Chapter 2.5

Humidity measures

i.e. psychrometry

Using gas law for the perfect gases

- The pressure in the room is p=1.01325bar, if it is the standard sea level atmospheric pressure
- Given this total pressure, what is the partial pressure of oxygen and nitrogen?
- $pV=mRT$
- p=pressure, V=volume, m=mass, R=specific gas constant, T=temperature
- Remember use SI units
- p $[N/m^2$, i.e. $kg \cdot m \cdot s^{-2} \cdot m^{-2} = kg \cdot m \cdot s^{-2}]$, V $[m^3]$, m [kg], R $[J \cdot kg^{-1}K^{-1} = kg \cdot m^2 s^{-2} kg^{-1} K^{-1} = m^2 s^{-2} K^{-1}]$, T [K]

To finish it off…

- $p_{O2} = (8314/32)(293)m_{O2}/V$
- $p_{N2} = (8314/28)(293)m_{N2}/V$
- $p_{O2} + p_{N2} = 101325$ Pa
- $m_{N2}/m_{O2} = 0.767/0.233$
- Divide second by first and substitute:

  $p_{N2}/p_{O2}=(32/28)(0.767/0.233)=3.76$

  Which strangely is the same as V_{N2}/V_{O2}

Hygrometry (or Psychrometry)

Study of atmospheric air i.e. air and water vapour mixtures.

This is relevant to air conditioning plant, and cooling tower analysis.

The level of humidity is defined by 3 measures:

specific humidity

relative humidity

dew point

Step 2: Specific humidity, ω:

The ratio of mass of water vapour to air in a given volume, V.

$$\omega = \frac{m_s\,(\text{vapour})}{m_a\,(\text{air})} = \frac{m_s / V}{m_a / V} = \frac{v_a}{v_s}$$

The last step is due to $m_s/V = 1/v_s$ also $m_a/V = 1/v_a$

It is useful to define specific humidity in terms of partial pressure. Water vapour can be regarded as an ideal gas when the partial pressure is below about 20 kPa (corresponding to p_s for 60C). If both are treated as perfect gases, then:

$$p_s V = m_s R_s T \rightarrow \frac{m_s}{V} = \frac{p_s}{R_s T}$$

$$p_a V = m_a R_a T \rightarrow \frac{m_a}{V} = \frac{p_a}{R_a T}$$

Where R is specific gas constant (i.e. kJ/kgK) and subscript is a=air, s=vapour

hence $$\omega = \frac{R_a p_s}{R_s p_a}$$

Since R_a is 287 J/kg.K and R_s is 461 J/kg.K and $P_{atmos} = P_a + P_s$, this equation becomes:

$$\omega = \frac{287 p_s}{461(p_{atmos} - p_s)} = \frac{0.622 p_s}{p_{atmos} - p_s}$$

Relative Humidity ϕ

$$\varphi = \frac{p_s}{p_g} = \frac{p_{partial\ pressure\ of\ vapour\ in\ air}}{p_{saturation\ temperature\ from\ tables\ for\ water\ at\ air\ temperature}}$$

p_s = partial pressure of water vapour – this notation subscript only used in air conditioning – otherwise subscript means saturation condition

p_g = partial pressure of vapour if the mixture is saturated at the temperature T of the mixture – this notation only used for air conditioning.

T [°C]	p_s [bar]	v_g [m³/kg]	h_f [kJ/kg]	h_{fg} [kJ/kg]	h_g [kJ/kg]	s_f [kJ/kg K]	s_{fg} [kJ/kg K]	s_g [kJ/kg K]
0.01	0.006112	206.1	0*	2500.8	2500.8	0†	9.155	9.155
1	0.006566	192.6	4.2	2498.3	2502.5	0.015	9.113	9.128
2	0.007054	179.9	8.4	2495.9	2504.3	0.031	9.071	[illegible]
3	0.007575	168.2	12.6	2493.6	2506.2			
4	0.008129	157.3	16.8	2491.3	2508.1			
5	0.008719	147.1	21.0	2488.9	2509.9			
6	0.009346	137.8	25.2	2486.6	2511.8			
7	0.01001	129.1	29.4	2484.3	2513.7			
8	0.01072	121.0	33.6	2481.9	2515.5			
9	0.01147	113.4	37.8	2479.6	2517.4			
10	0.01227	106.4	42.0	2477.2	2519.2			
11	0.01312	99.90	46.2	2474.9	2521.1			
12	0.01401	93.83	50.4	2472.5	2522.9			
13	0.01497	88.17	54.6	2470.2	2524.8			
14	0.01597	82.89	58.8	2467.8	2526.6			
15	0.01704	77.97	62.9	2465.5	2528.4			
16	0.01817	73.38	67.1	2463.1	2530.2			
17	0.01936	69.09	71.3	2460.8	2532.1	0.253	8.481	8.734
18	0.02063	65.08	75.5	2458.4	2533.9	0.268	8.444	8.712
19	0.02196	61.34	79.7	2456.0	2535.7	0.282	8.407	8.689