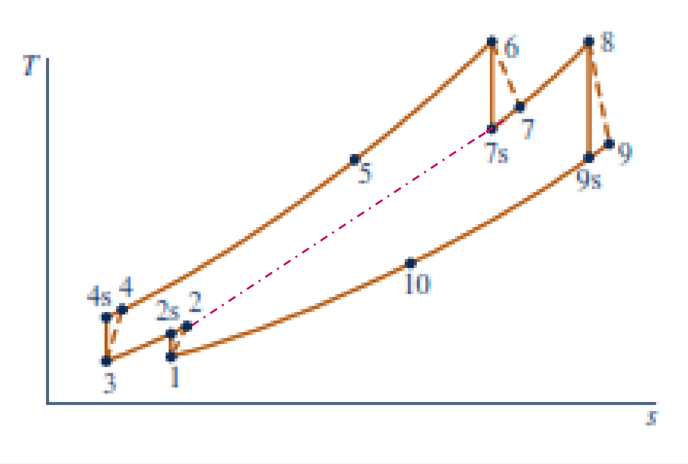
Gas Turbine Cycle

Lecture 8
Enhancements of gas cycle, Applications

Tikrit university\ engineering college\ mechanical dept.

example

A regenerative gas turbine with intercooling & reheat operates at steady-state. Air enters the compressor at 100 kPa, 300 K with a mass flow rate of 5.807 $\frac{kg}{s}$. The pressure ratio across the two stage compressor is 10. The pressure ratio across the two stage turbine is also 10. The intercooler & reheater each operates at 300 kPa. At the inlets to the turbine stages, the temp is 1400 K. The temp at the inlet to the second compressor stage is 300 K. The isentropic efficiency of each compressor & turbine stage is 80%. The regenerator effeteness is 80%. Determine:



a. The thermal efficiency of the cycle.
b. BWR
c. The net power developed in kW.

example

Sol.

State 1,3 @300 K

$h_1 = h_3 = 300.19$ kJ/kg

$Pr_1 = Pr_3 = 1.386$

State 2s @ 300 kPa

$$\frac{Pr_{2s}}{Pr_1} = \frac{P_2}{P_1} = \frac{300}{100}$$

$Pr_{2s} = 1.386*3 = 4.158$

From tables, by interpolation:

$h_{2s} = 411.25$ kJ/kg

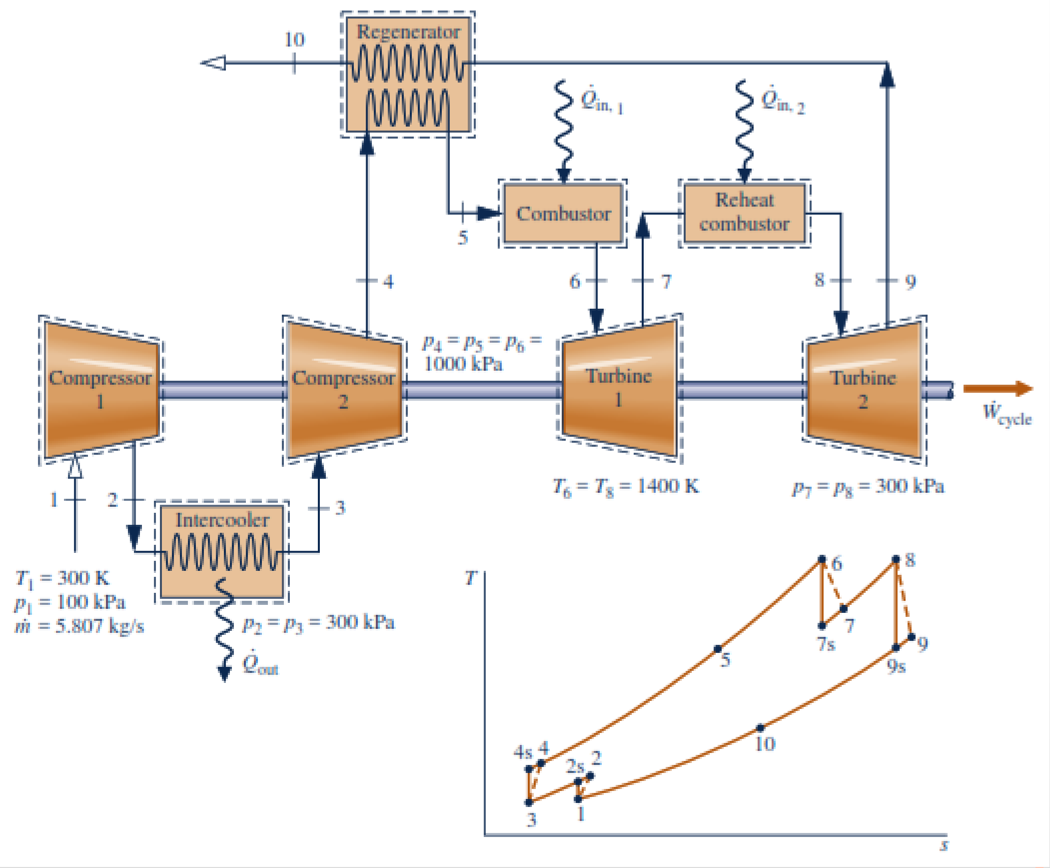
$$\eta_C = \frac{h_{2s} - h_1}{h_2 - h_1} = 0.8$$

