Lecture nine

Solved questions

Q1-The atmospheric air at 25°C dry bulb temperature and 12°C wet bulb temperature is flowing at a rate of 100m^3/min. through a duct. The saturated steam at 100°C is injected into the air stream at a rate of 1.2kg/min. Determine the specific humidity (W) and the enthalpy (h) of the leaving air. Also determine the dry bulb temperature, wet bulb temperature and relative humidity (ϕ) of the leaving air.

Solution. Given : t_{d1} = 25° C ; t_{w1} = 12° C ; v_1 = 100 m^3/min ; t_s = 100° C ; m_s = 72 kg / h = 1.2 kg / min

Specific humidity of the leaving air

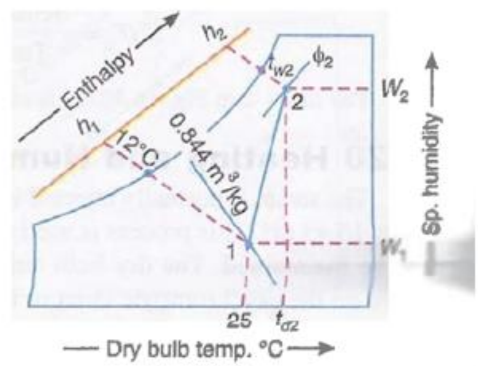
Let W_2 = Specific humidity of the leaving air.

First of all, mark the initial condition of air *i.e.* at 25° C dry bulb temperature and 12° C wet bulb temperature on the psychrometric chart at point 1, as shown in Fig. ∴ Now from the psychrometric chart, we find that the specific volume of air at point 1,

$$v_{s1} = 0.844 \text{ m}^3\text{/kg of dry air}$$

Specific humidity of air at point 1,

$$W_1 = 0.0034 \text{ kg/kg of dry air}$$



Enthalpy of air at point 1,

$$h_1 = 34.2 \text{ kJ/kg of dry air}$$

We know that mass of air flowing,

$$m_a = \frac{v_1}{v_{s1}} = \frac{100}{0.844} = 118.5 \text{ kg/min}$$

We know that $W_2 = W_1 + \frac{m_s}{m_a} = 0.0034 + \frac{1.2}{118.5} = 0.0135$ kg/kg of dry air **Ans.**

Enthalpy of leaving air

Let h_2 = Enthalpy of leaving air.

From steam tables, we find that enthalpy of dry saturated steam corresponding to 100° C is

$$h_s = 2676 \text{ kJ/kg}$$

We know that

$$h_2 = h_1 + \frac{m_s}{m_a} \times h_s = 34.2 + \frac{1.2}{118.5} \times 2676$$

$$= 61.3 \text{ kJ/kg of dry air}$$ **Ans.**

Dry bulb temperature, wet bulb temperature and relative humidity of the leaving air

Mark the condition of leaving air on the psychrometric chart as point 2 corresponding to $W_2 = 0.0135$ kg / kg of dry air and $h_2 = 61.3$ kJ / kg of dry air. Now from the psychrometric chart corresponding to point 2,

Dry bulb temperature of the leaving air,

$$t_{d2} = 26.1° \text{ C}$$ **Ans.**

Wet bulb temperature of the leaving air,

$$t_{w2} = 21.1° \text{ C}$$ **Ans.**

and relative humidity of the leaving air,

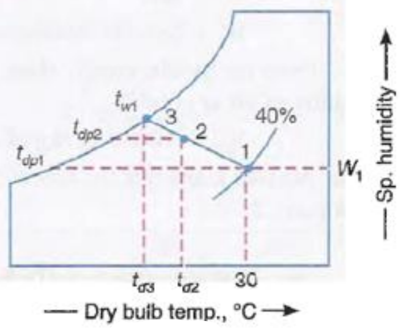
$$\phi_2 = 62\%$$ **Ans.**

Q2-At a certain space the dry bulb temperature of air is 30°C and the relative humidity (ϕ) is 40%. Determine the moisture content (W) and the dew point temperature and wet bulb temperature of air. If this air is cooled in an air washer using recirculated spray water and having efficiency of 0.9, what are the dew point temperature and dry bulb temperature of air leaving the air washer.

Solution. Given : $t_{d1} = 30°\,C$; $\phi_i = 40\%$; $\eta_H = 0.9$

Specific humidity, dew point and wet bulb temperature of air.

