Synopsis of “Propellant Tank Analysis and Design” City College CUNY Author:Samuel Payne 11/9/17.

Project Description	Secondary Content	Context	Result	Project Grade	Course Grade
a propellant force as a function of pressure, material and aperture	Pressure as Function of Syncopated Rhythm	Course Work CUNY. Thermodynamics. Fall 2017 Prof: Hoshanna	Unpublished Paper and Documentation including audio and video recording	A-	B+

Outline:

- Problem Statement
- Conventional Method of solution and equations used.
- Proposed Alternate Method of Solution to Problem and musical composition with variations.

Problem Statement:

The goal is to assess the pros and cons of the use of two different materials in the design of a small directional control rocket to operate in space by providing as many as 100 bursts of 5 seconds each with a mass flow rate of 0.5 lbm/si at a velocity of 400 ft/sec. Storage tanks that will contain up to 3000 psia are available and the tanks are located in a 40 degree Fahrenheit environment.

Conventional Method:

The subject of this paper is to evaluate the pros and cons of using R134-a verse Nitrogen as propellant. First the state of these possible propellants under various conditions is determined. After the state is determined, the substance with the minimum volume is specified. Next, two possible models for the tank are laid out. Both tank models have the same shape based on the minimal volume found. This shape was formed by rotating a function about an axis using appropriate integration methods from calculus. Tank 1 is a variable pressure tank with a changing outlet aperture and area of the aperture of exit as a function of density and velocity of the propellant is calculated. Tank 2, is a constant pressure tank and the Energy Balance and Mass balance equations are used to determine the internal energy at various states and the work done on the system. In addition, a brief cost analysis is provided.

Alternative Method:

What is pressure in terms of a composed song or rhythm. What would it mean to release 5 second bursts of a density out the bottom of a rhythm. I took a cascara rhythm from the Afro-Cuban tradition and laid it on top of a 3/2 clave rhythm with the Bombo bass drum notes on the *and* of 2 and 4.

The clave on its own can hold water or air or Nitrogen or R143-a just as well as any basket or tank can. But the added cascara rhythm increases the pressure to the necessary 20MPa.

I composed a piece of music where the rhythm is slowly made complete by an addition of notes over a series of measures and then the rhythm is slowly dissolved.

As I let density out of this pressurized pattern of beats by letting notes drop out at an average rate of one note per measure I found that the song does not propel in any direction in the way the proposed propellant tank does.

Newtons third law in relation to music is difficult to figure. When I let propellent out of the song Newtons 3rd law didn't hold. Though there is a sense of drift or dissolution.

Two methods of proposed future work to make up for the lack of pressure as the density fell out are to draft several compositions with the same structure but to displace the notes according to different rubrics or to add a bass line.

Selections from Normative Method of solution and Equations Used:

The shape of the tank is a function of volume and aerodynamics. A function was chosen and the shape was formed by integrating around the x axis.

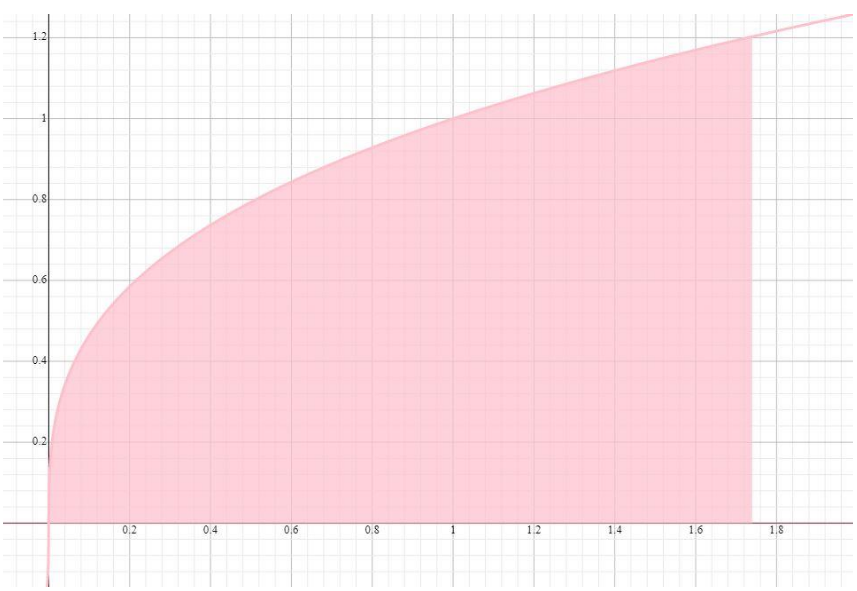
$$y = x^3 \; Redefine\ in\ terms\ of\ y \;\; \rightarrow \; x = \sqrt[3]{y} \; = r$$

