# 17. *Engineering Empires*: Chaps 1–2

## 1. Cultural History of Technology

*Whig history*

"...the history of the winning side, valuing the past only where it matches, or approaches, the present, and all but ignoring the 'failures', 'dead-ends' or paths not taken, except where they stand as salutary reminders of the extent of human folly, nurtured by arrogance or fashion". (MS05, pg. viii.)

"A central aim of our book... is to highlight the cultural contingencies which shaped the varied technologies of empire in the long 19th century [~1760–WWII]." (MS05, pg. ix.)

$$\textit{Cultural history of technology} = \begin{cases} \textit{history of technology} \\ \textit{history of science} \\ \textit{cultural history} \end{cases}$$

*Types of history of technology:*

(i) Popularized accounts: "...the inexorable march of material technological progress; the individual triumph over adversity and the forces of conservatism; and the moralized life of the engineering 'visionary', outside—and yet ahead of—his (always his) time."

(ii) Economic accounts: quantitative analyses of technologies based on "economic impact".

(iii) Antiquarian accounts: "Internal", detail-specific accounts, as opposed to "external" accounts of broader meanings or patterns of use.

*Cultural history* = "the study of the construction (or production) and the dissemination (or reproduction) of meanings in varying historical and cultural settings."

*Is there a distinction between "technology" and "culture"?*

- Does technology produce culture, or does culture produce technology?

"...we might instead prefer to see 'technology' and 'culture' in simultaneous reciprocal transformation—each involved in the other's production and each conferring meaning on the other." (MS05, pg. 5.)

"We accept, therefore, historical *contingency* rather than assuming the inevitable success of certain projects or technologies, especially those subsequently found to have been 'successful', in some sense, in the long term." (MS05, pg. 5.)

*Interpretive flexibility* = the idea that different social groups interpret a technology differently according to their own local needs and demands.

"The eventual stabilization of a technology in one particular form, and with one particular meaning, is as much a social event as a material one." (MS05, pg. 5.)

*Technological system* = network of societal, cultural, political, and material relations surrounding the design and deployment of a technology.

"...we gain interrogative purchase and narrative power, as historians, by considering technologies as complex systems of heterogeneous elements, given collective meaning by and within their social milieus." (MS05, pg. 8.)

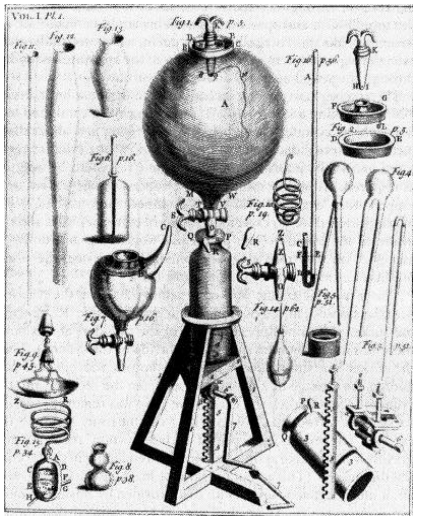
"Our study, then, attempts to penetrate the black boxes of 'steam-power', 'steamship', 'railroad' and 'telegraph' to see each of those 'tools of empire', not simply as a fixed product with a given role, but also as a dynamic system, formed according to the contexts of exhibitions, experiments, standardization and so on, for varied and specific ends including empire—but not limited to it." (MS05, pg. 11.)

# 2. Exploration, Mapping and Measurement

- *Cultural background in Great Britian*

"...a gentlemanly culture which found expression in the Whig party and its adherents, in metropolitan learned societies, and, increasingly, in provincial literary and philosophical societies." (MS05, pg. 13.)

- Cultural values of the scientific revolution (17th century):
  - "experiment, reliably undertaken and properly communicated by men of status; trust in observation".
  - *Royal Society of London (1660)*
  - *Royal Observatory at Greenwich (1675)*



- Cultural values of the enlightenment (18th century):
  As typified by the Whig party:

"...they consolidated a moderate Anglican theology at the core of the Church and State and regarded a knowledge of God's creation as a foundation of social and political order, a bastion against any return to the disorder of the earlier Civil War and the religious enthusiasm of much of the 16th and 17th centuries throughout Europe." (MS05, pg. 13.)

*Standards and cultures of measurement*:
Techniques by which systems of societal, cultural, political, and material relations associated with a given technology are built, stabilized and maintained.

*Example 1: Greenwich Mean Time (GMT).*

- 1884 International Meridian Conference: Establishes GMT as the international standard for time-keeping.
  - *Accepted basis of the world's time zones.*
  - *72% of world's commercial shipping used Greenwich as the first meridian.*

- Why Greenwich?
  - *1673. Committee to investigate proposals for measuring longitude at sea.*
  - *1674. Royal Commission for longitude.*
  - *1675. Greenwich Observatory built.*
  - *1714. Longitude Act. Funds for accurate method of calculating longitude at sea. John Harrison's clocks given initial funding.*

*How to determine longitude with an accurate clock:*

1. Determine local noon (by position of the sun) and record GMT (by ship's clock).
2. Calculate *time* difference in hours: $\Delta t$ = GMT − 12:00 (local time).
3. Translate into *spatial* difference in degrees of longitude $\ell$:
   $\ell = (\Delta t)hr \times 360°/24hr$, east(−) or west (+) of Prime Meridian.

*How to synchronzie clock with GMT:*

1. 1830s. Anchor ship in the Thames and wait for Time Ball to drop at 1pm!
2. 1835. George Biddell Airy ushers in an era of precision time-keeping.
3. 1840's onward. Construction of land and sea telegraph lines makes possible the near instantaneous transmission of Greenwich Time beyond the Thames.

This new culture of time discipline in Britian "marked a radical shift from traditional task-orienta-tion such as harvesting...to timed labor...that is, a shift from a rural economy to industrial capitalism."

