Steam Tables

4.1 SATURATED LIQUID AND SATURATED VAPOR STATES:

Saturated liquid. Liquid at the saturation temperature corresponding to the saturation pressure.

Saturated vapour. A term including wet and dry vapour

• The properties of saturated liquid and saturated vapor for water are listed in Tables A–4 and A–5. Both tables give the same information.

• The only difference is that in Table A–4 properties are listed under temperature and in Table A–5 under pressure.

• Therefore, it is more convenient to use Table A–4 when temperature is given and Table A–5 when pressure is given.

• Another subscript commonly used is "f g", which denotes the difference between the saturated vapor and saturated liquid.

• The subscript f is used to denote properties of a saturated liquid, and the subscript g to denote the properties of saturated vapor.

v_f = specific volume of saturated liquid

v_g = specific volume of saturated vapor

v_{fg} = difference between v_g and v_f (that is, $v_{fg} = v_g - v_f$)

The quantity hfg is called the enthalpy of vaporization (or latent heat of vaporization).

TABLE B.1 Saturated Water: Temperature Table 2

T °C	P kPa, MPa	$\hat{v}_f$ m³/kg	$\hat{v}_g$ m³/kg	$\hat{u}_f$ kJ/kg	$\Delta\hat{u}_{fg}$ kJ/kg	$\hat{u}_g$ kJ/kg	$\hat{h}_f$ kJ/kg	$\Delta\hat{h}_{fg}$ kJ/kg	$\hat{h}_g$ kJ/kg	$\hat{s}_f$ kJ/kg K	$\Delta\hat{s}_{fg}$ kJ/kg K	$\hat{s}_g$ kJ/kg K
0.01	0.6113	0.001000	206.132	0.00	2375.3	2375.3	0.00	2501.3	2501.3	0.0000	9.1562	9.1562
5	0.8721	0.001000	147.118	20.97	2361.3	2382.2	20.98	2489.6	2510.5	0.0761	8.9496	9.0257
10	1.2276	0.001000	106.377	41.99	2347.2	2389.2	41.99	2477.7	2519.7	0.1510	8.7498	8.9007
15	1.7051	0.001001	77.925	62.98	2333.1	2396.0	62.98	2465.9	2528.9	0.2245	8.5569	8.7813
20	2.3385	0.001002	57.790	83.94	2319.0	2402.9	83.94	2454.1	2538.1	0.2966	8.3706	8.6671
25	3.1691	0.001003	43.359	104.86	2304.9	2409.8	104.87	2442.3	2547.2	0.3673	8.1905	8.5579
30	4.2461	0.001004	32.893	125.77	2290.8	2416.6	125.77	2430.5	2556.2	0.4369	8.0164	8.4533
35	5.6280	0.001006	25.216	146.65	2276.7	2423.4	146.66	2418.6	2565.3	0.5052	7.8478	8.3530
40	7.3837	0.001008	19.523	167.53	2262.6	2430.1	167.54	2406.7	2574.3	0.5724	7.6845	8.2569
45	9.5934	0.001010	15.258	188.41	2248.4	2436.8	188.42	2394.8	2583.2	0.6386	7.5261	8.1647