$$\int_a^b \pi r^2 dy = \int_0^y \pi \sqrt[3]{y}\, dy = \pi \int_0^y y^{1/3} dy = \; Volume\ of\ tank \; = \; 0.484653\, m^3$$

$$\frac{3\pi}{5} y^{\frac{5}{3}}\ evaluated\ from\ 0\ to\ y = Volume$$

$$y = \sqrt[5]{\left(\frac{5\pi}{3} Volume\right)^3} \text{ = Height of tank = 1.7484m}$$

$$\sqrt[3]{y} \; = r \quad \text{= Radius of tank = } \sqrt[3]{Height\ of\ tank} \text{ = 1.2047}$$



Graph 1: 2 Dimensional shape of revolved form.

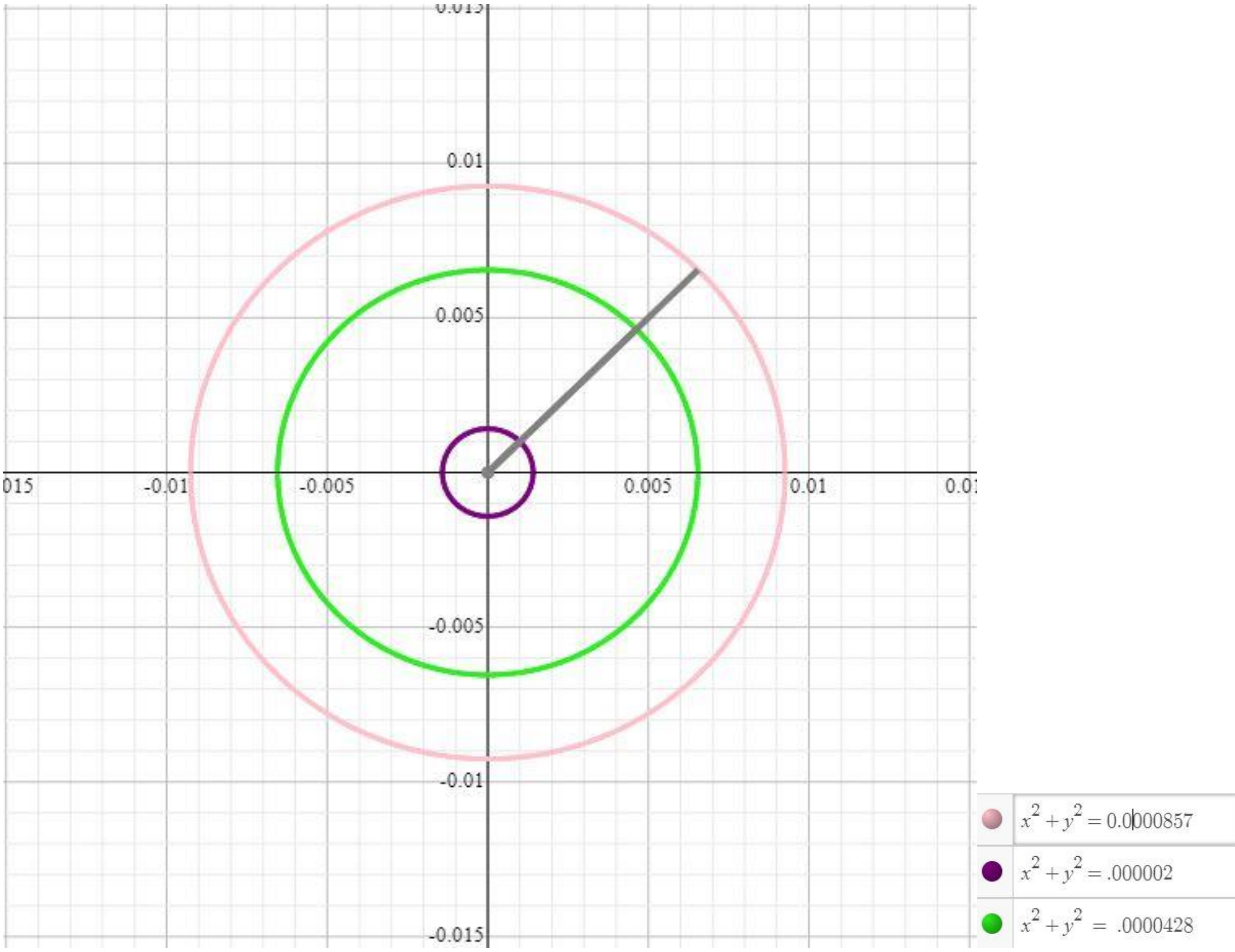
<u>Tank1 (Variable pressure):</u>

The aperture must change size to maintain flow rate and velocity as Pressure decreases with in rigid tank.

