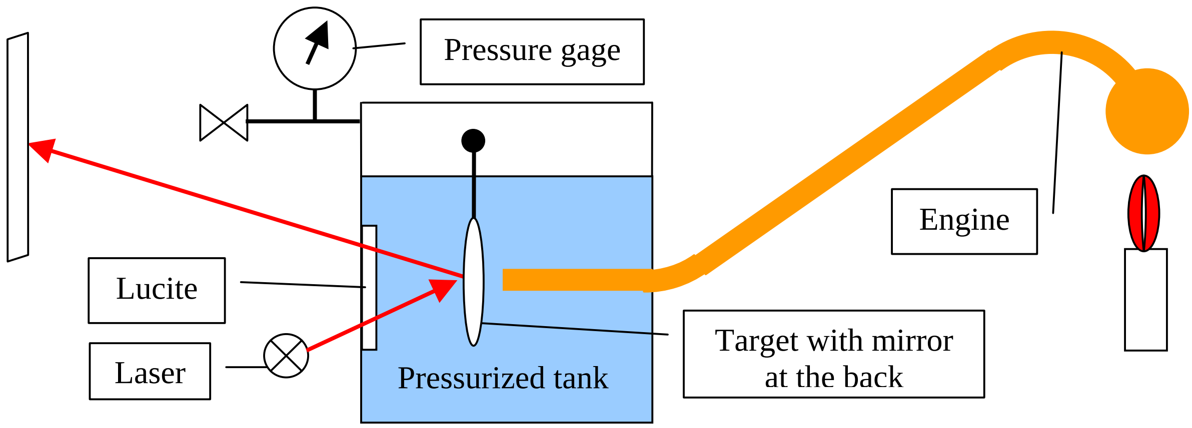
Performances of an immersed pop-pop engine

By Jean-Yves

With long engines, by changing the slope, we have already seen that there is no visible difference in thrust when the height between the boiler and the tank water level varies. But our tests were limited to approx 1m. This height is not enough to change drastically some parameters such as the boiling temperature. In March 2006, Christophe and I forecast to use a pressurized tank but we didn't know how to measure the thrust. Since that time, thanks to laser beams I developed several measuring instruments. Using a laser beam through a window could be the way to solve the problem. Therefore, a new test bench has been built as per following sketch.



While the engine is running it is easy to increase the air pressure by means of a compressor connected to the valve.

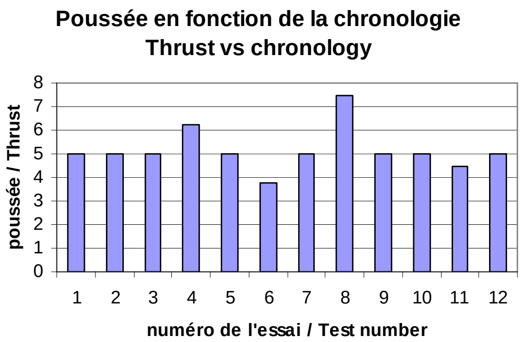
Note: obviously, this doesn't concern diaphragm engines because the pressure inside the engine wouldn't allow the diaphragm to move.

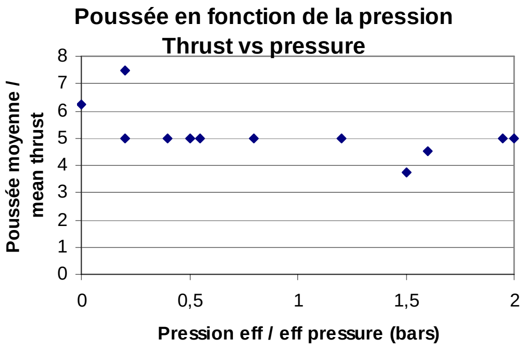
<u>Observations :</u>

- While the engine was running we increased the pressure. The engine stopped. We reduced the pressure. The engine restarted.
- At any pressure (up to 2b (29psi)) we heated the evaporator and the engine worked. (see the note below).
- When the pressure increases, the instantaneous thrust is more irregular or erratic. Due to that, it was not possible to measure exactly the frequency. However it's seems that the mean frequency increases with the pressure.
- Thanks to the shape of the engine and to the materials (stainless steel pipe and copper evaporator) the upper limit of the liquid water was known and we could checked that only the copper part was overheated (= much over 100°C).
- The needed heating power evolves very slowly with the pressure. We used electrical heating with a small piece of rock wool on top of the evaporator to limit the heat losses. At atmospheric pressure the heating power (including losses) was approx 45W. At 3 bars (absolute pressure) it was approx 65W.
- Mean thrust. See the diagrams.

Note: before closing the bowl I ran the engine for approx one hour. The thrust seemed normal for this size of engine. I didn't measure it but according to the movements of water it was something as 25mN. During all the tests the engine ran with a small thrust (approx 5mN). Once the tests were finished I opened the bowl and tried to repeat what I had observed before. The thrust was still approx 5mN. Then I put some air in the engine. Its thrust increased and after 50 minutes it stabilizes at approx 32mN (what I had estimated 25mN before). This is the best thrust that this engine can deliver. However, when the bowl was closed and pressurized I couldn't set air inside the engine. Therefore, the thrust was not optimized.

Diagrams :





The pressure was measured with accuracy (approx +/-0.1b). For the thrust it was more difficult because I couldn't damp the mobile (target and mirror) located inside the bowl. For the accuracy I would say +/-1.5mN.

