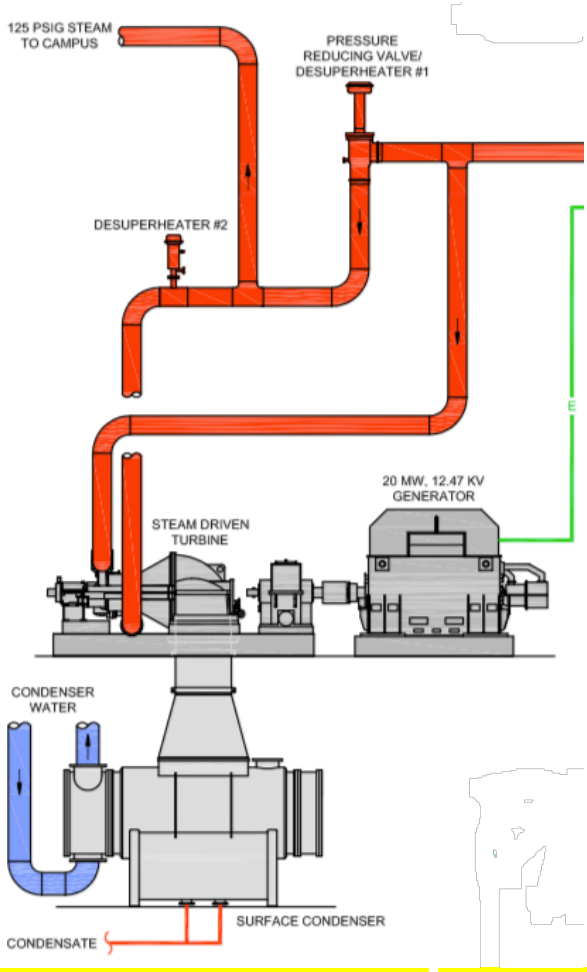
Chemical Engineering Thermodynamics
Quiz 5
February 14, 2019

