



"GIVEN: An ideal Rankine Cycle with superheat as shown"

```
s$ = 'steam_iapws'
P[1] = 1600[psia]
T[1] = 1100[F]
P[2] = 1[psia]
P[3] = P[2]
x[3] = 0
P[4] = P[1]
T_5 = 60[F]
T_6 = 80[F]
m_dot = 1.4E6[lbm/hr]
```

"FIND:

- (a) The net power developed (hp)
- (b) The thermal efficiency of the cycle
- (c) The heat rate of the cycle
- (d) The back work ratio of the cycle
- (e) The mass flow rate of the cooling water (lbm/hr)"

"SOLUTION:"

"Start by building the property table"

"!State 1 is defined from the given pressure and temperature."

```
h[1] = enthalpy(s$,P=P[1],T=T[1])
s[1] = entropy(s$,P=P[1],T=T[1])
x[1] = quality(s$, P=P[1], T=T[1])
```

"!State 2 (Ideal) is defined from the given pressure and knowing that the entropy is the same as state 1."

```
s[2] = s[1]
h[2] = enthalpy(s$,P=P[2],s=s[2])
T[2] = temperature(s$, P=P[2], s=s[2])
x[2] = quality(s$, P=P[2], s=s[2])
```

"!State 3 is defined from the given pressure and quality"

```
h[3] = enthalpy(s$,P=P[3],x=x[3])
T[3] = temperature(s$, P=P[3], x=x[3])
s[3] = entropy(s$,P=P[3],x=x[3])
```

"!State 4 (Ideal) is defined from the given pressure and knowing that the entropy is the same as state 3."

```
s[4] = s[3]
h[4] = enthalpy(s$,P=P[4],s=s[4])
T[4] = temperature(s$, P=P[4], s=s[4])
x[4] = quality(s$, P=P[4], s=s[4])
```

"Now that property table is built, apply First Law to each component"

"Turbine"

```
W_dot_t*convert(hp,Btu/hr) = m_dot*(h[1] - h[2])
```

"Boiler"

```
Q_dot_in = m_dot*(h[1] - h[4])
```

"Pump,"

```
W_dot_p*convert(hp,Btu/hr) = m_dot*(h[4] - h[3])
```

"Condensor"

```
Q_dot_out = m_dot*(h[2] - h[3])
```

"!Calculating Parameters for the Rankine Cycle with Superheat"

"The thermal efficiency of the cycle is defined as,"

```
eta_th = W_dot_net*convert(hp,Btu/hr)/Q_dot_in
```

"The heat rate (HR) is defined as,"

```
HR = Q_dot_in/(W_dot_net*convert(hp,kW))
```

"The back work ratio (bwr) is defined as,"

```
bwr = W_dot_p/W_dot_t
```

"Mass flow rate of the cooling water"

"To determine the cooling water flow rate, draw a system boundary that keeps the heat transferred between the condensing steam and the cooling water all internal. The First Law applied to this system is,"

$$Q_{\dot{\text{out}}} = m_{\dot{\text{w}}} \cdot c_{\text{p,w}} \cdot (T_6 - T_5)$$

"The heat capacity of the liquid can be estimated as the saturated liquid value at the average temperature"

$$T_{\text{avg}} = (T_5 + T_6)/2$$

$$c_{\text{p,w}} = \text{cp}(s\$, T=T_{\text{avg}}, x=0)$$

"!Net power delivery from the cycle"

"The net power developed by the cycle is,"

$$W_{\dot{\text{net}}} = W_{\dot{\text{t}}} - W_{\dot{\text{p}}}$$

"Calculate the Carnot Efficiency,"

$$\eta_{\text{Carnot}} = 1 - T_{\text{L}}/T_{\text{H}}$$

$$T_{\text{L}} = \text{converttemp}(F, R, T_{\text{sat}}(s\$, P=P[2]))$$

$$T_{\text{H}} = \text{converttemp}(F, R, T[1])$$

SOLUTION

Unit Settings: Eng F psia mass deg

$$\text{bwr} = 0.007483 \text{ [dim]}$$

$$\eta_{\text{Carnot}} = 0.6401 \text{ [dim]}$$

$$\text{HR} = 7957 \text{ [Btu/kW-hr]}$$

$$\dot{m}_{\text{w}} = 5.896\text{E}+07 \text{ [lbm/hr]}$$

$$\dot{Q}_{\text{out}} = 1.178\text{E}+09 \text{ [Btu/hr]}$$

$$T_5 = 60 \text{ [F]}$$

$$T_{\text{avg}} = 70 \text{ [F]}$$

$$T_{\text{L}} = 561.4 \text{ [R]}$$

$$\dot{W}_{\text{p}} = 2621 \text{ [hp]} \{6.669\text{E}+06 \text{ [Btu/hr]}\}$$

$$c_{\text{p,w}} = 0.9992 \text{ [Btu/lbm-R]}$$

$$\eta_{\text{th}} = 0.4288 \text{ [dim]}$$

$$\dot{m} = 1.400\text{E}+06 \text{ [lbm/hr]}$$

$$\dot{Q}_{\text{in}} = 2.063\text{E}+09 \text{ [Btu/hr]}$$

$$s\$ = \text{'steam_iapws'}$$

$$T_6 = 80 \text{ [F]}$$

$$T_{\text{H}} = 1560 \text{ [R]}$$

$$\dot{W}_{\text{net}} = 347635 \text{ [hp]} \{8.845\text{E}+08 \text{ [Btu/hr]}\}$$

$$\dot{W}_{\text{t}} = 350256 \text{ [hp]} \{8.912\text{E}+08 \text{ [Btu/hr]}\}$$

No unit problems were detected.

KEY VARIABLES

$$\dot{W}_{\text{t}} = 350256 \text{ [hp]} \{8.912\text{E}+08 \text{ [Btu/hr]}\} \text{ Total turbine power delivery}$$

$$\dot{m} = 1.400\text{E}+06 \text{ [lbm/hr]} \text{ Mass flow rate of steam in the cycle}$$

$$\dot{W}_{\text{p}} = 2621 \text{ [hp]} \{6.669\text{E}+06 \text{ [Btu/hr]}\} \text{ Pump power required}$$

$$\dot{W}_{\text{net}} = 347635 \text{ [hp]} \{8.845\text{E}+08 \text{ [Btu/hr]}\} \text{ Net power delivery from the cycle}$$

$$\dot{Q}_{\text{in}} = 2.063\text{E}+09 \text{ [Btu/hr]} \text{ Heat transfer rate at the boiler}$$

$$\eta_{\text{th}} = 0.4288 \text{ [dim]} \text{ Thermal efficiency of the cycle}$$

$$\text{HR} = 7957 \text{ [Btu/kW-hr]} \text{ Heat rate of the cycle}$$

$$\text{bwr} = 0.007483 \text{ [dim]} \text{ Back work ratio of the cycle}$$

$$\dot{m}_{\text{w}} = 5.896\text{E}+07 \text{ [lbm/hr]} \text{ Mass flow rate of cooling water}$$

Arrays Table: Main

	P_i [psia]	T_i [F]	h_i [Btu/lbm]	s_i [Btu/lbm-F]	x_i
1	1600	1100	1548	1.632	100
2	1	101.7	911.4	1.632	0.8126
3	1	101.7	69.72	0.1326	0

Arrays Table: Main

	P_i [psia]	T_i [F]	h_i [Btu/lbm]	s_i [Btu/lbm-F]	x_i
4	1600	102.3	74.49	0.1326	-100



