8.111 E Turbojet Aircraft $V_{ac} = 900\ ft/s$
20,000 ft

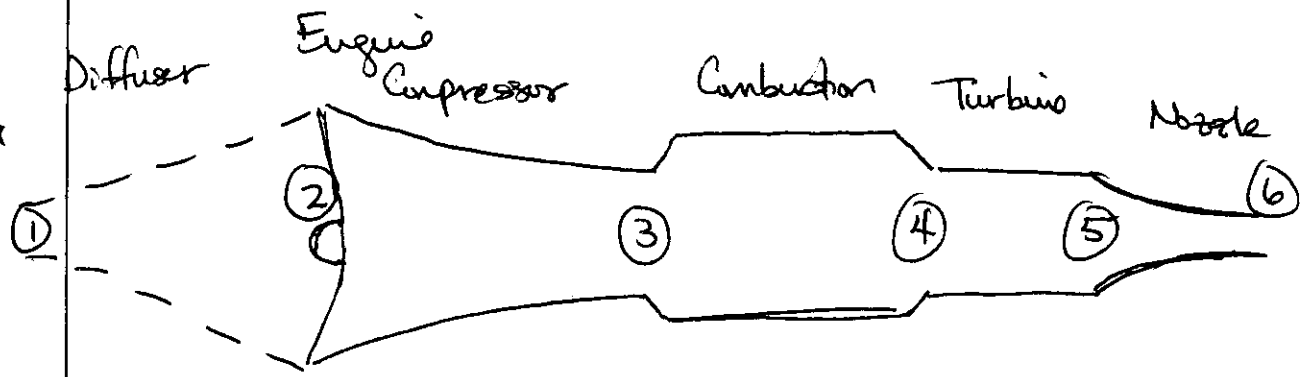
$P_1 = 7$ psia

$T_1 = 10°F = 470\ R$

Pressure ratio across the compressor is 13

$T_4 = 2400\ R$

a) Determine exhaust pressure of Turbine (P_5)



1 → 2 Isentropic Compression $Q=0$, $W=0$

$$h_1 + \frac{V_1^2}{2} = h_2 + \cancel{\frac{V_2^2}{2}} \quad \text{neglect } V_2$$

$C_p = 0.24$ Btu/lbm R

$$C_p(T_2 - T_1) = \frac{(900\ ft/s)^2}{2} \cdot \frac{Btu/lbm}{25{,}037\ ft^2/s^2}$$

$T_2 = 537.4\ R$

2 → 3 Isentropic Compression

$$\frac{T_3}{T_2} = \left(\frac{P_3}{P_2}\right)^{k-1/k} \qquad \frac{P_3}{P_2} = 13 \qquad k = 1.4$$

$$T_3 = 1118.3\ R \qquad \frac{T_3}{T_1} = \left(\frac{P_3}{P_1}\right)^{k-1/k} \qquad P_3 = 145.4\ psia$$

$T_4 = 2400\ R$

(Work of Compressor) = (Work of Turbine)

$$C_p\left[T_3 - T_2\right] = C_p\left[T_4 - T_5\right]$$

$$T_5 = 1819.1\ R$$

$$\frac{P_5}{P_4} = \left(\frac{T_5}{T_4}\right)^{k/k-1} \qquad \boxed{P_5 = 55.1\ \text{psia}}$$

b) Velocity of Exhaust gases

$$h_5 + \cancel{\frac{V_5^2}{2}} = h_6 + \frac{V_6^2}{2}$$

$$\frac{P_3}{P_1} = \frac{P_4}{P_6} \quad \therefore \left(\frac{T_3}{T_1}\right) = \left(\frac{T_4}{T_6}\right) \qquad T_6 = 1008.7\ R$$

$$\frac{V_6^2}{2} = C_p\left[T_5 - T_6\right]$$

$$\boxed{V_6 = 3120.7\ \text{ft/s}}$$

c) Propulsive Efficiency

$$W_p = (V_{exit} - V_{inlet})\,V_{aircraft} = 1998691\ \frac{ft^2}{s^2} = 79.8\ \frac{Btu}{lbm}$$

