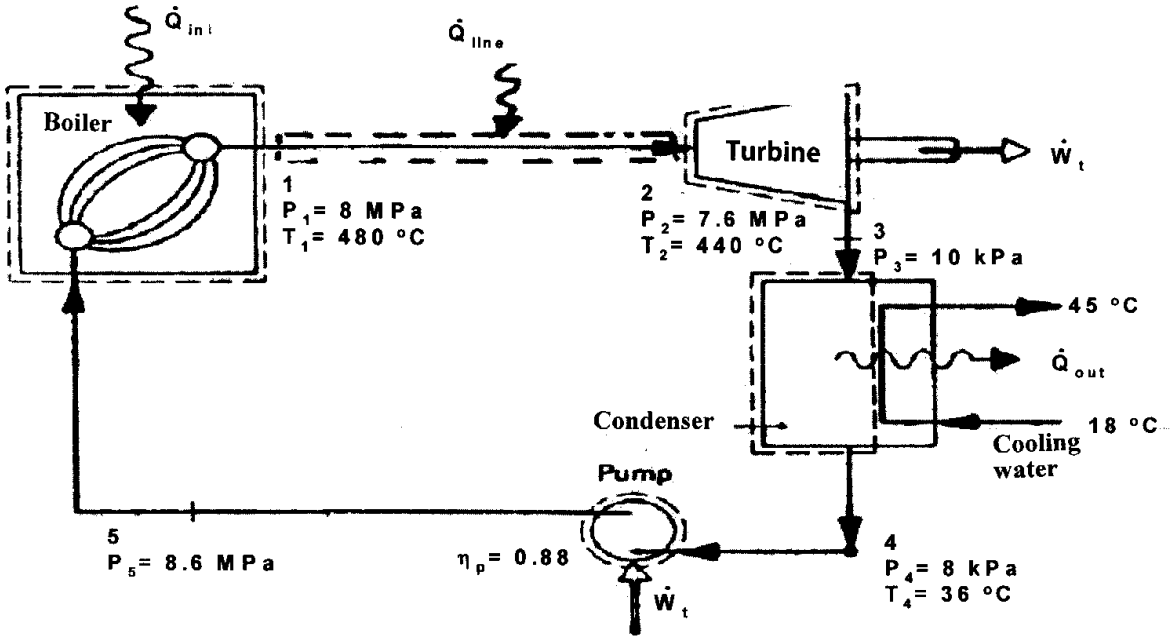
1. Superheated steam at 8MPa and 480℃ leaves the steam generator of a vapor power plant. Heat transfer and frictional effects in the line connecting the steam generator and the turbine reduce the pressure and temperature at the turbine inlet to 7.6MPa and 440 ℃, respectively. The pressure at the exit of the turbine is 10kPa, and the turbine operates adiabatically. Liquid leaves the condenser at 8kPa, 36℃. The pressure is increased to 8.6MPa across the pump. The turbine and pump efficiencies are 90% and 88%, respectively. The mass flow rate of steam across the turbine is 80 kg/s. The schematic of the steam power cycle is shown in the figure below.



(a). Draw the T-s diagram of the corresponding Rankine cycle indicating states 1,2,3,4,5 (note state 3 is a mixture of saturated vapor and liquid). (5%)

(b). Using the isentropic efficiency of the turbine, find the specific enthalpy at state 3. (5%)

(c). Using the isentropic efficiency of the pump, find the specific enthalpy at state 5. (5%)

(d). Find the net power output, in kW (5%)

(e). Find the thermal efficiency (10%)

State 1: $P_1 = 8MPa$, $T_1 = 480\ ℃ = 753K$

$h_1=3348.4$ kJ/kg, $s_1=6.6586$ kJ/kg·K

State 2: $P_2 = 7.6MPa$, $T_1 = 440\ ℃ = 713K$

$h_2 \cong 3252.3$ kJ/kg, $s_1 \cong 6.5526$ kJ/kg·K

State 4: $P_4 = 8kPa$, $T_4 = 36\ ℃ = 309K$

$h_4 \cong h_f(T)=150.86$ kJ/Kg, $v_4 \cong v_f=1.0063\times10^{-3}$ m^3/kg·

State 3: At 10 kPa, $s_f=0.6493$ kJ/kg·K, $s_g=8.1502$ kJ/kg·K, $h_f=191.83$ kJ/kg, $h_g=2584.7$ kJ/kg, $h_{fg}=2392.8$ kJ/kg

