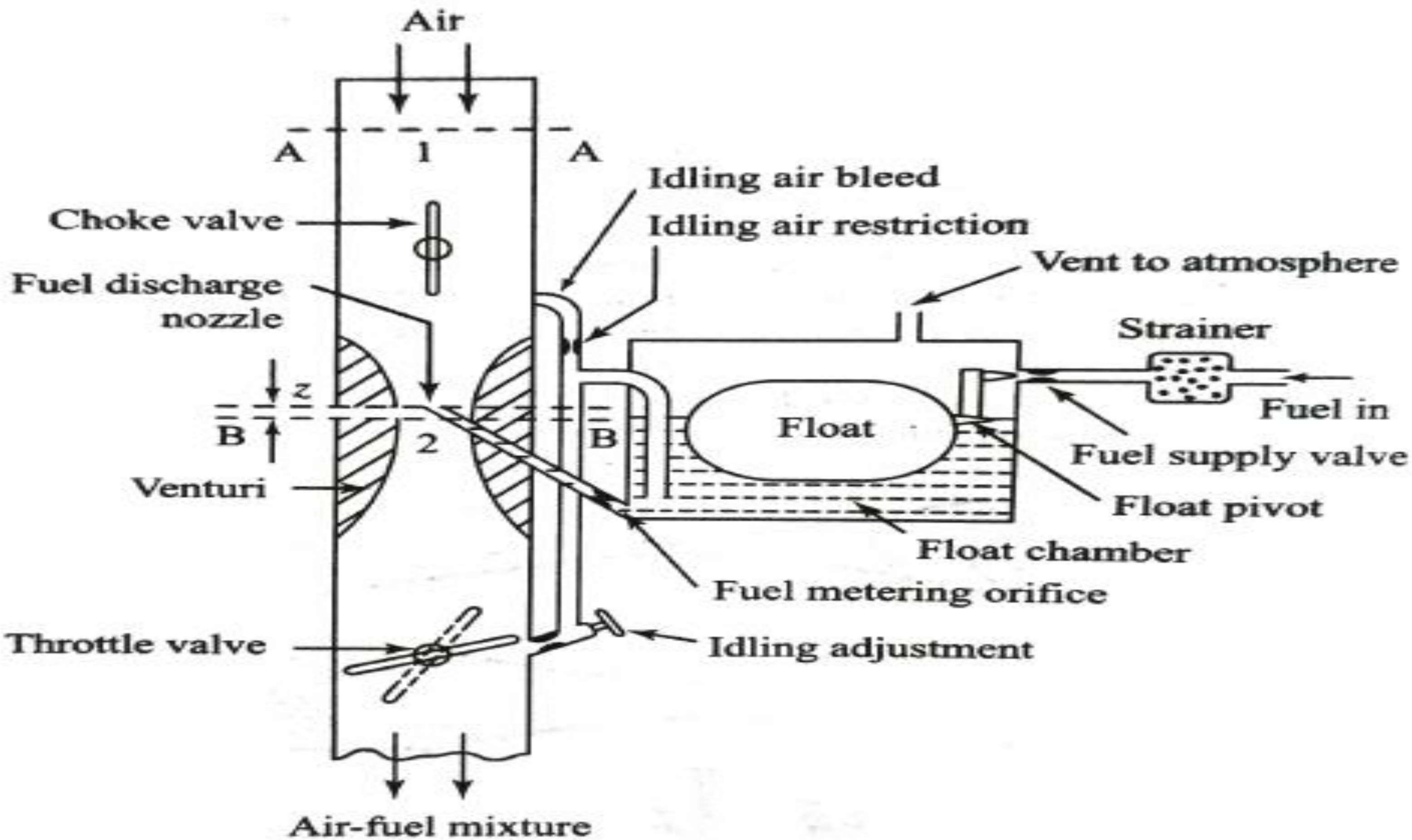
Calculation of Air Fuel Ratio



Applying the steady flow energy equation to sections AA and B-B and assuming unit mass flow of air, we have,

$$q - w = (h_2 - h_1) + \frac{1}{2}(C_2^2 - C_1^2)$$

Here q, w are the heat and work transfers from entrance to throat and h and C stand for enthalpy and velocity respectively.

