Date:

(Energy Equation)

Tank Volume
$52.11\ in^3 = 0.000853\ m^3$
$P = 900\ PSI$ or $62\ bar$
$6205500\ Pa$

$Pa = \frac{N}{m^2}$

$N = kg\frac{m}{s^2}$

ΣE (closed system, $\Delta M = 0$)

$$\cancelto{0}{(W_{in} - W_{out})} + \cancelto{0}{(Q_{in} - Q_{out})} = \cancelto{0}{\Delta U} + \Delta KE + \Delta PE$$

$$\Sigma E = \Delta KE + \Delta PE$$

Tank P.E.

$$\Delta PE = P(V)$$

$$\Delta PE = (6205500\ (N)/m^2)(0.000853\ m^3)$$

$$\Delta PE = 5293.29\ N \cdot m$$

Body Falling

$$\Delta KE = (5kg)(9.8\ m/s^2)(3m) + \frac{1}{2}(5kg)(5\frac{m}{s})^2$$

$$\Delta KE = 147\ kg\ m^2/s^2 + 62.5\ kg\ m^2/s^2$$

$$\Delta KE = 209.5\ N \cdot m$$

$$\Delta PE_{Tank} > \Delta KE_{Body}$$

$\varnothing = 2.88$ in

$\times$

8 in

3.2

Out 6 in

Date:

Redlich Kwong Eq of State

$$P = \frac{RT}{V - b'} - \frac{a'}{\sqrt{T}\, V(V + b')}$$

V = molar Volume $\frac{Vol}{mol}$
P = Pressure
T = Temp (kelvin or)
R = gas constant

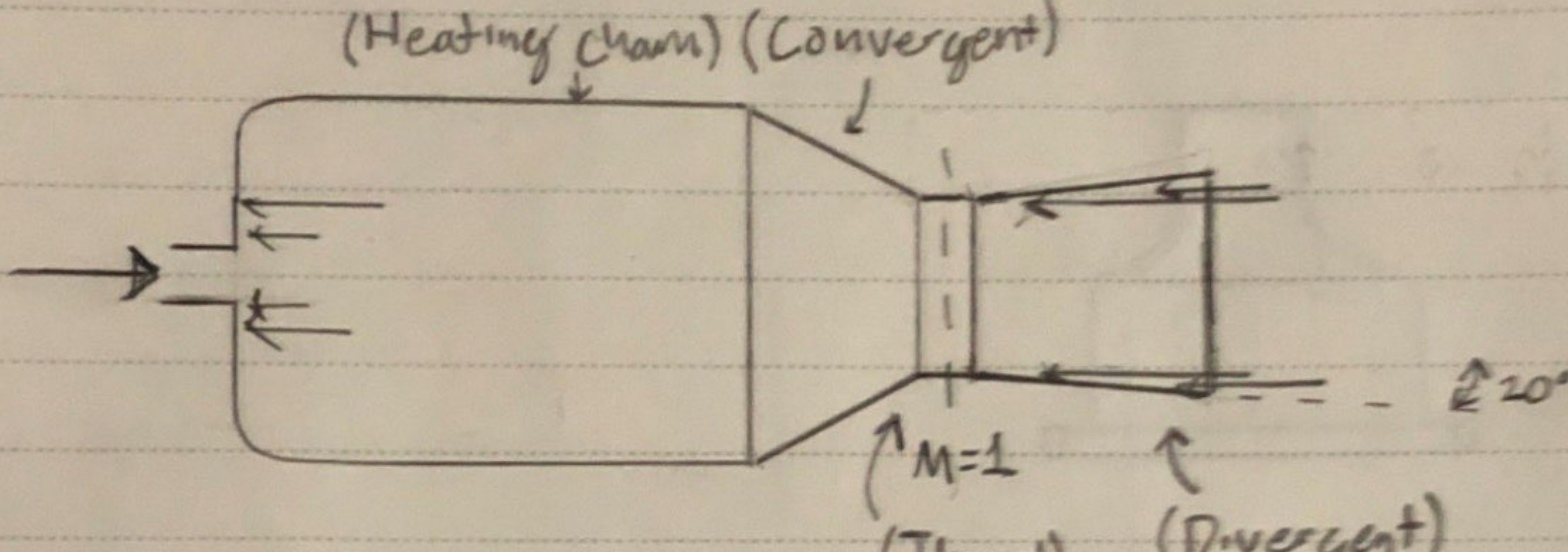
$$a' = \left(\frac{0.4278}{Z_c}\right) R V_c T_c^{3/2}$$

T_c, Z_c, P_c } all tabulated

$$V_c = \frac{R T_c Z_c}{P_c}$$

$$b' = \left(\frac{0.0867}{Z_c}\right) V_c$$

Rocket Nozzle



Specific (note) impulse (Efficiency)

$$I_s = V_2/g$$

Conservation of Momentum

(time = 0)

$$m_i v_i = 0 \Rightarrow m_r v_r = m_p v_p$$

$$m_r \underbrace{\frac{dv_r}{dt}}_{\text{acceleration}} = -\underbrace{\frac{dm}{dt}}_{\dot{m}} v_p$$

(note)

$$F = \dot{m} v_2 + (P_2 - P_3) A_2$$

F=ma

$$m_r a_r = -\dot{m} V_p$$

$$F = \dot{m} V_p$$

(Ideal Nozzel Expansion)

(Bernoullis Equation)

Date:

$$P_1 + \cancel{\tfrac{1}{2}\rho V_1^2}^{\,0} + \rho g z_1 = P_2 + \tfrac{1}{2}\rho V_2^2 + \cancel{\rho g z_2}^{\,0}$$

850 psi = 5.86 Mpa

(TANK)

$P_1 = 5.86$ Mpa

(ATM)

$P_2 = 0.1013$ Mpa

$= 101325$ Pa

kg/m s²

$$5.86\text{ Mpa} + (1.87\text{ kg/m}^3)(9.8\text{ m/s}^2)(0.3\text{ m}) = 0.1013\text{ Mpa} + \tfrac{1}{2}(1.87\text{ kg/m}^3)V_2^2$$

$$5.758\text{ Mpa} + 5.4978\text{ kg/ms}^2 = \tfrac{1}{2}(1.87\text{ kg/m}^3)V_2^2$$

$$11.5174\text{ Mpa} + 10.9956\text{ kg/ms}^2 = 1.87\text{ kg/m}^3\ V_2^2$$

$$1\text{ Pa} = \frac{N}{m^2} = \frac{kg\frac{m}{s^2}}{m^2}$$

$$\frac{1}{1.87}\frac{m^3}{kg}\left(11.5174\times10^6\ \frac{kg\frac{m}{s^2}}{m^2} + 10.9956\text{ kg/ms}^2\right) = V_2^2$$

$\rho = 1.87$ kg/m³ @ 850 Psi

$$6159037.43\ \frac{m^2}{s^2} + 5.88\ \frac{m^2}{s^2}$$

$$6159043.31\ \frac{m^2}{s^2} = V_2^2$$

$$\boxed{2481.74\text{ m/s} = V_2}$$

$\frac{m}{s} \doteq \frac{m^2}{} \frac{kg}{m^3}$

(time) note

20oz = 0.56 kg $\qquad \dot{m} = \rho A V$

Ø = 0.25in = 6.37mm

A = 0.00003167 m²

0.56 kg / $\dot{m}$ = 3.85 s $\qquad \boxed{\dot{m} = 0.1469\text{ kg/s}}$

$\boxed{\text{Time } 3.85\text{ s}}$

Conservation of Momentum (without Nozzle)

