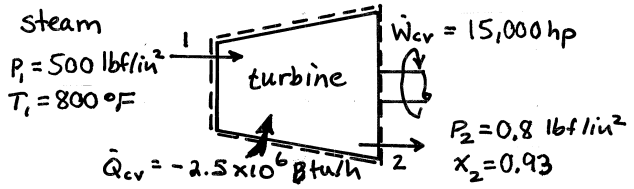
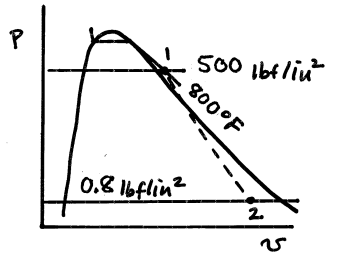
PROBLEM 4.36*

KNOWN: A steam turbine operates at steady state with known inlet and exit conditions. The power developed and the heat transfer rate between the turbine and its surroundings are specified.

FIND: Determine the volumetric flow rate of steam at the inlet.

SCHEMATIC & GIVEN DATA:





ASSUMPTIONS: (1) The control volume is at steady state. (2) Kinetic and potential energy changes from inlet to exit can be neglected.

ANALYSIS: To calculate the volume flow rate, begin with mass and energy rate balances for the one-inlet, one-exit control volume at steady state

$$0 = \dot{m}_1 - \dot{m}_2 \Rightarrow \dot{m}_1 = \dot{m}_2 = \dot{m}$$

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

Solving for the mass flow rate

$$\dot{m} = \frac{\dot{Q}_{cv} - \dot{W}_{cv}}{(h_2 - h_1)}$$

From Table A-4E, at $p_1 = 500$ lbf/in^2, $T_1 = 800$°F; $h_1 = 1412.1$ Btu/lb. From Table A-3E, at $p_2 = 0.8$ lbf/in^2

$$h_2 = h_{f_2} + x_2 h_{fg_2}$$
$$= (62.41) + (0.93)(1040.2) = 1029.80 \text{ Btu/lb}$$

Thus

$$\dot{m} = \frac{(-2.5 \times 10^6 \text{ Btu/h}) - (15{,}000 \text{ hp})\left|\frac{2545 \text{ Btu/h}}{1 \text{ hp}}\right|}{(1029.80 - 1412.1) \text{ Btu/lb}}$$

$$= 10.64 \times 10^4 \text{ lb/h}$$

Then, from Table A-4E at p_1 and T_1; $v_1 = 1.441$ ft^3/lb. The volume flow rate at the inlet is then

$$(AV)_1 = \dot{m} v_1 = \left(10.64 \times 10^4 \frac{\text{lb}}{\text{h}}\right)\left(1.441 \frac{\text{ft}^3}{\text{lb}}\right)$$

$$= 1.53 \times 10^5 \text{ ft}^3/\text{h} \longleftarrow (AV)_1$$