HW 2.1

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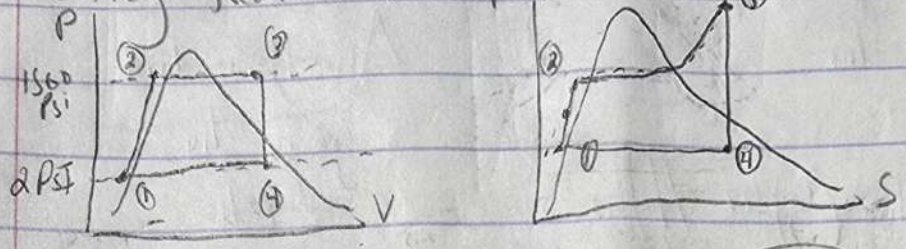



① Isen comp → ② P const → ③ Isen Turbine → ④ P const

$P_1 = 2$ Psia  $P_2 = 1500$ Psia  $P_3 = 1500$ Psia  $P_4 = 2$ Psia

$T_1 = 126.02$F  $T_3 = 800$°F

$h_1 = 94$ BTU/lbm  $h_2 = 118.313$  $h_3 = 1363.1$ BTU/lbm  $h_4 = 922.8$ BTU/lbm

$V_1 = 0.01623$  $S_3 = 1.506$  $S_4 = 1.506$

$x_1 = 0$  $V_3 = 0.4355$  $x_4 = 0.763$

$h_2 = V_1(P_2 - P_1) + h_1 = 0.01623(1500 - 2) + 94 = 118.313$

$S_{f4} = 0.17499$

$S_{fg4} = 1.744$  $x_4 = \frac{S_4 - S_f}{S_{fg}} = \frac{1.506 - 0.17499}{1.744} = 0.763$

$S_{g4} = 1.9194$

$h_{4s} = x_4 \cdot h_{fg} + h_f = 0.763 \cdot 1021.7 + 94.02 = 873.88$ BTU/lbm

$\eta_{th} = \frac{h_3 - h_4}{h_3 - h_{4s}} = 0.90 = \frac{1363.1 - h_4}{1363.1 - 873.88}$

$h_4 = 922.8$ BTU/lbm

$\dot{m} = \frac{\dot{W}}{q_{in} - q_{out}} = \frac{\dot{W}}{(h_3 - h_2) + (h_4 - h_1)} = \frac{2500 \text{ KJ/s}}{(1363.1 - 118.313) - (922.8 - 94)}$

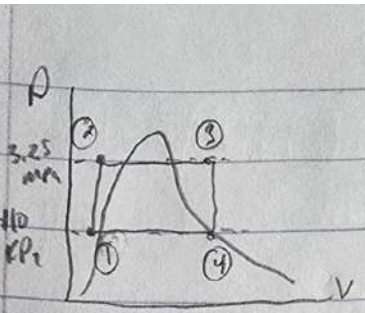
$\dot{m} = 6.0098$ lbm/s

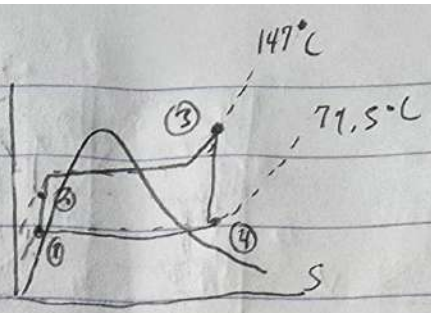
$P = \dot{m}(h_3 - h_4) = 6.0098(1363.1 - 722.8) = 2846.11$ BTU/s

$Q_{in} = \dot{m}(h_3 - h_2) = 6.0098(1363.1 - 118.313) = 7480.92$ BTU/lbm

$\eta_{th} = \frac{\dot{W}}{\dot{Q}_{in}} = \frac{2500}{7486.72} = 0.334 = 33.4\%$

