PSYCHOMETRY

PSYCHOMETRY:

It's a simultaneous control of temperature of air humidity of air, air velocity and purity of air for human comfort.

MOIST AIR	
DRY AIR	**WATER VAPOUR**
N_2, O_2, Etc… (Fixed Part)	H_2O (Fixed Part)

ANALYSIS OF MIXING OF TWO GASES:

1. AMAGAT Law of Additive Volume: The volume of an ideal gas mixture is equal to the sum of the volume that each individual component of gas would occupy if each gas is existed alone at the mixture temperature and pressure.
2. DALTON'S Law of Additive Volume: "Pressure of an ideal gas mixture is equal to the sum of the pressure of its individual components would exert if each is existed alone at the same volume and temperature of the mixture"

$x_i = \frac{n_i}{\sum n}$	$Mass\ Fraction_i = \frac{m_i}{\sum m}$	$\sum_{i=1}^{n} MF_i = \sum_{i=1}^{n} x_i = 1$	$R_{mix} = \frac{\sum m_i R_i}{\sum m_i}$	$M_{mix} = \frac{\sum n_i M_i}{\sum n_i}$
$V = V_1 = V_2$ $T = T_1 = T_2$	$m = \sum m_i\ \&\ n = \sum n_i$	$C_{mix} = \frac{\sum C_i m_i}{\sum m_i}$	$mu = \sum m_i u_i$	$P = \sum P_i$
$mh = \sum m_i h_i$	$C_P - C_V = R$ $C_P/C_V = \gamma$	$C_V = \frac{\overline{R}}{M(\gamma - 1)}, Where\ \overline{R} = MR$	For Ideal Gas, $u = f(T)\ Only,$ $dU = mC_V dT\ \&\ dH = mC_P dT$	

PSYCHOMETRY TERM:

1. **Specific Humidity:** It's defined as the ratio of mass of vapour to the mass of dry air in mixture (moist air). Or it can be defined as mass of vapour present in a single kg of dry air in mixture (moist air).

$\omega = \frac{m_V}{m_a} = \frac{kg\ of\ Vapour}{kg\ of\ Dry\ Air}$	For Dry Air (Ideal Gas), $P_a V = m_a R_a T$	For Water Vapour (Ideal Gas), $P_V V = m_V R_V T$	$\omega = \frac{P_V}{P_a}\frac{R_a}{R_V} = \frac{M_V}{M_a}\frac{P_V}{(P_t - P_V)}$

Where, $M_V/M_a = 18/29 = 0.622$. hence, $\omega = f(P_V)$ But in actual case, $P_t \gg P_V$

2. **Relative Humidity:** It's defined as the ratio of mass of vapour to the mass of vapour under saturation condition at same temperature & Volume.

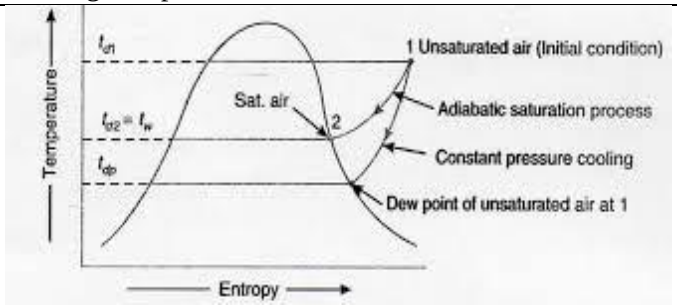
Under Unsaturated State, m_a, m_V, P_V, T, V For Vapour, $P_V V = m_V R_V T$	Saturated State, $m_a, m_{VS}, P_{VS}, T, V$ For Saturated Vapour, $P_{VS} V = m_{VS} R_V T$	
$\emptyset = \frac{m_V}{m_{VS}} = \frac{P_V}{P_{VS}}$	$P_{VS} = P_{sat}\ @\ T$	
	For Saturation, $\emptyset = 1$	For Unsaturation, $\emptyset < 1$

Note: Specific humidity represent the amount of water vapour present in moist air whereas relative humidity represent moisture absorbing capacity.

3. **Degree of Saturation:** It's defined as the ratio of specific humidity to the specific humidity under saturation state.

$\mu = \frac{\omega}{\omega_S} = \emptyset\left[\frac{P_t - P_{VS}}{P_t - P_V}\right]$	For Saturation, $\mu = 1$ For Unsaturation, $\mu < 1$

4. **Dry Bulb Temperature:** It's the temperature measured by ordinary thermometer.
5. **Wet Bulb Temperature:** It's the temperature measured by thermometer When its bulb is covered with wet cloth. WBT is achieved by adiabatic saturation. And Sling Psychrometer is use to observe WBD & DBT. E.g. Matka effect.
6. **Dew Point Temperature:** It's the temperature at which water vapour present into atmosphere start condensing. OR It's a temperature at which droplet of moisture is condensed. E.g. Droplet on the cooled surface.

