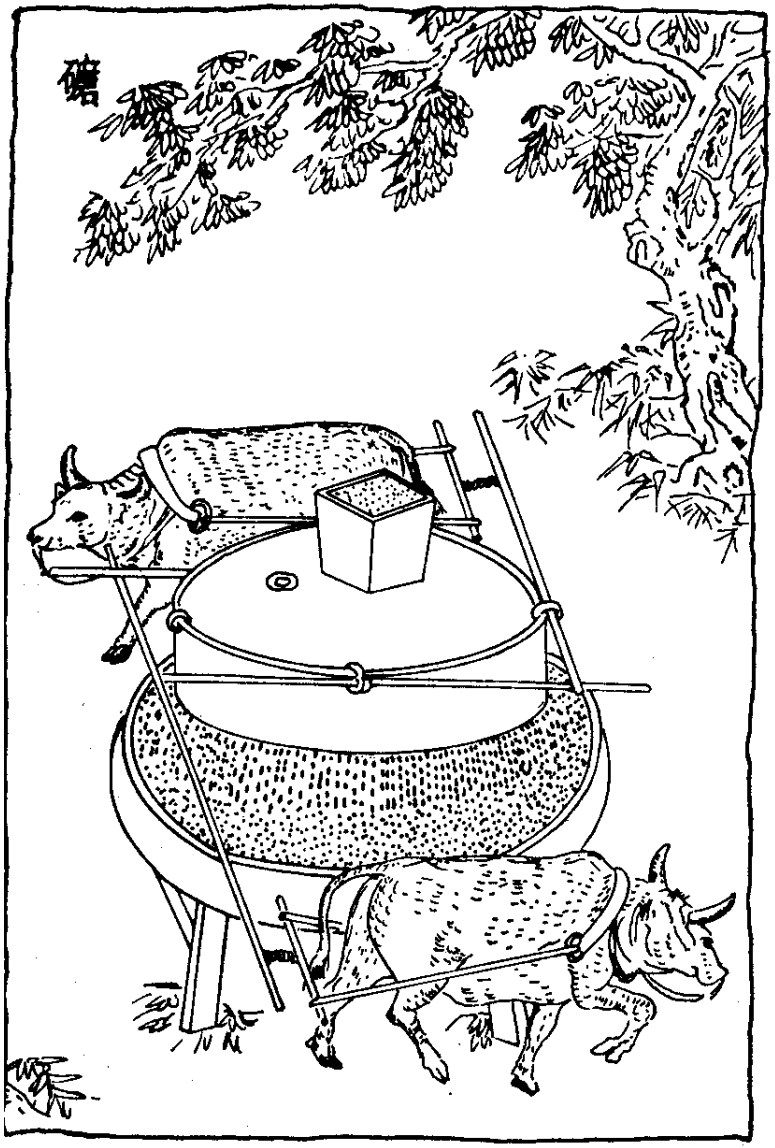
Lecture 5
GEOS24705

History of Energy Use II

Early uses of mechanical work from animals, wind, water



Grindstone, China from the encyclopedia "Tiangong Kaiwu", by Song Yingxing (1637)

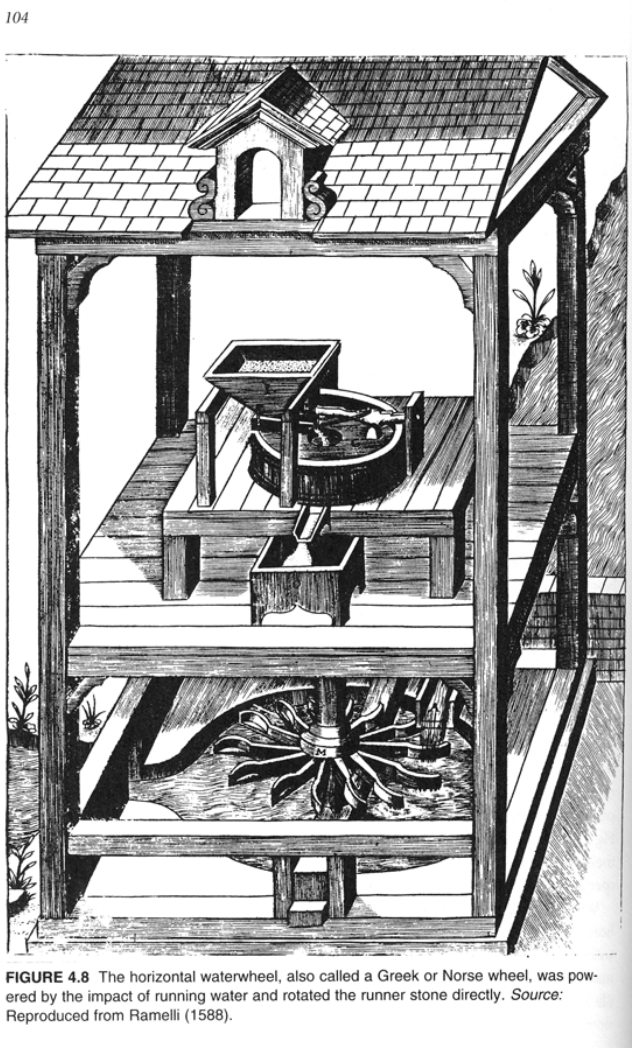
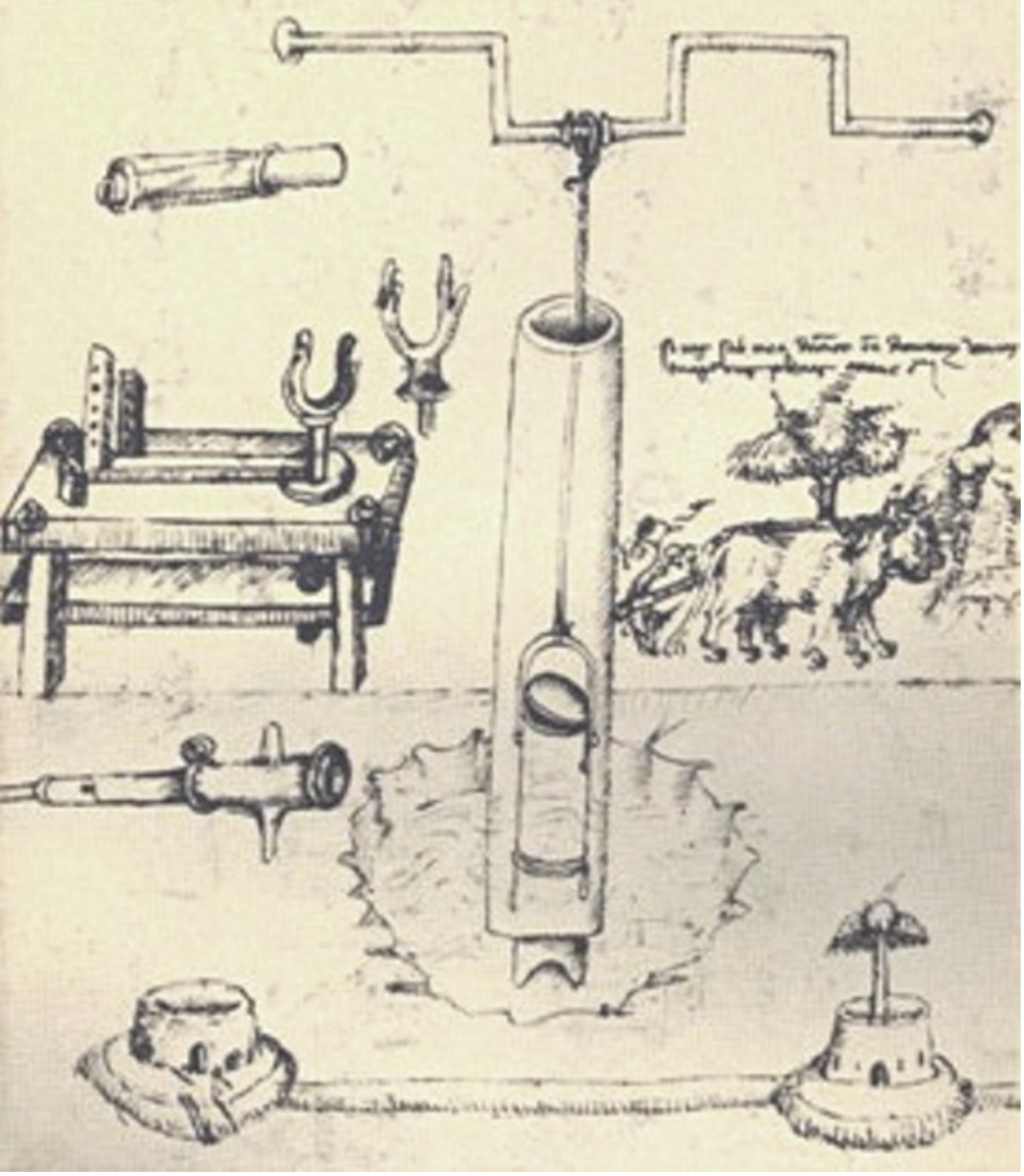


