Lecture two

3- Dew point temperature: The saturation temperature corresponding to the actual partial pressure of the water vapour in air.

Or: It is the temperature at which the weight of water vapour associated with a certain weight of dry air is adequate to saturate that weight of air.

e.g: Find the dew point temperature for air at 20°C d.b. & 15°C w.b. &P_B=95kP_a.

Sol: $P=P_{sw}-P_B.A.(t_d-t_w)$

$=1.7051-95*6.66*10^{-4}(20-15)=1.388kP_a$

then the dew point temperature is corresponding to P=1.388kPa.

From table at 10°C P=1.227kP_a, at 15°C P=1.7051kPa

Explanation for interpolation:

°C	P kp$_a$
10	1.227
T	1.388
15	1.7051

(15-10)(1.388-1.227) = (T-10)(1.7051-1.227)

$$T=\frac{(15-10)(1.388-1.227)}{(1.7051-1.227)}+10=11.68^{o}C$$

Note: If this air which is at 20°C d.b. &15°C w.b. is cooled sensibly to a dry bulb temperature of (11.68°C) it would be saturated and $t_d=t_=t_w=d_{.p}$.

6- Enthalpy of air:

The total enthalpy of an air-water vapour mixture is the sum of enthalpies of dry air and enthalpy of water vapour.

i.e. $h=h_a + W.h_{fg}$ per kg of dry air.

Now, $h_a=C_p\ (t-tr)$

Where (t_r) is the reference temperature at which (h_a) is taken.

For air-water vapour mixtures, the reference temperature is taken as 0°C for both air and steam.

For air (h) is not a linear function of temperature and for steam assume (C_p) is constant. For a barometric pressure of (101.325kPa):

$h_a=1.007t-0.026$ for $0\leq t \leq 60^oC$

& $h_a=1.005t$ for $-10\leq t < 0^oC$

$h_g= 2501+1.84\,t$ $0< t <60^oC$

(t) is in degree centigrade.

$h = (1.007\,t -0.026) + w\,(2501+1.84\,t)$

e.g: calculate the approximate enthalpy of moist air at a state of 20°C d.b. & 15°C w.b. and standard atmospheric pressure.

Sol:

: $P=P_{sw}-P_B.A.(t_d-t_w)$

$=1.7051-101.325*6.66*10^{-4}(20-15)=1.388kP_a$

$W=0.622\frac{P}{P_B-P} = 0.622 * \frac{1.388}{101.325-1.388} = 0.008638$ kg/kg dry air

$h = (1.007\,t -0.026) + w\,(2501+1.84\,t)$

$=(1.007*20-0.026)+0.008638(2501+1.84*20)$

$=20.114+21.9215=42.035$ kJ/kg dry air.

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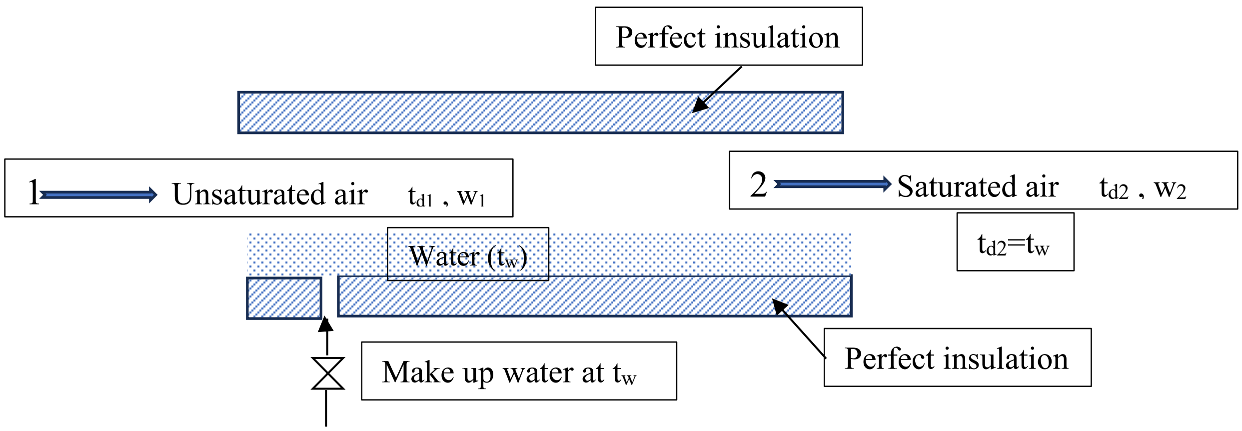
7- Adiabatic saturation:



Adiabatic process in which no external heat flows in or out of the system, but interchange of energy can occur. Water is supplied at (t_w). If the chamber is long enough and the water surface is adequate, experiments show that air leaves in a saturated state and at dry bulb temperature equaling the initial wet bulb temperature. i.e. $t_{w1}=t_{w2}$.

