AIR-CONDITIONING

It is the simultaneous control of temp. of air, vel. of air, purity of air & humidity of air.

Psychrometry

It is the branch of science which deals with the study of moist air

MOIST AIR = Dry air + H_2O vapour.

Moist air is a impure substance bcoz of the water vapour content. Moist air is a composition of Dry air and water vapour we have seen that at some places there is high humidity and at some place there is low humidity so the % of water vapour content is varying from place to place.

NOTE: Dry air is a pure substance

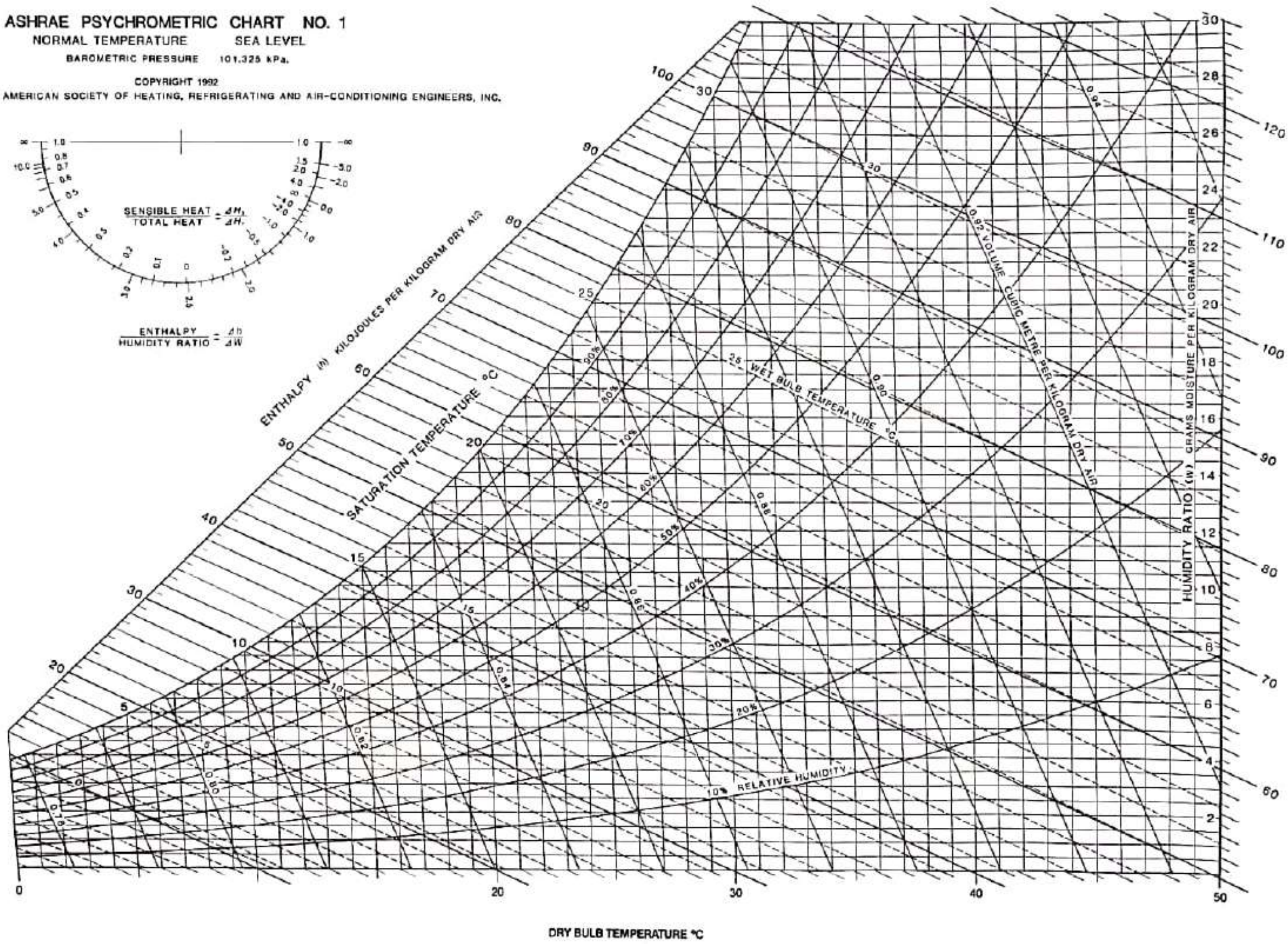
→ The state of moist air is in superheated region.

→ The state of Saturation at Temp T is reached when mass of water vapour in a given volume of air is max. ⇒ $m_v = m_s$

m_v → mass of water vapour in a given volume of air at temp 'T'.

m_s → mass of water vapour when the same volume of air is saturated at temp 'T'.

G - 3

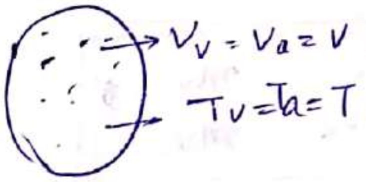

ASHRAE PSYCHROMETRIC CHART NO. 1
NORMAL TEMPERATURE SEA LEVEL
BAROMETRIC PRESSURE 101.325 kPa
COPYRIGHT 1992
AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.
SENSIBLE HEAT / TOTAL HEAT = ΔHs / ΔHt
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
ENTHALPY (h) KILOJOULES PER KILOGRAM DRY AIR
SATURATION TEMPERATURE °C
WET BULB TEMPERATURE °C
VOLUME CUBIC METRE PER KILOGRAM DRY AIR
RELATIVE HUMIDITY
HUMIDITY RATIO (W) GRAMS MOISTURE PER KILOGRAM DRY AIR
DRY BULB TEMPERATURE °C