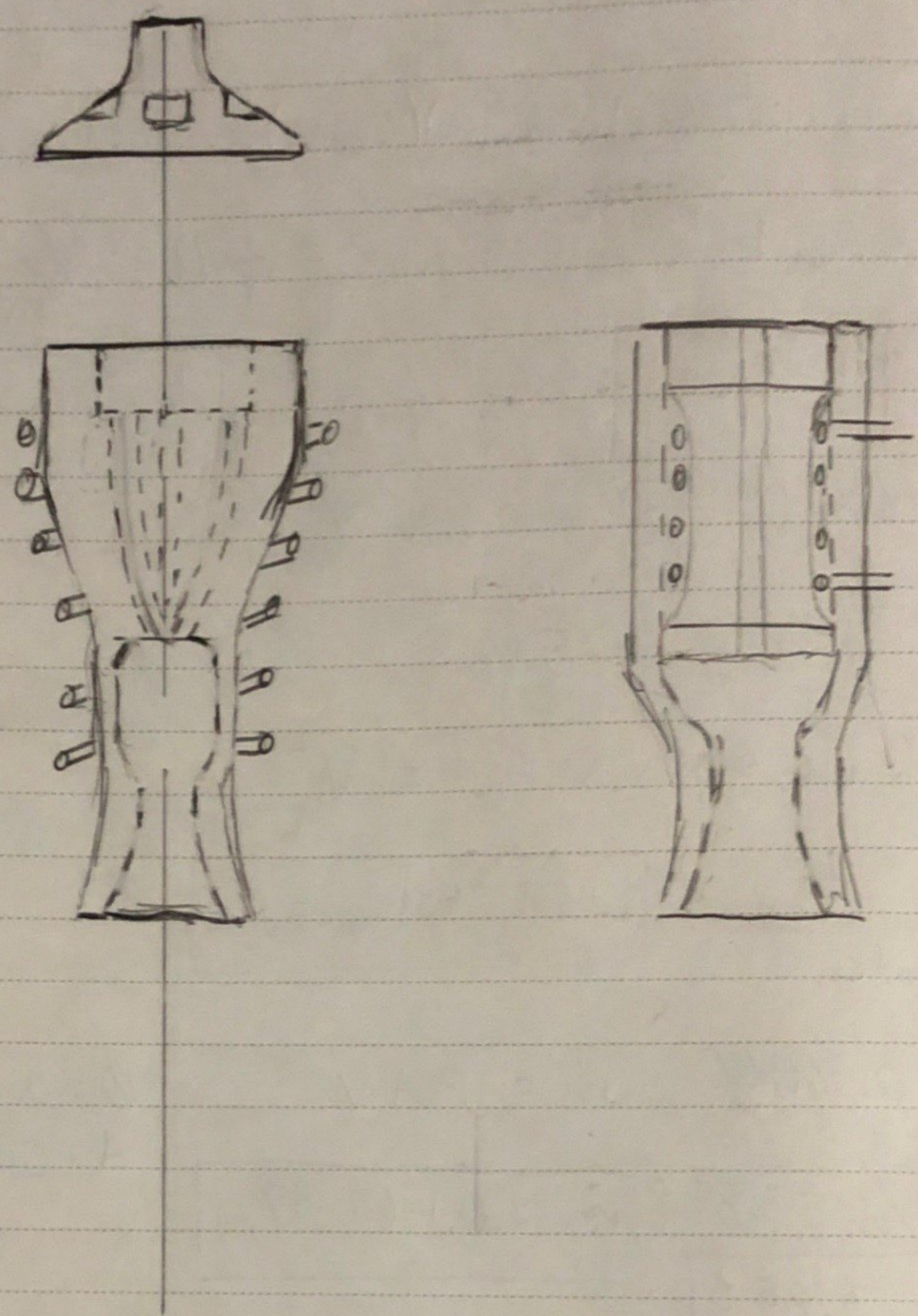
$$m_y a_y = -\dot{m} V_p$$

$$m_y(9.8\text{ m/s}^2) = -(0.1469\text{ kg/s})(2481.74\text{ m/s})$$

$$m_y(9.8\text{ m/s}^2) = -364.75\ \frac{kg\,m}{s^2}$$

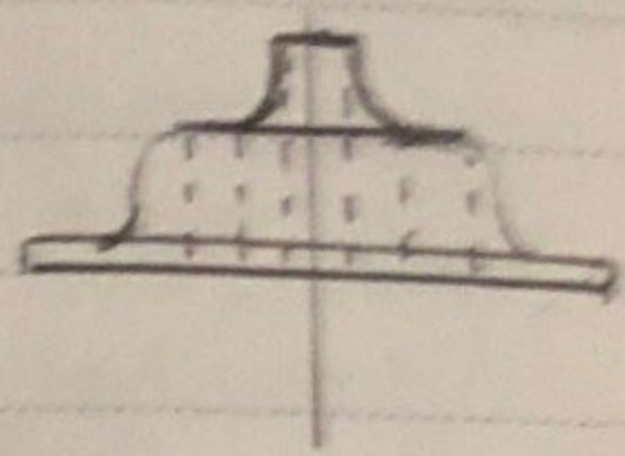
$$\boxed{m_y = 37.21\text{ kg}}$$

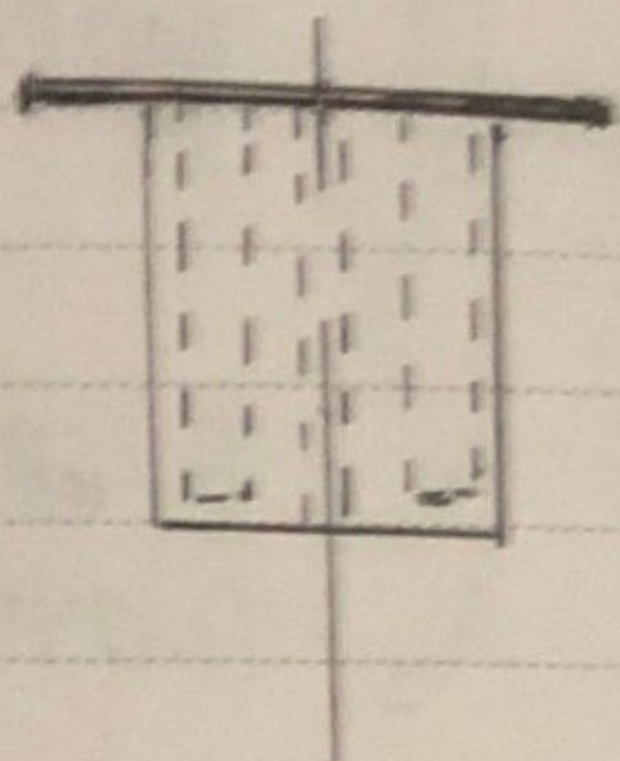
Date: 3D print 625 markforge

