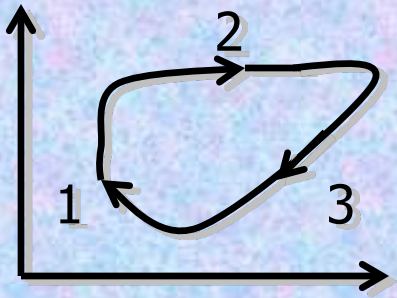


قانون اول ترمودینامیک

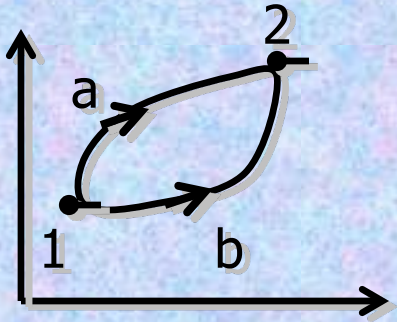


$$\oint \delta Q = \oint \delta W$$

1- برای یک چرخه:

کار انجام شده خالص طی یک چرخه = حرارت انتقال یافته خالص طی چرخه

$$Q_1 + Q_2 + Q_3 = W_1 + W_2 + W_3$$



2- برای یک فرایند (تغییر حالت):

$${}_1Q_2 = \Delta E + {}_1W_2$$

$${}_1Q_2 = E_2 - E_1 + {}_1W_2$$

حرارت انتقال یافته طی فرایند : ${}_1Q_2$

کار انجام شده طی فرایند : ${}_1W_2$

تغییر انرژی از نقطه شروع تا نقطه پایانی فرایند :

$$\Delta E = E_2 - E_1$$

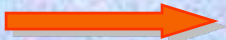
نکته: اگر فرایند طی فرایند b انجام می‌شود چون ΔE ثابت است و $Q_2 - W_2 = \Delta E$ پس نتیجه می‌شود $Q_2 - W_2$ چون تابع نقاط ابتدایی و انتهایی فرایند است و به مسیر طی شده بستگی ندارد ثابت می‌ماند.

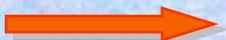
انرژی درونی + انرژی پتانسیل + انرژی جنبشی = انرژی سیستم

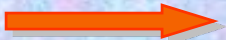
$$E = KE + PE + U$$

$$\frac{1}{2} m V^2 \longleftarrow \quad \quad \quad \longrightarrow mgz$$

 $\Delta E = \Delta KE + \Delta PE + \Delta U$

 $\Delta E = E_2 - E_1 = (KE_2 - KE_1) + (PE_2 - PE_1) + (U_2 - U_1)$

 $E_2 - E_1 = \frac{1}{2} m (V_2^2 - V_1^2) + mg(z_2 - z_1) + (U_2 - U_1)$

 $Q_2 = \frac{1}{2} m (V_2^2 - V_1^2) + mg(z_2 - z_1) + (U_2 - U_1) + W_2$

$Q_2 = U_2 - U_1 + W_2$ اگر $z_1 = z_2$ و $V_1 = V_2$ داریم:

انرژی درونی (داخلی): U [kj]

انرژی درونی در واحد جرم: $u = \frac{U}{m}$ [$\frac{kJ}{kg}$]

انرژی درونی حالت دو فازی:

