

ENGR 251 QUIZ 1
Fall 2017

Name: _____

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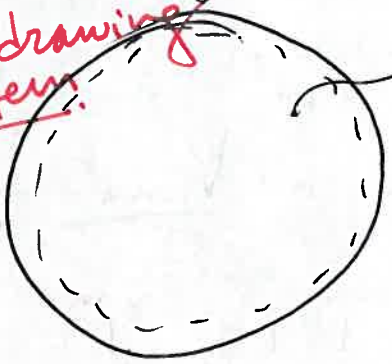
Solution

#1

5 Points

Question 1: A rigid tank contains superheated steam at 1000 kPa and 240 °C. The tank is now cooled until the temperature decreases to 140 °C. What is the pressure, quality and the enthalpy at the final state after the cooling?

① For drawing system



H₂O,

$dV=0$
Closed system
 $dm=0$

$P_1 = 1000 \text{ kPa}$, $T_1 = 240^\circ\text{C}$

From tables:

1000 kPa = 1 MPa

$v_1 = 0.2275 \text{ m}^3/\text{kg}$ ①

At $T_2 = 140^\circ\text{C}$, $v_2 = v_1 = 0.2275 \text{ m}^3/\text{kg}$ since we have a rigid, closed system. ①

$v_g = 0.5089 \text{ m}^3/\text{kg}$

$v_f = 1.0797 \times 10^{-3} \text{ m}^3/\text{kg}$

① $x_2 = \frac{v - v_f}{v_g - v_f} = 0.4459$ [Quality]

.5 $P_2 = P_{\text{sat}}(T_2) = 3.613 \text{ bars}$

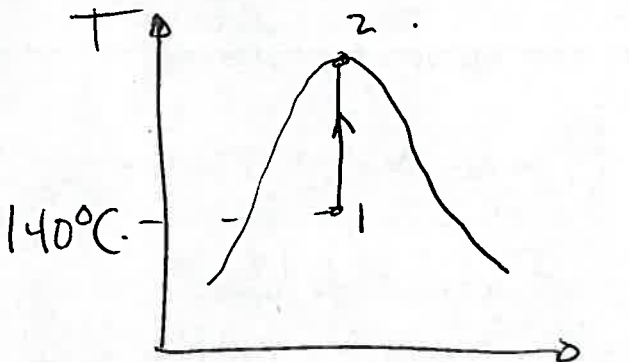
.5 $h_2 = h_f + x_2 h_{fg} = 589.13 \frac{\text{kJ}}{\text{kg}} + x_2 (2144.7 \frac{\text{kJ}}{\text{kg}})$

$h_2 = 1545.38 \text{ kJ/kg}$

7 points

Question 2: A 0.5-m^3 rigid tank initially contained a saturated liquid-vapor mixture of water at 140°C is now heated until the mixture reaches the critical state.

a) Draw the process on a T - v diagram. Determine the total mass of water in the tank.