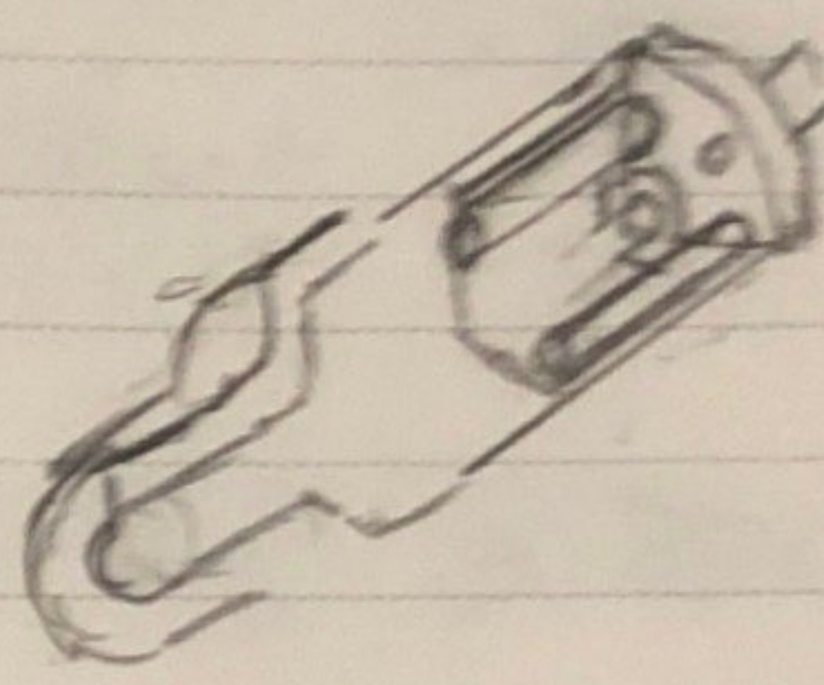


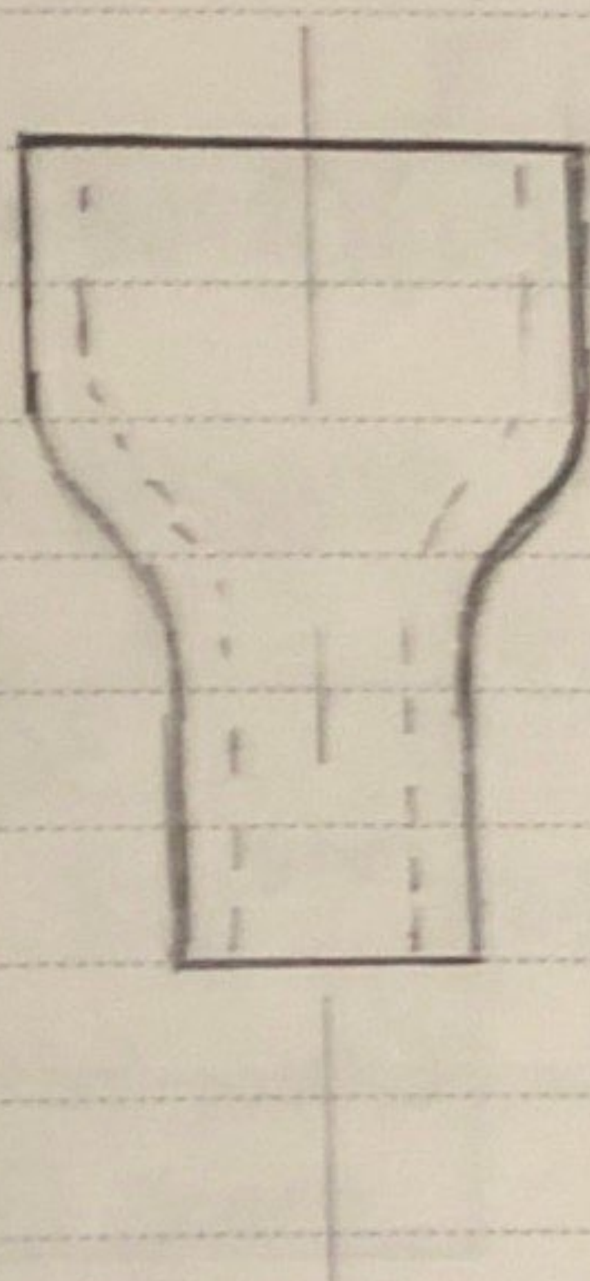
Mill / turn

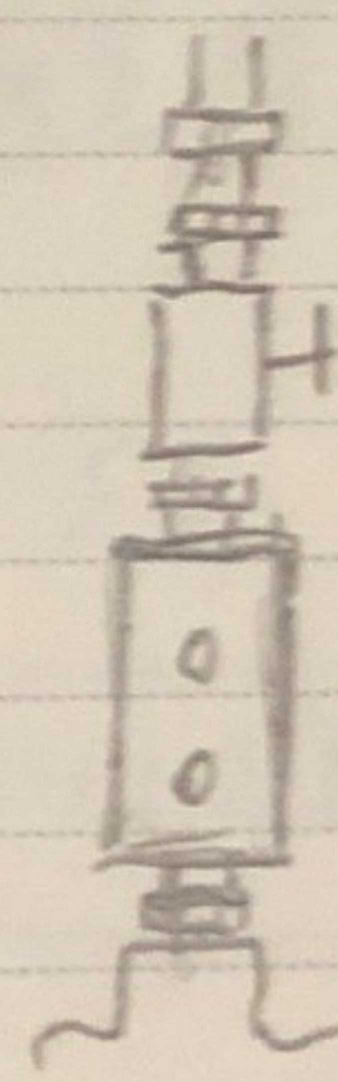
Date:











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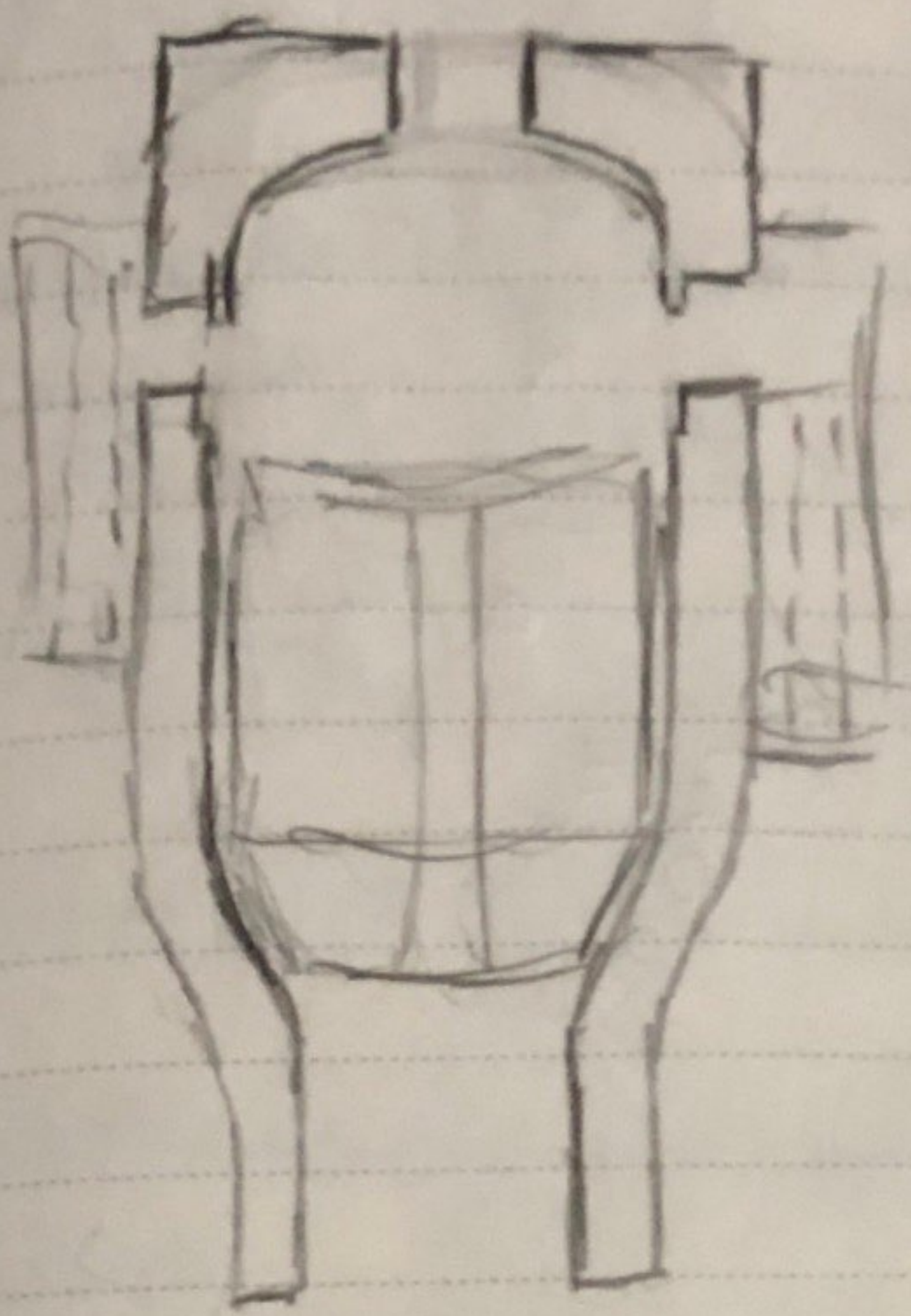
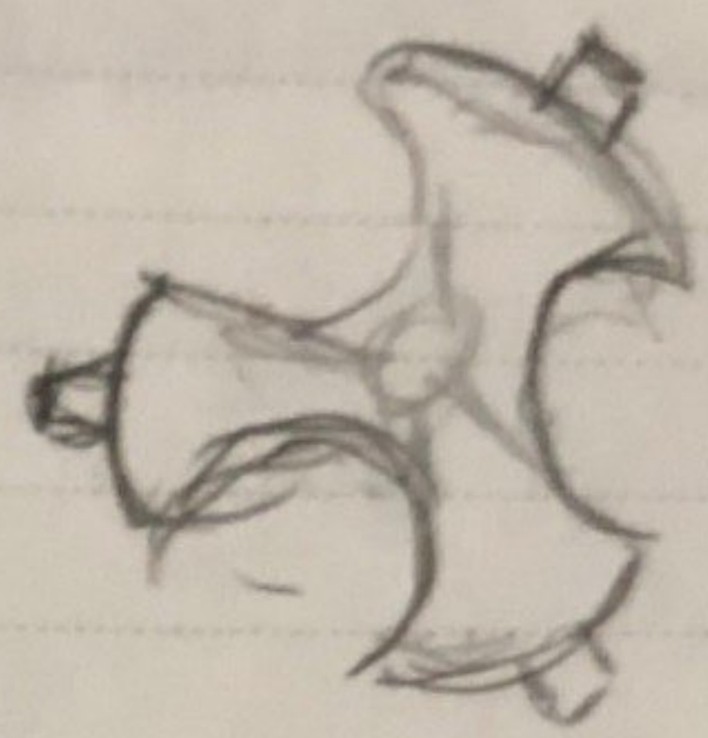
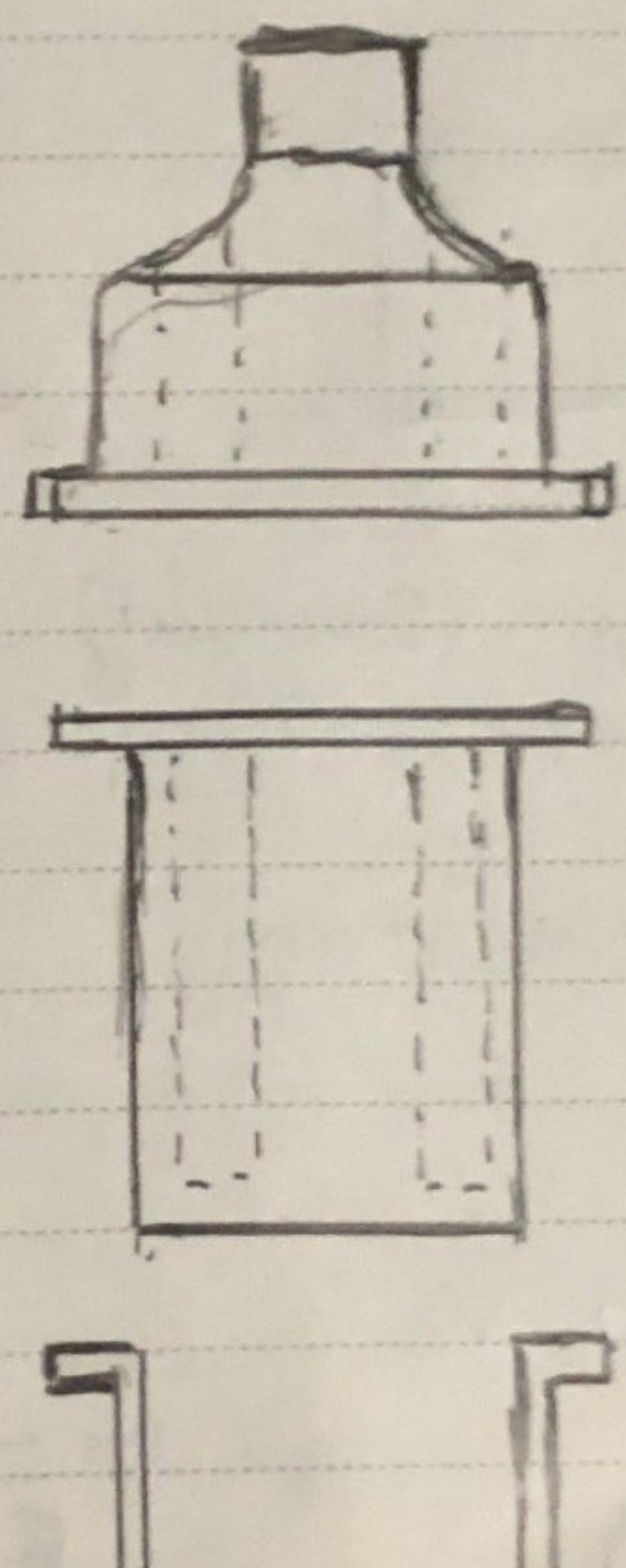






