University of Diyala
College of Engineering
Mechanical Department

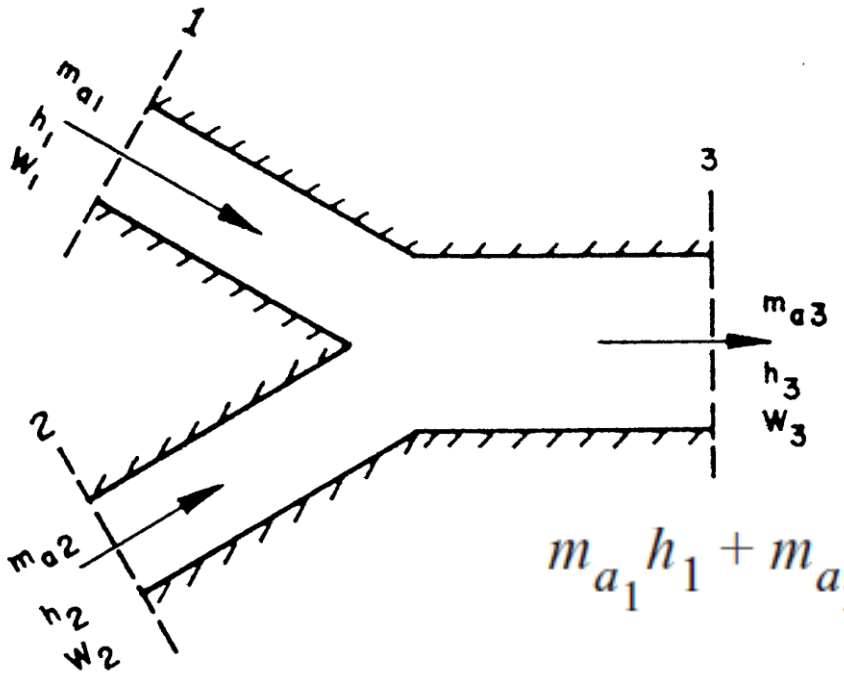
# Air Conditioning

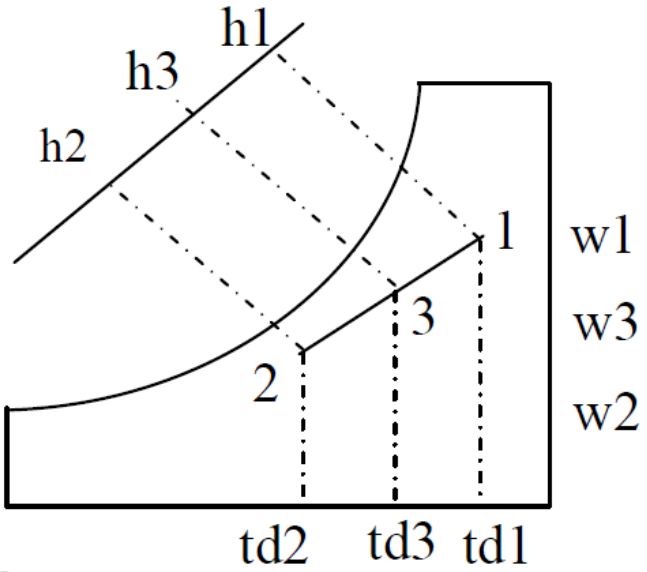
## 4-BASIC PSYCHROMETRIC PROCESSES CALCULATIONS

*Dr. Wameedh. T.M. Al-Tameemi*

## Adiabatic Mixing of Two Streams of Air

A common process involved in air conditioning is the adiabatic mixing of two streams of moist air