VARIOUS PSYCHROMETRIC TERMS

1) Sp. humidity or humidity ratio

It is defined as the ratio of mass of watervapour to the mass of dry air in a given vol. of mixture & at a certain temp.

$$w = \frac{m_v}{m_a} = \frac{0.622\, P_v}{P - P_v}$$



$PV = mRT$

$P_v V_v = m_v R_v T_v$ — (1)

$P_a V_a = m_a R_a T_a$ — (2)

(1) ÷ (2)

$$\Rightarrow \frac{m_v R_v T_v}{m_a R_a T_a} = \frac{P_v V_v}{P_a V_a} \Rightarrow \frac{m_v}{m_a} = \frac{R_a}{R_v} \times \frac{P_v}{P_a}$$

$$\Rightarrow \frac{m_v}{m_a} = \frac{(\bar{R}/\text{Mol. Wt}_a)}{(\bar{R}/\text{Mol. Wt}_v)} \times \frac{P_v}{P_a}$$

$$\Rightarrow \frac{m_v}{m_a} = \frac{(Wt)_v}{(Wt)_a} \times \frac{P_v}{P_a}$$

$[P = P_a + P_v]$ $\Rightarrow$

$$\frac{m_v}{m_a} = \frac{18}{29} \times \frac{P_v}{P - P_v}$$

unit

$w = \frac{m_v}{m_a}$ = kg of water vapour/kg of dry air

or

kg/kg of dry air.

2) Relative Humidity (ϕ)

It is defined as the ratio of mass of water vapour to the mass of water vapour under saturated cond. in a given volume of air and at a certain temp.

$$\phi = \frac{m_v}{m_{vs}} = \frac{P_v}{P_{vs}}$$

At state of saturation $\phi = 1$ $[m_v = m_{vs}]$

$$\frac{P_v V_v}{P_{vs} V_{vs}} = \frac{m_v R_v T_v}{m_{vs} R_{vs} T_{vs}} \Rightarrow \frac{P_v}{P_{vs}} = \frac{m_v}{m_{vs}} = \phi$$

→ Sp. humidity indicates the actual amount of water vapour present in a given volume of air whereas rel. humidity indicates indirectly the moistre absorption capacity of the present air.

3) Dry bulb temperature

It is the temp. of moist air measured by ordinary thermometer.

4) Wet Bulb temp

It is the temp. shown by the thermometer whose bulb is covered with wet cloth.

5) Wet Bulb Depression

It is the diff b/w the dry bulb temp. & wet bulb temp.

6) Dew pt. Temp

→ It is the saturation temp. corr. to the beginning of condensation.

or

water particle just start to condense.

→ It is also defined as the saturation temp. corresponding to the partial pressure of water vapour.

NOTE

1) In case of unsaturated air the relation among the three temp's is

DBT > WBT > DPT

2) In case of saturated air all the three temp's are having same value.

DBT = WBT = DPT

3) When the air is fully saturated then the value of R.H (ϕ) is 1 or 100%.

4) In case of fully saturated air the value of WBD is zero.

5) Sling Psychrometer measures both dry bulb as well as wet bulb temp.

6)

(7) Degree of saturation (μ)

The value of R.H lies b/w 0 & 1 or 100%

$$\mu = \frac{w}{w_s} = \phi \left[\frac{P - P_{vs}}{P - P_v} \right]$$

$$\mu = \frac{\frac{0.622\, P_v}{P - P_v}}{\frac{0.622\, P_{vs}}{P - P_{vs}}} = \left(\frac{P_v}{P_{vs}}\right)\left(\frac{P - P_{vs}}{P - P_v}\right) = \phi\left(\frac{P - P_{vs}}{P - P_v}\right)$$

$$\boxed{0 < \mu < 1}$$

(8) Enthalpy of moist air

$$\boxed{h_{MA} = 1.005t + w(2500 + 1.88t) \text{ KJ/kg of d.a}}$$

t = DBT (°C)

(9) APJOHN FORMULA

It is used to calculate the partial pressure of water vapour

$$\boxed{P_v = P'_v - \frac{1.8\, P(t - t')}{2700}}$$

$$P_v = P_w - \frac{(P_b - P_w)(t_d - t_w)}{1544 - 1.44 t_w}$$

P_w, T_w → wet bulb

P_b → Barometric pressure

DPT → Saturation temp. corr to partial pressure of water vapour

NOTE

$t \rightarrow$ dry bulb temp (°c)

$t' \rightarrow$ WBT (°C)

DPT $\rightarrow$ dew pt temp (°c)

$P_v \rightarrow$ Sat. Pressure corr to DPT.
or Partial pressure of water vapour corr to. P_v the saturation temp provides the value of Dew pt temp.

$P'_v \rightarrow$ Sat. pressure corresponding to wet bulb temp.

$P_{vs} \rightarrow$ sat pressure corresponding to dry bulb temp.

