

Lecture 6  
GEOS24705

Steam engines, heat engines

## *First true steam engine:*

Thomas Newcomen, 1712, blacksmith

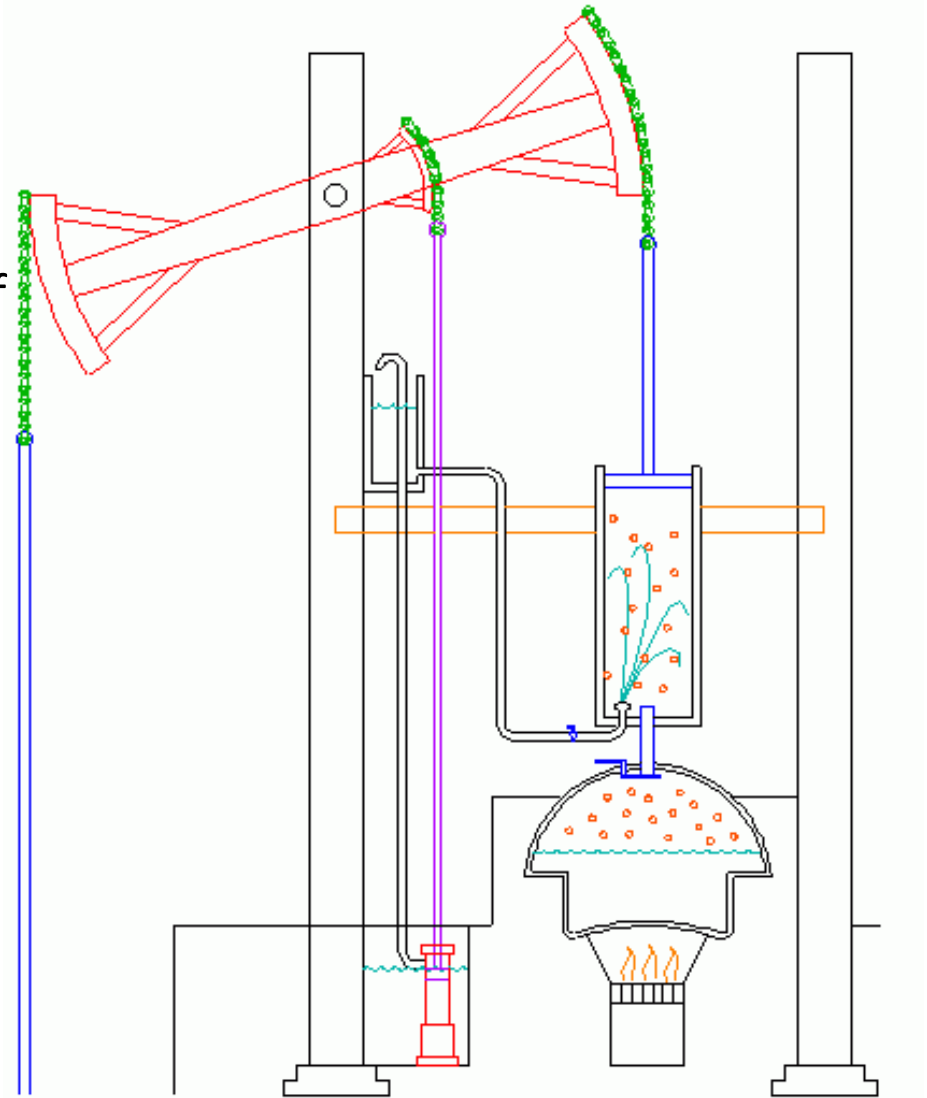
Copy of Papin's engine of design of 1690

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

*Issues:*

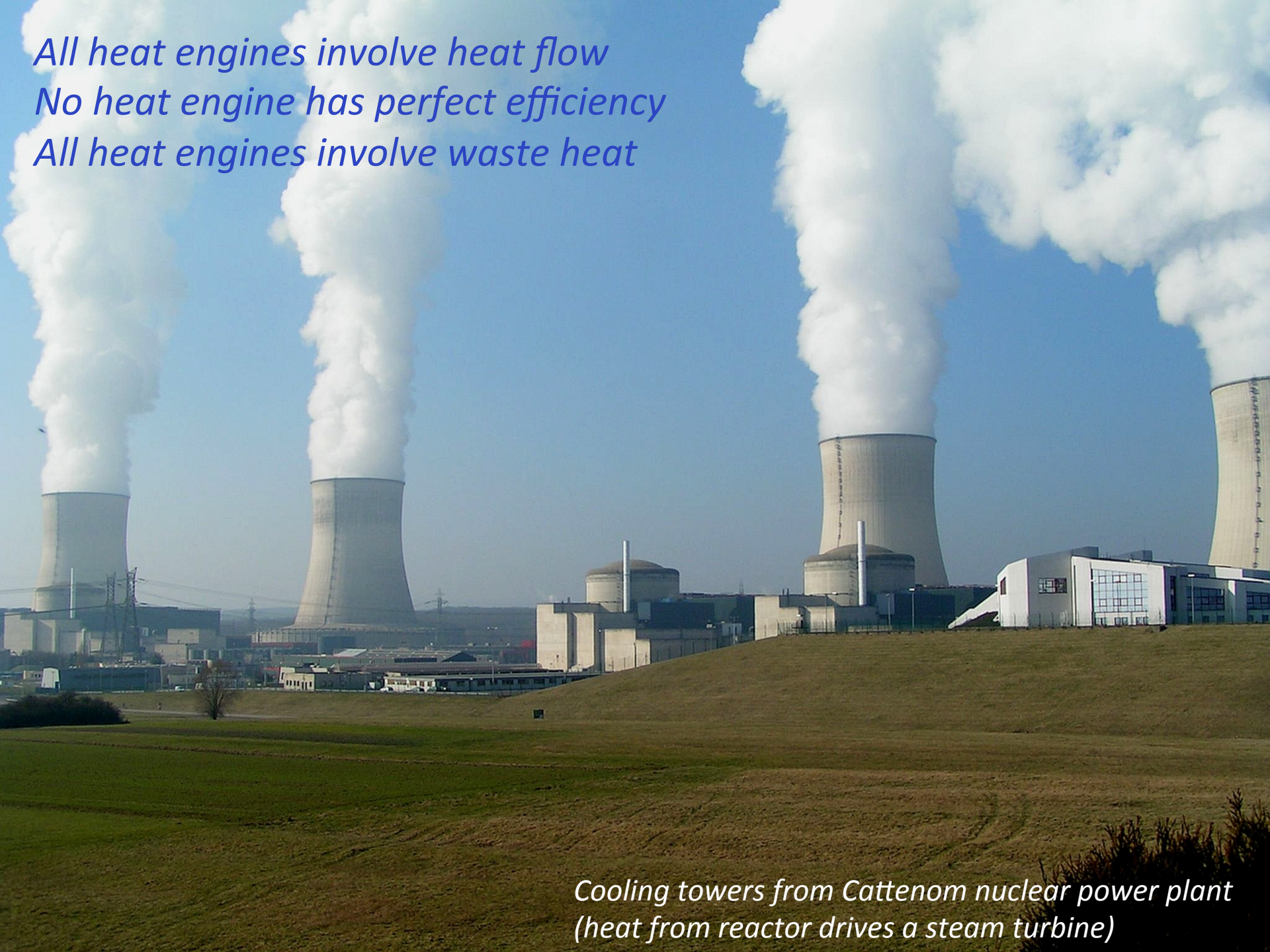
Very low efficiency: 0.5%?