FIGURE 4.8 The horizontal waterwheel, also called a Greek or Norse wheel, was powered by the impact of running water and rotated the runner stone directly. *Source:* Reproduced from Ramelli (1588).

Vertical-axis waterwheel
1500s or earlier



First recorded piston pump is in Renaissance

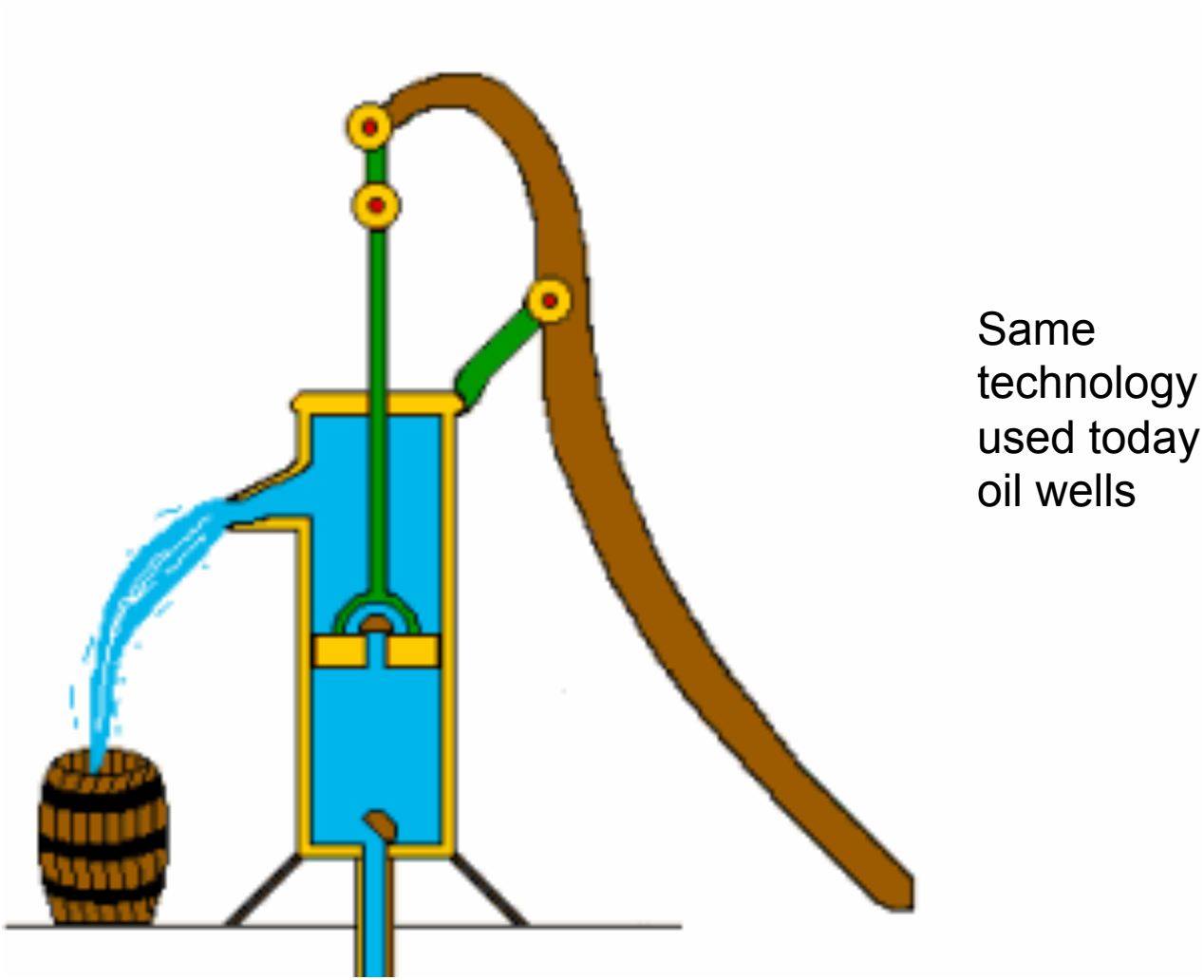
Taccola, 1450
Siena, Italy

De ingeneis 1433
(Concerning engines)
De machinis 1449
(Concerning machines)

but, pumps don't replace bucket chains in England until 1700s

reproduction from: Donald Routledge Hill: *A history of engineering in classical and medieval times*