$$Flow\ Rate = Density * Velocity\ Average * A_c$$

kPa	v m3/kg	Aperture Area m2	Radius m	radius squared
20684	0.004275722	0.000007014	0.001494197	0.00000222
1000	0.081967	0.000134461	0.00654219	
500	0.16424031	0.000269462	0.00926134	0.0000857

Table 9. Change in Aperture as function of pressure and specific volume.



Graph 3. Change in area of circle as function of change in density to maintain velocity as function of mass flow rate. Dimensions in meters.

Energy of the control volume changes with time as the rocket dumps material/propellant. This Energy change is dependent on the energy crossing the boundaries of the control volume of the tank in the form of changes in work (W) and Heat (Q) and the energy transported out of system by mass. These variables are put in relation by the mass balance equation and the Change in Energy equation (Newtons first law which results in the conservation of energy principle).

Mass Balance:

$$m_{in} - m_{out} = \Delta m_{system}$$

Or for control volume

$$m_{in} - m_{out} = (m_2 - m_1)_{control\ volume}$$

<u>Energy Balance (Newton's first law):</u>

$$E_{in-}\,E_{out} = \Delta E_{system}$$

$$Net\ Energy\ Transfer\ by\ Heat\ and\ Work\ and\ Mass$$
$$= Change\ in\ internal, kinetic\ and\ potential\ energies$$

Using two intensive properties at the initial state when the tank is full and at the final state when it is empty the remaining properties of the system can be established.

Energy Balance for Uniform- Flow system:

$$\left(Q_{in} + W_{in} + \sum_{in} m\theta\right) - \left(Q_{out} + W_{out} + \sum_{out} m\theta\right) = (m_2e_2 - m_1e_1)_{system}$$

(The Summation symbols show that an integral is not necessary as we are not dealing with rates -we are in a steady flow scenario we are simply dealing with a change rather than a differentiation).

$$\theta = The\ energy\ of\ fluid\ stream\ at\ exit\ per\ unit\ mass$$
$$\theta = Pv + e = Pv + (u + ke + pe)$$
$$Pv + u = h \ \rightarrow\ In\ this\ way\ the\ Work\ due\ to\ flow\ is\ laced\ into\ Enthalpy\ (h)$$

$$\theta = h + ke + pe$$
$$\theta = h + \frac{v^2}{2} + gz$$

$$e = u + ke + pe$$
$$= energy\ of\ non\ flowing\ fluid\ in\ control\ volume\ on\ the\ right\ side\ of\ the\ Energy\ Balance\ equation\ above.$$

<u>Simplifying Energy Balance to particular situation of Tank 2:</u>

The Potential Energies of the flow and the volume are negligible compared to energy of entire system and drops out. The kinetic Energy of the flow of the substance at the gate contributes more than expected to the internal Energy, a contribution of 65.5698kJ. The Energy calculation is first calculated without KE and then including KE. See calculations below.

The Work of the gas molecules compressing over the volume change (PV) is represented by enthalpy(h)

$$(W_{Boundary}) - mh = (m_2u_2 - m_1u_1)_{system}$$

m_2u_2 drops out as there is no mass left.

$$\left(W_{Boundary}\right) = (mh_{out} - m_1u_1)_{system}$$

Work is done on the system and is therefor negative as the change in state is isobaric(steady presssure)[i] and becomes positive in energy equation :

$$W_B = \ Boundary\ Work\ of\ compression\ device = PV = P(V_2 - V_1)$$

$$W_B = \ 10{,}024.56265kJ\ over\ a\ time\ of\ 500\ sec. = 20049.1353Watts = 27\ Hp$$

This is the same as the work required to lift a 1973 Cadillac Sedan Deville of curb weight 2280kg went up .44 meters in the air[ii].

$$P(V_2 - V_1) \ \ = m(h_{out} - u_1)_{system}$$

$$10{,}024.56265kJ \ \ = \left(113.35\ Kg(248.5327\frac{kJ}{kg} - u_1\right)_{system}$$

$$10{,}024.56265kJ \ = ((28174.276kJ - 113.35\ Kg * u_1)_{system}$$

$$\frac{-18150kJ}{-113.35kg} = (u_1)_{system} = 160.1235\frac{kJ}{kg} = u\ \ for\ Nitrogen\ at\ 20\ MPa$$
$$and\ 4.45\ Degrees\ Celcius$$

If the Kinetic Energy (KE) of the fluid stream were to be taken into consideration its calculation is as follows.

