JQ.3.2.Soln

October 6, 2014

(3.2) Propane and air are supplied to a combustion chamber so that 20 g/s of propane reacts. the reaction forms $H_2O, CO_2, $ and CO where the molar ratio of CO to CO_2 is 0.1. The exhaust gases flow at a rate of 360 g/s. Assuming the process is steady and conditions are uniform at the exit, compute the exit mass fraction of the CO.

Setup:

First sketch a three port reactor with fuel and air inlets and a product outlet. Recognize that the three port system also represents a chemical reaction. The fuel flow rate is greater than or equal to 20 g/s.

Balance the stoichiometric case using the constraint relationship between CO_2 and CO.

$$C_3H_8 + a(O_2 + 3.76N_2) \rightarrow bCO_2 + dH_2O + fN_2 + eCO$$

$C : 3 = b + e;\ H : 8 = 2d;\ O : 2a = 2b + d + e;\ e = 0.1 \times b;\ f = 3.76 \times a$

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In [46]: b=3./1.1; d=8./2.; e=0.1*b; a=(2.*b+d+e)/2.; f=3.76*a; a

Out[46]: 4.863636363636363
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$$C_3H_8 + 4.86(O_2 + 3.76N_2) \rightarrow 2.73CO_2 + 4H_2O + 17.78N2 + 0.27CO$$

For the stoichiometric case, we calculate how much air will be required to consume 20 g/s of propane.

The mass of air per mass of fuel is $4.73 \times 4.76 \times 28.8$ grams of air per 44 grams of fuel.

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In [47]: AF=a*4.76*28.8/44.; AF

Out[47]: 15.153322314049586
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The Air to Fuel ratio is 15.15. The mass of air required for 20 g/s of fuel is 15.15×20.

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In [48]: AF*20.

Out[48]: 303.0664462809917
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The mass flow rate of stoichiometric air is 295 g/s. The total flow rate of fuel and stoichiometric air is $303+20 = 323g/s$. An additional $37g/s$ of either fuel or air must have been available to the reactor. Because one of the products is CO, we might assume that reaction was actually fuel rich. The answer would not change if we assumed thet the additional $37g/s$ had been air.

$$C_3H_8 + 4.86(O_2 + 3.76N_2) + A(O_2 + 3.76N_2) \rightarrow 2.73CO_2 + 4H_2O + 17.78N2 + 0.27CO + A(O_2 + 3.76N_2)$$

We find A by assuming that the air flow rate must be $340g/s$. The additional $37g/s$ will come from the exces air. $340 = AF_{LN} \times 20$.

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In [49]: AF_LN=340./20.; M_AIR=AF_LN*44.; M_AIR_EXCESS= M_AIR-a*4.76*28.8; M_coeff_AIR_EXCESS=M_AIR_EXC

Out[49]: 0.5927128427128432
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$$C_3H_8 + 4.86(O_2 + 3.76N_2) + 0.59(O_2 + 3.76N_2) \rightarrow 2.73CO_2 + 4H_2O + 17.78N2 + 0.27CO + 0.59(O_2 + 3.76N_2)$$

For every mole of fuel we produce 0.27 mole of CO. The mass ratio of product CO to fuel burned is $\frac{0.27\times28}{44}$. The mass flow rate of CO is $\frac{20\times0.27\times28}{44}$

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In [52]: mdot_CO=20.*0.27*28./44.; Y_CO=mdot_CO/360.; Y_CO
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Out[52]: 0.009545454545454548
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We find that the CO mass fraction in the product gases is 0.01.