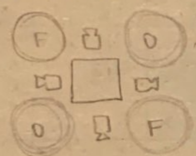
Name: Veronica Loomis
Problem 8.4

Given: N_2O_4 / MMH propellant combo
Equal volumes for both fuel & oxidizer tanks
Payload mass = 10 kg
I_{sp} = 300 sec
Required divert Δv = 1000 m/s
$\lambda = 0.5$

Find.: a) propellant mixture ratio
b) total propellant mass required
c) radius of spherical tanks
d) tank wall thickness if P_{burst} = 5 MPa and is titanium

Schematic:



Assumptions:
Each tank has same volume
Keep grav in Δv eq so units work
Thin wall tanks
$\rho_{ox} = 1440\ kg/m^3$
$\rho_f = 880\ kg/m^3$
googled

Basic Equations:

$$r = m_{ox}/m_f, \quad \rho = m/V, \quad MR = \frac{m_o}{m_f}, \quad m_o = m_{PL} + m_p + m_i, \quad \lambda = \frac{m_p}{m_p + m_i}$$

$$V_{sph} = \frac{4}{3}\pi R^3, \quad \Delta v = I_{sp} \ln\left(\frac{m_o}{m_f}\right), \quad m_p = m_{PL}\left(\frac{MR-1}{MR-(MR-1)/\lambda}\right)$$

$$t_c = P_t R/\sigma_w, \quad \sigma_w = \min(F_{ty}/1.1, F_{tu}/1.25)$$
↳ or 1.4

Analysis:

a) Propellant mixture ratio

$$\Delta v = g I_{sp} \ln\left(\frac{m_o}{m_f}\right) \longrightarrow \frac{m_o}{m_f} = e^{\Delta v / g I_{sp}}$$

$$\frac{m_o}{m_f} = e^{(1000\ m/s)/(9.81\ m/s^2)(300\ s)}$$

$$\boxed{\frac{m_o}{m_f} = 1.4 = MR}$$

b) Total propellant mass required

$$m_p = m_{PL}\left(\frac{MR-1}{MR-(MR-1)/\lambda}\right) = 10\left(\frac{0.4}{1.4 - \frac{0.4}{0.5}}\right)\ kg$$

$$\boxed{m_p = 6.67\ kg}$$

c) Radius of spherical tanks

know $m_p = 6.67\ kg$

need $r = \frac{m_{ox}}{m_f}$

have $\rho_{ox} = \frac{m_{ox}}{V_{ox}}$ & $\rho_f = \frac{m_f}{V_f}$

told $V_f = V_{ox}$

$\therefore$ we can say $\frac{\rho_{ox}}{\rho_f} = \frac{m_{ox}}{m_f}$

$\rho_{ox}/\rho_f = 1440/880 = 1.636 = r$

$m_f = \frac{m_p}{1+r} = 2.53\ kg$

$m_{ox} = r m_f = 4.14\ kg$

$$\left.\begin{array}{l} V_f = \frac{m_f}{\rho_f} = 0.002875\ m^3 \\ V_{ox} = \frac{m_{ox}}{\rho_{ox}} = 0.002875\ m^3 \end{array}\right\}$$ yes they are the same

$R = \sqrt[3]{\frac{3V}{4\pi}} = \sqrt[3]{\frac{3(0.002875 m^3)}{4\pi}}$

$\boxed{R = 0.0882\ m}$

d) Tank wall thickness

$t_c = \frac{P_{t(max)} R}{\sigma_w}$ $P_t = 5MPa$

$\sigma_w = \min\left(\frac{\text{yield}}{1.1}, \frac{\text{ult tens. strength}}{1.4}\right)$ look up for titanium

$\sigma_w = \min\left(\frac{241 MPa}{1.1}, \frac{1400 MPa}{1.4}\right) = 219.1\ MPa$

$t_c = \frac{5(0.0882)}{219.1} \frac{MPa\ m}{MPa}$

$\boxed{t_c = 0.00201\ m = 2.01\ mm}$

Comments:

The wall thickness is allowed to be SUPER thin because of the material.