Basic lift pump design basically unchanged

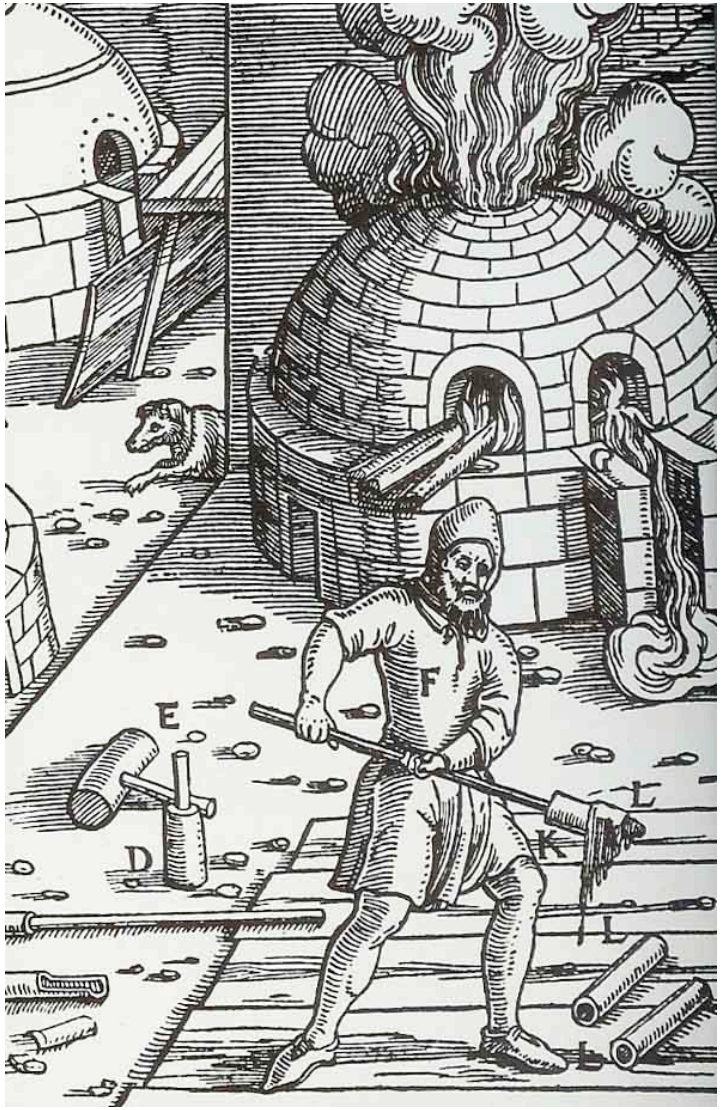


Same technology used today in oil wells

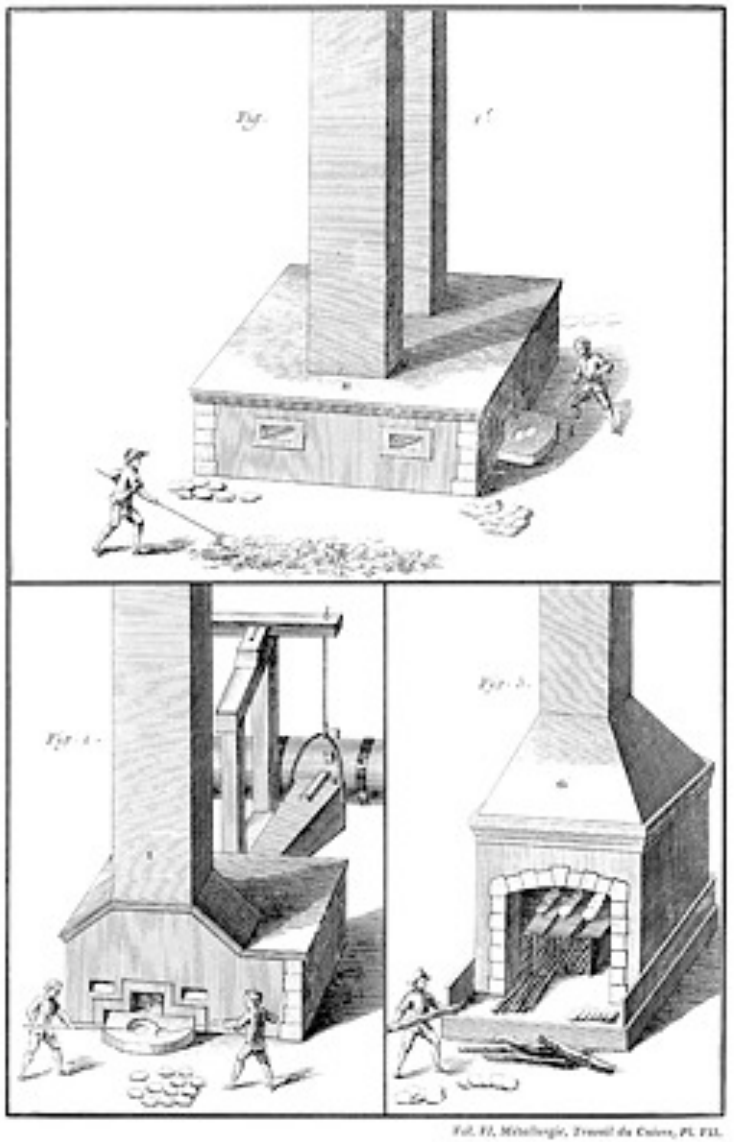
The lift pump

Animation from **Scuola Media di Calizzano**

Heating: Large-scale wood-burning for industry



Georg Acricola "De res metallica", Book XII (*"Manufacturing salt, soda, alum, vitriol, sulphur, bitumen, and glass"*), 1556.



D. Diderot & J. Le Rond d`Alembert eds, Encyclopédie méthodique. Paris 1763-1777 & 1783-87.

By the 18th century, Europe's energy crisis limits growth

"Lack of energy was the major handicap of the *ancien régime* economies"

--- F. Braudel, *The Structures of Everyday Life*

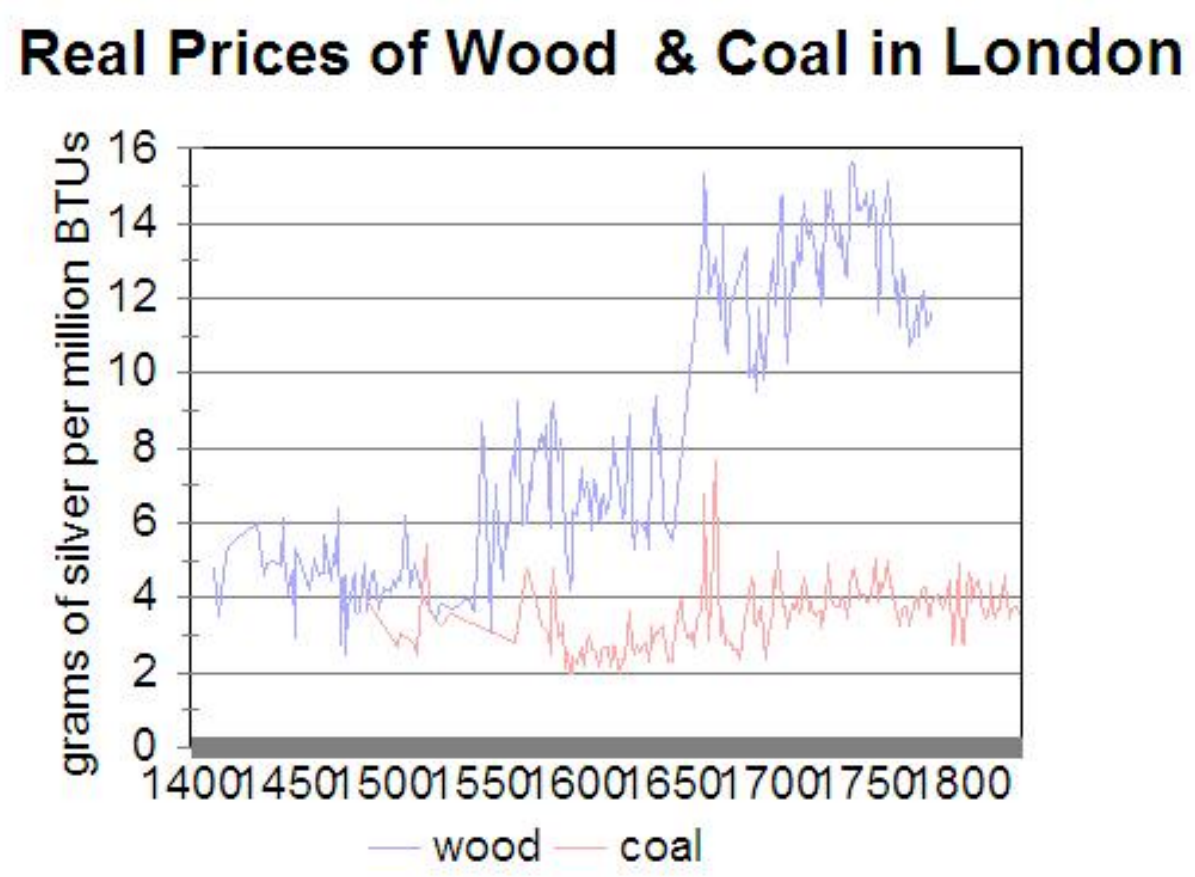
18th century Europeans had complex and sophisticated technology, and an abundance of industrial uses for energy, but not enough supply

Wood → coal: changing an energy system

1600

"Within a few years after the commencement of the seventeenth century the change from wood fuel to coal, for domestic purposes, was general and complete."