$t_{d2}= t_{w1}=t_{w2}=t_w$

i.e. a constant wet bulb temperature process.

Heat balance for the process.

$h_2=h_1+(w_2-w_1)h_{fw}$

where h_{fw} = enthalpy of saturated water at (t_w).

Note: $h_2=h_{a2}+w_2h_{g2}$ & $h_1=h_{a1}+w_1h_{g1}$

Usually $(w_2-w_1)h_{fw}$ is very small and referred to as the corrective term. h_2 & h_1 are calculated from equation

$h = (1.007\ t -0.026) + w\ (2501+1.84\ t)$

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For all practical purposes adiabatic saturation may be considered as a constant enthalpy process.

i.e. $h_2=h_1+D$, $D=(w_2-w_1)h_{fw}$ (corrective term)

e.g: Air at 20°C & 15°C enters an adiabatic device where it is saturated, water enters the device at 15°C, the barometric pressure is 101.325kPa. Find the initial and final enthalpies of this stream.

Sol: From the previous example:

$P_1=1.388kP_a$, $w_1=0.008638$kg/kg dry air., $h_1=42.035$kJ/kg.

At exit for saturated air $t_{d2}=t_w=15°C$. & $P_2=1.7051kP_a$ from table.

$$W_2=0.622\frac{P_2}{P_B-PP_2}=0.622*\frac{1.7051}{101.325-1.7051}=0.010646\text{kg/kg dry air}$$

$$h_2=(1.007\ t-0.026)+w\ (2501+1.84\ t)$$

$$=(1.007*15-0.026)+0.010646(2501+1.84*15)$$

$$=15.079+26.919=41.998\text{kJ/kg dry air.}$$

| | (comp. the difference nearly (5) (i.e. sensible heat converted to latent)

$h_1=20.114+21.9215=42.035$kJ/kg.

$h_2-h_1=41.998-42.035=-0.037$kJ/kg.

$D=(w_2-w_1)h_{fw}=(0.010646-0.008638)*62.99=0.1248$kJ/kg dry air.

The psychrometry of Air Conditioning Processes:

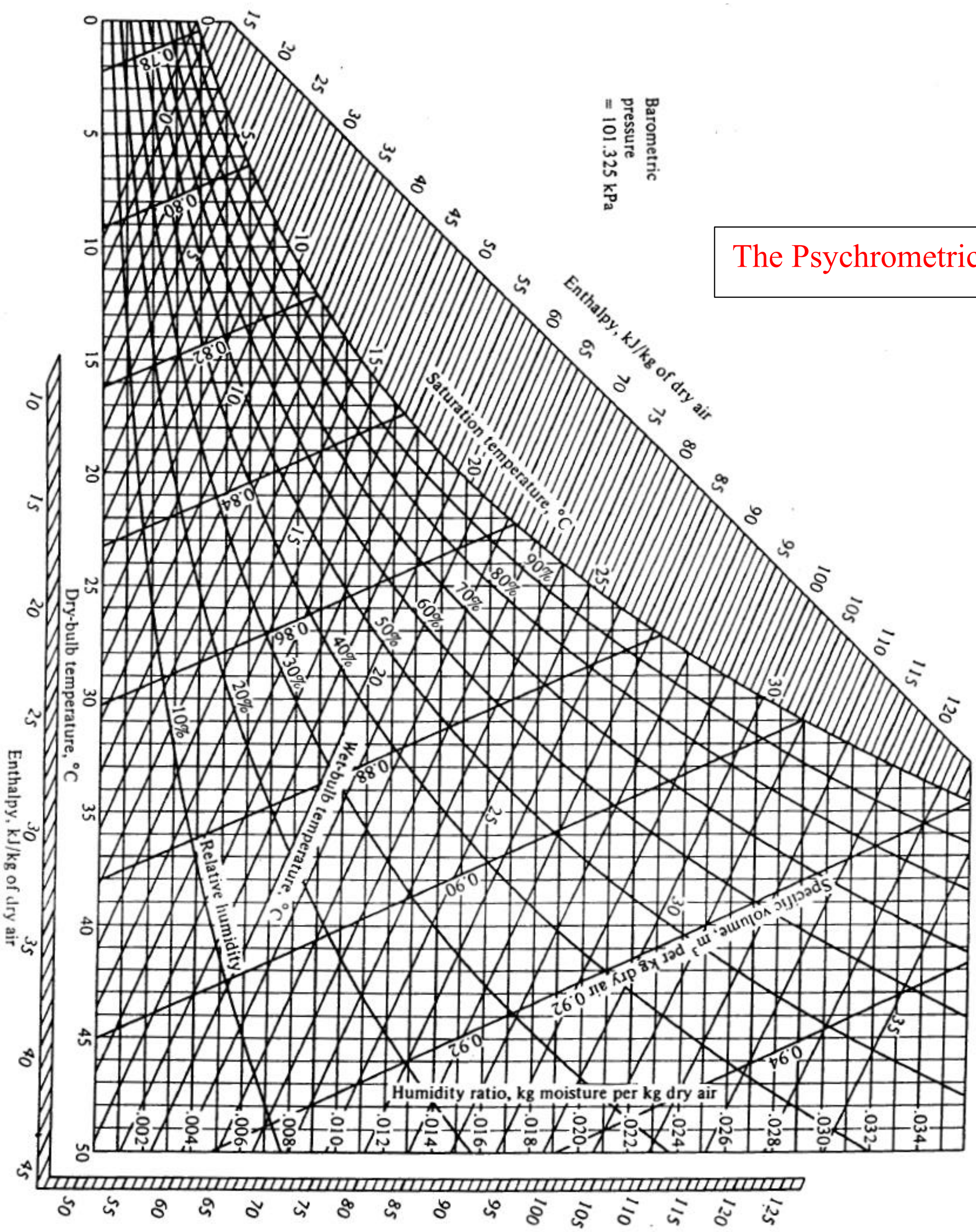
Although the equations that we have developed for the many properties of moist air are used for computer calculation. It is convenient to have the plotted in chart for easy reference during design HVAC system.

