Class: 4th Stage
Subject: air conditioning systems lab
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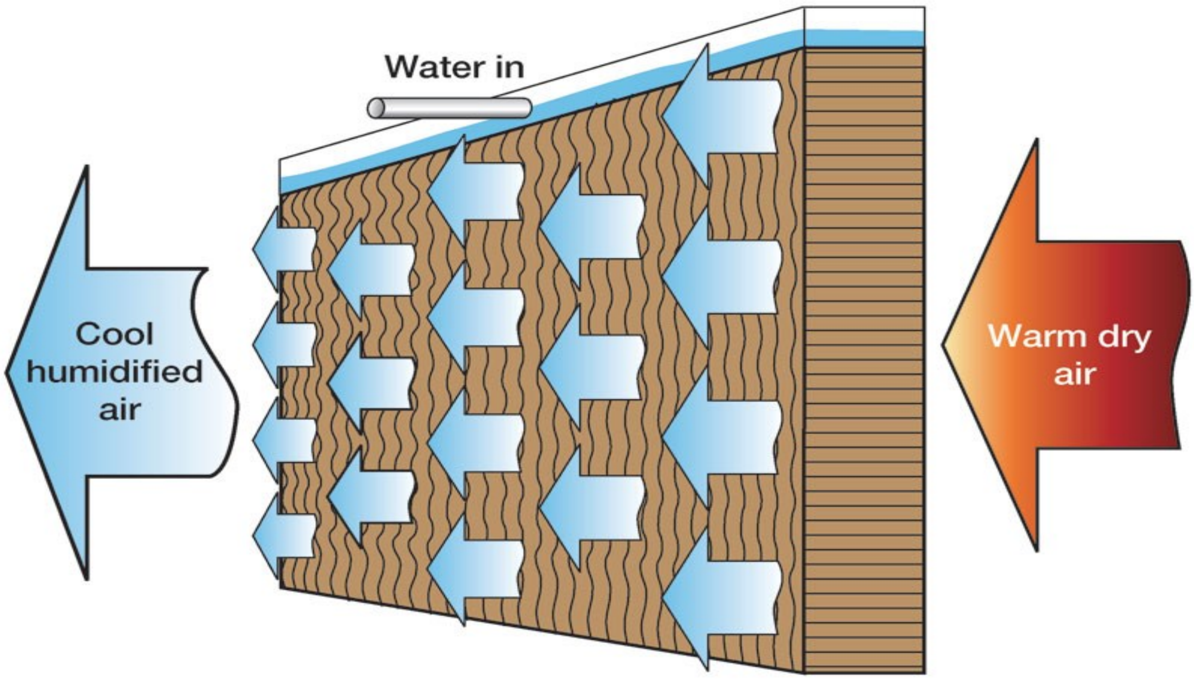
Cooling and humidification

What is Humidification Process?

The process in which the moisture or water vapor or humidity is added to the air without changing its dry bulb (DB) temperature is called as humidification process. This process is represented by a straight vertical line on the psychrometric chart starting from the initial value of relative humidity, extending upwards and ending at the final value of the relative humidity. In actual practice the pure humidification process is not possible, since the humidification is always accompanied by cooling or heating of the air. Humidification process along with cooling or heating is used in number of air conditioning applications. Let us see how these processes are obtained and how they are represented on the psychrometric chart.

Cooling and Humidification Process

Cooling and humidification process is one of the most commonly used air conditioning application for the cooling purposes. In this process the moisture is added to the air by passing it over the stream or spray of water which is at temperature lower than the dry bulb temperature of the air. When the ordinary air passes over the stream of water, the particles of water present within the stream tend to get evaporated by giving up the heat to the stream. The evaporated water is absorbed by the air so its moisture content, thus the humidity increases. At the same time, since the temperature of the absorbed moisture is less than the DB bulb temperature of the air, there is reduction in the overall temperature of the air. Since the heat is released in the stream or spray of water, its temperature increases.



