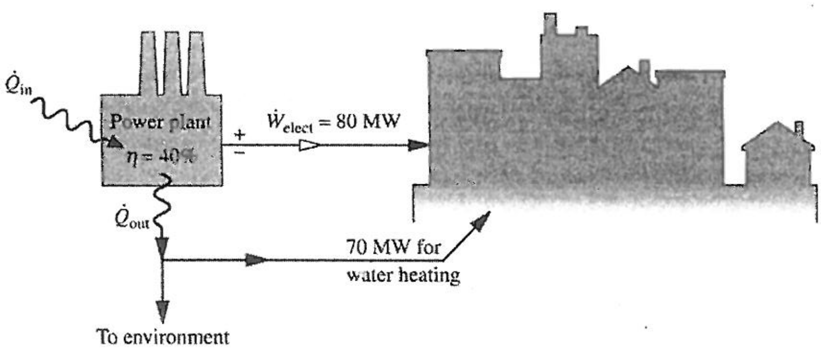
1. The following figure shows a cogeneration power plant operating in the thermodynamic cycle at steady state. The plant provides electricity to a community at a rate of 80 MW. The energy discarded from the power plant by heat transfer is denoted on the figure by $\dot{Q}_{out}$. Of this, 70 MW is provided to the community for water heating and the remainder is discharged to the environment without use. The electricity is valued \$0.08 per kWh. If the cycle thermal efficiency is 40%, determine the following:

(a) the rate energy is added by heat transfer, $\dot{Q}_{in}$, in MW; (5%)

(b) the rate energy is discarded to the environment, in MW; (5%)

(c) the value of the electricity generated, in \$ per year. (5%)



2. An inventor claims to have developed a power cycle capable of delivering a net work output of 410 kJ for an energy input by heat transfer of 1000 kJ. The system undergoing the cycle receives the heat transfer from hot gases at a temperature of 500 K and discharges energy by heat transfer to the atmosphere at 300 K. Evaluate this claim. (10%)

3. A stationary piston-cylinder device contains 2 kg of air at 27°C and 100 kPa. The air is now compressed to a pressure of 500 kPa according to the relation $PV^{1.4}$ = constant. Determine the following:

(a) the initial volume of air. (5%)

(b) the final volume of air. (5%)

(c) the work input during the process. (5%)

(d) the change in total internal energy of the system (U). (5%)

(e) the amount of heat transfer (Q) during the process. (5%)

Gas constant of air, $R = 0.287$ kJ/kgK

4. Air enters an insulated turbine operating at steady state with a pressure of 4 bar, a temperature of 450 K, and a mass flow rate of 15 kg/s. At the exit, the pressure is 1 bar. The isentropic turbine efficiency is 85%. Neglect the kinetic and potential energy effects. The temperature and pressure of the environment are 300 K and 1 bar, respectively.
(a) Sketch both the isentropic and actual processes on a *T-s* diagram. (5%)
(b) Determine the power developed by the turbine, in kW. (5%)
(c) Determine the exergy destruction rate, in kW. (5%)
(d) Determine the exergetic turbine efficiency (2nd law efficiency). (5%)

5. Air enters a window air conditioner at 1 bar, 30°C and 80% relative humidity at a dry air flow rate of 10 kg/min, and it leaves as saturated air at 15°C. Part of the moisture in the air that condenses during the process is also removed at 15°C. ($\bar{R} = 8.314$ kJ/kmol-K; $M_{\text{air}} = 28.97$ kg/kmol; $M_{\text{water}} = 18$ kg/kmol)
(a) Determine the humidity ratio of the air at the inlet of the air conditioner, in kg water per kg dry air, using given property table. (5%)
(b) Determine moisture removal from the air, in kg/min, using given property table. (6%)
(c) Determine the rates of heat, in kJ/min, using given psychrometric chart. (9%)

6. Helium undergoes a change of state from 100 kPa and 20°C to 600 kPa 300°C. Determine the change in the enthalpy using the state equation $p(v-a)=RT$ where $a = 0.01$ m^3/kg. (10%)
Given $dh = c_p dT + \left[v - T\left(\frac{\partial v}{\partial T}\right)_p \right] dp$. Assume $c_p = 5.2$ kJ/kg-K is constant.

