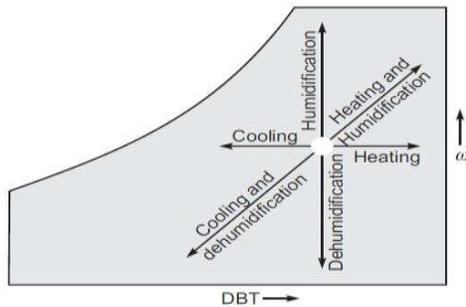


PSYCHROMETRIC PROCESSES (OR AIR-CONDITIONING PROCESS)



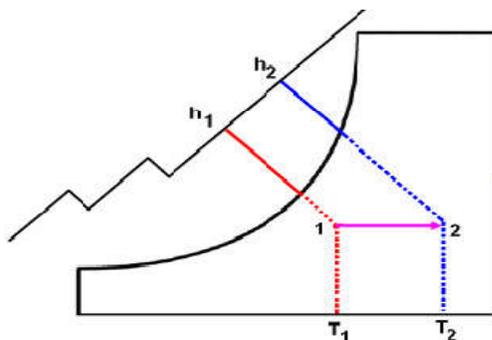
Basic air-conditioning processes

1. Sensible heating and cooling
2. Humidification and dehumidification
3. Humidification with heating/cooling
4. Dehumidification with heating/cooling
5. Mixing of two air streams

Sensible heating

The heating of air, without any change in its specific humidity, is known as sensible heating. For sensible heating, steam or hot water is passed through the heating coil. The heating coil may be electric resistance coil.

The sensible heating of moist air can be done to any desired temperature.



Sensible Heating

- The DBT increases
- The RH decreases
- The enthalpy increases
- The WBT increases
- The specific volume increases
- The humidity ratio, vapor pressure and DPT remain constant

Analysis of SH:

Let air at temperature t_{d1} , passes over a heating coil of temperature t_{d3} , as shown in Fig.

The point 3 represents the surface temperature of the heating coil.

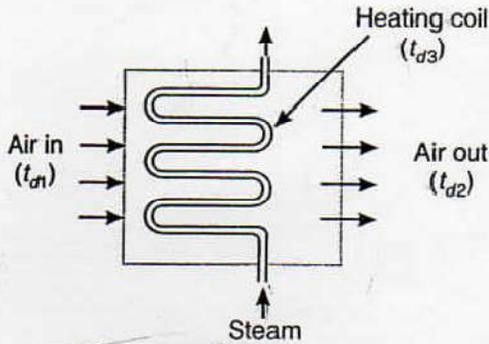
The heat absorbed by the air during sensible heating may be obtained from the psychrometric chart by the enthalpy difference ($h_2 - h_1$).

Heat added,

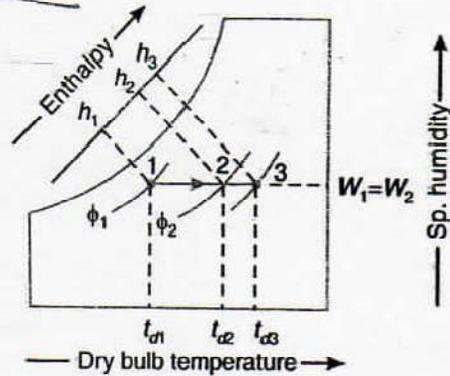
$$\begin{aligned}
 q &= h_2 - h_1 \\
 &= c_{pa} (t_{d2} - t_{d1}) + W c_{ps} (t_{d2} - t_{d1}) \\
 &= (c_{pa} + W c_{ps}) (t_{d2} - t_{d1}) = c_{pm} (t_{d2} - t_{d1})
 \end{aligned}$$

The term $(c_{pa} + W c_{ps})$ is called *humid specific heat* (c_{pm}) and its value is taken as 1.022 kJ/kg K.

\therefore Heat added, $q = 1.022 (t_{d2} - t_{d1})$ kJ/kg



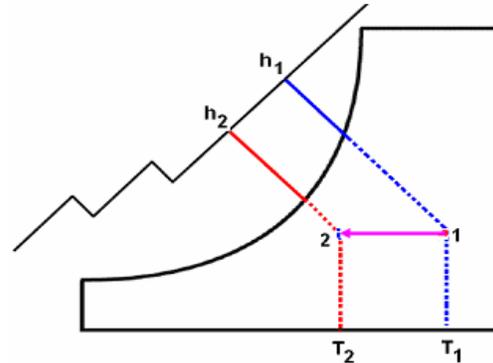
(a) Psychrometric process.



(b) Psychrometric chart.

