*The faculty of Computational Mathematics and Cybernetics of Lomonosov Moscow State University*



**Richard Trevithick**

**Vladislav Myakshin, 414**

**2020**

**Richard Trevithick**

Richard Trevithick (13 April 1771 – 22 April 1833) was a British inventor and mining engineer from Cornwall, England, UK. The son of a mining captain, and born in the mining heartland of Cornwall, Trevithick was immersed in mining and engineering from an early age. He performed poorly in school, but went on to be an early pioneer of steam-powered road and rail transport. His most significant contribution was the development of the first high-pressure steam engine. He also built the first working railway steam locomotive. The world's first locomotive-hauled railway journey took place on 21 February 1804, when Trevithick's unnamed steam locomotive hauled a train along the tramway of the Penydarren Ironworks, in Merthyr Tydfil, Wales.

Turning his interests abroad, Trevithick also worked as a mining consultant in Peru and later explored parts of Costa Rica. Throughout his professional career, he went through many ups and downs, and at one point faced financial ruin, also suffering from the strong rivalry of many mining and steam engineers of the day. During the prime of his career, he was a well-respected and known figure in mining and engineering, but near the end of his life he fell out of the public eye.

**Career**

Jane's father, John Harvey, formerly a blacksmith from Carnhell Green, formed the local foundry, Harveys of Hayle. His company became famous worldwide for building huge stationary "beam" engines for pumping water, usually from mines. Up to this time such steam engines were of the condensing or atmospheric type, originally invented by Thomas Newcomen in 1712, which also became known as low-pressure engines. James Watt, on behalf of his partnership with Matthew Boulton, held a number of patents for improving the efficiency of Newcomen's engine—including the "separate condenser patent", which proved the most contentious.

Trevithick became engineer at the Ding Dong Mine in 1797, and there (in conjunction with Edward Bull) he pioneered the use of high-pressure steam. He worked on building and modifying steam engines to avoid the royalties due to Watt on the separate condenser patent. Boulton & Watt served an injunction on him at Ding Dong, and posted it "on the minestuffs" and "most likely on the door" of the Count (Account) House which, although now a ruin, is the only surviving building from Trevithick's time there.

He also experimented with the plunger-pole pump, a type of pump—with a beam engine—used widely in Cornwall's tin mines, in which he reversed the plunger to change it into a water-power engine.

**High-pressure engine**

Trevithick's No. 14 engine, built by Hazledine and Company, Bridgnorth, about 1804, and illustrated after being rescued circa 1885; from Scientific American Supplement, Vol. XIX, No. 470, 3 January 1885. This engine is on view at the Science Museum (London).

As his experience grew, he realised that improvements in boiler technology now permitted the safe production of high-pressure steam, which could move a piston in a steam engine on its own account, instead of using pressure near to atmospheric, in a condensing engine.

He was not the first to think of so-called "strong steam" or steam of about 30 psi (210 kPa). William Murdoch had developed and demonstrated a model steam carriage, initially in 1784, and demonstrated it to Trevithick at his request in 1794. In fact, Trevithick lived next door to Murdoch in Redruth in 1797 and 1798. Oliver Evans in the U.S. had also concerned himself with the concept, but there is no indication that his ideas had ever come to Trevithick's attention.

Independently of this, Arthur Woolf was experimenting with higher pressures whilst working as the Chief Engineer of the Griffin Brewery (proprietors Meux and Reid). This was an Engine designed by Hornblower and Maberly, and the proprietors were keen to have the best steam engine in London. Around 1796, Woolf believed he could save substantial amounts of coal consumption.

According to his son Francis, Trevithick was the first to make high-pressure steam work in England in 1799, although other sources say he had invented his first high-pressure engine by 1797. Not only would a high-pressure steam engine eliminate the condenser, but it would allow the use of a smaller cylinder, saving space and weight. He reasoned that his engine could now be more compact, lighter, and small enough to carry its own weight even with a carriage attached. (Note this did not use the expansion of the steam, so-called "expansive working" came later)

**Early experiments**

Trevithick began building his first models of high-pressure (meaning a few atmospheres) steam engines – first a stationary one and subsequently one attached to a road carriage. A double-acting cylinder was used, with steam distribution by means of a four-way valve. Exhaust steam was vented via a vertical pipe or chimney straight into the atmosphere, thus avoiding a condenser and any possible infringements of Watt's patent. The linear motion was directly converted into circular motion via a crank instead of using a more cumbersome beam.

