

Thermodynamics
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Lecture 51
Tutorial problems on two-phase systems(2 numbers)

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A closed rigid vessel contains 1 m³ of steam at 7 bar and 500 °C. The steam is now cooled to a state where pressure is 0.5 bar. Determine

a) the temperature at which condensation may first occur
 b) the fraction of the total mass that will condense
 c) volume occupied by the saturated liquid at the final state

Handwritten notes:
 $V_1 = 1 \text{ m}^3$ steam
 $p_1 = 7 \text{ bar} = 0.7 \text{ MPa}$
 $T_1 = 500^\circ\text{C}$
 $p_2 = 0.5 \text{ bar} = 0.05 \text{ MPa}$
 $v_1 = \frac{0.5420 + 0.4433}{2} = 0.51765 \text{ m}^3/\text{kg}$
 $m = \frac{V_1}{v_1} = \frac{1}{0.5176} \Rightarrow m = 1.93 \text{ kg}$
 $v = c$

Graphs:
 1. T-v diagram showing the cooling path from 500°C at 0.7 MPa down to 0.5 MPa. The saturation curve is shown with critical point (Tc, vc).
 2. T-v diagram for the final state at 0.5 MPa, showing the mixture of saturated liquid (vf) and saturated vapor (vg).
 3. Table of properties at 0.5 MPa:
 T @ 130: vf = 0.1680, vg = 0.5085
 T @ 140: vf = 0.5085, vg = 0.6680
 Interpolation: $\frac{T-130}{140-130} = \frac{0.5176 - 0.1680}{0.5085 - 0.1680} \Rightarrow T = 139.42^\circ\text{C}$





Figure 1.

Handwritten notes:
 @ 0.05 MPa
 $v_f = 0.001026 \text{ m}^3/\text{kg}$
 $v_g = 0.001033 \text{ m}^3/\text{kg}$
 $v = 0.51765 \text{ m}^3/\text{kg}$
 $v = x v_f + (1-x) v_g$
 $\Rightarrow x = \frac{v - v_g}{v_f - v_g} = 0.1536$
 $m_f = \frac{m x}{1-x} = \frac{1.93 \times 0.1536}{1 - 0.1536} = 1.63 \text{ kg}$
 $V_f = m_f v_f = 1.63 \times 0.001026 = 1.67 \times 10^{-3} \text{ m}^3$





Figure 2.

Solution of the problem in Fig. 1:

$V_1 = 1 \text{ m}^3, p_1 = 7 \text{ bar} = 0.7 \text{ MPa}, T_1 = 500^\circ\text{C} = 773 \text{ K}, p_2 = 0.5 \text{ bar} = 0.05 \text{ MPa}$

Since the steam is going to condense, it must be in superheated zone initially.

At 0.7 MPa and $T_1 = 500^\circ\text{C}$, $v_1 = 0.51765 \frac{\text{m}^3}{\text{kg}}$ (it is average of values at 0.6 MPa and 0.8 MPa)

The initial state (state 1) is shown on a T-v diagram in Fig. 1. The isobar of 0.7 MPa is also shown.

$$\text{Now, } m_1 = \frac{V_1}{v_1} = 1.93 \text{ kg.}$$

Since the vessel is rigid, the cooling is a constant volume process. The condensation will start at the state where vertical line through the state 1 intersects the saturated vapor line. It is shown in Fig. 1. From steam tables, we need to find the state on the saturated vapor line where the specific volume is $v_g = v_1 = 0.51765 \frac{\text{m}^3}{\text{kg}}$.

