Heat-to-work

GEOS 24705/ ENST 24705

“lebes”: demonstration of lifting power of steam

“aeliopile”

Hero of Alexandria, “Treatise on Pneumatics”, 120 BC

First conceptual steam engine

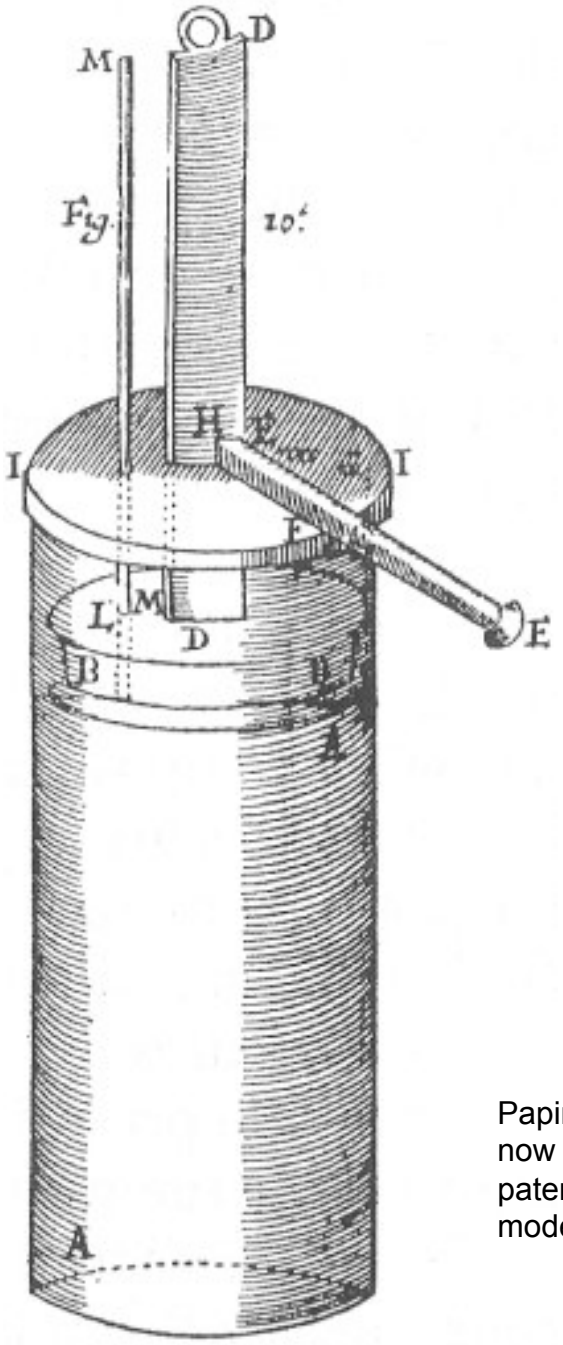
Denis Papin, 1690, publishes design

Set architecture of all engines through modern day – piston moves up and down through cylinder

Papin nearly invented the internal combustion engine (propelled by gunpowder) but couldn't get the valves right to vent air

Papin's cylinder is propelled by atmospheric pressure, not steam pressure - work done when steam is condensed and resulting vacuum draws piston down. Work on ***downstroke.***

Papin did not have the mechanical skill to actually build his engine successfully - couldn't machine the cylinder and piston pressure-tight



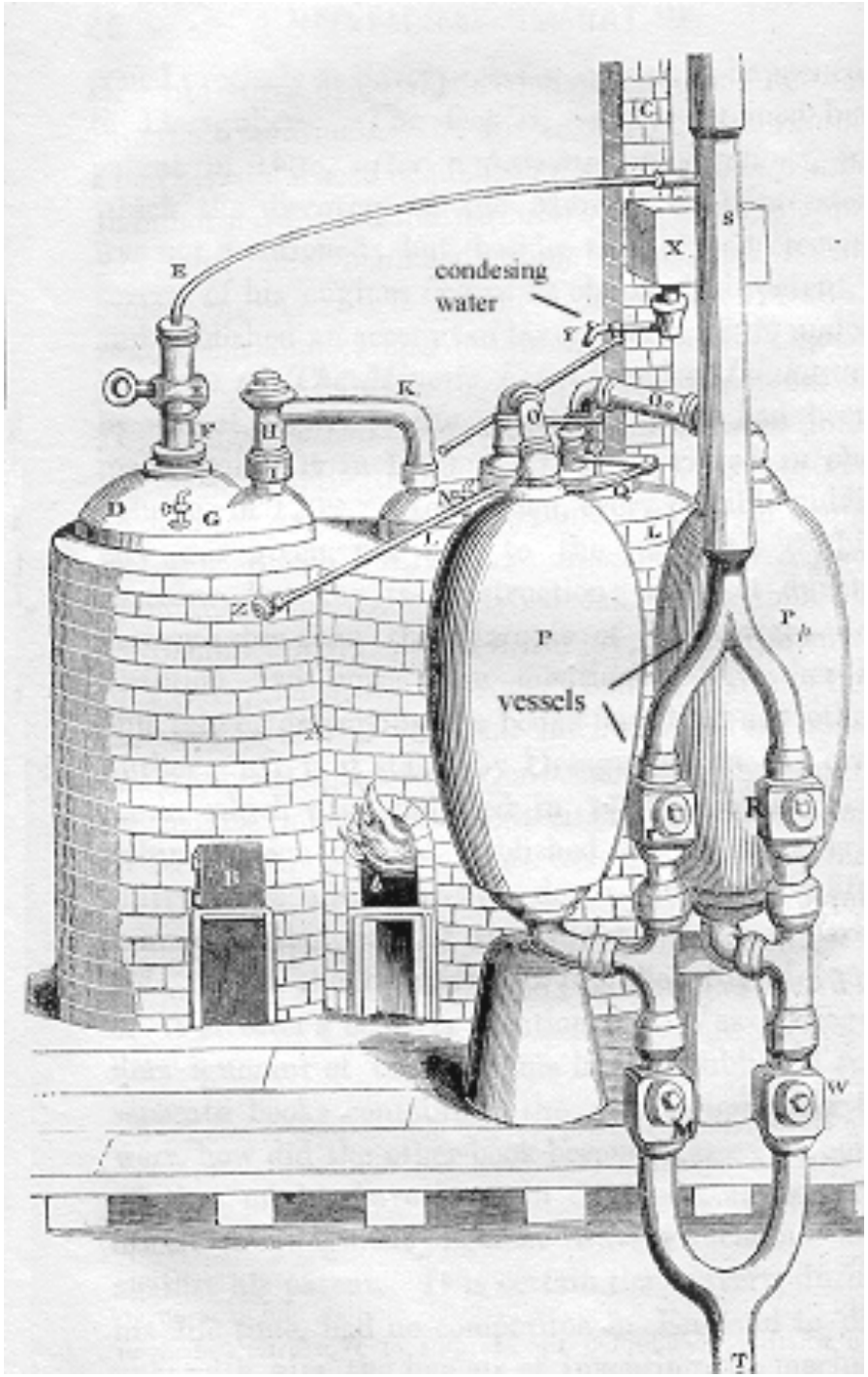
Papin's first design, now in Louvre. No patent, no working model.

