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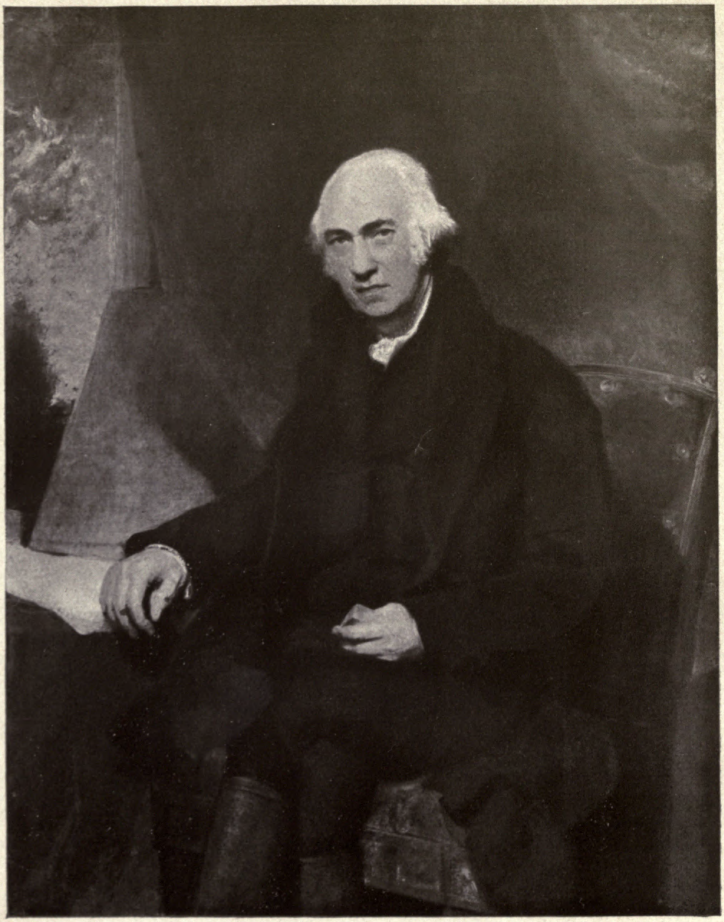

JAMES WATT

IN HIS 77TH YEAR

from the portrait by Sir Thomas Lawrence, P.R.A., 1813,
in the possession of the Boulton Family.

See p. 7.

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PREFATORY NOTE.

JAMES WATT was born at Greenock on the 19th January, 1736. He died at Heathfield, Staffordshire, on the 25th August, 1819.

His long life was one of continuous and varied activity. It was marked by notable inventions and by the successful application of these to engineering work. The inventions with which his name is most widely known are those concerned with the development of the steam engine, and it is these which embody his greatest services to Science and Industry. He found the steam engine an appliance of limited application and low efficiency, but nevertheless of material value for pumping water in situations where its wasteful use of fuel was not of great moment. He left it an efficient prime mover applicable to machinery in general. Even in his lifetime it proved the key to great industrial progress, while shortly before his death it was successfully applied to transport by sea and land.

The permanent Collections of the Science Museum are rich in examples illustrating Watt's inventions and his methods of experimental work. These objects and some connected with the work of his colleagues and contemporaries have been gathered from different sections of the Museum and grouped in the Central Hall (Room 3), which has been devoted for a few months to a Watt Centenary Exhibition. The Collections contain also illustrations of the leading developments of the steam engine by those who have worked upon it in the century which has passed since Watt died. These will be found grouped in the adjoining Gallery (Room 2).

The interest of the Exhibition is greatly augmented by valuable loans from other Institutions and from private sources. Special reference must be made to the loans from the Boulton and Watt Collection in the Birmingham Reference Library, and to those from the collect on of MSS., etc., preserved by the Boulton family. From the former some 80 drawings have been selected to illustrate as succinctly as possible the developments that the steam engine underwent in the hands of Watt. The difficulty of making such a selection may be realised when it is mentioned that the collection includes upwards of 10,000 drawings besides MSS., objects, etc., and that hitherto it has been inadequately explored. The collection of MSS. in the possession of the Boulton family includes holograph letters of James Watt extending from 1768 till his death. Some of them have been transcribed by Muirhead and by Smiles in their respective biographical memoirs; but there are many more which contain items of interest to engineers. Only a very few, however, of the more interesting letters can be exposed owing to the exigencies of space.

The necessities of the war time have delayed the completion of the new Museum Buildings, and have prevented the National Exhibition on the occasion of the Watt Centenary from being on the scale which had been contemplated. The number of objects which could be selected for exhibition has been restricted. Those which are shown could not be grouped in close accord with the classification, but th s

catalogue goes far to facilitate ready reference to related objects. Explanatory notes have been added to the individual items ; and the visitor who wishes further information may consult the Museum catalogues, especially that of Mechanical Engineering, Part I., where most of the objects connected with Watt are described in detail and some are illustrated.

In view of the limitations of this Exhibition it is specially gratifying to note that the Commemoration of the Centenary in Birmingham is to include the exhibition of much that illustrates James Watt's great work in that centre. Steps were taken to co-ordinate the efforts here with those in Birmingham, so that the two Exhibitions will be to a large extent complementary.

A number of the objects shown have been photographed ; prints may be seen in a guard book in charge of the Warder, and copies can be ordered at the Entrance Stile.

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CATALOGUE

OF

WATT CENTENARY EXHIBITION.

I. PICTURES. STATUARY.

PORTRAITS OF WATT AND OTHERS ; LOCAL VIEWS.

1. EDWARD SOMERSET, 2ND MARQUIS OF WORCESTER (1601-1667). Portrait in oils by A. Craig after Vandyck. Woodcroft Bequest, 1903.

Three-quarter length, half turned to right. Author of " A Century of Inventions " ; constructed a " Water commanding engine." Below is an autograph of the Marquis (on a promissory note dated 1655).

2. DENIS PAPIN (1647-1712). Portrait in oils. Woodcroft Bequest, 1903.

Half length, turned slightly to right : copy of the original at Marburg University. Papin condensed steam in a cylinder and moved a piston.

3. JAMES WATT. Portrait in oils by Charles Frederick von Breda, 1793. Lent by the Trustees of the National Portrait Gallery.

Seated figure, to below knees, face nearly in profile to left ; represents Watt at the age of 57. This, or a replica, was painted for John Rennie ; it was engraved in mezzotint by S. W. Reynolds in 1796. The portrait was presented to the Nation in 1865 by Matthew Piers Watt Boulton.

4. JAMES WATT. Painting in oils by Sir Thomas Lawrence, P.R.A., 1813. Lent by the Boulton Trustees.

Three-quarter length, seated, to below knees, facing left. This, though not the best known, was considered by J. P. Muirhead, the biographer of Watt, unrivalled among all portraits of him. The same writer states that the head was considered by the artist the finest he had ever painted (see frontispiece).

5. JAMES WATT. Bust in plaster, after Sir Francis Chantrey, 1819. Property of the Science Museum.

6. JAMES WATT. Photo of pastel by W. de Longastre. Lent by the Trustees of the National Portrait Gallery.

Bust, facing right. Painted in 1805 or 1806. Considered by Mr. J. P. Muirhead, the biographer of Watt, to be " a striking portrait and exact likeness." The original is in the possession of his family and a duplicate is in existence also.

7. JAMES WATT. Stipple engraving after the original portrait by Sir William Beechey, P.R.A., 1802. Drawn by W. Evans ; engraved by C. Picart, 1809. Lent by the Trustees of the National Portrait Gallery.

Half length, seated, quarter turned to left. The Beechey portrait is perhaps the best known and has often been reproduced.

8. JAMES WATT. Etching by William Nicholson, of Edinburgh, 1819. Lent by the Trustees of the National Portrait Gallery.

Half length, seated, full face.

9. JAMES WATT. Prints of life-size statue by Sir Francis Chantrey, 1824, in Handsworth Parish Church, nr. Birmingham. Presented by R. B. Asquith Ellis, Esq.

Considered possibly the artist's greatest work. Similar statues are in Greenock Library and Glasgow University. Another, of colossal size in marble, is in Westminster Abbey, and one in bronze in George Square, Glasgow. Another is in the Ashmolean Museum at Oxford.

10. JAMES WATT. Print from portrait in oils by John Graham-Gilbert in the Senate Room, University of Glasgow. Lent by the Trustees of the National Portrait Gallery.

Bust, quarter turned to left. Posthumous portrait from Chantrey's bust and Lawrence's portrait. Mrs. Watt considered it so like her husband that she had a duplicate painted.

11. JAMES WATT. Bust in marble by J. Heffernan, 1843, after the bust by Sir Francis Chantrey, 1815. Lent by the Council of the Royal Society.

Shown on a plinth designed by Professor A. Beresford Pite, F.R.I.B.A. ; the details executed by Mr. A. E. Harvey, of the Royal College of Art.

12. JAMES WATT. Portrait in oils by Abraham Wivell, 1856. After Sir William Beechey, P.R.A., 1802. Property of the Science Museum.

The Beechey portrait is the one of Watt that is best known and which has been most often reproduced. Muirhead, in his " Life of Watt," states that James Watt, jun., latterly came to prefer this portrait to any of the other paintings of his father.

13. JAMES WATT. From the painting by John McDonald, engraved in mezzotint by John le Conte, 1858. Lent by J. Macfarlan, Esq.

Full length, seated, turned to left. A posthumous portrait. Glasgow College is in the background.

14. JAMES WATT. Portrait in oils by Henry Howard, R.A. Lent by the Trustees of the National Portrait Gallery.

Bust, facing spectator. This portrait was presented to the Nation by Sir Theodore Martin in 1882.

15. CHANTREY MEDAL (issued by the Art Union of London). Bronze 2⅛″ diam. Lent by H. W. Dickinson, Esq.

Executed in 1846 by W. Wyon, R.A., in commemoration of Sir Francis Chantrey. On the reverse will be seen represented what was considered the latter's greatest work, viż., his seated statue of James Watt.

16. JAMES WATT MEDALS (Two). Bronze 1⅞″ diam. Lent by the Institution of Civil Engineers.

This medal was instituted in 1858 as a " means of rewarding strictly mechanical papers." For many years it was awarded in bronze, as shown, but is now given in standard gold. The obverse shows bust of Watt after Chantrey, with the inscription " James Watt, 1736-1819." The reverse shows the sun and planet engine with the inscription " Steam engine as constructed by James Watt." The medal was designed and executed in 1858 by Mr. J. S. Wyon.