--- R. Galloway, *A History of Coal Mining in Great Britain, 1882.*



Robert Allen, *The British Industrial Revolution in Global Perspective*

The 2nd British energy crisis:

1600s

The 2nd British energy crisis: flooding of the mines

1600s

"The miners, no less than the smelters, had their difficulties during the seventeenth century, but of a totally different kind; for while the latter were suffering from too little fire, the former were embarrassed by too much water… the exhaustion of he coal supply was considered to be already within sight. In 1610, Sir George Selby informed Parliament that the coal mines at Newcastle would not last for the term of their leases of twenty-one years."

--- R. Galloway, *A History of Coal Mining in Great Britain, 1882.*

The 18th century European energy crisis has 3 parts

1. **Fuel had become scarce even when only used for heat**
   - Wood was insufficient, & coal was getting hard to extract
   - Surface "sea coal" → deep-shaft mining below the water table

2. **There were limited ways to make motion**
   - No way to make motion other than through capturing existing motion or through muscle-power

3. **There was no good way to transport motion**
   - Water and wind weren't necessarily near demand

Early complaints about intermittent renewables

"In the year 1708 a plan was projected in Scotland for draining collieries by means of windmills and pumps... one John Young, a millwright of Montrose... had been sent to Holland at the expense of the town to inspect the machinery there... Wind mills were erected at several collieries, but though they were powerful their action was found to be too intermittent; the mines being drowned and all the workmen thrown idle during long periods of calm weather. "

--- R. Galloway, *A History of Coal Mining in Great Britain, 1882.*

The heat to work barrier
the 18th century technological impasse

All technology involved only two energy conversions

- Mechanical motion → mechanical motion
- Chemical energy → heat

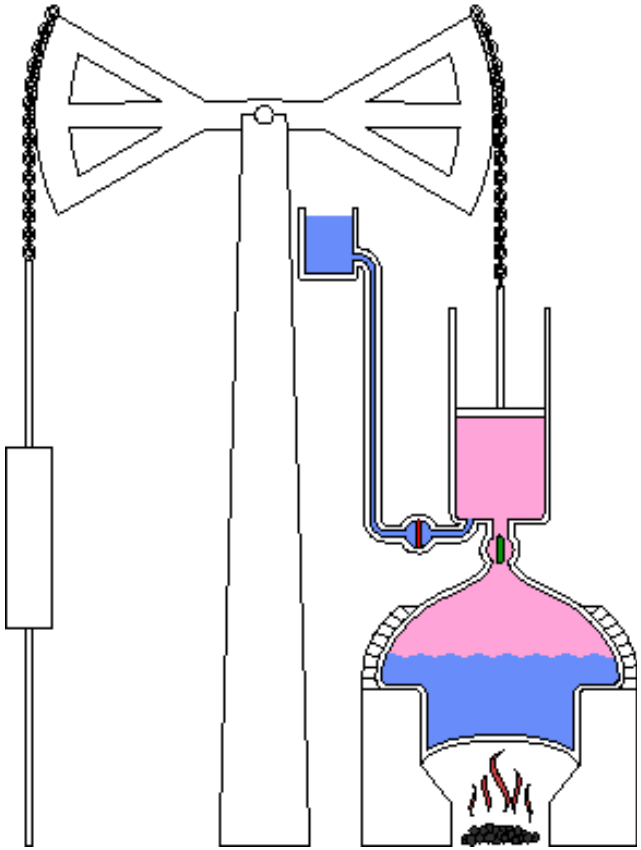
There was no way to convert chemical energy to motion other than muscles (human or animal)

– *no engine other than flesh*

The only means out of the energy crisis was coal

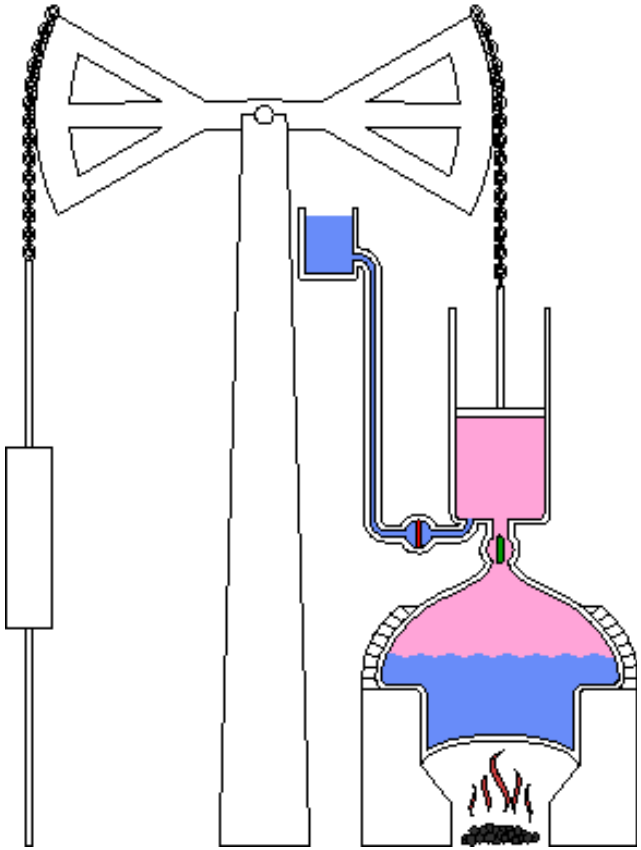
– *but to mine the coal required motion for pumps.*

The revolutionary solution = break the heat → work barrier



The revolutionary solution = break the heat → work barrier

use heat to make ordered motion



Newcomen "Atmospheric Engine", 1712

(Note that widespread use & Industrial Revolution followed invention by ~100 years – typical for energy technology)

What is a "heat engine"?

A device that generates converts thermal energy to mechanical work by exploiting a temperature gradient

- **Makes something more ordered**: random motions of molecules → ordered motion of entire body
- **Makes something less ordered:** degrades a temperature gradient (transfers heat from hot to cold)

