

Publisher's Note - Part - 3

Over 3500 drawings covering some 272 separate engines are brought together in this section devoted to original manuscript plans and diagrams.

Watt's original engine was a single-acting device for producing a reciprocating stroke. It had an efficiency four times that of the atmospheric engine and was used extensively for pumping water at reservoirs, by brine works, breweries, distilleries, and in the metal mines of Cornwall. To begin with it played a relatively small part in the coal industry. In the iron industry these early engines were used to raise water to turn the great wheels which operated the bellows, forge hammers, and rolling mills. Even at this first stage of development it had important effects on output.

However, Watt was extremely keen to make improvements on his initial invention. His mind had long been busy with the idea of converting the to and fro action into a rotary movement, capable of turning machinery and this was made possible by a number of devices, including the 'sun-and-planet', a patent for which was taken out in 1781. In the following year came the double-acting, rotative engine, in 1784 the parallel motion engine, and in 1788, a device known as the 'governor', which gave the greater regularity and smoothness of working essential in a prime mover for the more delicate and intricate of industrial processes.

The introduction of the rotative engine was a momentous event. By 1800 Boulton and Watt had built and put into operation over 500 engines, a large majority being of the 'sun and planet type'.

The Engineering Drawings reproduced here enable a thorough examination of developments between 1775 and 1800 and reflect the dominance of the 'Sun and Planet Type' of engine in this period. The material is made available under geographical headings to facilitate regional comparisons, analysis of distribution of engine types and method of use and employment.

The first 'Sun and Planet' engine was set up at Soho, in Birmingham, towards the end of 1782. By this time the call for rotative engines had become very insistent. In June 1781 Boulton wrote, "the people in London, Manchester, and Birmingham are steam mill mad", and Watt, in September 1782, exclaimed, "Surely the devil of rotations is afoot." Watt was now hard at work on rotative engines, dealing with schemes and with enquiries from people who wanted engines. His Blotting and Calculation Book of 1782-3 shows him making experiments on the friction of the engine, calculating the size of the flywheels, and working out the power required to drive corn-mills, cotton mills, and mills for rasping and grinding logwood. In October 1782 we find him complaining to Boulton that his research work on rotative engines had been taking up all his time with the result that much other business had been neglected.

The first rotative engine erected outside the Soho establishment was that put up for John Wilkinson at Bradley. It was in operation at the end of March 1783. The drawings for this engine are covered in this microfilm edition. They are part of Portfolio 249. The other engines made for Bradley between 1780 and 1791 are also covered and include engines for boring and turning, a Colliery Winding Engine and a Rolling and Slitting Engine. The 'Sun and Planet' gear and cam-shaft for the Bradley Forge Engine are well illustrated in a drawing dated July 1782.

The sun-wheel is 48 inches in diameter, and had 36 teeth, so that the pitch is about 4 in; it consists of two rings, 3 inches wide, bolted together with the teeth stepped; the shape of the teeth is shown in large scale in the top figure of the drawing. The outer ring is bolted to a disk formed on the end of the journal section of the cast-iron shaft; the periphery of the disk is formed with recesses to receive joggles on the rings.

The planet-wheel is half the size of the sun-wheel and consists of two toothed disks, separated by a disk of wrought iron engaging between the rings of the sun-wheel; the inner disk is formed with a gudgeon to receive one end of a link which at the other end embraces the shaft; the outer face of the other disk is formed with a cross-shaped recess to receive a corresponding joggle cast on the end of the connecting-rod, to which the planet-wheel is secured by bolts passing through disks.

Further examples of engines covered include:

- Aitchesons & Brown for a Distillery at Clackmannan (first drawings January 1787)
- Henry Coates and John Jarratt (see Portfolio No: 1) for their engine at Kingston-upon-Hull. They had the first double-acting engine with straight-line linkage (first drawings dated May 1784)
- Howard and Houghton's Oil Mill (see Portfolio No: 16) at Sculcoates (first drawings dated September 1786)
- Joshua Foster's Wool Manufactory at Horbury in the Parish of Wakefield. Payment £812. (first drawings October 1795)
- the Sun and Planet type engines supplied to the Cotton Manufactories in Lancashire (about 49 separate engines) including John Orrell for a Cotton Mill at Staleybridge and James Taylor and Son for a Cotton Mill in Rochdale.
- Samuel Oldknow of Stockport near Chester (see Portfolio No: 62) for a Cotton Mill at Stockport (first drawings 1791)
- Jonathan Stonard and James Curtis (see Portfolio No: 3) for their Starch Manufactory in the High Street, St Mary's Lambeth. (earliest drawings October 1784)
- Brown, Chalmers & Co for a Paper Mill in Aberdeen (first drawings July 1802)
- James Forbes Low & Co for a Cotton Mill in Aberdeen (first drawings May 1802)
- Dyker Smith for a Flour Mill at Peak House near Falkirk, occupied by Mr Renny in 1811. (first drawings May 1800)
- Walkers Ward & Co of Chester (see Portfolio No: 184) for their Lead Manufactory. (earliest drawings April 1799)
- G & J Robinson of Papplewick near Nottingham (see Portfolio No: 9)
- Thomas Dobbs (see Portfolio No: 6) for Lifford Rolling Mills at Kings Norton (Parchment dated 1st December 1785)
- Felix Calvert & Co (Portfolio No: 5) Engine for the Brewery in the Parish of All Hallows, Upper Thames Street, London. (Parchment dated 1st March 1786)
- Timothy Harris of Nottingham (see Portfolio No: 7) for a Cotton Mill at St Mary's, Nottingham. (first drawings December 1785)
- Samuel, Davey Liptrap & Co of Whitechapel Road for a Malt Distillery in Mile End, first parchment dated 1st March 1786.

- Albion Mill (see Portfolio No: 97) Engines for the large steam flour-mills excited a good deal of discussion at the time and the machinery was inspected by a great many people. Albion Mill was erected on the Surrey side of the River Thames near Blackfriars Bridge. Plans date from 1782.
- Benjamin Severn for his Sugar Manufactory in Whitechapel.
- Josiah Wedgwood (see Portfolio No: 97) for 3 separate engines dating from drawings as early as April 1782.
- Hawkesbury Colliery (see Portfolio No: 241) two Winding Engines, the first of these was repurchased by Boulton and Watt and sold on to the Lancaster Canal Company (earliest date of drawings February 1791)
- W E Chapman & Co for a Rope Manufactory in Newcastle-upon-Tyne
- Sir Richard Arkwright for a Cotton Mill at Nottingham. (first drawings March 1790).
- Royal Plate Glass Company (Portfolio No: 192)
- Birmingham Flour and Bread Co (Portfolio No: 141)
- Samuel Whitbread (Portfolio No: 4) for a Brewery in Chiswell Street, in the Parish of St Luke, Middlesex. This engine was of the Chain-Beam Type. (first drawings June 1784).
- Coalbrookdale (Portfolio No: 238)

At first Watt was not quite satisfied with the 'Sun and Planet' gear. He found that the revolutionary wheel had a tremulous motion that he did not like. He first proposed to remedy this by strengthening the swan-neck part of the connecting-rod, but he found that this was not an ideal solution. With further experiments he did resolve the problems.

How were the Engines made?

In 1775 there were no engine works in existence anywhere in Britain. Engines were put together on site, at the mine or mill in question, with the erection being supervised by an engineer.

The engineer, in some instances, entered into a contract to supply an engine, but more usually he seems to have been paid for his services, and the engine parts and materials were purchased directly by the mine or mill-owner, who also paid the workmen employed on the job. The principal parts bought in a condition ready for use were the cylinder, cylinder bottom, and the working barrels of the pumps. The bored cast-iron work - cylinders and pump barrels - all came from one of four ironworks - Coalbrookdale, New Willey, Bersham, or Carron. The smaller castings were sometimes obtained from the same place as the cylinders, at other times locally. The boiler, and all the wrought-iron work, was made on the spot, and the wooden beams also. Accordingly the engineer had under him a staff of smiths, carpenters, plumbers, and masons for building the engine house.

This, indeed, was the position of affairs when Boulton and Watt commenced erecting their engines, and it was substantially on these lines that the firm carried on work for a number of years.

Taking the period say about 1780 the valves and nozzles were the only parts of the engine made regularly at Soho. They cylinder, its cover and bottom, the piston, the air-pump, and the condenser were made at Bersham, then in the hands of John Wilkinson, who made nearly every one of Boulton and Watt's cylinders up to the year 1795. The nozzles themselves were cast at another of Wilkinson's works - Bradley, a few miles from Birmingham - and brought to Soho to be fitted. Beam gudgeons, plummer blocks, and sundry other castings were supplied from the same works, while the cylinder jacket, or outer cylinder, together with some smaller work were cast at the Eagle Foundry, Birmingham. Fire-bars and other furnace fittings and small parts were sometimes cast in the locality where the engine was to be erected. The copper eduction pipes were made in London, and the wrought-iron piston-rods either at Seaton in Cumberland or in London.

These parts were ordered by Boulton and Watt from the various makers on account of the mine - or mill-owner; Boulton and Watt sent the necessary drawings and instructions, and kept a staff of men to supervise and do part of the work of erecting. These men were paid by the person for whom the engine was being erected. It was one of the great difficulties of the firm to get together, and to retain, a suitable staff of erectors.

The course pursued in erecting an engine in the year 1778, is described in great detail by Watt himself in connection with an engine for pumping brine at Thirlewood at the Lawton Saltworks, Cheshire (Salmon's engine). His account is too long to reproduce in full. An outline of the main features is set out below:-

"When Watt arrived at Lawton on February 4, 1778, the engine materials were on the spot, and he found the engine-house ready for putting up the cylinder. Next day the beam was got up and the martingales at the cylinder end put on; also the cylinder bottom was set out for drilling. On the 6th the inner bottom was drilled for the holding-down screws, and the brick platform or foundation for the cylinder was begun; this was completed the following day, when also the windlass was fixed on the upper floor. On the 9th the upper flange of the cylinder was drilled and the small holes in the inner bottom were drilled and tapped; the inner bottom was then screwed down and the inner cylinder put in place. Next day an attempt was made to raise the outer cylinder; but, in consequence of a failure of the rope, this was not accomplished until the day after, when also the inner cylinder was levelled, the two cylinders set nearly parallel, and the lower part of the nozzle fitted; on this day too the boiler seat and the ash-hole were marked out.

On the 12th the setting parallel of the cylinders was completed, the bottom joints of the outer cylinder made with dung and blood, the upper part of the nozzle fitted, the condenser cistern moved into its place, and the copper eduction-pipes tried together. "

On this day Watt remarks:

"We had a good deal of chiselling at the flanches of inner cylinder opposite the holding down screws before would suffer front joint of outer cylinder and bottom to come fair and we had to cut off the outer side of ye washers under the pillars to a quarter inch broad, otherwise kept the bottom joint open."

"On the 13th both nozzles were screwed on 'for good', the joints being made with pasteboard and putty, the boiler setting was begun, and half the upper floor of the engine-house laid. Next day the two cylinders were set perpendicular, and the piston filled up with wood; the piston-rod, it was found, did not fit the piston, being 3in in diameter at the base of the cone instead of 2 5/8in; the boiler seat was finished and the chimney commenced.

On the 16th, the next working day, the boiler was put on its seat and the flues built up to the arch, the piston was put in, the screws of the stuffing-box lengthened, the guide-posts fixed up, the holes bored in the plug-tree, and staples made for the Y-

shafts. The following day the working-gear was fitted up, and on the day after more work was done on the gear, and the air-pump was screwed together. The 19th saw the joining up of the education pipe, 'by pouring lead with a small mixture of tin into copper bosses surrounding the joints', the drilling of the steam pipe flanges, more work on the working-gear, the completion of the boiler setting, and progress on the chimney.

The next day we have two men making screws, another soldering up the hot-water pump, another putting the arches for the air-pump chains on the beam. On the 21st certain defective joints in the education pipe were unsoldered and made afresh, and the beam was adjusted.

The next week was taken up in work connected with the pump end of the beam, and in fitting and fixing the steam-pipe, fixing down the condenser in its cistern, hanging the chains for working the air-pump, fitting the brake or lever for working that pump by hand, and fixing the manhole screws in the boiler. Later, there is an entry that: 'Manhole screws with T-heads would not answer, ordered bolt-head screws and fixed nuts'.

On March 3rd fire was put under the boiler, and the piston packed, and on the day after steam was turned on to the engine which was found 'in general very tight'. The succeeding days were taken up in minor jobs, and then on the afternoon of the 11th we read 'set the engine agoing, raised water to top of pitt trees, drew much air, and the condenser top let in much water, about a gallon pr stroke'. On the 12th the engine was christened in the presence of 'a great lot of people'. The engine went off very well, but not so the pumps; 'the upper lift soon begun to draw air, sett on ye jack-head but it proved very leaky ... with difficulty got a little brine to top of bank'. Although the engine worked, it was not doing what it should do, so the following day, in addition to overhauling the pumps, the air-pump and condenser were attended to, and Watt gave instructions for an alteration of the gear for working the exhaust valve. He left Lawton on March 14th.

It will be seen that the work of erection began on February 4th, and that the engine was set going on March 11th. There were some minor difficulties with the pumps, but the engine itself went off very well, and it continued to do well, for in August 1779 we find that Salmon had written 'a letter full of praises of his engine'."

[Reproduced from pages 257 et seq in James Watt and the Steam Engine by Dickinson & Jenkins (Clarendon Press 1927)].

See also letter Watt to Boulton, August 13, 1779 in the Matthew Boulton Papers (covered elsewhere in this microfilm project, see Part 1).

