Part 1

Power

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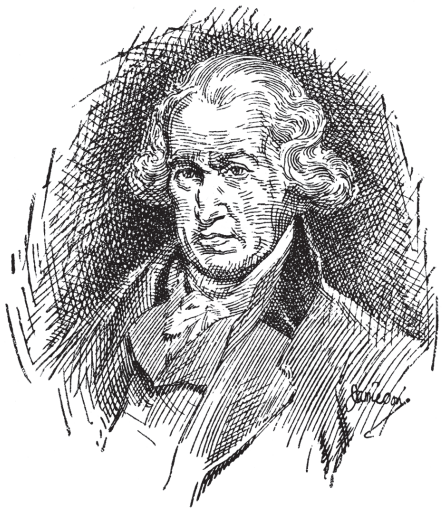
Chapter 1: James Watt and the Steam Engine

Until a little more than 250 years ago, the chief power used in the production of food, clothing, and shelter was hand power. Cattle and horses were used to cultivate the fields. Windmills and water wheels ground corn and wheat, but most tools and machines were worked by hand.



James Watt

For many years, men had dreamed of a new power that would be more useful than work animals, sails, windmills, or water wheels. Around the year 1750, a new power was found. This new power was steam. Yet no one had been able to apply the power of steam so that it would grind corn and wheat, spin and weave cotton and wool, or do any useful thing at all. The man who succeeded in giving this new power to the world was James Watt. Thanks to the efforts of James Watt, the power of steam was harnessed and, by the mid-1800s, was propelling large ships around the world and operating hundreds of steam-powered express trains. Numerous other inventions were created using steam power, as well. Although we seldom think of steam power today, we must not forget how much it helped America years ago.

Childhood and Early Education

James Watt was born in 1736, in Greenock, Scotland, not far from Glasgow. His early education was received at home, his mother giving him lessons in reading and teaching him to draw with pencil and chalk. His father drilled him in arithmetic and encouraged him in the use of tools. A few years later, James went to school, although he did not at first get along well. This was due to illness, which often kept him at home for weeks at a time. Still, he always did well in arithmetic and geometry, and, after the age of fourteen, he made rapid progress in all his studies.

Even as a small boy, James liked to tinker with things. This tinkering was not always appreciated by members of his family. His aunt would scold him, "James Watt, I never saw such an idle boy; read a book or employ yourself usefully! For the last hour, you have not spoken a word, but you have repeatedly taken off the lid of that kettle and put it on again. Why are you holding a cup and then a silver spoon over the

Watt and the Teakettle

steam while staring at the drops of water into which it turns? Are you not ashamed to spend your time in this way?"

Much of his time, as he grew older and stronger, was spent in his father's shop, where supplies for ships were kept and where ship repairing was done. He had a small forge and a workbench of his own. Here he made cranes, pulleys, and pumps, and learned to work with different metals and woods. He was so skillful that the men remarked, "James has a fortune at his fingers' ends."

The time at last came for choosing a trade. His father had wished James to follow him in his own business. But Mr. Watt had recently lost considerable money, and it now seemed best for the youth to choose a trade in which he could use his mechanical talents. James set out for Glasgow to become an instrument maker.

Learning Instrument Making

He began to work for a mechanic who dignified himself with the name of "optician." This mechanic, though the best in Glasgow, was a sort of Jack-of-all-trades, who earned a simple living by mending glasses, repairing fiddles, and making fishing tackle. Watt was useful enough to his master, but there was little that a skillful boy could learn from such a workman, so he decided to seek a teacher in London.

There were plenty of instrument makers in London, but they were bound together in a guild. A boy wishing to learn the trade had to train from five to seven years. Watt had no desire to bind himself for so long a period. He wished to learn what he needed to know in the shortest possible time; he wanted a shortcut. Master workman after master workman turned him away for that reason. Only after many weeks did he find a master teacher who was willing to take him. For a year's instruction, he paid $100 and agreed to work without pay for one year.

The hours in the London shops were long. "We work," wrote Watt, "until nine o'clock every night, except Saturdays."

To relieve his father of the burden of supporting him, he got up early and did extra work.

Towards the end of the year, he wrote, with no little pride, "I shall be able to get my bread anywhere, as I am now able to work as well as most journeymen, though I am not so quick as many."

Jack-Of-All-Trades

In order to open a shop of his own, Watt returned to Glasgow. He was opposed in this by the hammermen's guild. The hammermen said that he had not served an apprenticeship and had no right to begin a business. They would have succeeded in keeping him from making a start had not a friend, a teacher in the University of Glasgow, come to his aid, providing him with a shop in a small room of one of the college buildings.

