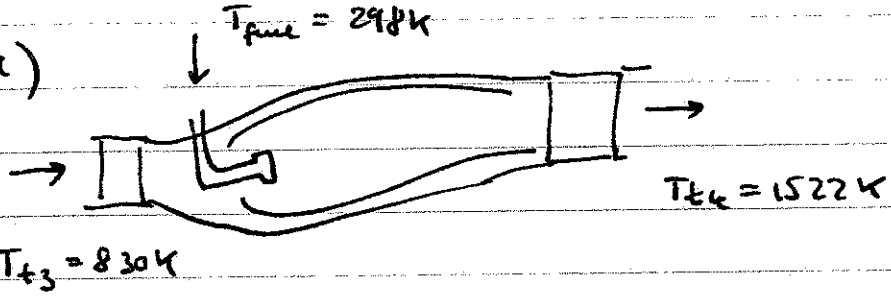
T15 16. Unified sp0975

Consider PW4000 engine, fuel: C_8H_{18} (liquid)

a)



Reaction: $C_8H_{18} + x(O_2 + 3.76N_2) \rightarrow 8CO_2 + 9H_2O + (x-12.5)O_2 + 3.76xN_2$

Stoichiometric: $x_s = 12.5$

1st Law: $\sum_R n_i (\bar{h}_f^\circ + \Delta\bar{h})_i = \sum_P n_e (\bar{h}_f^\circ + \Delta\bar{h})_e$, $H_R = H_P$

R: $\bar{h}_{C_8H_{18}} = \bar{h}_f^{\circ\, C_8H_{18}} = -249,910$ kJ/kmol

$\bar{h}_{O_2} = \bar{h}^{O_2}(830) - \bar{h}^{O_2}(298) = 16,855$ kJ/kmol

$\bar{h}_{N_2} = \bar{h}^{N_2}(830) - \bar{h}^{N_2}(298) = 15,989$ kJ/kmol

$H_R = \bar{h}_{C_8H_{18}} + x\bar{h}_{O_2} + 3.76x\bar{h}_{N_2} = 76,973x - 249,910$ kJ/kmol

P: $\bar{h}_{CO_2} = \bar{h}_f^{\circ\, CO_2} + \bar{h}^{CO_2}(1522) - \bar{h}^{CO_2}(298)$ $= 62,882$ kJ/kmol $- 393,520$ kJ/kmol

$\bar{h}_{H_2O} = \bar{h}_f^{\circ\, H_2O} + \bar{h}^{H_2O}(1522) - \bar{h}^{H_2O}(298)$ $= 49,038$ kJ/kmol $- 241,820$ kJ/kmol

$\bar{h}_{N_2} = \bar{h}^{N_2}(1522) - \bar{h}^{N_2}(298)$ $= 39,102$ kJ/kmol

$\bar{h}_{O_2} = \bar{h}^{O_2}(1522) - \bar{h}^{O_2}(298)$ $= 41,342$ kJ/kmol

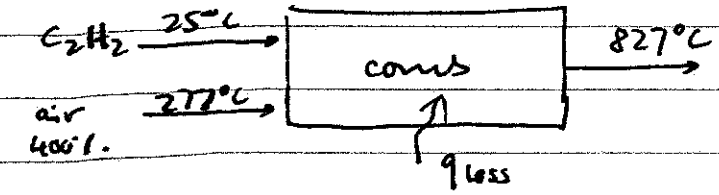
$H_P = 8\bar{h}_{CO_2} + 9\bar{h}_{H_2O} + (x-12.5)\bar{h}_{O_2} + 3.76x\bar{h}_{N_2} = -4,896,917 + 188,365x$

$H_R = H_P \rightarrow$ find $x = 41.72$, $\dot{m}_f/\dot{m}_a = 114/41.72(32+105.28)$

$\dot{m}_f/\dot{m}_a = 0.0199$

b) excess air is used to cool comb. gas to comply with turbine inlet temp. limitations

T16 — 16. Unified Sp 09 Z5



Reaction: $C_2H_2 + 10(O_2 + 3.76N_2) \rightarrow 2CO_2 + H_2O + 7.5O_2 + 37.6N_2$

C_2H_2: 298 K; $10(O_2 + 3.76N_2)$: 550 K; products: 1100 K

1st law: $\sum_R n_i(\bar{h}_f^\circ + \Delta\bar{h})_i + \bar{q}_{loss} = \sum_P n_e(\bar{h}_f^\circ + \Delta\bar{h})_e$

R: $\bar{h}_{C_2H_2} = \bar{h}_f^{\circ\,C_2H_2} = 226,730$ kJ/kmol

$\bar{h}_{O_2} = \bar{h}^{O_2}(550) - \bar{h}^{O_2}(298) = 7,656$ kJ/kmol

$\bar{h}_{N_2} = \bar{h}^{N_2}(550) - \bar{h}^{N_2}(298) = 7,395$ kJ/kmol

$H_R = \bar{h}^{C_2H_2} + 10\,\bar{h}^{O_2} + 37.6\,\bar{h}^{N_2} = 581,342$ kJ/kmol

P: $\bar{h}_{CO_2} = \bar{h}_f^{\circ\,CO_2} + \bar{h}^{CO_2}(1100) - \bar{h}^{CO_2}(298) = -354,626$ kJ/kmol

$\bar{h}_{H_2O} = \bar{h}_f^{\circ\,H_2O} + \bar{h}^{H_2O}(1100) - \bar{h}^{H_2O}(298) = -211,653$ kJ/kmol