First of all, mark the initial condition of air at 30° C dry bulb temperature and 40% relative humidity, on the psychrometric chart at point 1, as shown in Fig . From the psychrometric chart, we find that



Specific humidity of air,

$$W_1 = 0.0106 \text{ kg/kg of dry air} \quad \textbf{Ans.}$$

Dew point temperature of air,

$$t_{dp1} = 15°\,C \quad \textbf{Ans.}$$

Dry bulb temperature and dew point temperature of air leaving the air washer

Let t_{d2} = Dry bulb temperature of air leaving the air washer.

We know that humidifying efficiency of an air washer (η_H),

$$0.9 = \frac{t_{d1} - t_{d2}}{t_{d1} - t_{d3}} = \frac{30 - t_{d2}}{30 - 19.8} = \frac{30 - t_{d2}}{10.2} \qquad \ldots (\because\ t_{d3} = t_{w1})$$

$$\therefore \qquad t_{ap2} = 30 - 0.9 \times 10.2 = 20.82°\,C \quad \textbf{Ans.}$$

Now mark point 2 on the constant wet bulb temperature line 1-3 such that $t_{d2} = 20.82°$ C. The dew point temperature at point 2 is read as

$$\therefore \qquad t_{dp2} = 19.4°\,C \quad \textbf{Ans.}$$

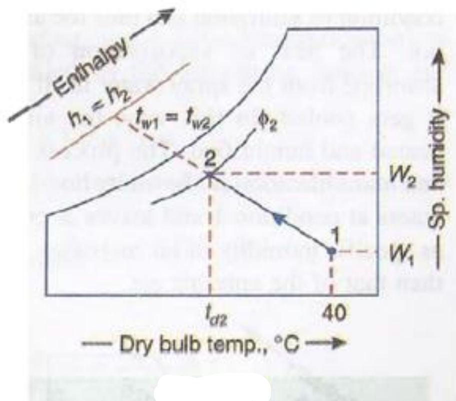
Q3-The atmospheric air at 40°C dry bulb temperature and 18°C wet bulb temperature is flowing at the rate of100m^3/min. through a space. Water at 18°C is injected into the air stream at a rate of 0.8 kg/min the effectiveness of the humidifier is (E=80%). Determine the specific humidity (W) and the enthalpy (h) of the leaving air. Also determine the dry bulb temperature, wet bulb temperature and relative humidity (ϕ) of the leaving air.

Solution. Given : $t_{d1} = 40°$ C ; $t_{w1} = 18°$ C ; $v_1 = 100$ m³/min ; $t_l = 18°$ C ; $m = 48$ kg/h $= 0.8$ kg / min

Specific humidity of the leaving air

Let W_2 = Specific humidity of the leaving air.

First of all, mark the initial condition of air *i.e.* at 40° C dry bulb temperature and 18° C wet bulb temperature, on the psychrometric chart at point 1, as shown in Fig. . Now from the psychrometric chart, we find that specific volume of air at point 1,



$$v_{s1} = 0.89 \text{ m}^3/\text{kg of dry air}$$

Specific humidity of air at point 1,

$$W_1 = 0.004 \text{ kg/kg of dry air}$$

Enthalpy of air at point 1,

$$h_1 = 51 \text{ kJ / kg of dry air}$$

We know that mass of air flowing,

$$m_a = \frac{v_1}{v_{s1}} = \frac{100}{0.89} = 112.4 \text{ kg/min}$$

$$\therefore \quad W_2 = W_1 + \frac{m_w}{m_a} = 0.004 + \frac{0.8}{112.4} = 0.0111 \text{ kg/kg of dry air} \quad \textbf{Ans.}$$

Enthalpy of the leaving air

Since the water is injected at a temperature ($t_l = 18°$ C) equal to the wet bulb temperature of the entering air ($t_{w1} = 18°$ C), therefore the process follows the path of constant wet bulb temperature line or constant enthalpy line, as shown in Fig. 16.41.

∴ Enthalpy of leaving air,

$$h_2 = \text{Enthalpy of entering air} = 51 \text{ kJ/kg of dry air} \quad \textbf{Ans.}$$

Dry bulb temperature, wet bulb temperature and relative humidity of the leaving air

Mark the condition of the leaving air on the psychrometric chart as point 2 corresponding to $W_2 = 0.0111$ kg / kg of dry air and $h_2 = 51$ kJ / kg of dry air. Now from the psychrometric chart, corresponding to point 2, we find that dry bulb temperature of the leaving air,

$$t_{d2} = 22.4° \text{ C} \quad \textbf{Ans.}$$

Wet bulb temperature of the leaving air,

$$t_{w2} = t_{w1} = 18° \text{ C} \quad \textbf{Ans.}$$

and relative humidity of the leaving air,

$$\phi_2 = 65\% \quad \textbf{Ans.}$$

Q4- An atmospheric air at 10°C DBT and 8°C WBT circulated at a rate of 0.3 m^3/min/person. The required inside condition for 50 persons is 20°C DBT and 60% (ϕ). The required condition is achived first by heating and then by adiabatic humidifying. Determine: 1- the heating capacity of the coil in kW and the surface temperature if the by-pass factor of the coil is (0.32), and 2- capacity of the humidifier.

