Where does the spent power of a pop-pop engine go?

The candle (or every other mean of heating) transfers the heat it produces to the evaporator and to surrounding air. When every day the media remind us to save energy we feel that here there is some waste. In a laboratory, during a pop-pop engine test it is possible to reduce the heat losses thanks to the use of electric heating and thermal insulation. But, on one hand it would be unrealistic to do that on a pop-pop boat, and on the other hand we are going to see that what could be saved –if it was possible- is not at that level.

We did some measurements on a test bench. The engine that we used was made of a copper evaporator and a single brass pipe of inner diameter 8mm.

1°) Heating of the dry evaporator (i.e. the engine containing only air). The engine was fitted on the test bench as it would have been if full of water. The bottom of the pipe was immersed at the depth it would have been for a normal running. At the top of the engine, the same temperature as in normal operating conditions was reached with a heating power of 14.5W.

We noticed that only the evaporator and the top of the pipe were hot. A quick calculation confirmed this. The heat losses through the thin brass pipe by conduction are minute (<<1W). In the hotter part there is mainly conduction and convection with surrounding air.

2°) Engine running in optimized conditions. To get this the heating power has been increased up to 45W. It was interesting to observe that the temperature gradient all along the pipe was roughly the same as when the engine was dry. (See graph in appendix). Hence, one can consider that the "useful" power transmitted to the engine was 45-14.5=30.5W. The frequency and the thrust developed by the engine were measured. Frequency: 3.2Hz. Thrust: 41.5mN.

As the movement of the liquid piston is roughly sinusoidal (we saw that on other occasions), we could calculate the stroke of the liquid piston (180mm) and the restituted power: 0.032W. It is very weak (alas!), but it is quite in accordance with all what measured on tenths of motors of various characteristics.

Conclusion: Approximately 1/3 of the heating power goes into the air, and 2/3 goes into the water. Only a very tiny amount is transformed into mechanical power.

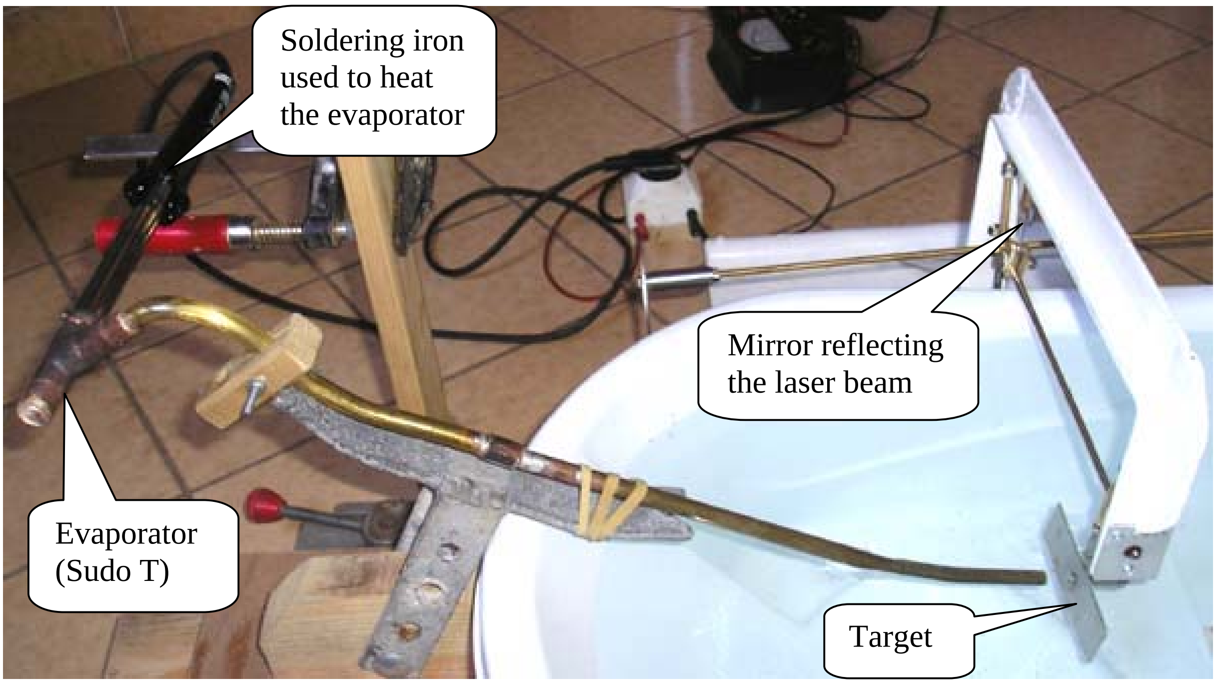
When using a candle or a burner with alcohol the figures can be worse.