Watt soon became a Jack-of-all-trades. He cleaned and repaired instruments for the university. Falling into the ways of his first master, he made and sold eyeglasses and fishing tackle. Though he had no ear for music and scarcely knew one note from another, he tried his hand at making organs. He was so successful that many "dumb flutes and gouty harps, dislocated violins, and fractured guitars" came to him to be cured of their ills.

All the while, Watt spent his leisure time in reading. The college library was nearby, so there was no lack of books. He turned his keen mind to chemistry, mathematics, and mechanics. By learning all he could and by doing everything well, Watt came to be known as a man "who knew much and who could make anything."

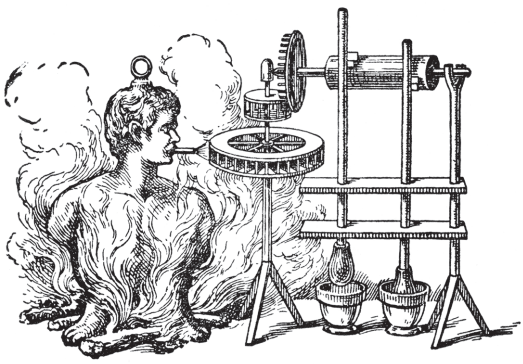
Captured by Steam

For a long time coal and tin mining had been important industries in Great Britain. Shallow mines were easy to work.

Men and women carried out the coal or tin ore in buckets, either by winding stairs or by using a windlass, which was turned by hand or with the aid of a horse. Water was taken out in the same way. As the shallow mines became exhausted, deeper ones were opened. The deeper the mine, the harder it was to lift out the coal or tin ore. Into these deeper mines also came quantities of water, flooding many of them. Unless a machine should be invented, which could be run at a small cost to pump out the water and to hoist the coal or tin inexpensively, these mines would have to be closed. The practical need for such a machine led to the invention of the first successful steam engine.

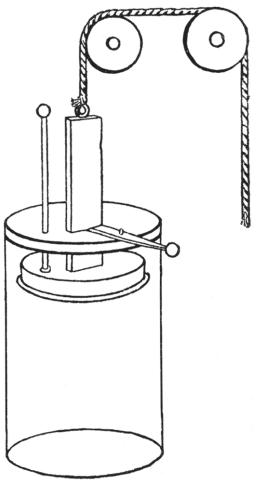
Watt first heard of the steam engine in 1759. The idea captivated him, and he began to read how others had tried to make successful engines. Finding that the best books on steam and "fire engines," as they were then called, were in Italian and German, he began the study of these languages.

In an Italian book, Watt read about Giovanni Branca's steam engine, invented in 1629. Branca's engine was little more than a toy. Its only practical application was smashing saltpeter and doing other simple things.



Branca's Steam Engine of 1629

In a German book, Watt read about the Huguenot Denis Papin and his engine, which was invented in 1690. In Papin's engine, steam was admitted into the cylinder. The steam was then allowed to condense—to turn back into water. This formed a vacuum—a space without any air in it—under the