*George Airy*
(1801–1892)

"I, as Senior Wrangler, was led up first to receive the degree, and rarely has the Senate House rung with such applause as then filled it. For many minutes, after I was brought in front of the Vice-Chancellor, it was impossible to proceed with the ceremony on account of the uproar."

*Example 2: Chartism.*

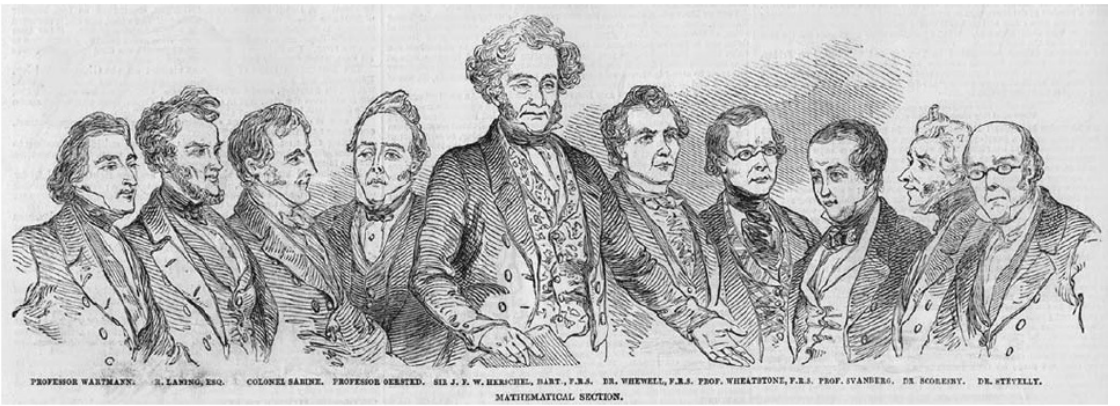
- 1660. Royal Society of London: pompous, aristocratic gentlemen of science.

- 19th century spin-offs:
  - *1807. Geological Society*
  - *1820. Astronomical Society*
  - *1831. British Association for the Advancement of Science (BAAS).*

- BAAS "House of Commons" to Royal Society "House of Lords".

*But still hierarchical*

- Section A: Mathematics and physical science
- Section B: Chemistry
- Section C: Geology
- Section D: Zoology
- Section E: Anatomy
- Section F: Statistics
- Section G: Mechanical science

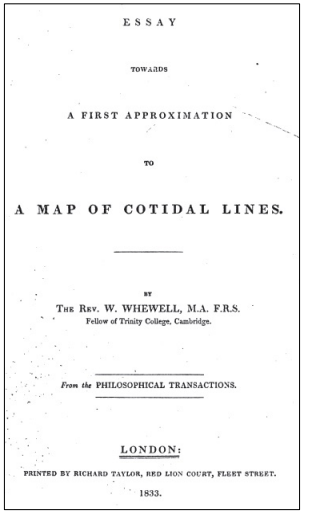


MATHEMATICAL SECTION.

"At the lowest end of the hierarch, Section G ('Mechanical Science') occupied a subservient position, professing to apply laws and theories of Section A while simlultaneously using that strategy to distance itself from the mechanical arts of the practical engineer." (MS05, pg. 22.)

*Chartism* = "the orderly mapping not only of land and sea but of terrestrial magnetism, tidal flows, meterological phenomena and of the health and diseases of the body politic..."

- *Typical mode of presentation at BAAS meetings.*
- *Becomes "...defining characteristic of British science in a period threatened by increasing political chaos."*
- *Emphasis on quantification as an enlightenment ideal.*


ESSAY

TOWARDS

A FIRST APPROXIMATION

TO

A MAP OF COTIDAL LINES.

BY

THE REV. W. WHEWELL, M.A. F.R.S.
Fellow of Trinity College, Cambridge.

From the PHILOSOPHICAL TRANSACTIONS.

LONDON:

PRINTED BY RICHARD TAYLOR, RED LION COURT, FLEET STREET.

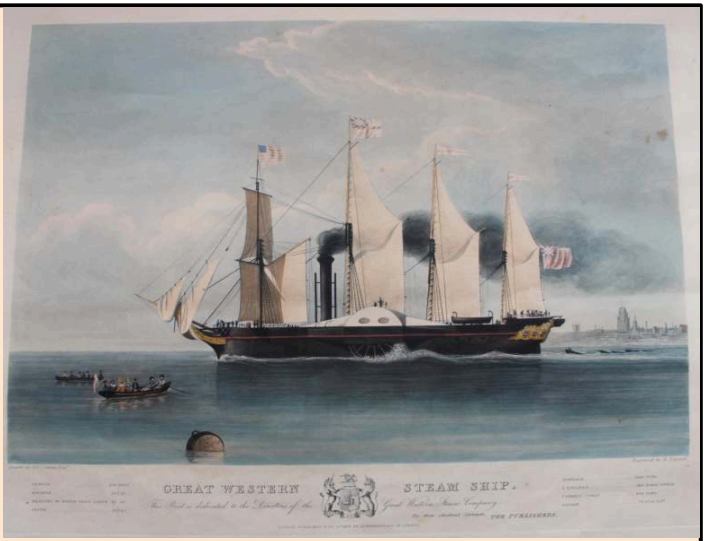
1833.

Whewell, W. (1833) *Essay Towards a First Approximation to a Map of Cotidal Lines*

- "Objects of national importance": tidal charts, meterology, terrestrial magnetism.