$$q_{in} = C_p\left[T_4 - T_3\right] = 307.6$$

$$\boxed{\eta_p = \frac{W_p}{q_{in}} = 25.9\%}$$

{Problem 115/116 - Aircraft powered by turbojet engine with rp=12. Aircraft is stationary on the ground. Given the information below calculate the force required to keep the plane stationary. Investigate the effect of the compressor inlet temperature on this force. Plot the force versus inlet compressor temperature in range of -20 C to 30 C}

```
{Given}
rp=12
T[1]=300
P[1]=95
Vdot_inlet=9.063
HV=42700
mdot_fuel=0.2

rho[1]=density(air,T=T[1],P=P[1])
mdot_air=rho[1]*Vdot_inlet
h[1]=enthalpy(air,T=T[1])
s[1]=entropy(air,T=T[1],P=P[1])

P[2]=P[1]*rp
s[2]=s[1]
h[2]=enthalpy(air,s=s[2],P=P[2])

P[3]=P[2]
qin=h[3]-h[2]
qin=mdot_fuel*HV/mdot_air
s[3]=entropy(air,P=P[3],h=h[3])

wc=h[1]-h[2]
wt+wc=0
wt=h[3]-h[4]
s[4]=s[3]

P[5]=P[1]
s[5]=s[3]
h[5]=enthalpy(air,P=P[5],s=s[5])

vexit^2=2000*(h[4]-h[5])

Force=vexit*mdot_air
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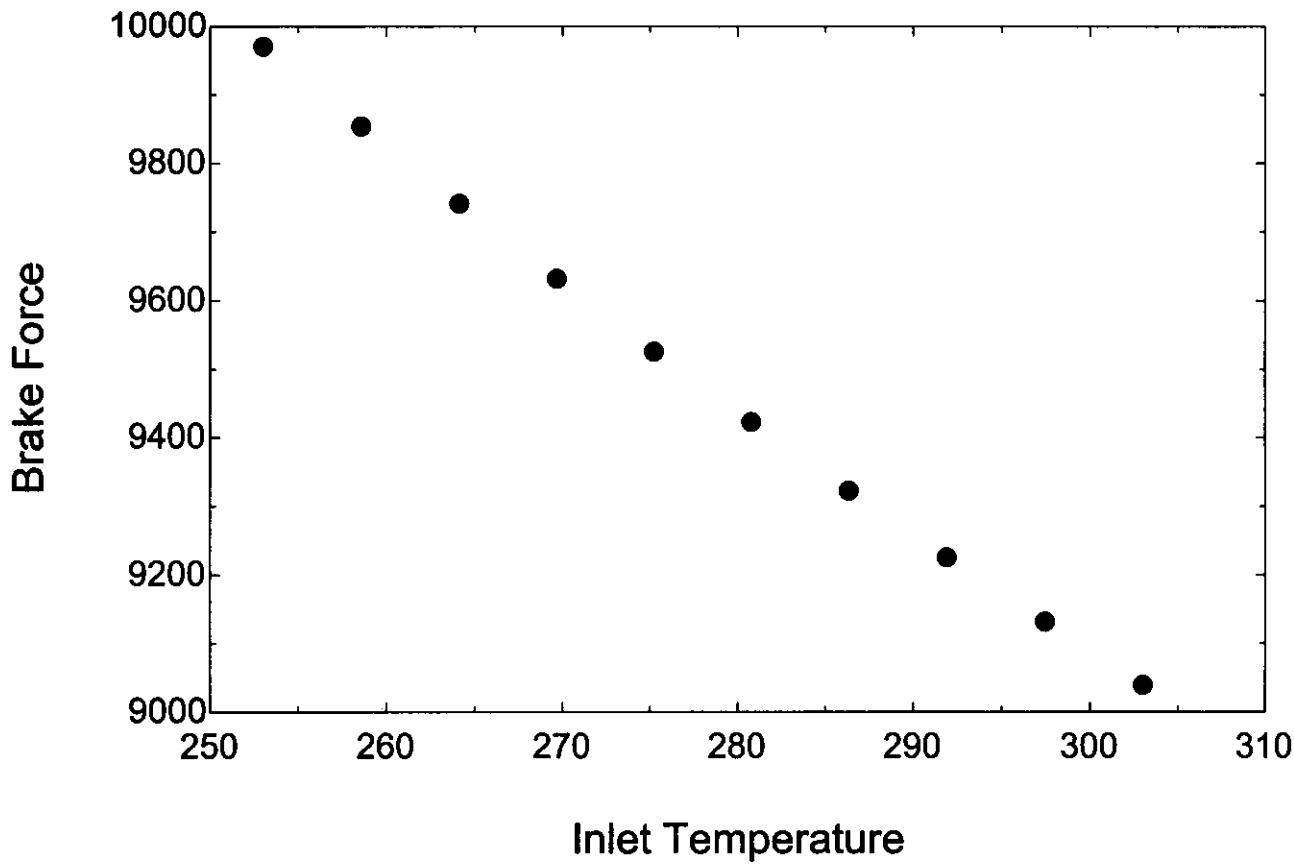
SOLUTION

Unit Settings: [kJ]/[K]/[kPa]/[kg]/[degrees]

Force = 9089	HV = 42700	$mdot_{air}$ = 9.999	$mdot_{fuel}$ = 0.2
qin = 854.1	rp = 12	$Vdot_{inlet}$ = 9.063	vexit = 909
wc = -310.6	wt = 310.6		

Arrays Table

	h_i [kJ/kg]	P_i	s_i [kJ/kg-K]	T_i	ρ_i [kg/m³]
1	300.4	95	5.716	300	1.103
2	611	1140	5.716		
3	1465	1140	6.626		
4	1155		6.626		
5	741.4	95	6.626		

Parametric Table: Table 1

	T_1	Force
Run 1	253	9971
Run 2	258.6	9854
Run 3	264.1	9741
Run 4	269.7	9632
Run 5	275.2	9526
Run 6	280.8	9423
Run 7	286.3	9323
Run 8	291.9	9226
Run 9	297.4	9131
Run 10	303	9040