Al-Mustaqbal University
Air conditioning and refrigeration
Technical Department

2nd year / Air conditioning 1
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Lecture eight

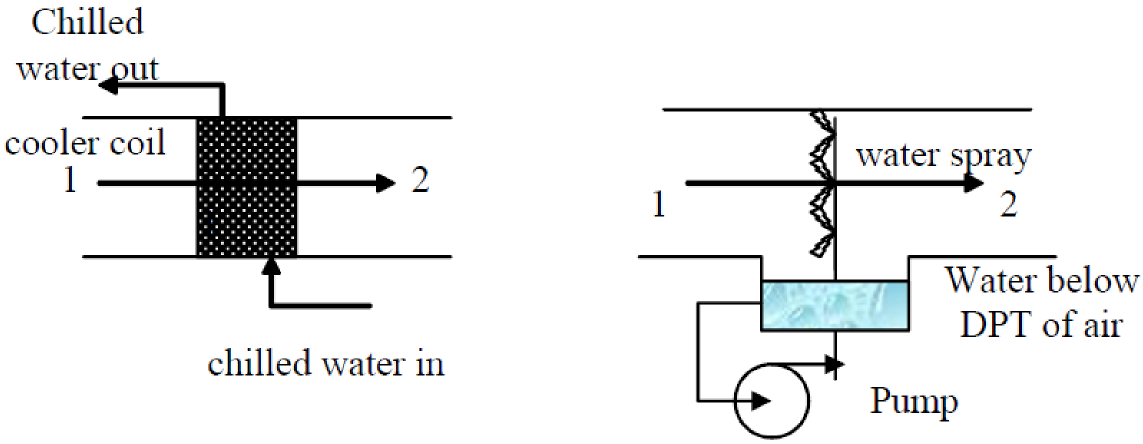
1- Dehumidification:

Removal of excess moisture from air, usually associated with air cooling applications.

Four ways to dehumidify:

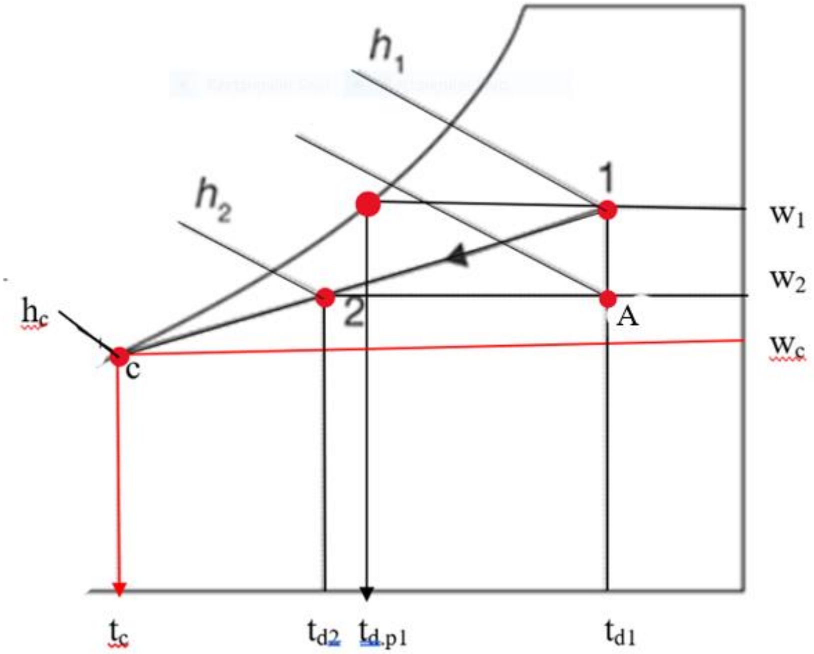
1. Cooling the air to a temperature below the dew point temperature.
2. Adsorption into a solid without phase change.
3. Absorption into solid or liquid usually with chemical change.
4. Compression followed by cooling to a temperature below the dew point.

The first method is most common to air conditioning (A/C). It is the required matter for this section. It is accomplished by passing moist air over a cooling coil or through an air washer whose spray water is chilled as shown in the figure below.



Cooling to a temperature below the dew point

The figure below shows a sketch of psychrometric chart what happens when moist air is cooled and dehumidified. Since dehumidification is the aim, some of spray water or same part of cooler coil, must be at a temperature less than dew point temperature of the air entering equipment.



- The air is initially at t_{d1}, w_1, h_1 & dew point temperature $t_{d.p1}$. for dehumidification, coil surface or washer temperature must be less than dew point temperature say (t_c).

t_c – is generally called the Apparatus dew point temperature [(adp) temp.]. This term is use for both coils and washer, but in the case of coil alone, tc is the mean coil surface temperature.