$v_g = 0.5176 \frac{\text{m}^3}{\text{kg}}$ lies between v_g values at 130°C and 140°C in the tables provided. Interpolating, we get the temperature as $T=139.4^\circ\text{C}$. This is the temperature at which the condensation starts. The corresponding saturation pressure for $T=139.4^\circ\text{C}$ is around 0.36 MPa. But, the cooling continues till the pressure reaches $p_2 = 0.05 \text{ MPa}$. It means the final state (state 2) is inside the liquid-vapor dome. We need to calculate the quality for $p_2=0.05 \text{ MPa}$ and $v_2 = 0.5176 \text{ m}^3/\text{kg}$.

$$x = \frac{v_2 - v_f}{v_g - v_f} = \frac{m_{vap}}{m_{total}} = 0.1536 \text{ and } m_{total} = m_1 = 1.93 \text{ kg.}$$

The mass of vapor at state 2 is $m_{vap} = 0.1536 \times 1.93 = 0.296 \text{ kg}$

Hence, the mass of liquid (condensate) at the state 2, $m_f = 1.93 - 0.296 = 1.63 \text{ kg}$.

Hence, the fraction of the total mass that condenses = $1.63/1.93 = 0.84$

Volume occupied by the saturated liquid at the final state, $V_f = m_f v_f = 1.67 \times 10^{-3} \text{ m}^3$ (v_f is the specific volume of saturated liquid at 0.05 MPa).

The T-v diagram drawn in Fig. 1 is corrected in Fig. 2 as the quality at the final state is low, but it is shown quite high in Fig. 1.

A large mass of liquid (1.63 kg) occupies a tiny volume ($1.67 \times 10^{-3} \text{ m}^3$) and a small mass of vapor (0.296 kg) occupies a large volume ($1 - 0.00167 = 0.998 \text{ m}^3$).

