

Cankaya University
 Faculty of Engineering
 Mechanical Engineering Department
 Me 211 Thermodynamics I
 Quiz # 6 Fall 2017-solution

Liquid water at 300 kPa and 20°C is heated in a chamber by mixing it with superheated steam at 300 kPa and 300°C. Cold water enters the chamber at a rate of 1.8 kg/s. If the mixture leaves the mixing chamber at 60°C, determine the mass flow rate of the superheated steam required.

Solution:

Properties Noting that $T < T_{\text{sat}} @ 300 \text{ kPa} = 133.52^\circ\text{C}$, the cold water stream and the mixture exist as a compressed liquid, which can be approximated as a saturated liquid at the given temperature. Thus, from steam tables (Tables A-4 through A-6)

$$h_1 \cong h_f @ 20^\circ\text{C} = 83.91 \text{ kJ/kg}$$

$$h_3 \cong h_f @ 60^\circ\text{C} = 251.18 \text{ kJ/kg}$$

and

$$\left. \begin{array}{l} P_2 = 300 \text{ kPa} \\ T_2 = 300^\circ\text{C} \end{array} \right\} h_2 = 3069.6 \text{ kJ/kg}$$

Analysis We take the mixing chamber as the system, which is a control volume since mass crosses the boundary. The mass and energy balances for this steady-flow system can be expressed in the rate form as

Mass balance: $\dot{m}_{\text{in}} - \dot{m}_{\text{out}} = \Delta \dot{m}_{\text{system}} \stackrel{\neq 0 \text{ (steady)}}{=} 0 \rightarrow \dot{m}_{\text{in}} = \dot{m}_{\text{out}} \rightarrow \dot{m}_1 + \dot{m}_2 = \dot{m}_3$

Energy balance:

$$\underbrace{\dot{E}_{\text{in}} - \dot{E}_{\text{out}}}_{\text{Rate of net energy transfer by heat, work, and mass}} = \underbrace{\Delta \dot{E}_{\text{system}}}_{\text{Rate of change in internal, kinetic, potential, etc. energies}} \stackrel{\neq 0 \text{ (steady)}}{=} 0$$

$$\dot{E}_{\text{in}} = \dot{E}_{\text{out}}$$

$$\dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3 \quad (\text{since } \dot{Q} = \dot{W} = \Delta \text{ke} \cong \Delta \text{pe} \cong 0)$$

Combining the two, $\dot{m}_1 h_1 + \dot{m}_2 h_2 = (\dot{m}_1 + \dot{m}_2) h_3$

Solving for \dot{m}_2 :
$$\dot{m}_2 = \frac{h_1 - h_3}{h_3 - h_2} \dot{m}_1$$

Substituting,

$$\dot{m}_2 = \frac{(83.91 - 251.18) \text{ kJ/kg}}{(251.18 - 3069.6) \text{ kJ/kg}} (1.8 \text{ kg/s}) = \mathbf{0.107 \text{ kg/s}}$$