- If state (2) is the outlet condition, the (adp) is obtained by extending process (1---2) to intersect the saturation curve line.

State (2) is the outlet condition and is usually not on the saturation line since the equipment is never 100% efficient.

- This process cools & dehumidifies the air, the temperature drops from [t_{d1} to t_{d2}], moisture content decreases from [w_1 to w_2], enthalpy decreases from [h_1 to h_2].
- The efficiency of a cooling & dehumidifying coil is measured by the [CONTACT] or [BY PASS FACTOR] (B.F].

Bypass factor [B.F]:is a measure of the percentage of air that does not come in contact with the coil surface.

Contact factor = 1-B.F

From the chart. B.F$=\frac{h_2-h_c}{h_1-h_c}=\frac{w_2-w_c}{w_1-w_c}$

It is generally defined in terms of d.b. temperature. B.F$=\frac{t_2-t_c}{t_1-t_c}$

or $(1\text{-B.F})=\frac{t_1-t_2}{t_1-t_c}$

The process is achieved at both sensible (process A-2) and latent heat (process 1-A) rejection, as follows:

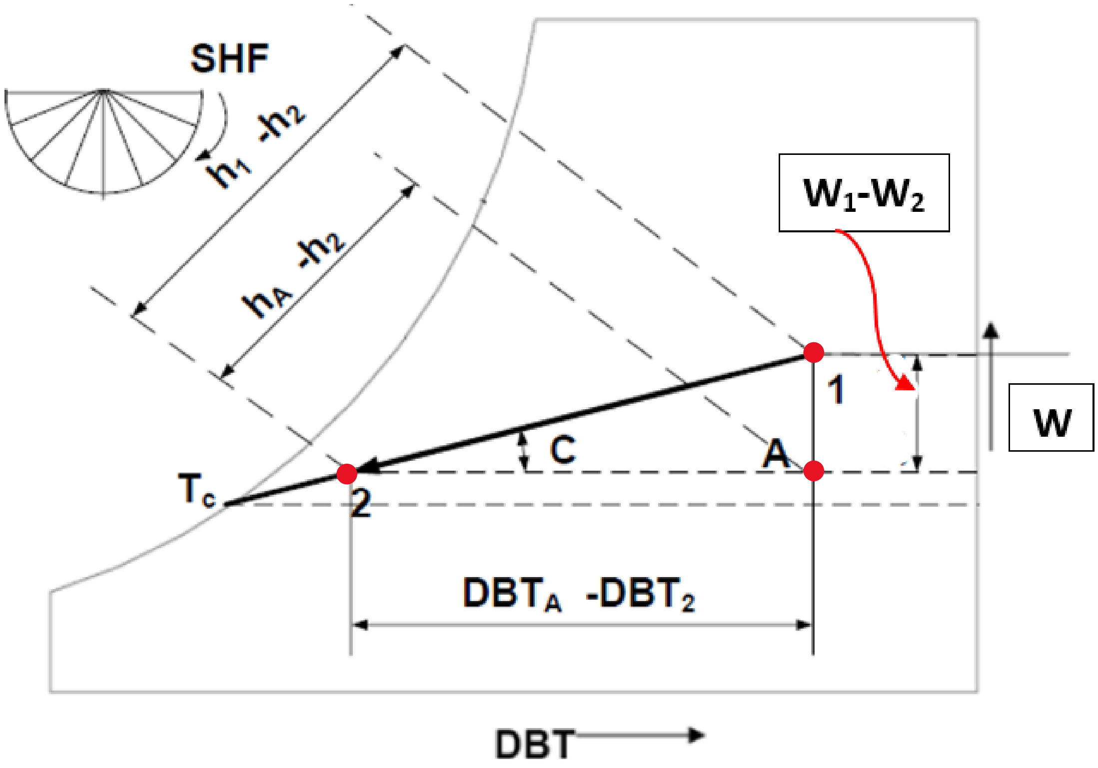
$Q_{s(A\text{-}2)}=\dot{m}_a(h_A-h_2)=\dot{m}_a C_{pa}(DBT_A-DBT_2)$

$Q_{l(1\text{-}A)}=\dot{m}_a(h_1-h_A)=\dot{m}_a h_{fg}(W_1-W_2)$, as $W_2=W_A$

By separating the total heat transfer rate from the cooling coil into sensible and latent heat transfer rates, a useful parameter called Sensible Heat Factor (SHF) is defined. SHF is defined as the ratio of sensible to total heat transfer rate (as previously mentioned):

$$\text{SHR}=\frac{Q_s}{Q_s+Q_l}=\frac{Q_s}{Q_T}$$

From the above equation, one can deduce that a SHF of 1.0 corresponds to no latent heat transfer and a SHF of 0 corresponds to no sensible heat transfer. A SHF of 0.75 to 0.80 is quite common in air conditioning systems in a normal dry climate. A lower value of SHF, say 0.6, implies a high latent heat load such as that occurs in a humid climate.