KE due to Flow: $\frac{v^2}{2}$ = $\frac{(121.92\mathrm{m/s})^2}{2} = \ 7{,}432 = KE \ \ \rightarrow \ \ \frac{KE}{m} = 65.5668\frac{kJ}{kg}$

$$\left(W_{Boundary}\right) - m(h + \frac{v^2}{2}) = (m_2u_2 - m_1u_1)_{system}$$

$$\left(W_{Boundary}\right) = \left(m(h + \frac{v^2}{2})_{out} - m_1u_1\right)_{system}$$

$$10{,}024.56265kJ \ \ = \left(113.35\ Kg((248.5327\frac{kJ}{kg} + 65.5668\frac{kJ}{kg}) - u_1)\right)_{system}$$

$$-25578.61568kJ \ = 113.35\ Kg\ (u_1)_{system} \qquad \rightarrow \ \ (u_1)_{system} \ = \ 225.6604\frac{kJ}{kg}$$

65.5698kJ is the difference in internal energy (u) if Kinetic Energy of Flow Energy is included in calculation.

Conclusion to Conventional method:

The minimum volume, the minimum cost and the possibility of intense expansion upon depressurization[iii] place Nitrogen as a candidate worth further research. With the current facts, air would be a definite candidate as it compresses further than nitrogen at the specified temperature. R-134a is not a valid choice for a propellant in this scenario due to high cost and high volume and the phase shift it would undergo on depressurization.

Selections from Alternative Method of solution:

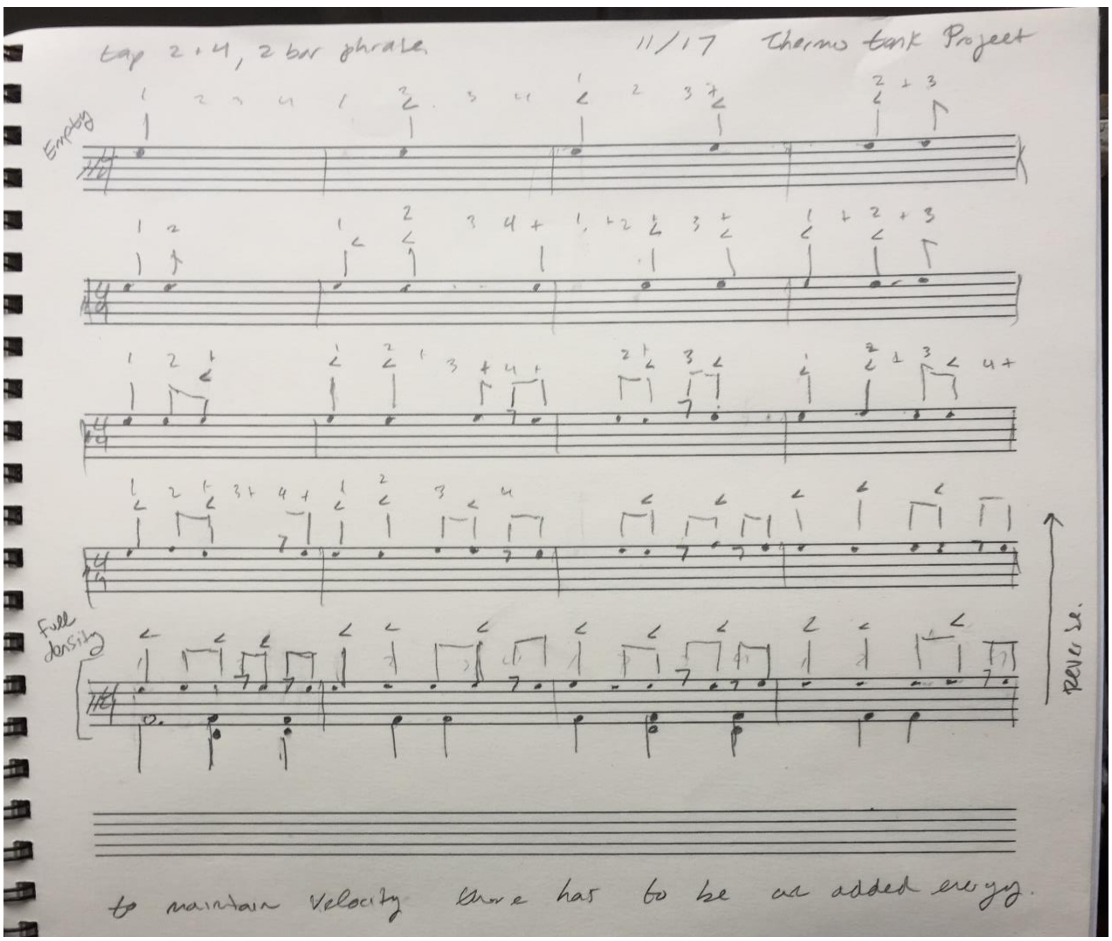


Image 1. Propellant Musical Notation Draft 1

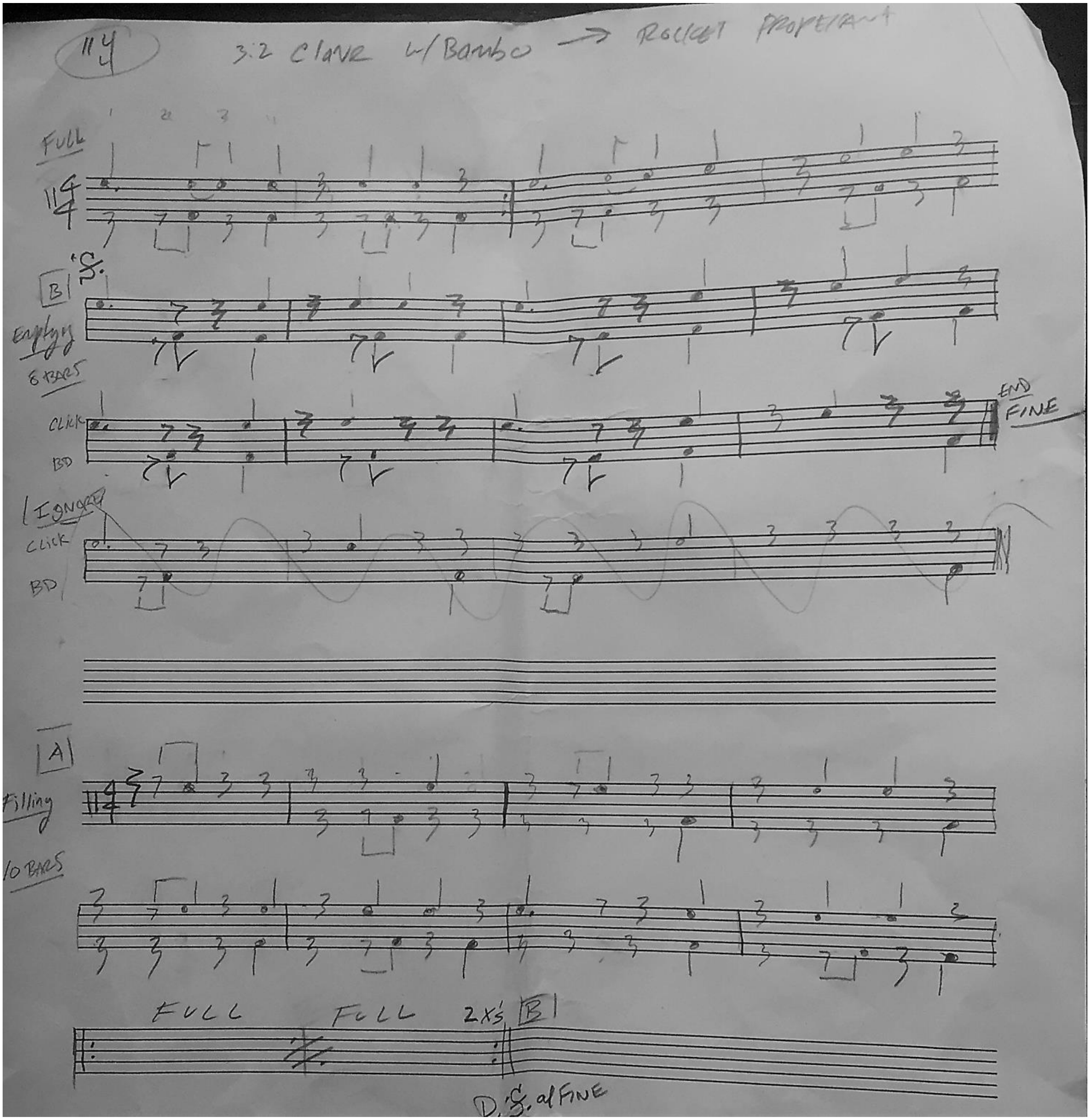