- Entropy change for ideal gas

$$ds = c_v(T)\frac{dT}{T} + R\frac{dv}{v}\ ;\ ds = c_p(T)\frac{dT}{T} - R\frac{dp}{p}\ ;\ s^\circ(T) = \int_0^T \frac{C_p(T)}{T}\,dT$$

- Entropy rate balance for control volumes

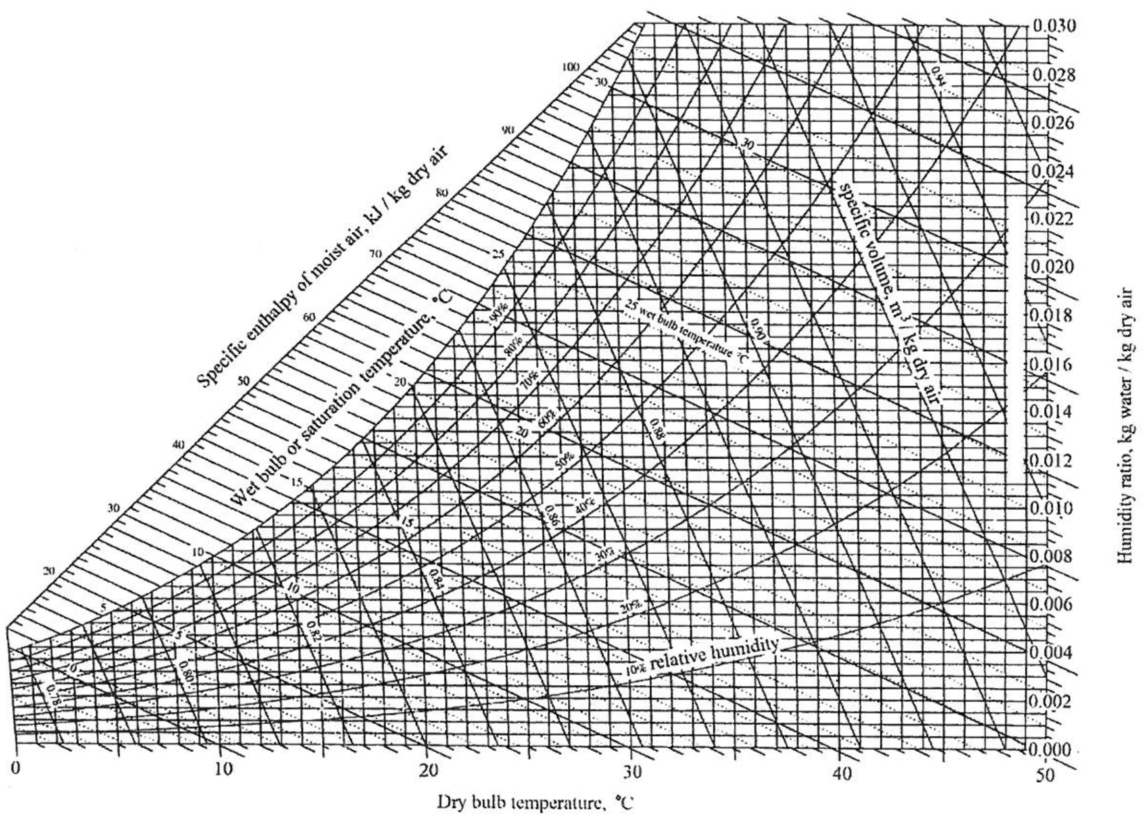
$$\frac{dS_{cv}}{dt} = \sum_j \frac{\dot{Q}_j}{T_j} + \sum_i \dot{m}_i s_i - \sum_e \dot{m}_e s_e - \dot{\sigma}_{cv}$$

- Specific flow exergy

$$e_f = (h - h_0) - T_0(s - s_0) + \frac{V^2}{2} + gz$$

- Exergy rate balance for control volumes

$$\frac{d\mathrm{E}_{cv}}{dt} = \sum_j \left(1 - \frac{T_0}{T_j}\right)\dot{Q}_j - \left(\dot{W}_{cv} - p_0\frac{dV_{cv}}{dt}\right) + \sum_i \dot{m}_i e_{fi} - \sum_e \dot{m}_e e_{fe} - \dot{\mathrm{E}}_d$$