The psychrometric chart is an *x y* plot with dry bulb temperature as the abscissa and the moisture content as the ordinate. Since these are two independent thermodynamics variable, all other properties of moist air can be expressed as function of them at a given atmospheric.

1- The psychrometry chart contains all the parameters of the air-water vapour mixture. Namely, d.b., w.b., dew point temperature, specific humidity (w), enthalpy (h), relative humidity (r.h), specific volume (υ), and sensible heat ratio (SHR) scale.

All the above properties can be found for any state point. A state point is fixed by any two properties.

The Psychrometric Chart



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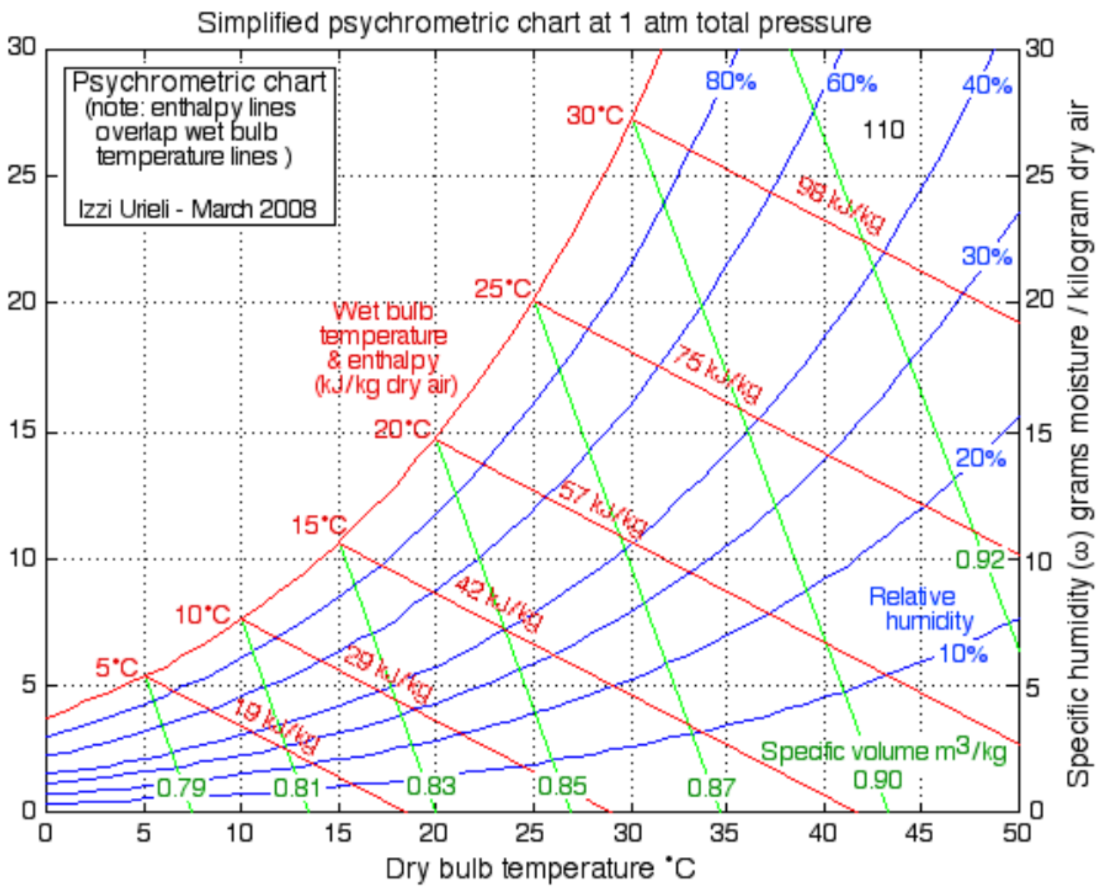
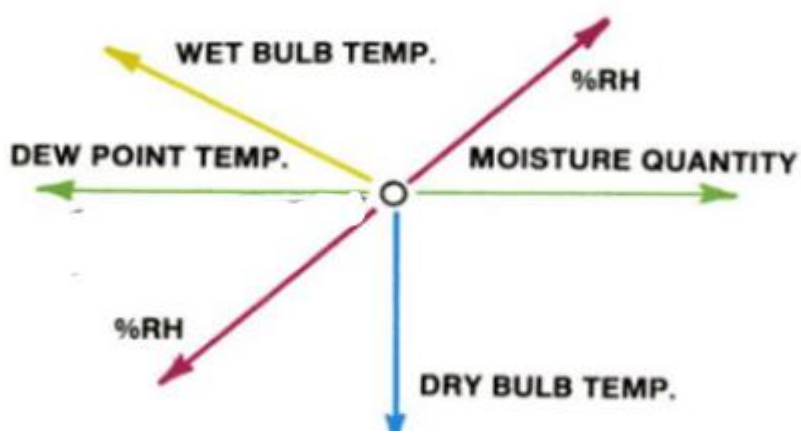
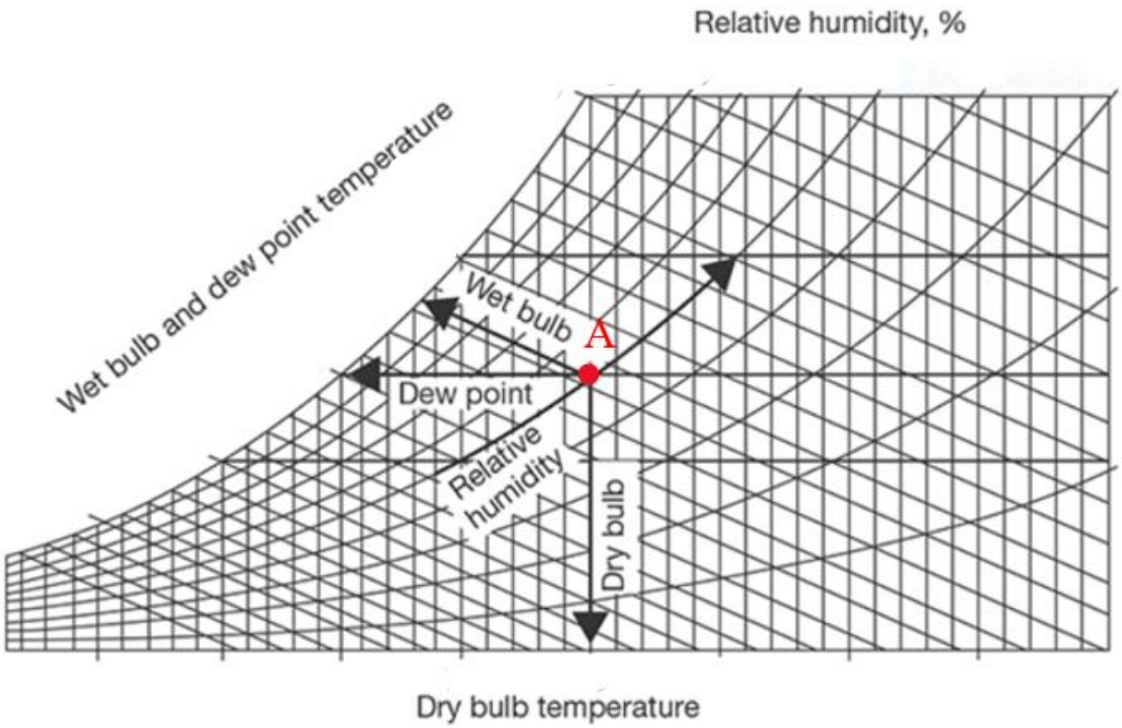


