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LOOP 1

$w\$ = \text{'Steam}_{IAPWS}\text{'}$

Evaporative Cooling Towers

Dead State

$h_0 = 27.36$ [Btu/lb$_m$] *Place Holder*

State 1

$h_1 = 40$ [Btu/lb$_m$] *Place Holder*

State 2

$h_2 = 40$ [Btu/lb$_m$] *Place Holder*

State 9

$$h_9 = \frac{h_7 + h_8}{2}$$

$$P_9 = \frac{P_7 + P_8}{2}$$

$$T_9 = \frac{T_7 + T_8}{2}$$

$$x_9 = \frac{x_7 + x_8}{2}$$

Cooling Tower 1

$$\dot{Q}_{CT1} = \dot{m}_{1,CT1} \cdot [h_0 - h_1]$$

$$\dot{Q}_{CT1} = \frac{\dot{m}_1}{2} \cdot [h_9 - h_3]$$

Cooling Tower 2

$$\dot{Q}_{CT2} = \dot{m}_{1,CT2} \cdot [h_0 - h_2]$$

$$\dot{Q}_{CT2} = \frac{\dot{m}_1}{2} \cdot [h_9 - h_4]$$

Chiller One

CTP 1

$$\dot{W}_{CTP,1} = 18.99 \text{ [kW]} \cdot \left| 3412 \cdot \frac{\text{Btu/hr}}{\text{kW}} \right|$$

$$\dot{W}_{CTP,1} = \dot{m}_{1,ch1} \cdot [h_5 - h_3]$$

Condenser Chiller One

$\dot{Q}_{Cond,ch1} = \dot{m}_{1,ch1} \cdot [h_7 - h_5]$

State 3

$x_3 = 0$ *Assumption*

$P_3 = \mathbf{P}[w\$, h = h_3, x = x_3]$

$T_3 = \mathbf{T}[w\$, h = h_3, x = x_3]$

State 5

$T_5 = 72.3$ [F]

$x_5 = 0$ *Assumption*

$P_5 = \mathbf{P}[w\$, T = T_5, x = x_5]$

$h_5 = \mathbf{h}[w\$, T = T_5, x = x_5]$

State 7

$P_7 = \mathbf{P}[w\$, T = T_7, x = x_7]$

$T_7 = 81$ [F]

$x_7 = 0$

$h_7 = \mathbf{h}[w\$, T = T_7, x = x_7]$

Chiller Two

CTP 2

$\dot{W}_{CTP,2} = 18.99$ [kW] $\cdot \left| 3412 \cdot \frac{\text{Btu/hr}}{\text{kW}} \right|$

$\dot{W}_{CTP,2} = \dot{m}_{1,ch2} \cdot [h_6 - h_4]$

Condenser Chiller Two

$\dot{Q}_{Cond,ch2} = \dot{m}_{1,ch2} \cdot [h_8 - h_6]$

State 4

$x_4 = 0$ *Assumption*

$P_4 = \mathbf{P}[w\$, h = h_4, x = x_4]$

$T_4 = \mathbf{T}[w\$, h = h_4, x = x_4]$

State 6

$T_6 = 72.3$ [F]

$x_6 = 0$ *Assumption*

$P_6 = \mathbf{P}[w\$, T = T_6, x = x_6]$

$h_6 = \mathbf{h}[w\$, T = T_6, x = x_6]$

State 8

$P_8 = \mathbf{P}[w\$, T = T_8, x = x_8]$

$T_8 = 81$ [F]

$x_8 = 0$

$h_8 = \mathbf{h}[w\$, T = T_8, x = x_8]$

Mass Flow Rate Loop 1

$\dot{m}_1 = \dot{m}_{1,ch1} + \dot{m}_{1,ch2}$

First Law of Loop 1

$\dot{Q}_{Cond,ch1} + \dot{Q}_{Cond,ch2} + \dot{W}_{CTP,1} + \dot{W}_{CTP,2} = \dot{Q}_{CT1} + \dot{Q}_{CT2}$

LOOP 2

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r$ = 'R134A'

Chiller One

Compressor 1

$\dot{W}_{c1} = 57.8$ [kW] $\cdot \left| 3412 \cdot \frac{\text{Btu/hr}}{\text{kW}} \right|$

$P_{15} = 35$ [psia]