17. WATT CLUB, Edinburgh. Medal in bronze 1⅞″ diam. Lent by F. G. Ogilvie, Esq., C.B., LL.D. Executed by Alexander Kirkwood, c. 1885. Obverse shows bust of James Watt with crest and motto ; reverse has the sun and planet engine.

The medal is now awarded in the Department of Engineering at Heriot-Watt College.

18. MATTHEW BOULTON. Engraving by W. Sharp, after by Sir William Beechey, P.R.A., 1802. Lent by H. W. Dickinson, Esq.

Half length, looking to right.

19. MATTHEW BOULTON. Drawn by W. Evans, engraved in stipple by A. Cardon, 1812, after the original portrait by Sir Wm. Beechey, P.R.A., 1802. Lent by J. Macfarlan, Esq.

Half length, looking to right. The original painting is in the possession of the Boulton family.

20. MATTHEW BOULTON. Medallion in tinted wax by Peter Rouw, 1814. In frame 14½″ diam. Property of the Victoria and Albert Museum. Received 1871.

This is a fine and particularly large example of this artist's work.

21. WILLIAM MURDOCK (1754-1839).. Bust in plaster. Property of the Science Museum. Received 1913.

After the original by Sir F. Chantrey, 1840, in Handsworth Parish Church, Birmingham. Murdock was Watt's ablest assistant.

22. RICHARD TREVITHICK (1771-1833). Portrait in oils by J. Linnell, 1816. Property of the Museum.

Three-quarter length, face half turned to right. Introduced the high pressure steam engine and applied it to locomotion.

23. RICHARD TREVITHICK (1771-1833). Bust after N. N. Burnard. Woodcroft Bequest, 1903.

24. DISTINGUISHED MEN OF SCIENCE OF GREAT BRITAIN living in the years 1807-8. Designed by Gilbert and drawn by F. Skill and W. Walker. Engraved by W. Walker and G. Zobel, 1862. Lent by H. W. Dickinson, Esq.

The original is in the National Portrait Gallery. The central portraits are those of Watt and Boulton ; they are based on their respective portraits by Sir Wm. Beechey.

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25. HEATHFIELD, the WATT GARRET there and HANDSWORTH PARISH CHURCH. Sepia drawings. Lent by Mrs. T. Edgar Pemberton.

Some of the originals by Percival L. Skelton prepared for the illustration of Smiles' " Life of Boulton and Watt " (See No. 299).

26. WATT GARRET at Heathfield. Water Colour by Jonathan Pratt, 1889. Lent by Geo. Tangye, Esq.

The garret which Watt fitted up and workshop and where he spent his spare time in mechanical pursuits.

27. HEATHFIELD. Prints. Presented by R. H. Kirton, Esq.

Watt's house from 1790 till his death.

28. SOHO MANUFACTORY. Coloured aquatint drawn and engraved by Francis Eginton. Lent by the Boulton Trustees.

View of the new factory built at Soho by Matthew Boulton in 1764, when, owing to increasing business, he removed thither from Snow Hill, Birmingham. It was the scene of Watt's experiments on his engine after its removal from Scotland. The plate was engraved for Shaw—History and Antiquities of Staffordshire, Vol. II., 1801, p. 117, where an account of the varied activities of the factory is given.

29. DEVELOPMENT OF THE STEAM ENGINE, 1600-1900. Chart, imperial size. Prepared in the Museum.

II. STEAM PUMPING ENGINE.

Steam engine before Watt ; separate condenser ; single and double-acting engines ; experimental beams ; working drawings showing development ; directions for erecting engines ; duty of engines ; royalty payments ; engine counter ; lawsuits.

30. NEWCOMEN'S ENGINE, near Dudley Castle, 1712. Engraving. Received 1912.

Dated 1719 ; the earliest documentary evidence establishing Newcomen's invention. Detailed particulars are given in letterpress at the side.

M. 4069.

31. NEWCOMEN'S ENGINE, near Dudley Castle, 1712. Photograph of engraving. Presented by W. L. Galloway, Esq.

The original is preserved at Birmingham Reference Library and is similar to the adjoining print (No. 30). An enlargement is shown ; also a sketch elucidatory of the valve gear. M 2570.

32. NEWCOMEN ENGINE, dated 1725. Photograph of a print. Presented by R. B. Prosser, Esq.

Reproduced on a reduced scale from an engraving, copies of which are preserved at the British Museum and at Birmingham Reference Library. The chief advance over the Dudley Castle engine is that the boiler is fed with hot water from the top of the cylinder. M.3468.

33. NEWCOMEN ENGINE MODEL at Glasgow University. Photo. Received 1890.

It was when putting this model into working order that Watt's attention was directed to its great waste of steam and he was led to the invention of the separate condenser.

34. NEWCOMEN ENGINE. Working model made in the Museum, 1891.

A full-sized copy of a model now at King's College, London, probably made by Dr. J. T. Desaguliers about 1740. M.2421.

35. ATMOSPHERIC ENGINE at Long Benton Colliery, near Newcastle, 1772. Model (Scale 1 : 12), made in the Museum, 1919.

Designed by John Smeaton. May be said to represent the highest point attained in construction at the time of Watt's improvements. Inv. 1919.

36. NEWCOMEN ENGINE, near Bristol. Drawing. Received 1905.

Believed to have been built in 1750, worked at Bedminster Colliery till dismantled in 1900. Cylinder 66 in. diameter by 6 ft. stroke. M.2570.

37. NEWCOMEN ENGINE in Fairbottom Valley. Prints. Received 1900.

Reported to have been built in 1750; re-erected at Bardsley, where it worked till 1827. Cylinder 27½ in. diameter by 6 ft. stroke. M.3114.

38. NEWCOMEN ENGINE. Photograph. Presented by Messrs. James Joicey & Co., 1891.

Built in 1754 by the Coalbrookdale Co. and erected at Tanfield Moor Colliery, Durham; dismantled 1891. Cylinder 48 in. diameter by 7 ft. stroke. M.2375.

39. NEWCOMEN ENGINE at Cronstadt, Russia. Drawing (Scale 1 : 36). Woodcroft Bequest, 1903.

Designed by Smeaton, 1773. Constructed at Carron and erected in 1777. Cylinder 66 in. diameter by 8ft. 6 in. stroke. M.3288.

40. GREGORY MINE ENGINE. Print. Presented by W. T. Anderson, Esq., 1917.

Represents the engine built by Francis Thompson, at Ashover, Derbyshire, 1794 (c.f. No. 75). Inv. 1917-34.

41. SYMINGTON'S ENGINE. Drawing. Woodcroft Bequest, 1903.

Copy of that enrolled with Symington's patent specification, 1787. The condenser is confined to the lower and enlarged part of the cylinder by means of a free piston. The arrangement was not considered to be an infringement of Watt's patent. M.1659.

42. NEWCOMEN ENGINE at Kilmarnock. Drawing (Scale 1 : 24). Presented by Robert Kennedy, Esq., 1898.

Erected in 1806 at Caprington Colliery and worked as late as 1901. Cylinder 30 in. diameter by 5 ft. 3 in. stroke. M.3032.

The two following models are part of a Collection presented to the Museum in 1876 by Gilbert Hamilton, Esq., in the name of James Watt & Co.

43. SEPARATE CONDENSER. Original experimental model, 1765. Watt Collection, 1876.

The apparatus with which Watt demonstrated the soundness of his first and most important invention in connection with the steam engine, and the one which was the subject of his first patent (No. 913, A.D. 1769). M.1823.

44. SEPARATE CONDENSER. Original model, tubular type, 1765. Watt Collection, 1876.

Tubular condenser, with air pump, probably made about the same time as No. 43, but not adopted because in advance of the mechanic arts of the period. M.1824.

45. EXTRACTS FROM OLD ACCOUNT BOOK. Presented by the Carron Company.

Particulars of goods supplied to James Watt by this firm between September, 1765, and December, 1770.

46. "EXPERIMENTS ON THE FIRST ENGINE AT SOHO, 18 in. CYLINDER." Photos of pages of notebook 8½ in. by 5½ in. Lent by Geo. Tangye, Esq.

Record, unfortunately incomplete, by Watt, of his experiments on the Kinneil engine commencing November 30th, 1774 (N.B.—The date 1773 is given on the document, but is in a different hand and should be as stated); breaks off June 15th, 1775. The book is preserved at Birmingham.

47. EARLY WATT PUMPING ENGINE. Photograph. Presented by G. R. Jebb, Esq., 1898.

Single-acting beam pumping engine, and constructed by Messrs. Boulton & Watt in 1776 for the Birmingham Canal Navigation's station pumping at Rolfe St., Smethwick. The cylinder is 32 in. diameter by 8 ft. stroke. It is still preserved in working order at Ocker Hill, Tipton. M.3036.

48. EARLY WATT PUMPING ENGINE. Portions. Presented by Messrs. Branson and Gwyther, 1861.

"Old Bess," a single-acting pumping engine, was erected by Matthew Boulton, in 1777, at Soho, to assist in driving his manufactory there. It embodied the first improvements made by Watt on Newcomen's engine. It remained in use till 1848, when this branch of the business was discontinued. Portions preserved are:—Steam cylinder, piston and rod, one length of pump barrel, beam complete with chains, and main bearings. M.317

49. EARLY WATT ENGINE. Model made in the Museum, 1894.

Shows the general arrangement of " Old Bess," erected at Soho in 1777. Boulton used the power from two waterwheels to drive his factory, but in dry weather the flow was insufficient and he had to employ from six to ten horses to assist in pumping water back from the tail race on to the wheels. Watt's original engine, " Beelzebub," which was brought from Kinneil, was used for this duty, but was destroyed by fire. It was then that " Old Bess " was built. Cylinder 33 in. diameter by 7 ft. stroke, pump 31 in. M.2559.

50. TWIN-CYLINDER ENGINE. Sectional model. Watt Collection, 1876.

Two cylinders, single-acting, with their pistons connected by a chain over a pulley so that they work alternately. They are equivalent to one double-acting cylinder, a fact which Watt must have realised, as there is no evidence that an engine resembling the model was ever constructed. M.1820.