Physics: long understood that steam exerted force

Evaporating water produces high pressure
Pressure = force / area

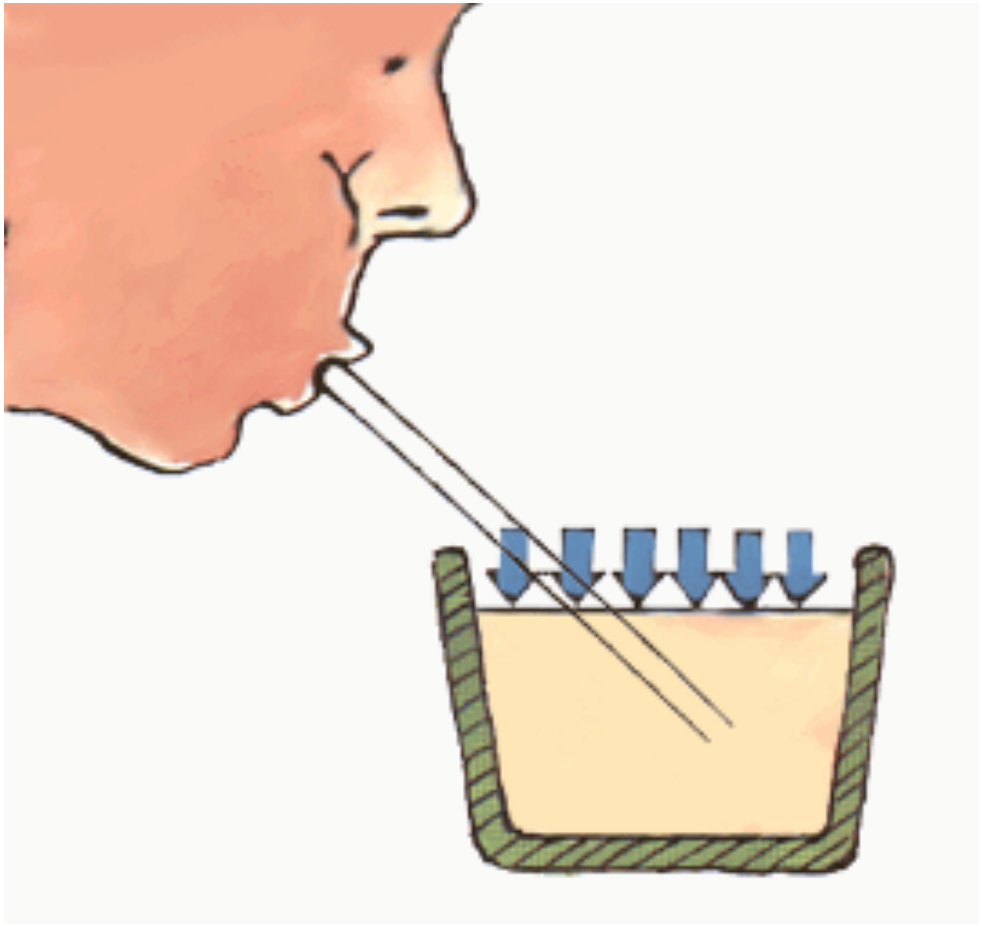
"lebes": demonstration of lifting power of steam

"aeliopile"

Hero of Alexandria, "Treatise on Pneumatics", 120 BC

Physics: condensing steam can produce suction force

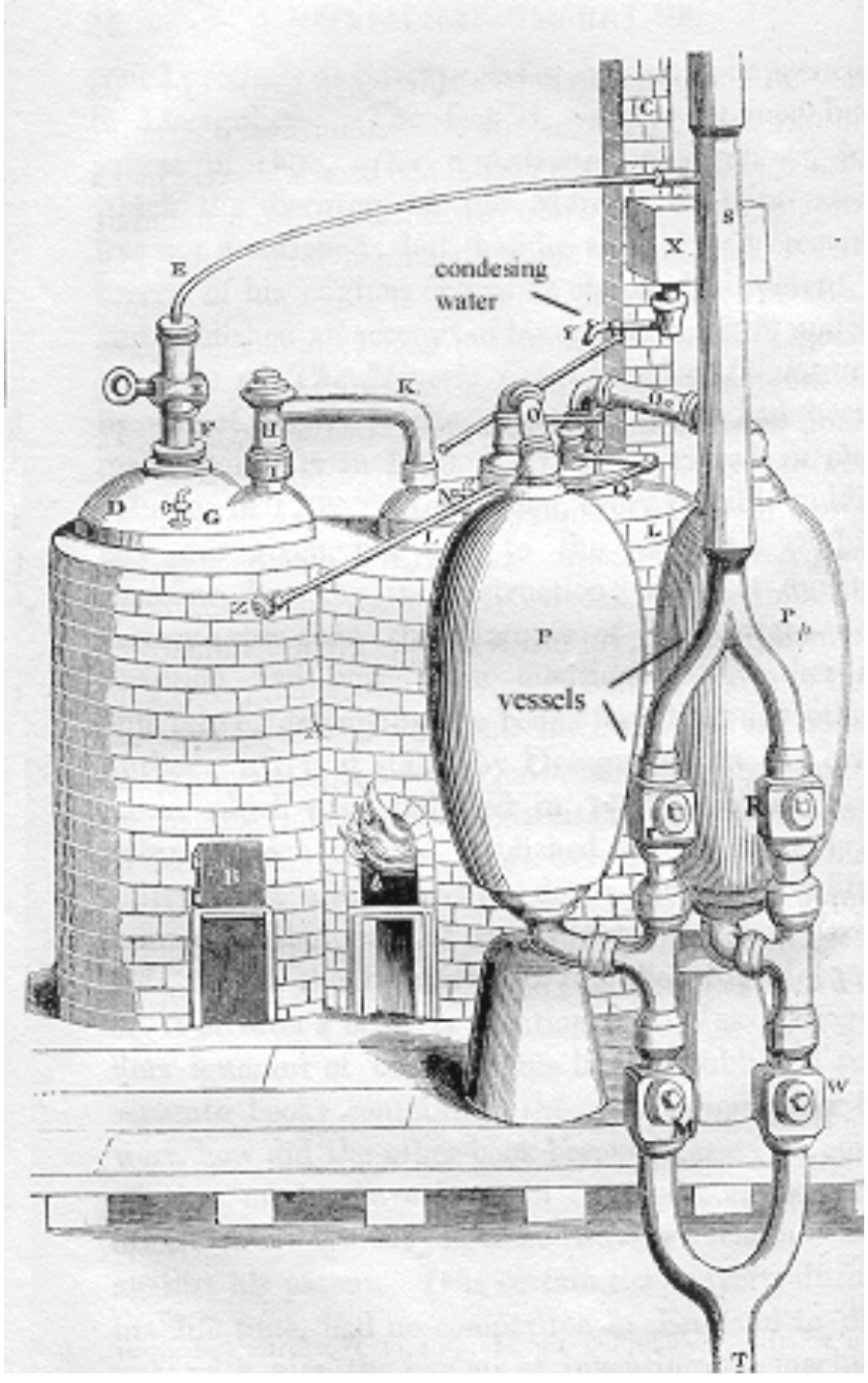
Low pressure in airtight container means *air* exerts force
Same physics that lets you suck liquid through a straw



First commercial use of steam: the Savery engine

"A new Invention for Raiseing of Water and occasioning Motion to all Sorts of Mill Work by the Impellent Force of Fire which will be of great vse and Advantage for Drayning Mines, serveing Towns with Water, and for the Working of all Sorts of Mills where they have not the benefitt of Water nor constant Windes."