انرژی درونی مایع اشباع: u_f

انرژی درونی بخار اشباع: u_g

$$u_{fg} = u_g - u_f$$

$$U = U_{\text{liq}} + U_{\text{vap}}$$

or

$$mu = m_{\text{liq}}u_f + m_{\text{vap}}u_g$$

Dividing by m and introducing the quality x gives

$$u = (1 - x)u_f + xu_g$$

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

انرژی درونی تابعی از دماست

TABLE B.1.2

Saturated Water Pressure Entry

Press. (kPa)	Temp. (°C)	Specific Volume, m ³ /kg			Internal Energy, kJ/kg		
		Sat. Liquid v_f	Evap. v_{fg}	Sat. Vapor v_g	Sat. Liquid u_f	Evap. u_{fg}	Sat. Vapor u_g
0.6113	0.01	0.001000	206.131	206.132	0	2375.3	2375.3
1	6.98	0.001000	129.20702	129.20802	29.29	2355.69	2384.98
1.5	13.03	0.001001	87.97913	87.98013	54.70	2338.63	2393.32
2	17.50	0.001001	67.00285	67.00385	73.47	2326.02	2399.48
2.5	21.08	0.001002	54.25285	54.25385	88.47	2315.93	2404.40
3	24.08	0.001003	45.66402	45.66502	101.03	2307.48	2408.51
4	28.96	0.001004	34.79915	34.80015	121.44	2293.73	2415.17
5	32.88	0.001005	28.19150	28.19251	137.79	2282.70	2420.49
7.5	40.29	0.001008	19.23674	19.23775	168.76	2261.74	2430.50
10	45.81	0.001010	14.67254	14.67355	191.79	2246.10	2437.89
15	53.97	0.001014	10.02117	10.02218	225.90	2222.83	2448.73
20	60.06	0.001017	7.64835	7.64937	251.35	2205.36	2456.71
25	64.97	0.001020	6.20322	6.20424	271.88	2191.21	2463.08
30	69.10	0.001022	5.22816	5.22918	289.18	2179.22	2468.40
40	75.87	0.001026	3.99243	3.99345	317.51	2159.49	2477.00
50	81.33	0.001030	3.23931	3.24034	340.42	2143.43	2483.85
75	91.77	0.001037	2.21607	2.21711	394.29	2112.39	2496.67
100	99.62	0.001043	1.69296	1.69400	417.33	2088.72	2506.06
125	105.99	0.001048	1.37385	1.37490	444.16	2069.32	2513.48
150	111.37	0.001053	1.15828	1.15933	466.92	2052.72	2519.64
175	116.06	0.001057	1.00257	1.00363	486.78	2038.12	2524.90
200	120.23	0.001061	0.88467	0.88573	504.47	2025.02	2529.49
225	124.00	0.001064	0.79219	0.79325	520.45	2013.10	2533.56
250	127.43	0.001067	0.71765	0.71871	535.08	2002.14	2537.21
275	130.60	0.001070	0.65624	0.65731	548.57	1991.95	2540.53
300	133.55	0.001073	0.60475	0.60582	561.13	1982.43	2543.55
325	136.30	0.001076	0.56093	0.56201	572.88	1973.46	2546.34
350	138.88	0.001079	0.52317	0.52425	583.93	1964.98	2548.92
375	141.32	0.001081	0.49029	0.49137	594.38	1956.93	2551.31
400	143.63	0.001084	0.46138	0.46246	604.29	1949.26	2553.55