$\therefore h_2 = 439.01$ kJ/kg

State 4s @ 1000 kPa

$$\frac{Pr_{4s}}{Pr_3} = \frac{P_4}{P_3} = \frac{1000}{300}$$

$Pr_{4s} = 4.62$



example

<u>From tables, by interpolation</u>:

h_{4s} = 423.79 kJ/kg

$\eta_C = \dfrac{h_{4s} - h_3}{h_4 - h_3}$ = 0.8

$\therefore$ h_4 = 454.69 kJ/kg

State 6,8 @1400 K

$h_6 = h_8$ = 1515.42 kJ/kg

$Pr_6 = Pr_8$ = 450.5

State 7 @ 300 kPa

$$\frac{Pr_{7s}}{Pr_6} = \frac{P_7}{P_6} = \frac{300}{1000}$$

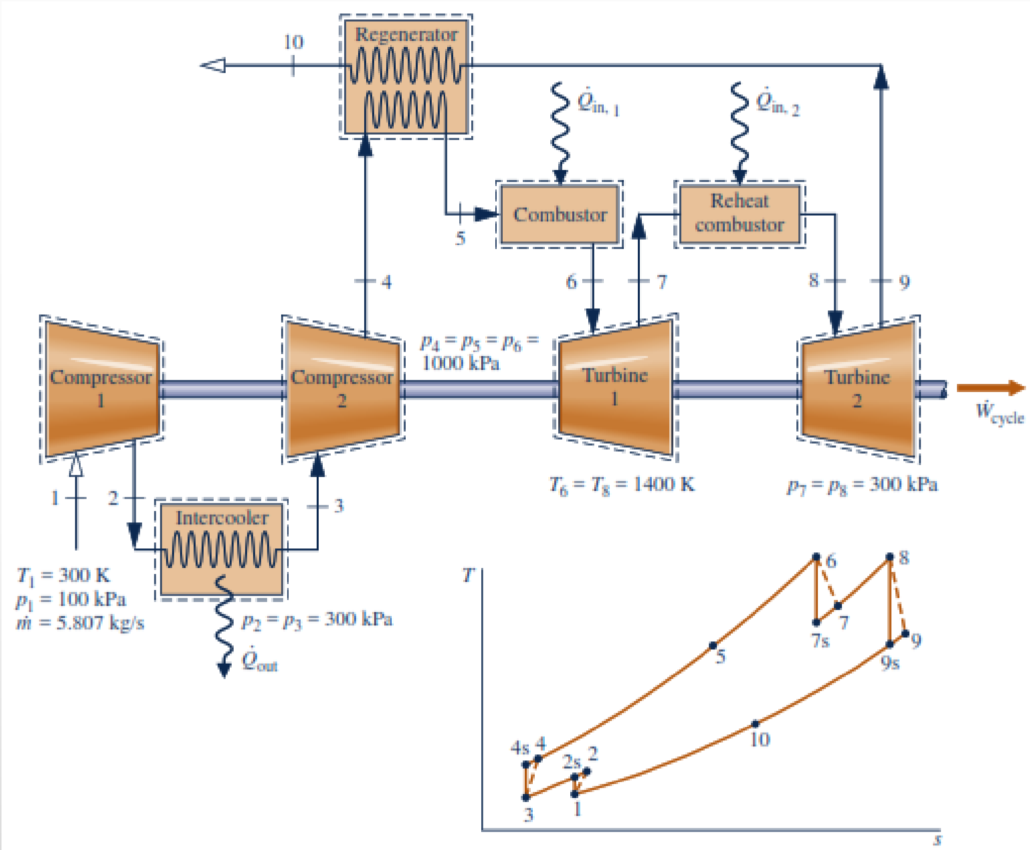
Pr_{7s} = 135.15

<u>From tables by interpolation</u>:

h_{7s} = 1095.86 kJ/kg

$\eta_T = \dfrac{h_6 - h_7}{h_6 - h_{7s}}$ = 0.8

