Heating, Ventilation & Air-Conditioning in Hospitals

Part 7 - Psychrometrics

Prof RN Basu

Psychrometrics

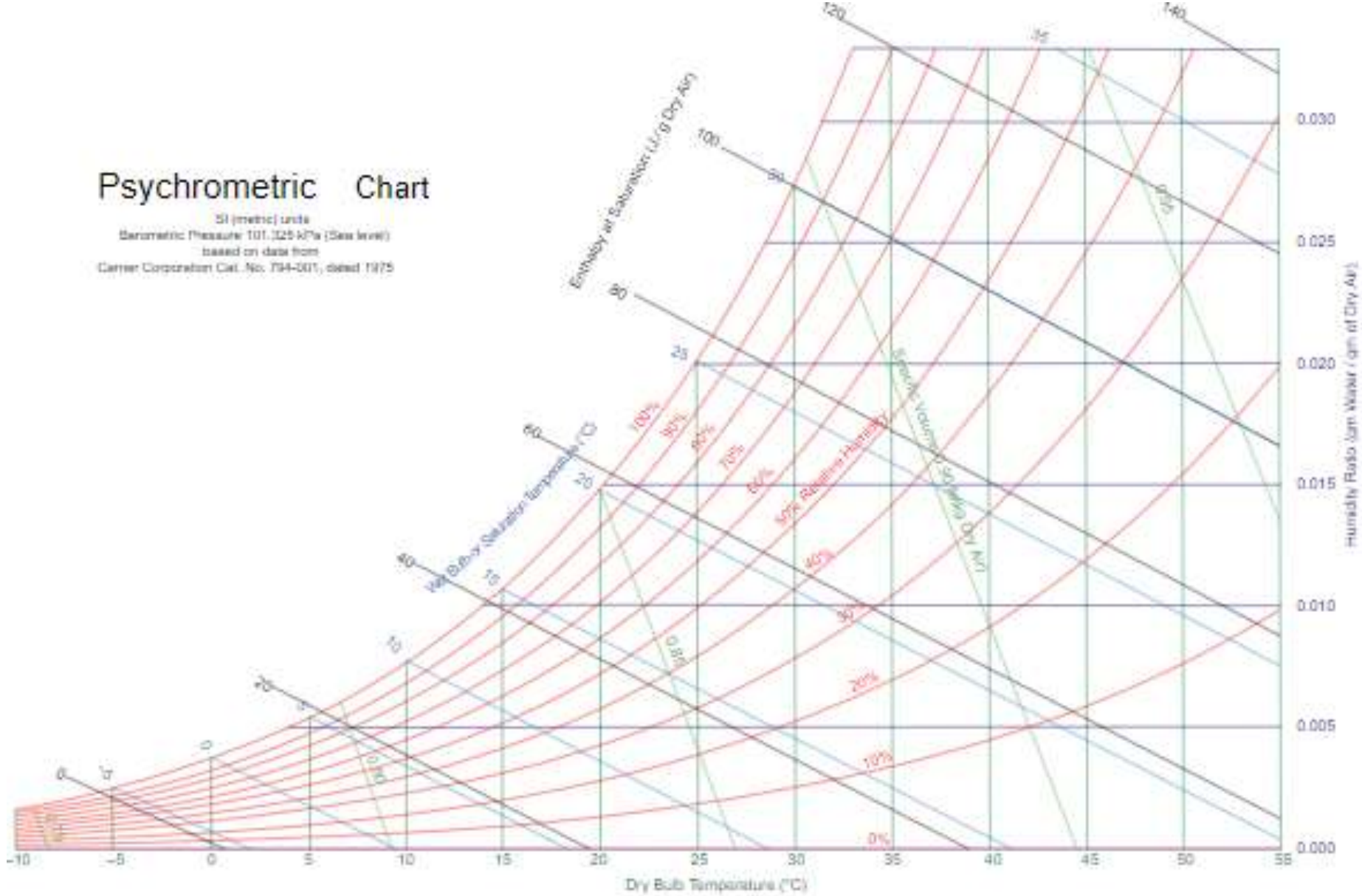
- Psycrometric chart looks very complex and intimidating for non-engineers[28]
- There are straight vertical lines, horizontal lines, oblique lines and curved lines
- The lines represent seven parameters of moist air
  - Knowledge of school physics is good enough to understand these basic properties
- If two parameters are known, other parameters can be derived from the chart

Psychrometrics

- Psychrometrics
  - This is a tool HVAC designers use to determine the
    - amount of moisture in the air and
    - to provide solutions to designers for
    - the ultimate comfort of building occupants.