By the year 1778 the procedure in erecting the engines had become regular and systematic. This is borne out by the fact that in the following year Watt set about the production of a hand-book bearing the title 'Directions for erecting and working the newly-invented steams engines. By Boulton and Watt.' This, the first book in the English language devoted to the steam engine, was not published in the ordinary way, but was produced for private circulation among the clients of the firm, who, it must be understood, were under no compulsion to have their engines put up by the Soho erectors. It seems that one hundred copies only were printed, and the book is accordingly very rare; it is reproduced in Part 2 of this microfilm project. The title-page bears no date, but certain entries in Watt's Journal make it clear that it was printed in 1779.

"1779:

May 25 Writing directions for putting engines together.

June 6 Writing directions for putting engines together.

June 7 Gave directions to Mr Rollason to be printed.

June 10 Corrected proofs of directions and sent them 20 more pages.

June 11 All day at directions, wrote 19 pages.

June 12 In forenoon at the printers, ordered 50 copies on copy paper and 50 on thin post paper.

June 29 Wrote to Mr Hornblower with copy of engine directions.

August 10 Writing directions for working and managing engines.

August 11 Finished engine directions which gave to the printer.

September 4 Rec'd the 1st plate, the piston, from the engraver, he charges 10/6 for it & says it took 3 days."

Some years later, after the introduction of the rotative engine, another set of 'Directions relating to the engine' was printed as a single sheet, no doubt with the intention that it should be pasted on a board and hung up in the engine-house. This also is reproduced in Part 2 of this microfilm project.

But apart from these 'Directions', we find Boulton and Watt making free use of printing in the course of their business. For their reply to an inquiry for a mine pumping-engine they had a seven-page quarto pamphlet: '*Proposals to the Adventurers in ... By Boulton and Watt*', setting forth in full the conditions for the grant of a licence to use the engine, and the manner in which the royalty was determined, with blank spaces for the insertion of such particulars as the name of the mine and the size of the engine. Printed lists of the materials for each engine came into use in 1778. These lists were filled in in writing with the names of the places from which the various parts were to be supplied and any necessary directions as to erecting, etc. For the engines in Cornwall printed forms were employed from 1780 for the periodical returns of the engine performances, and printed books were supplied to the mines for the same purpose. Curiously enough, as it may seem to us now, the firm did not make use of printed letter-headings.

When we consider the developed state of the means of transport at that period, it becomes an interesting subject for the study how the different parts from these widely separated localities were brought together at about the same time, for the erection of an engine, say, in Cornwall. It is clear that a good deal of fore-thought and an extensive organization were necessary, and that the commercial side of the Boulton and Watt concern had not a few difficulties to surmount.

The transport of goods made in London was the simplest problem of all, as there was a frequent service of ships direct between the Thames and one or other of the Cornish ports. The goods from Soho and Birmingham were carted to the Canal, along which they were taken to Stourport on the Severn. There they were transhipped and carried down the river to Gloucester, Bristol, or Chepstow, and again transhipped into a coasting vessel which completed the transit. The goods sent direct from Bradley could be loaded into the canal barge at the works. The Bersham goods were sent by road to Chester and there shipped to a Cornish port. Usually the cargo was made up with fire-bricks, in which there was a considerable trade to Cornwall. The piston-rods made at Seaton were usually shipped at Whitehaven or Workington to Liverpool, taken thence to Chester, where they were loaded on the same vessel as the cylinder, etc, from Bersham. At least this was the course that it desired to follow, but frequently the rod did not arrive to time.

The Soho Manufactory was established in 1765. It is only in 1781 that we find Boulton engaged about the plan of a new engine-shop, a two-story building that was completed by the end of the year and cost a little under £110.

A perusal of the Boulton and Watt papers show that Watt did not take any active part in the direction of the engine works, or

in the improvement of the methods of production. He had an office at his house at Harper's Hill, and it was there that he carried out his work, calculations, drawings, and correspondence; the mere bulk of the product forms abundant evidence that he worked very hard, and it is clear that frequently many days elapsed between his visits to Soho to inspect the progress of any new schemes on hand, and to discuss business matters with Boulton. Possibly in Boulton's absence his visits may have been more frequent, but on one occasion we find Boulton writing from Cornwall requesting him to try to go down to Soho, or else to send his assistant Playfair, to see that matters are going forward satisfactorily.

It was Boulton who managed the works, kept an eye on costs, and sought to improve the methods of production. Thus we find him writing, from Cornwall, that cast iron was not suitable material for the racks and sectors for operating the valves, and suggesting that 'it would be safer to forge them of steel & cut them down with a cutter in the mill', and then a little later on suggesting a machine for dividing and cutting the teeth. See letter, Boulton to Watt, November 6, 1780 in the Boulton and Watt Collection.

Boulton also writes to Watt on the subject of nozzle-fitting, in which they are much behind hand, suggests that the collars for the spindles be made of brass instead of steel as it would save time and expense, and comes back to the tooth-cutting machine and the grinding of the flats 'instead of chiselling'. See letter, Boulton to Watt, April 19, 1782 in the Boulton and Watt Collection.

Boulton next turns his attention to the castings themselves, and proposes to go over to Bradley Ironworks to see a nozzle moulded, and to discuss with the moulder the best means to avoid the considerable amount of chipping now entailed in fitting up the nozzles.

Apparently, it was not before the year of 1794 that the firm took the first serious steps towards doing more of the engine work themselves. The original idea was to have a boring-mill, and Peter Ewart, who was then in business as a millwright, and superintending the erection of Boulton and Watt's engines in Manchester, was brought to Soho to design and superintend the erection of a separate establishment at Smethwick, which became known as the Soho Foundry, and was about a mile distant from the parent establishment. Soho had the disadvantage that everything had to be brought there and taken away by road; when the question arose of dealing with large cylinders and other heavy articles this became an important matter; possibly it may have been the factor that determined the setting up of a new works. At any rate, in selecting a site for it the point was kept in view, and the plot of land acquired had a frontage to the Birmingham Canal, from which a branch was cut and a dock formed within the works.

The production of drawings for all these engines was a considerable endeavour. Drawings were made at Watt's own private residence, and when he got the assistance of Playfair, and afterwards of Southern, it was at his house that they attended. This remained the state of affairs until 1790 when the drawing office was moved to Soho Manufactory. There was no separate drawing office at the Foundry, although this was a distinct engine-making business; at least this seems to have been the case as late as 1826.

The development of the Soho Engine Manufactory during the fifteen years 1786-1801 is illustrated by a paper in the Muirhead Collection which summarises the amount of the inventory of the property, the number of the workmen, the wages paid, and the number of engines put up in these years. On October 1, 1786, the inventory showed the value of the property to be £2,319; on October 1, 1800, it amounted to £9,010. The wages paid to the workmen for the first year of this period amounted to £1,688, and for the last year £3,407. In 1786-7 from fifteen to twenty men were employed (not including the men engaged outside as erectors); in 1795-6 the number was from fifty to fifty-five.

For the period 1798-1803 some interesting particulars of the costs and methods of production at the Engine Manufactory are summarized later on with like information in respect of Soho Foundry. The two establishments were conducted as separate concerns, and the Engine Manufactory continued in operation until about 1850, when the Soho Manufactory was dismantled and the engineering establishment was concentrated at Soho Foundry.

This microfilm set provides a wide range of engineering drawings. It reveals the diverse use and disparate location of the 'Sun and Planet' type engines erected and supplied by Boulton and Watt in the period after 1775. They played a vital role in the Industrial Revolution. Their engines had important uses at collieries, cotton mills, flour mills, breweries, distilleries, glass-works, rolling mills and, increasingly, in the iron industry for raising water to operate bellows, forge hammers and other equipment.

As Professor Barry Supple (Master, St Catherine's College, Cambridge) comments, "*The revival of scholarly interest in the Industrial Revolution, and the debates and controversy surrounding it, should give even more prominence to the sort of archival material embodied in the Boulton and Watt Papers*".

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Technical Note - Part 3

Our microform publications have been prepared and produced in accordance with recommended and established guide-lines for the production of microform of superior quality. These conform to the recommendations of the standard guides to good microforming and micropublishing practice.

Attention should be drawn to the nature of the original material. Part 3 contains portfolios of engineering drawings. The size and dimensions of individual drawings varies considerably. Where necessary some very large drawings have been filmed in sections. These manuscript drawings have been compiled with a variety of inks, pens or pencils. Many drawings compose areas shaded or drawn in a variety of different colours. These have been reproduced as clearly and effectively as possible using archivally permanent black and white film. The choice of black and white film was governed by the need to provide a permanent film record of such a large number of drawings.

These original characteristics present difficulties of image and contrast which stringent tests and camera alterations cannot entirely overcome. Every effort has been made to minimise these difficulties. The outside covers of the portfolios have not been filmed. Portfolio numbers are identified by specific targets.

The most responsible care has been exercised in the filming of this unique collection and every effort has been made to ensure that this microform publication meets the standards established by the Association for Information and Image Management (AIIM), the American National Standards Institute (ANSI) and prevailing European standards

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Detailed Listing - Part 3

Note of Explanation:

The following list has been compiled from the Catalogue of Old Engines (which is reproduced at the start of Reel 29).

Data is provided under the following headings which run across a double page:

On the verso:

Portfolio Number

Approximate Number of Drawings in that particular portfolio.

Earliest Date on the Drawings

Number of Engines covered in that particular portfolio.

Type of Engine S = Single Acting D = Double Acting

Cylinder Diameter x Stroke

Horse Power

RPM = Revolutions per minute

On the recto (and relating to entries on the left hand page) :

Owner of the Engine

Other Details

This frequently gives information about the use of the engine eg: was it for a Flour Mill, a Cotton Mill, a Brewery, a Distillery etc; any subsequent sale of the engine; site and location of the engine; amounts paid; height and weight and any other useful details.

[Please click here to download a PDF of the Detailed Listing to Part 3](#) (49 pages)

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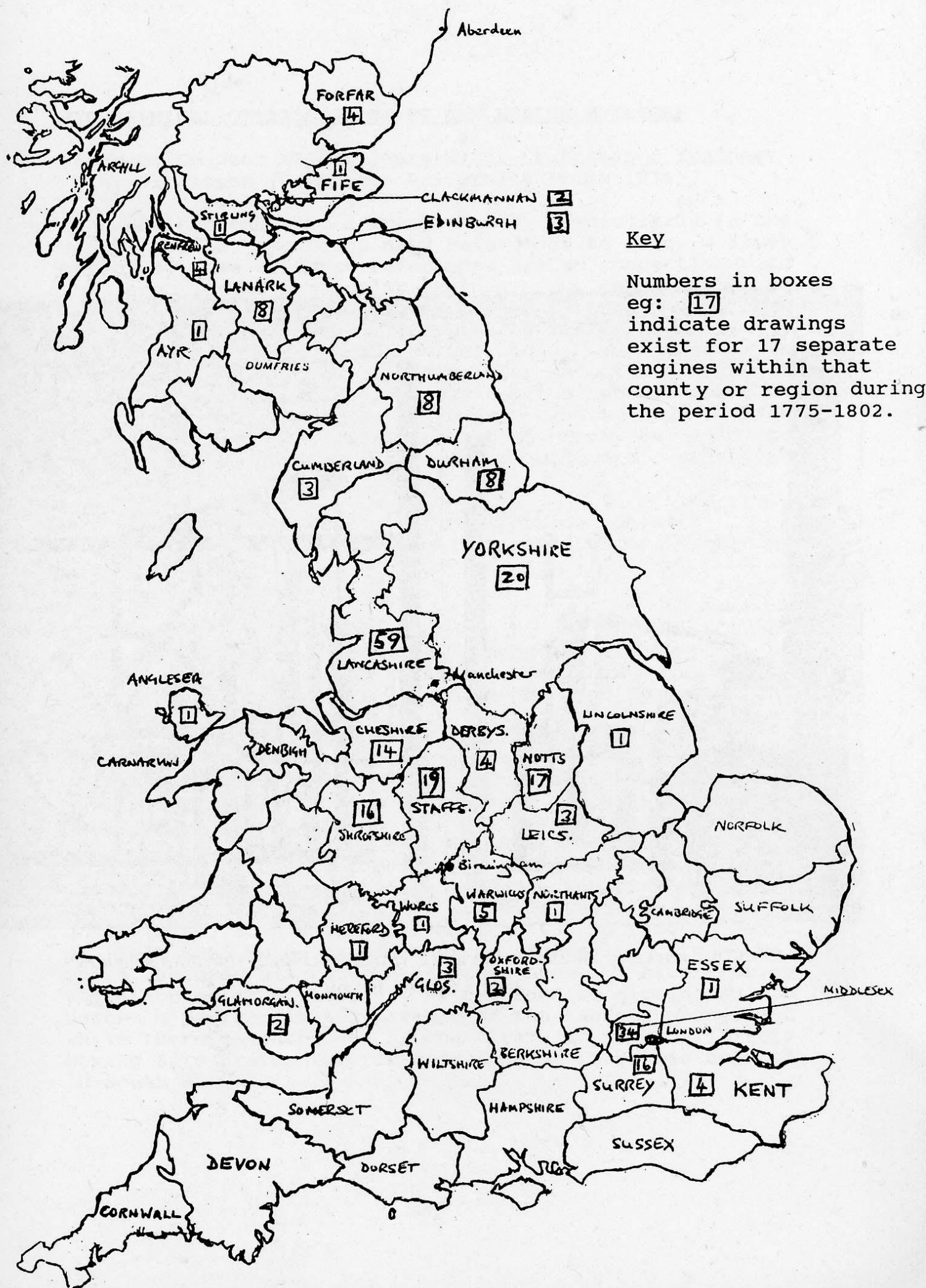
Watt Engines of the Sun and Planet Type, 1775-1802

(Site by geographical location)

[Please refer to this map for locations](#)

Country	Region	No of Engines	Please see Portfolios on Reel Nos:
SCOTLAND	Ayr	1	29
	Lanark	8	29
	Renfrewshire	4	29
	Stirling	1	29
	Clackmannan	2	29
	Edinburgh	3	29
	Fife	1	29
	Forfar	4	29
ENGLAND	Lancashire (Cotton Mills)	48	30 & 31
	Lancashire (Other than Cotton Mills)	11	31
	Yorkshire	20	31
	Cheshire	14	32
	Cumberland	3	32
	Northumberland	8	32
	Durham	8	32
	Lincolnshire	1	32
	Middlesex	34	33 & 34
	Surrey	16	34
	Worcestershire	1	34
	Derbyshire	4	34
	Leicestershire	3	34
	Shropshire	16	34
	Warwickshire	5	34
	Oxfordshire	2	34
	Gloucestershire	3	34
	Herefordshire	1	34
	Northamptonshire	1	35
	Nottinghamshire	17	35
	Staffordshire	19	36
	Kent	4	36
	Essex	1	36
WALES	Anglesey	1	36
	Glamorgan	2	36
IRELAND		2	36
FRANCE		1	36
SPAIN		2	36
		TOTAL 272	

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BIOGRAPHICAL DETAILS OF STAFF AND ENGINE ERECTORS

[Source: Chapter XXI in *James Watt: Craftsman & Engineer* H.W. Dickinson (Cambridge University Press 1936)].