$P \rightarrow$ Total pressure or if not provided in Ques. then taken as atm. pressure
$P_{atm} = 1.01325 \times 10^5$ Pa or 1.01325 bar or 101.325 kPa

---

Q) The DBT & WBT are 30°C & 20°C resp. The atmospheric pressure is 740 mm. of mercury. Find:

i) Partial pressure of water vapour & DPT.
ii) sp. humidity
iii) Rel. humidity
(iv) Degree of saturation
(v) enthalpy of moist air.
(vi) Vapour density

Temp (°C)	sat pressure (Bar)
30°c	0.04242
20°c	0.02337

$P_v = 0.02337 - \frac{1.8 \times \frac{740}{760}(30-20)}{2700}$

$\boxed{P_v = 0.01687 \text{ bar}}$

(ii) $\omega = 0.622 \frac{P_v}{P - P_v}$

$= 0.622 \times \frac{0.01687}{\frac{740}{760} - 0.01687}$

$\boxed{\omega = 0.0109}$

(iii) $\phi = \frac{P_v}{P_{v_s}} = \frac{0.01687}{0.04242} = 0.397689 = 39.76\%$

(iv) Degree of saturation

$\mu = \phi \left(\frac{P - P_{v_s}}{P - P_v} \right)$

$\mu = 0.397689 \left(\frac{0.97368 - 0.04242}{0.97368 - 0.01687} \right)$

$\boxed{\mu = 0.3870}$

(v) $h_{MA} = 1.005t + \omega(2500 + 1.88t)$

$= 1.005 \times 30 + 0.0109 (2500 + 1.88 \times 30)$

$\boxed{h_{MA} = 58 \text{ KJ/kg of dry air}}$

$P_v V_v = m_v R T_v$

$\frac{m_v}{V_v}, \frac{P_v}{R T_v}$

(vi) $\rho_v = \frac{m_v}{V_v} = \frac{0.01687 \times 1.01325 \times 10^{5}}{0.287 \times 303}$

$\boxed{\rho_v = 0.01965 \text{ kg/m}^3}$

vi) $\rho_v = ?$

$$\omega = \frac{m_v \cdot V}{m_a \cdot V}$$

$$\omega = \frac{\rho_v}{\rho_a}$$

$$\Rightarrow \boxed{\rho_v = \omega \rho_a}$$

$$PV = mRT$$

$$P = \left(\frac{m}{V}\right)RT$$

$$P = \rho RT$$

$$\boxed{\rho = \frac{P}{RT}}$$

$$\Rightarrow \rho_a = \frac{P_a}{R_a T_a}$$

$$\Rightarrow \boxed{P = P_a + P_v}$$

$$\Rightarrow \boxed{P_a = P - P_v}$$

$$\Rightarrow \rho_a = \frac{P - P_v}{R_a T_a}$$

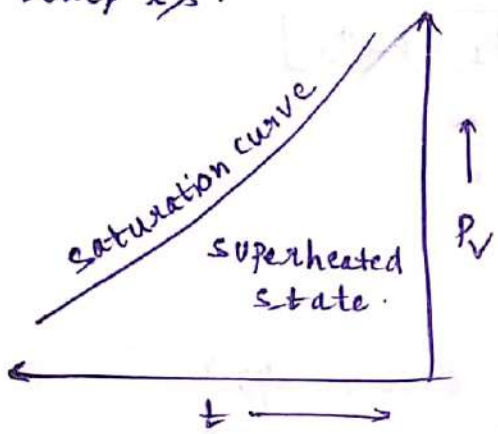
$$\rho_v = \omega\left(\frac{P - P_v}{R_a T_a}\right)$$

$$\rho_v = \frac{0.0107\,(0.9875 - 0.0167) \times 10^2}{0.287 \times 303}$$

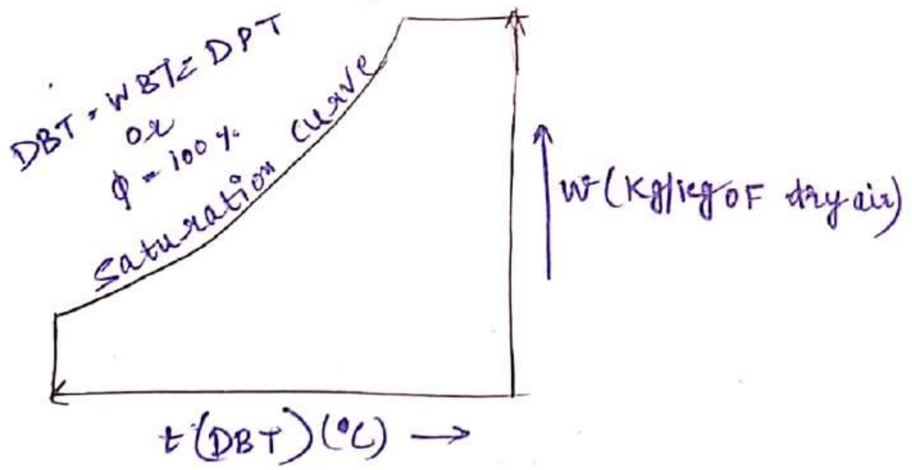
$$\boxed{\rho_v = 0.0119\ kg/m^3}$$

Development OF Psychrometric Chart

As we know that the saturation pressure increases the saturation temp. also increases so the graph b/w saturated pressure & temp is.



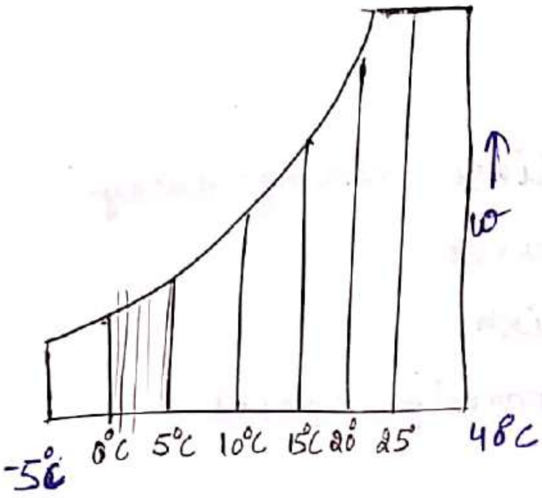
We know that the ω is a f^n OF partial pressure OF vapour therefore in the original Psychrometric chart the P_v is replaced with specific humidity.



