Chapter – 4
Draught System in Boilers

Prepared By:
Jalpesh H. Solanki
Assi. Prof. (LE College, Morbi)

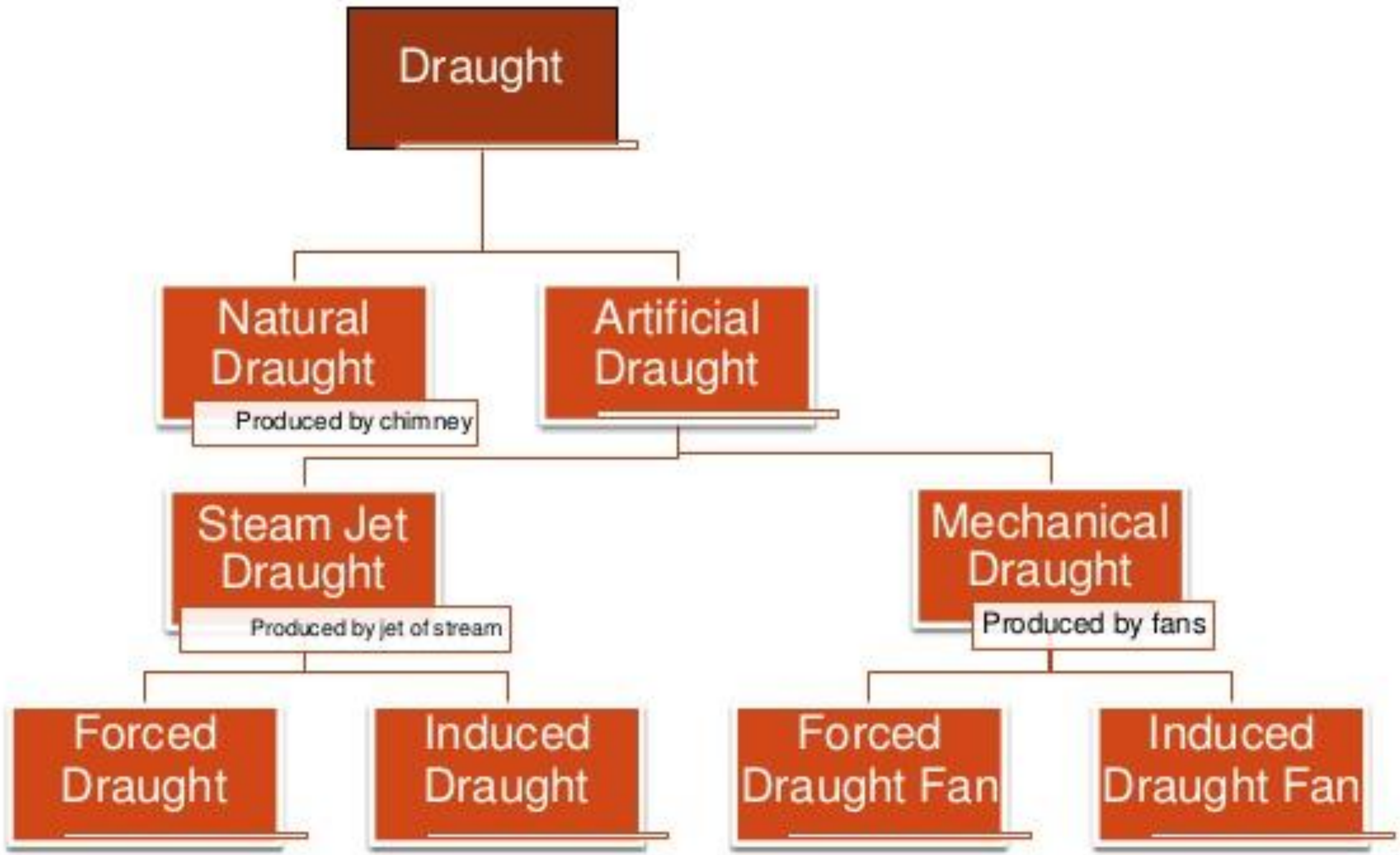
Introduction

- Draught system is used by coal gas plants to decreases the environment pollution.
- Defines as the difference between absolute gas pressure at any point in a gas flow passage and ambient (at sea level)atmospheric pressure.
- It is measured in millimeter or water.