The Sensible Heat Factor (SHF)

From the figure above, the slope of the process line 1-2 is given by:

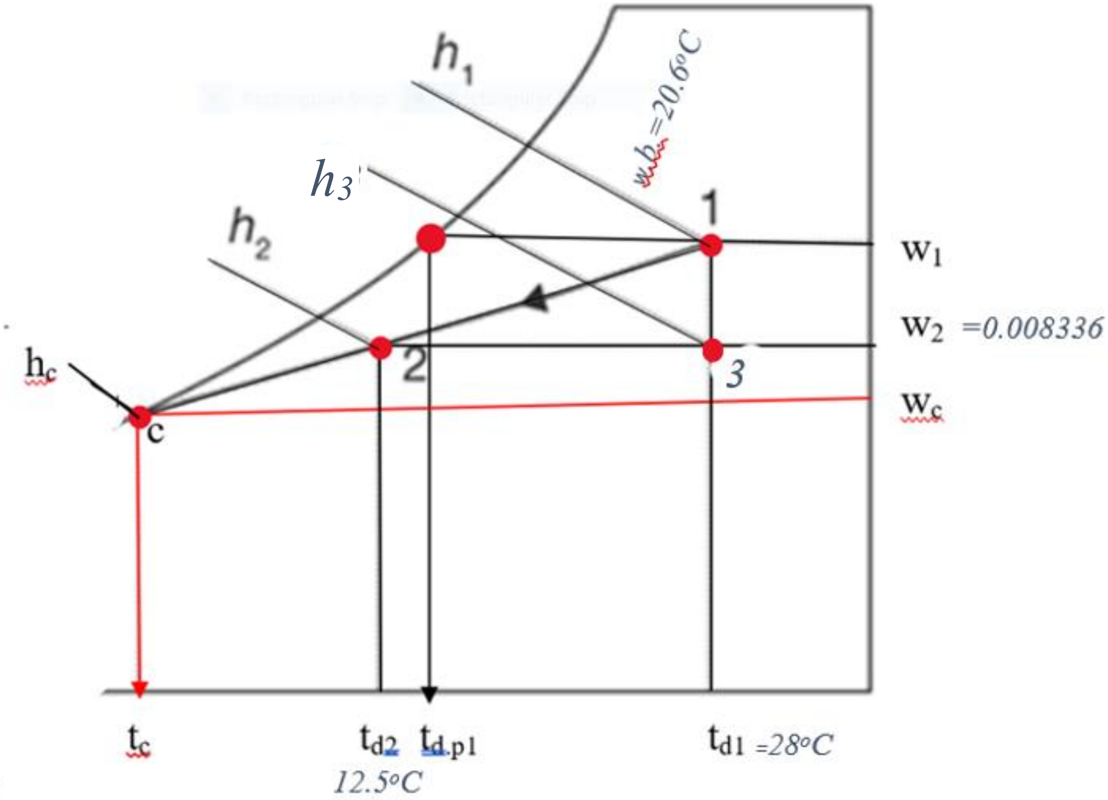
$$\tan(c) = \frac{Q_l}{Q_s} = \frac{\dot{m}_a h_{fg}.(W_1 - W_2)}{\dot{m}_a.c_{pa}.(DBT_A - DBT_2)} = \frac{\dot{m}_a.\ 2501.(W_1 - W_2)}{\dot{m}_a 1.007(DBT_A - DBT_2)}$$

$$\tan(c) = \frac{Q_l}{Q_s} = 2483.614\ \frac{(W_1 - W_2)}{(DBT_A - DBT_2)}$$

Thus, we can see that the slope of the cooling and de-humidification line is purely a function of the sensible heat factor, SHF. Hence, we can draw the cooling and dehumidification line on psychrometric chart if the initial state and the SHF are known. In some standard psychrometric charts, a protractor with different values of SHF is provided. The process line is drawn through the initial state point and in parallel to the given SHF line from the protractor as shown in Figure above.

e.g: 1.5m^3 of air at 28°C d.b. & 20.6°C w.b. and standard atmospheric pressure flows a cross a cooling coil and leaves the coil at 12.5°C d.b. and 0.008336kg/kg dry air moisture content. determine: a) adp. b)B.F c) the cooling load.