"The Boulton and Watt correspondence, particularly in the early period, contains many references to the workmen employed; some of these references are in connection with the erection of particular engines, but many relate to difficulties in the Soho workshop arising from the drunkenness and irregularities of the men. As time went on there is less evidence of this; no doubt the organization was improved, a steadier lot of men were got together, and it became possible to weed out the worst of them; indeed, later on, Soho men came to have a high reputation and the establishment may truly be said to have been a nursery for millwrights and mechanical engineers."

Set out below are some brief biographical details on a number of individuals, arranged in alphabetical sequence:

William Brunton

In 1796 Gilbert Hamilton was engaging men in the Glasgow district for Boulton and Watt. Among others he took on Brunton, who had been working under his (Brunton's) father, "making iron and brass machinery" for the New Lanark Mills. He came with a testimonial that he "is an ingenious lad in his business, that he has received a virtuous education, & is accordingly both temperate and attentive". Brunton very soon made his mark with Boulton and Watt. A little more than twelve months after he was engaged, we find John Southern reporting: "William Brunton is a very valuable hand, and has more "gumption" than most of his contemporary engine erectors." Less than five years after this he was made superintendent of the engine yard at Soho, a position that he retained until 1808, at a salary rising from £80 to £100 a year. He left Soho to go as engineer to Butterley Ironworks, where he made his celebrated steam horse. After seven years or so at Butterley, he returned to Birmingham to become a partner in and manager of the Eagle Foundry, and while there invented one of the first (if not the first) moving fire grates for furnaces. Later on he was engaged in South Wales.

Richard Dayus

Richard Dayus was employed by Boulton and Watt from 1786 until 1804. In 1791 he was sent to Nantes in France to erect an engine for a corn mill and seems to have witnessed some of the more exciting scenes of the French Revolution. In 1800 he was Boulton and Watt's principal erector in London. Rennie thought very highly of him and reports that Dayus was earning over half a guinea a day by this time.

Peter Ewart

The name Peter Ewart occurs in the Boulton and Watt correspondence at a comparatively early date. Thus in 1781 we find Boulton writing to Watt: "I have had a letter from Lady Hopton recommending a young man of ye name of Ewart, 15 years of age, but I presume he wishes to be a practical engineer and millwright. Enclosed you have a letter upon the same subject. I think he is a very likely subject from her Ladyship's description of him, and may be of use to us in time, and therefore if it is agreeable to you it will be so to me to take him. We shall find it conv^t to breed up a few

young men as our business will, I am persuaded, increase." Just before, Boulton had been alluding to the necessity of getting Watt some assistance in the drawing office.

The letter enclosed by Boulton was probably the letter from Professor Robison to Watt, given in Muirhead, in which Robison solicits-

"employment for a young lad, a near relation of mine, Peter Ewart by name, who wishes to be educated as a millwright or in any good branch of the business of a civil engineer. I could not find him so proper a master as yourself, and I flatter myself that you would find him a very deserving pupil. His father is a clergyman near Dumfries, and has given the boy a very good education, but with no other views. But the boy's inclinations are so much turned to mechanics, and his mind so much caught by anything of this kind, that we all agree that it is the line of business in which he is most likely to succeed. His constitution is healthy and strong, so that he is perfectly fitted for the hard labour by which he is to get his living. If therefore you can find employment for him I shall look on him as setting out in the most favourable manner."

Ewart, however, seems first to have been apprenticed to John Rennie at Musselburgh. When the latter came south to put up the Albion Mills in London Ewart accompanied him; and it was not until about 1790 that he became connected with Boulton and Watt in a more permanent fashion.

In 1788, Ewart was sent to Soho by Rennie to erect a water-wheel and other machinery for Boulton's rolling-construction of the millwork and machinery for his mint. From 1790 to 1792 Ewart was engaged in erecting Boulton and Watt engines in the Manchester district. In 1791 he informs Watt that he had taken a shop in Manchester, and was engaging some hands to begin upon the millwrighting and other work he had undertaken. This business was not of long continuance, for in September 1792 he entered into partnership in a bleaching and calico-printing firm; but this lasted only for a year. In 1795 and 1796 we find him again at Soho laying out shops and plant and devising machinery for Soho Foundry, and for the Engine Shop at Soho Manufactory, including the designs for the boring mill. In reference to the latter, he wrote early in 1797 from Manchester to James Watt junior, "I am exceedingly mortified by your account of the boring mill. I cannot think that the jarring is owing to the weakness of the wheel, for every part of it is much stronger than the rod in proportion to the distance from the centre."

From 1798 to 1835 Ewart was concerned in cotton-spinning in Manchester; he was then appointed chief engineer and inspector of machinery in the Royal Dockyards. He died at his official residence at Woolwich in September 1842, in the 76th year of his age, in consequence of injuries caused by the breaking of a chain while he was superintending the removal of a large boiler. Ewart took out three patents: the first in 1813 for working looms; the second in 1822 for coffer dams (this invention was used at the Liverpool docks); and the last in 1833 for spinning machines.

Joseph Harrison

The "father" of the Soho workmen was undoubtedly Joseph Harrison. Nothing is known of his antecedents, but it is reasonable to suppose that Boulton picked out a man who had some experience in the erection of the Newcomen engine. At any rate it was Harrison who re-erected the Kinneil engine at Soho, and in 1775, when the Bill for the

extension of Watt's patent was before Parliament, he was one of the witnesses examined by the Committee of the House of Commons; he then described himself as "a smith at the Soho Manufactory at Birmingham". With the increase in the engine business and the consequent enlargement of the staff, Harrison became the leading man in the Soho engine-yard, but he was frequently sent out erecting, and many of the earlier engines – Bow, Chelsea, Richmond – were put up or completed by him. One gathers that he was a genial, modest sort of man, not given to making difficulties about his work.

In 1779 Hallamannin, one of the first Boulton and Watt engines put up in Cornwall, was doing badly, the result mainly of faulty erection, and the firm decided upon sending Harrison to put it right.

Harrison's failing was the common one. From time to time he gave way to drinking bouts, moreover he was not a man of any education, so in 1778 when the firm decided to appoint a foreman at Soho, a man called Hall was bought in. Hall's tenure of the position was but a short one, and soon after he left Harrison seems to have been put in charge, and we find him referred to as foreman; possibly his duties were of a more restricted nature than the firm had had in view when engaging Hall. Harrison continued to be sent out erecting for a few years after this; he was erecting Shadwell and repairing Bloomfield in 1781; then, the work at Soho increasing and a number of other men having been trained for erecting, he seems to have remained at head-quarters for the rest of his life. His son, William Harrison, was in due course taken on at the works, was an erector for some years, and then was made foreman of the small engine manufactory in the 6-horse shop at Soho Foundry, 1st January 1800, and continued in that station until his death, 24th August 1815.

Logan Henderson

The first technical assistant engaged by Boulton and Watt was Henderson. Lieutenant Logan Henderson, according to Smiles, had been an officer of marines, and afterwards a sugar planter in the West Indies; he had lost all he possessed in Jamaica, but had gained a knowledge of levelling, draining, and machinery. In the Boulton and Watt correspondence, Henderson is met with for the first time early in the year 1776. He had submitted to Boulton, from Liverpool, a scheme for a rotary engine, and Boulton in reply had sent him an account of the performance of the rotary engines that had been tried at Soho and invited Henderson to call. Henderson paid a visit to Boulton, and being satisfied that his own scheme was inferior to that of Watt, laid it aside. The visit, however, resulted in his being engaged as an assistant, and early in 1777 we find him in London with Boulton, but living at Deptford and travelling to and fro every day. While in Birmingham he lived in Boulton's house. He had charge of the erection of the Torryburn and Byker engines in 1778, and in 1781 he was in Cornwall with Watt. Boulton had thought that Henderson would have lived with Watt and been an intelligent companion with whom he could have discussed engineering matters. Henderson, however, set up an establishment of his own where he lived with a lady referred to as "Miss Peggy"

Perhaps it was as well that Watt and Henderson did not live together; as it was Watt was far from pleased with him, and his letters of this period to Boulton contain frequent references to Henderson's bad temper and sullenness, and show that there was a good deal of friction between him and Wilson, the firm's agent in Cornwall. With Murdock, Henderson got on very well; indeed it is said that he had a great influence over him, and

that he, Henderson, had asserted that Murdock would leave Boulton and Watt if he did so. In 1782 Henderson returned to Birmingham, and about the beginning of the following year he terminated his connection with the firm very abruptly. In 1784 it seems that he was concerned in a foundry in London, and then in 1790 we find him applying, without success, for the post of Engineer to the Dublin Waterworks.

Jabez Hornblower

The son of Jonathan Hornblower the elder, he came from Cornwall to Soho in the same year that Murdock went from Soho to Cornwall; the firm had offered him work at a guinea a week, the same pay as Murdock was receiving, and he was for a few years one of their erectors. He worked on the Ketley, Donnington Wood, and Penryn-dee engines. However, after a few years he left the services of Boulton and Watt as he did not get on well with the other workmen or with his employers. He went on to become a rival engine-maker leading to further conflict with Boulton and Watt.

James Lawson

James Lawson started work at Soho in 1779 and for many years was connected with Boulton and Watt, Boulton's mint, and Boulton, Watt & Co. He was the son of the Reverend Archibald Lawson of Kirkmahoe, near Dumfries. When he first came to Birmingham he seems to have been in the office, for in 1781 we find him among others, signing letters on behalf of the firm. In the following year, however, he was one of the staff of engine erectors in Cornwall, and Boulton says of him that he can "manage the working of an engine better than any of their engine men."

When men like Lawson were not erecting engines, they were paid, not by Boulton and Watt, but by the person or firm for whom the engine was being erected. There were intervals when, due to the non-arrival of materials or for other reasons, no work was going forward, or there was not enough work for all the Soho men. In one such interlude in 1783 Lawson had taken up mine-surveying and for a long time he was at the Poldice mine in Cornwall.

In 1784 Boulton wrote: "Lawson is making plans and sections at the Cornish mines, certain of the mines propose employing him to record the progress of the workings. He can survey land or dial mines, & is expert under-ground, & I think it would answer to the mines to pay him to keep their drawings in course with their mine. The plans & sections which is Lawson's only employment at present will prove of great importance as they serve to detect great mistakes and to enable the adventurers to see clearly with their own eyes."

It is not clear how long Lawson was engaged on the mine-survey work. By 1791 he was engaged under Boulton himself at the Soho mint. He was in charge of the multiplication of the dies and of one press; he had also the office of Inspector of the 2 fire engines. Although there were many problems with the dies and Lawson was even talking of leaving, Boulton wished to retain him in some capacity or other, for although he found ground for complaint he fully recognized Lawson's skill and intelligence. Later on, in November 1793, when he had gone back to engine erecting, Boulton having entered into a contract to supply fifty tons of copper coin, asks him if he can leave his business at Leeds and "come to Soho for about a week, in order to see that the 6 presses are in the best order. I should be much obliged to you for I fear Busch is not so much master of

that subject, besides, he has his hands too full, & Perhaps Bill Harrison would like to spend his Xmas with his mother & at the same time could render us a little assistance which with all expenses I will pay with pleasure."

A few months before this he had been in London assisting in preparing models and in getting a case for Counsel for one of the lawsuits relating to Watt's patent.

By this time Lawson was taking a leading position as an outdoor man under Boulton and Watt, and he was representing the firm in Leeds and Manchester. He had formed a friendship with James Watt, junior, and in the autumn of 1800 the two made tour in North Wales; terminating in "a fortnight amongst our Lancashire friends & engines". At the conclusion of this tour Lawson entered into an agreement to act for the Soho firm in Scotland for five years, at a salary rising from £250 to £300 per annum with a commission of 1 per cent on all goods sent to Scotland and $\frac{1}{2}$ per cent upon all orders procured by him elsewhere, the firm guaranteeing that in all he should receive not less than £350 per annum during the first half of the term and £400 during the latter half.

James Watt, junior, was not altogether satisfied that the terms were fair to Lawson, whose services he says he would be sorry to underrate. Some years later, about 1811, Lawson was appointed superintendent of machinery to the Royal Mint at a salary of £800 per annum with a residence, but he continued to transact business, in London, for the Soho firm, and received an allowance from them until his death. Lawson was elected a Fellow of the Royal Society in 1812; he died in London on April 9, 1818.

Malcolm Logan

Malcolm Logan was employed to erect engines both in Italy and in Spain. In 1782 Boulton refers to him as "a handy, active and industrious fellow"; he seems soon after this to have given way to drink, but to have pulled himself up in time, for in 1788 when it was a question of selecting a man to go to Naples, "I think", writes Boulton, "he is the properest man we have to send to Naples, as he is a handy fellow either in wood or iron, or engine, or mill, or pumps." He must in addition have been a man of quick intelligence. Later on, 1795-6, he was at work in Spain.