2. (a). Please write down the stoichiometric combustion equation for methane with air. Assume that air consists of 21% O_2 and 79% N_2 by volume. (5%) How many moles of air are required when one mole of methane is burned with air at an equivalent ratio of 0.5? (5%)

(b). Considering the following reaction, please perform the molal analysis of the products of combustion (5%) and determine the dew point of the products if the pressure is 0.1 MPa. (5%)

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

(c). Considering that a mixture and its components are ideal gases, please explain what "the Dalton model" is (5%) and what "the Amagat model" is (5%).

TABLE A.1SI *Thermodynamic Properties of Water (SI Units)*
TABLE A.1.1SI *Saturated Water: Temperature Table (SI Units)*

		Specific Volume, m^3/kg		Internal Energy, kJ/kg			Enthalpy, kJ/kg			Entropy, kJ/kg K		
Temp. °C T	Press. kPa, MPa P	Sat. Liquid v_f	Sat. Vapor v_g	Sat. Liquid u_f	Evap. u_{fg}	Sat. Vapor u_g	Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g	Sat. Liquid s_f	Evap. s_{fg}	Sat. Vapor s_g
0.01	0.6113	0.001000	206.132	0.00	2375.3	2375.3	0.00	2501.3	2501.3	0.0000	9.1562	9.1562
5	0.8721	0.001000	147.118	20.97	2361.3	2382.2	20.98	2489.6	2510.5	0.0761	8.9496	9.0257
10	1.2276	0.001000	106.377	41.99	2347.2	2389.2	41.99	2477.7	2519.7	0.1510	8.7498	8.9007
15	1.7051	0.001001	77.925	62.98	2333.1	2396.0	62.98	2465.9	2528.9	0.2245	8.5569	8.7813
20	2.3385	0.001002	57.790	83.94	2319.0	2402.9	83.94	2454.1	2538.1	0.2966	8.3706	8.6671
25	3.1691	0.001003	43.359	104.86	2304.9	2409.8	104.87	2442.3	2547.2	0.3673	8.1905	8.5579
30	4.2461	0.001004	32.893	125.77	2290.8	2416.6	125.77	2430.5	2556.2	0.4369	8.0164	8.4533
35	5.6280	0.001006	25.216	146.65	2276.7	2423.4	146.66	2418.6	2565.3	0.5052	7.8478	8.3530
40	7.3837	0.001008	19.523	167.53	2262.6	2430.1	167.54	2406.7	2574.3	0.5724	7.6845	8.2569
45	9.5934	0.001010	15.258	188.41	2248.4	2436.8	188.42	2394.8	2583.2	0.6386	7.5261	8.1647
50	12.350	0.001012	12.032	209.30	2234.2	2443.5	209.31	2382.7	2592.1	0.7037	7.3725	8.0762
55	15.758	0.001015	9.568	230.19	2219.9	2450.1	230.20	2370.7	2600.9	0.7679	7.2234	7.9912
60	19.941	0.001017	7.671	251.09	2205.5	2456.6	251.11	2358.5	2609.6	0.8311	7.0784	7.9095
65	25.033	0.001020	6.197	272.00	2191.1	2463.1	272.03	2346.2	2618.2	0.8934	6.9375	7.8309
70	31.188	0.001023	5.042	292.93	2176.6	2469.5	292.96	2333.8	2626.8	0.9548	6.8004	7.7552
75	38.578	0.001026	4.131	313.87	2162.0	2475.9	313.91	2321.4	2635.3	1.0154	6.6670	7.6824
80	47.390	0.001029	3.407	334.84	2147.4	2482.2	334.88	2308.8	2643.7	1.0752	6.5369	7.6121
85	57.834	0.001032	2.828	355.82	2132.6	2488.4	355.88	2296.0	2651.9	1.1342	6.4102	7.5444
90	70.139	0.001036	2.361	376.82	2117.7	2494.5	376.90	2283.2	2660.1	1.1924	6.2866	7.4790
95	84.554	0.001040	1.982	397.86	2102.7	2500.6	397.94	2270.2	2668.1	1.2500	6.1659	7.4158
100	0.10135	0.001044	1.6729	418.91	2087.6	2506.5	419.02	2257.0	2676.0	1.3068	6.0480	7.3548

