RANDOM HOUSE eBOOKS

Fred Dibnah's Age of Steam

Fred Dibnah and David Hall

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About the Book

The late Fred Dibnah was passionate about steam-powered machines and spent much of his life studying their construction and history. In this, his final book, he tells us about some of his favourite engines and demonstrates how steam power played a fundamental role in the Industrial Revolution. Introducing us to the great pioneers of steam – including James Watt, Richard Trevithink, George and Robert Stephenson and his own particular hero, Isambard Kingdom Brunel – Fred explores the lives and works of these legendary figures and reveals the genius of their achievements.

Complete with a comprehensive list of steam-related sites to visit all over the UK, *Fred Dibnah's Age of Steam* is a compelling history of this romantic form of power and an essential guide for anyone fascinated by the wonderful world of steam.

About the Authors

FRED DIBNAH was a man born out of his time. Growing up in the 1940s in Bolton, Lancashire, he lived near the railway lines and there began a lifelong fascination with steam locomotives. As Fred grew up, and despite the disapproval of his parents, he pursued his first goal of becoming a steeplejack, and it was his outstanding skill in his chosen profession that led to his first appearance on television in *The Fred Dibnah Story*. He went on to make several succesful television series, including *Industrial Age*, and *Magnificent Monuments*.

A great English eccentric and national treasure, Fred was awarded MBE in 2003. He died in 2004 at the age of 66 only weeks after filming *Made in Britain*.

DAVID HALL, a former journalist and teaacher, has been a television producer for over 25 years making programmes for the BBC, ITV, Channel 4 and other broadcasters around the world. He worked with Fred from 1998 on *Industrial Age*, *Magnificent Monuments*, *Victorian Heroes*, *Buildings of Britain* and *Age of Steam*.

Fred Dibnah’s Age of Steam

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TED SMART

INTRODUCTION

I DEVELOPED MY great interest in steam a long, long time ago as a small boy living near the railway lines in Bolton when, of course, I used to climb over the fence and do things that little boys shouldn't do. I remember one thing that used to fascinate me; we knew the half-past four 'namer' was coming and we used to put a penny on the line and watch it dance up and down in between all the wheels. When the train had long gone past you went out and collected your penny, which, by this time, was about twice as big as it was before you put it on the railway line. We lived in close proximity to the engine sheds where, on my way home from school, there would be literally dozens of locomotives lined up all steaming and hissing away with water dripping off them and I'd always sneak in and have a look round. Time went by and I ended up actually riding on the things – it was highly illegal, but I had a lot of relations who worked on the railway, which was quite wonderful.

It's strange really, how a person becomes interested in steam. As a little lad I was surrounded by tall chimneys that fascinated me. They all had huge clouds coming out of the top of them – a bit like a Lowry painting – and when you wandered up the back streets you could hear the rumbling inside these great spinning mills. Then later on in my life, when I became a joiner, I used to get really brave and sneak into mill yards and climb up the engine-house steps to look at the engines. I remember as a young lad of about sixteen or seventeen, rather full of fear, looking into the engine-house through the window at the thing going round and seeing the engine minder snoozing in an easy chair. But, you know, he wouldn't really be asleep: he'd be listening for any strange change in the pattern of noise that was coming from the engine, which of course would indicate if something was going wrong.

These big mill engines with massive flywheels were very impressive – imagine a wheel like that, 40 feet (12 m) in diameter and 16 feet (5m) wide with 60 2-inch-diameter (5-cm-diameter) ropes going to wheels up five storeys of spinning mill, all going round almost silently: incredible pieces of machinery! It's sad now when you go to places like Oldham and Rochdale and see all these gaunt, empty engine rooms, very similar to the tin mines in Cornwall. They are just shells, but once they were graced by this beautiful machinery with fancy reeded pillars and handrails and all likes of beautiful brass-work and everything. Lovely! But now they are all gone.

In Bolton we were quite well blessed with steam-engine manufacturers. There were actually three major firms in the town. There was John and Edward Woods, who have a steam engine in Trencherfield Mill at Wigan Pier; then John Musgraves who manufactured all manner of steam engines from pit winding engines to iron-works blowing engines to big textile-mill engines. They, of course, have long faded away, but there are examples of the product still lying about, which are really quite beautiful. In fact, over my cooker in the back kitchen I've got the plate off one of the biggest steam engines that operated in Bolton. The third of these engine manufacturers was Hick, Hargreaves and Company, which was a really old firm started by Benjamin Hick in 1834 or thereabouts. They had a huge works, which was completely demolished to make way for a supermarket. Before the last vestiges of Hick, Hargreaves had hit the deck, the roof was being put on the supermarket.

It's sad now when you look around Bolton. Even in my short lifetime – and none of us is around for very long – many changes have come about. The interesting machinery that used to be around has all but disappeared completely. When I was a lad, there were 200 factory chimneys sticking up in between rows of houses. It was an incredible skyline, and of course most other industrial towns in Lancashire and the northern half of England were pretty much the same. What you've got to think is that at the bottom of every one of those chimneys was a steam engine of one sort or another. A steam engine is virtually indestructible, some of them were literally made in James Watt's period back in the eighteenth century. There's a great mill in Bolton called the Gilner Mill that was still driven right up to 1947 by a beam engine with Watt's parallel motion.