Psychrometrics

- It can be used to
  - size air handling units;
  - optimize energy performance;
  - identify control sensors for building automation;
  - describe the performance of
    - cooling coils,
    - cooling towers, and humidification equipment; and
    - evaluate heat recovery strategies.



Source: https://en.wikipedia.org/wiki/File:PsychrometricChart.SeaLevel.SI.svg

Psychrometrics

- Air always contains some amount of moisture
- The four basic process of HVAC systems are:
  - Cooling – lowering air temperature
  - Heating – raising the air temperature
  - Humidification – raising the moisture content of air
  - Dehumidification – lowering the moisture content of air
- HVAC processes can be a combination of these four basic actions done at the same time

Psychrometrics

- The HVAC process can also be a combination of these four factors
- The combinations can be:
  - Heating and humidification
    - increasing the temperature and moisture content
  - Heating and dehumidification
    - Increasing the temperature and decreasing the moisture content of the air
  - Cooling and humidification
    - Decreasing the temperature and increasing the moisture content
  - Cooling and dehumidification
    - Decreasing the temperature and moisture content

Psychrometrics

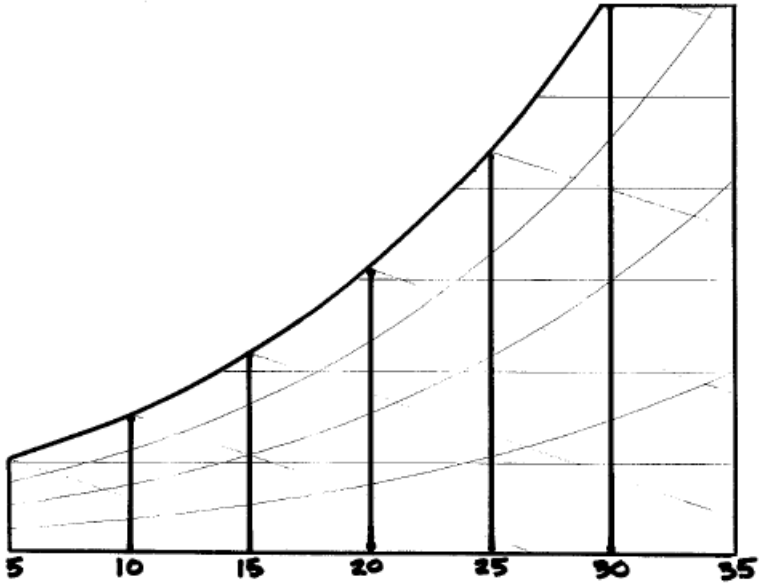
- Definition of the properties of most air drawn on the chart[29]
  - Dry-bulb temperature
    - *It* is the temperature of air measured by an ordinary thermometer
    - It is drawn as vertical lines on the horizontal axis (X-axis)
  - Wet-bulb temperature
    - It is the lowest dry-bulb temperature attained by evaporative cooling
    - The temperature indicated by an ordinary thermometer having its bulb covered by a wet muslin cloth
    - These are drawn as inclined (25^0 to 30^0) lines from x-axis