Representation of diff. constt Parameters on

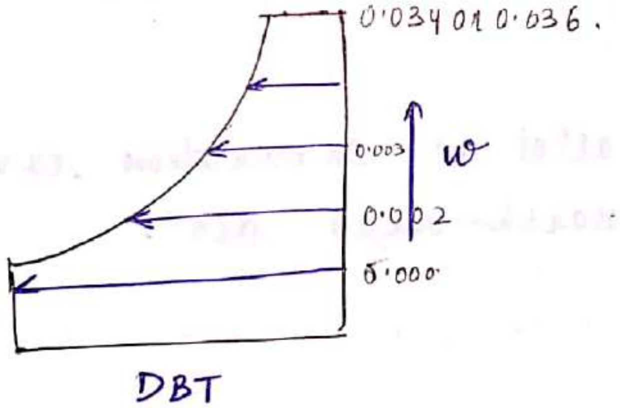
PSYCHROMETRIC CHART

1) constt DBT lines



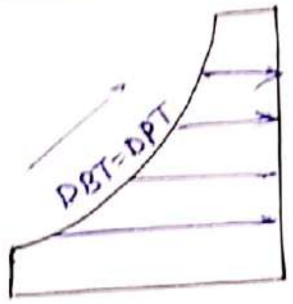
i) These are vertical lines
ii) Increasing order in +x direction.
iii) These are uniformly spaced.

2) constt sp. humidity lines



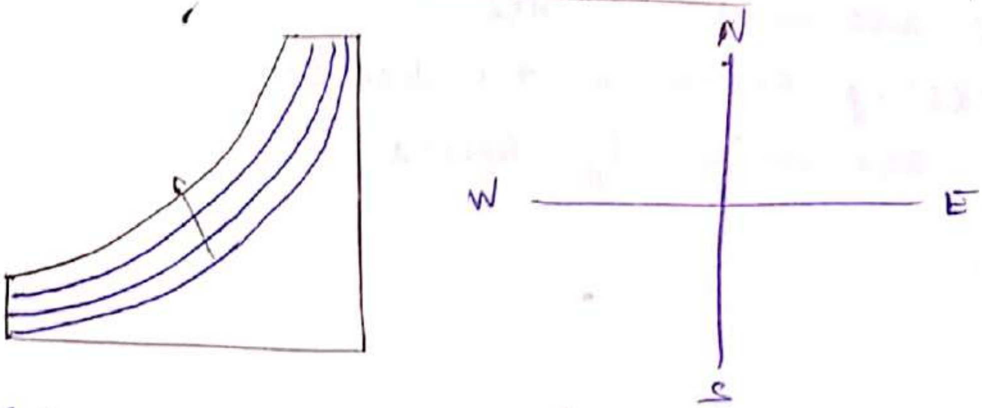
(i) constt. sp. humidity lines are the horizontal lines moving towards the saturation curve.
ii) Inc. order in +y dirn.
iii) These are also uniformly spaced.

3) constt. Dew pt. Temp. lines



i) These are horizontal lines moving away from the saturation curve
ii) Inc. order in +y dirn.
iii) These are non-uniformly spaced.

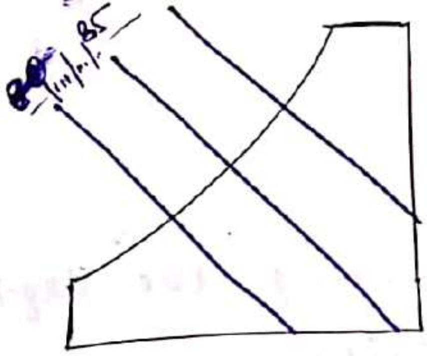
4) constt. Rel. humidity curves



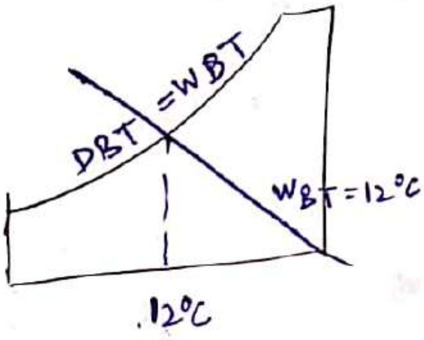
→ These are parallel to saturation curve. Inc. order in north-west dirn.

5) constt. sp. enthalpy lines, constt wet bulb temp. lines & constt sp. volume lines.

i) h / WBT / v
↓ ↓ ↓
KJ/kg °C m³/kg

2) 

const - enthalpy lines.

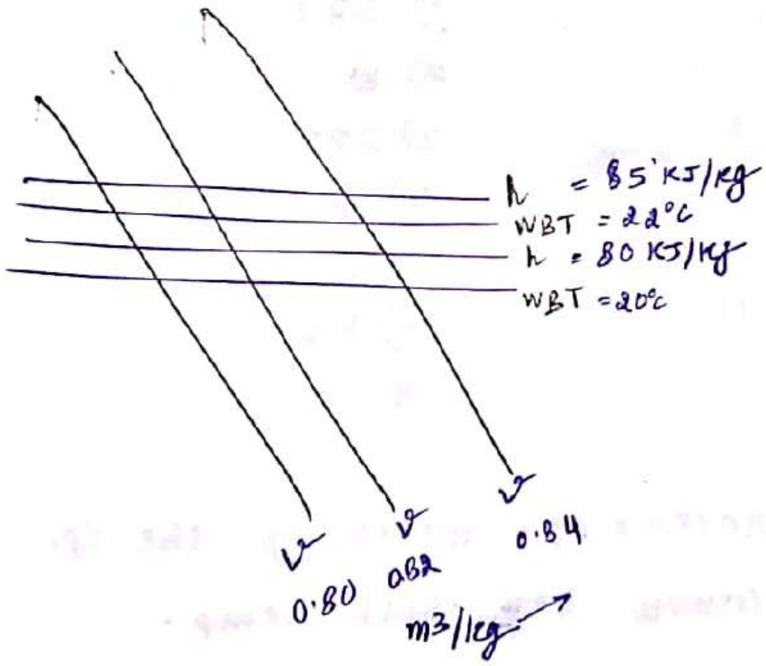
3) 

4) h, WBT] have same degree of Inclination

v → highest degree of Inclination.

