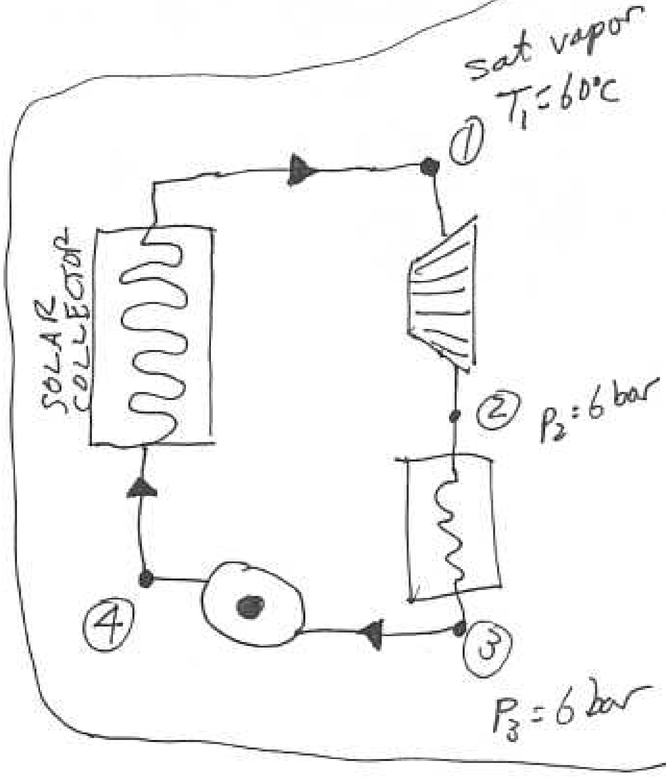
8.13 Given R-134a, Rankine cycle
state ① is sat. vapor



$\dot{Q}_{boiler} = 0.4 \frac{kW}{m^2} \cdot A_{collector}$

Find: Minimum possible $A_{collector}$ per kW of power developed

States

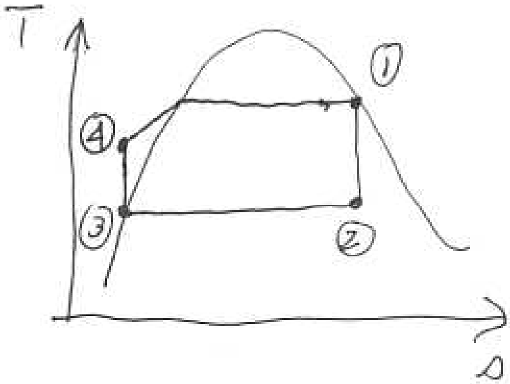
① $T_1 = 60°C$; sat. → $p_1 = 16.8$ bar
$h_1 = 276$ kJ/kg $s_1 = .897$ kJ/kg·K

② $s_2 = s_1 = 0.897$ kJ/kg·K
$P_2 = 6$ bar ⇐ saturated

$s_2 = (1-x)s_f + x s_g = (1-x_2)(.2999 \frac{kJ}{kg \cdot K}) + x_2(.9097 \text{ kJ/kg·K})$

$x_2 = 0.979$

$h_2 = (1-x)h_f + x h_g = 255.4$ kJ/kg



③ $h_3 = h_f(p = 6 \text{ bar}) = 79.48$ kJ/kg
$s_3 = s_f(p = 6 \text{ bar}) = 0.2999$ kJ/kg·K

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④ $s_4 = s_3 = 0.2999$ kJ/kg·K
$P_4 = 16.8$ bar
$h_4 = h_f$

} subcooled liquid, but no subcooled table. Also, don't know T_4.
Use TdS equation

$T ds = dh - v dp \Rightarrow dh = v dp$ (ds = 0)

$h_4 - h_3 = v_3 (P_4 - P_3)$ ← constant, assuming incompressible liquid.

$h_4 = h_3 + v_3(P_4 - P_3)$

$h_4 = (79.48 \frac{kJ}{kg}) + (.8196 \times 10^{-3} \text{ m}^3/\text{kg})(16.8 \times 10^2 \text{ kPa} - 600 \text{ kPa})$

8.13 continued

$h_4 = 80.4$ kJ/kg

$$\frac{\dot{Q}_{boiler}}{\dot{m}} = h_1 - h_4 = 195.6 \text{ kJ/kg}$$

$$\frac{\dot{W}_{net}}{\dot{m}} = (h_1 - h_2) - (h_4 - h_3) = 19.68 \text{ kJ/kg}$$

For each kW of net power developed, the mass flow rate is:

$$\dot{m} = (1 \text{ kW}) / 19.68 \text{ kJ/kg} = .051 \text{ kg/s}$$

Hence, for each kW of power developed the boiler heat transfer rate is:

$$\dot{Q}_{boiler} = (.051 \text{ kg/s})(195.6 \text{ kJ/kg}) = 9.94 \text{ kW}$$

The collector area is: $\left(0.4 \frac{kW}{m^2}\right) A_{collector} = 9.94 \text{ kW}$

$$\boxed{A_{collector} = 24.9 \text{ m}^2}$$

This is a minimum because we considered an ideal Rankine cycle (e.g. isentropic pumps/turbines, etc...).