An Elementary Heat Engine

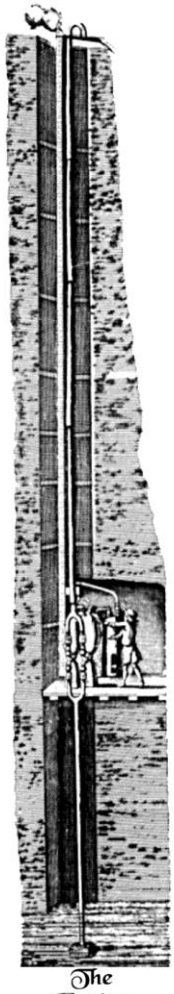
The first steam-powered commercial machine was a tank with taps and external pipes designed in England by Thomas Savery. The idea was to lift water using high pressure steam, make lots of copies, sell them and become rich. In common with Bell, Edison, Marconi and others, Savery was a businessman, not a physicist. The 1698 patent outlines his plans. Read carefully – the spelling is strange.

> *A new invention for raising of water and occasioning motion to all sorts of mill work by the impellent force of fire, which will be of great use and advantage for drayning mines, serveing townes with water, and for the working of all sorts of mills where they have not the benefitt of water nor constant windes.*

No Savery pump has survived into modern times. The tank below is from a replica made in the 18th century. There were no welders in those times. The tanks were put together with rivets.

Steam from a boiler was made to fill the tank by opening a tap. That tap was then closed (again by hand) and the tank was cooled by spraying cold water over it, creating a near vacuum. A second tap was then opened and air pressure forced water into the tank from below (less than 10 m). When it was full the lower tap was closed and high-pressure steam was let in to force that water up a long pipe. The hand operated pump was slow, expensive, and leaked steam. Savery demonstrated his pump at the royal court, installed one in a mine that exploded, and sold two or three to wealthy land-owners for their huge country houses. That was it. Savery's business failed, but the age of steam had begun and more practical ideas soon followed. Savery did eventually make money because he had the patent for all steam engines and Newcomen, who made and sold working water pumps a decade later, had to share the profits with him.

It is interesting now, more than 300 years after Savery's death in 1715, to note his singular focus on the Monarch, shown in his writing in *The Miners Friend* published in 1702. The text below is quoted from the web at …
http://himedo.net/TheHopkinThomasProject/TimeLine/Wales/Steam/URochesterCollection/Savery/index.htm



The Engine Working in a Mine

The Miners Friend ;
OR, AN
ENGINE
TO RAISE
WATER
BY
FIRE,
DESCRIBED.
AND
Of the manner of Fixing it in
MINES
WITH
An Account of the several other Uses it is applicable unto: and an
ANSWER
To the OBJECTIONS made against it.

by *Tho. Savery*, Gent.

Pigri est ingenii contentum este bis, que ab aliis inventa sunt. Seneca.

LONDON: Printed for S. Crouch 1702

To the King

Seeming satisfaction of the power and use of it: and having most graciously enabled me by your royal assent to a patent and act of parliament to pursue and perfect the same. By which your royal encouragement, it being now, fully completed, and put in practice in your dominions, with that repeated success and applause: that it is not to be doubted but it will be of universal benefit and use to all your majesties subjects. Of whom your majesty being the universal patron and father, all arts and inventions that may promote their good and advantage, seem to lay a just and natural claim to your majesties sacred protection. It is upon this consideration I am incouraged with a profound respect to throw this performance of mine, with the author, at your majesties royal feet, most humbly beseeching your majesty, that as it had birth in your majesties auspicious reign, you will vouch safe to perpetuate it to future ages by the sanction of your royal approbation, which is the utmost ambition of, May it please your Majesty,

Your Majesties most Humble, most Loyal, and most Obedient Subject,

Tho.Savery.

A model of something similar

Engines, are complicated, fast, and don't generate connections in student minds between what they see when they watch a working model and a simple abstract PV diagram on the whiteboard.

To connect, one step at a time, to a PV diagram and to introduce the concept of a cycle, of hot and cold reservoirs, of a working substance like air (or steam), of work being done, and of efficiency (or lack of it) it is helpful to make and operate a simple hand-held device with no valves or moving parts in the style of a Savery pump.

A first demonstration in thermodynamics

A plastic bottle with a little water in the bottom, aquarium hose that reaches to the bottom of the bottle, two aluminium pots, half a kg of ice and a little water in a beaker demonstrate a Savery-type pump.

1 The bottle (in one hand) is placed in the hot water at ~90°C (in the pot on the right). The pressure rises and a little water is lifted in the hose (held in the other hand) to fall from 20 cm above the beaker.

2 The end of the hose is put under the water in the beaker and the bottle is transferred to the iced water (in the pot on the left). The pressure falls and a little water is drawn into the bottle.

3 The cycle is repeated, again lifting a little water 20 cm above the beaker.

4 An idealized PV diagram is drawn with two constant volume processes.

A little work ($\Delta m\, gh$) is done each cycle but ice and hot water are expensive. The efficiency (what we get over what we have to pay for) is less than 1%. Our pump works: but not well. *What could you do to improve the efficiency*?

Make the reservoirs deeper. Replace the plastic bottle with an aluminium beer can (Why?). Equalize the amount of water transferred in and out of the bottle each cycle? Moving the bottle wastes energy. How could we avoid that and make the pump automatic? (Perhaps with valves?) Heat is 'lost' to the room. Avoid that. Why, and how, do we make the high and low temperatures more separated?

Animate a diagram of your improved design … and … think about building it.