$$v_2 = v_{cr.} = 0.003155 \text{ m}^3/\text{kg} \quad (1)$$

$$v_2 = v_1$$

$$V_{\text{tank}} = 0.5 \text{ m}^3$$

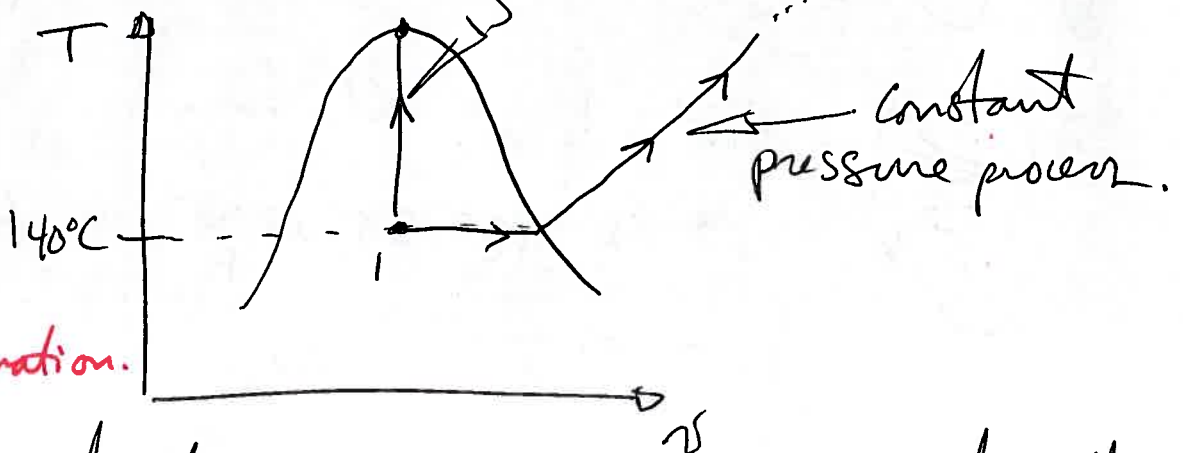
$$v \equiv \frac{V}{m} \Rightarrow m = \frac{V_{\text{tank}}}{v_2}$$

$$m = 158.48 \text{ kg} \quad (1)$$

(2) For correct T - v diagram

b) If instead of being heated at constant volume, it is heated at constant pressure. Can the water ever reach the critical state? Why? (max 3 sentences, no math.)

(1) \rightarrow It cannot.

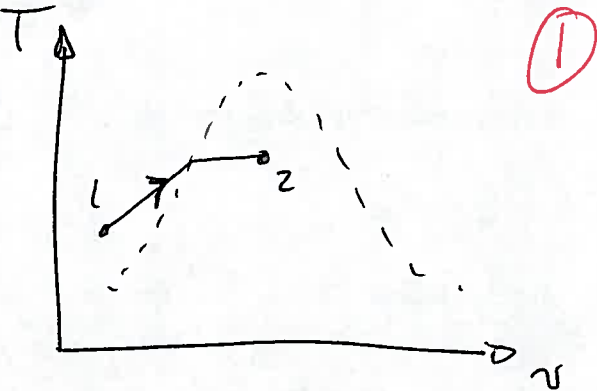
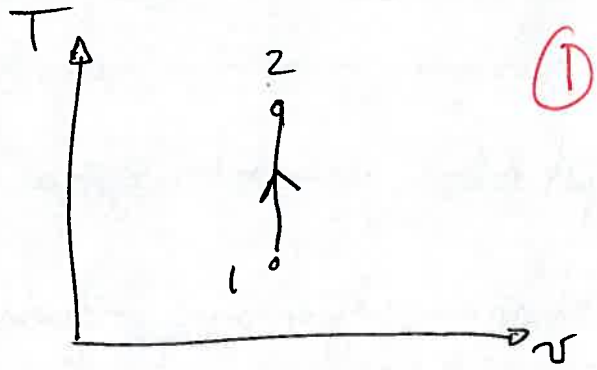
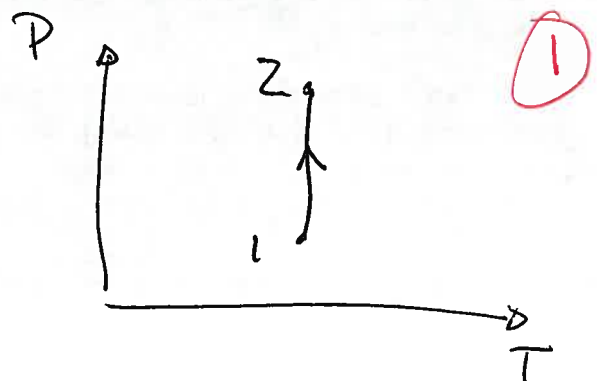


(2) for explanation.

- The constant pressure process never reaches the critical state.

Question 3: 8 points.

