# Gas in a pop-pop engine

By Jean-Yves

On several occasions we noticed the presence of gas inside the engine after a long running period. Why sometimes and not always ? Where does this gas come from ? Why ? How ? When ? What is this gas ?...

Hereafter we will try to answer some of these questions. To do that, we will display some figures got from our experiments. These figures are valid for the engines we used. For other engines the figures could be different, however, the laws should apply.

**Facts :**

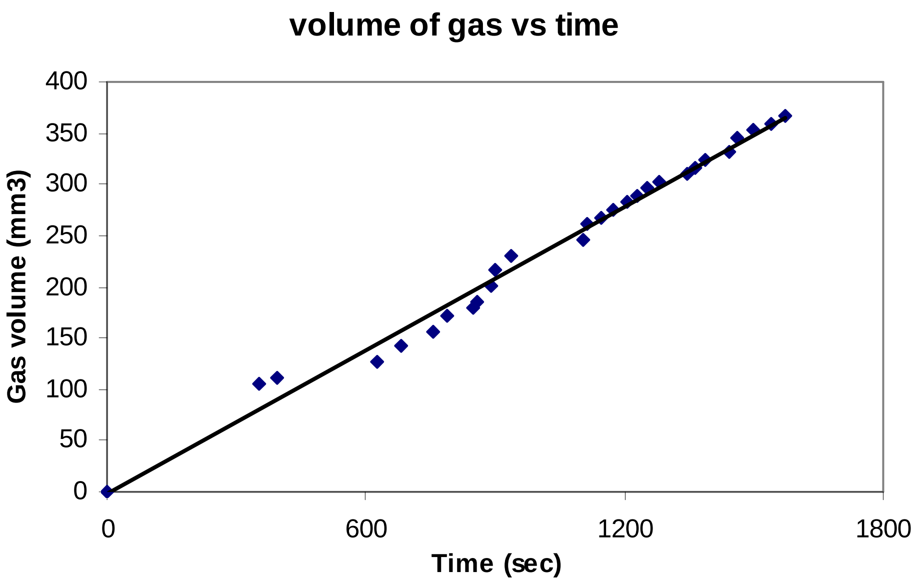
When an engine has run for a long time, even though it was full of water at the beginning, we could find some gas inside.

The amount of gas is higher when the water has just been drawn from the tap at the beginning of the test.

The gas (up to a certain amount) improves (drastically) the performances. This is confirmed by Slater's experiments (He fills his engines with water in order to wet the inside and before to starting them he drains almost all the water, in order to just let some drops inside).

## 1. Production of gas versus time :

With a coil engine described in appendix we counted the bubbles escaping from the nozzles, and we measured the size of the bubbles to estimate the flow.




Roughly for this engine the gas flow was constant and equal to 0.23mm$^3$ per second (or 14mm3/mn). During this test, the thrust was always between 0.4 and 1mN.
Note: This is valid for this engine and this particular test. It could be different for another engine, and also for this one with different conditions. This diagram is just there to give an example.

Later, we ran exactly the same test, but this time we used some water drawn from the tap several days before. First, the engine reacted as during the previous test. The thrust was limited to 1mN. After 541 seconds one bubble escaped. A smaller one escaped 107 seconds later. Then no bubble, but the thrust increased with time to reach 12mN after 4800 seconds. This maximum thrust is equal to the one got previously with similar engines. The pop-pop frequency was 7Hz. At t=6060 seconds the flame was withdrawn and 5 minutes later we measured the gas volume inside the engine. We got 2.54cc. If the degassing was linear (as for the first test), this means approximately 0.42mm3 per second. This is more than for the previous test. However, we expected less because we used water which should have degassed during the days it was stored in a bucket. The cause is very likely due to the big amount of water circulating in the engine because it delivered a high power.