First commercial use of steam:

"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

(good salesman, but he was wrong – this can only pump water)



First commercial use steam

Thomas Savery, 1698

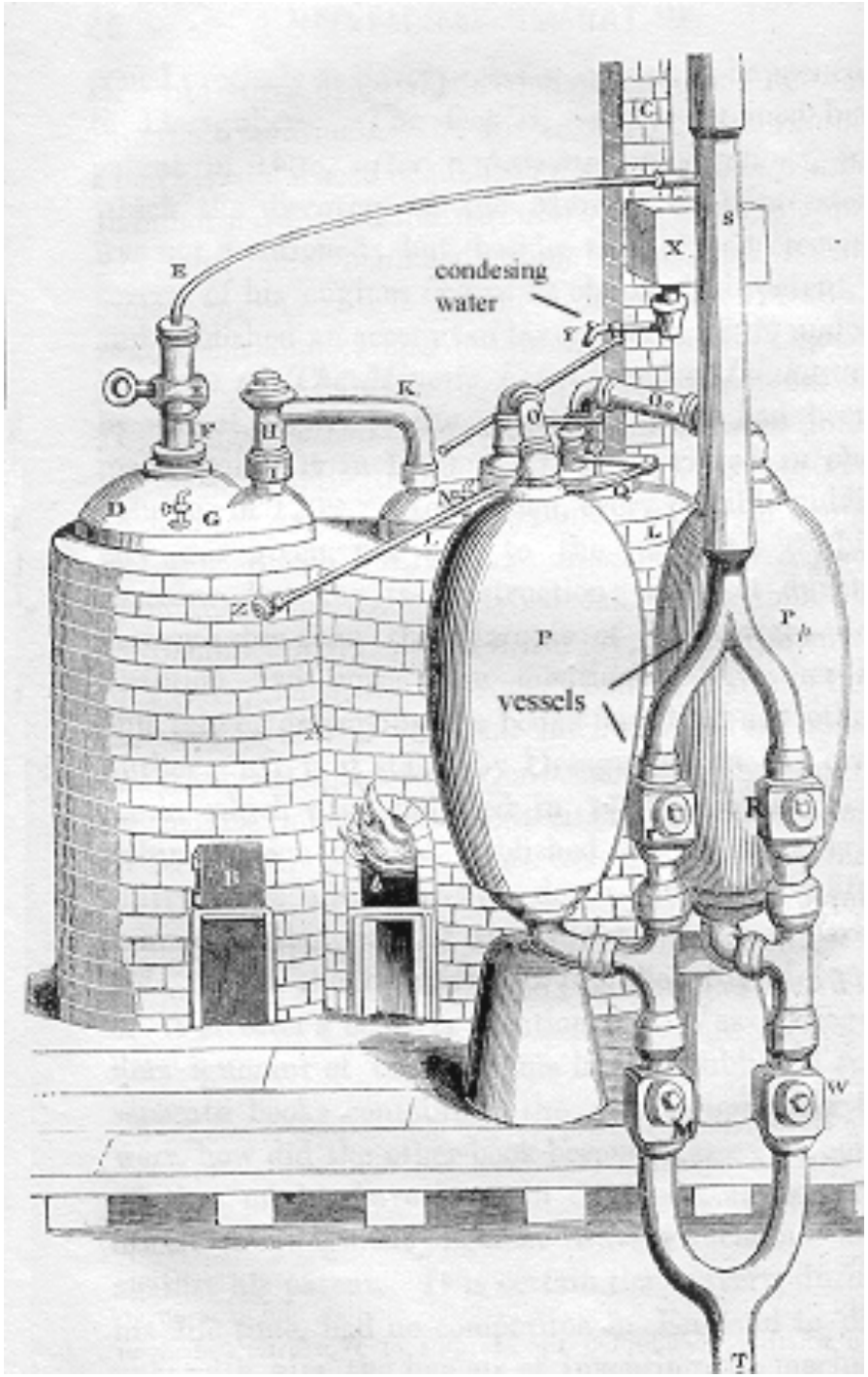
Essentially a steam-driven vacuum pump, good only for pumping liquids.

Max pumping height: ~30 ft. (atmospheric pressure)

Efficiency below 0.1%
(compare to horses..)

Why did anyone buy it? What for?

Found immediate use in Scottish and English mines, to pump out water. Fuel was essentially free. 2000 times less efficient than people or animals, but they can't eat coal.



First true steam engine:

Thomas Newcomen, 1712, blacksmith

Copy of Papin's engine of design of 1690, with piston falling as steam cooled, drawn down by the low pressure generated

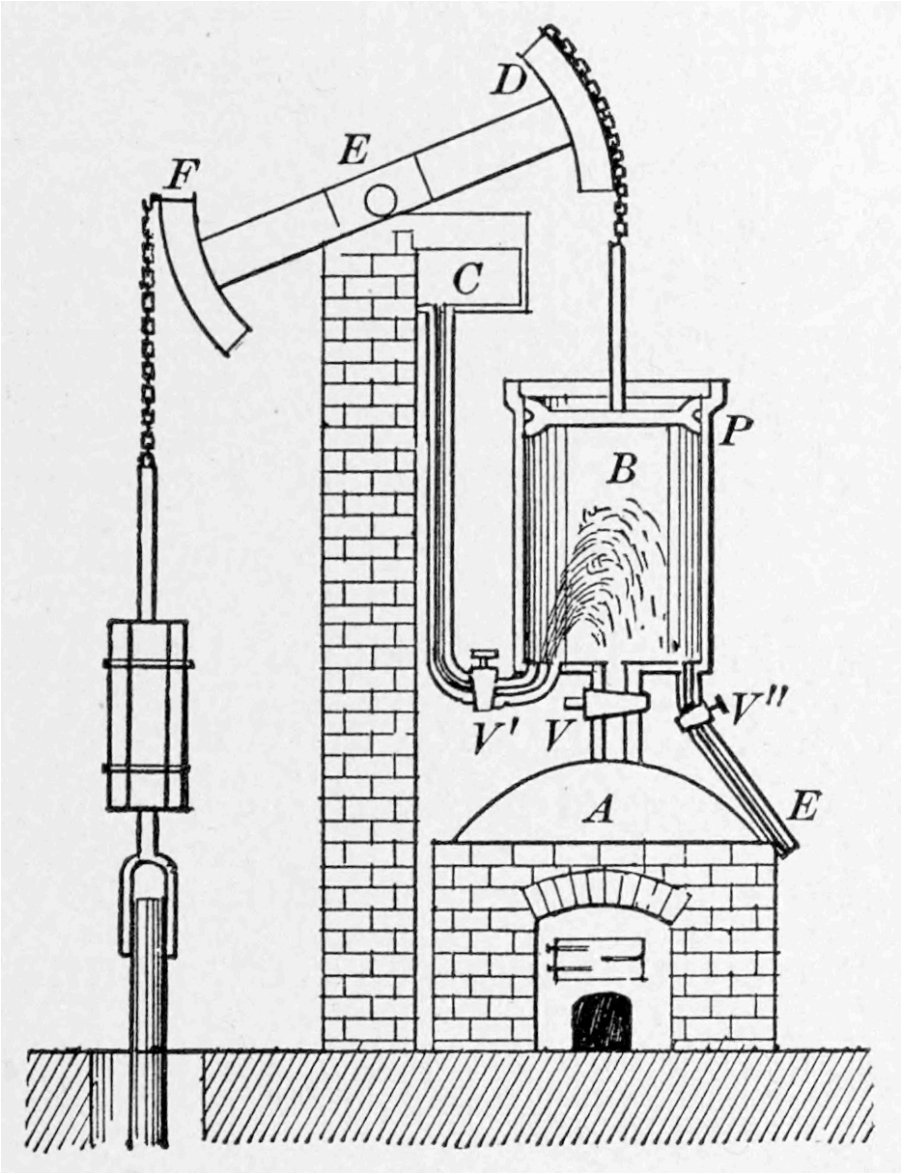
First *reciprocating engine*: force transmitted by motion of piston

Can pump water to arbitrary height.