Psychrometrics

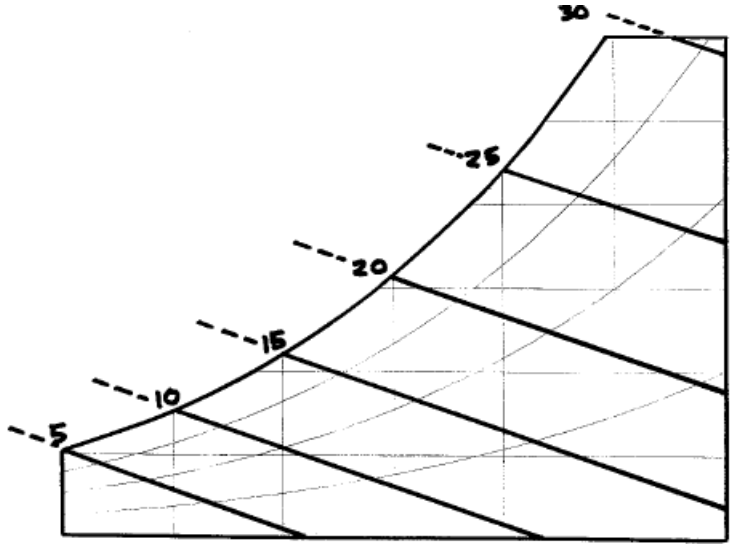
- Dew-point Temperature
  - The surface temperature at which water vapour in the air begins to condense
  - These are horizontal lines extending from the saturation (100% RH) curve on the left to the right-hand boundary of the chart.
  - Horizontal dew-point temperature lines and *water vapour* pressure lines are usually not plotted on the psychrometric chart
    - Because they are parallel to the humidity ratio lines and would add clutter, making the chart difficult to read.

Psychrometrics

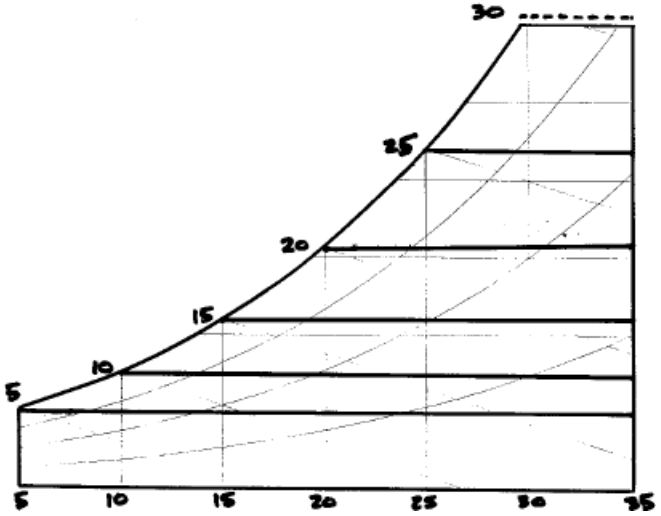
- Saturation Temperature
  - The temperature at which the air cannot hold any additional water vapour
  - At the saturation temperature, the dry bulb, wet-bulb, and due point temperature identical