5) h → uniformly spaced

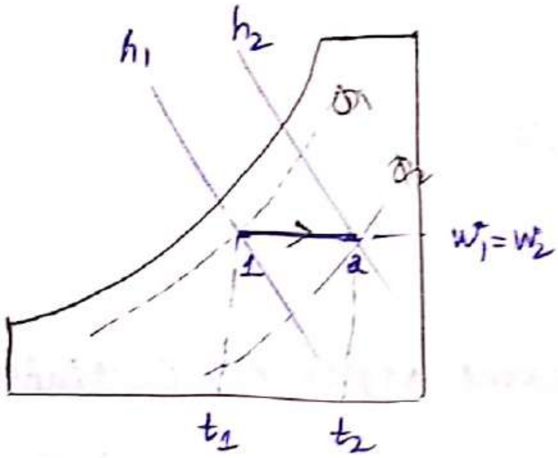
WBT → non-uniformly spaced.



Basic Psychrometric process

1) Sensible heating

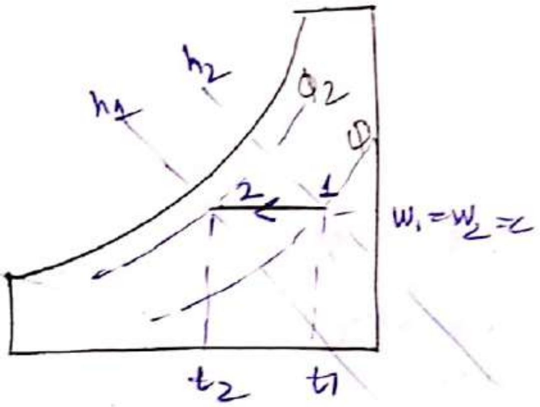
It is the process of increasing the dry bulb temp. at constt. sp. humidity.



1) DBT ↑
2) w = constt
3) DPT = constt
4) φ ↓
5) h ↑
6) WBT ↑
7) v ↑

2) Sensible cooling

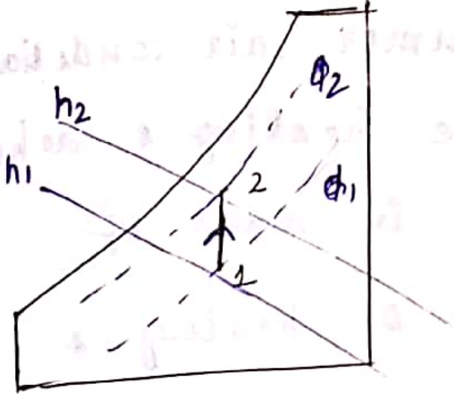
It is the process of decreasing the dry bulb temperature at constt sp. humidity.



1) DBT ↓
2) w = constt
3) DPT = constt
4) φ ↑
5) h ↓
6) WBT ↓
7) v ↓

3) Humidification

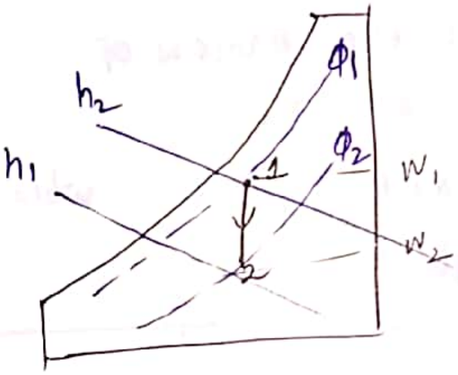
It is the process of increasing the sp. humidity at constt dry bulb temp.



1) DBT = const
2) W ↑
3) DPT ↑
4) φ ↑
5) h ↑
6) WBT ↑
7) v ↑

DEHUMIDIFACTION

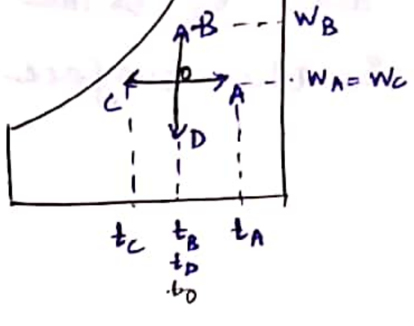
It is the process of decreasing the sp. humidity at constt dry bulb temp.

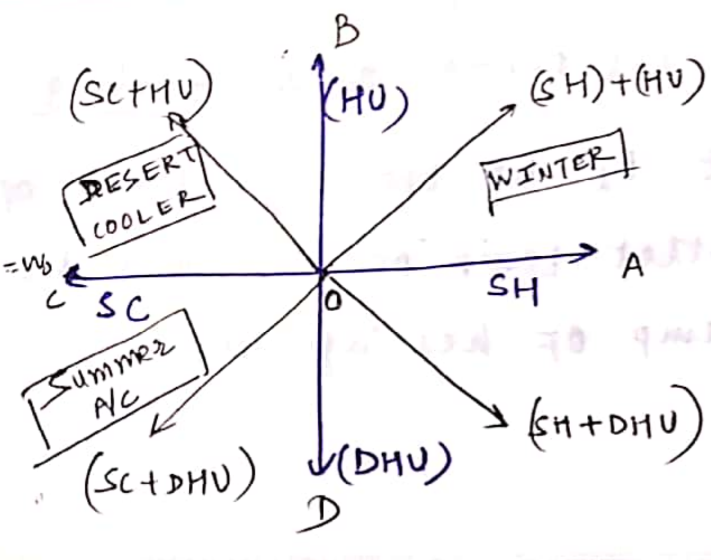


1) DBT = C
2) W ↓
3) DPT ↓
4) φ ↓
5) h ↓
6) WBT ↓
7) v ↓

NOTE Pure humidification & pure dehumidification are impossible to achieve practically therefore these are combined either with sensible heating or sensible cooling

Representation of all above processes on the same Psychrometric chart.