$\therefore$ h_7 = 1179.77 kJ/kg



example

State 9s @ 100 kPa

$$\frac{Pr_8}{Pr_{9s}} = \frac{P_8}{P_9} = \frac{300}{100}$$

Pr_{9s} = 150.16

From tables by interpolation:

h_{9s} = 1127.61 kJ/kg

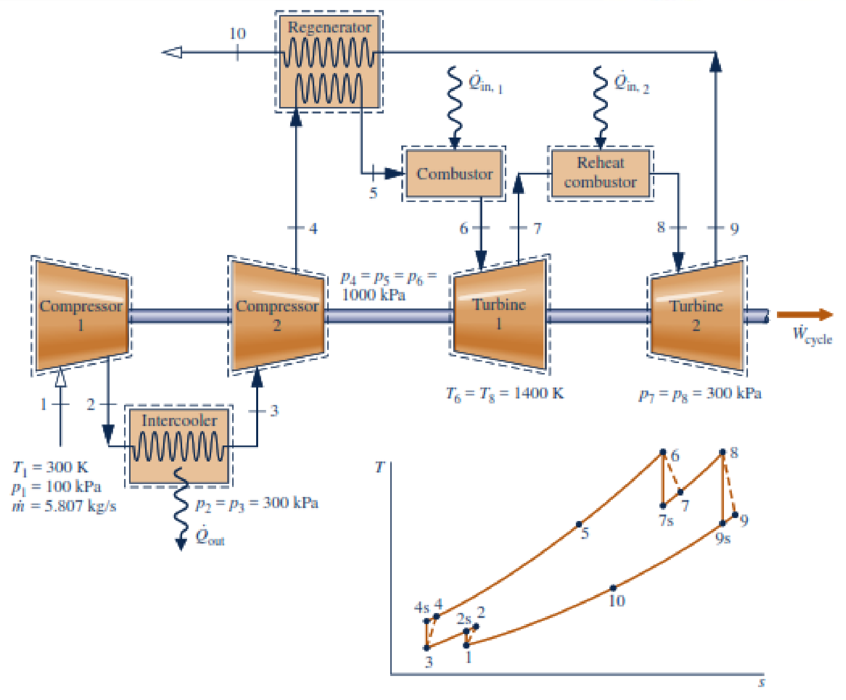
$$\eta_T = \frac{h_8 - h_9}{h_8 - h_{9s}} = 0.8$$

h_9 = 1205.17 kJ/kg

State 5:

$$\varepsilon_{reg} = \frac{h_5 - h_4}{h_9 - h_4} = 0.8$$

h_5 = 1055.07 kJ/kg



- $$\eta_{th} = \frac{[(h_6 - h_7)+(h_8 - h_9)]-[(h_2 - h_1)+(h_4 - h_3)]}{[(h_6 - h_5)+(h_8 - h_7)]} = 44.3\%$$
- B.W.R = $\frac{W_c}{W_T}$ = 0.454
- P = $\dot{m}\, w_{net}$ = 2046 kW

