Thermal Physics

Water and steam

Problem 1.- A rigid tank of volume 1.5 m^3 contains saturated steam at 50 kPa. If you cool the water to T=60.1 °C calculate the quality of the new mixture.

Solution: Since the water is in the state of saturated steam, its specific volume will be v_g, which we can find in steam tables:

$$v = v_g = 3.24\frac{m^3}{kg}$$

When dropping the temperature to T=60.1 °C, some of the water will condense giving a quality of less than one. In any case, the specific volume is constant, so at the new conditions:

$$3.24\frac{m^3}{kg} = v_f(1-x) + v_g(x)$$

We find the values of v_f and v_g and solve for x:

$$3.24\frac{m^3}{kg} = 0.001017\frac{m^3}{kg}(1-x) + 7.649\frac{m^3}{kg}(x) \rightarrow x = \mathbf{0.42}$$

Problem 2.-One kg of water-vapor mixture initially at a pressure of 400kPa and a quality of 0.5 is heated at constant pressure. If the final state is superheated steam at 400 °C, calculate the total amount of work done in the expansion.

Solution: Since the process occurs at constant pressure, the amount of work done is:

$$W = \int_{V_{initial}}^{V_{final}} pdV = p(V_{final} - V_{initial})$$

The pressure is already known (400kPa), so we just need the initial and final volumes:

$$v_{initial} = v_f(1-x) + v_g(x) = 0.001084\frac{m^3}{kg}(1-0.5) + 0.4625\frac{m^3}{kg}(0.5) = 0.2318\frac{m^3}{kg}$$

$$V_{initial} = mv_{initial} = (1kg)0.2318\frac{m^3}{kg} = 0.2318m^3$$

Also, from the superheated water tables at 400 °C and 400kPa:

$$v_{final} = 0.7649\frac{m^3}{kg} \rightarrow V_{final} = mv_{final} = 0.7649m^3$$

The work is then:

$$W = 400\times10^3 Pa(0.7649m^3 - 0.2318m^3) = \mathbf{216\ kJ}$$