50	12.350	0.001012	12.032	209.30	2234.2	2443.5	209.31	2382.7	2592.1	0.7037	7.3725	8.0762
55	15.758	0.001015	9.568	230.19	2219.9	2450.1	230.20	2370.7	2600.9	0.7679	7.2234	7.9912
60	19.941	0.001017	7.671	251.09	2205.5	2456.6	251.11	2358.5	2609.6	0.8311	7.0784	7.9095
65	25.033	0.001020	6.197	272.00	2191.1	2463.1	272.03	2346.2	2618.2	0.8934	6.9375	7.8309
70	31.188	0.001023	5.042	292.93	2176.6	2469.5	292.96	2333.8	2626.8	0.9548	6.8004	7.7552
75	38.578	0.001026	4.131	313.87	2162.0	2475.9	313.91	2321.4	2635.3	1.0154	6.6670	7.6824
80	47.390	0.001029	3.407	334.84	2147.4	2482.2	334.88	2308.8	2643.7	1.0752	6.5369	7.6121
85	57.834	0.001032	2.828	355.82	2132.6	2488.4	355.88	2296.0	2651.9	1.1342	6.4102	7.5444
90	70.139	0.001036	2.361	376.82	2117.7	2494.5	376.90	2283.2	2660.1	1.1924	6.2866	7.4790
95	84.554	0.001040	1.982	397.86	2102.7	2500.6	397.94	2270.2	2668.1	1.2500	6.1659	7.4158
100	0.10135	0.001044	1.6729	418.91	2087.6	2506.5	419.02	2257.0	2676.0	1.3068	6.0480	7.3548
105	0.12082	0.001047	1.4194	440.00	2072.3	2512.3	440.13	2243.7	2683.8	1.3629	5.9328	7.2958
110	0.14328	0.001052	1.2102	461.12	2057.0	2518.1	461.27	2230.2	2691.5	1.4184	5.8202	7.2386
115	0.16906	0.001056	1.0366	482.28	2041.4	2523.7	482.46	2216.5	2699.0	1.4733	5.7100	7.1832
120	0.19853	0.001060	0.8919	503.48	2025.8	2529.2	503.69	2202.6	2706.3	1.5275	5.6020	7.1295
125	0.2321	0.001065	0.77059	524.72	2009.9	2534.6	524.96	2188.5	2713.5	1.5812	5.4962	7.0774
130	0.2701	0.001070	0.66850	546.00	1993.9	2539.9	546.29	2174.2	2720.5	1.6343	5.3925	7.0269
135	0.3130	0.001075	0.58217	567.34	1977.7	2545.0	567.67	2159.6	2727.3	1.6869	5.2907	6.9777
140	0.3613	0.001080	0.50885	588.72	1961.3	2550.0	589.11	2144.8	2733.9	1.7390	5.1908	6.9298
145	0.4154	0.001085	0.44632	610.16	1944.7	2554.9	610.61	2129.6	2740.3	1.7906	5.0926	6.8832
150	0.4759	0.001090	0.39278	631.66	1927.9	2559.5	632.18	2114.3	2746.4	1.8417	4.9960	6.8378
155	0.5431	0.001096	0.34676	653.23	1910.8	2564.0	653.82	2098.6	2752.4	1.8924	4.9010	6.7934
160	0.6178	0.001102	0.30706	674.85	1893.5	2568.4	675.53	2082.6	2758.1	1.9426	4.8075	6.7501
165	0.7005	0.001108	0.27269	696.55	1876.0	2572.5	697.32	2066.2	2763.5	1.9924	4.7153	6.7078
170	0.7917	0.001114	0.24283	718.31	1858.1	2576.5	719.20	2049.5	2768.7	2.0418	4.6244	6.6663

