Department of Air Conditioning and Refrigeration Engineering Technology

Class: 2nd

Subject: Thermodynamics

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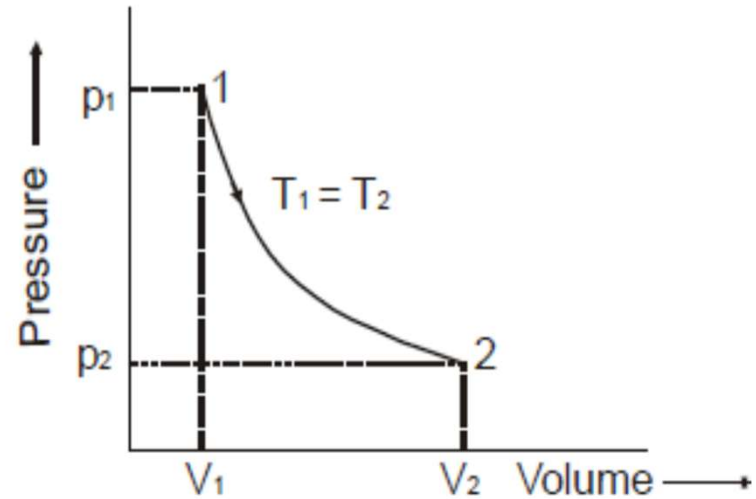
Closed System –Reversible

A- Constant Temperature process or isothermal process

$PV = C \quad \rightarrow P_1V_1 = P_2V_2 \rightarrow \boldsymbol{\frac{P_1}{P_2} = \frac{V_2}{V_1}}$

$W = \int_1^2 PdV \;\rightarrow P = \frac{C}{V}$



$W = C\int_1^2 \frac{dV}{V} = C\,[lnV]_1^2$

$W = C[lnV_2 - lnV_1] \rightarrow W = C \times \ln\left[\frac{V_2}{V_1}\right]$

$\boldsymbol{W = P_1V_1\, ln\left[\frac{V_2}{V_1}\right]}$

FIRST LAW OF THERMODYNAMIS IS : $Q - W = \Delta U$

$\Delta U = 0$?? Why

Q=W= $\boldsymbol{P_1V_1\, ln\left[\frac{V_2}{V_1}\right]}$ **= m**$\boldsymbol{RT\, ln\left[\frac{V_2}{V_1}\right]}$