$$m_{a_1} h_1 + m_{a_2} h_2 = m_{a_3} h_3$$

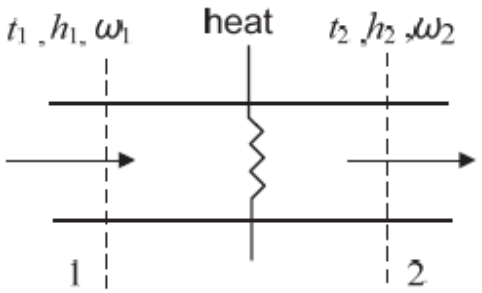
$$m_{a_1} + m_{a_2} = m_{a_3}$$

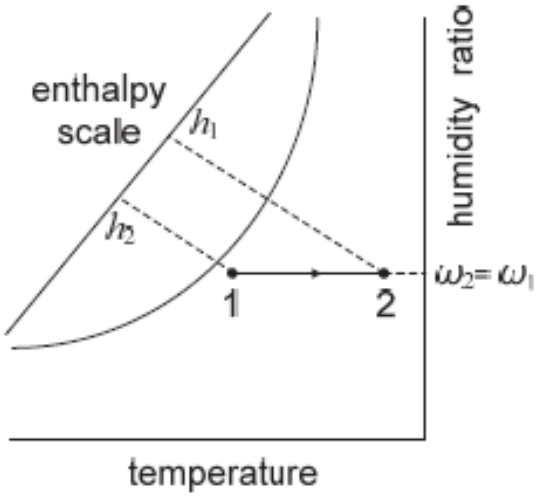
$$m_{a_1} W_1 + m_{a_2} W_2 = m_{a_3} W_3$$

**Exaple: 22-23**

## Heating or Cooling of Air (sensible heating or cooling)

When air is heated or cooled without moisture loss or gain, the process yields a straight horizontal line on the psychrometric chart because the humidity ratio is constant. Such processes can occur when moist air flows through a heat exchanger.




$$m_a h_1 - m_a h_2 + q = 0$$

$$W_2 = W_1$$

Compute heating load for heating coil warming 1.5 $\frac{m^3}{s}$ of moist air. The initial condition 21°C $t_d$ and 15°C $t_w$ and standard pressure. The air exit warmer than the inlet condition with 20°C. compute mass flow rate of hot water in the coil if the inlet and outlet temperatures of water are 85°C and 75°C respectively.

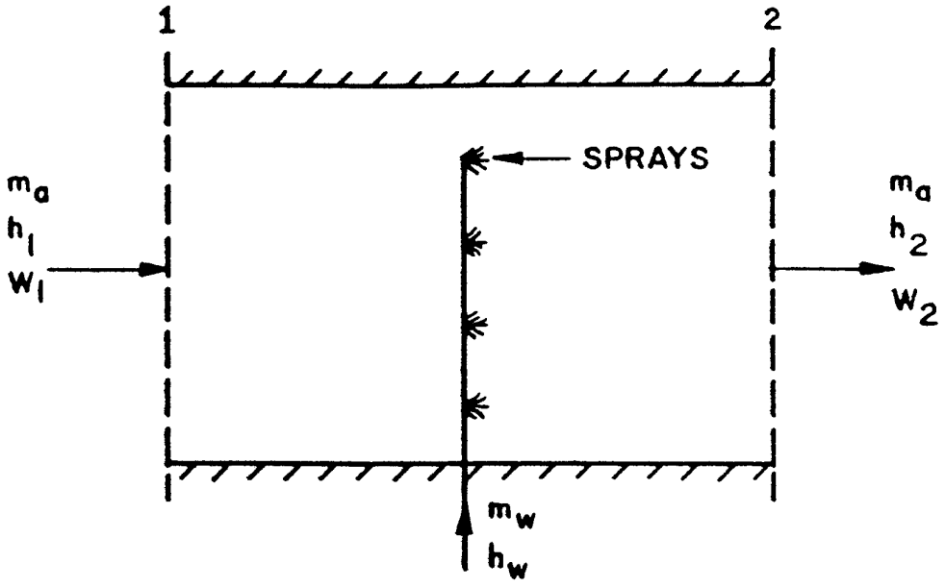
Compute heating load for heating coil warming 1.5 $\frac{m^3}{s}$ of moist air. The initial condition 21°C $t_d$ and 15°C $t_w$ and standard pressure. The air exit colder than the inlet condition with 5°C. compute mass flow rate of cold water in the coil if the inlet and outlet temperatures of water are 12°C and 17°C respectively.

## Humidifying

Injecting steam or liquid water into a moist air stream to raise the humidity ratio of the moist air is a frequent air conditioning process

