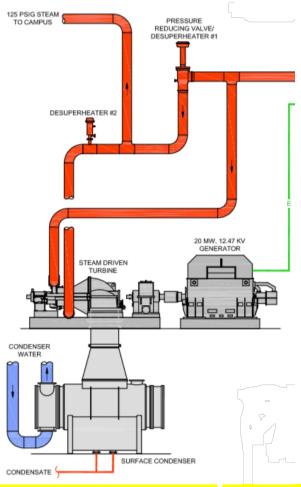
Chemical Engineering Thermodynamics Quiz 5 February 14, 2019

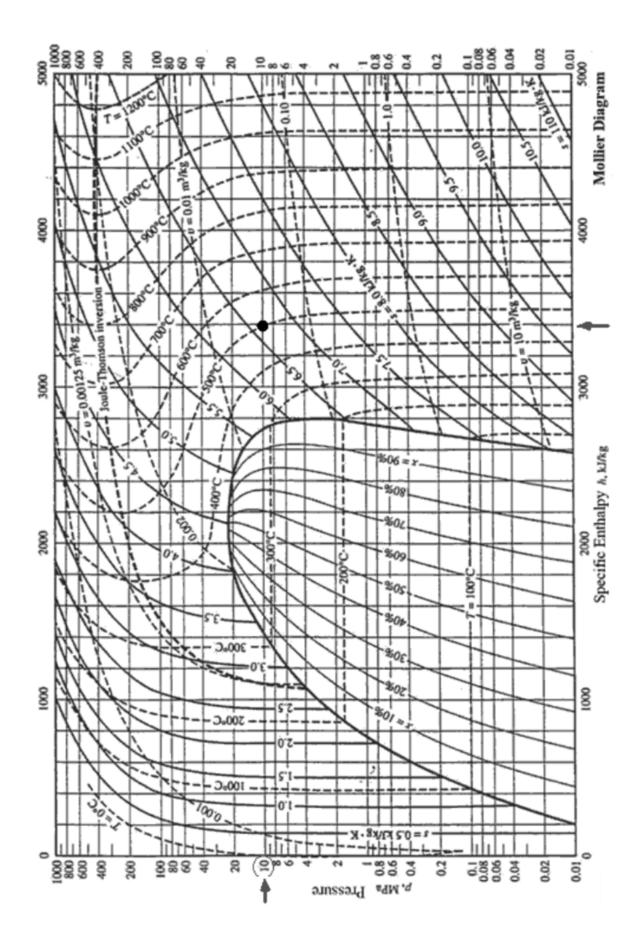


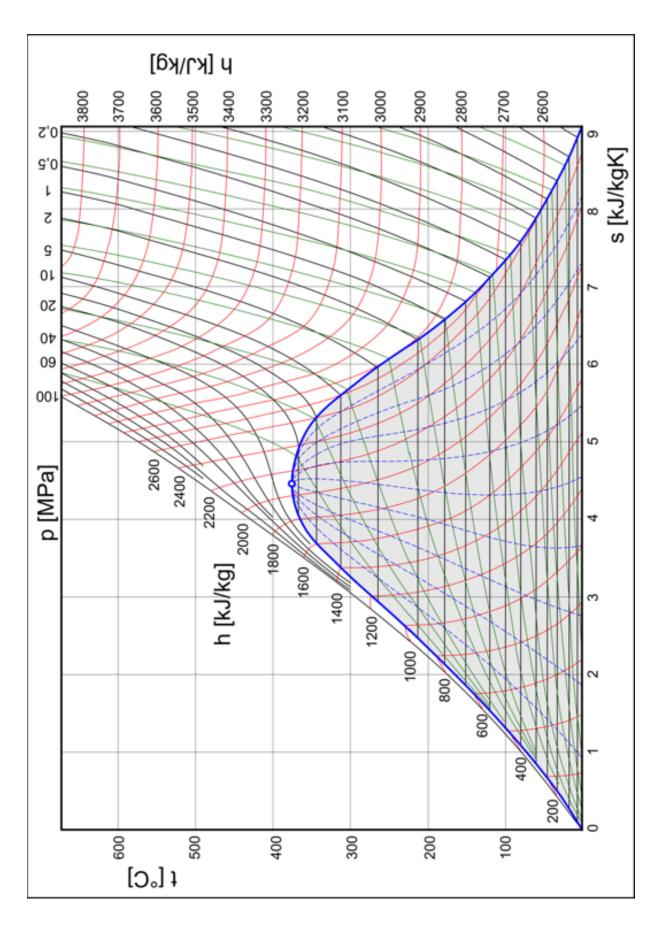
The UC steam plant uses 125 PSIG (0.881 MPa) steam produced by two gas turbines at 480°C to feed a steam turbine (*stream 1*). The output from the steam turbine (*stream 2*) is at 0.15 MPa and 140°C. The outflow from the steam turbine is fed into a condenser. The steam produces 20 MW of electrical power.

<u>Please fill out the following table.</u> <u>You can use the steam tables or the chart (recommended)</u>.

Stream	P MPa	T°C	S kJ/(kg K)	H kJ/kg	$V \mathrm{m}^3/\mathrm{kg}$	$\Delta H \text{kJ/kg}$	State
1	0.881	480					
2'	0.15						
2	0.15	140					
				Possible?		$\eta_{ m e}$ =	
						$\eta_{\rm e,Carnot} =$	

- a) What is the work output of an ideal turbine (reversible adiabatic)?
- b) What is the actual work output and efficiency, $\eta_{\rm eff}$, of this turbine? Is this possible?
- c) What is the efficiency of a Carnot engine for these conditions. Compare it with that of the steam turbine. Are the listed conditions possible? **Why?**
- d) **Plot the points** 1, 2', and 2 on both the pressure enthalpy and the temperature entropy diagrams that are attached. **Fill the missing values in the table above.**
- e) If the turbine produces 20 MW what is the flow rate of steam in kg/s? ($W = MPa \text{ cm}^3/s$)
- f) Extra Credit: Propose a method to extract useful energy from the 140°C stream 2.





