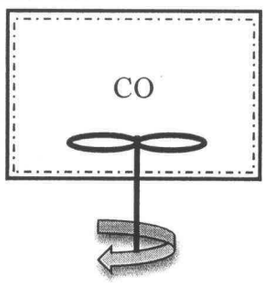
PROBLEM 2.64

Known: Carbon monoxide (CO) is contained in a rigid tank with a paddle wheel that transfers energy to the air at a constant rate of 14 W for 1 h. During the process, the specific internal energy of the carbon monoxide increases.

Find: Determine the specific volume at the final state, in m^3/kg; the energy transfer by work, in kJ; and the energy transfer by heat transfer, in kJ, with direction.

Schematic and Given Data:

$V = 1\ m^3$
$m = 4\ kg$
$\Delta u = 10\ kJ/kg$
$\dot{W} = -14\ W$
$\Delta t = 1\ h$



Engineering Model:
(1) The carbon monoxide within the tank is the closed system.
(2) The tank is rigid, therefore $V_1 = V_2$.
(3) The system experiences no change in potential and kinetic energy.

Analysis:

(a) The mass and volume remain constant in the process due to assumptions (1) and (2), therefore

$$v = \frac{V}{m} = \frac{1\ m^3}{4\ kg} = 0.25 \frac{m^3}{kg}$$ ←

(b) To evaluate W, in kJ, integrate the following

$$\int_0^{1\,h} \dot{W} dt = \int_0^{1\,h} (-14\ W) dt = (-14\ W)(1\ h) \left| \frac{3600\ s}{1\ h} \right| \left| \frac{1 \frac{J}{s}}{1\ W} \right| \left| \frac{1\ kJ}{1000\ J} \right| = -50.4\ kJ$$ ←

The minus sign for W indicates that energy is added to the system by work, as expected.

(c) To evaluate Q, in kJ, use the closed system energy balance

$$\Delta KE + \Delta PE + \Delta U = Q - W$$

$$Q = \Delta U + W = m\Delta u + W = (4\ kg)\left(10 \frac{kJ}{kg}\right) + (-50.4\ kJ) = -10.4\ kJ$$ ←

Energy is removed from the system through heat transfer. ←