ملاحظة : هذة القوانين تستخدم فقط في حالة الغاز المثالي

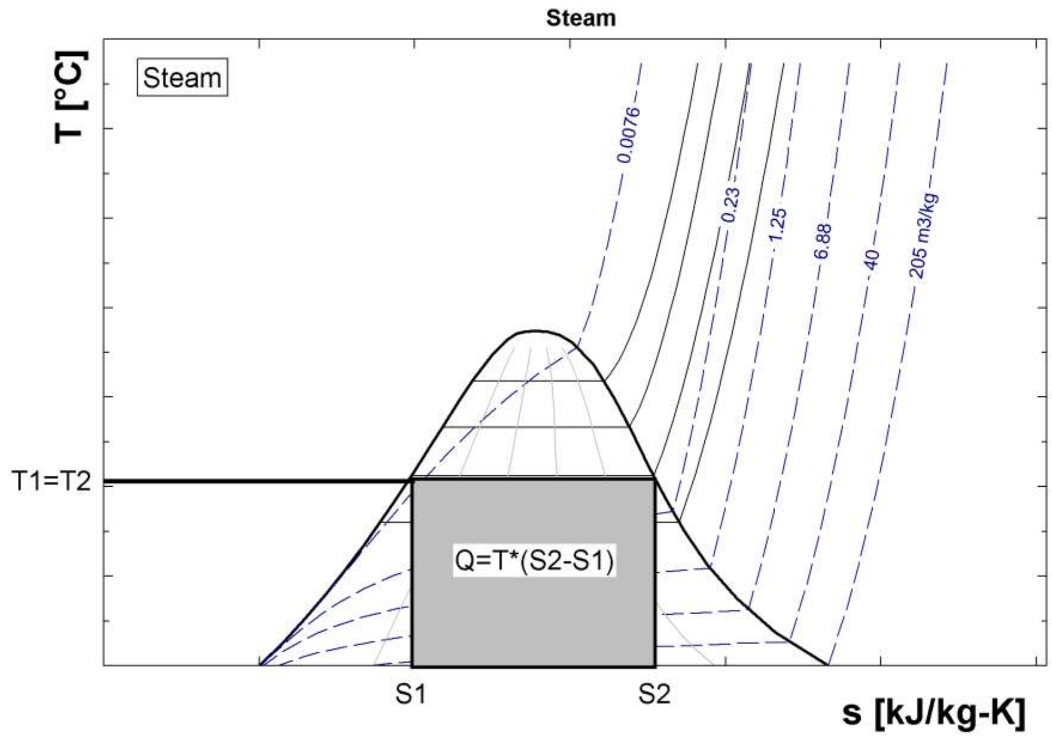
Process Using Steam

$$Q - W = \Delta U$$
$$\Delta U = m * (u2 - u1)$$

Q=T*(S2-S1)

T= vapor temperature

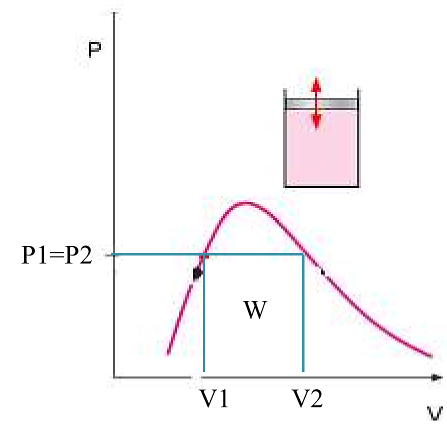
S = entropy of vapor



$$Q - W = \Delta U$$
$$W = Q - \Delta U \rightarrow W = T * (S2 - S1) - m * (u2 - u1)$$

B- Constant Pressure process or isobaric process

$$\frac{V}{T} = C \rightarrow \frac{V_1}{V_2} = \frac{T_1}{T_2}$$



$$\text{W} = \int_1^2 PdV = P(V_2 - V_1) \rightarrow W = m * R * (T_2 - T_1)$$

$$\text{Q} - \text{W} = \Delta U$$
$$Q = \Delta U + W$$
$$Q = m * CV * (T_2 - T_1) + m * R * (T_2 - T_1)$$
$$\text{Q} = m * (T_2 - T_1) * (\text{CV} + \text{R})$$

$$Q = CP * (T_2 - T_1)$$

$$\text{R} = \text{CP} - \text{CV} \rightarrow CP = CV + R$$

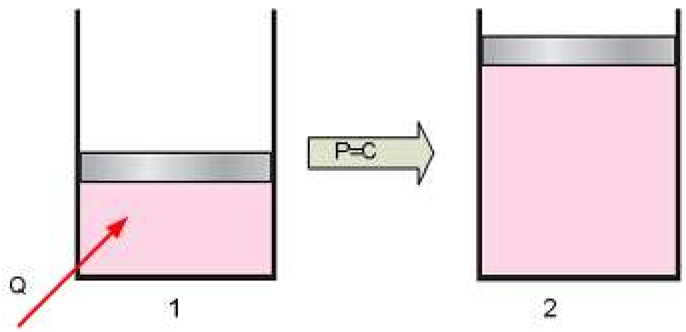
H.W : prove that $\rightarrow \boldsymbol{Q} = \boldsymbol{m} * \boldsymbol{R} * (\boldsymbol{T_2} - \boldsymbol{T_1}) \left[\frac{\mathbf{1}}{\boldsymbol{\gamma} - \mathbf{1}} + \mathbf{1}\right]$

IF we have Steam $W = P(V_2 - V_1)$

$$Q - W = \Delta U \rightarrow Q = \Delta U + W \rightarrow Q = (U_2 - U_1) + (P_2 \times V_2 - P_1 \times V_1)$$
$$Q = (P_2V_2 + U_2) - (P_1V_1 + U_1)$$

$$Q = (H_2 - H_1)$$

Example: A cylinder fitted with a piston has a volume of $0.1m^3$ and contains 0.5 kg of steam at 0.4 MPa. Heat is transfer to the steam until the temperature is 300°C, while the pressure remain constant . Determine the heat transfer and work done.