Date:

Pascal Principle

$$P_1 A_1 = P_2 A_2$$

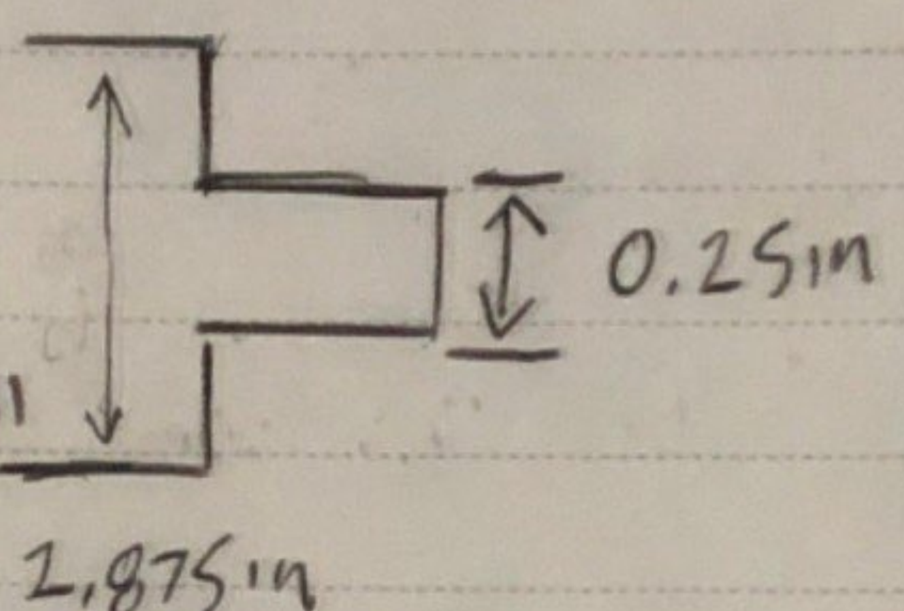
...

Thoughts:
pascals principle, to verify, none overpressurization of the main tank.
Assumption - noncompressible Fluid for ease of calculation

$P_1 = 1800\,PSI$
$P_2 = ?$

$A_1 = 8.168\,in^2$
$A_2 = 0.0490\,in^2$

TANK
$P_1 = 1800\,PSI$



walls 0.175in

Tank $\emptyset$ = 3.225in

$$(1800\,PSI)(8.168\,in^2) = P_2\,(0.0490\,in^2)$$

$$300{,}048.97\,PSI = P_2$$

$\boxed{P_{max} = 300.04\ kSI}$

Chamber Inlet max Pressure

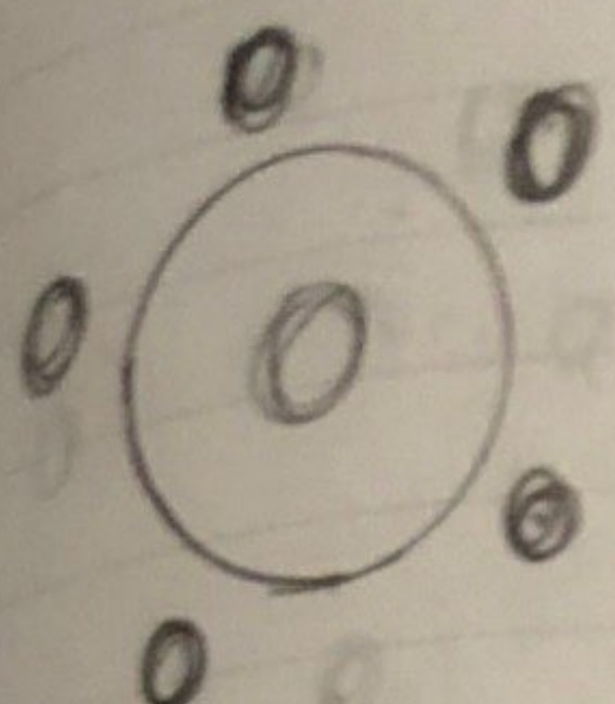
Bolt Pattern

Date:

60° degrees Apart

Aluminum 6061 — 26000 psi — 180 Mpa — 180×10^6 Pa

$M4 \times 0.7$



$F = \sigma \times A$ $\quad d = 4mm$

$A = \frac{\pi}{4}(d - 0.9382 \times P)^2$

$A = \frac{\pi}{4} \times (4 - 0.9382 \times 0.7)^2$

$A = 8.78 mm^2$

8.778

$Pa = \frac{N}{m^2}$

$F = (180 \times 10^6 \frac{N}{m^2})(8.78 \times 10^{-6} m^2)$

$F = 1580.4$ N

$F = 161.26$ kg

(All six with Preload)

$F_{max} = 9482.4$ N

75% F.S.

