Pipe material to be used to build a pop-pop engine

When a new engine doesn't work as expected the first reaction of its builder is to suspect something wrong in the design or in the pipe material. As the pipes of my first engines were made of plastics (to look through) I'm convinced that many materials can be used. Obviously, the material could have some influence on the design and on the heating power that will be requested.

Just to keep my mind busy (now that I am retired my doctor said I have to), I made some calculations concerning the heat dissipation through a pipe. The hypotheses are the following ones:

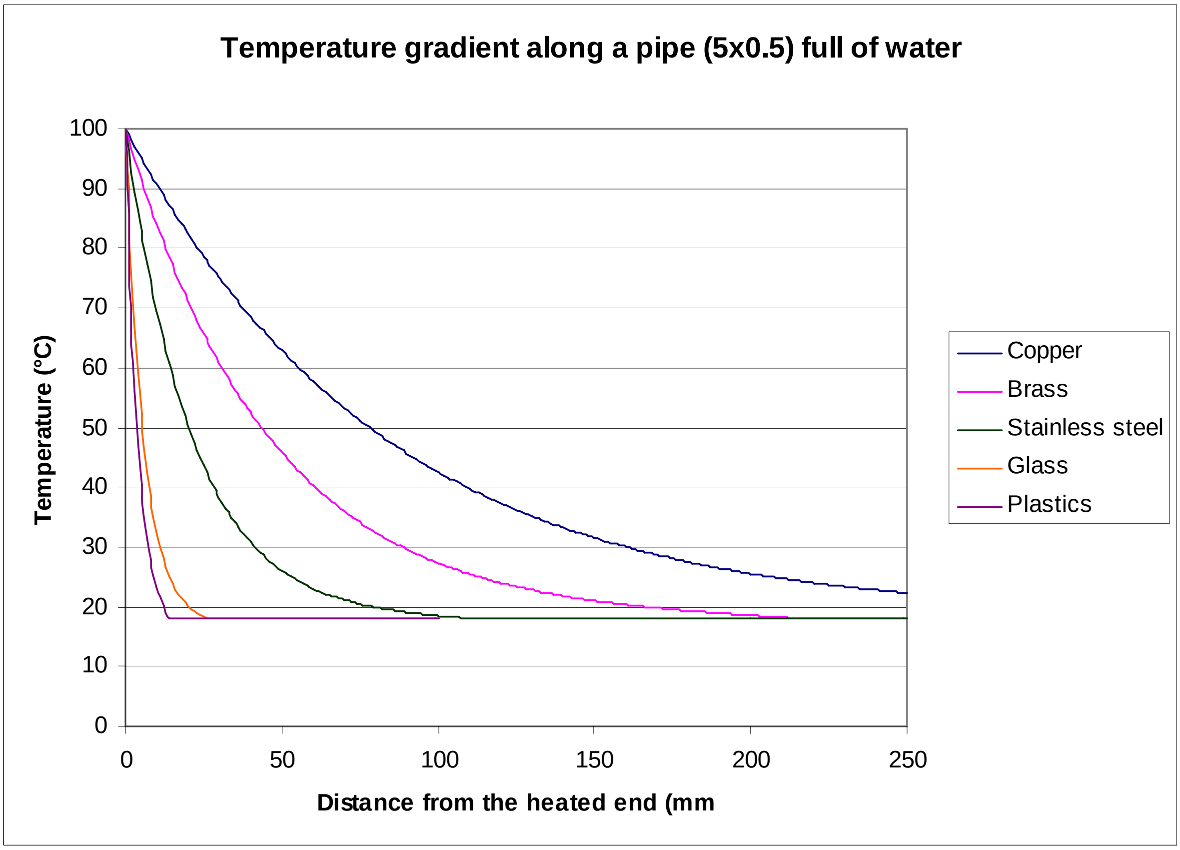
- Pipe full of water (that is generally the case when a pop-pop engine is ready to start)
- Pipe heated at its upper end up to 100°C (which is the boiling temperature at normal atmospheric pressure)
- Pipe surrounded by air at 18°C (to take a plausible value).