Properties of Superheated Water											
P=0.01 MPa (0.1 bar)			P=0.10 MPa (1.0 bar)			P=1.01 MPa (10.1 bar)			P=10.0 MPa (100.0 bar)		
Temp	Volume	Energy	Temp	Volume	Energy	Temp	Volume	Energy	Temp	Volume	Energy
[C]	[m³/kg]	[kJ/kg]	[C]	[m³/kg]	[kJ/kg]	[C]	[m³/kg]	[kJ/kg]	[C]	[m³/kg]	[kJ/kg]
150	1.720	2515.0	150	1.460	2523.0	150	1.000	2531.0	150	0.600	2539.0
160	1.610	2615.0	160	1.360	2623.0	160	0.900	2631.0	160	0.500	2639.0
170	1.510	2715.0	170	1.270	2723.0	170	0.800	2731.0	170	0.400	2739.0
180	1.420	2815.0	180	1.190	2823.0	180	0.700	2831.0	180	0.300	2839.0
190	1.340	2915.0	190	1.120	2923.0	190	0.600	2931.0	190	0.200	2939.0
200	1.270	3015.0	200	1.060	3023.0	200	0.500	3031.0	200	0.100	3039.0
210	1.210	3115.0	210	1.010	3123.0	210	0.400	3131.0	210	0.050	3139.0
220	1.160	3215.0	220	0.970	3223.0	220	0.300	3231.0	220	0.020	3239.0
230	1.120	3315.0	230	0.940	3323.0	230	0.200	3331.0	230	0.010	3339.0
240	1.090	3415.0	240	0.910	3423.0	240	0.150	3431.0	240	0.005	3439.0
250	1.060	3515.0	250	0.880	3523.0	250	0.100	3531.0	250	0.002	3539.0
260	1.040	3615.0	260	0.860	3623.0	260	0.070	3631.0	260	0.001	3639.0
270	1.020	3715.0	270	0.840	3723.0	270	0.050	3731.0	270	0.000	3739.0
280	1.000	3815.0	280	0.820	3823.0	280	0.030	3831.0	280	0.000	3839.0
290	0.980	3915.0	290	0.800	3923.0	290	0.020	3931.0	290	0.000	3939.0
300	0.960	4015.0	300	0.780	4023.0	300	0.010	4031.0	300	0.000	4039.0
310	0.940	4115.0	310	0.760	4123.0	310	0.005	4131.0	310	0.000	4139.0
320	0.920	4215.0	320	0.740	4223.0	320	0.002	4231.0	320	0.000	4239.0
330	0.900	4315.0	330	0.720	4323.0	330	0.001	4331.0	330	0.000	4339.0
340	0.880	4415.0	340	0.700	4423.0	340	0.000	4431.0	340	0.000	4439.0
350	0.860	4515.0	350	0.680	4523.0	350	0.000	4531.0	350	0.000	4539.0
360	0.840	4615.0	360	0.660	4623.0	360	0.000	4631.0	360	0.000	4639.0
370	0.820	4715.0	370	0.640	4723.0	370	0.000	4731.0	370	0.000	4739.0
380	0.800	4815.0	380	0.620	4823.0	380	0.000	4831.0	380	0.000	4839.0
390	0.780	4915.0	390	0.600	4923.0	390	0.000	4931.0	390	0.000	4939.0
400	0.760	5015.0	400	0.580	5023.0	400	0.000	5031.0	400	0.000	5039.0
410	0.740	5115.0	410	0.560	5123.0	410	0.000	5131.0	410	0.000	5139.0
420	0.720	5215.0	420	0.540	5223.0	420	0.000	5231.0	420	0.000	5239.0
430	0.700	5315.0	430	0.520	5323.0	430	0.000	5331.0	430	0.000	5339.0
440	0.680	5415.0	440	0.500	5423.0	440	0.000	5431.0	440	0.000	5439.0
450	0.660	5515.0	450	0.480	5523.0	450	0.000	5531.0	450	0.000	5539.0
460	0.640	5615.0	460	0.460	5623.0	460	0.000	5631.0	460	0.000	5639.0
470	0.620	5715.0	470	0.440	5723.0	470	0.000	5731.0	470	0.000	5739.0
480	0.600	5815.0	480	0.420	5823.0	480	0.000	5831.0	480	0.000	5839.0
490	0.580	5915.0	490	0.400	5923.0	490	0.000	5931.0	490	0.000	5939.0
500	0.560	6015.0	500	0.380	6023.0	500	0.000	6031.0	500	0.000	6039.0
510	0.540	6115.0	510	0.360	6123.0	510	0.000	6131.0	510	0.000	6139.0
520	0.520	6215.0	520	0.340	6223.0	520	0.000	6231.0	520	0.000	6239.0
530	0.500	6315.0	530	0.320	6323.0	530	0.000	6331.0	530	0.000	6339.0
540	0.480	6415.0	540	0.300	6423.0	540	0.000	6431.0	540	0.000	6439.0
550	0.460	6515.0	550	0.280	6523.0	550	0.000	6531.0	550	0.000	6539.0
560	0.440	6615.0	560	0.260	6623.0	560	0.000	6631.0	560	0.000	6639.0
570	0.420	6715.0	570	0.240	6723.0	570	0.000	6731.0	570	0.000	6739.0
580	0.400	6815.0	580	0.220	6823.0	580	0.000	6831.0	580	0.000	6839.0
590	0.380	6915.0	590	0.200	6923.0	590	0.000	6931.0	590	0.000	6939.0
600	0.360	7015.0	600	0.180	7023.0	600	0.000	7031.0	600	0.000	7039.0
610	0.340	7115.0	610	0.160	7123.0	610	0.000	7131.0	610	0.000	7139.0
620	0.320	7215.0	620	0.140	7223.0	620	0.000	7231.0	620	0.000	7239.0
630	0.300	7315.0	630	0.120	7323.0	630	0.000	7331.0	630	0.000	7339.0
640	0.280	7415.0	640	0.100	7423.0	640	0.000	7431.0	640	0.000	7439.0
650	0.260	7515.0	650	0.080	7523.0	650	0.000	7531.0	650	0.000	7539.0
660	0.240	7615.0	660	0.060	7623.0	660	0.000	7631.0	660	0.000	7639.0
670	0.220	7715.0	670	0.040	7723.0	670	0.000	7731.0	670	0.000	7739.0
680	0.200	7815.0	680	0.020	7823.0	680	0.000	7831.0	680	0.000	7839.0
690	0.180	7915.0	690	0.010	7923.0	690	0.000	7931.0	690	0.000	7939.0
700	0.160	8015.0	700	0.000	8023.0	700	0.000	8031.0	700	0.000	8039.0