A steam engine really is a fascinating thing. When it is running it comes alive in a strange way. It has an unbelievable smell about it for a start. Even people who come to my garden now notice it when they go near my boiler. We had an old guy come in the other day, eighty-odd years old, and he was sniffing away and he said, 'That brings back memories of my youth.' Oil and steam have a smell all of their own. It has been said that if you could put it in a bottle and cork it up you could sell it – it smells that good.

Then there's the noise that the engines made. Some of them were very quiet, but it depended on what sort they were and where they were and what sort of job they were doing. If you've got a colliery winding engine, winding in a shaft that was 800 yards (732 m) deep, with a cage hanging on the end of a rope with maybe 10 tons of coal in it and the engine's got to start from a standstill, it would make a heck of a racket. In the middle of a place called Leigh near Bolton, there was a pit known as Parsonage. There was a winding engine there that you could hear in the next town down the road when it set off. And what a sight it was. The roar of it into the clouds and a great cloud of steam over the top of the engine house! I think modern man has missed something in not seeing that sort of vision.

The boiler in my back garden makes the steam for turning a little steam engine round, and that engine drives all the machinery that I've got there. It all comes in handy, particularly for rebuilding the traction engine I'm working on. I've been restoring this engine for nearly twenty years and, despite some major setbacks, it's now nearly ready for the road. Just a bit more time and I'll be able to complete the job. It's going to be an unbelievable sense of achievement getting it finished, because by then I will have built the whole thing myself from scratch, with a complete new boiler and it will all have been done with the power of steam.

People say I'm eccentric running all the old machinery I have in my back garden, but it's more modern than some of the things I've come across that people have working for them in their back gardens. I know one man in Staffordshire who's built a windmill in his – that's really going back to an old-fashioned way of generating power. You've got to be pretty confident in your own abilities to take on something like that, but it's nothing to the confidence of the great pioneering engineers of the eighteenth and nineteenth centuries who built the first railways and the first iron steamships.

It took confidence on a massive scale, in the days of wooden-hulled ships, to build an ocean liner of metal, which was powered by steam. But Isambard Kingdom Brunel had a faith in himself and his abilities that was amazing even by the standards of his day. The Victorian age was one in which Britain led the world in the skills of making and inventing things. It was a time when the skills of mechanics and engineers were highly prized: the Age of Steam, when British industry led the world. Engineers were the heroes of the day whose exploits captured the imagination of the Victorian public. They were treated like pop stars or footballers are now. For me the greatest of the lot, my hero, was Brunel. He dominated every field of engineering –

railway-building, civil engineering, ship-building, bridge-building – and nothing seemed to be beyond his capacity. For a man like Brunel, no challenge was too great: throwing dramatic bridges across great rivers and gorges; building an iron steamship that would have to carry tons of coal across the Atlantic without sinking; digging a tunnel under the River Thames.

All this was made possible in the second half of the eighteenth century when there was a series of technological breakthroughs in the field of iron-working and in experiments in the use of steam power. These resulted in the invention of machinery that revolutionized the various processes in the manufacture of textiles. Yet, in spite of these technological breakthroughs, before Queen Victoria came to the throne Britain was still an agricultural land. It was still by and large the old world of stagecoaches, pack horses, highwaymen, sailing ships, water power and human effort. But the application of the new technology to transport, with the development of the world's first successful railways just before her reign began, meant that between her coronation and her death Victoria saw Britain change beyond recognition.

As well as seeing the country linked by railways, she witnessed sail give way to steam at sea and industry spread its smoky cities all over Britain. What made it all happen was the vast quantities of coal and iron ore that became available during the course of Victoria's reign, enabling the new technology to be harnessed and turning Britain from a land of farmers to an industrial giant dominating the world and ruling over a vast empire. The rise of manufacturing, mining, trade and transport brought a big increase in national prosperity and transformed the appearance of the country. The pithead winding gear of coal mines began to appear all over the land to provide the fuel for this great industrial expansion.

It was the age of the engineer; an age when men of great vision, energy and self-belief could flourish. These architects of change became the most important figures of the Victorian age. And it was the building of the railways that gave them their greatest opportunities. With the opening of the line linking Liverpool and Manchester in 1830, the railway era had begun in earnest. By the time Victoria came to the throne in 1837, armies of navvies were being employed building the railways. Railways became the great symbol of Victorian industrial and technical ingenuity, which formed the basis of the prosperity of the country at this time. It was an exciting period when anything seemed to be possible. It was the Age of Steam.

Of course, the development of the steam engine carried on right up to the 1920s when it became obvious that the steam turbine was a much better piece of equipment and much more economical. In fact, the steam turbine is still our main source of electricity. Its invention revolutionized electricity generation and, although he’s nothing like as well known, the man who invented it, Charles Parsons, and his steam turbine were to the twentieth century what James Watt and the steam engine were to the nineteenth.

Steam locomotives continued to be built and operated on the railways until the 1960s and many of the great steam-driven mill engines and colliery winding engines were used until the same time to provide direct steam power. But as transport and industry turned more and more to electrical power it was still steam that was at the heart of the power-generating process. And so it continues right up to today. Even the modern nuclear power station relies on steam. In a nuclear power station the turbine blades that are used to generate the electricity are driven by steam in very much the same way as those in a coal-fired power station. The main difference is that a nuclear plant uses uranium contained in metal fuel rods instead of coal as a fuel to make the steam. The fuel rods in a nuclear power station fill exactly the same function as the coal in my traction engine – basically they both heat the water, which raises the steam, which provides the power to drive the engines.