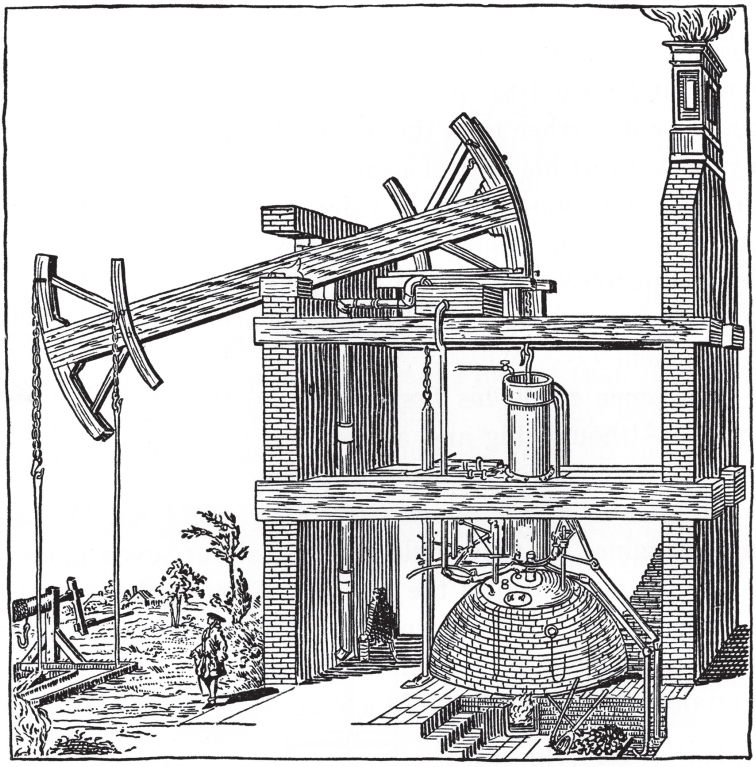
Papin's Engine

piston. The weight of the atmosphere (which is about fourteen pounds per square inch) on the upper side of the piston forced it down, and the descending piston raised a weight fastened to the rope. Papin never went further than making a model. However, his ideas of using steam to make a vacuum and using the pressure of the atmosphere to force down a piston were applied a few years later with some success by Thomas Newcomen.

Newcomen made his first engine in 1705. Although big and awkward, a number were used in England to pump water out of the mines. However, they could not be used in deep mines because they could lift only six or seven pounds for each square inch of the piston. They worked slowly, making only about fifteen strokes a minute. They were also expensive to operate, a single engine burning several thousand dollars' worth of coal in a month.

Finding the Trouble

Watt had been thinking about steam for four or five years before he saw one of Newcomen's engines. Even then, Watt only saw a model of one that had been brought to him from the university for repair. When he had repaired the model, he started it up. It made a few strokes and stopped. There was no more steam. The boiler seemed big enough, so he started a bigger fire. The engine now ran all right, but it required much fuel and used up quantities of steam, even though the load on the side of the pump was light. Most men would have thought nothing of this and would have sent the model back to the university. However, that was not Watt's way.



Newcomen's Engine

Everything he did not understand was a subject for study, and he never stopped until he understood. He set to work to discover why the engine used so much steam.

Steam was used, you will remember, to make a vacuum in the cylinder. Watt found that, to drive out the air and water, enough steam had to be let into the cylinder to fill it four times. Why was this? First, the cylinder was exposed to the air, which chilled it. The cold cylinder itself, before it was warm, changed considerable steam into water. Second, cold water was poured into the cylinder to condense the steam, and this made the cylinder cold again. Watt estimated that three fourths of all the steam used was thus wasted in heating and reheating the cylinder. That was the trouble with Newcomen's engine. Watt saw that, to remedy this defect, a

way must be found to keep the cylinder always as hot as the steam that entered it, and the vacuum must be made in the cylinder without cooling it.

Making the Invention

Watt spent much time and money in making experiments, but nothing he tried succeeded. "Nature has a weak side," he was fond of saying, "if we can only find it out." He went on, day after day, following one false hope after another.

"One Sunday afternoon early in 1765," writes Watt, "I had gone to take a walk in the parks of Glasgow. I was thinking about the engine and how to save the heat in the cylinder when the idea came into my mind that steam was an elastic body and would run into a vacuum. If a connection were made between the cylinder and a tank from which the air had been pumped, the steam would pass into the empty tank and might there be condensed without cooling the cylinder. I then saw that I must get rid of the condensed steam and the water used to produce it. It occurred to me that this could be done by using pumps."

With a separate condenser in mind, one to get rid of the steam after it had done its work without cooling the cylinder, Watt soon came up with other important improvements. In Newcomen's engine, the upper end of the cylinder was open to let the air act upon the piston. Watt now planned to put an airtight cover over the end of the cylinder, with a hole for the piston rod to slide through, and to let steam in above the piston to act upon it instead of making the air do the work. This change turned Newcomen's atmospheric engine into a steam engine. In Newcomen's engine, the power was the pressure of the atmosphere upon the piston, and this power acted in one direction only. In Watt's engine, steam was the power, and the piston was shoved both up and down by it; hence, Watt's engine was called a double acting engine.