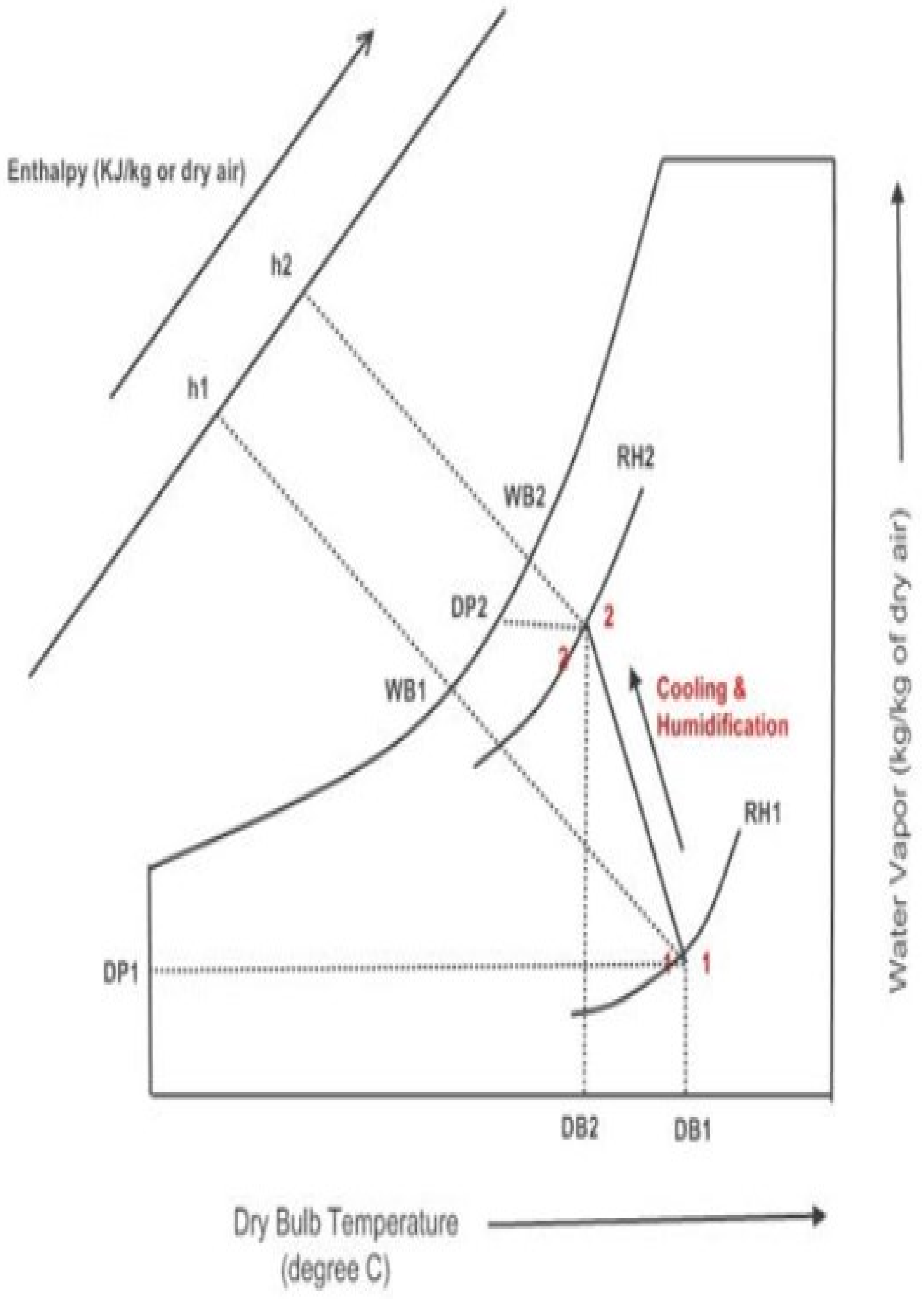
One of the most popular applications of cooling and humidification is the evaporative cooler, also called as the desert cooler. The evaporative cooler is the sort of big box inside which is a small water tank, small water pump and the fan. The water from the tank is circulated by the pump and is also sprayed inside the box. The fan blows strong currents of air over the water sprays, thus cooling the air and humidifying it simultaneously. The evaporative cooler is highly effective cooling devise having very low initial and running cost compared to the unitary air conditioners. For cooling purposes, the cooling and humidification process can be used only in dry and hot climates like desert areas, countries like India, China, Africa etc. This cooling process cannot be used in hot and high humidity climates.