Sol :

$$Q = W + \Delta U = m(h_2 - h_1)$$

$$v = \frac{V}{m} = \frac{0.1}{0.5} = 0.2 m^3/kg$$

Point 1

$$At\ 0.4MPa \quad vg = 0.4625 m^3/kg \quad Since \quad v < vg \quad then \quad wet \quad steam$$

$$v = v_f + x v_{fg} \rightarrow 0.2 = 1.084 \times 10^{-3} + x(0.4625 - 1.084 \times 10^{-3}) \Rightarrow x = 0.431$$

$$u_1 = 604.22 + 0.431 \times 1948.9 = 1444 \quad kJ/kg$$

$$h_1 = 604.66 + 0.431 \times 2133.4 = 1525 \quad kJ/kg$$

Point 2 $At\ P_2 = 0.4MPa\ ;\ T_2 = 400°C\ ;\ T_{sat} = 143.61°C < T_2$ Superheated

$$\therefore u_2 = 2805.1\ {}^{kJ}/_{kg}\ ;\ h_2 = 3067.1\ {}^{kJ}/_{kg}$$

$$\Delta U = m * (u_2 - u_1) = 0.5 * (2805.1 - 1444) = 680.6\ kJ$$

$$Q = m * (h_2 - h_1) = 0.5 * (3067.1 - 1525) = 771.1\ kJ$$

$$\rightarrow W = Q - \Delta U = 771.1 - 680.6 = 90.5\ kJ$$

TABLE A–5

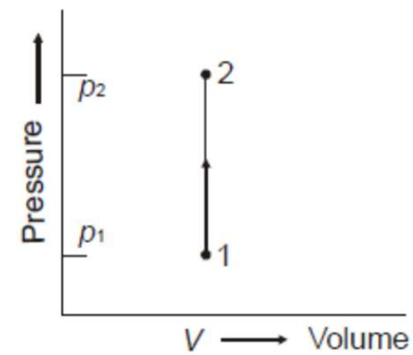
Saturated water—Pressure table

Press., P kPa	Sat. temp., T_{sat} °C	Specific volume, m³/kg: Sat. liquid, v_f	Sat. vapor, v_g	Internal energy, kJ/kg: Sat. liquid, u_f	Evap., u_{fg}	Sat. vapor, u_g	Enthalpy, kJ/kg: Sat. liquid, h_f	Evap., h_{fg}	Sat. vapor, h_g	Entropy, kJ/kg · K: 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
75	91.76	0.001037	2.2172	384.36	2111.8	2496.1	384.44	2278.0	2662.4	1.2132	6.2426	7.4558
100	99.61	0.001043	1.6941	417.40	2088.2	2505.6	417.51	2257.5	2675.0	1.3028	6.0562	7.3589
101.325	99.97	0.001043	1.6734	418.95	2087.0	2506.0	419.06	2256.5	2675.6	1.3069	6.0476	7.3545
125	105.97	0.001048	1.3750	444.23	2068.8	2513.0	444.36	2240.6	2684.9	1.3741	5.9100	7.2841
150	111.35	0.001053	1.1594	466.97	2052.3	2519.2	467.13	2226.0	2693.1	1.4337	5.7894	7.2231
175	116.04	0.001057	1.0037	486.82	2037.7	2524.5	487.01	2213.1	2700.2	1.4850	5.6865	7.1716
200	120.21	0.001061	0.88578	504.50	2024.6	2529.1	504.71	2201.6	2706.3	1.5302	5.5968	7.1270
225	123.97	0.001064	0.79329	520.47	2012.7	2533.2	520.71	2191.0	2711.7	1.5706	5.5171	7.0877
250	127.41	0.001067	0.71873	535.08	2001.8	2536.8	535.35	2181.2	2716.5	1.6072	5.4453	7.0525
275	130.58	0.001070	0.65732	548.57	1991.6	2540.1	548.86	2172.0	2720.9	1.6408	5.3800	7.0207
300	133.52	0.001073	0.60582	561.11	1982.1	2543.2	561.43	2163.5	2724.9	1.6717	5.3200	6.9917
325	136.27	0.001076	0.56199	572.84	1973.1	2545.9	573.19	2155.4	2728.6	1.7005	5.2645	6.9650
350	138.86	0.001079	0.52422	583.89	1964.6	2548.5	584.26	2147.7	2732.0	1.7274	5.2128	6.9402
375	141.30	0.001081	0.49133	[illegible]	1956.6	2550.9	594.73	2140.4	2735.1	1.7526	5.1645	6.9171
400	143.61	0.001084	0.46242	[illegible]	1948.9	2553.1	604.66	2133.4	2738.1	1.7765	5.1191	6.8955