$T_{15} = 33.2$ [F]

$P_{14} = 97.2$ [psia]

$T_{14} = 97.1$ [F]

$h_{15} = \mathbf{h}[r\$, P = P_{15}, T = T_{15}]$

$h_{14} = \mathbf{h}[r\$, P = P_{14}, T = T_{14}]$

$\dot{W}_{c1} = \dot{m}_{c1} \cdot [h_{14} - h_{15}]$

Compressor 2

$\dot{W}_{c2} = 57.8$ [kW] $\cdot \left| 3412 \cdot \frac{\text{Btu/hr}}{\text{kW}} \right|$

$P_{17} = 34.7$ [psia]

$T_{17} = 35$ [F]

$P_{16} = 98.1$ [psia]

$T_{16} = 96.7$ [F]

$h_{17} = \mathbf{h}[r\$, P = P_{17}, T = T_{17}]$

$h_{16} = \mathbf{h}[r\$, P = P_{16}, T = T_{16}]$

$\dot{W}_{c2} = \dot{m}_{c2} \cdot [h_{16} - h_{17}]$

Compressor 3

$\dot{W}_{c3} = 60.3$ [kW] $\cdot \left| 3412 \cdot \frac{\text{Btu/hr}}{\text{kW}} \right|$

$P_{19} = 35.3$ [psia]

$T_{19} = 33.2$ [F]

$P_{18} = 100.9$ [psia]

$T_{18} = 97.4$ [F]

$h_{19} = \mathbf{h}[r\$, P = P_{19}, T = T_{19}]$

$h_{18} = \mathbf{h}[r\$, P = P_{18}, T = T_{18}]$

$\dot{W}_{c3} = \dot{m}_{c3} \cdot [h_{18} - h_{19}]$

Compressor 4

$\dot{W}_{c4} = 58.3$ [kW] $\cdot \left| 3412 \cdot \frac{\text{Btu/hr}}{\text{kW}} \right|$

$P_{21} = 35.5$ [psia]

$T_{21} = 33.8$ [F]

$P_{20} = 98.8$ [psia]

$T_{20} = 96.6$ [F]

$h_{21} = \mathbf{h}[r\$, P = P_{21}, T = T_{21}]$

$h_{20} = \mathbf{h}[r\$, P = P_{20}, T = T_{20}]$

$\dot{W}_{c4} = \dot{m}_{c4} \cdot [h_{20} - h_{21}]$

Mass Flow Rate Chiller One

$\dot{m}_{2,ch1} = \mathbf{Sum}[\dot{m}_{c1}, \dot{m}_{c2}, \dot{m}_{c3}, \dot{m}_{c3}]$

$$f_{c1} = \frac{\dot{m}_{c1}}{\dot{m}_{2,ch1}}$$

$$f_{c2} = \frac{\dot{m}_{c2}}{\dot{m}_{2,ch1}}$$

$$f_{c3} = \frac{\dot{m}_{c3}}{\dot{m}_{2,ch1}}$$

$$f_{c4} = \frac{\dot{m}_{c4}}{\dot{m}_{2,ch1}}$$

State 10

$P_{10} = f_{c1} \cdot P_{14} + f_{c2} \cdot P_{16} + f_{c3} \cdot P_{18} + f_{c4} \cdot P_{20}$ *Assumption*

$T_{10} = f_{c1} \cdot T_{14} + f_{c2} \cdot T_{16} + f_{c3} \cdot T_{18} + f_{c4} \cdot T_{20}$ *Assumption*

$h_{10} = \mathbf{h}[r\$, P = P_{10}, T = T_{10}]$

$x_{10} = \mathbf{x}[r\$, P = P_{10}, T = T_{10}]$

State 11

$P_{11} = P_{10}$

$T_{11} = \mathbf{T}[r\$, P = P_{11}, h = h_{11}]$

$x_{11} = \mathbf{x}[r\$, P = P_{11}, h = h_{11}]$

State 12

$P_{12} = P_{13}$

$T_{12} = \mathbf{T}[r\$, P = P_{12}, h = h_{12}]$

$x_{12} = \mathbf{x}[r\$, P = P_{12}, h = h_{12}]$

State 13

$P_{13} = f_{c1} \cdot P_{15} + f_{c2} \cdot P_{17} + f_{c3} \cdot P_{19} + f_{c4} \cdot P_{21}$ *Assumption*