Intermittent force transmission



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

*All heat engines involve heat flow  
No heat engine has perfect efficiency  
All heat engines involve waste heat*



*Cooling towers from Cattenom nuclear power plant  
(heat from reactor drives a steam turbine)*

## First modern steam engine:

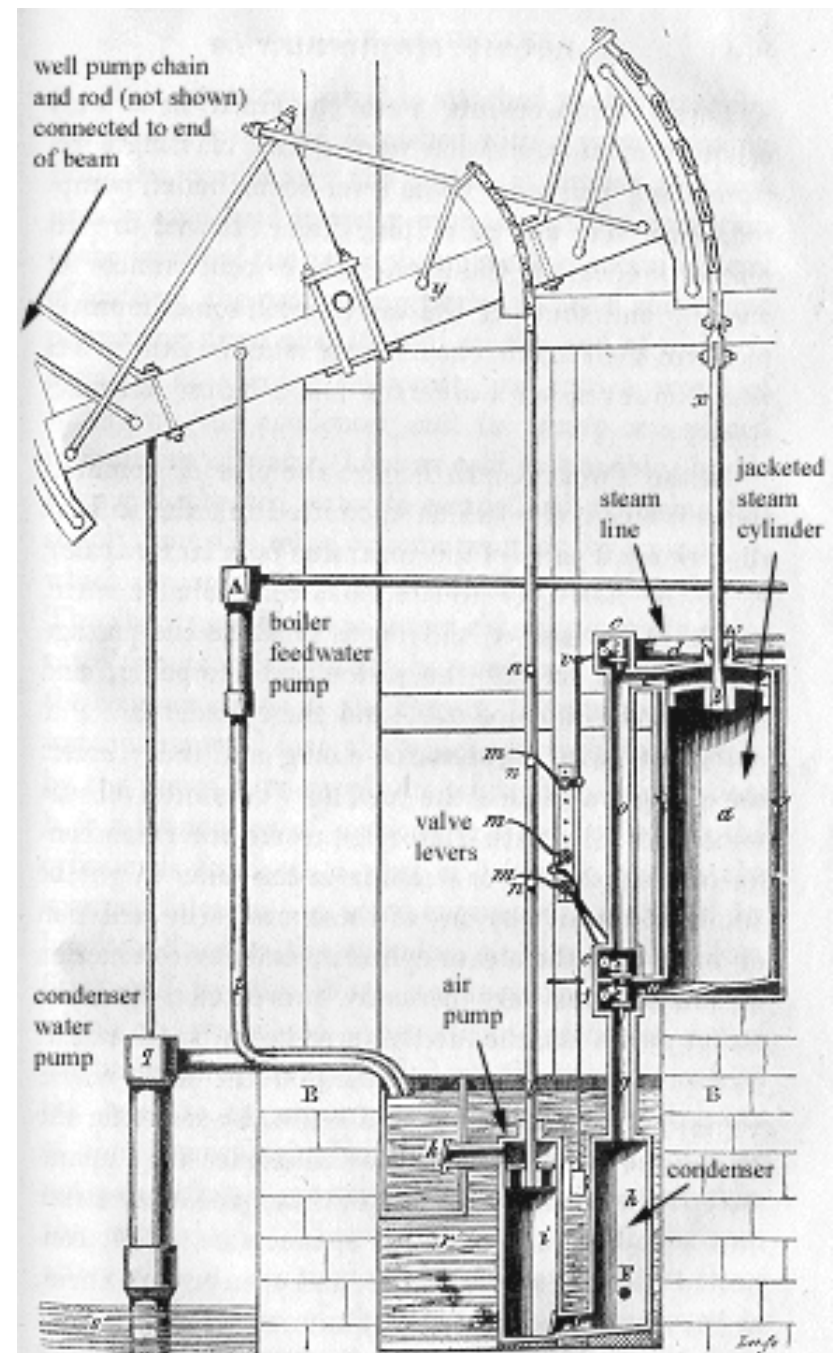
James Watt, 1769 patent  
(1774 production model)

