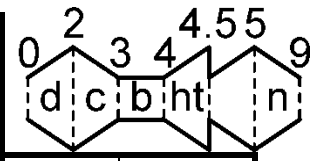
	2	3	4	4.5	5	9	
	diff	comp	CC	Tur	Tur	No	Prop
cp	1004			1152	J/kgs		
g	1.4			1.33			
p	0.99	35	0.96				
h, ec,t		0.92	0.99	0.8	0.859	0.95	0.85
Tt				1650			
M0	0.82				QR	42000	kJ/kgK
T0	258	K	p0	30,000	Pa		
alpha	0.75	m0	50	kg/s			



η_mH	0.99
η_mL	0.99
η_{gb}	0.995

$$k = \frac{\gamma - 1}{\gamma} = \frac{0.4}{1.4} = 0.2867 \quad k_5 = \frac{\gamma_5 - 1}{\gamma_5} = \frac{0.33}{1.33} = 0.2481$$

$$R = kc_p = 0.2867 \cdot 1004 = 286.9 J/kgK \quad R_5 = 0.2481 \cdot 1152 = 285.8 J/kgK$$

$$a_0 = \sqrt{\gamma R T_0} = 1.4 \cdot 286.9 \cdot 258 = 321.9 m/s$$

$$V_0 = M_0 \cdot a_0 = 0.82 \cdot 321.9 = 263.9 m/s$$

Presa d'aria

$$\tau_r = \psi_0 = 1 + \frac{\gamma - 1}{2} M_0^2 = 1 + 0.2 \cdot 0.81 = 1.134$$

$$T_{t0} = T_{t2} = T_0 \tau_r = 288 \cdot 1.134 = 292.7 K$$

$$p_{t0} = \tau_r^{\frac{1}{k}} p_0 = 1.135^{\frac{1}{0.2867}} 30.00 \cdot 10^3 = 46.66 kPa$$

$$p_{t2} = p_{t0} \pi_d = 46.66 \cdot 0.99 \cdot 10^3 = 46.19 kPa$$

Compressore

$$\tau_c = \pi_c^{\frac{k}{e_c}} = 35^{\frac{0.2867}{0.92}} = 3.017$$

$$p_{t3} = p_{t2} \pi_c = 46.19 \cdot 35 \cdot 10^3 = 1617 kPa$$

$$T_{t3} = T_{t2} \tau_c = 292.7 \cdot 3.017 = 883.0 K$$

Camera di combustione

$$p_{t4} = p_{t3} \pi_b = 1.617 \cdot 0.99 \cdot 10^3 = 1552 kPa$$

$$\tau_\lambda = \frac{c_{p5} T_{t4}}{c_p T_0} = \frac{1152 \cdot 1650}{258 \cdot 1004} = 7.338$$

$$f = \frac{\tau_\lambda - \tau_c \tau_r}{Q_R \eta_b / (c_p T_0) - \tau_\lambda} = \frac{7.338 - 3.017 \cdot 1.134}{42.0 \cdot 10^6 \cdot 0.99 / (258 \cdot 1004) - 7.338} = 0.02556$$

Turbina HP

$$\tau_{tH} = 1 - \frac{\tau_r(\tau_c - 1)}{\eta_{mH}(1+f)\tau_\lambda} = 1 - \frac{1.134(2.017)}{0.99 \cdot 1.026 \cdot 7.338} = 0.6929$$

$$\pi_{tH} = \tau_{tH}^{\frac{1}{k_5 e_{tH}}} = 0.6929^{\frac{1}{0.2481 \cdot 0.800}} = 0.1575$$

$$p_{t45} = p_{t4}\pi_{tH} = 155.2 \cdot 0.1575 \cdot 10^3 = 244.5kPa$$

$$T_{t45} = T_{t4}\tau_{tH} = 1650 \cdot 0.6929 = 1143K$$

Turbina LP

Supponendo funzionamento corretto nell'ugello: $\frac{p_9}{p_0}$=1

$$\tau_{tL} = 1 - \eta_{tL}\alpha_p \left[1 - \left(\frac{p_0}{p_{t45}}\right)^{k_5}\right] = 1 - \eta_{tL}0.75 \left[1 - \left(\frac{30}{244.5}\right)^{0.2481}\right] =$$

$$\tau_{tL} = 1 - \eta_{tL}0.75[1 - 0.5942] = 1 - \eta_{tL}0.3044$$

Supponendo $\eta_{tL} = 1 \rightarrow \tau_{tL} = 0.6956$

$$\eta_{tL} = \frac{1 - \tau_{tL}}{1 - \tau_{\tau L}^{\frac{1}{e_{tL}}}} = \frac{1 - 0.6956}{1 - 0.6956^{\frac{1}{0.859}}} = 0.8833$$

