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# JAMES WATT'S STEAM ENGINE FOR THE LEADHILLS MINES

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**Abstract:** In the spring of 1765, James Watt (1736-1819) had the inspiration for his separate condenser which would dramatically improve the performance of the Newcomen or atmospheric steam engine. At this time steam engines were only used to pump water from mines but Watt later developed his engine to give direct rotary motion while his pumping engine would form the basis of the Cornish engine which would be seen in mining areas throughout the world. However, in 1765, Watt called himself "merchant", for, while he still retained a workshop for making scientific instruments, his main business in Glasgow was a "toy" shop, something akin to a domestic hardware store of the present day.

During the spring and into the autumn of 1765 Watt was experimenting with his separate condenser on model engines and he over-optimistically reported to Dr. John Roebuck,[1] "I have tried my new engine with good success" but it must have become clear very quickly to him that, if this engine were to succeed, he needed experience designing, erecting, running and maintaining full-size engines. Surviving records for this period of Watt's life are sparse so it is impossible to draw up a detailed chronology. It has been suggested that, to learn how the Newcomen type of atmospheric engine worked, Watt took charge of one of Roebuck's engines at the School Yard Pit.[2] It may have been this engine on which Watt carried out some trials because, on a letter from Dr. Roebuck dated 2 October 1765, there is written in a different hand, "Calculation of Experiment on Old Engine", with a set of figures.[3] This addition has no date and there is a much later further comment in Watt's own hand, "This relates to an experiment on one of Dr. R.'s common engines, and served to show the great waste of fuel and steam". However surviving records show that Watt made a visit down the School Yard Pit only on 12 June 1770.[4]

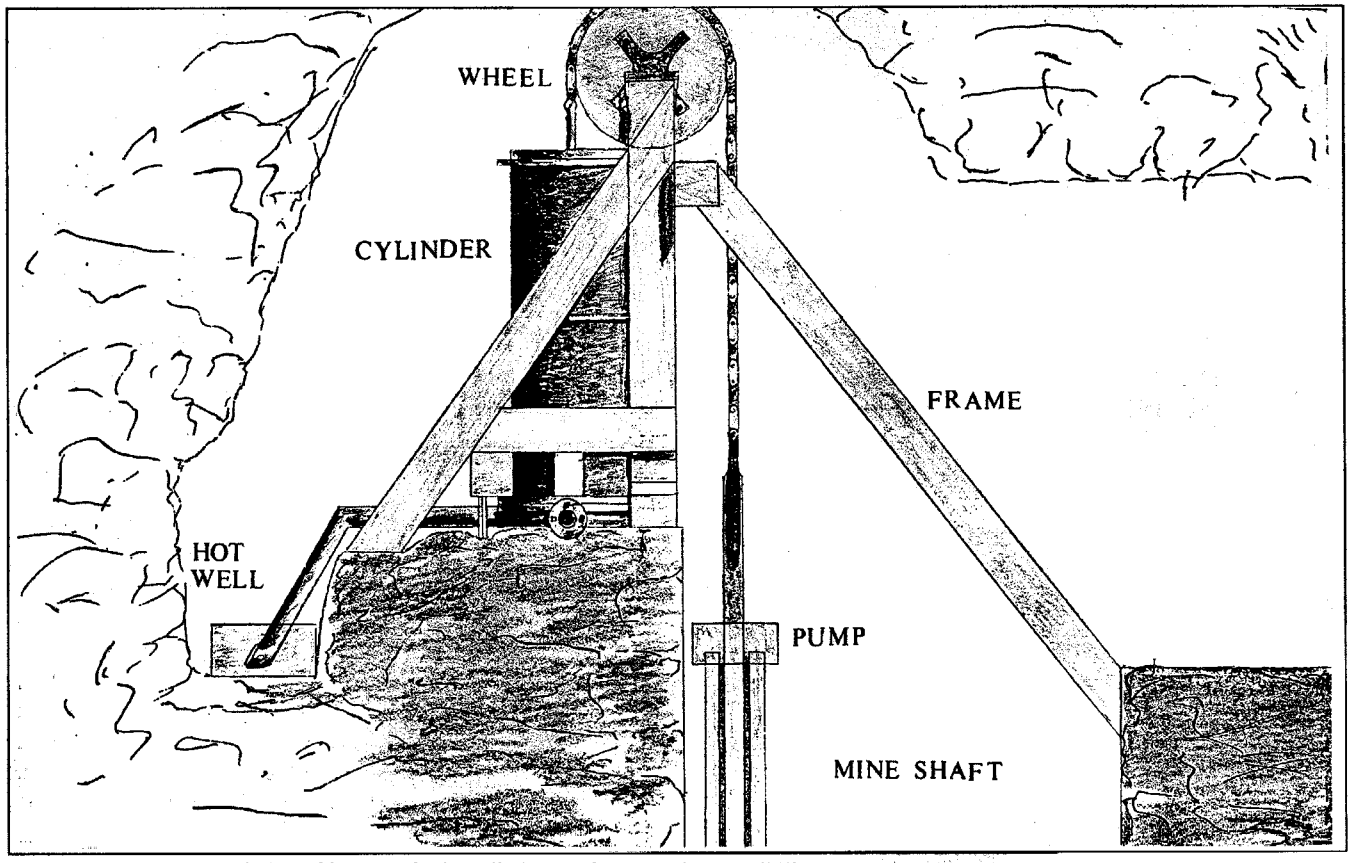
During the autumn of 1765, Watt was ordering parts for an engine to be erected at Kinneil where Roebuck was then living. This was aborted because the cylinder cast at the Carron iron foundry was so badly bored that it proved to be useless.[5] Watt did not succeed in building an engine with his separate condenser which worked successfully until after he had moved to Birmingham in 1774 and formed the famous partnership with Matthew Boulton. But over the winter of 1765, he must have been approached about building another engine for the mines at Leadhills. All that survives about this in the various Watt archives at Birmingham is an entry in his "Cash Memorandum Book" on 12 April 1766 for "Expenses at Leadhills, 11/7" with 7/- more for hire of a horse[6] and some drawings and estimates for an atmospheric steam engine.[7] He spent four days at Leadhills and one later for drawing plans. But, through the kind permission of Colonel Stirling of Garden, a search was made through his papers which shows that Watt tried to win an order for a steam engine to drain these mines but failed. This was Watt's first attempt to build an actual working steam engine of any type and the story shows that the steam engine did not sweep away all rival technologies but might be unsuitable in some instances.