3. (a). Please to define the entropy property on macroscopic and microscopic system. (5%)

   (b). Please take control mass system to find the entropy change for irreversible process. (5%)

   (c). Please take the control volume system to find the entropy change on irreversible process. (5%)

4. Giving the power plant system in which water-steam fluid flow shown in Fig problem 4, that the four component shown in pump, boiler, turbine, and condenser. Assume the water-steam flow through the boiler and condenser at constant pressure and the flow through the pump on adiabatic process.

(a). Sketch the cycle on P-v and T-s coordinates which the flow through the turbine and pump are reversible or irreversible process, where p is pressure, v is specific volume, T is temperature and s is specific entropy, (10%)

(b). Find the power of turbine on irreversible process by flow rate as 20kg/sec and entropy change relation as $s_4 - s_3 = 0.05\, s_3$, for s3 at saturated vapor state. (5%)

(c). Determine the thermal efficiency on isentropic process of pump and turbine, (5%)

(d). Determine the thermal efficiency on entropy change relation as

$s_2 - s_1 = 0.05\, s_1$, $s_4 - s_3 = 0.05\, s_3$. (5%)

Hint：steam table on Page 5

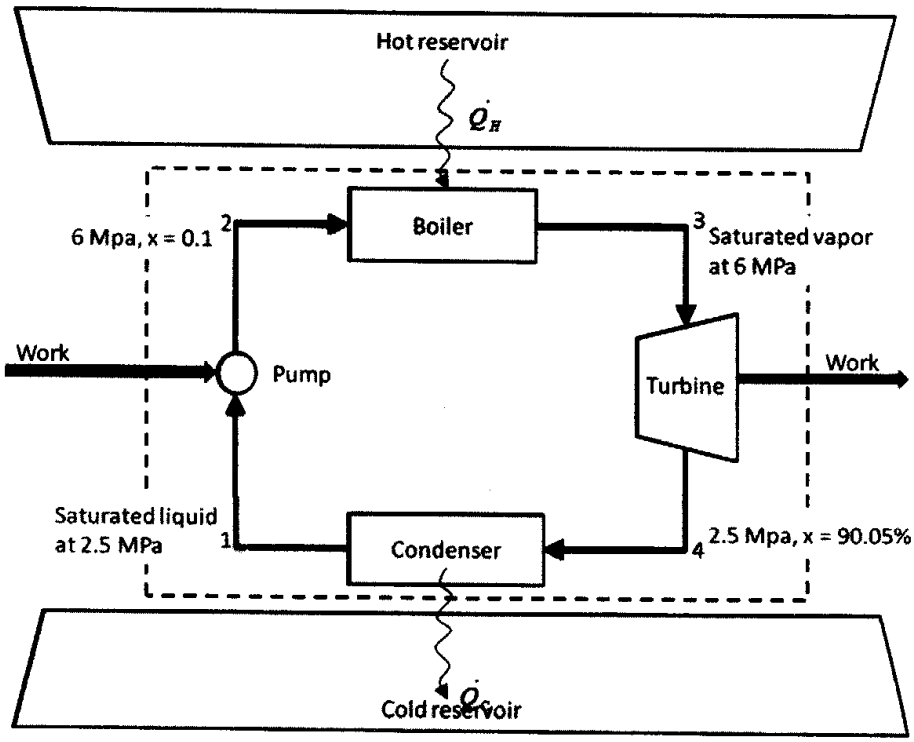


Fig problem 4

TABLE A.1.2SI (Continued) *Saturated Water: Pressure Table (SI Units)*

Press. MPa P	Temp. °C T	Specific Volume, m³/kg		Internal Energy, kJ/kg			Enthalpy, kJ/kg			Entropy, kJ/kg K		
		Sat. Liquid v_f	Sat. Vapor v_g	Sat. Liquid u_f	Evap. u_{fg}	Sat. Vapor u_g	Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g	Sat. Liquid s_f	Evap. s_{fg}	Sat. Vapor s_g
2.50	223.99	0.001197	0.07998	959.09	1644.0	2603.1	962.09	1841.0	2803.1	2.5546	3.7028	6.2574
2.75	229.12	0.001207	0.07275	982.65	1621.2	2603.8	985.97	1817.9	2803.9	2.6018	3.6190	6.2208
3.00	233.90	0.001216	0.06668	1004.76	1599.3	2604.1	1008.41	1795.7	2804.1	2.6456	3.5412	6.1869
3.25	238.38	0.001226	0.06152	1025.62	1578.4	2604.0	1029.60	1774.4	2804.0	2.6866	3.4685	6.1551