Theoretical approach/analysis :

The frequency evolves as the square root of PS^2/MV where P=inside pressure, S=area of the pipe cross section, M=mass of the water snake and V=evaporator volume. For a given engine, in steady state conditions the gas (steam) volume V and the liquid mass (water snake) M are constant. Therefore, the frequency evolves as the square root of the absolute pressure.

The mean thrust evolves as the square of the product LF where L is the stroke and F is the frequency. As we have measured that the mean thrust is constant, it means that the stroke is inversely proportional to the frequency.

Because the mean restituted power evolves as $(LF)^3$ and because LF is constant, the power is independent of the pressure. Another factor tends to confirm this: the needed heating power doesn't evolve much with the pressure. In fact the power consumption increased slightly (from 45W to 65W) but the useful power didn't increase so much because the boiling temperature at 3 bars (abs) is 120°C instead of 100°C at atmospheric pressure and the heat losses evolve with the temperature.

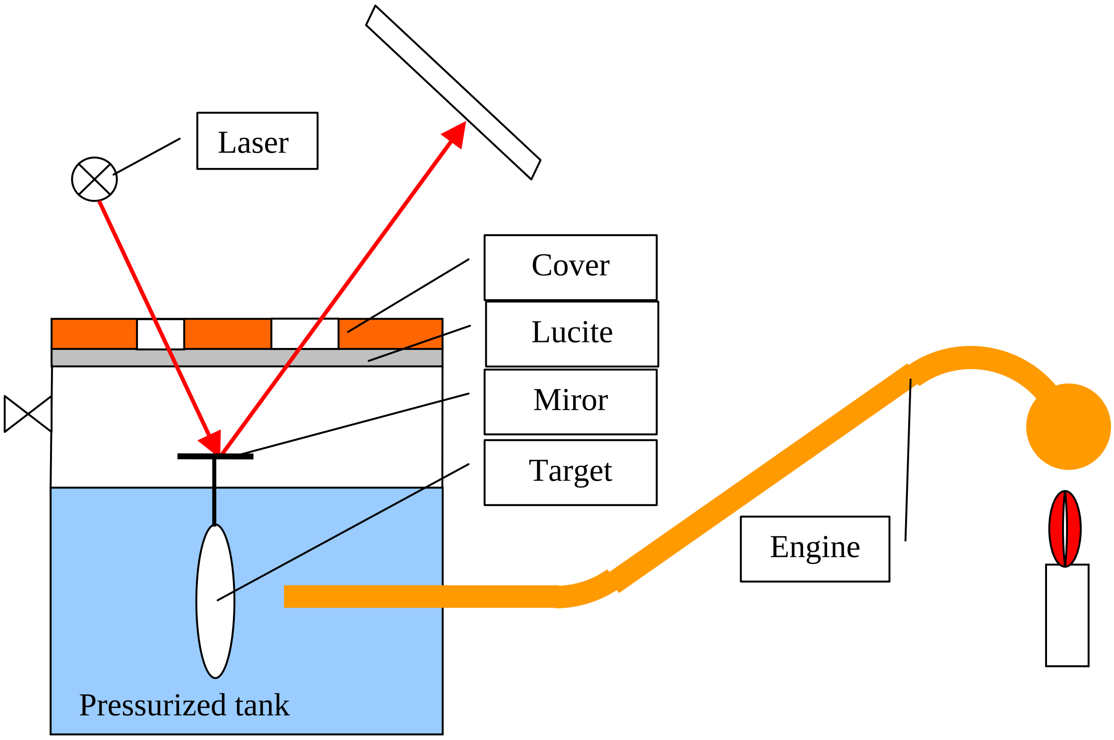
Conclusion :

It needs to be confirmed by other tests. However, it seems that for a given engine the frequency increases with the pressure while the mean thrust remains approximately constant.

Appendix

Comments for those who would like to test a pop-pop engine under pressure.

The first release of the test bench was built as follows and we expected to test the engine up to 7 bars (100psi). However, because of technical problems we couldn't exceed 2 bars.



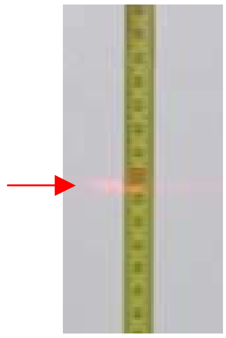
Main components from the left to the right: laser emitter, test tank (stainless steel bowl recovered from a professional coffee machine), lower flange, Lucite, upper flange. And at the bottom left is the engine which was designed to be electrically heated.

Note: the lower bends of the engine are due to the need of connecting it to the bowl at the bottom to allow the passage of the lower flange (made of plywood) after welding is completed.

On the top cover the two small holes were used for the laser beam and the larger one to observe the inside.

Unfortunately, very soon this test bench showed a problem: because of a big condensation on the window (as you can see on the side photo) it was impossible to look inside and the laser beam was too much widened and dimmed.

On the next release of the test bench I used a Lucite window that I had to curve as the bowl is. Due to that bending, the narrow laser beam sent by the emitter (a laser pointer, yellow on the photo) became a flat beam (visible on the upper window of the bowl).



Happily it was flattened in the right way. On the scale it gave a thin horizontal line, and it was easy to measure its vertical deviation. (In fact, due to the flashlight the photo is not so good as the reality).