Due point temperature is a saturation temperature corresponding to P_V where saturation is achieved isobarically. Wet bulb temperature is a saturation temperature corresponding to P_V where saturation is achieved adiabatically. In calculation of $\emptyset$, the saturation used is achieved isothermally. At saturated State, $DBT = DPT = WBT$	

7. **Enthalpy of Moist Air:** $H = H_a + H_V = m_a h_a + m_V h_V \Rightarrow h(KJ/kg\ of\ dry\ air) = h_a + \omega h_V$
   Where, h = Specific Enthalpy of Monist Air per kg of dry Air, h_a = Specific Enthalpy of Dry Air & h_V = Specific Enthalpy of Water Vapour

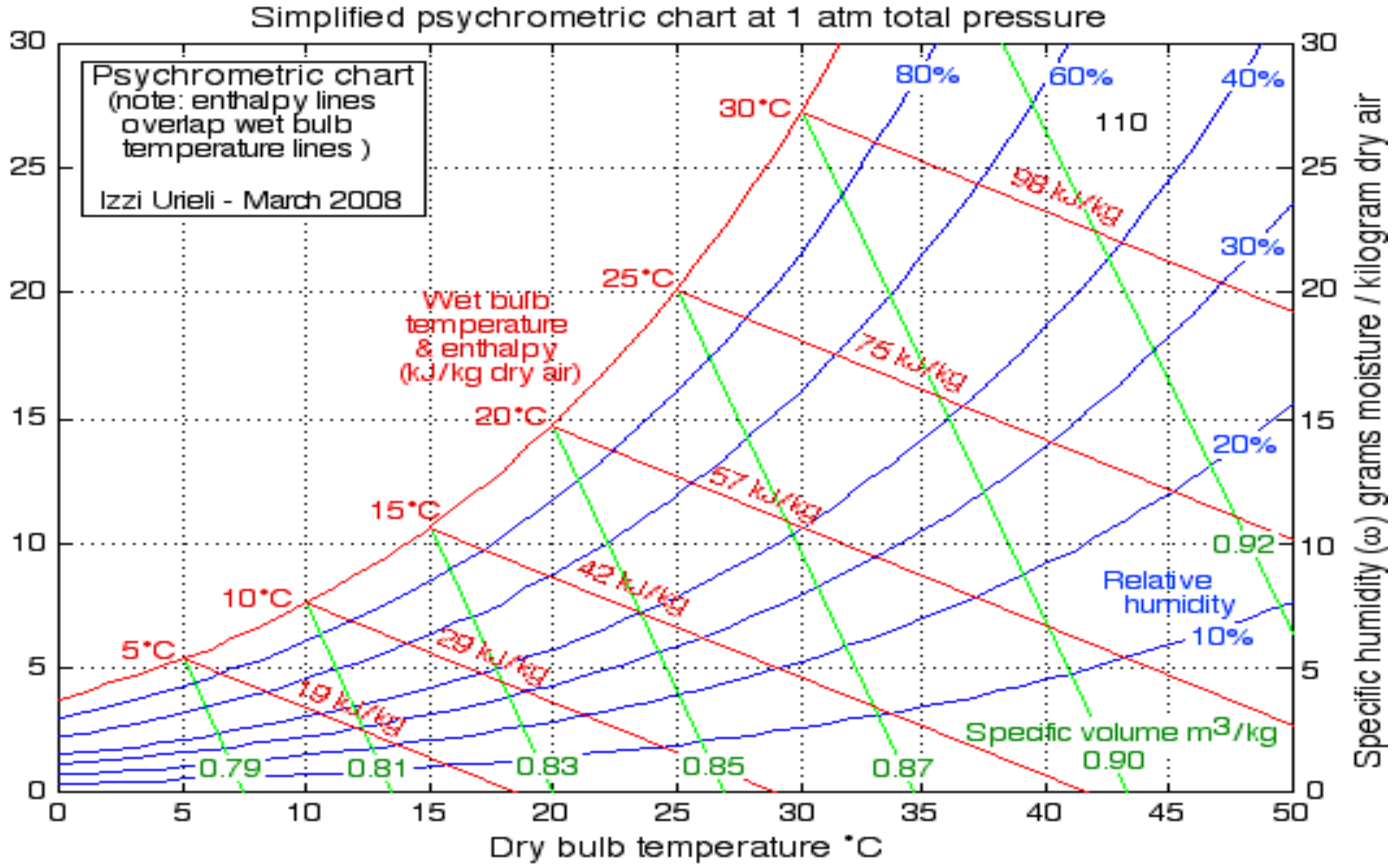
Specific Enthalpy of Dry Air (h_a): Enthalpy of dry air at $0°C$ is arbitrarily taken as zero to denote reference.