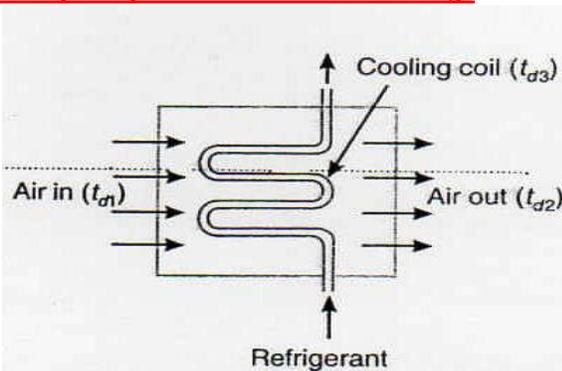
Sensible cooling: Cooling of air without changing specific humidity.

- The dry bulb temperature decreases
- The relative humidity increases
- The enthalpy decreases
- The wet bulb temperature decreases
- The specific volume decreases
- The humidity ratio, vapor pressure and dew point remains constant

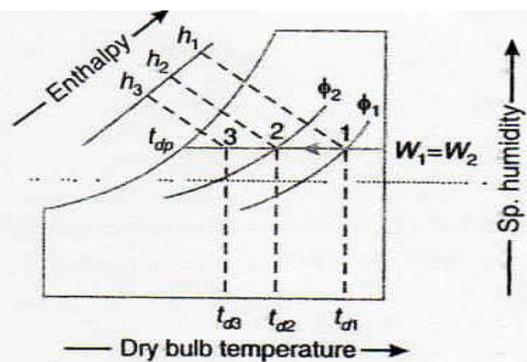


Sensible Cooling

Analysis of Heat in Sensible Cooling:



(a) Psychrometric process.



(b) Psychrometric chart.

Let air at temperature t_{d1} , passes over a cooling coil of temperature t_{d3} as shown in Fig.

Heat rejected,

$$q = h_1 - h_2$$

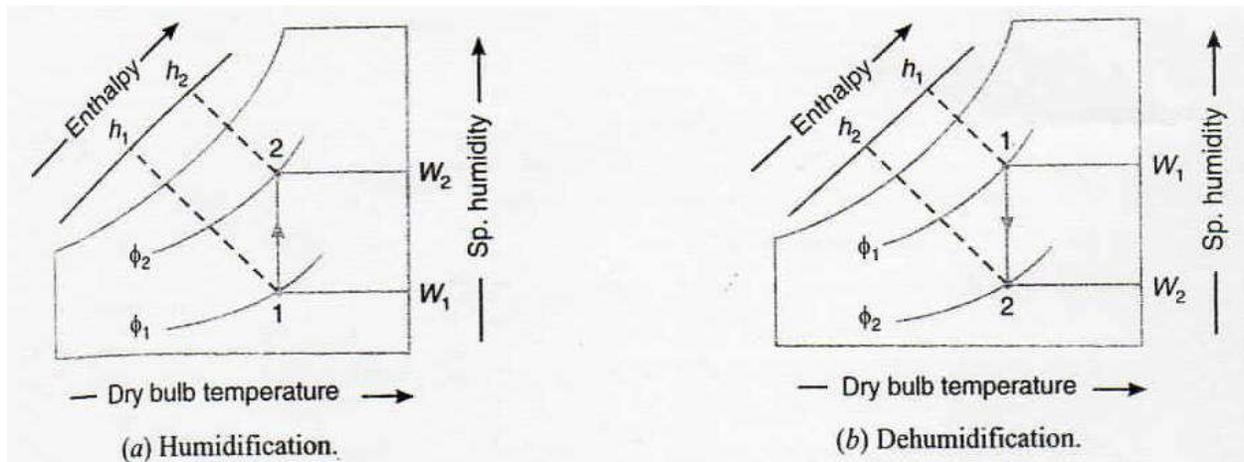
$$= C_{pa}(t_{d1} - t_{d2}) + W C_{ps}(t_{d1} - t_{d2})$$

$$= (C_{pa} + W C_{ps})(t_{d1} - t_{d2}) = C_{pm}(t_{d1} - t_{d2})$$

The term $(C_{pa} + W C_{ps})$ is called humid specific heat (C_{pm}) and its value is taken as 1.022 kJ/kg K.

$$\therefore \text{Heat rejected, } q = 1.022 (t_{d1} - t_{d2}) \text{ kJ/kg}$$

Humidification and Dehumidification:



- The addition of moisture to the air, without change in its dry bulb temperature, is known as *humidification* [process (1 – 2)].
- Removal of moisture from the air, without change in its dry bulb temperature, is known as *dehumidification* [process (1 – 2)].