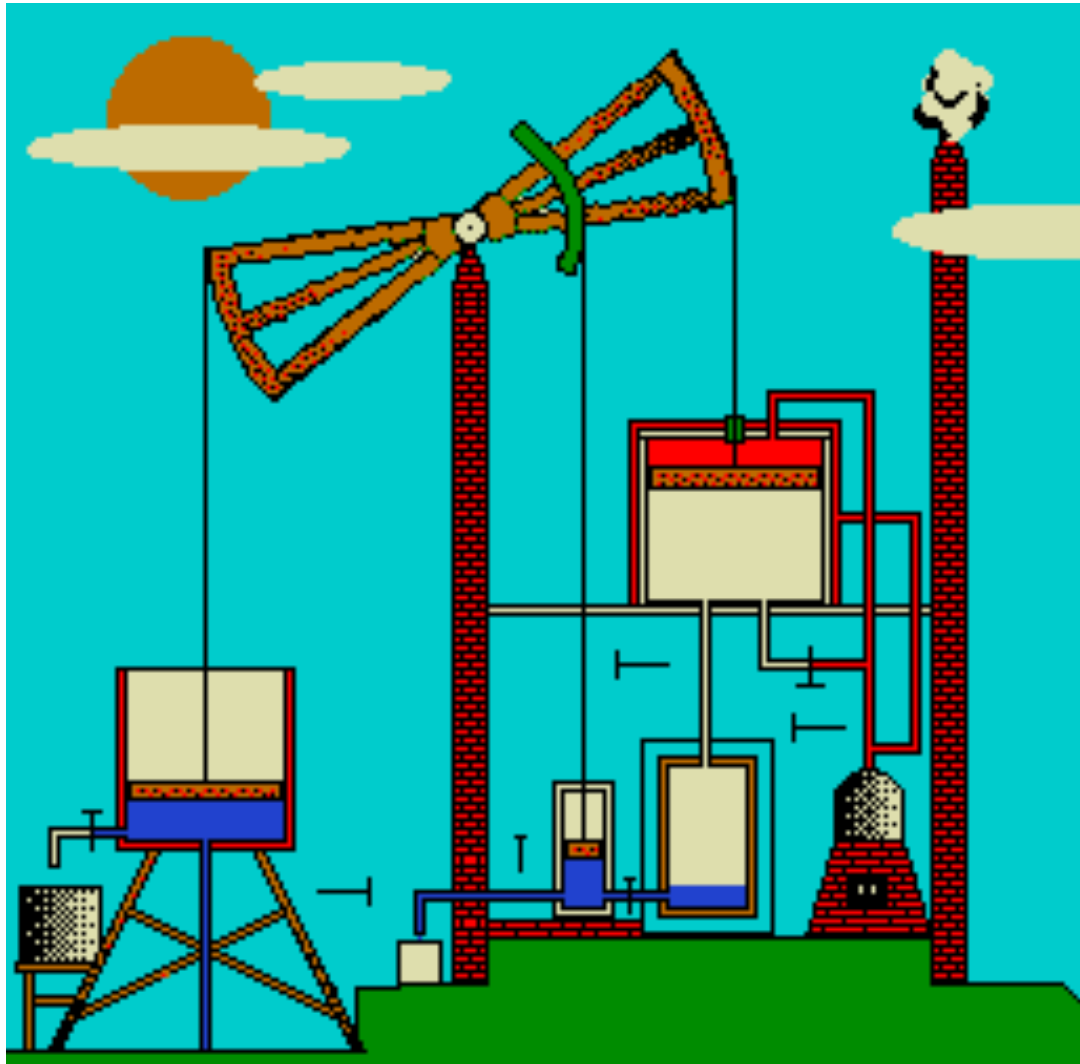
Similar to Newcomen's engine, but with steam now condensing in a separate condenser that is kept always cool.

In Newcomen's engine, the metal cylinder would alternately heat and cool when filled with steam or when cooling water is added in condensing step.

In Watt's engine, steam enters alternately at top and bottom of cylinder. As piston begins to move down, steam flushes into condenser where it condenses, providing the suction that is most of the force on the engine.

Lower fuel usage than Newcomen's engine.





### *First modern steam engine:*

James Watt, 1769 (patent), 1774 (prod.)

