PEAK OF FLIGHT NEWSLETTER

ISSUE 513/JANUARY 21ST 2020

IN THIS ISSUE

H_2O_2 LIQUID ENGINE

https://www.apogeerockets.com/Rocket-Kits/Skill-Level-4-Model-Rocket-Kits/Flying-Machine

www.ApogeeRockets.com
4960 Northpark Dr, Colorado Springs CO 80918
Ph# 719-535-9335

APOGEE COMPONENTS

PEAK OF FLIGHT

H_2O_2 Liquid Engine

By Bobby Potter

When Peter (Benny) Croonen first contacted me, I was a bit skeptical of his project, as his claims were quite extraordinary. The work he described was beyond an amateur project, but that of highly capable rocket scientists. He claimed they were working on liquid rocket engines on an amateur budget, and had been for the last couple decades. Even more extraordinary was the claim that they had succeeded with several iterations of their rocket engine.

I remained skeptical until the files started coming in. At a first glance, the content was far too vast and varied to be anything less than what Benny had described to me. I knew right away this was the real deal.

It took days for me to get through the files, to get a full understanding of what Benny was trying to show me. They'd been at this since '98, even longer depending on how you qualify it. They experimented with several fuel / oxidizer combinations, a half dozen methods of ignition, suffered 2 RUD's (rapid unscheduled disassembly, otherwise known as a big boom) and dozens of test failures. They meticulously documented the project, every test and design detailed by multi-page reports with a wealth of data behind them.

In Belgium, and much of the world, you cannot get manufactured rocket engines. Almost all model rocket engines are produced inside the United States and there are strict limitations of shipping these outside of the US borders. This leaves rocketeers in other nations few options, and those who want to experiment with rocketry have to start at the ground floor.

The ground floor for Benny Croonen and Jan Volckaert was still solid engines of their own making. They used several combinations of propellant / oxidizer; ZnS (Zinc sulfide), KNO_3 (Potassium nitrate) / sucrose and NH_4ClO_4 (Ammonium perchlorate) / polymers. By this time a couple decades had gone by, and they decided it was time to build a safe, affordable, and capable liquid motor for amateur rocketeers. They set 3 simple rules to guide the development of the project.

1- Safety First
2- All materials must be easy to find and cheap to acquire
3- All mechanical machinery and chemical installations must be done using basic equipment and relatively uncomplicated processes

- Author's note: This is not a complete, step-by-step, instructional document to building your own rocket engine. This is a high level overview of the steps, critical components, and journey through the development of this liquid engine. To build your own or replicate their engine, see their website and the full documentation on the development, testing and design. It includes hundreds of documents, pictures and video, including detailed testing and analysis.

H_2O_2 Decomposition and Useful Fuels

Of all the options available for the oxidizer of their first iteration of liquid motor, H_2O_2 (Hydrogen peroxide) stood out as the clear favorite. Liquid oxygen, the leading alternative, required storage at extremely low temperatures making it impractical. H_2O_2, on the other hand, remained in liquid form at essentially room temperature. There was a downside here though. You could acquire H_2O_2 relatively easily and at low cost, but the concentration was diluted to 50% at best. The first major decision in the development of the H_2O_2 engine was made for them; Increase the concentration of the H_2O_2 to at least 70%.

FIGURE 1: THE DISTILLATION APPARATUS

The theory behind H_2O_2 engines lies in the decomposition of the H_2O_2. When the H_2O_2 is passed through the appropriate catalyst, it decomposes into oxygen (used to oxidize the combustion) and water in the form of steam. In an effort to keep the engine as simple as possible, sodium iodine (NaI) was selected as the catalyst while the fuel itself would be methanol. These would be combined in the same tank and introduced to the H_2O_2 simultaneously.

Continued on page 3

About this Newsletter
You can subscribe to receive this e-zine FREE at the Apogee Components website www.ApogeeComponents.com, or by clicking the link here Newsletter Sign-Up

Newsletter Staff
Writers: Bobby Potter
Layout / Cover Artist: Matthew Martinez
Proofreader: Michelle Mason

H_2O_2 Liquid Engine

Continued from page 2

This provided a few advantages. The combination of sodium iodine and methanol meant the H_2O_2 would decompose at a high efficiency and in a single chamber, meaning you wouldn't need a decomposition chamber and a combustion chamber. The entire decomposition and combustion could effectively occur in the combustion chamber, limiting design complications.

The cons: Immediately this resulted in a series of "hard starts" or explosions at the moment of ignition. Upon review they discovered this was caused by the diluted H_2O_2 (85% H_2O_2 and 15% water) in combination with methanol. Methanol is soluble in water, and due to their diluted H_2O_2, explosions were commonplace in their early testing.

