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ME 3322A: Thermodynamics: Fall 2014
Homework Set # 6
Due Date: October 07, 2014

	Problem # in Textbook		Answer
	7th Ed	8th Ed.	
1	4.37	4.37	45 m/s
2	4.60	4.60	86.04 kW
3	4.74	4.74	9.06 E6 kg/h
4	4.82	4.82	120.01 kg/min
5	4.89	4.89	X_2=0.1936

PROBLEM 4.37

KNOWN: Steady-state operating data are provided for a jet engine.

FIND: Determine the velocity at the diffuser exit.

SCHEMATIC & GIVEN DATA:

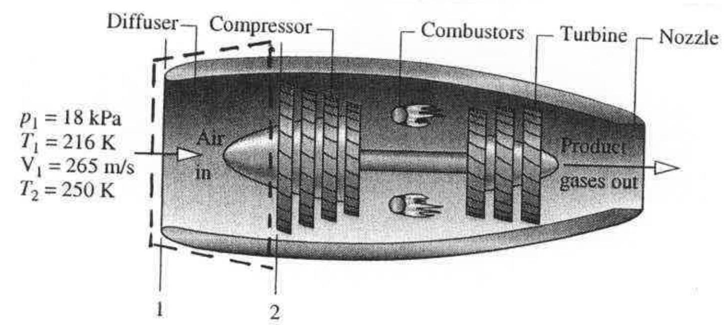


Fig. P4.37

ENGR. MODEL

1. As shown in the sketch, a control volume encloses the diffuser.
2. The control volume is at steady state.
3. For the control volume, $\dot{Q}_{cv} = 0$, $\dot{W}_{cv} = 0$ and potential energy effects can be ignored.
4. The air is modeled as an ideal gas.

ANALYSIS: For the control volume, $\dot{m}_1 = \dot{m}_2 \equiv \dot{m}_a$. An energy rate balance reads

$$0 = \cancel{\dot{Q}_{cv}} - \cancel{\dot{W}_{cv}} + \dot{m}_a\left[(h_1 - h_2) + \left(\frac{V_1^2 - V_2^2}{2}\right) + \cancel{g(z_1 - z_2)}\right]$$

Accordingly,

$$V_2 = \sqrt{V_1^2 + 2(h_1 - h_2)}$$

$$= \sqrt{\left(265\,\frac{m}{s}\right)^2 + 2\,(\underbrace{215.97 - 250.05}_{\text{Table A-22}})\,\frac{kJ}{kg}\left|\frac{10^3\,N\cdot m}{1\,kJ}\right|\left|\frac{1\,kg\cdot m/s^2}{1\,N}\right|}$$

$$= 45\ m/s$$

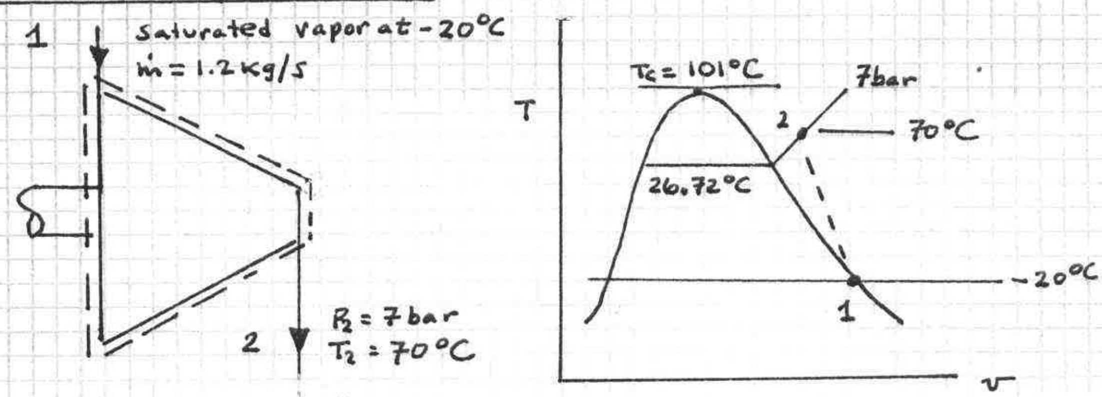
$\longleftarrow V_2$

PROBLEM 4.60

KNOWN: Steady-state data are provided for an insulated compressor operating with R-134a.

FIND: For the compressor, determine the inlet and exit volumetric flow rates, in m^3/s, and the power input, in kW.

SCHEMATIC & GIVEN DATA:



ENGINEERING MODEL:

1. The control volume enclosing the compressor is at steady state.
2. For the control volume $\dot{Q}_{cv} = 0$.
3. Kinetic and potential energy changes from inlet to exit are ignored.

