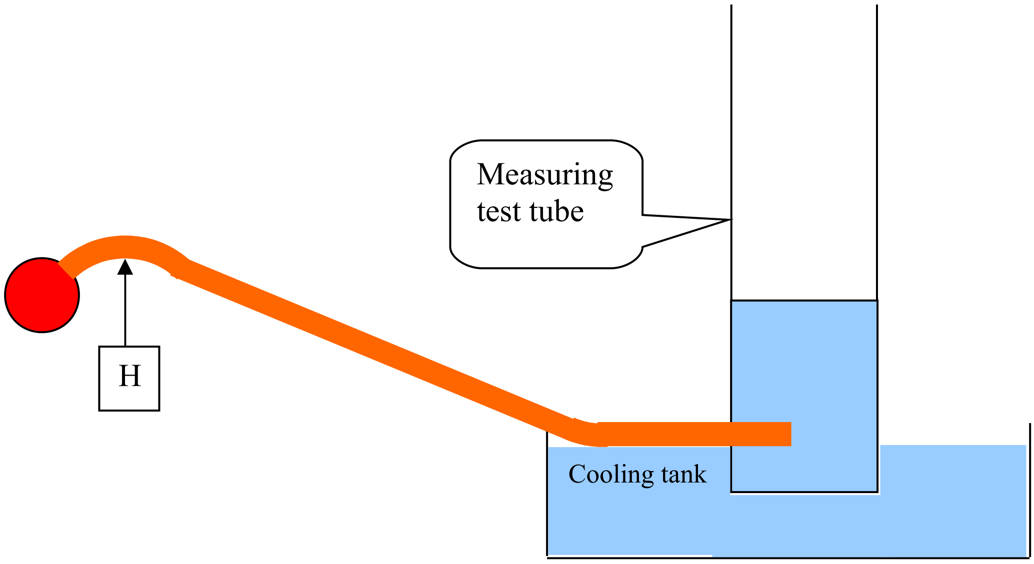
Amount of water inside a pop-pop engine

To determine the amount of water (and consequently the one of gas) inside a working pop-pop engine I imagined the following arrangement:



I reused a well known engine with electrical heating and I connected it to a Sudo T closed at the bottom and on its side by soldered lids. And on the top I connected a measuring test tube by means of a piece of bicycle inner tube.
Volume of the pipe at the right side of H: 23 cm^3
Total inner volume of the engine: 29.5 cm^3
To save some time in the starting process I introduced voluntarily 4.5 cm^3 of air inside the engine. Hence, there was 25 cm^3 of water and this corresponded to the zero graduation of the measuring test tube.
At the beginning of the heating, the volume in the measuring tube increased by 1.25 cm^3 before the engine started to pulsate. Little by little the pulsation amplitude increased. Approximately 3 minutes later, the engine reached its nominal working…in these special conditions. The mean volume in the measuring tube was then 11 cm^3. The evaporator was highly overheated, the steam mass was negligible and the water was located only in the right side of the pipe. This water quantity was 25-11=14 g.

14g for a piece of pipe of 26 cm^3. Therefore, without better knowledge, we can consider that when the engine runs well, the mass of water inside is approximately half the one that the falling part of the pipe can hold

This confirms visual observations through pop-pop engines made of glass. When the engine works well, at the bottom of the pipe it is liquid water, at the top it is very roughly the same volume of steam. And in between it is a progressive emulsion.

Complementary lessons drawn from this experiment:

During the previous tests this engine delivered 41.5mN at 3.2Hz. The calculated stroke was 180mm; that corresponds to a stroke volume of 9cm^3.

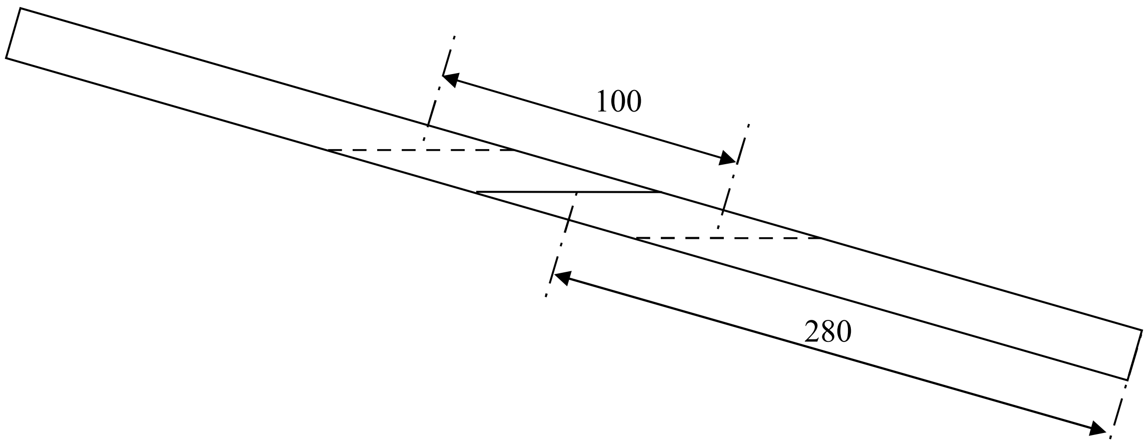
Thanks to the test tube I could measure the stroke volume: exactly 5 cm^3 and the frequency: 3.3Hz. Knowing that the inner diameter of the pipe is 8mm, this allows for calculating the stroke: 100mm. It is less than during the thrust measuring test. Two main reasons: 1°) Measured thrusts are always over estimated by 10 to 40% (see corresponding file). 2°) During this last test the engine didn't "breathe" as well as when tested in a big tank.

Additional analysis.

See first page. The initial volume of air was 4.5cm^3. When heated (air + steam?) it increased by 1.25cm^3. But, when heated from 20°C (293°F) to 100°C (373°C) the air volume becomes 4.5*373/293=5.73cm^3. Air only is 1.23cm^3 more (5.73-4.5).

If we consider the uncertainties (1.23cm^3 for 1.25cm^3) the engine started as soon as the boiling temperature had been reached.

When it reached its cruising speed it contained 14cm^3 of water and the stroke was 100mm. Due to the tube diameter, 14cm^3 correspond to 280mm on the falling part of the tube that is 460mm long.



No doubt that the amount of water is the one that was measured, but the interface is certainly not a beautiful flat and horizontal surface as on the sketch.

Luckily I still have this engine and it has not been modified. I will be able to test it again (when I have time). Perhaps that with more air injected inside, or with longer time or with more heating power I could get a stroke volume closer to the one got during thrust measurements.

Note: In practice, the slope of the tube is 15% and it ends by a long radius bend and a horizontal section.