Assuming an adiabatic flow, we get $q = 0$, $w = 0$ and $C_1 \approx 0$,

$$C_2 = \sqrt{2(h_1 - h_2)}$$

Assuming air to behave like ideal gas, we get $h = C_p T$. Hence, written as,

$$C_2 = \sqrt{2C_p(T_1 - T_2)}$$

As the flow process from inlet to the venturi throat can be considered to be isentropic, we have

$$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\left(\frac{\gamma-1}{\gamma}\right)}$$

$$T_1 - T_2 = T_1\left[1 - \left(\frac{p_2}{p_1}\right)^{\left(\frac{\gamma-1}{\gamma}\right)}\right]$$

Substituting Eq.7.5 in Eq.7.3, we get

$$C_2 = \sqrt{2C_pT_1\left[1 - \left(\frac{p_2}{p_1}\right)^{\left(\frac{\gamma-1}{\gamma}\right)}\right]}$$

Now, mass flow of air,

$$\dot{m}_a = \rho_1 A_1 C_1 = \rho_2 A_2 C_2$$

where A_1 and A_2 are the cross-sectional area at the air inlet (point 1) and venturi throat (point 2).

To calculate the mass flow rate of air at venturi throat, we have

$$
\begin{aligned}
p_1/\rho_1^\gamma &= p_2/\rho_2^\gamma \\
\rho_2 &= (p_2/p_1)^{1/\gamma}\rho_1 \\
\dot{m}_a &= \left(\frac{p_2}{p_1}\right)^{1/\gamma}\rho_1 A_2\sqrt{2C_pT_1\left[\left(1-\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}}\right]} \\
&= \left(\frac{p_2}{p_1}\right)^{1/\gamma}\frac{p_1}{RT_1}A_2\sqrt{2C_pT_1\left[1-\left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}}\right]}
\end{aligned}
$$

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

Substituting $C_p = 1005$ J/kg K, $\gamma = 1.4$ and $R = 287$ J/kg K for air,

$$\dot{m}_a = 0.1562 \frac{A_2 p_1}{\sqrt{T_1}} \sqrt{\left(\frac{p_2}{p_1}\right)^{1.43} - \left(\frac{p_2}{p_1}\right)^{1.71}}$$

$$= 0.1562 \frac{A_2 p_1}{\sqrt{T_1}} \phi \quad \text{kg/s}$$

where

$$\phi = \sqrt{\left(\frac{p_2}{p_1}\right)^{1.43} - \left(\frac{p_2}{p_1}\right)^{1.71}}$$

Here, p is in N/m^2, A is in m^2 and T is in K.

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To get the actual mass flow rate, the above equation should be multiplied by the co-efficient of discharge for the venturi, C_{da}.

$$\dot{m}_{a_{actual}} = 0.1562 C_{da} \frac{A_2 p_1}{\sqrt{T_1}} \phi$$

Since C_{da} and A_2 are constants for a given venturi,

$$\dot{m}_{a_{actual}} \propto \frac{p_1}{\sqrt{T_1}} \phi$$

In order to calculate the air-fuel ratio, fuel flow rate is to be calculated. As the fuel is incompressible, applying Bernoulli's Theorem we get

$$\frac{p_1}{\rho_f} - \frac{p_2}{\rho_f} = \frac{C_f^2}{2} + gz$$

where ρ_f is the density of fuel, C_f is the fuel velocity at the nozzle exit and z is the height of the nozzle exit above the level of fuel in the float bowl

$$C_f = \sqrt{2\left[\frac{p_1 - p_2}{\rho_f} - gz\right]}$$

Mass flow rate of fuel,

$$\dot{m}_f = A_f C_f \rho_f$$
$$= A_f \sqrt{2\rho_f (p_1 - p_2 - gz\rho_f)}$$

where A_f is the area of cross-section of the nozzle and ρ_f is the density of the fuel

$$\dot{m}_{f_{actual}} = C_{df} A_f \sqrt{2\rho_f (p_1 - p_2 - gz\rho_f)}$$

where C_{df} is the coefficient of discharge for fuel nozzle

$$A/F \text{ ratio} = \frac{\dot{m}_{a_{actual}}}{\dot{m}_{f_{actual}}}$$

$$\frac{A}{F} = 0.1562 \frac{C_{da}}{C_{df}} \frac{A_2}{A_f} \frac{p_1 \phi}{\sqrt{2T_1 \rho_f (p_1 - p_2 - gz\rho_f)}}$$