses.

Energy distribution for any engine

$$\text{Power generated} = \dot{W}_{shaft} + \dot{Q}_{exhaust} + \dot{Q}_{loss} + \dot{W}_{acc}$$

where:

$\dot{W}_{shaft}$ = brake output power off of the crankshaft

$\dot{Q}_{exhaust}$ = energy lost in the exhaust flow

$\dot{Q}_{loss}$ = all other energy lost to the surroundings by heat transfer

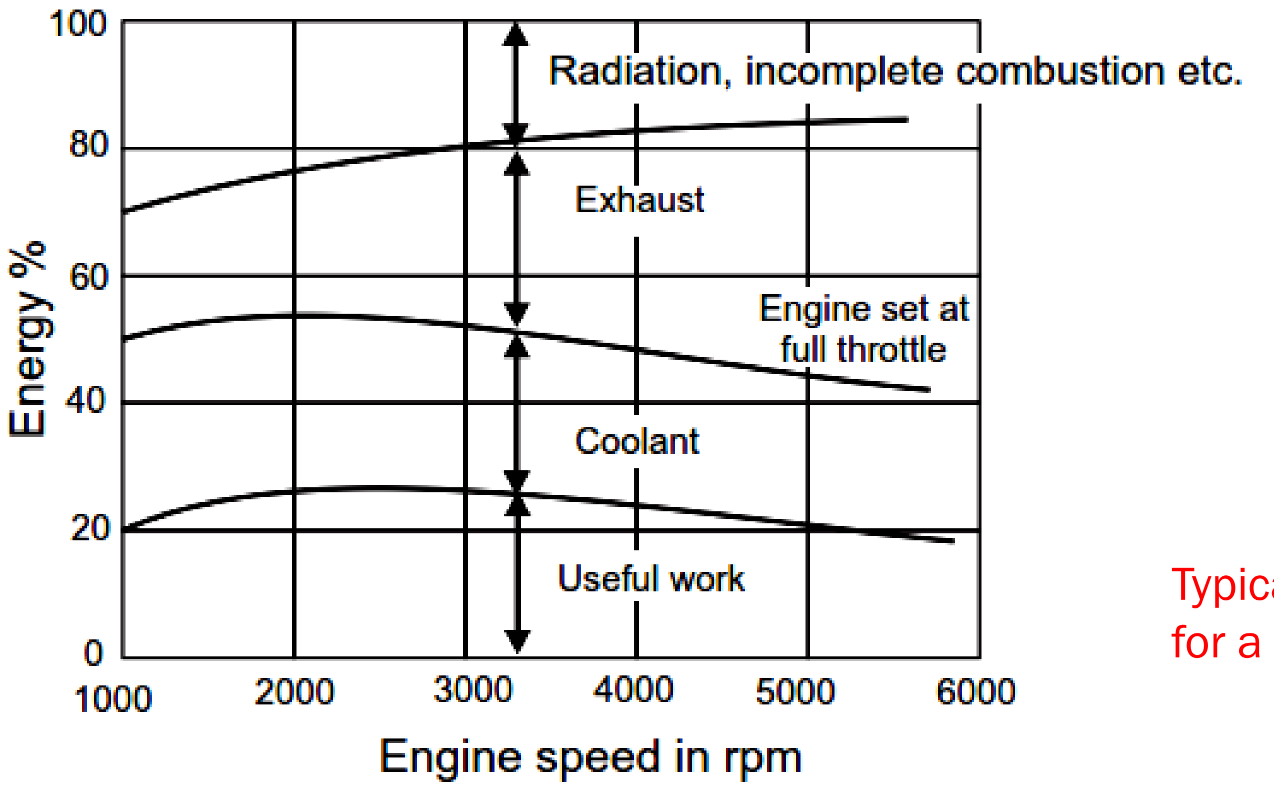
$\dot{W}_{acc}$ = power to run engine accessories

For many engines, the heat losses can be subdivided:

$$\dot{Q}_{loss} = \dot{Q}_{coolant} + \dot{Q}_{oil} + \dot{Q}_{ambient}$$

The following table gives the approximate percentage values of various losses in SI and CI engines:

Engine	% b.p	% heat to cooling water	% heat to exhaust gases	% unaccounted loss
S.I.	21-28	12-27	30-55	0-15
C.I.	29-42	15-35	25-45	10-20



Typical Figures of Heat Balance Vs. Speed for a Petrol Engine at Full Throttle