Ex./PE/T/311/2017(OLD)(S)

BACHELOR OF POWER ENGINEERING EXAMINATION, 2017

(3rd Year, 1st Semester, Supplementary)

Combustion & Pollution (Old Syllabus)

Time : Three hours

Full Marks : 100

Answer any ***five*** questions.

1. a) Define equivalence ratio. How is it related to percentage theoretical air and percentage excess air? (2+6)

   b) Propane is burnt in excess air so that complete combustion of the fuel takes place. If the product gas analysis on dry basis shows 85% nitrogen by volume, what is the percentage of excess air supplied? What will be the nitrogen percentage in the product gas by mass and on wet basis? (12)

2. a) What is the difference between "enthalpy of formation" and "enthalpy of combustion" of a fuel? Enthalpy of formation of CO_2 is equal to the enthalpy of combustion of carbon – Justify. (4+4)

   b) Determine the adiabatic flame temperature when a furnace is operating at an air-fuel ratio of 16 (by mass) with fuel injected at reference temperature and air preheated to 600 K. Assume the following simplified thermodynamic properties: T_{ref}=300 K, $MW_{fuel}=MW_{air}=MW_{prod}$=29 kg/kmol, $c_{p,fuel}=c_{p,air}=c_{p,prod}$=1200 J/kg-K, $\bar{h}^0_{F_{air}} = \bar{h}^0_{F_{prod}} = 0$, $\bar{h}^0_{F_{fuel}} = 4\times10^7$ J/kg. (12)

3. a) Define equilibrium constant. Derive its relation with the standard state Gibbs function change in a reaction? (2+8)

   b) Carbon monoxide reacts with 150% theoretical air in a combustor to give products at high temperature and 1 atm pressure. If the relative concentration of CO and CO_2 in the product mixture is in the ratio of 3:5, find the value of the equilibrium constant for the CO oxidation process. If instead of air, 150% theoretical oxygen is used and the same temperature is maintained, what would have been the relative concentrations of CO and CO_2? (10)

4. a) Define the rate of a combustion reaction. What is specific reaction rate and how is it represented by the Arrhenius equation? What are the significances of the terms in the Arrhenius equation? (2+4+4)

   b) Ethylene (C_2H_4) – air mixture having equivalence ratio of 0.85 is burned in a steady state steady flow well stirred reactor. The flow rate of the reactant mixture is 1.8 kg/min and the volume of the reactor is 675 cm^3. The product gas analysis at the exit of the reactor shows 800 ppm ethylene by mass. Determine (i) the rate of reaction within the reactor, (ii) mass fractions of O_2 and CO_2 in the product gas from the reactor. Assume that the fuel, which has burned, burned completely. (10)

5. a) What is thickness of a laminar premixed flame? What are the zones in a laminar premixed flame? Explain the differences between these zones. (3+2+5)

   b) What do you mean by flash back and blow off of a premixed flame on a burner? When do you observe these two phenomena in a flame? (5+5)

6. a) Define burning velocity of a premixed fuel-air mixture. How does the burning velocity depend on the equivalence ratio of the mixture and why? (2+6)

   b) What do you mean by constant diameter burning of coal char? When is such burning relevant? Derive an expression for the char burn out time under this model. (2+2+8)

7. a) Discuss the adverse effects of the major combustion generated pollutants on environment and life. (10)

   b) Discuss the routes of formation of NO_x in combustion and the methods of controlling it. (10)

Table: 1 – Heat of formation and Heating Values

Species	Enthalpy of Formation (kJ/kmol)	Higher Heating Value (kJ/kg)	Lower Heating Value (kJ/kg)
CO_2	- 393520	-	
H_2O (v)	- 241820	-	
H_2O (l)	-285830	-	
CO	- 110530	-	
C_2H_6	- 84667	51901	47489
C_3H_8	- 103847	50368	46357
C_6H_6 (g)	82930	42270	40580
C_8H_{18} (g)	-208450	48260	44790

Table-2: $\Delta h = \left(h_T^0 - h_{298}^0\right)$ at different temperatures for species

Temperature (K)	$\Delta h = \left(h_T^0 - h_{298}^0\right)$ (kJ/kmol)				
	CO_2	CO	H_2O	O_2	N_2
298	0	0	0	0	
500	8,301	5,943	6,947	6,097	0
800	22,810	15,176	18,005	15,838	5,920
1000	33,425	21,697	25,993	22,721	15,046
1500	61,681	38,847	48,181	40,590	21,468
2000	91,420	56,737	72,805	59,169	38,404
					56,130