51. SINGLE-ACTING BEAM PUMPING ENGINE. Model. Watt Collection, 1876.

Prepared 1792 for the lawsuit Watt & Boulton *v.* Bull. Both piston and piston-rod ends are guided by Watt's parallel motion. It resembles in fact the Cornish pumping engine. M.1804.

52. INVERTED CYLINDER PUMPING ENGINE. Models. Watt Collection, 1876.

Prepared 1792 for the lawsuit Watt & Boulton *v.* Bull. The arrangement had been proposed by Watt in 1765–6 when introducing his separate condenser, but abandoned in favour of the beam construction of Newcomen. Subsequently introduced and constructed on a practical scale by William and Edward Bull, father and son, who, with Trevithick, erected several important pumping plants, hence known as the " Bull " engine. These engineers were, however, infringing Watt's patent for the condenser, and in 1793–5 were stopped by legal proceedings. M.1806; M.1806A.

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53. EXPERIMENTAL MODEL BEAMS. Watt Collection, 1876.

The single balk and the compound beam used by the earlier engineers gave trouble owing to insufficient strength and rigidity, and these model trussed beams were probably made to find out experimentally the strength of such a design before its adoption; for this purpose gudgeons and hooks or staples are attached.

The two larger beams have two diagonal kingposts with tie rods and differ only in that one has its members in duplicate. The smaller beams are parallel girders with top and bottom booms and struts inclined at 60 deg. One of these has given way under the load applied, and this may have been a deciding factor against adapting the design in practice. M.1798.

54. VALVE AND SPINDLE. Watt Collection, 1876.

A conical-seated drop valve such as was introduced for the steam engine by Watt about 1776. M.1822.

The following drawings, Nos. 55 to 79, as well as subsequent items, are from the Boulton & Watt Collection, presented in 1911 by George Tangye, Esq., to the City of Birmingham.

The Collection is housed in the Reference Library, and the objects shown have been lent by the Libraries Committee.

55. NEWCOMEN TO WATT. Drawings showing development of engine.

The first shows the engine with cylinder over the boiler as in the earliest arrangement. The second shows the boiler separate from the engine. The third shows the application to the cylinder of Watt's separate condenser, and the fourth shows, in addition, the application of a closed top and a steam case to the cylinder.

56. ATMOSPHERIC ENGINE AT NEW RIVER HEAD. Drawing of boiler, cylinder and working gear. (Scale 1 : 12).

An excellent drawing of the valves of such an engine. It will be noticed that the haystack boiler employed has a cast iron internal furnace and flue, as was Smeaton's usual practice.

57. COLEVILLE'S ENGINE, 1776. Drawings (Scales 1: 24 and 1 : 4).

Made for Mr. Coleville, Torryburn, Fifeshire. Shows Watt's first form of engine in which the steam case is in direct communication with the boiler, there being no top valve. The condenser is a simple pipe, with a jet inside it, leading from the cylinder. Under the latter will be observed a small fireplace which was for re-evaporating the water condensed within the steam case. This is clearly shown in the plan. A fireplace of this kind was found under "Old Bess" engine. The valves are cylindrical discs working through similar openings. A full explanation in Watt's handwriting is on the drawing.

58. BEDWORTH ENGINE, 1776. Drawings (Scales 1 : 36 and 1 : 24).

For Hawkesbury Colliery, near Coventry. One of the earliest engines built by the firm. The cylinder is in a steam case and there is no top valve. Cylinder 58 in. diameter by 8 ft. stroke ; pumps 41½ in. diameter.

The steam case and air pump are shown ; the latter is peculiar in that it is divided into two barrels as explained in a note in James Watt's handwriting on the drawing.

59. TINGTANG ENGINE, 1777. Drawings (Scales 1 : 36 and 1 : 24).

Erected at TingTang in 1777 for John Beauchamp and co-adventurers. Probably the first Watt engine in Cornwall. The cylinder, which is 52 in. diameter and 8 ft. stroke, has a steam case with a fireplace under it. There is no top valve and the injection is in the eduction pipe.

Another point of interest is that the air pump is double, like that of Bedworth. The mine pump was 10 in. diameter and 7 ft. 9 in. stroke.

60. "OLD BESS" PUMPING ENGINE, 1777. Drawing (Scale 1 : 24).

Shows the original form of the engine (see No. 48). There is no steam case to the cylinder and the valves are at the top and at right angles to the usual position. With this arrangement the piston ascended in a vacuum, a method of working explained in No. 69. The boiler is in close proximity to the cylinder.

61. CHACEWATER ENGINE, 1778. Drawing (Scale 1 : 36).

Interesting as showing that when Watt converted an atmospheric engine to one of his own construction he was able to use the existing cylinder as the steam case for his own cylinder because the latter could be made smaller. This was due to the fact that his separate condenser enabled him to make the effective load on the piston 11 lb. or 12 lb. per square inch as against the 7–8 lb. of the Newcomen engines, and the engine would work more rapidly. At Chacewater, Watt used Smeaton's great beam and probably as many parts of the engine as possible.

62. POLDICE EASTERN ENGINE, 1778. Drawings (Scales 1 : 36 and 1 : 4).

Built in 1778 at Poldice Mine, in Cornwall, for H. H. Tremayne and Co-adventurers. Cylinder 63 in. diameter by 9 ft. stroke.

About this date an important modification was made in the design of the cylinder. Watt's first engines had their cylinders enclosed in a steam case and the upper side of the piston was in constant communication with the boiler steam and with the case. The modification consisted in the introduction of an upper regulator valve, and in separating the jacket steam from the working steam. The regulator was used only when the engine was underloaded, either as a hand-adjusted throttle valve or as a mechanically operated valve to cut off the steam before the end of the stroke and to use the steam expansively. The pumping engines were usually made with unequal-armed beams so that the pump stroke would not exceed 6 ft. or 7 ft., which the Cornishmen found the best in practice.

The valves are shown in detail; levers and pitch chains are used to lift them. (N.B.—The rack and sector came later). The exhaust valve consists of a cylinder with a closed top sliding on an internal guide and seating on the lower edge of its rim. In the top is a small conical pilot valve which opens first and admits the steam to the interior of the cylinder so as to balance it and render it easy to lift. A note on the drawing, in Watt's writing, shows that this was a new construction at this date; it is an early instance of a balanced valve.

63. ALE AND CAKES ENGINE, 1779. Drawing (Scale 1 : 36).

Ale & Cakes was one of the United Mines of Cornwall. Cylinder 58 in. diameter by 9 ft. stroke; pump 7 in. diameter by 6 ft. stroke, *i.e.*, an unequal-armed beam. The agreement for the erection of this engine is to be seen in a frame near at hand.

The cylinder has the sectional steam jacket, and is fitted with the upper working regulator as explained in No. 62. The exhaust valves are of the balanced form described in No. 62. The injection is in the eduction pipe.

64. PERIER'S ENGINE, 1779. Drawing (Scale 1 : 8).

Top working gear for the engine mentioned below, which had a cylinder 63 in. diameter by 8 ft. stroke.

65. LIST OF ENGINE AND BOILER PARTS. Sm. post fol.

These printed lists were sent out with the parts. The interest of this particular list is that there is a translation in French in the handwriting of Watt of the names of the parts for Perier's engine at Paris, 1779.

66. TRESAVEAN ENGINE, 1779. Drawing (Scale 1 : 8).

Built in 1779 for John Williams and co-adventurers. Shows the arrangement for working the valves. The cylinder was 28 in. diameter by 8 ft. stroke.

67. WHEAL VIRGIN ENGINE, 1780. Drawings (Scale 1 : 4).

Shows the connection of the piston rod by an equalising lever to the three chains on the arch-head for a 58 in. diameter cylinder. The correct proportions of this should be carefully noted. From the handwriting on the drawing it may be inferred that it is Watt's own design.

Another drawing shows the cylinder arch chain for a 58 in. or 56 in. diameter cylinder by 9 ft. stroke. Note that the side of the link next to the arch-head is curved so as to bed evenly against the timber.

68. COALBROOKDALE PUMPING ENGINE, 1781. Drawings of details (Scales full size, 1 : 2, 1 : 4, 1 : 8, 1 : 12, 1 : 24).

The engine to which these details relate was erected in 1781 for Messrs. Rathbone, Reynolds & Co. The cylinder was 66 in. diameter by 9 ft. stroke, and worked two pumps 26 in. diameter by 7 ft. stroke. The steam and exhaust valves for the cylinder are of the sector and rack moved type and the latter of the two is of the balanced form described in No. 62. The beam forgings and the chain for it are also shown.

69. NEW RIVER ENGINE, 1783. Drawing (Scale 1 : 36).

Had a cylinder 32 in. diameter by 7 ft. 9 in. stroke. The steam and exhaust valves were placed at the top of the cylinder and the lower end was in continuous communication with the condenser, so that the piston ascended in a vacuum instead of in steam as in Watt's original arrangement. This system appears to have been adopted in the Soho engine of 1777 (see No. 60), and in other engines, but it was abandoned owing to the increased steam consumption. The engine was probably arranged to work expansively, the steam valve being closed by the valve gear before the end of the stroke ; a fly-wheel driven by a sun and planet gear was added to equalise the motion when thus working. A similar engine was erected at Chelsea Waterworks about the same time.

70. POLDICE No. 3 ENGINE, 1783. Drawing (Scale 1 : 36).

Cylinder 63 in. diameter by 9 ft. stroke, and pump 17 in. diameter by 5ft. 6 in. stroke. The engine was removed in 1791 to the Manor Mine, when a new cylinder, 64 in. diameter, was put in.

71. POLGOOTH ENGINE, 1783. Drawing (Scale 1 : 24).

Shows the built-up wooden beam ; the arms are of unequal length and the construction is of the kingpost truss type. Cylinder 63 in. diameter by 9 ft. stroke.

On the same drawing is shown the wagon boiler for the engine. This is 16 ft. long by 7 ft. wide and has a rectangular through flue, 39 in. by 20 in.

72. CROUCHLEY'S ENGINE, 1783. Drawings (Scale 1 : 36).

Made for Mr. Joseph Crouchley of Leigh, Lancs. Of the single-acting type, cylinder 34 in. diameter by 8 ft. stroke, with chains on both ends of the beam. Closely resembles " Old Bess." The injection is in the pipe leading to the air pump, which is outside the engine house.