Terrestrial magnetism:

- *1830s. Problems with employing magnetic compasses on iron-hulled steam-ships.*
- *1838. Airy's fixed magnets and iron correctors. Requires expert to make precise adjustments.*
- *1854. William Scoresby (former whaling captain, Anglican preacher) criticizes iron-hulls at Liverpool meeting of BAAS Section G.*
- *1870s. William Thomson's modified compass for iron-hulls. System allows ship-master to use without need for experts.*



- Issue of trust: Are steam-driven iron hulls to be trusted over sails and wooden hulls?
  - *1854. Loss of iron-hulled Tayleur and 290 lives.*

- Issue of BAAS authority:
  - *Elite mathematicians of Section A (Airy, Thomson) versus practical-minded members of Section G (Scoresby).*
  - *Liberal Presbytarians versus conservative Anglicans:*

> "[Scoresby's Anglican] evangelical perspective interpreted nature, especially the sea, as expressing the infinite power of Providence...In contrast, liberal Presbytarians and Unitarians had no reservations about 'consulting' and even 'cross-examining' nature through experiment with a view to 'imitating Providence' through the harmony of human artefacts with nature's mechanisms." (MS05, pg. 30.)

*George Airy* (1801–1892)

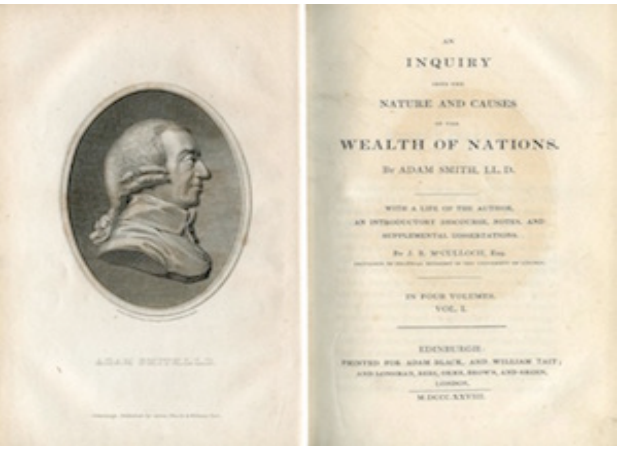
*William Thomson* (1824-1907)

*William Scoresby* (1789-1857)

- Legitimatization of mechanical science (engineering):
  - *Engineering projects as "experiments" (ships, railways, telegraphs).*
  - *Section G advocates appeal to the authority of science and view them as scientific and progressive.*
  - *Critics sceptical of untested experimental schemes that challenge tried and tested practices and traditions.*

# 3. Steam Culture

- *Background*: 18th century Scottish Enlightenment.
  - *Productive labor (marketable goods) versus non-productive labor (servents in employ of aristocratic gentleman).*
  - *Calvinist distinction between moral value of work and sinful nature of idleness and waste.*

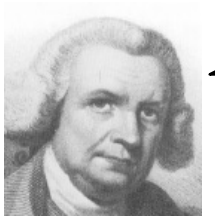



*Ex. 1*: Adam Smith's (1776) *Wealth of Nations.*

- *Labor theory of value: Value of a commodity = the labor required to produce it.*

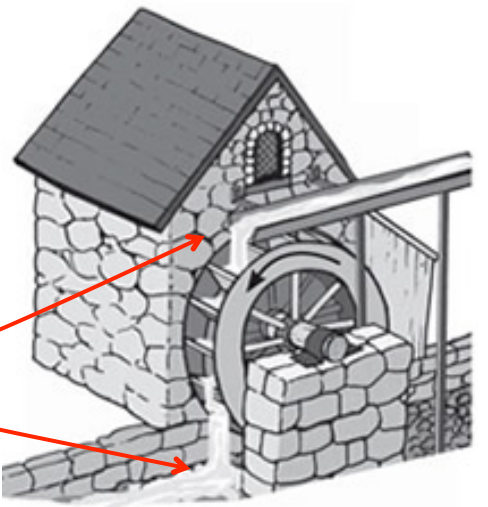
*Ex. 2*: John Smeaton's (1759) analysis of efficiency of waterwheels:

- *Ideal waterwheel pumps same amount of water used to drive it.*
- *Ratio of water pumped (multiplied by height pumped) to water used up gives simple measure of efficiency.*
- *1771. Helps found "Society of Civil Engineers".*



*John Smeaton*
(1724-1792)

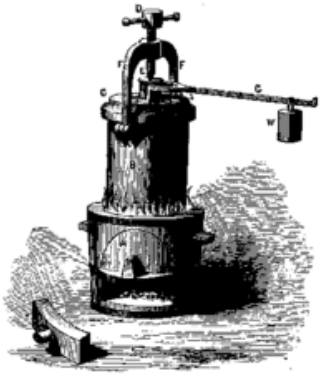
*Max. efficiency when flow between stream and water-wheel occurs at equal heights.*



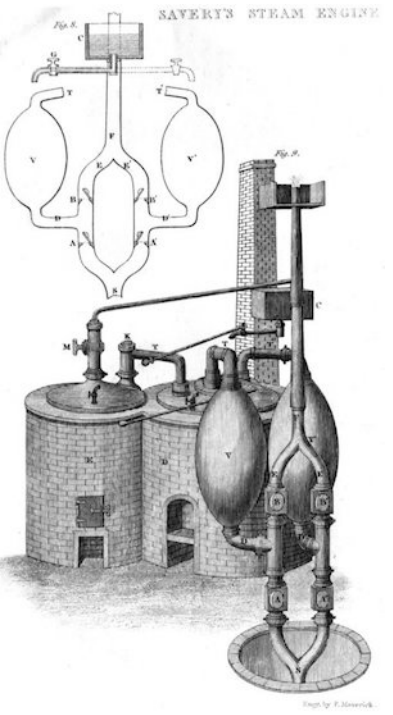
*minimize splashing at high flume and low flume*