The principal lead mines in Scotland were situated at Leadhills and Wanlockhead on the borders of Lanark and Dumfries-shire. Those at Leadhills were the property of the Earl of Hopetoun who had leased part of them to the Scots Mining Company.[8] Its shareholders were chiefly gentlemen in London who had appointed James Stirling as manager at Leadhills in 1735. It is from his correspondence with the secretaries in London that the background to Watt's attempts can be discovered. Stirling had devised water courses, waterwheel pumps, adits and drainage channels to keep the mines clear of water.[9] However by the middle 1760s, the mines had to be sunk deeper if new areas of ore were to be extracted. Although Stirling proposed building a third water-powered pumping engine, he pointed out to Lord Hopetoun that they were already "so much pinched for water" and resort had to be made to pumps operated by men.[10]

This mining area lies near the tops of the hills around 1,500 feet above sea level where climatic conditions are harsh. We can gain a picture of the layout of the mine and the problems of operating it from a report of a visit there in August 1779 by John Smeaton. From this, we know that springs and streams on the hillsides above the mine had been diverted through channels down a shaft to a twenty-four foot diameter overshot waterwheel inside the mine which operated lever pumps to drain lower levels. The water flowed out along an adit. However the vein was being mined at levels below the bottoms of these pumps and presumably the waterwheel was not powerful enough to drive pumps with a deeper lift. Later in 1779, the Company was planning either to install a second waterwheel to replace the hand pumps which drained the Susannah Level or to sink a new shaft and place a steam engine at the top of it. Smeaton considered building a steam engine at the mouth of the adit which could operate pumps inside the mine by "sliding rods" along the adit but recommended installing a reciprocating water-pressure engine instead inside the mine.[11]

Watt must have become involved when the Scots Mining Company was trying to drive the Susannah Level deeper in 1765. The Company wanted to show that it was operating the mines properly because their lease, which may have been granted or taken out again in 1747,[12] did not have long to run and they feared "the improbability of its being renewed".[13] One way of convincing Lord Hopetoun to grant them a new lease was to raise more ore, which meant extending the mining galleries. That June, the secretary, James Farquharson, wrote to Stirling that, "It would be a great pity if this Society should be deprived of the benefit of the Ore yet remaining for want of more Level to carry off the water".[14]