Vg

C- Constant Volume process or isochoric process

$$\frac{P}{T} = C \rightarrow \frac{P_1}{P_2} = \frac{T_1}{T_2}$$



$$W = \int_1^2 PdV \rightarrow V = C \rightarrow dV = 0 \rightarrow W = 0$$

For Perfect gas

$\Delta U = CV * (T_2 - T_1)$

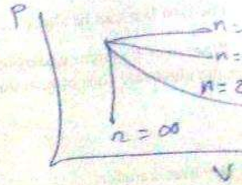
$Q - W = \Delta U$

$Q = \Delta U$

$For\ Steam \rightarrow Q = m * (u_2 - u_1)$

D- Polytropic process

Polytropic :- $n = 2$ & $pv^n = c$



$P_1 V_1^n = P_2 V_2^2$

$$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^n$$

&

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{n-1}$$

&

$$\left(\frac{T_2}{T_1}\right) = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}$$

$$W_{1-2} = \int_{V_1}^{V_2} P\,dV$$

① $W_{1-2} = \dfrac{P_1V_1 - P_2V_2}{n-1} = \dfrac{mR(T_1 - T_2)}{n-1}$

② Heat interaction

$Q - W = \Delta U$

$Q = \Delta U + W$

$$\int_1^2 dQ = \int_1^2 dU + \int_1^2 dW$$

OR

$$Q_{1-2} = (U_2 - U_1) + \frac{P_1V_1 - P_2V_2}{n-1}$$

$$Q_{1-2} = m c_v \Delta T + \frac{mR(T_1 - T_2)}{n-1}$$

But $\longrightarrow c_v = \dfrac{R}{\gamma - 1} \longrightarrow R = c_v(\gamma - 1)$

$q - w = \Delta u$

$q = \Delta u + w$

$$q = c_v(T_2 - T_1) + \frac{R(T_1 - T_2)}{n-1}$$

But $c_v = \dfrac{R}{\gamma - 1}$ ⇓

$\gamma = \dfrac{c_p}{c_v}$, $R = c_p - c_v$

$c_p = \gamma c_v \Rightarrow R = \gamma c_v - c_v$

$R = c_v(\gamma - 1)$

$c_v = \dfrac{R}{\gamma - 1}$

$$q = \frac{R}{\gamma - 1}(T_2 - T_1) + \frac{R}{n-1}(T_1 - T_2)$$

$$q = R(T_1 - T_2)\left[-\frac{1}{\gamma - 1} + \frac{1}{n-1}\right]$$

$$q = R(T_1 - T_2)\left[\frac{-(n-1) + (\gamma - 1)}{(n-1)(\gamma - 1)}\right]$$

$$q = \frac{R(T_1 - T_2)}{n-1}\left[\frac{\gamma - n}{\gamma - 1}\right]$$

$$q = W \times \left[\frac{\gamma - n}{\gamma - 1}\right]$$

E- Adiabatic process واجب