# Events in the historical development of the steam engine

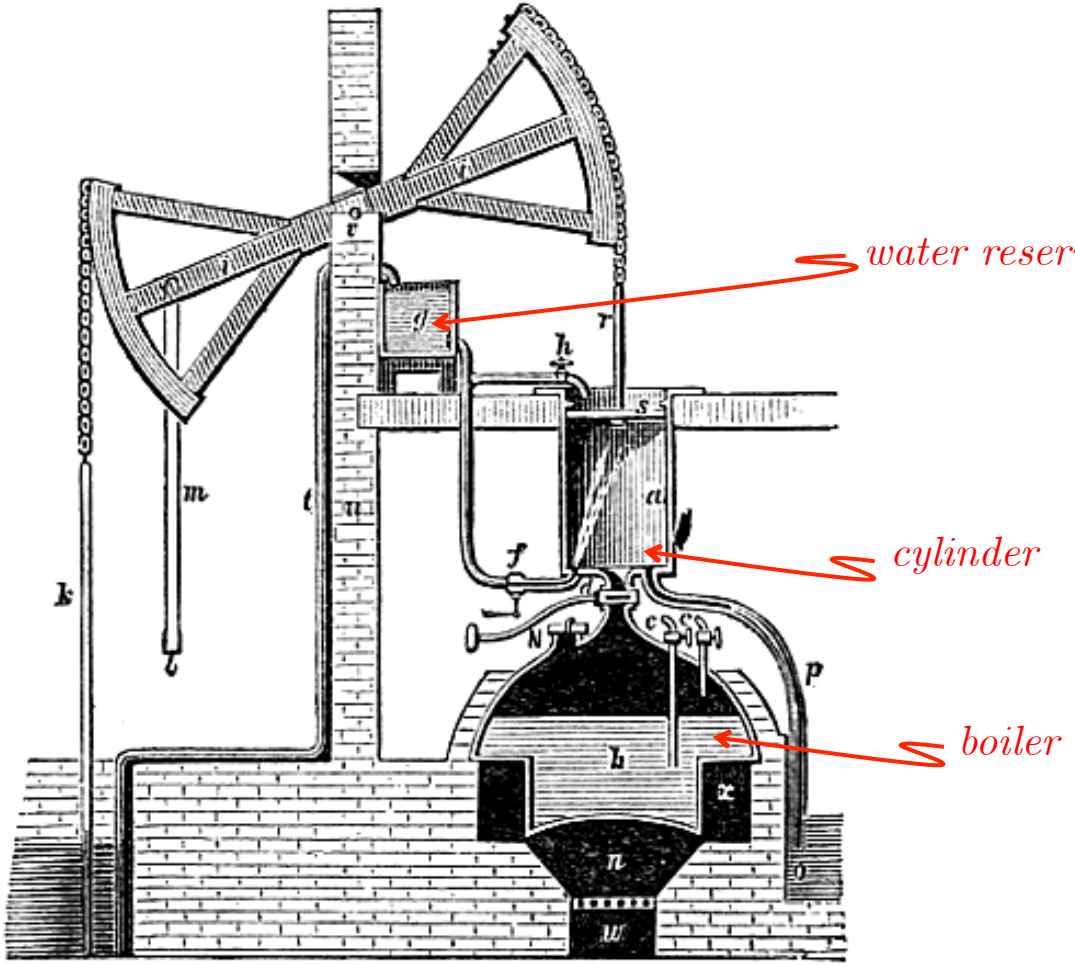
- 17th century demonstrations by Robert Hooke and Denis Papin: vessels filled with steam, quickly cooled, create vaccum. Atmospheric pressure delivers power.
- 1698. Thomas Savery obtains patent on steam-driven pump.
- 1712. Thomas Newcomen's steam engine.