TABLE B.1.3

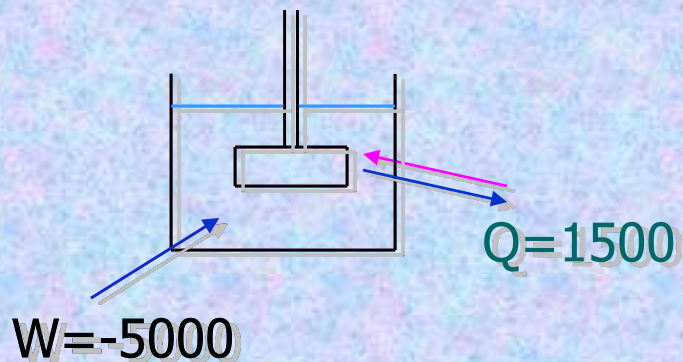
Superheated Vapor Water

Temp. (°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)
	$P = 10 \text{ kPa (45.81}^\circ\text{C)}$				$P = 50 \text{ kPa (81.33}^\circ\text{C)}$			
Sat.	14.67355	2437.89	2584.63	8.1501	3.24034	2483.85	2645.87	7.5939
50	14.86920	2443.87	2592.56	8.1749	—	—	—	—
100	17.19561	2515.50	2687.46	8.4479	3.41833	2511.61	2682.52	7.6947
150	19.51251	2587.86	2782.99	8.6881	3.88937	2585.61	2780.08	7.9400
200	21.82507	2661.27	2879.52	8.9037	4.35595	2659.85	2877.64	8.1579
250	24.13559	2735.95	2977.31	9.1002	4.82045	2734.97	2975.99	8.3555
300	26.44508	2812.06	3076.51	9.2812	5.28391	2811.33	3075.52	8.5372
400	31.06252	2968.89	3279.51	9.6076	6.20929	2968.43	3278.89	8.8641
500	35.67896	3132.26	3489.05	9.8977	7.13364	3131.94	3488.62	9.1545
600	40.29488	3302.45	3705.40	10.1608	8.05748	3302.22	3705.10	9.4177
700	44.91052	3479.63	3928.73	10.4028	8.98104	3479.45	3928.51	9.6599
800	49.52599	3663.84	4159.10	10.6281	9.90444	3663.70	4158.92	9.8852
900	54.14137	3855.03	4396.44	10.8395	10.82773	3854.91	4396.30	10.0967
1000	58.75669	4053.01	4640.58	11.0392	11.75097	4052.91	4640.46	10.2964
1100	63.37198	4257.47	4891.19	11.2287	12.67418	4257.37	4891.08	10.4858
1200	67.98724	4467.91	5147.78	11.4090	13.59737	4467.82	5147.69	10.6662
1300	72.60250	4683.68	5409.70	14.5810	14.52054	4683.58	5409.61	10.8382
	$100 \text{ kPa (99.62}^\circ\text{C)}$				$200 \text{ kPa (120.23}^\circ\text{C)}$			
Sat.	1.69400	2506.06	2675.46	7.3593	0.88573	2529.49	2706.63	7.1271
150	1.93636	2582.75	2776.38	7.6133	0.95964	2576.87	2768.80	7.2795
200	2.17226	2658.05	2875.27	7.8342	1.08034	2654.39	2870.46	7.5066
250	2.40604	2733.73	2974.33	8.0332	1.19880	2731.22	2970.98	7.7085
300	2.63876	2810.41	3074.28	8.2157	1.31616	2808.55	3071.79	7.8926
400	3.10263	2967.85	3278.11	8.5434	1.54930	2966.69	3276.55	8.2217
500	3.56547	3131.54	3488.09	8.8341	1.78139	3130.75	3487.03	8.5132
600	4.02781	3301.94	3704.72	9.0975	2.01297	3301.36	3703.96	8.7769
700	4.48986	3479.24	3928.23	9.3398	2.24426	3478.81	3927.66	9.0194
800	4.95174	3663.53	4158.71	9.5652	2.47539	3663.19	4158.27	9.2450
900	5.41353	3854.77	4396.12	9.7767	2.70643	3854.49	4395.77	9.4565
1000	5.87526	4052.78	4640.31	9.9764	2.93740	4052.53	4640.01	9.6563

مثال: همزن درون مخزني را در نظر بگيريد كه مایعي را هم مي‌زند در هر يك از حالات زیر تغییر انرژی دروني سيستم را بدست آورید.

(الف) کاری كه به همزن داده مي‌شود 5000 KJ و گرمای گرفته شده از مخزن 1500 KJ است.

(ب) کار داده شده به همزن 5000 KJ و گرمای داده شده 1500 KJ می‌باشد.



$$Q = \Delta u + W \longrightarrow 1500 = \Delta u - 5000 \longrightarrow \Delta u = 6500$$

مثال: $P=0.6 \text{ Mpa}$ و $x=95\%$ و $u=?$ و حالت آن بخار آب اشباع است.

$$u_f = 666.9$$

$$u_{fg} = 1897.5$$

$$u = u_f + xu_{fg} = 666.9 + 0.95 \times 1897.5 = 2469.52$$

$$u = 2469.52 \frac{\text{Kj}}{\text{Kg}}$$

Determine the missing property (P , T , or x) and v for water at each of the following states:

- a. $T = 300^\circ\text{C}$, $u = 2780 \text{ kJ/kg}$
- b. $P = 2000 \text{ kPa}$, $u = 2000 \text{ kJ/kg}$

For each case, the two properties given are independent properties and therefore fix the state. For each, we must first determine the phase by comparison of the given information with phase boundary values.

- a. At 300°C , from Table B.1.1, $u_g = 2563.0 \text{ kJ/kg}$. The given $u > u_g$, so the state is in the superheated vapor region at some P less than P_g , which is 8581 kPa . Searching through Table B.1.3 at 300°C , we find that the value $u = 2780$ is between given values of u at 1600 kPa (2781.0) and 1800 kPa (2776.8). Interpolating linearly, we obtain

$$P = 1648 \text{ kPa}$$

Note that quality is undefined in the superheated vapor region. At this pressure, by linear interpolation, we have $v = 0.1542 \text{ m}^3/\text{kg}$.