$F = 1,185.3$ N $= 120.94$ kg

$\boxed{F_{max} = 7111.8 N = 725.6 kg}$

50% F.S.

$\boxed{F_{max} = 4741.2 N = 483.79 kg}$

$\boxed{M5 \times 0.8mm \quad d = 5mm}$

$A = \frac{\pi}{4}(d - 0.9382 \times P)^2$

$A = 14.1825 \, mm^2$

$A = 1.4182 \times 10^{-5} m^2$

$F = \sigma \times A$

$F = (180 \cdot 10^6 N/m^2)(1.4182 \times 10^{-5} m^2)$

$F = 2552.85 N \times 3$

$F_{max} = 7658.57$ N

F.S. 0.75

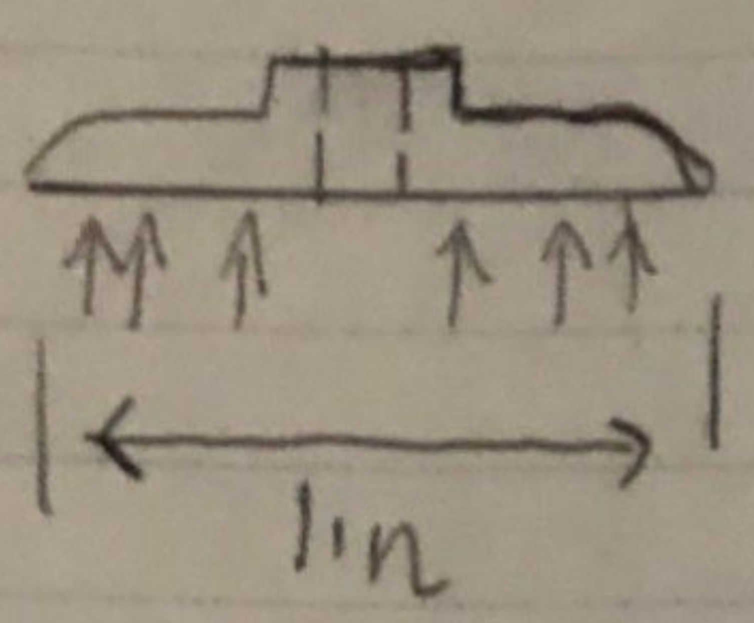
$F_{max} = 5743.91$ N

F.S 0.91

$F_{max} = 7000$ N

Date Force on cap

$P_{max} = 300.04$ ksi



$A = 0.000506\ m^2$

$A = 0.7854\ in^2 - 0.04909\ in^2 = 0.736$

~~$F = (P_{max})(A) = 220922.5$ lbs~~

~~$F = 100419.29$ kg~~

$P_{max} < 300.04$ ksi

In the event of stop in flow P_{max} is equal to max champer pressure

f.s. 75%

$F_{max} = 725.6$ kg $= 1596.5$ lbs

$1596.5\ lbs = (P_{max})(0.7363\ in^2)$

$\boxed{P^{75\%}_{max} = 2168.3\ PSI}$

$P^{75\%}_{max} \approx 2100$ PSI

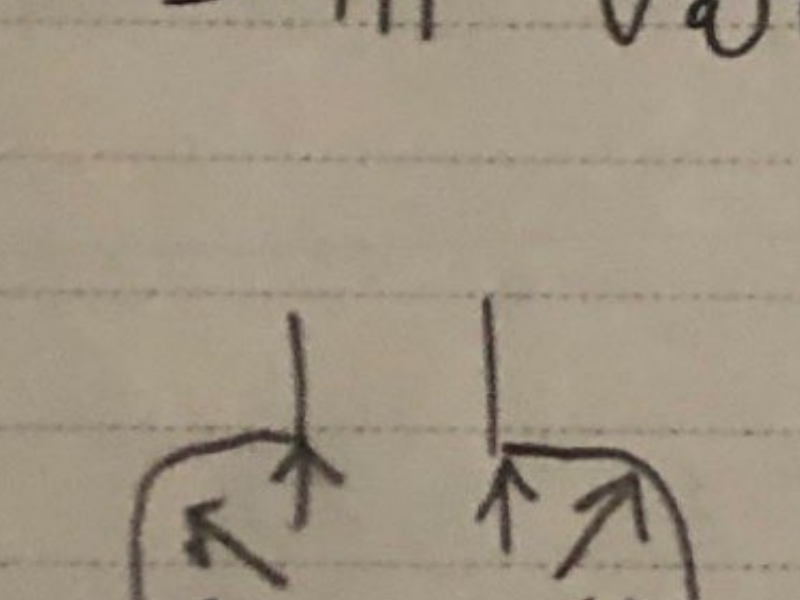
$F_{max} = 483.7$ kg $= 1064.33$ lbs

$(1064.33\ lbs) = (P_{max})(0.7363\ in^2)$

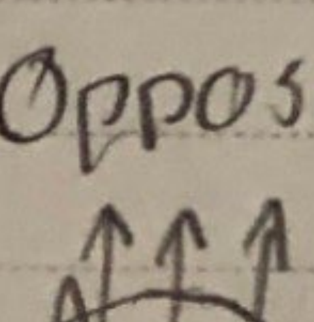
$\boxed{1445.52\ PSi = P^{50\%}_{max}}$

$P^{50\%}_{max} \approx 1500$ Psi

Still valid with hemisphere chambe.



