

MCG2131 Midterm 2015 - Solutions

Version A

1. (a) $p_V = \phi P_{SAT}$, $P_{SAT} = 2.339$ kPa, $p_V = 1.1695$ kPa, and $\omega_1 = 0.00729$ kg/kg dry air

By interpolation in the steam table, $T_{DP} = 9.2^\circ\text{C}$.

(b) $m_a = V p_{a1} / R_a T_1$ and $p_a = P - p_V$, so that $m_a = 11.87$ kg dry air/s

(c) Since water condenses, final state is saturated, and by definition $\phi_2 = 100\%$

then $p_{V2} = P_{SAT} = 7.384$ kPa and $\omega_2 = 0.00463$ kg/kg dry air

water balance: $m_a \omega_1 = m_a \omega_2 + m_W$, from which $m_W = 0.0316$ kg/s

(d) steady flow first law, neglect PE and KE:

$$Q + m_a h_{A1} = W + m_a h_{A2} + m_W h_f$$

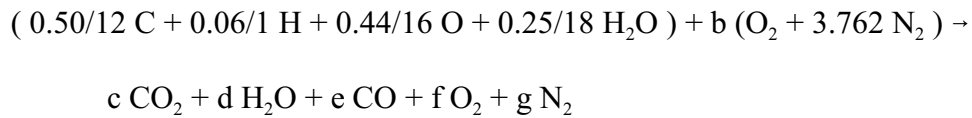
$$h_{A1} = c_{Pa} (T - T_{REF}) + \omega_1 h_g = 58.65 \text{ kJ/kg dry air } (h_g = 2538.1 \text{ kJ/kg})$$

$$h_{A2} = 72.15 \text{ kJ/kg dry air } (h_g = 2574.3 \text{ kJ/kg})$$

$$h_f = 167.57 \text{ kJ/kg}$$

and $Q = -134$ kW (note that W is negative!)

2. (a) Stoichiometric combustion:



- for stoichiometric combustion, $e = f = 0$

- balances give $c = 0.04167$, $d = 0.04389$, and $b_{\text{STOICH}} = 0.04292$ kmol/kg dry fuel

(b) Actual combustion: $b = 1.30 b_{\text{STOICH}}$

Re-balance equation, again with $a = 1$ kg. Coefficient e is still $= 0$, since no information is given on CO.

$c = 0.04167$, $d = 0.04389$, $f = 0.01287$, and $g = 0.20989$ kmol / kg dry fuel

(c) Energy balance with HHV:

$$Q + m_{\text{FUEL}} \text{ HHV} + \sum (n_i \Delta h_i)_{\text{REACTANTS}} = \sum (n_i \Delta h_i)_{\text{PRODUCTS}} + n_{\text{H}_2\text{O VAP}} h_{\text{fg}}$$

$$\sum_{\text{REACTANTS}} = 0 (25^\circ\text{C}); \sum_{\text{PRODUCTS}} = 980.8 \text{ kJ/kg dry fuel}$$

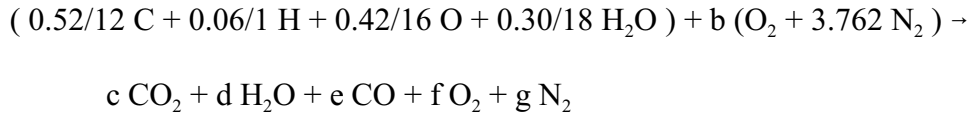
$$Q = -17.09 \text{ MJ/kg dry fuel}, \eta = |Q| / \text{HHV} = 85.4\%$$

$$(d) V = (\sum n_{i\text{PROD}}) \bar{R} T_{\text{PROD}} / P = 10.15 \text{ m}^3 / \text{kg dry fuel}$$

MCG2131 Midterm 2015 - Solutions

Version B

1. (a) Stoichiometric combustion:



- for stoichiometric combustion, $e = f = 0$

- balances give $c = 0.04333$, $d = 0.04667$, and $b_{\text{STOICH}} = 0.04521$ kmol/kg dry fuel

(b) Actual combustion: $b = 1.35 b_{\text{STOICH}} = 0.06103$ kmol/kg dry fuel

Re-balance equation, again with $a = 1$ kg. Coefficient e is still $= 0$, since no information is given on CO.

$c = 0.04333$, $d = 0.04667$, $f = 0.0158$, and $g = 0.2296$ kmol / kg dry fuel

(c) Energy balance with HHV:

$$Q + m_{\text{FUEL}} \text{ HHV} + \sum (n_i \Delta h_i)_{\text{REACTANTS}} = \sum (n_i \Delta h_i)_{\text{PRODUCTS}} + n_{\text{H}_2\text{O VAP}} h_{\text{fg}}$$

$$\sum_{\text{REACTANTS}} = 0 (25^\circ\text{C}); \sum_{\text{PRODUCTS}} = 2136.4 \text{ kJ/kg dry fuel}$$

$$Q = -16.81 \text{ MJ/kg dry fuel}, \eta = |Q| / \text{HHV} = 80.05\%$$

$$(d) V = (\sum n_{i\text{PROD}}) \bar{R} T_{\text{PROD}} / P = 13.81 \text{ m}^3 / \text{kg dry fuel}$$

2. (a) $p_V = \phi P_{SAT}$, $P_{SAT} = 3.169$ kPa, $p_V = 1.2676$ kPa, and $\omega_1 = 0.00791$ kg/kg dry air

By interpolation in the steam table, $T_{DP} = 10.4^\circ\text{C}$.