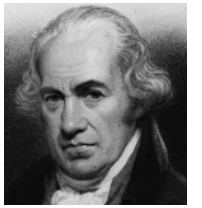
*Papin "steam digester"*



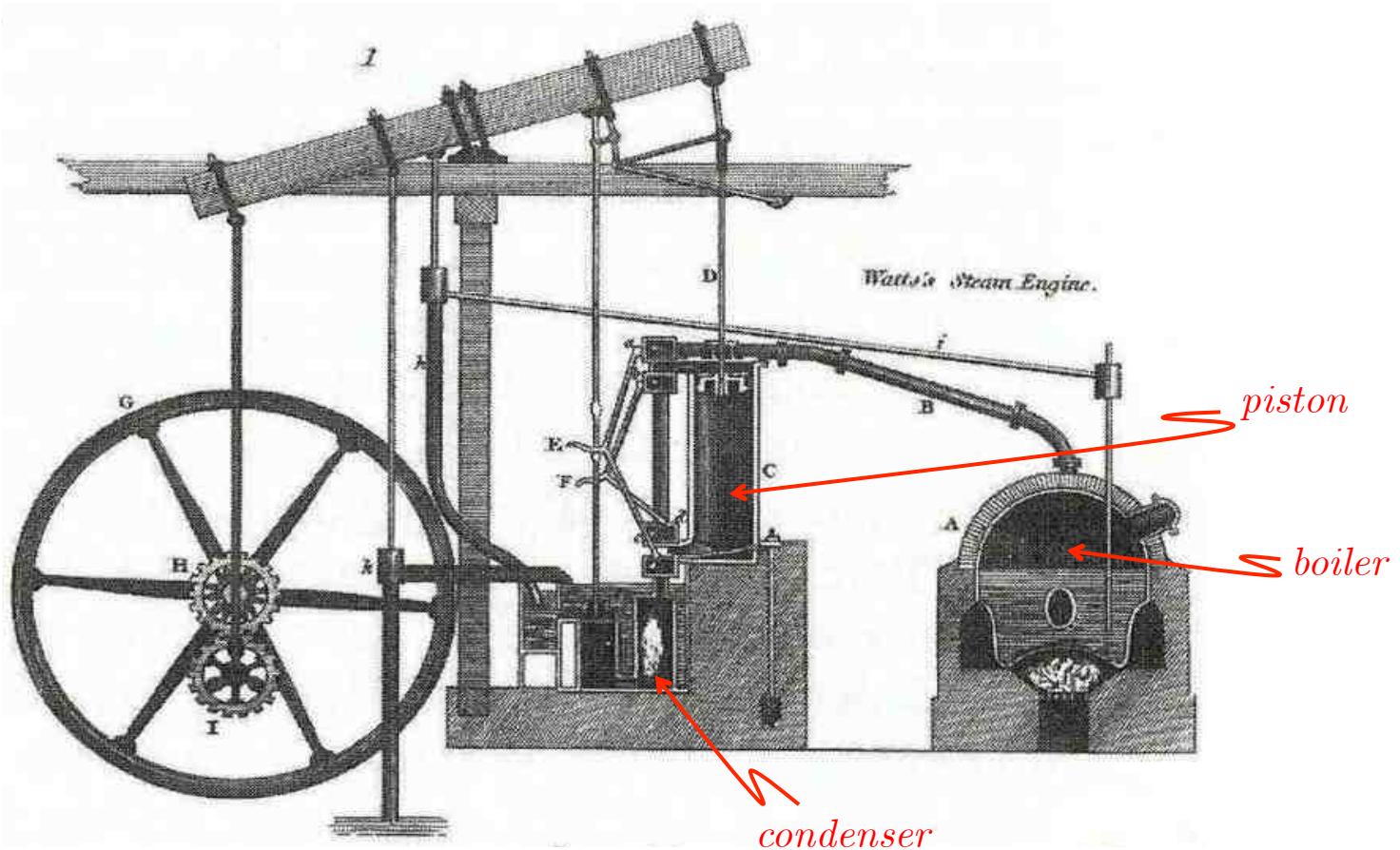

*"an engine to raise water by fire"*



- 1757. James Watt becomes instrument maker at Glasgow College.
- 1759. Glasgow student John Robison urges Watt to think about steam engines.
- 1763-64. Watt repairs Glasgow College's Newcomen steam engine.



*James Watt*
(1736-1819)



- 1769. Watt obtains patent for modified Newcomen engine, with backing of financier John Roebuck.
- 1770. Roebuck goes bankrupt; Watt refashions himself as canal surveyer.

A.D. 1769 . . . . . N° 913.

## Steam Engines, &c.

WATT'S SPECIFICATION.

TO ALL TO WHOM THESE PRESENTS SHALL COME, I, JAMES WATT, of Glasgow, in Scotland, Merchant, send greeting.

WHEREAS His most Excellent Majesty King George the Third, by His Letters Patent under the Great Seal of Great Britain, bearing date the Fifth day of January, in the ninth year of His said Majesty's reign, did give and grant unto me, the said James Watt, His special licence, full power, sole priviledge and authority, that I, the said James Watt, my exors, admors, and assigns, should and lawfully might, during the term of years therein expressed, use, exercise, and vend, throughout that part of His Majesty's Kingdom of Great Britain called England, the Dominion of Wales, and Town of Berwick upon Tweed, and also in His Majesty's Colonies and Plantations abroad, my "NEW INVENTED METHOD OF LESSENING THE CONSUMPTION OF STEAM AND FUEL IN FIRE ENGINES;" in which said recited Letters Patent is contained a proviso obliging me, the said James Watt, by writing under my hand and seal, to cause a particular description of the nature of the said Invention to be inrolled in His Majesties High Court of Chancery within four calendar months after the date of the said recited Letters Patent, as in and by the said Letters Patent, and the Statute in that behalf made, relation being thereunto respectively had, may more at large appear.

NOW KNOW YE, that in compliance with the said provisoe, and in pursuance of the said Statute, I, the said James Watt, do hereby declare that the



following is a particular description of the nature of my said Invention, and of the manner in which the same is to be performed (that is to say):—

My method of lessening the consumption of steam, and consequently fuel, in fire engines consists of the following principles:—

First, that vessell in which the powers of steam are to be employed to work the engine, which is called the cylinder in common fire engines, and which I call the steam vessell, must during the whole time the engine is at work be kept as hot as the steam that enters it, first, by enclosing it in a case of wood or any other materials that transmit heat slowly; secondly, by surrounding it with steam or other heated bodies; and, thirdly, by suffering neither water or any other substance colder than the steam to enter or touch it during that time.

Secondly, in engines that are to be worked wholly or partially by condensation of steam, the steam is to be condensed in vessells distinct from the steam vessells or cylinders, although occasionally communicating with them. These vessells I call condensers, and whilst the engines are working, these condensers ought at least to be kept as cold as the air in the neighbourhood of the engines by application of water or other cold bodies.

Thirdly, whatever air or other elastic vapour is not condensed by the cold of the condenser, and may impede the working of the engine, is to be drawn out of the steam vessells or condensers, by means of pumps wrought by the engines themselves, or otherwise.

Fourthly, I intend in many cases to employ the expansive force of steam to press on the pistons, or whatever may be used instead of them, in the same manner as the pressure of the atmosphere is now employed in common fire engines. In cases where cold water cannot be had in plenty, the engines may be wrought by this force of steam only, by discharging the steam into the open air after it has done its office.

Fifthly, where motions round an axis are required, I make the steam vessells in form of hollow rings or circular channels, with proper inletts and outletts for the steam, mounted on horizontal axles like the wheels of a water mill; within them are placed a number of valves that suffer any body to go round the channell in one direction only. In these steam vessells are placed weights, so fitted to them as intirely to fill up a part or portion of their channels, yet rendered capable of moving freely in them by the means herein-after mentioned or specified. When the steam is admitted in these engines between these weights and the valves, it acts equally on both, so as to raise the weight to one side of the wheel, and by the reaction on the valves successively to give a circular motion to the wheel, the valves opening in the direction in which the



weights are pressed, but not in the contrary. As the steam vessel moves round it is supplied with steam from the boiler, and that which has performed its office may either be discharged by means of condensers, or into the open air.

Sixthly, I intend in some cases to apply a degree of cold not capable of reducing the steam to water, but of contracting it considerably, so that the engines shall be worked by the alternate expansion and constraction of the steam.

