Psychrometric Processes

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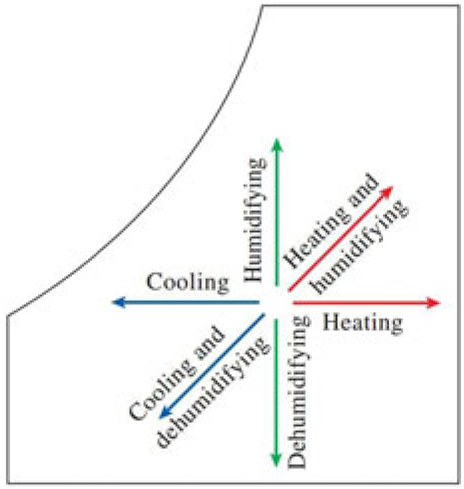
In this lecture...

- Air Conditioning Processes
  - Temperature Control
    - Sensible Heating and Sensible Cooling
  - Mixing of Airstreams
  - Humidity Control
    - Adiabatic saturation
    - Steam injection
    - Air washer
    - Cooling and dehumidifying coil
- Multi-Step Processes
- Practical Air Treatment Cycles

Air conditioning processes

- Air conditioning processes are most commonly used to achieve a more comfortable interior environment. This is done by controlling the temperature and humidity of the interior space and ensuring adequate amount of fresh air in the space.
- Temperature Control: Sensible Heating, Sensible Cooling
- Humidity Control: Adiabatic saturation, steam injection, air washer, cooling and dehumidifying coil
- Fresh air: Adiabatic Mixing of airstreams



ME340A: Refrigeration and Air Conditioning
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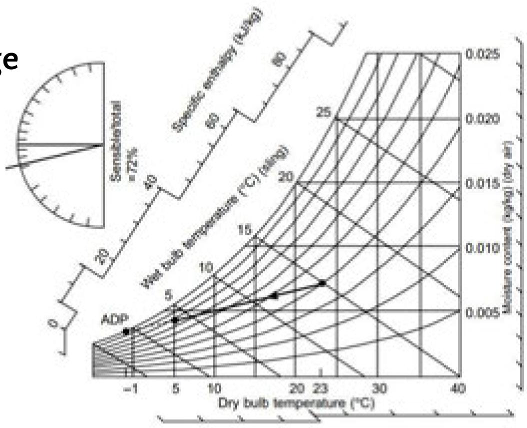
Sensible Heat-Latent Heat Ratio

- Sensible–latent ratio: The horizontal component of the process line is the change of sensible heat, and the vertical component gives the latent heat. It follows that the slope of the line shows the ratio between them.
- On the psychrometric chart the ratio of sensible to total heat is indicated as angles in a segment to one side of the chart. This can be used as a guide to coil and plant selection.
- Sensible Heat factor = SE/(SE+LE)



1 Temperature Control

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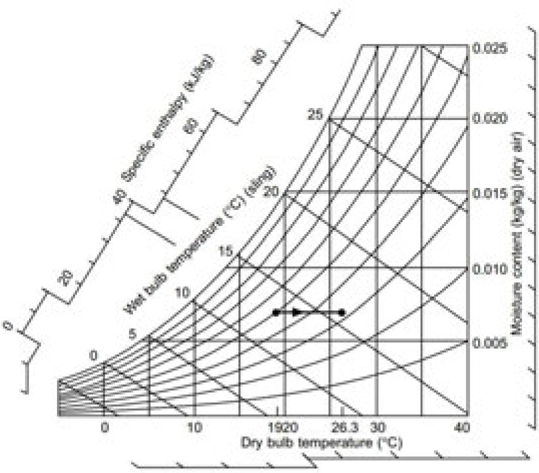
Sensible Heating of Air