- b. At $P = 2000 \text{ kPa}$, from Table B.1.2, the given u of 2000 kJ/kg is greater than u_f (906.4) but less than u_g (2600.3). Therefore, this state is in the two-phase region with $T = T_g = 212.4^\circ\text{C}$, and

$$u = 2000 = 906.4 + x1693.8, \quad x = 0.6456$$

Then,

$$v = 0.001177 + 0.6456 \times 0.09845 = 0.06474 \text{ m}^3/\text{kg}.$$

$$H=U+PV, \quad h=u+Pv$$

آنتالپی: (H)

آنتالپی در واحد جرم : $h = \frac{H}{m}$ $[\frac{kJ}{kg}]$, آنتالپی حالت دوفازی : $h = h_f + xh_{fg}$

قانون اول :
ترمودینامیک

$${}_1Q_2 = \Delta U + {}_1W_2 \xrightarrow{\text{فشار ثابت باشد}} {}_1W_2 = P(V_2 - V_1)$$

$$\longrightarrow {}_1Q_2 = U_2 - U_1 + P(V_2 - V_1)$$

$$\longrightarrow {}_1Q_2 = U_2 - U_1 + P_2V_2 - P_1V_1$$

$$\longrightarrow {}_1Q_2 = (U_2 + P_2V_2) - (U_1 + P_1V_1)$$

فرایند
فشار ثابت

$$\longrightarrow {}_1Q_2 = H_2 - H_1 \Rightarrow {}_1Q_2 = m(h_2 - h_1)$$

TABLE B.1.2 (continued)

Saturated Water Pressure Entry

Press. (kPa)	Temp. (°C)	Enthalpy, kJ/kg			Entropy, kJ/kg-K		
		Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g	Sat. Liquid s_f	Evap. s_{fg}	Sat. Vapor s_g
0.6113	0.01	0.00	2501.3	2501.3	0	9.1562	9.1562
1.0	6.98	29.29	2484.89	2514.18	0.1059	8.8697	8.9756
1.5	13.03	54.70	2470.59	2525.30	0.1956	8.6322	8.8278
2.0	17.50	73.47	2460.02	2533.49	0.2607	8.4629	8.7236
2.5	21.08	88.47	2451.56	2540.03	0.3120	8.3311	8.6431
3.0	24.08	101.03	2444.47	2545.50	0.3545	8.2231	8.5775
4.0	28.96	121.44	2432.93	2554.37	0.4226	8.0520	8.4746
5.0	32.88	137.79	2423.66	2561.45	0.4763	7.9187	8.3950
7.5	40.29	168.77	2406.02	2574.79	0.5763	7.6751	8.2514
10	45.81	191.81	2392.82	2584.63	0.6492	7.5010	8.1501
15	53.97	225.91	2373.14	2599.06	0.7548	7.2536	8.0084
20	60.06	251.38	2358.33	2609.70	0.8319	7.0766	7.9085
25	64.97	271.90	2346.29	2618.19	0.8930	6.9383	7.8313
30	69.10	289.21	2336.07	2625.28	0.9439	6.8247	7.7686
40	75.87	317.55	2319.19	2636.74	1.0258	6.6441	7.6700
50	81.33	340.47	2305.40	2645.87	1.0910	6.5029	7.5939
75	91.77	384.36	2278.59	2662.96	1.2129	6.2434	7.4563
100	99.62	417.44	2258.02	2675.46	1.3025	6.0568	7.3593
125	105.99	444.30	2241.05	2685.35	1.3739	5.9104	7.2843
150	111.37	467.08	2226.46	2693.54	1.4335	5.7897	7.2232
175	116.06	486.97	2213.57	2700.53	1.4848	5.6868	7.1717
200	120.23	504.68	2201.96	2706.63	1.5300	5.5970	7.1271
225	124.00	520.69	2191.35	2712.04	1.5705	5.5173	7.0878
250	127.43	535.34	2181.55	2716.89	1.6072	5.4455	7.0526
275	130.60	548.87	2172.42	2721.29	1.6407	5.3801	7.0208
300	133.55	561.45	2163.85	2725.30	1.6717	5.3201	6.9918
325	136.30	573.23	2155.76	2728.99	1.7005	5.2646	6.9651
350	138.88	584.31	2148.10	2732.40	1.7274	5.2130	6.9404
375	141.32	594.79	2140.79	2735.58	1.7527	5.1647	6.9174
400	143.63	604.73	2133.81	2738.53	1.7766	5.1193	6.8958

TABLE B.1.3 (continued)

