Module-7

Air-conditioning Systems

PSYCHROMETRY

- The Branch of Engineering Science, which deals with the study of **moist air** and its property.
- The properties of water vapour and air mixture is known psychrometric properties
- Psychrometry attempts to understand the behavior of the moist air in various condition.

Psychrometric properties

- **Dry air: The mixture of nitrogen and oxygen.**
- **Moist Air: It is a mixture of dry air and water vapour**
  - **The maximum quantity of water vapour that can be present in air depends upon the temperature of air.**
  - **Saturation capacity of air**

PSYCHROMETRIC PROPERTIES

- **Dry-bulb temperature**: It is the temperature of the air recordered by a thermometer when it is not affected by the moisture present in air
- **Wet-bulb temperature:** It is the temperature recorded by a thermometer when its bulb is surrounded by a wet cloth exposed to air.
  - The evaporation of moisture from the wick will lower the thermometer reading (temperature)
  - If the air surrounding a wet-bulb thermometer is dry, evaporation from the moist wick will be more rapid than if the air is moist.
  - When the air is saturated, no water will evaporate from the wick and the temperature of the wet-bulb thermometer will be the same as the reading on the dry-bulb thermometer.
  - If the air is not saturated, water will evaporate from the wick causing the temperature reading to be lower.
  - Wet bulb depression = DBT-WBT

PSYCHROMETRIC PROPERTIES

- **Dew point temperature : It is the temperature recorded by a thermometer when water vapour in air begins to condense or dew is formed.**
  - The saturation temperature of the moisture present in the sample
  - When the air is saturated with water vapour, the partial pressure of water vapour is equal to the saturation pressure of water vapour corresponding to air temperature.
  - **For saturated air, All temp will be equal**

DBT = WBT = DPT

PSYCHROMETRIC PROPERTIES

- **Humidity ratio or Specific Humidity**

  It is the mass of water (g) vapour present in 1 kg of dry air and is expressed as g/kg of air or kg/kg of air.

- **Relative Humidity (RH)**

It is a measure of how much water vapour is present in the air compared to the maximum amount the air can hold at a given temperature.

$$\mathrm{RH} = \frac{\text{Actual water vapor in air}}{\text{Maximum water vapour air can hold at same temperature}} \times 100$$

PSYCHROMETRIC PROPERTIES

Explanation:

- If RH = **100%** → Air is fully saturated (cannot hold more moisture, condensation may occur)
- If RH = **50%** → Air contains half of the moisture it can hold
- If RH = **0%** → Completely dry air

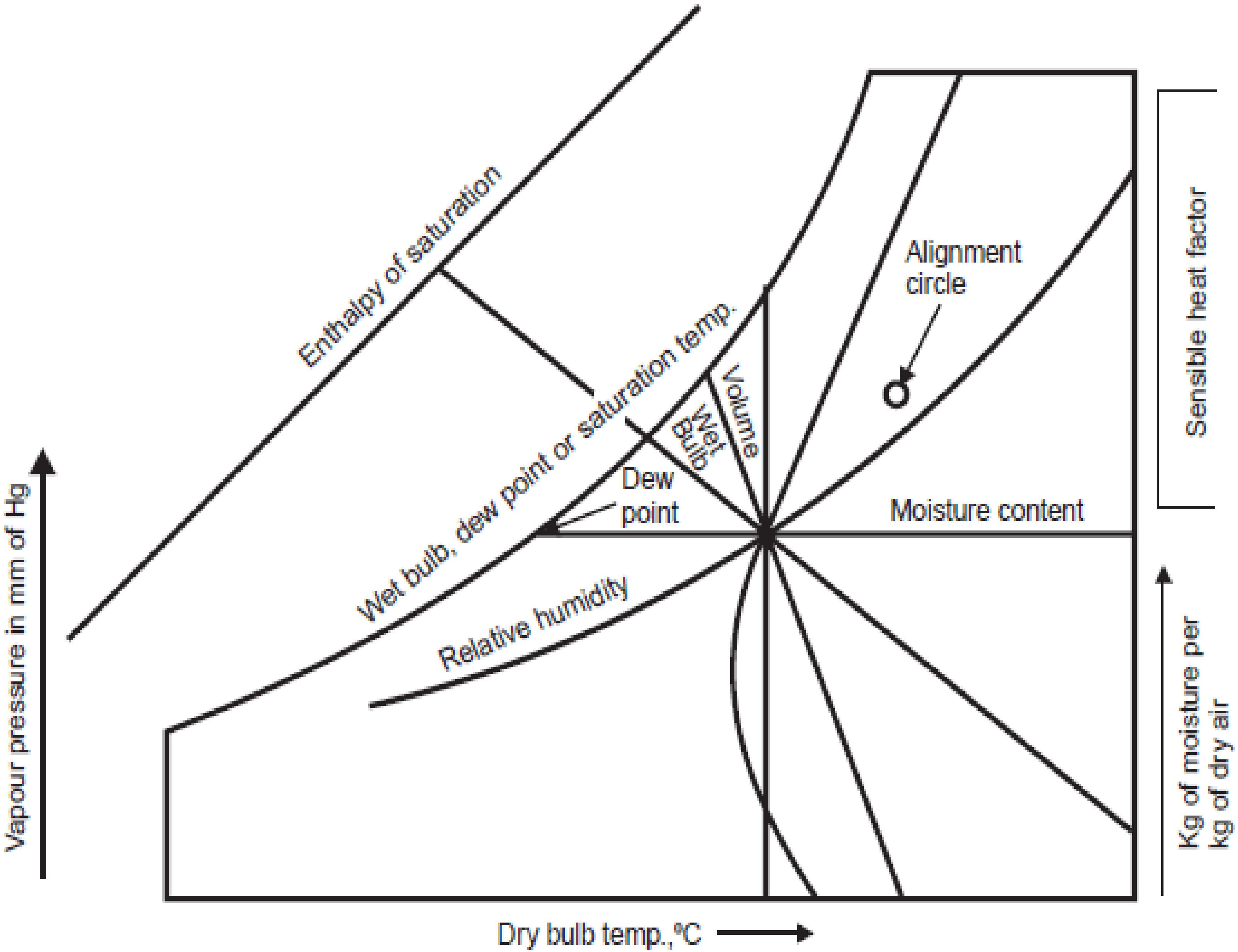
Note:

- Warm air can hold **more moisture** than cold air
- RH depends on **temperature** as well as moisture content
- When RH is high, we feel **more humid and uncomfortable**
- When RH is low, the air feels **dry**

Relative Humidity Vs Specific Humidity

Aspect	Relative Humidity (RH)	Specific Humidity (ω)
Definition	Ratio of actual water vapor to the maximum possible at the same temperature	Mass of water vapor per unit mass of moist air
Formula	RH = (Actual vapor / Saturation vapor) × 100	ω = mass of vapor / mass of moist air
Unit	Percentage (%)	kg/kg (or g/kg)
Depends on Temperature?	✅ Yes (strongly dependent)	❌ No (independent of temperature)
Indicates	How close air is to saturation	Actual moisture content in air
Changes with Heating/ Cooling	Changes even if moisture is constant	Remains constant if no moisture is added/ removed
Use	Comfort level, weather reports	Engineering calculations (HVAC, psychrometrics)

PSYCHROMETRIC CHART



COOLING LOAD CACULATIONS

Basic Processes in Conditioning of Air:

Four basic thermodynamic processes and four combinations of processes by which the state of moist air can be altered.

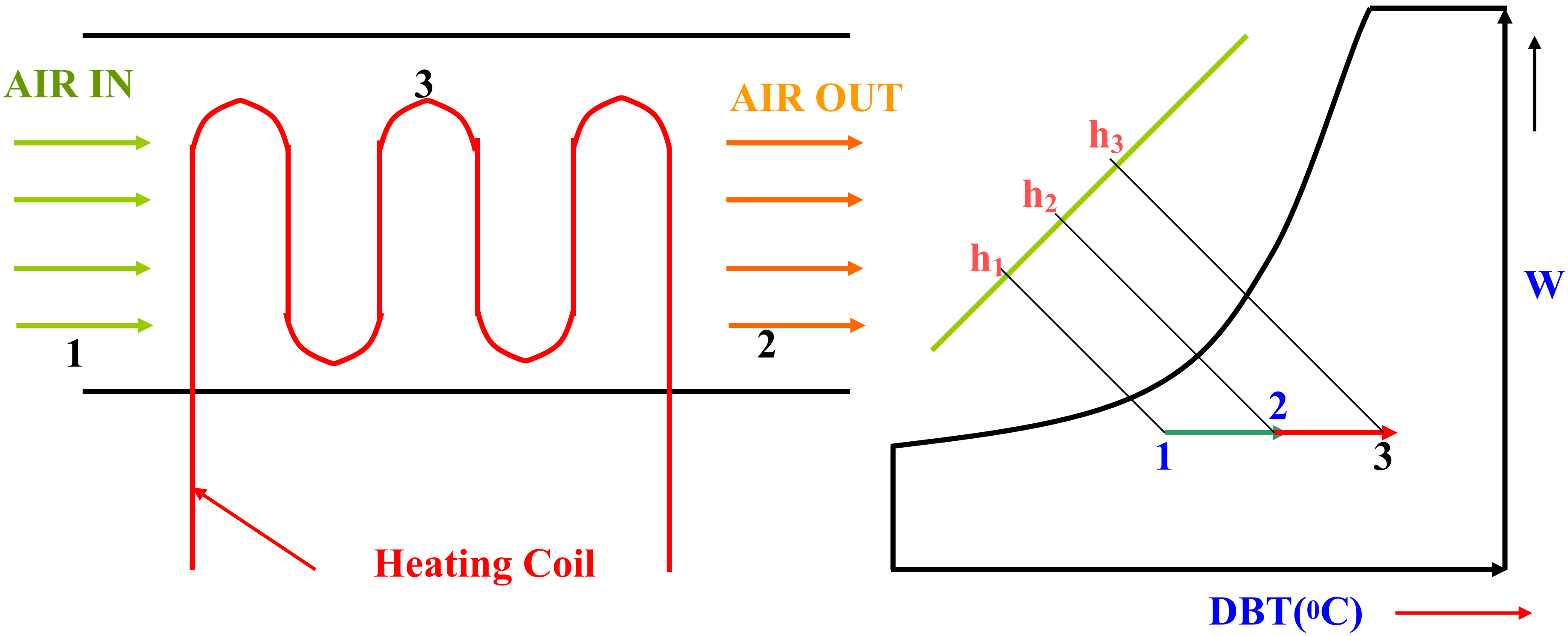
1. Sensible Heating Process
2. Sensible Cooling Process
3. Humidifying process
4. Dehumidifying Process
5. Heating and humidifying process
6. Cooling and Dehumidifying process
7. Cooling and humidifying process
8. Heating and Dehumidifying process.