TABLE A-22 Ideal Gas Properties of Air

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

				when $\Delta s = 0$[1]						when $\Delta s = 0$	
T	h	u	$s°$	p_r	v_r	T	h	u	$s°$	p_r	v_r
200	199.97	142.56	1.29559	0.3363	1707.	450	451.80	322.62	2.11161	5.775	223.6
210	209.97	149.69	1.34444	0.3987	1512.	460	462.02	329.97	2.13407	6.245	211.4
220	219.97	156.82	1.39105	0.4690	1346.	470	472.24	337.32	2.15604	6.742	200.1
230	230.02	164.00	1.43557	0.5477	1205.	480	482.49	344.70	2.17760	7.268	189.5
240	240.02	171.13	1.47824	0.6355	1084.	490	492.74	352.08	2.19876	7.824	179.7
250	250.05	178.28	1.51917	0.7329	979.	500	503.02	359.49	2.21952	8.411	170.6
260	260.09	185.45	1.55848	0.8405	887.8	510	513.32	366.92	2.23993	9.031	162.1
270	270.11	192.60	1.59634	0.9590	808.0	520	523.63	374.36	2.25997	9.684	154.1
280	280.13	199.75	1.63279	1.0889	738.0	530	533.98	381.84	2.27967	10.37	146.7
285	285.14	203.33	1.65055	1.1584	706.1	540	544.35	389.34	2.29906	11.10	139.7
290	290.16	206.91	1.66802	1.2311	676.1	550	554.74	396.86	2.31809	11.86	133.1
295	295.17	210.49	1.68515	1.3068	647.9	560	565.17	404.42	2.33685	12.66	127.0
300	300.19	214.07	1.70203	1.3860	621.2	570	575.59	411.97	2.35531	13.50	121.2
305	305.22	217.67	1.71865	1.4686	596.0	580	586.04	419.55	2.37348	14.38	115.7
310	310.24	221.25	1.73498	1.5546	572.3	590	596.52	427.15	2.39140	15.31	110.6
315	315.27	224.85	1.75106	1.6442	549.8	600	607.02	434.78	2.40902	16.28	105.8
320	320.29	228.42	1.76690	1.7375	528.6	610	617.53	442.42	2.42644	17.30	101.2
325	325.31	232.02	1.78249	1.8345	508.4	620	628.07	450.09	2.44356	18.36	96.92
330	330.34	235.61	1.79783	1.9352	489.4	630	638.63	457.78	2.46048	19.84	92.84
340	340.42	242.82	1.82790	2.149	454.1	640	649.22	465.50	2.47716	20.64	88.99
350	350.49	250.02	1.85708	2.379	422.2	650	659.84	473.25	2.49364	21.86	85.34
360	360.58	257.24	1.88543	2.626	393.4	660	670.47	481.01	2.50985	23.13	81.89
370	370.67	264.46	1.91313	2.892	367.2	670	681.14	488.81	2.52589	24.46	78.61
380	380.77	271.69	1.94001	3.176	343.4	680	691.82	496.62	2.54175	25.85	75.50
390	390.88	278.93	1.96633	3.481	321.5	690	702.52	504.45	2.55731	27.29	72.56
400	400.98	286.16	1.99194	3.806	301.6	700	713.27	512.33	2.57277	28.80	69.76
410	411.12	293.43	2.01699	4.153	283.3	710	724.04	520.23	2.58810	30.38	67.07
420	421.26	300.69	2.04142	4.522	266.6	720	734.82	528.14	2.60319	32.02	64.53
430	431.43	307.99	2.06533	4.915	251.1	730	745.62	536.07	2.61803	33.72	62.13
440	441.61	315.30	2.08870	5.332	236.8	740	756.44	544.02	2.63280	35.50	59.82

1. p_r and v_r data for use with Eqs. 6.43 and 6.44, respectively.