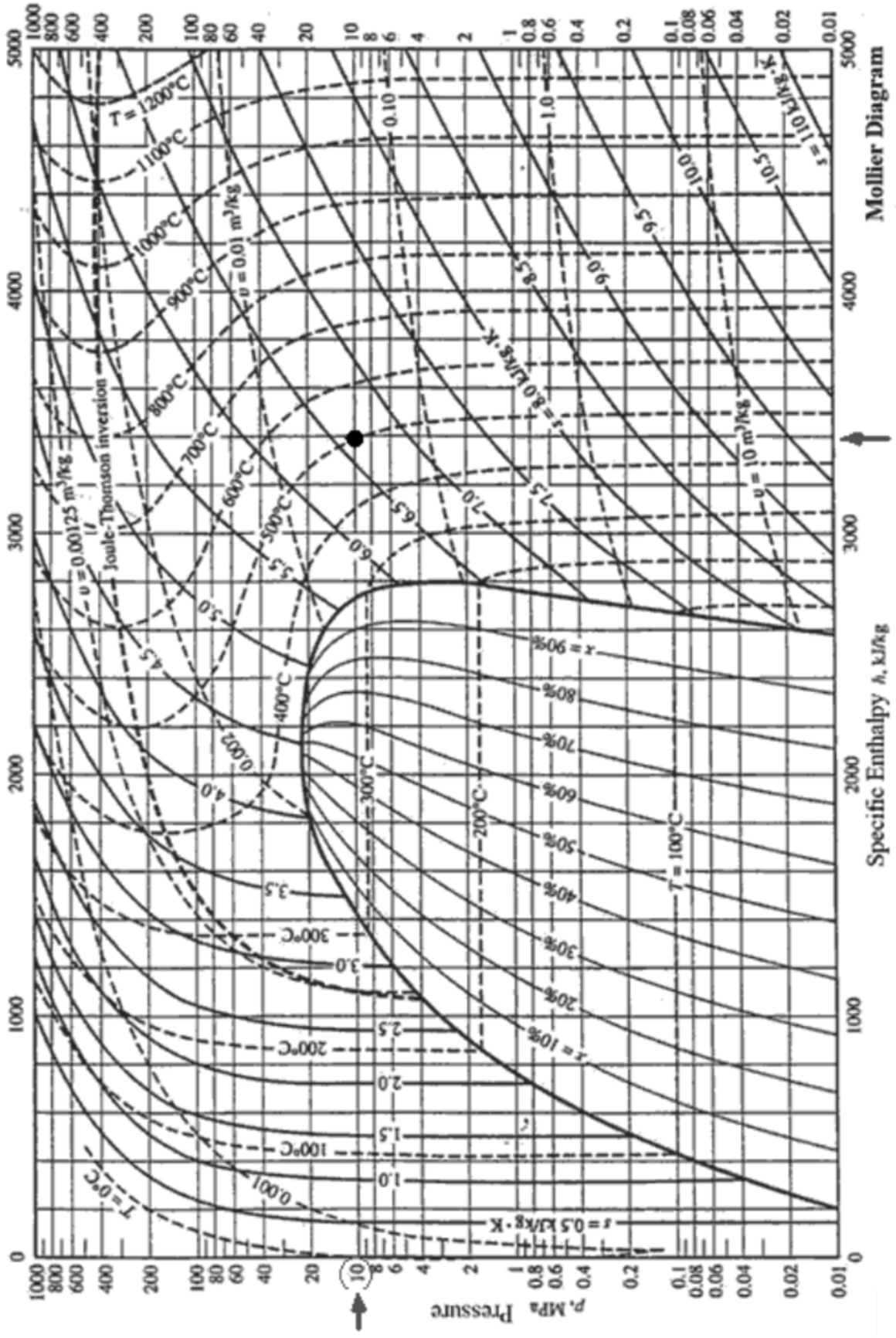


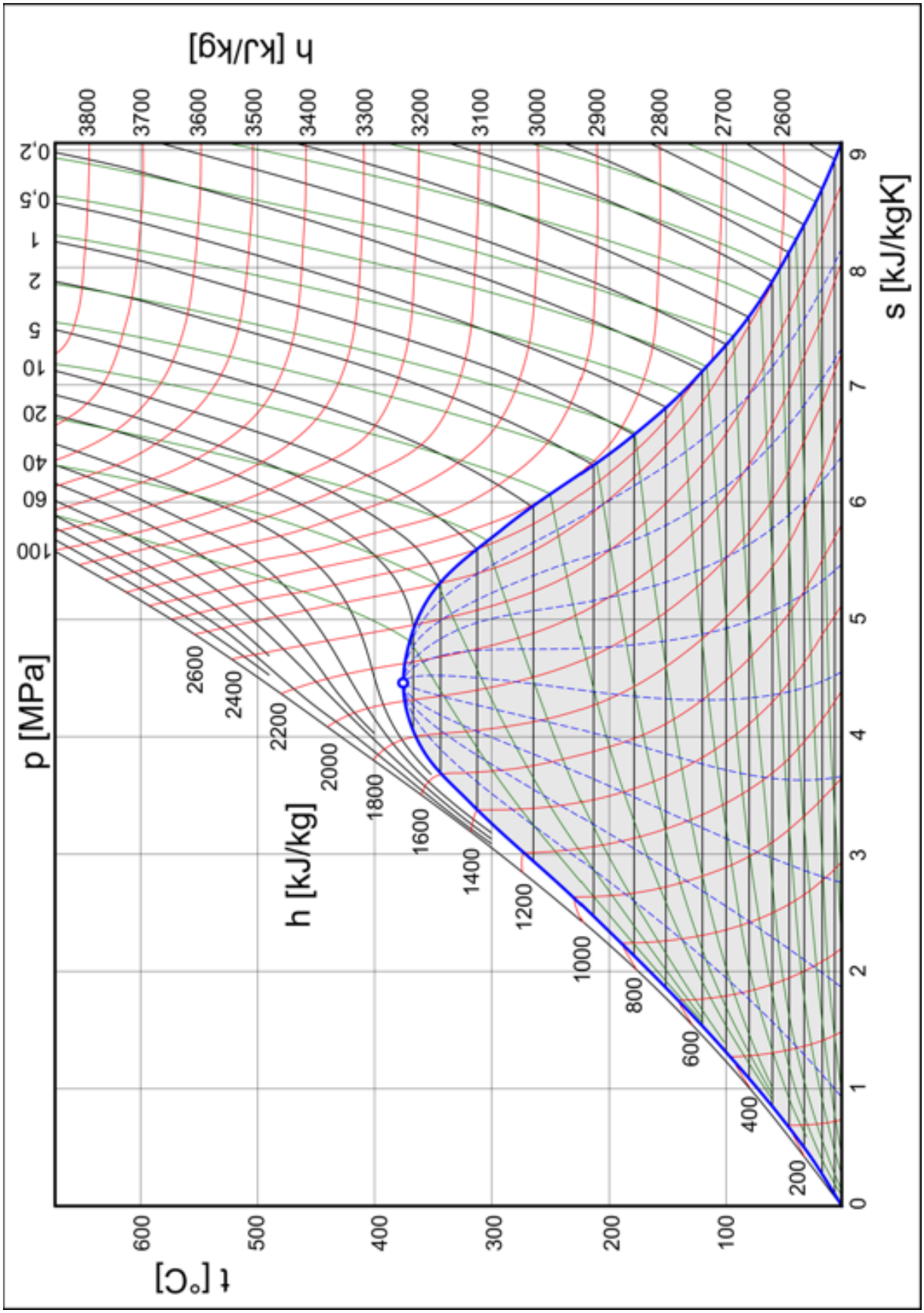
The UC steam plant uses 125 PSIG (0.881 MPa) steam produced by two gas turbines at 480°C to feed a steam turbine (*stream 1*). The output from the steam turbine (*stream 2*) is at 0.15 MPa and 140°C. The outflow from the steam turbine is fed into a condenser. The steam produces 20 MW of electrical power.

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

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

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? 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 cm^3/s)
f) Extra Credit: Propose a method to extract useful energy from the 140°C stream 2.


Mollier Diagram
Specific Enthalpy h, kJ/kg
Pressure
p, MPa
Joule-Thomson inversion
T = 1200°C
1100°C
1000°C
900°C
800°C
700°C
600°C
500°C
400°C
300°C
200°C
100°C
T = 0°C
T = 100°C
x = 90%
80%
70%
60%
50%
40%
30%
20%
x = 10%
v = 0.01 m³/kg
v = 0.00125 m³/kg
v = 10 m³/kg
s = 0.5 kJ/kg·K
s = 8.0 kJ/kg·K
s = 11.0 kJ/kg·K


t [°C]
p [MPa]
h [kJ/kg]
s [kJ/kgK]
h [kJ/kg]

P = 0.10MPa (99.6)

T(°C)	V(m³/kg)	U(kJ/kg)	H(kJ/kg)	S(kJ/kg-K)
99.6	1.6939	2505.6	2675.0	7.3588
100	1.6959	2506.2	2675.8	7.3610
150	1.9367	2582.9	2776.6	7.6148
200	2.1724	2658.2	2875.5	7.8356
250	2.4062	2733.9	2974.5	8.0346
300	2.6388	2810.6	3074.5	8.2172
350	2.8710	2888.7	3175.8	8.3866
400	3.1027	2968.3	3278.6	8.5452
450	3.3342	3049.4	3382.8	8.6946
500	3.5655	3132.2	3488.7	8.8361
550	3.7968	3216.6	3596.3	8.9709
600	4.0279	3302.8	3705.6	9.0998
650	4.2590	3390.7	3816.6	9.2234
700	4.4900	3480.4	3929.4	9.3424
750	4.7209	3571.8	4043.9	9.4572
800	4.9519	3665.0	4160.2	9.5681
850	5.1828	3760.0	4278.2	9.6757
900	5.4137	3856.6	4398.0	9.7800
950	5.6446	3955.0	4519.5	9.8813
1000	5.8754	4055.0	4642.6	9.9800
1050	6.1063	4156.6	4767.3	10.0761
1100	6.3371	4259.8	4893.5	10.1697
1150	6.5680	4364.5	5021.3	10.2611
1200	6.7988	4470.7	5150.6	10.3504
1250	7.0296	4578.3	5281.2	10.4376
1300	7.2604	4687.2	5413.2	10.5229

P = 0.20MPa (120.3)

T(°C)	V(m³/kg)	U(kJ/kg)	H(kJ/kg)	S(kJ/kg-K)
120.3	0.8857	2529.1	2706.2	7.1269
150	0.9599	2577.1	2769.1	7.2810
200	1.0805	2654.6	2870.7	7.5081
250	1.1989	2731.4	2971.2	7.7100
300	1.3162	2808.8	3072.1	7.8941
350	1.4330	2887.3	3173.9	8.0644
400	1.5493	2967.1	3277.0	8.2236
450	1.6655	3048.5	3381.6	8.3734
500	1.7814	3131.4	3487.7	8.5152
550	1.8973	3215.9	3595.4	8.6502
600	2.0130	3302.2	3704.8	8.7792
650	2.1287	3390.2	3815.9	8.9030
700	2.2443	3479.9	3928.8	9.0220
750	2.3599	3571.4	4043.4	9.1369
800	2.4755	3664.7	4159.8	9.2479
850	2.5910	3759.6	4277.8	9.3555
900	2.7066	3856.3	4397.6	9.4598
950	2.8221	3954.7	4519.1	9.5612
1000	2.9375	4054.8	4642.3	9.6599
1050	3.0530	4156.4	4767.0	9.7560
1100	3.1685	4259.6	4893.3	9.8497
1150	3.2839	4364.3	5021.1	9.9411
1200	3.3994	4470.5	5150.4	10.0304
1250	3.5148	4578.1	5281.1	10.1176
1300	3.6302	4687.0	5413.1	10.2029