SENSIBLE HEATING PROCESS

- The sensible heat of the air is mainly due to the dry air present in the air.
- When the temperature of the air is changed, it is the temperature of the dry air that changes and it either absorbs or liberates the sensible heat.
- The water vapor present within the air also absorbs or liberates the sensible heat, but this quantity is very small so it is not taken into account.
- Sensible heat of the air depends on dry bulb temperature of the air and the mass of the dry air.

When the state of moist air is altered, along the ω = constant line such as 1-2 in figure. the heat is transferred which goes to change the temperature of the air. The heat transfer is given by, $Q_s = m_a (h_2-h_1)$

SENSIBLE HEATING PROCESS



1 –Inlet Fluid Temperature

2 – Outlet Fluid Temperature

3 - Heating coil surface temperature

SENSIBLE HEATING PROCESS

By pass factor:

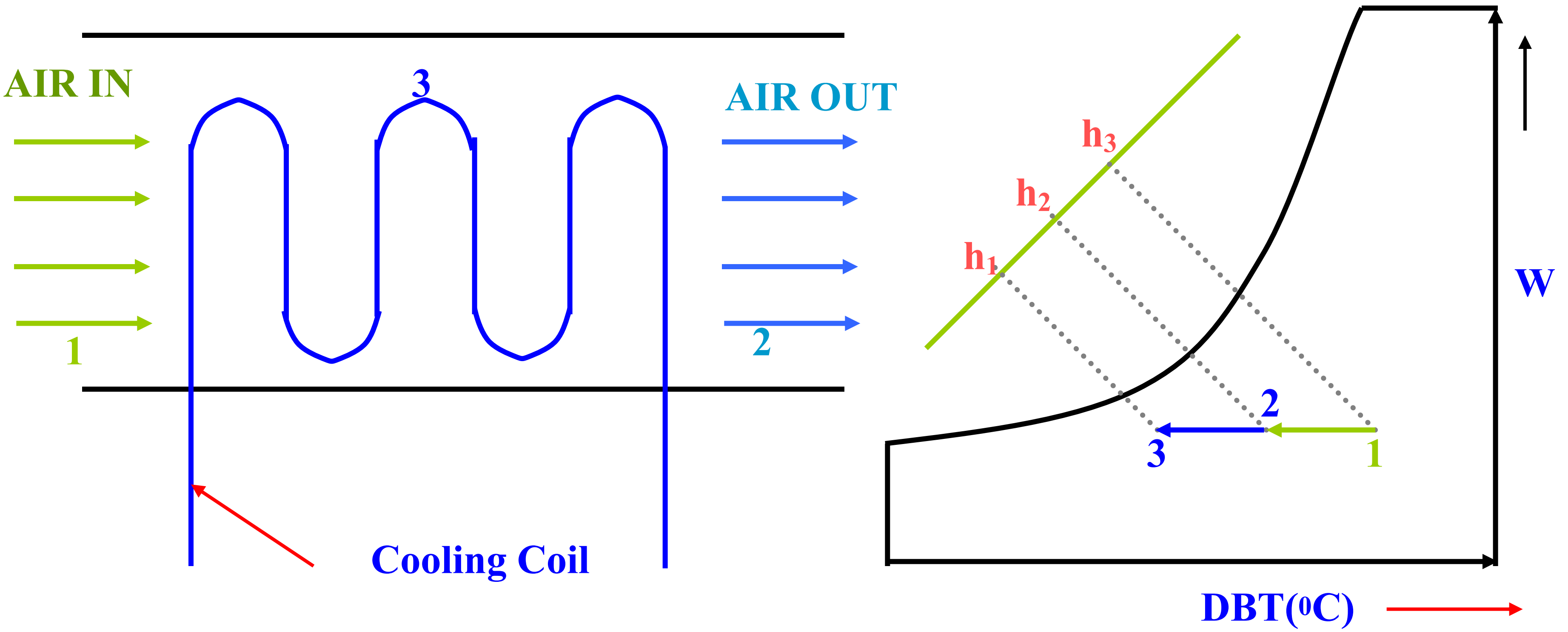
It is defined as the ratio of the difference between the mean surface temperature of the coil and leaving air temperature to the difference between the mean surface temperature and the entering air temperature.

By Pass factor (BPF)

$$BPF = \frac{\Delta T_{actual}}{\Delta T_{Maximum}} = \frac{T_3 - T_2}{T_3 - T_1}$$

Note: **By pass factor gives the fraction of air which does not come into contact with heating coil surface.**

SENSIBLE COOLING PROCESS



1 – Fluid in Temperature
2 – Fluid out Temperature
3 - Cooling coil surface temperature

SENSIBLE COOLING PROCESS

By pass factor:

It is defined as the ratio of the difference between the mean surface temperature of the coil and leaving air temperature to the difference between the mean surface temperature and the entering air temperature.

i.e., Air at temperature T_{DBT1} passes over a Cooling coil of temperature T_{DBT3} and leaves the temperature of T_{DBT2}.

By Pass factor (BPF)

$$BPF = \frac{\Delta T_{actual}}{\Delta T_{Maximum}} = \frac{T_2 - T_3}{T_1 - T_3}$$

Note: **By pass factor gives the fraction of air which does not come into contact with Cooling coil surface.**

SENSIBLE COOLING PROCESS

When the state of moist air is altered, along the ω = constant line such as 1-2 in fig. the heat is transferred which goes to change the temperature of the air. The heat transfer is calculated using,

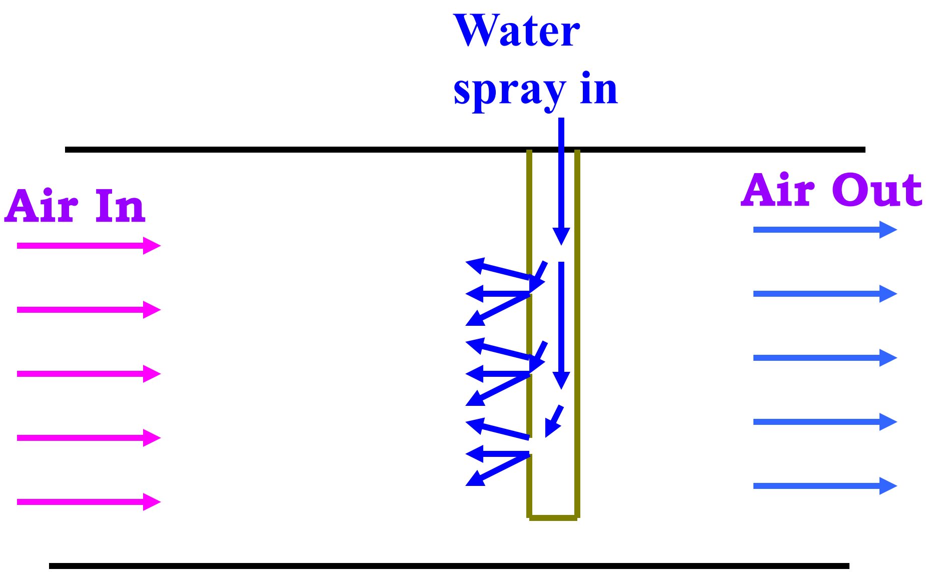
$$Q_s = m_a (h_1 - h_2)$$

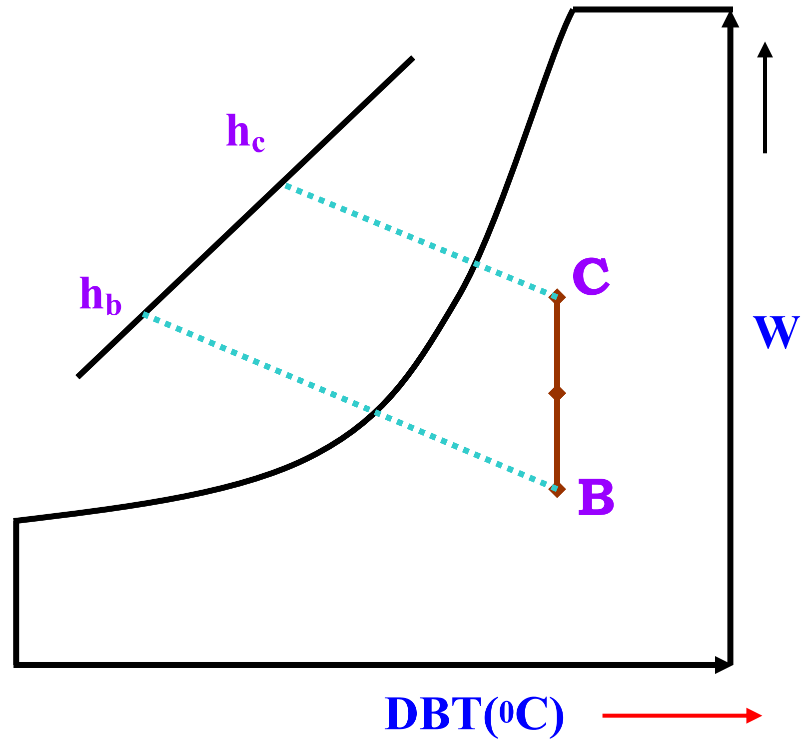
The subscript 's' denoted by 'Sensible Cool'.

Humidification or Dehumidification Process

- No change in the phase of the dry air present in the air mixture, it does not have any latent heat
- Water vapor present within the air undergoes changes in the phase when the air is either cooled or heated hence the latent heat within the air is present due to water vapor.
- The dew point temperature of the air when it is saturated decides the amount of moisture content present within the air.
- Latent heat of air depends on the dew point temperature of air
- The sensible heat depends on dry bulb temperature of air while latent heat depends on dew point temperature of the air. Total quantity of heat in the air depends on the dry bulb and dew point temperature of the air

Humidification or Dehumidification Process





Chemicals:

Calcium chloride

Silica gel and activated carbon

COOLING LOAD CALCULATIONS

Total Heat Process:

Consider now a change in the state of air along the path B-C; this involves both a change in temperature and the humidity ratio.