So the Age of Steam isn’t dead yet. In fact, engineers and scientists are looking at steam power again because, with growing concern over the build-up of toxic and smog-producing gases created by the internal combustion engine, people are looking for more environmentally friendly technologies for transport. And one of the answers could be steam. A new generation of British engineers and scientists has become interested in steam and is now building a steam-powered car to mount a challenge on the world land speed record for a steam-powered vehicle. As well as breaking the record, the aim is also to create interest in the use of alternative fuels.

At the height of the Industrial Revolution and for much of the twentieth century the fuel used for the steam engine was coal, and it was the coal that caused all the pollution, not the steam engine itself. A steam engine isn’t reliant on coal. In fact it’s not fuel-specific, which means that any fuel can be used for it, including the cleanest that is available: direct sunlight. The vehicle being developed for the world land-speed record incorporates leading-edge technologies to create a fast, efficient environmentally friendly method of transport. The project couples the wealth of steam technology gained from the eighteenth century onwards with some of the most advanced technologies known to man today. And it’s not all as far-fetched as it might seem. As long ago as 1906, a steam-powered car was driven at the amazing speed of 127 miles per hour (204 kmph). So, with today’s technologies the target of 200 miles per hour (321 kmph) for the new record is attainable. With developments like this going on, perhaps the twenty-first century will be the new Age of Steam.

CHAPTER ONE

THE EARLY PIONEERS

STEAM POWER WAS the driving force behind the Industrial Revolution. It developed out of an ever-increasing need to pump water from mines to enable miners to dig deeper. At first this was performed by human beings and animals – reasonably efficient for a time but, by the end of the seventeenth century, as populations grew and towns expanded, there was an increasing need to get more and more raw materials like coal, tin and iron ore. There had to be another source of power for the pumping operations. Steam was the answer.

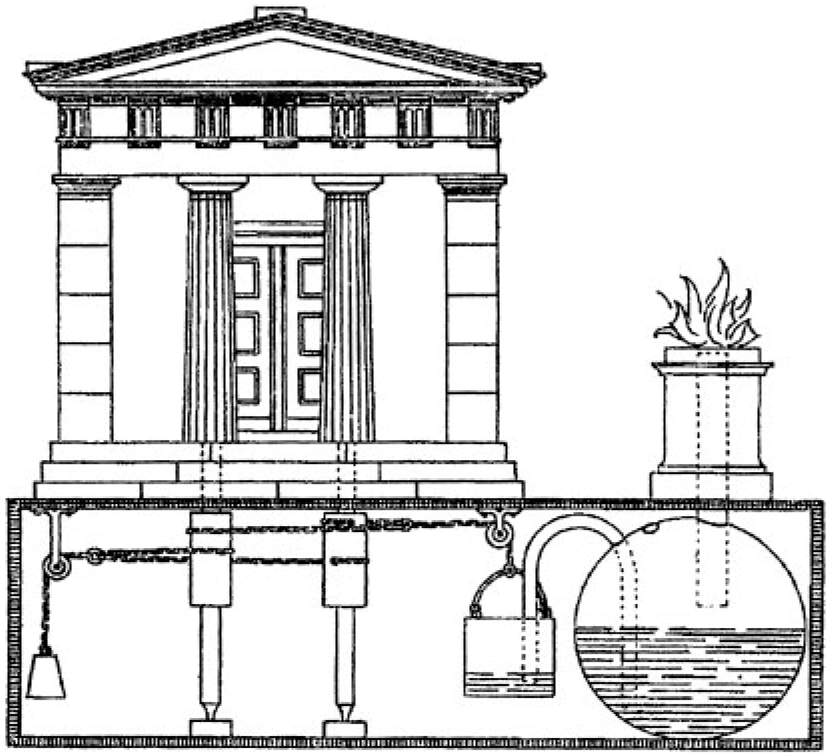
The steam engine is really a fairly simple machine. The principles of steam power are based around two major properties. First, the expansion of steam in an enclosed cylinder pushing a piston which is connected to a crankshaft by a connecting rod. And second, the sudden condensation of steam, which creates a vacuum in the cylinder, making it easier for the steam to push the piston back along the cylinder to its starting place.

Thomas Newcomen invented the first successful steam engine in 1705, but later in the eighteenth century it was greatly improved by James Watt. Before this time, though, it had been known for many centuries that steam was capable of moving a mass. From the ancient world up to the beginning of the Industrial Revolution men of science had tried to find ways of harnessing it in some way.

The first steam engine for which we have any record was devised by a Greek mathematician, Hero of Alexandria. No one is sure of the exact date when he lived, but historians have deduced from his writings that it was during the first century AD. Hero wrote a number of books about ingenious inventions, gadgets and magical tricks. One of these included his description of the very first idea for a steam engine, including multiple pulleys, cogwheels and levers.

His interests were in mechanics and engineering and he came up with a wonderful piece of tackle like a sphere with two exhaust pipes, one on top and one underneath. This sphere was supported by two brackets standing on the lid of a basin of boiling water. When the steam was produced, it squirted out of the two exhaust pipes and caused the thing to revolve. The movement of the ball was used to make puppets dance: you could call it the very first mechanical toy that actually revolved. It must have been a weird thing – a bit like a sputnik; a kind of very early jet engine. It was only in the light of what followed eighteen centuries later that Hero's *aeolipyle*, as it was called, was recognized as a simple form of steam turbine.