P = 0.80MPa (170.4)

T(°C)	V(m³/kg)	U(kJ/kg)	H(kJ/kg)	S(kJ/kg-K)
170.4	0.2403	2576.0	2768.3	6.6616
200	0.2609	2631.0	2839.7	6.8176
250	0.2932	2715.9	2950.4	7.0401
300	0.3242	2797.5	3056.9	7.2345
350	0.3544	2878.6	3162.2	7.4106
400	0.3843	2960.2	3267.6	7.5734
450	0.4139	3042.8	3373.9	7.7257
500	0.4433	3126.6	3481.3	7.8692
550	0.4726	3211.9	3590.0	8.0054
600	0.5019	3298.7	3700.1	8.1354
650	0.5310	3387.1	3811.9	8.2598
700	0.5601	3477.2	3925.3	8.3794
750	0.5892	3569.0	4040.3	8.4947
800	0.6182	3662.4	4157.0	8.6061
850	0.6472	3757.6	4275.4	8.7139
900	0.6762	3854.5	4395.5	8.8185
950	0.7052	3953.1	4517.2	8.9201
1000	0.7341	4053.2	4640.5	9.0189
1050	0.7630	4155.0	4765.4	9.1151
1100	0.7920	4258.3	4891.9	9.2089
1150	0.8209	4363.1	5019.8	9.3004
1200	0.8498	4469.4	5149.2	9.3898
1250	0.8787	4577.1	5280.0	9.4771
1300	0.9076	4686.1	5412.2	9.5625

P = 1.00MPa (179.9)

T(°C)	V(m³/kg)	U(kJ/kg)	H(kJ/kg)	S(kJ/kg-K)
179.9	0.1944	2582.8	2777.1	6.5850
200	0.2060	2622.2	2828.3	6.6955
250	0.2327	2710.4	2943.1	6.9265
300	0.2580	2793.6	3051.6	7.1246
350	0.2825	2875.7	3158.2	7.3029
400	0.3066	2957.9	3264.5	7.4669
450	0.3304	3040.9	3371.3	7.6200
500	0.3541	3125.0	3479.1	7.7641
550	0.3777	3210.5	3588.1	7.9008
600	0.4011	3297.5	3698.6	8.0310
650	0.4245	3386.0	3810.5	8.1557
700	0.4478	3476.2	3924.1	8.2755
750	0.4711	3568.1	4039.3	8.3909
800	0.4944	3661.7	4156.1	8.5024
850	0.5176	3757.0	4274.6	8.6103
900	0.5408	3853.9	4394.8	8.7150
950	0.5640	3952.5	4516.5	8.8166
1000	0.5872	4052.7	4639.9	8.9155
1050	0.6104	4154.5	4764.9	9.0118
1100	0.6335	4257.9	4891.4	9.1056
1150	0.6567	4362.7	5019.4	9.1972
1200	0.6798	4469.0	5148.9	9.2866
1250	0.7030	4576.7	5279.7	9.3739
1300	0.7261	4685.8	5411.9	9.4593

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
$\Delta H = W_S = \Delta H' / \eta_{eff}$

Turbine $\Delta S = 0$ for adiabatic reversible
$\Delta H = W_S = \Delta H' \eta_{eff}$

Carnot (Use °K)

Engine $\eta_{eff} = (T_H - T_C)/T_H$
Refrigerator $COP = T_C/(T_H - T_C)$
Heat Pump $COP = T_H/(T_H - T_C)$

Isothermal $(\Delta S)_T = R\ln[V_2/V_1]$ i.g.
$= -R\ln[P_2/P_1]$
$(\Delta H)_T = 0$

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

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 $\Delta S_{trans} = \Delta H_{trans}/T_{trans}$

Answers: **Chemical Engineering Thermodynamics**
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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

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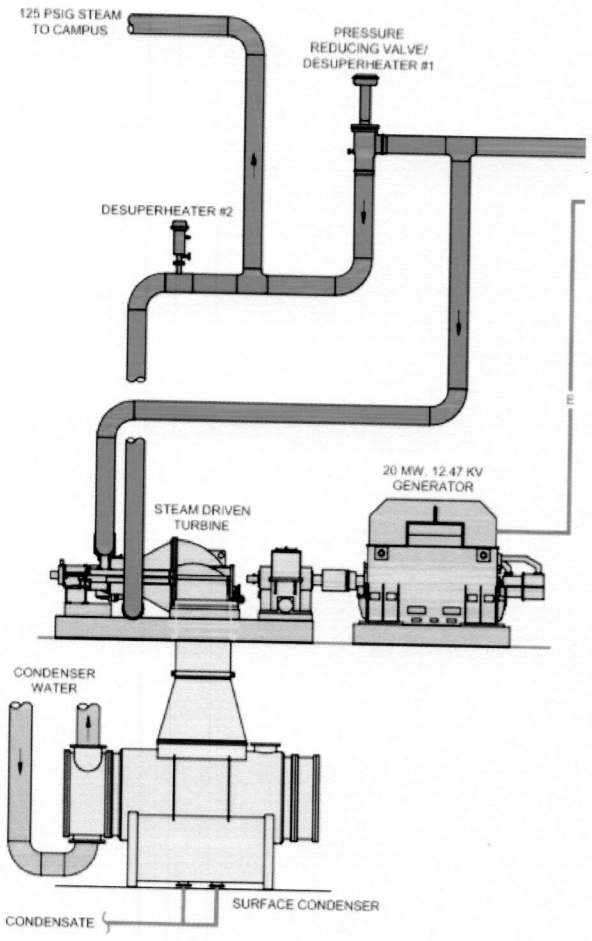


The UC steam plant uses 125 PSIG (0.881 MPa) steam produced by two gas turbines at 480°C to feed a steam turbine (*stream 1*). The output from the steam turbine (*stream 2*) is at 0.15 MPa and 140°C. The outflow from the steam turbine is fed into a condenser. The steam produces 20 MW of electrical power.

Please fill out the following table using the steam tables.

