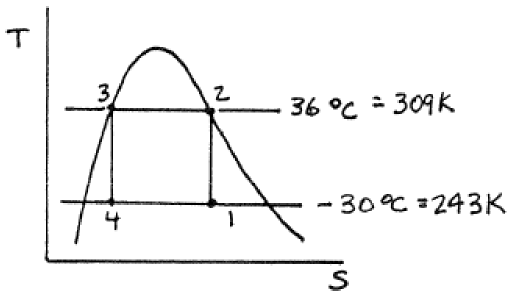
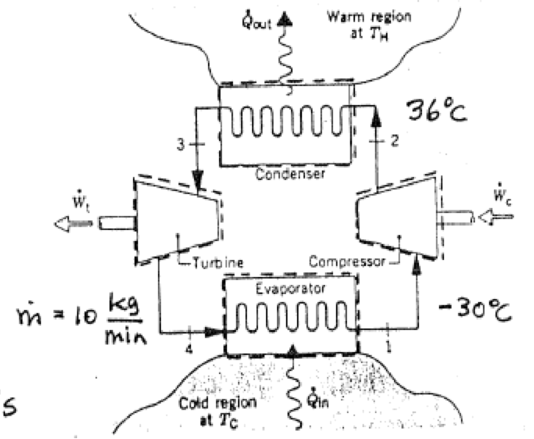
PROBLEM 10.2

KNOWN: Refrigerant 22 is the working fluid in a Carnot vapor refrigration cycle. Data are known at various locations and the mass flow rate is specified.

FIND: Determine (a) the rate of heat transfer to the R-22 passing through the evaporator, (b) the net power input, (c) the coefficient of performance, and (d) the refrigerating capacity.

SCHEMATIC & GIVEN DATA:





ENGINEERING MODEL: (1) Each component is analyzed as a control volume at steady state. (2) All processes of the R-22 are internally reversible. (3) The compression and expansion are adiabatic. (4) Kinetic and potential energy effects are negligible.

ANALYSIS: First, fix each of the principal states (Table A-7).

State 2 $T_2 = 36°C$, sat. vapor $\Rightarrow h_2 = 260.11$ kJ/kg, $s_2 = 0.8790$ kJ/kg·K

State 1 $T_1 = -30°C$, $s_2 = s_1 \Rightarrow x_1 = 0.8931$; $h_1 = 213.53$ kJ/kg

State 3 $T_3 = 36°C$, sat. liquid $\Rightarrow h_3 = 89.29$ kJ/kg, $s_3 = 0.3265$ kJ/kg·K

State 4 $T_4 = -30°C$, $s_4 = s_3 \Rightarrow x_4 = 0.3007$; $h_4 = 79.19$ kJ/kg

(a) For the evaporator

$$\dot{Q}_{in} = \dot{m}(h_1 - h_4) = \left(10 \frac{kg}{min}\right)(213.53 - 79.19)\frac{kJ}{kg}\left|\frac{1\ min}{60\ s}\right|\left|\frac{1\ kW}{1\ kJ/s}\right| = 22.39\ kW \longleftarrow \dot{Q}_{in}$$

(b) The net power input is

$$\dot{W}_{cycle} = \dot{W}_c - \dot{W}_t = \dot{m}\left[(h_2 - h_1) - (h_3 - h_4)\right]$$

$$= (10)\left[(260.11 - 213.53) - (89.29 - 79.19)\right]\left|\frac{1}{60}\right| = 6.08\ kW \longleftarrow \dot{W}_{cycle}$$

(c) The coefficient of performance is

① $$\beta = \frac{\dot{Q}_{in}}{\dot{W}_{cycle}} = \frac{22.39}{6.08} = 3.68 \longleftarrow \beta$$

(d) The refrigerating capacity is

$$\text{refrig. capacity} = \dot{Q}_{in} = 22.39\ kW\left|\frac{1\ kJ/s}{1\ kW}\right|\left|\frac{60\ s}{1\ min}\right|\left|\frac{1\ ton}{211\ kJ/min}\right|$$

$$= 6.37\ tons \longleftarrow \text{refrigerating capacity}$$

1. Alternatively $\beta = T_C/(T_H - T_C) = 243/(309 - 243) = 3.68$