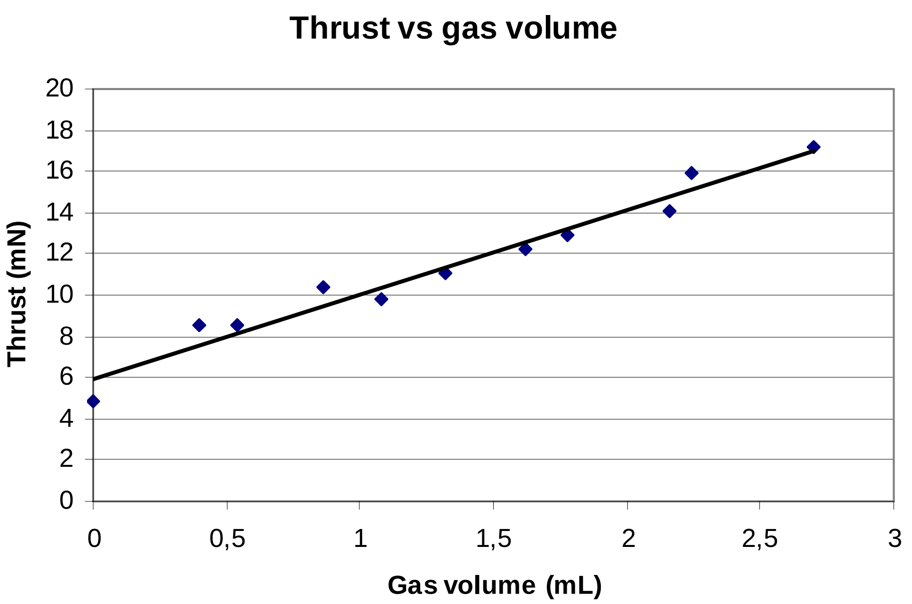
## 2. Thrust versus gas volume :

The thrust evolves with the gas volume inside the engine. What we call "gas" here doesn't include steam. Unfortunately, we cannot measure simultaneously the gas volume and the thrust. Nevertheless, we can measure the thrust versus time and for a measured thrust we can stop the engine and wait for cooling and then measure the gas volume remaining inside. We did that a couple of times. Only a couple of times, not because each step needs a long time to be done, but because after heating stop there are generally some steam blasts and most of the gas escapes at this occasion. The method we used to solve the problem is the following one:

Thrust measurement.
Stop of the heating.
Both ends of the pipes closed with fingers
Wait for a couple of minutes for cooling down
Fingers off (Perfect red circles on the skin where the vacuum was sucking blood)
Put a glass bell full of water on one nozzle
Push violently water through the other end (with a big syringe)
Suck the gas trapped in the bell by means of a small graduated syringe.

Thus, for a particular pop-pop engine (4D12 type) we succeeded to measure that the best thrust was got for approximately 1.7cc of gas (at 20°C). And, depending on the quality of the water (just drawn from the tap or drawn the day before…), this volume could be reached in one, two or three hours, or even more, using the same heating power.

Then, to save time we used a simpler method. Once the engine was ready and full of water, we introduced a well known quantity of air by means of a syringe and a capillary tube. We ran this test on a rather big engine for better relative accuracy. The diaphragm engine that we used is described in appendix. We got the following result.



One could object that in addition to the air voluntarily introduced with a syringe in the engine there was some gas produced as per chapter one description. That is true, but:

We re-used some water already used in several pop-pop engines and drawn from the tap one week before; i.e. some gassed had already escaped.

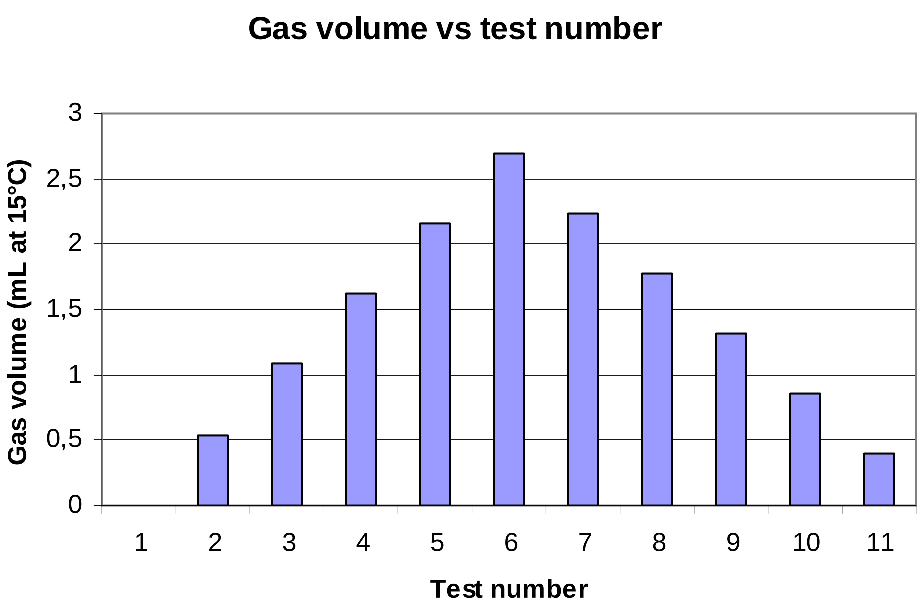
We used an electric heater for constant and appropriate heating power.