Higher efficiency than Newcomen by introducing separate condenser

Reduces wasted heat by not heating and cooling entire cylinder

## Improved Watt steam engine:

James Watt, 1783 model  
Albion Mill, London

*As before:*

Separate condenser

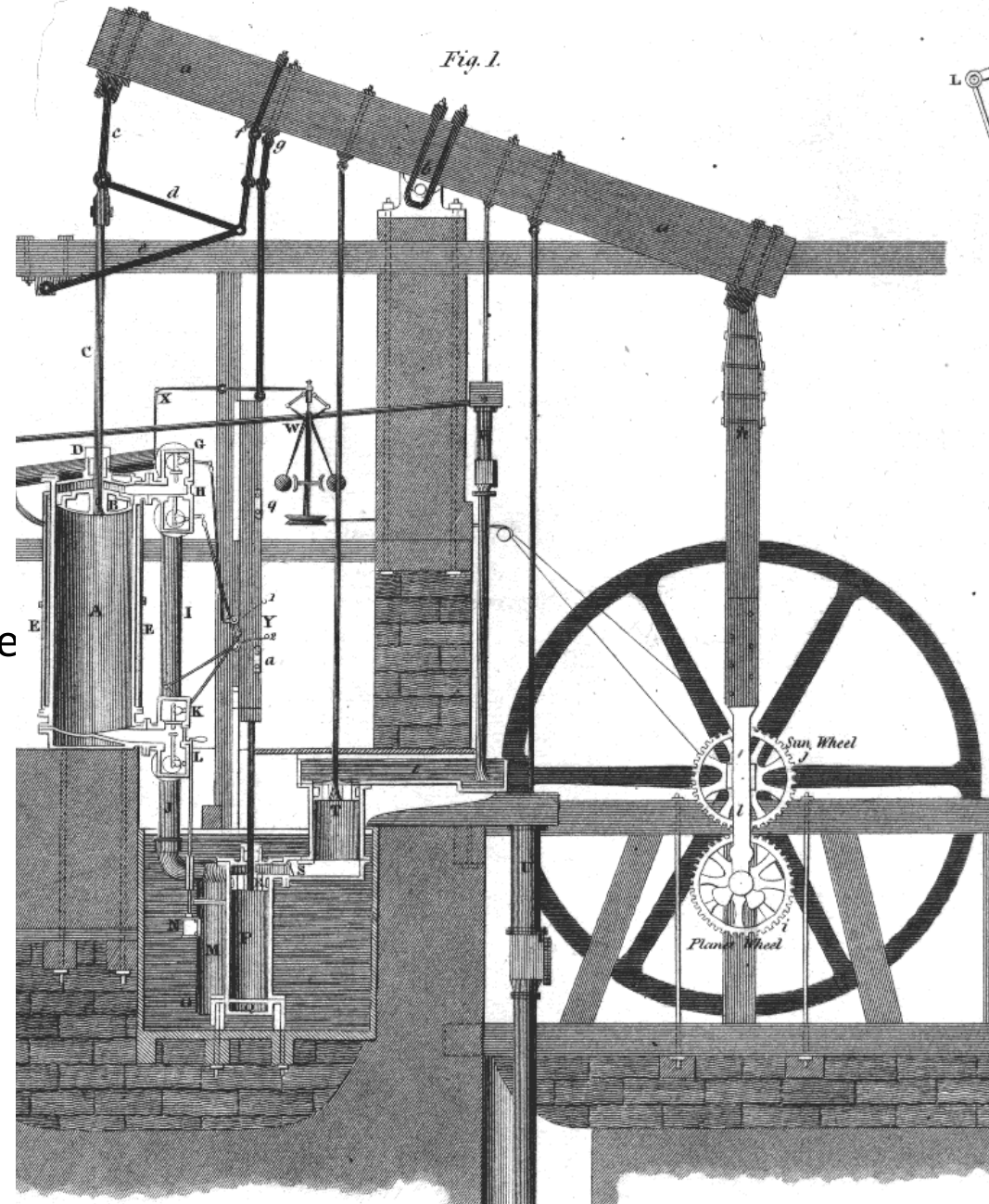
*Improvements:*

- Force on both up- and downstroke
- Continuous force transmission
- Rotational motion
- Engine speed regulator
- Higher efficiency: ca. 3%

Engineers cared about efficiency –  
coal = money

[video of 1788 engine](#)

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

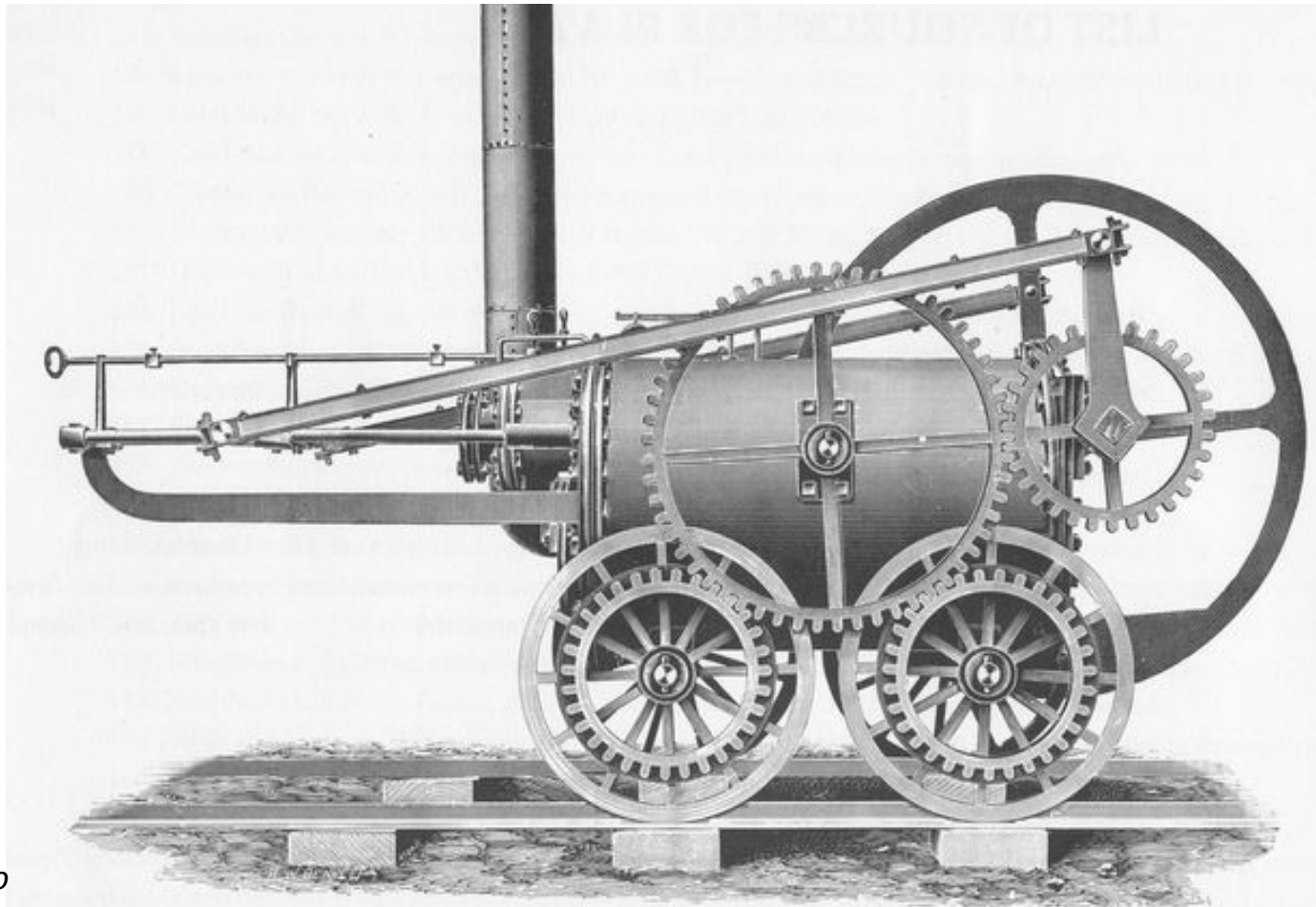


## *First locomotives – attempts to convert stationary steam engines*

built by Richard Trevithick, mining engineer

Experimented with “high-pressure” steam (50 psi), double-acting cylinders.

