

PRINCIPLES of AIR CONDITIONING

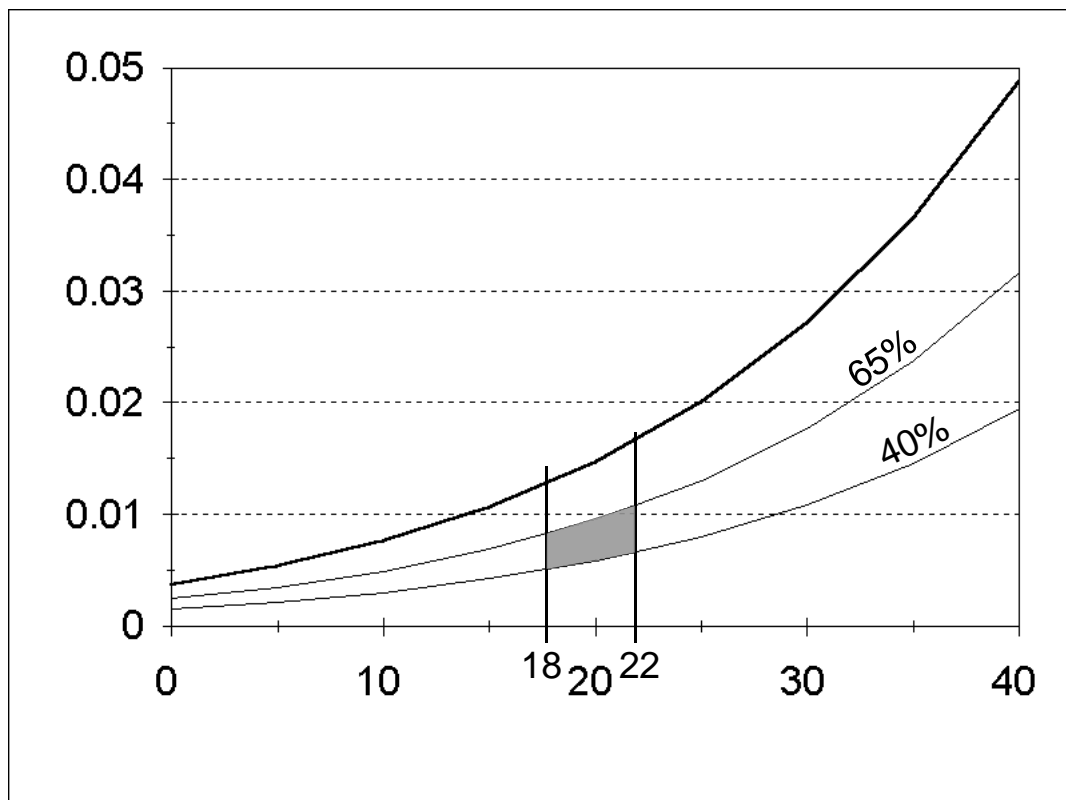
Air conditioning is the process whereby the condition of air, as defined by its temperature and moisture content, is changed.

Note that in practice other factors must also be taken into account especially cleanliness; odour; velocity & distribution pattern.

Human comfort

Inevitably 'comfort' is a very subjective matter. The Engineer aims to ensure 'comfort' for most people found from statistical surveys .

Most people (90%) are comfortable when the air temperature is between 18-22°C and the %sat is between 40-65%. This zone can be shown on the psychrometric chart., and is known as the **comfort zone**.



Outside air is quite likely to be at a different condition from the required comfort zone condition. In order to bring its condition to within the comfort zone we may need to do one or more of the following :-

heat it; cool it; dehumidify it; humidify it; or mix it.

Dry air mass flow

In order to use the psychrometric chart for air-conditioning work we need to find & use *dry air mass flows*. However, in practice air-flows are frequently measured in terms of *volume flow*.

In order to find dry air mass flow we need to use the *specific volume* of the air.