73. WATT SINGLE-ACTING PUMPING ENGINE, 1784 onwards. Drawing (Scale 1 : 24).

Both the piston and pumping rod are guided by Watt's parallel motion. The valves are of the drop type with rack and sector. The air pump is outside the engine house.

74. NORTH DOWNS ENGINE, 1785. Drawings (Scales 1 : 36, 1 : 24 and 1 : 12).

Cylinder, 42 in. diameter by 8 ft. stroke, double-acting ; the condenser and air pump are placed close to cylinder and inside the engine house. A parallel motion, formed of wooden rods, is fitted to the cylinder end of the beam, that arm being longer than the pump arm. The method of lifting a second line of pump spears with two T bobs is shown.

The parallel motion and also the construction of the beam is shown in detail. The truss is of the kingpost type, and the beam is built up of six balks, owing to the difficulty in obtaining a single tree of large enough dimensions.

75. GREGORY MINE ENGINE, 1786. Drawings (Scale 1 : 36).

Built for Joseph Banks and adventurers at the Gregory Mine, Ashover, Derbyshire, to replace an atmospheric pumping engine (see adjoining drawing). Cylinder 45 in. diameter by 8 ft. stroke.

76. HUYAS ENGINE, 1793. Drawings (Scales 1 : 36, 1 : 12).

Built for Edward Fox and co-adventurers at Huyas, in Cornwall. The engine is double-acting and the piston is connected to the beam by Watt's parallel motion. The air pump is worked from a second beam attached by a link to the engine beam. There are pump spears on both ends of the beam, that on the side next to the cylinder being at an incline and led into the shaft by a V bob.

The parallel motion and the strutting of the beam are shown in considerable detail.

77. BRANDLING'S ENGINE, 1794. Drawings (Scales 1 : 36 and 1 : 8).

This single-acting engine, cylinder 60 in. diameter by 8 ft. stroke, was built for Charles Brandling, of Gateshead. The connections to the arch-head and pump rods are by chains. The condenser and air pump are inside the engine house. The haystack boiler with its connections and fittings is also shown. A drawing of the beam shows that the parallel motion as an alternative to the chain was under consideration. The drawing is of further interest in that it shows the method of connecting the arch-head to the beam by a mortise and tenon joint.

78. COLLIERY PUMPING ENGINE, 1794. Drawing (Scales 1 : 36 and 1 : 8).

Constructed for Mr. J. C. Curwen, of Workington. The double-acting cylinder is 33 in. diameter by 6 ft. stroke, and there is a parallel motion to the piston rod, while an extension of it works the air pump. Motion to a winding drum was given by a connecting rod and a crank (the patent for which had just expired) and a fly-wheel. The pump rod is worked by a beam connected by a link with the main beam.

The cast-iron crank, also the connecting rod end, are shown to a larger scale.

79. HEBBURN COLLIERY ENGINE, 1798. Drawings (Scales 1 : 36, 1 : 8 and 1 : 4).

In this double-acting engine, cylinder 63 in. diameter by 8 ft. stroke, pump rods are attached to both ends of the beam, that on the cylinder end being at an angle, as shown in No. 76 *ante*, and led into the pit by V bobs as seen in the drawing below. The air pump is outside the house and is driven by an independent beam. The main beam is of the diagonal king post truss type. The steam and exhaust valves are worked by rack and sector. The exhaust valve is of the balanced form. Described in No. 62.

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80. ATMOSPHERIC PUMPING ENGINE at Elsecar. Drawing (Scale 1 : 24). Presented by C. O. Becker, Esq., 1919.

Believed to have been built in 1788. Still working at Earl Fitzwilliam's Collieries, Elsecar, nr. Sheffield. Cylinder 46 in. diameter by 5 ft. stroke.
Inv. 1919.

81. ATMOSPHERIC ENGINE at Pentrich, Derbyshire. Prints. Presented by W . T. Anderson, Esq., 1917. Drawing (Scale 1 : 24). Presented by C. O. Becker, Esq., 1919.

Built at Chesterfield in 1791 by Francis Thompson, and at work till 1917. Cylinder 57 in. diameter by 6 ft. 6 in. stroke. Inv. 1917–34 and 1919.

82. ATMOSPHERIC TYPE ENGINE at Newmarket. Drawing (Scale 1 : 24). Presented by C. O. Becker, Esq., 1919.

Known as " Old Sarah." Worked at Newmarket Silkstone Colliery till dismantled in 1918. Had a separate condenser. Cylinder 54 in. diameter by 5 ft. stroke. Inv. 1919.

83. ATMOSPHERIC TYPE PUMPING ENGINE at Gildersome. Photograph, and Drawing (Scale 1 : 32). Received 1912.

Worked at Philadelphia Pit, Gildersome, nr. Leeds, till 1912. Resembles Watt's earliest single acting engine in that the cylinder is open-topped and the equilibrium valve is dispensed with. Cylinder 24 in. diameter by 5 ft. stroke.
M.4062.

84. " DIRECTIONS FOR PUTTING THE ENGINE TOGETHER." MS. Notebook 4to. Lent by the Boulton Trustees.

MS. original of matter which appears in the printed booklet (No. 86). Two sections of pistons showing packing are given. This fixes the date at about 1778.

85. " DIRECTIONS FOR PUTTING THE STEAM ENGINE TOGETHER." MS. 4to. Lent by the Boulton Trustees.

MS. original of part of the matter printed in the booklet (No. 86). Illustrated with a drawing (Scale 1 : 72) of Wrensnest engine and of other engines. It must therefore date about 1778.

86. BOULTON AND WATT ENGINE : " Directions for erecting and working the newly invented steam engine by Boulton & Watt." 6 copper plates. 12mo. Lent by the Birmingham Reference Libraries Committee.

Gives instructions in the minutest detail for building the engine house, putting the engine together and for working it, with additional directions at the end. A set of the plates is shown separately in a frame. The date is probably 1780.

87. PERFORMANCES OF ATMOSPHERIC ENGINES, 1764-1779. MS. Notebook 7¼ in. by 4½ in. Lent by the Boulton Trustees.

In this have been entered on printed forms, data and tests concerning a large number of atmospheric engines in different parts of the country. Some of the tests are by Watt himself. The book is open at the test of Long Benton engine. (See No. 35).

88. " CALCULATIONS AND PERFORMANCES OF CORNISH ENGINES, 1778." MS. Notebook 7 in. by 4½ in. Lent by the Boulton Trustees.

Calculations are given for fixing the duty of Watt engines as compared with atmospheric ones. The book is open at the calculation for Wheal Union, Hallamannin and Tingtang.

89. " MONTHLY PERFORMANCES OF CORNISH ENGINES, Jan., 1778, to Jan., 1782." MS. Notebook 7⅝ in. by 5¾ in. Lent by the Boulton Trustees.

This tabulates under printed headings performances of Watt engines, consumption of coals and value in money of the one-third saving which was Boulton & Watt's share. The book is open at Tingtang engine.

90. MONTHLY PERFORMANCES OF CORNISH ENGINES, 1779 to 1782. MS. Notebook, 7 in. by 4½ in. Lent by the Boulton Trustees.

Information is tabulated similarly to that in the adjoining book, but it would appear to be earlier. The book is open where the " Method of calculating saving " is given.

91. ORIGINAL INDENTURE. Lent by H.M. Patent Office.

Indenture of agreement made 30th December, 1779, between Watt & Boulton and Joseph Beauchamp and co-adventurers for the erection and working in Cornwall at Ale and Cakes Mine of an engine, cylinder 58 in. diameter by 9 ft. stroke (see No. 63), and at Poldory Mine of an engine, cylinder 48 in. diameter by 8 ft. stroke, and for the payment of one-third of the value of the saving in fuel obtained, as compared with a common fire-engine of corresponding size.

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92. WATT'S ENGINE COUNTER. Contributed by James Brown, Esq., 1861.

When Boulton & Watt's pumping engine was being introduced into the Cornish mines, payment was based on the work performed. Hence Watt, about 1779, introduced the apparatus shown. A pendulum by a reversed escapement drives dials advancing in powers of ten. The pendulum got its motion from the beam to which the counter was fixed. The mine owners objected to these counters on the ground that they did not differentiate the short strokes of the beam from the complete ones. M.526.

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93. A SHORT STATEMENT on the part of Messrs. Boulton & Watt in opposition to Mr. Jonathan Hornblower's application to Parliament for an Act to prolong the term of his patent, 1792. 2pp. foolscap. Lent by Geo. Tangye, Esq.

94. LAW SUIT: Special case in the cause of Boulton and Watt against Bull, 1795. 8vo. Lent by Geo. Tangye, Esq.

Contains the shorthand report of the case, with the arguments of the Judges upon it and an Appendix. The matter is given at length in the adjoining pamphlet.

95. LAW SUITS. The arguments of the Judges in two causes relating to the letters patent granted to James Watt, Engineer, 1799. 8vo. Lent by Geo. Tangye, Esq.

This in two parts. The first recites the patent of James Watt, No. 913, A.D. 1769, and the Act for extending the patent for 25 years from 1775; the second part contains the report of the cases Boulton & Watt *v.* Bull, and Boulton & Watt *v.* Hornblower.

III. ROTATIVE STEAM ENGINES.

Substitutes for crank; engines and models; engine details; engine testing steam boilers; working drawings; agreements for erection of engines; steam engine contemporary with Watt; cylinder boring.

96. SUN AND PLANET GEARING. Model made by James Watt. Watt Collection, 1871.

Watt was working on the application of the crank and connecting rod to an engine beam as a means of converting reciprocating into circular motion when he was forestalled by the patent taken out in 1780 by James Pickard. Instead of contesting the patent, Watt decided to employ other means. This and the four succeeding models show some of the mechanisms for this purpose which he patented in 1781. Of these, the one shown—sun and planet gearing—alone came into considerable use. M.1811.

97. LADDER CONNECTING ROD. Model by James Watt. Watt Collection, 1871.

This is another of the mechanisms schemed by Watt as an equivalent for the crank and embodied in his patent of 1781. It resembles somewhat a mangle wheel motion reversed. M.1789.

98. LADDER CONNECTING ROD. Model by James Watt. Watt Collection, 1871.

Shows a mechanism similar to that of the adjoining model. Patented by Watt in 1781 as an equivalent for the crank. M.1790.

