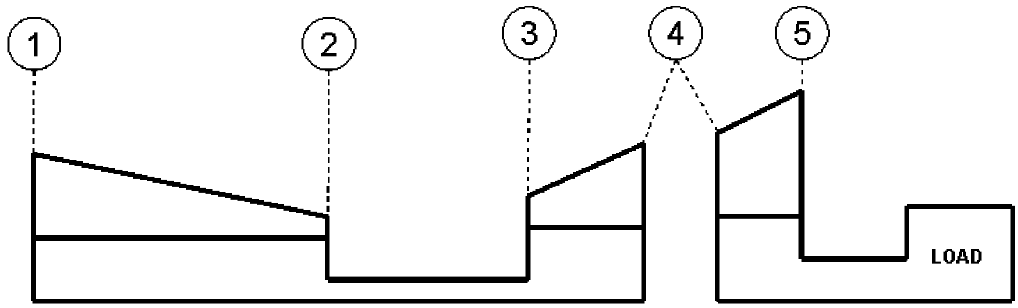
Problem 2.2



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

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

Compressor and turbine work required per unit mass flow is:

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

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

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

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

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

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

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

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

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

Specific power output:

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

Hence mass flow required = $\dfrac{20\times10^3}{166.64} = 120.019\,\text{kg/sec}$

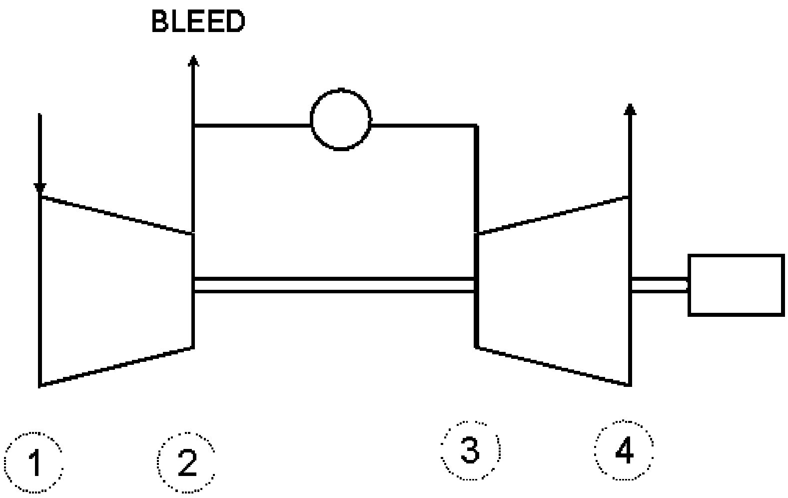
$$T_{02} = 288 + 345.6 = 633.6\text{K}$$
$$T_{03} - T_{02} = 1150 - 633.6 = 516.4\text{K}$$

Theoretical f = 0.01415 (from Fig. 2.15)

Actual f = $0.01415/0.99 = 0.01429$

$$S.F.C = \frac{3600f}{W_N} = \frac{3600\times0.01429}{166.64} = 0.308\,\text{kg/kW} - \text{hr}$$

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

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

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

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

(a) $m = 4.788$ kg/sec

With no bleed flow:

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

$$= 633.11\text{ kW}$$

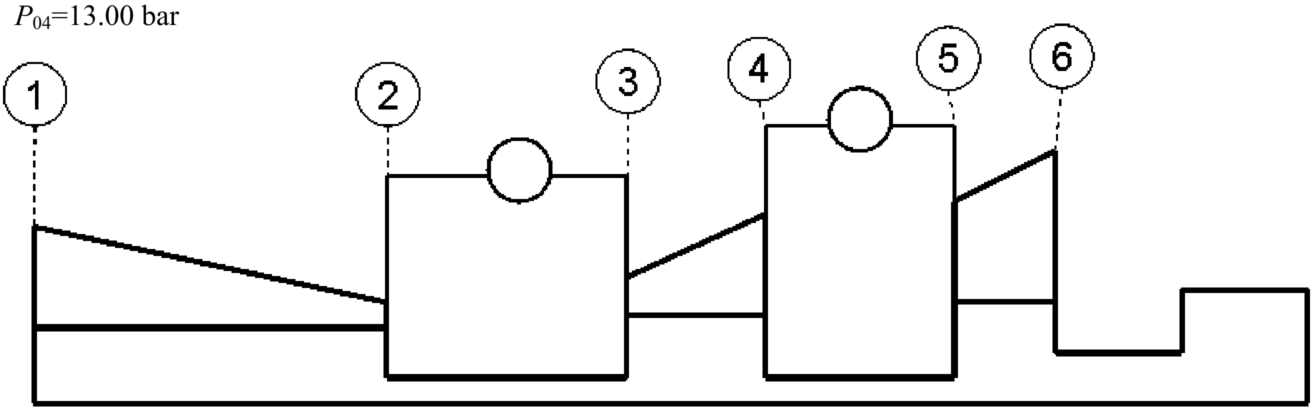
(b) The power output with no bleed = 633.11kW

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 Base	22,912 +59.4%	31,093 +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 base	0.268 11.8%	0.251 17.4%
$EGT\ (^\circ\mathrm{C})$	440	547	606

Problem 2.5

T_{03}=1525 K
P_{03}=29.69 bar
P_{04}=13.00 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 K, $\Delta T_{hp} = 256.3$