William Murdock

Murdock's entire life was spent in the service of the firm and his story is closely connected with that of James Watt.

Murdock entered the service of Boulton and Watt in the year 1777, when he was 23 years of age; his name first appears in the books of the firm as "Wm. Mordach"; he was paid at the rate of 15s. a week, and some of his first work seems to have been at pattern-making. He very soon made his mark as a man of ability and intelligence, and as early as January 1779 we find Boulton writing: "I think W^m. Murdock a valuable man & deserves every civility & encouragement." Murdock was at this time engaged in repairs and alterations to the Bedworth engine. A few months later was sent to take charge of the erection of the Wanlockhead engine, and Boulton writes of him to one of the proprietors: "He hath a good deal of experience in our engines and is capable of putting your people to rights in any matter they may not understand, & we doubt not but he will acquit himself to you & to our satisfaction, as he is a man we have a good opinion of. Pray don't keep him longer than necessary as we want him in Cornwall."

About the same time Watt informed the same customer that he is "a very sober, ingenious young man, who has a good deal of experience under us in putting engines together and knows all the little niceties, the omission of which might cause a bad performance in your engine."

Upon his return from Scotland, Murdock was sent to replace Jabez Homblower in the erection of the Ketley and Donnington Wood engines; in September he and another erector, James Law, were sent to Cornwall. As a precaution, in case of their being taken by the press-gang on the way, they were furnished with letters addressed to prominent men in Bristol and Exeter requesting protection. For the first twenty years Cornwall was Murdock's home; there he married, and there his sons were born. From the first he assimilated with the Cornish men far better than Watt ever did, and with occasional interludes of disfavour he was well liked by the great majority of the people concerned in the mines during the whole of his stay in Cornwall. Temperance in the matter of strong drink was a characteristic that distinguished him from most of his fellow erectors. He was particularly dexterous and resourceful in erecting new engines and repairing the old ones, and he was very hard-working – "indefatigable" is the term applied to him in some of the letters. Thus Boulton, writing on September 30, 1782 from Cosgarne, says:

"Murdock hath been indefatigable, ever since they began he has scarcely been in bed or taken necessary food, for everyone seems helpless in comparison of him....After Murdock had been slaved day & night on Thursday & Fryday last, he rec^d. a letter from W¹. Virgin in the West insisting upon his coming over directly as they could not se their engine to work, & if he did not come instantly they would let out ye fire. He accordingly went on Saturday morn^g, set ye engine to work, wch. went on very well during 5 or 6 hours, & then left it & returned back to ye Cons^d. Mines about 11 at night and was employed about the engines till 4 this morn^g & then went to bed. I found him at 10 this morn^g in Poldice cistern, searching for pins & cotters that had jumped out, and I insisted upon his going home to bed for he had a bad cold."

Two years later Boulton, again writing from Cornwall, expresses his satisfaction in even warmer terms in a letter to Watt, November 8, 1784:

"We want more Murdocks, for of all others he is the most active man & best engine erector I every saw, of w^{ch} I had a strong proof this day. They stoped Poldice lower engine last Wednesday & took her all to pieces, took out the condenser, took up out of the shaft the greater part of the pumps, took the Nossells to pieces, cut out the iron seatings and put in brass ones wth new valves, mended ye education pipe & did a great number of repairs about the beam & engine, put the pumps down into the new engine shaft, did much work at the new engine, & this day about noon both the engines, new and old were set to work again compleat. When I look at the work done it astonishes me & is entirely owing to the spirit & activity of Murdock who had not gone to bed 3 of the nights, & I expect the mine will be in fork again by Wednesday night. I have got him into good humour again without any coaxing, but have spoke plainly to him in presence of Wilson, have prevail'd upon him not to give W¹ Virgin engines up, which he has resolved to do from the ungenerous treatment he rec^d. from ye Captⁿ."

Although he was such a valuable man, his pay, for the first few years at any rate, was on a very low scale. When he started in Cornwall in 1779 he received 21s. a week; Law, his travelling companion, had 20s. Twelve months later he wanted an increase of pay,

and thought he was entitled to two guineas a week. Boulton seems to have sympathized with his wishes, but Watt objected and thought it would be very wrong to give this sum, "an example of that kind would ruin us by stimulating every other man we had to similar demands". It is not very clear why Boulton and Watt should have kept the pay so low; it affected them only in so far as it increased the total cost of the engine; the erectors were not paid by them, but by the adventurers for whom the engine was being erected. Boulton managed to stave off the difficulty by persuading one of the mine companies to make Murdock a present of ten guineas, to which he added another ten on behalf of Boulton and Watt. At about this time John Budge, one of the most highly respected of the Cornish engineers, was pressing Murdock to enter into partnership with him. It was the practice in Cornwall for the mine-owners to entrust the management and supervision of their engines to an engineer, such as Jonathan Hornblower or John Budge, who made periodical visits, and might have a number of engines in his care. In this instance Budge has offered Murdock the half of all his engines. However, towards the end of 1782 Murdock obtained an appointment of this nature on his own account – the seven new Boulton and Watt engines at Wheal Virgin and Poldice were placed in his charge at a fee of £6 per month. Boulton seems to have been in high glee at this event.

"Murdock will be well off but it fixes him firm to us and our interest." This fee was in addition to his pay for erecting engines, and no doubt, as time went on, Murdock had more work of this and other kinds, and possibly he was getting into such a position that he could make his own terms with the mine companies for erecting new engines. We find Boulton writing from Cornwall in 1784 that "people in general are much prejudiced in fav^r of W. Murdock and he is thereby intoxicated to a great degree." And in the same letter we have an indication that he was undertaking work on his own account. "He hath erected a new balance bob at W. Maid wch. hangs in a joint & rolls upon a vertical plane, but it is not so good as your old one and I don't believe he now prides himself upon it."

Moreover, he was now taking upon himself, in erecting new engines, to depart in important features from the drawings supplied from Soho. Thus:

"The small rotative engine at W1. Maid will be set to work in a day or two, but he hath in that varied from your drawings, for he hath hung the spear upon the top of the beam, i.e. ye centre of motion of the top end of the spear or connecting rod is upon the beam whilst the centre of motion of the beam itself is under the beam. This he hath done on order that the revolving wheel shall always stand right to begin its stroke."

Murdock's connection with the invention of the sun-and-planet gear and his iron cement were notable contributions. A more important invention with which his name is identified is the introduction of coal-gas as a lighting agent. His first experiments in this direction were made in Cornwall in 1792, but it was not until his return to Birmingham that anything was done on a commercial scale. The Soho Manufactory was fully equipped for lighting by gas in 1803, and the manufacture of gas-making plant became a distinct branch of the business at the Foundry, which became the training-ground of the early gas engineers.

Another project that Murdock engaged upon during his stay in Cornwall, much to the distaste of Watt and his partner, was that of steam carriages. Murdock had in view an air-cooled surface condenser, and a variable-speed gear; apparently he intended to use the sun-and planet gear with a set of plant-wheels of different diameters.

Watt at this time was engaged in draughting the specification for his patent of 1784, covering the parallel motion and other inventions, and he at once proceeded to incorporate in it such a description of a steam carriage as he could do in the time and space at his disposal. This procedure effectually forestalled other steam-carriage projectors for the time being and allayed Murdock's fears on this point.

Boulton and Watt were, however, keen for Murdock to devote most of his time to sorting out various engines (such as North Downs, as mentioned in a letter from Boulton to Watt, November 8, 1784) rather than to experiments with steam carriages. Boulton made this known to Murdock and the latter modified his activities in line with Boulton's wishes. Yet Murdock did not stop his activities with steam carriages altogether. On the contrary, two years later, there is a distinct evidence that a model had been made, for in August 1786 Wilson writes from Chacewater to Watt: "W^m. Murdock desires me to inform you that he has made a small engine $\frac{3}{4}$ dia. & 1½ inch stroke that he has applied to a small carriage which answers amazingly." From the terms of the letter that can be little doubt that this was, as far as Wilson knew, Murdock's first model, and that it had been made quite recently.

The next invention of Murdock's that we learn of is for raising water "without pumps or great beam." This is news that Boulton hears in London and transmits to Watt. Wilson a little later sends a more circumstantial account which suggests something in the nature of air-lift pumping; he says that Murdock "let me see his new method of raising water; it is by compressing air at the surface which is forced down small pipes to the bottom of the shaft & there communicates with the main pump & forces up the water, what machinery he has at the bottom I cannot tell, only there is no bucket, but there is a clack to prevent the water falling back; his present machinery is a copper tube of 1 inch dia^r. & 9 inches long, in this he works a wooden plug, from the side is a very small tube, which goes from the top of his house to his well 40 feet & another larger tube by the side up which the water ascends & runs off continually in an equal stream...He proposes writing to you on the business. He says pipes of 3 inches diameter will do for forcing down the air to work 17 inch pumps; if so there must be a great saving in erecting for deep mines. He has a very small string which goes down to the bottom, which he pulls when he sets to work, I suppose to open a valve."

We learn nothing more about this scheme, so presumably it did not answer Murdock's expectations. Ten years later, just before he left Cornwall for Soho, he was constructing a water-pressure engine at Wheal Fanny, and about the same time he was sending mica to Soho for use in the packing of pistons.

Murdock's sojourn in Cornwall was now drawing to an end. Watt's original patent and the Boulton-Watt partnership would terminate in 1800. Watt himself had ceased to take an active share in the direction of affairs; his son James, and Boulton's son, Matthew Robinson, had now taken over the reins, and the Soho Foundry had been commenced. Business in Cornwall was likely to fall off, and the young men felt, no doubt, that it would be wise to have a man of Murdock's experience, capacity, and energy at their disposal. So Murdock was given a post at head-quarters. He did not finally leave Cornwall until the end of 1798, but he had, before this, visited Birmingham to assist in the deliberations upon the new establishment. At the beginning of 1796 we find a letter from James Watt, junior: "P. Ewart leaves us this evening. The last three days have been spent in scheming between him, Murdock, Mr. Southern and A. Story, they have concluded upon the different lathes, boring and drilling apparatus and drawings of all are made." Peter

Ewart, as we have explained, had been bought to Soho for the purpose of designing the machinery for the new works which were being planned; Storey was the manager of the foundry.

From the early part of 1797 James Watt, junior, was calling for the presence of Murdock at Soho, but there were still many jobs to finish. It had by this time become known in the county that he was leaving Cornwall, and the Cornishmen had begun to realize what his departure would mean to them. An engine was to be put up at Wheal Jewel, and at first the adventurers declined to sign the agreement unless a clause was inserted that Murdock was to erect the engine; on this occasion one of the adventurers said that "two years ago M. might have gone to the devil for anything the county cared, but that by the blessing of God their eyes were now opened", and even after he had left Cornwall he was pressed to come back to their assistance at North Downs and other mines.

Upon his arrival at Soho, Murdock set himself with great vigour to getting the boring-mill completed. When this had been done, it seems that it did not answer very well, and there was some delay in settling the plan of a new mill.

Murdock then felt himself at a loose end: "he will begin to think he is losing his time here", writes the younger Boulton; "I have endeavoured to occupy his attention with several other schemes which are going forward, but the construction of the boring-mill being his principal hobby-horse, his thoughts are continually recurring to this favourite subject."

Possibly as one means of occupying his attention about this time, Murdock, with Storey the foundry manager for his companion, was sent on a voyage of discovery to Leeds. Matthew Murray was turning out iron castings and smithwork far superior to the Soho productions, and it was desired to find out how he managed this.

Another project in which Murdock's aid was enlisted was the production of a smaller and cheaper engine than had been made hitherto at Soho. The young partners were convinced that there was a wide field for such engines, and Murdock appears to have been responsible, in the main, for the design of a self-contained engine, known as the "bell-crank" engine. It did not prove a success, but it embodied one of Murdock's most important inventions – the long D-slide valve. This is one of the inventions covered by his patent of 1799. Another is the use of a worm and wheel for driving the bar of a boring-mill; this was applied at Soho both for boring and for large turning-lathes. In his specification he says that the screw "I have commonly used has three threads, is 16 inches diameter, and the advance by one revolution is 6 inches." Probably this was the size used for the boring-mill referred to above.

No doubt from time to time Murdock paid business and other visits to Cornwall. One such visit was in the early part of 1800, and he writes to James Watt, junior, that some of the Cornish mining people say they "are going to make an offer that will be greatly for my benefit if I will remain in Cornwall", and he asks for directions as to the answer he is to make. It appears, too, that Murdock had been asked to recruit smiths for Soho, and in the same letter he states: "I hoped to have sent three before this, but there is a report circulates here that you have starved Simon [Vivian] and his family and at this time I cannot prevail on any of them to go."

Murdock's position at Soho was put on a definite basis in the year 1800 when he entered into an agreement to serve for five years at a salary of £300 per annum, with an

allowance of 1 per cent on all orders for Soho Foundry. This arrangement prevailed up to the year 1810; but he was then getting, in addition, a commission of 1.5 per cent, on all the gas-lighting apparatus made, and his total income amounted to £684.

He was in 1810 put on the footing of a partner at Soho Foundry, but in lieu of a share in the profits, he elected to take a salary of £1000 a year, and this he received for the next twenty years, up to 1830, nine years before his death.