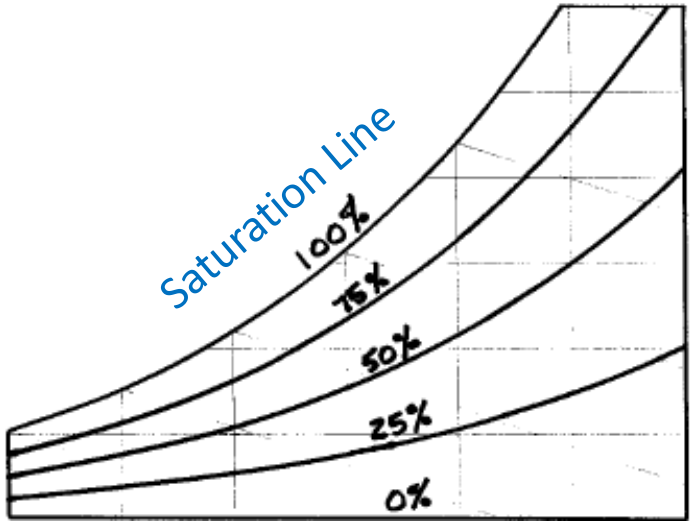
Dry-bulb temperature line



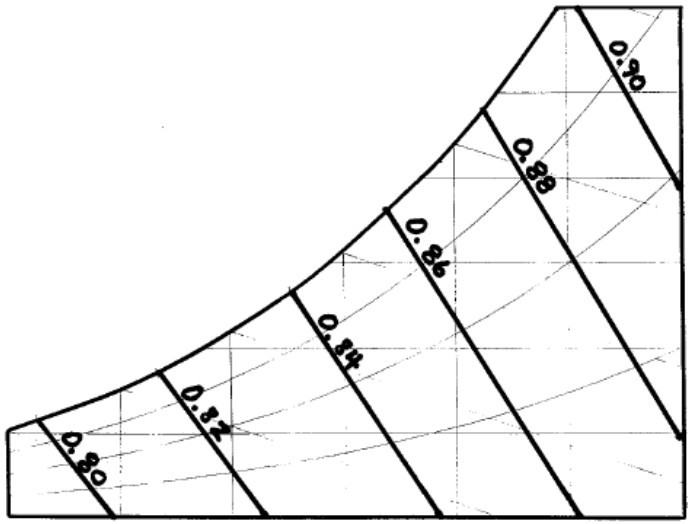
Wet-bulb temperature



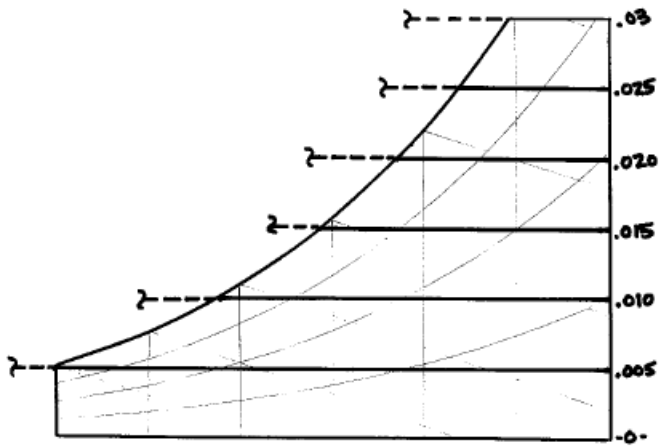
Dew-point temperature



Relative humidity



Specific Volume



Humidity ratio

Psychrometrics

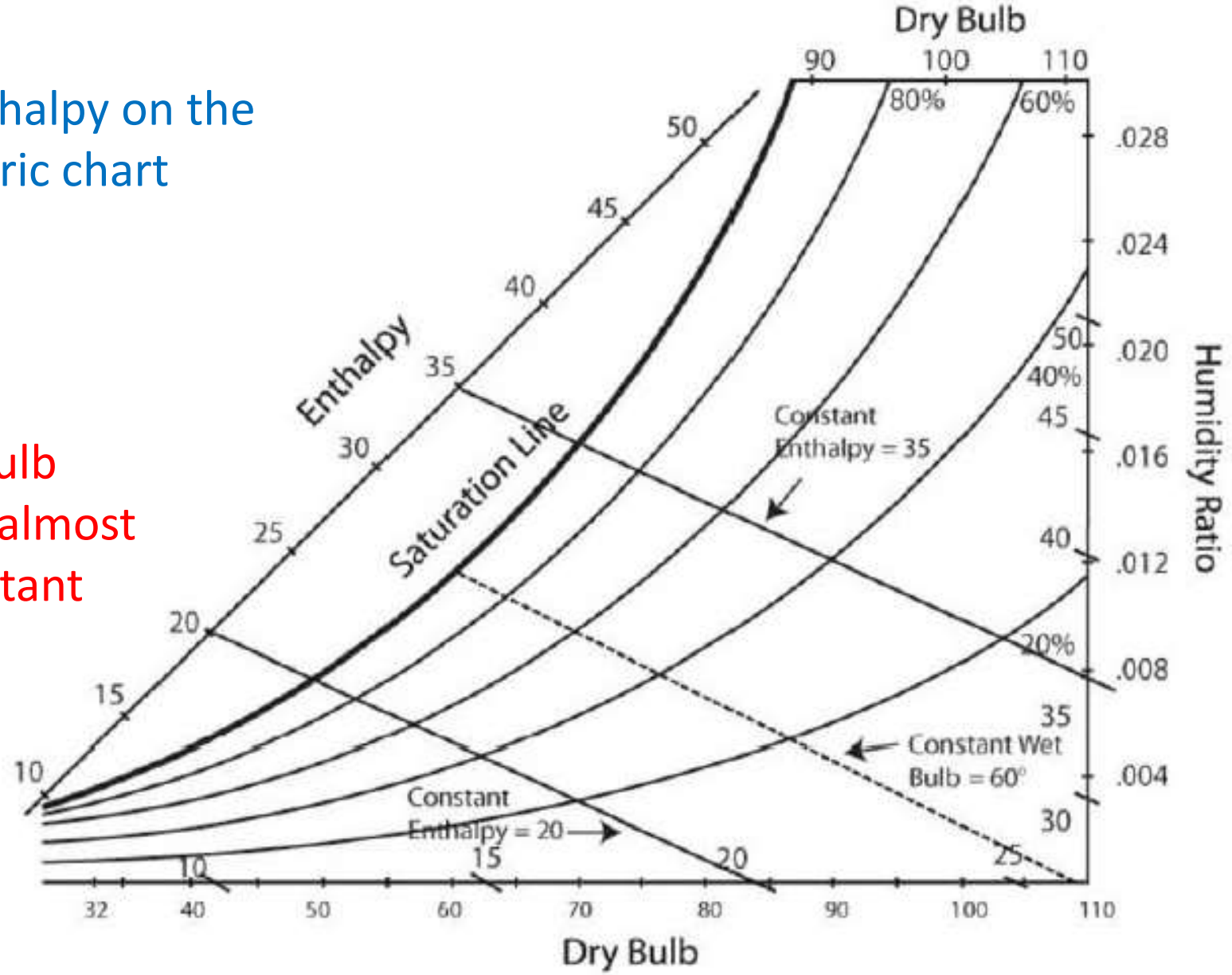
- Relative humidity
  - It is the ratio, expressed in percent, between the actual mass of water vapour present in a given volume, space or parcel and the maximum mass of water vapour in that same volume, space or parcel at the same dry-bulb temperature.
  - These are represented as curved lines from left to right curving upwards
- Humidity Ratio
  - It is the ratio of mass of water vapour to the mass of dry air in a parcel, sample, or volume of moist air