Superheated Vapor Water

Temp. (°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)
300 kPa (133.55°C)								
250	0.79636	2728.69	2967.59	7.5165	0.59512	2726.11	2964.16	7.3788
300	0.87529	2806.69	3069.28	7.7022	0.65484	2804.81	3066.75	7.5661
400	1.03151	2965.53	3274.98	8.0329	0.77262	2964.36	3273.41	7.8984
500	1.18669	3129.95	3485.96	8.3250	0.88934	3129.15	3484.89	8.1912
600	1.34136	3300.79	3703.20	8.5892	1.00555	3300.22	3702.44	8.4557
700	1.49573	3478.38	3927.10	8.8319	1.12147	3477.95	3926.53	8.6987
800	1.64994	3662.85	4157.83	9.0575	1.23722	3662.51	4157.40	8.9244
900	1.80406	3854.20	4395.42	9.2691	1.35288	3853.91	4395.06	9.1361
1000	1.95812	4052.27	4639.71	9.4689	1.46847	4052.02	4639.41	9.3360
1100	2.11214	4256.77	4890.41	9.6585	1.58404	4256.53	4890.15	9.5255
1200	2.26614	4467.23	5147.07	9.8389	1.69958	4466.99	5146.83	9.7059
1300	2.42013	4682.99	5409.03	10.0109	1.81511	4682.75	5408.80	9.8780
500 kPa (151.86°C)								
Sat.	0.37489	2561.23	2748.67	6.8212	0.31567	2567.40	2756.80	6.7600
200	0.42492	2642.91	2855.37	7.0592	0.35202	2638.91	2850.12	6.9665
250	0.47436	2723.50	2960.68	7.2708	0.39383	2720.86	2957.16	7.1816
300	0.52256	2802.91	3064.20	7.4598	0.43437	2801.00	3061.63	7.3723
350	0.57012	2882.59	3167.65	7.6328	0.47424	2881.12	3165.66	7.5463
400	0.61728	2963.19	3271.83	7.7937	0.51372	2962.02	3270.25	7.7078
500	0.71093	3128.35	3483.82	8.0872	0.59199	3127.55	3482.75	8.0020
600	0.80406	3299.64	3701.67	8.3521	0.66974	3299.07	3700.91	8.2673
700	0.89691	3477.52	3925.97	8.5952	0.74720	3477.08	3925.41	8.5107
800	0.98959	3662.17	4156.96	8.8211	0.82450	3661.83	4156.52	8.7367
900	1.08217	3853.63	4394.71	9.0329	0.90169	3853.34	4394.36	8.9485
1000	1.17469	4051.76	4639.11	9.2328	0.97883	4051.51	4638.81	9.1484
600 kPa (158.85°C)								

گرمای ویژه: مقدار گرمای لازم برای افزایش دمای جرم واحد به اندازه 1° را گرمای ویژه وجود دارد که با C_p و C_v نمایش داده می‌شوند.

$$C_p = \frac{\Delta h}{\Delta T} \longrightarrow h_2 - h_1 = C_p (T_2 - T_1)$$

$$C_v = \frac{\Delta u}{\Delta T} \longrightarrow u_2 - u_1 = C_v (T_2 - T_1)$$

برای مایعات و جامدات: $C_p \cong C_v \longrightarrow \Delta h \approx \Delta u = C_p (T_2 - T_1)$

برای گاز ایده‌آل: $C_p - C_v = R \longrightarrow \Delta h = C_p (T_2 - T_1) , \Delta u = C_v (T_2 - T_1)$