P = 0.10		(99.6) U(kJ/kg	H(kJ/kg	g) S(kJ/kg-K)		20MPa	(120.3)		
T(°C)	V(m ³ /kg) 1.6939	2505.6	2675.0	7.3588	T(°C)		U(kJ/kg)	H(kJ/kg)	S/LUka V
99.6	1.0939	230010			120.3	0.8857	2529.1	2706.2	S(kJ/kg-K) 7.1269
100	1.6959	2506.2	2675.8	7.3610	150	0.9599	2577.1	2769.1	7.1269
150	1.9367	2582.9	2776.6	7.6148 7.8356	200	1.0805	2654.6	2870.7	7.5081
200	2.1724	2658.2	2875.5	8.0346	250	1.1989	2731.4	2971.2	7.7100
250	2.4062	2733.9	2974.5 3074.5	8.2172	300	1.3162	2808.8	3072.1	7.8941
300	2.6388	2810.6	3175.8	8.3866	350	1.4330	2887.3	3173.9	8.0644
350	2.8710	2888.7 2968.3	3278.6	8.5452	400	1.5493	2967.1	3277.0	8.2236
400	3.1027	3049.4	3382.8	8.6946	450	1.6655	3048.5	3381.6	8.3734
450	3.3342 3.5655	3132.2	3488.7	8.8361	500	1.7814	3131.4	3487.7	8.5152
500	3.7968	3216.6	3596.3	8.9709	550	1.8973	3215.9	3595.4	8.6502
550 600	4.0279	3302.8	3705.6	9.0998	600	2.0130	3302.2	3704.8	8.7792
650	4.2590	3390.7	3816.6	9.2234	650	2.1287	3390.2	3815.9	8.9030
700	4,4900	3480.4	3929.4	9.3424	700	2.2443	3479.9	3928.8	9.0220
750	4.7209	3571.8	4043.9	9.4572	750 800	2.3599	3571.4	4043.4	9.1369
800	4.9519	3665.0	4160.2		850	2.4755	3664.7	4159.8	9.2479
850	5.1828	3760.0	4278.2		900	2.5910	3759.6	4277.8	9.3555
900	5.4137	3856.6			950	2.7066	3856.3	4397.6	9.4598
950	5.6446	3955.0			1000	2.8221 2.9375	3954.7	4519.1	9.5612
1000	5.8754	4055.0			1050	3.0530	4054.8	4642.3	9.6599
1050	6.1063	4156.6			1100	3.1685	4156.4 4259.6	4767.0	9.7560
1100	6.3371	4259.8			1150	3.2839	4364.3	4893.3	9.8497
1150	6.5680	4364.5			1200	3.3994	4470.5	5021.1	9.9411
1200	6.7988	4470.7				3.5148	4578.1	5150.4 5281.1	10.0304
1250 1300	7.0296 7.2604	4578.3 4687.2			1250 1300	3.6302	4687.0	5413.1	10.1176 10.2029
	7.2604 0MPa	4687.2 (170.4) <i>U</i> (kJ/kg)	2 5413. H(kJ/kg)	2 10.5229 S(kJ/kg-K)	1300	3.6302	4687.0		
1300 P = 0.80 T(°C') 170.4 200	7.2604 0MPa V(m ³ /kg) 0.2403 0.2609	4687.2 (170.4) <i>U</i> (kJ/kg) 2576.0 2631.0	2 5413.	2 10.5229 S(kJ/kg-K) 6.6616	1300 P = 1.00	3.6302 OMPa (4687.0 179.9)	5413.1	10.2029
1300 P = 0.80 T(°C) 170.4 200 250	7.2604 0MPa V(m ³ /kg) 0.2403 0.2609 0.2932	4687.3 (170.4) <i>U</i> (kJ/kg) 2576.0 2631.0 2715.9	H(kJ/kg) 2768.3 2839.7 2950.4	2 10.5229 S(kJ/kg-K) 6.6616 6.8176 7.0401	1300 P = 1.00 T(°C)	3.6302 OMPa (V(m ³ /kg)	4687.0 179.9) <i>U</i> (kJ/kg)	5413.1 H(kJ/kg)	10.2029 S(kJ/kg-K)
1300 P = 0.80 T(°C) 170.4 200 250 300	7.2604 0MPa V(m ³ /kg) 0.2403 0.2609 0.2932 0.3242	4687.2 (170.4) U(kJ/kg) 2576.0 2631.0 2715.9 2797.5	H(kJ/kg) 2768.3 2839.7 2950.4 3056.9	2 10.5229 S(kJ/kg-K) 6.6616 6.8176 7.0401 7.2345	1300 P = 1.00 T(°C) 179.9	3.6302 OMPa (V(m ³ /kg) 0.1944	4687.0 179.9) <i>U</i> (kJ/kg) 2582.8	5413.1 H(kJ/kg) 2777.1	10.2029 S(kJ/kg-K) 6.5850
1300 P = 0.80 T(°C) 170.4 200 250 300 350	7.2604 0MPa V(m ³ /kg) 0.2403 0.2609 0.2932 0.3242 0.3544	4687.2 (170.4) U(kJ/kg) 2576.0 2631.0 2715.9 2797.5 2878.6	H(kJ/kg) 2768.3 2839.7 2950.4 3056.9 3162.2	2 10.5229 S(kJ/kg-K) 6.6616 6.8176 7.0401 7.2345 7.4106	P = 1.00 T(°C) 179.9 200	3.6302 OMPa (V(m ³ /kg) 0.1944 0.2060	4687.0 179.9) U(kJ/kg) 2582.8 2622.2	5413.1 H(kJ/kg) 2777.1 2828.3	10.2029 S(kJ/kg-K) 6.5850 6.6955
1300 P = 0.80 T(°C) 170.4 200 250 300 350 400	7.2604 0MPa V(m ³ /kg) 0.2403 0.2609 0.2932 0.3242 0.3544 0.3843	4687.2 (170.4) U(kJ/kg) 2576.0 2631.0 2715.9 2797.5 2878.6 2960.2	H(kJ/kg) 2768.3 2839.7 2950.4 3056.9 3162.2 3267.6	S(kJ/kg-K) 6.6616 6.8176 7.0401 7.2345 7.4106 7.5734	1300 P = 1.00 T(°C) 179.9 200 250	3.6302 OMPa (V(m ³ /kg) 0.1944 0.2060 0.2327	4687.0 179.9) U(kJ/kg) 2582.8 2622.2 2710.4	5413.1 H(kJ/kg) 2777.1	10.2029 S(kJ/kg-K) 6.5850 6.6955 6.9265 7.1246
1300 P = 0.80 T(°C) 170.4 200 250 300 350	7.2604 0MPa V(m ³ /kg) 0.2403 0.2609 0.2932 0.3242 0.3544 0.3843 0.4139	4687.2 (170.4) U(kJ/kg) 2576.0 2631.0 2715.9 2797.5 2878.6 2960.2 3042.8	H(kJ/kg) 2768.3 2839.7 2950.4 3056.9 3162.2 3267.6 3373.9	S(kJ/kg-K) 6.6616 6.8176 7.0401 7.2345 7.4106 7.5734 7.7257	1300 P = 1.00 T(°C) 179.9 200 250 300	3.6302 OMPa (V(m ³ /kg) 0.1944 0.2060 0.2327 0.2580	4687.0 179.9) U(kJ/kg) 2582.8 2622.2	5413.1 H(kJ/kg) 2777.1 2828.3 2943.1	10.2029 S(kJ/kg-K) 6.5850 6.6955 6.9265
1300 P = 0.80 T(°C) 170.4 200 250 300 350 400 450 500 550	7.2604 0MPa V(m³/kg) 0.2403 0.2609 0.2932 0.3242 0.3544 0.3843 0.4139 0.4433 0.4726	4687.2 (170.4) U(kJ/kg) 2576.0 2631.0 2715.9 2797.5 2878.6 2960.2 3042.8 3126.6 3211.9	H(kJ/kg) 2768.3 2839.7 2950.4 3056.9 3162.2 3267.6	S(kJ/kg-K) 6.6616 6.8176 7.0401 7.2345 7.4106 7.5734 7.7257 7.8692	1300 P = 1.00 T(°C) 179.9 200 250	3.6302 OMPa (V(m ³ /kg) 0.1944 0.2060 0.2327 0.2580 0.2825 0.3066	4687.0 179.9) U(kJ/kg) 2582.8 2622.2 2710.4 2793.6 2875.7 2957.9	5413.1 H(kJ/kg) 2777.1 2828.3 2943.1 3051.6 3158.2 3264.5	S(kJ/kg-K) 6.5850 6.6955 6.9265 7.1246 7.3029 7.4669
1300 P = 0.80 T(°C) 170.4 200 250 300 350 400 450 550 600	7.2604 0MPa V(m³/kg) 0.2403 0.2609 0.2932 0.3242 0.3544 0.3843 0.4139 0.4433 0.4726 0.5019	4687.2 (170.4) U(kJ/kg) 2576.0 2631.0 2715.9 2797.5 2878.6 2960.2 3042.8 3126.6 3211.9 3298.7	H(kJ/kg) 2768.3 2839.7 2950.4 3056.9 3162.2 3267.6 3373.9 3481.3 3590.0 3700.1	S(kJ/kg-K) 6.6616 6.8176 7.0401 7.2345 7.4106 7.5734 7.7257 7.8692 8.0054 8.1354	1300 P = 1.00 T(°C) 179.9 200 250 300 350 400 450	3.6302 OMPa (V(m ³ /kg) 0.1944 0.2060 0.2327 0.2580 0.2825 0.3066 0.3304	4687.0 179.9) U(kJ/kg) 2582.8 2622.2 2710.4 2793.6 2875.7 2957.9 3040.9	5413.1 H(kJ/kg) 2777.1 2828.3 2943.1 3051.6 3158.2 3264.5 3371.3	S(kJ/kg-K) 6.5850 6.6955 6.9265 7.1246 7.3029 7.4669 7.6200
1300 P = 0.86 T(°C) 170.4 200 250 300 350 400 450 500 550 600 650	7.2604 0MPa V(m³/kg) 0.2403 0.2609 0.2932 0.3242 0.3544 0.3843 0.4139 0.4433 0.4726 0.5019 0.5310	4687.2 (170.4) U(kJ/kg) 2576.0 2631.0 2715.9 2797.5 2878.6 2960.2 3042.8 3126.6 3211.9 3298.7 3387.1	H(kJ/kg) 2768.3 2839.7 2950.4 3056.9 3162.2 3267.6 3373.9 3481.3 3590.0 3700.1 3811.9	S(kJ/kg-K) 6.6616 6.8176 7.0401 7.2345 7.4106 7.5734 7.7257 7.8692 8.0054 8.1354 8.2598	1300 P = 1.00 T(°C) 179.9 200 250 300 350 400 450 500	3.6302 OMPa (V(m ³ /kg) 0.1944 0.2060 0.2327 0.2580 0.2825 0.3066 0.3304 0.3541	4687.0 179.9) U(kJ/kg) 2582.8 2622.2 2710.4 2793.6 2875.7 2957.9 3040.9 3125.0	5413.1 H(kJ/kg) 2777.1 2828.3 2943.1 3051.6 3158.2 3264.5 3371.3 3479.1	S(kJ/kg-K) 6.5850 6.6955 6.9265 7.1246 7.3029 7.4669 7.6200 7.7641
1300 P = 0.86 T(°C) 170.4 200 250 300 350 400 450 500 550 600 650 700	7.2604 0MPa V(m³/kg) 0.2403 0.2609 0.2932 0.3242 0.3544 0.3843 0.4139 0.4433 0.4726 0.5019 0.5310 0.5601	4687.2 (170.4) U(kJ/kg) 2576.0 2631.0 2715.9 2797.5 2878.6 2960.2 3042.8 3126.6 3211.9 3298.7 3387.1 3477.2	H(kJ/kg) 2768.3 2839.7 2950.4 3056.9 3162.2 3267.6 3373.9 3481.3 3590.0 3700.1 3811.9 3925.3	S(kJ/kg-K) 6.6616 6.8176 7.0401 7.2345 7.4106 7.5734 7.7257 7.8692 8.0054 8.1354 8.2598 8.3794	1300 P = 1.00 T(°C) 179.9 200 250 300 350 400 450 500 550	3.6302 OMPa (V(m ³ /kg) 0.1944 0.2060 0.2327 0.2580 0.2825 0.3066 0.3304 0.3541 0.3777	4687.0 179.9) U(kJ/kg) 2582.8 2622.2 2710.4 2793.6 2875.7 2957.9 3040.9 3125.0 3210.5	5413.1 H(kJ/kg) 2777.1 2828.3 2943.1 3051.6 3158.2 3264.5 3371.3 3479.1 3588.1	S(kJ/kg-K) 6.5850 6.6955 6.9265 7.1246 7.3029 7.4669 7.6200 7.7641 7.9008