99. INTERNALLY GEARED CONNECTING RODS. Models by James Watt. Watt Collection, 1871.

Further mechanism patented in 1781 by Watt as an equivalent of the crank. The connecting rod end is formed into a large internal spur wheel which gears with a spur wheel on the fly-wheel shaft. M.1790A.

100. CROWN CAM MOTION. Adapted to a winding gear. Model. Watt Collection, 1876.

This is another of the mechanisms patented in 1781 by Watt as an equivalent of the crank. The drawing which is shown adjoining indicates that this motion was actually adopted in practice, in one instance at any rate. M.1821.

101. ROTATIVE ENGINE. Specification of an invention of certain new IMPROVEMENTS upon STEAM or Fire ENGINES, by James Watt, Engineer [1798]. 4to. Lent by Geo. Tangye, Esq.

Recites Watt's letters patent of 1782 ; is illustrated with four copper plates (Scales 1:48 and 1:72) of the specification drawings, as reproduced for Hall's Encyclopædia of 1795.

102. " MILLS AND ROTATIVE MOTIONS, 1782." MS. Notebook 8 in. by 6½ in. Lent by the Boulton Trustees.

Open to show a drawing (Scale 1:48) of an edge runner mill for grinding clay, &c.

103. BOULTON AND WATT'S ROTATIVE ENGINE. Presented by Matthew Piers Watt Boulton, Esq., 1861.

Early example of Watt's double acting rotative beam engine embodying the separate condenser and air pump. Erected at Soho Factory in 1788 to drive the machinery for lapping or polishing the steel ornaments which were then a staple of Boulton's productions, hence known as the " Lap " engine. M.318.

104. SUN AND PLANET ENGINE. Presented by G. Atkinson, Esq., 1885.

Built by Boulton & Watt in 1797 for John Maud, Wholesale Chemist, 66, Aldersgate Street, E.C., where it continued working till presented to the Museum. Originally of 8 nominal h.p., cylinder 16 in. diameter, by 4 ft. stroke, in 1806 a new cylinder 19¼ in. diameter was put in, giving 12 nominal h.p. The original drawings from which the engine was constructed are shown adjoining. M.1620A.

105. BEAM ENGINE. Model (Scale about 1:8). Lent by C. W. Osman, Esq., 1886.

Made by William Tongue while apprentice with Boulton & Watt between 1797 and 1804. (See No. 125.)
The general arrangement is similar to No. 106. The valves are of the tubular or socket type introduced by William Murdock, rendering only one opening into the valve box necessary. Inv. 1861-47.

106. DOUBLE-ACTING BEAM ENGINE. Model. Watt Collection, 1876.

Probably made subsequently to 1800, and although generally on the lines of Boulton & Watt engines of that date, many of the details are different to those of say No. 104. The cylinder is 1⅝ in. diameter by 4½ in. stroke. M.1805.

107. CABINET STEAM ENGINE. Contributed by A. Greig, Esq., 1858.

The property of James Watt, who bequeathed it to John Kennedy, of Manchester.
It may be said to represent the steam engine as left by Watt in 1800. In its general arrangement it hardly differs from similar engines of 50 years subsequently. Inv. 1858-1.

108. CABINET STEAM ENGINE. Sectional Model, made in the Museum, 1866.

Copy in wood, sectioned, of the adjacent engine. The slide valve is the long D type actuated by a single eccentric with a gab engagement. Watt's parallel motion and conical pendulum are used, also the simple crank and connecting rod. M.1002.

109. BEAM ENGINE. Motion diagram. Watt Collection, 1876.

This model shows the long D valve actuated by an eccentric applied to a beam engine. The idea was due to William Murdock in 1797, and was adopted by the firm of Boulton, Watt & Co., after 1800. M.1807.

110. BELL-CRANK ENGINE. Diagram Model. Watt Collection, 1876.

Probably made to test the general convenience of the arrangement when the design was first mooted (see No. 141). The valve is of the long D type driven intermediately from an eccentric on the shaft instead of by the elliptical cam shown in the adjacent drawing. M.1808.

111. BEAM ENGINE FRAME. Model. Watt Collection, 1876.

Resembles the framing adopted in rotative engines, and was probably prepared when the design was under consideration. M.1799.

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112. VACUUM GAUGE. By James Watt. Watt Collection, 1876.

This simple instrument has a cylinder whose piston is connected with a spring through a rocking beam on which is a pointer. By making a connection to the cylinder or condenser, an indication of the pressure at any point of the stroke is obtainable. Probably the instrument was at the root of the invention of the steam engine indicator. (No. 115). M.1816.

113. VACUUM GAUGE. Presented by Messrs. Watney, Combe, Reid & Co., 1899.

Supplied for the same engine as the succeeding and used to indicate the degree of exhaustion in the condenser. It is on the principle of the mercurial barometer. M.3076.

114. PRESSURE GAUGE. Presented by Messrs. Watney, Combe, Reid & Co., 1899.

Fitted to the cylinder jacket of a rotative beam engine supplied in 1808 by Boulton, Watt & Co., to Reid's Brewery, Clerkenwell. Typical of the arrangement in use till about 1850 when increasing pressures caused the adoption of dial gauges. M.3075.

115. WATT STEAM ENGINE INDICATOR, in case. Lent by E. A. Cowper, Esq., 1890.

This instrument was introduced by Watt, but the date of its invention is uncertain. In 1796 he published a description of a pressure gauge consisting of small spring-loaded piston, but this is only a modification of his vacuum gauge. (No. 112). The important addition of a pencil on the piston rod marking on a sheet of paper moved transversely to it is believed to be due to John Southern, Watt's indoor assistant. In this way the pressure at every point of the stroke is recorded and a closed diagram obtained whose area is proportional to the work done.

The instrument shown was formerly in the possession of Mr. Bennett, Boulton & Watt's agent in Manchester, and the diagram was taken in 1840 by Prof. E. Cowper. M.2299.

116. WATT INDICATOR, in case. Property of the Science Museum. Received 1901.

Of slightly later date than the instrument beside it. The reciprocating frame is in metal instead of wood and has clips by which the paper is held. Various fittings, such as a guide pulley frame, are shown in the box. M.3168.

117. INDICATOR DIAGRAM. Lent by the Boulton Trustees.

Taken in 1832 by the adjoining instrument. As will be noticed, the method of measuring the area is the one still in use.

118. "TABLE OF CYLINDERS, STROKES, POWER AND COAL." 2pp. MS., 4½ in. by 7 in. Lent by the Boulton Trustees.

For rotative engines based on a piston load of 16 lb. per square inch and a h.p. of 35,900 ft. lb. per min.

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119. HAYSTACK BOILER. Model (Scale 1 : 12). Made in the Museum, 1907.

Type used throughout the 18th century; survived in the Staffordshire district till late in the 19th. As the pressure was practically only that of the atmosphere, questions of construction were subsidiary to those of heating surface. M.3502.

120. WAGON BOILER. Model (Scale 1 : 12). Made in the Museum, 1901.

Introduced by James Watt about 1780, and remained in common use till about 1850, when the gradual increase that had taken place in boiler pressures led to its abandonment owing to the inherent weakness of its shape. M.3174.

121. ORIGINAL INDENTURE. Presented by Messrs. J. S. Smith, Druce & Co., 1908.

Indenture of agreement made March 1st, 1786, between Watt and Boulton and Samuel D. Liptrap and partners, for the erection and maintenance in London of a double-acting beam engine cylinder, 17 in. diameter by 5 ft. stroke, and for the payment of an annual premium of £63 during the unexpired term, viz., 14 years of Watt's patent. M.3542.

122. INDENTURE. Lent by Birmingham Reference Libraries Committee.

Indenture of agreement made June, 1797, between James Watt and Matthew Boulton and John Maud for the erection of an engine 16 in. diameter by 4 ft. stroke at 66, Aldersgate Street, and for the payment of a sum of £562 10s. 0d. This is the engine preserved close by. It will be noticed that a lump sum and not an annual premium is now charged, no doubt in view of the imminent expiry of Watt's patent.

123. ORIGINAL INDENTURE. Lent by H.M. Patent Office.

Indenture of agreement made June 1st, 1799, between Watt and Boulton and James Lees and Partners, for the erection and working at Werneth Colliery, Prestwich, Lancs., of two double-acting pumping and winding engines, cylinders 14¾ in. diameter by 3 ft. stroke, 6 h.p., and for the payment of a lump sum of £710 to include certain scheduled materials.

124. 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 at the Patent Office Library, 1872. 8vo. Lent by H.M. Patent Office.

The originals of these deeds will be found on the walls. Drawings of the first named of these engines will be found in the Exhibition. (See No. 63.)

125. INDENTURE. Facsimile. Lent by C. W. Osman, Esq., 1886.

A lithographed facsimile of the indenture of apprenticeship entered into in 1797 by William Tongue with Matthew Boulton and James Watt. The period was the usual one of seven years. The document is a printed one and contains the usual provisos as to good conduct; in lieu of board and lodging, a sum of money was payable. M.319.

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126. WATT'S ROTARY ENGINE WITH CONDENSER. Drawing (Scale 1 : 16), made in the Museum.

Copied from Watt's patent specification of 1782 (No. 1321). He abandoned this kind of engine after unsuccessful trials.

The arrangement has been re-invented and worked out in a practicable form. M.2557.

127. WATT'S SEMI-ROTARY ENGINE. Drawing (Scale 1:10).

Copied from Watt's patent specification of 1782. He had had the idea in his mind since 1765 or 1766, and there is an unfinished model in the Watt garret at Heathfield, showing that he had still some hope of making something of it. M.2557.

The drawings following Nos. 128 to 143 are lent by the Birmingham Reference Libraries Committee (see note p. 13).

128. FORGE ENGINE, 1782. Drawings (Scales 1 : 36 and 1 : 12).

Shows an engine made for Mr. Wilkinson's forge mill at Bradley. The cylinder was 42 in. diameter by 6 ft. stroke, and the condenser and air pump were indoors. The chief point of interest in this is that an eccentric wheel, embraced by a frame fitted with anti-friction rollers, is used for converting reciprocating into rotative motion ; this expedient is included in Watt's patent of 1781. The engine was used to drive a tilt hammer, some of the details of which are shown.