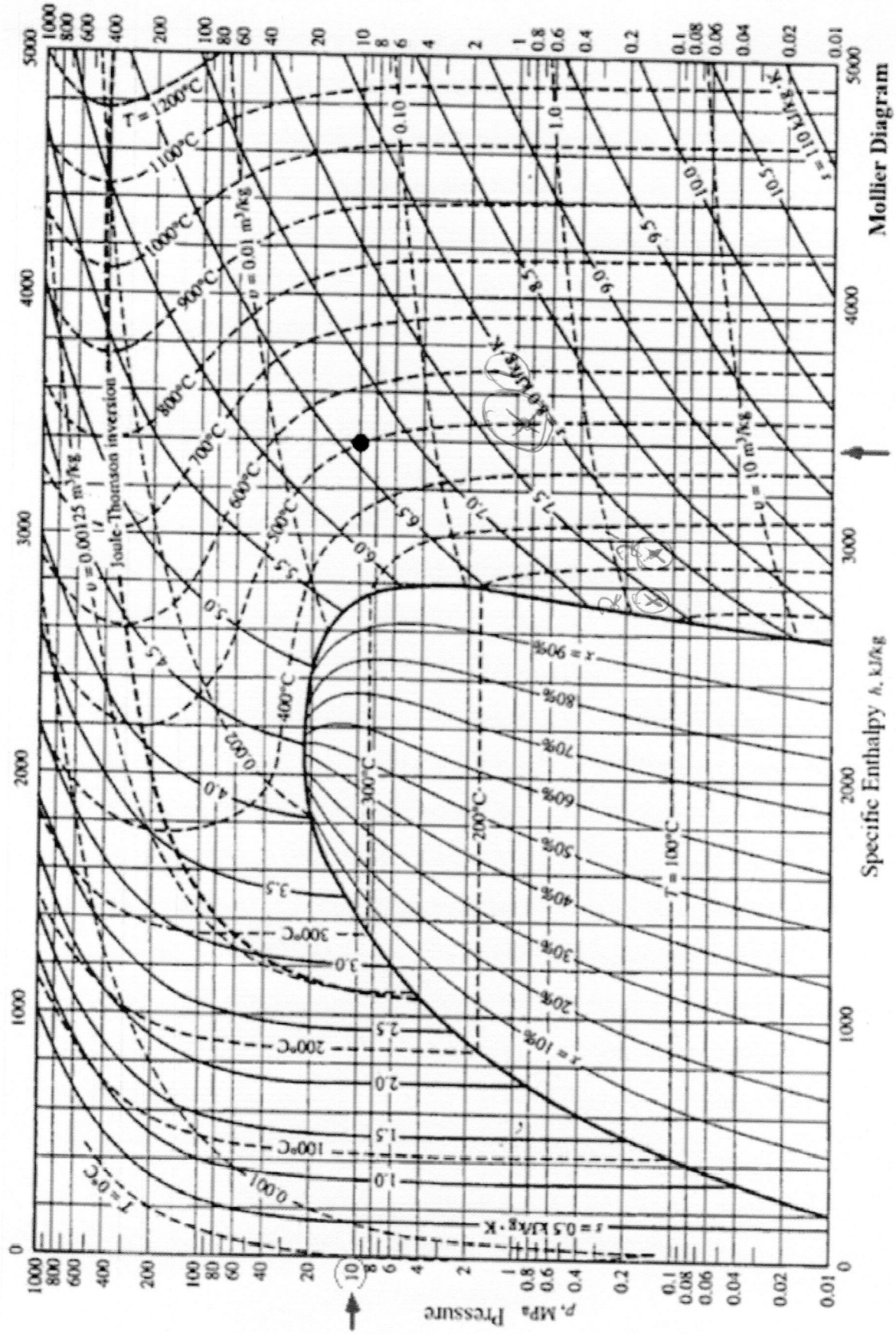
Stream	*P* MPa	*T* °C	*S* kJ/(kg K)	*H* kJ/kg	*V* m3/kg	Δ*H* kJ/kg	State
1	0.881	480	7.84	3460	0.441	----	SHS
2'	0.15	243	7.84	2960	1.677	500	SHS
2	0.15	140	7.40	2760	1.41	700	SHS

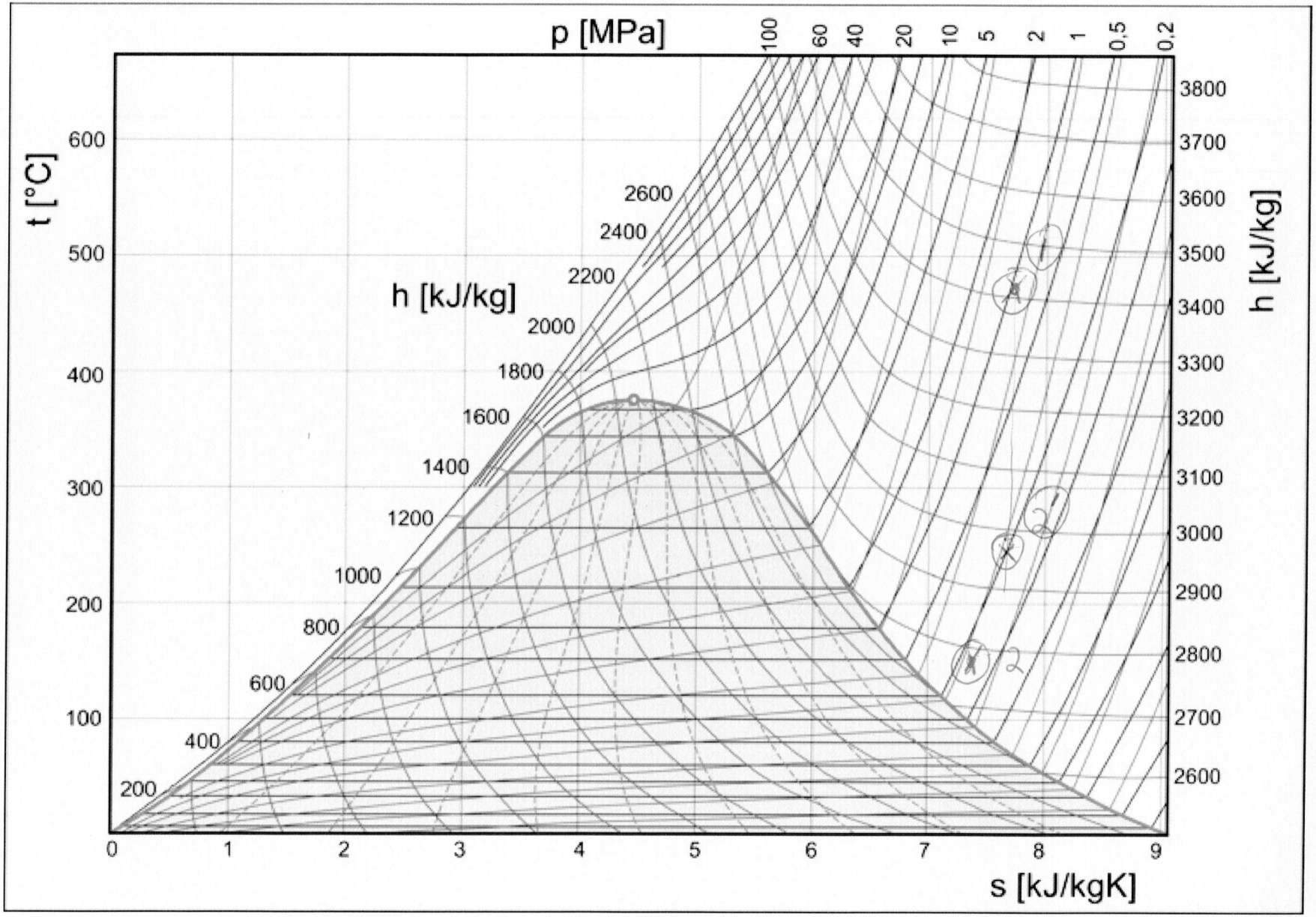
a) What is the work output of an ideal turbine (reversible adiabatic)?
b) What is the actual work output and efficiency, η_{eff}, of this turbine?
c) What is the efficiency of a Carnot engine for these conditions. Compare it with that of the steam turbine. Are the listed conditions possible?
d) **Plot 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.