A) Sketch the following:

<p>An isobaric process on a T-v diagram. The initial state is a compressed liquid and the final state is a mixture of liquid and vapour. Draw the vapour dome as a dashed line.</p>	
<p>An isochoric process on a T-v diagram.</p>	
<p>An isothermal process on a P-T diagram.</p>	

varies with mass (1)

B) An extensive property is one which depends on mass
depends on the extent of the syst

C) A synonym for "closed system" is control mass (1)

D) At an altitude of 2000 m, water boils at a temperature of ~~93.32~~ 366.47 K. (1) [0.5 for 93.32]

E) At the conditions of (D), the reduced pressure is $Pr = 3.6 \times 10^{-4}$.5 and the reduced temperature is $Tr = 0.566$.5

F) Thermodynamic equilibrium requires the system to be at chemical equilibrium (4x .25)
phase equilibrium, mechanical equilibrium
thermodynamic equilibrium.

BONUS QUESTION) Given the temperature you found in part (D), which of the following teas cannot be properly brewed:

Pilgrim's white tea (a very delicate and light tea)

Sencha Uchiyama (a japanese green tea)

Lapsang Souchong (a chinese black tea)

+1 Bonus.

TABLE C.2 *CANADIAN*
Properties of the U.S. Standard Atmosphere (SI Units)^a

Altitude (m)	Temperature (°C)	Acceleration of Gravity, g (m/s ²)	Pressure, p [N/m ² (abs)]	Density, ρ (kg/m ³)	Dyna Visco μ (N·s/
-1.000	21.50	9.810	1.139 E + 5	1.347 E + 0	1.821
0	15.00	9.807	1.013 E + 5	1.225 E + 0	1.789
1,000	8.50	9.804	8.988 E + 4	1.112 E + 0	1.758
2,000	2.00	9.801	7.950 E + 4	1.007 E + 0	1.726
3,000	-4.49	9.797	7.012 E + 4	9.093 E - 1	1.694
4,000	-10.98	9.794	6.166 E + 4	8.194 E - 1	1.661
5,000	-17.47	9.791	5.405 E + 4	7.364 E - 1	1.628
6,000	-23.96	9.788	4.722 E + 4	6.601 E - 1	1.595
7,000	-30.45	9.785	4.111 E + 4	5.900 E - 1	1.561
8,000	-36.94	9.782	3.565 E + 4	5.258 E - 1	1.527
9,000	-43.42	9.779	3.080 E + 4	4.671 E - 1	1.493
10,000	-49.90	9.776	2.650 E + 4	4.135 E - 1	1.458
15,000	-56.50	9.761	1.211 E + 4	1.948 E - 1	1.422
20,000	-56.50	9.745	5.529 E + 3	8.891 E - 2	1.422
25,000	-51.60	9.730	2.549 E + 3	4.008 E - 2	1.448
30,000	-46.64	9.715	1.197 E + 3	1.841 E - 2	1.475
40,000	-22.80	9.684	2.871 E + 2	3.996 E - 3	1.601
50,000	-2.50	9.654	7.978 E + 1	1.027 E - 3	1.704
60,000	-26.13	9.624	2.196 E + 1	3.097 E - 4	1.584
70,000	-53.57	9.594	5.221 E + 0	8.283 E - 5	1.438
80,000	-74.51	9.564	1.052 E + 0	1.846 E - 5	1.321

^aData abridged from *U.S. Standard Atmosphere*, 1976. U.S. Government Printing Office, Washington, D.C.