$$m_a h_1 + m_w h_w = m_a h_2$$

$$m_a W_1 + m_w = m_a W_2$$

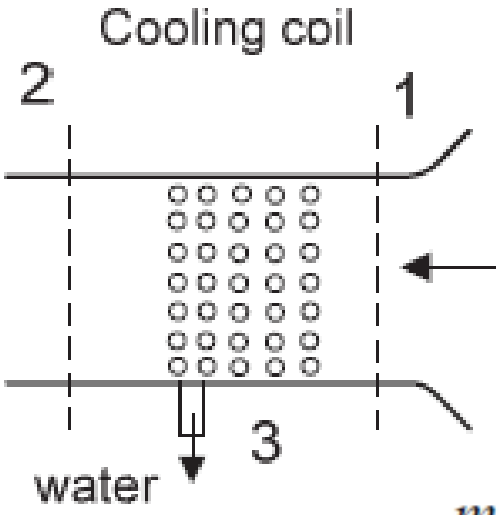


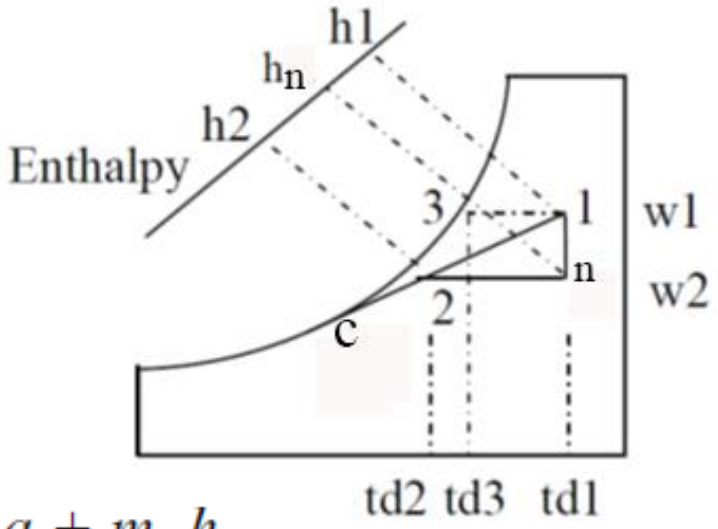
Moist air at 21°C $t_d$ and 15°C $t_w$ and 101.325 KPa $P_B$ mixed with 0.002 kg/$kg_{d.a}$ evaporated water at 100° C . Compute moist air properties at the exit.

Saturated water vapor with h=2803 KJ/Kg, 0.01 Kg/s injected in air stream of 1 kg/s dry air at 28°C $t_d$ and 11.9°C $t_w$. find moist air properties after humidifying process.

## Cooling and Dehumidifying Air

When moist air is cooled to a temperature below its dew point, some of the water vapor condenses and leaves the air stream.




$$m_a h_1 = m_a h_2 + q + m_w h_{w_2}$$

$$m_a W_1 = m_a W_2 + m_w$$

$$m_w = m_a (W_1 - W_2)$$

$$q = m_a[(h_1 - h_2) - (W_1 - W_2)h_{w_2}]$$

## Bypass factor

$$B.F. = \frac{h_2 - h_c}{h_1 - h_c} = \frac{W_2 - W_c}{W_1 - W_c} = \frac{t_2 - t_c}{t_1 - t_c}$$

## Contact factor

$$1 - B.F. = \frac{h_1 - h_2}{h_1 - h_c} = \frac{W_1 - W_2}{W_1 - W_c} = \frac{t_1 - t_2}{t_1 - t_c}$$

**Latent** heat load (air): $Q_l = m(W_1 - W_2)h_{vd} = m\Delta h_l = m(h_1 - h_n)$

**Sensible** heat load (air):

$$Q_s = m.c_{pm}(t_2 - t_1) = m(h_n - h_2) = m\Delta h_s = m[(h_n - h_2) - (W_1 - W_2)(h_{vd} + h_{fd})]$$

**Sensible** heat load (**water**): $Q_s = m_w.c_{pw}(t_d - t_c) = m_w(W_1 - W_2)(h_{fd} - h_{fc})$

Moist air at 28°C $t_d$ and 21°C $t_w$ flows at 1.5 $m^3$ /s over a cooling coil and exit at 12.5°C $t_d$ and w= 8.35 g/$Kg_{da}$ , find 1. dew point temperature 2. contact factor 3. cooling load 4. sensible and latent loads.

Air at 30°C $t_d$ and 25°C $t_w$ flows over a cooling coil and exit at 15°C $t_d$ and saturation condition, the conditioned air supplied to the space at $3m^3$/s find 1. air properties at inlet and exit 2. Heat transfer through the coil 3. The rate of moisture removal through the coil.