Image 2. Propellant Draft 2

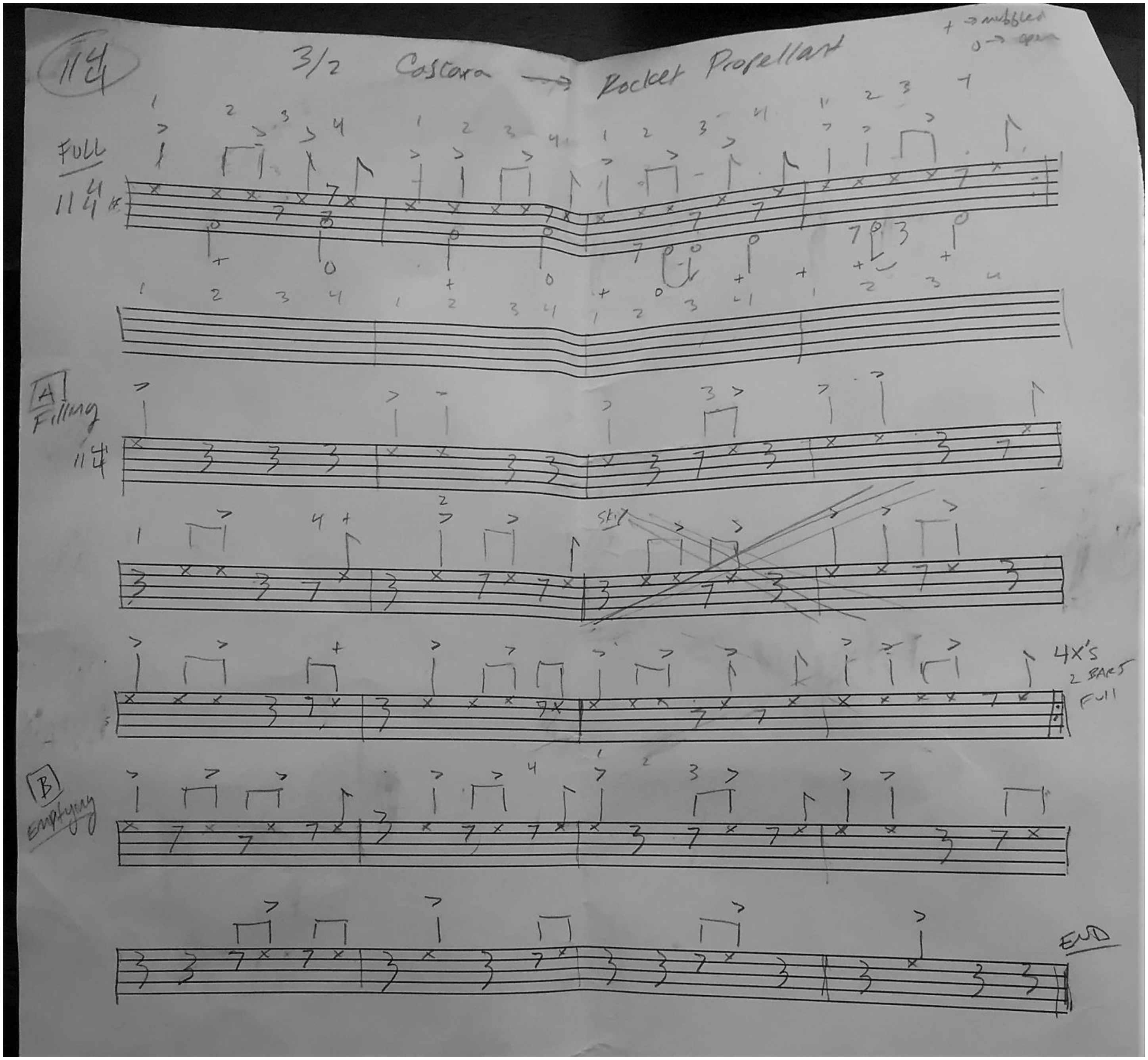


Image 3. Propllant Draft 3.