1804 Pen-y-Darren locomotive, carrying iron in Wales, replacing horse-drawn tramway. Ran ~10 miles at ~2 mph but destroyed track.

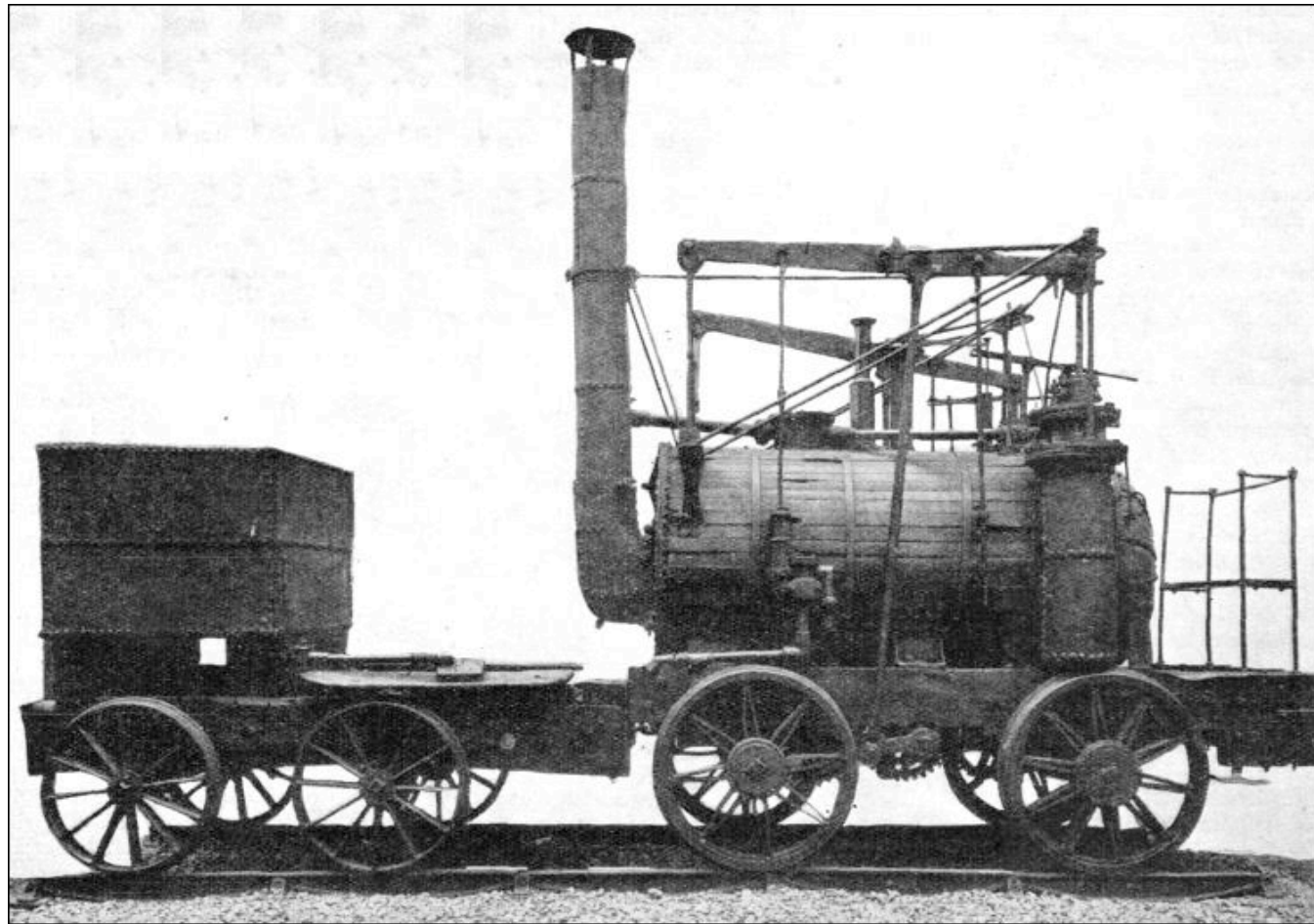


*Image: 1804 Coalbrookdale locomotive, which failed. No images of Pen-y-Darren survive*

## *First practical locomotives begin 1814*

“Puffing Billy”, designed by William Hedley, (mine manager),  
built by the mine’s blacksmith and enginewright  
Coal hauler, 9” x 36” cylinders