3.50	242.60	0.001235	0.05707	1045.41	1558.3	2603.7	1049.73	1753.7	2803.4	2.7252	3.4000	6.1252
4.0	250.40	0.001252	0.049778	1082.28	1520.0	2602.3	1087.29	1714.1	2801.4	2.7963	3.2737	6.0700
5.0	263.99	0.001286	0.039441	1147.78	1449.3	2597.1	1154.21	1640.1	2794.3	2.9201	3.0532	5.9733
6.0	275.64	0.001319	0.032440	1205.41	1384.3	2589.7	1213.32	1571.0	2784.3	3.0266	2.8625	5.8891
7.0	285.88	0.001351	0.027370	1257.51	1323.0	2580.5	1266.97	1505.1	2772.1	3.1210	2.6922	5.8132
8.0	295.06	0.001384	0.023518	1305.54	1264.3	2569.8	1316.61	1441.3	2757.9	3.2067	2.5365	5.7431
9.0	303.40	0.001418	0.020484	1350.47	1207.3	2557.8	1363.23	1378.9	2742.1	3.2857	2.3915	5.6771
10.0	311.06	0.001452	0.018026	1393.00	1151.4	2544.4	1407.53	1317.1	2724.7	3.3595	2.2545	5.6140
11.0	318.15	0.001489	0.015987	1433.68	1096.1	2529.7	1450.05	1255.5	2705.6	3.4294	2.1233	5.5527
12.0	324.75	0.001527	0.014263	1472.92	1040.8	2513.7	1491.24	1193.6	2684.8	3.4961	1.9962	5.4923
13.0	330.93	0.001567	0.012780	1511.09	985.0	2496.1	1531.46	1130.8	2662.2	3.5604	1.8718	5.4323
14.0	336.75	0.001611	0.011485	1548.53	928.2	2476.8	1571.08	1066.5	2637.5	3.6231	1.7485	5.3716
15.0	342.24	0.001658	0.010338	1585.58	869.8	2455.4	1610.45	1000.0	2610.5	3.6847	1.6250	5.3097
16.0	347.43	0.001711	0.009306	1622.63	809.1	2431.7	1650.00	930.6	2580.6	3.7460	1.4995	5.2454
17.0	352.37	0.001770	0.008365	1660.16	744.8	2405.0	1690.25	856.9	2547.2	3.8078	1.3698	5.1776
18.0	357.06	0.001840	0.007490	1698.86	675.4	2374.3	1731.97	777.1	2509.1	3.8713	1.2330	5.1044
19.0	361.54	0.001924	0.006657	1739.87	598.2	2338.1	1776.43	688.1	2464.5	3.9387	1.0841	5.0227
20.0	365.81	0.002035	0.005834	1785.47	507.6	2293.1	1826.18	583.6	2409.7	4.0137	0.9132	4.9269
21.0	369.89	0.002206	0.004953	1841.97	388.7	2230.7	1888.30	446.4	2334.7	4.1073	0.6942	4.8015
22.0	373.80	0.002808	0.003526	1973.16	108.2	2081.4	2034.92	124.0	2159.0	4.3307	0.1917	4.5224
22.09	374.14	0.003155	0.003155	2029.58	0	2029.6	2099.26	0	2099.3	4.4297	0	4.4297