1300 P = 0.86 T(°C) 170.4 200 250 300 350 400 450 500 550 600 650	7.2604 0MPa V(m³/kg) 0.2403 0.2609 0.2932 0.3242 0.3544 0.3843 0.4139 0.4433 0.4726 0.5019 0.5310	4687.2 (170.4) U(kJ/kg) 2576.0 2631.0 2715.9 2797.5 2878.6 2960.2 3042.8 3126.6 3211.9 3298.7 3387.1 3477.2 3569.0	H(kJ/kg) 2768.3 2839.7 2950.4 3056.9 3162.2 3267.6 3373.9 3481.3 3590.0 3700.1 3811.9 3925.3 4040.3	S(kJ/kg-K) 6.6616 6.8176 7.0401 7.2345 7.4106 7.5734 7.7257 7.8692 8.0054 8.1354 8.2598 8.3794 8.4947	1300 P = 1.00 T(°C) 179.9 200 250 300 350 400 450 500 550 600	3.6302 OMPa (V(m³/kg) 0.1944 0.2060 0.2327 0.2580 0.2825 0.3066 0.3304 0.3777 0.4011	4687.0 179.9) U(kJ/kg) 2582.8 2622.2 2710.4 2793.6 2875.7 2957.9 3040.9 3125.0 3210.5 3297.5	5413.1 H(kJ/kg) 2777.1 2828.3 2943.1 3051.6 3158.2 3264.5 3371.3 3479.1 3588.1 3698.6	S(kJ/kg-K) 6.5850 6.6955 6.9265 7.1246 7.3029 7.4669 7.6200 7.7641 7.9008 8.0310
1300 P = 0.86 T(°C) 170.4 200 250 300 350 400 450 500 550 600 650 700 750	7.2604 0MPa V(m³/kg) 0.2403 0.2609 0.2932 0.3242 0.3544 0.3843 0.4139 0.4433 0.4726 0.5019 0.5310 0.5601 0.5892	4687.2 (170.4) U(kJ/kg) 2576.0 2631.0 2715.9 2797.5 2878.6 2960.2 3042.8 3126.6 3211.9 3298.7 3387.1 3477.2	H(kJ/kg) 2768.3 2839.7 2950.4 3056.9 3162.2 3267.6 3373.9 3481.3 3590.0 3700.1 3811.9 3925.3	S(kJ/kg-K) 6.6616 6.8176 7.0401 7.2345 7.4106 7.5734 7.7257 7.8692 8.0054 8.1354 8.2598 8.3794 8.4947 8.6061	P = 1.00 T(°C) 179.9 200 250 300 350 400 450 500 650	3.6302 OMPa (V(m³/kg) 0.1944 0.2060 0.2327 0.2580 0.2825 0.3066 0.3304 0.3541 0.3777 0.4011 0.4245	4687.0 179.9) U(kJ/kg) 2582.8 2622.2 2710.4 2793.6 2875.7 2957.9 3040.9 3125.0 3210.5 3297.5 3386.0	5413.1 H(kJ/kg) 2777.1 2828.3 2943.1 3051.6 3158.2 3264.5 3371.3 3479.1 3588.1 3698.6 3810.5	S(kJ/kg-K) 6.5850 6.6955 6.9265 7.1246 7.3029 7.4669 7.6200 7.7641 7.9008 8.0310 8.1557
1300 P = 0.80 T(°C) 170.4 200 250 300 350 400 450 500 550 660 670 770 750 800	7.2604 0MPa V(m³/kg) 0.2403 0.2609 0.2932 0.3242 0.3544 0.3843 0.4139 0.4433 0.4726 0.5019 0.5310 0.5601 0.5892 0.6182	4687.2 (170.4) U(kJ/kg) 2576.0 2631.0 2715.9 2797.5 2878.6 2960.2 3042.8 3126.6 3211.9 3298.7 3387.1 3477.2 3569.0 3662.4	H(kJ/kg) 2768.3 2839.7 2950.4 3056.9 3162.2 3267.6 3373.9 3481.3 3590.0 3700.1 3811.9 3925.3 4040.3 4157.0	S(kJ/kg-K) 6.6616 6.8176 7.0401 7.2345 7.4106 7.5734 7.7257 7.8692 8.0054 8.1354 8.2598 8.3794 8.4947	P = 1.00 T(°C) 179.9 200 250 300 350 400 450 500 650 700	3.6302 OMPa (V(m³/kg) 0.1944 0.2060 0.2327 0.2580 0.2825 0.3066 0.3304 0.3541 0.3777 0.4011 0.4245 0.4478	4687.0 179.9) U(kJ/kg) 2582.8 2622.2 2710.4 2793.6 2875.7 2957.9 3040.9 3125.0 3210.5 3297.5 3386.0 3476.2	5413.1 H(kJ/kg) 2777.1 2828.3 2943.1 3051.6 3158.2 3264.5 3371.3 3479.1 3588.1 3698.6 3810.5 3924.1	S(kJ/kg-K) 6.5850 6.6955 6.9265 7.1246 7.3029 7.4669 7.6200 7.7641 7.9008 8.0310 8.1557 8.2755
1300 P = 0.80 T(°C) 170.4 200 250 300 350 400 450 500 550 660 670 770 750 800	7.2604 0MPa V(m³/kg) 0.2403 0.2609 0.2932 0.3242 0.3544 0.3843 0.4139 0.4433 0.4726 0.5019 0.5310 0.5601 0.5892 0.6182	4687.2 (170.4) U(kJ/kg) 2576.0 2631.0 2715.9 2797.5 2878.6 2960.2 3042.8 3126.6 3211.9 3298.7 3387.1 3477.2 3569.0 3662.4	H(kJ/kg) 2768.3 2839.7 2950.4 3056.9 3162.2 3267.6 3373.9 3481.3 3590.0 3700.1 3811.9 3925.3 4040.3 4157.0	S(kJ/kg-K) 6.6616 6.8176 7.0401 7.2345 7.4106 7.5734 7.7257 7.8692 8.0054 8.1354 8.2598 8.3794 8.4947 8.6061	1300 P = 1.00 T(°C) 179.9 200 250 300 350 400 450 500 650 700 750	3.6302 OMPa (V(m³/kg) 0.1944 0.2060 0.2327 0.2580 0.2825 0.3066 0.3304 0.3541 0.3777 0.4011 0.4245 0.4478 0.4711	4687.0 179.9) U(kJ/kg) 2582.8 2622.2 2710.4 2793.6 2875.7 2957.9 3040.9 3125.0 3210.5 3297.5 3386.0 3476.2 3568.1	5413.1 H(kJ/kg) 2777.1 2828.3 2943.1 3051.6 3158.2 3264.5 3371.3 3479.1 3588.1 3588.1 3698.6 3810.5 3924.1 4039.3	S(kJ/kg-K) 6.5850 6.6955 6.9265 7.1246 7.3029 7.4669 7.6200 7.7641 7.9008 8.0310 8.1557 8.2755 8.3909
1300 P = 0.80 T(°C) 170.4 200 250 300 350 400 450 500 550 660 670 770 750 800	7.2604 0MPa V(m³/kg) 0.2403 0.2609 0.2932 0.3242 0.3544 0.3843 0.4139 0.4433 0.4726 0.5019 0.5310 0.5601 0.5892 0.6182	4687.2 (170.4) U(kJ/kg) 2576.0 2631.0 2715.9 2797.5 2878.6 2960.2 3042.8 3126.6 3211.9 3298.7 3387.1 3477.2 3569.0 3662.4	H(kJ/kg) 2768.3 2839.7 2950.4 3056.9 3162.2 3267.6 3373.9 3481.3 3590.0 3700.1 3811.9 3925.3 4040.3 4157.0	S(kJ/kg-K) 6.6616 6.8176 7.0401 7.2345 7.4106 7.5734 7.7257 7.8692 8.0054 8.1354 8.2598 8.3794 8.4947 8.6061	1300 P = 1.00 T(°C) 179.9 200 250 300 350 400 450 500 650 700 750 800	3.6302 OMPa (V(m ³ /kg) 0.1944 0.2060 0.2327 0.2580 0.2825 0.3066 0.3304 0.3541 0.3777 0.4011 0.4245 0.4478 0.4711 0.4944	4687.0 179.9) U(kJ/kg) 2582.8 2622.2 2710.4 2793.6 2875.7 2957.9 3040.9 3125.0 3210.5 3297.5 3386.0 3476.2 3568.1 3661.7	5413.1 H(kJ/kg) 2777.1 2828.3 2943.1 3051.6 3158.2 3264.5 3371.3 3479.1 3588.1 3698.6 3810.5 3924.1	S(kJ/kg-K) 6.5850 6.6955 6.9265 7.1246 7.3029 7.4669 7.6200 7.7641 7.9008 8.0310 8.1557 8.2755
1300 P = 0.80 T(°C) 170.4 200 250 300 350 400 450 500 550 660 670 770 750 800	7.2604 0MPa V(m³/kg) 0.2403 0.2609 0.2932 0.3242 0.3544 0.3843 0.4139 0.4433 0.4726 0.5019 0.5310 0.5601 0.5892 0.6182	4687.2 (170.4) U(kJ/kg) 2576.0 2631.0 2715.9 2797.5 2878.6 2960.2 3042.8 3126.6 3211.9 3298.7 3387.1 3477.2 3569.0 3662.4	H(kJ/kg) 2768.3 2839.7 2950.4 3056.9 3162.2 3267.6 3373.9 3481.3 3590.0 3700.1 3811.9 3925.3 4040.3 4157.0	S(kJ/kg-K) 6.6616 6.8176 7.0401 7.2345 7.4106 7.5734 7.7257 7.8692 8.0054 8.1354 8.2598 8.3794 8.4947 8.6061	1300 P = 1.00 T(°C) 179.9 200 250 300 350 400 450 500 650 700 750 800 850	3.6302 OMPa (V(m³/kg) 0.1944 0.2060 0.2327 0.2580 0.2825 0.3066 0.3304 0.3541 0.3777 0.4011 0.4245 0.4478 0.4711	4687.0 179.9) U(kJ/kg) 2582.8 2622.2 2710.4 2793.6 2875.7 2957.9 3040.9 3125.0 3210.5 3297.5 3386.0 3476.2 3568.1	5413.1 H(kJ/kg) 2777.1 2828.3 2943.1 3051.6 3158.2 3264.5 3371.3 3479.1 3588.1 3698.6 3810.5 3924.1 4039.3 4156.1	S(kJ/kg-K) 6.5850 6.6955 6.9265 7.1246 7.3029 7.4669 7.6200 7.7641 7.9008 8.0310 8.1557 8.2755 8.3909 8.5024
1300 P = 0.86 T(°C) 170.4 200 250 300 350 400 450 550 600 650 700 750 800 850	7.2604 0MPa V(m³/kg) 0.2403 0.2609 0.2932 0.3242 0.3544 0.3843 0.4139 0.4433 0.4726 0.5019 0.5310 0.5601 0.5892 0.6182 0.6472	4687.2 (170.4) U(kJ/kg) 2576.0 2631.0 2715.9 2797.5 2878.6 2960.2 3042.8 3126.6 3211.9 3298.7 3387.1 3477.2 3569.0 3662.4 3757.6	H(kJ/kg) 2768.3 2839.7 2950.4 3056.9 3162.2 3267.6 3373.9 3481.3 3590.0 3700.1 3811.9 3925.3 4040.3 4157.0 4275.4	S(kJ/kg-K) 6.6616 6.8176 7.0401 7.2345 7.4106 7.5734 7.7257 7.8692 8.0054 8.1354 8.2598 8.3794 8.4947 8.6061 8.7139	1300 P = 1.00 T(°C) 179.9 200 250 300 350 400 450 500 600 650 700 750 800 850 900 950	3.6302 OMPa (V(m ³ /kg) 0.1944 0.2060 0.2327 0.2580 0.2825 0.3066 0.3304 0.3541 0.3777 0.4011 0.4245 0.4478 0.4711 0.4944 0.5176 0.5408 0.5640	4687.0 179.9) U(kJ/kg) 2582.8 2622.2 2710.4 2793.6 2875.7 2957.9 3040.9 3125.0 3210.5 3297.5 3386.0 3476.2 3568.1 3661.7 3757.0 3853.9 3952.5	5413.1 H(kJ/kg) 2777.1 2828.3 2943.1 3051.6 3158.2 3264.5 3371.3 3479.1 3588.1 3698.6 3810.5 3924.1 4039.3 4156.1 4274.6 4394.8 4516.5	S(kJ/kg-K) 6.5850 6.6955 6.9265 7.1246 7.3029 7.4669 7.6200 7.7641 7.9008 8.0310 8.1557 8.2755 8.3909 8.5024 8.6103 8.7150 8.8166