(b) $m_a = V p_{a1} / R_a T_1$ and $p_a = P - p_V$, so that $m_a = 58.3$ kg dry air/s

(c) Since water condenses, final state is saturated, and by definition $\phi_2 = 100\%$

then $p_{V2} = P_{SAT} = 7.384$ kPa and $\omega_2 = 0.00579$ kg/kg dry air

water balance: $m_a \omega_1 = m_a \omega_2 + m_W$, from which $m_W = 0.1231$ kg/s

(d) steady flow first law, neglect PE and KE:

$$Q + m_a h_{A1} = W + m_a h_{A2} + m_W h_f$$

$$h_{A1} = c_{Pa} (T - T_{REF}) + \omega_1 h_g = 65.32 \text{ kJ/kg dry air } (h_g = 2547.2 \text{ kJ/kg})$$

$$h_{A2} = 75.16 \text{ kJ/kg dry air } (h_g = 2574.3 \text{ kJ/kg})$$

$$h_f = 167.57 \text{ kJ/kg}$$

and $Q = -606$ kW (note that W is negative!)

MCG2131 Midterm 2015 - Solutions

Version C

1. (a) $p_V = \phi P_{SAT}$, $P_{SAT} = 1.705$ kPa, $p_V = 1.023$ kPa, and $\omega_1 = 0.00636$ kg/kg dry air

By interpolation in the steam table, $T_{DP} = 7.1^\circ\text{C}$.

(b) Since water condenses, final state is saturated, and by definition $\phi_2 = 100\%$

then $p_{V2} = P_{SAT} = 7.384$ kPa and $\omega_2 = 0.00385$ kg/kg dry air

water balance: $m_a \omega_1 = m_a \omega_2 + m_w$, from which $m_w = 0.0152$ kg/s

(c) $m_a = V p_{a1} / R_a T_1$ and $p_a = P - p_V$, so that $m_a = 6.046$ kg dry air/s

(d) steady flow first law, neglect PE and KE:

$$Q + m_a h_{A1} = W + m_a h_{A2} + m_w h_f$$

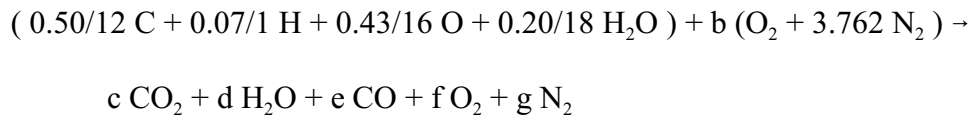
$$h_{A1} = c_{Pa} (T - T_{REF}) + \omega_1 h_g = 51.24 \text{ kJ/kg dry air } (h_g = 2528.9 \text{ kJ/kg})$$

$$h_{A2} = 70.15 \text{ kJ/kg dry air } (h_g = 2574.3 \text{ kJ/kg})$$

$$h_f = 167.57 \text{ kJ/kg}$$

and $Q = -33.1$ kW (note that W is negative!)

2. (a) Stoichiometric combustion:



- for stoichiometric combustion, $e = f = 0$

- balances give $c = 0.04167$, $d = 0.04611$, and $b_{\text{STOICH}} = 0.04573$ kmol/kg dry fuel

(b) Actual combustion: $b = 1.30 b_{\text{STOICH}} = 0.05716$ kmol/kg dry fuel

Re-balance equation, again with $a = 1$ kg. Coefficient e is still $= 0$, since no information is given on CO.

$c = 0.04167$, $d = 0.04611$, $f = 0.01143$, and $g = 0.2150$ kmol / kg dry fuel

(c) Energy balance with HHV:

$$Q + m_{\text{FUEL}} \text{ HHV} + \sum (n_i \Delta h_i)_{\text{REACTANTS}} = \sum (n_i \Delta h_i)_{\text{PRODUCTS}} + n_{\text{H}_2\text{O VAP}} h_{\text{fg}}$$

$$\sum_{\text{REACTANTS}} = 0 (25^\circ\text{C}); \sum_{\text{PRODUCTS}} = 2005.9 \text{ kJ/kg dry fuel}$$

$$Q = -15.97 \text{ MJ/kg dry fuel}, \eta = |Q| / \text{HHV} = 79.8\%$$

$$(d) V = (\sum n_{i\text{PROD}}) \bar{R} T_{\text{PROD}} / P = 12.93 \text{ m}^3 / \text{kg dry fuel}$$