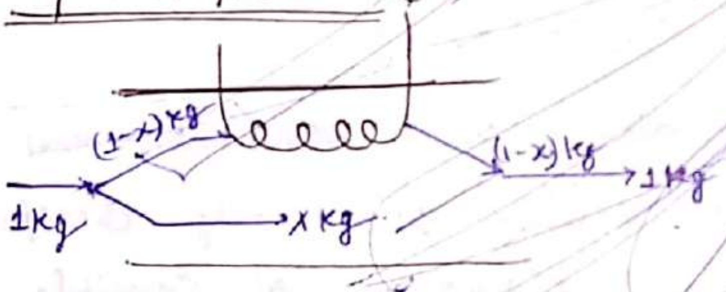
NOTE → In the case of summer air conditioning the process of sensible cooling & dehumidification occurs whereas in case of winter A/c the process of heating + humidification occurs.

→ In the case of desert coolers the process of cooling and humidification occurs. Or adiabatic saturation

→ In case of desert cooler the process of cooling and humidification occurs.

→ Desert coolers are the most effective when the value of WBD is high.

By Pass Factor (X)



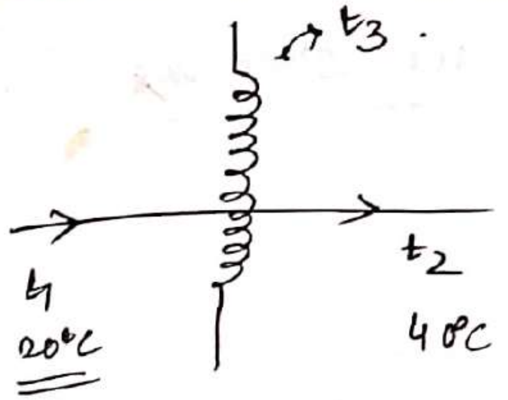
$\eta = 1 - BPF$

It simply represents the loss. By pass factor represents the fractional part of the total air which is not coming in contact with the coil.

By pass factor of a Heating coil

Let t_1 be the inlet temp. of air, t_2 is the outlet temp of air and t_3 is the surface temp of heating coil.

Trick:- BPF = $\frac{\text{min Temp. diff}}{\text{max Temp. diff}}$



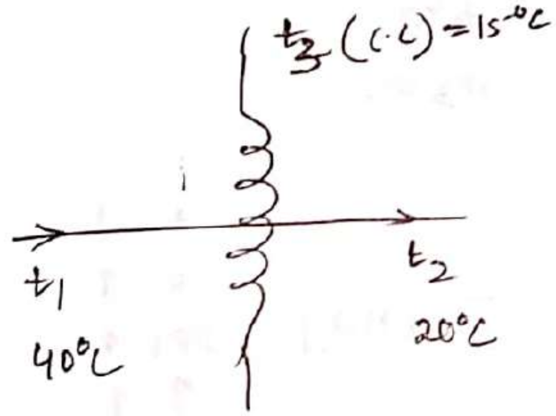
$t_3 \geq t_2 > t_1$

$$BPF = \frac{t_3 - t_2}{t_3 - t_1}$$

$$\eta_{H.C} = 1 - BPF_{HC}$$

Bye pass Factor of a cooling coil

Let t_3 be the surface temp. of cooling coil.

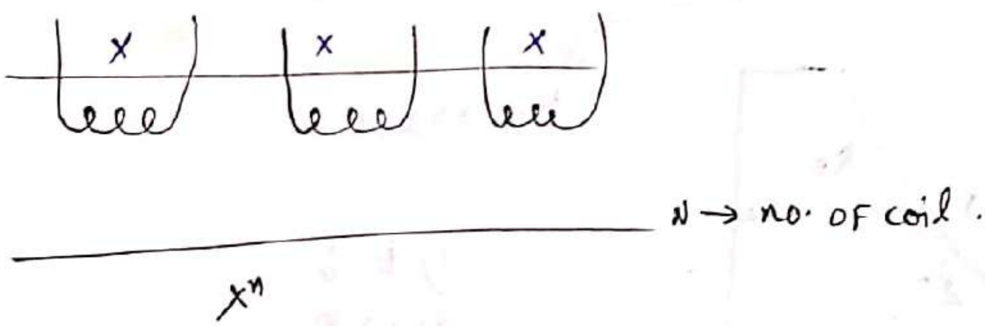


$$BPF = \frac{t_2 - t_3}{t_1 - t_3}$$

$$\eta_{cc} = 1 - (BPF)_{cc}$$

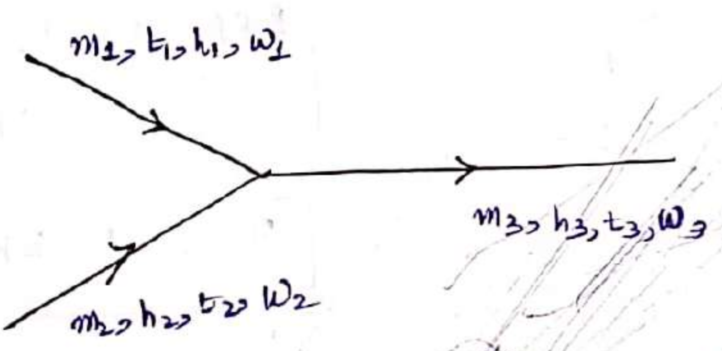
NOTE

1) By pass Factor of a combined coil (when there is more than one row of a coil) is x^n



2) By pass of cooling coil decreases with the increase in no of rows of a coil or decrease in coil spacing or decrease in velocity.