For Ideal Gas as air, $dh = C_P dT$	$\therefore h_a - h_{aR} = C_{Pa}(T - T_R)$ Where, $h_a - 0 = 1.005(T - 0)\ \&\ T\ (in\ °C)$

Specific Enthalpy of Water Vapour (h_V): Enthalpy of Water Vapour at $0°C$ is arbitrarily taken as zero to denote reference. $h_V = h_R + LH + \Delta h = 0 + 2500 + C_{PV}(T - 0)$, Where, $C_{PV} = 1.88$ & T $(in\ °C)$

$$h\ (KJ/kg\ of\ dry\ air) = 1.005T + \omega[2500 + 1.88T]$$

DEVELOPMENT OF PSYCHOMETRY CHART:



1. Consider, $\emptyset = x$ $$\emptyset = \frac{m_V}{m_{VS}} = \frac{P_V}{P_{VS}} = x$$	2. From property table, At $0°C$, $P_t = 1\ atm$, $P_V = xP_{VS}$ & $P_{VS} = P_{sat}$ @ T $$\omega = \frac{P_V}{P_a}\frac{R_a}{R_V} = 0.622\frac{P_V}{(P_t - P_V)}$$
3. By changing Temperature, we can find Curve line for constant $\emptyset$.	4. From below mentioned equation, constant enthalpy line at constant temperature is obtained. $$h = 1.005T + \omega[2500 + 1.88T]$$

5. Constant Wet Bulb Line: Though there is small deviation between constant WBT line & constant Enthalpy line but for all calculation purpose this deviation is neglected and constant WBT line follows constant enthalpy line.

NOTE: Adiabatic process in psychometric chart follows isentropic process.

6. Constant Dew Point Temp. Line: DPT is a saturation temperature corresponding to P_V. If P_V is constant them DPT is also constant. We know that specific humidity is function of P_V $(\omega = f(P_V))$.

- If P_V is constant then specific humidity is also constant. Therefore, constant DPT line follow constant specific humidity lines which are horizontal.

NOTE: DPT is isobaric saturation process.

7. Constant Specific Volume line: From ideal Gas Equation.

NOTE: To fix the state in psychometry chart two properties are needed but according to Gibb's Phase Rule. Because 1 Property for psychometry chart is already fix. $P + F = C + 2 \Rightarrow 1 + F = 2 + 2$

Hence, Psychometry chart is drawn for a fixed total pressure.

BASIC PSYCHOMETRIC PROCESS:

1. Sensible Heating: It's a process of increasing the DBT of air at constant specific humidity.

$T_2 > T_1$	$\omega_2 = \omega_1$	$WBT_2 > WBT_1$
$DPT_2 = DPT_1$	$h_2 = h_1 + q_{in}$	$\dot{Q}_{in} = \dot{m}_a(h_2 - h_1)$
By Providing heater in the flow of air. Adiabatic line follows constant enthalpy Line.		

Bypass factor/ Uncontacted factor/ Loss Factor:

$BPF = \frac{\Delta T_{Loss}}{\Delta T_{Max}}$	$BPF + \eta_{Coil} = 1$

2. Sensible Cooling: It's a process of decreasing the DBT of air at constant specific humidity.

NOTE: To achieve sensible cooling the coil temperature must be greater than DPT.

$T_2 < T_1$	$\omega_2 = \omega_1$	$WBT_2 < WBT_1$
$DPT_2 = DPT_1$	$h_2 = h_1 - q_{out}$	$\dot{Q}_{out} = -\dot{m}_a(h_2 - h_1)$
By Providing cooling coil in the flow of air. Adiabatic cooling line follows constant enthalpy Line.		

3. Humidification: It's a process of increasing the specific humidity of air at constant DBT.
4. Dehumidification: It's a process of decreasing the specific humidity of air at constant DBT.

NOTE: Pure humidification and pure dehumidification is not possible to achieve practically these processes are always associated with temperature changes.