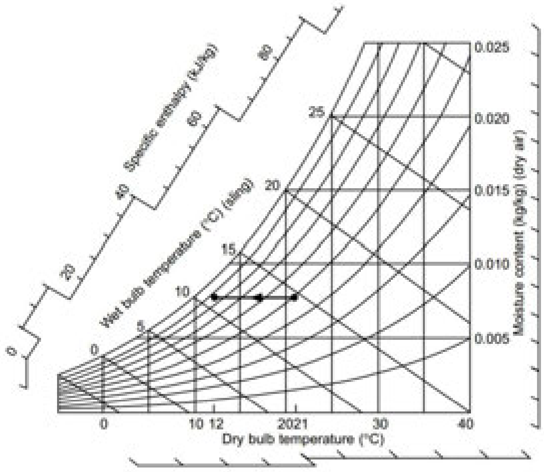
- DBT increases, moisture content remains constant
- Note that RH of air decreases, which may cause dry skin, respiratory difficulties, and an increase in static electricity
- Heating can be achieved by:
  - Hot water or steam coils
  - Direct-fired – gas and sometimes oil
  - Electric resistance elements
  - Refrigerant condenser coils of heat pump or heat reclaim systems



Sensible Heating

Sensible Cooling of Air

- DBT decreases, moisture content remains constant
- Note that RH of air increases
- Cooling can be achieved by passing the air over some coils through which a refrigerant or chilled water flows.



Sensible Cooling

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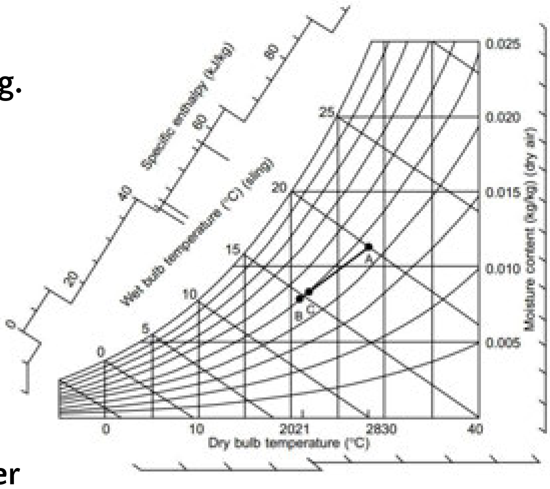
2 Mixing of Airstreams

Adiabatic mixing of airstreams

- Many air-conditioning applications require the mixing of two airstreams. E.g. Air conditioning in hospitals, large buildings etc. require that the conditioned air be mixed with a certain fraction of fresh outside air
- The heat transfer with the surroundings is usually small, and thus the mixing processes can be assumed to be adiabatic.
- Sensible heat before = sensible heat after
- Latent heat before = latent heat after



Adiabatic mixing of airstreams

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Adiabatic mixing of airstreams

- Mass and energy balances for the adiabatic mixing of two airstreams give:

Mass of dry air: $\dot{m}_{a_1} + \dot{m}_{a_2} = \dot{m}_{a_3}$

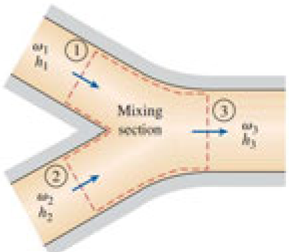
Mass of water vapor: $\omega_1 \dot{m}_{a_1} + \omega_2 \dot{m}_{a_2} = \omega_3 \dot{m}_{a_3}$

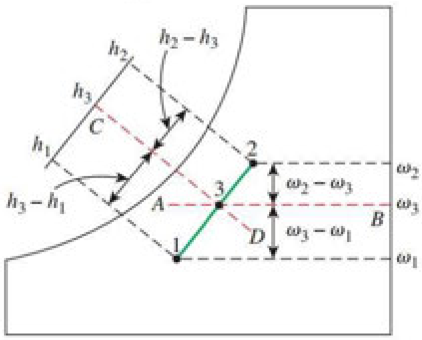
Energy: $\dot{m}_{a_1} h_1 + \dot{m}_{a_2} h_2 = \dot{m}_{a_3} h_3$