Properties of Subcooled Water - Temperature Table											
P=0.01 MPa (0.1 bar)			P=0.10 MPa (1.0 bar)			P=1.01 MPa (10.1 bar)			P=10.0 MPa (100.0 bar)		
Temp	Volume	Energy	Temp	Volume	Energy	Temp	Volume	Energy	Temp	Volume	Energy
[C]	[m³/kg]	[kJ/kg]	[C]	[m³/kg]	[kJ/kg]	[C]	[m³/kg]	[kJ/kg]	[C]	[m³/kg]	[kJ/kg]
10	0.001	42	10	0.001	42	10	0.001	42	10	0.001	42
20	0.001	84	20	0.001	84	20	0.001	84	20	0.001	84
30	0.001	126	30	0.001	126	30	0.001	126	30	0.001	126
40	0.001	168	40	0.001	168	40	0.001	168	40	0.001	168
50	0.001	210	50	0.001	210	50	0.001	210	50	0.001	210
60	0.001	252	60	0.001	252	60	0.001	252	60	0.001	252
70	0.001	294	70	0.001	294	70	0.001	294	70	0.001	294
80	0.001	336	80	0.001	336	80	0.001	336	80	0.001	336
90	0.001	378	90	0.001	378	90	0.001	378	90	0.001	378
100	0.001	420	100	0.001	420	100	0.001	420	100	0.001	420
110	0.001	462	110	0.001	462	110	0.001	462	110	0.001	462
120	0.001	504	120	0.001	504	120	0.001	504	120	0.001	504
130	0.001	546	130	0.001	546	130	0.001	546	130	0.001	546
140	0.001	588	140	0.001	588	140	0.001	588	140	0.001	588
150	0.001	630	150	0.001	630	150	0.001	630	150	0.001	630
160	0.001	672	160	0.001	672	160	0.001	672	160	0.001	672
170	0.001	714	170	0.001	714	170	0.001	714	170	0.001	714
180	0.001	756	180	0.001	756	180	0.001	756	180	0.001	756
190	0.001	798	190	0.001	798	190	0.001	798	190	0.001	798
200	0.001	840	200	0.001	840	200	0.001	840	200	0.001	840
210	0.001	882	210	0.001	882	210	0.001	882	210	0.001	882
220	0.001	924	220	0.001	924	220	0.001	924	220	0.001	924
230	0.001	966	230	0.001	966	230	0.001	966	230	0.001	966
240	0.001	1008	240	0.001	1008	240	0.001	1008	240	0.001	1008
250	0.001	1050	250	0.001	1050	250	0.001	1050	250	0.001	1050
260	0.001	1092	260	0.001	1092	260	0.001	1092	260	0.001	1092
270	0.001	1134	270	0.001	1134	270	0.001	1134	270	0.001	1134
280	0.001	1176	280	0.001	1176	280	0.001	1176	280	0.001	1176
290	0.001	1218	290	0.001	1218	290	0.001	1218	290	0.001	1218
300	0.001	1260	300	0.001	1260	300	0.001	1260	300	0.001	1260
310	0.001	1302	310	0.001	1302	310	0.001	1302	310	0.001	1302
320	0.001	1344	320	0.001	1344	320	0.001	1344	320	0.001	1344
330	0.001	1386	330	0.001	1386	330					

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Determine the specific volume of water at 20 MPa and 400 °C in m³/kg using

(a) Steam tables

$$v = 0.00995 \text{ m}^3/\text{kg}$$

$p = 20 \text{ MPa}$ $T = 400^\circ\text{C}$
 $T_{sat} = 365^\circ\text{C}$
 superheated region