<p>For Humidification:</p> <ul style="list-style-type: none"> ➤ The dry bulb temperature Constant, ➤ The relative humidity increases, ➤ The enthalpy increases ➤ The wet bulb temperature increases ➤ The humidity ratio & dew point increases 	<p>Dehumidification:</p> <ul style="list-style-type: none"> ➤ The dry bulb temperature Constant, ➤ The relative humidity decreases, ➤ The enthalpy decreases ➤ The wet bulb temperature decreases ➤ The humidity ratio & dew point decreases
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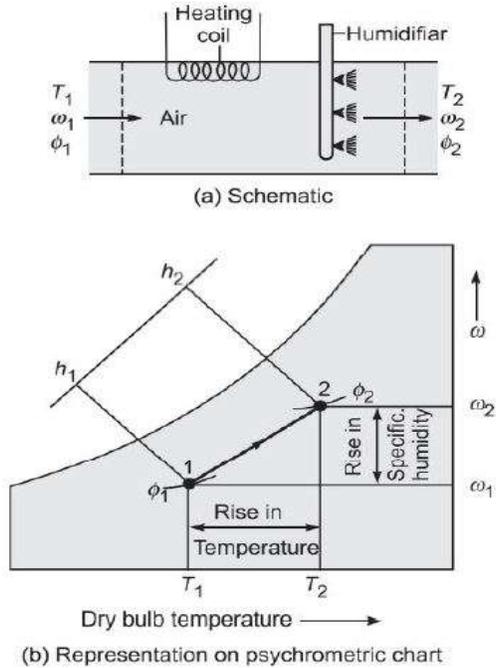
Note:

Actually, there is no method by which one can obtain simply humidification or dehumidification of air. These processes are accomplished by either simultaneous heating or cooling.

Heating and Humidification:

This process is generally used in winter air-conditioning. It involves warming and humidifying of air simultaneously. In this process, the air passes through a humidifier where the hot water (or steam) is injected, both the humidity ratio and dry-bulb temperature increase. The process of heating and humidification is shown by the line 1–2 on the psychrometric chart in Fig.

- DBT ↑
- WBT ↑
- Enthalpy ↑
- Specific humidity ↑
- DPT ↑
- ϕ ↑↔→



Heating with humidification

Cooling And humidification: Or Evaporative cooling:

Cooling and humidification, simultaneously can be accomplished by evaporative cooling. It involves either spraying of liquid water into air or forcing the air through a soaked pad that is kept saturated with water as in desert coolers, also known as evaporative coolers. A schematic of an evaporative cooler is shown in Fig.

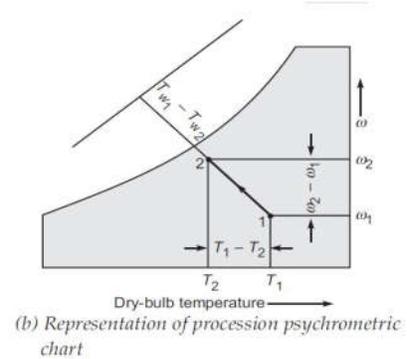
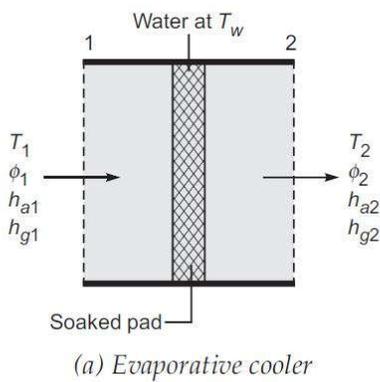


Fig. Cooling and humidification process

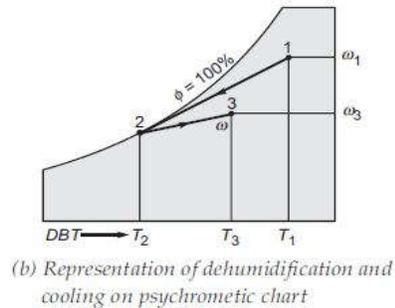
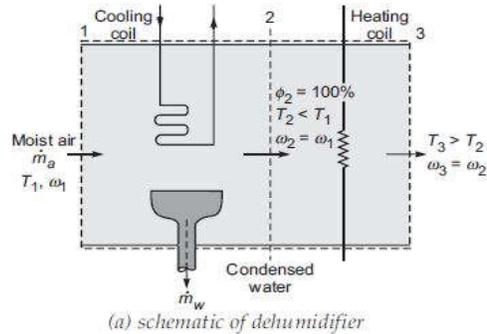
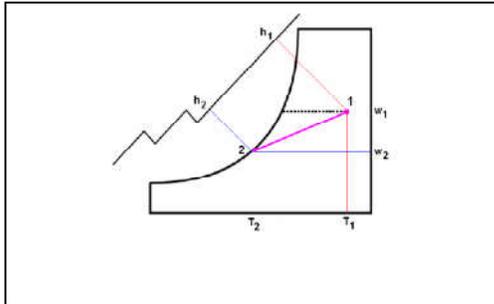
- DBT ↓
- WBT ↑↔→
- Enthalpy ↑
- Specific humidity ↑↔→
- DPT ↓
- ϕ ↑

The evaporative cooling (humidification and cooling) takes place in cooling towers, evaporative Condensers and desert coolers.

