4

Draught system

Course Contents

4.1 Introduction

Draught is mechanism of creation of small pressure difference that is required maintain the constant flow of air for combustion of fuel and to discharge the gases through the chimney to atmosphere. Draught can be produced by using chimney, fans, steam or air jet or combination of these.

The purpose of draught is to,

1) Helps in allowing desired volume of air flow in to the furnace.
2) Helps in overcoming the resistances offered to the flow of air through the furnace.
3) Discharge gases at sufficient height to avoid pollution to atmosphere.

4.2 Natural draught- Estimation of height of chimney

If the draught is produced only with the help of chimney it is known as natural draught. The natural draught is produced by chimney or stack. It is caused by the density difference between the atmospheric air and the hot gas in the stack. This type of draught is useful for small capacity boiler and it does not play much important role in the high capacity thermal power plant.

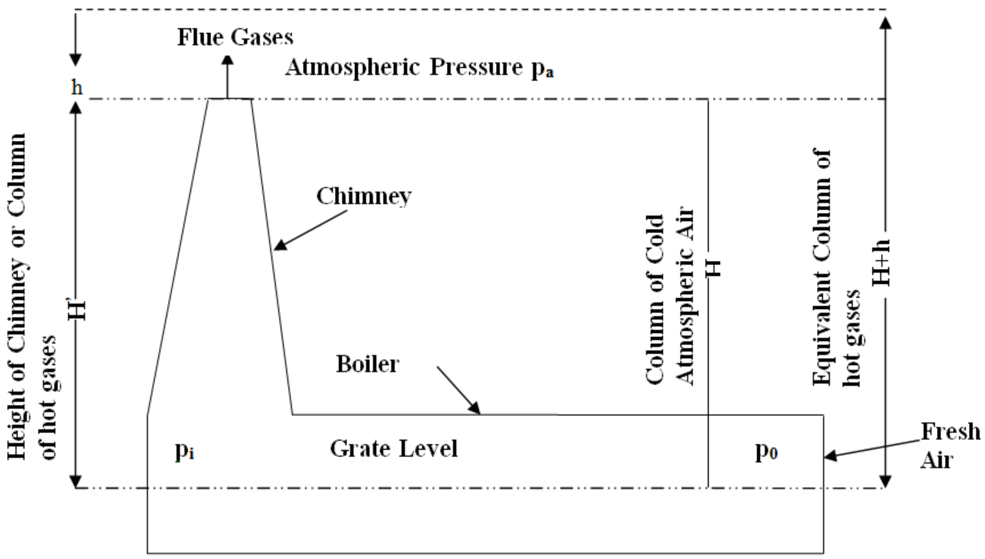

Figure 4.1 Natural draught

Consider the chimney above grate level is H. The pressure acting on the grate from chimney side,

P_0 = Pa + Wg H

= Pa + ρ_g gH………………..1)

Where, Pa= Atmospheric pressure at chimney top.

ρ_g gH =Pressure due to the column of hot gas of height H meters.

ρ_g = Average mass density of hot gas Kg/m^3

Similarly the pressure acting on the grate on open side

$P_i = Pa + \rho_a gH$ ………………2)

$\rho_a gH$ – Pressure acting on the grate on open side by the column of cold air outside the chimney of height H meters.

ρ_a – Average mass density of cold air outside the chimney.

The net pressure acting on the grate $P = P_i - P_o$

$= gH(\rho_a - \rho_g)$………………………3)

If the acting pressure is in terms of mm of water (head),

$h_w \times Ww = H\,(Wa - Wg)$

$h_w\ \rho_w g = gH(\rho_a - \rho_g)$

$(h_w \times 1000 \times g)/1000 = gH(\rho_a - \rho_g)$

$h_w = H(\rho_a - \rho_g)$ mm of water………………………4)

Draught in terms of hot column of gas,

Let Hg is the hot column of gas in meters.

$H_g \times Wg = H\,(Wa - Wg)$

$H_g \times \rho_g g = gH(\rho_a - \rho_g)$

$Hg = H(\rho a/\rho g - 1)$ Meters of hot column of gas……………..5)

If m kg be the mass of air supplied per kg of fuel. Then m+1 will be the mass of flue gases. Assuming volume of air and gas is same at same temperature, at 0^0c or 273^0 K and at atmospheric pressure one kg of air occupies volume equal to

$v = RT/P = 287 \times 273 / 1.013 \times 10^5 = 0.7734\ m^3$

The volume of the gases at higher temperature can be calculated as follows.

Let Tg – Mean absolute temperature of flue gases ^{0}K

Ta – Mean absolute temperature of outside air ^{0}K.