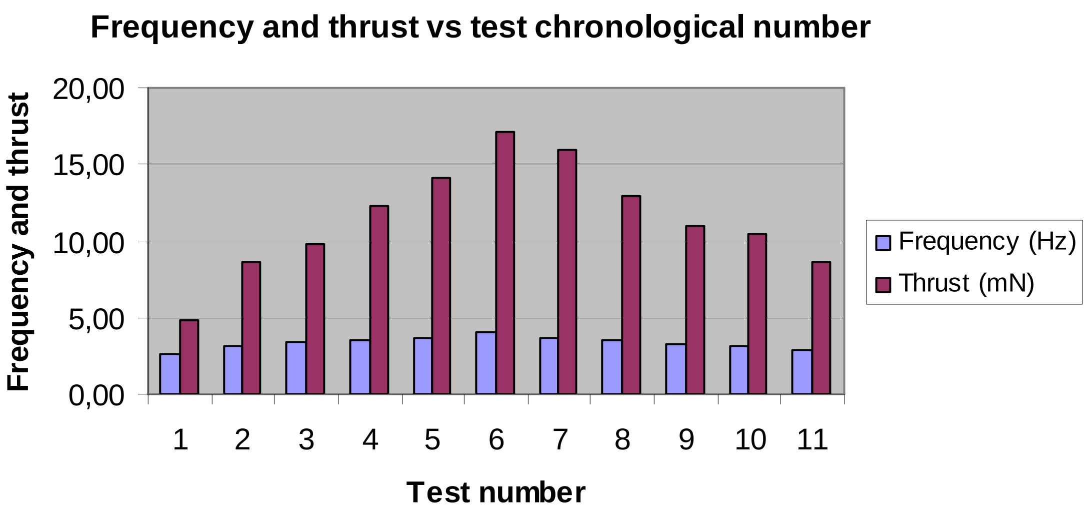
The series of test were run in a short time (one hour for 11 steps)

We increased the air volume and then decreased it.

We measured the volume of gas produced during this hour.

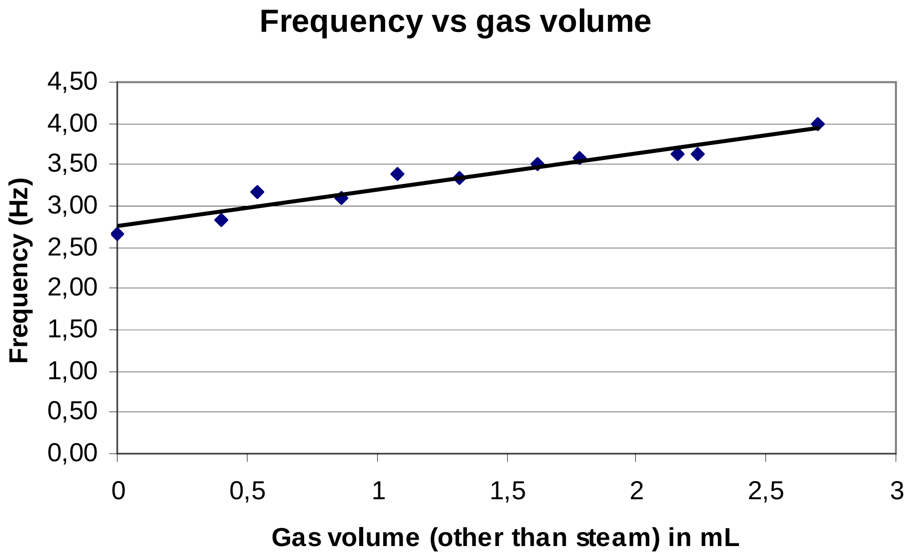
After one hour, the volume of gas inside the engine (after withdrawal of the air voluntarily introduced) was 0,4mL. As expected, it is not much. Nevertheless, we took it into account. We added 0.04mL at each step in the final analysis.



## 3. Frequency versus gas volume.

The heating power being constant, we can draw the curve of frequency versus gas volume.

