3. SUPERHEATED VAPOR:

When water is in the superheated vapor phase, Table (A-6) is used to get the required properties. To use this table, two properties must be known:

$$\text{Superheated vapor@ P + T = given} \Rightarrow \text{Table (A} - 6) \Rightarrow \text{ properties}$$

$$P + any\ other\ property\ (v, u, h, s) \Rightarrow Table\ (\text{A} - 6) \Rightarrow \text{ properties}$$

$$T + any\ other\ property\ (v, u, h, s) \Rightarrow Table\ (\text{A} - 6) \Rightarrow \text{ properties}$$

4. COMPRESSED (SUBCOOLED) LIQUID:

When water is in the compressed liquid phase, Table (A-4) or Table (A-5) is used to get the required properties (of fluid). To use this table, two properties must be known. So the same rules as with the superheated vapor are applied here.

We can identify the state of water using the saturation tables, i.e. Table (A-4) and Table (A-5). Two known properties are required to identify the state of water as follows:

$@T = given \Rightarrow P < P_{sat}$ or $@P = given \Rightarrow T > T_{sat}$

then

$v > v_g\ @\ T\ or\ P \Rightarrow$ water is in the superheated vapor

$u > u_g\ @\ T\ or\ P \Rightarrow$ water is in the superheated vapor

$h > h_g\ @\ T\ or\ P \Rightarrow$ water is in the superheated vapor

$s > s_g\ @\ T\ or\ P \Rightarrow$ water is in the superheated vapor

$@T = given \Rightarrow P > P_{sat}$ or $@P = given \Rightarrow T < T_{sat}$

$v < v_f\ @\ T\ or\ P \Rightarrow$ water is in the compressed liquid

$u < u_f\ @\ T\ or\ P \Rightarrow$ water is in the compressed liquid

$h < h_f\ @\ T\ or\ P \Rightarrow$ water is in the compressed liquid

$s < s_f\ @\ T\ or\ P \Rightarrow$ water is in the compressed liquid

If the property equals the saturation value, then the water is in the saturated state (vapor or liquid).

If $(property_f < property < property_g)$, then the water is in the wet vapor state.

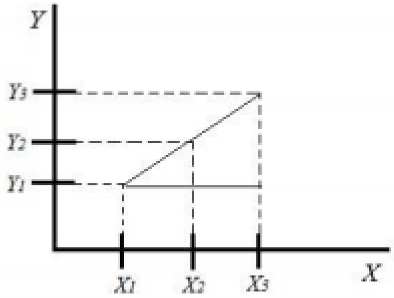
Linear Interpolation

When the required property value is located between two known values in the tables, we can calculate the required value by linear interpolation. Assume that (Y_1, Y_2, Y_3, X_1, X_3) are known and (X_2) is the required value. By assuming a linear relationship:

X_1	Y_1
X_2	Y_2
X_3	Y_3

$$\frac{(X_2 - X_1)}{(X_3 - X_1)} = \frac{(Y_2 - Y_1)}{(Y_3 - Y_1)}$$

$$X_2 = X_1 + \left(\frac{Y_2 - Y_1}{Y_3 - Y_1}\right)(X_3 - X_1)$$



Example (4): A rigid tank contains saturated liquid water at (95 °C). Determine the pressure in the tank and the specific volume of the water.

Solution:

$Saturated$ water @ T = 95 ℃ ⇒ Table (A − 4) ⇒ $P = P_{sat} = 84.609\ kPa$

$Saturated$ water @ T = 95 ℃ ⇒ Table (A − 4) ⇒ $v = v_f = 0.001040\ kg/m^3$

Example (5): Determine the specific volume, internal energy, enthalpy and entropy for a mixture of (10 %) quality at (0.15 MPa).

Given, $x = 0.1$

@ P = 0.15 MPa = 150 kPa ⇒ Table (A − 5)

$v_g = 1.1593 \text{ m}^3/\text{kg}$

$u_f = 466.94 \text{ kJ/kg},$ $u_{fg} = 2052.7 \text{ kJ/kg}$

$h_f = 467.11 \text{ kJ/kg},$ $h_{fg} = 2226.5 \text{ kJ/kg}$

$s_f = 1.4336 \text{ kJ/kg.K},$ $s_{fg} = 5.7897 \text{ kJ/kg.K}$

Specific volume, $v = x.v_g$

$= 0.1 \times 1.159 = 0.1159 \text{ m}^3/\text{kg}$

Internal energy, $u = u_f + x.u_{fg}$

$= 466.94 + 0.1 \times 2052.7 = 672.21 \text{ kJ/kg}$

Enthalpy, $h = h_f + x.h_{fg}$

$= 467.11 + 0.1 \times 2226.5 = 689.759 \text{ kJ/kg}$

Entropy, $s = s_f + x.s_{fg}$

$= 1.4336 + 0.1 \times 5.7897 = 2.01257 \text{ kJ/kg.K}$

Example (6): Determine the temperature of superheated steam at a state of (0.5 MPa) and enthalpy (2960.7 kJ/kg).