Then, I calculated the requested heating power allowing to maintaining 100°C for different materials and different sizes. Ex:

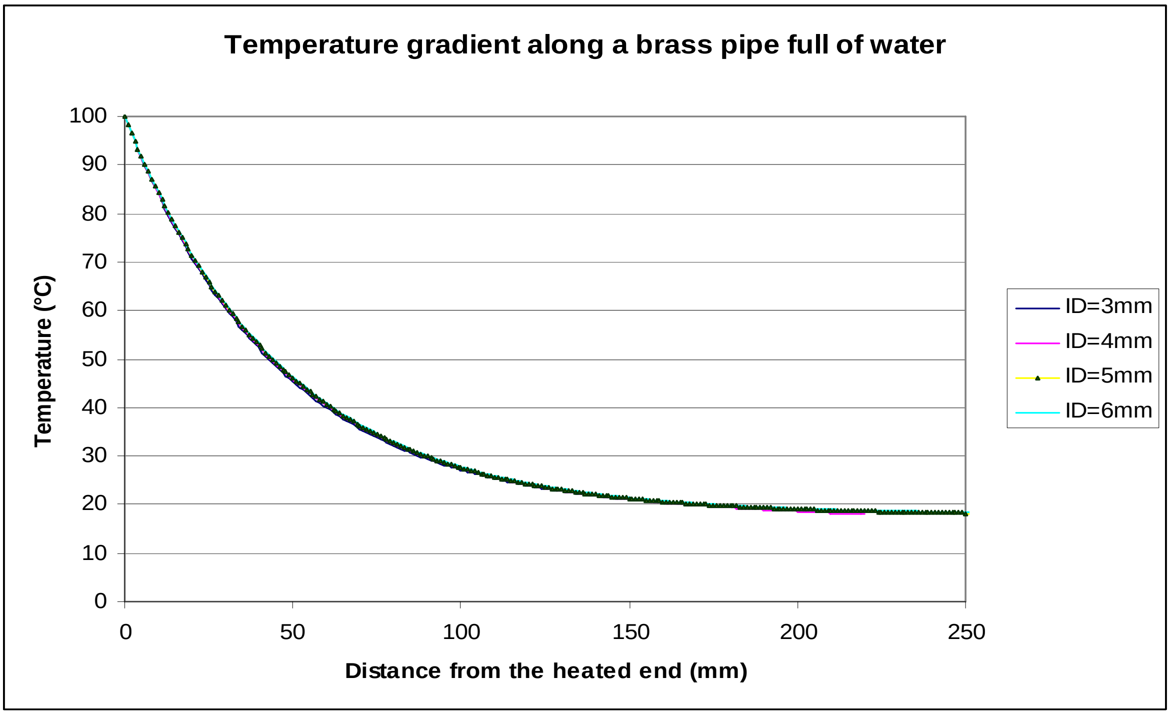
Material	copper	brass	stainless steel	glass	plastics
Pipe 10x1 (inner diameter 8mm) L=350mm	7.5W	4.2W	2W	0.6W	0.4
Pipe 5x1 (inner diameter 3mm) L=250mm	2.7W	1.7W	0.7W	0.2W	0.14W

All these power values could seem very small, but this is not the power of a candle. It is the transferred power from the candle to the pipe and the water herein in order to maintain 100°C. No less, no more. This means that such a small power suffices (with time) to reach the boiling water temperature (100°C) at the upper end.

Then I studied the temperature all along the pipe for different materials. For instance, for a pipe 5x0.5 (inner diameter 4mm) it is displayed on the following graph.