Hero also described and sketched a method of opening temple doors by means of steam power, which is quite a wonderful thing. This ingenious device, which he wrote about in his book *Spiritalia*, contained many of the elements of the modern steam engine. And this was nearly 2,000 years ago! Basically, the way it worked was that beneath the temple doors was a spherical vessel containing water. A pipe connected the upper part of the sphere with the hollow shell of the altar above, which was airtight. To open the doors you lit a fire on the altar, which heated the air inside a box. The heated air would expand and this, in turn, would force water up a pipe and into a bucket. When the bucket was full of water, it descended, turning a number of barrels as it did, which in turn would raise a counterbalance on the end of a rope and this would open the doors. When the fire was extinguished, the air condensed inside the chamber and forced the water by vacuum up a pipe and back into the sphere. This caused the counterbalance weight to shut the doors again. It was a very clever piece of tackle. Whether Hero ever made one nobody knows, but the drawings he produced for it still exist.

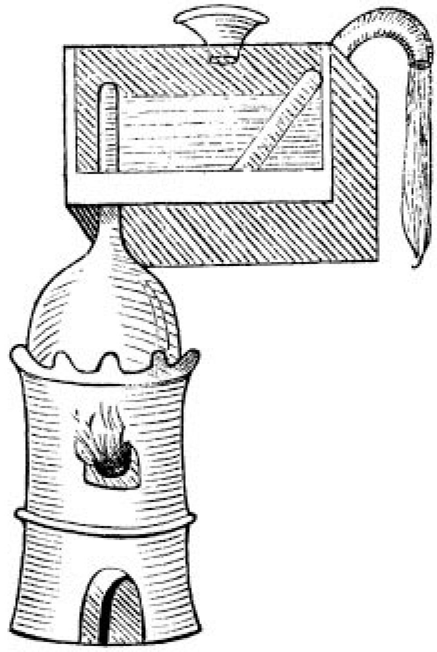


Hero's design for opening the temple doors.

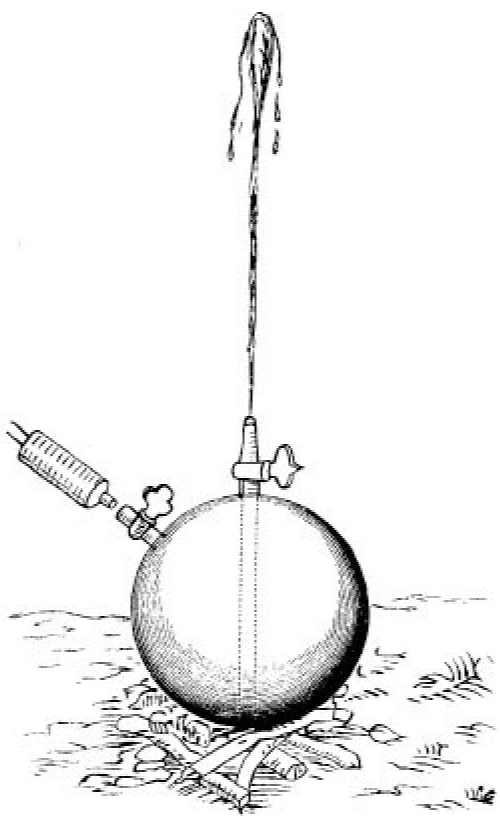
In the ancient world experiments like this were carried out more as a sort of novelty to achieve 'surprising results'. There was no need or wish to use the power of steam for any real practical purpose or material benefit. It was for magic and religion, not industry and the economy, that experiments were carried out. Ingenuity was much more prized than any material gain or practicality. So, in spite of these amazing spectacles, it was another 1,500 years before anybody tried to make any serious investigations into the application of steam power.

The next record we have of the practical use of steam is from 1543 when a Spanish naval officer, Blasco de Garay, turned his attention to propelling ships by steam. He reputedly sailed a boat called the *Trinity* across the harbour of Barcelona by steam power. However, like a lot of old inventors, he was very guarded about his work and he did things with a great deal of secrecy, so nobody really knows whether what is written down actually happened or not. He refused to let anyone know how his ship worked, but apparently it contained a large copper boiler and paddle-wheels, which were suspended over the sides of the vessel. When the *Trinity* sailed in a trial, some people approved but others said it was too slow. Of course, boiler technology then was quite poor and it could have been very dangerous. Yet however primitive it was and however many drawbacks it had, it was the first recorded attempt to put steam to a practical use in propelling a vessel.

Another important development in the sixteenth century was recorded by an Italian called Giambattista della Porta. Born in 1535, he had been well educated at home by private tutors and is described as a mathematician, chemist, physicist and engineer; a gentleman of fortune and an enthusiastic student of science, a ‘natural philosopher’. Della Porta was able to devote most of his time to study because he’d never had any real need to work on account of his family’s wealth. He lived in Naples and his home became a meeting place for all sorts of students, artists and men who were distinguished in every branch of science. In his nineteenth book of ‘natural magick’ he described a machine that made water rise. It was a very similar idea to Hero’s temple-door-opening machine and he may have copied it from him, but instead of using hot air, della Porta employed steam pressure to force liquid out of a closed container. He called his new machine an improved ‘Hero’s fountain’ and he named it his ‘steam fountain’. He was the first person to describe the action of condensation creating a vacuum, and he made sketches for a device in which the vacuum was filled by water, which was forced in by the external atmospheric pressure. Apparently this was never put to any useful mechanical purpose.



This is della Porta’s piece of apparatus which demonstrated the expansive power of steam.



de Caus’s sphere.