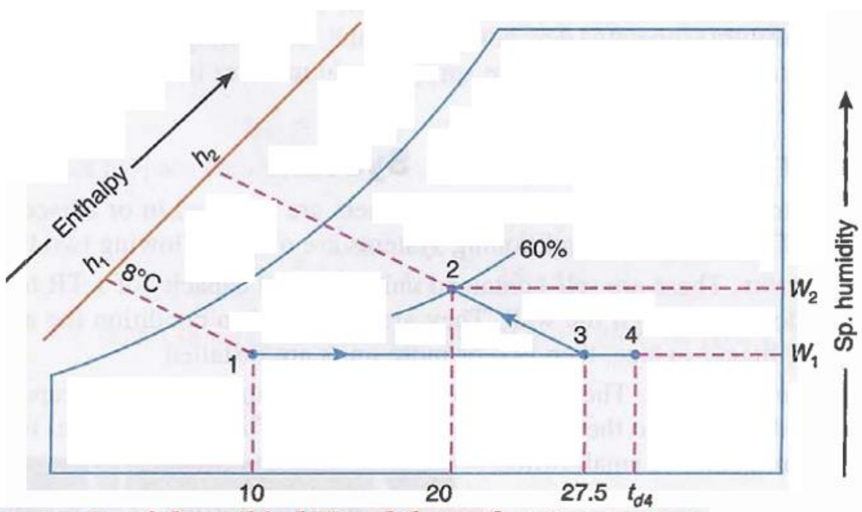
Solution. Given : $t_{d1} = 10°C$; $t_{w1} = 8°C$; $t_{d2} = 20°C$; $\phi_2 = 60\%$; seating capacity = 50 persons; $v_1 = 0.3$ m³/min/person $= 0.3 \times 50 = 15$ m³/min ; $BPF = 0.32$

First of all, mark the initial condition of air at 10°C dry bulb temperature and 8°C wet bulb temperature on the psychrometric chart as point 1, as shown in Fig. . Now mark the final condition of air at 20°C dry bulb temperature and 60% relative humidity on the chart as point 2. Now locate point 3 on the chart by drawing horizontal line through point 1 and constant enthalpy line through point 2, From the psychrometric chart, we find that the specific volume at point 1,

$$v_{s1} = 0.81 \text{ m}^3/\text{kg of dry air}$$

∴ Mass of air supplied per minute,

$$m_a = \frac{v_1}{v_{s1}} = \frac{15}{0.81} = 18.52 \text{ kg / min}$$



1. *Heating capacity of the coil in kW and the surface temperature*

From the psychrometric chart, we find that enthalpy at point 1,

$$h_1 = 24.8 \text{ kJ / kg of dry air}$$

and enthalpy at point 2, $h_2 = 42.6$ kJ / kg of dry air

We know that heating capacity of the coil

$$= m_a (h_2 - h_1) = 18.52\ (42.6 - 24.8) = 329.66 \text{ kJ/min}$$

$$= 329.66 / 60 = 5.5 \text{ kW}$$ **Ans.**

Let t_{d4} = Surface temperature of the coil.

We know that by-pass factor (*BPF*),

$$0.32 = \frac{t_{d4} - t_{d3}}{t_{d4} - t_{d1}} = \frac{t_{d4} - 27.5}{t_{d4} - 10}$$ ...[From psychrometric chart, $t_{d3} = 27.5$°C]

or $0.32\ (t_{d4} - 10) = t_{d4} - 27.5$ or $0.32\ t_{d4} - 3.2 = t_{d4} - 27.5$

$\therefore$ $t_{d4} = 24.3 / 0.68 = 35.7$°C **Ans.**

2. *Capacity of the humidifier*

From the psychrometric chart, we find that specific humidity at **point 1,**

$$W_1 = 0.0058 \text{ kg / kg of dry air}$$

and specific humidity at point 2,

$$W_2 = 0.0088 \text{ kg / kg of dry air}$$

We know that capacity of the humidifier,

$$= m_a (W_2 - W_1) = 18.52\ (0.0088 - 0.0058) = 0.055 \text{ kg / min}$$

$$= 0.055 \times 60 = 3.3 \text{ kg / h}$$ **Ans.**