2 APPENDIX

SATURATED WATER TABLE (TEMPERATURE)

3LE A-2 (Continued)

mp. °C	Press. bars	Specific Volume m ³ /kg		Internal Energy kJ/kg		Enthalpy kJ/kg			Entropy kJ/kg · K		Temp. °C
		Sat. Liquid $v_f \times 10^3$	Sat. Vapour v_g	Sat. Liquid u_f	Sat. Vapour u_g	Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapour h_g	Sat. Liquid s_f	Sat. Vapour s_g	
50	.1235	1.0121	12.032	209.32	2443.5	209.33	2382.7	2592.1	.7038	8.0763	50
55	.1576	1.0146	9.568	230.21	2450.1	230.23	2370.7	2600.9	.7679	7.9913	55
60	.1994	1.0172	7.671	251.11	2456.6	251.13	2358.5	2609.6	.8312	7.9096	60
65	.2503	1.0199	6.197	272.02	2463.1	272.06	2346.2	2618.3	.8935	7.8310	65
70	.3119	1.0228	5.042	292.95	2469.6	292.98	2333.8	2626.8	.9549	7.7553	70
75	.3858	1.0259	4.131	313.90	2475.9	313.93	2321.4	2635.3	1.0155	7.6824	75
80	.4739	1.0291	3.407	334.86	2482.2	334.91	2308.8	2643.7	1.0753	7.6122	80
85	.5783	1.0325	2.828	355.84	2488.4	355.90	2296.0	2651.9	1.1343	7.5445	85
90	.7014	1.0360	2.361	376.85	2494.5	376.92	2283.2	2660.1	1.1925	7.4791	90
95	.8455	1.0397	1.982	397.88	2500.6	397.96	2270.2	2668.1	1.2500	7.4159	95
100	1.014	1.0435	1.673	418.94	2506.5	419.04	2257.0	2676.1	1.3069	7.3549	100
110	1.433	1.0516	1.210	461.14	2518.1	461.30	2230.2	2691.5	1.4185	7.2387	110
120	1.985	1.0603	0.8919	503.50	2529.3	503.71	2202.6	2706.3	1.5276	7.1296	120
130	2.701	1.0697	0.6685	546.02	2539.9	546.31	2174.2	2720.5	1.6344	7.0269	130
140	3.613	1.0797	0.5089	588.74	2550.0	589.13	2144.7	2733.9	1.7391	6.9299	140
150	4.758	1.0905	0.3928	631.68	2559.5	632.20	2114.3	2746.5	1.8418	6.8379	150
160	6.178	1.1020	0.3071	674.86	2568.4	675.55	2082.6	2758.1	1.9427	6.7502	160
170	7.917	1.1143	0.2428	718.33	2576.5	719.21	2049.5	2768.7	2.0419	6.6663	170
180	10.02	1.1274	0.1941	762.09	2583.7	763.22	2015.0	2778.2	2.1396	6.5857	180
190	12.54	1.1414	0.1565	806.19	2590.0	807.62	1978.8	2786.4	2.2359	6.5079	190
200	15.54	1.1565	0.1274	850.65	2595.3	852.45	1940.7	2793.2	2.3309	6.4323	200
210	19.06	1.1726	0.1044	895.53	2599.5	897.76	1900.7	2798.5	2.4248	6.3585	210
220	23.18	1.1900	0.08619	940.87	2602.4	943.62	1858.5	2802.1	2.5178	6.2861	220
230	27.95	1.2088	0.07158	986.74	2603.9	990.12	1813.8	2804.0	2.6099	6.2146	230
240	33.44	1.2291	0.05976	1033.2	2604.0	1037.3	1766.5	2803.8	2.7015	6.1437	240
250	39.73	1.2512	0.05013	1080.4	2602.4	1085.4	1716.2	2801.5	2.7927	6.0730	250
260	46.88	1.2755	0.04221	1128.4	2599.0	1134.4	1662.5	2796.6	2.8838	6.0019	260
270	54.99	1.3023	0.03564	1177.4	2593.7	1184.5	1605.2	2789.7	2.9751	5.9301	270
280	64.12	1.3321	0.03017	1227.5	2586.1	1236.0	1543.6	2779.6	3.0668	5.8571	280
290	74.36	1.3656	0.02557	1278.9	2576.0	1289.1	1477.1	2766.2	3.1594	5.7821	290
300	85.81	1.4036	0.02167	1332.0	2563.0	1344.0	1404.9	2749.0	3.2534	5.7045	300
320	112.7	1.4988	0.01549	1444.6	2525.5	1461.5	1238.6	2700.1	3.4480	5.5362	320
340	145.9	1.6379	0.01080	1570.3	2464.6	1594.2	1027.9	2622.0	3.6594	5.3357	340
360	186.5	1.8925	0.006945	1725.2	2351.5	1760.5	720.5	2481.0	3.9147	5.0526	360
4.14	220.9	3.155	0.003155	2029.6	2029.6	2099.3	0	2099.3	4.4298	4.4298	374.14