$\eta_e = 1.4$ (>1)

why? $\eta_e = \frac{340K}{(480+273)K} = 0.45$

W_S and $1.4 > 0.45$


Mollier Diagram
Specific Enthalpy h, kJ/kg
p, MPa Pressure
Joule-Thomson inversion
T = 1200°C
1100°C
1000°C
900°C
800°C
700°C
600°C
500°C
400°C
300°C
200°C
100°C
T = 100°C
x = 90%
80%
70%
60%
50%
40%
30%
20%
x = 10%
v = 0.00125 m³/kg
v = 0.01 m³/kg
v = 10 m³/kg
s = 0.5 kJ/kg · K
s = 11.0 kJ/kg · K


p [MPa]
100
60
40
20
10
5
2
1
0,5
0,2
t [°C]
600
500
400
300
200
100
h [kJ/kg]
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
h [kJ/kg]
3800
3700
3600
3500
3400
3300
3200
3100
3000
2900
2800
2700
2600
0
1
2
3
4
5
6
7
8
9
s [kJ/kgK]

P = 0,50MPa (151.8)

T(°C)	V(m³/kg)	U(kJ/kg)	H(kJ/kg)	S(kJ/kg-K)
151.8	0.3748	2560.7	2748.1	6.8207
200	0.4250	2643.3	2855.8	7.0610
250	0.4744	2723.8	2961.0	7.2724
300	0.5226	2803.2	3064.6	7.4614
350	0.5702	2883.0	3168.1	7.6346
400	0.6173	2963.7	3272.3	7.7955
450	0.6642	3045.6	3377.7	7.9465
500	0.7109	3129.0	3484.5	8.0892
550	0.7576	3213.9	3592.7	8.2249
600	0.8041	3300.4	3702.5	8.3543
650	0.8505	3388.6	3813.9	8.4784
700	0.8970	3478.5	3927.0	8.5977
750	0.9433	3570.2	4041.8	8.7128
800	0.9897	3663.6	4158.4	8.8240
850	1.0360	3758.6	4276.6	8.9317
900	1.0823	3855.4	4396.6	9.0362
950	1.1285	3953.9	4518.2	9.1377
1000	1.1748	4054.0	4641.4	9.2364
1050	1.2210	4155.7	4766.2	9.3326
1100	1.2673	4259.0	4892.6	9.4263
1150	1.3135	4363.7	5020.5	9.5178
1200	1.3597	4470.0	5149.8	9.6071
1250	1.4059	4577.6	5280.5	9.6944
1300	1.4521	4686.6	5412.6	9.7797

P = 0.60MPa (158.8)

T(°C)	V(m³/kg)	U(kJ/kg)	H(kJ/kg)	S(kJ/kg-K)
158.8	0.3156	2566.8	2756.1	6.7593
200	0.3521	2639.3	2850.6	6.9683
250	0.3939	2721.2	2957.6	7.1832
300	0.4344	2801.4	3062.0	7.3740
350	0.4743	2881.6	3166.1	7.5481
400	0.5137	2962.5	3270.8	7.7097
450	0.5530	3044.7	3376.5	7.8611
500	0.5920	3128.2	3483.4	8.0041
550	0.6309	3213.2	3591.8	8.1399
600	0.6698	3299.8	3701.7	8.2695
650	0.7085	3388.1	3813.2	8.3937
700	0.7472	3478.1	3926.4	8.5131
750	0.7859	3569.8	4041.3	8.6283
800	0.8246	3663.2	4157.9	8.7395
850	0.8632	3758.3	4276.2	8.8472
900	0.9018	3855.1	4396.2	8.9518
950	0.9404	3953.6	4517.8	9.0533
1000	0.9789	4053.7	4641.1	9.1521
1050	1.0175	4155.5	4766.0	9.2482
1100	1.0560	4258.7	4892.4	9.3420
1150	1.0946	4363.5	5020.3	9.4335
1200	1.1331	4469.8	5149.6	9.5228
1250	1.1716	4577.4	5280.4	9.6101
1300	1.2101	4686.4	5412.5	9.6954

P = 0,80MPa (170.4)

T(°C)	V(m³/kg)	U(kJ/kg)	H(kJ/kg)	S(kJ/kg-K)
170.4	0.2403	2576.0	2768.3	6.6616
200	0.2608	2631.0	2839.7	6.8176
250	0.2932	2715.9	2950.4	7.0401
300	0.3242	2797.5	3056.9	7.2345
350	0.3544	2878.6	3162.2	7.4106
400	0.3843	2960.2	3267.8	7.5734
450	0.4139	3042.8	3373.9	7.7257
500	0.4433	3126.6	3481.3	7.8692
550	0.4726	3211.9	3590.0	8.0054
600	0.5018	3298.7	3700.1	8.1354
650	0.5310	3387.1	3811.9	8.2598
700	0.5601	3477.2	3925.3	8.3794
750	0.5892	3569.0	4040.3	8.4947
800	0.6182	3662.4	4157.0	8.6061
850	0.6472	3757.6	4275.4	8.7139
900	0.6762	3854.5	4395.5	8.8185
950	0.7052	3953.1	4517.2	8.9201
1000	0.7341	4053.2	4640.5	9.0189
1050	0.7630	4155.0	4765.4	9.1151
1100	0.7920	4258.3	4891.9	9.2089
1150	0.8209	4363.1	5019.8	9.3004
1200	0.8498	4469.4	5149.2	9.3898
1250	0.8787	4577.1	5280.0	9.4771
1300	0.9076	4686.1	5412.2	9.5625

P = 1,00MPa (179.9)