129. BRADLEY FORGE ENGINE, 1782. Drawings (Scale 1 : 12 and 1 : 8).

Shows details of the construction of the eccentric wheel gear and of the cams or wipers for lifting the tilt hammer. The valve gear is interesting as showing the development for a single acting engine.

130. CROWN CAM WINDING GEAR, 1782. Drawing (Scale 1:4).

Shows a gear similar to that of the adjoining model ; it would appear that it was constructed for John Wilkinson, at Bradley. The cylinder was 15 in. diameter by 4 ft. stroke. The method of construction is described on the drawing.

131. FORGE ENGINE, 1784. Drawings (Scales 1 : 36 and 1 : 4).

Shows a single-acting beam engine 26 in. diameter by 6 ft. stroke, with sun and planet gear, made for John Wilkinson, at Horsehay. There is a detail of the " perpendicular " (*i.e.*, parallel) motion for this engine which would appear to be a very early design, because the radius rod has its centre beyond the end of the beam.

132. ALBION MILLS No. 1 ENGINE, 1784. Drawings (Scales 1 : 36 and 1 : 8).

Shows the general arrangement of the engine and the flour mill. A sun and planet gear is used. The cylinder was double-acting, 34 in. diameter by 8 ft. stroke. The chief peculiarity is that the piston rod is extended upward in the form of a rack which gears with a sector on the archhead ; this arrangement was included in Watt's patent of 1782 for the double-acting engine. It is probable, however, that before the engine was made, the parallel motion had been introduced, as the next drawing, dated 1785, shows such a motion with wooden radius rods for this engine.

133. LAP ENGINE, 1788. Drawings (Scales 1 : 36 and 1 : 4).

Of particular interest as being the original drawings of the adjoining engine (see No. 103) which has been preserved. The wagon boiler that supplied the steam was 6 ft. long, 3 ft. 6 in. wide by 4 ft. high. The valve gear as originally constructed is seen and also the governor, which is of interest, because it is an early example of governor construction.

134. COLLIERY WINDING GEAR, 1788. Drawings (Scales 1 : 36 and 1 : 12).

The main framing, the fly-wheel, the gearing and the pit framing of an engine built for John Christian, of Workington, are shown. The drawing is of particular interest in showing that a spiral winding drum was in use at this early date. Of this details are given showing how it was built up in sections.

135. WINDING ENGINE, 1791. Drawing (Scale 1 : 8).

Shows the cast-iron crank and connecting rod ends of the engine at Wrensnest for the Coalbrookdale Co.

136. MILL ENGINE, 1792. Drawings (Scale 1 : 8).

Shows very clearly the parallel motion, also the valve gear for the engine built for Mr. Abraham Illingworth's Cotton M ll at Stockport. Cylinder 24½ in. diameter by 5 ft. stroke.

137. MILL ENGINE, 1794. Drawing (Scale 1 : 8).

Details of connecting rod ends for an engine, cylinder 27 in. diameter by 6 ft. stroke, made for Messrs. Marshall & Benyon's Flax Mill, nr. Leeds. The very careful and correct design should be noted ; it must be borne in mind in all cases that owing to the lack of machine tools, all forged and cast work has to be designed so as to require the minimum of fitting.

138. MILL ENGINE, 1795. Drawings (Scale 1 : 36 and 1 : 8).

Double-acting engine made for Messrs. William Hawks & Co. Cylinder 19 in. diameter by 4 ft. stroke ; the crank arm of the beam is longer than that of the cylinder. The parallel motion and the working gear are shown in detail. The externally-fired wagon boiler and its setting are also shown.

139. FACTORY ENGINE, 1797. Drawings (Scales 1 : 36 and 1 : 8).

Original drawings from which the engine (now preserved in the Museum adjoining) were made. Although subsequent to the expiration of the crank patent, the sun and planet motion is still used. The cylinder was 16 in. diameter and the stroke 4 ft. The boiler was of the externally fired wagon type, 9 ft. long by 3 ft. 6 in. wide and 5 ft. 3 in. high ; the setting of this is shown. Details of the parallel motion and of the connecting rod end are given. It will be noted that they differ only slightly from those described elsewhere.

140. BLOWING ENGINE, 1800. Drawings (Scales 1 : 36 and 1 : 12).

Erected for Thomas Hill & Co., at Blaenavon Iron Works, 1800. Cylinder 40 in. diameter by 8 ft. stroke. Watt's parallel motion is used for both ends of the beam which is of cast iron, a material which was introduced for the purpose by Murdock at this date. Details of the valve gear of the beam and of the parallel motion are shown.

141. BELL-CRANK ENGINE, 1802. Drawing (Scale 1 : 36).

Shows the arrangement of a bell-crank engine (see No. 110) adapted for blowing purposes, for Mr. Fulton, of Glasgow. The cylinder, 13 in. diameter by 2 ft. stroke, was fitted with a long D valve. An externally-fired wagon boiler is shown.

142. HAYSTACK BOILER, 1790. Drawing (Scale 1 : 24).

Shows the boiler, grate and setting of a haystack boiler for an engine of 10 h.p., cylinder 17½ in. diameter by 4 ft. stroke, for Messrs. Bayly & Co.'s lead works. The grate is steeply inclined.

143. DAMPER AND FEED APPARATUS, 1810. Drawing (Scale 1 : 12).

Shows that at the date indicated the damper and feed apparatus for boilers had been standardised. The construction is explained in the model of the haystack boiler (see No. 119).

144. SUN AND PLANET ENGINE WITH BOILER. Drawings (Scales 1 : 36 and 1 : 8). Lent by the Institution of Mechanical Engineers.

Rotative engine made for Messrs. Grimshaw, Webster, Hills & Smith, 1795. Cylinder 21¾ in. diameter by 5 ft. stroke. The two wagon boilers were 9 ft. 6 in. long, 7 ft. 3 in. high and 5 ft. 6 in. wide. This set of 13 drawings is interesting in that it shows what were considered necessary for a purchaser in erecting an engine ; the cylinder and working parts were of course supplied by the firm. On the back of most of the drawings is a note which reads :—" This drawing is the property of Boulton & Watt, who beg that it may be kept clean, not permitted to be copied and returned to them as soon as the engine is finished." This note will be found on the back of most of the drawings in the Boulton & Watt Collection.

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145. MURDOCK'S ROAD LOCOMOTIVE : Copy made in the Museum, 1894.

William Murdock, while in Cornwall erecting pumping engines for Boulton & Watt, made the original between the years 1781 and 1786 (see Letter No. 278). Altogether he made three locomotives, but under pressure from the firm he abandoned the invention. The original model is at Birmingham. M.2413.

146. OSCILLATING ENGINE. Model. Lent by W. Murdock, Esq., 1894.

Original model constructed by William Murdock in 1785 at the Soho Works. Made mainly of wood, it was probably only meant to be tried with compressed air. The valve is of the piston type actuated by the rock of the cylinder ; the feed pump is moved by an eccentric. Both of these features anticipated by many years the date of their actual adoption, which was about 1799, when Watt was retiring, and Murdock had assumed the management of the works. The oscillating engine was not adopted till later.

It is worth noting that at the time the model was made, Watt was employing the sun and planet gear to avoid using a crank. M.2554.

147. BEAM ENGINE MODEL WITH SUN AND PLANET MOTION. (Scale about 1 : 8). Received 1869.

The sun and planet gear and parallel motion are fitted ; the main parallelogram is extended as a pantograph to get a guided point to attach the air pump rod. The tappets strike a fork keyed to an enternally geared segment which controls a four-way cock. M.1175.

148. NEWCOMEN ROTATIVE ENGINE. Model (Scale about 1 : 8). Property of the Museum. Received 1912.

This represents the atmospheric engine erected in 1790 at the " Crank " Mill, Morley, Yorks.

In order to meet the demand, at the close of the 18th century, of those people who wanted engines for working mills but who did not care to pay the royalties demanded by Boulton and Watt, the somewhat clumsy method shown was adopted. The outdoor end of the beam has a connecting rod to the crank on the mill shaft to which was keyed a fly-wheel heavily weighted on the crank side so as to store one-half of the work done on the downward stroke and restore it on the upward stroke. M.4148.

149. SINGLE-ACTING ROTATIVE ENGINE. Model (Scale 1 : 8). Lent by W. W. S. Westwood, Esq., 1894.

For many years at Corbyn's Hall Ironworks, whither it had been sent from Soho Foundry. It illustrates how from an open-topped cylinder rotative motion can be obtained, and may have been made to show some client how his atmospheric engine could be converted and improved by the separate condenser and the parallel motion. We have evidence, however, that the firm of Boulton and Watt never undertook such conversion. M.2657.

150. HESLOP'S BEAM ENGINE. Presented by the Earl of Lonsdale. 1878.

This winding and pumping engine was erected about 1795 by Adam Heslop at Kells Pit, Whitehaven, where it worked for many years; subsequently it was used at other pits till its removal to South Kensington.

The arrangement is really a combination of a single acting high-pressure cylinder with a Newcomen cylinder, and was patented by Heslop in 1790, although it would appear to have been an infringement of Watt's patent for the separate condenser which remained in force till 1800. M.1464,

151. HIGH PRESSURE ENGINE AND BOILER. Received 1879.

Made by Richard Trevithick in 1811 and in constant use for thrashing, etc., till removed to London. Cylinder 9.5 in. diameter by 26 in. stroke; boiler, 7 ft. long by 4.5 ft. diameter, with a single flue; pressure 40 lb. per square inch. M.1470.

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152. BORING MILL. Drawing (Scale about 1 : 36). Lent by the Birmingham Reference Libraries Committee.

Drawing (undated) by John Gilpin, of the Boring Mill at Bersham, the Works of John Wilkinson, who had invented about 1775 an improved boring mill which was the only one capable of boring Watt's cylinders with sufficient accuracy.

This mill differed from earlier designs in that the cylinder was fixed and the boring head was moved along a straight bar rotating in bearings at each end. The bar was hollow and the boring head was connected, through a longitudinal slot, with a central rack bar, the outer end of which was pulled along by the action of a pinion and weighted lever. Two such bars with cylinders in position are shown driven by the same water wheel. The boring bar shown in the Machine Tool Section is reputed to be an original Bersham bar, and its dimensions agree with those of the larger bar on this drawing.