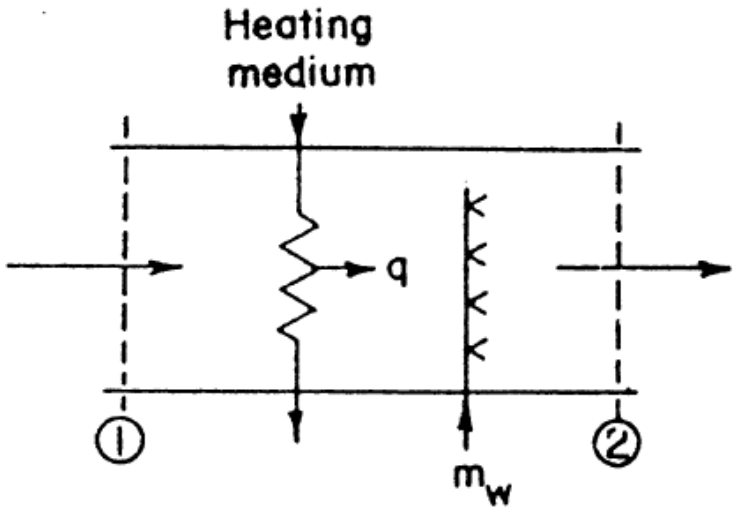
## Heating and Humidifying Air

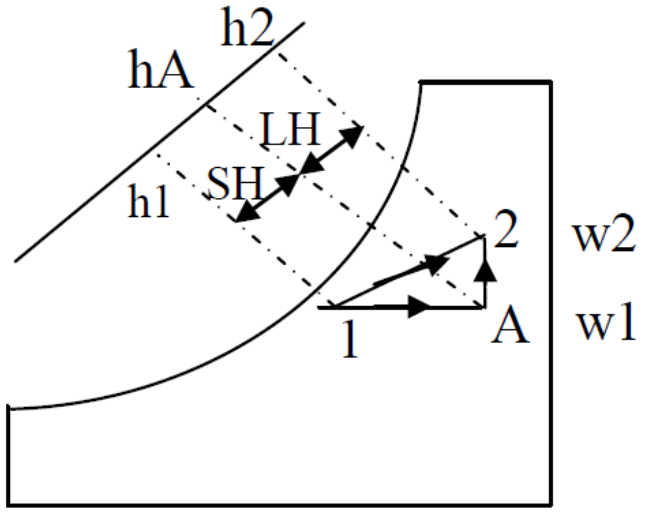
This process is generally required during the cold months of the year. An energy balance on the device yields

$$m_a h_1 + q + m_w h_w = m_a h_2$$

and a mass balance on the water gives

$$m_a W_1 + m_w = m_a W_2$$



Outdoor air enters an HVAC unit at 5°C $t_d$ and 40% Φ. It is first heated to 25°C $t_d$, and then humidified until its relative humidity reaches Φ =50%. The humidification process occurs at a constant dry bulb temperature of 25°C. Calculate:

1. The heat added (per kg of dry air).
2. The amount of moisture added (per kg of dry air).
3. The total heat added during the humidifying (latent heat only, per kg of dry air).