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

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

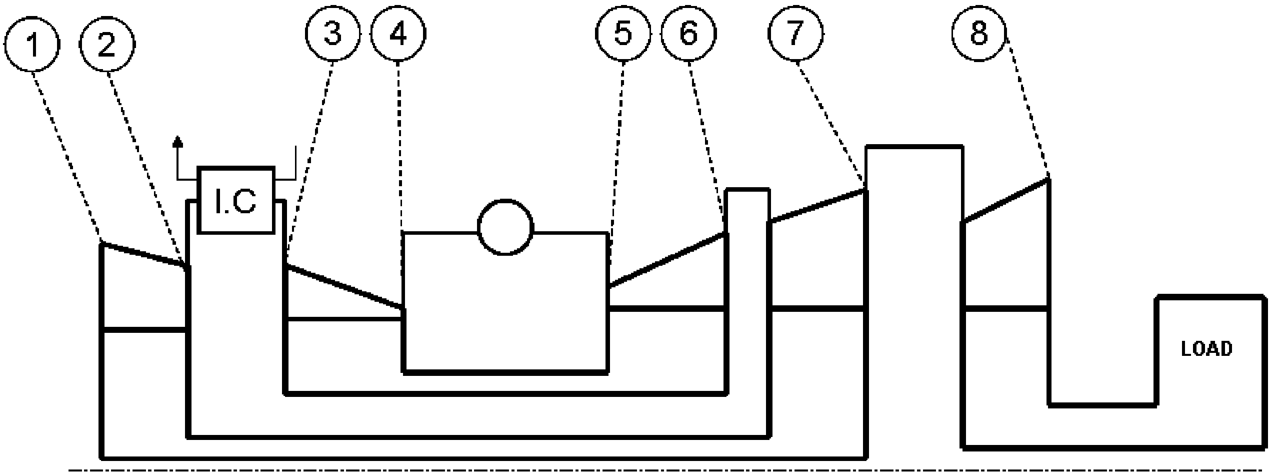
T_{05}	1525	1425	1325
T_{06}	874	816.6	759.3
T_{05}–T_{06}	651.0	608.4	565.7
T_{03}–T_{04}	256.3	256.3	256.3
ΔT total	907.3	864.7	822.0
ΔT total$\times 1.148 \times 0.99$	1031.1	982.7	934.2
$-\Delta T_c \times 1.004$	573.0	573.0	573.0
	458.1	409.7	361.2

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

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



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

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

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

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

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

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

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

$$LPT,\ 182.9 = 0.89 \times 1300\left[1 - \frac{1}{R^{0.25}}\right] RLP = 1.990 \ P7 = 8.76 \text{ bar}$$

$$P_8 = P_1 = 1.00$$

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

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

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

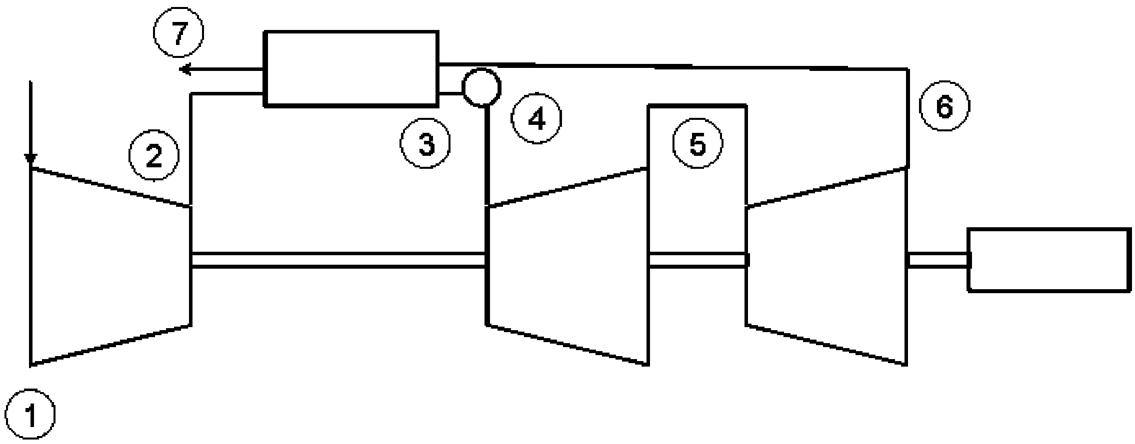
Specific output $= 1.148 \times 0.99 \times 416.3 = 473.1$

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

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

Problem 2.8

P_a=1.013 bar , T_a=15 °C



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

T_{02}=567.5 K

P_{04}=1.013×8.5×[1−0.015]×[1−0.042] = 8.125 bar

$$\Delta T_{45} = \frac{279.5\times1.004}{1.147\times0.99} = 247.1 \quad T_5 = 1037.8\text{ K}$$

$$247.1 = 0.87\times1285\left[1-\frac{1}{(P4/P5)^{0.25}}\right] \Rightarrow \frac{P_4}{P_5} = 2.716,\ \ P_5 = 2.991\text{ bar}$$

$$P_6 = 1.013\times1.02 = 1.0333 \qquad \Rightarrow \frac{P_5}{P_6} = 2.895$$

$$\therefore \Delta T_{56} = 0.88\times1037.8\left[1-\frac{1}{2.895^{0.25}}\right] = 213.1 \quad \therefore T_6 = 824.7\text{ K}$$

$\therefore$ Power $= 112.0\times1.147\times0.99\times213.1 = 27{,}106$ kW

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

T_3=231.5+567.5=799K

$\Delta T_{cc} = 1285 - 799 = 486$°C

T_{in}=799-273=526 °C

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

m_f= 0.0139×112.0 =1.56 kg/s

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

$\therefore$ Efficiency =40.3 %