Sol:



a) On the chart locate points (1 & 2) and extend the line until it intersects the saturation line, read:
adp =t_c=10.25°C.

b) $\text{B.F}=\frac{t_2-t_c}{t_1-t_c}=\frac{12.5-10.25}{28-10.25}=0.126$
Contact factor=1-0.126=0.874=$\eta_{\text{cooling coil}}$.

c) Cooling load =$\dot{m}(h_1-h_2)$
From chart: h_1=59.1kJ/kg.----- h_2=33.6kJ/kg.

$\dot{m} = \frac{V}{\upsilon}$,v=1.5m^3/sec. (given), υ_1=0.87m^3/kg (from chart).

$\therefore$ cooling load=$\frac{1.5}{0.87}(59.1 - 33.6) = 43.965$kJ/sec (kW).

Also: cooling load=sensible heat + latent heat

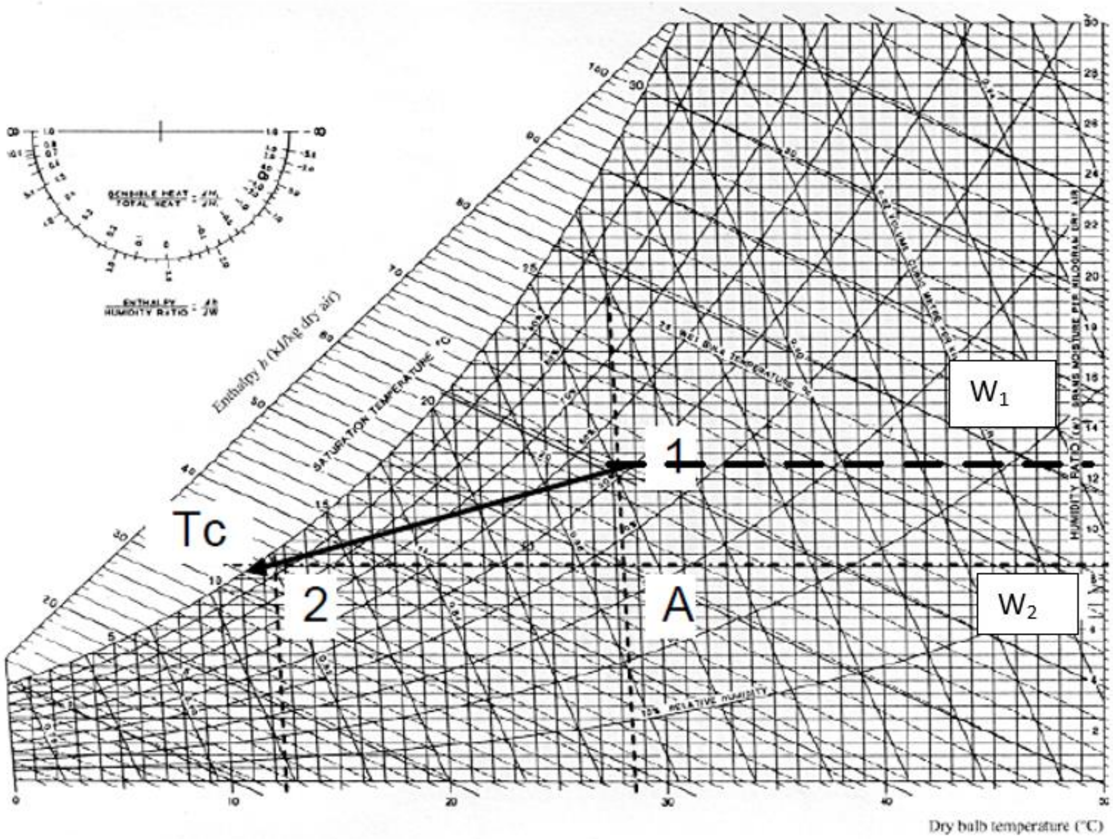
$$=\dot{m}(h_3 - h_2) + \dot{m}(h_1 - h_3)$$
$$= \dot{m}(h_1 - h_2)$$

Or, read h_3 from chart at intersection of vertical line from point (1) and horizontal line from point (2). [h_3=48.7kJ/kg].

Sensible load = $\frac{1.5}{0.87}(48.7 - 33.6) = 26.034$kJ/sec. (kw).

latent load = $(43.965 - 26.034) = 17.93$kJ/sec. (kw).

Or, latent load = $\frac{1.5}{0.87}(59.1 - 48.7) = 17.931$kJ/sec. (kw).


SENSIBLE HEAT / TOTAL HEAT
ENTHALPY / HUMIDITY RATIO
Enthalpy h (kJ/kg dry air)
SATURATION TEMPERATURE °C
WET BULB TEMPERATURE °C
RELATIVE HUMIDITY
HUMIDITY RATIO (W) GRAMS MOISTURE PER KILOGRAM DRY AIR
W1
1
Tc
2
A
W2
Dry bulb temperature (°C)