In this example the global efficiency is 0.07%. (It is to be reminded that this is a relatively big engine which is more or less optimized (with insulation). For a small *lambda* engine bought on the market it is worse).

It is confirmed that a big amount of the power is transferred to the water of the tank. We could check that on others occasions by measuring the water temperature increase during long duration tests with a small amount of water into the tank. Why and how is it possible? If the engine was full of still water one could calculate the transferred power by means of the dimensions of the engine and the thermal conductivity of water (0.556W/m.K). Tiny result: less than 10mW. But the water is not still. It has a reciprocating movement. Each period (in our example) 9 cm3 of water are renewed. And this occurs 3.2 times per second. With such a flow, it would be enough to have the exiting water 0.25°C above the tank temperature to transfer 30.5W. [30.5/(4.18x19)]. That is why the bottom of the pipe is always cold during a normal running of a pop-pop engine.

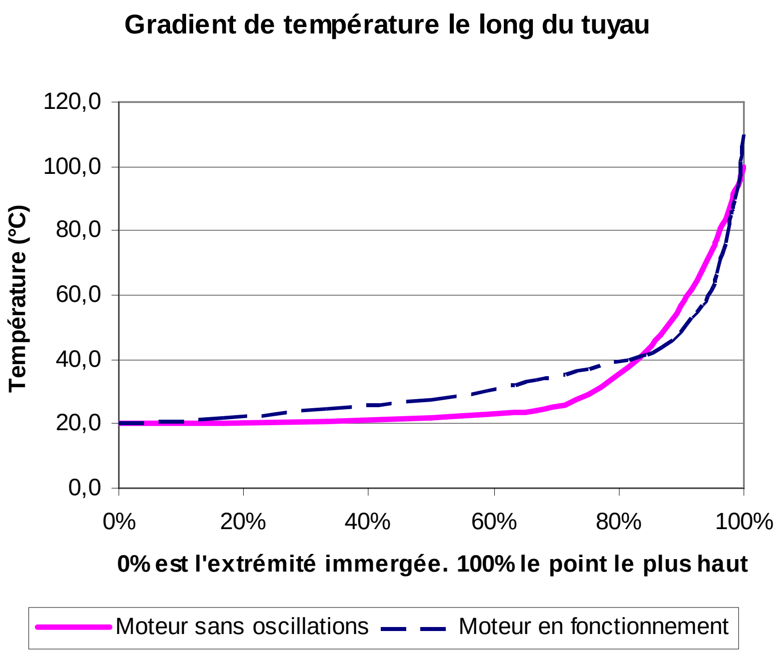
Appendix

Partial view of the test bench. For a better understanding, refer to the document which describes the test bench principle: *Test bench for pop-pop engines*.



The soldering iron is powered through a dimmer. Voltage and current are measured to know the power.

The graph hereunder shows the temperature gradient along the pipe in two cases.



In blue dashes the measured gradient. Not measured on this engine, but measured on a smaller one and on a bigger one, both curves being similar. We just modify them slightly to refer to 20°C at the tank.

In purple the result of a rough calculation corresponding to a moderate heating of an engine which doesn't oscillate.