Necessity of Draught

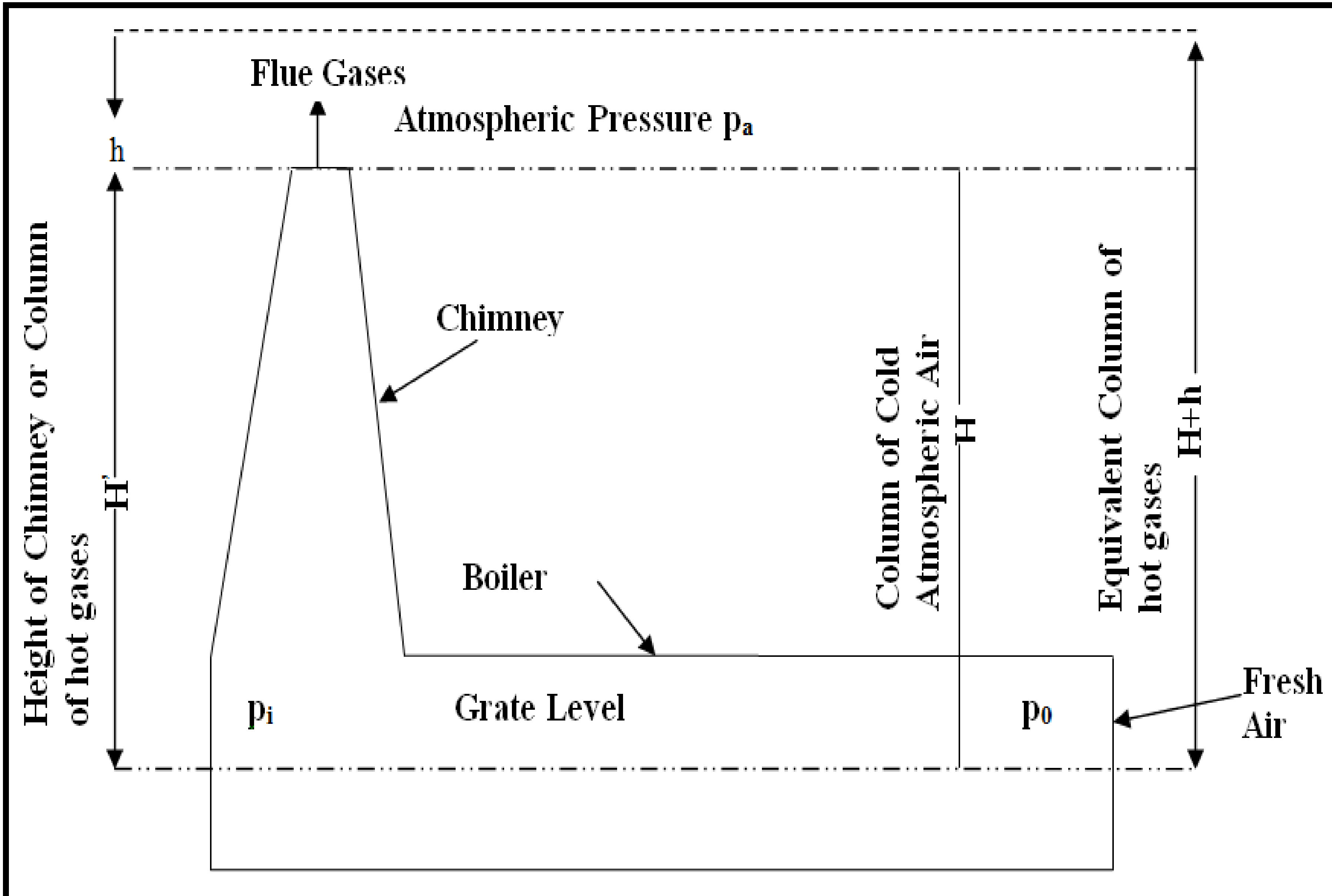
- To supply required amount of air to the furnace for combustion of fuel.
- To remove gaseous products of combustion.
- The amount of fuel that can be burnt per square root of grate area depends upon the quantity of air circulated through fuel bed.

Classification of Draught



Pramod Kathamore

Determination of Height of Draught



Determination of Height of Draught

- We know,

$$P_1 = P_a + \rho_g \cdot gH$$

$$P_a = \text{Atmospheric pressure.}$$

$$\rho_g \cdot gH = \text{Pressure due to hot gases.}$$

$$P_1 = \text{Pressure at grate level.}$$

$$\rho_g = \text{Mass density of hot gases.}$$

Similarly we can write,

$$P_2 = P_a + \rho_a \cdot gH$$

$\rho_a \cdot gH$ = Pressure exerted by column of cold air outside chimney.