Force only on downstroke of piston

Very low efficiency: ~0.5%

Intermittent force transmission



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

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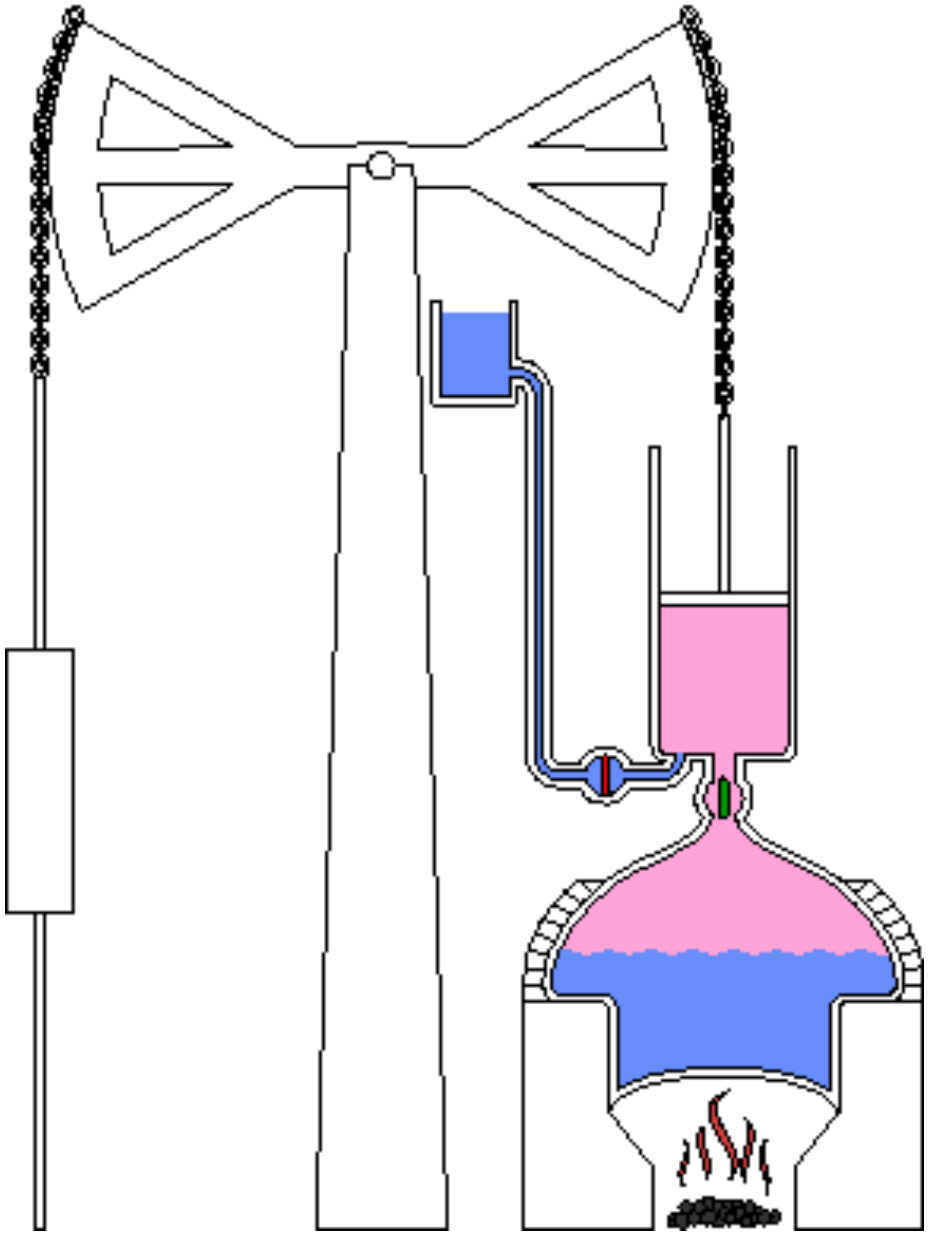

