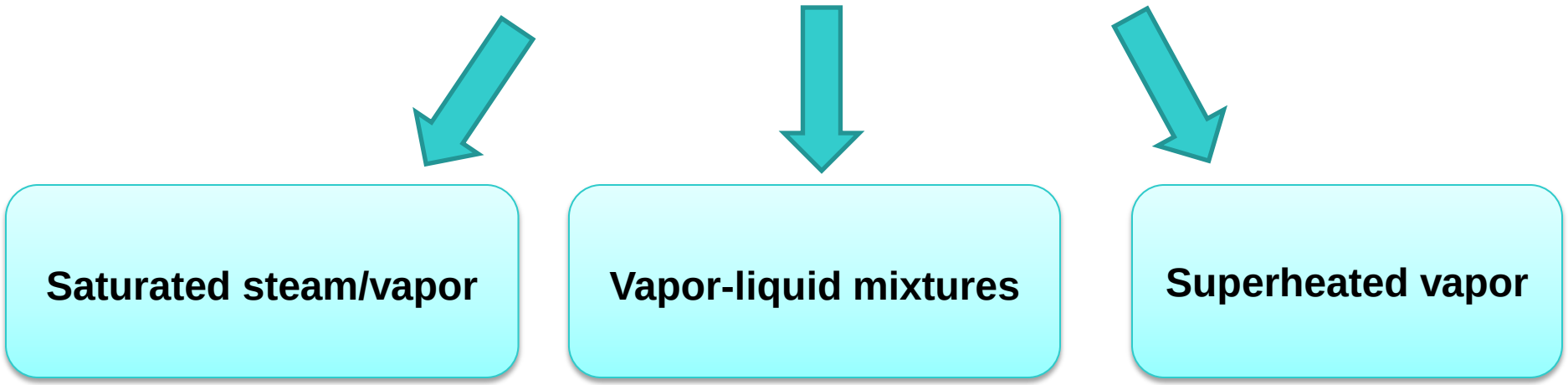
Properties of saturated and superheated steam

most frequently utilized heat transfer media in food processing

- Steam
- Water

Depending on the heat and water content of steam



Saturated steam

- **Vapor at boiling point (temp.) of water.**
- Do not contain water droplets.

If heat is removed from the system;

- Temperature and pressure will remain constant until all vapors are converted to liquid.
- Phase change is accompanied by a release of heat.

If heat is given to the system;

- Causes to change either the temperature or the pressure or both!!

At atmospheric pressure;

1 kg of saturated vapor,

- Occupies 1675 L of volume.

- **If cooloed,** 540 kcal of latent heat of condensation is released.

Vapor-Liquid mixtures

- Steam containing some water.
- In this mixture, steam and water are at the same temperature.
- Vapor-liquid mixtures are obtained from the cooling of saturated vapor.
- Steam with %95 quality:95 kg dry vapor+5 kg water
- Quality depends on the water content. The higher the water content, the lower the heat content.
- Heat of vapor with 95% quality:

539 x 0.95 = 512 kcal/kg

Superheated steam

- Steam at the temperature above boiling point water.
- Obtained by increasing the temperature of saturated steam at a constant pressure.
- Used in food industry when high temperatures of steam are needed. (For the removal of the peels of onions and peppers as well as to heat frying oil.)

If superheated steam is cooled:

- first **saturated steam** at the same pressure

- then **vapor-liquid mixture** are obtained at the same pressure

- Saturated steam is the most commonly used in food industry because it has high heat transfer capacity.

- The purity of steam is as important as its water content. Steam should **not contain** other gases.

Steam tables

- Steam tables list the properties of steam.
- Steam tables contain tabulated values for the properties of saturated and superheated steam.
- Used to determine the heat exchange involving a food product and steam or water.

Saturated steam table

- Includes temperature, absolute pressure, and specific volume and **enthalpy** of steam and water.
- Temperature and absolute pressure correspond to **boiling point of water**.
- Specific volume and entalphy values are given for liquid, evaporation and steam.

- **Saturated liquid** gives **enthalpy** and specific volume of water at the indicated temperature.

- **Evaporation** gives **enthalpy** and specific volume during phase transformation. Calculated from the difference between properties of saturated vapor and saturated liquid.

- **Saturated vapor** gives **enthalpy** and specific volume of steam at the boiling point of water.

Specific volume

- Reciprocal of the density.
- Volume in "ft^3" occupied by 1 lb_m of water or steam under the temperature and absolute. pressure given.

Entalphy

- Heat content of steam or water at the indicated temperature and pressure.
- Enthalpy values in the steam tables are calculated from a base temperature of 0°C.

- **Example 4.19**: At what vacuum would water boil at 80°F? a) Express this in inches of mercury vacuum. b) absolute pressure in kilopascals.

Answer

a) $P_{vacuum} = 28.89$ in Hg

b) $P_{absolute} = 3.494$ kPa

- **Example 4.20**: How much heat would be given off by cooling steam at 252°F and 30.883 psia to 248°F at the same pressure?

Answer

Heat given off= $q = h_{252}(\text{sat. vapor}) - h_{248}(\text{water})$

$$q = 1164.78 - 216.56$$

$$q = 948.22 \text{ BTU/lb}_m$$

Superheated steam table

To define **entalphy** or specific volume of superheated steam accurately;

- Temperature and abolute pressure must be specified.

- **Example 4.21**: How much heat is required to convert 1 lb_m of water at 70°F to steam at 14.696 psia and 250°F?

Answer

- Heat required = h_g(250°F and 14.696 psia) – h_f (70°F)

$$q = 1168.8 - 38.05$$

$$q = 1130.75 \text{ BTU/lb}_m$$

- **Example 4.22**: How much heat would be given off by cooling steam at 14.696 psia and 500°F to 250°F at the same pressure?

Answer

- Heat given off = h (14.696 psia and 500°F) –

  h (14.696 psia and 250°F)

  $q = 1287.4 - 1168.8$

  $q = 118.6\ BTU/lb_m$

Double interpolation

- **Example 4.23**: Calculate the enthalpy of superheated steam at 320°F and 17 psia.

Answer

- $h_{(320°F,\ 17\ psia)} = 1201.59\ BTU/lb_m$