Around the same time in 1605, a French landscape gardener called Solomon de Caus, whose work took him to England, Italy and Germany, invented a machine that would, in his own words ‘demonstrate that water will mount by help of fire higher than its own level’. It was a sphere like Hero’s, but instead of turning round and round it just squirted water up into the sky, which would have been quite a novelty for the rich people who employed him to make fountains, pumps and waterwheels for their gardens.

Like the other inventors before him, de Caus never really discovered any practical use for his steam fountain. But he was one of the first men to be involved in the pumping of water and it was this that proved to be the turning point in the development of steam power, because pumping water was one of the great challenges of the eighteenth century. This was the period when removing water from deep mines became important for the wealth of the nation.

All over Europe the growing economic importance of mining had been turning the search for a way to harness the power of steam into a necessity. In Italy in 1641 Cosimo de Medici, Grand Duke of Tuscany, required his engineers to make a suction pump that would draw water from a depth of 50 feet (15 m). When they found that the water wouldn’t rise further than about 25 feet (7.5 m) up their pipe, leaving an unfilled vacuum above, they asked the great inventor, Galileo, for an explanation. His reply was that it needed a lot more investigation, which others should do. The philosophers and scientists who carried out the investigation thought, at first, that wherever there was a vacuum, air or water would rush to fill it. But when they found that water didn’t rush to fill the vacuum in the pipe, they realized that air has weight and can exert pressure. Water rose in a pipe because it was pushed, but would only go as high as the level where it balanced with air. The demonstration of ‘the spring and weight of the air' was made in Italy by Evangelista Torricelli and Vincenzio Viviani, both followers of Galileo. It was also made in France by Blaise Pascal in 1647, and in Germany by a scientist called Otto von Guericke, who was mayor of Madgeburg.

A particularly dramatic demonstration to show that the atmosphere was a source of power was carried out by von Guericke in 1654, using a piston-and-cylinder apparatus. In this the cylinder stood upright with the open end to the top and a rod from a piston protruding. A strong rope attached to the piston rod was taken over a pulley above and twenty men pulled the piston up the cylinder to hold it against the partial vacuum they created. Guericke connected the base to a copper sphere, from which all the air had been pumped out. Then the cocks on the connecting pipe were opened and the residual air in the cylinder rushed into the space with so much power that the piston was driven down and the twenty men were all pulled over.

It was clear from this that a powerful engine that was independent of human, animal, water or wind power could be built, but needed to obtain a vacuum under the piston in some way besides an air pump – which is what von Guericke had used. The search for alternatives included trying gunpowder, but about a fifth of the air was still left in the cylinder, so it didn't really work. In the meantime, steam provided an answer and it came from an English lord.

All of this, so far, had been mere experimentation. Nobody had yet built anything resembling a steam engine that had done any useful work. Edward Somerset, the second Marquis of Worcester, is reputed to be the first man to build a steam engine and demonstrate the expansive properties of steam in a more practical way. Worcester is described as being a learned, thoughtful, studious and good man; a Romanist (that is, a Roman Catholic) without prejudice or bigotry; a loyal subject and honourable public figure. He was a mechanic of wonderful ingenuity and of clear, almost intuitive apprehension.

In 1663 he produced a curious collection of descriptions of his inventions, as he called it, and one of these involved raising water by steam. The way it worked was that steam was generated in a boiler that went through a pipe into a vessel filled with water. When the steam came in, it forced the water out of a pipe. The vessel was then shut off from the boiler and the whole process was repeated by filling up the vessel with water again. This method was actually used for raising water at Vauxhall in London, but the Marquis did not make any money out of it. He never managed to succeed in setting up the company that he would have needed to operate on a proper commercial basis and, in spite of the fact that he started out as a wealthy and influential man, he spent a fortune on his experiments until he was left penniless, with no home. His fate was that of nearly all inventors of the time: he ended up poor and unsuccessful.

From the time of the Marquis of Worcester onwards, steam development entered a new stage, which was one of application rather than mere experimentation. During the reign of Charles II there was a great growth of activity in the field of applied science. The King himself had a laboratory built and he employed learned men to carry out experiments. It was the first stage of Britain attaining a superiority over the continent that was to blossom with the Industrial Revolution. Around this time, towards the end of the seventeenth century, English miners were digging deeper and deeper and the problem of how to clear water from their shafts was becoming almost insurmountable. Something had to be done about it. The experiments of a French doctor called Dionysius Papiri and the practical application of known principles by an Englishman, Thomas Savery, gave them the machinery that they needed.

Papin was a key figure in the story of steam. Although he came from a Protestant family, he was educated in the school of the Jesuits at Blois, which is where he acquired his knowledge of maths. He went on to study medicine in Paris and settled there in 1672 with the intention of practising his profession. Apparently he devoted all his spare time to studying physics and moved to London in 1678 to pursue his studies. Papin became one of the most celebrated engineers of his day and took his place among the most talented and famous of mechanics. He invented the pressure cooker, christening it the ‘digester’. This really put him at the forefront of controlling pressurized steam. Food would be cooked in water that was heated by a fire, and the pressure was determined and limited by a weight on the safety valve lever.