Solution:

$@P = 0.5\ MPa\ \ \&\ h = 2960.7\ \text{kJ/kg}\ \ \Rightarrow Table\ (A-6) \Rightarrow T = 250\ ℃$

Example (7): Determine the phase for each of the following water states:

a. 120 °C, 500 kPa

b. 120 °C, 0.5 m^3/kg

Solution:

(a) $@\ \mathrm{T} = 120\ ℃\ \ \&\ \ \mathrm{P} = 500\ \mathrm{KPa} \Rightarrow \mathrm{Table\ (A-4)}$

$\Rightarrow @\ T = 120\ ℃ \Rightarrow P_{sat} = 198.5 kPa\ < P \Rightarrow \text{compretssed liquid}$

We could also have used Table (A-5)

$@\ P\ =\ 500\ kPa\ \Rightarrow \mathrm{Table\ (A-5)} \Rightarrow\ Tsat = 151.86°C\ > T \Rightarrow compressed\ liquid$

(b) $@\ \mathrm{T} = 120\ ℃\ \Rightarrow \mathrm{Table\ (A-4)} \Rightarrow\ v_f =\ 0.00106\ \mathrm{m^3/kg}\ \&\ v_g = 0.89133\ \mathrm{m^3/kg}$

$v_f <\ v\ <\ v_g \Rightarrow \text{two phase mixture of liquid and vapor}$

Example (8): Determine the temperature for water at a pressure of (300 kPa) and (1 m^3/kg).

Solution:

$@\ P = 300\ kPa \Rightarrow \text{Table (A} - 5) \Rightarrow v_g = 0.60582\ \text{m}^3/\text{kg} \Rightarrow v > v_g$

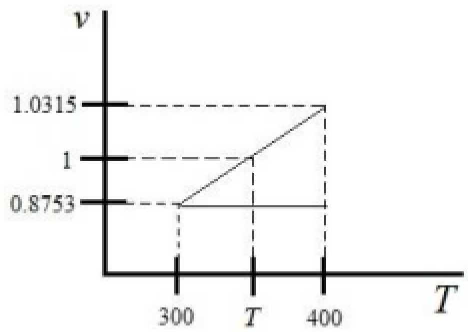
$\Rightarrow superheated\ vapor$

$@\ P = 300\ kPa = 0.3\ MPa\ \ \&\ v = 1\ m^3/kg \Rightarrow \text{Table (A} - 6) \Rightarrow T$

T can be found by interpolation between 300°C and 400°C at 300 kPa.

$$\frac{T - 300}{400 - 300} = \frac{1 - 0.8753}{1.0315 - 0.8753}$$

$\boldsymbol{T = 379.8°C}$ **Ans.**



HOMEWORK (4)

1- A (1.8 m^3) rigid tank contains steam at (220°C). Onethird of the volume is in the liquid phase and the rest is in the vapor form. Determine (*a*) the pressure of the steam, (*b*) the quality of the saturated mixture, and (*c*) the density of the mixture.

2- A piston–cylinder device contains (0.1 m^3) of liquid water and (0.9 m^3) of water vapor in equilibrium at (800 kPa). Heat is transferred at constant pressure until the temperature reaches (350 °C). (*a*) What is the initial temperature of the water? (*b*) Determine the total mass of the water. (*c*) Calculate the final volume. (*d*) Show the process on a *P-v* diagram with respect to saturation lines.

3-A piston–cylinder device initially contains (0.05 m^3)of liquid water at (40 °C) and (200 kPa). Heat is transferred to the water at constant pressure until the entire liquid is vaporized. (*a*) What is the mass of the water? (*b*) What is the final temperature?
(*c*) Determine the total enthalpy change. (*d*) Show the process on a *T-v* diagram with respect to saturation lines.

4- Determine the specific volume, internal energy, and enthalpy of compressed liquid water at (100 °C) and (15 MPa) using the saturated liquid approximation.

5- A piston cylinder device contains steam initially at (1 MPa), (450 °C), and (2.5 m^3). Steam is allowed to cool at constant pressure until it first starts condensing. Show the process on a *T-v* diagram with respect to saturation lines and determine
(*a*) The mass of the steam, (*b*) the final temperature, and (*c*) the amount of heat transfer.