ANALYSIS:

At steady state the mass rate balance reads $\dot{m}_2 = \dot{m}_1 \; (= \dot{m})$. Also,

$$\dot{m} = \frac{(AV)_1}{v_1} = \frac{(AV)_2}{v_2}$$

Table A-10 at -20°C

$$\Rightarrow (AV)_1 = \dot{m} v_1 = \left(1.2 \frac{kg}{s}\right)(0.1464 \; m^3/kg) = 0.1757 \frac{m^3}{s}$$

$$(AV)_2 = \dot{m} v_2 = \left(1.2 \frac{kg}{s}\right)(0.03634 \; m^3/kg) = 0.0436 \frac{m^3}{s}$$

Table A-12

Reducing Eq. 4.20 a,

$$0 = \cancel{\dot{Q}_{cv}} - \dot{W}_{cv} + \dot{m}\left[h_1 - h_2 + \cancel{\frac{V_1^2 - V_2^2}{2}} + \cancel{g(z_1 - z_2)}\right]$$

$$\dot{W}_{cv} = \dot{m}\left[h_1 - h_2\right]$$

$$= \left(1.2 \frac{kg}{s}\right)\left[235.31 - 307.01\right] \frac{kJ}{kg} \left| \frac{1 \; kW}{1 \; kJ/s} \right|$$

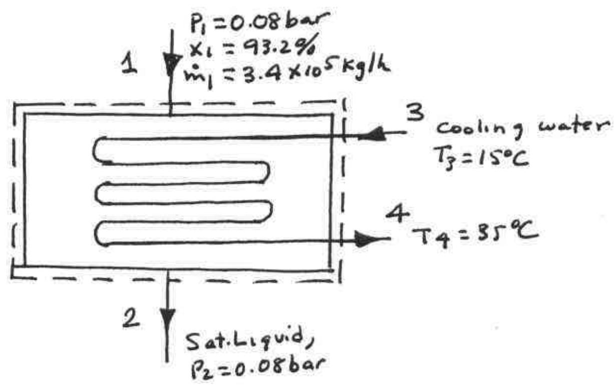
$$= -86.04 \; kW$$

$$\therefore (-\dot{W}_{cv}) = +86.04 \; kW \quad \text{(Power input)}$$

PROBLEM 4.74

Steam at a pressure of 0.08 bar and a quality of 93.2% enters a shell-and-tube heat exchanger where it condenses on the outside of tubes through which cooling water flows, exiting as saturated liquid at 0.08 bar. The mass flow rate of the condensing steam is 3.4×10^5 kg/h. Cooling water enters the tubes at 15°C and exits at 35°C with negligible change in pressure. Neglecting stray heat transfer and ignoring kinetic and potential energy effects, determine the mass flow rate of the cooling water, in kg/h, for steady-state operation.

SCHEMATIC & GIVEN DATA:



ENGR. MODEL:

1. The control volume shown in the sketch is at steady state.
2. For the control volume, $\dot W_{cv} = 0$, $\dot Q_{cv} \approx 0$, and kinetic and potential energy effects can be ignored.
3. For the cooling water, $h \approx h_f(T)$.

ANALYSIS: Reducing Eq. 4.18,

$$0 = \cancel{\dot Q_{cv}} - \cancel{\dot W_{cv}} + \dot m_1 \left[h_1 - h_2 + \cancel{\frac{V_1^2 - V_2^2}{2}} + \cancel{g(z_1 - z_2)} \right] + \dot m_3 \left[h_3 - h_4 + \cancel{\frac{V_3^2 - V_4^2}{2}} + \cancel{g(z_3 - z_4)} \right]$$

$$\Rightarrow \quad \dot m_3 = \dot m_1 \frac{[h_1 - h_2]}{[h_4 - h_3]} \qquad (1)$$

where with data from Table A-3,

$$h_1 = \underbrace{h_f}_{= h_2} + x_1 (h_g - h_f) = 173.88 + 0.932(2403.1) = 2413.6 \frac{kJ}{kg}.$$

And with data from Table A-2, $h_3 \approx h_f(15°C) = 62.99 \frac{kJ}{kg}$, $h_4 \approx h_f(35°C) = 146.68 \frac{kJ}{kg}$.

Inserting values into Eq. (1), we get

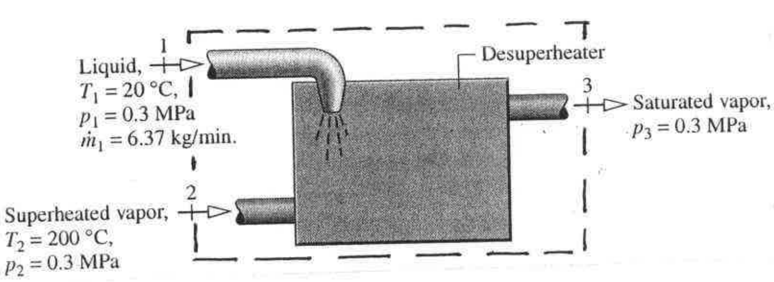
$$\dot m_3 = 3.4 \times 10^5 \frac{kg}{h} \left[\frac{2413.6 - 173.88}{146.68 - 62.99} \right]$$

$$= 9.06 \times 10^6 \frac{kg}{h}$$

PROBLEM 4.82

For the *desuperheater* shown in Fig. P4.82, liquid water at state 1 is injected into a stream of superheated vapor entering at state 2. As a result, saturated vapor exits at state 3. Data for steady state operation are shown on the figure. Ignoring stray heat transfer and kinetic and potential energy effects, determine the mass flow rate of the incoming superheated vapor, in kg/min.