153. BORING MILL, 1795. Drawing (Scale 1 : 36). Lent by the Birmingham Reference Libraries Committee.

A vertical cylinder boring mill and an evident adaptation of Wilkinson's. The cylinder to be bored is supported from the sides of the pit by four adjustable struts. The bar is solid, and there are two rack bars and pinions for feeding the boring head.

IV. OTHER INVENTIONS OF WATT.

PROSPECTIVE MACHINE; COPYING PRESS; MICROMETER; MISCELLANEOUS WATT MODELS; SCULPTURE LATHE.

154. PERSPECTIVE APPARATUS. Made by James Watt. Woodcroft Bequest, 1903.

Engraved " J. Watt, Glasgow, invt. fecit," and must have been made about 1760. It is remarkable for neatness of workmanship and inventiveness in detail. Consists of a peep-hole adjustable in position to a slight extent, with a fixed board for holding the paper, the whole being on a tripod whose legs are made to nest into one another. By means of a double parallel motion, an inverted T-piece can move over the surface of the board. The upper end of this piece is a sighting point which is made to trace the outline of the object to be drawn as seen by the eye placed at the peep-hole. The pencil is carried by a tube at the double angle of the T-piece. (See Muirhead, " Mechanical Inventions of James Watt," 1854, vol. I., p. cxii.)

155. COPYING PRESS. Woodcroft Bequest, 1903.

Designed by James Watt to carry out his invention for copying MSS., etc.; patented by him in 1780. The process is essentially the same as that still in use and consists in pressing the original MSS. written in hygroscopic ink against a damped sheet of tissue paper. The press itself is on the lines of a copper-plate printing press. The book for damping the tissue paper, the oiled paper for putting next to the tissue, and the board with its pad for passing between the rollers, is seen in the case, while the table on which the press stood, with a drawer for holding the wetting book and with another drawer for leaving the sheets in while drying is shown close by. The press shown (No. 3793) is of the counting house pattern, very largely used for multiplying drawings, as will be seen by examples from the Boulton and Watt Collection on the walls; in this case the lettering, figuring and colouring were inserted subsequently.
M.1837.

156. PORTABLE COPYING MACHINE. Woodcroft Bequest, 1903.

Owing to the bulk and weight of the counting house type of machine (see No. 155), Watt was led to design the portable pattern shown (see Letter No. 290). This was made in three sizes—quarto, foolscap and folio—the one shown being of quarto size. With it are shown books of directions printed in French and English. M.1837.

157. LETTER-BOOK of the firm of JAMES WATT & CO., 1780-1786. Lent by the Birmingham Public Libraries Committee.

Concerned with the business arising out of the firm which was established to manufacture the copying-press patented by James Watt in 1780. It will be noted that the flimsies produced by the press are pasted into the letter-book. The latter is open at page 76 where the price of the machines, etc., is stated.

158. END MEASURING INSTRUMENT. Watt Collection, 1876.

Date uncertain. There are two jaws, one fixed to a slide and the other movable by a fine-threaded screw. A pinion working into the screw records the number of complete turns, and a pointer attached to the screw registers on a graduated dial fractions of a revolution.

The principle of the instrument is, in fact, that employed in the most accurate of modern micrometers. M.1814.

159. TREADLE BAR LATHE. Said to have been the property of James Watt. Woodcroft Bequest, 1903.

Is of the same pattern as those preserved in Watt's garret at Heathfield.

160. BACHELOR'S STOVE. Presented by J. W. G. Watt, Esq., 1863.

Believed to have been designed and used by James Watt. Consists of a container with false bottom or grate, apparently for taking solid fuel. A shallow stew pan and kettle are alternatively accommodated. The whole is arranged for compact stowage. M.942.

The models following, Nos. 161 to 176, are part of the Watt Collection (see note on p. 12).

161. ATMOSPHERIC ENGINE PISTON. Model. M.1817.

162. TILT HAMMERS. Model of a pair.

May have been prepared when the application of the steam engine to a tilt hammer at John Wilkinson's works at Bradley, in 1782, was being made. M.1809.

163. FORGE HAMMER AND A TILT HAMMER. Model.

Probably prepared at the same time as the adjoining model. M.1795.

164. ROLLING MILL. Model.

Included in Watt's patent of 1784. May have been prepared when some extensions were in contemplation at Boulton's works, or may have been a scheme for some iron-works such as those of John Wilkinson. M.1794.

165. ROLLING AND SLITTING MILL. Model.

Probably prepared at the same time as the adjoining model. M.1793.

166. FLOUR MILL DRIVEN BY A CRANK AND CONNECTING ROD. Model.

It is probable that this and the model beside it were prepared when the arrangements of the Albion Mill, 1785, were under consideration. M.1792.

167. FLOUR MILL MODEL DRIVEN BY SUN AND PLANET GEAR.

Doubtless this was prepared at the same time as the adjoining model. M.1791.

168. BEAM AND CONNECTING RODS. Model.

The horizontal lever which probably represents an engine beam is by two connecting rods coupled to beams working in a vertical plane at right angles to the main beam. It is not clear what this was intended to subserve. M.1803.

169. SPUR GEARING. Model.

Of unspecified application. M.1802.

170. WOODEN SHAFT.

Of unspecified application. M.1819.

171. GRINDING MACHINE. Model.

May have been prepared in connection with Boulton's hardware business. M.1796.

172. HORSE GEAR AND CRUSHING ROLL. Model.

M.1801.

173. WATER WHEEL. Model.

Overshot type. The chief point for remark is that the power is taken off from the rim, which is toothed for that purpose, instead of transmission through the main shaft as was the practice previously. M.1813.

174. DISCONNECTING CRANKS.

Of later date than other Watt models. M.1818.

175. MARINE ENGINE FRAME. Model.

Of much later date than the other models as the firm of Boulton, Watt & Co. did not take up the marine engine till about 1819. M.1800.

176. EARLY ROLLER BEARINGS.

A horizontal shaft carrying a fly-wheel is supported on a roller bearing which is stamped " Garnett & Co., No. 1 patent " (*i.e.*, January 6th, 1797, granted to John Garnett, of Bristol).

Possibly this specimen was submitted to Boulton & Watt with a view to their adoption of such bearings. M.1815.

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177. WATT GARRET at Heathfield. Print presented by R. H. Kirton, Esq.

The garret which Watt fitted up as a workshop. The sculpture lathe, the perfecting of which occupied his declining years, is on the left. It is a copying machine with arrangements for rotating copy and work together.

V. HOLOGRAPH LETTERS FROM JAMES WATT.

The letters, of which brief précis follow, form part of the MSS. in the possession of the Boulton family, lent for the purposes of the exhibition by the Trustees. The letters are about 1,000 in number, and the selection below has been made with a view to bring out points of technical interest. Some of the letters have already appeared in Muirhead's memoirs and elsewhere.

With few exceptions the letters are from Watt to Boulton, and, as usual in correspondence of that day, they are written on small post 4to paper folded to serve for the address. This is to be assumed to be the case unless a note appears to the contrary.

1768.

178. Glasgow, October 20th (flscp.).

First letter preserved of the correspondence between Watt and Boulton, written after the former's first visit to the latter. Gives details of his relation with Roebuck.

179. Glasgow, December 12th (flscp.).

Forwarding various pieces of apparatus of his manufacture. Mentions having almost finished a complete model of his reciprocating engine.

1769.

The letters below, up to December 11th, 1773, are written to Dr. William Small.

180. Glasgow, January 28th (sm. post fol.).

Relative to taking out his specification and giving details of experimental work.

181. Glasgow. February 22nd (half flscp.)

Has made a trial of a new form of condenser (*i.e.*, addition of the air pump).

182. Glasgow, March.

Gives rough draft of the specification (*i.e.*, for the separate condenser).

183. Glasgow, April 28th (sm. post fol.).

Has signed the specification on April 25th. Mentions working his model steam engine by the force of steam only as well as by condensation. Mentions that Mr. Boulton wants a " circulator," *i.e.*, rotary engine.

184. Glasgow, May 28th (sm. post fol.).

Has just made a conclusive trial of the condenser with the air pump. Makes the first suggestion of using steam expansively.

185. Glasgow, September 20th (sm. post fol., 3 pp.).

Gives a very detailed account of a trial of his engine, on which he says : " the tryal has not been decisive but I am still allowed to flatter myself with hopes."

186. Glasgow, October 21st (flscp.).

Mentions using tin cylinder $\frac{1}{4}$ in. thick and the long diameter exceeding the short by about $\frac{3}{8}$ in. at the worst place.

187. Glasgow, November 3rd (flscp.).

Mentions new form of condenser, *i.e.*, tube or surface type. Mentions a new method of adjusting telescopes for levelling.

188. Glasgow, December 12th (flscp.).

Is concerned with suggested improvements in the surveyor's level ; the idea has been recently embodied in an instrument as quite new. It should be remembered at this time Watt was practising as a Civil Engineer, and was in a fair way of becoming one of the leading men of the day.

1770.

189. Glasgow, January 3rd (sm. post fol.).

Improvements on the condenser. (Sketch.)

190. Glasgow, January 31st (flscp.).

Different substances for piston packing. Mentions having entered the 35th year of his life, but adds he has hardly done 35 pence worth of good in the world.

191. Glasgow, February 25th (flscp.).

Concerned with rotary engine.

192. Kinneil, March 10th.

Describes trial of the engine with the new condenser. Difficulties with piston packing. Mentions his engagements as a civil engineer.

193. Glasgow, March 16th (flscp.).

Gives sketch of the improved condenser made of pipes.

1771.

194. Glasgow, December 24th.

Is solvent, but considers his present life is one of much vexation.

1773.

195. Glasgow, March 7th.

Mentions his screw for dividing to a thousandth of an inch. Mentions also his optical instrument.

196. Glasgow, July 25th (flscp.).

Announces that Dr. Roebuck is in the creditors' hands. "None of his creditors value the engine at a farthing." Suggests assigning to Boulton, Roebuck's share in the invention.

197. Glasgow, August 17th.

Thinks of writing a book on the elements of the theory of steam engines.

198. Glasgow, December 11th.

Mentions having invented a drawing machine.

1775.

199. London, March 7th.

Apropos of the bill for extending the steam engine patent which has gone to be printed.

200. London, March 29th.

Mentions the Vacuum Gauge (sketch). Recommends the trial of a brass piston for "Beelzebub."