Volume of one kg of air at temperature Ta = (0.7734 x Ta) / 273

Volume of m kg of air at temperature Ta= (0.7734 x Ta x m) / 273

Volume of m+1 kg of flue gases at temperature Tg = (0.7734 x Tg x m) / 273

Hence density of air at temperature Ta = Mass / Volume (air)

$\rho_a = (m \times 273) / (0.773 \times Ta \times m)$

= 353 / Ta…………….6)

Similarly density of gases at temperature Tg = Mass of hot flue gas / Volume of hot flue gas,

ρ_g = (m+1) x 273 / (0.7734 x m x Tg)

= [353/Tg] x [(m+1) / m]……………………7)

Substituting values of equation 6 and 7 in equation 3,

$$P = 353gH\ [\frac{1}{T_a} - \left(\frac{m+1}{m}\right)\frac{353}{T_g}\ ]$$

If h_{mm} be the draught measured in water column then,

h = H(ρ_a - ρ_g) mm of water.

$$= 353\ H\ [\frac{1}{T_a} - (\frac{m+1}{m})\frac{1}{T_g}]$$

If Hg is the height of a column of hot gas expressed in meters which would produce the pressure P in N/ m^2 then,

$$H_g = H[\ \frac{T_g}{T\ _a}\left(\frac{m}{m+1}\right) - 1\ ]$$

4.3 Maximum discharge condition

Theoretical velocity of flue gases produced by static draught is,

C = $(2gH_g)^{1/2}$

$$= \left\{2gH\left[\ \frac{T_g}{T_a}\left(\frac{m}{m+1}\right) - 1\ \right]\right\}^{1/2}$$

The mass of gas discharged per second is given by,

$$m_g = A \times C \times \rho_g$$

$$= A \times \left\{2gH\left[\ \frac{T_g}{T_a}\left(\frac{m}{m+1}\right) - 1\ \right]\right\}^{1/2} \times \frac{p}{R\,T_g}$$

$$= K \times \left\{\left[\ \frac{1}{T_g T_a}\left(\frac{m}{m+1}\right) - \frac{1}{{T_g}^2}\ \right]\right\}^{1/2}$$

Where, $K = A\frac{p}{R}(2gH)^{1/2}$

For maximum discharge, differentiating above equation with respect to Tg and equating it to zero, we get

$$\frac{d(m)_g}{d(T)_g} = \frac{d}{d(T_{g)}}\left\{K \times \left\{\left[\frac{1}{T_g T_a}\left(\frac{m}{m+1}\right) - \frac{1}{{T_g}^2}\right]\right\}^{1/2}\right\} = 0$$

$$\left(\frac{m}{m+1}\right)\frac{1}{T_a} \times \left(-\frac{1}{{T_g}^2}\right) + \frac{2}{{T_g}^3} = 0$$

$$\therefore \frac{T_g}{T_a} = \frac{2(m_a + 1)}{m_a} \quad \ldots\ldots\ldots\ldots..8)$$

Above equation is the condition for maximum discharge through the chimney and the temperature of flue gases is slightly greater than twice the atmospheric temperature.

4.4 Forced, Induced and balanced draught

Those are the types of artificial draught in which draught can be produced either by using fan or using steam jet.

4.4.1 Forced Draught

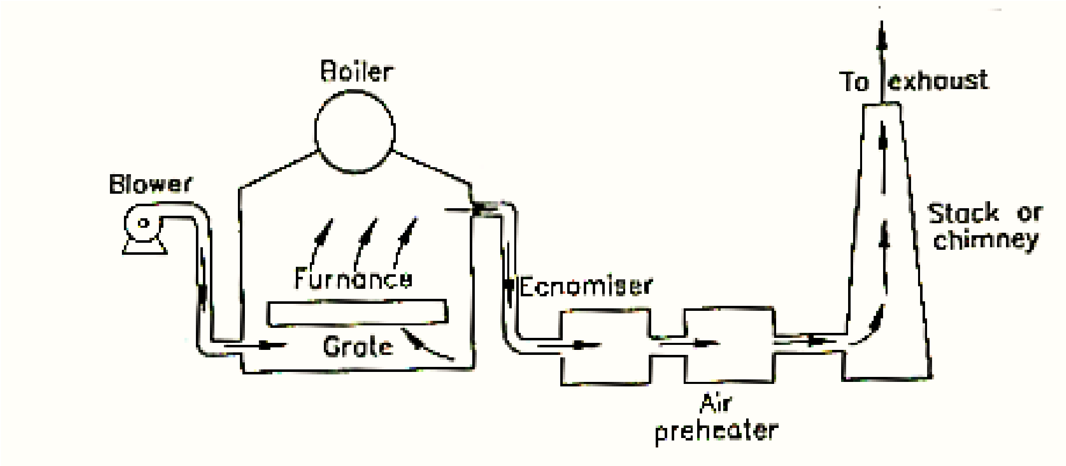

Figure 4.2 forced draught

The forced draught system fans are installed at the base of the boiler. This draught system is known as the positive draught system. The fans or blowers installed at the base of the boiler forces the air through the fuel bed, Economiser, air preheater and to the chimney. The furnace has to be gas tight to prevent the leakage of gases in the boiler house. Since the FD fans handle cold air, so they consume less power and less maintenance problems.

