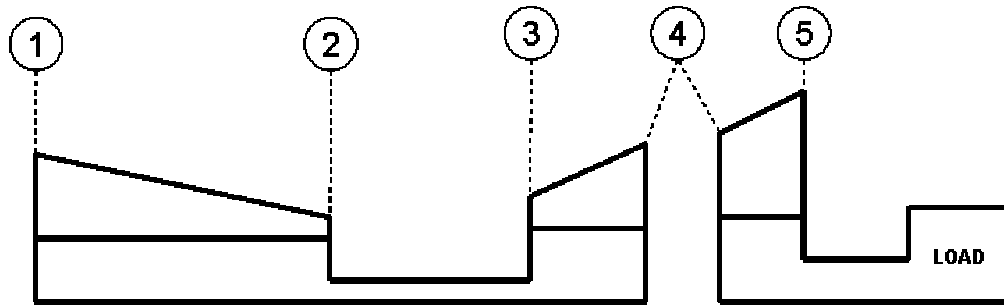


Problem 2.2



$$T_{02} - T_a = \frac{T_a}{\eta_c} \left[\left(\frac{P_{02}}{P_a} \right)^{\frac{\gamma-1}{\gamma}} - 1 \right]$$

$$= \frac{288}{0.82} \left[(11)^{\frac{1}{3.5}} - 1 \right] = 345.598 \text{ K}$$

Compressor and turbine work required per unit mass flow is:

$$W_{tc} = \frac{C_{pa}(T_{02} - T_a)}{\eta_m} = C_{pg}(T_{03} - T_{04})$$

$$T_{03} - T_{04} = \frac{1.005 \times 345.598}{0.98 \times 1.147} = 308.992 \text{ K}$$

$$T_{04} = 1150 - 309 = 841 \text{ K}$$

$$T_{03} - T_{04} = \eta_t T_{03} \left[1 - \left(\frac{1}{P_{03}/P_{04}} \right)^{\frac{\gamma-1}{\gamma}} \right]$$

$$308.992 = 0.87 \times 1150 \left[1 - \left(\frac{1}{P_{03}/P_{04}} \right)^{\frac{1}{4}} \right]$$

$$\frac{P_{03}}{P_{04}} = 4.382$$

$$P_{03} = 11.0 - 0.4 = 10.6 \text{ bar}$$

$$P_{04} = 2.418 \text{ bar}, P_{05} = P_a$$

$$T_{04} - T_{05} = 0.89 \times 841 \left[1 - \left(\frac{1}{2.418} \right)^{\frac{1}{4}} \right] = 148.254 \text{ K}$$

Specific power output:

$$W_N = 1.147 \times 0.98 \times 148.254 = 166.64 \text{ kW/kg}$$

$$\text{Hence mass flow required} = \frac{20 \times 10^3}{166.64} = 120.019 \text{ kg/sec}$$

$$T_{02} = 288 + 345.6 = 633.6 \text{ K}$$

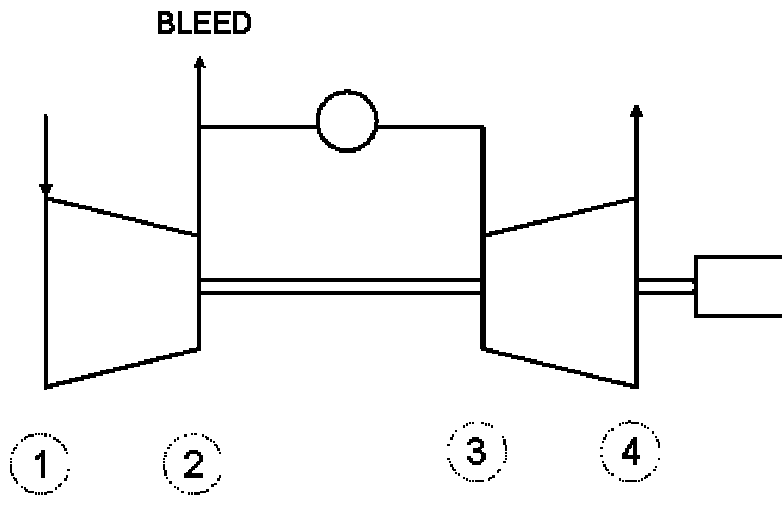
$$T_{03} - T_{02} = 1150 - 633.6 = 516.4 \text{ K}$$

Theoretical $f = 0.01415$ (from Fig. 2.15)

$$\text{Actual } f = 0.01415 / 0.99 = 0.01429$$

$$S.F.C = \frac{3600f}{W_N} = \frac{3600 \times 0.01429}{166.64} = 0.308 \text{ kg/kW-hr}$$