e: Tables A-2 to A-5 are adapted from K. Wark, *Thermodynamics*, 4th ed., McGraw-Hill, New York, 1983, as extracted from Keenan, F. G. Keyes, P. G. Hill, and J. G. Moore, *Steam Tables*, Wiley, New York, 1969

TABLE A-3 Properties of Saturated Water (Liquid-Vapour): Pressure Table

SATURATED WATER TABLE (PRESSURE)

Press. bars	Temp. °C	Specific Volume m ³ /kg		Internal Energy kJ/kg		Enthalpy kJ/kg			Entropy kJ/kg · K		Pre ba
		Sat. Liquid $v_f \times 10^3$	Sat. Vapour v_g	Sat. Liquid u_f	Sat. Vapour u_g	Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapour h_g	Sat. Liquid s_f	Sat. Vapour s_g	
0.04	28.96	1.0040	34.800	121.45	2415.2	121.46	2432.9	2554.4	0.4226	8.4746	0.0
0.06	36.16	1.0064	23.739	151.53	2425.0	151.53	2415.9	2567.4	0.5210	8.3304	0.0
0.08	41.51	1.0084	18.103	173.87	2432.2	173.88	2403.1	2577.0	0.5926	8.2287	0.0
0.10	45.81	1.0102	14.674	191.82	2437.9	191.83	2392.8	2584.7	0.6493	8.1502	0.
0.20	60.06	1.0172	7.649	251.38	2456.7	251.40	2358.3	2609.7	0.8320	7.9085	0.
0.30	69.10	1.0223	5.229	289.20	2468.4	289.23	2336.1	2625.3	0.9439	7.7686	0.
0.40	75.87	1.0265	3.993	317.53	2477.0	317.58	2319.2	2636.8	1.0259	7.6700	0.
0.50	81.33	1.0300	3.240	340.44	2483.9	340.49	2305.4	2645.9	1.0910	7.5939	0.
0.60	85.94	1.0331	2.732	359.79	2489.6	359.86	2293.6	2653.5	1.1453	7.5320	0.
0.70	89.95	1.0360	2.365	376.63	2494.5	376.70	2283.3	2660.0	1.1919	7.4797	0.
0.80	93.50	1.0380	2.087	391.58	2498.8	391.66	2274.1	2665.8	1.2329	7.4346	0.
0.90	96.71	1.0410	1.869	405.06	2502.6	405.15	2265.7	2670.9	1.2695	7.3949	0.
1.00	99.63	1.0432	1.694	417.36	2506.1	417.46	2258.0	2675.5	1.3026	7.3594	1.
1.50	111.4	1.0528	1.159	466.94	2519.7	467.11	2226.5	2693.6	1.4336	7.2233	1.
2.00	120.2	1.0605	0.8857	504.49	2529.5	504.70	2201.9	2706.7	1.5301	7.1271	2.
2.50	127.4	1.0672	0.7187	535.10	2537.2	535.37	2181.5	2716.9	1.6072	7.0527	2.
3.00	133.6	1.0732	0.6058	561.15	2543.6	561.47	2163.8	2725.3	1.6718	6.9919	3.