The Change in temperature causes a sensible heat load is given by

$$Q_s = m_a(h_c-h_b) = m_a\, C_p\, (T_c-T_b)$$

The change in the humidity ratio causes a moisture transfer is given by

$$G = m_a\, (\omega_c - \omega_b)$$

and a latent heat load given by,

$$Q_L = m_a(h_c-h_b)= m_a\, h_{fgo}\, (\omega_c - \omega_b)$$

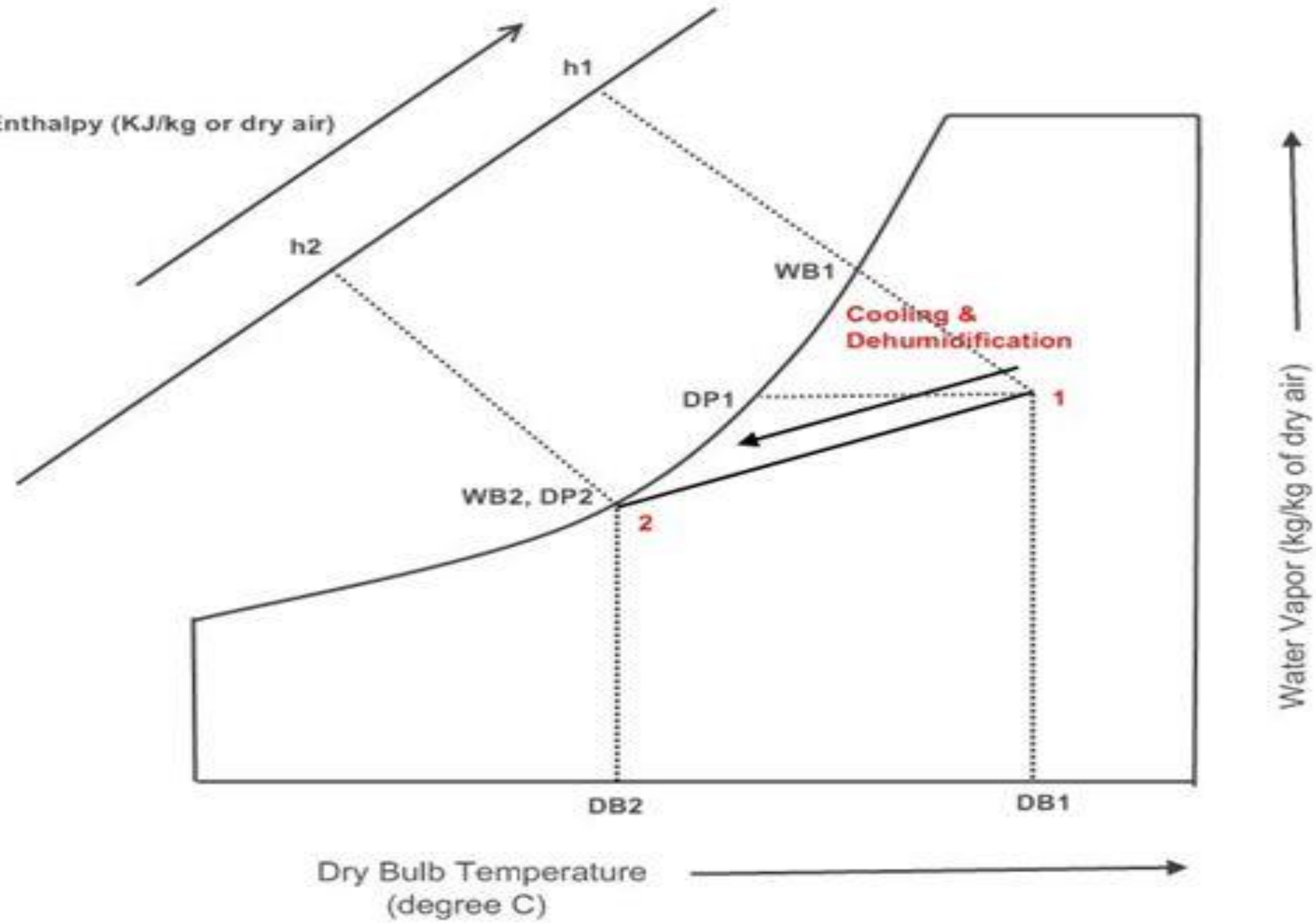
adding the sensible heat load and latent heat load is given as Total heat load is given by

$$Q_T = Q_s + Q_L = m_a(h_c-h_b)$$

$$= m_a\, [C_p(T_c-T_b) + h_{fgo}\, (\omega_c - \omega_b)]$$

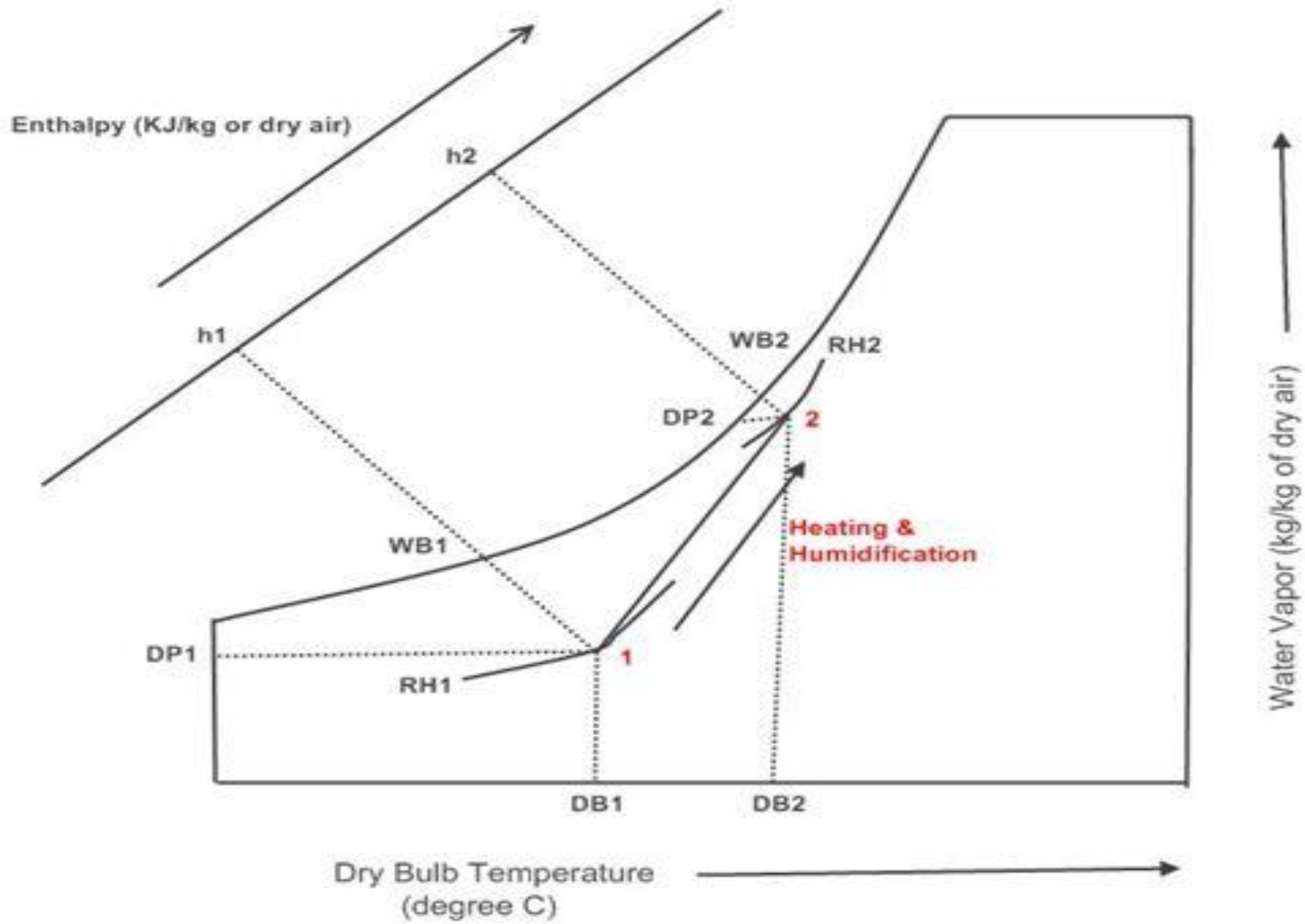
Cooling and Dehumidification process

- Cooling and dehumidification process is obtained when the air at the given dry bulb and dew point (DP) temperature is cooled below the dew point temperature
- During the cooling and dehumidification process the dry bulb, wet bulb and the dew point temperature of air reduces
- Similarly, the sensible heat and the latent heat of the air also reduce leading to overall reduction in the enthalpy of the air.


Enthalpy (KJ/kg or dry air)
h1
h2
WB1
Cooling &
Dehumidification
DP1
1
WB2, DP2
2
DB2
DB1
Water Vapor (kg/kg of dry air)
Dry Bulb Temperature
(degree C)

Heating and Humidification Process

- The dry bulb temperature as well as the humidity of the air increases.
- The heating and humidification process is carried out by passing the air over spray of water, which is maintained at temperature higher than the dry bulb temperature of air or by mixing air and the steam.
- During the heating and humidification process, the dry bulb, wet bulb, and dew point temperature of the air increases along with its relative humidity.