The Company faced two problems with water. One was water




***Newcomen-type engine designed by Watt for installation underground at Leadhills.***

penetrating the mine workings which flooded them and prevented the miners extracting the ore. This could be solved by pumps, and at that time the most powerful pumps were driven by waterwheels. The other problem was to ensure an adequate supply of running water outside the mine which could be diverted to turn waterwheels. Waterpower might also be used to operate stamps for crushing the ore, for washing the ore and for driving bellows at any smelt mill. Smeaton noted that the water supply for the wheel in the mine was sometimes frozen up for four months in the winter which stopped both the wheel and the men working.[15] On the other hand, work might also come to a halt in the summer through a drought, as may have occurred in July 1765 when it was reported ,[16]

*The Company's Works at Leadhills, except the carriage of Lead, are almost at a stand for want of water. They [the Committee] are no less concerned at the difficulties you apprehend you shall have to encounter with regard to the Works in the Susanna Vein.*

With waterwheels inoperative for long periods of the year, either through frost or drought, Stirling considered replacing or supplementing them by steam engines. At their meeting on 8 August 1765, the Court of Directors discussed an estimate sent by Stirling as well as the renewal of their lease.[17]

*As to the former [the estimate] the Court observes your opinion, for which they will always have the highest regard, is quite against the Water Engine proposed, and that you rather incline to a Fire Engine, and are going to obtain the best Information you can whether a small one of the latter Sort may not be sufficiently effectual for draining the Water from the Susanna Vein. In the meantime, they wish you to avail yourself of all the advantage you can from Hand Pumps & will be glad to hear your further opinion on that important affair.*

Later correspondence shows that this part of the mine was being drained by twenty-four men daily operating lever pumps, so it is unsurprising that a more economical method was being sought.

Unfortunately James Watt's estimates for his engines at Leadhills are not dated but it is possible, from the following letter, that Stirling sought his advice at this time in August 1765 when Watt was experimenting with model engines.[18]

*They [the Committee] approve & commend your zeal & activity in the pains you are taking to obtain the best Information possible in Scotland, touching the uses & improvements of Fire-engines, that you may be the better enabled to get one constructed for the company at the Susanna Vein, where the use of it may be of the greatest advantage. But if you should not obtain there all the satisfaction you could wish it might perhaps be worthwhile to see what is done by the various machines used in the North of England for draining of Mines & Coal Pits, where they say great Improvements have of late years been made in that way.*

During the autumn Stirling must have proposed testing some other form of pump, for which approval was given[19] "provided it will not interfere with Erecting an Engine" and he was asked to obtain the necessary information about the construction and expense of fire engines "with all convenient dispatch". Hamilton, who had replaced Farquharson as secretary, supposed that Stirling was away during November and the early part of December making his enquiries as there had been no communications from him.[20] Hand pumps had been used with success to drain the Susannah Level so presumably ore was being won which Thomas Watts, the Treasurer, hoped would please Lord Hopetoun and encourage him to renew their lease.[21] Watts was also

*glad to find that the Engine necessary to be erected there should be done at so small an Expence, as the Gentleman whom you have consulted, imagines, but perhaps he may think otherwise, when he views the Works.*

A letter from Hamilton at the end of January confirms that the gentleman was Mr. Watt and Hamilton urged "as much dispatch in that affair as the nature of it will admit".[22] But Watt had not

visited Leadhills by early March when Hamilton again enquired about costs of erecting a steam engine as well as its fuel consumption and other annual running costs such as keeping it in repair. He wished to have these figures as well as figures of the amount of water to be raised and the height for the next meeting of the Committee in the middle of April because the Company had been approached by another person who had obtained a patent for a new machine for drawing off water worked by men.[23] The rival machine had been invented by a Mr. Erskine who demonstrated it to some members of the Committee.[24]

*From the simplicity of them [the machines], & the description we have been able to give him of the Engine necessary for our Purpose, we have great reason to imagine, he will make one much better & cheaper than any that we have yet heard of. However this matter is not absolutely determined as yet.*

This letter was written on 10 April, at the same time was Watt went to Leadhills. We will never know whether he had hoped to install an engine at Leadhills with a separate condenser and whether these hopes were dashed by the failure to erect that engine at Kinneil. He inspected the site but could not send in his estimates immediately because he had to work out the costs of erecting the engine and Stirling had to calculate the price of forming a chamber in the rock to house it underground.[25] In the meantime, Thomas Watts had[26]

*seen some Modells of Machines belonging to the Man & particularly one which if it answers in the large, as well as in the Modell, will answer the Purpose better, & come much cheaper than that proposed by Mr. Watt.*

The model was 3 feet in length, just over a foot wide and 4 feet high and threw up water in a continuous stream to the height of 45 feet. If this type would not do, Erskine proposed one of another design. He was asked to go to Leadhills to inspect the site and set out at the end of April.

