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Génie mécanique

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Faculty of Engineering
Mechanical Engineering

MCG2175 - THERMODYNAMICS II

Mid-term Examination
15 February 2007
Prof. W. Hallett

Time: 75 minutes

Closed Book

1. (12 marks total) Descriptive questions - no calculations required.
(a) (6 marks) Sketch a psychrometric chart, labelling the axes and showing on it
(i) the saturation line; (ii) a humidification process using cool liquid water; (iii) a heating process.
For (ii) and (iii), state what variable(s) remain constant during the process.

(b) (6 marks) A moist air mixture is initially at a given pressure, temperature and relative humidity. The mixture is then compressed while the temperature remains constant. State what happens to
(i) the relative humidity; (ii) the specific humidity; (iii) the partial pressure of water vapour.
Give reasons for your answers.

2. (28 marks total) Propane heaters are often used on construction sites, and they usually discharge their combustion products directly to the space being heated. The sketch shows such a heater discharging its exhaust to a 300 m^3 room. The possibility of dangerous levels of carbon monoxide arising is a cause for concern.

(a) (10 marks) The heater burns propane (C_3H_8) in air (3.76 kmol N_2/kmol O_2), and the exhaust contains 9% CO_2 and 0.3% CO by volume on a dry basis. Determine the product composition in kmols of each product species per kmol of fuel and in mol fraction (ie kmol of each species per kmol of products).

(b) (3 marks) Determine the mass fraction of CO in the products. The molecular masses of product species are: CO_2: 44 kg/kmol; H_2O: 18 kg/kmol; CO: 28 kg/kmol; O_2: 32 kg/kmol; N_2: 28 kg/kmol.

(c) (2 marks) If the heater burns 5 kg/hr of propane, determine the total product flow rate in kmol/hr. The molecular mass of propane is 44 kg/kmol.

(d) (8 marks) Leaks in the building cause dry air at 0°C and 101.3 kPa to enter at a rate of 500 m^3/hr. Assuming that the air can be considered to enter at one place (point 1 on the diagram) and to leave at point 3 on the diagram after mixing with the heater exhaust, calculate the mol fraction of CO at point 3. If the maximum allowable long-term exposure level for CO is a volume fraction of 0.01%, is there a danger to health? The universal gas constant is 8.314 kJ/kmol K.

(e) (5 marks) Determine the partial pressure of water vapour at the exit (point 3), and state whether water will condense on a surface at 10°C. What is the dew point of the gas at point 3?

Saturation pressure of water:

T (°C)	0	5	10	15	20
P_{SAT} (kPa)	0.610	0.8721	1.2276	1.7051	2.339

Total marks for this paper: 40

Solutions to midterm:

2. (a) Stoichiometric equation balanced for 100 kmol dry products is

$$3.10\ C_3H_8 + 22.28\ (O_2 + 3.76\ N_2) = 9\ CO_2 + 12.4\ H_2O + 0.3\ CO + 6.93\ O_2 + 83.77\ N_2$$

Divide by a to get product quantities per kmol fuel; divide by total product quantity to get mol fraction:

	CO_2	H_2O	CO	O_2	N_2
Quantity kmol/kmol fuel	2.90	4.00	0.10	2.24	27.02
x_i	0.0801	0.1103	0.0027	0.0616	0.7453

(b) $Y_{CO} = x_{CO}\ M_{CO} / M$, and $M = \Sigma x_i\ M_i = 28.42$ kg/kmol, so $Y_{CO} = 0.0026$.

(c) Total product quantity per kmol of fuel = 36.26 kmol, so product flow rate is

$$\dot{n}_2 = \frac{\dot{m}_{FUEL}}{M_{FUEL}}\ (kmol\ fuel/hr) \times n_{PRODUCTS}\ (kmol/kmol\ fuel) = 4.120\ kmol/hr$$

(d) Mol balance:

$$\dot{n}_1\, x_{1\,CO} + \dot{n}_2\, x_{2\,CO} = (\dot{n}_1 + \dot{n}_2)\, x_{3\,CO}$$

or since $x_{1\,CO} = 0$,

$$x_{3\,CO} = x_{2\,CO}\, \dot{n}_2 / (\dot{n}_1 + \dot{n}_2)$$

Air mol flow rate

$$\dot{n}_1 = P_1\, \dot{V}_1 / (\bar{R}\, T_1) = 22.31\ kmol/hr$$

then $x_{3\,CO} = 4.16 \cdot 10^{-4}$, which is above the allowable limit, and in fact is sufficient to produce symptoms of poisoning such as headache and nausea in less than an hour.

(e) Balance for CO also holds for water, giving $x_{3\,H2O} = 0.0172$ and $p_V = 1.742$ kPa. Interpolation in the steam table gives $T_{DP} = 15.6°C$, which is greater than 10°C, so that condensation occurs.