ρ_a = Mass density of air.

- By using above two equations. Net pressure difference can be calculated as,

$$\Delta P = P_2 - P_1$$

$$\Delta P = (\rho_a - \rho_g)gH \quad \ldots \text{(i)}$$

- Now to determine the height of chimney consider,

m_a = Mass of air supplied.

m_{a+1} = Mass of chimney gases.

T_a = Temperature of atmosphere

T_g = Average temperature of chimney gases.

$$\frac{\text{Mass of chimeny gases}}{\text{Mass of air}} = \frac{m_a + 1}{m_a}$$

Now, we have the equation,

$$\rho_a = \frac{P}{RT_a}$$

where P = Atmospheric pressure

P = 1.013 bar

$P = 1.013 \times 10^5 \ \text{N/m}^2$

$$\therefore \quad \rho_a = \frac{1}{T_a} \times \frac{1.013 \times 10^5}{287} \quad (R = 287 \text{ J/kgK}))$$

$$\rho_a = 353 \times \frac{1}{T_a} \qquad \dots \text{(ii)}$$

and,

$$\rho_g = \frac{P}{RT_g} \times \left(\frac{m_a + 1}{m_a} \right)$$

$$\rho_g = \frac{1.033 \times 10^5}{287} \times \frac{1}{T_g} \times \left(\frac{m_a + 1}{m_a} \right)$$

$$\rho_g = 353 \times \frac{1}{T_g} \times \left(\frac{m_a + 1}{m_a} \right) \qquad \dots \text{(iii)}$$

Put the values of ρ_a and ρ_g in equation (i)

$$\Delta P = 353\, gH \left[\frac{1}{T_a} - \frac{1}{T_g} \times \left(\frac{m_a + 1}{m_a} \right) \right] \qquad \dots \text{(iv)}$$

- Now equation (iv) shows the pressure difference in terms of N/m^2.
- To find out the pressure difference in terms of mm of water column (h_w).

$$\Delta P = \rho_w g h_w$$

$$\therefore \quad h_w = \frac{\Delta P}{\rho_w g} \text{ 'm' of water column.}$$

$$h_w = \frac{\Delta P}{g} \text{ ... mm of water column.} \qquad \dots \text{(v)}$$

Now put the value of ΔP i.e. equation (iv) in equation (v).

$$h_w = 353\, gH \left[\frac{1}{T_a} - \frac{1}{T_g} \times \left(\frac{m_a + 1}{m_a} \right) \right]$$

$$\boxed{h_w = 353\, gH \left[\frac{1}{T_a} - \frac{1}{T_g} \times \left(\frac{m_a + 1}{m_a} \right) \right]} \quad \text{mm of water column,}$$

- 1 mm of water = 9.81 Pa.

Condition for Maximum Discharge through Chimney

The chimney draught is most effective when the maximum weight of hot gases is discharged in a given time, and it will be shown that this occurs when the absolute temperature of the chimney gase bears a certain relation to the absolute temperature the outside air.

The velocity of gas through the chimney, assuming the losses to be negligible, is given by,

$$C = \sqrt{2gH_1} \quad \text{where } h' = 0$$

Inserting the value of H_1 from equation

$$C = \sqrt{2gH\left[\left(\frac{m_a}{m_a+1}\right)\frac{T_g}{T_a} - 1\right]} \qquad \ldots(4.2$$

The density of the hot gas is given by,

$$p_g = \frac{p}{RT_g} \qquad \ldots(4.2$$

The mass of gas discharged per second $m_g = A \times C \times p_g$

Put values of C and p_g in equation (4.2.1) and (4.2.2) we get,

$$m_g = A\sqrt{2gH\left[\left(\frac{m_a}{m_a+1}\right)\frac{T_g}{T_a}-1\right]}\frac{p}{RT_g} = \frac{K}{T_g}\sqrt{\left(\frac{m_a}{m_a+1}\right)\frac{T_g}{T_a}-1} \quad \text{...(4.2.3)}$$