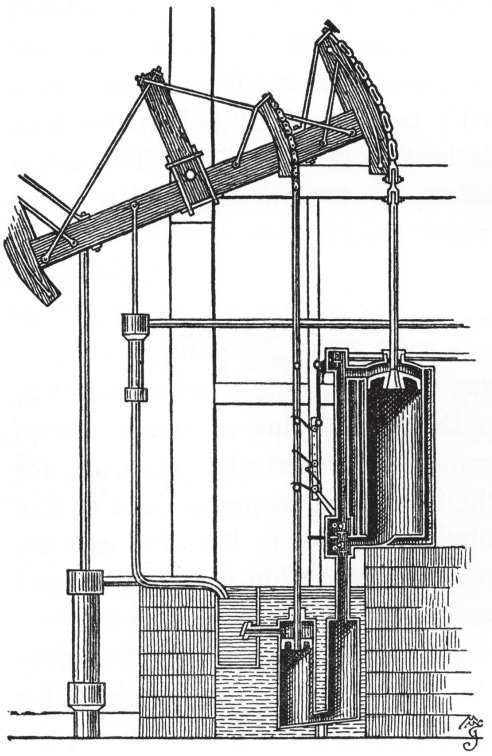
"All these improvements," says Watt, "followed … in quick succession, so that in the course of one or two days the invention was … complete in my mind."

The next step was to make a model—to put the invention into working form. Making the drawings was easy, but carrying them out was hard. A lack of good workmen was the main difficulty. There were no skilled mechanics in those days, or automatic tool-making machines; everything had to be made by hand. Blacksmiths and tinsmiths were the only men that could be hired, and they were bungling workers even at their own trades. After eight months of racking labor, the model was ready to start. It worked, but, despite all Watt's efforts, it "sniffed at many joints." The condenser did not work well; the cylinder leaked, and the piston was far from being steam-tight. To add to Watt's troubles, his "old White Iron man," a tinsmith who was his best workman, died. The crossbeam on the engine also broke. Nevertheless, Watt knew that he was on the right track.

Beelzebub, the Trial Engine

Watt's great need was money, for it was necessary to build a trial engine to show the value of steam power. Finally, in 1767, he secured a partner who promised, for a two-thirds share in the invention, to pay a debt of $5,000 owed by Watt and to bear the expense of further experiments. The partnership was formed, and Watt turned to the plans for the trial engine.

As the trial engine neared completion, Watt's "anxiety for his approaching doom kept him sleepless at night, for his fears were even greater than his hopes." Alas! The trial engine did not work well. The new condenser worked badly. The cylinder was almost useless. The piston, despite all that could be done, leaked quantities of steam. The whole machine was a "clumsy job." From the way it wheezed, snorted, and puffed fire and smoke, the engine was nicknamed Beelzebub.



The Engine Beelzebub, 1767

Months were spent in overhauling him, but he behaved only slightly better during the second trial. Beelzebub was far from being a practical engine, and he was left for the time to rest and rust.

There is little wonder that Watt was downhearted and wrote to his friends, "Of all things in life, there is nothing more foolish than inventing.... I am resolved ... if I can resist it, to invent no more." On his next birthday, he wrote, "Today I enter the thirty-fifth year of my life, and I think I have hardly yet done thirty-four cents worth of good in the world."

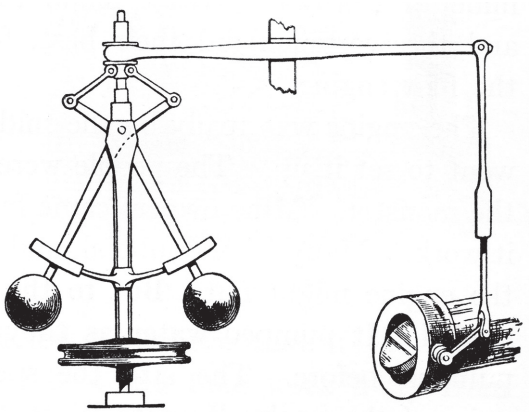
Completing the Engine

Watt had, by this time, spent ten years and several thousand dollars on his invention, but it was still only a dream. Brighter days were, however, at hand. Matthew Boulton, owner of the largest hardware factory in England and the employer of the best mechanics in Europe, became interested in the fire engine. In 1774, he became Watt's partner.

Meanwhile, old Beelzebub was shipped to Birmingham. The best mechanics of Soho began to work upon him. One

by one, the separate parts were repaired and improved. In a few months, Beelzebub was ready for trial. It puffed as much smoke and fire as ever, but it worked surprisingly well, thanks to the good workmanship of the mechanics. Everyone who saw Beelzebub run felt sure that the invention would prove a success. Even modest Watt wrote this to his father: "The fire engine I have invented is now going, and it works much better than any other that has yet been made, and I expect that the invention will be very beneficial to me."

Though success was promised, much remained to be done to make the engine practical. It was found, for example, that if the load Beelzebub was pulling suddenly became lighter, it would run too fast; if the load suddenly became heavier, it would run too slowly.