T(°C)	V(m³/kg)	U(kJ/kg)	H(kJ/kg)	S(kJ/kg-K)
179.9	0.1944	2582.8	2777.1	6.5850
200	0.2060	2622.2	2828.3	6.6955
250	0.2327	2710.4	2943.1	6.9265
300	0.2583	2793.6	3051.6	7.1246
350	0.2825	2875.7	3158.2	7.3029
400	0.3066	2957.9	3264.5	7.4669
450	0.3304	3040.9	3371.3	7.6200
500	0.3541	3125.0	3479.1	7.7641
550	0.3777	3210.5	3588.1	7.9008
600	0.4011	3297.5	3698.6	8.0310
650	0.4245	3386.0	3810.5	8.1557
700	0.4478	3476.2	3924.1	8.2755
750	0.4711	3568.1	4039.3	8.3909
800	0.4944	3661.7	4156.1	8.5024
850	0.5176	3757.0	4274.6	8.6103
900	0.5408	3853.9	4394.8	8.7150
950	0.5640	3952.5	4516.5	8.8166
1000	0.5872	4052.7	4639.9	8.9155
1050	0.6104	4154.5	4764.9	9.0118
1100	0.6335	4257.9	4891.4	9.1056
1150	0.6567	4362.7	5019.4	9.1972
1200	0.6798	4469.0	5148.9	9.2866
1250	0.7030	4576.7	5279.7	9.3739
1300	0.7261	4685.8	5411.9	9.4593

P = 1.20MPa (188.0)

T(°C)	V(m³/kg)	U(kJ/kg)	H(kJ/kg)	S(kJ/kg-K)
188.0	0.1633	2587.8	2783.7	6.5217
200	0.1693	2612.9	2816.1	6.5909
250	0.1924	2704.7	2935.6	6.8313
300	0.2139	2789.7	3046.3	7.0335
350	0.2346	2872.7	3154.2	7.2139
400	0.2548	2955.5	3261.3	7.3793
450	0.2748	3038.9	3368.7	7.5332
500	0.2946	3123.4	3476.9	7.6779
550	0.3143	3209.1	3586.3	7.8150
600	0.3339	3296.3	3697.0	7.9455
650	0.3535	3385.0	3809.2	8.0704
700	0.3730	3475.3	3922.9	8.1904
750	0.3924	3567.3	4038.2	8.3060
800	0.4118	3661.0	4155.2	8.4176
850	0.4312	3756.3	4273.8	8.5256
900	0.4506	3853.3	4394.0	8.6303
950	0.4699	3952.0	4515.9	8.7320
1000	0.4893	4052.2	4639.4	8.8310
1050	0.5086	4154.1	4764.4	8.9273
1100	0.5279	4257.5	4891.0	9.0212
1150	0.5472	4362.3	5019.0	9.1128
1200	0.5665	4468.7	5148.5	9.2022
1250	0.5858	4576.4	5279.3	9.2895
1300	0.6051	4685.4	5411.5	9.3749

P = 1.40MPa (195.0)

T(°C)	V(m³/kg)	U(kJ/kg)	H(kJ/kg)	S(kJ/kg-K)
195.0	0.1408	2591.8	2788.9	6.4675
200	0.1430	2602.7	2803.0	6.4975
250	0.1636	2698.9	2927.9	6.7488
300	0.1823	2785.7	3040.9	6.9552
350	0.2003	2869.7	3150.1	7.1379
400	0.2178	2953.1	3258.1	7.3046
450	0.2351	3037.0	3366.1	7.4594
500	0.2522	3121.8	3474.8	7.6047
550	0.2691	3207.7	3584.5	7.7422
600	0.2860	3295.1	3695.4	7.8730
650	0.3028	3384.0	3807.8	7.9982
700	0.3195	3474.4	3921.7	8.1183
750	0.3362	3566.5	4037.2	8.2340
800	0.3529	3660.2	4154.3	8.3457
850	0.3695	3755.6	4273.0	8.4538
900	0.3861	3852.7	4393.3	8.5587
950	0.4027	3951.4	4515.2	8.6604
1000	0.4193	4051.7	4638.8	8.7594
1050	0.4359	4153.6	4763.9	8.8558
1100	0.4525	4257.0	4890.5	8.9497
1150	0.4690	4361.9	5018.6	9.0413
1200	0.4856	4468.3	5148.1	9.1308
1250	0.5021	4576.0	5279.0	9.2182
1300	0.5187	4685.1	5411.2	9.3036

0.80 480

H 3490 − 0.2(3490 − 3370) = 3460 kJ/kg

S 7.87 − 0.2(7.87 − 7.73) = 7.89 kJ/kg·K

V 0.443 − 0.2(0.443 − .414) = 0.437 m³/kg

0.88 H 3460 + 0 = 3460 kJ/kg

S 7.84 + 0.04(7.84 − 7.8) = 7.84 kJ/kg·K

V 0.437 + 0.04(0.437 − 0.399) = 0.441 m³/kg

1.00 480

H 3480 − 0.2(3480 − 3370) = 3460 kJ/kg

S 7.76 − 0.2(7.76 − 7.62) = 7.73 kJ/kg·K

V 0.3546 − 0.2(0.3546 − 0.330) = 0.349 m³/kg

$P = 0{,}01$MPa (45.8)

T(°C)	V(m³/kg)	U(kJ/kg)	H(kJ/kg)	S(kJ/kg-K)
45.8	14.6701	2437.2	2583.9	8.1488
50	14.9139	2443.3	2592.4	8.1755
100	17.1964	2515.5	2687.5	8.4489
150	19.5132	2587.9	2783.0	8.6892
200	21.8256	2661.3	2879.6	8.9049
250	24.1361	2736.1	2977.4	9.1015
300	26.4456	2812.3	3076.7	9.2827
350	28.7545	2889.0	3177.5	9.4513
400	31.0631	2969.3	3279.9	9.6094
450	33.3714	3050.3	3384.0	9.7584
500	35.6796	3132.9	3489.7	9.8998
550	37.9876	3217.2	3597.1	10.0344
600	40.2956	3303.3	3706.3	10.1631
650	42.6035	3391.2	3817.2	10.2866
700	44.9113	3480.8	3929.9	10.4055
750	47.2191	3572.2	4044.4	10.5202
800	49.5269	3665.3	4160.6	10.6311
850	51.8347	3760.3	4278.6	10.7386
900	54.1424	3856.9	4398.3	10.8429
950	56.4501	3955.2	4519.7	10.9442
1000	58.7578	4055.2	4642.8	11.0428
1050	61.0655	4156.8	4767.5	11.1389
1100	63.3732	4260.0	4893.7	11.2325
1150	65.6808	4364.7	5021.5	11.3235
1200	67.9885	4470.9	5150.7	11.4122
1250	70.2961	4578.4	5281.4	11.5004
1300	72.6038	4687.4	5413.4	11.5857

$P = 0.05$MPa (81.3)