- Eliminating $\dot{m}_{a3}$, we get:

$$\frac{\dot{m}_{a_1}}{\dot{m}_{a_2}} = \frac{\omega_2 - \omega_3}{\omega_3 - \omega_1} = \frac{h_2 - h_3}{h_3 - h_1}$$

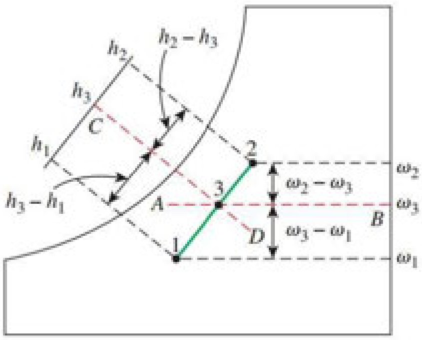
- Geometric Interpretation:





Adiabatic mixing of airstreams

- So, when two airstreams at two different states (states 1 and 2) are mixed adiabatically, the state of the mixture (state 3) lies on the straight line connecting states 1 and 2 on the psychrometric chart, and the ratio of the distances 2-3 and 3-1 is equal to the ratio of mass flow rates $\dot{m}_{a1}$ and $\dot{m}_{a2}$
- Note that when states 1 and 2 are located close to the saturation curve, the straight line connecting the two states will cross the saturation curve, and state 3 may lie to the left of the saturation curve. In this case, some water will inevitably condense during the mixing process.



Adiabatic mixing of airstreams

3 Humidity control

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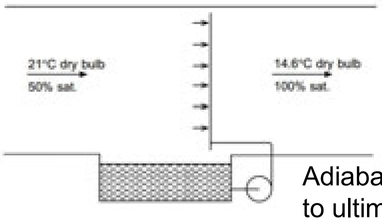
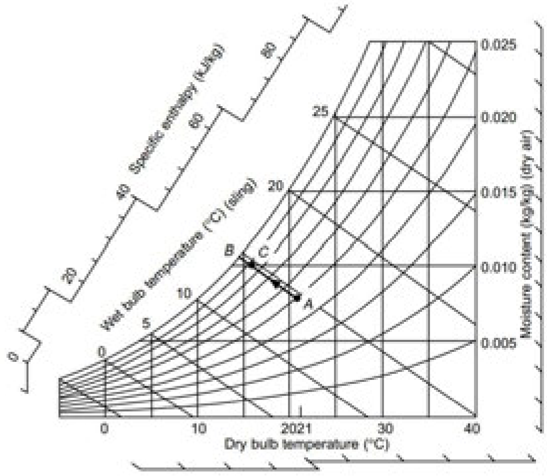
Adiabatic Saturation (Water Spray)

- When water is sprayed into an airstream that is not already saturated, evaporation will take place and water will take its latent heat from air
- DBT decreases, moisture content increases



Adiabatic Saturation to ultimate condition



Adiabatic Saturation

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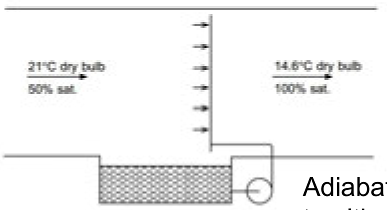
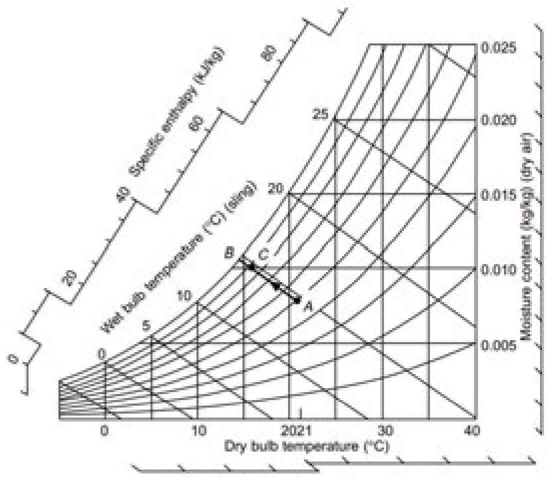
Adiabatic Saturation (Water Spray)