(b) Ideal gas equation of state

$$p \frac{v}{M} = RT \quad \text{or} \quad v = \frac{RT}{p}$$

$$= \frac{8314 \frac{\text{J}}{\text{kmol}\cdot\text{K}} \times 673 \text{ K}}{20 \times 10^6 \text{ Pa}}$$

$$= 0.01762 \text{ m}^3/\text{kg}$$

H_2O
 $M = 18$
 $400 + 273$

(c) Generalized compressibility charts

$$k = \frac{p}{p_c} = \frac{20 \text{ MPa}}{22.064 \text{ MPa}} \quad T_r = \frac{T}{T_c} = \frac{400 + 273}{373.95 + 273} = 1.04$$

$$k = 0.906 \quad z = \frac{p v}{RT} = 0.01762 \times \frac{20 \times 10^6}{8314} = 0.42$$

$z = \frac{RT}{p v}$
 $z = \frac{8314}{20 \times 10^6 \times 0.01762} = 0.232$



Figure 3.

Properties of Saturated Water - Pressure Table									
Pressure	Temp.	sat. vapor	sat. liquid						
MPa	°C	v_f	v_g	u_f	u_g	h_f	h_g	s_f	s_g
0.01	6.97	0.001000	203.51	0.000000	2335.3	0.01	2335.3	0.000000	8.8344
0.05	32.87	0.001000	105.03	0.000000	1188.8	0.04	2382.7	0.000000	8.8344
0.10	50.06	0.001000	70.63	0.000000	837.5	0.08	2397.1	0.000000	8.8344
0.20	70.07	0.001000	47.32	0.000000	588.4	0.16	2402.0	0.000000	8.8344
0.30	81.33	0.001000	38.92	0.000000	512.0	0.24	2405.8	0.000000	8.8344
0.40	89.40	0.001000	33.49	0.000000	463.5	0.32	2408.7	0.000000	8.8344
0.50	95.03	0.001000	29.98	0.000000	428.1	0.40	2410.9	0.000000	8.8344
0.60	99.06	0.001000	27.51	0.000000	401.3	0.48	2412.5	0.000000	8.8344
0.70	102.06	0.001000	25.67	0.000000	379.7	0.56	2413.6	0.000000	8.8344
0.80	104.43	0.001000	24.14	0.000000	361.6	0.64	2414.3	0.000000	8.8344
0.90	106.32	0.001000	22.82	0.000000	345.8	0.72	2414.7	0.000000	8.8344
1.00	107.81	0.001000	21.72	0.000000	332.0	0.80	2414.9	0.000000	8.8344
1.50	113.32	0.001000	18.27	0.000000	288.4	1.12	2415.3	0.000000	8.8344
2.00	117.06	0.001000	15.49	0.000000	253.4	1.44	2415.5	0.000000	8.8344
3.00	121.06	0.001000	12.03	0.000000	209.3	1.92	2415.6	0.000000	8.8344
4.00	124.42	0.001000	9.25	0.000000	173.4	2.40	2415.6	0.000000	8.8344
5.00	127.06	0.001000	7.10	0.000000	143.3	2.88	2415.6	0.000000	8.8344
6.00	129.06	0.001000	5.61	0.000000	117.1	3.36	2415.6	0.000000	8.8344
7.00	130.34	0.001000	4.58	0.000000	93.0	3.84	2415.6	0.000000	8.8344
8.00	131.06	0.001000	3.83	0.000000	73.3	4.32	2415.6	0.000000	8.8344
9.00	131.53	0.001000	3.26	0.000000	4.80	2415.6	0.000000	8.8344	
10.00	131.83	0.001000	2.84	0.000000	45.8	5.28	2415.6	0.000000	8.8344
15.00	134.86	0.001000	2.16	0.000000	28.9	6.72	2415.6	0.000000	8.8344
20.00	136.84	0.001000	1.64	0.000000	18.4	8.16	2415.6	0.000000	8.8344
30.00	140.06	0.001000	1.04	0.000000	9.3	9.60	2415.6	0.000000	8.8344
40.00	142.63	0.001000	0.72	0.000000	5.4	11.04	2415.6	0.000000	8.8344
50.00	144.63	0.001000	0.53	0.000000	3.8	12.48	2415.6	0.000000	8.8344
60.00	146.19	0.001000	0.41	0.000000	2.8	13.92	2415.6	0.000000	8.8344
70.00	147.43	0.001000	0.33	0.000000	2.1	15.36	2415.6	0.000000	8.8344
80.00	148.39	0.001000	0.28	0.000000	1.6	16.80	2415.6	0.000000	8.8344
90.00	149.13	0.001000	0.24	0.000000	1.2	18.24	2415.6	0.000000	8.8344
100.00	149.61	0.001000	0.21	0.000000	0.9	19.68	2415.6	0.000000	8.8344