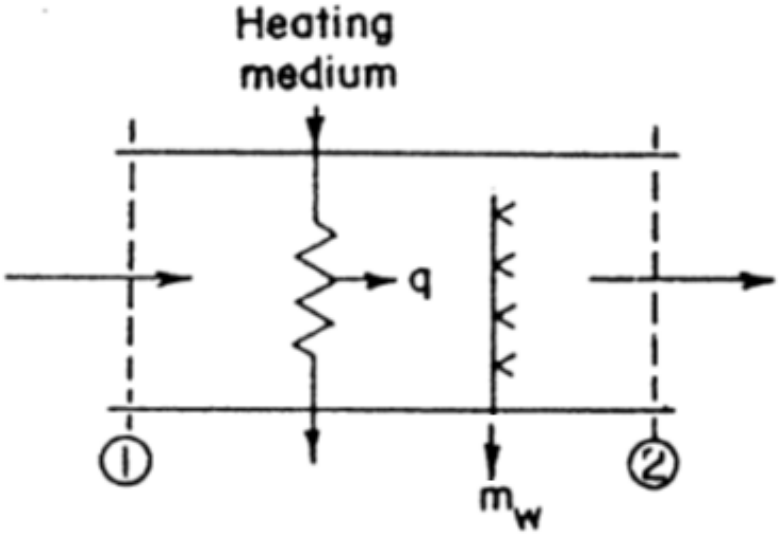
## Heating and Dehumidifying Air

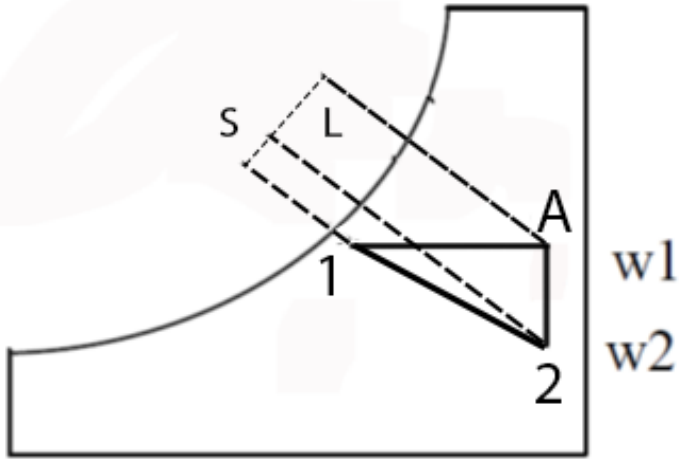
This process involves the removal of water vapor from the air, followed by heating the air to a desired temperature. An energy balance on the device yields

$$m_a h_1 + q - m_w h_w = m_a h_2$$

and a mass balance on the water gives

$$m_a W_1 - m_w = m_a W_2$$

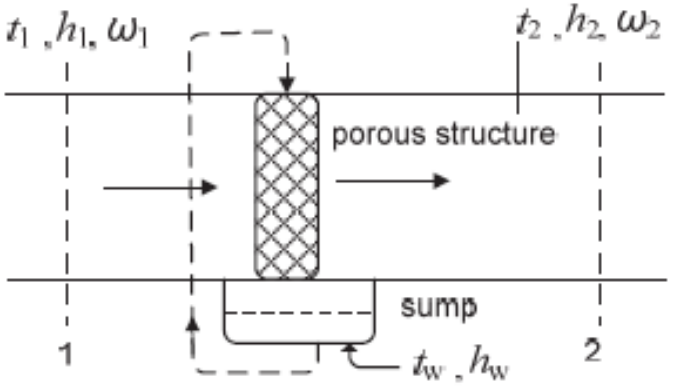


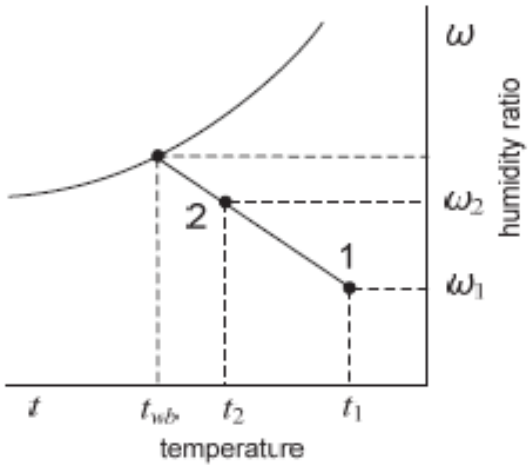



Humid air at $2m^3$/s enters a condition unit at 20°C $t_d$ and Φ= 90%. The air is processed to a final state of 25°C $t_d$ and Φ =50% . Determine: 1. the mass flow rate of dry air 2. the rate of moisture removed 3. the total rate of heat added to the air.

## Cooling and Humidifying (Evaporative cooling)

Evaporative cooling offers an effective and convenient method for cooling air in hot and dry climates. In practical evaporative coolers or air washers ambient air is passed through a porous structure, supplied with water from an external source




$$e_c = \frac{t_1 - t_2}{t_1 - t_{wb}}$$

Ambient air at 38°C $t_d$ and 20°C $t_w$ enters an evaporative cooler with 0.75 kg/s rate and a pressure of 95 Kpa. Air leaves at 25°C $t_d$ , calculate: 1. Relative humidity at inlet and exit 2. water flow rate in the cooler 3. Saturation effectiveness.

## Reference:

**- Principles of heating ventilating and air conditioning a textbook with design data based on the 2017 ASHRAE handbook fundamentals by Sauer, Harry J. Howell, Ronald Hunter Coad, William**

- **Prof. Dr. Mushtaq I. Hasan, 2020, Lectures of Ac and refrigeration, University of Thi-Qar.**
- **Nihal E Wijeysundera; 2015. Principles of heating ventilating and air conditioning- with worked examples**

*Thank you very much*