ES 202
Fluid and Thermal Systems

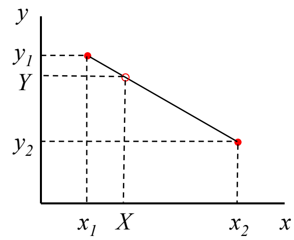
Lecture 18:
Making the Connection
(1/23/2003)

Road Map of Lecture 18

- The "How to" of linear interpolation
- Review of what you can do
  - property tables (compressed liquid, saturated mixture, superheated vapor)
  - Compressed Liquid Approximation
- Relationship between property tables and your familiar models in ES 201 (ideal gas, incompressible substance)
  - fill in the gaps to make the picture complete
  - coupling between new and old materials
- Application of conservation and accounting principles to real substance
- Emphasis on thinking in terms of *P-v, T-v* and *P-T* diagrams

Illustration on Interpolation

- Consider the following figure with two known data points (x_1, y_1), (x_2, y_2) and a "to be determined" data point (X, Y):



- Simple fact: If three points lie on a straight line, the slope of the line segment formed between any two points must be the same as that of other line segments.

- Mathematically, the above statement can be expressed as

$$\frac{y_1 - Y}{x_1 - X} = \frac{y_1 - y_2}{x_1 - x_2} \longrightarrow Y = y_1 - \left(\frac{y_1 - y_2}{x_1 - x_2}\right)(x_1 - X)$$

A Check List for You

- Phase determination of a substance at a specific set of conditions
- Find out thermodynamics properties from appropriate tables:
  - compressed liquid table
  - saturated mixture table (quality of a mixture)
  - superheated vapor table
  - interpolation procedure
- Compressed Liquid Approximation
- Familiarity with phase diagrams *(P-v, T-v, P-T)*
  - constant pressure line (piston-cylinder model)
  - constant specific volume line (rigid system boundaries)
  - constant temperature line (isothermal process)

Making the Connection (I)

- Recall your familiar models in ES 201:
  - ideal gas
  - incompressible substance
- These models are limited and represent “simplified” behavior of real substances under particular conditions:
  - ideal gas (good for gases at low pressures)
  - incompressible substance (good for liquids and solids)
- The models are good as long as the working conditions are not far from the underlying assumptions.
- The phase and property tables tabulate the exact measures of real substance behavior, *i.e.* tells you the true stories over the range reported on tables.

Making the Connection (II)

- Conceptually, you can think of the tables as the data which fills in the gaps between different models.
  - provides a larger range of applicability and operation
- The conservation and accounting principles which you learned in ES 201 are still true no matter you are working with models or real substances. They are physical principles which cannot be violated.
  - conservation of mass
  - conservation of linear and angular momentum
  - conservation of energy
  - production of entropy
- However, changes in properties can be obtained differently now.

Making the Connection (III)

- For examples: $\Delta u = c_v \Delta T$ $\Delta h = c_p \Delta T$

  In the perfect gas model, the specific heats are taken to be constant. In this way, the change in specific internal energy or enthalpy can be related to the change in temperature directly.

- In treating real substances, such assumptions are not necessary.
- You can directly find out the specific internal energy or enthalpy from the property tables if you know any two independent, intensive properties about the state (State Principle).
- Main point: The rest of the engineering analysis (involving conservation laws) remains exactly the same. No new materials here!! It is a matter of working out familiar problems with new properties.

Goal:

Integration of different pieces of materials learned in ES 201 and ES 202 to do system analysis for a general substance