Table A-22

TABLE A-22 (*Continued*)

T(K), h and u(kJ/kg), s° (kJ/kg · K)

				when $\Delta s = 0$[1]						when $\Delta s = 0$	
T	h	u	s°	p_r	v_r	T	h	u	s°	p_r	v_r
750	767.29	551.99	2.64737	37.35	57.63	1300	1395.97	1022.82	3.27345	330.9	11.275
760	778.18	560.01	2.66176	39.27	55.54	1320	1419.76	1040.88	3.29160	352.5	10.747
770	789.11	568.07	2.67595	41.31	53.39	1340	1443.60	1058.94	3.30959	375.3	10.247
780	800.03	576.12	2.69013	43.35	51.64	1360	1467.49	1077.10	3.32724	399.1	9.780
790	810.99	584.21	2.70400	45.55	49.86	1380	1491.44	1095.26	3.34474	424.2	9.337
800	821.95	592.30	2.71787	47.75	48.08	1400	1515.42	1113.52	3.36200	450.5	8.919
820	843.98	608.59	2.74504	52.59	44.84	1420	1539.44	1131.77	3.37901	478.0	8.526
840	866.08	624.95	2.77170	57.60	41.85	1440	1563.51	1150.13	3.39586	506.9	8.153
860	888.27	641.40	2.79783	63.09	39.12	1460	1587.63	1168.49	3.41247	537.1	7.801
880	910.56	657.95	2.82344	68.98	36.61	1480	1611.79	1186.95	3.42892	568.8	7.468
900	932.93	674.58	2.84856	75.29	34.31	1500	1635.97	1205.41	3.44516	601.9	7.152
920	955.38	691.28	2.87324	82.05	32.18	1520	1660.23	1223.87	3.46120	636.5	6.854
940	977.92	708.08	2.89748	89.28	30.22	1540	1684.51	1242.43	3.47712	672.8	6.569
960	1000.55	725.02	2.92128	97.00	28.40	1560	1708.82	1260.99	3.49276	710.5	6.301
980	1023.25	741.98	2.94468	105.2	26.73	1580	1733.17	1279.65	3.50829	750.0	6.046
1000	1046.04	758.94	2.96770	114.0	25.17	1600	1757.57	1298.30	3.52364	791.2	5.804
1020	1068.89	776.10	2.99034	123.4	23.72	1620	1782.00	1316.96	3.53879	834.1	5.574
1040	1091.85	793.36	3.01260	133.3	22.39	1640	1806.46	1335.72	3.55381	878.9	5.355
1060	1114.86	810.62	3.03449	143.9	21.14	1660	1830.96	1354.48	3.56867	925.6	5.147
1080	1137.89	827.88	3.05608	155.2	19.98	1680	1855.50	1373.24	3.58335	974.2	4.949
1100	1161.07	845.33	3.07732	167.1	18.896	1700	1880.1	1392.7	3.5979	1025	4.761
1120	1184.28	862.79	3.09825	179.7	17.886	1750	1941.6	1439.8	3.6336	1161	4.328
1140	1207.57	880.35	3.11883	193.1	16.946	1800	2003.3	1487.2	3.6684	1310	3.944
1160	1230.92	897.91	3.13916	207.2	16.064	1850	2065.3	1534.9	3.7023	1475	3.601
1180	1254.34	915.57	3.15916	222.2	15.241	1900	2127.4	1582.6	3.7354	1655	3.295
1200	1277.79	933.33	3.17888	238.0	14.470	1950	2189.7	1630.6	3.7677	1852	3.022
1220	1301.31	951.09	3.19834	254.7	13.747	2000	2252.1	1678.7	3.7994	2068	2.776
1240	1324.93	968.95	3.21751	272.3	13.069	2050	2314.6	1726.8	3.8303	2303	2.555
1260	1348.55	986.90	3.23638	290.8	12.435	2100	2377.4	1775.3	3.8605	2559	2.356
1280	1372.24	1004.76	3.25510	310.4	11.835	2150	2440.3	1823.8	3.8901	2837	2.175
						2200	2503.2	1872.4	3.9191	3138	2.012
						2250	2566.4	1921.3	3.9474	3464	1.864

Source: Tables A-22 are based on J. H. Keenan and J. Kaye, *Gas Tables*, Wiley, New York, 1945.