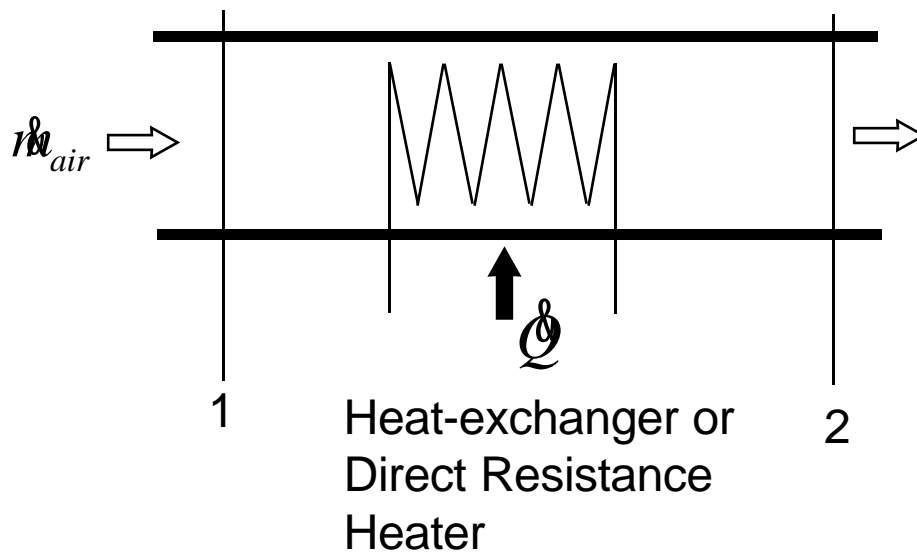
$$\text{specific volume} = \frac{\text{volume}}{\text{mass}}$$

$$\backslash \quad m = \frac{V}{v} \quad \text{i.e.} \quad \boxed{\dot{m}_{air} = \frac{V_{mix}}{v}}$$

NB: the specific volume of the air is given from the psychrometric chart in m³/kg of ***dry air***, therefore the mass flow will be in terms of dry air mass flow.

Obviously the condition of the air must be known (typically d.b. temp. & %sat) in order to find the specific volume.

Air heating

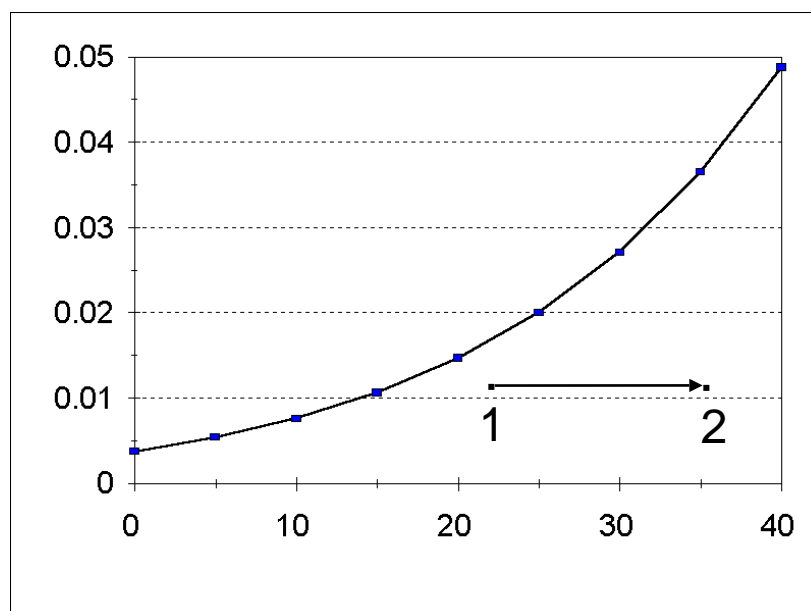


Applying the SFEE:

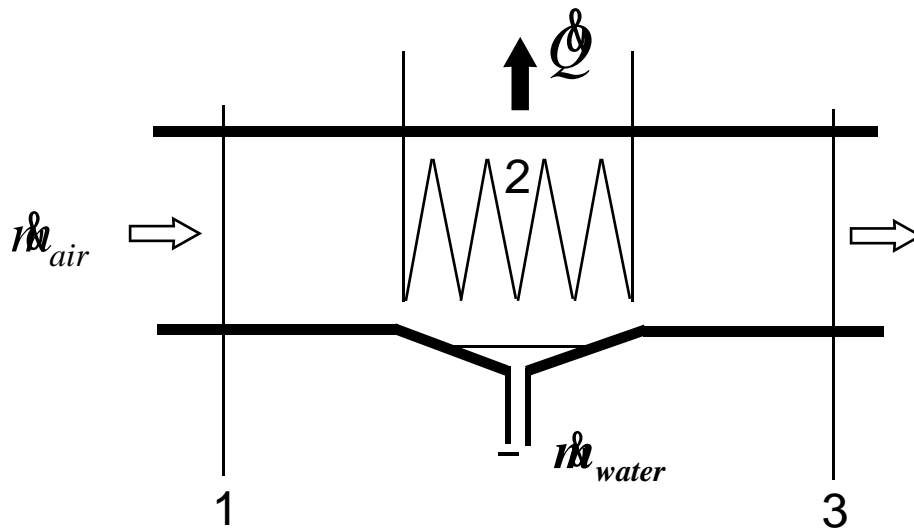
$$\cancel{Q} + \cancel{W} = \dot{m}_{air} D \left(\cancel{\frac{1}{2} v^2} + \cancel{gz} + h \right)$$

i.e. $\boxed{Q = \dot{m}_{air} (h_2 - h_1)}$

The heating process can be illustrated on the psychrometric chart thus:



Cooling/Dehumidification



In the case of cooling, the mixture will firstly be sensibly cooled (a to b) to the point of saturation (called the dew point) then liquid water will precipitate if we cool further (b to c). Because moisture is removed dehumidification is achieved.