Psychrometrics

- Specific Enthalpy
  - It is the mathematical sum of two energy components associated with a substance
  - It is the most important property in psychrometric calculations
  - It cannot be measured directly
  - It represents total heat content of air measured in Jule/gram
  - Enthalpy isolines are straight , evenly spaced, and parallel to each other
- These charts use an oblique enthalpy grid or scale as one plotting coordinate with horizontal humidity ratio as the other plotting coordinate
  - These charts are not drawn on psychrometric chart through the body of the chart because enthalpy isolines are nearly parallel to wet-bulb temperature isolines

Plotting Enthalpy on the Psychrometric chart

Constant wet bulb temperature is almost parallel to Constant Enthalpy



Psychrometrics

- Specific Volume
  - It is the volume per unit mass of dry air component
  - It is expressed as cubic metre per kilogram of dry air
  - Specific volume changes as the dry-bulb temperature changes,
    - But not nearly as much as it changes with the effect of higher altitude.

Dehumidification

- Standard Cooling Cycle
  - A part of the return air is exhausted
  - The balance return air is mixed with outdoor air
  - This mixed air cooled in the chiller
  - By this cooling of air below due point, excess water vapour condenses
  - Thus latent cooling occurs in addition to sensible cooling
  - Latent and sensible heat is defined in the next slide

Dehumidification

- Definition
  - Sensible heat
    - Heat that is added or removed from a material that causes a change in temperature
  - Latent heat
    - Heat energy when added or removed causes a change in the state of a material with no change in temperature