$T_{13} = f_{c1} \cdot T_{15} + f_{c2} \cdot T_{17} + f_{c3} \cdot T_{19} + f_{c4} \cdot T_{21}$ *Assumption*

$h_{13} = \mathbf{h}[r\$, P = P_{13}, T = T_{13}]$

$x_{13} = \mathbf{x}[r\$, P = P_{13}, T = T_{13}]$

Evaporator Chiller One

$\dot{Q}_{Evap,ch1} = \dot{m}_{2,ch1} \cdot [h_{13} - h_{12}]$

Condenser Chiller One

$\dot{Q}_{Cond,ch1} = \dot{m}_{2,ch1} \cdot [h_{10} - h_{11}]$

First Law of Loop 2 Chiller One

$$\dot{Q}_{Evap,ch1} = \dot{Q}_{Cond,ch1} - [\dot{W}_{c1} + \dot{W}_{c2} + \dot{W}_{c3} + \dot{W}_{c4}]$$

Chiller Two

Compressor 5- Change P/T

$$\dot{W}_{c5} = 62.3 \text{ [kW]} \cdot \left| 3412 \cdot \frac{\text{Btu/hr}}{\text{kW}} \right|$$

$P_{27} = 33.8$ [psia]

$T_{27} = 34.7$ [F]

$P_{26} = 97.7$ [psia]

$T_{26} = 98.2$ [F]

$h_{27} = \mathbf{h}[r\$, P = P_{27}, T = T_{27}]$

$h_{26} = \mathbf{h}[r\$, P = P_{26}, T = T_{26}]$

$\dot{W}_{c5} = \dot{m}_{c5} \cdot [h_{26} - h_{27}]$

Compressor 6- Change P/T

$$\dot{W}_{c6} = 61.4 \text{ [kW]} \cdot \left| 3412 \cdot \frac{\text{Btu/hr}}{\text{kW}} \right|$$

$P_{29} = 34.7$ [psia]

$T_{29} = 31.5$ [F]

$P_{28} = 97.5$ [psia]

$T_{28} = 97.9$ [F]

$h_{29} = \mathbf{h}[r\$, P = P_{29}, T = T_{29}]$

$h_{28} = \mathbf{h}[r\$, P = P_{28}, T = T_{28}]$

$\dot{W}_{c6} = \dot{m}_{c6} \cdot [h_{28} - h_{29}]$

Compressor 7- Change P/T

$$\dot{W}_{c7} = 64.1 \text{ [kW]} \cdot \left| 3412 \cdot \frac{\text{Btu/hr}}{\text{kW}} \right|$$

$P_{31} = 35$ [psia]

$T_{31} = 34.1$ [F]

$P_{30} = 100.8$ [psia]

$T_{30} = 98$ [F]

$h_{31} = \mathbf{h}[r\$, P = P_{31}, T = T_{31}]$

$h_{30} = \mathbf{h}[r\$, P = P_{30}, T = T_{30}]$

$\dot{W}_{c7} = \dot{m}_{c7} \cdot [h_{30} - h_{31}]$

Compressor 8- Change P/T

$\dot{W}_{c8} = 62.7$ [kW] $\cdot \left| 3412 \cdot \frac{\text{Btu/hr}}{\text{kW}} \right|$

$P_{33} = 34.6$ [psia]

$T_{33} = 34.8$ [F]

$P_{32} = 98.9$ [psia]

$T_{32} = 98.2$ [F]

$h_{33} = \mathbf{h}[r\$, P = P_{33}, T = T_{33}]$

$h_{32} = \mathbf{h}[r\$, P = P_{32}, T = T_{32}]$

$\dot{W}_{c8} = \dot{m}_{c8} \cdot [h_{32} - h_{33}]$

Mass Flow Rate Chiller Two

$\dot{m}_{2,ch2} = \mathbf{Sum}[\dot{m}_{c5}, \dot{m}_{c6}, \dot{m}_{c7}, \dot{m}_{c8}]$