In 1687 Papin produced the first piston steam engine. For a long time scientists had been looking at ways to create a vacuum into which a piston could move. Papin was the first man to use an air pump to pump the air out. This enabled the atmospheric pressure to push the piston back the other way into the vacuum in the cylinder and lift a weight. But he wanted to create a better vacuum, so he used steam to displace the air and used condensation to create the vacuum. When he did this, he really produced the first mechanical steam engine and the first piston steam engine in which condensation was produced to create a vacuum. His experiment involved a small brass cylinder 2½ inches (6 cm) in diameter, fitted with a piston. Water was boiled in the bottom of this cylinder and the resulting steam went to the top where it was held by a catch. When the fire was removed the steam condensed, causing a partial vacuum, and, once the catch was released, the piston went down with sufficient force to raise a weight of 60 lbs (27 kg) by a cord and pulley. With these experiments successfully completed, Papin put his inventive mind to a new engine to drive a waterwheel and later on to another form of power to drive ships. But none of these was a success and he died in about 1712, an unhappy and disheartened man, without seeing any of his wonderful ingenious inventions put to any form of use.

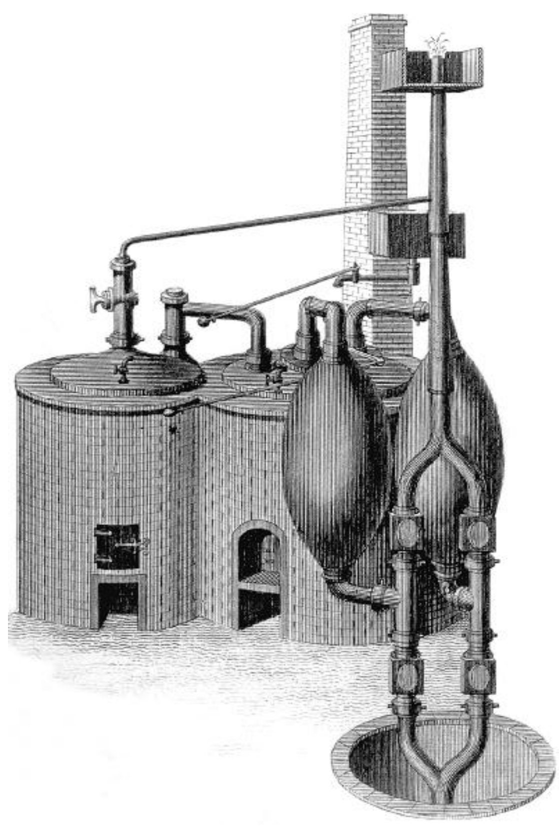
Thomas Savery was next on the scene and he was the first man to invent and design an engine that was actually used for pumping water out of mines. From a well-known Devonshire family, he was born at Shilston around 1650. Well educated, he became a military engineer. He was very fond of mathematics, mechanics and natural philosophy and he spent a lot of his time experimenting, inventing and creating things. One of his first inventions, which he patented, was a device for propelling ships in calm weather. This amounted to two paddlewheels and a capstan: when the wind wasn't bending the sails, the lads on deck could turn the capstan and the paddles went round. He offered this to the Admiralty but they decided that it was too slow and were not interested in it.

From this moment on, Savery concentrated on developing steam pumping gear. He'd noted the constant and expensive engineering problems that were involved in keeping mine shafts free of water, and in 1698 he invented what he called his 'fire engine'. This was a steam pump for draining water from mine shafts. It consisted of a furnace heating a boiler, which was connected by pipes to two copper receivers. From the bottom of these receivers branch pipes turned upwards and were united to form a raising main or 'forcing pipe'. Then from the top of each receiver there was also a pipe, which was turned downwards, and these pipes united to form a suction pipe, which was led to the bottom of the shaft from where the water was to be drawn. The maximum lift was 24 feet (7.3 m).

In 1702 he began marketing the engine as the *Miner's Friend*, but of course the deeper the mine shaft, the more dangerous the business of playing around with steam became, and the mine owners were quite worried about it.

The problems arose when water needed to be raised from any considerable depth, because the pressure of steam required would cause the engine to blow up, and they only had poor-quality materials to make boilers out of – it was a recipe for disaster and there were quite a few fatalities. Savery spent a lot of time experimenting with boilers and the like to try to perfect the engine, but he never fitted his boilers with safety valves. This was something that only came later.

One of the big advantages of Savery’s engine was that it was capable of a continuous delivery because the boiler could be refilled without stopping the engine. A second, smaller boiler was heated to provide a higher pressure of steam than that in the engine itself, and the water forced by steam pressure into the main boiler. But these engines consumed a lot of fuel. They were not economical because the boilers were of such simple form and the heating surface was too small.



Thomas Savery’s engine. Savery was the first to design an engine that was capable of pumping water out of mines.

Savery was the very first inventor to try to market a steam engine and, unlike a lot of other inventors at that time, he was very open about his work and liked everybody to know how his machines worked. He also found other uses for his steam engine, such as pumping water for towns, large estates and country houses. In another, more simple engine that he built at Kensington, he followed the same general plan but combined it with a suction pipe. The engine included a single receiver capable of containing 13 gallons (60 litres) of water, a boiler with a 40-gallon (182-litre) capacity and a forcing pipe with connecting pipe and cogs. The Kensington engine cost £50 and raised 3,000 gallons (13,638 litres) per hour, filling the receiver four times a minute. But the Kensington engine was too small for the coal mines. It could have been used for domestic purposes like watering the garden but Savery did not sell this type of engine. It was the later and more efficient engine the *Miner’s Friend* that became a real commercial concern.