Isaac Perrins

One of the first engines put up by Boulton and Watt was that at Bloomfield Colliery. The proprietors had arranged to put up a Newcomen engine and an engineer named Perrins had undertaken the erection. When they were induced to put up a Boulton and Watt engine instead, Perrins retained his position and erected it; afterwards he was concerned in the erection of Bedworth, Bog Mine, and Minsterley engines. Perrins seems to have been advanced in years; he died in 1780 and is then referred to as "old Perrins", although the adjective may have been used merely to distinguish him from his sons. One of the sons, Issac, was offered a job under the firm in Cornwall in 1780, and this he declined, but early in 1782 he applied for work and was taken on at twelve shillings a week. He was connected with Boulton and Watt for some years, and of all the men under the firm, Issac Perrins was the best known to contemporaries and his name must have been an even more familiar one to the public than that of James Watt himself, for he was a prize-fighter. One morning in 1788 Watt, in Boulton's absence, dealing with the correspondence of the firm, opened a letter from a gentleman in London enclosing a newspaper cutting, and saying "In the enclosed paper of mine is an offer from a person living with you, to fight any man in London; would you please to inform me by a letter of what age Perrins is, what weight he has been known to carry, and something of his mode of life, that I may see whether a match cannot be made for him."

One can picture the consternation with which the staid Watt must have perused this letter, Watt who for a few years before had made it a condition in engaging Southern that he was to enter into a bond to give up music! It is clear that Watt was not aware of Perrin's proclivities, for he minuted the letter "Mr. Roberts, please inform me of the truth of this matter, that I may write to Mr. Boulton." Boulton, however, was not in such ignorance; five or six years before Perrins had fought "the famous Jimmy Sargent" and had beaten him thoroughly, and Boulton was dully informed of that event by Scales. The fight that followed Perrin's challenge on the present occasion terminated quite differently, for he was badly beaten by his opponent, Thomas Johnson, a smaller and lighter man. Perrins was a big fellow, over six feet high and judging from the picture, which is extant, of the fight, he must have been a fine-looking man.

His defeat does not seem to have checked his ardour for fighting; eighteen months after we find James Watt, junior, writing to Southern:

"I advise you to get I. Perrins sent off into the country as soon as you can, for he has received a letter from Mendoza pressing him to fight Big Ben, and offering to back him with £100. If the Birmingham gamblers hear of this, as he seems well inclined to inform them, I am certain they will find it no difficult matter to work up his passions, so as to induce him to challenge his rival, in which case you may bid adieu to him for ever."

Soon after this Perrins was sent to erect engines in Manchester and towards the end of 1793 he moved his household there and took a public-house, still keeping on his work as engine erector, but about a year later, having quarrelled with and threatened Lawson, Boulton and Watt discharged him from their service. Among the points made against him on this occasion was the slovenly condition in which the Boulton and Watt engines in Manchester were kept; but, as Perrins points out in a very outspoken manner, the firm had never paid him anything to look after the engines: "If you had allowed me a competency to have kept them clean, I should not be afraid of dirtying my hands with doing it as some of your servants are that you send here with ruffles at hands and powdered heads, more like some Lord than an engineer. It cannot be thought that I can lose my time and neglect my own business without some consideration for it."

In spite of this shortcomings, no doubt Perrins was a capable man as an engine erector; the terms of James Watt junior's letter, referred to above, make it clear that the firm did not wish to lose him, and for years after he had ceased to be an accredited erector for Boulton and Watt he continued to be employed to put up their engines in the Manchester district. Some of the mill-owners preferred to employ him rather than rely upon the men sent from Soho, and he was able to keep a staff of men employed.

William Playfair

Early in 1778 the increase in work and some troubles with the men led to the appointment of a foreman at Soho. Hall was selected for the post, but he did not prove suitable. Watt wanted to turn him out straight away, especially as Hall had been found making things for himself at Soho with the firm's materials. In the event, he was sent out as an erector and worked on the Ketley, Wren's Nest and Snedhill engines; after which he was dropped from the firm's list of erectors.

To make up in some respect for the loss of Hall at Soho, Watt suggested to Boulton (June 27, 1778) "I would recall Playfair who can do part of the business, and I think now that you are at home you can contrive to give him proper assistance. I must warn you that Playfair is a blunderer." Playfair was brother to John Playfair, a professor at Edinburgh University, and son of the Reverend James Playfair of Bervie near Dundee; like Rennie he served an apprenticeship to Andrew Meikle. He had been employed as draughtsman and clerk to Watt for a brief period before this. Evidently Watt had not a high opinion of him; however, he bought back, but again he was with the firm for but a limited time, and his connection ceased in 1781, when we find Boulton writing (October 23rd) that he was sorry Playfair is going, only on account of Watt not having any proper assistant in drawing. Playfair went into business on his own account in London; he took out several patents, but finally dropped into literary work. He wrote a memoir of Watt for the *New Monthly Magazine* which James Watt, junior, found very displeasing; there is a bundle of correspondence on this matter among the papers at Doldowlod.

John Southern

With increasing business, Watt's work had become very heavy, and we find Boulton constantly urging him to get an assistant. After the departure of Playfair in 1781, Boulton suggested a number of young men, and among them John Southern. "I think young Southern would be a very likely person, he seem good-humoured and very obliging. He is now with his brother as a surgeon, but says that though he is keen in the study of surgery, yet he had rather have been employed under you as a draughtsman and

assistant, and if you wish to have him I know he will gladly come. He draws tolerably neat."

John Southern was one of the sons of Thomas Southern, residing at that time at Wensley, near Wirksworth, Derbyshire, and interested in mining affairs in various parts of the country.

Boulton followed up the letter by another again recommending the employment of Southern. To this Watt, then in Cornwall, replies: "If you have a notion that young Southern would be sufficiently sedate, would come to us for a reasonable sum annually, and would engage for a sufficient time, I should be very glad to engage him for a drawer, provided he gives bond to give up music, otherwise I am sure he will do no good, it being the source of idleness."

Other letters follow, and in June 1782 Southern, then at the age of 24, starts with Boulton and Watt on a three years' agreement, and with them he remained until the end of his life. He seems to have dropped into his place without hesitation or friction of any kind, even Watt makes no complaints of him, and he soon proved a valuable assistant and relieved his chief of a good deal of work.

In 1793 Southern married the daughter of Thomas Dobbs of Kings Norton. Dobbs had a Boulton and Watt engine put up in his rolling-mill in 1787, and it may be that Southern's visits on this business led to his acquaintance with the lady.

At one time Southern seems to have interested himself with political affairs, and in 1794 we find Boulton writing that he had called on the Marquis of Stafford, and had learnt that from papers lately seized it appeared "that the country was upon the brink of a ruinous attempt to overthrow its Constitution...I hope to God our Southern is out of the mess, & that none of his letters will be found amongst these papers, & I wish you would speak to him about it, for I have reasons for my fears & wish to guard him."

With this exception Southern seems to have passed a quiet, uneventful life, devoting himself to his business and to scientific research. Whether he gave up music in deference to Watt's desire is not known. There is good reason for thinking that he was the inventor of the steam-engine indicator, that is, as we now understand the term, an instrument with a pencil for tracing the diagram of the varying pressure in the cylinder of an engine.

When in 1791 the Birmingham rioters attacked Edgbaston Hall, then in the occupation of Dr. Withering, we learn that "Mr. Sutherne, a clerk to Boulton and Watt" was one of the party who engaged in the defence of the house.

In 1800 Southern was given in addition to his salary a percentage upon all goods produced at the Soho Engine works, or in lieu thereof £600 per annum, and later in 1810 he was admitted a partner in the firm of Boulton, Watt & Co., to receive one-sixth of the profits. After his death the firm settled £2,000 on Mrs. Southern and the children.

One imagines that Southern was not a man of robust health. In 1812 he was ill in London and in the hands of a doctor; two years later he spent some time at Aberystwyth; he seems to have had a fall and to have gone there to recuperate his health.

He returned to his duties but died at the age of 57 years, in July of the following year, 1815, at his house at Handsworth. Southern was buried in the King's Norton church in the family vault of his wife's father Thomas Dobbs.

Thomas Wilson

In connection with the affairs of Boulton and Watt in Cornwall, the name of Thomas Wilson regularly occurs. He was at Chacewater in 1777 when the Wheal Busy engine (the first Watt engine set up in Cornwall) was ordered, acting as agent for the proprietors, Fentons and the Yorkshire Copper Company. Watt stayed in his house on his first visit to Cornwall, and possibly it was on this occasion that arrangements were made with him to act as the commercial or financial agent for the firm in Cornwall, a position that he continued to hold until the expiry of Watt's patent in 1800. He was an active and intelligent man, but it would seem that he engaged in too many different undertakings to make a great success in any of them. A lively account of his activities in the year 1785 is given by Boulton, who, after discussing the conditions at Chacewater and the difficulty of making the mine pay, goes on:

"I know Mr. Wilson says he had a very good opinion of her, but I will form mine only upon facts, & not opinions. Mr W. hath now several partnerships in shares of ships, he hath always had the tickiting to attend, the assay office, the accts of the Welsh works, the several mine accounts, in wch, he, we & Wilkinson are concerned; he hath a partnership with Ned Rogers in 2 or 3 farms; he hath another with Lantie Atkinson in other farms; his candle trade is a very large concern; he hath several partnerships with diff. persons in pairs of mules. He hath B & W. business to manage, with gunpowder, candle accounts, stamps, & c., and he hath a large family. I heartily wish him success in these & all other undertakings, but it must be evident to you that he cannot bestow any attention to the mine."

For his services to Boulton and Watt, Wilson was paid a commission of 2.5 per cent on the premiums derived from Cornwall. For the twenty years 1781-1800 he received the sum of £3,485 or a little over £174 per annum on average. He died in 1820, at the age of 72 years, and was buried at Falmouth.

BIBLIOGRAPHY CONCERNING JAMES WATT

BIBLIOGRAPHY reprinted from *James Watt and the Steam Engine*. H.W. Dickinson and R. Jenkins (2nd edition 1981. Moorland Publishers).

See Appendix I, pp.359-372.

First published in 1927.

GENERAL NOTES

It is a matter for regret that James Watt, although so ready with his pen, as evidenced by his voluminous letter-writing, wrote practically nothing for publication; what he did write might be said to have been almost exclusively for professional or business purposes. He had some thoughts in 1773 of writing a book on "the elements of the theory of steam engines", in order to advertise the engine (see letter from Watt to Small, August 17, 1773). Again, in 1778 it was stated: "The result of these experiments (i.e. on the volume of steam) he intends to lay before the publick, in a treatise upon that subject." (see Pryce: *Mineralogica Cornubiensis*, p.309) Nothing came of these, however.

After his retirement from business, at the solicitations of his friends, his thoughts reverted to the subject of writing a history of his improvements in the steam engine, and there is evidence that about 1808 he collected and annotated a good deal of matter for the purpose. His disinclination to court publicity, and his advancing age led to the project being shelved. The occasion of the publication of the collected works of his old friend Robison, however, stirred Watt to action in 1814, but the result was rather annotations on the former's work than an original monograph such as we, at the present day, should have prized.

A very valuable source of information about Watt personally is to be found in the documentary matter preserved by the present representative of the family. This matter covers the whole of his life and comprises letters, letter-books, note-books, journals, accounts, reports, memoranda, patent specifications, law cases, drawings, and books on the steam engine. Of the letters alone, there are several thousands. (Referred to by Dickinson and Jenkins as the Doldowlod Papers.) Speaking broadly, this is the material used by Muirhead in his biographical works on Watt mentioned below.

An equally valuable source of information, more particularly from the technical point of view, for the period 1775-1800 and, indeed, later still, is the Boulton and Watt Collection. This material constitutes the records of the firm, and comprises upwards of 10,000 drawings with a very large number of documents such as correspondence and letter-books, together with printed books, models, and plant.

When the effects of the firm were dispersed in 1895 these objects were purchased by the late Mr. George Tangye, who presented them in 1911 to the City of Birmingham; they are now housed in the Free Reference Library (now known as the Central Library, Birmingham and referred to by Dickinson and Jenkins as the B. & W. Colln.) This matter has not been utilized hitherto to any extent and has consequently been drawn on extensively for the present volume (Dickinson and Jenkins point out).

Another collection comprising journals, deeds, ledgers, letters, printed matter, and other documents, in the main complementary to the two collections named above, was in the possession of Lionel B.C.L. Muirhead, Esq., a relative of the biographer of Watt, till September 1921 when it was handed over to the care of the Free Reference Library, Birmingham (now known as the Central Library, Birmingham and referred to by Dickinson and Jenkins as the Muirhead Papers).

About a thousand letters from Watt to Matthew Boulton, together with a few to Dr. William Small, covering the period 1768 till his death, along with a large amount of documentary matter

concerning Boulton's business undertakings, were preserved by the Boulton family at the family seat, Tew Park, Oxon., till last year when they were removed to the Assay Office, Birmingham. (Referred to by Dickinson and Jenkins as the Boulton Papers and now also at the Central Library, Birmingham.) This material was used both by Muirhead and Smiles.

The Central Library, Birmingham also possesses the following papers:

Letters from James WATT to John SOUTHERN, 1789 to 1815. In I vol.4to. (Referred to in this volume as the Southern Papers.)

Collection of original letters, &c., relating to WATT and BOULTON and SOHO (1761 et seq.) formed by Samuel TIMMINS. I vol.fol.

Letters from R. CARRUTHERS, five in number, to W.C. Aitken, relating to Burns and James WATT, 1851-69.

Letters from Samuel SMILES to W.C. Aitken relating to James WATT and James KEIR, 1861-70. (In a collection of papers of W.C. Aitken.) 8vo.

Extracts relating to BOULTON, WATT AND EGINTON, 1808-95 (c.1895), by G.N. Osborne. I vol. 4to.

Other bibliographical matter is arranged below chronologically, explanatory notes being appended to any item where this course seems to be needed. Some sifting has been effected, and mere compilations of matter already published have been excluded.

DETAILED NOTES

MACKELL, Robert, and WATT, James.

An account of the navigable Canal, proposed to be cut from the Tiver Clyde to the River Carron, as surveyed by Robert Mackell and James Watt.
London, 1767. 18pp., 4to. 1 engraved map.

This was a scheme for joining the rivers Forth and Clyde by a canal via the Loch Lomond passage. As eventually carried out by Brindley and Smeaton, the direct route for the Canal was adopted.

WATT, James.

