7 - The Psychrometric Chart

The Psychrometric Chart is a plot of the thermodynamic variables of moist air. Each variable depends only on the Humidity Ratio HR (or Absolute Humidity or Specific Humidity) and on the air temperature t_{DRY} (the dry bulb temperature or air temperature). The plot is shown in the Excel spreadsheet **7-psy-chart.xls**

Starting with equation (5) section (4),

$$HR = \frac{m_{VAPOR}}{m_{DRY-AIR}} = \left(\frac{M_{VAPOR}}{M_{DRY-AIR}}\right)\left(\frac{p_{VAPOR}}{p_{ATM} - p_{VAPOR}}\right) \qquad (1)$$

As noted, p_{VAPOR} can be expressed as a function of two variables only: HR and the atmospheric pressure p_{ATM}:

$$\boxed{p_{VAPOR} = \frac{p_{ATM}}{1 + \left(\frac{M_{VAPOR}}{M_{DRY-AIR}}\right)\left(\frac{1}{HR}\right)}} \qquad (2)$$

Observe that in this equation p_{VAPOR} does not depend on temperatures.

M_{VAPOR} = molecular mass of water vapor = 18 grams
$M_{DRY-AIR}$ = molecular mass of dry air = 29 grams
$M_{VAPOR} / M_{DRY-AIR}$ = 0.62069

1. Plotting the wet bulb temperature t_{WET}

From equation (10) section (4):

$$\boxed{p_{VAPOR} = p_{SAT}(t_{WET}) - k\ (t_{DRY} - t_{WET})\ p_{ATM}}$$

For each value of t_{WET} = 0, 5, ..., 30ºC, compute p_{VAPOR} (t_{DRY}) and then HR(t_{DRY}) from eq. (1) above. Plot the curve HR(t_{DRY}) for each value of t_{WET}.

k = 0.000662 / ºC

2. Plotting the Relative Humidity RH

Start from equation (11) section (4):

$$RH\ \% = 100\ \frac{p_{VAPOR}}{p_{SAT}(t_{DRY})}$$

and using equation (2) above, HR can be computed as:

$$HR = \frac{\left(\frac{M_{VAPOR}}{M_{DRY-AIR}}\right)}{\left(\frac{100\,p_{ATM}}{RH\%\;p_{SAT}(t_{DRY})} - 1\right)} \qquad (3)$$

For each value of RH%, plot the curve HR(t_{DRY})

$M_{VAPOR} / M_{DRY-AIR} = 0.62069$

3. Plotting the Specific Volume SV

Specific Volume = m^3 of air / kg of dry air

Starting from eqs. (3) and (4) of section (4):

$$HR = \frac{m_{VAPOR}}{m_{DRY-AIR}} = \left(\frac{p_{VAPOR}\,V_{IN}\,M_{VAPOR}}{R\,T_{DRY}}\right)\left(\frac{1}{m_{DRY-AIR}}\right) = \left(\frac{V_{IN}}{m_{DRY-AIR}}\right)\left(\frac{p_{vapor}\,M_{VAPOR}}{R\,T_{DRY}}\right)$$

$$SV = \text{specific volume} = \frac{V_{IN}}{m_{DRY-AIR}}$$

$$HR = SV\left(\frac{p_{vapor}}{273.15 + t_{DRY}}\right)\left(\frac{M_{VAPOR}}{R}\right)$$

Using equation (2) above and solving for HR:

$$HR = \frac{SV\;M_{VAPOR}\;p_{ATM}}{R\;(273.15 + t_{DRY})} - \frac{M_{VAPOR}}{M_{DRY\text{-}AIR}}$$

R = universal constant of gases = 0.06237 (m^3 mmHg / ºC)
$M_{VAPOR} / M_{DRY-AIR} = 0.62069$
M_{VAPOR} = 18 grams

4. Plotting the dew point temperature (t_{DEW})

Given the dew point temperature, the relative humidity is determined, according to equation (3) section (5):

$$RH\% = 100\,\frac{p_S(t_{DEW})}{p_S(t_{AMB})}$$

Inserting this equation in equation (3) above, with $t_{AMB} = t_{DRY}$:

$$HR = \frac{\left(\frac{M_{VAPOR}}{M_{DRY-AIR}} \right)}{\left(\frac{p_{ATM}}{p_{SAT}(t_{DEW})} - 1 \right)}$$

which represents horizontal lines for each value of t_{DEW}.