Lastly, instead of using water to render the piston or other parts of the engines air and steam tight, I employ oils, wax, rosinous bodies, fat of animals, quicksilver and other metalls, in their fluid state.

In witness whereof, I have hereunto set my hand and seal, this Twenty-fifth day of April, in the year of our Lord One thousand seven hundred and sixty-nine.

JAMES WATT. (L.S.)

Sealed and delivered in the presence of
COLL. WILKIE.
GEO. JARDINE.
JOHN ROEBUCK.

Be it remembered, that the said James Watt doth not intend that any thing in the fourth article shall be understood to extend to any engine where the water to be raised enters the steam vessell itself, or any vessell having an open communication with it.

JAMES WATT.

Witnesses,
COLL. WILKIE.
GEO. JARDINE.

AND BE IT REMEMBERED, that on the Twenty-fifth day of April, in the year of our Lord 1769, the aforesaid James Watt came before our said Lord the King in His Chancery, and acknowledged the Specification aforesaid, and all and every thing therein contained and specified, in form above written. And also the Specification aforesaid was stampt according to the tenor of the Statute made in the sixth year of the reign of the late King and Queen William and Mary of England, and so forth.

Inrolled the Twenty-ninth day of April, in the year of our Lord One thousand seven hundred and sixty-nine.

LONDON:
Printed by GEORGE EDWARD EYRE and WILLIAM SPOTTISWOODE,
Printers to the Queen's most Excellent Majesty. 1855.

- 1774. Watt moves to Birmingham to get back into steam engine business with Lunar Society fellow-member Matthew Boulton.
- 1775. Boulton and Watt partnership extends Watt's patent to the end of the century.

*Matthew Boulton*
(1728-1809)

- 1784. Albion Flour Mill in London as a public display of steam culture.



- 1780s-90s. Boulton & Watt go after patent infringers.

"The irony here is that by blocking innovation in engine design... the men popularly held responsible for the engine that powered the industrial revolution may have promoted atrophy in mechanical engineering." (MS05, pg. 63.)

## Was steam inevitable?

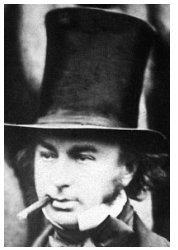
### 1. *Gaz ($CO_2$) engine:*

- 1823. Michael Faraday liquifies $CO_2$.
- 1825. Marc Isambard Brunel patents "differential machine".

*Marc Isambard Brunel* (1769-1849)

*Advantages over steam:*

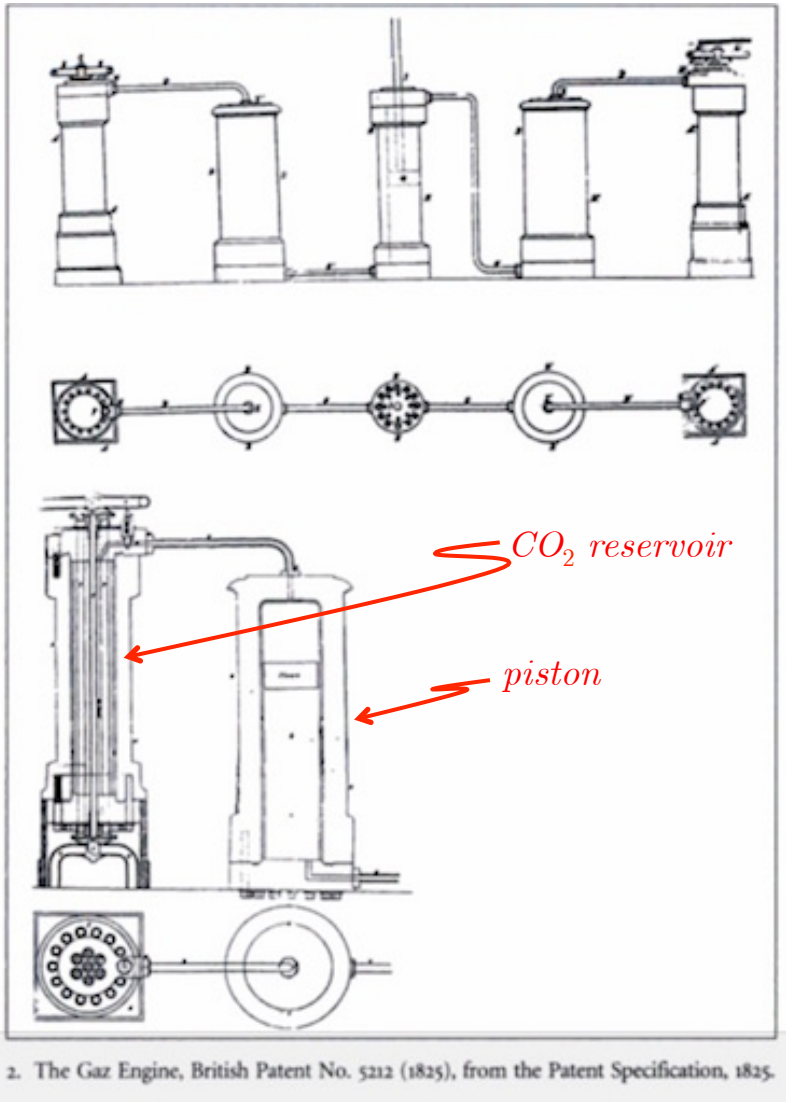
- Less heat needed to transform liquid $CO_2$ into gas.
- Greater pressure differential.



*Isambard Kingdom Brunel* (1806-1859)

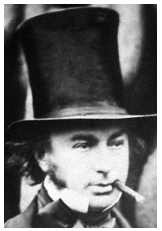
- 1825-33. Isambard Kingdom Brunel attempts to perfect gaz engine (one of many grand projects).