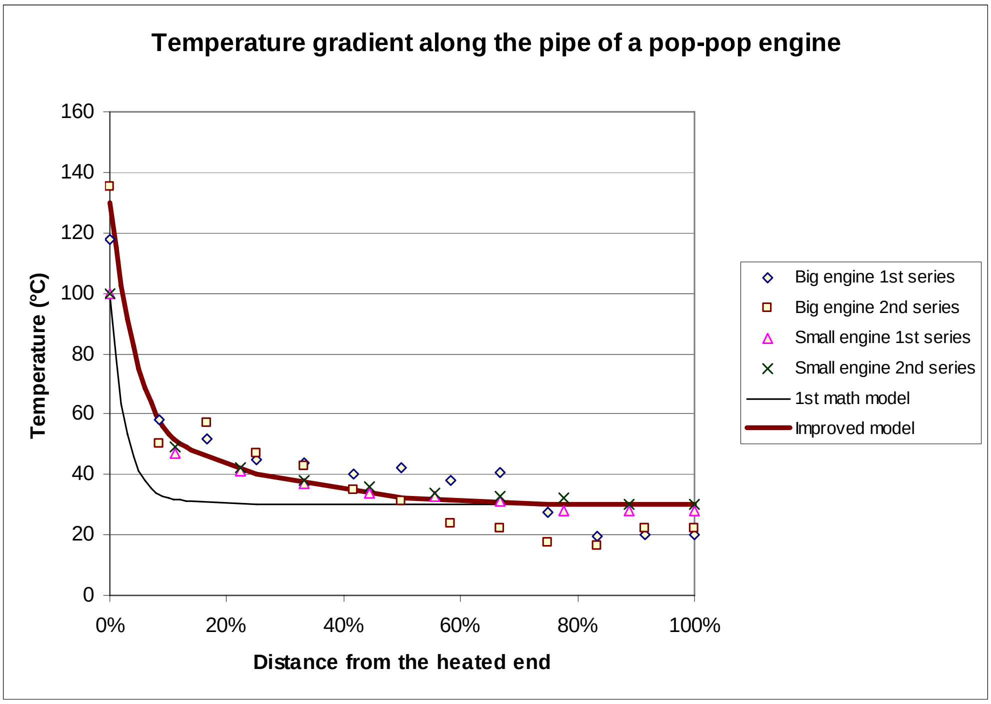


Then, for a given material I studied the temperature gradient for different pipe diameters. An example is displayed hereafter for brass pipes of thickness 0.5mm.



It can be seen that the 4 curves are approximately the same. This is mainly due to the bad conductivity of water compared to the one of brass (0,556W/mK for water and 120W/mK for brass).

All we have seen here above corresponds to static conditions. When a pop-pop engine is running the behaviour of the water is not the same. As it is shaking “hard” the apparent conductivity of the water is much more. For the big engine, instead of the “static” curve (the thin black one) the actual curve is approx the brown one. All the dots on this graph were recorded on two different engines. I don’t know enough about what happens inside the pipe to calculate the curve with accuracy. However, I got this brown curve easily by only replacing the thermal conductivity of static water (0.556W/mK) by a quite bigger one (33W/mK) to take into account the convection. And the result looks rather fine.



All what has been calculated corresponds to a small heating power. Quite small compared to the actual heating power because in this model it is considered that there is no thermal exchange with the water in the tank. Obviously, this is wrong. Now, let's have a look at the bottom end of the pipe.

To "stick" to the reality I'm going to take the data of one of my engines. Single pipe made of brass 10x1 (ID=8mm). It delivers its best thrust with a stroke of 180mm at a frequency of 3.2Hz. In these conditions its power consumption is 30.5W (measured thanks to electrical heating).

From these data we can deduce the stroke volume ($9cm^3$) and the mean flow ($29cm^3/s$). At that flow, the mean temperature of the outgoing water is only 0.25°C higher than the one of the tank [30.5/(4.18x19)=0.25]. This explains why the lower part of a pop-pop engine is always cold when it is in operation.

Both the mathematical model and the records allow to saying that on the lower part of the pipe the temperature is low. We saw that on several dozens of engines.

Conclusion:

The pipe material (at least for the lower 2/3) has a negligible influence on the performance of a pop-pop engine.

For instance, on one end Guus built performing coil engines made of copper. On the other end Slater used plastic straws for his performing engines. In between we all know good examples of pop-pop engines with pipes made of steel, aluminium, glass, brass…

Warning:

The assertion that the material is not a key factor is based on the sole thermal conductivity. However, the characteristics of the inner surface could play a role. When an engine delivers a very weak thrust the cause (among many others) could be a non adhering water film and therefore a bad thermal exchange at the upper part of the pipe.

One way to improve this is to clean the surface. Guus worked on that with his glass engines. He used glass pipes which were treated with (dangerous!) fluoridric acid to get a good adherence of water.

On another way Professor Le Bot modified the water by adding a *wetting agent* (English is not my first language. I'm not sure that these words are the right ones). And Christophe ran successfully his glass engine with alcohol instead of water.

To conclude with an anecdote, pop-pop is not an exact science. One day Loïc suggested me to run a test with some oil at the upper end of a transparent pipe in order "to check that the engine wouldn't work" with oil on the meniscus. I ran this test and the engine worked!!! However, after a short time I could see nothing inside because it was full of mayonnaise.