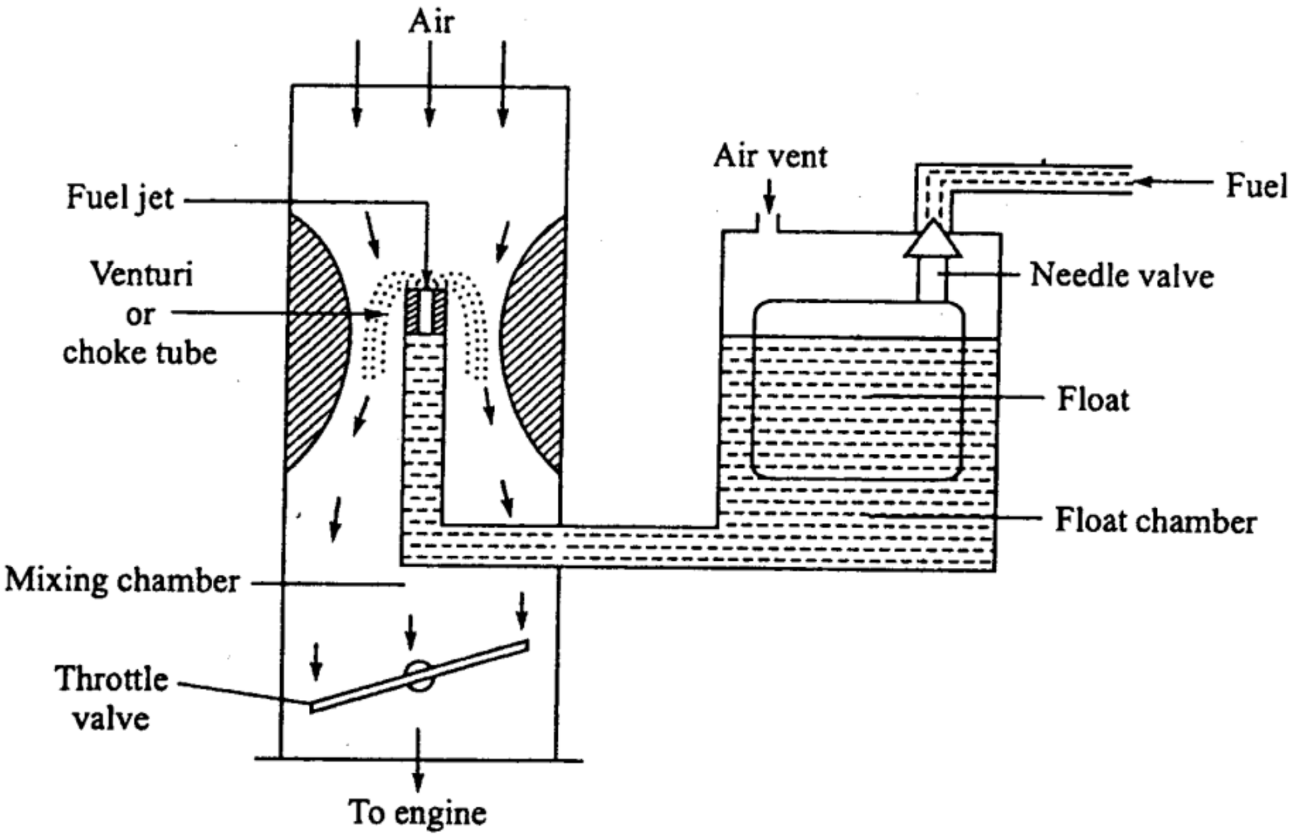
The Simple Carburettor



Calculation of Air-Fuel Ratio Neglecting compressibility of Air (Approximate Analysis)

$$\frac{p_1}{\rho_a} + \frac{C_{a1}^2}{2} = \frac{p_2}{\rho_a} + \frac{C_{a2}^2}{2}$$