Watt's Engine Governor

Some way had to be found to make him run faster when there was need of more power, and to run more slowly when less power was needed. Two heavy balls were fixed to swing around an upright rod. When the engine ran fast, the upright rod turned fast, and the balls swung out and directed the engine to admit less steam. When the engine ran slowly, the rod turned slowly, and the balls swung down and let in more steam. By the use of this contrivance, called a governor, Beelzebub was made to run at consistent speed; and, when in operation, it became its own engineer.

Other inventions were made, and the separate condenser, piston, and cylinder were improved. Thus, after years of thought and labor, the steam engine stood full grown and ready for all kinds of work.

Making the Business Pay

To make an invention is one thing. To get people to use it and so make it profitable is another. It is difficult to say which is the harder. In any case, Watt's troubles were not over.

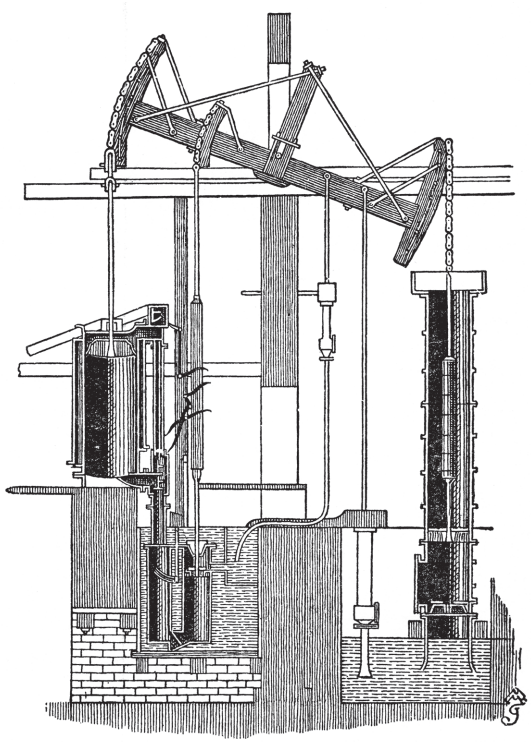
All the time that Watt was working on his invention, mines were being abandoned because they had become flooded with water. Among the first orders for engines was one for a mine in Cornwall. Watt made the drawing with care, and the workmen did their best, for much depended on the first engine for their future success.

The engine was ready by the middle of 1777, and Watt went to set it up. The people were eager to get a look at the monster. Mine owners came from far and near to see it work. Many were doubtful, and some even wished for the engine to fail. To the surprise of all, it succeeded. It pumped water as they had never seen water pumped before. The size, the speed, and "the horrible noise of the engine," wrote Watt, "give satisfaction, and the noise seems to give great ideas of its powers." In a few days, the mine was dry. It was the deepest mine in the district, and orders for engines began to pour in. They came so fast that, in the course of the next four or five years, almost all the mines in England and Scotland were supplied.

Matthew Boulton, Watt's partner, felt from the first that the greatest field for the steam engine was in mills and factories. When orders for pumping engines fell off, Watt went to work on a factory engine. His first factory engine was built for use in a corn mill in 1782. The new Boulton and Watt engine was four times more powerful than Thomas

Newcomen's original design and could be adapted to drive all sorts of machinery.

The use of the steam engine in mills was opposed by the millers. They saw that putting steam engines to work grinding corn and wheat would do away with windmills and water mills in many places. The working people also were stirred up. They were led to believe that, if the steam engine were put in mills, it would take work away from them.



A Mine Engine

"It seems," wrote Watt, "the meddlers are determined to be masters of us. To put a stop to fire engine mills, because they come in competition with water mills, would be as absurd as to put a stop to canals, because they interfere with wagoners…. The argument that men are deprived of a livelihood would put a stop to the use of all machines whereby labor is saved. Carry out this argument, and we must do away with water mills themselves, and go back again to grinding corn by hand labor."

The opposition was so strong that Watt and Boulton decided to build a flourmill to show what could be done. They built one at a cost of $60,000 and put their newest

and best engine into it. The mill attracted much attention. However, it was not allowed to run long. So bitter was the feeling against the steam engine that the mill was set on fire and burned to the ground.

Though the mill was a total loss, it served its purpose. Orders for factory engines came in rapidly from France, Italy, and America. The advantages of steam power were now apparent to some people. Water mills were stopped in the summer by lack of water and in the winter by frost, while steam mills worked on, day and night, in all kinds of weather and in all seasons.