1300 P = 0.80 T(°C) 170.4 200 250 300 350 400 450 500 650 700 750 800 850	7.2604 0MPa V(m³/kg) 0.2403 0.2609 0.2932 0.3242 0.3544 0.3843 0.4139 0.4433 0.4726 0.5019 0.5310 0.5601 0.5892 0.6182 0.6472	4687.2 (170.4) U(kJ/kg) 2576.0 2631.0 2715.9 2797.5 2878.6 2960.2 3042.8 3126.6 3211.9 3298.7 3387.1 3477.2 3569.0 3662.4 3757.6	H(kJ/kg) 2768.3 2839.7 2950.4 3056.9 3162.2 3267.6 3373.9 3481.3 3590.0 3700.1 3811.9 3925.3 4040.3 4157.0 4275.4	S(kJ/kg-K) 6.6616 6.8176 7.0401 7.2345 7.4106 7.5734 7.7257 7.8692 8.0054 8.1354 8.2598 8.3794 8.4947 8.6061 8.7139	1300 P = 1.00 T(°C) 179.9 200 250 300 350 400 450 500 650 700 750 800 850 900 950 1000	3.6302 OMPa (V(m ³ /kg) 0.1944 0.2060 0.2327 0.2580 0.2825 0.3066 0.3304 0.3541 0.3777 0.4011 0.4245 0.4478 0.4478 0.4711 0.4944 0.5176 0.5408 0.5640 0.5872	4687.0 179.9) U(kJ/kg) 2582.8 2622.2 2710.4 2793.6 2875.7 2957.9 3040.9 3125.0 3210.5 3297.5 3386.0 3476.2 3568.1 3661.7 3757.0 3853.9 3952.5 4052.7	5413.1 H(kJ/kg) 2777.1 2828.3 2943.1 3051.6 3158.2 3264.5 3371.3 3479.1 3588.1 3698.6 3810.5 3924.1 4039.3 4156.1 4274.6 4394.8 4516.5 4639.9	S(kJ/kg-K) 6.5850 6.6955 6.9265 7.1246 7.3029 7.4669 7.6200 7.7641 7.9008 8.0310 8.1557 8.2755 8.3909 8.5024 8.6103 8.7150 8.8166 8.9155
1300 P = 0.80 T(°C) 170.4 200 250 300 350 400 450 550 600 650 750 800 850 000 000 000	7.2604 0MPa V(m³/kg) 0.2403 0.2609 0.2932 0.3242 0.3544 0.3843 0.4139 0.4433 0.4726 0.5019 0.5310 0.5601 0.5892 0.6182 0.6472	4687.2 (170.4) U(kJ/kg) 2576.0 2631.0 2715.9 2797.5 2878.6 2960.2 3042.8 3126.6 3211.9 3298.7 3387.1 3477.2 3569.0 3662.4 3757.6	H(kJ/kg) 2768.3 2839.7 2950.4 3056.9 3162.2 3267.6 3373.9 3481.3 3590.0 3700.1 3811.9 3925.3 4040.3 4157.0 4275.4	S(kJ/kg-K) 6.6616 6.8176 7.0401 7.2345 7.4106 7.5734 7.7257 7.8692 8.0054 8.1354 8.2598 8.3794 8.4947 8.6061 8.7139	1300 P = 1.00 T(°C) 179.9 200 250 300 350 400 450 500 650 700 750 800 850 900 950 1000 1050	3.6302 OMPa (V(m ³ /kg) 0.1944 0.2060 0.2327 0.2580 0.2825 0.3066 0.3304 0.3541 0.3777 0.4011 0.4245 0.4478 0.4711 0.4944 0.5176 0.5408 0.5640 0.5872 0.6104	4687.0 179.9) U(kJ/kg) 2582.8 2622.2 2710.4 2793.6 2875.7 2957.9 3040.9 3125.0 3210.5 3297.5 3386.0 3476.2 3568.1 3661.7 3757.0 3853.9 3952.5 4052.7 4154.5	5413.1 H(kJ/kg) 2777.1 2828.3 2943.1 3051.6 3158.2 3264.5 3371.3 3479.1 3588.1 3698.6 3810.5 3924.1 4039.3 4156.1 4274.6 4394.8 4516.5 4639.9 4764.9	S(kJ/kg-K) 6.5850 6.6955 6.9265 7.1246 7.3029 7.4669 7.6200 7.7641 7.9008 8.0310 8.1557 8.2755 8.3909 8.5024 8.6103 8.7150 8.8166 8.9155 9.0118
1300 P = 0.86 T(°C) 170.4 200 250 300 350 400 450 550 600 650 700 750 800 850 000 000 000 0	7.2604 0MPa V(m³/kg) 0.2403 0.2609 0.2932 0.3242 0.3544 0.3843 0.4139 0.4433 0.4726 0.5019 0.5310 0.5601 0.5892 0.6182 0.6472	4687.3 (170.4) U(kJ/kg) 2576.0 2631.0 2715.9 2797.5 2878.6 2960.2 3042.8 3126.6 3211.9 3298.7 3387.1 3477.2 3569.0 3662.4 3757.6	H(kJ/kg) 2768.3 2839.7 2950.4 3056.9 3162.2 3267.6 3373.9 3481.3 3590.0 3700.1 3811.9 3925.3 4040.3 4157.0 4275.4	2 10.5229 S(kJ/kg-K) 6.6616 6.8176 7.0401 7.2345 7.4106 7.5734 7.7257 7.8692 8.0054 8.1354 8.2598 8.3794 8.4947 8.6061 8.7139	1300 P = 1.00 T(°C) 179.9 200 250 300 350 400 450 500 650 700 750 800 850 900 950 1000 1050 1100	3.6302 OMPa (V(m ³ /kg) 0.1944 0.2060 0.2327 0.2580 0.2825 0.3066 0.3304 0.3541 0.3777 0.4011 0.4245 0.4478 0.4711 0.4944 0.5176 0.5408 0.5640 0.5872 0.6104 0.6335	4687.0 179.9) U(kJ/kg) 2582.8 2622.2 2710.4 2793.6 2875.7 2957.9 3040.9 3125.0 3210.5 3297.5 3386.0 3476.2 3568.1 3661.7 3757.0 3853.9 3952.5 4052.7 4154.5 4257.9	5413.1 H(kJ/kg) 2777.1 2828.3 2943.1 3051.6 3158.2 3264.5 3371.3 3479.1 3588.1 3698.6 3810.5 3924.1 4039.3 4156.1 4274.6 4394.8 4516.5 4639.9 4764.9 4891.4	S(kJ/kg-K) 6.5850 6.6955 6.9265 7.1246 7.3029 7.4669 7.6200 7.7641 7.9008 8.0310 8.1557 8.2755 8.3909 8.5024 8.6103 8.7150 8.8166 8.9155 9.0118 9.1056
1300 P = 0.80 T(°C) 170.4 200 250 300 350 400 450 550 660 650 700 750 800 850 000 000 000 01150	7.2604 0MPa V(m³/kg) 0.2403 0.2609 0.2932 0.3242 0.3544 0.3843 0.4139 0.4433 0.4726 0.5019 0.5310 0.5601 0.5892 0.6182 0.6472	4687.2 (170.4) U(kJ/kg) 2576.0 2631.0 2715.9 2797.5 2878.6 2960.2 3042.8 3126.6 3211.9 3298.7 3387.1 3477.2 3569.0 3662.4 3757.6	H(kJ/kg) 2768.3 2839.7 2950.4 3056.9 3162.2 3267.6 3373.9 3481.3 3590.0 3700.1 3811.9 3925.3 4040.3 4157.0 4275.4	S(kJ/kg-K) 6.6616 6.8176 7.0401 7.2345 7.4106 7.5734 7.7257 7.8692 8.0054 8.1354 8.2598 8.3794 8.4947 8.6061 8.7139	1300 P = 1.00 T(°C) 179.9 200 250 300 350 400 450 500 650 700 750 800 850 900 950 1000 1050 1100 1150	3.6302 OMPa (V(m³/kg) 0.1944 0.2060 0.2327 0.2580 0.2825 0.3066 0.3304 0.3777 0.4011 0.4245 0.4478 0.4711 0.4944 0.5176 0.5408 0.5640 0.5872 0.6104 0.6335 0.6567	4687.0 179.9) U(kJ/kg) 2582.8 2622.2 2710.4 2793.6 2875.7 2957.9 3040.9 3125.0 3210.5 3297.5 3386.0 3476.2 3568.1 3661.7 3757.0 3853.9 3952.5 4052.7 4154.5 4257.9 4362.7	5413.1 H(kJ/kg) 2777.1 2828.3 2943.1 3051.6 3158.2 3264.5 3371.3 3479.1 3588.1 3698.6 3810.5 3924.1 4039.3 4156.1 4274.6 4394.8 4516.5 4639.9 4764.9 4891.4 5019.4	S(kJ/kg-K) 6.5850 6.6955 6.9265 7.1246 7.3029 7.4669 7.6200 7.7641 7.9008 8.0310 8.1557 8.2755 8.3909 8.5024 8.6103 8.7150 8.8166 8.9155 9.0118 9.1056 9.1972
1300 P = 0.80 T(°C) 170.4 200 250 300 350 400 450 500 650 700 750 800 850 000 000 01100 1150 1200	7.2604 0MPa V(m³/kg) 0.2403 0.2609 0.2932 0.3242 0.3544 0.3843 0.4139 0.4433 0.4726 0.5019 0.5310 0.5601 0.5892 0.6182 0.6472	4687.3 (170.4) U(kJ/kg) 2576.0 2631.0 2715.9 2797.5 2878.6 2960.2 3042.8 3126.6 3211.9 3298.7 3387.1 3477.2 3569.0 3662.4 3757.6	H(kJ/kg) 2768.3 2839.7 2950.4 3056.9 3162.2 3267.6 3373.9 3481.3 3590.0 3700.1 3811.9 3925.3 4040.3 4157.0 4275.4	2 10.5229 S(kJ/kg-K) 6.6616 6.8176 7.0401 7.2345 7.4106 7.5734 7.7257 7.8692 8.0054 8.1354 8.2598 8.3794 8.4947 8.6061 8.7139	1300 P = 1.00 T(°C) 179.9 200 250 300 350 400 450 500 650 700 750 800 850 900 950 1000 1050 1100	3.6302 OMPa (V(m ³ /kg) 0.1944 0.2060 0.2327 0.2580 0.2825 0.3066 0.3304 0.3541 0.3777 0.4011 0.4245 0.4478 0.4711 0.4944 0.5176 0.5408 0.5640 0.5872 0.6104 0.6335	4687.0 179.9) U(kJ/kg) 2582.8 2622.2 2710.4 2793.6 2875.7 2957.9 3040.9 3125.0 3210.5 3297.5 3386.0 3476.2 3568.1 3661.7 3757.0 3853.9 3952.5 4052.7 4154.5 4257.9	5413.1 H(kJ/kg) 2777.1 2828.3 2943.1 3051.6 3158.2 3264.5 3371.3 3479.1 3588.1 3698.6 3810.5 3924.1 4039.3 4156.1 4274.6 4394.8 4516.5 4639.9 4764.9 4891.4	S(kJ/kg-K) 6.5850 6.6955 6.9265 7.1246 7.3029 7.4669 7.6200 7.7641 7.9008 8.0310 8.1557 8.2755 8.3909 8.5024 8.6103 8.7150 8.8166 8.9155 9.0118 9.1056