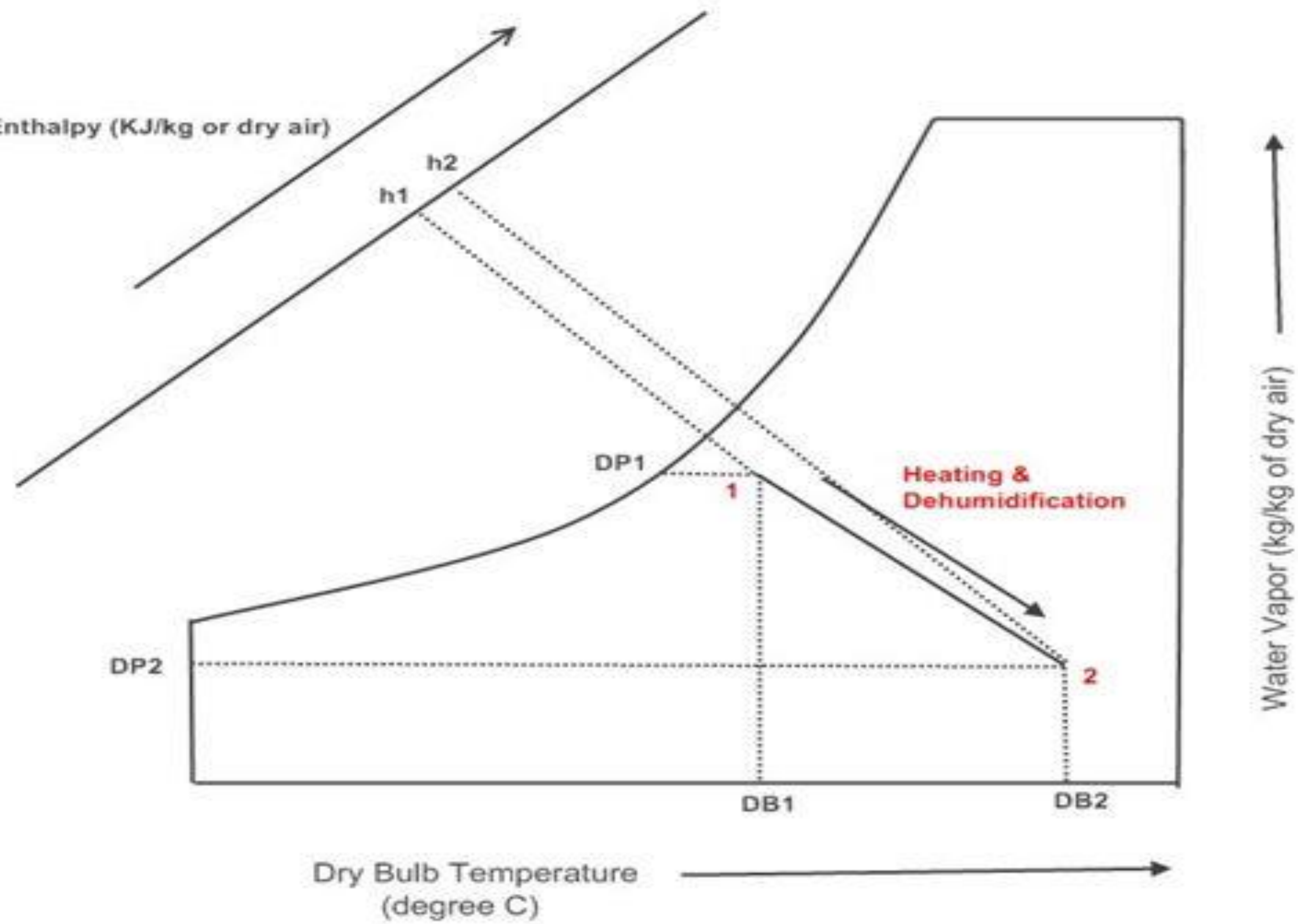


Enthalpy (KJ/kg or dry air)
h2
h1
WB2
RH2
DP2
2
Heating &
Humidification
WB1
DP1
1
RH1
DB1
DB2
Dry Bulb Temperature
(degree C)
Water Vapor (kg/kg of dry air)

Heating and Dehumidification Process

- This process is obtained by passing the air over certain chemicals like silica jel , alumina and molecular sieves

- During the heating and dehumidification process **dry bulb temperature of the air increases while its dew point and wet bulb temperature reduces.**


Enthalpy (KJ/kg or dry air)
h2
h1
DP1
1
Heating &
Dehumidification
DP2
2
DB1
DB2
Dry Bulb Temperature
(degree C)
Water Vapor (kg/kg of dry air)

COOLING LOAD CALCULATIONS

Sensible Heat Factor (SHF):

The ratio of the sensible heat transfer to the total heat transfer is termed as the Sensible Heat Factor.

$$SHF = (Q_S)/(Q_s+Q_L)$$

Where,

Q_s = **Sensible Heat Load**

Q_L = **Latent Heat Load**

Sensible Heat Factor = SH/(SH+LH)

Effect of psychrometric processes on their properties:

S. No	**Psychrometric Property**	**Effect of Psychrometric processes**			
		Sensible Heating	***Sensible Cooling***	***Cooling and Dehumidi cation***	***Heating and humidifi c ation***
1	DBT	Increase	Decreases	Decreases	Increases
2	WBT	Increase	Decreases	Decreases	Increases
3	Specific Volume	Increase	Decreases	Decreases	Increases
4	Relative Humdity	Decreases	Increases	Decreases	Decreases
5	Moisture Contact	Constant	Constant	Decreases	Increases
6	Enthalpy	Increase	Decreases	---	---

Classification of Air Conditioning Systems

According to purpose

a. Comfort air conditioning system

b. Industrial air conditioning system

According to season of the year

a. Winter air conditioning system

b. Summer air conditioning system

c. Year round air conditioning system

According to the arrangement of equipment

a. Unitary air conditioning system

b. Central air conditioning system (>25 TR, 300 m^3/min)

SUMMER AIR CONDITIONING SYSTEMS

In summer, the air temperature and humidity both are high.

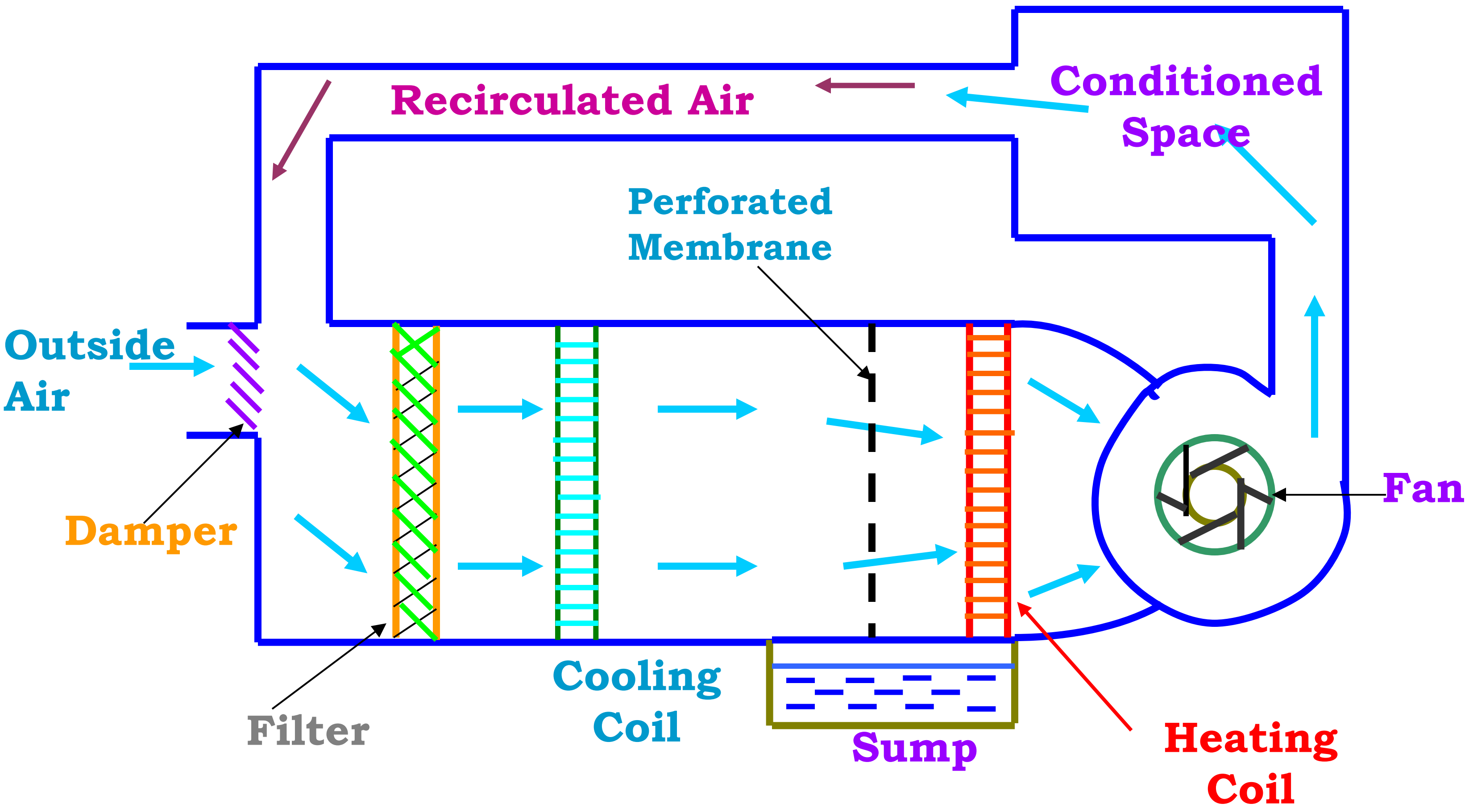
Therefore, the room Lose heat as well as moisture.

It is thus required to cool and dehumidify the recirculated room air in the air – conditioning apparatus either by the use of cooling coil or by an air drier in which chilled water is collected.

The process follows as the Room Sensible Heat Factor (RSHF)

RSHF = RSH / (RSH+RLH)

SUMMER AIR CONDITIONING SYSTEMS



SUMMER AIR CONDITIONING SYSTEMS

Working principle of Summer Air-Conditioning System:

The outside air flows through the damper and mixes up with recirculated air

The mixed air passes through a filter to remove dirt, dust and other impurities.

The air now passes through a Cooling coil.

The coil has a temperature much below the required DBT of air in the conditioned space.

The Cooled air passes through the perforated membrane and looses its moisture in the condensed form which is collected in a sump.

After that, the air is made to pass through the heating coil which heats up the air slightly.

This is done to bring the air to designed DBT and relative humidity.

Now the conditioned air is supplied to the conditioned space by a fan.

From the conditioned space, a part of used air is exhausted to atmosphere by the exhaust fans or ventilators.

The remaining part of the used air again recirculated.

- Auditoriums, Theaters - SHR : 0.65 - 0.75
- Apartments - SHR : 0.80 - 0.95
- Banks, Court Houses, Municipal Buildings - SHR : 0.75 - 0.90
- Computer Rooms - SHR : 0.80 - 0.95
- Jails - SHR : 0.80 - 0.95
- Hospital Patient Rooms, Nursing Home, Patient Rooms - SHR : 0.75 - 0.85
- Kitchens - SHR : 0.60 - 0.70
- Restaurants - SHR : 0.65 - 0.80
- Residences - SHR : 0.80 - 0.95

WINTER AIR CONDITIONING SYSTEMS

In Winter, the air temperature and humidity both are low.