- *Backing of Faraday and Royal Institution.*
- *1832. Royal Admiralty commissions study.*




2. The Gaz Engine, British Patent No. 5212 (1825), from the Patent Specification, 1825.

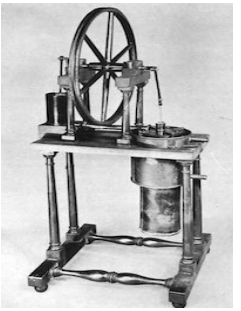
- *But*:

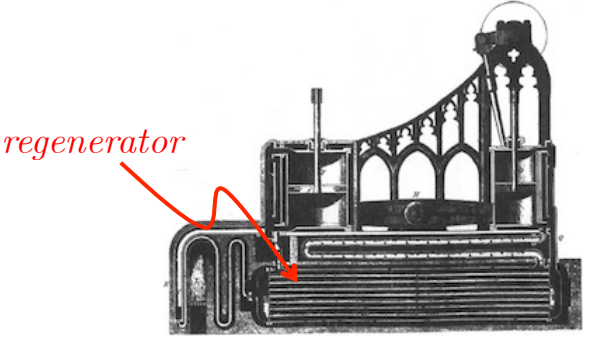


"no sufficient advantage [over steam] on the score of economy can be obtained. All the time and expense, both enormous, devoted to this thing for nearly 10 years are therefore wated...It must therefore die and with it all my fine hopes—crash—gone—well, well, it can't be helped." (1833)

## 2. *Atmospheric (air) engines:*

- 1816. Robert Stirling patents atmospheric engine with "economizer".
- 1833. John Ericsson patents "caloric engine" with "regenerator".





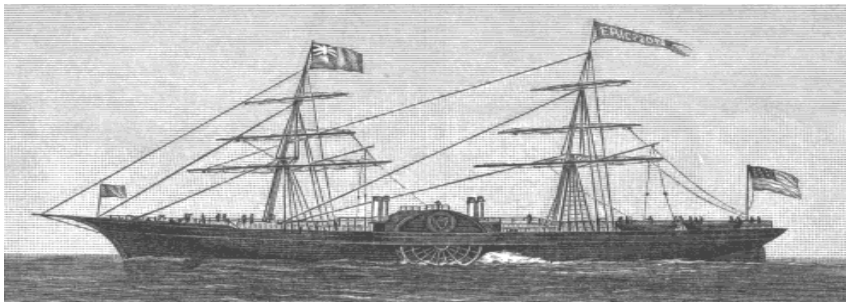

### *Ericsson champions "caloric engine"*

- More efficient.
- Easier to use: no need for "steam experts".
- Safer: operates at lower pressure.
- Working fluid (air) easier to handle.

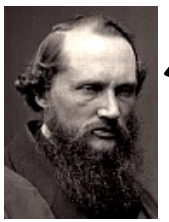
*John Ericsson* (1803-1889)

"The heat which is required to give motion to the engine at the commencement, is returned by a peculiar process of transfer, and thereby made to act over and over again, instead of being, as in the Steam Engine, thrown into a condenser, or into the atmosphere as so much waste fuel." (1833)*

- *Set backs*:
  - 1853. Caloric-powered ship *Ericsson* sinks.
  - Claims about regenerator are questioned by developments in the theory of heat engines.



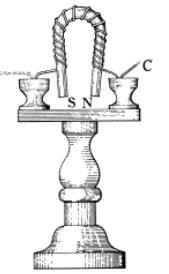
- *But*: 1840s-50s. Theoreticians (Rankine, Thomson, Joule) see air engines as successors to steam.



"If the practical difficulty in the construction of an efficient Air Engine can ever be removed to nearly the same extent as already has been done in the case of the Steam Engine, a much greater amount of mechanical effect would be obtained by the consumption of a given quantity of fuel." (1847)*

* Quoted in Marsden, B. (1998) 'Blowing Hot and Cold...', *History of Science 36*, pp. 373-420.

## 3. *Electro-magnetic engines:*




- 1820. Oersted's current-carrying wire with magnetic effect.
- 1824-25. William Sturgeon's "electro-magnet".
- 1834. Thomas Davenport's rotary motor.
- 1830s-40s. Toy models and mock-ups of electric carriages, trains, boats.
- 1840. Hermann von Jacobi addresses 10th meeting of BAAS:

"I must, on the present occasion, confess frankly and without reserve, that hitherto the construction of electro-magnetic machines has been regulated in a great measure by mere trials; that even the machines constructed according to the indisputable laws established with regard to the statical effects of electro-magnetics, have been found inefficient, as soon as we came to deal with motion.

*Hermann von Jacobi* (1801-1874)

"I consider that there will not be much difficulty in determining with sufficient precision the duty of one pound of zinc, by its transformation into the sulphate, in the same manner that in the steam-engine the duty of one bushel of coal serves as a measure to estimate the effect of different combinations. The future use and application of electro-magnetic machines appears to me quite certain..."

- <u>*But*</u>: 1841. James Joule, "On a new Class of Magnetic Forces", *Annals of Electricity.*

*James Joule* (1818-1889)

"This comparison is so very unfavorable that I confess I almost despair of the success of electromagnetic attractions as an economical source of power; for although my machine is by no means perfect, I do not see how the arrangement of its parts could be improved so far as to make the duty per lb. of zinc superior to the duty of the best steam-engines per lb. of coal."

"Steam's hardiness came from constant innovation within steam culture, often in conflict with the principles of caution, necessary to maintain business confidence, adhered to by Watt after his frenzy of invention in the early 1780s." (MS05, pg. 81.)

- 1804. Arthur Woolf patents the compound steam engine.
- 1850s-60s. Compound steam engine adopted for steamships.

"One aspect, then, of the failure of the challengers to steam was that particular steam engines were themselves superseded—by others more suited, through economy or durability or a host of other factors, to developing environments." (MS05, pg. 82.)