**Puffing Devil**

Trevithick built a full-size steam road locomotive in 1801, on a site near present-day Fore Street in Camborne. (A steam wagon built in 1770 by Nicolas-Joseph Cugnot may have an earlier claim.) Trevithick named his carriage Puffing Devil and on Christmas Eve that year, he demonstrated it by successfully carrying six passengers up Fore Street and then continuing on up Camborne Hill, from Camborne Cross, to the nearby village of Beacon. His cousin and associate, Andrew Vivian, steered the machine. This is widely recognised as the first demonstration of transportation powered by steam. It inspired the popular Cornish folk song "Camborne Hill".

During further tests, Trevithick's locomotive broke down three days later after passing over a gully in the road. The vehicle was left under some shelter with the fire still burning whilst the operators retired to a nearby public house for a meal of roast goose and drinks. Meanwhile, the water boiled off, the engine overheated and the machine burned, destroying it. Trevithick did not consider this a serious setback, but rather operator error.

In 1802, Trevithick took out a patent for his high-pressure steam engine. To prove his ideas, he built a stationary engine at the Coalbrookdale Company's works in Shropshire in 1802, forcing water to a measured height to measure the work done. The engine ran at forty piston strokes a minute, with an unprecedented boiler pressure of 145 psi (1,000 kPa).

**Coalbrookdale Locomotive**

In 1802, the Coalbrookdale company built a rail locomotive for him, but little is known about it, including whether or not it actually ran. To date, the only known information about it comes from a drawing preserved at the Science Museum, London, together with a letter written by Trevithick to his friend Davies Giddy. The design incorporated a single horizontal cylinder enclosed in a return-flue boiler. A flywheel drove the wheels on one side through spur gears, and the axles were mounted directly on the boiler, with no frame. On the drawing, the piston-rod, guide-bars and cross-head are located directly above the firebox door, thus making the engine extremely dangerous to fire while moving. Furthermore, the drawing indicates that the locomotive ran on a plateway with a track gauge of 3 ft (914 mm).

**London Steam Carriage**

The Puffing Devil was unable to maintain sufficient steam pressure for long periods, and would have been of little practical use. He built another steam-powered road vehicle in 1803, called the London Steam Carriage, which attracted much attention from the public and press when he drove it that year in London from Holborn to Paddington and back. It was uncomfortable for passengers and proved more expensive to run than a horse-drawn carriage, and was abandoned.

**Tragedy at Greenwich**

Also in 1803, one of Trevithick's stationary pumping engines in use at Greenwich exploded, killing four men. Although Trevithick considered the explosion to be caused by a case of careless operation rather than design error, the incident was exploited relentlessly by James Watt and Matthew Boulton (competitors and promoters of the low-pressure engine) who highlighted the perceived risks of using high-pressure steam.

Trevithick's response was to incorporate two safety valves into future designs, only one of which could be adjusted by the operator. The adjustable valve comprised a disc covering a small hole at the top of the boiler above the water level in the steam chest. The force exerted by the steam pressure was equalised by an opposite force created by a weight attached to a pivoted lever. The position of the weight on the lever was adjustable thus allowing the operator to set the maximum steam pressure. Trevithick also added a fusible plug of lead, positioned in the boiler just below the minimum safe water level. Under normal operation the water temperature could not exceed that of boiling water and kept the lead below its melting point. If the water ran low, it exposed the lead plug, and the cooling effect of the water was lost. The temperature would then rise sufficiently to melt the lead, releasing steam into the fire, reducing the boiler pressure and providing an audible alarm in sufficient time for the operator to damp the fire, and let the boiler cool before damage could occur. He also introduced the hydraulic testing of boilers, and the use of a mercury manometer to indicate the pressure.

**"Pen-y-Darren" locomotive**

In 1802, Trevithick built one of his high-pressure steam engines to drive a hammer at the Pen-y-Darren Ironworks in Merthyr Tydfil, Mid Glamorgan . With the assistance of Rees Jones, an employee of the iron works and under the supervision of Samuel Homfray, the proprietor, he mounted the engine on wheels and turned it into a locomotive. In 1803, Trevithick sold the patents for his locomotives to Samuel Homfray.

Homfray was so impressed with Trevithick's locomotive that he made a bet with another ironmaster, Richard Crawshay, for 500 guineas that Trevithick's steam locomotive could haul ten tons of iron along the Merthyr Tydfil Tramroad from Penydarren (51°45′03″N 3°22′33″W) to Abercynon (51°38′44″N 3°19′27″W), a distance of 9.75 miles (15.69 km). Amid great interest from the public, on 21 February 1804 it successfully carried 10 tons of iron, 5 wagons and 70 men the full distance in 4 hours and 5 minutes, an average speed of approximately 2.4 mph (3.9 km/h). As well as Homfray, Crawshay and the passengers, other witnesses included Mr. Giddy, a respected patron of Trevithick and an 'engineer from the Government'. The engineer from the government was probably a safety inspector and particularly interested in the boiler's ability to withstand high steam pressures.