Properties of Saturated Water - Temperature Table									
Temp.	Pressure	sat. vapor	sat. liquid						
°C	MPa	v_f	v_g	u_f	u_g	h_f	h_g	s_f	s_g
0	0.000611	0.001000	203.51	0.000000	2335.3	0.01	2335.3	0.000000	8.8344
5	0.000870	0.001000	196.13	0.000000	2282.7	0.02	2335.3	0.000000	8.8344
10	0.001170	0.001000	189.06	0.000000	2230.1	0.04	2335.3	0.000000	8.8344
15	0.001510	0.001000	182.81	0.000000	2177.5	0.06	2335.3	0.000000	8.8344
20	0.001890	0.001000	177.29	0.000000	2124.9	0.08	2335.3	0.000000	8.8344
25	0.002310	0.001000	172.42	0.000000	2072.3	0.10	2335.3	0.000000	8.8344
30	0.002770	0.001000	168.07	0.000000	2019.7	0.12	2335.3	0.000000	8.8344
35	0.003270	0.001000	164.06	0.000000	1967.1	0.14	2335.3	0.000000	8.8344
40	0.003810	0.001000	160.23	0.000000	1914.5	0.16	2335.3	0.000000	8.8344
45	0.004390	0.001000	156.51	0.000000	1861.9	0.18	2335.3	0.000000	8.8344
50	0.005010	0.001000	152.93	0.000000	1809.3	0.20	2335.3	0.000000	8.8344
55	0.005670	0.001000	149.51	0.000000	1756.7	0.22	2335.3	0.000000	8.8344
60	0.006370	0.001000	146.23	0.000000	1704.1	0.24	2335.3	0.000000	8.8344
65	0.007110	0.001000	143.09	0.000000	1651.5	0.26	2335.3	0.000000	8.8344
70	0.007890	0.001000	140.08	0.000000	1598.9	0.28	2335.3	0.000000	8.8344
75	0.008710	0.001000	137.20	0.000000	1546.3	0.30	2335.3	0.000000	8.8344
80	0.009570	0.001000	134.43	0.000000	1493.7	0.32	2335.3	0.000000	8.8344
85	0.010470	0.001000	131.77	0.000000	1441.1	0.34	2335.3	0.000000	8.8344
90	0.011410	0.001000	129.21	0.000000	1388.5	0.36	2335.3	0.000000	8.8344
95	0.012390	0.001000	126.74	0.000000	1335.9	0.38	2335.3	0.000000	8.8344
100	0.013410	0.001000	124.36	0.000000	1283.3	0.40	2335.3	0.000000	8.8344
105	0.014470	0.001000	122.06	0.000000	1230.7	0.42	2335.3	0.000000	8.8344
110	0.015570	0.001000	119.83	0.000000	1178.1	0.44	2335.3	0.000000	8.8344
115	0.016710	0.001000	117.66	0.000000	1125.5	0.46	2335.3	0.000000	8.8344
120	0.017890	0.001000	115.54	0.000000	1072.9	0.48	2335.3	0.000000	8.8344
125	0.019110	0.001000	113.47	0.000000	1020.3	0.50	2335.3	0.000000	8.8344
130	0.020370	0.001000	111.44	0.000000	967.7	0.52	2335.3	0.000000	8.8344
135	0.021670	0.001000	109.45	0.000000	915.1	0.54	2335.3	0.000000	8.8344
140	0.023010	0.001000	107.50	0.000000	862.5	0.56	2335.3	0.000000	8.8344
145	0.024390	0.001000	105.59	0.000000	809.9	0.58	2335.3	0.000000	8.8344
150	0.025810	0.001000	103.72	0.000000	757.3	0.60	2335.3	0.000000	8.8344
155	0.027270	0.001000	101.89	0.000000	704.7	0.62	2335.3	0.000000	8.8344
160	0.028770	0.001000	100.09	0.000000	652.1	0.64	2335.3	0.000000	8.8344
165	0.030310	0.001000	98.32	0.000000	599.5	0.66	2335.3	0.000000	8.8344
170	0.031890	0.001000	96.58	0.000000	546.9	0.68	2335.3	0.000000	8.8344
175	0.033510	0.001000	94.87	0.000000	494.3	0.70	2335.3	0.000000	8.8344
180	0.035170	0.001000	93.19	0.000000	441.7	0.72	2335.3	0.000000	8.8344
185	0.036870	0.001000	91.54	0.000000	389.1	0.74	2335.3	0.000000	8.8344
190	0.038610	0.001000	89.91	0.000000	336.5	0.76	2335.3	0.000000	8.8344
195	0.040390	0.001000	88.30	0.000000	283.9	0.78	2335.3	0.000000	8.8344
200	0.042210	0.001000	86.71	0.000000	231.3	0.80	2335.3	0.000000	8.8344