Problem 2.3



$$T_{02} - T_a = \frac{288}{0.85} [3.8^{\frac{1}{3.5}} - 1] = 157.3\text{K}$$

$$P_{03} = 3.8 - 0.12 = 3.68\text{ bar}$$

$$\frac{P_{03}}{P_a} = 3.68$$

$$T_{03} - T_{04} = 1050 \times 0.88 [1 - (\frac{1}{3.68})^{\frac{1}{4}}] = 256.87\text{K}$$

Net work output

$$W = \eta_{m(load)} [(m - m_c) C_{pg} (T_{03} - T_{04}) - \frac{m C_{pa} (T_{02} - T_a)}{\eta_{m(comp.rotor)}}]$$

$$200 = 0.98 [(m - 1.5) \times 1.147 \times 256.87 - \frac{m \times 1.005 \times 157.3}{0.99}]$$

$$200 = 288.73m - 433.1 - 156.5m$$

(a) $m = 4.788\text{ kg/sec}$

With no bleed flow:

$$\text{Net work output} = 0.98 \times 4.788 [1.147 \times 256.87 - \frac{1.005 \times 157.3}{0.99}]$$

$$= 633.11\text{ kW}$$

(b) The power output with no bleed = 633.11kW

Problem 2.4

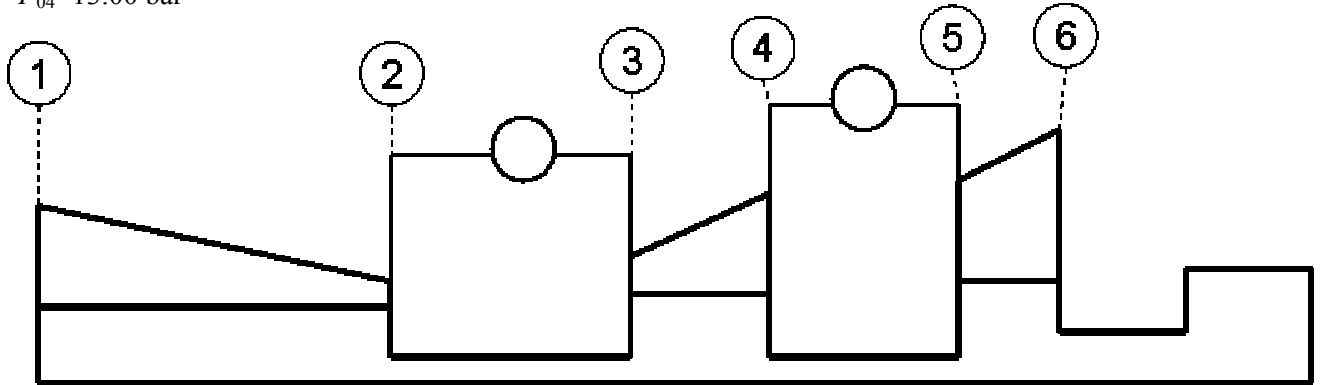
	A	B	C
$\left(\frac{n-1}{n}\right)_c$	0.3287	0.3250	0.3213
$\left(\frac{n-1}{n}\right)_t$	0.2225	0.2205	0.2205
T_{02}/T_{01}	2.059	2.242	2.437
ΔT_{012} (K)	305	357.8	413.9
T_{02} (K)	593	645.8	701.9
P_{03}/P_{04}	8.55	11.40	15.2
$T_{03}/T_{04} = \left(\frac{P_{03}}{P_{04}}\right)^{\frac{n-1}{n}}$	1.612	1.708	1.820
T_{03}	1150	1400	1600
T_{04}	713.4	819.6	879.2
ΔT_{034}	436.6	580.4	720.7
$W_c = (1.005 \times \Delta T_{12}) / 0.99$	309.6	363.2	420.2
$W_t = 1.148(1 - B)\Delta T_{034}$	501.2	649.6	786.0
$W_{net} = W_t - W_c$	191.6	286.4	365.8
Power	14,370	22,912	31,093
	Base	+59.4%	+116%
ΔT_{cc}	557	754	898
f/a	0.0162	0.0219	0.0268
$m_f = m_a \times f \times (1 - B)$	4374	6150	7791
SFC (kg/kwhr)	0.304	0.268	0.251
	base	11.8%	17.4%
EGT ($^{\circ}$ C)	440	547	606