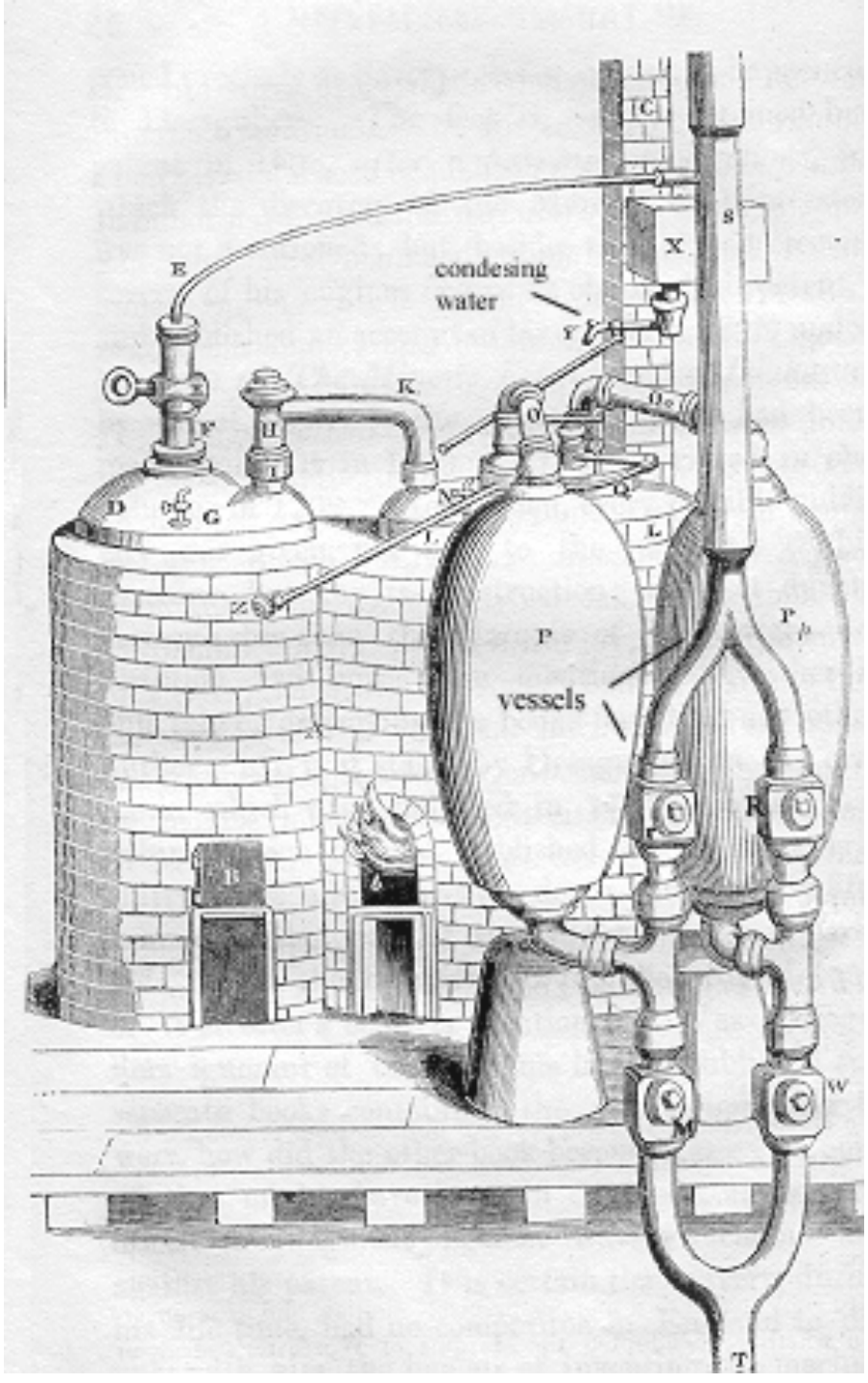
Thomas Savery, patent application, filed 1698



Savery engine is not a commercial success

".. Savery's engine was wholly unsuited for draining mines, and he failed to induce the miners to take it up. The greatest height to which it could raise water was.. not more than sixty or eighty feet...Moreover the miners [were]...afraid to introduce furnaces into their shafts, on account of ...their giving rise to explosions... "

Robert Galloway, "A History of Coal Mining in Great Britain"



Principles of Savery engine

Sucks water as one would with a straw

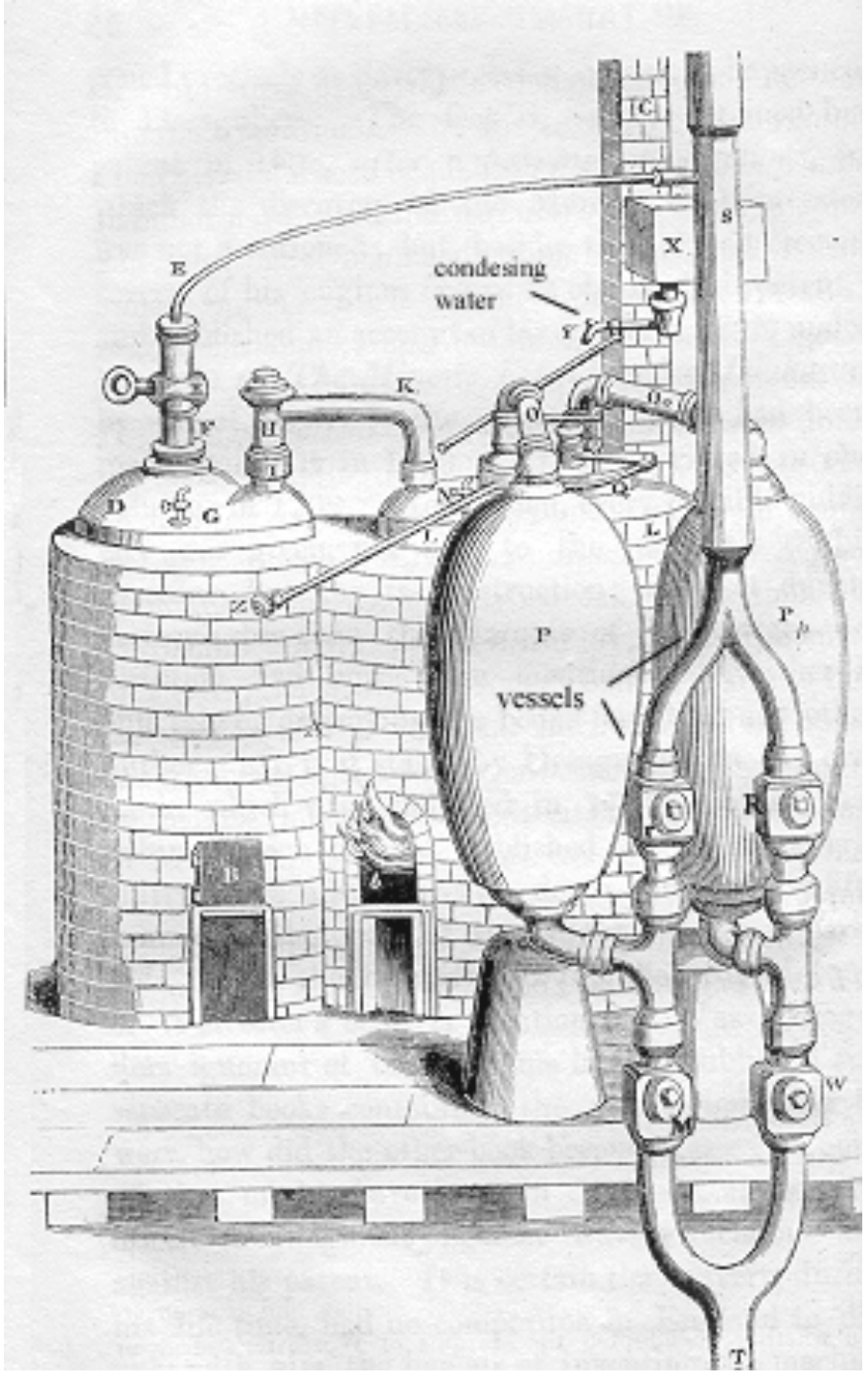
- Heat water to make steam
- Fill chamber with steam
- Cool chamber, steam condenses
- Pressure in chamber is now lower than atmospheric pressure
- Open up valve connecting chamber to pipe in water
- Atmospheric pressure causes water to flow up into chamber

Issues:

Good only for pumping liquids.

Efficiency below 0.1%

Why used at all? Because the coal was essentially free and the industry was desperate for a solution.