Superheated Steam				Saturated Vapor				Saturated Liquid				Saturated Vapor			
P, MPa	T, °C	v, m³/kg	h, kJ/kg	T, °C	v, m³/kg	h, kJ/kg	u, kJ/kg	T, °C	v, m³/kg	h, kJ/kg	u, kJ/kg	T, °C	v, m³/kg	h, kJ/kg	u, kJ/kg
0.01	101.06	1.673	2675.4	101.06	1.673	2675.4	1981.5	101.06	0.001043	417.46	1981.5	101.06	0.001043	417.46	1981.5
0.02	120.06	0.8857	2706.3	120.06	0.8857	2706.3	1984.5	120.06	0.001058	418.10	1984.5	120.06	0.001058	418.10	1984.5
0.05	161.61	0.3844	2755.7	161.61	0.3844	2755.7	1989.8	161.61	0.001075	419.04	1989.8	161.61	0.001075	419.04	1989.8
0.1	199.06	0.2446	2797.2	199.06	0.2446	2797.2	1993.3	199.06	0.001084	419.41	1993.3	199.06	0.001084	419.41	1993.3
0.2	233.90	0.1483	2832.1	233.90	0.1483	2832.1	1995.3	233.90	0.001091	419.58	1995.3	233.90	0.001091	419.58	1995.3
0.5	281.07	0.0751	2880.8	281.07	0.0751	2880.8	1996.3	281.07	0.001096	419.68	1996.3	281.07	0.001096	419.68	1996.3
1.0	311.06	0.0474	2908.3	311.06	0.0474	2908.3	1996.5	311.06	0.001099	419.71	1996.5	311.06	0.001099	419.71	1996.5
2.0	340.06	0.0296	2928.3	340.06	0.0296	2928.3	1996.6	340.06	0.001101	419.72	1996.6	340.06	0.001101	419.72	1996.6
5.0	381.51	0.0161	2948.3	381.51	0.0161	2948.3	1996.6	381.51	0.001102	419.72	1996.6	381.51	0.001102	419.72	1996.6
10.0	400.06	0.0100	2958.3	400.06	0.0100	2958.3	1996.6	400.06	0.001102	419.72	1996.6	400.06	0.001102	419.72	1996.6