TABLE B.1 Continued

175	0.8920	0.001121	0.21680	740.16	1840.0	2580.2	741.16	2032.4	2773.6	2.0909	4.5347	6.6256
180	1.0022	0.001127	0.19405	762.08	1821.6	2583.7	763.21	2015.0	2778.2	2.1395	4.4461	6.5857
185	1.1227	0.001134	0.17409	784.08	1802.9	2587.0	785.36	1997.1	2782.4	2.1878	4.3596	6.5464
190	1.2544	0.001141	0.15654	806.17	1783.8	2590.0	807.61	1978.8	2786.4	2.2358	4.2720	6.5078
195	1.3978	0.001149	0.14105	828.36	1764.4	2592.8	829.96	1960.0	2790.0	2.2835	4.1863	6.4697
200	1.5538	0.001156	0.12736	850.64	1744.7	2595.3	852.43	1940.7	2793.2	2.3308	4.1014	6.4322
205	1.7230	0.001164	0.11521	873.02	1724.5	2597.5	875.03	1921.0	2796.0	2.3779	4.0172	6.3951
210	1.9063	0.001173	0.10441	895.51	1703.9	2599.4	897.75	1900.7	2798.5	2.4247	3.9337	6.3584
215	2.1042	0.001181	0.09479	918.12	1682.9	2601.1	920.61	1879.9	2800.5	2.4713	3.8507	6.3221
220	2.3178	0.001190	0.08619	940.85	1661.5	2602.3	943.61	1858.5	2802.1	2.5177	3.7683	6.2860
225	2.5477	0.001199	0.07849	963.72	1639.6	2603.3	966.77	1836.5	2803.3	2.5639	3.6863	6.2502
230	2.7949	0.001209	0.07158	986.72	1617.2	2603.9	990.10	1813.8	2803.9	2.6099	3.6047	6.2146
235	3.0601	0.001219	0.06536	1009.88	1594.2	2604.1	1013.61	1790.5	2804.1	2.6557	3.5233	6.1791
240	3.3442	0.001229	0.05976	1033.19	1570.8	2603.9	1037.31	1766.5	2803.8	2.7015	3.4422	6.1436
245	3.6482	0.001240	0.05470	1056.69	1546.7	2603.4	1061.21	1741.7	2802.9	2.7471	3.3612	6.1083
250	3.9730	0.001251	0.05013	1080.37	1522.0	2602.4	1085.34	1716.2	2801.5	2.7927	3.2802	6.0729
255	4.3195	0.001263	0.04598	1104.26	1496.7	2600.9	1109.72	1689.8	2799.5	2.8382	3.1992	6.0374
260	4.6886	0.001276	0.04220	1128.37	1470.6	2599.0	1134.35	1662.5	2796.9	2.8837	3.1181	6.0018
265	5.0813	0.001289	0.03877	1152.72	1443.9	2596.6	1159.27	1634.3	2793.6	2.9293	3.0368	5.9661
270	5.4987	0.001302	0.03564	1177.33	1416.3	2593.7	1184.49	1605.2	2789.7	2.9750	2.9551	5.9301
275	5.9418	0.001317	0.03279	1202.23	1387.9	2590.2	1210.05	1574.9	2785.0	3.0208	2.8730	5.8937
280	6.4117	0.001332	0.03017	1227.43	1358.7	2586.1	1235.97	1543.6	2779.5	3.0667	2.7903	5.8570
285	6.9094	0.001348	0.02777	1252.98	1328.4	2581.4	1262.29	1511.0	2773.3	3.1129	2.7069	5.8198
290	7.4360	0.001366	0.02557	1278.89	1297.1	2576.0	1289.04	1477.1	2766.1	3.1593	2.6227	5.7821
295	7.9928	0.001384	0.02354	1305.21	1264.7	2569.9	1316.27	1441.8	2758.0	3.2061	2.5375	5.7436
300	8.5810	0.001404	0.02167	1331.97	1231.0	2563.0	1344.01	1404.9	2748.9	3.2533	2.4511	5.7044
305	9.2018	0.001425	0.01995	1359.22	1195.9	2555.2	1372.33	1366.4	2738.7	3.3009	2.3633	5.6642
310	9.8566	0.001447	0.01835	1387.03	1159.4	2546.4	1401.29	1326.0	2727.3	3.3492	2.2737	5.6229
315	10.547	0.001472	0.01687	1415.44	1121.1	2536.6	1430.97	1283.5	2714.4	3.3981	2.1821	5.5803
320	11.274	0.001499	0.01549	1444.55	1080.9	2525.5	1461.45	1238.6	2700.1	3.4479	2.0882	5.5361
330	12.845	0.001561	0.012996	1505.24	993.7	2498.9	1525.29	1140.6	2665.8	3.5506	1.8909	5.4416
340	14.586	0.001638	0.010797	1570.26	894.3	2464.5	1594.15	1027.9	2622.0	3.6593	1.6763	5.3356
350	16.514	0.001740	0.008813	1641.81	776.6	2418.4	1670.54	893.4	2563.9	3.7776	1.4336	5.2111
360	18.651	0.001892	0.006945	1725.19	626.3	2351.5	1760.48	720.5	2481.0	3.9146	1.1379	5.0525
370	21.028	0.002213	0.004926	1843.84	384.7	2228.5	1890.37	441.8	2332.1	4.1104	0.6868	4.7972
374.14	22.089	0.003155	0.003155	2029.58	0	2029.6	2099.26	0	2099.3	4.4297	0	4.4297