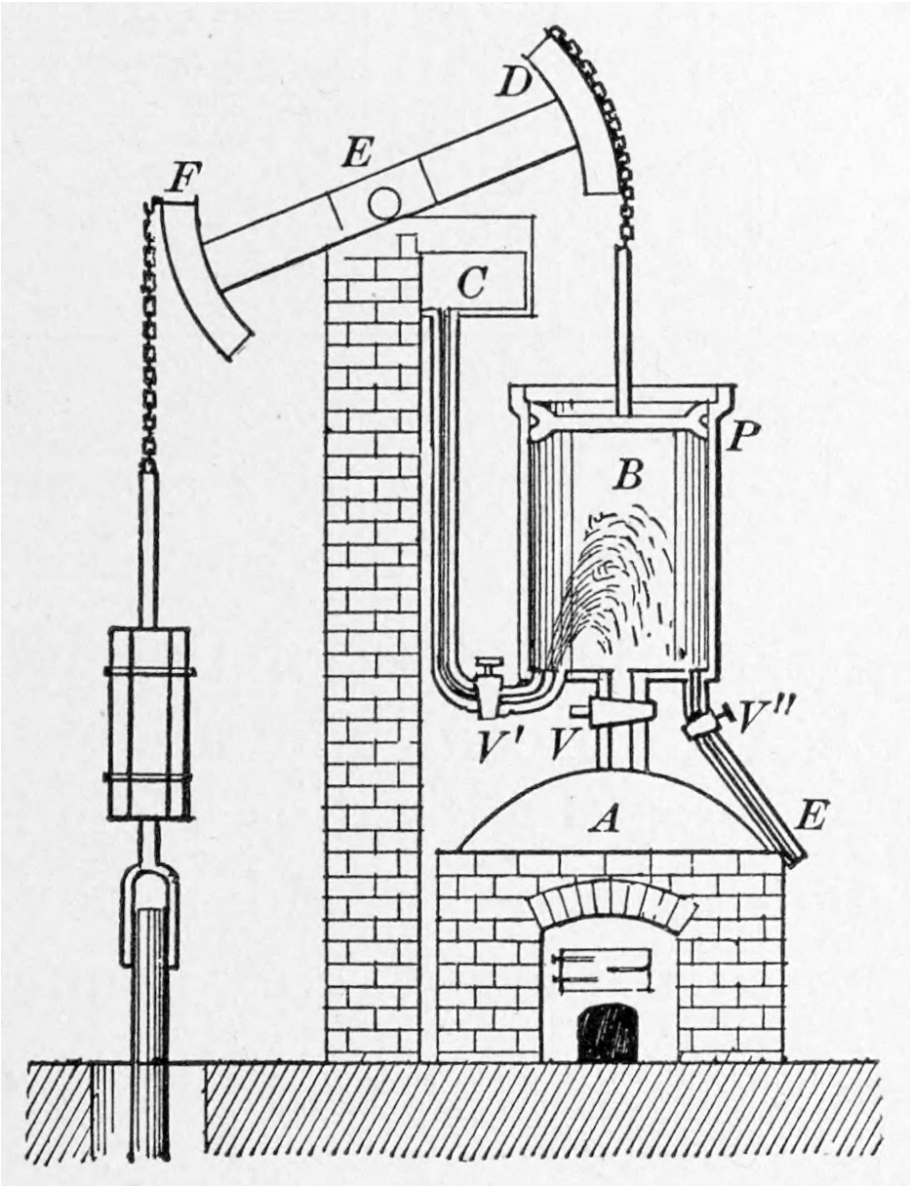


First true steam engine:

Thomas Newcomen, 1712, blacksmith

"It was at this juncture that the miners had put into their hands the most wonderful invention which human ingenuity had yet produced – the Newcomen steam-engine.. a machine capable of draining with ease the deepest mines; applicable anywhere; requiring little or no attention; so docile that its movements might be governed by the strength of a child; so powerful that it could put forth the strength of hundreds of horses; so safe that... the utmost damage that can come to it, is its standing still for want of fire."

Robert Galloway, "A History of Coal Mining in Great Britain"



Newcomen's design is state of the art for 60+ years

First true steam engine:

Thomas Newcomen, 1712, blacksmith

Copy of Papin's engine of design of 1690

First ***reciprocating engine***: linear motion of piston that transmits force

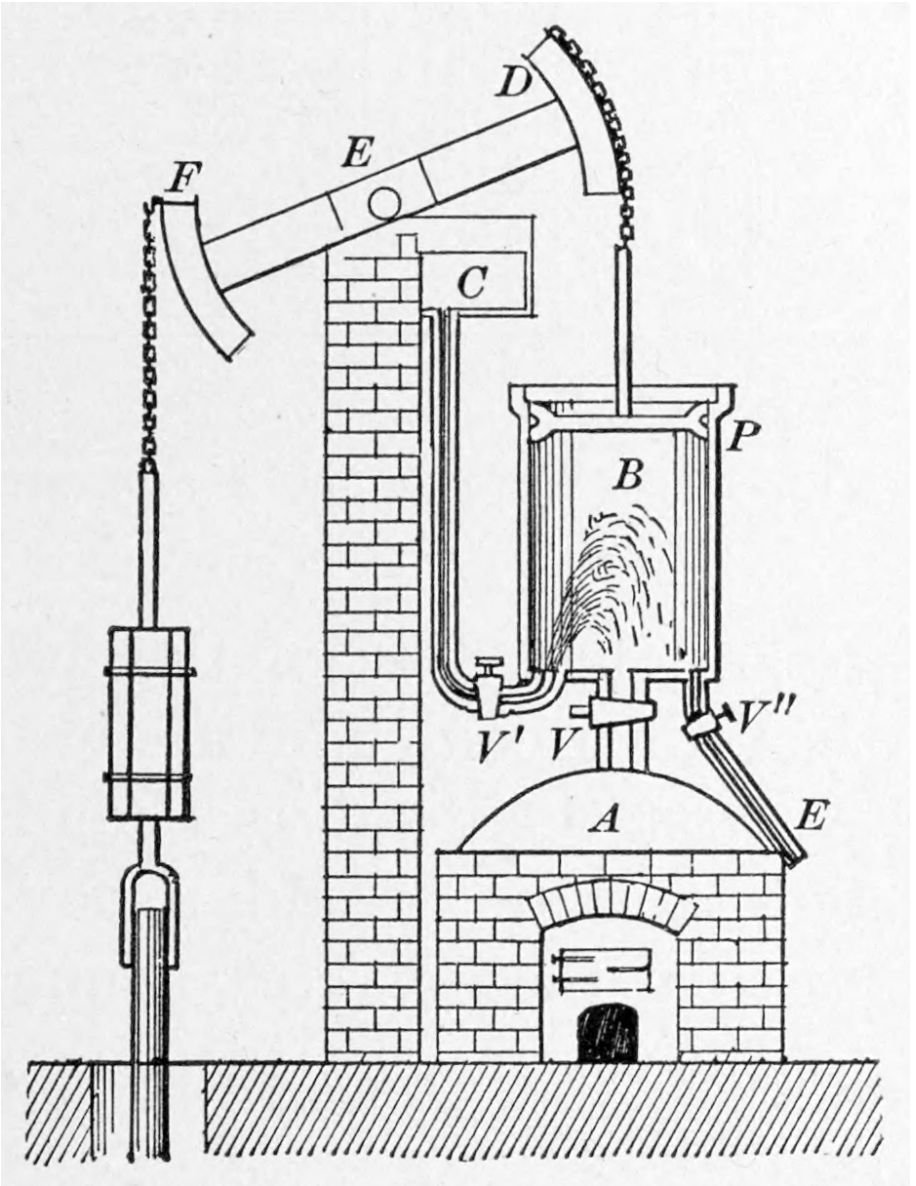
Steps

- Fill chamber with steam
- Cool the chamber to condense steam
- Low pressure in chamber pulls piston down, lifts pump side
- Open valve at bottom of piston, let gravity pull pump side down again
- Steam fills chamber as piston rises

