

Considerations about the static fire of the RATTworks H70 rocket motor

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Introduction

During the degree of aeronautical engineering the students improve their theoretical knowledge about this discipline. But the feeling among the students is that we can't apply this knowledge until we finish studying and start working. This is the reason why some of us join a student's team such as Terrassa Rocket Team (TRT) where we can join other students interested in rocket modeling. Together we improve our skills in making different types of rockets like a two-stage rocket, a supersonic one, rockets with deployable wings, etc. Some of us inside TRT are focusing in a new challenge: a hybrid rocket. All the same, before launching a rocket with a hybrid motor, we've organized a static fire to assess the thrust curve and test the launching process.

Objectives

The main objectives that need to be accomplished with the static fire are:

- Perfect the launch and ignition sequence and assess its correct operation. The work on this sequence is not done from scratch since several years ago former and current students of the TRT already ignited the hybrid motor. All the same they never managed to fly a rocket with the motor.
- Familiarize the part of the team that has never worked with this engine with the sequences, peculiarities and behavior of this type of rocket engines.
- Improve the security measures. Since the operation of this rocket engine requires high pressure oxidant gas security measures are more important than ever.

- Improve the thrust curve quality. The completely new test bench and electronics will ensure more reliable and constant data.

How does the engine works?

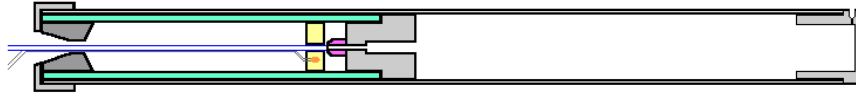


Figure 0.1: Empty motor

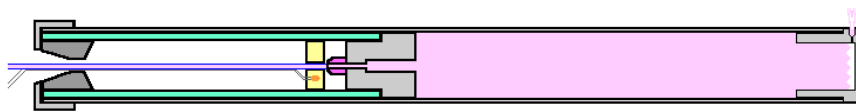


Figure 0.2: Motor filled with N_2O and venting

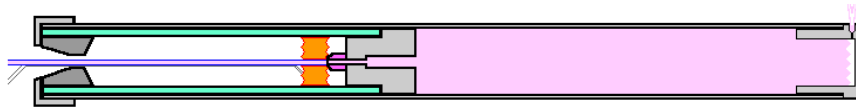


Figure 0.3: The ignitor starts the combustion of the solid grain

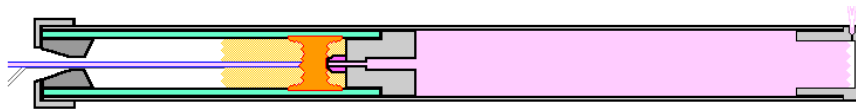


Figure 0.4: The combustion of the solid grain burns the gas tube

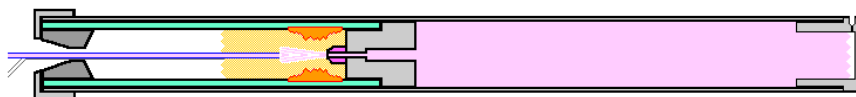


Figure 0.5: The gas leaks through the tube

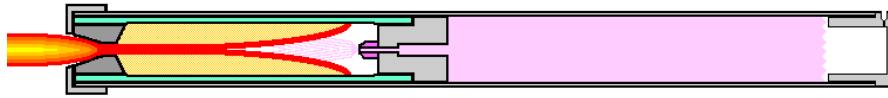


Figure 0.6: The motor is now functioning

Gas state and pressure

A basic theoretical study of the gas state and pressure inside the tanks has been conducted. To do so, the properties of the N_2O have been extracted from [2]. With the equations presented on the former source, a simple Matlab code has been built that generate the chart in Figure 0.7, said code can be found in [1].

It's important to realize that its difficult to measure the amount of nitrous oxide remaining in the tank because the pressure inside the tank remains constant until the tank is almost empty. The reason why this happens is because inside the tank there is N_2O in both vapor and liquid states. When this happens the pressure inside the tank remains constant at a value named vapor pressure.

This state where the two phases co-exist can only happen at a given pressure temperature and specific volume of the substance. A graphic representing this can be seen on the figure 0.7.

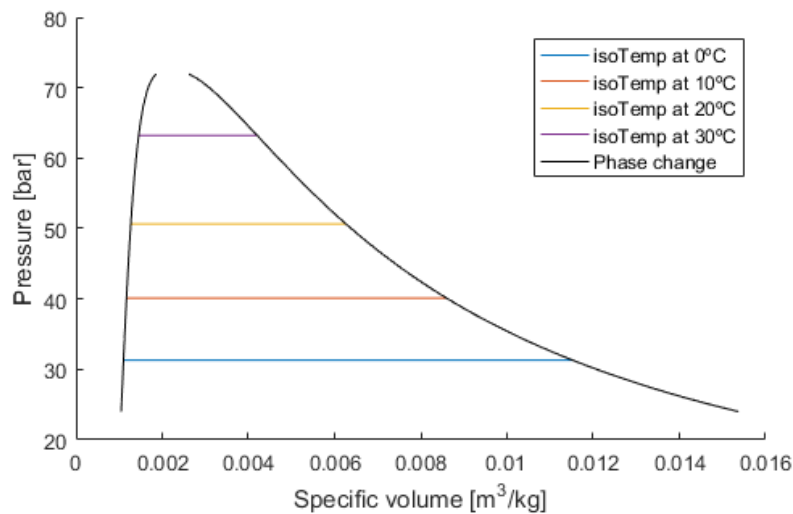


Figure 0.7: P vs v chart of N_2O

The tank currently used to supply the gas is 5L and stored 3.75Kg of gas when it was full. That is $(0.005m^3)/(3.75kg) = 0.00133m^3/kg$. Looking at the previous chart it's possible to see that this point was at the limit of the vapor-liquid zone and thus the tank was probably full of liquid at atmospheric temperature. However, this tank has already been used once and it's estimated that one-fourth of the content is gone. Then,

the current specific volume is $(0.005\text{m}^3)/(2.625\text{kg}) = 0.0019\text{m}^3/\text{kg}$. This value ensures that the substance will remain at vapor-liquid phase at any reasonable temperature.

When the rocket engine is connected to the gas tank and the valves are open, the pressure and the specific volume stabilize between the two recipients; this fills the engine integrated tank with liquid and vapor nitrous oxide.

The previous graph also shows the vapor pressure of the gas at different temperatures. It's important to notice the difference in pressure between common atmospheric temperatures. The current loading system has been prepared to withstand up to 70 bars plus security margins. This means that the launch or test ignition should be delayed if the temperatures are superior to 34.7°C .

However, it must be noted, that thanks to the security margins and the fact that the gas cools down when expanded, the system would probably withstand a launch at more than this ambient temperature. All the same, security is a top priority and ANY LAUNCH WILL BE DELAYED if it's not possible to assure a tank temperature lower than that.

Control software

Safety concerns

References

- [1] *Matlab code for generating the P-V chart of N₂O*. 2016. URL: <https://github.com/TerrassaRocketTeam/H70-rattworks-previousReport/tree/master/matlab>.
- [2] *Thermophysical properties of nitrous oxide*. 1991. URL: <http://edge.rit.edu/edge/P07106/public/Nox.pdf>.