10-25




(1) Isen comp → (2) P-const → (3) Isen Turbine → (4) P const

$P_1 = 410\ kPa$ $P_2 = 3.25\ MPa$ $P_3 = 3.25\ MPa$ $P_4 = 410\ kPa$

$x = 0$ $T_3 = 147°C$ $T_4 = 79.5c$

$h_1 = 279.85$ $h_3 = 562.88\ KJ/kg$ $h_4 = 510.50\ KJ/kg$

$v_1 = 0.001506\ m^3/kg$ $h_{4s} = 492.64\ KJ/kg$

$$\eta_{th} = \frac{h_3 - h_4}{h_3 - h_{4s}} = \frac{562.88 - 510.50}{562.88 - 492.64} = 0.7455 = 74.55\%$$

$W_{out} = \dot{m}(h_3 - h_4) = 305.6\ kg/s\,(562.88 - 510.50) = 15999.73\ kW$

$W_{in} = 0.001506\,(3250 - 410) = 4.28\ KJ/kg$

$$W_{pump} = \frac{W_{in}}{\eta_{pump}} = \frac{4.28}{0.9} = 4.75\ KJ/kg$$

$W_{pump} = 305.6\ kg/s \cdot 4.75\ KJ/kg = 1451.6\ kW$

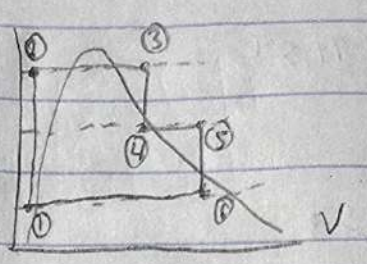
$W_{net} = W_{out} - W_{in} = 15999.73 - 1451.6 = 14,548.1\ kW$

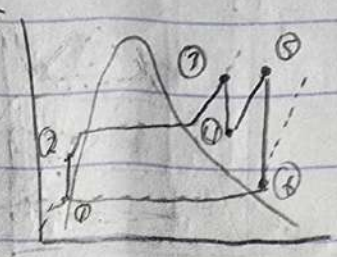
$Q_{in} = \dot{m}(h_{in} - h_{out})$

$Q_{in} = 555.9\ kg/s\,(675.49\ KJ/kg - 376.97\ KJ/kg) = 166,057.1\ kW$

$$\eta_{thermal} = \frac{14,548.1}{166057.1} = 0.0876 = 8.76\%$$

10-34




① Isen Pump → ② P const → ③ Isen turbine → ④ P const → ⑤ Isen turbine → ⑥ P const

$P_1 = 20kPa$ $P_2 = 5000kPa$ $P_3 = 5000kPa$ $P_4 = 1200kPa$ $P_5 = 1200kPa$ $P_6 = 20kPa$

$T_1 = 60.06°C$ $T_3 = 328.7°$ $x_4 = 0.96$ $T_5 = 481.9$ $x_6 = 0.96$

$h_1 = 251.42 kJ/kg$ $h_2 = 256.485$ $h_3 = 3008$ $h_f = 798.33$ $h_5 = 5438$ $h_f = 251.42$