*** گرمای منتقل شده برای گاز ایده‌آل طی فرایند فشار ثابت اینگونه محاسبه می‌شود:**

$$Q = H_2 - H_1 = m(h_2 - h_1) \longrightarrow Q = mc_p(T_2 - T_1)$$

TABLE A.5

Properties of Various Ideal Gases at 25°C, 100 kPa (SI Units)*

Gas	Chemical Formula	Molecular Mass (kg/kmol)	R (kJ/kg-K)	ρ (kg/m ³)	C_{p0} (kJ/kg-K)	C_{v0} (kJ/kg-K)	$k = \frac{C_p}{C_v}$
Steam	H ₂ O	18.015	0.4615	0.0231	1.872	1.410	1.327
Acetylene	C ₂ H ₂	26.038	0.3193	1.05	1.699	1.380	1.231
Air	—	28.97	0.287	1.169	1.004	0.717	1.400
Ammonia	NH ₃	17.031	0.4882	0.694	2.130	1.642	1.297
Argon	Ar	39.948	0.2081	1.613	0.520	0.312	1.667
Butane	C ₄ H ₁₀	58.124	0.1430	2.407	1.716	1.573	1.091
Carbon dioxide	CO ₂	44.01	0.1889	1.775	0.842	0.653	1.289
Carbon monoxide	CO	28.01	0.2968	1.13	1.041	0.744	1.399
Ethane	C ₂ H ₆	30.07	0.2765	1.222	1.766	1.490	1.186
Ethanol	C ₂ H ₅ OH	46.069	0.1805	1.883	1.427	1.246	1.145
Ethylene	C ₂ H ₄	28.054	0.2964	1.138	1.548	1.252	1.237
Helium	He	4.003	2.0771	0.1615	5.193	3.116	1.667
Hydrogen	H ₂	2.016	4.1243	0.0813	14.209	10.085	1.409
Methane	CH ₄	16.043	0.5183	0.648	2.254	1.736	1.299
Methanol	CH ₃ OH	32.042	0.2595	1.31	1.405	1.146	1.227
Neon	Ne	20.183	0.4120	0.814	1.03	0.618	1.667
Nitric oxide	NO	30.006	0.2771	1.21	0.993	0.716	1.387
Nitrogen	N ₂	28.013	0.2968	1.13	1.042	0.745	1.400
Nitrous oxide	N ₂ O	44.013	0.1889	1.775	0.879	0.690	1.274
<i>n</i> -Octane	C ₈ H ₁₈	114.23	0.07279	0.092	1.711	1.638	1.044
Oxygen	O ₂	31.999	0.2598	1.292	0.922	0.662	1.393
Propane	C ₃ H ₈	44.094	0.1886	1.808	1.679	1.490	1.126
R-12	CCl ₂ F ₂	120.914	0.06876	4.98	0.616	0.547	1.126
R-22	CHClF ₂	86.469	0.09616	3.54	0.658	0.562	1.171
R-32	CF ₂ H ₂	52.024	0.1598	2.125	0.822	0.662	1.242
R-125	CHF ₂ CF ₃	120.022	0.06927	4.918	0.791	0.722	1.097
R-134a	CF ₃ CH ₂ F	102.03	0.08149	4.20	0.852	0.771	1.106
R-410a	—	72.585	0.11455	2.967	0.809	0.694	1.165
Sulfur dioxide	SO ₂	64.059	0.1298	2.618	0.624	0.494	1.263
Sulfur trioxide	SO ₃	80.053	0.10386	3.272	0.635	0.531	1.196

Example 3.9

A vessel having a volume of 5 m^3 contains 0.05 m^3 of saturated liquid water and 4.95 m^3 of saturated water vapor at 0.1 MPa . Heat is transferred until the vessel is filled with saturated vapor. Determine the heat transfer for this process.

Control mass: All the water inside the vessel.

Sketch: Fig. 3.17.

Initial state: Pressure, volume of liquid, volume of vapor; therefore, state 1 is fixed.

Final state: Somewhere along the saturated-vapor curve; the water was heated, so $P_2 > P_1$.

Process: Constant volume and mass; therefore, constant specific volume.

Diagram: Fig. 3.18.

Model: Steam tables.

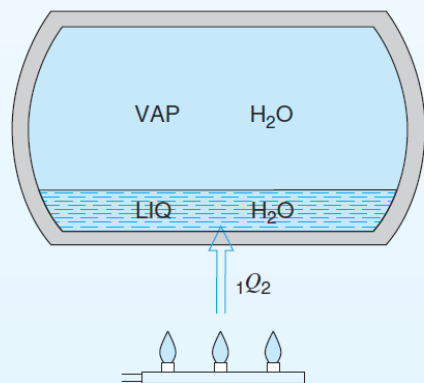


FIGURE 3.17 Sketch for Example 3.9.

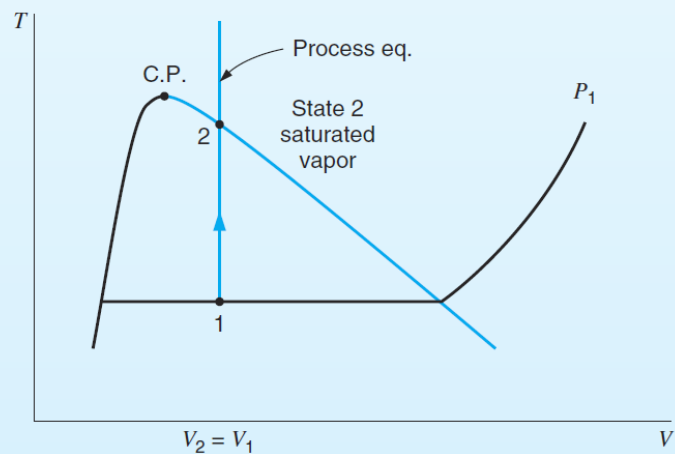


FIGURE 3.18 Diagram for Example 3.9.