All sorts of rumours were put out about Savery: that he was heavily influenced by Papin and that he had seen the Marquis of Worcester’s engine and basically copied his idea. It is also said that he bought up all the books he could find on the subject of steam power and burned them so that nobody would find out where he got his information. Another story claims that Savery had discovered the enormous power of steam by chance and, to cover it up, he invented a tale about how he filled a wine glass with steam and plunged it upside down into a vessel full of water. Of course, when the steam condensed, the atmospheric pressure caused the wine glass to fill with water. If you just got a wine glass and shoved it upside down into a tub of water, the air would be contained inside and no water would go inside it, as with a diving bell.

Whether or not these stories are true, in 1699 Savery certainly demonstrated a model of his steam pump to the Royal Society. It was the first time that a steam-powered engine had been shown to a learned society and it was met with approval. The machine had no moving parts except for hand-operated steam and water cocks and it was basically a steam pump operating on the principle described by Della Porta. But the distinct advantage over previous engines was that it also used atmospheric pressure to drive water up a suction pipe and into a receiver ready to be forced out again and up the delivery pipe when steam was next admitted from the boiler.

Savery faced the same problem as the engineers of Cosimo de Medici: that you couldn't raise water by atmospheric pressure for more than about 25 feet (7.5 m). To resolve this a different pump would be needed every 25 or 30 feet (7.5 or 9 m) down the shaft. This would have been expensive and dangerous – all these boilers part-way down under the ground. Another problem was the energy loss, which came about from steam being brought into direct contact with cold water in the receiver. Savery's most obvious failure was with an engine he installed at York Buildings near the Strand in London to replace a waterwheel under London Bridge. The waterwheel was used to pump Thames water to supply homes and buildings for people in Picadilly and Whitehall. Savery's engine was installed in 1712 for the same purpose. But the engine used steam at pressures higher than the pipework could stand, so it had to be taken out of use. But Savery still remained a pioneer in the eyes of his contemporaries.

At the end of the eighteenth century Savery's engines were still being used in Leeds in a flax mill and in a number of cotton mills. The interesting thing here is that the actual steam engine wasn't used to drive the machinery but to raise the water, and it was the waterwheel that did the driving of the machinery. In other words, they recycled the water: possibly during the night they would pump it up into a reservoir and then use the wheel during the day. The principle is very similar to that of modern hydroelectric stations where they generate all day and pump the water back up all night when the demand for power is not there. As late as 1820 a Savery engine was employed to work a waterwheel turning machinery in an engineering works in Kentish Town in London.

But in spite of all these developments, until 1712 the ‘engines’ that were available for pumping water from flooded mines were totally inadequate. The owners of coal and tin mines just couldn’t keep up with the problems caused by water, which cut into profits, threatened jobs and claimed human lives without warning, especially where shafts were sunk along the coastline and extended under the sea. This was particularly the case in Cornwall. One traveller to the county in the late eighteenth century wrote: They even work on the Lord’s Day to keep the mines open – one thousand men and boys working on the drainage of twenty mines.’ Even so, the sea frequently won, as dozens of mines were lost to the waves.

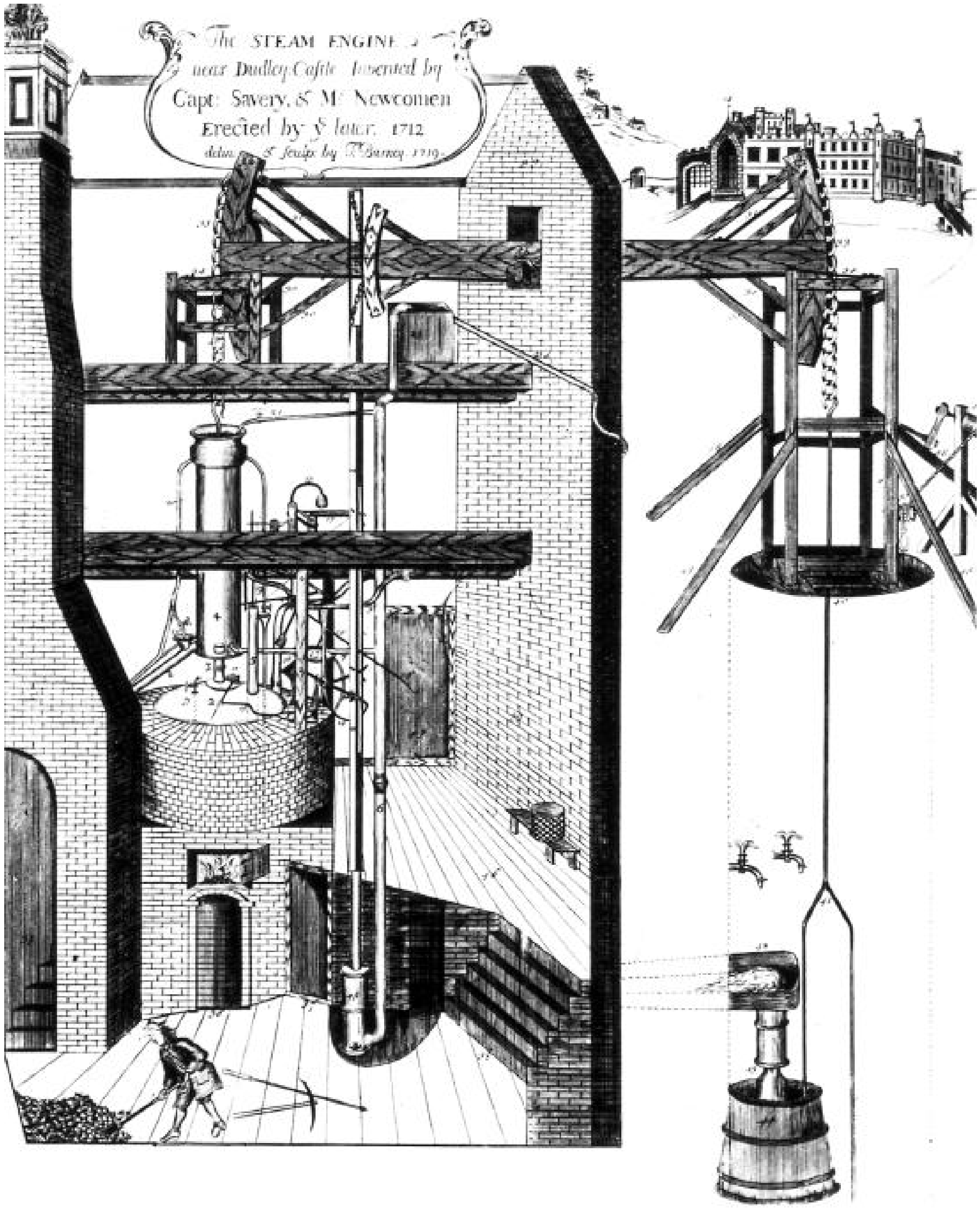
The problems of water pumping and drainage had been met with varying degrees of success throughout history since the early empires of Babylon and Egypt. The early ‘chain of pots’ system of drainage used then hadn’t changed much by the eighteenth century. Power to drive this sort of bucket elevator system could be provided by man, beast, wind or water, each of which was either inefficient or unreliable. Certainly this method couldn’t cope with the pressing drainage problems that faced the coal owners and the Cornish tin-mine owners at the start of the eighteenth century. The search for a more efficient and reliable source of power for draining mines was the most pressing technological problem of the time. And so the steam engine was born.