- Note that 100% saturation (point B) is difficult to achieve practically
- Final condition in a practical process may be resembled by point C
- So, effectiveness of spray system is equal to the proportion AC/AB



Adiabatic Saturation to ultimate condition



Adiabatic Saturation

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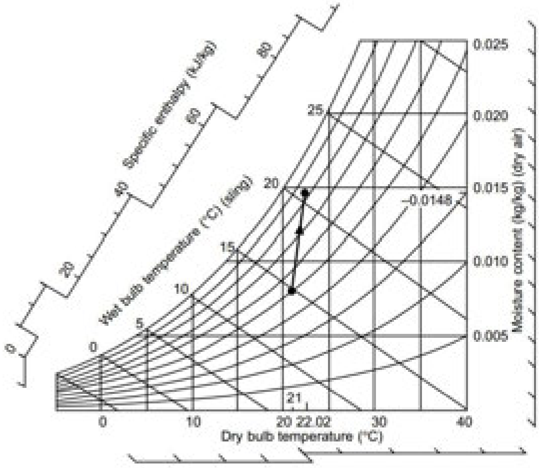
Steam Injection

- Moisture can also be added to air by injecting steam. This will not need the latent heat from air, which otherwise would have decreased DBT
- However, DBT will increase slightly because of air mixing with high temperature steam



Steam Injection

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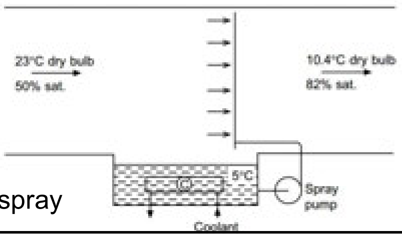
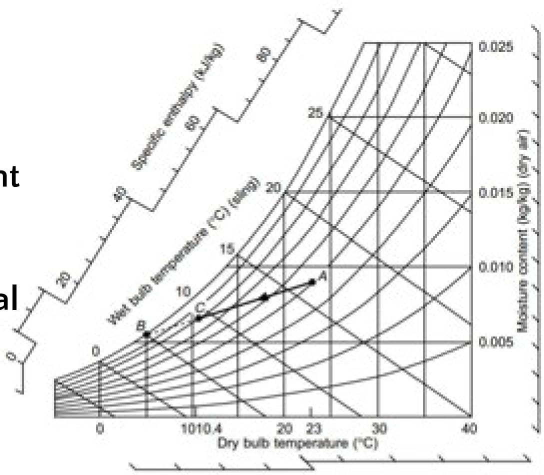
Air washer with chilled water

- If a large mass of water is used in comparison with the mass of air, the final condition will approach the water temp.
- If this water is chilled below the dew point of the air, air moisture will condense, and air will leave the washer with a lower moisture content but higher RH than initial value.



Chilled water spray



Air washer with chilled water

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Cooling and dehumidifying coil

- If the air is brought into contact with a solid surface, maintained at a temperature below its dew point, sensible heat will be transferred to the surface by convection and condensation of water vapour will take place at the same time.
- Both the sensible and latent heats must be conducted through the solid and removed. The simplest form is a metal tube, and the heat is carried away by refrigerant or a chilled fluid within the pipes.
- The tube temperature will be the ultimate dew point of an infinite sized coil and is thus called Apparatus Dew Point (ADP).