T(°C)	V(m³/kg)	U(kJ/kg)	H(kJ/kg)	S(kJ/kg-K)
81.3	3.2400	2483.2	2645.2	7.5930
100	3.4187	2511.5	2682.4	7.6953
150	3.8897	2585.7	2780.2	7.9413
200	4.3562	2660.0	2877.8	8.1592
250	4.8206	2735.1	2976.1	8.3568
300	5.2840	2811.6	3075.8	8.5386
350	5.7469	2889.4	3176.8	8.7076
400	6.2094	2968.9	3279.3	8.8659
450	6.6717	3049.9	3383.5	9.0151
500	7.1338	3132.6	3489.3	9.1566
550	7.5957	3217.0	3596.8	9.2913
600	8.0576	3303.1	3706.0	9.4201
650	8.5195	3391.0	3816.9	9.5436
700	8.9812	3480.6	3929.7	9.6625
750	9.4430	3572.0	4044.2	9.7773
800	9.9047	3665.2	4160.4	9.8882
850	10.3663	3760.1	4278.5	9.9957
900	10.8280	3856.8	4398.2	10.1000
950	11.2896	3955.1	4519.6	10.2014
1000	11.7513	4055.1	4642.7	10.3000
1050	12.2129	4156.8	4767.4	10.3960
1100	12.6745	4259.9	4893.7	10.4897
1150	13.1361	4364.6	5021.4	10.5811
1200	13.5977	4470.8	5150.7	10.6703
1250	14.0592	4578.4	5281.3	10.7576
1300	14.5208	4687.3	5413.3	10.8428

$P = 0.10$MPa (99.6)

T(°C)	V(m³/kg)	U(kJ/kg)	H(kJ/kg)	S(kJ/kg-K)
99.6	1.6939	2505.6	2675.0	7.3588
100	1.6959	2506.2	2675.8	7.3610
150	1.9367	2582.9	2776.6	7.6148
200	2.1724	2658.2	2875.5	7.8356
250	2.4062	2733.9	2974.5	8.0346
300	2.6388	2810.6	3074.5	8.2172
350	2.8710	2888.7	3175.8	8.3866
400	3.1027	2968.3	3278.6	8.5452
450	3.3342	3049.4	3382.8	8.6946
500	3.5655	3132.2	3488.7	8.8361
550	3.7968	3216.6	3596.3	8.9709
600	4.0279	3302.8	3705.6	9.0998
650	4.2590	3390.7	3816.6	9.2234
700	4.4900	3480.4	3929.4	9.3424
750	4.7209	3571.8	4043.9	9.4572
800	4.9519	3665.0	4160.2	9.5681
850	5.1828	3760.0	4278.2	9.6757
900	5.4137	3856.6	4398.0	9.7800
950	5.6446	3955.0	4519.5	9.8813
1000	5.8754	4055.0	4642.6	9.9800
1050	6.1063	4156.6	4767.3	10.0761
1100	6.3371	4259.8	4893.5	10.1697
1150	6.5680	4364.5	5021.3	10.2611
1200	6.7988	4470.7	5150.6	10.3504
1250	7.0296	4578.3	5281.2	10.4376
1300	7.2604	4687.2	5413.2	10.5229

$P = 0.20$MPa (120.3)

T(°C)	V(m³/kg)	U(kJ/kg)	H(kJ/kg)	S(kJ/kg-K)
120.3	0.8857	2529.1	2706.2	7.1269
150	0.9599	2577.1	2769.1	7.2810
200	1.0805	2654.6	2870.7	7.5081
250	1.1989	2731.4	2971.2	7.7100
300	1.3162	2808.8	3072.1	7.8941
350	1.4330	2887.3	3173.5	8.0644
400	1.5493	2967.1	3277.0	8.2236
450	1.6655	3048.5	3381.6	8.3734
500	1.7814	3131.4	3487.7	8.5152
550	1.8973	3215.9	3595.4	8.6502
600	2.0130	3302.2	3704.8	8.7792
650	2.1287	3390.2	3815.9	8.9030
700	2.2443	3479.9	3928.8	9.0220
750	2.3599	3571.4	4043.4	9.1369
800	2.4755	3664.7	4159.8	9.2479
850	2.5910	3759.6	4277.8	9.3555
900	2.7066	3856.3	4397.6	9.4598
950	2.8221	3954.7	4519.1	9.5612
1000	2.9375	4054.8	4642.3	9.6599
1050	3.0530	4156.4	4767.0	9.7560
1100	3.1685	4259.6	4893.3	9.8497
1150	3.2839	4364.3	5021.1	9.9411
1200	3.3994	4470.5	5150.4	10.0301
1250	3.5148	4578.1	5281.1	10.1176
1300	3.6302	4587.0	5413.1	10.2029

$P = 0.30$MPa (133.5)

T(°C)	V(m³/kg)	U(kJ/kg)	H(kJ/kg)	S(kJ/kg-K)
133.5	0.6058	2543.2	2724.9	6.9916
150	0.6340	2571.0	2761.2	7.0791
200	0.7164	2651.0	2865.9	7.3131
250	0.7964	2728.9	2967.9	7.5180
300	0.8753	2807.0	3069.6	7.7037
350	0.9536	2885.9	3172.0	7.8750
400	1.0315	2966.0	3275.5	8.0347
450	1.1092	3047.5	3380.3	8.1849
500	1.1867	3130.6	3486.6	8.3271
550	1.2641	3215.3	3594.5	8.4623
600	1.3414	3301.6	3704.0	8.5914
650	1.4186	3389.7	3815.3	8.7153
700	1.4958	3479.5	3928.2	8.8344
750	1.5729	3571.0	4042.9	8.9494
800	1.6500	3664.3	4159.3	9.0604
850	1.7271	3759.3	4277.4	9.1680
900	1.8042	3856.0	4397.3	9.2724
950	1.8812	3954.4	4518.8	9.3739
1000	1.9582	4054.5	4642.0	9.4726
1050	2.0352	4156.2	4766.7	9.5687
1100	2.1122	4259.4	4893.1	9.6624
1150	2.1892	4364.1	5020.9	9.7538
1200	2.2662	4470.3	5150.2	9.8431
1250	2.3432	4577.9	5280.9	9.9303
1300	2.4202	4686.9	5412.9	10.0156

$P = 0.40$MPa (143.6)

T(°C)	V(m³/kg)	U(kJ/kg)	H(kJ/kg)	S(kJ/kg-K)
143.6	0.4624	2553.1	2738.1	6.8955
150	0.4708	2564.4	2752.8	6.9386
200	0.5343	2647.2	2860.9	7.1723
250	0.5952	2726.4	2964.5	7.3804
300	0.6548	2805.1	3067.1	7.5677
350	0.7140	2884.4	3170.0	7.7399
400	0.7726	2964.9	3273.9	7.9002
450	0.8311	3046.6	3379.0	8.0508
500	0.8894	3129.8	3485.5	8.1933
550	0.9475	3214.6	3593.6	8.3287
600	1.0056	3301.0	3703.2	8.4580
650	1.0636	3389.1	3814.6	8.5820
700	1.1215	3479.0	3927.6	8.7012
750	1.1794	3570.6	4042.4	8.8162
800	1.2373	3663.9	4158.8	8.9273
850	1.2951	3759.0	4277.0	9.0350
900	1.3530	3855.7	4396.9	9.1394
950	1.4108	3954.2	4518.5	9.2409
1000	1.4686	4054.3	4641.7	9.3396
1050	1.5264	4155.9	4766.5	9.4357
1100	1.5841	4259.2	4892.8	9.5295
1150	1.6419	4363.9	5020.7	9.6209
1200	1.6997	4470.1	5150.0	9.7102
1250	1.7574	4577.8	5280.7	9.7975
1300	1.8152	4686.7	5412.8	9.8828