Superheated Steam				Saturated Vapor				Saturated Liquid				Saturated Vapor			
P, MPa	T, °C	v, m³/kg	h, kJ/kg	T, °C	v, m³/kg	h, kJ/kg	u, kJ/kg	T, °C	v, m³/kg	h, kJ/kg	u, kJ/kg	T, °C	v, m³/kg	h, kJ/kg	u, kJ/kg
0.01	101.06	1.673	2675.4	101.06	1.673	2675.4	1981.5	101.06	0.001043	417.46	1981.5	101.06	0.001043	417.46	1981.5
0.02	120.06	0.8857	2706.3	120.06	0.8857	2706.3	1984.5	120.06	0.001058	418.10	1984.5	120.06	0.001058	418.10	1984.5
0.05	161.61	0.3844	2755.7	161.61	0.3844	2755.7	1989.8	161.61	0.001075	419.04	1989.8	161.61	0.001075	419.04	1989.8
0.1	199.06	0.2446	2797.2	199.06	0.2446	2797.2	1993.3	199.06	0.001084	419.41	1993.3	199.06	0.001084	419.41	1993.3
0.2	233.90	0.1483	2832.1	233.90	0.1483	2832.1	1995.3	233.90	0.001091	419.58	1995.3	233.90	0.001091	419.58	1995.3
0.5	281.07	0.0751	2880.8	281.07	0.0751	2880.8	1996.3	281.07	0.001096	419.68	1996.3	281.07	0.001096	419.68	1996.3
1.0	311.06	0.0474	2908.3	311.06	0.0474	2908.3	1996.5	311.06	0.001099	419.71	1996.5	311.06	0.001099	419.71	1996.5
2.0	340.06	0.0296	2928.3	340.06	0.0296	2928.3	1996.6	340.06	0.001101	419.72	1996.6	340.06	0.001101	419.72	1996.6
5.0	381.51	0.0161	2948.3	381.51	0.0161	2948.3	1996.6	381.51	0.001102	419.72	1996.6	381.51	0.001102	419.72	1996.6
10.0	400.06	0.0100	2958.3	400.06	0.0100	2958.3	1996.6	400.06	0.001102	419.72	1996.6	400.06	0.001102	419.72	1996.6



Solution of the problem in Fig. 3:

(a) Steam tables

At 20 MPa, the saturation temperature, T_{sat} is 365 °C. Since, $400^{\circ}\text{C} > T_{sat}$, the state is in the superheated zone. From the tables for the superheated steam, $v = 0.00995 \text{ m}^3/\text{kg}$.

(b) Ideal gas equation

$$pv = RT \rightarrow v = \frac{RT}{p} = \frac{\left(\frac{\bar{R}}{M_{H_2O}}\right)T}{p} = \frac{(8314.5/18)673}{20 \times 10^6} = 0.01762 \frac{\text{m}^3}{\text{kg}}$$

This value quite far from the actual value calculated using the tables.

(c) Generalized compressibility chart

$$p_R = \frac{p}{p_c} = \frac{20}{20.064} = 0.906, T_R = \frac{T}{T_c} = \frac{400 + 273}{373.95 + 273} = 1.04$$

The corresponding Z value for the above p_R and T_R values is around $Z=0.5$.

$$\text{Now, } v = Z \frac{RT}{p} = 0.5 \times 0.01762 = 0.0088 \text{ m}^3/\text{kg}$$

This value is closer to the actual value compared to the one obtained using the ideal gas equation. If the tables are available, we should always prefer tables to get the property values.

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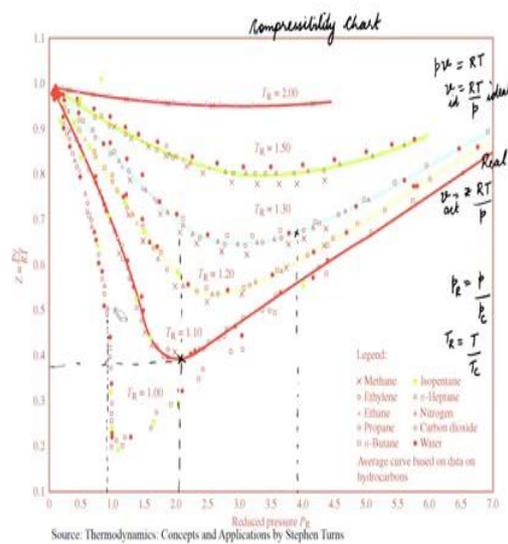


Figure 4.