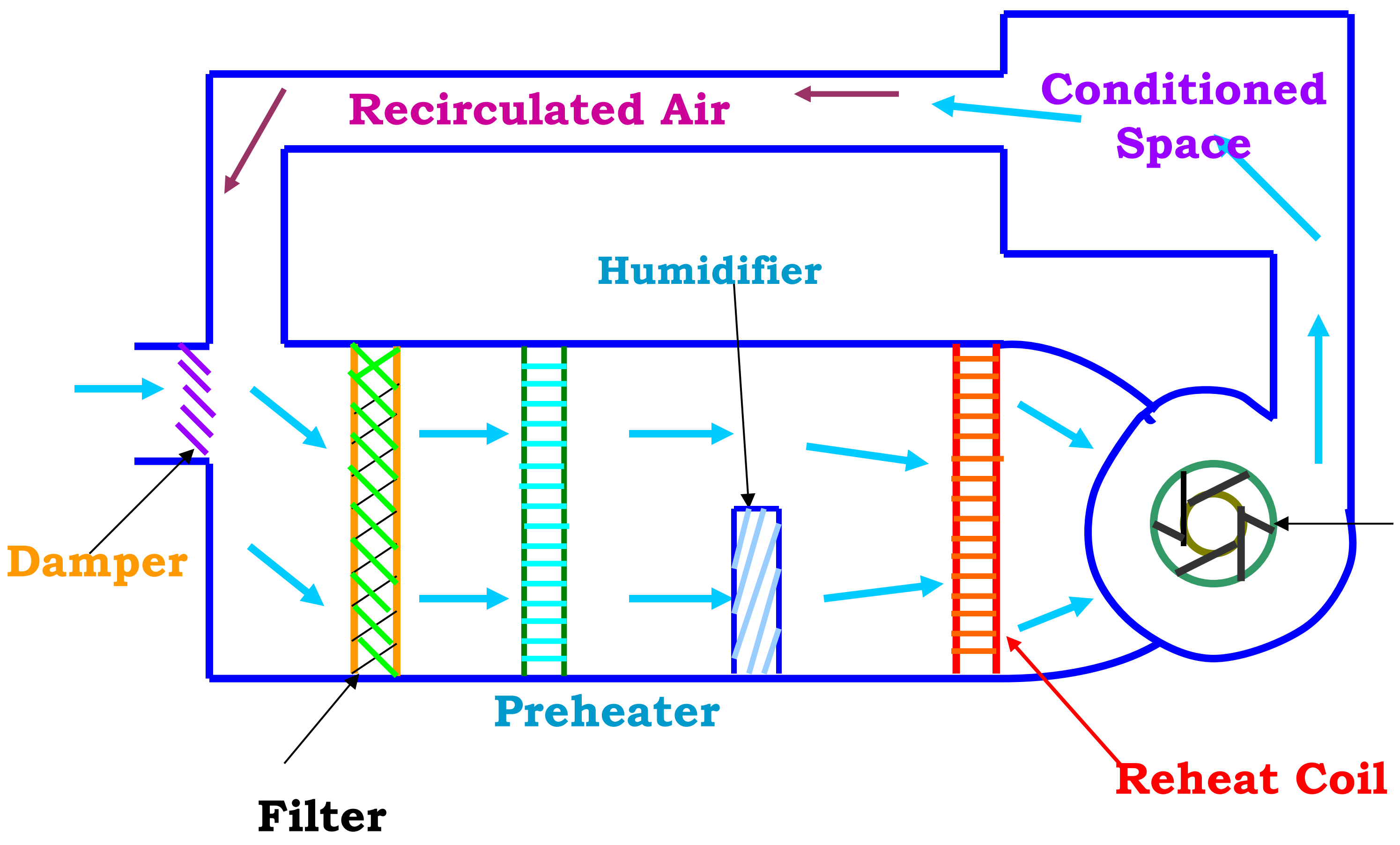
Therefore, the room gains heat as well as moisture.

It is thus required to heat and humidify the recirculated room air in the air – conditioning apparatus either by the use of heating coil and in humidifier in which chilled water is sprayed.

The process follows as the Room Sensible Heat Factor (RSHF)

RSHF = RSH / (RSH+RLH)

WINTER AIR CONDITIONING SYSTEMS



WINTER AIR CONDITIONING SYSTEMS

Working principle of Winter Air-Conditioning System:

The outside air flows through the damper and mixes up with recirculated air

The mixed air passes through a filter to remove dirt, dust and other impurities.

The air now passes through a pre heater coil in order to prevent the possible freezing of water and to control the evaporation of water in the humidifier.

After that, the air is made to pass through a reheat coil to bring the air to desired DBT.

Now the conditioned air is supplied to the conditioned space by a fan.

From the conditioned space, a part of used air is exhausted to atmosphere by the exhaust fans or ventilators.

The remaining part of the used air again recirculated.

COOLING LOAD CALCULATIONS

Important consideration on cooling load calculations:

Date and time at which these calculations are made.

The date would depend on local climate conditions.

The longest day in summer is June 21

The hottest and most humid day may occur in July

The coldest day may occur in December or even in January.

The maximum temperature may occur outside is at AROUND 1 PM

The maximum heat gain by the room may occur at 2 to 3 PM due to direct solar radiation through the glass on the west side, or even later due to the time lag for the heat transfer through the building structure.

The application for which the building is intended to be used would also govern the choice of time.

For eg.,

An office room in summer the maximum cooling load at 7 PM due to the time lag, but since no occupants present at that time, then the time for cooling load calculation may be taken as 4 to 5 PM.

COOLING LOAD CALCULATIONS

Internal heat gains:

The sensible and latent heat gains due to occupant, lights, appliances, machines, piping etc., within the conditioned space form the components of internal heat gain.

COOLING LOAD CALCULATIONS

1. Occupancy load:

The occupants in a conditioned rate space give due heat at metabolic rate the more or less depends on their rate of working.

The lower the DBT, the greater the heat given out as sensible heat.

Activity	Metabolic rate in Watts
Seated at rest	115
Office work	140
Standing	150
Eating	160
Dancing	265
Light work	235

COOLING LOAD CALCULATIONS

Appliances Load:

Most appliances contribute both sensible and latent heats.

Latent heat produced depends on the function the appliance perform, such as drying, cooking etc.,

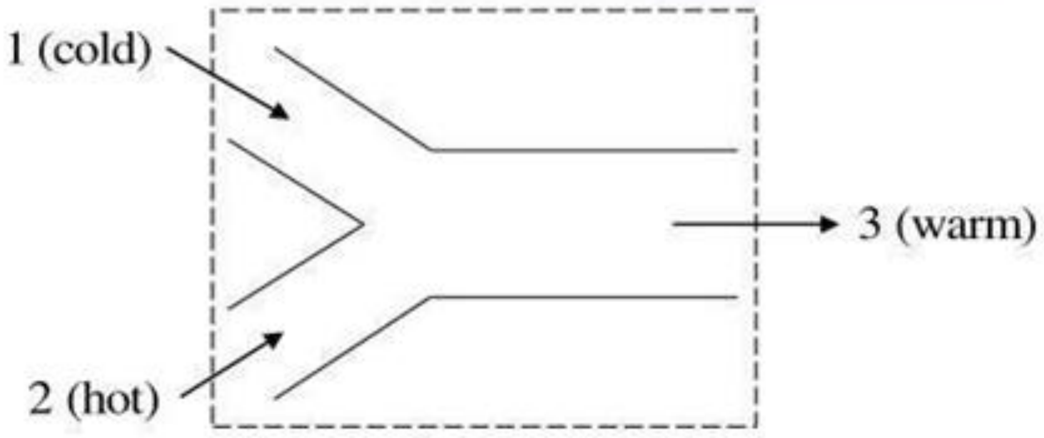
Electric motor contribute sensible heat load to the conditioned space.

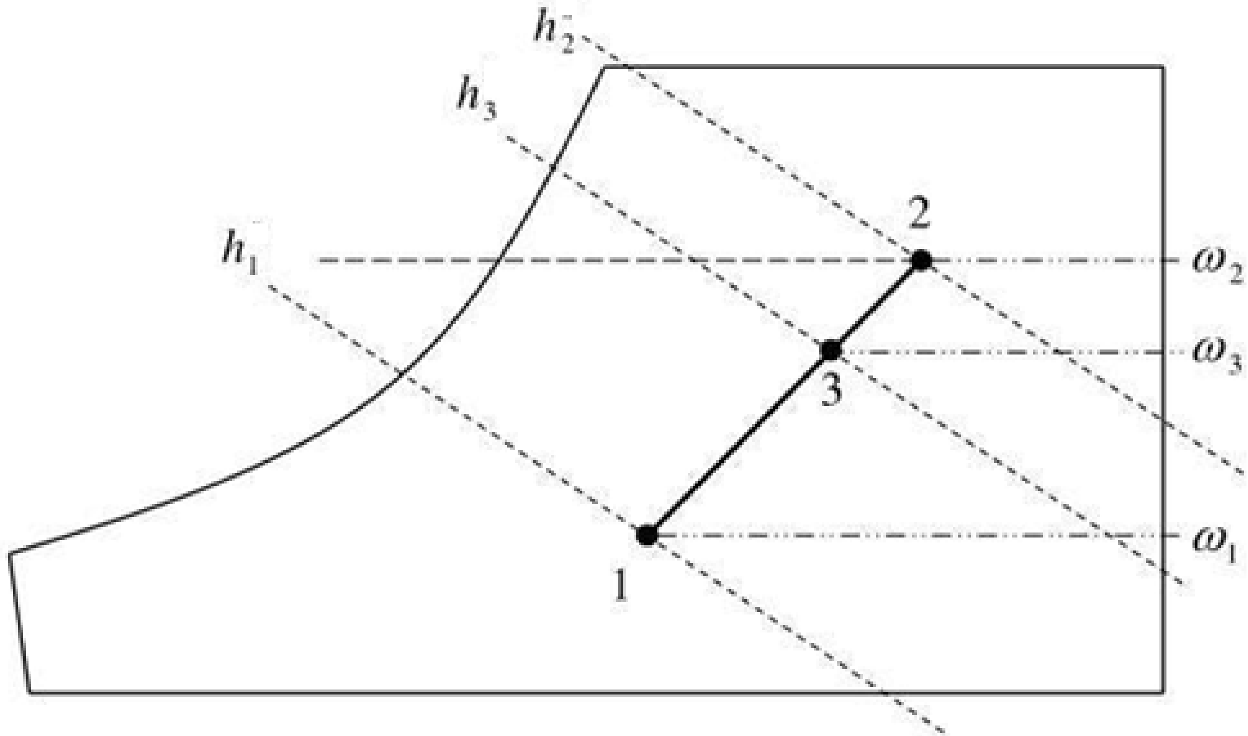
The rest of power input is utilized by the driven mechanism for doing work which may or may not result in heat gain to the space.

Appliance	Sensible	Latent	Total heat
Coffee brewer	265	65	329
Egg boiler	353	235	588
Toaster	1500	382	1882

All units are given per hour basis.