The configuration of the Pen-y-Darren engine differed from the Coalbrookdale engine. The cylinder was moved to the other end of the boiler so that the fire door was out of the way of the moving parts. This obviously also involved putting the crankshaft at the chimney end. The locomotive comprised a boiler with a single return flue mounted on a four-wheel frame. At one end, a single cylinder with very long stroke was mounted partly in the boiler, and a piston rod crosshead ran out along a sidebar, an arrangement that looked like a giant trombone. As there was only one cylinder, this was coupled to a large flywheel mounted on one side. The rotational inertia of the flywheel would even out the movement that was transmitted to a central cog-wheel that was, in turn connected to the driving wheels. It used a high-pressure cylinder without a condenser; the exhaust steam was sent up the chimney assisting the draught through the fire, increasing efficiency even more.

The bet was won. Despite many people's doubts, it had been shown that, provided that the gradient was sufficiently gentle, it was possible to successfully haul heavy carriages along a smooth iron road using the adhesive weight alone of a suitably heavy and powerful steam locomotive. Trevithick's was probably the first to do so; however some of the short cast iron plates of the tramroad broke under the locomotive as they were intended only to support the lighter axle load of horse-drawn wagons and so the tramroad returned to horse power after the initial test run.

Homfray was pleased he won his bet. The engine was placed on blocks and reverted to its original stationary job of driving hammers.

In modern-day Merthyr Tydfil, behind the monument to Trevithick's locomotive lies a stone wall, the sole remainder of the former boundary wall of Homfray's Penydarren House.

A full-scale working reconstruction of the Pen-y-darren locomotive was commissioned in 1981 and delivered to the Welsh Industrial and Maritime Museum in Cardiff; when that closed, it was moved to the National Waterfront Museum in Swansea. Several times a year it is run on a 40 m (130 ft) length of rail outside the museum.

**"Newcastle" locomotive**

Christopher Blackett, proprietor of the Wylam colliery near Newcastle, heard of the success in Wales and wrote to Trevithick asking for locomotive designs. These were sent to John Whitfield at Gateshead, Trevithick's agent, who in 1804 built what was probably the first locomotive to have flanged wheels. Blackett was using wooden rails for his tramway and, once again, Trevithick's machine was to prove too heavy for its track.

**Catch Me Who Can**

In 1808, Trevithick publicized his steam railway locomotive expertise by building a new locomotive called Catch Me Who Can, built for him by John Hazledine and John Urpeth Rastrick at Bridgnorth in Shropshire, and named by Davies Giddy's daughter. The configuration differed from the previous locomotives in that the cylinder was mounted vertically and drove a pair of wheels directly without a flywheel or gearing. This was probably Trevithick's fourth locomotive, after those used at Coalbrookdale, Pen-y-darren ironworks, and the Wylam colliery. He ran it on a circular track just south of the present-day Euston Square tube station in London. The site in Bloomsbury has recently been identified archaeologically as that occupied by the Chadwick Building, part of University College London.

Admission to the "steam circus" was one shilling including a ride and it was intended to show that rail travel was faster than by horse. This venture also suffered from weak tracks and public interest was limited.

Trevithick was disappointed by the response and designed no more railway locomotives. It was not until 1812 that twin-cylinder steam locomotives, built by Matthew Murray in Holbeck, successfully started replacing horses for hauling coal wagons on the edge railed, rack and pinion Middleton Railway from Middleton colliery to Leeds, West Yorkshire.

**Thames tunnel**

Robert Vazie, another Cornish engineer, was selected by the Thames Archway Company in 1805 to drive a tunnel under the River Thames at Rotherhithe. Vazie encountered serious problems with water influx, and had got no further than sinking the end shafts when the directors called in Trevithick for consultation. The directors agreed to pay Trevithick £1000 (the equivalent of £80,173 in 2019) if he could successfully complete the tunnel, a length of 1,220 feet (370 m). In August 1807, he began driving a small pilot tunnel or drift way 5 feet (1.5 m) high tapering from 2 feet 6 inches (0.76 m) at the top to 3 feet (0.91 m) at the bottom. By 23 December, after it had progressed 950 feet (290 m), progress was delayed after a sudden inrush of water; and only one month later on 26 January 1808, at 1,040 feet (320 m), a more serious inrush occurred. The tunnel was flooded; Trevithick, being the last to leave, was nearly drowned. Clay was dumped on the river bed to seal the hole, and the tunnel was drained, but mining was now more difficult. Progress stalled, and a few of the directors attempted to discredit Trevithick, but the quality of his work was eventually upheld by two colliery engineers from the North of England. Despite suggesting various building techniques to complete the project, including a submerged cast iron tube, Trevithick's links with the company ceased and the project was never actually completed.