How to use the psychrometric chart



Sketch below show how to find (relative humidity (dry bulb, wet bulb & dew point temperatures) for a state point (A).



Psychrometric Chart

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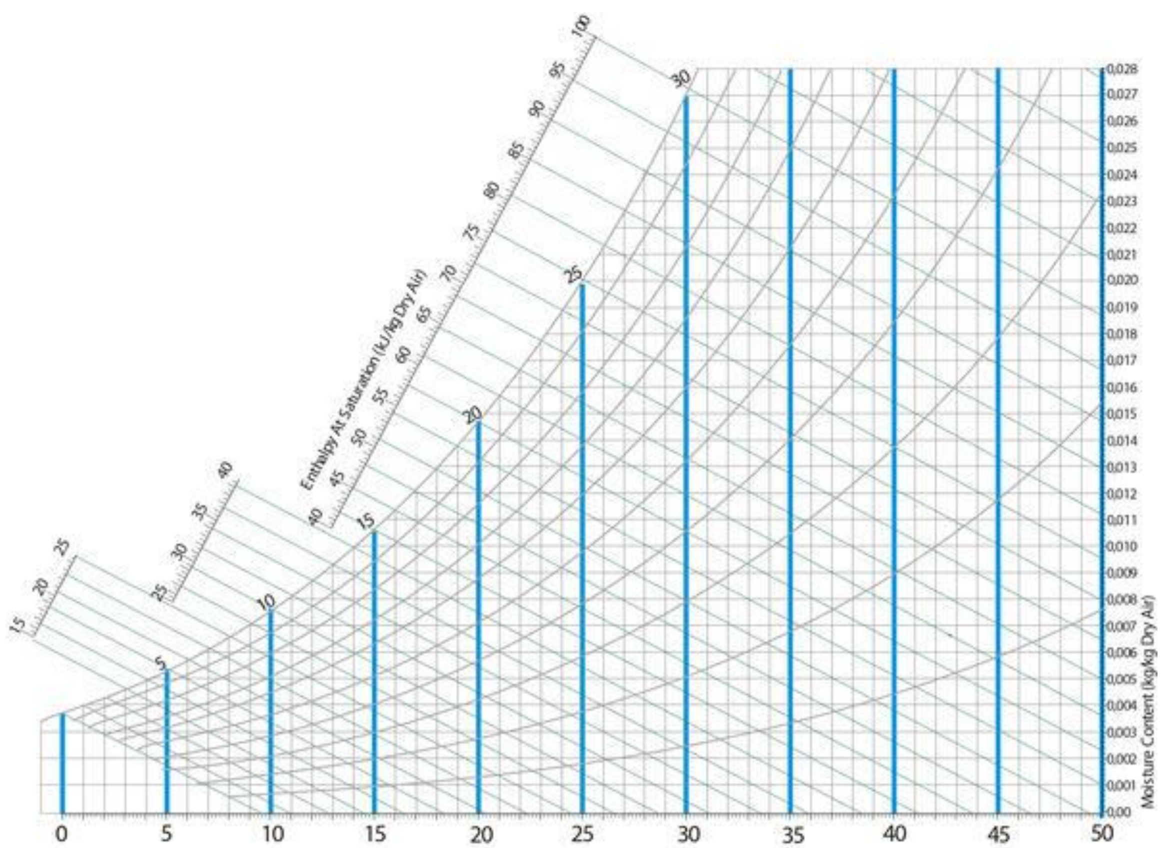
Figures below shows how line of constant properties listed appear on the psychrometric chart.

Dry bulb temperatures:

Every psychrometric chart includes vertical lines that represent the dry bulb temperatures. Air temperature increases from left to right.