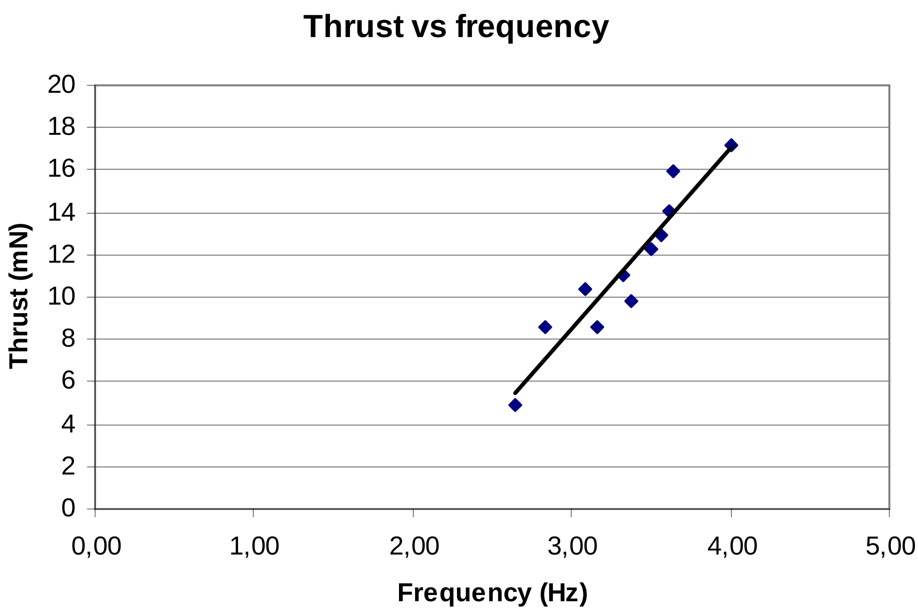



This confirms what we observed before. The frequency increases with the volume of gas (other than steam) inside the engine. That is something that we are not able to explain totally today, but the result is there.

Note: On some engines one could see an apparent stability, even sometimes a slight decrease of the frequency at the beginning, but after a while the frequency always increases with the gas volume.

## 4. Thrust versus frequency.

The common denominator for thrust and frequency is very likely the gas volume; however, we can draw the curve of the thrust versus frequency.



**5. What is the gas** (in normal conditions)?

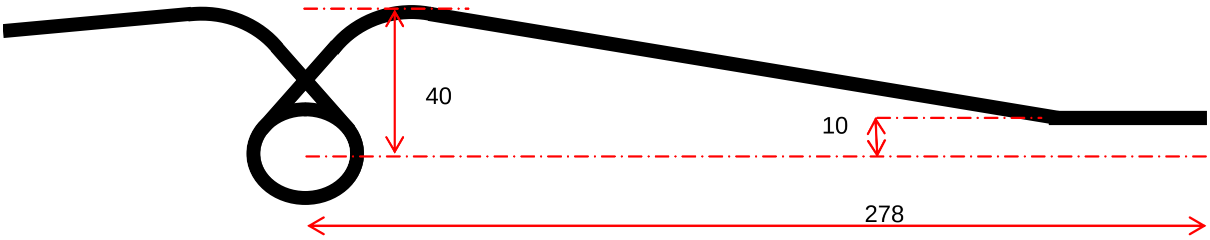
For this small chapter I have got figures from Loïc. In the water some gasses are dissolved. When we use water from the tap, there could be some chloride but most of all the dissolved gasses are nitrogen and oxygen. The maximum amount depends on the temperature. At 20°C there could be 9.54mg of oxygen per liter. At 100°C it is only 3.15mg. For nitrogen, the figures are respectively 15.3 and 5.9mg/L. Therefore, when heating the water from approximately 20°C to approximately 100°C, there could be 6.4mg of oxygen and 9.4mg of nitrogen per liter that escape.

The volume of a pop-pop engine is small. However, due to its principle, the whole content of the test tank is concerned because the water is alternatively pushed and pulled in the engine pipe(s). When an engine is delivering a small thrust the water is renewed slowly and the gasses are escaping slowly. But when an engine is shaking hard, the gas flow should be bigger.

## Appendix.

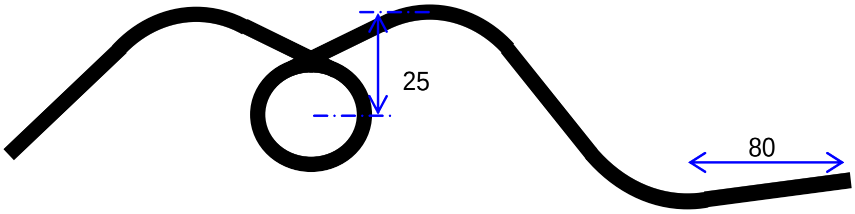
**Description of the engines.**

The one used for the gas production measurement was this one.




4 turns. Internal coil diameter: 12mm. Pipe ID 4mm. OD 6mm.
Both ends of the engine were connected to water tanks.

For the measurement of thrust versus time we used a similar engine, but shorter and with steeper slopes.




80mm includes the nozzle which is part of the test tank.

For the last series of measurements, we used the PPVG engine on which we placed an aluminum diaphragm. And to heat it we used a soldering iron.

A particular adaptation piece (made of copper) has been designed and built to transfer most of the electric power of the soldering iron to the engine (as heating power).