TABLE A–5

Saturated water—Pressure table

		Specific volume, m³/kg		Internal energy, kJ/kg			Enthalpy, kJ/kg			Entropy, kJ/kg·K		
Press., P kPa	Sat. temp., T_{sat} °C	Sat. liquid, v_f	Sat. vapor, v_g	Sat. liquid, u_f	Evap., u_{fg}	Sat. vapor, u_g	Sat. liquid, h_f	Evap., h_{fg}	Sat. vapor, h_g	Sat. liquid, s_f	Evap., s_{fg}	Sat. vapor, s_g
1.0	6.97	0.001000	129.19	29.302	2355.2	2384.5	29.303	2484.4	2513.7	0.1059	8.8690	8.9749
1.5	13.02	0.001001	87.964	54.686	2338.1	2392.8	54.688	2470.1	2524.7	0.1956	8.6314	8.8270
2.0	17.50	0.001001	66.990	73.431	2325.5	2398.9	73.433	2459.5	2532.9	0.2606	8.4621	8.7227
2.5	21.08	0.001002	54.242	88.422	2315.4	2403.8	88.424	2451.0	2539.4	0.3118	8.3302	8.6421
3.0	24.08	0.001003	45.654	100.98	2306.9	2407.9	100.98	2443.9	2544.8	0.3543	8.2222	8.5765
4.0	28.96	0.001004	34.791	121.39	2293.1	2414.5	121.39	2432.3	2553.7	0.4224	8.0510	8.4734
5.0	32.87	0.001005	28.185	137.75	2282.1	2419.8	137.75	2423.0	2560.7	0.4762	7.9176	8.3938
7.5	40.29	0.001008	19.233	168.74	2261.1	2429.8	168.75	2405.3	2574.0	0.5763	7.6738	8.2501
10	45.81	0.001010	14.670	191.79	2245.4	2437.2	191.81	2392.1	2583.9	0.6492	7.4996	8.1488
15	53.97	0.001014	10.020	225.93	2222.1	2448.0	225.94	2372.3	2598.3	0.7549	7.2522	8.0071
20	60.06	0.001017	7.6481	251.40	2204.6	2456.0	251.42	2357.5	2608.9	0.8320	7.0752	7.9073
25	64.96	0.001020	6.2034	271.93	2190.4	2462.4	271.96	2345.5	2617.5	0.8932	6.9370	7.8302
30	69.09	0.001022	5.2287	289.24	2178.5	2467.7	289.27	2335.3	2624.6	0.9441	6.8234	7.7675
40	75.86	0.001026	3.9933	317.58	2158.8	2476.3	317.62	2318.4	2636.1	1.0261	6.6430	7.6691
50	81.32	0.001030	3.2403	340.49	2142.7	2483.2	340.54	2304.7	2645.2	1.0912	6.5019	7.5931

1.Saturated Liquid–Vapor Mixture

To analyze this mixture properly, we need to know the proportions of the liquid and vapor phases in the mixture. This is done by defining a new property called **the quality x as the ratio of the mass of vapor to the total mass of the mixture:**

$$x = \frac{m_g}{m_t} = \frac{m_g}{m_f + m_g}$$

Where m_g is the mass of vapor (kg)

m_f is the mass of liquid (kg)

m_t is total the mass of mixture (kg)

For saturated liquid line x = 0 (which is said to have a quality of 0%).

For dry saturated vapor x = 1 (which is said to have a quality of 100%).

For mixed region $0 < x < 1$

For (1 kg) of wet vapor, there are (x kg) of vapor, and (1 − x) kg of liquid. Hence to calculate the specific volume at this point:

$$v = (1 - x)v_f + xv_g$$

$$v = v_f + xv_{fg}$$

The volume of the liquid is negligibly small compared to the volume

$$v = xv_g$$

The enthalpy of a wet vapor is given by the sum of the enthalpy of the liquid plus the enthalpy of the dry vapor:

$$h = (1 - x)h_f + xh_g$$

$$h = h_f + x(h_g - h_f)$$

$$h = h_f + xh_{fg}$$

Similarly the internal energy equation is:

$$u = u_f + xu_{fg}$$

And the entropy equation is:

$$s = s_f + xs_{fg}$$

Example (1): A rigid tank contains (50 kg) of saturated liquid water at (90 °C). Determine the pressure in the tank and the volume of the tank.