Dry bulb temperature lines on a psychrometric chart

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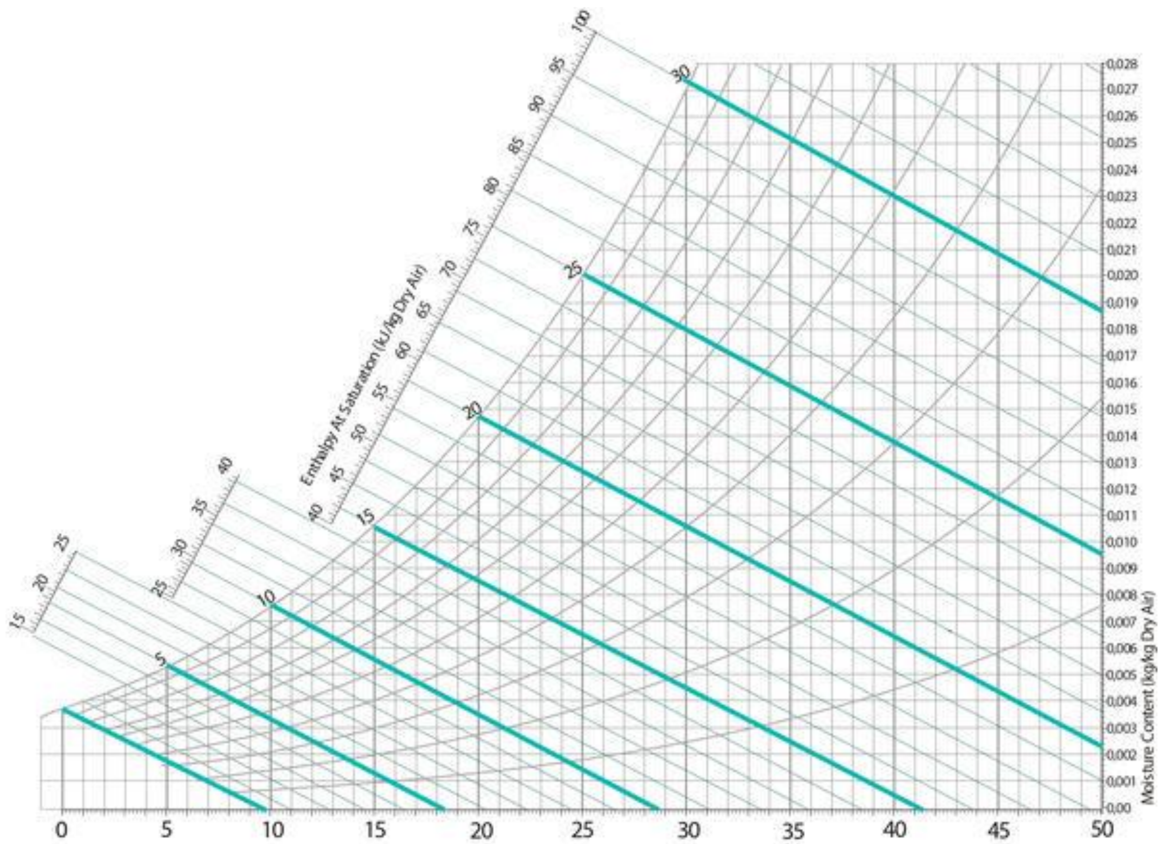
Wet bulb temperatures and enthalpies:

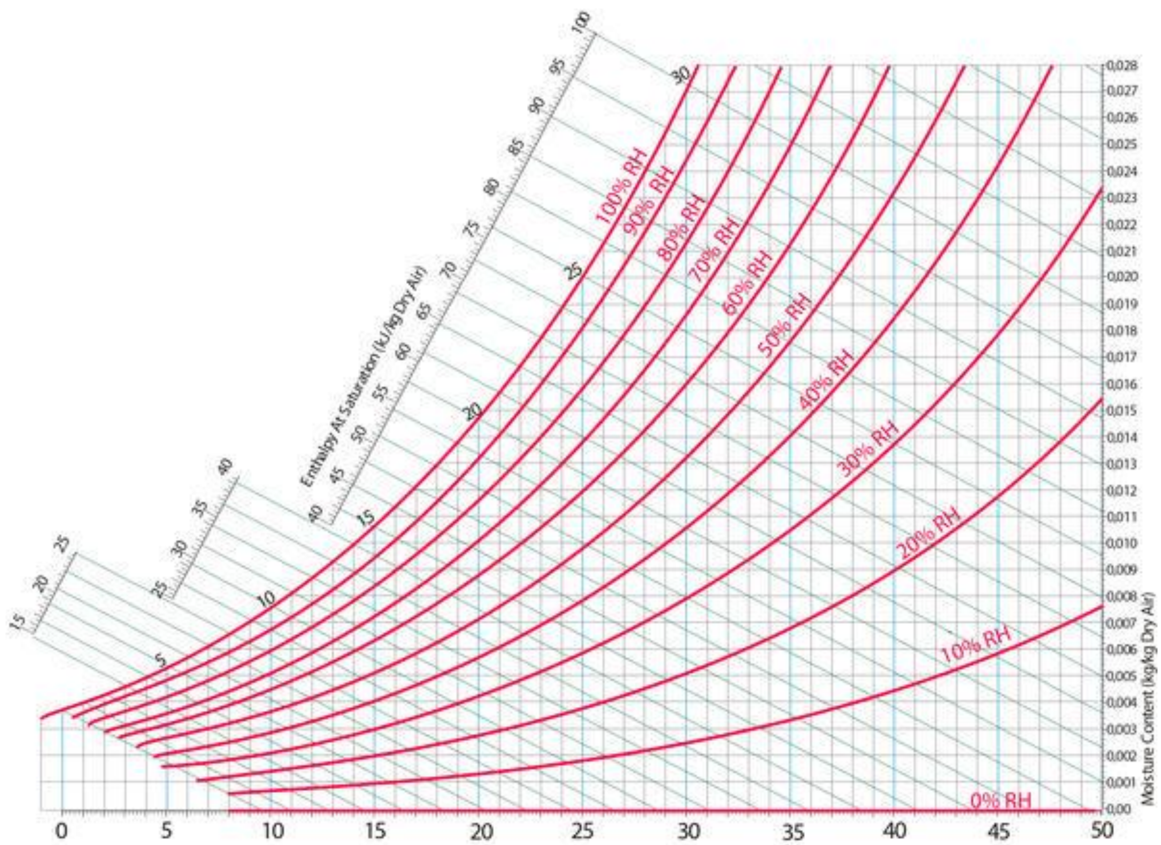
Every psychrometric chart also includes wet bulb temperatures and enthalpies. These lines are indicated at diagonals, and like dry bulb temperatures they increase from left to right.



Wet bulb temperature & enthalpy lines (on a psychrometric chart

Relative humidity:

Another feature indicated on every psychrometric chart is relative humidity lines. These lines are curved and begin at 100% along the top of the chart and decrease moving downward. It is fairly common for these lines to be indicated in intervals of ten.



Relative humidity lines on a psychrometric chart

Specific humidity and enthalpy (mass and energy) are the basic properties to construct the psychrometric chart.

Dry bulb temperature is shown along the horizontal axis. When you draw lines through a chart along which the quantity under consideration remains the same, they're called isolines.

Lines of constant dry bulb temperature are straight but divergent.

Coordinates of dry bulb & (w) are not rectangular but oblique to make dry bulb dry bulb lines vertical.

Specific humidity (w) lines are parallel, also the enthalpy lines are parallel and equally spaced.

Lines of wet bulb temperature and specific volume are slightly curved and divergent.

e.g: Air at 30ºC d.b. & 25ºC w.b. enters a cooling and dehumidifying coil at a rate of $3m^3$/sec. and leaves as saturated air at 15ºC. Find:

a) all the properties of entering and leaving air. b) the heat transfer rate of the coil. c) the rate of moisture removal.

Sol: a) at point (1) h_1=76kJ/kg dry air. at point (2) h_2=42kJ/kg dry air.

W_1=0.018kg/kg dry air. W_2=0.0107kg/kg dry air.

$\upsilon_1=0.882m^3/kg$. $\upsilon_2=0.831m^3/kg$.

ϕ_1=66% ϕ_2=100%.

d.p.$)_1$=23.2ºC d.p.$)_2$=15ºC

b) Rate of heat transfer $=\dot{m}(h_1-h_2)$, $\dot{m}=\dot{\upsilon}.d=\frac{\dot{\upsilon}}{\upsilon}=\frac{3}{0.882}=3.401$kg/sec.

rate of heat transfer= 3.401(76-42)=115.65kJ/sec.

c) Rate of moisture removal$=\dot{m}(w_1-w_2)$=3.401*(0.018-0.0107)=0.0248kg/sec.

