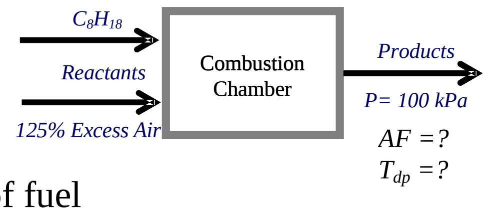
Thermodynamics II ***Test #3*** *Saturday 29 January 2011 Time 1 hr 30 min*

Sec….เลขที่สอบ…. Name ……Solution by *Sommai Priprem*………

Examiner: *Assoc.Prof.Sommai Priprem, PhD.*

1) Octane (C_8H_{18}) is burned with 125 percent excess air during a combustion process. Assuming complete combustion and a total pressure of 100 kPa, determine (a) the air-fuel ratio and (b) the dew-point temperature of the products.

System: Combustion: **C_8H_{18} + 125 % ExAir**
Assumption: SSSF, neglect ΔKE, ΔPE



Solution

Theoretical combustion equation based on 1 kmol of fuel

$$C_8H_{18}\ (l) + 12.5\ (O_2 + 3.76\ N_2) \rightarrow 8CO_2 + 9H_2O + 12.5*3.76\ N_2$$

Combustion equation at 50% Excess Air or 150% theoretical air is

$$C_3H_8\ (l) + (2.25*12.5)(O_2 + 3.76\ N_2) \rightarrow 8CO_2 + 9H_2O + 15.6O_2 + 105.8N_2$$

(a) m_{air} = (2.25*12.5*4.76*28.97) = 3,878 kg

m_{fuel} = (8*12) + (18*1) = 114kg

AF ratio = m_{air} / m_{fuel} = (3,878 kg air)/(114 kg fuel)

= 34.0 kg air/kg fuel **Answer**

(b) T_{dp} of product = T_{sat} at P_{H2O} in product

Assume the products are ideal gases,

therefore: P_{H2O}/P = n_{H2O}/n

Number of kmol in products, n = 8 + 9 + 15.6 + 105.8

= 138.38 kmol

kmol of H_2O in products, n_{H2O} = 9 kmol

Therefore; P_{H2O} = $(n_{H2O}/n)P$

= (9/138.38)(100 kPa)

= 6.5041 kPa

Interporation: Table A-5

P (kPa)	*T (C)*
5	*32.88*
6.5041	*37.34*
7.5	*40.29*

ตรวจ	
รูป	1
Comb. eqn.	3
AF ratio	2
Tdp	3
สะอาด/เรียบร้อย	1

(b) the dew point temperature of the products, T_{dp} is 37.34 °C ***Answer***

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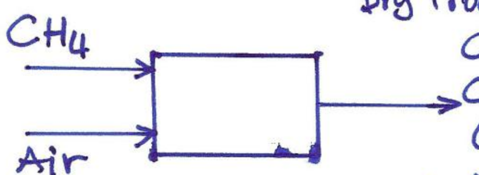
2) Methane (CH_4) is burned with dry air. The volumetric analysis of the products on a dry basis is 5.20 percent CO_2, 0.33 percent CO, 11.24 percent O_2, and 83.23 percent N_2. Determine (a) the air-fuel ratio and (b) the percentage of theoretical air used.

used. Answers: (a) 34.5 kg air/kg fuel, (b) 200 percent

Solution



Dry Prod. %V
$CO_2 = 5.2\%$
$CO = 0.33\%$
$O_2 = 11.24\%$
$N_2 = 83.23\%$

(a) AF = ? (b) %theor = ?

write combustion equation based on 100 kmol of dry products:

$$p\,CH_4 + q(O_2 + 3.76N_2) \rightarrow 5.2CO_2 + 0.33CO + r\,H_2O + 11.24O_2 + 83.23N_2$$

N_2 balance: $q = 83.23/3.76 = 22.14$

C balance: $p = (5.2 + 0.33) = 5.53$

H balance: $r = (4 \times 5.53)/2 = 11.06$

Check: O-LHS $= 2q = 44.27$ } OK

O-RHS $= (5.2\times2) + (0.33) + r + 11.24 = 44.27$

Divided by p, yields:

$$CH_4 + 4(O_2 + 3.76N_2) \rightarrow 0.94CO_2 + 0.06CO + 2H_2O + 2.03O_2 + 15.05N_2$$