*Still basically a stationary steam engine placed on wheels*



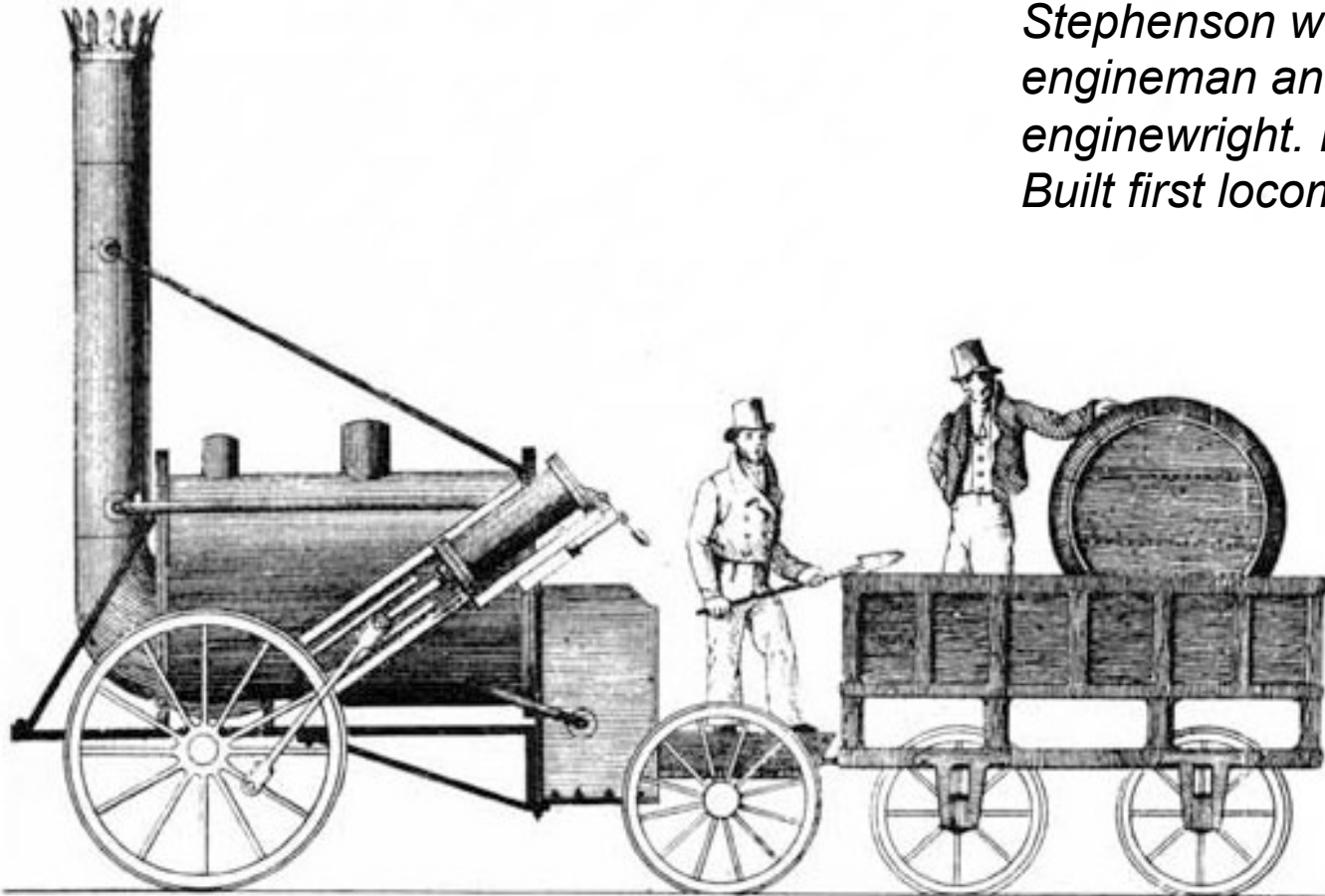
*Image: source unknown*



## *First passenger locomotive, 1829*

George Stephenson's "Rocket", built for Liverpool and Manchester Railway won the Rainhill trials at 29 mph (unloaded), 14 mph loaded  
first example of single pair of drive wheels

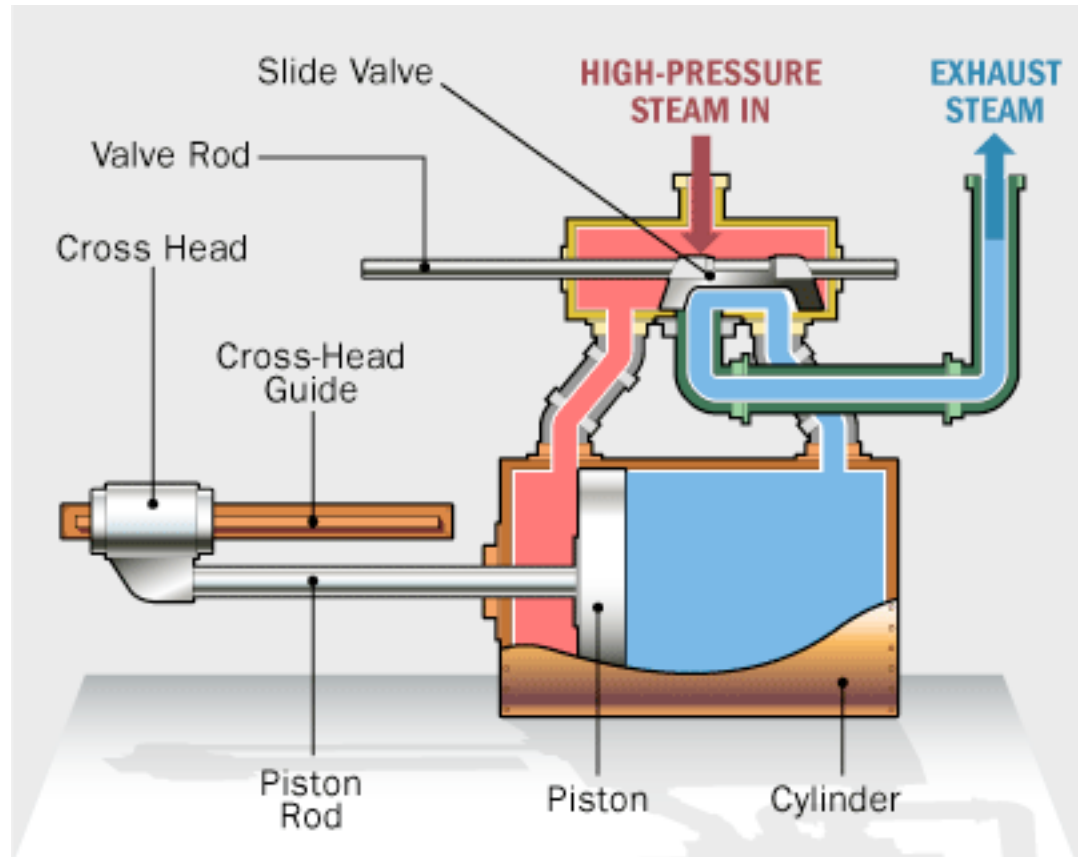
*Stephenson was a mine  
engineman and brakeman, then  
enginewright. Illiterate til age 18.  
Built first locomotive in 1814.*