5) Adiabatic Mixing of air streams



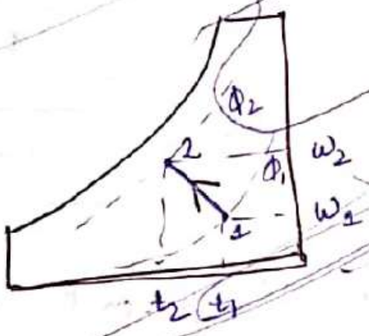
$$m_1 + m_2 = m_3$$

$$m_1 h_1 + m_2 h_2 = m_3 h_3$$

$$m_1 t_1 + m_2 t_2 = m_3 t_3$$

$$m_1 \omega_1 + m_2 \omega_2 = m_3 \omega_3$$

NOTE

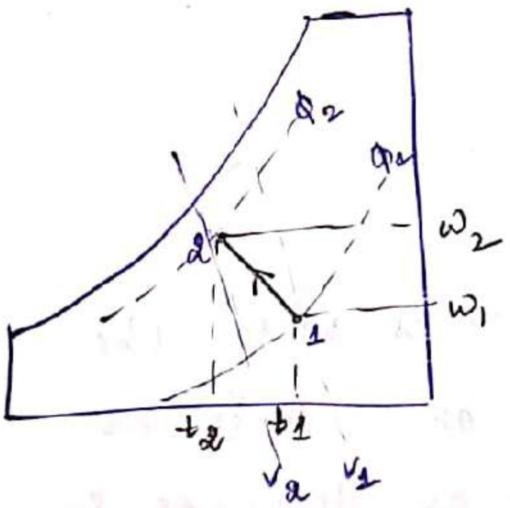


SC + HU

- t ↓
- ω ↑
- DPT ↑
- ϕ ↑
- h, WBT → depends upon slope
- v

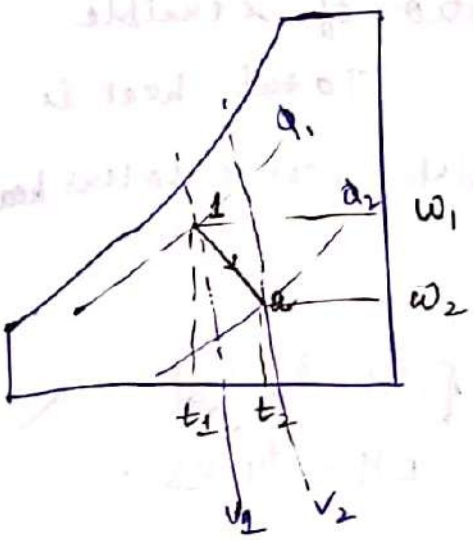
Adiabatic or Chemical humidification

→ h – constt



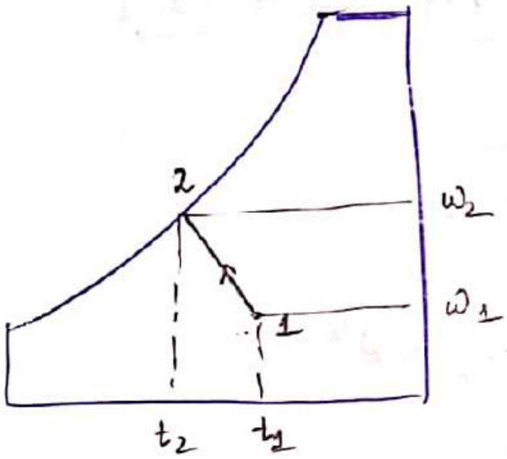
1) t ↓
2) ω ↑
3) DPT ↑
4) ϕ ↑
5) $h = c$
6) WBT $= c$
7) v ↓

Adiabatic or Chemical dehumidification



t ↑
ω ↓
DPT ↓
φ ↓
h = C
WBT = C
V ↑

Adiabatic saturation

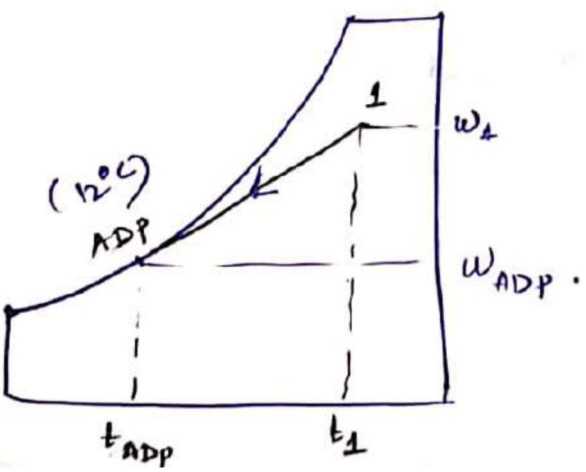


SC + HU

1) t ↓
2) ω ↑
3) DPT ↑
4) φ ↑
5) h = C
6) WBT = C
7) V ↓.

Apparatus dew point (ADP)

It is the point obtained by the intersection of cooling and Dehumidification with the saturation curve. The Rel. humidity is 100%.