5. Heating & Humidification: By adding steam in the air flow this process is achieved.

$T_2 > T_1$	$\omega_2 > \omega_1$
$\Delta m_V = m_{V2} - m_{V1} \Rightarrow \Delta \dot{m}_V = \dot{m}_a(\omega_2 - \omega_1)$	$Sensible\ Heat\ Factor = \frac{Sensible\ Heat}{Sensible\ Heat\ + Latent\ Heat}$

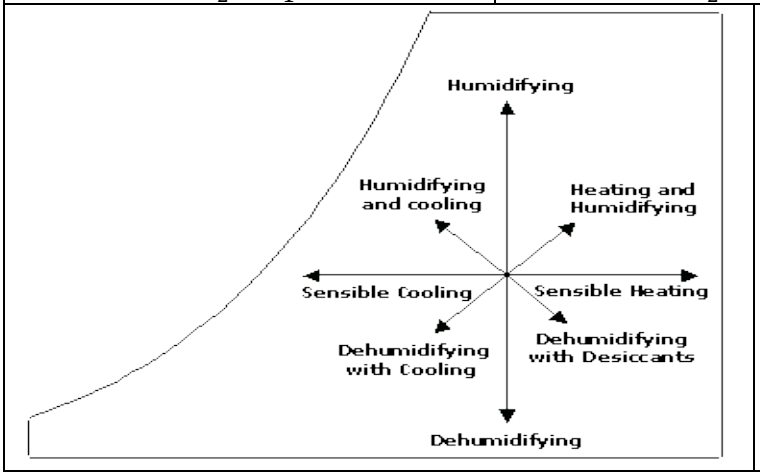
6. Cooling & Dehumidification: This process followed by summer air conditioner. To achieve cooling and dehumidification coil temperature must be less than DPT. Here, $T_2 < T_1$ & $\omega_2 < \omega_1$
7. Cooling & humidification: This kind of process is followed by Desert cooler or Cooling Tower. To achieve cooling and humidification, air sprinkle/ Cold Storage of water is provided in the direction of air flow. And due to vaporization cooling effect is observed. Here, $T_2 < T_1$ & $\omega_2 > \omega_1$

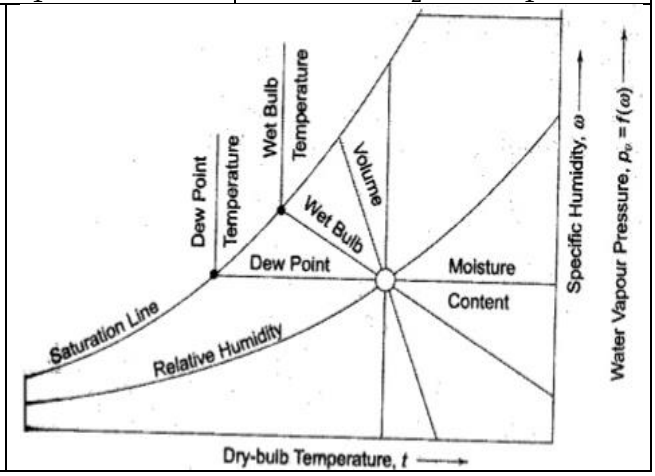
NOTE: This process is called adiabatic saturation process and it follows constant enthalpy line. At the end of adiabatic saturation process minimum temperature obtained is WBT.

8. Heating & Dehumidification: It's also known as adiabatic chemical dehumidification.

- Certain chemical like silica gel, alumina gel is used to absorb the moisture.
- When moisture absorbed by the chemicals. Latent heat of condensation is released which increases the temperature of air.

$T_2 > T_1$	$\omega_2 < \omega_1$	$WBT_2 < WBT_1$





MIXING OF TWO AIR STEAMS:

$$\begin{matrix} m_{a1}, m_{V1}, \omega_1 \\ T_1, h_1, \phi_1 \end{matrix} + \begin{matrix} m_{a2}, m_{V2}, \omega_2 \\ T_2, h_2, \phi_2 \end{matrix} = \begin{matrix} m_{a3}, m_{V3}, \omega_3 \\ T_3, h_3, \phi_3 \end{matrix}$$

$m_{a1} + m_{a2} = m_{a3}$ $m_{V1} + m_{V2} = m_{V3}$	$\omega_1 m_{a1} + \omega_2 m_{a2} = \omega_3 m_{a3}$	From Energy Balance, $H_1 + H_2 = H_3$
$\therefore h_1 m_{a1} + h_2 m_{a2} = h_3 m_{a3}$	$\therefore \frac{m_{a1}}{m_{a2}} = \frac{\omega_3 - \omega_2}{\omega_1 - \omega_3}$	$\therefore \frac{m_{a1}}{m_{a2}} = \frac{h_3 - h_2}{h_1 - h_3} = \frac{T_3 - T_2}{T_1 - T_3}$