CAPE1330 MASS AND ENERGY BALANCES

Psychrometric Chart

Dr Bao Xu

General procedures:

1. **Perform** all the required materials balance calculations
2. **Use** the appropriate form of the energy balances

   closed system: $Q + W = \Delta U + \Delta E_k + \Delta E_p$

   open system: $\dot{Q} + \dot{W}_s = \Delta \dot{H} + \Delta \dot{E}_k + \Delta \dot{E}_p$

3. **Choose** a reference state (phase, temperature, and pressure) for each species involved in the process
4. **Calculate** all the required values of $\widehat{U}_i$ or $\widehat{H}_i$
5. **Solve** the energy balances for unknown variables

Psychrometric charts

The most common of the psychrometric charts for the air-water system at 1 atm is shown in Fig. 1 with H_2O (liquid, 0°C, 1 atm) and dry air (0°C, 1 atm) as **reference states**.

On such a chart, several properties of an air-water mixture are cross-plotted, providing a concise compilation of a large quantity of physical property data.

These data include **dry-bulb temperature**, **absolute humidity, relative humidity**, **dew point**, **humid volume**, **wet-bulb temperature**, **specific enthalpy of saturated air** and **enthalpy deviation**.

Once you know the values of any two of these properties, you can use the chart to determine the values of the others. The psychrometric chart is used extensively in the analysis of humidification, drying and air-conditioning processes.

Psychrometric charts

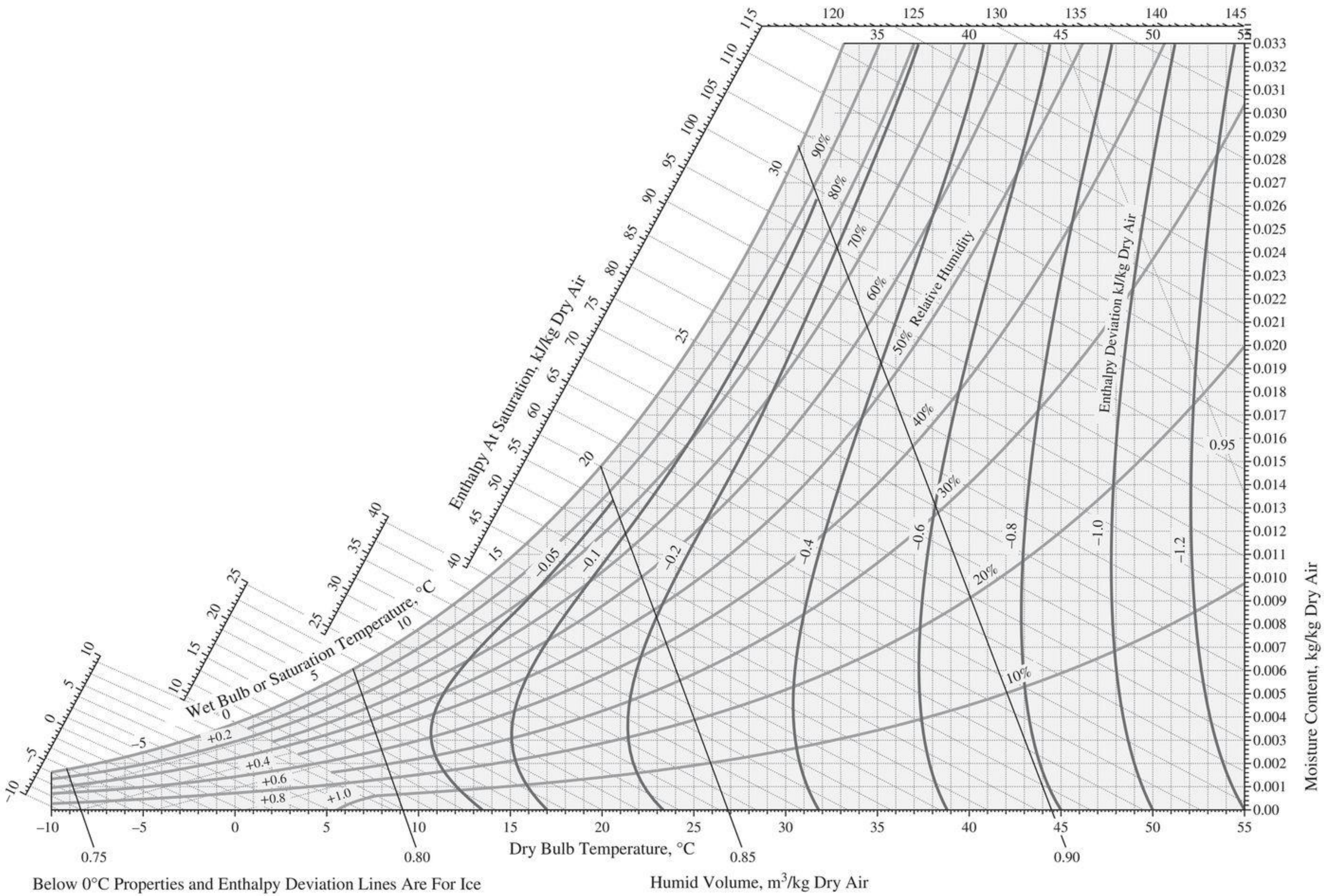

Fig.1 A psychrometric chart in SI units for the air–water system.