4 Multi-Step processes

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Multi-step processes

- Some air treatment processes cannot be made in a single operation, and the air must pass through two or more consecutive steps to obtain the required leaving condition.
- Some examples of multi step processes are given in upcoming slides

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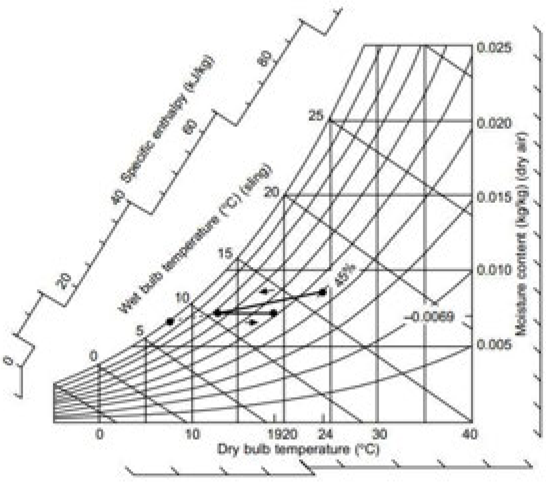
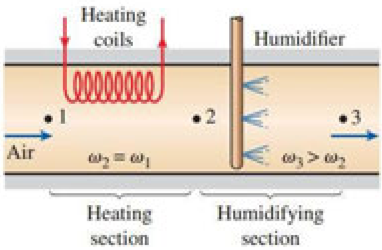
Cooling with Dehumidification followed by Reheating

- If air is to be cooled and dehumidified, it may be found that the process line joining the inlet and outlet conditions does not meet the saturation line, e.g. in cooling air from 24°C dry bulb, 45% saturation, to 19°C dry bulb, 50% saturation, the process line shows this to be impossible in one step.
- The air must first be cooled and dehumidified to reach the right moisture level of 0.0069 kg/kg and then re-heated to get it back to 19°C



Heating with Humidification

- Sensible heating decreases RH. This can be eliminated by humidifying the heated air. This is accomplished by passing the air first through a heating section (process 1-2) and then through a humidifying section (process 2-3)
- The properties of air at state 3 depend on how the humidification is accomplished – steam injection/adiabatic spraying. So, the heating (excess or lower) should be done accordingly in the heating section



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5 Practical Air Treatment cycles

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Heating

- The majority of air-conditioned buildings are offices or are used for similar indoor activities, and are occupied intermittently. The heating system must bring them up to comfortable working conditions by the time work is due to start, so the heating must come into operation earlier to warm up the building.
- A large part of the heating load when operating in daytime will be for fresh or outside air, which is not needed before occupation, and the heat-up time will be reduced if the fresh air supply can remain inoperative for this time. The required warm-up time will vary with ambient conditions, being longer in cold weather and least in warm. This is done using Optimum-start controllers which set the heating plant going only when needed.

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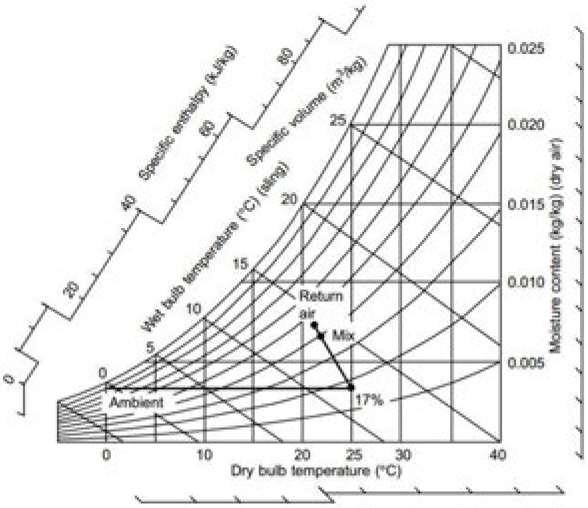
Heating

- Example: With a winter ambient of 0°C dry bulb, 90% saturation, outside air pre-heated to 25°C will then be 17% saturation, which could itself cause discomfort.
- However, this is diluted with the return air, and it is unlikely that indoor humidity will fall below 35% saturation.