$f_{c5} = \frac{\dot{m}_{c5}}{\dot{m}_{2,ch2}}$

$f_{c6} = \frac{\dot{m}_{c6}}{\dot{m}_{2,ch2}}$

$f_{c7} = \frac{\dot{m}_{c7}}{\dot{m}_{2,ch2}}$

$f_{c8} = \frac{\dot{m}_{c8}}{\dot{m}_{2,ch2}}$

State 22

$P_{22} = f_{c5} \cdot P_{26} + f_{c6} \cdot P_{28} + f_{c7} \cdot P_{30} + f_{c8} \cdot P_{32}$ *Assumption*

$T_{22} = f_{c5} \cdot T_{26} + f_{c6} \cdot T_{28} + f_{c7} \cdot T_{30} + f_{c8} \cdot T_{32}$ *Assumption*

$h_{22} = \mathbf{h}[r\$, P = P_{22}, T = T_{22}]$

$x_{22} = \mathbf{x}[r\$, P = P_{22}, T = T_{22}]$

State 23

$P_{23} = P_{22}$

$T_{23} = \mathbf{T}[r\$, P = P_{23}, h = h_{23}]$

$x_{23} = \mathbf{x}[r\$, P = P_{23}, h = h_{23}]$

State 24

$P_{24} = P_{25}$

$T_{24} = \mathbf{T}[r\$, P = P_{24}, h = h_{24}]$

$x_{24} = \mathbf{x}[r\$, P = P_{24}, h = h_{24}]$

State 25

$P_{25} = f_{c5} \cdot P_{27} + f_{c6} \cdot P_{29} + f_{c7} \cdot P_{31} + f_{c8} \cdot P_{33}$ *Assumption*

$T_{25} = f_{c5} \cdot T_{27} + f_{c6} \cdot T_{29} + f_{c7} \cdot T_{31} + f_{c8} \cdot T_{33}$ *Assumption*

$h_{25} = \mathbf{h}[r\$, P = P_{25}, T = T_{25}]$

$x_{25} = \mathbf{x}[r\$, P = P_{25}, T = T_{25}]$

Evaporator Chiller Two

$\dot{Q}_{Evap,ch2} = \dot{m}_{2,ch2} \cdot [h_{25} - h_{24}]$

Condenser Chiller Two

$\dot{Q}_{Cond,ch2} = \dot{m}_{2,ch2} \cdot [h_{22} - h_{23}]$

First Law of Loop 2 Chiller Two

$\dot{Q}_{Evap,ch2} = \dot{Q}_{Cond,ch2} - [\dot{W}_{c5} + \dot{W}_{c6} + \dot{W}_{c7} + \dot{W}_{c8}]$

LOOP 3

Chiller One

Evaporator Chiller One

$\dot{Q}_{Evap,ch1} = \dot{m}_{3,ch1} \cdot [h_{41} - h_{34}]$

State 41

$T_{41} = 54.1$ [F]

$x_{41} = 0$

$Flow_{ch1} = 802$ [GPM] $\cdot \left| 8.021 \cdot \frac{ft^3/hr}{GPM} \right|$

$\rho_{ch1} = \rho[w\$, T = T_{41}, x = x_{41}]$

$\dot{m}_{3,ch1} = Flow_{ch1} \cdot \rho_{ch1}$

$h_{41} = \mathbf{h}[w\$, T = T_{41}, x = x_{41}]$

$P_{41} = \mathbf{P}[w\$, T = T_{41}, x = x_{41}]$

State 34

$T_{34} = 40.9$ [F]

$x_{34} = 0$

$h_{34} = \mathbf{h}[w\$, T = T_{34}, x = x_{34}]$

$P_{34} = \mathbf{P}[w\$, T = T_{34}, x = x_{34}]$

Hours of Operation

Time = 5 [min]