Summary of Process and General Rules

Nozzle
$$\Delta S = 0$$

 $\Delta H=1/2 \ mv^2$

Throttle $\Delta S = -R \ln(P_2/P_1)$ (i.g.)

 $\Delta H=1/2 \ mv^2$

Pump
$$\Delta S = 0$$
 for adiabatic reversible

 $\Delta H = W_{\rm S} = \Delta H' / \eta_{\rm eff}$

Turbine
$$\Delta S = 0$$
 for adiabatic reversible

 $\Delta H = W_{\rm S} = \Delta H' \, \eta_{\rm eff}$

Carnot (Use °K)

Engine $\eta_{\text{eff}} = (T_{\text{H}} - T_{\text{C}})/T_{\text{H}}$ Refrigerator $COP = T_{\text{C}}/(T_{\text{H}} - T_{\text{C}})$

Heat Pump $COP = T_H/(T_H - T_C)$

Isothermal $(\Delta S)_T = R \ln t$

 $(\Delta S)_T = R \ln[V_2/V_1]$ i.g. = -R $\ln[P_2/P_1]$

 $(\Delta H)_T = 0$

Ideal Mixing $\Delta S_{\text{mix}} = -R \Sigma x_i \ln x_i$

Adiabatic, Reversible

$$\Delta S = 0$$

Isobaric $(dS)_P = C_p (dT)_P / T$

 $(dS/dT)_P = C_p/T$

Constant Volume

$$(dS)_V = C_V (dT)_V / T$$
$$(dS/dT)_V = C_V / T$$

Phase Change $\Delta S_{\text{trans}} = \Delta H_{\text{trans}} / T_{\text{trans}}$

Answers: Chemical Engineering Thermodynamics Quiz 5 February 14, 2019

Estimated values from the enthalpy chart:

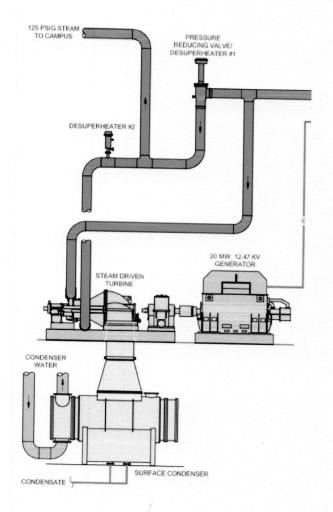
Stream	P MPa	T °C	S kJ/(kg K)	H kJ/kg	$V m^3/kg$
1	0.881	480	7.8	3410	0.43
2'	0.15	250	7.8	2900	2.40
2	0.15	140	7.3	2680	1.7

Extra Credit: Propose a method to extract useful energy from the 0.15 MPa stream. Sterling Engine could be used (capital costs would be an issue). Thermoelectric Device could be used (technology in development https://sites.google.com/site/jhbahk/members/jehyeongbahk UC Professor working on thermoelectric devices, Dr. Je-Hyeong Bahk, next to my office. There are limited options for low grade steam and heat sources. The capital costs hinder investment in energy harvesting. It is a major problem faced by this generation.

Values below are from double extrapolation from the steam tables. Values are generally similar to those estimated from the chart. The main conclusion is clear, that this is not a feasible operation with the temperature and pressure of the outflow stream as stated.