ADP

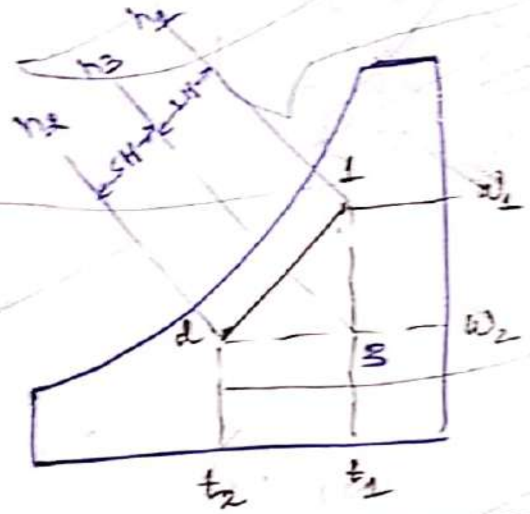
a) C & DH

b) sat. curve

c) $\phi_{ADP} = 100\%$

Sensible heat Factor

It is defined as the ratio of sensible heat to the total heat. Total heat is the summation of sensible heat & Latent heat.



$SH = h_3 - h_2$

$LH = h_1 - h_3$.

$TH = SH + LH$

$TH = (h_1 - h_2)$

$\Rightarrow$ $$SHF = \frac{h_3 - h_2}{h_1 - h_2}$$

NOTE

1) Sensible heat Factor For various cond's.

Various cond's	SHF
1) Res. & private office	0.9
2) Restaurants & Busy offices	0.8
3) Auditorium & cinema halls	0.7
4) Dance hall room	0.6

Effective Temp

It is the temp. of saturated air at which a person would experience same feeling of comfort as in actual environment so effective temp. includes humidity, comfort temp and air motion.

Factors affecting Effective Temp

1) Climatic and seasonal diff:-

People living in colder climate are comfortable at lower effective temp. Then the people living in warmer regions. In winters the optimum eff. temp. is 20°C and in summers the optimum eff temp is 21.6°C.

2) Age and Gender

Womens of all age require higher eff. temp. than men. and similar is the case with old aged persons and infants. A effective temp of 2-3°C higher is required.

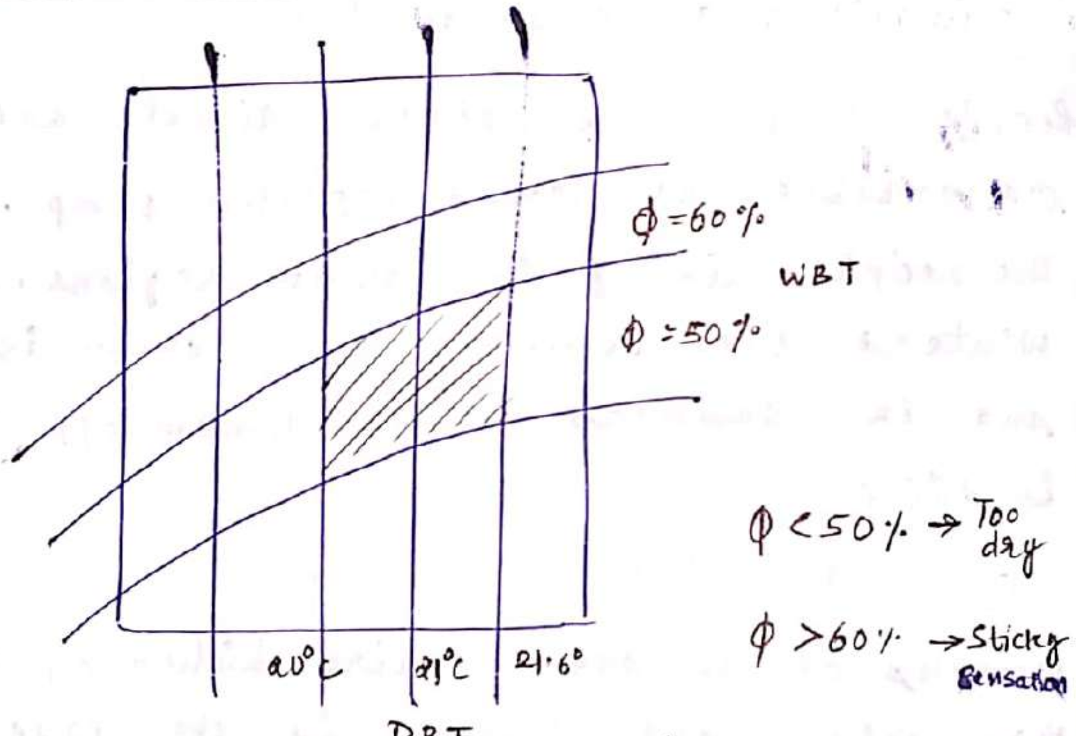
3) Kind of activity

If a person is involved in activities like in production factory, dancing etc require lower effective temp then the person which are in rest condn or steady state condn.

4) Density of occupance.

The effect of body radiates heat from person to person varies and it is very high in densly occupied areas so lower effective temp is required for densly occupied areas.

Comfort Chart.



This chart is the result made by ASHRAE (American Society of heating, Refrigeration & air conditioning engineers) society on the different kinds of people subjected to wide range of envioronmental temp's, humidity and air velocity. This chart is drawn b/w DBT taken on X axis & WBT taken on Y-axis.

If the Rel. humidity (ϕ) is less than 50% then the skin surface is too dry whereas if the Rel. humidity goes beyond 60% then there is a tendency of sticky sensation is developed.

Ventilation air

It is the amount of fresh air supplied to the a.c coil in order to maintain the purity of air. human beings are generally feeling comfort within a temp range of 24-26°C & 50-60% R.H.

NOTE: In case of operation theatres 100% fresh air or outside air is supplied.