SCHEMATIC & GIVEN DATA:



ENGR. MODEL:

1. The control volume shown in the sketch is at steady state.
2. For the control volume, stray heat transfer and kinetic and potential energy effects can be ignored. $\dot{W}_{cv} \equiv 0$.
3. At state 1, $h_1 \approx h_f(T_1)$.

ANALYSIS:

Mass rate balance: $\dot{m}_3 = \dot{m}_1 + \dot{m}_2$ (1)

Energy rate balance,

$$0 = \cancel{\dot{Q}_{cv}} - \cancel{\dot{W}_{cv}} + \dot{m}_1\left[h_1 + \cancel{\frac{V_1^2}{2}} + \cancel{gz_1}\right] + \dot{m}_2\left[h_2 + \cancel{\frac{V_2^2}{2}} + \cancel{gz_2}\right] - \dot{m}_3\left[h_3 + \cancel{\frac{V_3^2}{2}} + \cancel{gz_3}\right]$$

$$\Rightarrow 0 = \dot{m}_1 h_1 + \dot{m}_2 h_2 - \dot{m}_3 h_3 \qquad (2)$$

Combining Eqs. (1), (2)

$$0 = \dot{m}_1 h_1 + \dot{m}_2 h_2 - (\dot{m}_1 + \dot{m}_2) h_3$$

$$\Rightarrow \dot{m}_2 = \dot{m}_1 \left[\frac{h_3 - h_1}{h_2 - h_3}\right] \qquad (3)$$

From Table A-2, $h_1 \approx 83.96$ kJ/kg. From Table A-3, $h_3 = 2725.3$ kJ/kg. From Table A-4, $h_2 = 2865.5$ kJ/kg. Inserting values in Eq. (3),

$$\dot{m}_2 = 6.37\,\frac{kg}{min}\left[\frac{2725.3 - 83.96}{2865.5 - 2725.3}\right] = 120.01\,\frac{kg}{min}$$

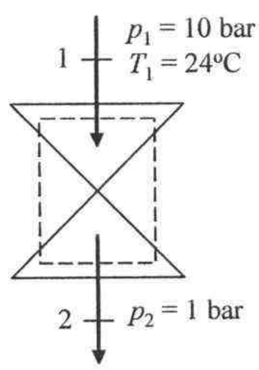
PROBLEM 4.89

4.89 Ammonia enters the expansion valve of a refrigeration system at a pressure of 10 bar and a temperature of 24°C and exits at 1 bar. If the refrigerant undergoes a throttling process, what is the quality of the refrigerant exiting the expansion valve?

KNOWN: Ammonia enters an expansion valve at given pressure and temperature and exits at given pressure.

FIND: Determine the quality of the refrigerant at the exit.

SCHEMATIC AND GIVEN DATA:



ENGINEERING MODEL:
1. The control volume shown on the accompanying figure is at steady state.
2. Heat transfer and kinetic and potential energy effects can be neglected.
3. $\dot{W}_{cv} = 0$.

ANALYSIS:
The steady-state, one-inlet, one-exit energy balance gives

$$0 = \dot{Q}_{cv} - \dot{W}_{cv} + \dot{m}\,[(h_1 - h_2) + \tfrac{1}{2}(V_1^2 - V_2^2) + g(z_1 - z_2)]$$

Neglecting heat transfer and kinetic and potential energy effects and recognizing no work $\dot{W}_{cv}$ is associated with an expansion valve, the energy balance simplifies to

$$0 = h_1 - h_2$$

Solving for the exit enthalpy gives

$$h_2 = h_1$$

(at 24°C)

The ammonia at State 1 is compressed liquid. From Table A-13, $h_1 \approx h_{f1} = 293.45$ kJ/kg.

Thus, $h_2 = 293.45$ kJ/kg.

The quality at state 2 can be determined from the relation

PROBLEM 4.89 (Continued)

$$x_2 = \frac{h_2 - h_{f2}}{h_{fg2}}$$

From Table A-14, $h_{f2} = 28.18$ kJ/kg and $h_{fg2} = 1370.23$ kJ/kg. Substituting in the quality relation gives

$$x_2 = \frac{293.45\frac{\text{kJ}}{\text{kg}} - 28.18\frac{\text{kJ}}{\text{kg}}}{1370.23\frac{\text{kJ}}{\text{kg}}} = \underline{\mathbf{0.1936}}$$

The T-v diagram for the process is shown below.