

AAE439 Test #1 Solns

Fa 2011

1.3
20pts

$$E = 40 \quad \gamma = 1.4 \quad C_{fu} = 1.721$$

$$\text{Target } I_{sp} = \frac{I}{m_p} = \frac{10,000}{1.00} = \frac{100}{6.7} \text{ s.u.}$$

$$\text{Required } c^* = \frac{g I_{sp}}{C_{fu}} = \frac{1860 \cdot 1248}{1.721} \text{ f/s}$$

$$c^* = \sqrt{\frac{\gamma R T_c}{\gamma M}} \left(\frac{\gamma}{\gamma-1}\right)^{\frac{\gamma-1}{2(\gamma-1)}}$$

$$= \left[\frac{1545 \frac{\text{ft}}{\text{op}}}{28 \cdot 1.4} \cdot 32.2 \frac{\text{ft}}{\text{s}^2} T_c \right]^{\frac{1}{2}} \left(\frac{\gamma}{\gamma-1}\right)^{-\frac{1.2}{0.4}}$$

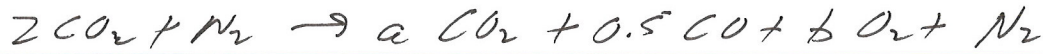
$$\frac{1860}{1.721} = 1.721 \left[126.9 T_c \right]^{\frac{1}{2}}$$

1248

$$T_c = 910 \text{ R} \quad (450^\circ\text{F})$$

410 (-50°F)

40 pts 20



mass balances

Carbon $2 = a + 0.5 \Rightarrow a = 1.5$

Oxygen $4 = 2a + 0.5 + 2b \quad b = \frac{4 - 3.5}{2} = 0.25$

mole fractions

$$m_f = a + 0.5 + b + 1 = 3.25$$

$$x_{\text{CO}_2} = 1.5/3.25 \quad x_{\text{CO}} = 0.5/3.25 \quad x_{\text{O}_2} = 0.25/3.25 \quad x_{\text{N}_2} = \frac{1}{3.25}$$

Dissociation Rxn



$$K_p = \frac{x_{\text{CO}} \sqrt{x_{\text{O}_2}}}{x_{\text{CO}_2}} \sqrt{P} = \frac{0.5 \sqrt{0.25}}{\sqrt{3.25} \cdot 1.5} \sqrt{10} = 0.292$$

From Table 3.2

$$K_p = K_{p9} / K_{p10} = 0.292$$

\textcircled{a} $\frac{2750}{3500} K \quad K_p = \frac{1.184 \cdot 0.45}{2.811 \cdot 3.3} = 0.15$
 \textcircled{b} $\frac{3750}{3000} K \quad K_p = \frac{9.15 \cdot 2.6}{3.120 \cdot 2.7} = 2.92$

interpolating

$$T = 3512 K$$

Mass fractions

$$m_f = 1.5(44) + 0.5(28) + 0.25(32) + 28 = 116$$

$$y_{\text{CO}_2} = m_{\text{CO}_2} / m_f = 0.57 \quad y_{\text{CO}} = \frac{14}{116} = 0.12$$

$$y_{\text{O}_2} = 8/116 = 0.07 \quad y_{\text{N}_2} = 28/116 = 0.24$$

(ii) Since $T = \text{const}$ $K_p = \text{const} = \frac{\sqrt{x_{\text{O}_2}} x_{\text{CO}}}{x_{\text{CO}_2}} \sqrt{P}$
 since P decreases dissociation increases CO , O_2 increase
 and CO_2 decreases. N_2 unaffected.



$$n_f = 3.5$$

$K_p = \text{same as before} = 0.292 = \frac{1 \sqrt{0.5}}{\sqrt{3.5}} \sqrt{P}$

$$P = 0.6 \text{ atm}$$

3. Plug n_f is altitude compensating, implying that plume expansion adjusts to local P_a . Best estimate (upper bound) is to assume optimal expansion at all altitudes i.e. $\zeta = \zeta_{opt}$

30 4. i $P_{a\text{jet}} = P_{at} + \rho gh = 0.1 \times 10^6 + 1020 \cdot 9.8 (5) = 150 \text{ kPa}$

5 $\frac{P_e}{P_c} = \frac{P_{a\text{jet}}}{P_c} = 0.03 \quad \begin{matrix} C_f \text{ Tabh} \\ \xrightarrow{J=1.2} \end{matrix} \quad \epsilon \approx 5 \quad C_{f\text{opt}} = 1.48$

5 $I_{sp} = \frac{C_f C^*}{g} = 241 \text{ sec}$

5 $\dot{m}_i = \frac{F}{g I_{sp}} = \frac{4000}{9.8 \cdot 241} = 1.69 \text{ kg/s}$

(ii) $A_t = \frac{\dot{m}_i C^*}{P_c} = 5.4 \times 10^{-4} \text{ m}^2 = 5.4 \text{ cm}^2$

8 $D_t = \sqrt{\frac{4A_t}{\pi}} = 2.62 \text{ cm} \quad D_e = \sqrt{\epsilon} D_t = 5.86 \text{ cm}$

(iii) To increase D_e must decrease P_c - unfortunately ϵ also decreases in process

7 ~~40~~ Guess $\epsilon = 3 \quad P_c = P_e / 0.0656 = 2.29 \text{ MPa} \quad C_{f\text{opt}} = 1.34$

Then

$I_{sp} = 222 \text{ sec} \quad \dot{m}_i = 1.84 \text{ kg/s} \quad A_t = 12.8 \text{ cm}^2$

$D_t = 4.0 \text{ cm} \quad D_e = 7 \text{ cm} \quad \text{Close - need lower } \epsilon, P_c$

↳ continue ---