A scheme for making a navigable Canal from the City of Glasgow to the Monkland Coalierys.
Glasgow, [1769]. 12 pp., 4to.

This was the Monkland Canal, the first part of which was carried out entirely by Watt.

WATT, James.

Report concerning the Harbour of Port-Glasgow, made to the Magistrates of Glasgow, by James Watt, Engineer, and submitted to the consideration of the Merchants.
Glasgow, Aug. 9, 1771. 8 pp., 4to.

WATT, James.

A Report to the Honorable His Majesty's Commissioners for managing the Annexed States in Scotland concerning the Isthmusses of Tarbert and Crinan.
Glasgow, Dec. 21, 1772. 107 pp., 4to.

Only known to the Editors in the manuscript state. One copy, no part of which is in Watt's handwriting, is preserved in the British Museum. (Add. MS. 9059.)

WATT, James.

An account of the scheme for rendering navigable the Rivers Forth and Devon with estimates of the Expense by James Watt.
Edinburgh, MDCCLXXIV. 4to.

WATT, James.

An account of JAMES WATT'S Improvements upon the Steam or Fire Engine.
(London 1774.) 8 pp., fcp. 4to.

This was the statement that Watt distributed to Members of Parliament when the Bill for extending his patent was before the House, as evidenced by his note on one copy in the Boulton and Watt Collection: "Delivered to the members of the House of Commons, 1774-5."

PARLIAMENT, Houses of.

An Act for vesting in James Watt, Engineer, his executors, administrators and assigns the sole use and property of certain steam engines commonly called fire engines, of his invention, for a limited time.

15 Geo. III, clxi, pp. 1587-94.

London (1775), fol.

Prior to its passage into law, it was printed as a Bill. It was reprinted subsequently in several forms.

PRYCE, William.

Mineralogia Cornubiensis.

London, 1778, fol.

In the Appendix, p. 308, a full description of and historical notes on Watt's engine are given, but no drawing. The information was supplied by Watt (Boulton to Henderson, 1777 Aug. 13) and is the first public notice of the engine in print. Both Boulton and Watt were subscribers to the book.

BOULTON and WATT.

Proposals to the adventurers in...by Boulton and Watt.

(Birmingham, 1778) 8 pp., 4to.

A form to be filled up for any one wishing to erect their engines. The experiments at Poldice on the coal consumption of the existing fire-engine are described. One paragraph reads: (3) "The profit which we require for such licence drawings and instructions is to be such sums...as shall be equal in value to a third part of the savings in fuel."

WATT, James.

Directions for erecting and working the newly-invented steam engines by Boulton and Watt.

(Birmingham, 1779) iv+24+16 pp., 6 plates, 12 mo.

Reproduced in full in Appendix II. Comprises "General Directions for building the engine house"; "Directions for putting the engine together"; "Directions for working the engine"; "Additional directions" and "Explanation of plates". These directions are detailed and precise, clearly revealing Watt's hand. The booklet was meant for private circulation among the firm's engine erectors and clients.

It is obviously a compilation. E.g. the "additional directions" are separately paged and the plates are numbered X to XII. This is known to be the case, as separate portions exist in manuscript in the Boulton and Watt Collection. Five of the copper plates are still preserved there. The date is fixed by entries in Watt's journals, see Chap. XX, showing when he was at work upon it.

PRIESTLEY, Joseph, LL.D.

Experiments and observations relating to various branches of Natural Philosophy.

Birmingham, 1781. 8 vo.

The second volume has on p. 388 an appendix Number III, entitled "Observations on this volume with which I was favoured by Mr. Watt". This is one page of notes which reveal Watt's acquaintance with the chemistry of the day.

[BOULTON and WATT.]
Directions relating to the Engine.
[Birmingham, 1784.] 1 sh., post.

Reproduced in full in Appendix III. The sheet was obviously meant to be hung up on the wall of the engine house.

[WATT, James.]
Remarks on a Government Paper entitled Iron Trade, England and Ireland.
(London, 1784), 3 pp., fcp.

Several copies of this paper exist in the Boulton and Watt Collection, but there is no definite evidence that Watt wrote it; the subject matter would point rather to Boulton or Wilkinson as the author. The occasion was a proposal by Mr. Pitt to impose additional duties on manufactures exported to Ireland from Gt. Britain.

There is another paper in existence, entitled "An Answer to the Treasury paper on the Iron Trade of England and Ireland", whose composition much more savours of the hand of Watt.

WATT, James.
Thoughts on the Constituent Parts of Water and Dephlogistigated Air; with an account of some Experiments on that Subject. In a letter from Mr. James Watt, Engineer, to Mr. De Luc, F.R.S. Read Apl. 29, 1784 (before the Royal Society). Printed in *Phil. Trans.*, LXXIV, pp. 329-53.
Sequel to the Thoughts on the Constituent Parts of Water and Dephlogistigated Air: in a subsequent letter from Mr. James Watt, Engineer, to Mr. De Luc, F.R.S. Read May 6, 1784. Printed in same vol. of *Transactions*: pp. 354-7.

The original letters are still in the possession of the Royal Society (Guard Book No. 74). These letters gave rise to a bitter controversy between the supporters of Watt and Cavendish as to which of them had the prior claim to the discovery of the composition of water. The letters, with much additional matter, were subsequently reprinted in volume form.

DALRYMPLE, Sir John.
Address and proposals from Sir John Dalrymple on the subject of the Coal, Tar and Iron Branches of the trade.
London and Edinburgh, 1784. 15 pp., 8 vo.

Sir John was one of the Barons of Exchequer in Scotland. Writing to Matthew Boulton on Aug. 6, 1784, he encloses a copy of what he calls "a little pamphlet" in one part of which he says: "I have done justice to your and Mr Watt's great improvements upon the Fire Engine."

WATT, James.
Heads of a Bill to explain and amend the laws relative to Letters Patent and grants of privilege for new Inventions.
B. & W. Colln. MS. 15 pages, 4 to.

Probably drafted in 1785 or 1786 when there was some talk by opulent manufacturers of combining to attack patents just as Arkwright's had been treated. Watt says:
"A pursuance of such decisions as have been given lately in several cases must at length drive men of invention to take shelter in countries where their ingenuity will be protected."

Boulton writing to De Luc was still stronger.
"Some late decisions against the validity of certain patents have raised the spirits of the illiberal, sordid, unjust, ungenerous and inventionless misers who prey upon the vitals of the ingenious, and make haste to seize upon what their laborious and often costly application has produced." (see Boulton Papers: Watt to Boulton, March, 1786).

[BOULTON and WATT.]
Short Statement on the part of Messrs. Boulton and Watt, in Opposition to Mr. Jonathan Hornblower's Application to Parliament for an Act to prolong the Terms of his Patent.
Birmingham, 1792. 1 sheet fcp., folded.

Hornblower was only trying to do for his compound engine patent what Watt and Boulton had done for the separate condenser patent. It appears from the Boulton MS. that Watt got thoroughly alarmed at the competition threatened by

Hornblower, and it is said that they lobbied actively against the prolongation of the patent with the result that it was not granted.

[BOULTON and WATT.]

Observations on the part of Messrs. Boulton and Watt re: Hornblower's steam engine bill.
[Birmingham], Apl. 17, 1792. 1 p., fcp.

WILSON, Thomas.

A comparative statement of the effects of Messrs. Boulton and Watt's Steam Engines with Newcomen's and Mr. Hornblower's. Addresses to the lords of, and adventurers in mines in Cornwall.

Truro, 1792. 25 pp., 8 vo.

WILSON, Thomas.

An address to the Mining Interest of Cornwall on the subject of Messrs. Boulton and Watt's and Mr. Hornblower's engines.

Truro, 1793. 22 pp., 8 vo.

Addressed similarly to the last.

Wilson was the agent in Cornwall of Boulton and Watt, and there can be little doubt that the above two pamphlets were prepared by him at the firm's instigation, or possibly by Watt himself, to counteract the Hornblower competition.

COURT OF COMMON PLEAS.

The Special Case in the cause of Boulton and Watt against Bull, in the Court of Common Pleas, with the arguments of the Judges thereon; and an Appendix of matters referred to.

London, 1795. 3 pp., fcp.

Quite probably edited by Watt.

The Special Case in the cause of Boulton and Watt against Bull, in the Court of Common Pleas, with the arguments of the Judges thereon; and an Appendix of matters referred to.

London, 1795. 8 pp., 8 vo.

This is merely a reprint of the preceding in handier format. Contains the shorthand report of the case. The Appendix is a list of patents in which *methods* of doing something were specified.

BEDDOES, Thomas, M.D., and WATT, James.

Considerations on the medicinal use of factitious airs, and the manner of obtaining them in large quantities. In two parts. Part I by Thomas Beddoes, M.D. Part II by James Watt, Esq.

Bristol, 1794. 8 vo. Separately paged, Part I, 48 pp., and Part II, 33 pp.

The sub-title of Part II is: Description of an Air Apparatus; with hints respecting the use and properties of different elastic fluids. By James Watt, Esq.

Consists of a series of letters of various dates from June 17 to Oct. 2, 1794, giving descriptions and drawings of the apparatus. Under date July 14th, Watt mentions that at Dr. Beddoe's desire: "Boulton and Watt have agreed to manufacture these machines for the Public."

BEDDOES, Thomas, M.D. and WATT, James.

Considerations on the medicinal use, and on the production of factitious airs Part I by Thomas Beddoes, M.D. Part II by James Watt, Engineer. Edition the second, to which are added communications from Doctors Carmichael, Darwin, Ewart...and others.

Bristol, 1795. 8 vo. Separately paged, part I has 172 pp., Part II has 40 pp., 5 copper-plates, and two tables.

In Part I there is a note that "at Mr. Chippendale's, *Salisbury Court, Fleet Street, London*, Mr Watt's Air apparatus may be seen".

Part II has the sub-title, "Description of a pneumatic apparatus with directions for procuring the factitious airs, by James Watt, engineer." The preface dated January 1795 says: "The Author has also availed himself of this opportunity to methodize and elucidate his description in a manner which the former hasty publication would not admit of."

Both second and third editions were printed also at Birmingham. "Edition the third, corrected and enlarged", appeared in 1796. Paged continuously 222 pp., 5 pl.

BEDDOES, Thomas, M.D. and WATT, James.

Considerations on the medicinal use and production of factitious airs. By Thomas Beddoes, M.D., and James Watt, Engineer. Part III. Bristol, 1795. x + 121 pp., 3 pl., 8 vo.

Contains letters from physicians and others as to the treatment, among them being three from Watt (pp. 34, 36, and 105).

A 'Second Edition, corrected and enlarged' appeared the following year.

Bristol, 1796. xx+178 pp., 3p., 8 vo.

BEDDOES, Thomas, M.D., and WATT, James.

Medical cases and speculations; including Parts IV and V, of consideration on the medicinal powers, and the production of factitious airs by Thomas Beddoes, M.D., and James Watt, Engineer.

Bristol, 1796. 8 vo. Part IV, XV + 168 pp. Part V separately paged, 96 + (25 to 42 bis), 2 plates Nos. 4 and 5, is entitled: "Supplement to the description of a pneumatic apparatus, for preparing factitious airs; containing a description of a simplified apparatus and of a portable apparatus. By James Watt, Engineer." 42 pp. of this is devoted to a description of the apparatus. A price list is given. The descriptive portion of Part V was reprinted with the same title as a separate pamphlet, evidently to push the sale of the apparatus.

Birmingham, 1796. 48 pp., 8 vo.

The reason why Watt was led to the study of this branch of medicinal treatment, viz. inhalation of oxygen, &c., was that his youngest son Gregory, by his second wife, a lad of great promise, suffered from consumption. In fact, consumption was in the family, for a daughter, Jessy, had died of the complaint in 1794. In spite of all the care expended on Gregory he, too, died of the disease in 1804, while staying in Devon on account of his health; he was buried in Exeter.

Thomas Beddoes was the well-known and enterprising physician who founded the Pneumatic Institution.

WATT, James, junior.

Directions for using the patent portable Copying Machines. Invented & made by James Watt and Company of Soho, near Birmingham. [Birmingham, 1795.] 18 pp., 12 mo.

Some copies have as a frontispiece a copperplate engraving of the desk. The pamphlet states that machines are to be had from Richardson and Harrison, Leadenhall St.

Directions for using the patent portable Copying Machines invented and made by James Watt & Company of Soho, near Birmingham.

Birmingham, 1813. 16 pp., 12 mo.

With the exception that some of the introductory matter is deleted, and a few mistakes corrected, this is only a reprint of the preceding. Reprints of this were bought out in 1818 and 1830.

Manière de se servir de la Machine Portative à Copier. Inventée & Patentée par Jacques Watt & Co., de Soho, près de Birmingham.

Birmingham, 1805. 16 pp., 12 mo.

A French translation of the pamphlet became necessary owing to the fact that a sale for the copying machine had been created abroad. This is possibly not the earliest edition.

Manière de se servir de la machine à copier. Inventée & patentée par Jacques Watt & Co., a Soho, près de Birmingham.

Birmingham, 1807. 24 pp., 12 mo, 1 plate.

Practically a reprint of the preceding. A further reprint was bought out in 1818, 16 pp., 12 mo.

Anweisung zum Gebrauch der tragbaren Kopir-Maschinen erfunden und verfertigt von James Watt und Comp. zu Soho bei Birmingham.

Birmingham (? 1805). 24 pp., 12 mo.

Probably prepared at the same time as the French translation. The agent for the machines was G. H. Busch, Hamburg.

Watt patented the press copying system, and the machine therefore in 1781. A separate firm, James Watt & Co., was formed to exploit the invention, and their letter book, the first in which the system now so wide-spread was used, is preserved in the Boulton and Watt Collection. The sale of the machine was hindered by the prejudice of bankers and business people generally, and it was not till the patent had well nigh run its course that this opposition gave way before the merits of the system. It was at this time that James Watt, the younger, saw that the firm would not reap where they had sown unless the manufacture of the machines was taken up more vigorously, as another firm was already making machines. He bought out a portable form of the machine, combined with a writing-case and, as we learn from the Boulton correspondence [Boulton Papers] which fixes the date, compiled the above "Directions" in order to push the invention. It is not unlikely that Watt may have revised the manuscript.