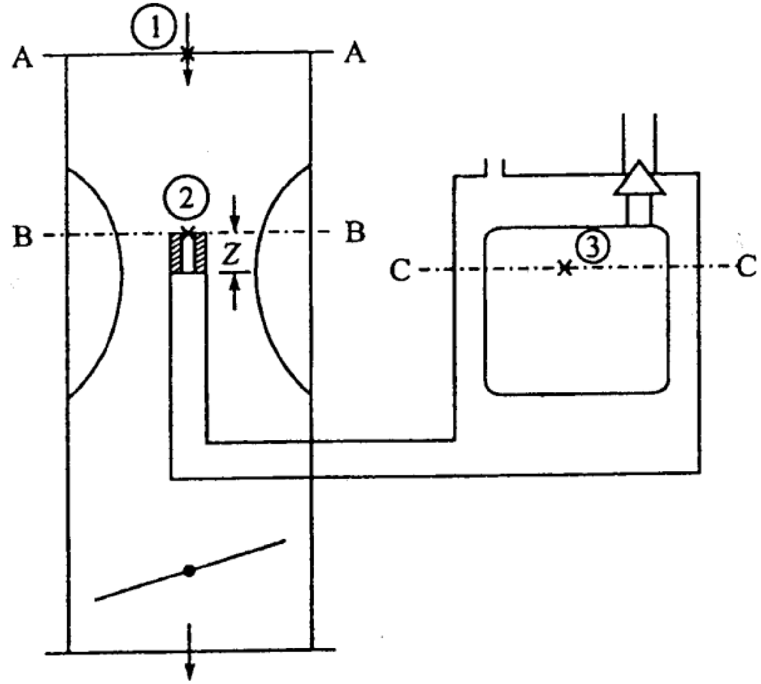
The approach velocity C_{a1} may be neglected.

$$C_{a2} = \sqrt{\frac{2(p_1 - p_2)}{\rho_a}} = \sqrt{\frac{2\Delta p}{\rho_a}}$$

$$\dot{m}_a = A_2 C_{a_2} \rho_a$$

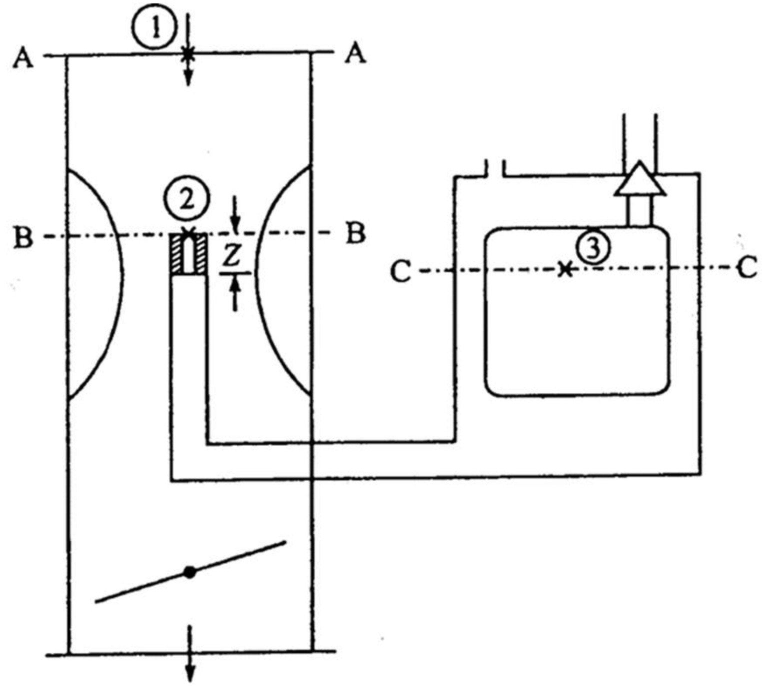
$$= A_2 \sqrt{2\rho_a \Delta p}$$

$$(\dot{m}_a)_{\text{actual}} = Cd_a A_2 \sqrt{2\rho_a \Delta p}$$



$$\frac{p_3}{\rho_f} + \frac{C_{f_3}^2}{2} = \frac{p_2}{\rho_f} + \frac{C_{f_2}^2}{2} + gZ$$

$$C_{f2} = \sqrt{2\left(\frac{p_3 - p_2}{\rho_f} - gZ\right)}$$



Pressures at plane 1 and plane 3 are both atmospheric, therefore, $p_3 = p_1$.

$$C_{f2} = \sqrt{2\left(\frac{p_1 - p_2}{\rho_f} - gZ\right)}$$

$$= \sqrt{\frac{2}{\rho_f}(\Delta p - \rho_f gZ)}$$

$$\dot{m}_f = A_j C_{f2} \rho_f = A_j \sqrt{2\rho_f(\Delta p - \rho_f gZ)}$$

$$(\dot{m}_f)_{\text{actual}} = Cd_f \cdot A_j \sqrt{2\rho_f(\Delta p - \rho_f gZ)}$$

Calculation of Air-Fuel Ratio (Exact Analysis)