Analysis ${}_1Q_2 = \frac{1}{2}m(V_2^2 - V_1^2) + mg(z_2 - z_1) + (U_2 - U_1) + {}_1W_2$

By examining the control surface for various work modes, we conclude that the work for this process is zero. Furthermore, the system is not moving, so there is no change in kinetic energy. There is a small change in the center of mass of the system, but we will assume that the corresponding change in potential energy (in kilojoules) is negligible. Therefore,

$${}_1Q_2 = U_2 - U_1$$

Solution

The heat transfer will be found from the energy equation. State 1 is known, so U_1 can be calculated. The specific volume at state 2 is also known (from state 1 and the process). Since state 2 is saturated vapor, state 2 is fixed, as is seen in Fig. 3.18. Therefore, U_2 can also be found.

The solution proceeds as follows:

$$m_{1 \text{ liq}} = \frac{V_{\text{liq}}}{v_f} = \frac{0.05}{0.001043} = 47.94 \text{ kg}$$

$$m_{1 \text{ vap}} = \frac{V_{\text{vap}}}{v_g} = \frac{4.95}{1.6940} = 2.92 \text{ kg}$$

Then

$$\begin{aligned} U_1 &= m_{1 \text{ liq}}u_{1 \text{ liq}} + m_{1 \text{ vap}}u_{1 \text{ vap}} \\ &= 47.94(417.36) + 2.92(2506.1) = 27\,326 \text{ kJ} \end{aligned}$$

To determine u_2 we need to know two thermodynamic properties, since this determines the final state. The properties we know are the quality, $x = 100\%$, and v_2 , the final specific volume, which can readily be determined.

$$m = m_{1 \text{ liq}} + m_{1 \text{ vap}} = 47.94 + 2.92 = 50.86 \text{ kg}$$

$$v_2 = \frac{V}{m} = \frac{5.0}{50.86} = 0.09831 \text{ m}^3/\text{kg}$$

In Table B.1.2 we find, by interpolation, that at a pressure of 2.03 MPa, $v_g = 0.09831 \text{ m}^3/\text{kg}$. The final pressure of the steam is therefore 2.03 MPa. Then

$$u_2 = 2600.5 \text{ kJ/kg}$$

$$U_2 = mu_2 = 50.86(2600.5) = 132261 \text{ kJ}$$

$${}_1Q_2 = U_2 - U_1 = 132261 - 27326 = 104935 \text{ kJ}$$

تمرین: ظرفی به حجم 5 m^3 دارای 0.05 m^3 آب مایع اشباع و بقیه حجم بخار اشباع است که در $P=100 \text{ Kpa}$ قرار دارد آنقدر گرما می‌دهیم تا ظرف پر از بخار اشباع گردد. گرمای انتقال یافته طی فرایند را بدست آورید.

$${}_1Q_2 = U_2 - U_1 + {}_1W_2$$

$$\left\{ \begin{array}{l} V = 5 \text{ m}^3 \\ V_F = 0.05 \text{ m}^3 \\ P = 100 \text{ Kpa} \end{array} \right. \xrightarrow{\text{دوفازی}} \left\{ \begin{array}{l} V_g = 1.694 \\ v_f = 0.001043 \end{array} \right.$$

$$\left. \begin{array}{l} mv = \frac{V_g}{v_g} = \frac{4.95}{1.694} = 2.922 \text{ Kg} \\ mf = \frac{V_F}{v_f} = \frac{0.05}{0.001043} = 47.93 \end{array} \right\} \Rightarrow m_t = 50.85 \text{ Kg} \Rightarrow x_1 = \frac{m_g}{m_t} = \%5.7$$

$$u_1 = u_f + x_1 u_{fg} \xrightarrow[\text{جدول اشباع}]{P=100 \text{ Kpa}} \left\{ \begin{array}{l} u_f = 417.36 \\ u_{fg} = 2088.7 \end{array} \right. \Rightarrow \left\{ \begin{array}{l} u_1 = 536.41 \frac{\text{Kj}}{\text{Kg}} \\ U_1 = u_1 \times m_t = 27276.44 \text{ Kj} \end{array} \right.$$

حالت نهائي

بخار اشباع

$$V_1 = V_2 \longrightarrow v_1 = v_2 \longrightarrow v_1 = \frac{V_1}{m_1} = \frac{5}{50.85} = 0.09832$$

v	جدول اشباع	u
0.08875		2602.0
0.09832		u_2
0.09963		2600.6

$$u_2 = 2600.76$$

$$U_2 = m_2 \times u_2 = 50.85 \times 2600.76 = 132248.646$$

$${}_1Q_2 = U_2 - U_1 = 132248.646 - 27276.44 = 109472.1975$$

Example 3.12

A cylinder fitted with a piston has a volume of 0.1 m^3 and contains 0.5 kg of steam at 0.4 MPa . Heat is transferred to the steam until the temperature is 300°C , while the pressure remains constant.