Applying the SFEE:

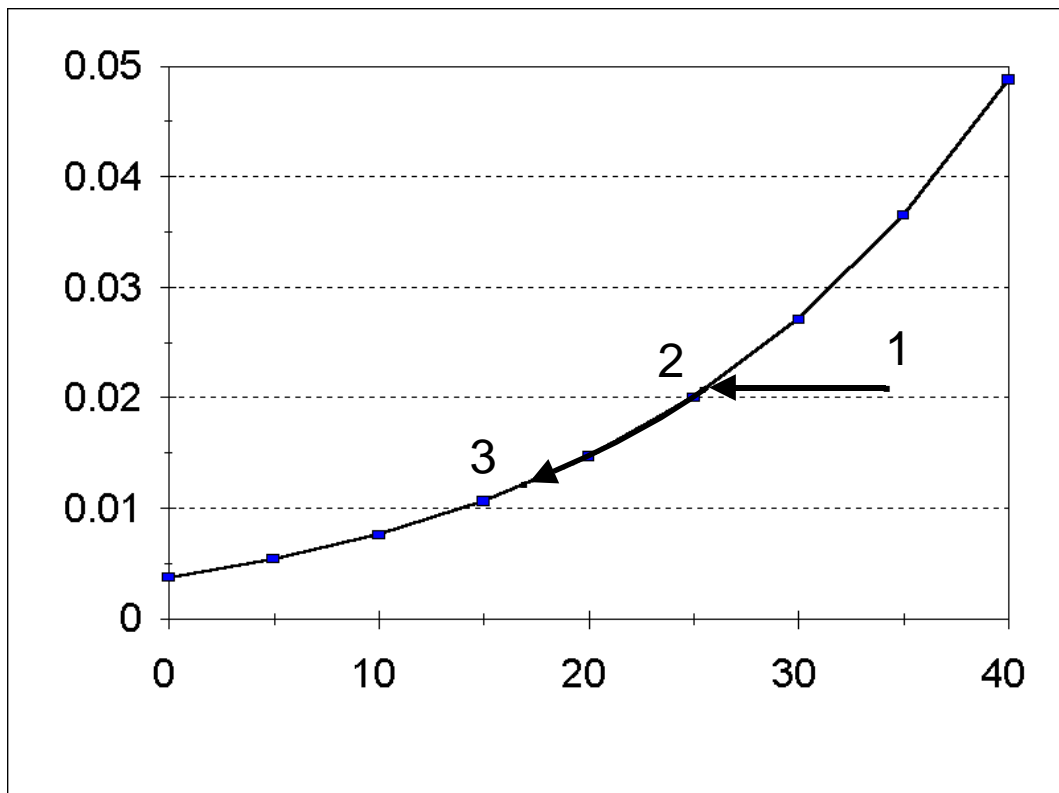
$$\dot{Q} = \dot{m}_{air} (h_3 - h_1) + \dot{m}_{water} h_{f2}$$

We can also write a mass flow balance equation for the water/steam.

If the initial moisture content is w_1 and final m.c. is w_3 then:

$$\dot{m}_{air} w_1 = \dot{m}_{air} w_3 + \dot{m}_{water}$$

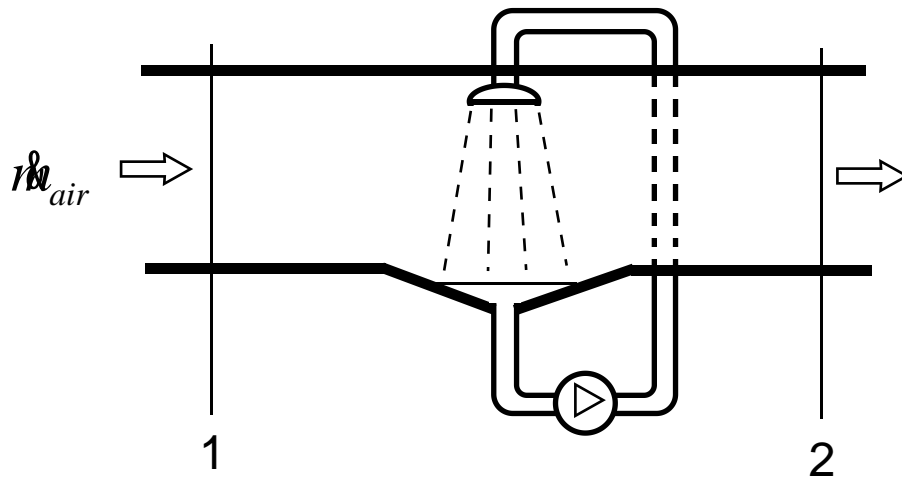
The cooling/dehumidification process can be illustrated on the psychrometric chart thus:



In practice the mass flow of liquid water is usually very small compared with the air mass flows and can normally be omitted from the energy balance equation without undue error. i.e.

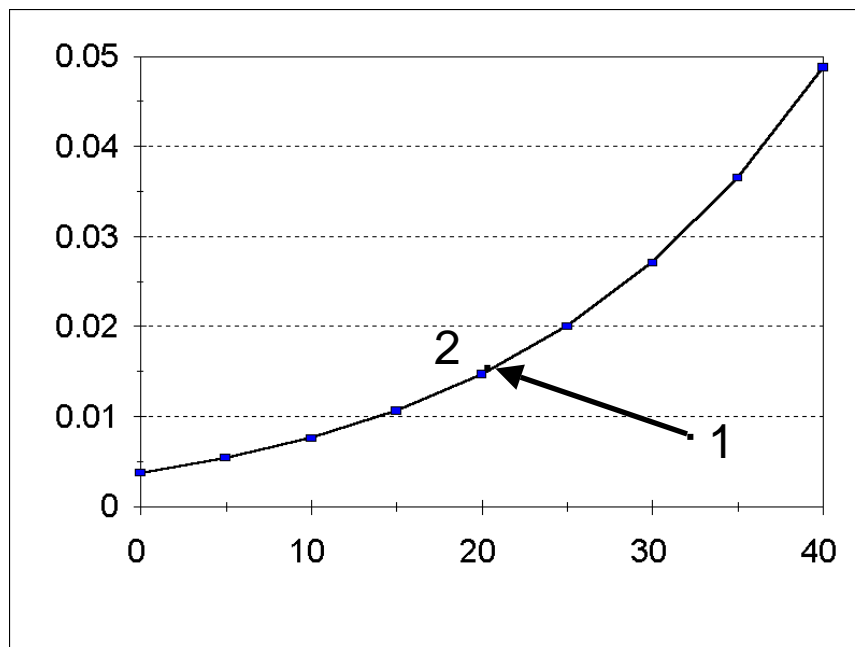
$$\dot{Q} \gg \dot{m}_{air} (h_3 - h_1)$$

Humidification



The process of humidification allows the air to mix with extra water. A sufficient contact time between the air and water will normally result in the air reaching 100% saturation.

The process is very close to the evaporation from a wet bulb. It therefore follows a line of constant wet bulb temperature.

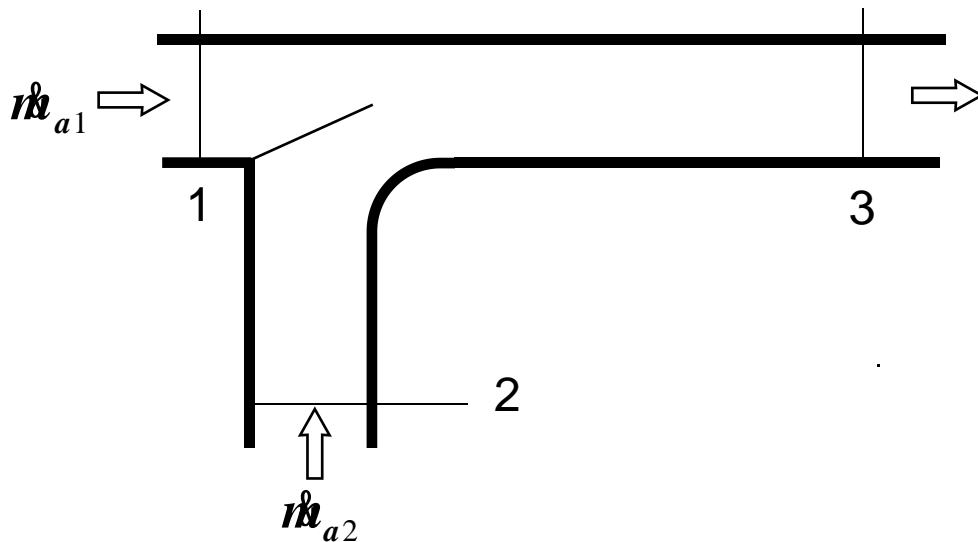


An alternative method involves boiling water to steam and injecting the steam into the air-flow.