Properties of Saturated Water (Liquid–Vapor): Temperature Table

Temp. °C	Press. bar	Specific Volume m^3/kg Sat. Liquid $v_f \times 10^3$	Sat. Vapor v_g	Internal Energy kJ/kg Sat. Liquid u_f	Sat. Vapor u_g	Enthalpy kJ/kg Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g
15	0.01705	1.0009	77.926	62.99	2396.1	62.99	2465.9	2528.9
20	0.02339	1.0018	57.791	83.95	2402.9	83.96	2454.1	2538.1
25	0.03169	1.0029	43.360	104.88	2409.8	104.89	2442.3	2547.2
30	0.04246	1.0043	32.894	125.78	2416.6	125.79	2430.5	2556.3

Ideal Gas Properties of Air

T(K), h and u(kJ/kg), $s°$ (kJ/kg · K)

T	h	u	$s°$	when $\Delta s = 0$[1] p_r	v_r	T	h	u	$s°$	when $\Delta s = 0$ p_r	v_r
250	250.05	178.28	1.51917	0.7329	979.	450	451.80	322.62	2.11161	5.775	223.6
260	260.09	185.45	1.55848	0.8405	887.8	460	462.02	329.97	2.13407	6.245	211.4
270	270.11	192.60	1.59634	0.9590	808.0	470	472.24	337.32	2.15604	6.742	200.1
280	280.13	199.75	1.63279	1.0889	738.0	480	482.49	344.70	2.17760	7.268	189.5
285	285.14	203.33	1.65055	1.1584	706.1	490	492.74	352.08	2.19876	7.824	179.7
290	290.16	206.91	1.66802	1.2311	676.1	500	503.02	359.49	2.21952	8.411	170.6
295	295.17	210.49	1.68515	1.3068	647.9	510	513.32	366.92	2.23993	9.031	162.1
300	300.19	214.07	1.70203	1.3860	621.2	520	523.63	374.36	2.25997	9.684	154.1
305	305.22	217.67	1.71865	1.4686	596.0	530	533.98	381.84	2.27967	10.37	146.7
310	310.24	221.25	1.73498	1.5546	572.3	540	544.35	389.34	2.29906	11.10	139.7
315	315.27	224.85	1.75106	1.6442	549.8	550	554.74	396.86	2.31809	11.86	133.1
320	320.29	228.42	1.76690	1.7375	528.6	560	565.17	404.42	2.33685	12.66	127.0
325	325.31	232.02	1.78249	1.8345	508.4	570	575.59	411.97	2.35531	13.50	121.2
330	330.34	235.61	1.79783	1.9352	489.4	580	586.04	419.55	2.37348	14.38	115.7
340	340.42	242.82	1.82790	2.149	454.1	590	596.52	427.15	2.39140	15.31	110.6
350	350.49	250.02	1.85708	2.379	422.2	600	607.02	434.78	2.40902	16.28	105.8
360	360.58	257.24	1.88543	2.626	393.4	610	617.53	442.42	2.42644	17.30	101.2
370	370.67	264.46	1.91313	2.892	367.2	620	628.07	450.09	2.44356	18.36	96.92
380	380.77	271.69	1.94001	3.176	343.4	630	638.63	457.78	2.46048	19.84	92.84
390	390.88	278.93	1.96633	3.481	321.5	640	649.22	465.50	2.47716	20.64	88.99
400	400.98	286.16	1.99194	3.806	301.6	650	659.84	473.25	2.49364	21.86	85.34
410	411.12	293.43	2.01699	4.153	283.3	660	670.47	481.01	2.50985	23.13	81.89
420	421.26	300.69	2.04142	4.522	266.6	670	681.14	488.81	2.52589	24.46	78.61
430	431.43	307.99	2.06533	4.915	251.1	680	691.82	496.62	2.54175	25.85	75.50
440	441.61	315.30	2.08870	5.332	236.8	690	702.52	504.45	2.55731	27.29	72.56