## *Double-acting steam engine*

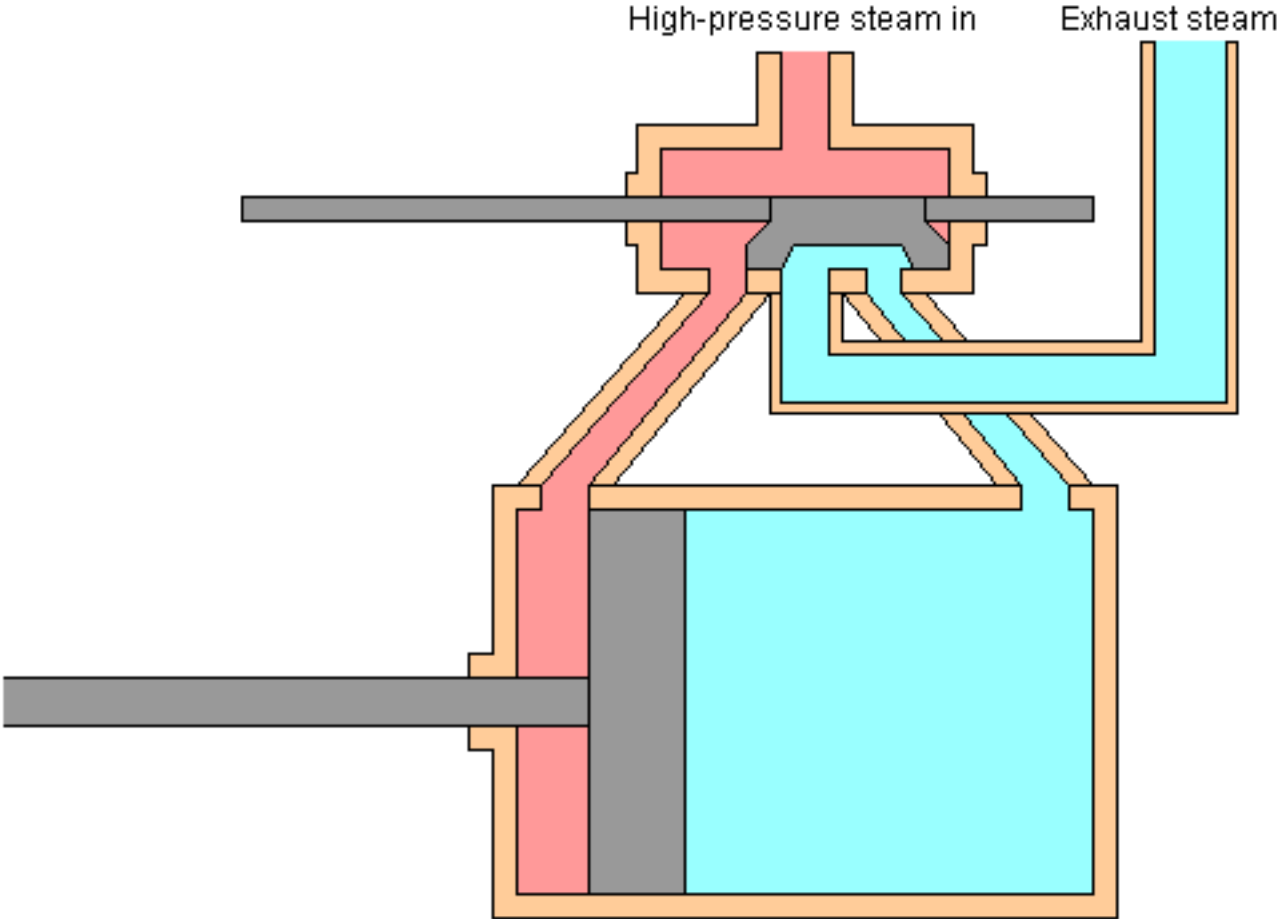
Piston pushed by steam on both up- and down-stroke.