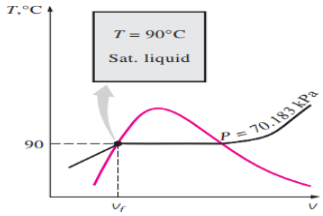
Solution:

$$\textbf{Saturated water @ T} = \textbf{90 °C} \Rightarrow \textbf{Table} \Rightarrow P = P_{sat} = 70.139\ kPa$$

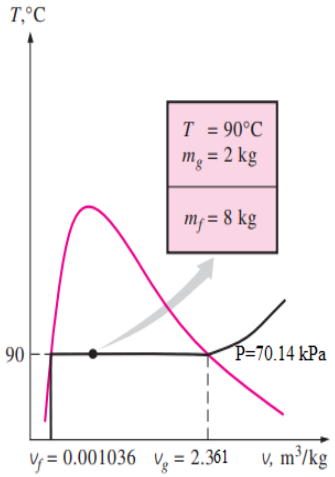
$$\textbf{Saturated water @ T} = \textbf{90 °C} \Rightarrow \textbf{Table} \Rightarrow v = v_f = 0.001036\ kg/m^3$$

Then the total volume of the tank becomes

$$V = v_f m = 0.001036 * 50 = 0.0518\ m^3$$



Example (2): A rigid tank contains (10 kg) of water at (90 °C). If (8 kg) of the water is in the liquid form and the rest is in the vapor form, determine (a) the pressure in the tank and (b) the volume of the tank.



Solution:

a) The state of the saturated liquid–vapor mixture is shown in Figure below. Since the two phases coexist in equilibrium, we have a saturated mixture, and the pressure must be the saturation pressure at the given temperature:

$$Saturated \text{ water @ T} = 90\ ^\circ\text{C}$$
$$\Rightarrow \text{Table (A} - 4)$$

$$\Rightarrow P = P_{sat} = 70.139\ kPa$$

(b)

$Saturated$ water @ T = 90 °C ⇒ Table (A − 4)

$$\Rightarrow v_f = 0.001036\ m^3/kg \qquad and \qquad v_g = 2.3593\ m^3/kg$$

$$V = V_f + V_g = m_f v_f + m_g v_g$$

$$V = 8 * 0.001036 + 2 * 2.361 = 4.73\ m^3$$

Example (3): A rigid tank contains saturated liquid water at (95 °C). Determine the pressure in the tank and the specific volume of the water.

Solution:

$$Saturated \text{ water @ T} = 95\ ^\circ\text{C} \Rightarrow \text{Table (A} - 4) \Rightarrow P = P_{sat} = 84.554\ kPa$$

$$Saturated \text{ water @ T} = 95\ ^\circ\text{C} \Rightarrow \text{Table (A} - 4) \Rightarrow v = v_f = 0.001040\ kg/m^3$$

2.Superheated Vapor

Compared to saturated vapor, superheated vapor Table (A-6) is characterized by

Lower pressures ($P < P_{sat}$ at a given T)
Higher tempreatures ($T > T_{sat}$ at a given P)
Higher specific volumes ($v > v_g$ at a given P or T)
Higher internal energies ($u > u_g$ at a given P or T)
Higher enthalpies ($h > h_g$ at a given P or T)

TABLE A–6

Superheated water

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg·K	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg·K
	P = 0.01 MPa (45.81°C)*				P = 0.05 MPa (81.32°C)			
Sat.†	14.670	2437.2	2583.9	8.1488	3.2403	2483.2	2645.2	7.5931
50	14.867	2443.3	2592.0	8.1741				
100	17.196	2515.5	2687.5	8.4489	3.4187	2511.5	2682.4	7.6953
150	19.513	2587.9	2783.0	8.6893	3.8897	2585.7	2780.2	7.9413
200	21.826	2661.4	2879.6	8.9049	4.3562	2660.0	2877.8	8.1592
250	24.136	2736.1	2977.5	9.1015	4.8206	2735.1	2976.2	8.3568
300	26.446	2812.3	3076.7	9.2827	5.2841	2811.6	3075.8	8.5387
400	31.063	2969.3	3280.0	9.6094	6.2094	2968.9	3279.3	8.8659
500	35.680	3132.9	3489.7	9.8998	7.1338	3132.6	3489.3	9.1566
600	40.296	3303.3	3706.3	10.1631	8.0577	3303.1	3706.0	9.4201
700	44.911	3480.8	3929.9	10.4056	8.9813	3480.6	3929.7	9.6626
800	49.527	3665.4	4160.6	10.6312	9.9047	3665.2	4160.4	9.8883
900	54.143	3856.9	4398.3	10.8429	10.8280	3856.8	4398.2	10.1000
1000	58.758	4055.3	4642.8	11.0429	11.7513	4055.2	4642.7	10.3000
1100	63.373	4260.0	4893.8	11.2326	12.6745	4259.9	4893.7	10.4897
1200	67.989	4470.9	5150.8	11.4132	13.5977	4470.8	5150.7	10.6704
1300	72.604	4687.4	5413.4	11.5857	14.5209	4687.3	5413.3	10.8429