By the beginning of the eighteenth century all the known elements of the modern steam engine had been discovered. They'd each been put to individual use and all that remained was for some really good inventor to screw everything together into a practical machine capable of using the power of steam economically. Thomas Newcomen, who came to be known as the 'father of the steam engine', provided the great step forward that was needed. Born into an aristocratic family that had fallen on hard times, he ran an ironmonger's shop in Dartmouth, Devon. In the 1680s he formed a partnership with a man called John Calley. Calley was a local plumber and he and Newcomen toured the tin mines of Devon and Cornwall providing the mine owners with iron and doing plumbing and blacksmithing jobs for them on site. On these tours they were able to see the problem of flooding for themselves at first hand.

In 1710, with Calley's assistance, Newcomen designed an engine for pumping water at Helston in Cornwall. This first attempt was a failure – it didn't work properly – but during the next two years he invented an entirely new kind of engine, which he called the 'atmospheric engine'. What we all breathe every day is the atmosphere, or air, which has a pressure of about 15 lbs per square inch (1 kg per cm^2). The atmospheric engine uses this power to its advantage. An atmospheric engine is basically an open-ended cylinder with a piston in it and a piston rod protruding out of the top. Steam is introduced into the cylinder and then cold water condenses the steam, creating a vacuum below the piston. Then the atmosphere, at 15 lbs per square inch (1 kg per cm^2), pushes the piston down to the bottom, lifting up the beam and sending the pump rods down the shaft. Then it goes back by gravity the other way and the same thing happens again: the steam goes into the cylinder, the water condenses it, the vacuum is caused and it pushes the piston down one more time. Newcomen's engine did eight to ten strokes a minute and its own valve gear controlled it automatically. Unlike Savery, Newcomen didn't make use of the expansive properties of steam. Instead he used it to create the vacuum and then let atmospheric pressure do the work, hence the name 'atmospheric engine'. The advantage was that he didn't have to control high-pressure steam. The Newcomen engine was designed for one purpose alone – to pump water from mine shafts and mines. The first example was installed at a colliery in Staffordshire and it was an unbelievable success. It proved to be the world's first successful steam engine, and over the next fifty years Newcomen engines were installed all over England and the Continent.

Little is known about Newcomen himself other than that he was a fairly humble man who wasn't held in very high esteem, even among his own people. He was classed as an eccentric sort of inventor. Newcomen certainly owed a lot to the men who came before him. Papin can be credited as the first to develop the idea of the use of steam and Savery actually invented and patented an engine that had been used for pumping water from mines. Newcomen took the idea of Papin's cylinder and piston and married it up with Savery's principle of condensing steam. The end product, the actual engine that he built, was so much like Savery's that Savery was only stopped from taking him to court because Newcomen made him a partner.

Basically, Newcomen's engine evolved from the principle of the common hand pump that was used to bring water up from a well. With a hand pump the hand is applied to a rod connected with a pivoted lever. As the rod is pushed down by the hand, the plunger, which is fixed to the other end of the lever, is raised so that it discharges water from the spout of the pump. What Newcomen did was to replace the human hand with a simple steam-powered piston and cylinder. The device he invented was an ingenious combination of what would soon become familiar elements of the industrial age: a piston and cylinder, pumps, valves, levers and a process of producing low pressure by the condensation of steam in a vessel.



Newcomen’s engine installed at Dudley Castle, Wolverhampton in 1712.

Newcomen produced his first successful working model in 1705, but by 1712 he’d made the real thing and installed it at Dudley Castle in Tipton near Wolverhampton. It marked the beginning of the Steam Age proper. Rather than lift