Where constant $K = \frac{A \times p \times \sqrt{2gH}}{R}$

The value of m_g will be maximum, if

$$\frac{dm_g}{dT_g} = 0 \text{ as } T_a \text{ and } m_a \text{ are fixed quantities.}$$

$$\frac{d}{dT_g}\left[\frac{k}{T_g}\sqrt{\left(\frac{m_a}{m_a+1}\right)\frac{T_g}{T_a}-1}\right] = 0$$

$$\frac{d}{dT_g}\left[\frac{1}{T_g}\sqrt{\left(\frac{m_a}{m_a+1}\right)\frac{T_g}{T_a}-1}\right] = 0$$

$$\frac{d}{dT_g}\left[\frac{(zT_g-1)^{1/2}}{T_g}\right] = 0$$

Where $Z = \frac{m_a}{m_a+1}\cdot\frac{1}{T_a}$

$$\frac{d}{dT_g}[(zT_g-1)^{1/2} \times T_g^{-1}] = 0$$

$$(z\cdot T_g-1)^{1/2}\cdot(-1)(T_g)^{-2} + T_g^{-1} \times \frac{1}{2}(zT_g-1)^{-1/2} \times z = 0$$

$$\frac{(-zT_g-1)^{1/2}}{T_g^2} + \frac{z}{2T_g(zT_g-1)^{1/2}} = 0$$

$$\frac{-2(zT_g-1)+zT_g}{2(T_g)^3(zT_g-1)^{1/2}} = 0$$

$$-2(zT_g-1)+zT_g = 0$$

$$zT_g = 2$$

$$\frac{m_a}{m_a+1}\cdot\frac{T_g}{T_a} = 2$$

$$\frac{T_g}{T_a} = 2\left(\frac{m_a+1}{m_a}\right) \quad \text{... (4.2.4)}$$

Absolute temperature of the chimney gas bears a certain ratio to the absolute temperature of the

Putting the value of $\frac{T_g}{T_a}$ in (4.2.1)

$$(H_1)_{max} = H\left[\left(\frac{m_a}{m_a+1}\right)\times 2\left(\frac{m_a+1}{m_a}\right)-1\right]$$

$$= H\,(2-1) = H$$

$$(H_1)_{max} = H \qquad \text{....(4.2.5)}$$

The draught in mm of water column for maximum discharge can be evaluated by inserting the value of $\frac{T_g}{T_a}$.

$$(h_w)_{max} = 353\,H\left(\frac{1}{T_a}-\frac{1}{2T_a}\right)$$

$$= \frac{176.5}{T_a}\text{ mm of water.} \qquad \text{... (4.2.6)}$$

Draught Losses

- Frictional resistance between flue gases and passage to the flow of flue gases.
- Loss due to frictional head.
- Loss due to imparting velocity of flue gases.

- **FORCED DRAUGHT:**
- It is a positive pressure draught.
- The fan is installed at the base of the boiler before grate which forces the outside air through fuel bed, furnace and air pre-heater and then flue gases through flue passage, economizer etc.
- The enclosure for the furnace has to be very tightly sealed so that gases from the furnace do not leak out in the boiler house.

- **INDUCED DRAUGHT:**
- In this system a fan or blower is located at or near the base of the chimney which creates a partial vacuum in the furnace and flue passage.
- Thus the air and flue gases are drawn through the boiler due to comparatively higher pressure of outside air.
- It is convenient to produce induced draught and like in forced draught, any type of fan/blower may be used. .

- **BALANCED DRAUGHT:**
- It is a combination of forced and induced draught.
- Forced draught fan overcomes the resistance in air pre-heater and grate.
- Induced draught fan overcomes draught losses through boiler, economizer and connecting flue passages etc.
- Depending on the type of fuel burnt and type of boiler, the fan or blower used may be of any type as radial or axial etc.

- **ADVANTAGES OF MECHANICAL DRAUGHT:**
- It is more economical and its control is easy.
- Desired value of draught can be produced by mechanical means which cannot be produced by means of natural draught.
- It increases the rate of combustion by which low grade fuel can also be used.
- It reduces the smoke level and increases the heat transfer co-efficient on flue gases side thus increases the thermal efficiency of boiler.
- It saves the energy and the heat of flue gases can be best utilized by it.

- **DISADVANTAGES OF MECHANICAL DRAUGHT:**
- Initial costs of mechanical draught system are high.
- Running cost is also high due to requirement of electricity but that is easily compensated by the savings in fuel consumption.
- Maintenance cost is also on higher side.
- Noise level of boiler is also high due to noisy fan/blower etc.