I also realized afterwards that (c) could just have been $V = \frac{m_p}{\rho_f + \rho_{ox}}$ ... but i guess it was good to make sure $V_f = V_{ox}$ like we assumed.

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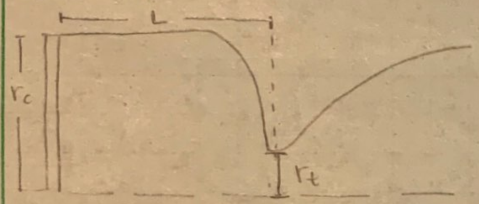
Name: Veronica Loomis
Problem 8.6

Given: LOX & Ethanol
$c^* = 5900$ ft/s
$\gamma = 1.2$
$F_v = 30000$ lbf
$\varepsilon = 50$
$P_c = 1200$ psi
$M \leq 0.1$
$L^* = 40$ inches - char. chamber dim.

Find: a) Isp
b) r_t
c) r_c
d) L (chamber)

Schematic:



Assumptions:
Purdue tables

~~Analysis~~: Basic Equations:

$$I_{sp} = \frac{C_{fv} \cdot c^*}{g}, \quad F_v = C_{fv} P_c A_t, \quad A_c = (N_{ox} + N_{fuel}) / N_D$$

$$\varepsilon_c = A_c / A_t \qquad \frac{A_i}{A_t} = \frac{1}{M}\left[\frac{2+(\gamma-1)M^2}{\gamma+1}\right]^{(\gamma+1)/2(\gamma-1)}$$

$$L^* = \frac{V_c}{A_t}$$

Analysis:

a) Isp

$$I_{sp} = \frac{C_{fv} \cdot c^*}{g}$$

Using $\gamma = 1.2$, $\varepsilon = 50$
$C_{fv} = 1.90236$

$$I_{sp} = \frac{(1.90236)(5900 \text{ ft/s})}{32.2 \text{ ft/s}^2}$$

$$\boxed{I_{sp} = 348.57 \text{ sec}}$$

b) r_t

$F_v = C_{Fv} P_c A_t$

$A_t = \frac{F_v}{C_{Fv} P_c} = \frac{30\,000 \text{ lbf}}{(1.90236)(1200 \text{ lbf/in}^2)}$

$A_t = 13.14 \text{ in}^2$

$r_t = \sqrt{A_t/\pi}$

$\boxed{r_t = 2.045 \text{ in}}$

c) r_c $(M=0.1)$

$A_c = A_t \left(\frac{1}{0.1} \left[\frac{2 + (0.2)(0.1)^2}{2.2} \right]^{2.2/0.4} \right)$

$A_c = 78.22 \text{ in}^2$

$r_c = \sqrt{A_c/\pi}$

$\boxed{r_c = 5.0 \text{ in}}$

d) L (chamber)

$L^* = V_c/A_t$

$L^* = \frac{\pi r_c^2 L_c}{A_t}$

$L_c = \frac{L^* A_t}{\pi r_c^2} = \frac{40 \text{ in } (13.14 \text{ in}^2)}{\pi \ (5.0 \text{ in})^2}$

$\boxed{L_c = 6.69 \text{ in}}$

Comment

$r_c > r_t$ → expected

L_c is close to r_c

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SP05A

Name Veronica Loomis

Given:	Mixture Ratio	5.5
	Area Ratio	16
	Oxidizer	LOX
	Fuel	LH

Find	Tc
	C*
	M
	Isp, v

Analysis

Pc (Bar)	OF	**T (K)**	**MW**	**CSTAR (m/s)**	ISPV (m/s)	**ISP(sec)**
40	16	1563.140259	22.72205925	1710	3120.118408	318.0548836
50	16	1559.670044	22.72236633	1712	3121.952393	318.2418341
60	16	1556.937988	22.72259521	1714	3123.390137	318.3883931
80	16	1552.812744	22.72292328	1717	3125.551025	318.6086672
100	16	1549.766479	22.72314835	1719	3127.138916	318.7705317