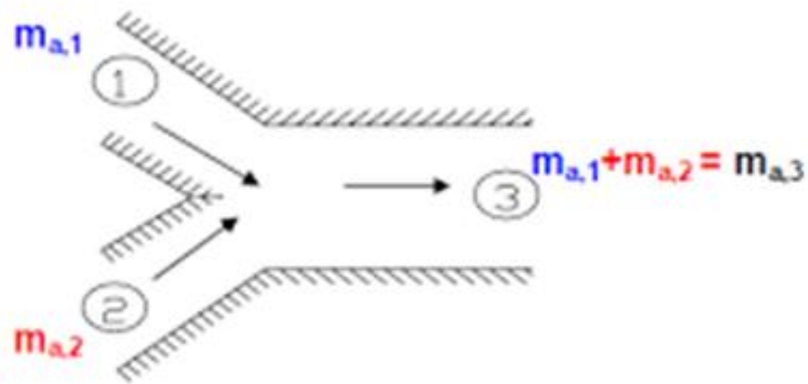
Adiabatic Mixing of Hot and Cold Air Streams





Adiabatic Mixing of Hot and Cold Air Streams

Mass Balance of dry air (Eqn. 1)



$$\dot{m}_{a1} + \dot{m}_{a2} = \dot{m}_{a3}$$

Energy Balance : (Eqn. 2)

$$\dot{m}_{a1} h_1 + \dot{m}_{a2} h_2 = \dot{m}_{a3} h_3$$

Mass Balance of water vapour (Eqn. 3)

$$\omega_1 \dot{m}_{a1} + \omega_2 \dot{m}_{a2} = \omega_3 \dot{m}_{a3}$$

Substituting m_{a3} from eqn. 1 in Eqn. 2 and in Eqn. 3 we get,

$$\dot{m}_{a1} h_1 + \dot{m}_{a2} h_2 = \left(\dot{m}_{a1} + \dot{m}_{a2}\right) h_3$$

$$\frac{\dot{m}_{a1}}{\dot{m}_{a2}} = \frac{h_2 - h_3}{h_3 - h_1}$$

$$\omega_1 \dot{m}_{a1} + \omega_2 \dot{m}_{a2} = \left(\dot{m}_{a1} + \dot{m}_{a2}\right) \omega_3$$

$$\frac{\dot{m}_{a1}}{\dot{m}_{a2}} = \frac{\omega_2 - \omega_3}{\omega_3 - \omega_1}$$

Numerical on Adiabatic Mixing of Hot and Cold Air Streams

1. Fresh air of 300 m^3/min is at 30°C (DBT) and 50% relative humidity is to be mixed with 800 m^3/min of recirculated air at 22°C DBT and 10°C dew point temperature. Determine the specific enthalpy and specific volume, humidity ratio and dew point temperature of the mixture.

Numerical on Adiabatic Mixing of Hot and Cold Air Streams

1. Fresh air of 300 m^3/min is at 30°C (DBT) and 50% relative humidity is to be mixed with 800 m^3/min of recirculated air at 22°C DBT and 10°C dew point temperature. Determine the specific enthalpy and specific volume, humidity ratio and dew point temperature of the mixture.

Given data :

$m_{a1} = 300\, m^3 / \min$

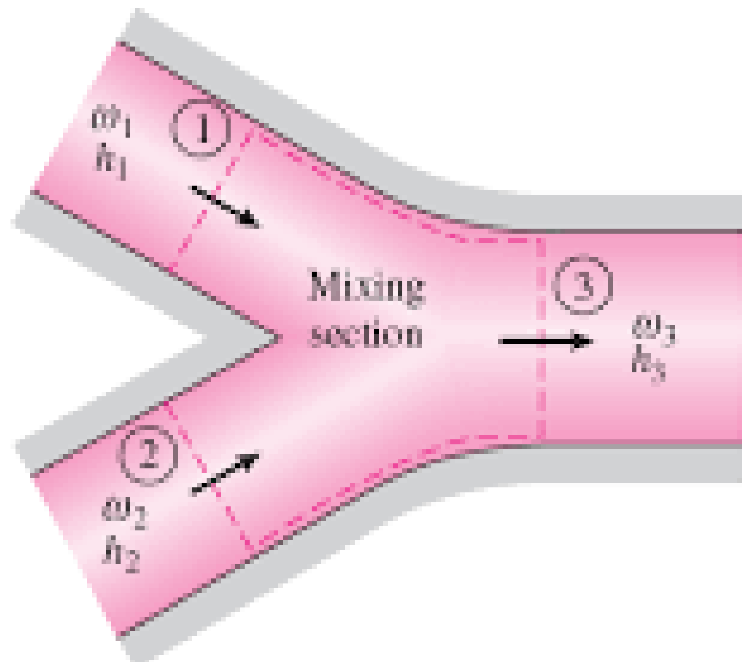
$DBT_1 = 30^\circ C$

$\phi_1 = 50\%$

$m_{a2} = 800\, m^3 / \min$

$DBT_2 = 22^\circ C$

$DPT_2 = 10^\circ C$



To Find :

h_3, vs_3, w_3, DPT_3

Numerical on Adiabatic Mixing of Hot and Cold Air Streams

$Given\,data:$

$m_{a1} = 300\,m^3/\text{min}$

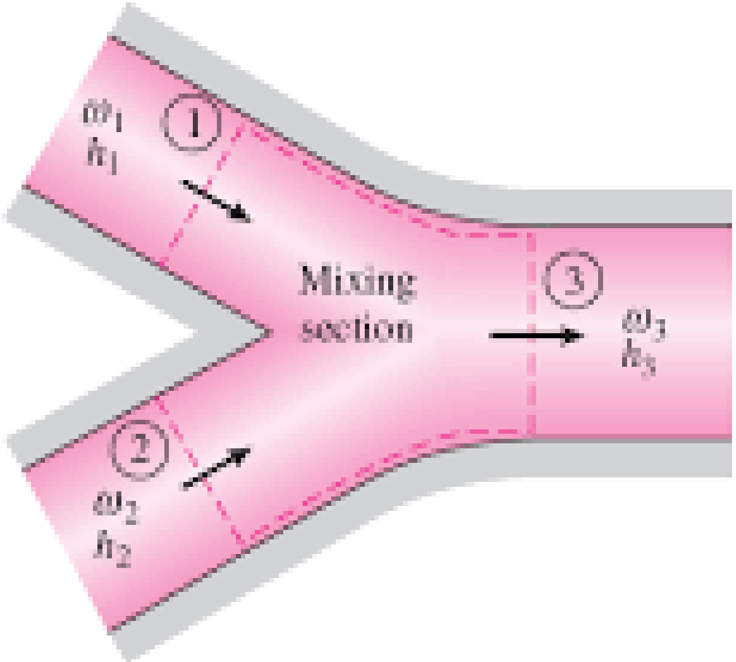
$DBT_1 = 30^\circ C$

$\phi_1 = 50\%$

$m_{a2} = 800\,m^3/\text{min}$

$DBT_2 = 22^\circ C$

$DPT_2 = 10^\circ C$



$To\,Find:$

h_3, vs_3, w_3, DPT_3

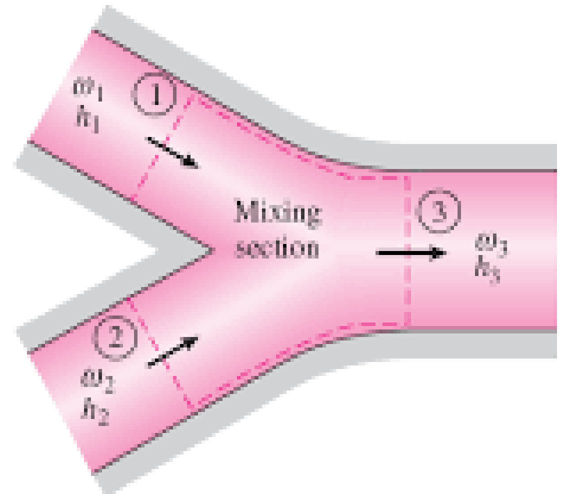
$$\frac{\dot{m}_{a1}}{\dot{m}_{a2}} = \frac{h_2 - h_3}{h_3 - h_1}$$

$$\frac{\dot{m}_{a1}}{\dot{m}_{a2}} = \frac{\omega_2 - \omega_3}{\omega_3 - \omega_1}$$

Numerical on Adiabatic Mixing of Hot and Cold Air Streams

$To\ Find:$

h_3, vs_3, w_3, DPT_3



$From\ Psychrometric\ Chart,$

$h_2 = 64.6\, kJ/kg\ of\ dry\ air$

$h_1 = 41.8\, kJ/kg\ of\ dry\ air$

$w_2 = 0.014\, kg/kg\ of\ dry\ air$

$w_1 = 0.0076\, kg/kg\ of\ dry\ air$

$vs_2 = 0.877\, m^3/kg\ of\ dry\ air$

$vs_1 = 0.846\, m^3/kg\ of\ dry\ air$

$$m_{a2} = \frac{300\, m^3/\min}{v_{s2}} = 342.07\, kg/\min$$

$$m_{a1} = \frac{800\, m^3/\min}{v_{s1}} = 945.6\, kg/\min$$

$w.k.t$

$$\frac{m_{a1}}{m_{a2}} = \frac{h_2 - h_3}{h_3 - h_1} \qquad h_3\ ?$$

Numerical on Adiabatic Mixing of Hot and Cold Air Streams

$$To\ Find:$$

$$h_3, vs_3, w_3, DPT_3$$

$$w.k.t$$

$$\frac{m_{a1}}{m_{a2}} = \frac{h_3 - h_2}{h_1 - h_3} \qquad h_3 = 47.86\, kJ / kg\ of\ dry\ air\ ?$$

Mark state-3 on the line joining the state-1 and state-2 corresponds to enthalpy h_3 on psychrometric chart.

For state-3 we get,

$$vs_3 = 0.855\, m^3 / kg\ of\ dry\ air$$

$$w_3 = 0.0092\ kg / kg\ of\ dry\ air$$

$$DPT_3 \approx 12.7^\circ C$$

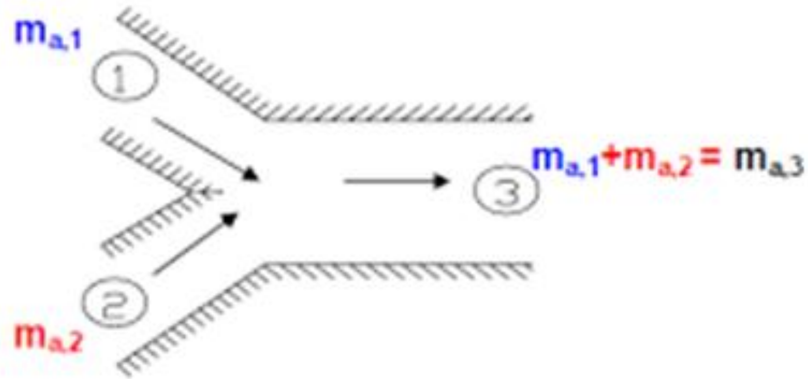
Numerical on Adiabatic Mixing of Hot and Cold Air Streams

1. Fresh air of 200 m^3/min is at 40°C (DBT) and 50% relative humidity is to be mixed with 900 m^3/min of recirculated air at 20°C DBT and 10°C dew point temperature. Determine the specific enthalpy and specific volume, humidity ratio and dew point temperature of the mixture.