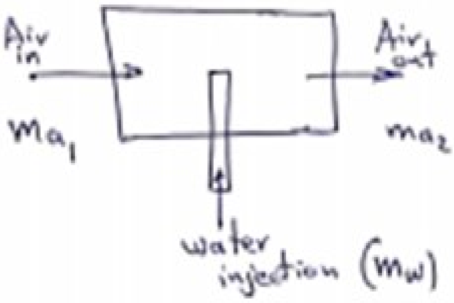
The cooling and humidification process is also used in various industries like textile, where certain level of temperature and moisture content has to be maintained. In such cases large quantity of water is sprayed, and large blowers are used to blow the air over the spray of water.

During the cooling and humidification process the dry bulb of the air reduces, its wet bulb and the dew point temperature increases, while its moisture content and thus the relative humidity also increases. Also, the sensible heat of the air reduces, while the latent heat of the air increases resulting in the overall increase in the enthalpy of the air.

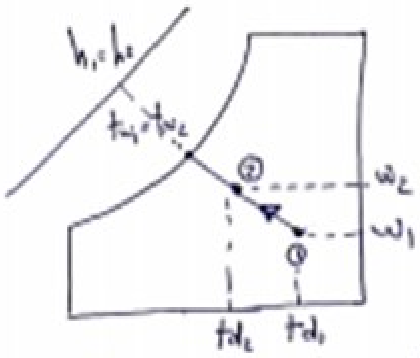
Cooling and humidification process is represented by an angular line on the psychrometric chart starting from the given value of the dry bulb temperature and the relative humidity and extending upwards toward left.

Represent cooling and humidification on psychrometric chart





Fig(2)-a- Psychrometric process



Fig(2)-b- Psychrometric chart

m_w → mass of water injection kg/s

m_a → mass of dry air kg/s

W_1 → moisture content of air enter kgv/kga

W_2 → 〃 〃 〃 〃 out kgv/kga

h → enthalpy of dry air kJ/kga

<u>Note</u>

1. $td_2 < td_1$
2. $w_2 > w_1$
3. $tw_1 = tw_2$
4. $h_1 = h_2$
5. $m_{a_1} = m_{a_2} = m_a$

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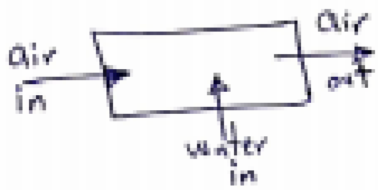
When anlaysize any system must apply 2-general equation

① mass Conservation equation
② energy Conservation equation



So, when apply these equation on Evaporative Cooling

① apply mass balance

$$\sum \text{mass in} = \frac{\partial m}{\partial t} + \sum \text{mass out}$$

$\frac{\partial m}{\partial t} = 0$ (for steady state)

خطأ شائع

$m_{a_1} + m_w = m_{a_2}$ note $(m_{a_1} = m_{a_2})$

$m_a + m_w = m_a$

- لا يمكن استخدام توازن وحفظ الكتلة لنوعين مختلفين اي الهواء وبخار الماء او الماء حيث ان

مختلفين ← [$m_a \to kg_a$, $m_w \to kg_w$]

لذلك لغرض عمل تطبيق لقانون حفظ الكتلة يجب ان يكون كل حد متشابه من حيث الوحدات لهذا سنطبق قانون حفظ الكتلة على المحتوى الرطوبي فيصبح القانون

$$\boxed{\sum \text{mass in} = \sum \text{mass out}}$$

$$\underbrace{W_1}_{\text{air in}} + \underbrace{W_w}_{\text{water in}} = \underbrace{W_2}_{\text{air out}} \quad \longrightarrow \text{OR} \quad \boxed{W_w = W_2 - W_1}$$

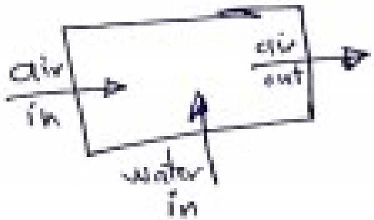
$$W_1 + \frac{m_w}{m_a} = W_2$$

② apply energy equation

عند تطبيق معادلة حفظ الطاقة على المنظومة يجب ان يكون الخواص متشابهة من حيث النوع والوحدات ولهذا يجب مراعاة الخواص المراد تطبيقها

$$\sum Energ\ in = \frac{\partial E}{\partial t} + \sum Energy\ out$$

$\frac{\partial E}{\partial t} \rightarrow 0$ (For steady state)