Applying SFEE between A-A (point 1) and B-B (point 2) and considering unit mass of airflow

$$h_1 + \frac{C_{a1}^2}{2} + q = h_2 + \frac{C_{a2}^2}{2} + w$$

The flow is assumed to be reversible adiabatic flow,

$$q = 0,\ w = 0,\ and\ c_{a1} \approx 0$$

$$C_{a2} = \sqrt{2(h_1 - h_2)}$$

$$C_{a2} = \sqrt{2c_p(T_1 - T_2)} = \sqrt{2c_p T_1\left(1 - \frac{T_2}{T_1}\right)}$$

$$C_{a2} = \sqrt{2c_p T_1\left[1 - \left(\frac{p_2}{p_1}\right)^{(\gamma-1)/\gamma}\right]}$$

$$\dot{m}_a = \rho_1 A_1 C_{a1} = \rho_2 A_2 C_{a2}$$

$$\frac{p_2}{p_1} = \left(\frac{v_1}{v_2}\right)^{\gamma} = \left(\frac{\rho_2}{\rho_1}\right)^{\gamma}$$

$$\rho_2 = \rho_1\left(\frac{p_2}{p_1}\right)^{1/\gamma}$$

$$\dot{m}_a = \rho_2 A_2 C_{a2}$$

$$= \rho_1\left(\frac{p_2}{p_1}\right)^{1/\gamma} A_2 \sqrt{2c_p T_1\left[1 - \left(\frac{p_2}{p_1}\right)^{(\gamma-1)/\gamma}\right]}$$

$$= \rho_1 A_2 \sqrt{2c_p T_1\left[\left(\frac{p_2}{p_1}\right)^{2/\gamma} - \left(\frac{p_2}{p_1}\right)^{(\gamma+1)/\gamma}\right]}$$

From equation of state, $\rho_1 = \frac{p_1}{RT_1}$

$$\therefore \qquad \dot{m}_a = \frac{p_1}{R\sqrt{T_1}} \cdot A_2 \sqrt{2c_p\left[\left(\frac{p_2}{p_1}\right)^{2/\gamma} - \left(\frac{p_2}{p_1}\right)^{(\gamma+1)/\gamma}\right]}$$

The actual rate of mass flow of air is given by

$$(\dot{m}_a)_{\text{actual}} = Cd_a\, \dot{m}_a,$$

where Cd_a is the coefficient of discharge for the venturi.

$$\therefore \qquad (\dot{m}_a)_{\text{actual}} = Cd_a \frac{p_1}{R\sqrt{T_1}} A_2 \sqrt{2c_p\left[\left(\frac{p_2}{p_1}\right)^{2/\gamma} - \left(\frac{p_2}{p_1}\right)^{(\gamma+1)/\gamma}\right]}$$

Remarks

$$\dot{m}_f = A_j C_{f2} \rho_f = A_j \sqrt{2\rho_f(\Delta p - \rho_f g Z)}$$

when $\Delta p \le \rho_f gZ$, there will be no flow of fuel.

flow will take place only when $\Delta p > \rho_f gZ$. As this pressure difference increases the rate of mass flow of fuel increases and the mixture becomes progressively richer.

Minimum air velocity at the throat which may cause fuel flow can be estimated

$$C_{a2} = \sqrt{\frac{2(p_1 - p_2)}{\rho_a}} = \sqrt{\frac{2\Delta p}{\rho_a}}$$

$$C_{a_2} = \sqrt{\frac{2\Delta p}{\rho_a}} = \sqrt{\frac{2\rho_f gZ}{\rho_a}}$$

At high rate of flow of air, Δp is very large compared to $\rho_f gZ$.

$$\frac{A}{F} = \frac{Cd_a}{Cd_f} \cdot \frac{A_2}{A_j} \sqrt{\frac{\rho_a \Delta p}{\rho_f(\Delta p - \rho_f gZ)}} = \frac{Cd_a}{Cd_f} \cdot \frac{A_2}{A_j} \sqrt{\frac{\rho_a}{\rho_f}}$$

Above Equation also reveals that as the density of air reduces the air/fuel ratio also decreases, i.e. the mixture becomes richer. At high altitudes, the density of air is low. The density of air at the throat also reduces for a high rate of air flow through the carburettor.

Drawback of Simple Carburettor

- A simple carburetor as described suffers from the fact that it provides the required air-fuel ratio only at one throttle position.
- At all other throttle positions, the mixture is either leaner or richer depending on whether the throttle is opened less or more.
- Throttle opening changes the velocity of air. The opening changes the pressure differential between the float chamber and venturi throat, and regulates the fuel flow through the nozzle.
- Increased throttle opening gives a rich mixture. Opening of throttle usually increases engine speed. However, as load is also a factor (e.g., climbing an uphill), opening the throttle may not increase the speed.