Example (4): Determine the temperature of superheated steam at a state of (0.05 MPa) and enthalpy (2780.2 kJ/kg).

Solution:

$$@P = 0.05\ MPa \ \ \& \ \ h = 2585.7\ \text{kJ/kg} \ \ \Rightarrow Table\ (A-6) \Rightarrow T = 150\ ℃$$

COMPRESSED (SUBCOOLED) LIQUID:

When water is in the compressed liquid phase, Table (A-4) or Table (A-5) is used to get the required properties (of fluid). To use this table, two properties must be known. So the same rules as with the superheated vapor are applied here.

We can identify the state of water using the saturation tables, i.e. Table (A-4) and Table (A-5). Two known properties are required to identify the state of water as follows:

$@T = given \Rightarrow P < P_{sat}$ or $@P = given \Rightarrow T > T_{sat}$

then

$v > v_g \ @\ T \ or \ P \Rightarrow$ water is in the superheated vapor

$u > u_g \ @\ T \ or \ P \Rightarrow$ water is in the superheated vapor

$h > h_g \ @\ T \ or \ P \Rightarrow$ water is in the superheated vapor

$s > s_g \ @\ T \ or \ P \Rightarrow$ water is in the superheated vapor

$@T = given \Rightarrow P > P_{sat}$ or $@P = given \Rightarrow T < T_{sat}$

$v < v_f \ @\ T \ or \ P \Rightarrow$ water is in the compressed liquid

$u < u_f \ @\ T \ or \ P \Rightarrow$ water is in the compressed liquid

$h < h_f \ @\ T \ or \ P \Rightarrow$ water is in the compressed liquid

$s < s_f$ @ T *or* $P \Rightarrow$ water is in the compressed liquid

If the property equals the saturation value, then the water is in the saturated state (vapor or liquid).

If ($property_f < property < property_g$), then the water is in the wet vapor state.

TABLE A–7

Compressed liquid water

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg·K	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg·K
	P = 5 MPa (263.94°C)				P = 10 MPa (311.00°C)			
Sat.	0.0012862	1148.1	1154.5	2.9207	0.0014522	1393.3	1407.9	3.3603
0	0.0009977	0.04	5.03	0.0001	0.0009952	0.12	10.07	0.0003
20	0.0009996	83.61	88.61	0.2954	0.0009973	83.31	93.28	0.2943
40	0.0010057	166.92	171.95	0.5705	0.0010035	166.33	176.37	0.5685
60	0.0010149	250.29	255.36	0.8287	0.0010127	249.43	259.55	0.8260
80	0.0010267	333.82	338.96	1.0723	0.0010244	332.69	342.94	1.0691
100	0.0010410	417.65	422.85	1.3034	0.0010385	416.23	426.62	1.2996
120	0.0010576	501.91	507.19	1.5236	0.0010549	500.18	510.73	1.5191
140	0.0010769	586.80	592.18	1.7344	0.0010738	584.72	595.45	1.7293
160	0.0010988	672.55	678.04	1.9374	0.0010954	670.06	681.01	1.9316
180	0.0011240	759.47	765.09	2.1338	0.0011200	756.48	767.68	2.1271
200	0.0011531	847.92	853.68	2.3251	0.0011482	844.32	855.80	2.3174
220	0.0011868	938.39	944.32	2.5127	0.0011809	934.01	945.82	2.5037
240	0.0012268	1031.6	1037.7	2.6983	0.0012192	1026.2	1038.3	2.6876
260	0.0012755	1128.5	1134.9	2.8841	0.0012653	1121.6	1134.3	2.8710
280					0.0013226	1221.8	1235.0	3.0565
300					0.0013980	1329.4	1343.3	3.2488
320								