Opposing Forces cancel

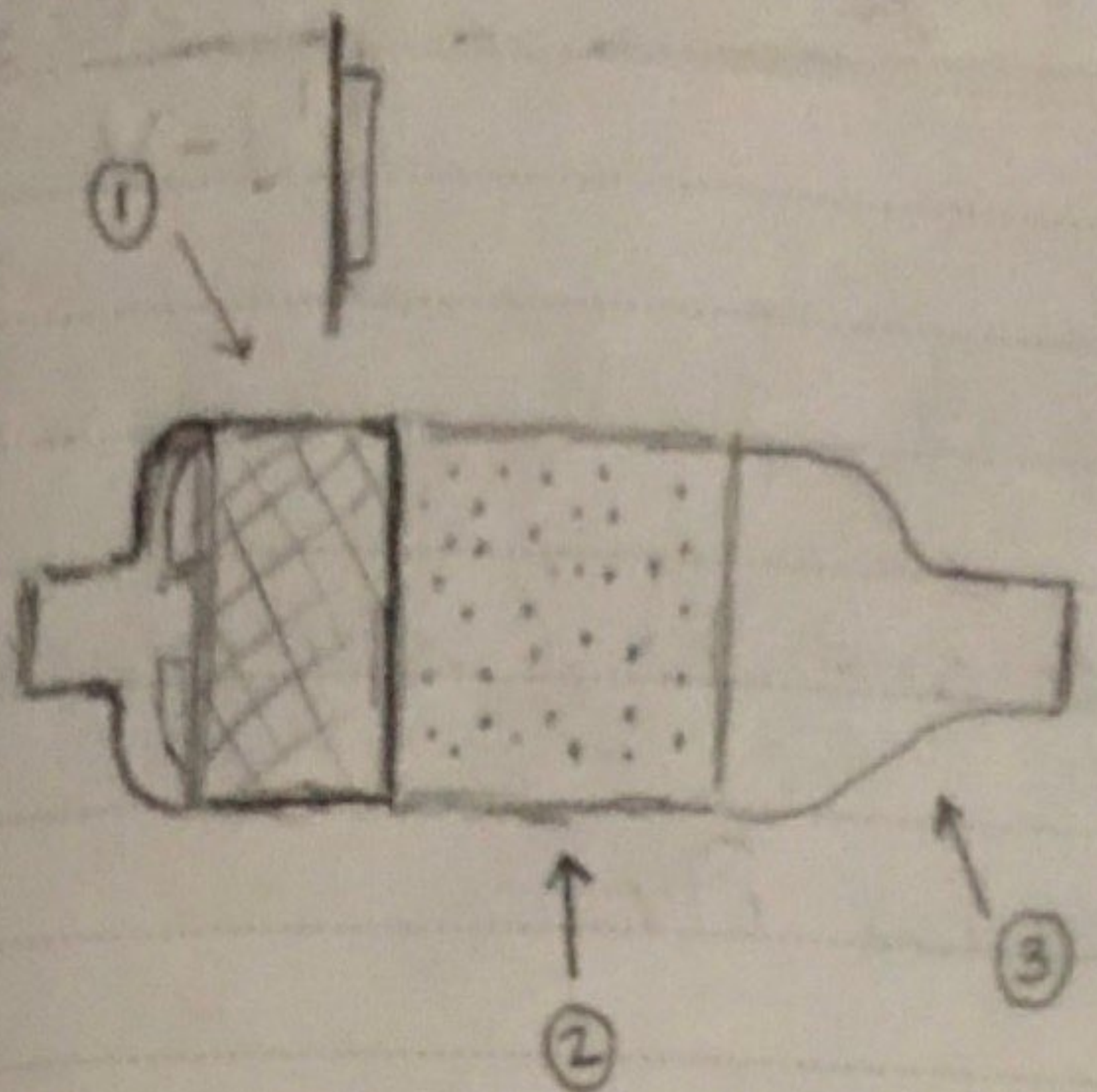


the Forces Z are the only ones left

$\Sigma F_x = 0$

$\Sigma F_y = P_{max}$

Date

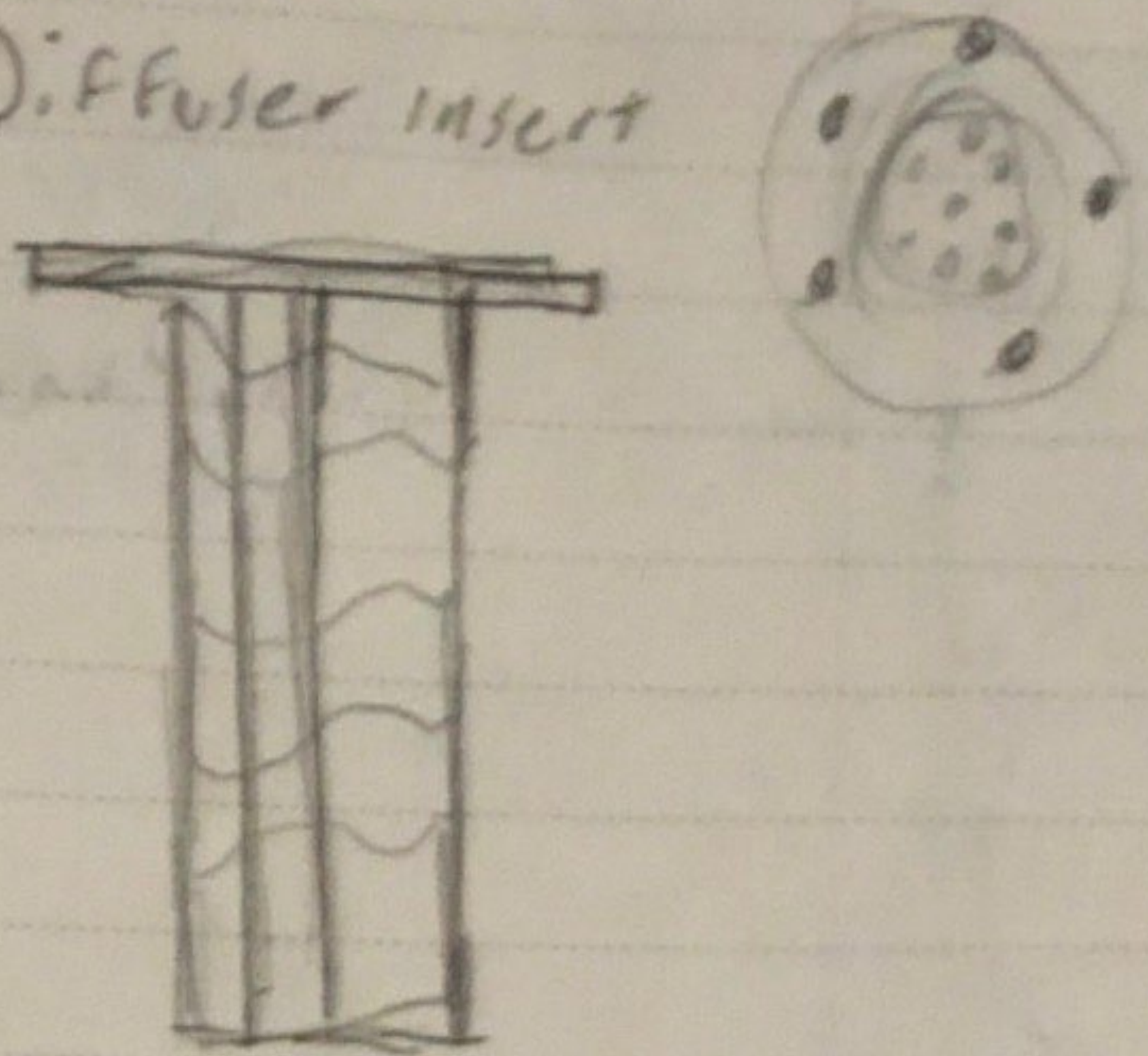


1) Diffusing chamber cap

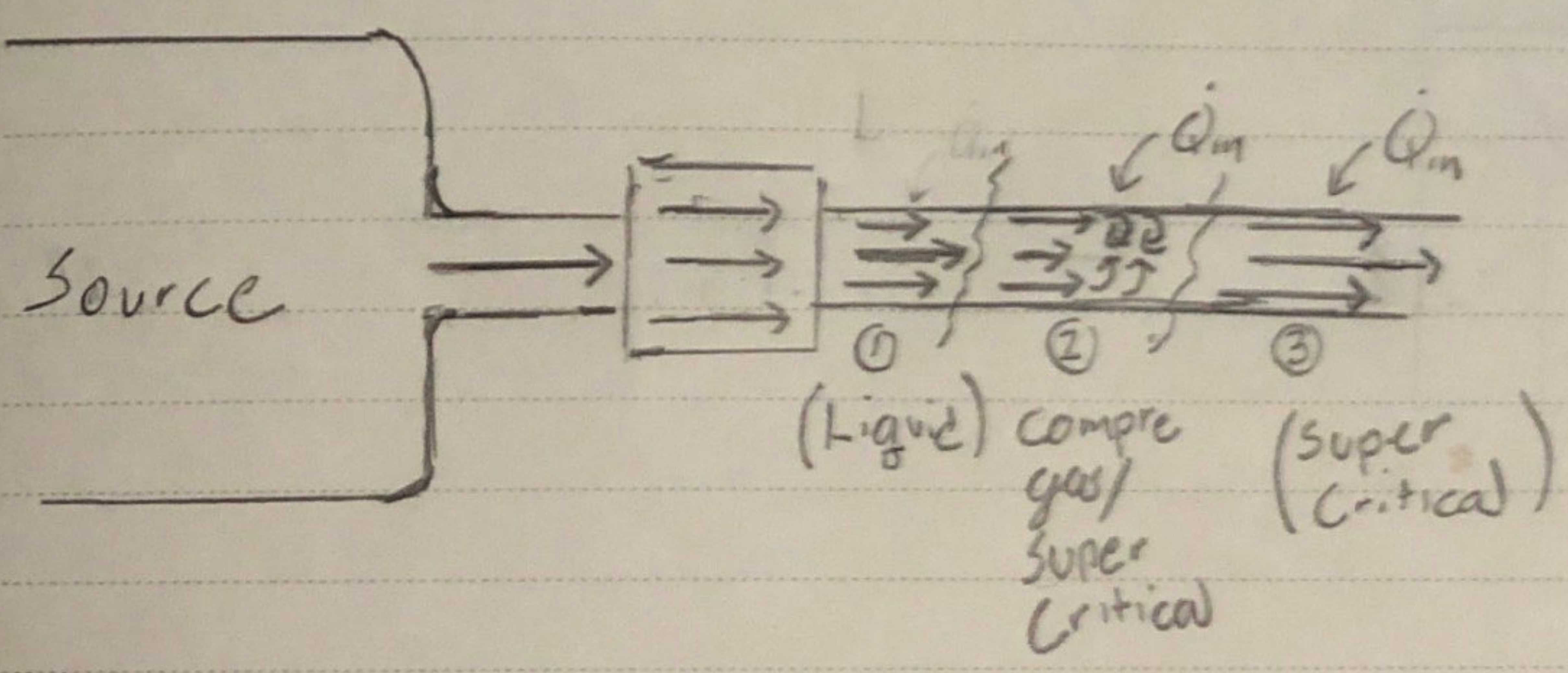
2) Expansion chamber

3) Nozzel

Diffuser insert



Theoretical Prediction