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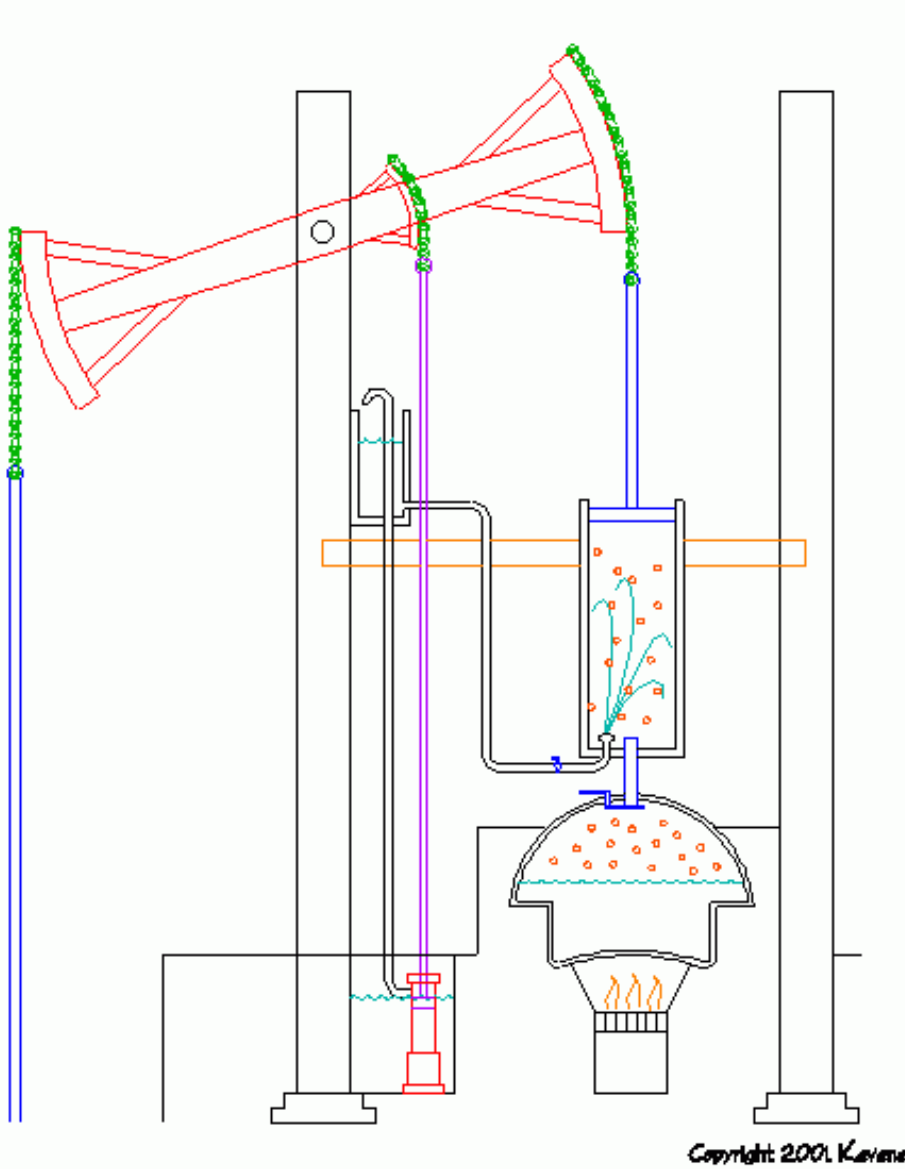
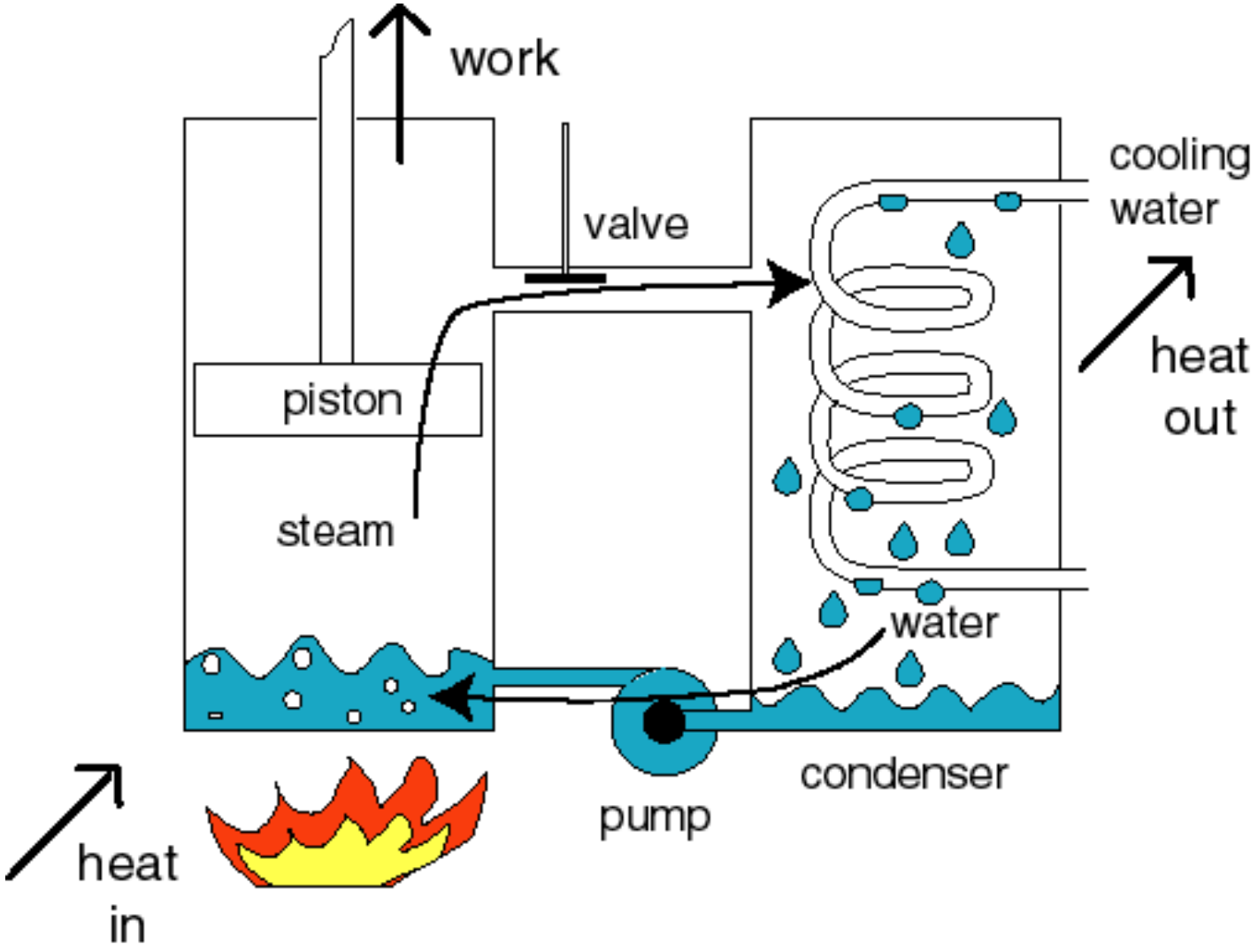
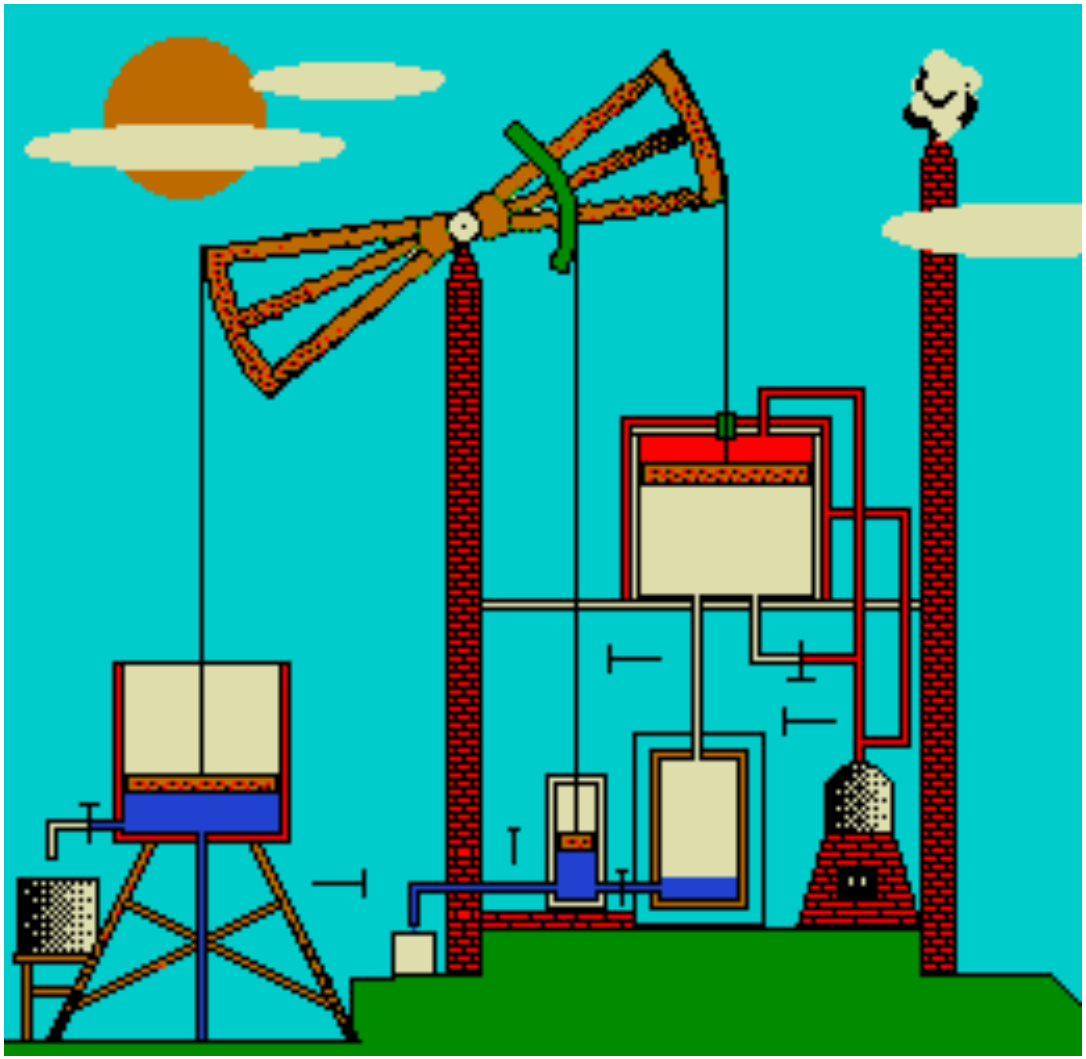


Newcomen's design is state of the art for 60+ years

First modern steam engine:

James Watt, 1769 (patent), 1774 (prod.)
Higher efficiency than Newcomen by introducing separate condense
Reduces wasted heat by not requiring heating and cooling entire cylinder





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First modern steam engine:

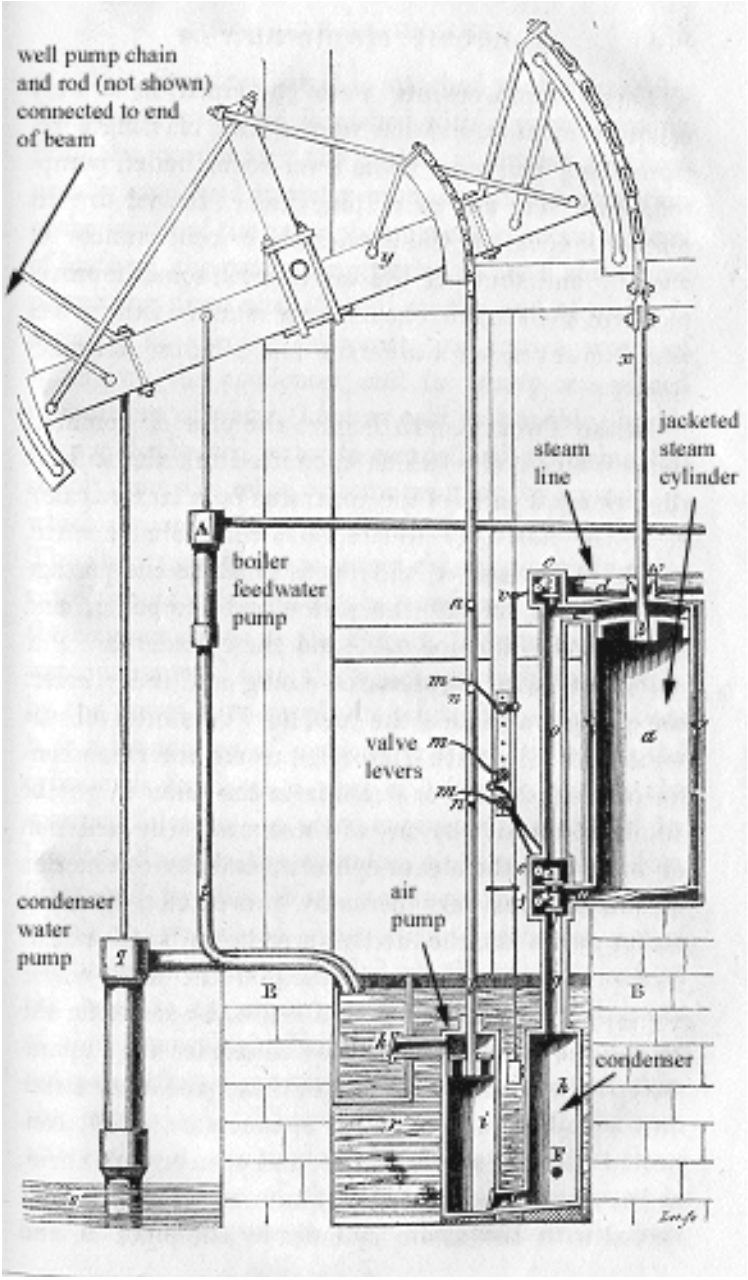
James Watt, 1769 patent
(1774 production model)

Like Newcomen engine only with separate condenser
Higher efficiency: 2%

Force only on downstroke of piston

Intermittent force transmission

No rotational motion



Improved Watt steam engine:

James Watt, 1783 model
Albion Mill, London

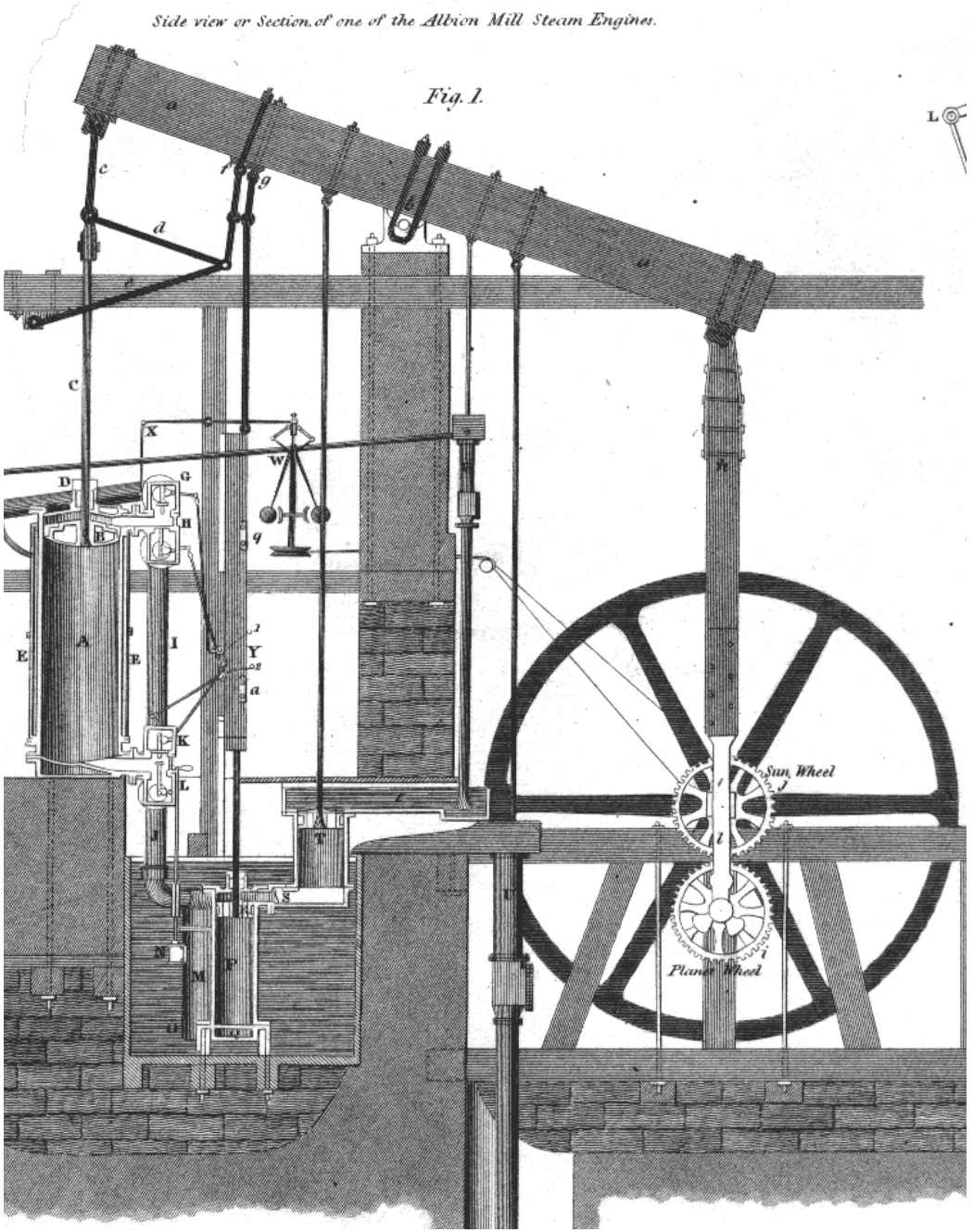
Separate condenser
Higher efficiency: ca. 3%

Force on both up- and downstroke

Continuous force transmission

Rotational motion
(sun and planet gearing)

Engine speed regulator



Side view or Section of one of the Albion Mill Steam Engines.

Fig. 3.

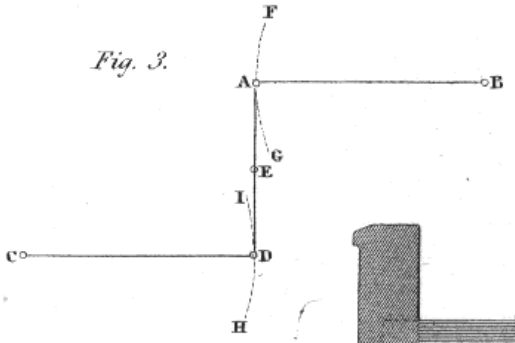


Fig. 1.