PRONY, Gaspard Clair François Marie Riche de. Nouvelle Architecture Hydraulique.
Paris, 1796. 2 vols. 4 to, plates.

The double-acting engine described is stated (vol. I, p. 571) to be that constructed by MM. Périer Frères in 1790, based on a model to the scale of 1 in. to a foot made by M. le Chevalier de Bettancourt as a result of a visit to England in 1788. It is stated to have been "entièrement de l'invention" of that gentleman, but this claim was afterwards withdrawn and it was admitted that the information was taken from Watt's engines. The drawings are therefore the earliest published representing the Watt engine.

BRAMAH, Joseph.

A Letter to the Rt. Hon. Sir James Eyre, Lord Chief Justice of the Common Pleas: on the subject of the case, Boulton and Watt v. Hornblower and Maberley, for infringement of Mr. Watt's patent for an improvement on the Steam Engine, by Joseph Bramah, Engineer.

London 1797. 90 pp., 8 vo.

Substance of matter prepared by him as witness for the defence in the above trial.

ROBISON, John, M.A., LL.D., F.R.S.E.

Articles "Steam" and "Steam Engine" in the *Encyclopaedia Britannica*, 3rd edition, vol. XVI.

Edinburgh, 1797. 4 to, 3 plates.

WATT, James.

Specification of an invention of certain improvements upon Steam or Fire Engines for raising water and other mechanical purposes, and certain new pieces of mechanism applicable to the same by James Watt, Engineer.

[London, 1798.] 4 to, 19 pp. + 7 pp. references, 2 pl.

Simply a transcript of the patent specification of Mar. 12, 1782 (No. 1321). It is not obvious why it was printed, as the patent had then expired – probably it was intended for private circulation.

COURT OF COMMON PLEAS.

The arguments of the Judges in two Cases relating to the Letters Patent granted to James Watt, Engineer, for his method of lessening the consumption of steam and fuel in Fire Engines. Taken in shorthand by Mr. Gurney. In two parts: with an Appendix.

London, 1799. 104 pp., 8 vo.

The first part is a transcript of Watt's first patent specification, Jan. 5, 1769 (no. 913), and of the Act for extending the patent for twenty-five years from May 22, 1775.

The second part contains the reports of the cases *Boulton and Watt v. Bull*, and the same plaintiffs *v. Hornblower and Maberley*. As to the first of these two, the pamphlet merely reprints the matter given earlier, dated 1795.

ROBISON, John, LL.D., F.R.S.E.

Two articles, "Steam" and "Steam Engines", written for the *Encyclopaedia Britannica*...with notes and additions, by James Watt...And a letter on "Some Properties of Steam" by the late John Southern, Esq.

Edinburgh, 1818. 184 pp., 8 vo., 8 plates.

This is a reprint of the article above, with much additional matter comprising corrections in the text, footnotes, and an appendix from Watt's own pen, together with a covering letter to Sir David Brewster from Watt, dated Heathfield, May 1814.

The reason which had moved Watt to take all this trouble was his great regard for the memory of his old friend, Robison, an edition of whose works (see below) was then being prepared under the editorship of Sir David Brewster. This is explained in a pencil note on the copy now in the British Museum, which Watt sent inscribed "To the Right Hon. Sir Jos. Banks, Bart., G.C.B., etc., etc., from his obliged servant James Watt." The note reads: "The book of which this forms a part will not be published till winter, and until that time Sir Joseph is respectfully requested to keep this in his own possession, June, 1818."

In the covering letter to Brewster, which, by the way, was also printed in *Edin. Phil. Journ.*, 1820, II, by permission of James Watt, junior, Watt says: "I have not attempted to render Dr. Robison's memoir a complete history of the Steam-engine; nor have I even given a *detailed* account of my own improvements upon it. The former would have been an undertaking beyond my present powers, and the latter must have exceeded the limits of a commentary upon my friend's work. I have therefore confined myself to correcting such part as appeared necessary, and to adding such matter as he had not an opportunity of knowing."

Watt takes the opportunity of correcting the statement that he had been the pupil of Dr. Black at Glasgow, and that he had owed the improvements on the steam engine to Black's instruction.

The importance of the memoranda, for we can call them nothing more, is that they are really all we have at first hand from Watt himself upon his inventions. The letter from Southern is addressed to Watt under date March 1814, and gives the result of his and William Creighton's experiments and calculations on the temperance and pressure of steam, figures which remained the authority till superseded by the more precise figures established by Rankine. One or two letters passed between Watt and Southern about this time. For example, Watt writes: "I am at work on the Proffrs acct of my invention in the Dictionary, which I find will be a difficult thing to correct leaving any of the Proffrs words." (See Southern papers: Watt to Southern, December 20, 1813).

FAREY, John

Article "Steam Engine" in Rees's *Cyclopaedia*, vol. XXXIV.

London, 1819. 4 to, plates.

The fullest practical account of the steam engine that had appeared up to that date. Written subsequently to 1816 with information obtained from Watt. The plates alluded to are dated 1812 to 1818. The author subsequently expanded the matter into book form (see below).

HACHETTE, Jean Nicolas Pierre.

Notice sur la vie et les travaux de James Watt.

Bulletin de la Société d'Encouragement, CLXXXII, August 1819.

Very brief-Hachette had just been in England and had received from James Watt, junior, a bust by Chantrey for the Société d'Encouragement.

JEFFREY, Hon. Francis, Lord.

Character of Mr. Watt. Obituary eulogy in *Scotsman* newspaper. Edinburgh, Sept. 4, 1819. This was reprinted in *Edinburgh Magazine*, September 1819, no: 203.

PLAYFAIR, William.

Original memoirs of Eminent Persons. The late James Watt, Esq., F.R.S., & c., & c., communicated by Mr. Wm. Playfair.

Monthly Magazine or British Register, XLVIII, 1819, pp. 230-9.

Playfair was in the employ of the firm from 1777 to 1782 and therefore had inside knowledge of this period.

PLAYFAIR, William.
Memoir of James Watt, F.R.S.
New Monthly Magazine and Universal Register, 1819, vol.xii, p.576.

In a prefatory note the Editor states that it was written by Mr. Playfair and remarks that he had disposed of a copy of the rival magazine (i.e. the above); the memoirs are, however, quite different in matter.

WATT, James.
Thirteen letters from the late James Watt, Esq., to James Lind.
Monthly magazine or British Register, L, 1820, p. 239.

These cover the period 1764-99 and deal with Watt's scientific pursuits.

ROBISON, John, LL.D.
A system of mechanical philosophy. With notes by (Sir) David Brewster.
Edinburgh, 1822. 5 vols., 8 vo.

The first part of Vol. II consists of the matter given above under date 1818, in fact the pagination, even to the title-page, is identical; obviously the type had been kept standing.

[WATT, James, jun., and JEFFREY, Francis, Lord].
Article "James Watt" in the supplement to the fourth, fifth, and sixth editions of the *Encyclopaedia Britannica*, vol.VI, pp. 778-85.
Edinburgh, 1824. 4 to.

The first satisfactory biographical memoir of Watt. Three-fourths is from the pen of James Watt, jun.; the rest of it is taken up by an eulogy on Watt from the pen of Lord Jeffery, being, in fact, a reprint of his *Scotsman* article (*see ante*).

[WATT, James, jun., and JEFFREY, Francis, Lord].
Memoir of James Watt, F.R.S., L & E., from the supplement to the *Encyclopaedia Britannica*, vol.VI.
[Edinburgh, 1824.] 32 pp., 8 vo, privately printed.

Consists of above matter paged up in book form.

[TURNER, Charles Hampden, *Chairman*.]
Proceedings of the public meeting held at Freemasons' Hall [London] on the 18th June, 1824, for erecting a monument to the late James Watt.
London, 1824. 96 pp., 8 vo. A large paper copy was also issued.

As a result of this meeting, a public subscription was started, and the outcome was the Chantrey statue in Henry VII's Chapel, Westminster Abbey.

FAREY, John.
A treatise on the Steam Engine, historical, practical, and descriptive.
London, 1827. 4.to.

An expansion in volume form of the article in the *Encyclopaedia Britannica* mentioned above. Contains a large amount of first-hand detailed information about the Watt engines.

STUART, Robert. (Pseudonym of Robert Meikleham.)
Historical and descriptive Anecdotes of Steam Engines, and of their Inventors and Improvers.
London, 1829. 2 vols, 16 mo, portraits and plates.

ARAGO, Dominique François Jean.
Éloge historique de James Watt.
Mémoires de l'Académie Royale des Sciences de l'Institut de France, vol. XVII, pp. 1xix1xxxviii.
Paris, 1840. 127 pp., 4 to.

Watt occupied the distinguished position of being one of the eight foreign Associates of the Academy, an honour which was bestowed upon him in 1814; he had been a corresponding Member of the Institute since 1808. In 1833, by direction of the Academy, M. Arago, the Perpetual secretary, was charged with the task of writing a memoir of Watt. For this purpose he came to this country, and gleaned much information at first hand, notably from James Watt, junior, and Lord Brougham. The result was this eulogy, which was read at a public meeting of the Institute on Dec. 8, 1834. The Éloge is a valuable contribution to the biography of Watt.

To the Éloge is appended a translation of an historical account of the discovery of water by Lord Brougham who, before transmitting the manuscript to Arago, submitted it to James Watt, junior. The latter added a number of notes, which Lord Brougham considered so valuable that he asked Arago to retain them in printing. This he did, and there is a note to that effect on p. clxxxviii.

It may be remarked that the above matter was printed off by itself with new pagination, pp. 128, but without a title-page. Copies were presented to his friends by James Watt, jun.

ARAGO, D.F.J.

Biographical Memoir of James Watt, one of the Eight Foreign Associates of the Academy of Sciences, by M. Arago, Perpetual Secretary.
Edinburgh New Philosophical Journal, XXVII. October 1839, pp. 221-324. 12 mo.

A translation made by Hyde Clarke of the Éloge mentioned above. To it is appended Arago's essay "On Machinery considered in Relation to the Prosperity of the Working Classes", which did not appear in the Mémoires. This essay is intended to show that inventions such as those of Watt are not detrimental to the interests of workers, as was then maintained by some.

ARAGO, D.F.J.

Life of James Watt, to which are subjoined, "Memoir on Machinery considered in relation to the prosperity of the working classes", by M. Arago; and "Historical Account of Discovery of the Composition of Water", by Lord Brougham.
Edinburgh, October 1839. 142 pp., 12 mo.

This is the matter from the *Edin. New Phil. Journ.* Above, in book form. Its early appearance was apparently due to the enterprise of the Editor and proprietors of that Journal.

Although not mentioned in the title-page, the volume contains on p. 125 the *Eulogium of James Watt* by Lord Jeffrey (from the *Encyclopaedia Britannica* already cited).

This Life of Watt ran into a second and third edition the same year (1839); the latter was illustrated with engravings and ran to 222 pp.

ARAGO, D.F.J.

Historical Éloge of James Watt. Translated from the French, with additional notes and an appendix, by James Patrick Muirhead, Esq., M.A.
London and Edinburgh, November 1839. ix + 261 pp., 8 vo, portrait. A large paper copy was also issued.

Although this contains the same matter as the preceding book, the translation is different and in some respects of greater merit. The Appendix includes: The Article on the Composition of Water by Lord Brougham; the Eulogy by Jeffrey; the Memoir on Machinery by Arago, and a reprint of the proceedings of the Meeting for Erecting a Monument to Watt, already cite *ante*.

WILLIAMSON, George.

Letters respecting the Watt Family.
Greenock, 1840. 69 pp., 8 vo. Privately printed.

Practically all the matter is incorporated in the author's "Memorials" (see *infra*).

BROUGHAM, Henry, Lord, F.R.S.

Lives of Men of Letters and Science who flourished in the time of George III.
London, 1845, 8 vo., steel engraved portrait.

The biography of Watt occupies pp. 353-401 and includes an appendix on the discovery of the theory of the composition of water.

MUIRHEAD, James Patrick, M.A., F.R.S.E.

Correspondence of the late James Watt on his Discovery of the theory of the Composition of Water with a letter from his son. Edited with introductory remarks and an appendix by James Patrick Muirhead, Esq., F.R.S.E.

London, 1846. 264 pp., 8 vo, portrait. A large paper copy was also issued.

As we have said above, acrimonious discussion arose between the partisans of Watt and Cavendish as to their respective claim to priority in the discovery of the composition of water. The writer, being a relative of Watt, is naturally biased. It is now conceded that while Watt was the first to adduce reasoned arguments to show that water was not an element, Cavendish independently supplied the experimental data on which accurate knowledge alone could be founded.

ENGLISH, Henry.

Mining Almanack.

London, 1849. 8 vo.

English was the Editor of the *Mining Journal*. On p. 301 there is a "Life of James Watt" by the Editor and on p. 302 we read: "An éloge has been published by M. Arago, translations of which had been written by Mr. Muirhead and Mr. Hyde Clark."

ANON. (Religious Tract Society.)

James Watt, and the Steam Engine.

London, 1852. 192 pp., 16 mo.

[MURRAY, Thomas, LL.D., Secretary.]

Inauguration of the Statue of James Watt in connection with the Watt Institution and Edinburgh School of Arts.

Edinburgh, 1854. 23 pp., 8 vo.

In 1824 a public meeting was held in Edinburgh for the purpose of erecting a memorial in honour of Watt. The original idea was to erect a building "for the accommodation of the Edinburgh School of Arts, whereby the memory of Watt may be for ever connected with the promotion, among a class to which he himself originally belonged, of those mechanical arts from which his own usefulness and glory arose".