Problem 2.5

$$T_{03} = 1525 \text{ K}$$

$$P_{03} = 29.69 \text{ bar}$$

$$P_{04} = 13.00 \text{ bar}$$



$$\therefore \frac{P_{03}}{P_{04}} = 2.284 \quad \therefore \frac{T_{03}}{T_{04}} = (2.284)^{0.2223} = 1.202$$

$$T_{04} = 1268.7 \text{ K}, \quad \Delta T_{hp} = 256.3$$

$$\frac{P_{05}}{P_{06}} = \frac{13.00 \times 0.96}{1.02} = 12.24 \quad \therefore \frac{T_{05}}{T_{06}} = (12.24)^{0.223} = 1.745$$

$$T_{03} - T_{04} = 256.3$$

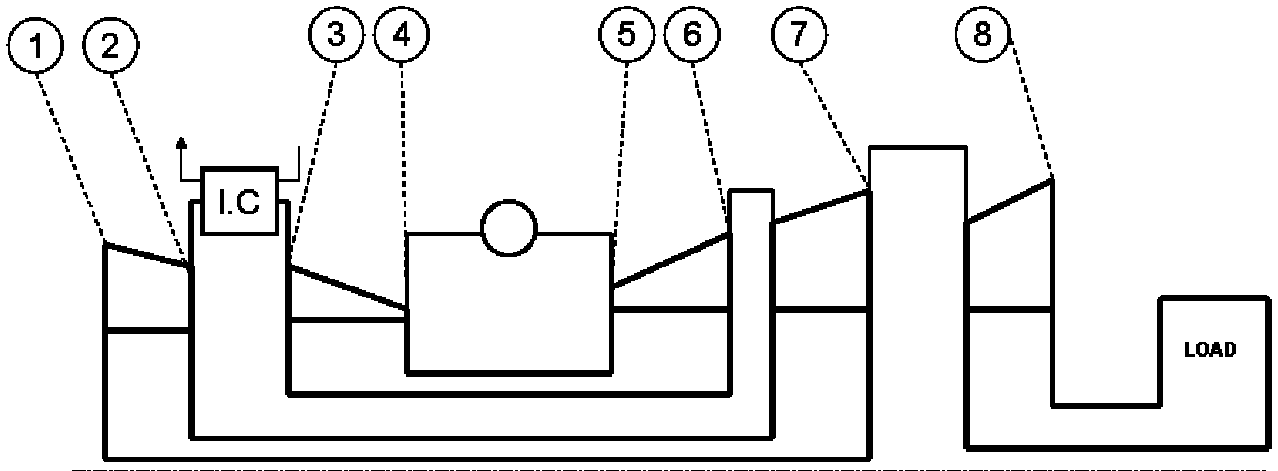
T_{05}	1525	1425	1325
T_{06}	874	816.6	759.3
$T_{05} - T_{06}$	651.0	608.4	565.7
$T_{03} - T_{04}$	256.3	256.3	256.3
ΔT_{total}	907.3	864.7	822.0
$\Delta T_{\text{total}} \times 1.148 \times 0.99$	1031.1	982.7	934.2
$-\Delta T_c \times 1.004$	573.0	573.0	573.0
	458.1	409.7	361.2

$$\therefore m \text{ for } 240 \text{ MW} = \frac{240000}{458.1} = 523.9 \text{ kg/s}$$

MW	240.0	214.6	189.2
$(f/a)_1$	0.0197	0.0197	0.0197
$(f/a)_2$	0.0085	0.0050	0.0030
	0.0282	0.0247	0.0227
η_{th}	458.1	409.7	361.2
	0.0282×43100	0.0247×43100	0.0227×43100
	37.7	38.5	36.9

So η_{th} remains high as power reduced. May be difficult to control low fuel: air ratio in 2nd combustor.

Problem 2.6



$$\Delta T_{12} = \frac{288}{0.875} \left[(5.5)^{0.286} - 1 \right] = 206.8 \quad T_2 = 494.8 \text{ K}$$

$$\Delta T_{34} = \frac{300}{0.870} \left[(7.5)^{0.286} - 1 \right] = 268.7 \quad T_4 = 568.7 \text{ K}$$

$$\Delta T_{cc} = 1550 - 569 = 981^\circ \text{ C}$$

$$\Delta T_{56} = \frac{268.7 \times 1.005}{1.148 \times 0.95 \times 0.99} = 250.1 \quad T_6 = 1550 - 250 = 1300 \text{ K}$$

$$\Delta T_{67} = \frac{206.8 \times 1.005}{1.148 \times 0.99} = 182.9 \quad T_7 = 1300 - 182.9 = 1117.1 \text{ K}$$

$$HPT, 250.1 = 0.88 \times 1550 \left[1 - \frac{1}{R^{0.25}} \right] R_{hp} = 2.248$$

$$CDP = 1.00 \times 5.5 \times 7.5 \times 0.95 = 39.19 \text{ bar} \quad P_6 = \frac{39.19}{2.248} = 17.43 \text{ bar}$$