Psychrometric charts

Dry-bulb temperature, the abscissa of the chart. This is the air temperature as measured by a thermometer, thermocouple, or other conventional temperature-measuring instrument.

Absolute humidity (moisture content on Fig.1), the ordinate of the chart.

Relative humidity, the curve that forms the left boundary of the chart corresponds to 100% relative humidity and is known as the saturation curve.

Dew point, the temperature at which humid air becomes saturated if it is cooled at constant pressure.

Humid volume, is the volume occupied by 1 kg of dry air plus the water vapor that accompanies it.

Psychrometric charts

Wet-bulb temperature, this quantity is best defined in terms of how it is measured. The lower the humidity, the greater the difference between the dry-bulb temperature and wet-bulb temperature.

Specific enthalpy of saturated air, the diagonal scale above the saturation curve on the psychrometric chart shows the enthalpy of a unit mass of dry air plus the water vapor it contains at saturation. The **reference states** are liquid water at 1 atm and 0°C and dry air at 1 atm and 0°C

Enthalpy deviation, these curves are used to determine the enthalpy of humid air that is not saturated.

The basis for the construction of the psychrometric chart is the Gibbs phase rule, which states that specifying a certain number of the intensive variables of a system automatically fixes the value of the remaining intensive variables.

Example 1

Use the psychrometric chart to estimate the following properties of humid air at 41°C and 10% relative humidity

(a) the absolute humidity, wet-bulb temperature, humid volume, dew point, and specific enthalpy of humid air.

(b) the amount of water in 150 m^3 of air at these conditions.

Use heat capacity data from Table B.2 and steam table data from Table B.5 to calculate the specific enthalpy of humid air and compare the results with the value estimated from the psychrometric chart.

Example 1

From Table B.2 (heat capacities):

$Substance$	$a \times 10^3$	$b \times 10^5$	$c \times 10^8$	$d \times 10^{12}$	$Range$ (°C)
$Air\ (g)$	28.94	0.4147	0.3191	−1.965	0 − 1500
$H_2O(v)$	33.46	0.6880	0.7604	−3.593	0 − 1500
$H_2O(l)$	75.40	—	—	—	0 − 100

From Table B.5 (properties of saturated steam):

T(°C)	$P(bar)$	$\hat{V}\ (m^3/kg)$		$\hat{U}\ (kJ/kg)$		$\hat{H}\ (kJ/kg)$	
		$Water$	$Steam$	$Water$	$Steam$	$Water$	$Steam$
0.01	0.00611	0.001000	206.2	0.0	2375.6	0.0	2501.6
40	0.0738	0.001008	19.55	167.4	2430.2	167.5	2574.4
42	0.0820	0.001009	17.69	175.8	2432.9	175.8	2577.9

Psychrometric charts

The psychrometric chart can be used to simplify the solution of mass and energy balance problems for constant-pressure air–water systems, at the expense of some precision.

- Heating or cooling humid air at temperatures above the dew point corresponds to horizontal movement on the psychrometric chart if no condensation occurs.
- If superheated humid air is cooled at 1 atm, the system follows a horizontal path to the left on the chart until the dew point is reached; thereafter, the gas phase follows the saturation curve.
- Since the psychrometric chart plots the mass ratio kg H_2O/kg DA rather than the mass fraction of water, it is usually convenient to assume a quantity of dry air in a feed or product stream as a basis of calculation.

Example 2

Wet solids pass through a continuous dryer. Hot dry air enters the dryer at a rate of 400 kg/min and mixes with the water that evaporates from the solids. Humid air leaves the dryer at 50°C containing 2.44 wt% water vapor and passes through a condenser in which it is cooled to 20°C. The pressure is constant at 1 atm throughout the system.

(a) At what rate in kg/min is water evaporating in the dryer?

(b) Use the psychrometric chart to estimate the wet-bulb temperature, relative humidity, dew point, and specific enthalpy of the air leaving the dryer.

(c) Use the psychrometric chart to estimate the absolute humidity and specific enthalpy of the air leaving the condenser.

Example 2

(d) Use the results of Parts (b) and (c) to calculate the rate of condensation of water (kg/min) and the rate at which heat must be transferred from the condenser (kW).

(e) If the dryer operates adiabatically, what can you conclude about the temperature of the entering air? Briefly explain your reasoning. What additional information would you need to calculate this temperature?