FIGURE 2: A RAPID UNSCHEDULED DISASSEMBLY DURING TEST LX58 CAUSED BY THE DISABLING OF THE HEAT CHECK SAFETY SYSTEM.

After this revelation, Benny and Jan adjusted the designs to focus on a hot engine, as the ambient temperature of these designs exceeds the point where natural decomposition of the H_2O_2 occurs. This eliminates the need for a catalyst such as the sodium iodine. Since the heat took care of the decomposition of the H_2O_2, the fuel source became flexible and they replaced the methanol with petroleum. A hot engine also eliminated the worries behind the 15% of water remaining in the H_2O_2 as a hot combustion chamber vaporized that almost immediately.

The Direct Injection System

In accordance with the ground rules, the engine was kept simple so it could be constructed with basic mechanical tools. This system, as the name suggests, used a single chamber with direct injection for the decomposition of the H_2O_2 and combustion of the petroleum. There was also a block of solid propellant, called VOX fuel (KNO_3/Sugar/Sorbitol), placed at the base of the rocket to ensure a smooth ignition.

The entire system worked like this: The VOX fuel was ignited (T -2.5s). Once the VOX fuel was at full thrust (T -1.0s) the H_2O_2 pneumatic valve was opened and H_2O_2 flowed into the combustion chamber. As the VOX fuel burns at 1,300 degrees celsius, the conditions were already met for the H_2O_2 to decompose and the excess water to be evaporated.

At T -0.5s the fuel valve was opened and the true propellant (petroleum) flooded the combustion chamber. At this time, the engine reached full power.

Injectors

For a fuel and oxidizer to work optimally, to ignite quickly and uniformly across all the volume going into the combustion chamber, it is important to inject it in the form of a spray of fine droplets. The materials used, specifically in H_2O_2 engines, also comes into play. For an effective solution, they used petroleum injectors. This worked for a time, but once they needed to scale the project up for a larger rocket motor, this solution was no longer capable of handling the pure volume.

Continued on page 4

H_2O_2 Liquid Engine

Continued from page 3

This is when they began to make their own injectors. Using plans they made from reverse engineering "ProFessional Injectors" (ProFessional being the brand), they were able to build a comparable injector that was able to handle the workload. It is important for the injectors of an H_2O_2 engine to be made entirely of stainless steel. This is to prevent a reaction between the metal used and the H_2O_2.

Solid Propellant Blocks for the Startup Phase

The VOX propellant blocks, which are used to startup the liquid engine, are 67.5% KNO_3 (oxidizer), 17.5% white crystal sugar (fuel), and 15% sorbitol (prevents the caramelization of sugar while melting) by weight.

This formula has several advantages in comparison to the alternatives. For example, a 70/30 split between KNO_3 and sorbitol could be used, however this will produce about 20 seconds less specific impulse and have a higher cost.

A warning to all you would be warriors, small mistakes here could lead to your propellant going up in flames. This would not cause a rapid reaction (an explosion), but it could easily result in you burning your own house down. Proceed with extreme caution.

Creating these fuels is complex and can be extremely dangerous, we do not recommend following this process unless you are an extremely experienced rocketeer or have extensive lab experience under your belt.

For the VOX mix, the components are weighed and then mixed together. The powder is then moved into a stainless steel receptacle for the melting process. The components are then heated to 90 celsius (Just below the melting point of Sorbitol). *Warning* It is essential to use an electric heating plate and an oil (motor oil) bath to uniformly heat the mixture. Hot spots or ANY open flame could result in the ignition of your propellant.

FIGURE 3: THE COMPONENTS BEING MIXED UNDER HEAT

The propellant is heated and stirred constantly for 3 hours (mechanical stirring), again with all components touching the propellant being stainless steel. The stainless steel is important to prevent any chemical reactions between the stirrer, receptacle and the propellant.

After the 3 hours, the temperature needs to be raised again, this time to 170 degrees (celsius). It needs to be continuously stirred at 170 degrees for the next hour, and finally increased for the final stage to 190 degrees for 15 minutes.

At this time, the mold (fitted with a transparent silicone liner) is heated to 150 degrees (celsius).

Join The NAR.org
Mention Apogee Components

Continued on page 5

H_2O_2 Liquid Engine

Continued from page 4

The propellant is then poured into its mold and immediately mounted on the lathe to be centrifuged for the next 3 hours at about 300 RPM.

FIGURE 4: VOX BLOCK MOLD AND SILICONE LINING

The VOX block is then placed in an air tight drum with a few hundred grams of silica-gel. Store for at least 12 hours.

Finally the VOX block is placed back on the lathe for a final time, rotated at 50-60 RPM in an effort to turn away the inner part of the propellant and to bring the central mandrel to the desired diameter. Exceeding 50-60 RPM could cause excessive heating at this stage.