Issues:

Very low efficiency: 0.5%

Intermittent force transmission



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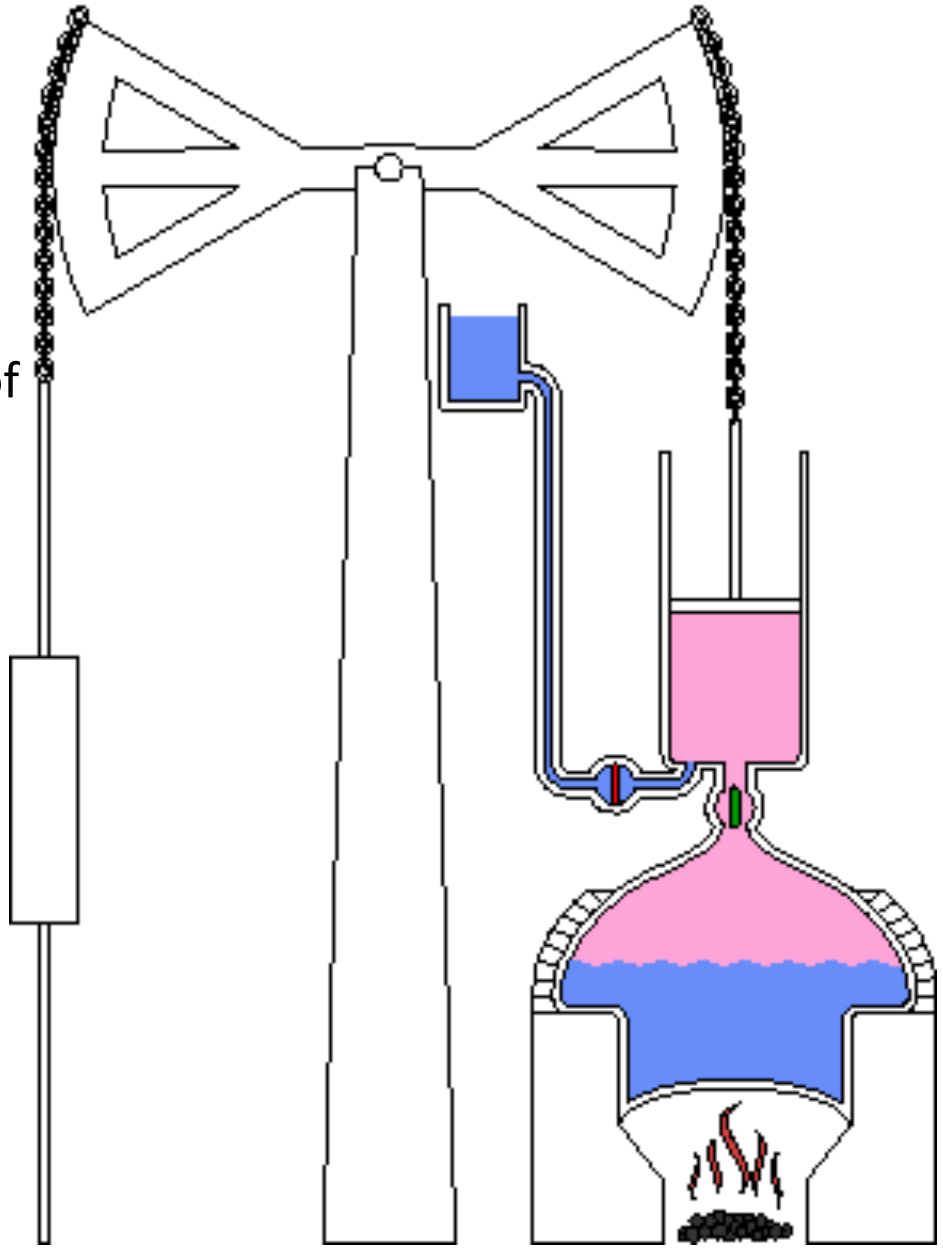

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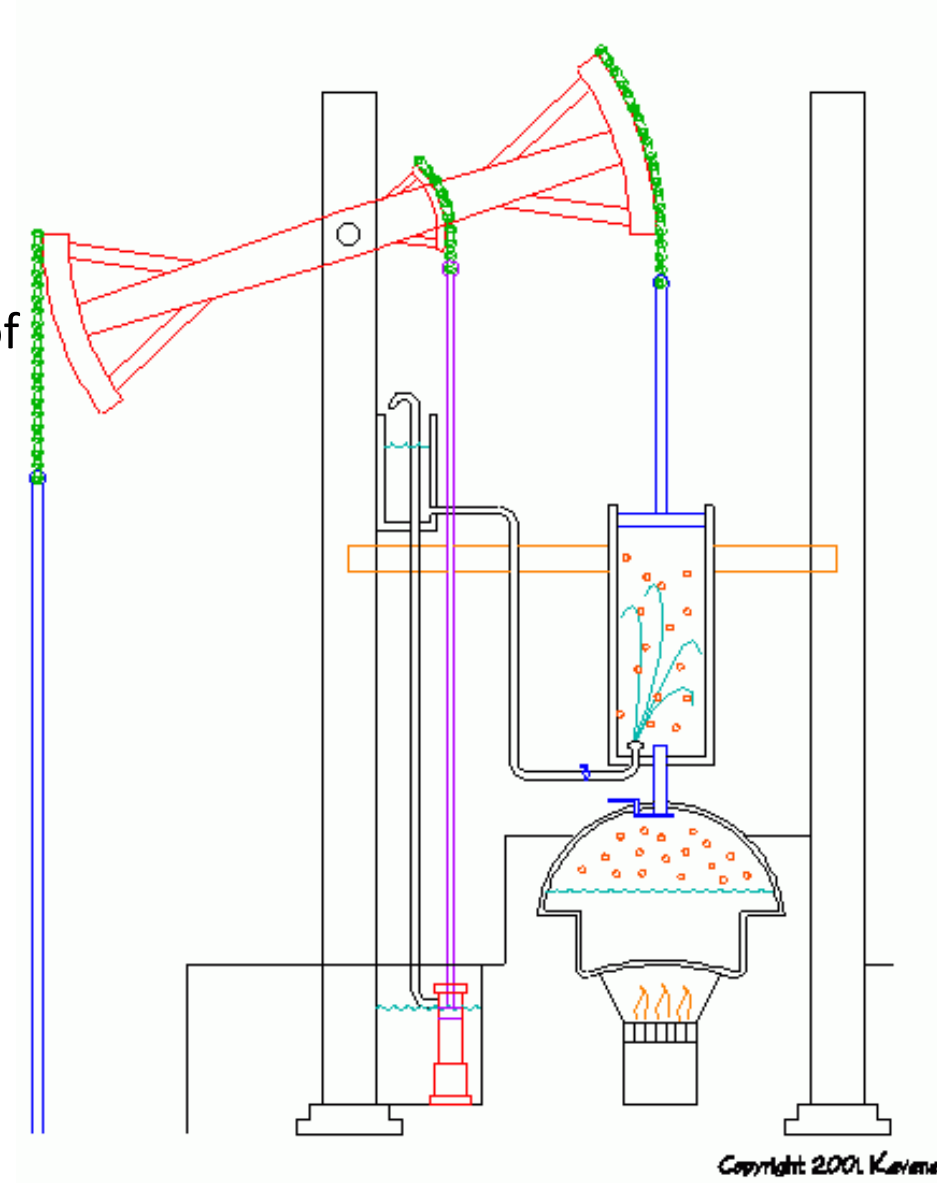

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