Adiabatic Mixing of Hot and Cold Air Streams

Mass Balance of dry air (Eqn. 1)

$$\dot{m}_{a1} + \dot{m}_{a2} = \dot{m}_{a3}$$



Energy Balance : (Eqn. 2)

$$\dot{m}_{a1}h_1 + \dot{m}_{a2}h_2 = \dot{m}_{a3}h_3$$

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Substituting m_{a3} from eqn. 1 in Eqn. 2 and in Eqn. 3 we get,

$$\dot{m}_{a1}h_1 + \dot{m}_{a2}h_2 = \left(\dot{m}_{a1} + \dot{m}_{a2}\right)h_3$$

$$\frac{\dot{m}_{a1}}{\dot{m}_{a2}} = \frac{h_2 - h_3}{h_3 - h_1}$$

$$\omega_1\dot{m}_{a1} + \omega_2\dot{m}_{a2} = \left(\dot{m}_{a1} + \dot{m}_{a2}\right)\omega_3$$

$$\frac{\dot{m}_{a1}}{\dot{m}_{a2}} = \frac{\omega_2 - \omega_3}{\omega_3 - \omega_1}$$

Cooling Load Calculation

2. It is required to design an air conditioning plant for a small office room for the following winter conditions:

Outdoor conditions = 14°C DBT and 10°C WBT

Required Conditions= 20°C DBT and 60% RH

Amount of air circulation= 0.3 m^3 /min /person

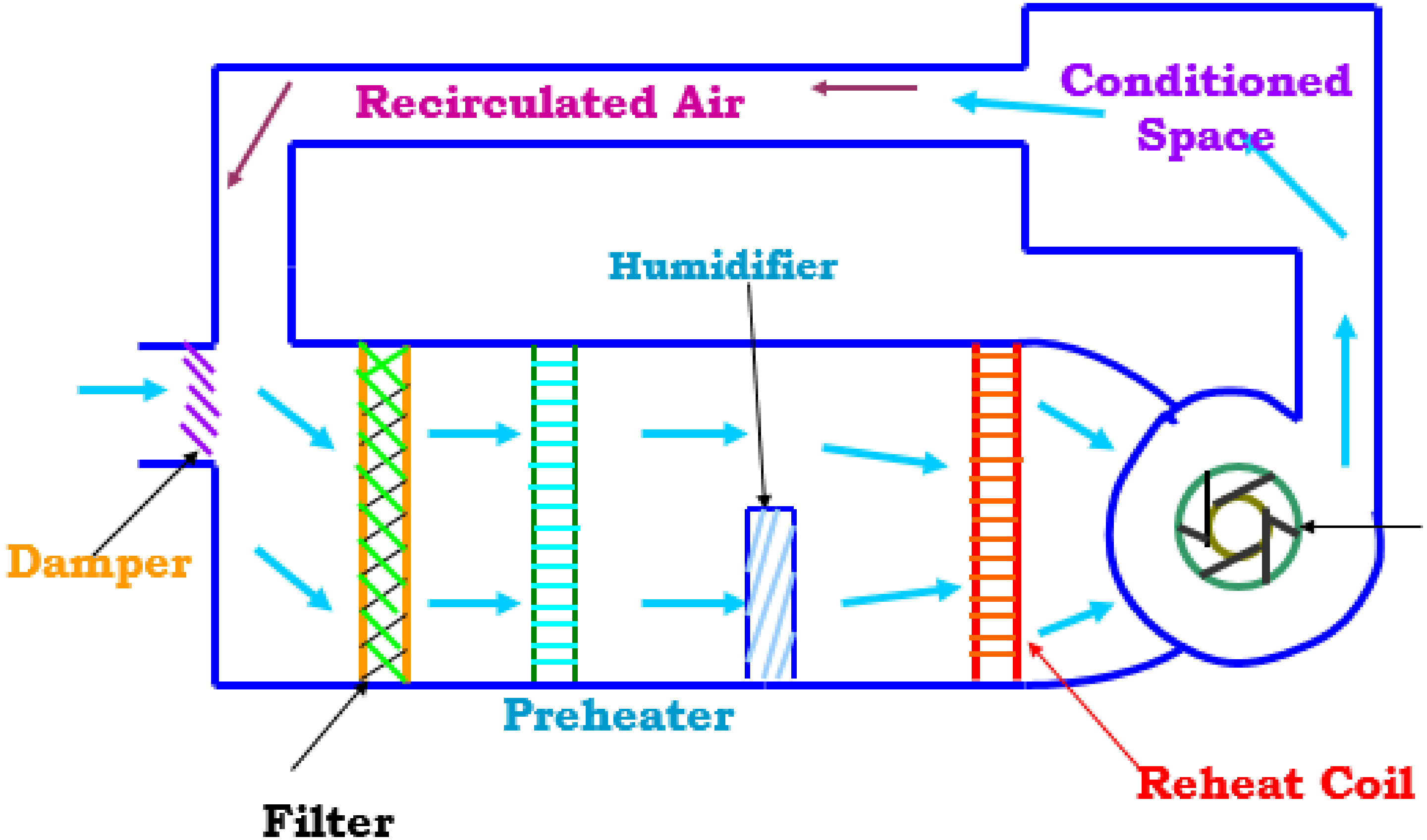
Seating Capacity of office = 60

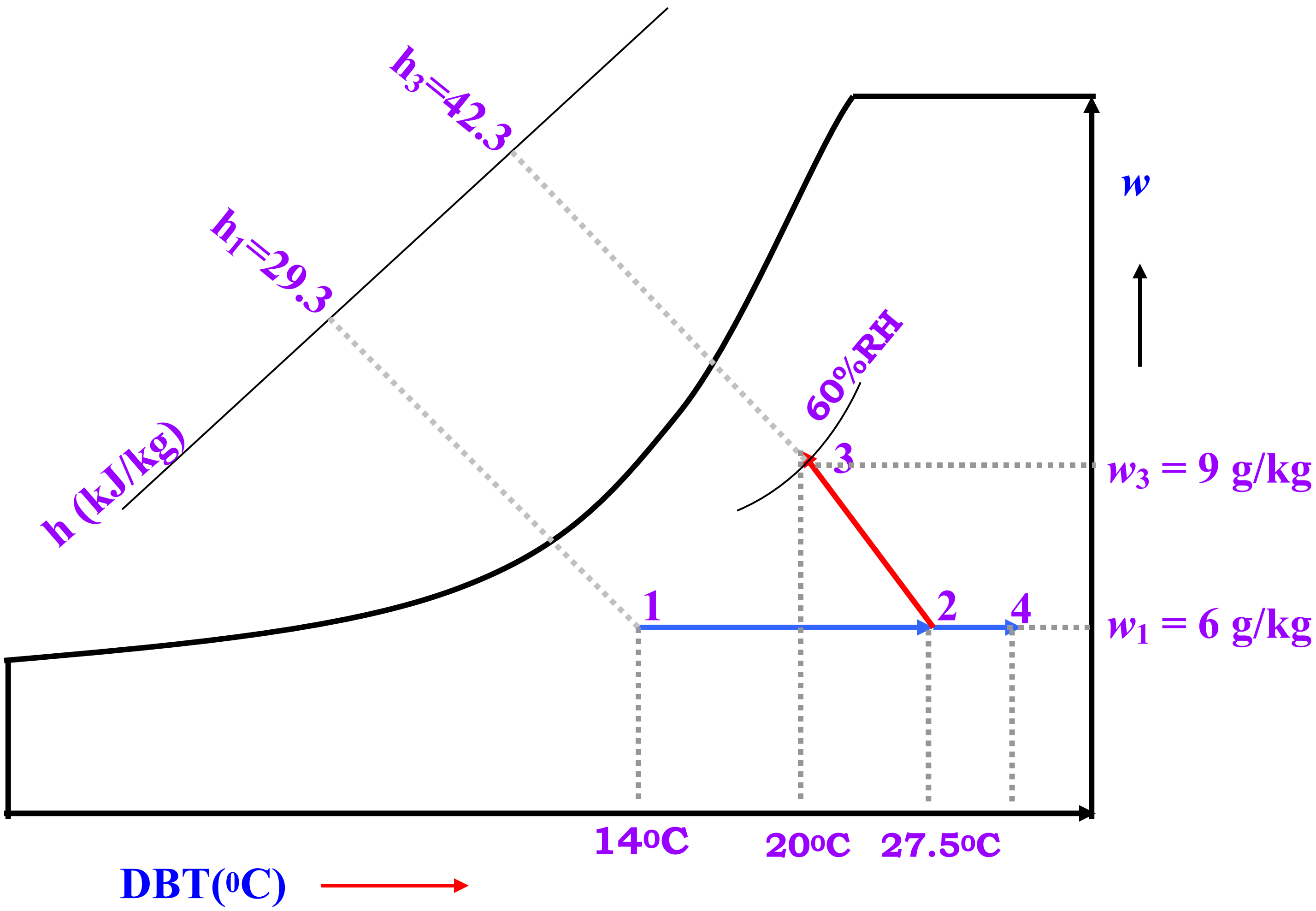
Determine the following:

a. Heating capacity of the preheating coil in kW and the surface temperature required if the bypass factor of the coil is 0.4.

b. The capacity of the humidifier.

WINTER AIR CONDITIONING SYSTEMS





h (kJ/kg)
h1=29.3
h3=42.3
60%RH
w
w3 = 9 g/kg
w1 = 6 g/kg
1
2
3
4
14⁰C
20⁰C
27.5⁰C
DBT(⁰C)

Cooling Load Calculation

Steps to plot the points in the Psychrometric Chart:

1. Locate points 1 and 3 using the conditions given on the psychrometric chart.
2. Draw a constant enthalpy line through 3 and a constant specific humidity line through 1.
3. Locate the point 2, where the two lines intersect each other.

