

Pop Pop Boat

This is a classic science toy and one of the simplest steam engines around.

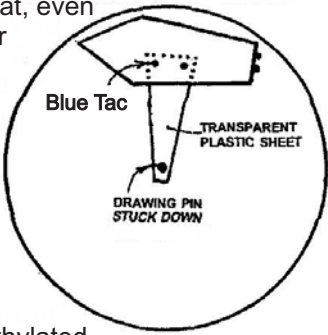
Run the boat

You have to fill the boiler with water:

- ▶ Point the boat nose down so that the two exhaust tubes point up.
- ▶ Hold one tube under a thin stream of water from a tap until water comes out the other tube. You may want to do this with a syringe or plastic pipette.
- ▶ Float the boat in water, light one of the candles and place this on the metal tray. Try to position the flame as close as possible to the centre of the boiler.
- ▶ After about 15 seconds bubbles form at the exhaust tubes and pulsing starts slowly before picking up speed and strength. The boat should begin to move.

Tips

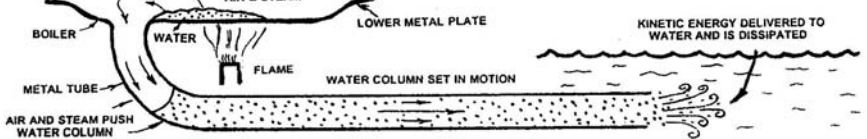
- Although a swimming pool is an obvious place to run the boat, even small waves can sink the boat. Large circular plastic trays or washbaskets are the best. You can tether the boat to the center using a transparent plastic sheet that is stuck down by a drawing pin. Stick the drawing pin to the centre of the tray using sticky stuff such as "Blue Tac".
- The boiler-engine is a complex little machine that will burn out when the boiler runs dry. If the pulsing dies away, blow out the flame and fill the boiler with water as before.
- You can also run the boat using a small cotton wad and methylated spirits or a few drops of cooking oil.



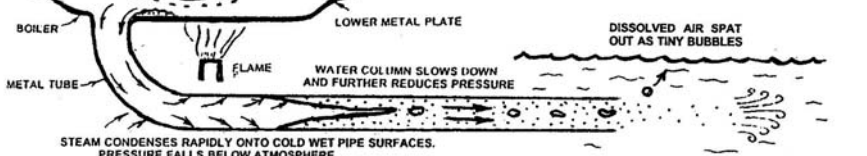
The Principles of the Pop-Pop Engine

A Pop-Pop engine is a water pulse jet. The space between two metal plates (the "boiler") is filled such that both air and water are present. Two metal pipes full of water lead from below the boiler to the back of the boat below the water-line. The rigid bottom plate is heated by a flame and when the water reaches its boiling point, it starts to turn into steam. The upper plate is flexible.

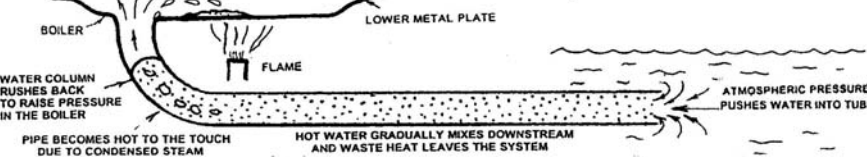
Because steam has a volume 1700 times larger than water, it pushes outwards, mixes with the air and starts to move and accelerate the water in the tubes. Because water has mass and inertia, a fairly high pressure is able to form while the water gathers speed. The pressure will make the upper plate bulge outwards.



But the wet metal surfaces left behind by the water are cold, much colder than the steam. When steam encounters a surface colder than that which boiled it, it condenses very rapidly back into water. The air also starts to cool down. The volume and pressure start to decrease. When it falls below atmosphere, it will start to slow down the now fast moving columns of water. The momentum of the water columns allows the motion to continue so that when it eventually does stop, the combination of condensation, air cooling and momentum will have reduced the pressure so far that the atmosphere will slam the upper plate hard against the bottom plate.



The atmosphere will now accelerate and push water back into the tubes. This will compress the air and steam while more steam continues to be formed by the flame. The pressure starts to rise and slow down the columns of water. But the momentum of the columns is such that the pressure rises well above the atmosphere which will deflect the upper plate vigorously outwards and the cycle is now ready to repeat itself. The air in the boiler is essential because it cannot "vanish" like steam does when it condenses and hence acts like a spring to help "bounce" back the water columns.



The water entering the engine is cold. Like the water you boil on a stove, it contains dissolved air that is released as the water is heated. This gradually fills the boiler and the air and steam pushes further and further down the tubes until tiny bubbles are spat out as shown in the middle figure.

Only the water ejected propels the engine. When water is sucked in, there is an initial backwards repulsion as the water is set in motion. But as this water is forced to stop there is an exactly equal forwards propulsion.

Safety

The boat should only be used under strict supervision of a teacher. Boat parts can become VERY hot. Be careful when lifting the boat from water. Take extreme care with flammable liquids and matches.