**Completion**

The first successful tunnel under the Thames was started by Sir Marc Isambard Brunel in 1823, 0.75 miles (1,200 m) upstream, assisted by his son Isambard Kingdom Brunel (who also nearly died in a tunnel collapse). Marc Brunel finally completed it in 1843, the delays being due to problems with funding.

Trevithick's suggestion of a submerged tube approach was successfully implemented for the first time across the Detroit River between Michigan in the United States and Ontario in Canada with the construction of the Michigan Central Railway Tunnel, under the engineering supervision of The New York Central Railway's engineering vice president, William J Wilgus. Construction began in 1903 and was completed in 1910. The Detroit–Windsor Tunnel which was completed in 1930 for automotive traffic, and the tunnel under the Hong Kong Harbour were also submerged-tube designs.

**Return to London**

Trevithick went on to research other projects to exploit his high-pressure steam engines: boring brass for cannon manufacture, stone crushing, rolling mills, forge hammers, blast furnace blowers as well as the traditional mining applications. He also built a barge powered by paddle wheels and several dredgers.

Trevithick saw opportunities in London and persuaded his wife and four children reluctantly to join him in 1808 for two and a half years lodging first in Rotherhithe and then in Limehouse.

**Nautical projects**

In 1808, Trevithick entered a partnership with Robert Dickinson, a West India merchant. Dickinson supported several of Trevithick's patents. The first of these was the Nautical Labourer; a steam tug with a floating crane propelled by paddle wheels. However, it did not meet the fire regulations for the docks, and the Society of Coal Whippers, worried about losing their livelihood, even threatened the life of Trevithick.

Another patent was for the installation of iron tanks in ships for storage of cargo and water instead of in wooden casks. A small works was set up at Limehouse to manufacture them, employing three men. The tanks were also used to raise sunken wrecks by placing them under the wreck and creating buoyancy by pumping them full of air. In 1810 a wreck near Margate was raised in this way but there was a dispute over payment and Trevithick was driven to cut the lashings loose and let it sink again.

In 1809, Trevithick worked on various ideas on improvements for ships: iron floating docks, iron ships, telescopic iron masts, improved ship structures, iron buoys and using heat from the ships boilers for cooking.

**Illness, financial difficulties and return to Cornwall**

In May 1810, Trevithick caught typhoid and nearly died. By September, he had recovered sufficiently to travel back to Cornwall by ship, and in February 1811 he and Dickinson were declared bankrupt. They were not discharged until 1814, Trevithick having paid off most of the partnership debts from his own funds.

**Cornish boiler and engine**

In about 1812, Trevithick designed the ‘Cornish boiler’. These were horizontal, cylindrical boilers with a single internal fire tube or flue passing horizontally through the middle. Hot exhaust gases from the fire passed through the flue thus increasing the surface area heating the water and improving efficiency. These types were installed in the Boulton and Watt pumping engines at Dolcoath and more than doubled their efficiency.

Again in 1812, he installed a new 'high-pressure' experimental condensing steam engine at Wheal Prosper. This became known as the Cornish engine, and was the most efficient in the world at that time. Other Cornish engineers contributed to its development but Trevithick's work was predominant. In the same year he installed another high-pressure engine, though non-condensing, in a threshing machine on a farm at Probus, Cornwall. It was very successful and proved to be cheaper to run than the horses it replaced. It was in use for 70 years, and was then retired to an exhibit at the Science Museum.

**Recoil engine**

In one of Trevithick's more unusual projects, he attempted to build a 'recoil engine' similar to the aeolipile described by Hero of Alexandria in about AD 50. Trevithick's engine comprised a boiler feeding a hollow axle to route the steam to a Catherine wheel with two fine-bore steam jets on its circumference. The first wheel was 15 feet (4.6 m) in diameter and a later attempt was 24 feet (7.3 m) in diameter. To get any usable torque, steam had to issue from the nozzles at a very high velocity and in such large volume that it proved not to operate with adequate efficiency. Today this would be recognized as a reaction turbine.

**References:**

* "Catalog Record: Life of Richard Trevithick, with an account... | Hathi Trust Digital Library". Catalog.hathitrust.org. Retrieved 30 April 2017.
* Crump, Thomas (2007). The Age of Steam: The Power that Drove the Industrial Revolution. Carroll & Graf.
* "Richard Trevithick's steam locomotive | Rhagor". Museumwales.ac.uk. Hodge, James (2002).
* Richard Trevithick. Lifelines. Aylesbury: Shire Publications.