Answers

Chemical Engineering Thermodynamics Quiz 5 February 14, 2019

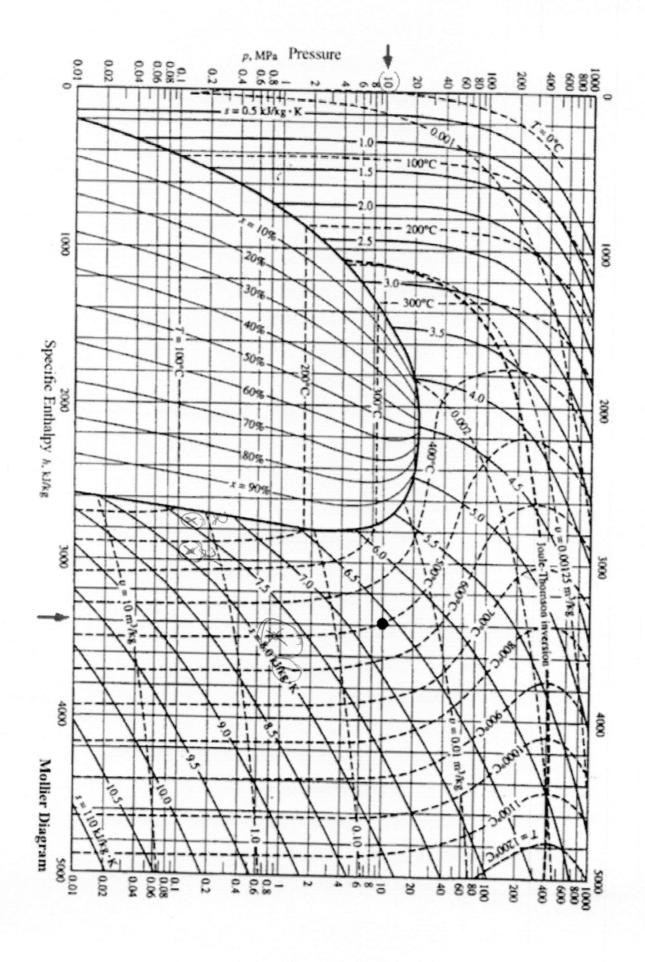


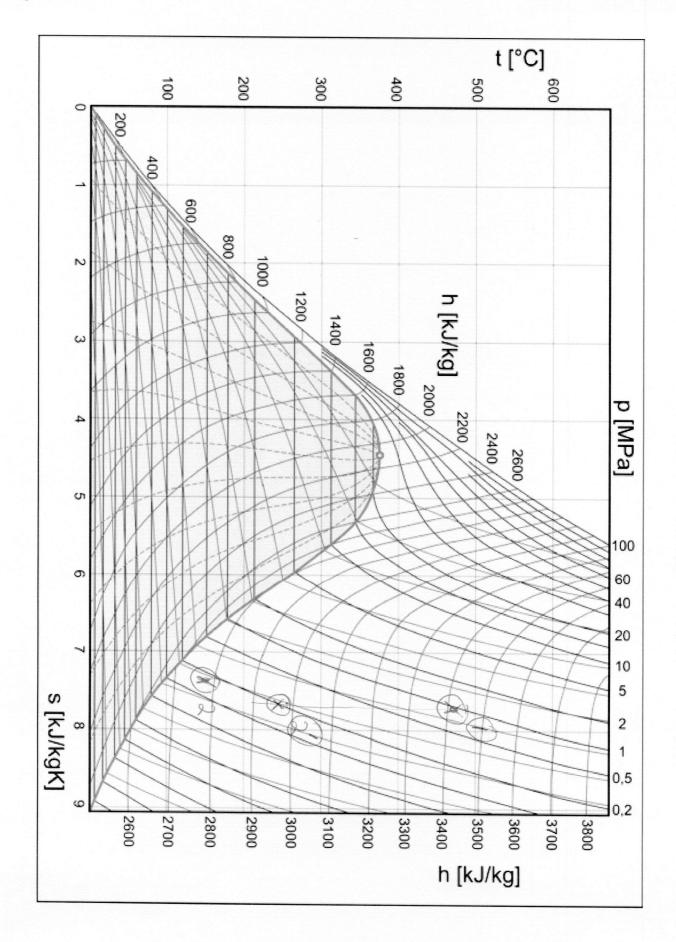
The UC steam plant uses 125 PSIG (0.881 MPa) steam produced by two gas turbines at 480°C to feed a steam turbine (*stream 1*). The output from the steam turbine (*stream 2*) is at 0.15 MPa and 140°C. The outflow from the steam turbine is fed into a condenser. The steam produces 20 MW of electrical power.

Please fill out the following table using the steam tables.

Stream	P MPa	T°C	S kJ/(kg K)	H kJ/kg	V m3/kg	$\Delta H \text{kJ/kg}$	State
1	0.881	480	7.84	3460	0441		6/10
2'	0.15	243	784	2960	1.77	100	2115
2	0.15	140	7.40	2760	141	300	145

- a) What is the work output of an ideal turbine (reversible adiabatic)?
- b) What is the actual work output and efficiency, η_{eff} , of this turbine?
- c) What is the efficiency of a Carnot engine for these conditions. Compare it with that of the steam turbine. Are the listed conditions possible?
- d) Plot the points 1, 2', and 2 on both the pressure enthalpy and the temperature entropy diagrams that are attached. Fill the missing values in the table above.
- e) If the turbine produces 20 MW what is the flow rate of steam in kg/s?
- f) Extra Credit: Propose a method to extract useful energy from the 0.14 MPa stream.





	D = 0.500	Maria /	151.8)			P = 0.61	0MPa	(158.8)			P = 0.86)MPa	(170.4)		W. 11 - 10	
	P = 0.508 $T(^{\circ}C)$			H(kJ/kg)	S(kJ/kg-K)		V(m ³ /kg)		H(kJAkg)	S(kJ/kg-K)	T(°C)				S(kJ/kg-K) 6.6616	
		0.3748	2560.7	2748.1	6.8207	158.8	0.3156	2566.8	2756.1	6.7593	170.4 200	0.2403 0.2609	2576.0 2631.0	2768.3 2839.7	6.8176	
	200	0.4250	2543.3	2855.8	7.0610		0.3521	2639.3 2721.2	2850.6 2957.6	6.9683 7.1832	250	0.2932	2713.9	2950,4	7,0401	
		0.4744	2723.8 2803.2	2961.0 3064.6	7.2724 7.4614		0.4344	2801.4	3062.0	7.3740	300	0.3242	2797.5	3056.9	7.2345	
		0.5226	2883.0	3168,1	7.6346	350	0.4743	2881.6	3166.1	7,5481	350	0.3544 0.3843	2878.6	3162.2	7,4106 7,5734	
	400	0.6173	2963.7	3272.3	7.7958		0.5137	2962.5 3044.7	3270.8 3376.5	7,7097 7,8611	450	0.4139	3042.8	3373.9	7.7257	
	450	0.6642	3045.6	3377.7 3484.5	7.9465 8.0892		0.5530 0.5920	3128.2	3483.4	8.0041	500	0.4433	3126.6	3481.3	7,8692	
	500 550	0.7109	3129.0 3213.9	3592.7	8.2249		0.6309	3213.2	3591.8	8.1399	550	0.5019	3211.9 3298.7	3590.0 3700.1	8,0054 8,1354	
	600	0.8041	3300.4	3702.5	8.3543	600	0.6698	3299.8 3388.1	3701.7 3813.2	8.2695 8.3937	600 650	0.5310	3387.1	38 1.9	8.2598	
	650	0.8505	3388.6	3813.9 3927.0	8.4784 8.5977	650 700	0.7085	3478.1	3926.4	8.5131	700	0.5601	3477.2	3925.3	8.3794	
	700 750	0.8970 0.9433	3478.5 3570.2	4041.8	8.7128	750	0.7859	3569.8	4041.3	8.6283	750 800	0.5892 0.6182	3569.0 3662.4	4040.3 4157.0	8,4947 8,6061	
	800	0.9897	3563.6	4158.4	8.8240	800	0.8246 0.8632	3663.2 3738.3	4157.9 4276.2	8.7395 8.8472	850	0.6472	3757.6	4275.4	8.7139	
	850 900	1.0360	3758.6 3855.4	4276.6 4396.6	8.9317 9.0352	850 900	0.9018	3855.1	4396.2	8,9518	900	0,6762	3854.5	4395.5	8.8185 8.9201	
	950	1.1285	3953.9	4518.2	9.1377	950	0.9404	3953.5	4517.8	9,0533 9,1521	950 1000	0.7052 0.7341	3953.1 4053.2	4517.2 4640.5	9.0189	
	1000	1.1748	4054.0	4641.4	9.2364	1003	0.9789 1.0175	4053.7 4155.5	4641.1 4766.0	9.2482	1050	0.7630	4155.0	4765.4	9.1151	
	1050	1.2210	4155.7 4259.0	4766.2 4892.6	9.3326 9.4263	1100	1.0560	4258.7	4892.4	9.3420	1100	0,7920	4258.3	4891.9 5019.8	9,2089 9,3004	
	1150	1.3135	4363.7	5020.5	9.5178	1150	1.0946	4353.5	5020.3	9.4335 9.5228	1150 1200	0.8209 0.8498	4363.1 4469.4	5149.2	9.3898	
	1200	1,3597	4470.0	5149.8	9.5071	1200 1250	1.1331	4469.8 4577.4	5149.6 5280.4	9,6101	1250	0.8787	4577.1	5280.0	5.4771	
	1250	1.4059	4577.6	5280.5 5412.6	9.6944 9.7797			4685.4 (188.0)	5412.5	9,6954	1300	0.9076 40MPa	(195.0)	5412.2	9.5625	
	P = 1.0	1.4521 XXMPa	(179.9)				20MPa		110.15	NI-14- 1/2			(193.0) g) U(kJ/kg) Hikliko) S(kJ/kg-K)	
	T(°C)	$V(m^3/kg)$	U(kJ/kg) H(kJ/kg			V(m³/kg	41) S[kJ/kg-K]	7(°C) 195.0	0.1408	2591.8	2788.9	6,4675	
	179,9	0,1944	2582.8	2777.1	6.5850		0.1633	2587.8 2612.9	2783,7 2816,1	6.5217 6.5909	200	0.1430	2602.7	2803/0	6,4975	
	200	0.2060	2622.2 2710.4	2828.3 2943.1	6.6955	200 250	0.1693 0.1924	2704.7	2935.6	6.8313	250	0.1636	2698.9	2927.9	6.7488	
	250 300	0.2327 0.2580	2793.6	3051.6	7.1246	300	0.2139	2789.7	3046,3	7.0335	300	0.1823	2785.7	3040.9 3150.1	6.9552 7.1379	
	350	0.2825	2875.7	3158.2	7.3029	350	0.2346	2872.7	3154.2	7.2139 7.3793	350 400	0.2003 0.2178	2869.7 2953.1	3258.1	7.3046	
	400	0.3066	2957.9	3264.5	7,4669	400	0.2548	2955.5 3038.9	3261.3 3368.7	7.5332	450	0.2351	3037.0	3366.1	7,4594	
	450	0.3304	3040.9 3125.0	3371.3 3479.1	7.6200	450 500	0.2946	3123.4	3476.9	7.6779	500	0.2522	3121.8	3474.8	7,5047	
	500	9,3777	3210.5	3588.1	7.9008	550	0.3143	3209.1	3586.3	7.8150	550	0.2691	3207.7 3295.1	3584.5 3695.4	7.7422 7.8730	
	600	9,4911	3297.5	3698.6	8.0310	600	0.3339	3296.3	3697.0	7,9455	600 650	0.2860 0.3028	3384.0	3807.8	7.9982	
	650	0.4245	3386.0	3810.5	8.1557 8.2755	650 700	0.3535 0.3730	3385.0 3475.3	3809.2 3922.9	8.0704 8.1904	700	0.3195	3474.4	3921.7	8.1183	
	700 750	0.4478 0.4711	3476.2 3568.1	3924.1 4039.3	8.3909	750	0.3924	3567.3	4038.2	8.3060	750	0.3362	3566.5	4037.2	8.2340	
	800	0,4944	3651.7	4156.1	8.5024	800	0.4118	3661.0	4155.2	8.4176	800	0.3529	3660.2 3755.6	4154.3 4273.0	8,3457 8,4538	
	850	0.5176	3757.0	4274,6	8.61.03	850	0.4312	3756.3	4273.8	8.5256 8.6303	850 900	0.3695 0.3861	3852.7	4393.3	8.5587	
	900	0.5408	3853.9	4394,8	8.7150	900 950	0,4506 0,4699	3853.3 3952.0	4394.0 4515.9	8.7320	950	0.4027	3951.4	4515.2	8,6604	
	950 1000	0.5640 0.5872	3952.5 4052.7	4516.5 4639.9	8.81.66 8.91.55	1000		4052.2	4639.4	8.8310	1000	0.4193	4051.7	4638.8	8.7594	
	1050	0.6104	4154.5	4764.9	9.0118	1050	0.5086	4154.1	4764.4	8.9273	1050		4153.6 4257.0	4763.9 4890.5	8.8558 8.9497	
	1100	0.6335	4257.9	4891.4	9.1056	1100		4257.5	4891.0 5019.0	9.0212 9.1128	1100		4351.9	5018.6	9.0413	
	1150	0,6567	4352.7	5019.4 5148.9	9.1972 9.2866	1150		4362.3 4468.7	5148.5		1200			5148.1	9.1308	
	1200 1250	0.6798	4459.0 4576.7	5279.7	9.3739		0.5858	4576.4	5279.3	9,2895	1250		4576.0			
	1300	0,7261	4585,8	5411.9	9,4593	1300	0,6051	4685.4	5411.5	9,3749	1300					
												1.1/		1/. /.	4.18	-3460 kT/Ly
										11	?	600	11/20	60 -3	370 1 =	-3400-16
							0.81	7	486	n H	J	480-	0,2(3)	100	11111	, ,
			1 27-	. 27		1	0.0(/		With	00/	207	7737	7.84 W/kgk
	/		K119	WILA	10-61	/					7	51-	0.2 (7.07	7,77/2	1.01 1091
006	4.	3460	7 +	0=3	760 =					7		2º /hr		m/4	45	11/22 43/
0.20	1/	100	11.6	1.5/	1 1					11	1.40	42 -	0.21	443	-,419)	CU,407
	0	2 01	gn	KIK	12 May.	nonk	8			V	001					=0,437 m36
	7	4.84	+0,0	4/7.8	9-11/5/61	1091	-					K/lac.		K 1/4	4, 1/2	346067/
		(m)//	3			4	1 1	(1)	160	N	14	50 -	G2(3450-	33701-	3 8 6 0 h 7 kg
0.68	11 0	4771	0.11	MI	4	1	1001	J	120	#	01	MI			161	
	1	13/1	C104(437	-0,3991					-	7	76	Tak.	77 6	WIK 41/2 V	77761/
					A L MA	3/)	1	40-	8.20	1.70	1-7.62/=	+.10 WW
				= 0x	441 m	1kg				11	- 2 - 1	n3/6,	/	4016	0.14	(1) (2)
						1				V	0.354	6 - (2.2(0	17) 40	- asso).	7.73 MK = 0,349 mily
																/
																_