Iterando si ha in sequenza: $\tau_{tL} = 0.7312$, $\eta_{tL} = 0.88010$, $\tau_{tL} = 0.7321$, $\eta_{tL} = 0.8800$, $\tau_{tL} = 0.7322$

$$\pi_{tL} = \tau_{tL}^{\frac{1}{k_5 e_{tL}}} = 0.7322^{\frac{1}{0.2481 \cdot 0.859}} = 0.2316$$

$$p_{t5} = p_{t45}\pi_{tL} = 244.5 \cdot 0.2316 \cdot 10^3 = 56.63kPa$$

$$T_{t5} = T_{t45}\tau_{tL} = 1143 \cdot 0.7322 = 837.1K$$

Ugello

$$\eta_n = \frac{\left(\frac{p_{t5}}{p_9}\right)^{k_5} - \pi_n^{-k_5}}{\left(\frac{p_{t5}}{p_9}\right)^{k_5} - 1} \rightarrow \pi_n = \left\{\left(\frac{p_{t5}}{p_9}\right)^{k_9} - \eta_n\left[\left(\frac{p_{t5}}{p_9}\right)^{k_9} - 1\right]\right\}^{-\frac{1}{k_5}}$$

$$\left(\frac{p_{t5}}{p_9}\right)^{k_5} = \left(\frac{p_{t5}}{p_0}\right)^{k_5} = \left(\frac{56.63}{30}\right)^{0.2481} = 1.171$$

$$\pi_n = \{1.171 - 0.95[1.171 - 1]\}^{-\frac{1}{0.2481}} = 0.9663$$

$$p_{t9} = p_{t5}\pi_n = 56.63 \cdot 0.9663 \cdot 10^3 = 54.72kPa$$

$$\frac{p_{t9}}{p_9} = \frac{54.72}{30} = 1.824$$

$$\psi_9 = \left(\frac{p_{t9}}{p_9}\right)^{k_5} = 1.824^{0.2481} = 1.161$$

$$M_9 = \sqrt{\frac{2}{\gamma_5 - 1}[\psi_9 - 1]} = \sqrt{\frac{2}{.33}[1.161 - 1]} = 0.9873$$

$M_9 < 1 \rightarrow p_9 = p_0$ (OK)

$T_9 = T_{t9}/\psi_9 = T_{t5}/\psi_9 = 837.1/1.161 = 721.1K$

$a_9 = \sqrt{\gamma_5 R_5 T_9} = 1.33 \cdot 285.8 \cdot 721.1 = 523.6m/s$

$V_9 = M_9 \cdot a_9 = 0.9873 \cdot 523.6 = 516.9m/s$

$$\frac{V_9}{\mathrm{a}_0} = \frac{516.9}{321.9} = 1.606 > M_0 \quad (OK)$$

Propeller

$$\frac{\mathcal{P}_\mathrm{s}}{\dot{m}_0} = (1+f)\eta_{gb}\eta_{m_{tL}}(1-\tau_{tL})c_{p5}T_{t45} =$$

$$\frac{\mathcal{P}_\mathrm{s}}{\dot{m}_0} = 1.026 \cdot 0.995 \cdot 0.99 \cdot (1 - 0.7322) \cdot 1152 \cdot 1143 = 356.4\frac{kJ}{kg}$$

Spinta

$$\frac{F_{u.c}}{\dot{m}_0 a_0} = (1+f)\frac{V_{9.e}}{a_0} - M_0 = 1.026 \cdot 1.606 - 0.82 = 0.8270$$

$$\frac{F_{u.p}}{\dot{m}_0 a_0} = \frac{\eta_{prop}\mathcal{P}_s}{\dot{m}_0 V_0 a_0} = \frac{0.85 \cdot 356.4}{263.9 \cdot 321.9}10^3 = 3.565$$

$$\frac{F_u}{\dot{m}_0 a_0} = \left(\frac{F_{u.c}}{\dot{m}_0 a_0} + \frac{F_{u.o}}{\dot{m}_0 a_0}\right) = 0.8279 + 3.565 = 4.392$$

$$TSFC = \frac{f}{F_u/\dot{m}_0} = \frac{0.02556 \cdot 10^3}{4.392 \cdot 321.9} = 0.01808\frac{g}{s}\frac{1}{N}$$

$$\eta_{th} = \frac{\mathrm{a}_0^2[(1+f)V_{9.e}^2/\mathrm{a}_0^2 - M_0^2] + 2\mathcal{P}_S/\dot{m}_0}{2fQ_R} =$$

$$\eta_{th} = \frac{321.9^2[1.026 \cdot 0.8279^2 - 0.82^2] + 2 \cdot 356.4}{2 \cdot 0.02556 \cdot 42.0 \cdot 10^6} = \frac{9.171 \cdot 10^5}{2.147 \cdot 10^6} = 0.4271$$

$$\eta_p = \frac{2\frac{F_u}{\dot{m}_0 a_0}a_0 V_0}{\mathrm{a}_0^2[(1+f)V_{9.e}^2/\mathrm{a}_0^2 - M_0^2] + 2\mathcal{P}_S/\dot{m}_0} = \frac{2 \cdot 4.392 \cdot 263.9 \cdot 321.9}{9.171 \cdot 10^5} = 0.8138$$

$$\eta_0 = \eta_{th}\eta_p = 0.4271 \cdot 0.8138 = 0.3476$$