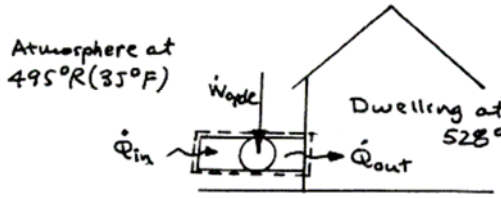
PROBLEM 5.54

KNOWN: A heat pump provides heating to a dwelling. Operating data are provided.

FIND: Determine the actual operating cost and compare with the minimum theoretical operating cost for each day of operation.

SCHEMATIC & GIVEN DATA:



$\dot{Q}_{out} = 30{,}000$ Btu/h

$\dot{W}_{cycle} = 5$ hp

ENGR. MODEL: (1) The system shown in the figure undergoes a heat pump cycle. (2) All data are for operation at steady state. (3) The atmosphere and the dwelling play the roles of cold and hot reservoirs, respectively. (4) The cost of electricity is 8 cents per kW·h.

ANALYSIS: Using given data, the actual operating cost is

$$\left(\text{Cost per day}\right) = (5\,\text{hp})\left|\frac{1\,\text{kW}}{1.341\,\text{hp}}\right|\left|\frac{24\,\text{h}}{1\,\text{day}}\right|\left(\frac{0.08\,\$}{\text{kW}\cdot\text{h}}\right) = \$7.16/\text{day}$$

The minimum theoretical operating cost corresponds to the minimum theoretical power requirement. Since $\beta < \beta_{MAX}$,

$$\rightarrow \quad \frac{\dot{Q}_{out}}{\dot{W}_{cycle}} \leq \frac{T_H}{T_H - T_C}$$

or

$$\frac{30{,}000\,\text{Btu/h}}{\dot{W}_{cycle}} \leq \frac{528\,^\circ\text{R}}{(528-495)\,^\circ\text{R}} = 16$$

$$\rightarrow \quad \frac{30{,}000\,\text{Btu/h}}{16} \leq \dot{W}_{cycle}$$

$$1875\,\frac{\text{Btu}}{\text{h}} \leq \dot{W}_{cycle}$$

The minimum cost is then

$$\left(\text{minimum cost per day}\right) = \left(1875\,\frac{\text{Btu}}{\text{h}}\right)\left(\frac{1\,\text{kW}}{3413\,\text{Btu/h}}\right)\left(\frac{24\,\text{h}}{1\,\text{day}}\right)\left(\frac{0.08\,\$}{\text{kW}\cdot\text{h}}\right)$$

$$= \$1.05/\text{day}$$

The actual operating cost is about 7 times higher than the minimum theoretical cost.