Name: Veronica Loomis_____________

Two-Page Annotated Bibliography Template

A. Summarize

Reference Document Examined:	Schulte, G., "Fuel Regression and Flame Stabilization Studies of Solid-Fuel Ramjets," *AIAA Journal of Propulsion and Power*, VOL. 2, NO. 4, July-August, 1986.
Reviewer:	Veronica Loomis
Source of Document:	Canvas
Date of Review:	March 8, 2023
Electronic File Name:	1986_Schulte_JPP_2_4.pdf

Summary:

This paper analyzes fuel regression and flame stabilization in solid fuel ramjets. This was tested by varying flight speed, altitude, chamber pressure, air mass flux, and inlet temperature over wide ranges. The aim was to minimize the ratios of the fuel port to nozzle throat area and the fuel port to injector area.

B. Assess:

Important Facts from Document:

1. To be considered as a realistic alternative system for propulsion, a SFRJ must operate over the expected operating envelope of Mach numbers and altitudes.
2. The point of transition from recirculation zone to boundary layer redevelopment is not always obvious on fuel surface.
3. Flame holding limits are not sensitive to fuel changes.
4. As port diameter of solid fuel grain increases, average regression rate decreases because of diminished heat transfer to wall.
5. Flame holding limits play an important role in ramjet motor design.

Key Figure from Document:

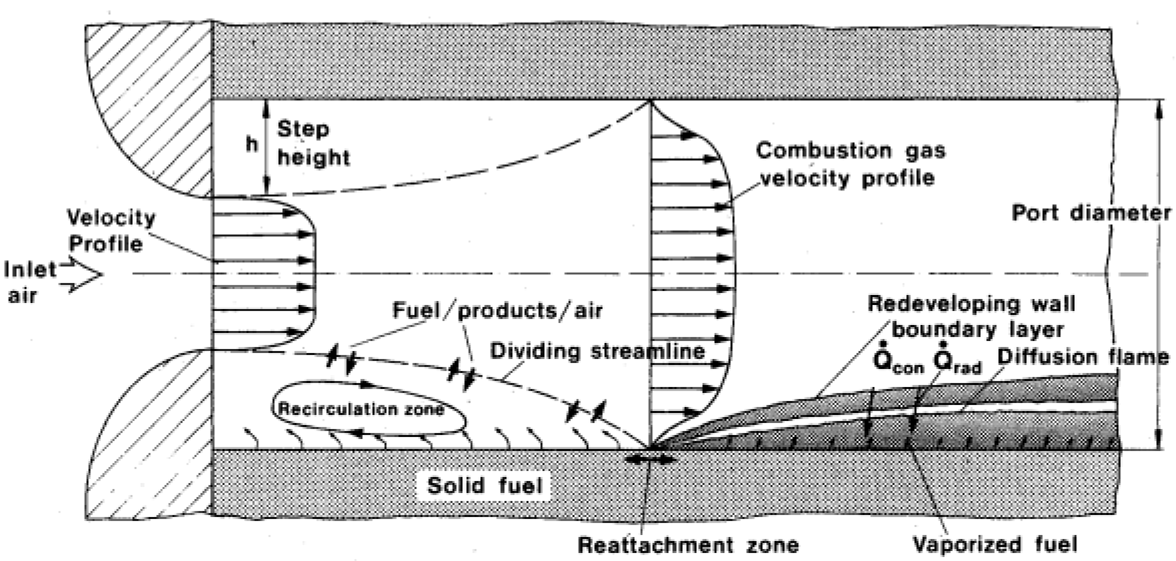

Figure 1: Schematic illustration of SFRJ dump combustor flow field.

Important Relationships among Parameters Described in the Paper:

1. The rate of solid fuel decomposition depends mainly on the air inlet temp, combustion pressure, and air mass flux.

2. As port diameter increases, regression rate decreases if all other parameters stay constant.

Important Conclusion(s):

1. You can improve motor performance by increasing fuel loading and decreasing pressure losses.
2. Flame holding limits play an important role in ramjet motor design.