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Outside air proportion

- The high internal heat load of many modern buildings means that comfort cooling may be needed even when the ambient is down to 10°C or lower.
- Under these conditions, a high proportion of outside air can remove building heat and save refrigeration energy. This presupposes that:
  1. The fresh air ducting and fan can provide more air.
  2. This outside air can be filtered.
  3. There are adequate automatic controls to admit this extra air only when wanted.
  4. Surplus air in the building can be extracted.

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Cooling with dehumidification

- The cooling load will always be greatest in the early afternoon, so no extra start-up capacity is required.
- The general practice of using a single coil for cooling and dehumidification without reheat, for comfort cooling, will give design balance conditions only at full load conditions.
- Slightly different conditions must be accepted at other times. Closer control can be obtained by variation of the coolant temperature and air mass flow over the coil, but such systems can be thrown out of calibration, and measures should be taken to avoid unauthorized persons changing the control settings or energy will be wasted with no benefit in the final conditions.

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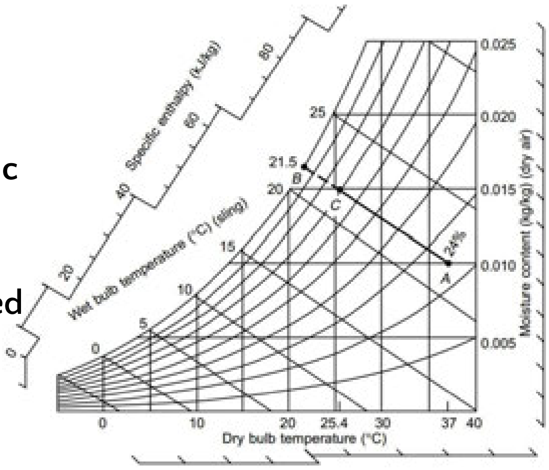
Evaporative Cooling

Desert Coolers

- Many of the warmer climates have a dry atmosphere. In such areas, considerable DBT reduction can be gained by adiabatic saturation (discussed previously).
- The apparatus draws air over a wetted pad and discharges it into the conditioned space. It is termed an evaporative or desert cooler. There is no refrigeration involved



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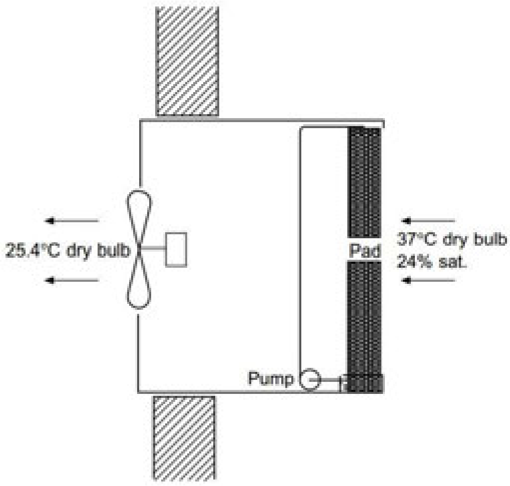
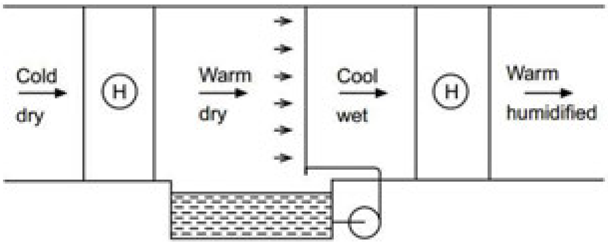
Desert Coolers



Addition of moisture

- Methods of adding moisture to the airstream discussed previously are difficult to control, since a lot of water remains in the apparatus at the moment of switching off humidification. For this reason, the heat–humidify–re-heat cycle is preferred, as the final heater control can compensate for overshoot.



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Thanks!

Any questions ?

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