Erskine arrived on May 7th and the next day was "preparing himself for a long journey underground with the overseers whom I ordered to take time enough to shew him everything that can in anywise affect his Engine".[27] Stirling's account of this visit tells us a great deal about Erskine's pump and the problems Watt had to face in the design of his engine. Stirling had sent a sketch of the place where the engine was to be erected underground. It was not possible to transport there any parts of an engine longer than ten feet, or perhaps twelve if some sections of the rock were cut away.[28] Erskine's pump was wrought by a wheel, so must have been some form of rotary pump and not like the lever pumps used at Leadhills up to that time. It would not require much of the rock to be cut away and Erskine undertook to employ only eight men to pump the water up from 20 fathoms compared with the twenty-four then needed daily. To raise the water from thirty fathoms, he would employ only twelve men compared with the thirty-two in Stirling's way. Stirling foresaw one problem, that the mine might be flooded when it became necessary to lower Erskine's engine as the levels were sunk deeper because the engine had to be taken to pieces and re-erected to move it. Also, to repair it, parts would have to be ordered from Edinburgh. However Erskine's engine would cost only £100.[29]

*Mr Watt said that a Fire Engine sufficient for our business would come to £150, besides the cutting out of some part of the rock. It would be a troublesome thing to supply it with coal underground, and bring the ashes up to the surface. It has one advantage that it would be fixt on the level never to be removed and could never be laid under water. Mr Watt is very remiss in sending some computations which he promised to send long ago and with which one must be furnished in order to estimate the whole expence of his machine.*

No consideration seems to have been taken about water for the boiler or for condensation, presumably that for the waterwheel would have sufficed. Nor is there mention of how the smoke would escape, possibly up the shaft down which the water fell to the wheel. It seems hardly practical to have placed a Newcomen engine and boiler deep underground, although Smeaton mentions that there was one in the coal mines of Whitehaven.[30] On the other hand, there would be no problem getting Erskine's machine "through the subterraneous passages" and, on 24 May, Stirling said, "I shal [sic] therefore write to Mr Watt to do nothing in that affair till he hear from me".[31]

Stirling's comments show that he had received some estimates from James Watt which may have been based on figures surviving in the James Watt Papers.[32] Watt must have been asked to design an engine to pump from the lower level of 30 fathoms or 180 feet. Watt observed that raising water from the existing 20 fathom level required five pumps, each 5 inches diameter and a lift of 4 fathoms. The top pumps were worked by two men at a rate of 32 or 34 strokes a minute. The engine would work a pair of pumps, each of 15 fathoms, 9½ inches diameter, having a three foot stroke at 20 strokes a minute. To raise this water, he proposed a cylinder of 44 inches diameter, price £8, and a boiler between 6 to 7 feet diameter, price £19. The total cost for the engine without the mine pumps was only £56. There are no dates on these documents and it could be that this estimate was the one sent in January which Thomas Watts was pleased to find so low. However there is a further set of calculations in the James Watt Papers in which the boiler is priced at £32.17.6 and the cylinder with bottom and piston at £26. The total for this second engine came to £104.2.8 and for the mine pumps £48.1.6, which corresponds with Stirling's figure in May of £150. No allowance was made for transport of the parts but there was £5 for erection. Even this second estimate seems low when compared with one a little later for an engine at Carron for nearly £1,000.[33] No estimates have survived either for annual coal consumption or maintenance.

Watt's papers also include two drawings of the Leadhills engine which show a novel layout. The cylinder is upright, in the customary Newcomen engine position, but the round topped haystack type of boiler is to one side at a lower level and a hot well also at one side lower down. The cylinder is situated right on the edge of the mine shaft, down which the top of a pump can be seen. So that his engine parts could be carried underground, and to save making a large chamber in which to house his engine, Watt replaced the long rocking lever beam with a wheel. The piston inside the steam cylinder was connected to the pumps down the mine by a chain passing over this wheel. The pivots of the wheel were supported on wooden framing with one vertical leg and a brace at either side like a letter "A". The wood for this framing would have cost £2.6.8 and 10/- for the wheel.

While Watt failed to win this order which was probably his first attempt to build a full-size atmospheric steam engine, this Leadhills design does show Watt's willingness to experiment and venture into new and original forms of construction.

## ACKNOWLEDGEMENTS

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