$M_{VAPOR} / M_{DRY-AIR} = 0.62069$

5. Plotting the Enthalpy h

The Enthalpy used in the Psychrometric Chart is the total amount of heat energy, per kilogram of dry air, needed to heat the moist air from 0ºC (liquid water) to t_{DRY}. This amount is (according to Thermodynamics):

To vaporize liquid water: 2445 (kjoules / kg of water)
To heat water vapor from 0º to t_{DRY}: 2.006 t_{DRY} (kjoules / kg of water)

Energy needed per kg of dry-air:

$(2445 + 2.006\ t_{DRY})\ HR$ (kjoules / kg of dry air)

To heat the dry air from 0º to t_{DRY}:

$1.022\ t_{DRY}$ (kjoules / kg of dry air)

Specific Enthalpy h:

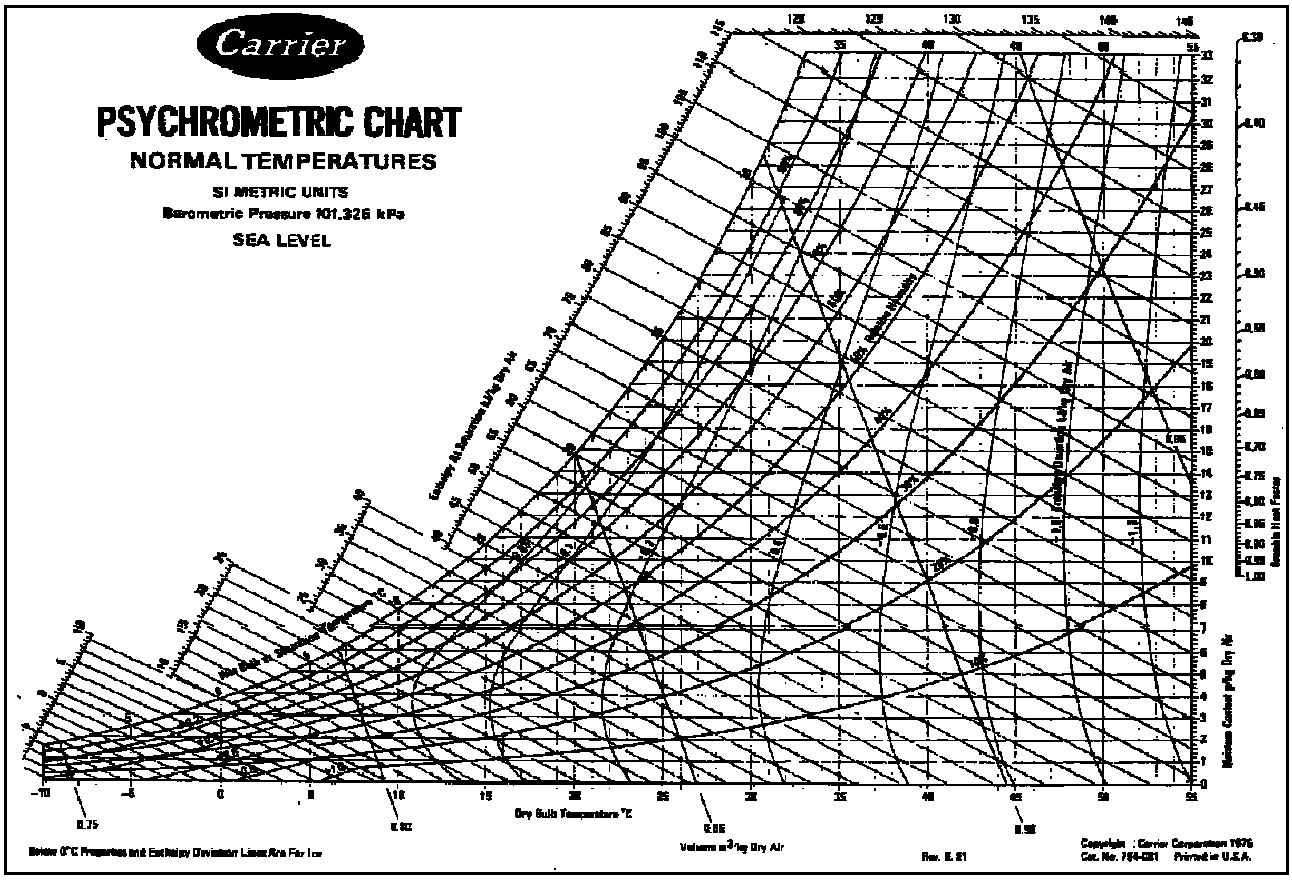
$h = 1.022\ t_{DRY} + (2445 + 2.006\ t_{DRY})\ HR$

To plot the curves for each value of **h**, solve above equation to **HR**:

$$HR = \frac{h - 1.022\ t_{DRY}}{2445 + 2.006\ t_{DRY}}$$

6. An example of a commercial psychrometric chart

Here is an example of a very useful chart, published on paper by the well known company Carrier. This section (7) has shown how it may be created using the Excel spreadsheet "Psy-Chart-XLS.xls", with the advantage that it may be easily customized according to user needs.


Carrier
PSYCHROMETRIC CHART
NORMAL TEMPERATURES
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Barometric Pressure 101.325 kPa
SEA LEVEL
Dry Bulb Temperature °C
Volume m³/kg Dry Air
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