This has to be dealt with from first principles.

Mixing

Often, instead of exhausting 'stale' air completely some of it is filtered, de-odourised and mixed with fresh incoming air. This conserves energy and narrows the operating conditions for the air-conditioning system



from continuity:- $\dot{m}_{a3} = \dot{m}_{a1} + \dot{m}_{a2}$ (dry air)

also:- $W_1 \dot{m}_{a1} + W_2 \dot{m}_{a2} = W_3 \dot{m}_{a3}$ (steam)

therefore:- $W_3 = \frac{\dot{m}_{a1}}{\dot{m}_{a1} + \dot{m}_{a2}} W_1 + \frac{\dot{m}_{a2}}{\dot{m}_{a1} + \dot{m}_{a2}} W_2$

energy:- $\dot{m}_{a1} h_1 + \dot{m}_{a2} h_2 = \dot{m}_{a3} h_3$

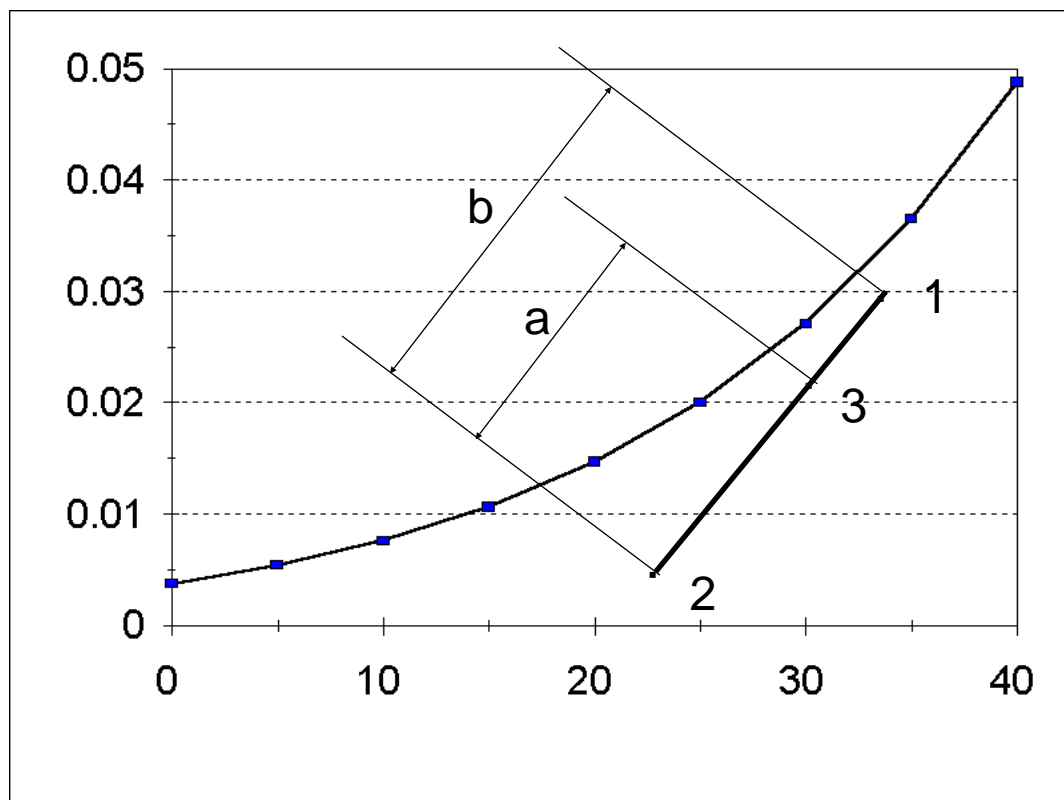
assuming: $h = c_p t$

$$\dot{m}_{a1} t_1 + \dot{m}_{a2} t_2 = \dot{m}_{a3} t_3$$

$$t_3 = \frac{\dot{m}_{a1}}{\dot{m}_{a1} + \dot{m}_{a2}} t_1 + \frac{\dot{m}_{a2}}{\dot{m}_{a1} + \dot{m}_{a2}} t_2$$

i.e. the condition of the mixed air-stream is found from the weighted average of the moisture contents and the d.b. temps. of the separate air-streams.

Because these properties correspond to the psychrometric chart axes, mixing can be interpreted graphically :-



$$\frac{a}{b} = \frac{W_{a1}}{W_{a1} + W_{a2}}$$