$h_{fg} = 1985.4$ $h_{fg} = 2357.5$

$v_1 = 0.001017$ $h_4 = 2704.31$ $s_5 = 1.624$ $h_6 = 2514.62$

$s_3 = 6.349$ $s_4 = 6.349$ $x_5 = 1.256$ $s_6 = 7.624$

$h_2 = v_1(P_2 - P_1) + h_1 = 0.001017(5000 - 20) + 251.42 = 256.485$

$h_4 = h_{f4} + x_4(h_{fg4}) = 798.33 + 0.96(1985.4) = 2704.31$

$h_6 = h_{f6} + x_6(h_{fg6}) = 251.42 + 0.96(2357.5) = 2514.62$

$s_4 = s_f + x(s_{fg}) = 2.2159 + 0.96(4.3058) = 6.349$

$s_6 = s_f + x(s_{fg}) = 0.8320 + 0.96(7.0752) = 7.624$

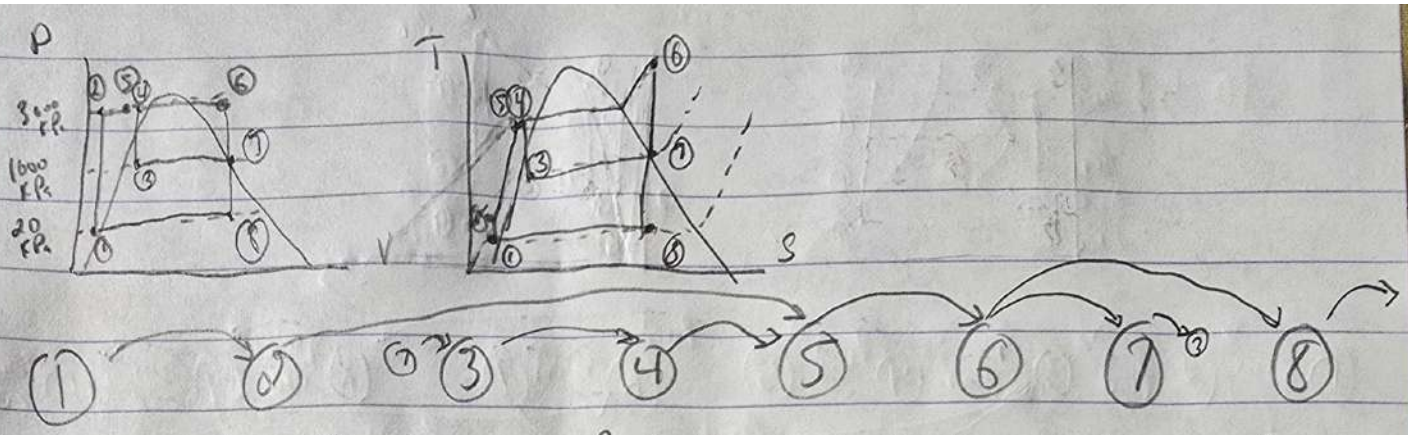
$W_{net} = (h_3 - h_4) + (h_5 - h_6) + (h_2 - h_1) = (3008 - 2704.31) + (3438 - 2514.62) + (256.485 - 251.42) = 1232.14$

$Q_{in} = (h_3 - h_2) + (h_5 - h_4) = (3008 - 256.485) + (3436 - 2704.31)$

$Q_{in} = 3485.21$

$\eta_{th} = \frac{W_{net}}{Q_{in}} = \frac{1232.14}{3485.21} = 0.353 = 35.3\%$

10-48




$P_1 = 20\ kPa$ $P_2 = 3000\ kPa$ $P_3 = 1000\ kPa$ $P_4 = 5000\ kPa$ $P_5 = 3000\ kPa$ $P_6 = 3000\ kPa$ $P_7 = 1000\ kPa$ $P_8 = 20\ kPa$

$T_1 = 60.06°C$ $T_6 = 350°C$ $T_7 = 210.7°C$

$v_1 = 0.001017$ $h_3 = 762.52$ $h_5 = 762.52$ $S_6 = 6.7450$ $S_7 = 6.7450$ $S_8 = 6.7450$