Dehumidification

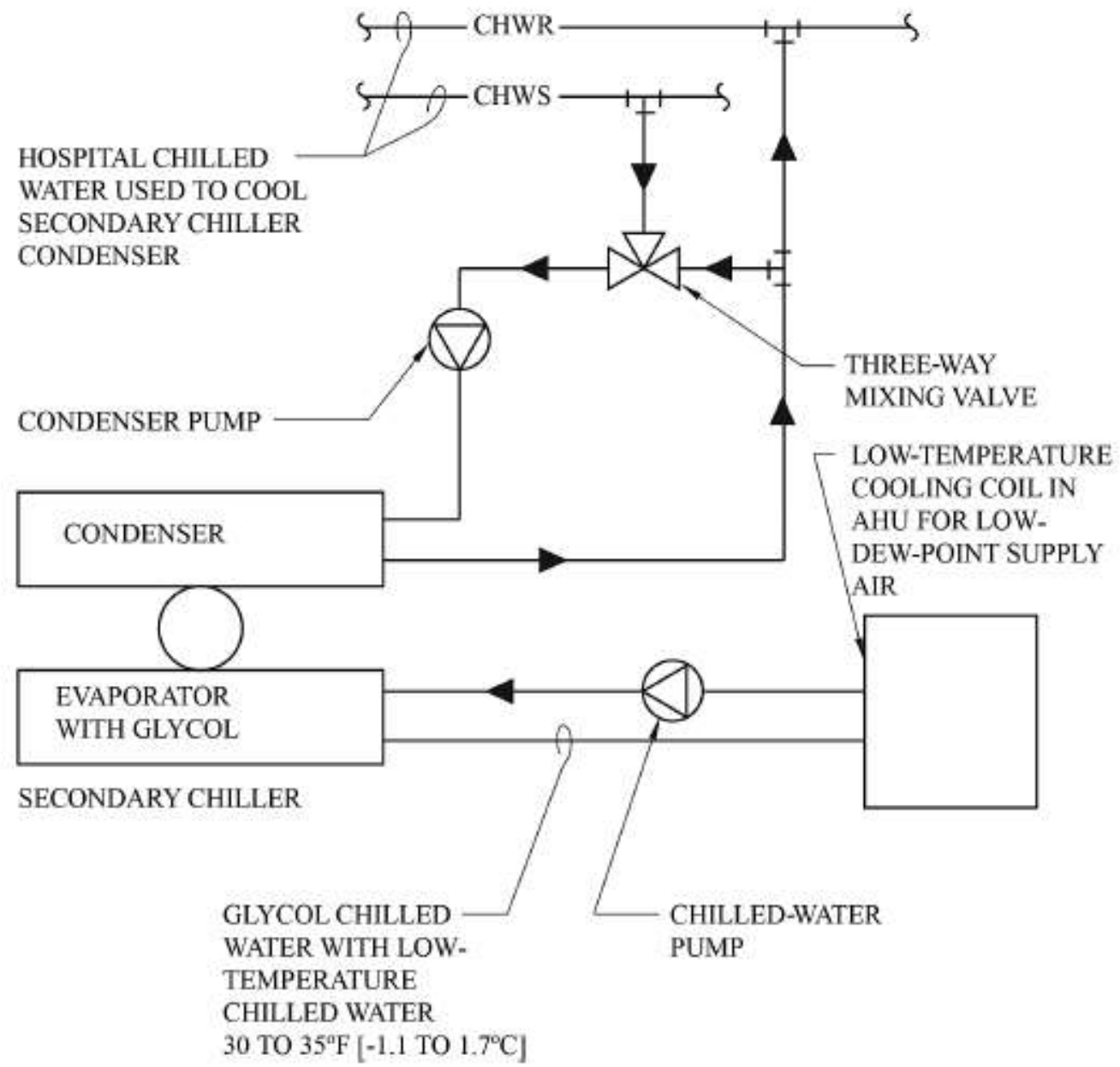
- The supply air to the room must have a dew point below the room dew-point temperature to offset the latent loads in the room
- Usual environmental condition in a hospital space is
  - Temperature 21 to 24^0C
  - Relative humidity 50 to 60%
  - Moderate latent heat load
- In this condition, the standard cooling cycle provides sufficient dehumidification
- Spaces with very low due point and /or high latent heat load dehumidification is challenging and may require less traditional systems

Dehumidification

- Areas requiring low temperatures and/or low relative humidity may include:
  - operating rooms,
  - procedure rooms,
  - pharmacy compounding,
  - autopsy rooms,
  - sterile processing rooms, and
  - computer rooms.
- Some of the most challenging conditions are often in the operating room.
  - Surgeons and staff often request temperatures and relative humidities that are significantly below ASHRAE Standard 170 design values
- To design HVAC, detailed psychrometric analysis is required

Dehumidification

- As mentioned earlier, supply air due point must be lower than the room air due point
- In more extreme conditions, that demand supply air dew points below the space dew points, the situation becomes challenging
  - Example:
    - At room due point of 7.7°C, the supply air due point may be 5.2°C
  - These requirements can be obtained from analysis of psychrometric chart.
- Such conditions require specialized systems such as Glycol chiller



A secondary glycol chiller can be used for low-dew-point applications.

By using a glycol mix in the secondary chiller, AHU coil, and piping, the chilled-water supply temperature can be lowered to 32°F [0°C] and even lower.

This will allow the AHU coil to produce extremely low supply air temperatures.

Source: ASHRAE Design manual for Hospitals

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End of Part 7 (Final)