

PART 1 - A

Equations

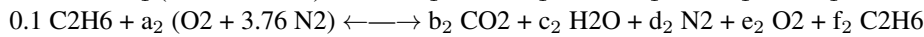
$$\text{function } getenthalpy(S\$, T) \quad (1)$$

This function uses the NASA external procedure to return the enthalpy of species S\$ at T.

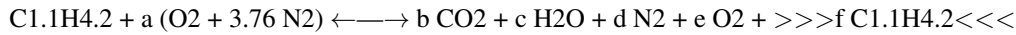
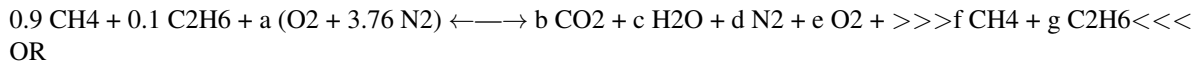
$$\text{call } NASA(S\$, T : cp, geTenthalpy, s) \quad (2)$$

$$\text{end } getenthalpy \quad (3)$$

Considering that for this segment, the equilibrium equations are not given to us, we assume the only tool in our disposal for figuring out the mole fractions in the products in conservation of mass.



this form of the equation too is sufficiently good enough if we use $HR_1 + HR_2 = HP_1 + HP_2$, but if we change our energy equation to $HR_1 = HP_1$ & $HR_2 = HP_2$ meaning we assume that the two combustion reactions are completely isolated from each other (there is no heat exchange between them). here we are finally able to solve for our mole fractions only after removing O₂ from our products. I did not opt for this solution however as it seemed to make one assumption too many. Thus we arrive to the solution I found the most satisfying:



by combining the CH₄ and the C₂H₆ fuels into a hybrid C_{1.1}H_{4.2} (just as how we did it for natural gas) our equation is finally solveable. the only downside is that we cannot determine that in our unburnt fuel what percentage is CH₄ and what amount of it belongs to C₂H₆, but since our problem only is only concerned with input air, I found this to be an acceptable compromise

$$T_{air} = 460 \text{ [K]} \quad (4)$$

$$T_{fuel} = 430 \text{ [K]} \quad (5)$$

$$T_{final,1} = 1700 \text{ [K]} \quad (6)$$

$$T_{final,2} = 1600 \text{ [K]} \quad (7)$$

$$T_{final,3} = 1300 \text{ [K]} \quad (8)$$

$$h_{N_2,inlet} = getenthalpy('N_2', T_{air}) \quad (9)$$

$$h_{O_2,inlet} = getenthalpy('O_2', T_{air}) \quad (10)$$

$$h_{CH_4,inlet} = getenthalpy('CH_4', T_{fuel}) \quad (11)$$

$$h_{C_2H_6,inlet} = getenthalpy('C_2H_6', T_{fuel}) \quad (12)$$

$$h_{fuel,inlet} = 0.9 \cdot h_{CH_4,inlet} + 0.1 \cdot h_{C_2H_6,inlet} \quad (13)$$

Stoichiometry for a basis of 1 kmol of fuel

$$1.1 = b \quad \text{Carbon balance} \quad (14)$$

$$4.2 = 2 \cdot c \quad \text{Hydrogen balance} \quad (15)$$

$$\text{duplicate } i = 1, 3 \quad (16)$$

Stoichiometry for a basis of 1 kmol of fuel - Continued

$$2 \cdot a_i = 2 \cdot b + c + 2 \cdot e_i \quad \text{Oxygen balance} \quad (17)$$

$$3.76 \cdot 2 \cdot a_i = 2 \cdot d_i \quad \text{Nitrogen balance} \quad (18)$$

The following equations provide the enthalpy for each chemical species at the inlet temperatures and T_{final} and the reference pressure of 10 bar. The NASA external procedure is used in the Function `getenthalpy` to calculate h at the equilibrium temperature, which is determined from an energy balance.

$$h_{CO_2,i} = \text{getenthalpy}('CO_2', T_{final,i}) \quad (19)$$

$$h_{H_2O,i} = \text{getenthalpy}('H_2O', T_{final,i}) \quad (20)$$

$$h_{N_2,i} = \text{getenthalpy}('N_2', T_{final,i}) \quad (21)$$

$$h_{O_2,i} = \text{getenthalpy}('O_2', T_{final,i}) \quad (22)$$

$$h_{CH_4,i} = \text{getenthalpy}('CH_4', T_{final,i})$$

$$h_{C_2H_6,i} = \text{getenthalpy}('C_2H_6', T_{final,i})$$

$h_{fuel,i} = 0.9 \cdot h_{CH_4,i} + 0.1 \cdot h_{C_2H_6,i}$ truly accurate if our fuels burn at a rate proportional to their initial molar fraction, but is servisable enough as an estimate

Find the enthalpy of the reactants

$$HR_i = h_{fuel,inlet} + a_i \cdot h_{O_2,inlet} + 3.76 \cdot a_i \cdot h_{N_2,inlet} \quad (23)$$

Find the enthalpy of products

$$HP_i = b \cdot h_{CO_2,i} + c \cdot h_{H_2O,i} + d_i \cdot h_{N_2,i} + e_i \cdot h_{O_2,i} \quad (24)$$

Apply an adiabatic energy balance to determine the product temperature

$$HR_i = HP_i \quad (25)$$

$$\text{end} \quad (26)$$

1 kmol of fuel weighs the same as 0.9 kmol of CH₄ and 0.1 kmol of C₂H₆, = 0.9 * 16.043 + 0.1 * 30.07 = 17.4457 kg/kmol, so 0.07 kg/s fuel equals to 0.0040124501 kmol/s of fuel.

and as 1 kmol of air weighs 28.97 kg/kmol, then a kmols of air per 1 kmol of fuels equals [0.0040124501*28.97]*a = 0.1162406782*a kg/s of air for 0.07 kg/s fuel

$$\dot{m}_1 = (1 + 3.76) \cdot a_1 \cdot 0.1162406782 \text{ [kg/s]} \quad (27)$$

$$\dot{m}_1 + \dot{m}_2 = (1 + 3.76) \cdot a_2 \cdot 0.1162406782 \text{ [kg/s]} \quad (28)$$

$$\dot{m}_1 + \dot{m}_2 + \dot{m}_3 = (1 + 3.76) \cdot a_3 \cdot 0.1162406782 \text{ [kg/s]} \quad (29)$$