$h_1 = 251.42$ $h_2 = 254.451$ $h_6 = 3116.1$ $h_7 = 2943.1$ $h_8 = 2221.62$

$h_2 = v_1(P_2 - P_1) + h_1 = 0.001017(3000 - 20) + 251.42 =$

$h_{f8} = 251.42$ $h_{fg8} = 2357.5$ $S_{f8} = 0.8320$ $S_{fg8} = 7.0752$

$S_8 = S_{f8} + x_8(S_{fg8})$ $6.7450 = 0.8320 + x_8(7.0752)$

$x_8 = 0.8357$ $h_8 = h_{f8} + x_8(h_{fg8}) = 251.42 + 0.8357(2357.5) = 2221.62$

$y = (h_7 - h_5) = (h_3 - h_2) = (2943.1 - 762.52) = (762.52 - 254.451)$

$y = \frac{2180.58}{2190.58} = \frac{508.069}{2180.58} = 0.232$

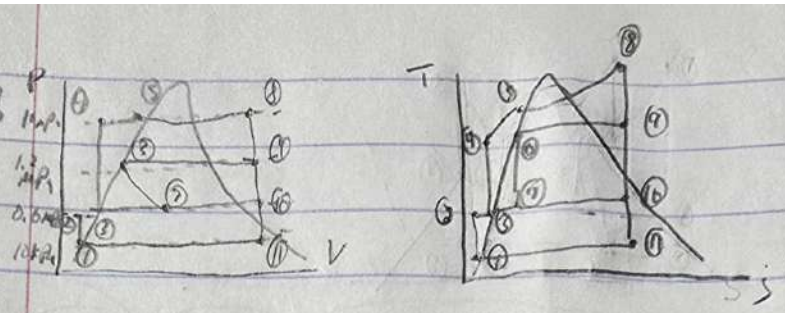
$W_T = (h_6 - h_7) + (1 - y)(h_7 - h_8) = (3116.1 - 2943.1) + (1 - 0.232)(2943.1 - 2221.62)$

$W_T = 727.097\ kJ/kg$

$W_p = v_1(P_2 - P_1) = 0.001017(3000 - 20) = 3.03\ kJ/kg$

$Q_{in}(h_6 - h_5) = 3116.1 - 762.52 = 2353.58\ kJ/kg$

10-53




(1) Isen pump (2) P const (3) Isen Pump (4) P const (5) P const (6) Isothrm (7) (8) Isen exp (9) Isen exp (10) Isen exp (11)

P const

P const

$P_1 = 10kPa$ $P_2 = 0.6MPa$ $P_3 = 0.6MPa$ $P_4 = 10MPa$ $P_5 = 10MPa$ $T_5 = 184$ $P_6 = 1.2MPa$ $T_6 = 184$ $P_7 = 0.6MPa$ $P_8 = 10MPa$ $T_8 = 600C$ $P_9 = 1.2MPa$ $P_{10} = 0.6MPa$ $P_{11} = 10kPa$

$X_1 = 0$ $X_3 = 0$ $X_6 = 0$ $X_{11} = 0.834$

$V_1 = 0.001010$ $V_3 = 0.001101$ $V_6 = 0.001138$

$h_1 = 191.81$ $h_2 = 192.406$ $h_3 = 670.38$ $h_4 = 680.73$ $h_5 = 798.33$ $h_6 = 798.33$ $h_7 = 798.33$ $h_8 = 3625.8$ $h_9 = 2974.5$ $h_{10} = 2820$ $h_{11} = 2187$

$S_1 = 0.6492$ $S_3 = 1.9508$ $S_6 = 2.2159$ $S_8 = 6.9045$ $S_7 = 6.9045$ $S_{10} = 6.9045$ $S_{11} = 6.9045$

$h_2 = V_1(P_2 - P_1) + h_1 = 0.001010(600 - 10) + 191.81 = 192.406$

$h_4 = V_3(P_4 - P_3) + h_3 = 0.001101(10000 - 600) + 670.38 = 680.73$

$X_{11} = \frac{S_{11} - S_f}{S_{fg}} \quad \frac{6.9045 - 0.6492}{7.4996} = 0.834$

$h_{11} = h_f + X_{11}(h_{fg}) = 191.81 + 0.834(2392.1) = 2187 \ KJ/kg$

$y = (h_9 - h_6) = (h_5 - h_4) = (2974.5 - 798.33) = (798.33 - 680.73)$

$y = \frac{117.6}{2176.17} = 0.0544$

$z = \frac{(h_3 - h_2) - y(h_7 - h_2)}{(h_{10} - h_2)} = \frac{(670.38 - 192.40) - (0.0504)(798.33 - 192.4)}{(2820.9 - 192.4)}$

$z = 0.1694$

$q_{in} = h_8 - h_5 = 3625.8 - 798.33 = 2827 \ KJ/kg$

$q_{out} = (1 - y - z)(h_{11} - h_1) = (1 - 0.05404 - 0.1694)(2187 - 191.81)$

$q_{out} = 1549.38 \ KJ/kg$

$W_{net} = q_{in} - q_{out} = 2827 - 1549 = 1278 \ KJ/kg$

(a) $\dot{m} = \frac{400{,}000}{1278} = 313 \text{ kg/s}$

(b) $\eta = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{1549}{2827} = 0.452 = 45.2\%$