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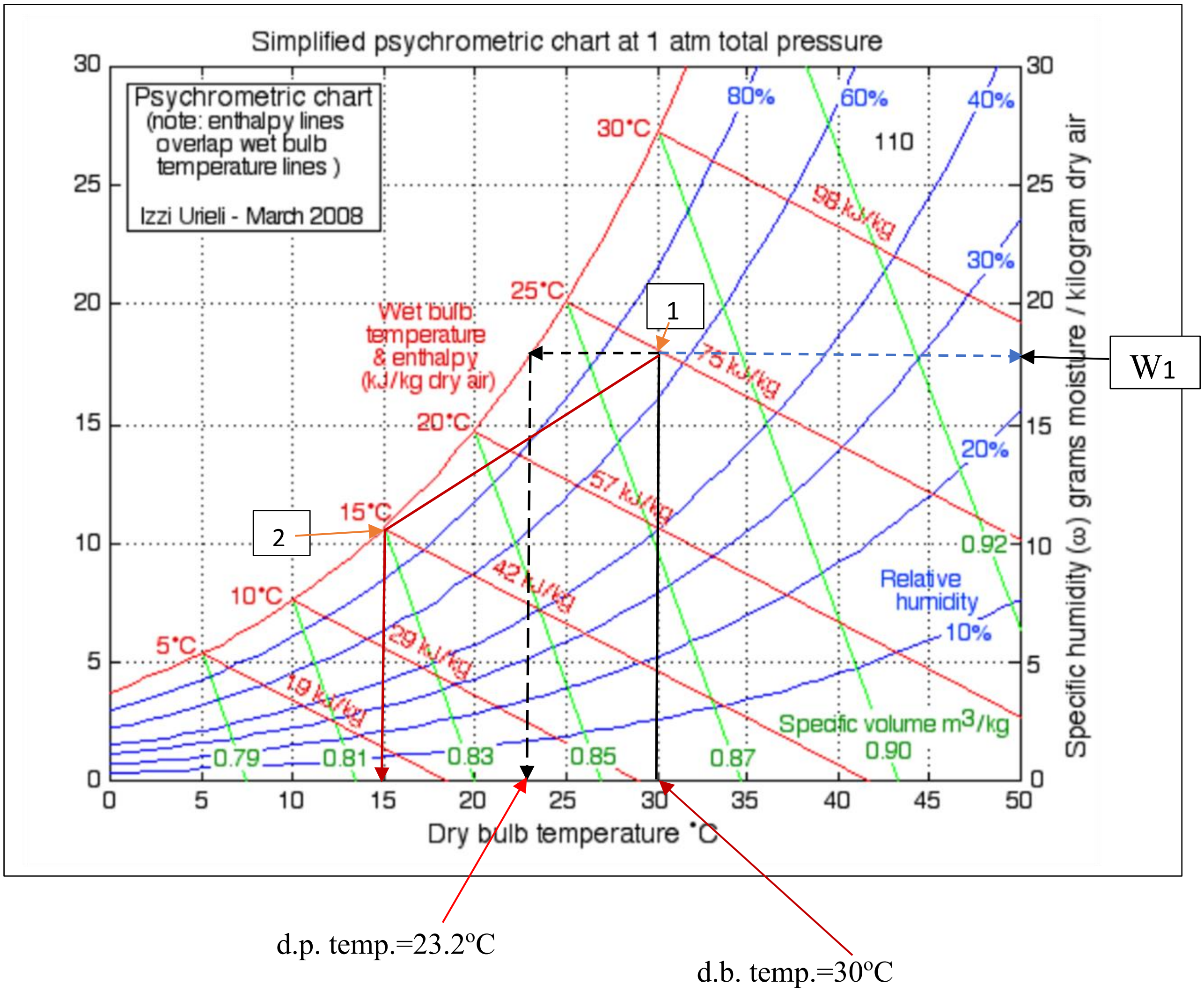
Simplified psychrometric chart at 1 atm total pressure
Psychrometric chart
(note: enthalpy lines overlap wet bulb temperature lines)
Izzi Urieli - March 2008
Wet bulb temperature & enthalpy (kJ/kg dry air)
30°C
25°C
20°C
15°C
10°C
5°C
98 kJ/kg
75 kJ/kg
57 kJ/kg
42 kJ/kg
29 kJ/kg
19 kJ/kg
80%
60%
40%
30%
20%
10%
Relative humidity
110
Specific volume m3/kg
0.79
0.81
0.83
0.85
0.87
0.90
0.92
Dry bulb temperature °C
Specific humidity (ω) grams moisture / kilogram dry air
1
2
W1
d.p. temp.=23.2°C
d.b. temp.=30°C