$$\sum Energy\ in = \sum Energy\ out$$

✗ $h_{a_1,in} + h_{water} = h_{a_1,out}$ ← لا يمكن ذلك لان الوحدات غير متجانسة

$h_a \rightarrow KJ/kg_a$

$h_w \rightarrow KJ/kg_w$

ولهذا يجب التجانس

$$\sum E_{in} = \sum E_{out}$$

$$h_w * W = \frac{KJ}{kg_w} \times \frac{m_w}{m_a} = \frac{KJ}{kg_a}$$

لهنا يصبح القانون ممكن تطبيقه

$$h_a + h_w * W_w = h_{a_2}$$

$W_w = W_2 - W_1$ ← راجع الورقة السابقة

$$h_{a_2} = h_{a_1} + (W_2 - W_1)\, h_w$$

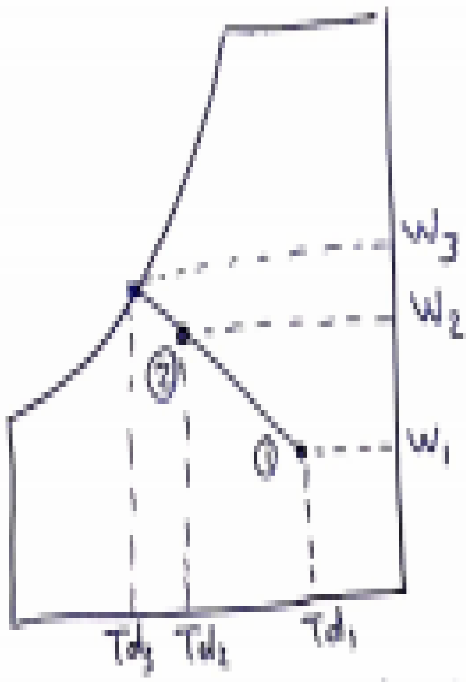
فيهذه العملية يمكن اهمال هذا الجزء وذلك لانه قيمة قليلة جداً مقارنة مع h_2 و h_1 لذلك هذه العملية تحدث بثبوت المحتوى الحراري $h_1 \cong h_2$

The effectiveness of evaporative Cooling

$$\eta_H = \frac{\text{Actual drop in DBT}}{\text{Ideal drop in DBT}}$$ ← humidifing efficiency

$$\eta_H = \frac{T_{d_1} - T_{d_2}}{T_{d_1} - T_w}$$

$$\eta_H = \frac{W_2 - W_1}{W_3 - W_1}$$



$$W_1 < W_2 < W_3$$

$$T_{d_1} > T_{d_2} > T_{d_3}$$

Cooling and Dehumidifying

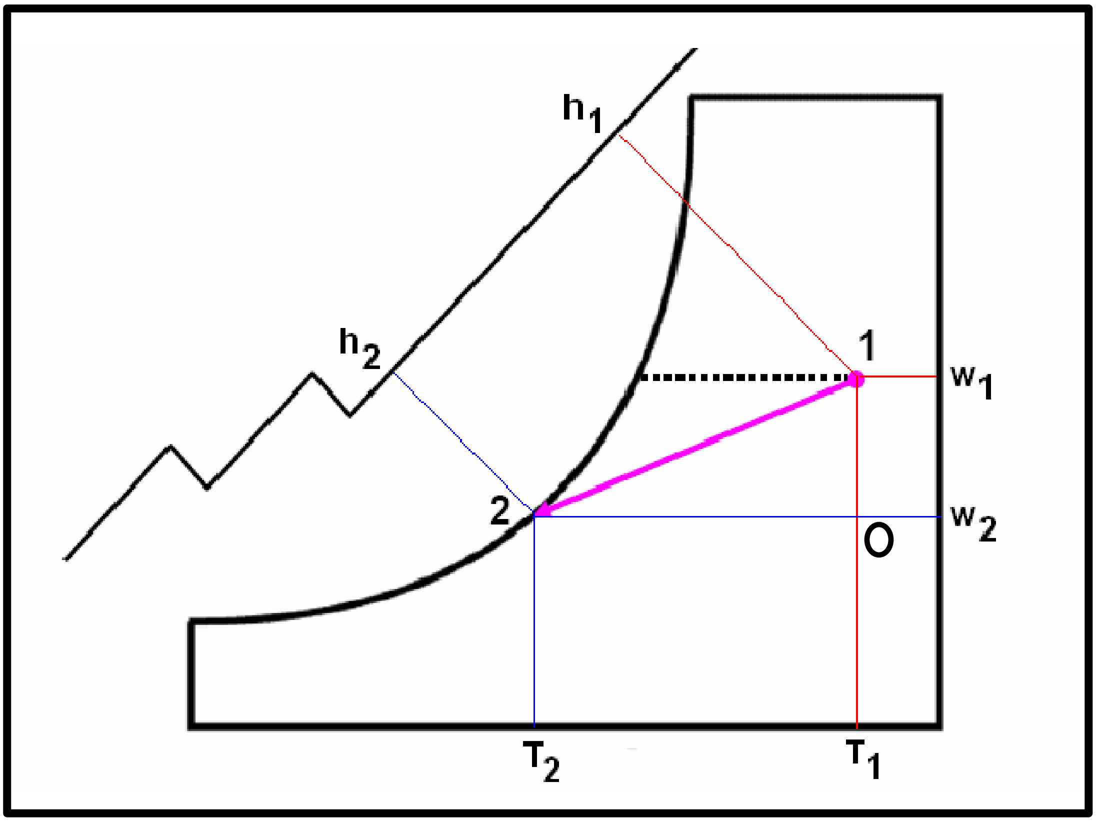
Objectives Examine the staining processes in practice for air cooling with dehumidification