SOLUTION

Unit Settings: Eng F psia mass deg

$Flow_{ch1}$ = 6433 [ft^3/hr]
f_{c2} = 0.2537
f_{c4} = 0.2493
f_{c6} = 0.2324
f_{c8} = 0.2549
$\dot{m}_{1,ch1}$ = 703289 [lb_m/hr]
$\dot{m}_{1,CT1}$ = -488719 [lb_m/hr]
$\dot{m}_{2,ch1}$ = 83797 [lb_m/hr]
$\dot{m}_{3,ch1}$ = 401347 [lb_m/hr]
$\dot{m}_{c2}$ = 21255 [lb_m/hr]
$\dot{m}_{c4}$ = 20889 [lb_m/hr]
$\dot{m}_{c6}$ = 20283 [lb_m/hr]
$\dot{m}_{c8}$ = 22240 [lb_m/hr]
$\dot{Q}_{Cond,ch2}$ = 6.114E+06 [Btu/hr]
$\dot{Q}_{CT2}$ = 6.177E+06 [Btu/hr]
$\dot{Q}_{Evap,ch2}$ = 5.259E+06 [Btu/hr] {438.2 [Ton]}
ρ_{ch1} = 62.39 [lb_m/ft^3]
w$ = 'Steam_IAPWS'
$\dot{W}_{c2}$ = 197222 [Btu/hr]
$\dot{W}_{c4}$ = 198928 [Btu/hr]
$\dot{W}_{c6}$ = 209505 [Btu/hr]
$\dot{W}_{c8}$ = 213941 [Btu/hr]
$\dot{W}_{CTP,2}$ = 64797 [Btu/hr]

f_{c1} = 0.2394
f_{c3} = 0.2535
f_{c5} = 0.2524
f_{c7} = 0.2603
$\dot{m}_1$ = 1.407E+06 [lb_m/hr]
$\dot{m}_{1,ch2}$ = 703534 [lb_m/hr]
$\dot{m}_{1,CT2}$ = -488717 [lb_m/hr]
$\dot{m}_{2,ch2}$ = 87265 [lb_m/hr]
$\dot{m}_{c1}$ = 20065 [lb_m/hr]
$\dot{m}_{c3}$ = 21238 [lb_m/hr]
$\dot{m}_{c5}$ = 22023 [lb_m/hr]
$\dot{m}_{c7}$ = 22719 [lb_m/hr]
$\dot{Q}_{Cond,ch1}$ = 6.112E+06 [Btu/hr]
$\dot{Q}_{CT1}$ = 6.177E+06 [Btu/hr]
$\dot{Q}_{Evap,ch1}$ = 5.312E+06 [Btu/hr] {442.7 [Ton]}
r$ = 'R134A'
Time = 5 [min]
$\dot{W}_{c1}$ = 197222 [Btu/hr]
$\dot{W}_{c3}$ = 205752 [Btu/hr]
$\dot{W}_{c5}$ = 212576 [Btu/hr]
$\dot{W}_{c7}$ = 218718 [Btu/hr]
$\dot{W}_{CTP,1}$ = 64797 [Btu/hr]

No unit problems were detected.

KEY VARIABLES

$\dot{Q}_{Evap,ch1}$ = 5.312E+06 [Btu/hr] {442.7 [Ton]} *Predicted Chilling Capacity*
$\dot{Q}_{Evap,ch2}$ = 5.259E+06 [Btu/hr] {438.2 [Ton]} *Predicted Chilling Capacity*

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Arrays Table: Main

	h_i [Btu/lb$_m$]	P_i [psia]	T_i [F]	x_i
0	27.36			
1	40			
2	40			
3	40.28	0.3916	72.21	0
4	40.28	0.3916	72.21	0
5	40.37	0.3929	72.3	0
6	40.37	0.3929	72.3	0
7	49.06	0.5243	81	0
8	49.06	0.5243	81	0
9	49.06	0.5243	81	0
10	118.2	98.36	96.55	100
11	45.25	98.36	78.12	0.1014
12	45.26	34.98	22.54	0.2985
13	108.7	34.98	33.67	100
14	118.4	97.2	97.1	
15	108.6	35	33.2	
16	118.2	98.1	96.7	
17	109	34.7	35	
18	118.2	100.9	97.4	
19	108.5	35.3	33.2	
20	118.2	98.8	96.6	
21	108.6	35.5	33.8	
22	118.5	98.77	98.08	100
23	48.46	98.77	78.37	0.1426
24	48.46	34.53	21.92	0.3371
25	108.7	34.53	33.83	100
26	118.6	97.7	98.2	
27	109	33.8	34.7	
28	118.6	97.5	97.9	
29	108.2	34.7	31.5	
30	118.4	100.8	98	
31	108.7	35	34.1	
32	118.5	98.9	98.2	
33	108.9	34.6	34.8	
34	8.937	0.1261	40.9	0
35				
36				
37				
38				
39				
40				
41	22.17	0.2072	54.1	0