P = 0.0	1MPa (45.8)				15MPa	(81.3)			P=0,1	0MPa	(99.6)	17/1 18 ->	C. Lloy V
∏°C)	V(m ³ /kg)		H(kJ/kg)	S(kJ/kg-K)	$R^{\circ}C$	$V(m^3/kg)$	U(kJ/kg)	H(kJ/kg)	S(kJ/kg-K)	7(°C)		U(kJ/kg)		
45.8	14,6701	2437.2	2583.9	8.1488	8.3	3.2400	2483.2	2645.2	7,5930	99.6	1.6939	2505.6	2675.0	7.3588
50	14.9139	2443.3	2592.4	8.1755						1			2477.0	77/10
100	17,1964	2515.5	2687.5	8.4489	100	3.4187	2511.5	2682.4	7.6953	100	1.6959	2506.2	2675.8	7.3610
150	19.5132	2587.9	2783.0	8.6892	150	3.8897	2585.7	2780.2	7.9413	150	1.9367	2582.9	2776.5	7.6148
200	21.8256	2651.3	2879.6	8.9049	200	4,3562	2660.0	2877.8	8.1592	200	2.1724	2658.2	2875.5	7.8356
250	24.1361	2736.1	2977.4	9.1015	250	4.8206	2735.1	2976.1	8.3568	250	2.4062	2733.9	2974.5	8.0346
300	26,4456	2812.3	3076,7	9.2827	300	5,2840	2811.6	3075.8	8.5386	300	2.6388	2810.6	3074.5	8.2172
	28.7545	2890.0	3177.5	9,4513	350	5.7469	2889.4	3176.8	8.7076	350	2.8710	2888.7	3175.8	8,3866
350 400	31.0631	2969.3	3279.9	9,6094	400	6.2094	2968.9	3279.3	8.8659	400	3.1027	2968.3	3278.5	8.5452
	33.3714	3050.3	3384.0	9.7584	450	6.6717	3049.9	3383.5	9.0151	450	3.3342	3049.4	3382.8	8.6946
450	35.6796	3132.9	3489.7	9.8998	500	7.1338	3132.6	3489.3	9.1566	500	3.5655	3132.2	3488.7	8.8361
500		3217.2	3597.1	10.0344	550	7.5957	3217.0	3596.8	9.2913	550	3.7968	3216.6	3595.3	8.9709
550	37.9876			10.1631	600	8.0576	3303.1	3706.0	9.4201	600	4,0279	3302.8	3705.6	9,0998
600	40.2956	3303.3	3706.3	10.2866	650	8,5195	3391.0	3816,9	9.5436	650	4,2590	3390.7	3816.6	9.2234
650	42.6035	3391.2	3817.2	10.4055	700	8.9812	3480.6	3929.7	9.6625	700	4,4900	3480.4	3929,4	9,3424
700	44.9113	3480.8	3929.9		750	9,4430	3572.0	4844.2	9,7773	750	4,7209	3571.8	4043.9	9,4572
759	47,2191	3572.2	4044.4	10.5202	800	9,9047	3665.2	4160,4	9.8882	800	4.9519	3665.0	4160.2	9.5681
800	49,5259	3655.3	4160.6	10.6311	850	10,3663	3760.1	4278.5	9,9957	850	5.1828	3760.0	4278.2	9.6757
850	51.8347	3750.3	4278.6	10.7386	900	10,8280	3856.8	4398,2	10,1000	900	5,4137	3856.6	4398/0	9,7800
900	54,1424	3856.9	4398.3	10.8429	950	11,2896	3955.1	4519,6	10.2014	950	5.6446	3955.0	4519.5	9,8813
950	56,4501	3955.2	4519.7	10,9442	1000	11.7513	4055.1	4642.7	10.3000	1000	5.8754	4055.0	4642.5	9,9800
1000	58,7578	4055.2	4642.8	11.0428	1050	12.2129	4156.8	4767.4	10.3960	1050	6.1063	4156.6	4767.3	10,0761
1050	61.0655	4156.8	4767.5	11.1389			4259.9	4893.7	16.4897	1100	6.3371	4259.8	4893.5	10.1697
1100	63,3732	4250.0	4893.7	11.2325	1100	12.6745			10.5811	1150	6.5680	4364.5	5021.3	10,2611
1150	55,5838	4364.7	5021.5	11.3239	1150	13.1361	4364.6	5021.4	10.6703	1200	5.7988	4470.7	5150.6	10,3504
1200	67,9885	4470.9	5150.7	11,4132	1200	13.5977	4470.8	5150.7	10.7576	1250	7.0296	4578.3	5281.2	10.4376
1250	70,2961	4578.4	5281.4	11.5004	1250		4578.4	5281.3				4687.7	5413.2	10,5229
[300]	72,6038 .20MPa	4687.4 (120.3)	5413.4	11.5857	1300	14.5208 0.30MPa	4687.3 (133.5)	5413.3	16.8428	P = (7.2604 0.40MPa	4687.2 (143.6)	211216	1010au
			OF Life	Skukg-Ki) V(m ³ /kg) H(kJ/kg	() S(kJ/kg-K)	R°C) H(kJ/kg	S(kJ/kg-
_TCC		U(kJ/kg		7.1269	133.5		2543.2	2724.9	5.9916	143.6		2553.1	2738.1	6.8955
120,3	0.8857	2529.1	2706.2 2769.1	7.1209	150	0.6340	2571.0	2761.2	7.0791	150	0.4709	2564.4	2752.8	6.9306
150	0.9599	2577.1 2654.6	2870.7	7.5081	200	0.7164	2651.0	2865.9	7.3131	200	0.5343	2647.2	2860.9	7.1723
200 250	1.0805	2731.4	2971.2	7.7100	250	0.7964	2728.9	2967.9	7.5180	250	0.5952	2726.4	2964.5	7.3804
300	1.3162	2808.8	3072.1	7.8941	300	0.8753	2807.0	3069.6	7.7037	300	0.6549	2805.1	3057.1	7.5677
350	1,4330	2887.3	3173.9	8.0614	350	0.9536	2885.9	3172.0	7.8750	350	0.7140	2884.4	3170.0	7.7399
400	1.5493	2967.1	3277.0	8.2236	400	1.0315	2966.0	3275.5	8.0347	400	0.7726	2964.9	3273.9	7.9002
450	1,6655	3048.5	3381.6	8.3734	450	1.1092	3047.5	3380.3	8.1849	450	0.8311	3046.6	3379.0 3485.5	8.0508 8.1933
500	1.7814	3131.4	3487.7	8.5152	500	1.1367	3130.6	3486.6	8.3271	500	0.8894	3129.8 3214.6	3593.6	8.3287
550	1.8973	3215.9	3595.4	8.6502	550	1.2641	3215.3	3594.5	8.4623	550 600	1,0056	3301.0	3703.2	8.4580
600	2.0130	3302.2	3704.8	8.7792	600	1.3414	3301.6	3704.0	8.5914 8.7153	650	1.0636	3389.1	3814.6	8.5820
650	2.1287	3390.2	3815.9	8.9030	650	1.4186	3389.7	3815.3 3928.2	8,8344	700	1.1215	3479.0	3927.6	8,7012
700	2,2443	3479.9	3928.8	9.0220	700 750	1,4958	3479.5 3571.0	4042.9	8.9494	750	1.1794	3570.6	4042.4	8.8162
750	2.3599	3571.4	4043.4	9.1369	800	1.6500	3664.3	4159.3	9.0604	800	1.2373	3663.9	4158.8	8.9273
800	2.4755	3564.7	4159.8	9.2479 9.3555	850	1.7271	3759.3	4277,4	9,1680	850	1.2951	3759.0	4277.0	9,0350
850	2.5910	3759.6	4277.8	9,4598	900	1.8042	1856.0	4397.3	9,2724	900	1.3530	3855.7	4395.9	9,1394
900	2.7066 2.8221	3856.3 3954.7	4397.6 4519.1	9.3612	950	1.8812	3934.4	4518.8	9.3739	950	1.4108	3954.2	4518.5	9.2409
0.66		4054.8	4542.3	9.6599	100		4054.5	4642.0	9.4726	1000		4054.3	4641.7	9.3396
950	2,9013	4156.4	4767.0	9.7560	105		4156.2	4766.7	9,5687	1050		4155.9	4766.5	9.4357
1000	3.0530				1100		4259.4	4893.1	9.6624	110		4259.2	4892.8	9,5295
1000			4893.3	9.8497				2050.0	0.7720	115	1.6419	4363.9	5020.7	9,6209
1000 1050 1101	3.1685	4259.6	4893.3 5021.1	9.9411	115	0 2.1892	4364.1	5020.9	9.7538					
1000 1050 1100 1150	3.1685 3.2839		4893.3 5021.1 5150.4		1150 120	0 2.2662	4470.3	5150.2	9.8431	120	1.6997	4470.1	5150.0	9,7102
1900 1950 1101	3.1685 3.2839 3.3994	4259.6 4364.3	5021.1	9.9411	115	0 2.2662			9,8431 9,9303		0 1.6997 0 1.7574			