$P = 0.15$ MPa

T	V	U	H	S kJ/kg,K
200°C	1.69	2677	7.67	25° C = 0.15 a
250	1.80	2972	7.87	
243	1.77	2960	7.89	

0.1P

150 - .20 V=1.41 H=2760 S = 7.40

150 - 0.3370

140 1.29 2760 7.56

140 0.935 — 2760 7.23

P = 0.10MPa (99.6)

T(°C)	V(m³/kg)	U(kJ/kg)	H(kJ/kg)	S(kJ/kg-K)
99.6	1.6939	2505.6	2675.0	7.3588
100	1.6959	2506.2	2675.8	7.3610
150	1.9367	2582.9	2776.6	7.6148
200	2.1724	2658.2	2875.5	7.8356
250	2.4062	2733.9	2974.5	8.0346
300	2.6388	2810.6	3074.5	8.2172
350	2.8710	2888.7	3175.8	8.3866
400	3.1027	2968.3	3278.6	8.5452
450	3.3342	3049.4	3382.8	8.6946
500	3.5655	3132.2	3488.7	8.8361
550	3.7968	3216.6	3596.3	8.9709
600	4.0279	3302.8	3705.6	9.0998
650	4.2590	3390.7	3816.6	9.2234
700	4.4900	3480.4	3929.4	9.3424
750	4.7209	3571.8	4043.9	9.4572
800	4.9519	3665.0	4160.2	9.5681
850	5.1828	3760.0	4278.2	9.6757
900	5.4137	3856.6	4398.0	9.7800
950	5.6446	3955.0	4519.5	9.8813
1000	5.8754	4055.0	4642.6	9.9800
1050	6.1063	4156.6	4767.3	10.0761
1100	6.3371	4259.8	4893.5	10.1697
1150	6.5680	4364.5	5021.3	10.2611
1200	6.7988	4470.7	5150.6	10.3504
1250	7.0296	4578.3	5281.2	10.4376
1300	7.2604	4687.2	5413.2	10.5229

P = 0.20MPa (120.3)

T(°C)	V(m³/kg)	U(kJ/kg)	H(kJ/kg)	S(kJ/kg-K)
120.3	0.8857	2529.1	2706.2	7.1269
150	0.9599	2577.1	2769.1	7.2810
200	1.0805	2654.6	2870.7	7.5081
250	1.1989	2731.4	2971.2	7.7100
300	1.3162	2808.8	3072.1	7.8941
350	1.4330	2887.3	3173.9	8.0644
400	1.5493	2967.1	3277.0	8.2236
450	1.6655	3048.5	3381.6	8.3734
500	1.7814	3131.4	3487.7	8.5152
550	1.8973	3215.9	3595.4	8.6502
600	2.0130	3302.2	3704.8	8.7792
650	2.1287	3390.2	3815.9	8.9030
700	2.2443	3479.9	3928.8	9.0220
750	2.3599	3571.4	4043.4	9.1369
800	2.4755	3664.7	4159.8	9.2479
850	2.5910	3759.6	4277.8	9.3555
900	2.7066	3856.3	4397.6	9.4598
950	2.8221	3954.7	4519.1	9.5612
1000	2.9375	4054.8	4642.3	9.6599
1050	3.0530	4156.4	4767.0	9.7560
1100	3.1685	4259.6	4893.3	9.8497
1150	3.2839	4364.3	5021.1	9.9411
1200	3.3994	4470.5	5150.4	10.0304
1250	3.5148	4578.1	5281.1	10.1176
1300	3.6302	4687.0	5413.1	10.2029

P = 0.80MPa (170.4)

T(°C)	V(m³/kg)	U(kJ/kg)	H(kJ/kg)	S(kJ/kg-K)
170.4	0.2403	2576.0	2768.3	6.6616
200	0.2609	2631.0	2839.7	6.8176
250	0.2932	2715.9	2950.4	7.0401
300	0.3242	2797.5	3056.9	7.2345
350	0.3544	2878.6	3162.2	7.4106
400	0.3843	2960.2	3267.6	7.5734
450	0.4139	3042.8	3373.9	7.7257
500	0.4433	3126.6	3481.3	7.8692
550	0.4726	3211.9	3590.0	8.0054
600	0.5019	3298.7	3700.1	8.1354
650	0.5310	3387.1	3811.9	8.2598
700	0.5601	3477.2	3925.3	8.3794
750	0.5892	3569.0	4040.3	8.4947
800	0.6182	3662.4	4157.0	8.6061
850	0.6472	3757.6	4275.4	8.7139
900	0.6762	3854.5	4395.5	8.8185
950	0.7052	3953.1	4517.2	8.9201
1000	0.7341	4053.2	4640.5	9.0189
1050	0.7630	4155.0	4765.4	9.1151
1100	0.7920	4258.3	4891.9	9.2089
1150	0.8209	4363.1	5019.8	9.3004
1200	0.8498	4469.4	5149.2	9.3898
1250	0.8787	4577.1	5280.0	9.4771
1300	0.9076	4686.1	5412.2	9.5625

P = 1.00MPa (179.9)

T(°C)	V(m³/kg)	U(kJ/kg)	H(kJ/kg)	S(kJ/kg-K)
179.9	0.1944	2582.8	2777.1	6.5850
200	0.2060	2622.2	2828.3	6.6955
250	0.2327	2710.4	2943.1	6.9265
300	0.2580	2793.6	3051.6	7.1246
350	0.2825	2875.7	3158.2	7.3029
400	0.3066	2957.9	3264.5	7.4669
450	0.3304	3040.9	3371.3	7.6200
500	0.3541	3125.0	3479.1	7.7641
550	0.3777	3210.5	3588.1	7.9008
600	0.4011	3297.5	3698.6	8.0310
650	0.4245	3386.0	3810.5	8.1557
700	0.4478	3476.2	3924.1	8.2755
750	0.4711	3568.1	4039.3	8.3909
800	0.4944	3661.7	4156.1	8.5024
850	0.5176	3757.0	4274.6	8.6103
900	0.5408	3853.9	4394.8	8.7150
950	0.5640	3952.5	4516.5	8.8166
1000	0.5872	4052.7	4639.9	8.9155
1050	0.6104	4154.5	4764.9	9.0118
1100	0.6335	4257.9	4891.4	9.1056
1150	0.6567	4362.7	5019.4	9.1972
1200	0.6798	4469.0	5148.9	9.2866
1250	0.7030	4576.7	5279.7	9.3739
1300	0.7261	4685.8	5411.9	9.4593