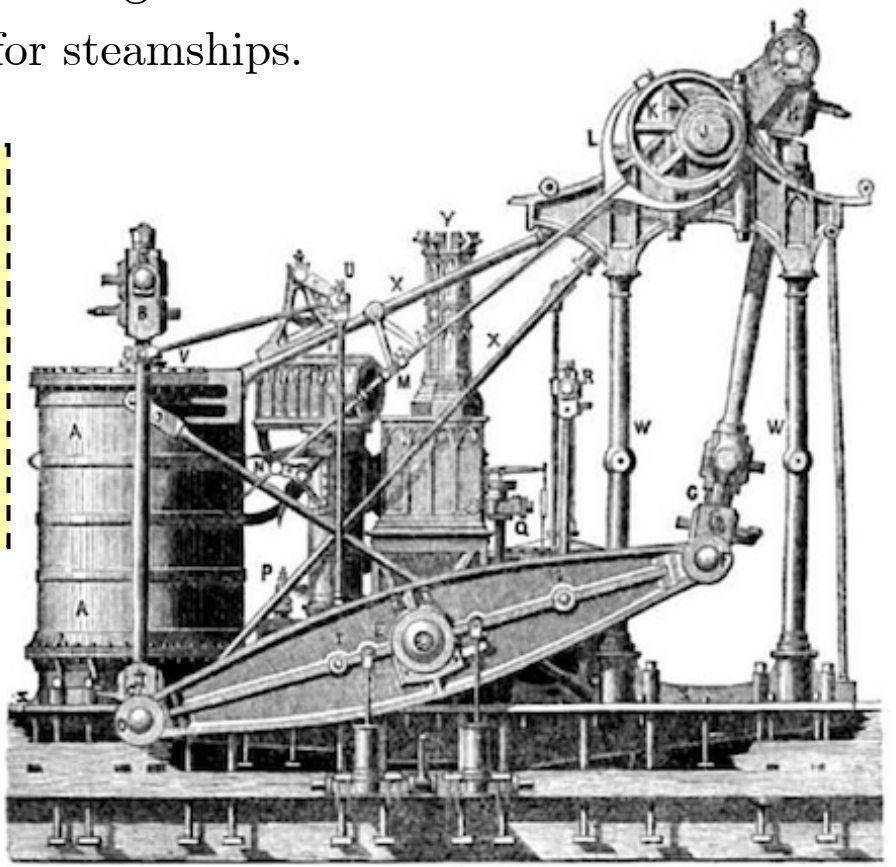
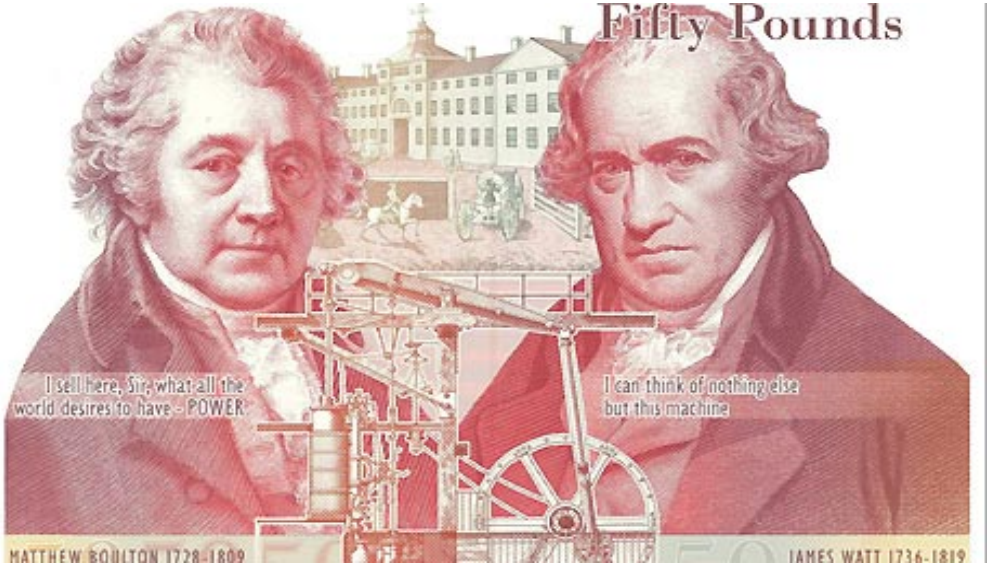


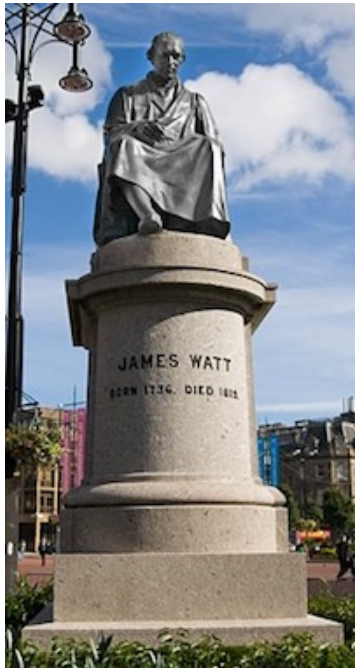

Fig. 92.—The Side-Lever Engine, 1849.

- Icons of Steam




Leeds

Manchester




Glasgow

Birmingham


Greenock


Edinburgh

Westminster Abbey

- Watt and the steam kettle (Newton and the apple).

"His aunt Mrs Muirhead, sitting with him one evening at the tea-table, said, 'James, I never saw such an idle boy! Take a book or employ yourself usefully. For the last half hour you have not spoken a word, but taken off the lid of that kettle and put it on again, holding now a cup and now a silver sppon over the steam; watching how it rises from the spout, and catching and couting the drops of water formed by condensation.'"*

* pg. 225, Arago, F. (1839) "Biographical memoir of James Watt...", *Edinburgh New Philosophical Journal 27*, 297-310.