(a) $AF = \dfrac{(4\times4.76)(28.97)}{(12+4)} = 34.5$ kg air/kg fuel Ans

(b) Stoichiometic combustion equation (100 x theor.air)

$$CH_4 + 2(O_2 + 3.76N_2) \rightarrow CO_2 + 2H_2O + 2\times3.76N_2$$

$$\%\text{theor. air} = \frac{AF_{actual}}{AF_{stoic}} = \frac{n_{O_2,actual}}{n_{O_2,stoic}}$$

$$= \frac{4}{2}\times100\% = 200\%$$ Answer

Sommai
14 January 2010

ตรวจ	
รูป	1
Comb. eqn.	3
AF ratio	2
%Theor.Air	3
สะอาด/เรียบร้อย	1

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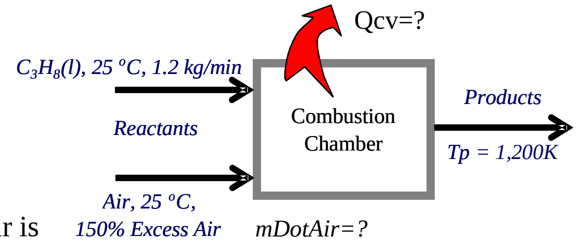
3) Liquid propane (C_3H_8) enters a combustion chamber at 25°C at a rate of 1.5 kg/min where it is mixed and burned with 50 percent excess air that enters the combustion chamber at 25°C. If the combustion is complete and the exit temperature of the combustion gases is 1200 K, determine (a) the mass flow rate of air (in kg/min) and (b) the rate of heat transfer from the combustion chamber (in kJ/min)

Solution



Theoretical combustion equation based on 1 kmol of fuel

C_3H_8 (l) + 5(O_2 + 3.76 N_2) → 3CO_2 + 4H_2O + 18.8 N_2

Combustion equation at 50% Excess Air or 150% theoretical air is

C_3H_8 (l) + (1.5*5)(O_2 + 3.76 N_2) → 3CO_2 + 4H_2O + 2.5O_2 + 28.2N_2

ตรวจ	
รูป	1
Comb. eqn.	2
AF ratio	1
Qdot	5
สะอาด/เรียบร้อย	1

(a) m_{air} = (7.5*4.76*28.97) = 1,034.2 kg

m_{fuel} = (3*12) + (8*1) = 44 kg

AF ratio = m_{air} / m_{fuel} = (1,034.2kg air)/(44kg fuel)

= 23.51 kg air/kg fuel

$m_{dot,\ air}$ = $m_{dot,\ fuel}$ AF = (1.5 kg/min)(23.51 kg air/kg fuel)

= 35.3 kg air/min Answer

(b) 1[st] Law: cv. Combustion Chamber, SSSF, neglect Wcv, ΔKE, ΔPE

$$Q_{CV} + H_R = H_P$$

because T_R *at 25 C then all* $\Delta h_i = 0$ *then* $H_R = \sum_R n_i(\bar{h}^o_f + \Delta\bar{h})_i = \bar{h}^o_{f,C_3H_8(l)}$

$$H_P = \sum_P n_e(\bar{h}^o_f + \Delta\bar{h})_e$$

Table A-26 enthalpy of formation of $C_3H_{8(g)}$, $\bar{h}^o_{f,C_3H_{8(g)}}$ = -103,850 kJ/kmol

Table A-26 enthalpy of vaporization of C_3H_8, $\bar{h}_{fg,C_3H_8}$ = 15,060 kJ/kmol

H_R = $\bar{h}^o_{f,C_3H_{8(l)}}$ = $h^o_{f,C_3H_{8(g)}}$ - $\bar{h}_{fg,C_3H_8}$ = -118,910 kJ/kmol

Calculation for H_R : Products: at 1200 K

Components	*n*	$\bar{h}^o_f$	$\bar{h}_{1200}$	$\bar{h}_{298}$	$\bar{h}_T - \bar{h}_{298}$	$n_e(\bar{h}^o_f + \Delta\bar{h})_e$
CO2	3.0	-393,520	53,848	9,364	44,484	-1,047,108
H2O	4.0	-241,820	44,380	9,904	34,476	-829,376
O2	2.5	-	38,447	8,682	29,765	74,413
N2	28.2	-	36,777	8,669	28,108	792,646
					$H_P = \sum_P n_e(\bar{h}^o_f + \Delta\bar{h})_e$	-1,009,426

Qcv = HP - HR = [(-1,009,426) – (118,910)] kJ/kmol fuel

= -890,516 kJ/kmol fuel

Qdot = mfuel (Qcv/M) = (1.5 kg/min)(-890,516 kJ/kmol fuel/44 kg/kmol)

the rate of heat transfer from the combustion chamber , **Qdot is 30,358 kJ/min**

Answer