Dehumidification and Cooling (Summer A/C):

When a moist air stream is cooled at constant pressure to a temperature below its dew point Temperature, some of the water vapour initially present would condense. Fig. shows the Schematic of a dehumidifier and cooling process on psychrometric chart.

- DBT ↓
- WBT ↓
- Enthalpy ↓
- Specific humidity ↓
- DPT ↓
- ϕ ↑ ↓ →

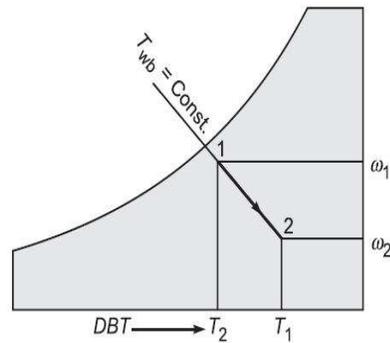


The moist air enters the state 1, flows across a cooling coil, some of the water vapour initially present in the moist air condenses and a saturated moist air mixture leaves the dehumidifier section at the state 2. Since the moist air leaving the cooling coil is saturated at temperature below the temperature of the moist air entering, the moist air stream might be unsuitable for direct use in occupied space. Thus this stream passes the heating section and is brought to the comfort condition at the state 3.

Heating and dehumidification:

It is based on the principle of adsorption, i.e., capillary action. Thermodynamically, an adsorption process is the nerve of the adiabatic saturation process. In this process, the air is passed over the adsorbing surface (chemicals are silica gel, activated alumina, etc. which have affinity for moisture). As the water vapour comes in contact of these substances, the moisture gets condensed out of air and gives up its latent heat, resulting into rise in temperature of air. The dehumidification and heating process is shown in Fig.

- DBT ↑
- WBT ↓ ↑ →
- Enthalpy ↓ ↑ →
- Specific humidity ↓
- DPT ↓
- ϕ ↓



Adsorption dehumidification process

Adiabatic mixing of two moist Air:

It is a common practice in air conditioning that the fresh and recirculated moist air streams are mixed as shown in Fig. 15.28. During such mixing, normally no heat is transferred to the surroundings, and thus mixing is almost adiabatic.

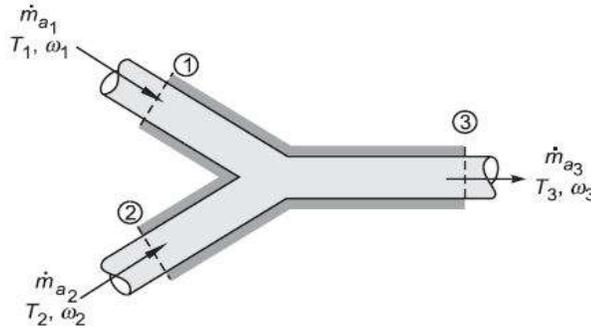


Fig. Adiabatic mixing of two streams of moist air

Applying mass and energy balance on the control volume:

Mass balance

$$\dot{m}_{a_1} + \dot{m}_{a_2} = \dot{m}_{a_3} \text{ (dry air)}$$

$$\dot{m}_{v_1} + \dot{m}_{v_2} = \dot{m}_{v_3} \text{ (water vapour)}$$

Using $\dot{m}_v = \omega \dot{m}_a$, we get

$$\omega_1 \dot{m}_{a_1} + \omega_2 \dot{m}_{a_2} = \omega_3 \dot{m}_{a_3} \text{ (water vapour)}$$

$$\text{or } \omega_3 = \frac{\omega_1 \dot{m}_{a_1} + \omega_2 \dot{m}_{a_2}}{\dot{m}_{a_3}} = \frac{\omega_1 \dot{m}_{a_1} + \omega_2 \dot{m}_{a_2}}{\dot{m}_{a_1} + \dot{m}_{a_2}}$$

Energy balance

$$\dot{m}_{a_1} h_1 + \dot{m}_{a_2} h_2 = \dot{m}_{a_3} h_3$$

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

where $h = h_a + \omega h_g$; the specific enthalpy of entering and exiting water vapour are evaluated at saturated vapour values at the respective dry-bulb temperatures.