Determine the heat transfer and the work for this process.

Control mass: Water inside cylinder.

Process: Constant pressure, $P_2 = P_1$

Initial state: P_1, V_1, m ; therefore, v_1 is known, state 1 is fixed (at P_1, v_1 , check steam tables—two-phase region).

Final state: P_2, T_2 ; therefore, state 2 is fixed (superheated).

Diagram: Fig. 3.23.

Model: Steam tables.

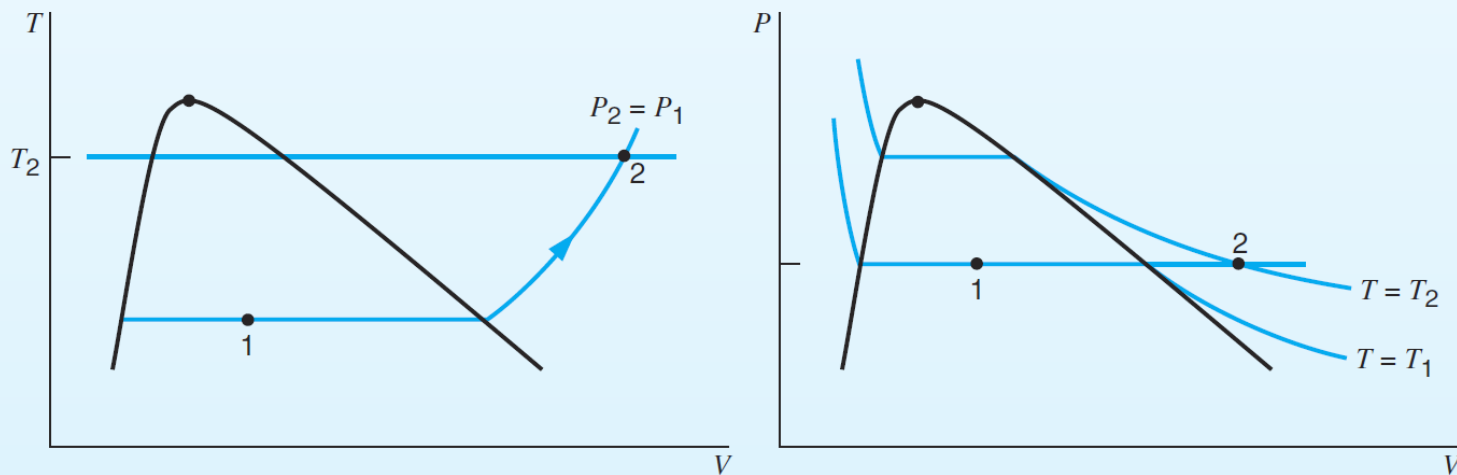


FIGURE 3.23 The constant-pressure quasi-equilibrium process.

مسئله: سیلندری به حجم 0.1 m^3 که یک پیستون در آن جای دارد دارای 0.5 Kg بخار آب دارای فشار 400 Kpa است به این بخار گرما می‌دهیم با دمای آن با ثابت ماندن فشار به 300°C برسد، گرمای منتقل شده و کار را برای این فرایند بدست آورید.

$$\begin{aligned} V &= 0.1 \text{ m}^3 \\ m &= 0.5 \text{ Kg} \\ P &= 0.4 \text{ Mpa} \end{aligned}$$

$$0.001084 < v = 0.1 \div 0.5 = 0.2 < 0.4652 \longrightarrow \text{حالت دوفازی}$$

$$x = \frac{v - v_f}{v_{fg}} = \frac{0.2 - 0.001084}{0.4625 - 0.001084} = 0.431099$$

$$h_1 = h_f + xh_{fg} \Rightarrow h_1 = 604.74 + 0.431099 \times 2133.8 = 1524.619$$

$$Q = m(h_2 - h_1)$$

حالت نهائی

$$\begin{aligned} P &= 0.4 \text{ Mpa} \\ T &= 300^\circ\text{C} \\ \text{حالت بخار داغ} \end{aligned}$$

$$h_2 = 3066.8$$

$$v = 0.6548$$

$$\begin{aligned} V_2 &= 0.6548 \times 0.5 \\ &= 0.3274 \text{ m}^3 \end{aligned}$$

$$Q = 0.5(3066.8 - 1524.619) = 771.0905 \text{ Kj}$$

$$W = P(V_2 - V_1) = 0.4(0.3274 - 0.1) = 0.09096 \text{ Kj}$$