PROBLEM 6.86

Figure P6.86 provides steady-state operating data for a well-insulated device having steam entering at one location and exiting at another. Neglecting kinetic and potential energy effects, determine (a) the direction of flow and (b) the power output or input, as appropriate, in kJ per kg of steam flowing.

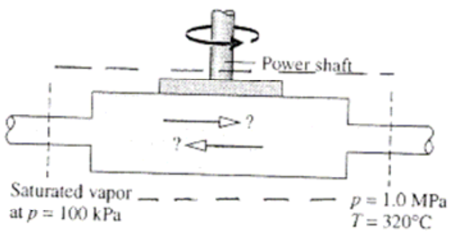


Fig. P6.86

ENGR. MODEL:

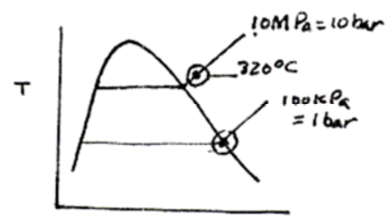
1. The control volume shown in the sketch is at steady state.
2. For the control volume, $\dot{Q}_{cv}=0$ and kinetic and potential energy effects can be neglected.

ANALYSIS: As discussed in Secs. 5.1 and 6.8, directionality normally can be established using the 2nd law. Here, a direction is assumed and the associated entropy production is evaluated. To begin, property data are found:

Table A-4: saturated vapor at 100 kPa: $h = 2675.5$ kJ/kg, $s = 7.3594$ kJ/kg·K
$p = 1.0$ MPa, 320°C: $h = 3093.9$ kJ/kg, $s = 7.1962$ kJ/kg·K

Taking the inlet as the saturated vapor at 100 kPa, an entropy rate balance gives

$$\frac{dS}{dt}^{0} = \sum \frac{\dot{Q}_j}{T_j}^{0} + \dot{m}(s_{in} - s_{out}) + \dot{\sigma}_{cv}$$



$$\Rightarrow \quad \frac{\dot{\sigma}_{cv}}{\dot{m}} = s_{out} - s_{in}$$

$$= (7.1962 - 7.3594)\frac{kJ}{kg \cdot K} = -0.1632 \frac{kJ}{kg \cdot K}$$

As $\dot{\sigma}_{cv}/\dot{m}$ must be ≥ 0, the direction of flow must be opposite to that assumed: from 1.0 MPa, 320°C to saturated vapor at 100 kPa. ← (a)

Then, an energy rate balance reads,

$$\frac{dE}{dt}^{0} = \dot{Q}_{cv}^{0} - \dot{W}_{cv} + \dot{m}(h_{in} - h_{out})$$

$$\Rightarrow \quad \frac{\dot{W}_{cv}}{\dot{m}} = h_{in} - h_{out}$$

$$= (3093.9 - 2675.5)\frac{kJ}{kg}$$

$$= 418.4 \text{ kJ/kg}$$ ← (b)