Both the bottom and top sides are then roughened for an optimal burn and the VOX block is ready to use. This propellant is then stored in an air tight container and under ample silica-gel until use.

The Nitrogen Pressure System

The entire system is pressure fed using nitrogen gas. The nitrogen itself is a standard 5.3 cubic meter nitrogen bottle at 200 bar (1 bar = pressure of the atmosphere at sea level). This is enough pressure to efficiently feed the entire system. This gas is set to put 60 bars of force onto the oxidizer and fuel tanks. The flow of nitrogen is controlled by two pressure electro pneumatic valves.

FIGURE 5: THE NITROGEN PRESSURE SYSTEM

Below the fuel and oxidizer tanks are two more pneumatic valves, this time controlling the flow of these fluids into the combustion chamber. For the correct chemical processes to take place, the H_2O_2 would be pushed about a half a second earlier into the already heated combustion chamber. This

Continued on page 6

H_2O_2 Liquid Engine

Continued from page 5

would allow a little time for the H_2O_2 to decompose before the petroleum was pushed into the system for a full ignition.

A Basic Sequencer

In the beginning of this project, they ran the ignition sequence manually through a series of mechanical switches. It became apparent as the system became more complex, and human error began drastically affecting test results, that a new system would be needed. At this stage they developed a simple microprocessor. Only basic parts were used here, again for simplicity, such as relays, switches, control lamps, resistors and a capacitor.

FIGURE 6: THE BASIC SEQUENCER

Obviously these sequencers can get quite complex and control nearly every aspect of the rocket, but Jan and Benny outlined what they say is the bare minimum to effectively control this system as:

1) T -40s: The two pressure electro pneumatic valves controlling the flow between the nitrogen and fuel / oxidizer tanks are opened simultaneously. This pressurizes the liquids in their respective tanks.

2) At -1s the pneumatic valves for the fuel and oxidizer must be closed (safety check).

3) At +0s the electrical igniter is activated and the VOX block is ignited.

4) System Wait - the VOX block burns until it reaches full thrust. At full thrust this cuts the break wire.

5) The break wire signal opens the main oxidizer pneumatic valve allowing for the H_2O_2 to flood into the combustion chamber.

6) A half second later the main fuel pneumatic valve opens allowing for the petroleum to flood into the combustion chamber.

At this point your rocket engine has reached full power.

Continued on page 7

H_2O_2 Liquid Engine

Continued from page 6

Lining the Combustion Chamber

As the project went on and the testing became more and more stressful on the system it became apparent that the combustion chamber was exceeding safe temperatures at about 8 seconds of burn time.

As 8 seconds was the max burn time for a safe test, exceeding this limit caused a discoloration (meaning erosion) in the combustion chamber due to extended durations of extreme temperatures. The longest static fire test to this point was a 27 second burn time, an impressive feat, but they immediately noticed the erosion within the combustion chamber.

FIGURE 7: DISCOLORATION DUE TO EXCESS HEATING

To solve for this problem, they choose to line the combustion chamber with "Fireproof Mortar", a cheap and readily available product. Although they eventually moved away from this system when they launched the new direct injection system, they saw a lot of great successes with this relatively cheap fire retardant.

The fireproofing was an 8mm lining, uniformly spread by applying a semi wet mortar and spinning the combustion chamber through a centrifuge (in this case a lathe).

As they switched to the direct injection system, which did not need this fireproofing, there was never a full stress test done on the combustion chamber lining. Several tests were done at around the 20-30 second range, each time reducing the available lining by about 2mm (out of a total of 8mm). Extrapolating these results out, a full stress test should have been able to exceed a full minute burn at maximum thrust without compromising the integrity of the combustion chamber.

Eyes to the Future

This project is done. The team has created a reliable, cheap, and (relatively) easy to construct liquid rocket engine for amateurs. Benny and Jan have moved on to bigger and more ambitious projects. Today they are using that same engine, with the direct injection system, to develop systems for thrust control and vectoring. Achieving this goal would allow for them to launch a rocket without a guide rail / rod or aerodynamic stabilization.

This would be an impressive feat, but I think with their level of dedication, it'll be a breeze. A special thanks to the team, Peter (Benny) Croonen and Jan Volckaert for sharing their work with us! You can see much more about this project and others that they are working on at their website: http://users.telenet.be/H2O2rocketengine.

Written by Bobby Potter, a staff member of Apogee Components. This article was based on the work, accomplishments and direction of Peter (Benny) Croonen and Jan Volckaert.

Join Tripoli.org
Mention Apogee Components

CHECK OUT THE APOGEE YouTube PAGE
CLICK OR SUBSCRIBE HERE FOR OUR HELPFUL
AND INFORMATIVE HOW-TO VIDEOS
ON MODEL ROCKETRY
APOGEE COMPONENTS