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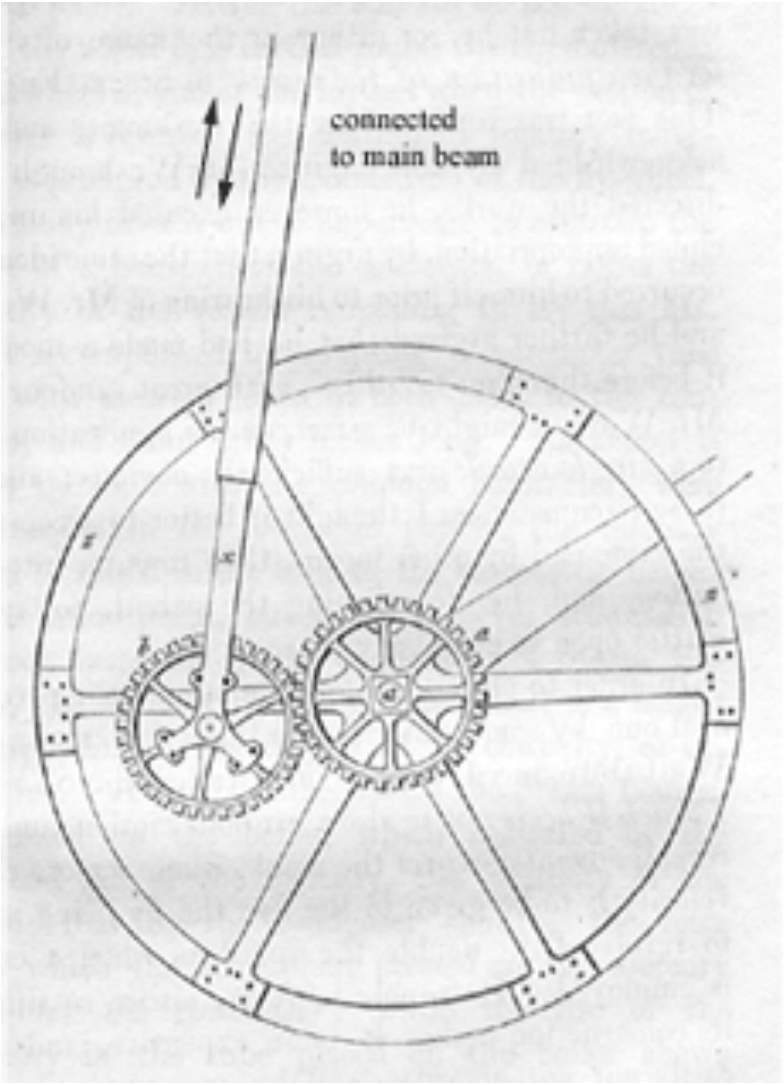

sun and planet gearing

Gearing lets the linear-motion engine produce rotation, mimic a water wheel

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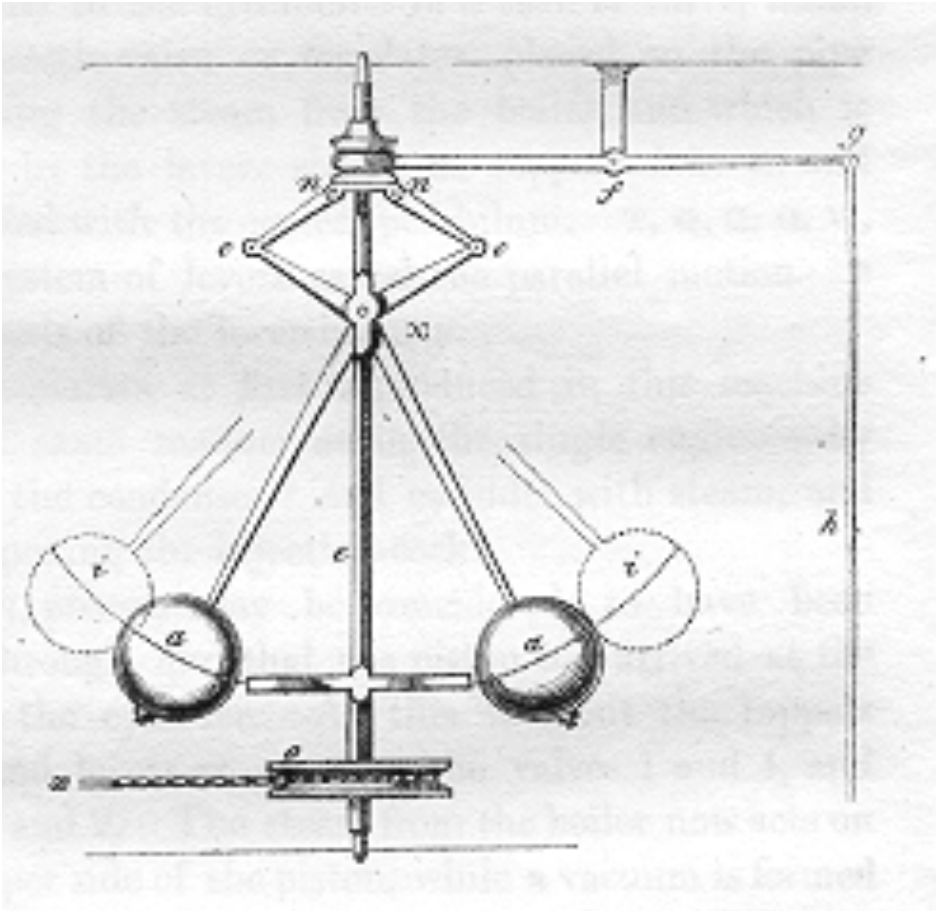


engine speed governor

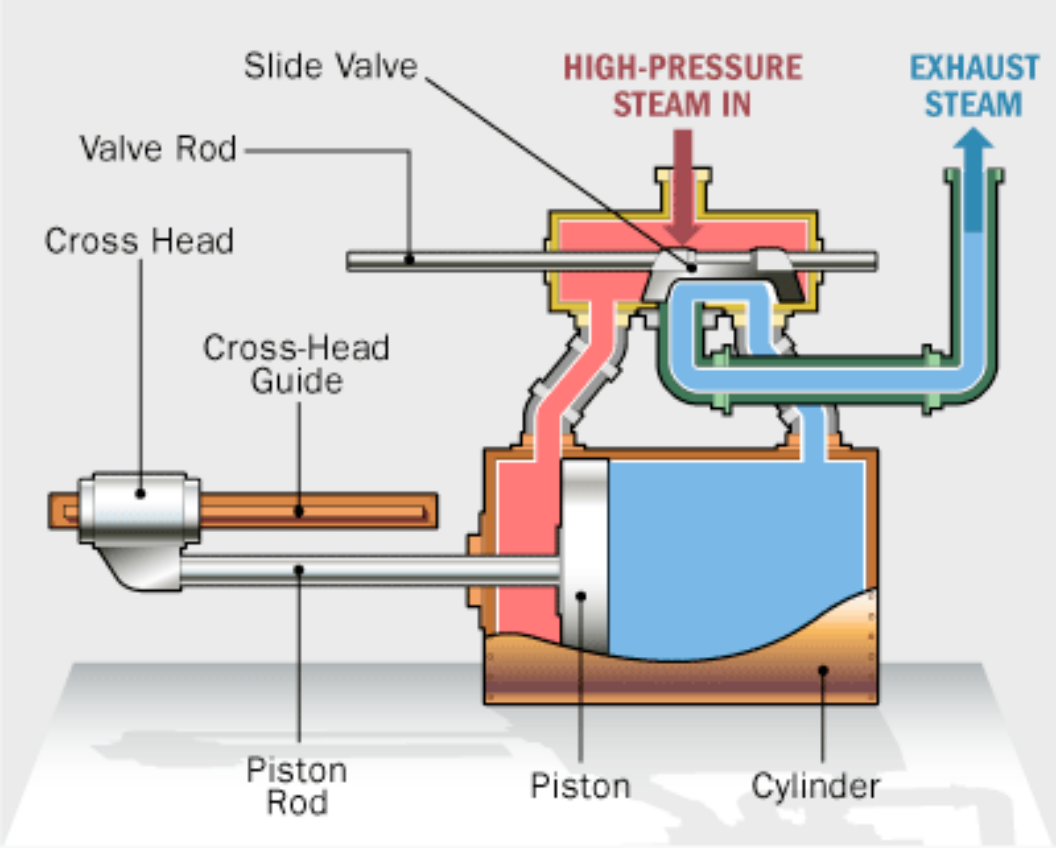
No need for electronics for controls – can use mechanical system