No more need for a condenser. Steam is simply vented at high temperature

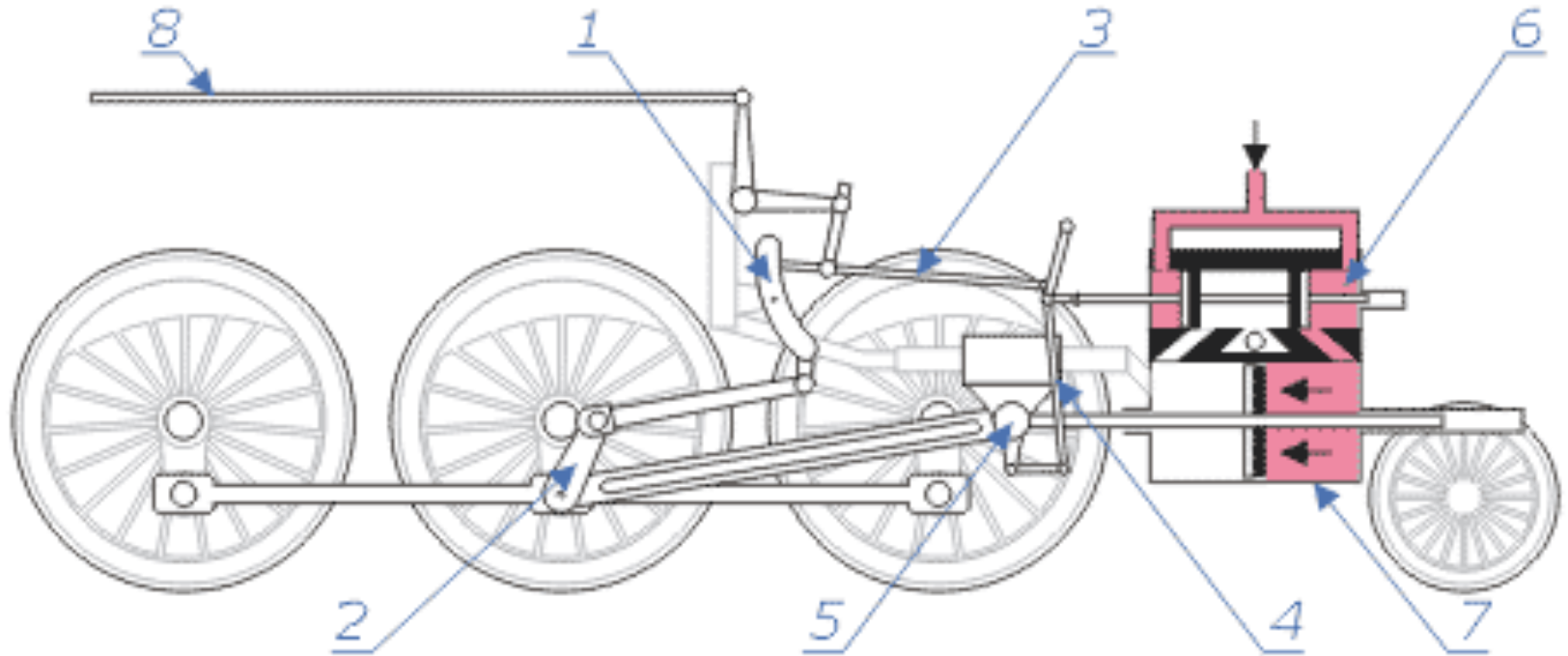


slide valve alternates input & exhaust

*Double-acting steam engine*



## Double-acting steam engine



primary use: *transportation*

# Double-acting steam engine

What are benefits?

What are drawbacks?

# Double-acting 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-acting steam engine:*



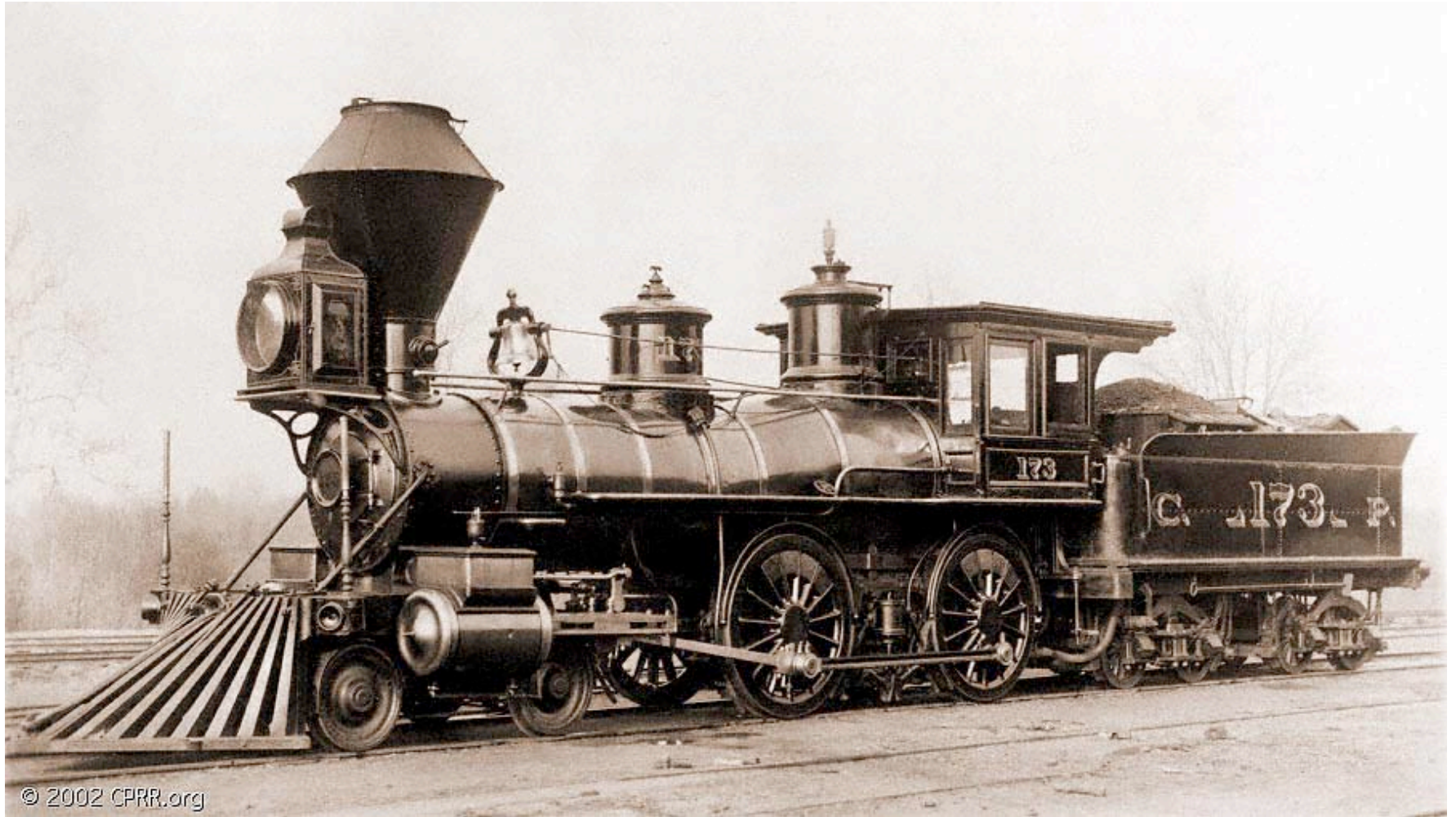
*Images top, left: Sandia Software  
Image bottom: Ivan S. Abrams*

*water-intensive,  
fuel-intensive –  
requires many  
stops to take on  
water and fuel.*



## *History of locomotives*

Central Pacific Railroad locomotive #173, Type 4-4-0, 1864



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*Image: Central Pacific Railroad  
Photographic History Museum*



## *History of locomotives*

Northern Pacific Railway steam locomotive #2681, 1930



*Image: Buckbee Mears Company, Photograph Collection ca. 1930, Location no. HE6.1N p11, Negative no. 25337. Source: Minnesota Historical Society*