3.50	138.9	1.0786	0.5243	583.95	2546.9	584.33	2148.1	2732.4	1.7275	6.9405	3.
4.00	143.6	1.0836	0.4625	604.31	2553.6	604.74	2133.8	2738.6	1.7766	6.8959	4.
4.50	147.9	1.0882	0.4140	622.25	2557.6	623.25	2120.7	2743.9	1.8207	6.8565	4.
5.00	151.9	1.0926	0.3749	639.68	2561.2	640.23	2108.5	2748.7	1.8607	6.8212	5.
6.00	158.9	1.1006	0.3157	669.90	2567.4	670.56	2086.3	2756.8	1.9312	6.7600	6.
7.00	165.0	1.1080	0.2729	696.44	2572.5	697.22	2066.3	2763.5	1.9922	6.7080	7.
8.00	170.4	1.1148	0.2404	720.22	2576.8	721.11	2048.0	2769.1	2.0462	6.6628	8.
9.00	175.4	1.1212	0.2150	741.83	2580.5	742.83	2031.1	2773.9	2.0946	6.6226	9.
10.0	179.9	1.1273	0.1944	761.68	2583.6	762.81	2015.3	2778.1	2.1387	6.5863	10
15.0	198.3	1.1539	0.1318	843.16	2594.5	844.84	1947.3	2792.2	2.3150	6.4448	15
20.0	212.4	1.1767	0.09963	906.44	2600.3	908.79	1890.7	2799.5	2.4474	6.3409	20
25.0	224.0	1.1973	0.07998	959.11	2603.1	962.11	1841.0	2803.1	2.5547	6.2575	25
30.0	233.9	1.2165	0.06668	1004.8	2604.1	1008.4	1795.7	2804.2	2.6457	6.1869	30
35.0	242.6	1.2347	0.05707	1045.4	2603.7	1049.8	1753.7	2803.4	2.7253	6.1253	35
40.0	250.4	1.2522	0.04978	1082.3	2602.3	1087.3	1714.1	2801.4	2.7964	6.0701	40
45.0	257.5	1.2692	0.04406	1116.2	2600.1	1121.9	1676.4	2798.3	2.8610	6.0199	45
50.0	264.0	1.2859	0.03944	1147.8	2597.1	1154.2	1640.1	2794.3	2.9202	5.9734	50
60.0	275.6	1.3187	0.03244	1205.4	2589.7	1213.4	1571.0	2784.3	3.0267	5.8892	60
70.0	285.9	1.3513	0.02737	1257.6	2580.5	1267.0	1505.1	2772.1	3.1211	5.8133	70
80.0	295.1	1.3842	0.02352	1305.6	2569.8	1316.6	1441.3	2758.0	3.2068	5.7432	80
90.0	303.4	1.4178	0.02048	1350.5	2557.8	1363.3	1378.9	2742.1	3.2858	5.6772	90
100.	311.1	1.4524	0.01803	1393.0	2544.4	1407.6	1317.1	2724.7	3.3596	5.6141	100
110.	318.2	1.4886	0.01599	1433.7	2529.8	1450.1	1255.5	2705.6	3.4295	5.5527	110

SUPERHEATED WATER TABLE

TABLE A-4 (Continued)