To bring the world to appreciate the value of the steam engine was, therefore, a hard struggle. Until the year 1785 every penny made from the sale of engines, amounting to more than $2,000, was put back into the business. Besides this staggering amount, large sums had to be borrowed. So great was the need for money that even the patents were mortgaged. Time after time, it seemed that all would be lost. More than once, Watt and Boulton felt that this might be a blessing. The mine owners, for instance, refused to pay for the engines that had saved them thousands of dollars. Dishonest persons stole and used their patents. They were continually annoyed by rumors that a better engine was on the point of being completed. Efforts were even made to get Parliament to take away their patents.

"We are in the same state as the old Roman," Watt wrote, "who was found guilty of raising better crops than his neighbors and was ordered to bring before the assembly of the people his farming instruments for inspection. He complied, and, when he was able to speak, he said, 'These, O Romans, are the instruments of our art; but I cannot bring into our meeting the labors, the sweats, the watchings, the anxieties, the cares which produce the crops.' So everyone sees the reward which we may yet probably receive from our labors;

but few consider the price we have paid for that reward, which is by no means certain."

Despite this uncertainty, Watt and Boulton battled down difficulty after difficulty. Parliament refused to take away the patents. Persons who used them without right were punished. The mine owners were forced to pay what they owed. The business, after long waiting and untold distress, began to prosper. Richard Arkwright pioneered the steam engine's use in his cotton mills; and, within fifteen years, there were more than 500 Boulton and Watt steam engines in British factories and mines. Boulton also arranged an act of Parliament extending the term of Watt's 1769 patent to 1799. In 1800, the two partners retired from the business, which they handed over to their sons, Matthew Robinson Boulton and James Watt Junior.

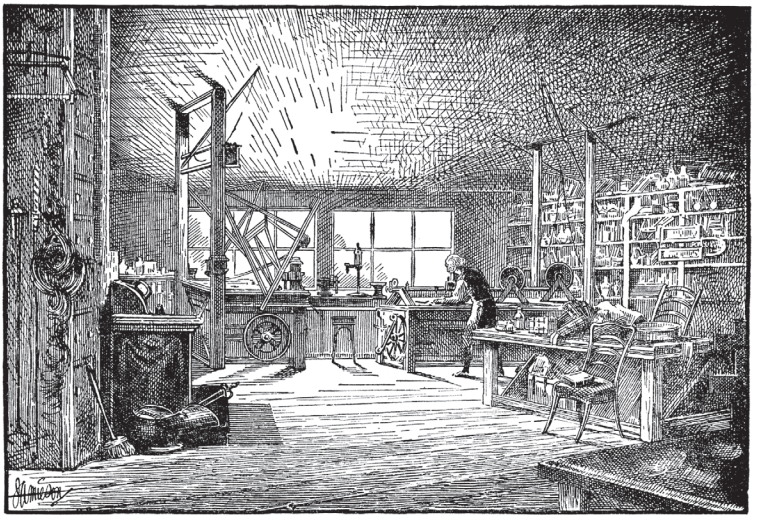
Old Age at Hearthfield

By the time the partnership between Watt and Boulton had ended, Watt had become quite rich. Relieved of business cares and worries, his health improved. He built a beautiful country home at Hearthfield. From there, he made trips to different parts of Scotland, Wales, and England. In addition, old friends and the greatest men of England came to Hearthfield to visit him. Inventing also continued to give him the greatest pleasure. A room was built in the attic of his house, and there he would work for days at a time. This room remains just as it was in 1819; Mr. Watt's home was preserved as a museum.

James Watt spent a great deal of his life making improvements in engines of various kinds. His tireless efforts proved to the world that machines could give human beings great power and prosperity.

Even today, people in Europe and America commonly honor the memory of this great inventor by referring to a unit of electric power as a "Watt." If you buy a light bulb, it

will normally be stamped with the amount of light it will give off, for example, "60 Watts." This is one small way that people around the world have honored the memory of this gifted inventor.



Watt's Workroom at Hearthfield

Comprehension Questions

1. What was the chief means of power used in the production of food and shelter during the 1700s? Give some examples.
2. What was James Watt's most significant invention?
3. Why was Watt's engine called Beelzebub?
4. How did people make use of the steam engine during the time that Watt lived?
5. What types of problems did Watt and Boulton have when they tried to sell their new steam engine?
6. What tribute or honor was given to Mr. Watt by people around the world?