Eventually the fund was devoted to the purchase in 1852 of the premises that had been long used for the purposes of the School of Art, when the name was changed to the "Watt Institution and Edinburgh School of Arts". It was felt that, in addition, something distinctive should be done to mark the concatenation: accordingly a statue was erected in front of the School. The School is now merged in the Heriot-Watt College.

MUIRHEAD, James Patrick, M.A., F.R.S.E.

The Origin and Progress of the Mechanical Inventions of James Watt illustrated by his correspondence with his friends and the specifications of his patents.

London, 1854. 3 vols., 8 vo., portrait. A large paper copy was also issued.

Based almost entirely on letters in the Doldowlod Papers, it is undoubtedly the richest mine of information about Watt.

The first volume is mainly taken up with an account, not sufficiently discriminating perhaps, of Watt's life. The second is devoted to transcripts of his letters commencing in 1765, and continuing till the year before his death. Possibly the letters have been chosen too much for their social and literary rather than for their scientific interest, but on the other hand such a choice appeals to the widest circle. The third volume gives the patent specifications and reprints of the Patent Cases already referred to.

WILLIAMSON, George.

Memorials of the lineage, early life, education, and development of the genius of James Watt. Printed for the Watt Club.

(Greenock), 1856. 4 to.

Authoritative on Watt's ancestry and early life. There are two portraits: one, frontpiece, an engraving of the Henning portrait, 1803; the other facing p. 120, a lithograph of the oil painting by Partridge.

COMMISSIONERS OF PATENTS.

A.D. 1769, No. 913. Specification of James Watt. Steam Engines, &c.

New invented method of lessening the Consumption of Steam and Fuel in Fire Engines. Dated Jan. 5, 1769. It is important to note that the patent only covered England, Wales, and the Colonies.

London, 1855. 3 pp., 4 to.

A.D. 1769, No. 913*. Extension of Patent of James Watt. Steam Engines, &c.

London, 1857. 6 pp., 4 to.

An Act for vesting in James Watt, Engineer, his executors administrators and assigns, the sole use and property of certain Steam Engines commonly called Fire Engines, of his Invention, described in the said Act, throughout his Majesty's Dominions, for a limited time (22nd May, 1775).

A point to be noted is that this Act extended the Patent to Scotland.

A.D. 1780. No. 1244. Specification of James Watt. Copying Letters, &c.

A new method of copying letters and other writings expeditiously. Dated Feb 14, 1780.

London, 1856. 4 pp., 4 to.

A.D. 1781. No. 1306. Specification of James Watt. Steam Engines.

Certain new methods of applying the vibrating or reciprocating motion of steam or fire engines to produce a continued rotative or circular motion round an axis or centre, and thereby to give motion to the wheels of mills and other machines. Dated Oct. 25, 1781.

London, 1855. 9 pp., 4 to, plates.

A.D. 1782. No. 1321. Specification of James Watt. Steam Engines

Certain new improvements upon steam or fire engines for raising water, and other mechanical purposes, and certain new pieces of mechanism applicable to the same. Dated Mar. 12, 1782.

London, 1855. 16 pp., 4to, plates.

A.D. 1784. No. 1432. Specification of James Watt. Fire and Steam Engines, &c.

Certain new improvement on fire and steam engines, and upon machines worked or moved by the same. Dated Ap. 28, 1784.

London, 1855. 14pp., 4to, plates.

A.D. 1785. No. 1485. Specification of James Watt. Furnaces and Fireplaces.

Certain newly improved methods of constructing furnaces or fireplaces for heating, boiling, or evaporating of water and other liquids, which are applicable to steam engines and other purposes; and also for heating, melting, and smelting of metals and their ores, whereby greater effects are produced from the fuel, and the smoke is in a great measure prevented or consumed. Dated June 14, 1785.

London, 1854. 4pp., 4to, plates.

SCHIMMEL PENNINCK, Mary Anne.

Life of, edited by Christiana C. Hankin.

London, 1858. 8 vo.

Reminiscent character sketches written in 1856 of Matthew Boulton, James Watt, and the family of the latter as they were in 1788-90.

MUIRHEAD, James Patrick, M.A., F.R.S.E.

Life of James Watt, with selections from his correspondence.

London, 1859. 8 vo.

This is in substance the memoir from the author's *Mechanical Inventions* referred to above. It ran into a second revised edition, 1859.

HART, Robert.

Reminiscences of James Watt. *Trans. Glasgow Archaeological Society*, Pt. I, i.
Glasgow, 1859. 8 vo.

Valuable recollections of Watt in his old age, i.e. in 1813 or 1814.

SMILES, Samuel, LL.D.

Lives of Boulton and Watt, principally from the original Soho MSS. comprising also a History of the Invention and Introduction of the Steam Engine.
London, 1865. xvi+521 pp., 8 vo in 1 or 2 vols.

Attractively written, avoids the introduction of technical detail, but is not always accurate. This ran into a second edition the following year.

COMMISSIONERS OF PATENTS.

Contributions to the History of the Steam Engine being two deeds relating to the Erection by Messrs. Boulton and Watt of Steam Engines on the United Mines at Gwennap, Cornwall, and at Werneth Colliery, near Oldham, Lancashire, from the originals in the Patent Office Library.
London, 1872. 16 pp., 8 vo.

The date of these deeds is 1779 and 1799 respectively. The title should read: "...Werneth Colliery in the parish of Prestwich, Lancashire..."

TIMMINS, Samuel.

James Watt, from *Trans. Archaeol.* Section of the Birmingham and Midland Inst., 1872.
Birmingham, 1873. 4 to.

SMILES, Samuel, LL.D.

Lives of the Engineers. The Steam Engine-Boulton and Watt, New and revised edition.
London, 1878. Plates, 12 mo.

Vo.IV of the "Lives" slightly abridged from the author's larger work, *ante*.

COWPER, Edward A., M.I.Mech.E.

On the Inventions of James Watt and his models preserved at Handsworth and South Kensington. Excerpt *Proc. Inst. Mech Eng.*, 1883. Pp. 599-631, and plates 55-87.
London, 1883. 8 vo.

Written by a capable engineer who had made a study of the subject; perhaps the best description extant of Watt's inventions.

TANGYE, [Sir] R[ichard] and G[eorge].

James Watt and William Murdock.
Birmingham (1888). II pp., 2 prints, 12 mo.

Comprises: "The Earliest Locomotive in England" and "James Watt's Garret".

BARR, Archibald, LL.D., D.Sc.

James Watt and the Application of Science to the Mechanical Arts: An Address.
Glasgow, 1889. 27 pp., 8 vo.

PREECE, Sir William H., C.B., F.R.S., M.Inst.C.E.

Watt and the Measurement of Power. Watt Anniversary Lecture delivered before the Greenock Philosophical Society, 1897.
Greenock, 1897. 13 pp., 8 vo., 2 figs.

THORPE, Sir Thomas E., D.Sc., LL.D., F.R.S.

James Watt and the Discovery of the Composition of Water. Watt Anniversary Lecture delivered before the Greenock Philosophical Society, 1898.
Greenock, 1898. 19 pp., 8 vo.

A full, impartial, and judicious summing up, by a chemist of world-wide fame, of the long drawn-out controversy among the partisans of Watt, Cavenish, and Lavoisier, as to what were their respective shares in this great discovery.

BRAMWELL, Sir Fredrick, Bart., LL.D., F.R.S., M.Inst.C.E.

Article, "James Watt" in *Dictionary of National Biography*, vol. 1x, pp. 51-62. Also paged up separately as a booklet of 24 pp.
London, 1899. 8 vo.

The best short biography extant, by an engineer of ripe experience.

BECK, Theodor.

Beiträge zur Geschichte des Maschinenbaues.
Berlin, 1900. 582 pp., 8 vo.

THOMSON, William, Baron Kelvin, P.R.S.

James Watt, an Oration delivered in the University of Glasgow on the commemoration of its ninth Jubilee.
Glasgow, 1901. 2 pp., 8 vo.

Deals in the main with Watt's connection with the College of Glasgow.

THORPE, Sir Thomas E., F.R.S., &c.,

Essays in Historical Chemistry.
London, 1902. 8 vo.

Essay V, pp. 98-122, is devoted to "James Watt and the Discovery of the Composition of Water". This is a reprint of the Watt Anniversary Lecture noted above. This Essay was not, of course, in the author's earlier volume under the same title published in 1894. A third edition appeared in 1911.

JACKS, William, LL.D., D.L.

James Watt.
Glasgow, 1901. 215 pp., portrait, 12 mo.

Repeats some misstatements of former writers, and is not sufficiently critical.

HELE-SHAW, H.A., F.R.S., M.Inst.C.E., M.I.Mech.E.

James Watt, Inventor. Watt Anniversary Lecture delivered before the Greenock Philosophical Society, 1902.
Greenock, 1902. 28 pp., 4 plates, 8 vo.

PEMBERTON, T. Edgar.

James Watt of Soho and Heathfield. *Annals of Industry and Genius*.
Birmingham 1905. 233 pp., portrait, 3 plates, 12 mo.

The Pemberton family occupied Heathfield from 1857 to 1876. Gives matter relative to Watt's connection with the house and estate, his associates at Soho, and with the Lunar Society. From 1876 to 1920 Heathfield was occupied by the late Mr. George Tangye.

CARNEGIE, Andrew.

James Watt.
London, 1905. 240 pp., 8 vo.

Painstaking and eulogistic, but brings out no new facts.

CARNEGIE, Andrew.
James Watt. (Famous Scots Series.)
Edinburgh and London [1905]. 164 pp., 12 mo.

Condensed from the preceding.

MATSCHOSS, Conrad, Ph.D., Dipl. Eng.
Die Entwicklung der Dampfmaschine.
Berlin, 1908. 2 vols., 4 to.

Appraises Watt's experiments and discoveries, pp. 339-72. Comments upon his influence on the progress of machine design.

BURSTALL, Henry Frederic William, M.A.M.Inst.C.E.
Nine Famous Birmingham Men. Lectures delivered in the University, edited by J.H. Muirhead, LL.D.
Birmingham, 1909. Portraits, 8 vo.

The Fourth Lecture, pp. 109-30 is devoted to James Watt, by Prof. Burstall.

FOX, Howard, F.G.S.
Boulton and Watt.
Reprinted from the Report of the Royal Cornwall Polytechnic Society for 1909.
Penryn, 1910. 20 pp., 8 vo.

Letters, or extracts there from, received by Thomas Wilson, agent of Boulton and Watt in Cornwall, during the period 1794-1802.

CAIRD, Robert, LL.D., F.R.S.E., M.Inst.C.E.
James Watt's Contribution to the Advancement of Engineering. Watt Anniversary Lecture delivered before the Greenock Philosophical Society, 1910.
Greenock, 1910. 23 pp., 8 vo.

CORMACK, J.D., C.M.G., D.Sc., M.Inst.C.E.
In the Days of Watt... Watt Anniversary Lecture delivered before the Greenock Philosophical Society, 1915.
[Greenock, 1915.] 17 pp., 8 vo.

DICKINSON, Henry Winram, M.I.Mech.E.
Some unpublished letters of James Watt. Excerpt *Proc.Inst.Mech.Eng.*, pp.487-534.
London, 1913. 8 vo.

Annotated transcripts of letters from the Boulton and Watt Collection and from the Boulton Papers, bringing out points of technical interest.

GRANT, John W
James Watt and the Steam Age.
London, 1917. pp.223, portrait, 8 vo.

A gossiping sketch.

BOARD OF EDUCATION.
Catalogue of Mechanical Engineering Collection in the Science Museum, South Kensington. Pt.I, 6th edition, with a supplement containing illustrations.
London, 1919. 8 vo.

Includes technical description of original Watt models preserved at South Kensington.

HENDERSON, H., *Librarian*.

James Watt Centenary Exhibition [at the Watt Monument, Greenock], Sept. 4, 1919.
Greenock, 1919. 19 pp., portrait, 8 vo.

WATT CENTENARY COMMITTEE.

James Watt Centenary Commemoration, Sept. 16-20, 1919. Souvenir Guide Book of Special Exhibit in the Art Gallery, Birmingham.
Birmingham, 1919. 60 pp., 8 vo.

BOARD OF EDUCATION, Science Museum.

Catalogue of Watt Centenary Exhibition.
London, 1919. 45 pp., portrait, 8 vo.

A Collection of portraits, drawings, holograph letters, original models, books, &c.

GALLOWAY, T. Lindsay, M.A., F.G.S.

James Watt.

Proc. Roy. Phil. Soc. Glasgow, vol. L, 154.
Glasgow, 1921. 16 pp., 8 vo.

FLEMING, James Arnold, O.B.E., F.R.S.E., F.S.A., Scot., F.C.S.

Scottish Pottery.

Glasgow, 1923. 8 vo.

Gives *inter alia* an account of Watt's connection with pottery manufacture-a hitherto little-known activity of his.

LORD, John, B.A.

Capital and Steam-Power, 1750-1800.

London, 1923. 8 vo.

Deals with the economics of the introduction of the steam engine into industry. Uses the history of the firm of Boulton and Watt as the basis of his thesis. Employs the same material very largely, although from a different angle, as do the authors of the present volume, in conjunction with which it should be read.

MARSHALL, Thomas Humphrey, M.A.

James Watt (1736-1819). Roadmaker Series.

London and Boston, 1925. 8 vo.

Racily written - effectively uses the known material, including the preceding volume, well set in relationship to contemporary events.

JENKIN, A.K. Hamilton, M.A.B.Litt.

Boulton and Watt in Cornwall. Excerpt Rept. Roy.

Cornwall Polytechnic Soc., N.S., vol. V. 1926.

Camborne, 1926. 8 vo.

Extracts are given from a collection of about 1,000 letters from the firm to Thomas Wilson, their agent. The letters are now the property of the Society and are preserved in their Library.