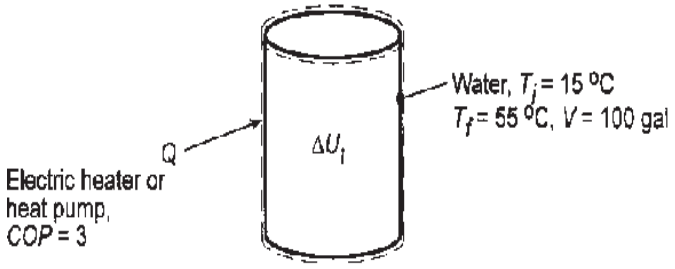
PROBLEM 1.48

KNOWN: Daily hot water consumption for a family of four and temperatures associated with ground water and water storage tank. Unit cost of electric power. Heat pump COP.

FIND: Annual heating requirement and costs associated with using electric resistance heating or a heat pump.

SCHEMATIC:



ASSUMPTIONS: (1) Process may be modeled as one involving heat addition in a closed system, (2) Properties of water are constant.

PROPERTIES: Table A-6, Water (T_{avg} = 308 K): $\rho = v_f^{-1}$ = 993 kg/m^3, $c_{p,f}$ = 4.178 kJ/kg·K.

ANALYSIS: From Eq. 1.12a, the daily heating requirement is $Q_{daily} = \Delta U_t = Mc\Delta T$ $= \rho Vc\left(T_f - T_i\right)$. With V = 100 gal/264.17 gal/m^3 = 0.379 m^3,

$$Q_{daily} = 993\text{kg/m}^3\left(0.379\,\text{m}^3\right)4.178\text{kJ/kg}\cdot\text{K}\left(40^\circ\text{C}\right) = 62,900\,\text{kJ}$$

The annual heating requirement is then, $Q_{annual} = 365\,\text{days}\left(62,900\,\text{kJ/day}\right) = 2.30\times10^7$ kJ , or, with 1 kWh = 1 kJ/s (3600 s) = 3600 kJ,

$$Q_{annual} = 6380\,\text{kWh} \quad <$$

With electric resistance heating, $Q_{annual} = Q_{elec}$ and the associated cost, C, is

$$C = 6380\,\text{kWh}\left(\$0.18/\text{kWh}\right) = \$1150 \quad <$$

If a heat pump is used, $Q_{annual} = \text{COP}\left(W_{elec}\right)$. Hence,

$$W_{elec} = Q_{annual}/\left(\text{COP}\right) = 6380\text{kWh}/\left(3\right) = 2130\,\text{kWh}$$

The corresponding cost is

$$C = 2130\,\text{kWh}\left(\$0.18/\text{kWh}\right) = \$383 \quad <$$

COMMENTS: Although annual operating costs are significantly lower for a heat pump, corresponding capital costs are higher. The feasibility of this approach depends on other factors such as geography and seasonal variations in COP, as well as the time value of money.