1) Liquid CO_2 laminar Flow

2) Compressed gas / super critical turbulent Flow

3) super critical gas laminar Flow

Date:

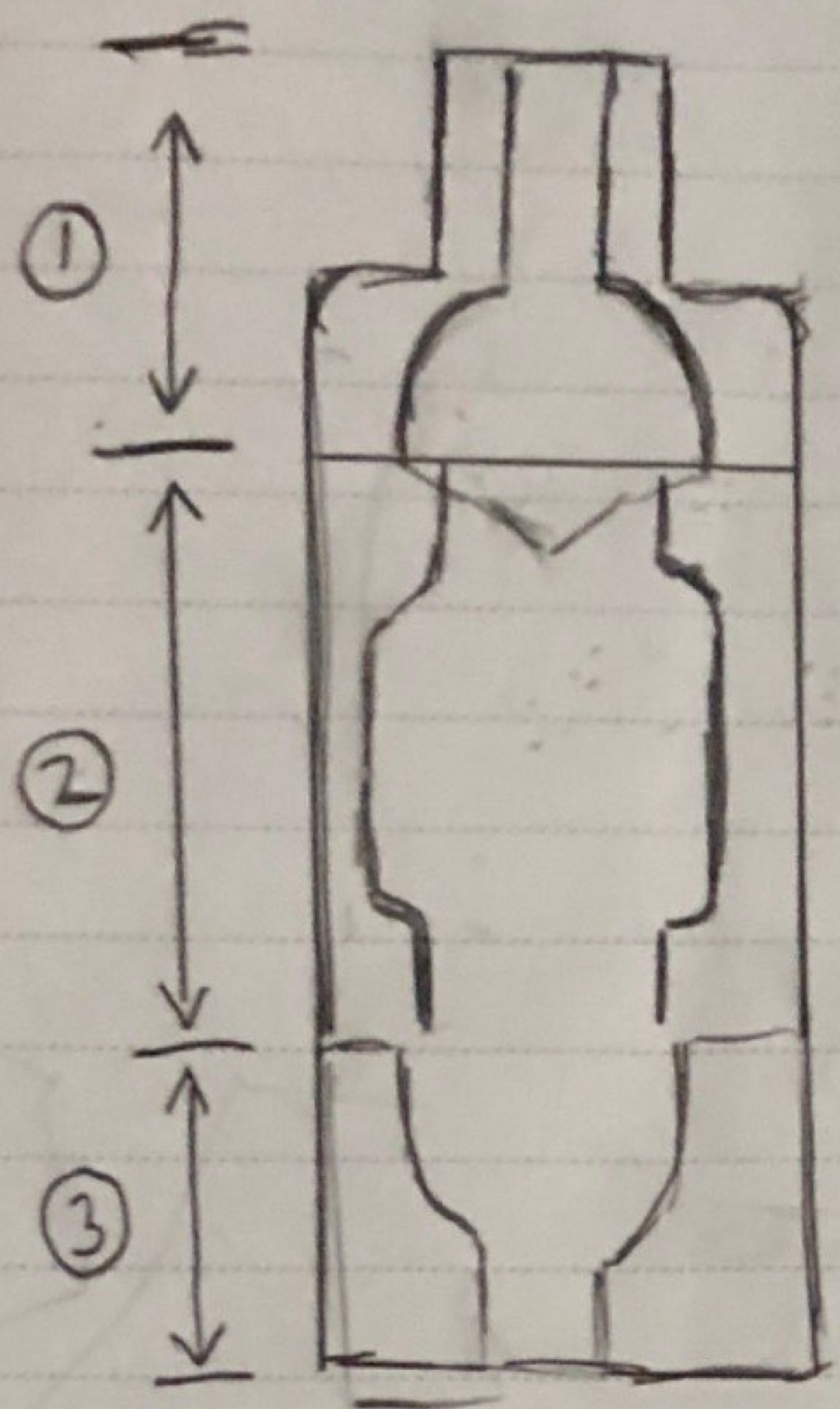
Phase Diagram

1) liquid Phase near Cp @ 90C

2) supercritical / compressable liquid Phase @ T = 50-75°C

3) gaseous Phase

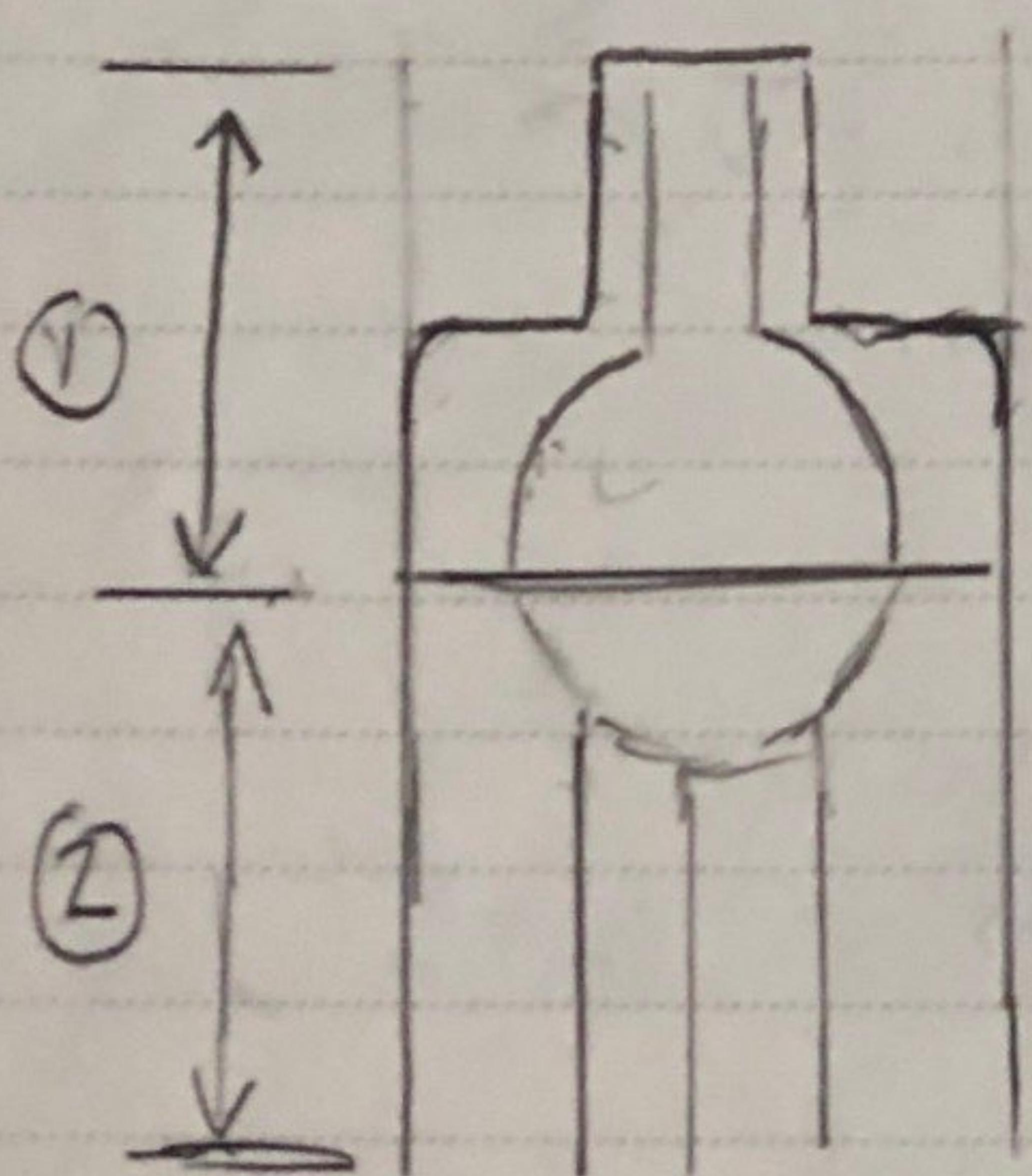
(Inductive)