Introduction

Cooling and dehumidifying is the process of lowering both the dry-bulb temperature and the humidity ratio of the moist air. If moist air comes in contact with a surface that is below the dew-point temperature of the air, moisture will condense on the surface and the air will be dehumidified i.e. becomes saturated (RH-100%). This process is used in air-conditioning systems operating in hot, humid climates. It is accomplished by using a cooling coil with a surface temperature below the dew-point temperature of water vapor in air. Typical cooling coils in air conditioning systems operate at approximately 40° - 50°F, below the dew-point temperature of typical indoor air conditions. The calculations are identical to those for heating and humidifying the only difference being that the initial state (state 1) is the warmer more humid state. As before, the total heat change (Q or q) in going from the initial to the final condition can be broken into a sensible and latent heat portion.

On psychrometric chart, this process is represented as line sloping downward and to the left. This process is assumed to occur as simple cooling first and then condensation. While the moisture is condensing the air is assumed to remain saturated.

The combined process of cooling and dehumidification is one of the most common methods of dehumidification used in the science of air conditioning. The reason is that this is by far the easiest or simplest way to remove moisture from the air.



Governing Equation for Heating and Humidification

If the condition of the air is changing from state 1 to state 2, consider that the intersection of a horizontal line through state 1 and a vertical line through state 2 occurs at state 0. Then the change in heat can be expressed as:

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$Q_s = m_a \times (h_o - h_1)\ \ OR\ q_s = (h_o - h_1)$ ………………………….(1)

$Q_l = m_a \times (h_2 - h_o)\ \ OR\ q_s = (h_2 - h_o)$ …………………………..(2)

$Q_T = m_a \times (h_2 - h_1)\ \ OR\ Q_T = (Q_s + Q_L)$ …………………………..(3)

Where:

- Q_s = sensible heat added.
- Q_L= latent heat added.
- Q_T= Total heat added.
- m_a = Mass of dry air, [= (volume of air)/(specific volume of moist air]
- h = Enthalpy of dry air.

The rate of moisture addition to the air, Mw, is determined by a water vapor mass balance:

$M_w = m_a \times (W_1 - W_2)$ ……………………………………….(4)

Where:

- W_2 = humidity ratio of the moist air upstream of the humidifier.
- W_0 = humidity ratio of the moist air downstream of the humidifier.

Example

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Observable characteristics of a cooling and dehumidifying process are:

1. Dry bulb temperature decreases

2. humidity ratio decreases

3. vapor pressure decreases

4. dew point temperature decreases

5. wet bulb temperature decreases

6. enthalpy decreases (there is a decrease in the energy level and with the loss of energy, condensation occurs)

7. relative humidity increases

This process is used in air-conditioning systems operating in hot, humid climates. Typical cooling and dehumidifying process include chilled water and refrigerant cooling coils which condition re-circulated room air or mixtures of re-circulated air and outdoor air which is introduced for ventilation. The cooling coil shall have a surface temperature below the dewpoint temperature of water vapor in air for effective condensation.