$\bar{h}_{O_2} = \bar{h}^{O_2}(1100) - \bar{h}^{O_2}(298) = 26,217$ kJ/kmol

$\bar{h}_{N_2} = \bar{h}^{N_2}(1100) - \bar{h}^{N_2}(298) = 24,757$ kJ/kmol

$H_P = 2\bar{h}_{CO_2} + \bar{h}_{H_2O} + 7.5\bar{h}_{O_2} + 37.6\bar{h}_{N_2} = 206,586$ kJ/kmol

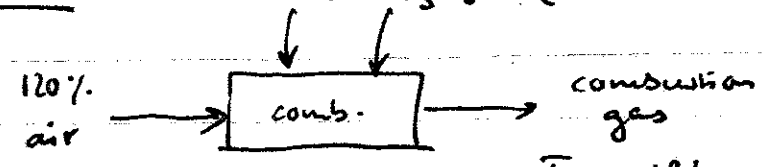
find heat loss: $\bar{q}_{loss} = H_P - H_R$

$\bar{q}_{loss} = -374,756$ kJ/kmol

per kg C_2H_2: $q_{loss} = \dfrac{\bar{q}}{M_{C_2H_2}}$, $M_{C_2H_2} = 26$ kg/kmol, $q_{loss} = 14.414$ MJ/kg

T 17

16. Unified Sp09 25

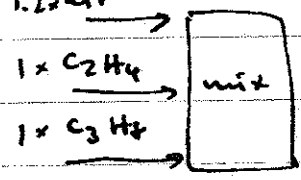


$C_2H_4 + 3(O_2 + 3.76N_2) \rightarrow 2CO_2 + 2H_2O + 11.28N_2$

$C_3H_8 + 5(O_2 + 3.76N_2) \rightarrow 3CO_2 + 4H_2O + 18.8N_2$

$C_2H_4 + C_3H_8 + 9.6(O_2 + 3.76N_2) \rightarrow 5CO_2 + 6H_2O + 36.08N_2$ + $1.6(O_2 + 3.76N_2)$

a) fuel-air mixture:



1st law: $\sum_R \dot{n}_i h_i = h_{mix} = \frac{\sum n_i \bar{c}_{pi} T_{mix} \cdot \sum n_i}{\sum n_i} \rightarrow T_{mix} = \frac{\sum n_i T_{Ri} \bar{c}_{pi}}{\sum n_i \bar{c}_{pi}}$

Table p. 17:

C_2H_4: $\bar{c}_p (T = 25°C) = 43.25$ J/kmol K

C_3H_8: $\bar{c}_p (T = 25°C) = 73.89$ J/kmol K

O_2: $\bar{c}_p (T = 303.2°C) = 31.83$ J/kmol K

N_2: $\bar{c}_p (T = 303.2°C) \cong 30$ J/kmol K

$T_3 = T_0 \left(\frac{P_3}{P_0}\right)^{\frac{k-1}{k}} = 575.3\,K = 303.2\,°C$

→ find $T_{mix} = 553.7$ K

b) 1st law: $\sum_R \dot{n}_i (\bar{h}_f + \Delta\bar{h})_i = \sum_P \dot{n}_e (\bar{h}_f + \Delta\bar{h})_e$, short: $\sum n_i h_{Ri} = \sum n_e h_{pe}$

$H_R = H_P$

Reactants: $H_R = \bar{h}_f^{\circ\,C_2H_4} + \bar{h}_f^{\circ\,C_3H_8} + 9.3\Delta\bar{h}^{O_2} + 36.1\Delta\bar{h}^{N_2}$

using tables p. 17-18 → $H_R = 323.8$ kJ/mol

Products: $H_P = 5\bar{h}_f^{\circ\,CO_2} + 6\bar{h}_f^{\circ\,H_2O} + 36.1\Delta\bar{h}^{N_2} + 1.6\Delta\bar{h}^{O_2} + 5\Delta\bar{h}^{CO_2} + 6\Delta\bar{h}^{H_2O}$

$= -3851.6 + 5\bar{h}^{CO_2}(T_f) + 6\bar{h}^{H_2O}(T_f) + 1.6\bar{h}^{O_2}(T_f) + 36.1\bar{h}^{N_2}(T_f)$

So $H_R = H_P \rightarrow 5\bar{h}^{CO_2}(T_f) + 6\bar{h}^{H_2O}(T_f) + 1.6\bar{h}^{O_2}(T_f) + 36.1\bar{h}^{N_2}(T_f) = R = 4{,}175.4$ kJ/mol

tables p. 20-27

T = 2350 K	5x122,091	6x100,846	1.6x81,243	36.1x77,496	4,143,125 kJ/kmol
T = 2400 K	5x125,152	6x103,508	1.6x83,174	36.1x79,320	4,243,338 kJ/kmol

$R = 4{,}175{,}400$ kJ/kmol ← interpolate ← $T_f = 2366.1$ K

c) $W_{net} = W_T - W_C = \bar{c}_{p\,mix\,turb.}(T_4 - T_5) - \bar{c}_{p\,air}(T_3 - T_2)$

$\bar{c}_p = \frac{k}{k-1} R$, $R = \frac{\bar{R}}{M}$, $M_{mix} = \frac{\sum n_i M_i}{n_i}$

$\bar{c}_{p\,mix\,turb} = 1946.5$ J/kg-K

$\bar{c}_{p\,air} = 1008.5$ J/kg-K

$W_{net} = 2.79$ MJ/kg