C. Reflect

This source does not seem helpful to my current situation. However, it is good to learn more about different types of propulsion systems and their benefits and disadvantages as well as how they are tested.

OF	75.389	
Pc	50	atm
Pc	50.6625	Bar
2Pc	101.325	Bar
T	198	K
Pc	50.6625	
OF	75.38899994	DIMENSIONLESS
FPCT	1.309089065	DIMENSIONLESS
ERATIO	0.250019759	DIMENSIONLESS
Phi	0.250019759	DIMENSIONLESS
AR	0	DIMENSIONLESS
P	50.66249847	BAR
T	1800.416626	DEG K
RHO	7.754610062	KG/M^3
H	5.64978E-06	KJ/KG
U	-653.3210449	KJ/KG
GFE	-15377.97461	KJ/KG
S	8.541342735	KJ/(KG K)
Z	1	DIMENSIONLESS
MW	22.91305733	MOL WT
CP	5.016849518	KJ/(KG K)
CPG	1.223860383	KJ/(KG K)
GammaG	1.421459913	DIMENSIONLESS
Gamma	1.22964263	DIMENSIONLESS
C	896.2987061	M/S
MW_MIX	22.91305733	MOL WT
Viscosity	0.773292243	milliPOISE
Specific_Heat_Eq	5.016848087	KJ/(KG K)
Conductivity_Eq	4.860545158	milliW/(CM K)
Prandtl_Eq	0.79815942	DIMENSIONLESS
Specific_Heat_Fr	1.223860383	KJ/(KG K)
Conductivity_Fr	1.323586464	milliWATTS/(CM K)
Prandtl_FR	0.715028286	DIMENSIONLESS
PINJ_P	-999.9990234	N/A
PC_P	1	DIMENSIONLESS
MACH	0	DIMENSIONLESS
AR	0	DIMENSIONLESS
CSTAR	0	M/S
CF		DIMENSIONLESS
ISPV		M/S
ISP		M/S
ISPVRHO		KG/(M^2 S)
F	0.51214689	MOLE
F2	0.190263689	MOLE
HF	0.297589451	MOLE

Pc	101.325	
OF	75.38899994	DIMENSIONLESS
FPCT	1.309089065	DIMENSIONLESS
ERATIO	0.250019759	DIMENSIONLESS
Phi	0.250019759	DIMENSIONLESS
AR	0	DIMENSIONLESS
P	101.3249969	BAR
T	1887.346558	DEG K
RHO	15.01261616	KG/M^3
H	1.62737E-05	KJ/KG
U	-674.932312	KJ/KG
GFE	-15649.16406	KJ/KG
S	8.291622162	KJ/(KG K)
Z	1	DIMENSIONLESS
MW	23.25027466	MOL WT
CP	4.665799141	KJ/(KG K)
CPG	1.226409674	KJ/(KG K)
GammaG	1.411612272	DIMENSIONLESS
Gamma	1.237751126	DIMENSIONLESS
C	914.0012207	M/S
MW_MIX	23.25027466	MOL WT
Viscosity	0.801559567	milliPOISE
Specific_Heat_Eq	4.665798187	KJ/(KG K)
Conductivity_Eq	4.74695015	milliW/(CM K)
Prandtl_Eq	0.78785646	DIMENSIONLESS
Specific_Heat_Fr	1.226409793	KJ/(KG K)
Conductivity_Fr	1.375738144	milliWATTS/(CM K)
Prandtl_FR	0.714554906	DIMENSIONLESS
PINJ_P	-999.9990234	N/A
PC_P	1	DIMENSIONLESS
MACH	0	DIMENSIONLESS
AR	0	DIMENSIONLESS
CSTAR	0	M/S
CF		DIMENSIONLESS
ISPV		M/S
ISP		M/S
ISPVRHO		KG/(M^2 S)
F	0.490249723	MOLE
F2	0.207781121	MOLE
HF	0.301969141	MOLE