P=0.15 an/a 5 kl/gk 200°C 1663 287 7.67 2000150 200°C 1663 2972 7.87 200°C 1663 2972 7.87

40	1.29	1 Km	2760	7.16	140	0.931		1750	7,23
P = 0.10	· ·	(99.6)		S(kJ/kg-K)	P = 0.20		120.3)		
$\pi(^{\circ}C)$	$V(m^3/kg)$	U(kJ/kg)	H(kJ/kg)	7.3588	∏°C)			110.10	60110 10
99.6	1.6939	2505.6	2675.0	1.3300		$V(m^3/kg)$	U(kJ/kg)		S(kJ/kg-K)
77.0	1.00			7.3610	120.3	0.8857	2529.1	2706.2	7.1269
100	1.6959	2506.2	2675.8	7.6148	150	0.9599	2577.1	2769.1	7.2810
150	1.9367	2582.9	2776.6	7.8356	200	1.0805	2654.6	2870.7	7.5081
200	2.1724	2658.2	2875.5	8.0346	250	1.1989	2731.4	2971.2	7.7100
250	2.4062	2733.9	2974.5	8.2172	300	1.3162	2808.8	3072.1	7.8941
300	2.6388	2810.6	3074.5	8.3866	350	1.4330	2887.3	3173.9	8.0644
350	2.8710	2888.7	3175.8	8.5452	400	1.5493	2967.1	3277.0	8.2236
400	3.1027	2968.3	3278.6	8.6946	450	1.6655	3048.5	3381.6	8.3734
450	3.3342	3049.4	3382.8	8.8361	500	1.7814	3131.4	3487.7	8.5152
500	3.5655	3132.2	3488.7	8.9709	550	1.8973	3215.9	3595.4	8.6502
550	3.7968	3216.6	3596.3	9.0998	600	2.0130	3302.2	3704.8	8.7792
000	4.0279	3302.8	3705.6	9.2234	650	2.1287	3390.2	3815.9	8.9030
650	4.2590	3390.7	3816.6	9.3424	700	2.2443	3479.9	3928.8	9.0220
700	4.4900	3480.4	3929.4	9.4572	750	2.3599	3571.4	4043.4	9.1369
750	4.7209	3571.8	4043.9	9.5681	800	2.4755	3664.7	4159.8	9.2479
800	4.9519	3665.0	4160.2	9.6757	850	2.5910	3759.6	4277.8	9.3555
850	5.1828	3760.0	4278.2	9.7800	900	2.7066	3856.3	4397.6	9.4598
900	5.4137	3856.6	4398.0	9.8813	950	2.8221	3954.7	4519.1	9.5612
950	5.6446	3955.0	4519.5	9.9800	1000	2.9375	4054.8	4642.3	9.6599
1000	5.8754	4055.0	4642.6		1050	3.0530	4156.4	4767.0	9.7560
1050	6.1063	4156.6		10.0761	1100	3.1685	4259.6	4893.3	9.8497
1100	6.3371	4259.8		10.1697	1150	3.2839	4364.3	5021.1	9.9411
1150	6.5680	4364.5	5021.3	10.2611	1200	3.3994	4470.5	5150.4	10.0304
1200	6.7988	4470.7	5150.6		1250	3.5148	4578.1	5281.1	10.1176
1250		4578.3			1300	3.6302	4687.0	5413.1	10.2029
1300		4687.2	5413.2	10.5229	1300	5.0502	1007.0	2713.1	1000027
P = 0.8		(170.4)		00.14					
T(°C)		U(kJ/kg)		S(kJ/kg-K)	P = 1.00	MPa (179.9)		
170.4	0.2403	2576.0	2768.3	6.6616				H(kJ/kg)	S(kJ/kg-K
200 250	0.2609 0.2932	2631.0 2715.9	2839.7 2950.4	6.8176	T(°C)	$V(m^3/kg)$	U(kJ/kg)		6.5850
300	0.3242	2797.5	3056.9	7.0401 7.2345	179.9	0.1944	2582.8	2777.1	6.6955
350	0.3544	2878.6	3162.2	7.4106	200	0.2060	2622.2	2828.3	6.9265
400	0.3843	2960.2	3267.6	7.5734	250	0.2327	2710.4	2943.1 3051.6	7.1246
450	0.4139	3042.8	3373.9	7.7257	300	0.2580	2793.6	3158.2	7.3029
500	0.4433	3126.6	3481.3	7.8692	350	0.2825	2875.7	3264.5	7.4669
550	0.4726	3211.9	3590.0	8.0054	400	0.3066	2957.9	3371.3	7.6200
600	0.5019	3298.7	3700.1	8.1354	450	0.3304	3040.9	3479.1	7.7641
650	0.5310	3387.1	3811.9	8.2598	500	0.3541	3125.0 3210.5	3588.1	7.9008
700	0.5601	3477.2	3925.3	8.3794	550	0.3777	3210.5	3698.6	8.0310
750 800	0.5892	3569.0 3662.4	4040.3 4157.0	8.4947	600	0.4011	3386.0	3810.5	8.1557
850	0.6472	3757.6	4157.0	8.6061 8.7139	650	0.4245	3476.2	3924.1	8.2755
and a	0.04.2	312130	4275.4	0.7133	700	0.4478	3568.1	4039.3	8.3909
					750	0.4944	3661.7	4156.1	8.5024
					800	0.5176	3757.0	4274.6	8.6103
					850 900	0.5408	3853.9	4394.8	8.7150
				1.8185	950	0.5640	3952.5	4516.5	8.8166
900	0.6762	3854.5	4395.5	8.9201	1000	0.5872	4052.7	4639.9	8.9155
950	0.7052	4053.2	4640.5	9.0189	1050	0.6104	4154.5	4764.9	9.0118
1000	0.7630	4155.0	4765.4	9.1151	1100	0.6335	4257.9	4891.4	9.1056
1100	0.7920	4258.3	4891.9	9.2089	1150	0.6567	4362.7	5019.4	9.1972
1150	0.8209	4363.1	5019.8	9.3898	1200		4469.0	5148.9	9.2866
1200	0.8498	4469.4	5149.2 5280.0	9.4771	1250		4576.7	5279.7	9.3739
1250	0.8787	4577.1 4686.1	5412.2	9.5625	1300		4685.8	5411.9	9.4593
1300	0.9076	4050.1	5-112-0		1,500				