Inductive Heater $\dot{Q} = 500w \quad \frac{J}{s}$

Resistance Heater $\dot{Q} = 180w$ or $\frac{J}{s}$

(Resistance)



(R K E)

$$P = \frac{RT}{V - b'} - \frac{a'}{\sqrt{T}\,V(V+b')}$$

$$a' = \left(\frac{0.4278}{Z_c}\right) R V_c T_c^{3/2}$$

$$b' = \left(\frac{0.0867}{Z_c}\right) V_c$$

$$V_c = \frac{R T_c Z_c}{P_c}$$

V = molar volume $\frac{vol}{mol}$
P = Pressure
R = gas constant

$T_c, Z_c, P_c \}$ Table

11 Date

(Energy Equation)

Tank Volume
$52.11\ in^3 = 0.000853 m^3$
$P = 900 PSI$ or 62 bar
$6205500 Pa$

$Pa = \frac{N}{m^2}$

$N = kg\frac{m}{s^2}$

ΣE (closed system, $\Delta M = 0$)

$$\cancelto{0}{(w_{in} - w_{out})} + \cancelto{0}{(Q_{in} - Q_{out})} = \cancelto{0}{\Delta U} + \Delta KE + \Delta PE$$

$$\Sigma E = \Delta KE + \Delta PE$$

Tank P.E.

$$\Delta PE = P(V)$$

$$\Delta PE = (6205500 (N)/m^2)(0.000853 m^3)$$

$$\Delta PE = 5293.29\ N \cdot m$$

Body Falling

$$\Delta KE = (5kg)(9.8 m/s^2)(3m) + \frac{1}{2}(5kg)(5\tfrac{m}{s})^2$$

$$\Delta KE = 147\ kg\ m^2/s^2 + 62.5\ kg\ m^2/s^2$$

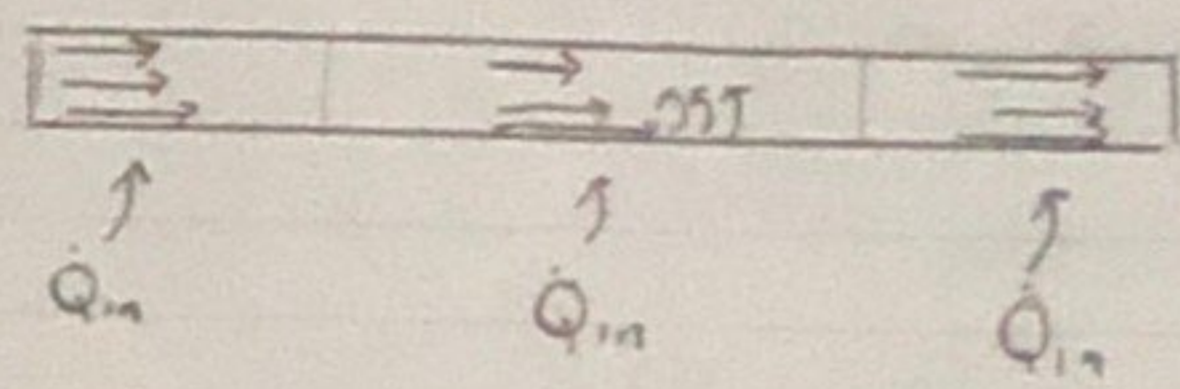
$$\Delta KE = 209.5\ N \cdot m$$

$$\Delta PE_{Tank} > \Delta KE_{Body}$$

$\theta = 2.98^\circ$
x
$8m$
3.2

$0.16m$

Theoretical Prediction



$\dot{m} = \frac{0.1469 \text{ kg/s}}{6}$

$\dot{m} = 0.0244 \text{ kg/s}$

Heat eng

heat capacity

$Q_{in} = m \; c \; \Delta t$

mass

$20^\circ C = 293.15K$ $\qquad \dot{Q}_{in} = \frac{500 \text{ J/s}}{6}$

mol mass $= 12.01 \text{ g/mol}$ $\qquad \dot{Q}_{in} = 80 \text{ J/s}$

0.01201 kg/mol $\qquad C_v = 28.96 \text{ J/mol·K}$

$$80 \text{ J/s} = (0.0244 \text{ kg/s})(28.96 \text{ J/mol·K})(t_f - 293.5K)$$

$$80 \text{ J/s} = (2.0316 \text{ mol/s})(28.96 \text{ J/mol·K})(t_f - 293.15K)$$

$$80 \text{ J/s} = (58.836 \text{ J/s·K})(t_f - 293.5K)$$

$$1.357K + 293.5K = t_f$$

$$294.85K = t_f$$

1000 watts

160 J/s

$$160 \text{ J/s} = (58.836 \text{ J/s·K})(t_f - 293.5K)$$

$$2.719 + 293.5K = t_f$$

$$296.21K = t_f$$

$\Delta T = (50^\circ C - 20^\circ C)$

$50^\circ C = 323.15K$

$$\frac{Q_{in}}{6} = (2.0316 \text{ mol/s})(28.96 \text{ J/mol·K})(323.15 - 293.5)$$

$$(2.0316 \text{ mol/s})(28.96 \text{ J/mol·K})(29.65K)$$

$$\boxed{Q_{in} = 10466.8 \text{ J/s}}$$

180 watts

$\dot{m} = 0.1469 \text{ kg/s}$

$\dot{m} = 12.2314 \text{ mol/s}$

mol mass = $0.01201 \frac{kg}{mol}$

$$\dot{Q}_{in} = \dot{m}(c)(\Delta t)$$

$$180 \text{ J/s} = (12.231 \text{ mol/s})(28.96 \text{ J/mol} \cdot \text{K})(\Delta t)$$

$$0.508 \text{ K} = \Delta T$$

2500 watts

$$2500 \text{ J/s} = (12.231 \text{ mol/s})(28.96 \text{ J/mol} \cdot \text{K})(\Delta t)$$

$$7.05 \text{ K} = \Delta T$$

1/4 $\dot{m}$

$$\Delta T = 28.23$$

~~A =~~ $\boxed{D = 0.125}$

$$\dot{m} = \rho A v$$

$$0.0367 \text{ kg/s} = (1.87 \text{ kg/m}^3) A (2481.74 \text{ m/s})$$

$$7.9134 \times 10^{-6} = A$$

Date:

① 1/4 opening

$\dot{m} = 0.1469 \ kg/s$

$V = 2481.74 \ m/s$

$\rho = 131.6 \ kg/m^3$

3/16 Opening

$0.1875 in = 0.004762 m$

$A = 0.00001781 m^2$

1/8 Opening

$0.125 in = 0.00031$

$A = 0.000007917 m^2$

$$\dot{m} = \rho A V$$

3/16

$$\dot{m} = \left(131.6 \frac{kg}{m^3}\right)(0.00001781 m^2)(2481.74 \ m/s)$$

$$\dot{m} = 5.816 \ kg/s$$

15 Date.

CO_2 cooling loop