Double-action steam engine:

No vacuum-induced downstroke

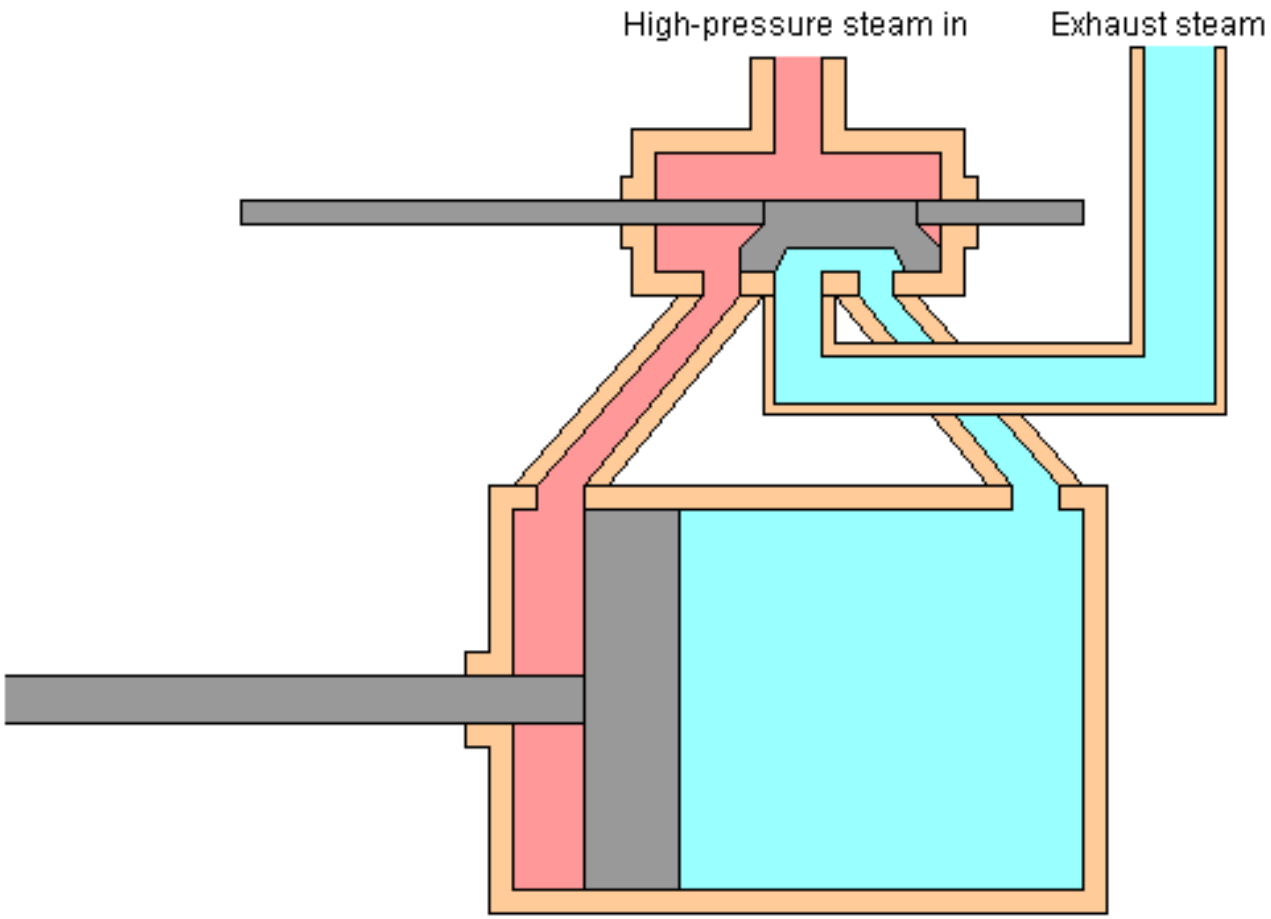
Piston pushed by steam on both up- and down-stroke

Steam vented at high temperature



slide valve alternates input & exhaust

Double-action steam engine:



Double-action steam engine

What are benefits?

What are drawbacks?

What would you use one for?

Double-action steam engine

What are benefits?

Faster cycle – no need to wait for condensation. Can get more power, higher rate of doing mechanical work.

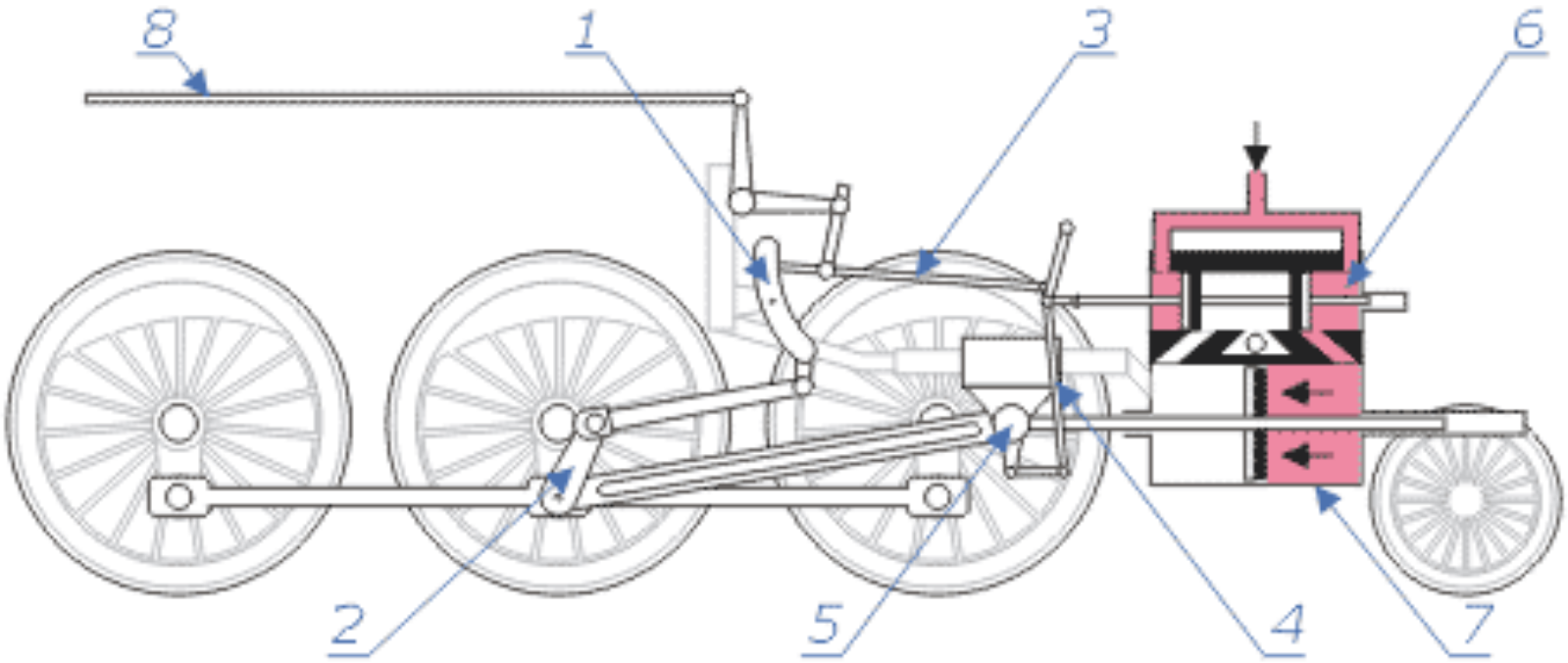
Also lighter and smaller – no need to carry a condenser around.