4.4.2 Induced Draught

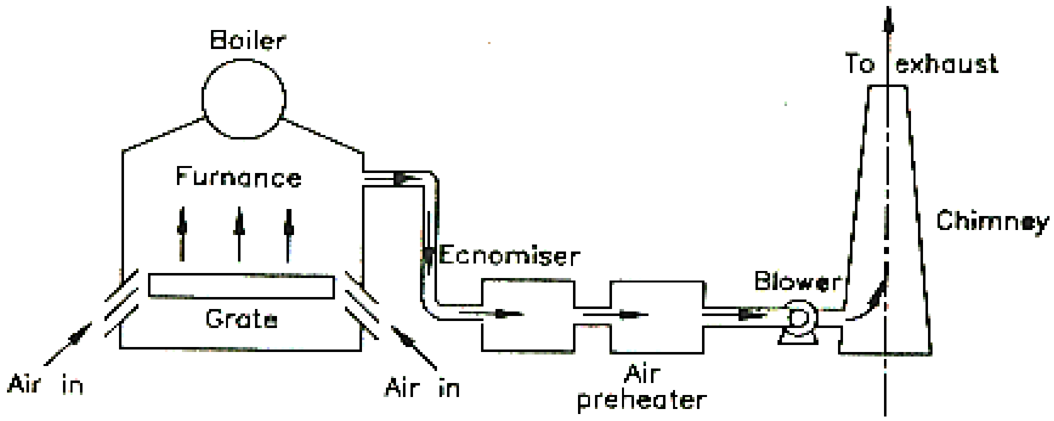

Figure 4.3 Induced draught

In this type of draught system a fan or blower is located at the base of the chimney. The ID fan sucks the burned gases from furnace and the pressure inside the furnace is reduced below atmosphere and induces the atmospheric air to flow through the furnace. The draught produced is independent of the temperature of the gases. This draught is similar to the natural draught system in action but the total draught produced is the sum of draught produced by the fans and chimney.

Advantages of Forced draught over induced draught:

1) Forced draught fans does not require water cooled bearing.
2) The tendency of air leak in to the furnace reduced.
3) The life of the FD fan blades is high.
4) The power required for FD fans is less compared to Induced draught fans.

4.4.3 Balanced draught.

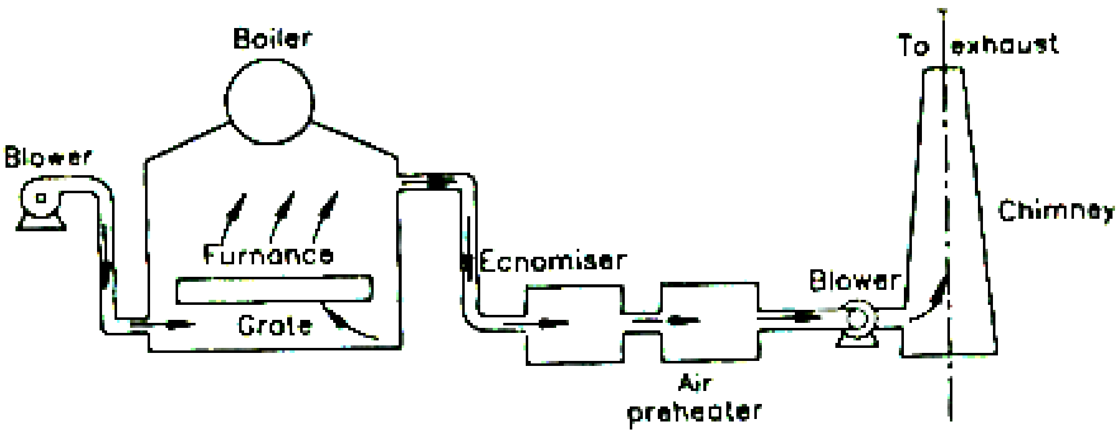

Figure 4.4 Balanced draught

It is the combination of the both forced draught and induced draught system. In this system FD fan over comes the resistance of fuel bed and air pre heater. The induced draught fan removes the gases from the furnace maintaining the pressure in the furnace just below atmosphere.

4.5 Power requirement by fans

Let us consider,

V = Volume of the flow gases through the fan m^3/min.

H= Draught produced by the fan mm of water.

P = Draught in N/m^2

η= Efficiency of fan.

We have,

$P = \rho_w gh = 1000 \times g \times (h/1000) \quad N/m^2$

The work done on the gas,

W = PV / 60 = (gh) V/60 Watts

Power required to drive the fan $= \frac{ghV}{60} \times \eta$ watts