$$LPT, 182.9 = 0.89 \times 1300 \left[1 - \frac{1}{R^{0.25}} \right] RLP = 1.990 \quad P_7 = 8.76 \text{ bar}$$

$$P_8 = P_1 = 1.00$$

$$\therefore \Delta T_{78} = 0.89 \times 1117.1 \left[1 - \frac{1}{8.76^{0.25}} \right] = 416.3 \text{ K}$$

$$\therefore m \times 1.148 \times 0.99 \times 416.3 = 100,000 \quad \therefore m = 211.3 \text{ kg/s}$$

$$f/a = \frac{0.028}{0.99} = 0.0283$$

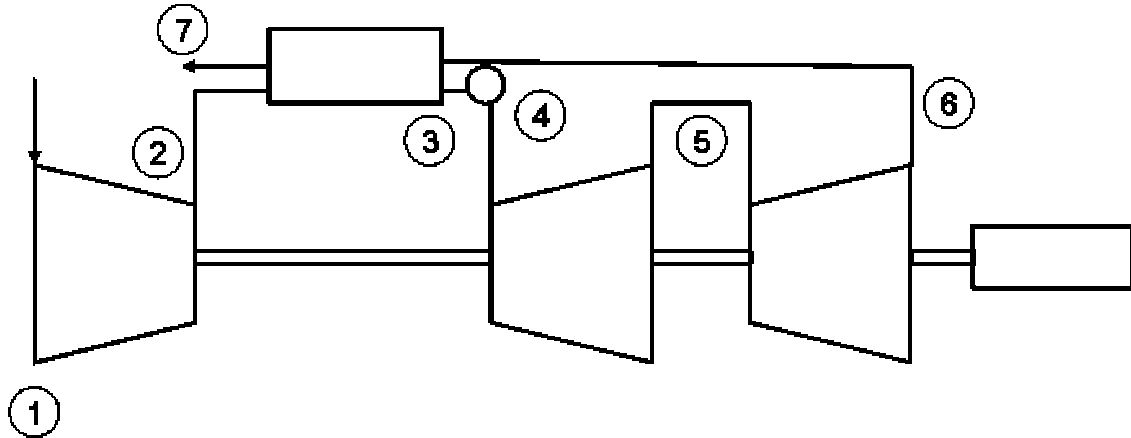
$$\text{Specific output} = 1.148 \times 0.99 \times 416.3 = 473.1$$

$$\therefore \eta_{th} = \frac{473.1}{0.283 \times 43100} = 38.8\%$$

$$EGT = 1117.7 - 416.3 = 701.4 \text{ K} = 428.4^\circ \text{ C}$$

Problem 2.8

$$P_a = 1.013 \text{ bar}, T_a = 15^\circ \text{C}$$



$$\Delta T_{12} = \frac{288}{0.87} [8.5^{0.286} - 1] = 279.5 \text{ K}$$

$$T_{02} = 567.5 \text{ K}$$

$$P_{04} = 1.013 \times 8.5 \times [1 - 0.015] \times [1 - 0.042] = 8.125 \text{ bar}$$

$$\Delta T_{45} = \frac{279.5 \times 1.004}{1.147 \times 0.99} = 247.1 \text{ K}, T_5 = 1037.8 \text{ K}$$

$$247.1 = 0.87 \times 1285 \left[1 - \frac{1}{(P_4/P_5)^{0.25}} \right] \Rightarrow \frac{P_4}{P_5} = 2.716, P_5 = 2.991 \text{ bar}$$

$$P_6 = 1.013 \times 1.02 = 1.0333 \Rightarrow \frac{P_5}{P_6} = 2.895$$

$$\therefore \Delta T_{56} = 0.88 \times 1037.8 \left[1 - \frac{1}{2.895^{0.25}} \right] = 213.1 \therefore T_6 = 824.7 \text{ K}$$

$$\therefore \text{Power} = 112.0 \times 1.147 \times 0.99 \times 213.1 = 27,106 \text{ kW}$$

$$T_3 - T_2 = 0.90(824.7 - 567.5) = 231.5$$

$$T_3 = 231.5 + 567.5 = 799 \text{ K}$$

$$\Delta T_{cc} = 1285 - 799 = 486^\circ \text{C}$$

$$T_{in} = 799 - 273 = 526^\circ \text{C}$$

$$(f/a)_{id} = 0.0138 \quad f/a = \frac{0.0138}{0.99} = 0.0139$$

$$m_f = 0.0139 \times 112.0 = 1.56 \text{ kg/s}$$

$$\text{Heat input} = 1.56 \times 43,100 \frac{\text{kJ kg}}{\text{kg s}} = 67,288 \text{ kW}$$

$$\therefore \text{Efficiency} = 40.3 \%$$