What are drawbacks?

Inefficiency – venting hot steam means you are wasting energy.

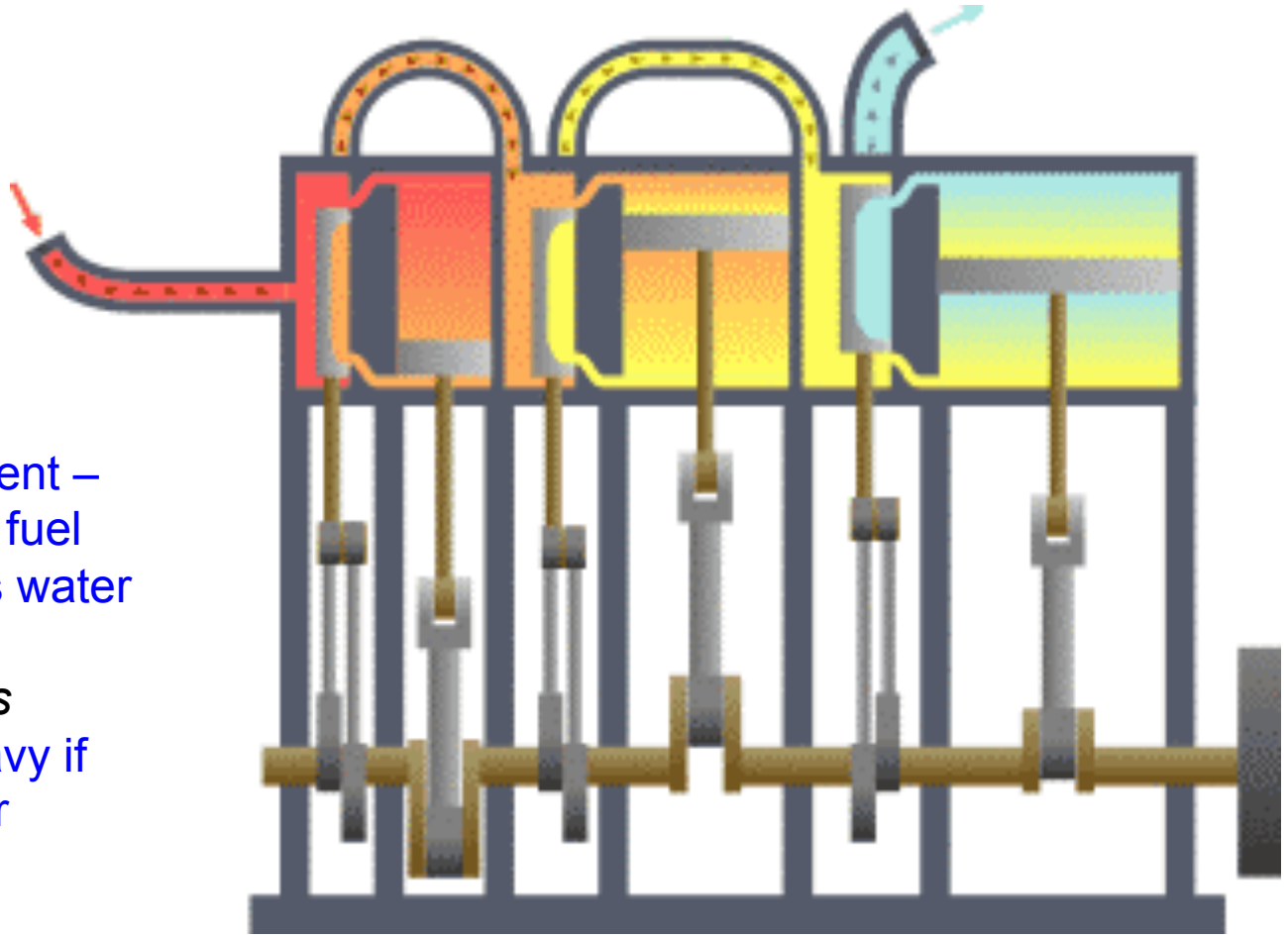
High water usage – since lose steam, have to keep replacing the water

Double-action steam engine:



primary use: *transportation*

Triple-expansion steam engine:



Benefits:
More efficient – conserves fuel
Conserves water

Drawbacks
Large, heavy if high power

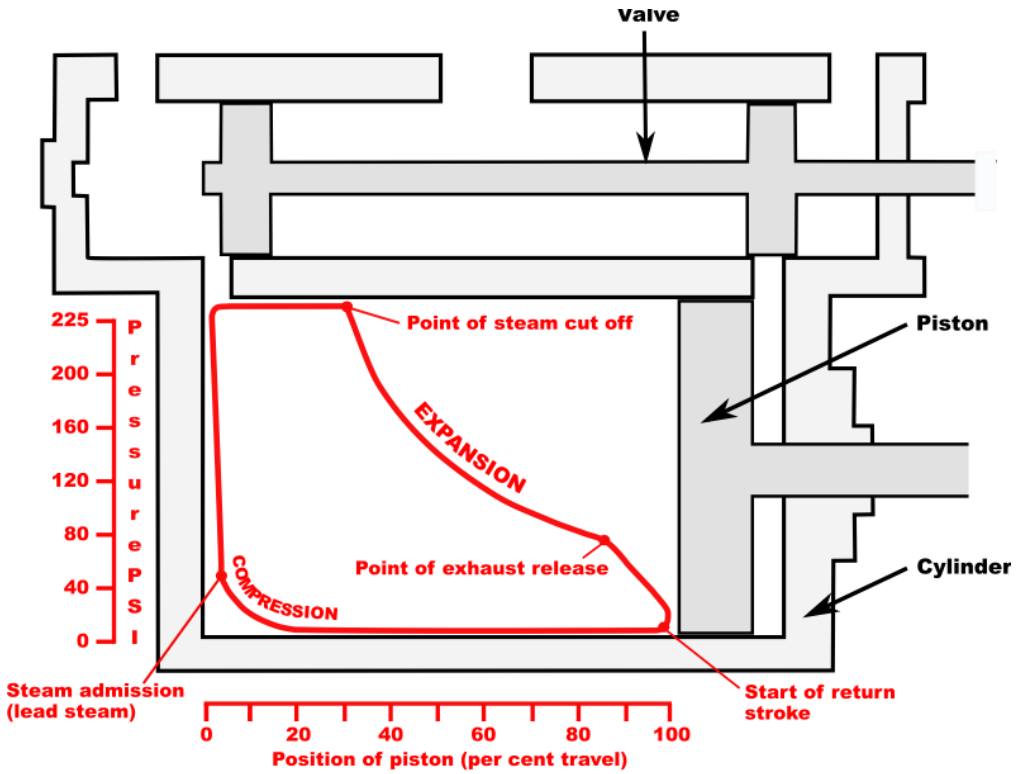
primary use: *steamships*

Indicator diagram for double-acting steam engine:

also termed: “P-V diagram”

$$\text{Work} = \int F\,dx = \int P\,dV$$

which is the *area* enclosed by the PV curve



What is maximum work that you can get out of an engine, relative to the energy you put in?

also termed: “P-V diagram”

$$\text{Work} = \int F\,dx = \int P\,dV$$

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