From the psychrometric chart,

h_1 = 29.3 kJ/kg; h_2 = h_3= 42.3 kJ/kg; T_{DBT2} = 27.5^{0}C ; v_{s1} = 0.817 m^3/kg

The mass of air circulated per minute (m_a) = (0.3 × 60 / 0.8227) = 22 kg/min

(a) Capacity of the Heating Coil:

$= m_a (h_2 - h_1) = 22.03\ (42.3-29.3) = 286.4$ kJ/min

$= 286.4/60 = 4.77$ Kw

(b) Surface Temperature of the heating coil: (T_4)

$$BPF = \frac{(T_C - DBT_2)}{(T_C - DBT_1)} = 0.4$$

$$= \frac{(T_C - 27)}{(T_C - 14)}$$

$$T_C = 34^\circ C$$

(c) The Capacity of the humidifier:

$$= m_a(\omega_3 - \omega_1) \times 60$$

$$= 22.03\left(9 - 6.2\right) / \left(60/1000\right)$$

$$= 3.7\ kg/hr$$

Cooling Load Calculation

3. A restaurant with a capacity of 150 seats is to be air-conditioned when outdoor conditions are 30°C DBT and 70% RH. Desired inside conditions are 23°C DBT and 55% RH. The quantity of outdoor air supplied is 0.6 m^3 / min/person.

The desired conditions are achieved by cooling, dehumidifying, and then heating.

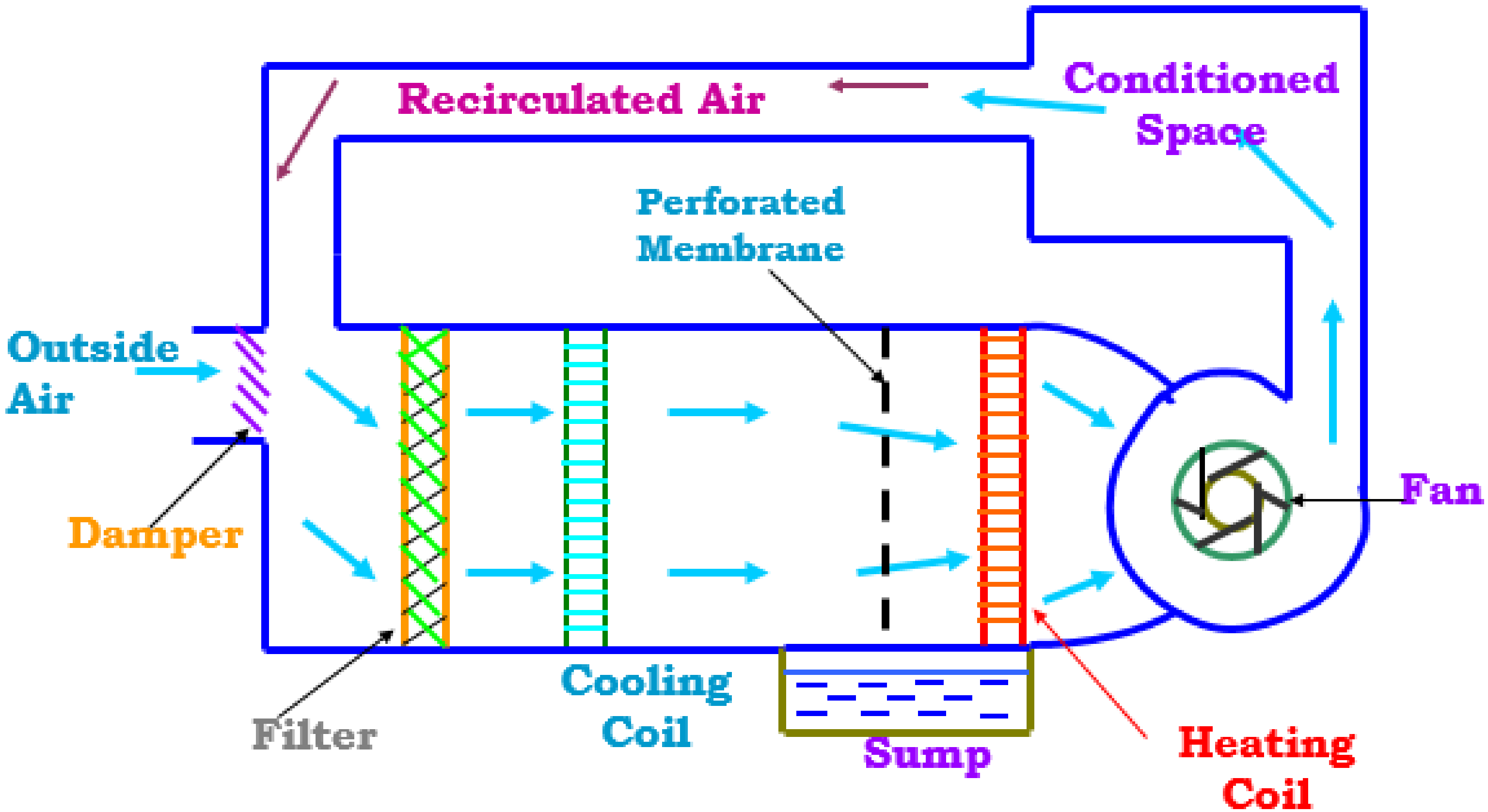
Calculate,

(i) Capacity of cooling coil (ii) Capacity of heating coil

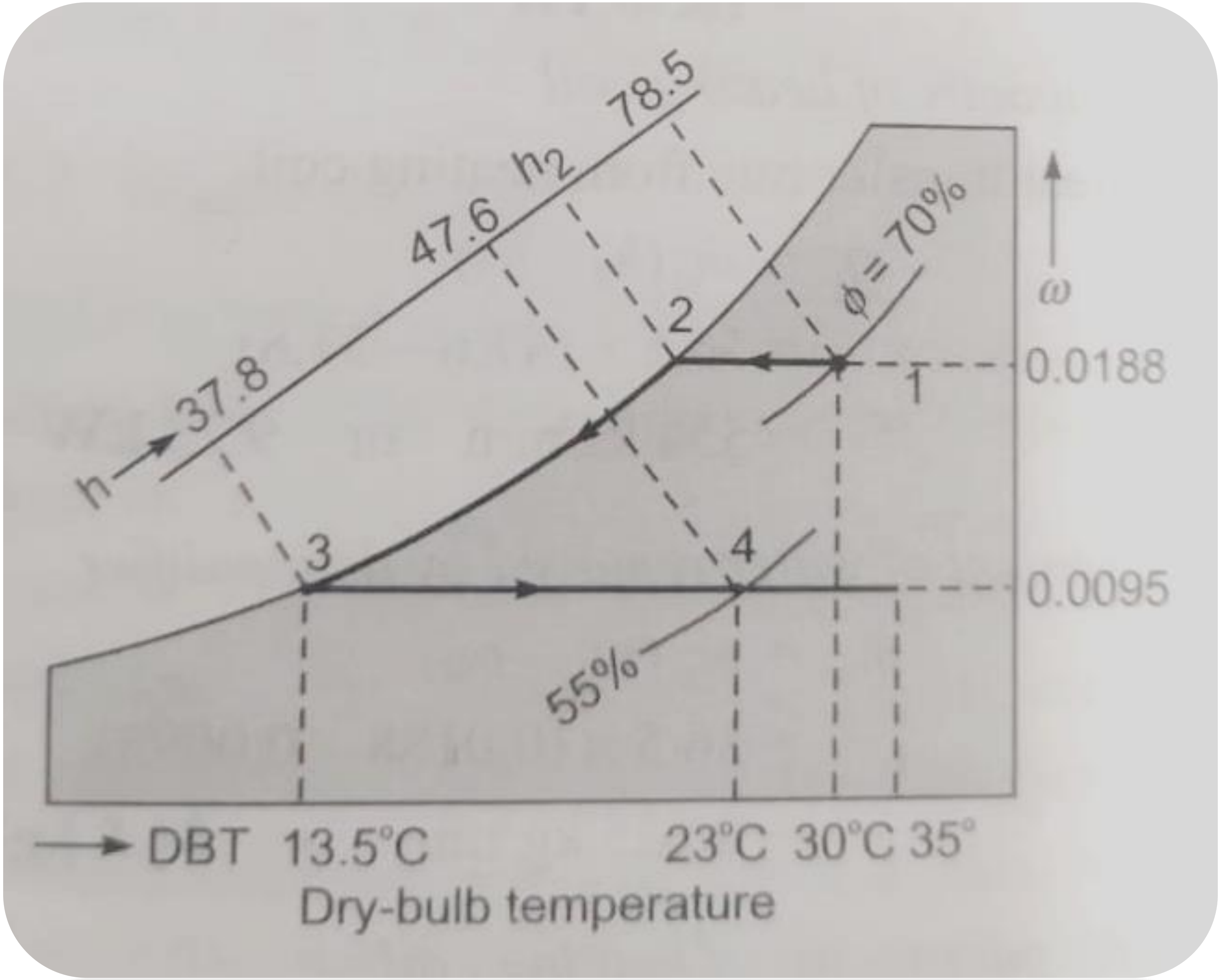
(iii) Amount of water removed by dehumidifier

(iv) Bypass factor of the heating coil, if the surface temperature is 35°C.

SUMMER AIR CONDITIONING SYSTEMS



Cooling Load Calculation



State-1: Outdoor conditions 30°C and 70% RH

$$h_1 = 82\, kJ / kg$$

$$vs_1 = 0.887\, m^3 / kg\ of\ dry\ air$$

$$w_1 = 19.5\ g / kg\ of\ dry\ air$$

State-4: Indoor conditions 30°C and 70% RH

$$h_4 = 48.5\, kJ / kg$$

$$w_4 = 10\ g / kg\ of\ dry\ air$$

State-2 and State- 3:Intermediate States

$$h_2 = 75\, kJ / kg$$

$$DBT_2 = 23.5^\circ C$$

$$h_3 = 39.5\, kJ / kg$$

$$DBT_3 = 13.5^\circ C$$

To find the mass of air supplied per minute: (m_a)

$$(ma) = 150\ persons \times volume\ flow\ / v_{s1}$$
$$= 101.69\ kg / min = 1.69\ kg / s$$

(i) Capacity of the cooling coil:

$$Heat\ transfer\ Rate = (m_a)\ (h_1 - h_2)$$
$$= 11.83\ \mathrm{kW}$$

$$Coil\ Capacity = \frac{11.83\ kW}{3.5\ kW} = 3.38\ T.R.$$

(ii) Capacity of the Heating coil:

$$Heat\ transfer\ Rate = (m_a)\ (h_4 - h_3)$$
$$= 15.21\ kW$$

(iii) Amount of water removed by dehumidifier

$$= m_a (w_1 - w_4) / 1000$$
$$= 101.69(19.5 - 10) / 1000$$
$$= 0.963\ kg / min \ = \ 57.83\ kg / hr$$

(iv) Bypass factor of the heating coil:

$$BPF = \frac{T_{coil} - DBT_4}{T_{coil} - DBT_3} = \frac{35 - 23}{35 - 13.5} = 0.558$$