T °C	v m ³ /kg	u kJ/kg	h kJ/kg	s kJ/kg · K	v m ³ /kg	u kJ/kg	h kJ/kg	s kJ/kg · K
$p = 5.0$ bars = 0.50 MPa ($T_{\text{sat}} = 151.86^\circ\text{C}$)					$p = 7.0$ bars = 0.70 MPa ($T_{\text{sat}} = 164.97^\circ\text{C}$)			
Sat.	0.3749	2561.2	2748.7	6.8213	0.2729	2572.5	2763.5	6.7080
180	0.4045	2609.7	2812.0	6.9656	0.2847	2599.8	2799.1	6.7880
200	0.4249	2642.9	2855.4	7.0592	0.2999	2634.8	2844.8	6.8865
240	0.4646	2707.6	2939.9	7.2307	0.3292	2701.8	2932.2	7.0641
280	0.5034	2771.2	3022.9	7.3865	0.3574	2766.9	3017.1	7.2233
320	0.5416	2834.7	3105.6	7.5308	0.3852	2831.3	3100.9	7.3697
360	0.5796	2898.7	3188.4	7.6660	0.4126	2895.8	3184.7	7.5063
400	0.6173	2963.2	3271.9	7.7938	0.4397	2960.9	3268.7	7.6350
440	0.6548	3028.6	3356.0	7.9152	0.4667	3026.6	3353.3	7.7571
500	0.7109	3128.4	3483.9	8.0873	0.5070	3126.8	3481.7	7.9299
600	0.8041	3299.6	3701.7	8.3522	0.5738	3298.5	3700.2	8.1956
700	0.8969	3477.5	3925.9	8.5952	0.6403	3476.6	3924.8	8.4391

$p = 10.0$ bars = 1.0 MPa ($T_{\text{sat}} = 179.91^\circ\text{C}$)					$p = 15.0$ bars = 1.5 MPa ($T_{\text{sat}} = 198.32^\circ\text{C}$)			
Sat.	0.1944	2583.6	2778.1	6.5865	0.1318	2594.5	2792.2	6.4448
200	0.2060	2621.9	2827.9	6.6940	0.1325	2598.1	2796.8	6.4546
240	0.2275	2692.9	2920.4	6.8817	0.1483	2676.9	2899.3	6.6628
280	0.2480	2760.2	3008.2	7.0465	0.1627	2748.6	2992.7	6.8381
320	0.2678	2826.1	3093.9	7.1962	0.1765	2817.1	3081.9	6.9938
360	0.2873	2891.6	3178.9	7.3349	0.1899	2884.4	3169.2	7.1363
400	0.3066	2957.3	3263.9	7.4651	0.2030	2951.3	3255.8	7.2690
440	0.3257	3023.6	3349.3	7.5883	0.2160	3018.5	3342.5	7.3940
500	0.3541	3124.4	3478.5	7.7622	0.2352	3120.3	3473.1	7.5698
540	0.3729	3192.6	3565.6	7.8720	0.2478	3189.1	3560.9	7.6805
600	0.4011	3296.8	3697.9	8.0290	0.2668	3293.9	3694.0	7.8385
640	0.4198	3367.4	3787.2	8.1290	0.2793	3364.8	3783.8	7.9391

$p = 20.0$ bars = 2.0 MPa ($T_{\text{sat}} = 212.42^\circ\text{C}$)					$p = 30.0$ bars = 3.0 MPa ($T_{\text{sat}} = 233.90^\circ\text{C}$)			
Sat.	0.0996	2600.3	2799.5	6.3409	0.0667	2604.1	2804.2	6.1869
240	0.1085	2659.6	2876.5	6.4952	0.0682	2619.7	2824.3	6.2265
280	0.1200	2736.4	2976.4	6.6828	0.0771	2709.9	2941.3	6.4462
320	0.1308	2807.9	3069.5	6.8452	0.0850	2788.4	3043.4	6.6245
360	0.1411	2877.0	3159.3	6.9917	0.0923	2861.7	3138.7	6.7801
400	0.1512	2945.2	3247.6	7.1271	0.0994	2932.8	3230.9	6.9212
440	0.1611	3013.4	3335.5	7.2540	0.1062	3002.9	3321.5	7.0520
500	0.1757	3116.2	3467.6	7.4317	0.1162	3108.0	3456.5	7.2338
540	0.1853	3185.6	3556.1	7.5434	0.1227	3178.4	3546.6	7.3474
600	0.1996	3290.9	3690.1	7.7024	0.1324	3285.0	3682.3	7.5085
640	0.2091	3362.2	3780.4	7.8035	0.1388	3357.0	3773.5	7.6106
700	0.2232	3470.9	3917.4	7.9487	0.1484	3466.5	3911.7	7.7571