201. Birmingham, April 22nd.

The plug valves seem to perform all that was expected from them.

202. Birmingham, May 27th.

Gives a sketch for the piston of Soho Engine (*i.e.*, "Beelzebub").

1776.

203. Glasgow, July 3rd (4pp.).

Relates to the terms of his partnership with Boulton; also to his second marriage. Mentions also having undertaken an engine for Mr. Coleville at Torryburn, in Fife. (Drawing of this will be found adjoining.)

204. Glasgow, July 8th.

Mentions that his intended father-in-law wishes to see the agreement of partnership.

The extraordinary fact emerges that this document, upon which so much depended, had not even then—more than a year after the beginning of the partnership—been executed. Such was the confidence of Watt and Boulton in one another.

205. London, December 3rd.

Relates to the engine at Shadwell, and mentions that the barometer is still to fix on.

1777.

206. London, April 20th.

Relates to the policy to be pursued with regard to the engine for Perrier in Paris.

Smeaton's opinion of the Stratford Engine, viz., that it is too complex, is quoted.

207. Birmingham, May 2nd.

Mentions that Perrier has obtained a decree empowering him to raise water from the Seine to supply Paris, and that he has been to Broseley to Wilkinson for an engine.

208. Birmingham, May 3rd (sm. post fol.).

Suggests with regard to charging for the Shadwell engine that a certificate be obtained as to the quantity of water that 1 cwt. of coals will raise with their engine. Then ascertain the duty of the Watt Engine and agree with the Company for an annual premium. Mentions that Wilkinson wants an engine to work a tilt hammer.

209. Chacewater, August 4th.

Suggests schemes for equalising the power of "Beelzebub," and says: "I would have you first make a model in the true proportions which will . . . . . show any difficulty which may be in execution."

210. Chacewater, August 14th.

Mentions Hornblower, and gives an uncomplimentary opinion about Cornishmen. Remarks: "In general the engines here are clumsy and nasty, the house is crackt and everything dropping with water from their house systems."

211. Chacewater, August 25th.

States that the Cornish people are great sceptics about the performances of his engine. Has not been impressed by the engines he has seen.

212. Chacewater, September 20th.

Suggests finding someone to undertake the work of the Firm as the non-execution of orders must hurt them ultimately. Says, "The voice of the country seems to be at present in our favour."

1778.

213. Redruth, June 8th.

Watt has arrived in Cornwall for the second time. A pessimistic letter lamenting mistakes. Gives sketch of eduction pipe.

214. Redruth, June 27th.

Deeply immersed in details of the engine business and worrying over the mistakes caused by his assistants.

215. Redruth, July 8th.

States that the Cornish miners are remarkably cautious and that they have little faith in his engine, and few of them believe it to be materially better than the existing one. Suggests Wilkinson being brought in as a partner.

216. Redruth, July 11th.

Has made himself agreeable to Captain Trevithick (*i.e.*, father of Richard Trevithick).

217. Redruth, July 20th.

Gives a copy of account for all goods supplied for Richmond engine.

218. Redruth, July 22nd.

The adventurers of Tingtang mine will delay paying for the engine till after they have seen it at work.

219. Redruth, August 3rd.

Gives sketches of a new design for Piston packing.

220. Redruth, August 6th.

Gives a favourable report about Chacewater engine. Gives his opinion about making engines for abroad.

221. Redruth, August 8th.

Both Tingtang and Chacewater engines are going well.

222. Redruth, August 13th (sm. post fol.).

Sends a drawing of the pump bucket and clack for Wrensnest engine, Coalbrookdale. Also gives instructions for making joints in steam pipes.

223. Redruth, August 22nd (sm. post fol.).

Relates at great length misfortunes at Chacewater.

224. Redruth, August 29th (sm. post fol.).

Gives information about tin mining in Cornwall and about the performance of the atmospheric engine at Owen Vain. On the assumption that the bushel of coal weighed 94 lbs., the duty of the engine comes out at 10,878,000 lb. of water raised one foot high.

225. Redruth, September 6th (4 pp.).

Gives a long report of trial of the engine at Wheal Union. Gives a sketch of an improvement in the working gear. Has also been at Tingtang, where everything is satisfactory.

226. Redruth, September 9th.

Gives sketch of fire bridge for boiler at Wheal Union. Is attending a meeting on the Poldice adventurers, who want an engine.

227. Redruth, September 12th.

Concerned mostly with experiments on piston packing.

228. Redruth, October 2nd. To Mr. J. Turner (half flscp.).

Enclosed a drawing for Poldice. Mentions having in prospect a considerable alteration to the lower nozzles. Asks that Murdock should be sent for immediately.

229. Redruth, December 1st (half fiscp.).

Details of engine construction in Cornwall. Mentions an accident to the barometer at Hallamannin engine.

1779.

230. Birmingham, January 27th.

A party of Germans have been over the factory contrary to his orders. Recommends " discountenancing every foreigner who does not come avowedly to have an engine."

231. Birmingham, June 26th.

Mentions having been out at the Navigation (*i.e.*, Birmingham Canal) engine the preceding day, and that the engine goes very well now.

232. Birmingham, June 28th.

Sends enclosed " some of Mr. Nobody's draughts with authentic copies of them." This is the first mention of Watt's invention for copying letters.

233. Birmingham, June 31st.

A jubilant letter announcing a satisfactory agreement with Hawkesbury Colliery (*i.e.*, the Bedworth engine).

234. Chacewater, September 30th.

Tingtang engine is in excellent order.

235. Chacewater, October 4th.

Mentions that the drawing of injection valves with the barometer for Wheal Chance have not arrived yet. Will apply the circular motion as soon as he can.

236. Chacewater, October 16th (sm. post fol.).

Reports a meeting at Wheal Union. Fears opposition of Captain Trevithick. Hallamannin is now in very good order and loaded to 9.6 lb. on the inch.

237. Chacewater, October 28th.

Says that the Cornishmen have proposed to settle an annual fixed sum for their engines. Accordingly wishes Boulton to come into Cornwall at once.

1780.

238. Birmingham, April 11th.

Memo of experiment made on York buildings engine, April, 1775.

239. Birmingham, May 2nd.

More details about letter copying and the construction of the press.

240. Birmingham, May 3rd.

Remarks on construction of letter copying press.

241. Birmingham, September 16th.

Gives details of the calculations of the saving in fuel of Wheal Chance.

242. Birmingham, September 29th.

Gives detailed calculations for the Pool engine table.

243. Birmingham, November 11th.

Is now making the racks of the nozzles of iron case-hardened, which he considers better than steel.

244. Birmingham, November 19th (sm. post fol.).

Mentions that Wasborough has got a single crank on his engine at Snow Hill.

245. Birmingham, November 21st (sm. post fol.).

Dealing with Wasborough's engine. Gives a detailed examination based on data supplied to him.

1781.

246. Birmingham, April 2nd.

Suggests getting advice of counsel before engaging in a lawsuit about the crank.

247. Birmingham, April 4th.

Estimate for the cost of damping boxes for the copying press.

248. Birmingham, April 7th.

Considers it better to "pursue the spirals" rather than make an agreement with Wasborough.

249. Birmingham, April 15th.

Has contrived another substitute for the crank.

250. Birmingham, April 21st (sm. post fol.).

Will make no agreement with Wasborough now that he knows that the crank is his own contrivance and has been stolen by infamous means; intends therefore to scheme something to do without it.

251. Cosgarne, July 21st (sm. post fol.).

Does not wish to be engaged in two lawsuits at once, one to demolish, the other to establish a patent; therefore wishes the idea of working Wilkinson's forge by cranks to be set aside. States that he abhors lawsuits.

252. Cosgarne, July 26th (sm. post fol.).

Suggests reprisals against the Hornblower family.

253. Cosgarne, July 28th (sm. post fol.).

Apprehension at the success of the Hornblower's Engine.

254. Cosgarne, September 20th.

As soon as he knows the success of the equalising beam he will have a trial on Soho large engine. "I think it must be done by racks and toothed wheels." Shows how he calculates the power of the equalising wheels. (Sketch).

255. Cosgarne, September 20th (sm. post fol.).

Proposes to make engines go to twice the depth, or work on their present depth with half the steam by giving them equalising beams and making the stroke of the pump half the length and double the number in a minute, or by employing the steam expansively. (Sketch.)

1782.

256. Cosgarne, January 3rd.

Has tried a model of " one of my old plans of rotative engines revived and executed by W. M. and which merits being included in the specification as a fifth method." (Sun and planet motion. Sketch.)

257. Cosgarne, January 15th. To James Keir.

Gives detailed description for the preparation of copying ink for the copying machine. (See No. 155).

258. Cosgarne, January 16th (sm. post fol.).

Has thought of a new expansive engine with a heavy fly-wheel moved by a pinion so as to make three turns every down stroke, a weight equal to half the load to be put upon the inner end of the beam.

259. Cosgarne, January 26th (sm. post fol.).

Concerned with the internally and externally geared connecting rod. (See No. 99).

260. Cosgarne, April 5th (sm. post fol. 3 pp.).

Has now found out and gives details of the Hornblower's engine. (Sketch.)

261. Birmingham, November 28th.

Report of the trial of the steam tilt hammer.

262. Birmingham, November 30th.

Reports the success of the steam hammer.

263. Birmingham, December 14th.

Mentions having received a visit from Mr. Cort, of Gosport, who " has found out some grand secret in the making of iron." This was Cort's well-known invention of the puddling process.

1784.

264. Birmingham, January 31st.

Has " started a new hare " (*i.e.*, the first description of the parallel motion).

265. Birmingham, May 11th (sm. post fol.).

On the subject of the steam turbine, which Watt examines in detail and comes to the conclusion that such a high speed of revolution is necessary as to be in the then state of the art impracticable. With his customary caution he desires that the suggestions he makes for improving the machine be not disclosed to the patentee for fear of adding to the value of his invention.

266. Birmingham, July 11th.

Has made a " large model of the new substitute for racks and sectors which seems to bid fair to answer " (*i.e.*, the parallel motion).

267. Birmingham, August 31st (sm. post fol., 4 pp.).

Dissertation on the subject of wheeled carriages.

1785.

268. Birmingham, July 21st.

Has made an alteration in the working gear of the small double engine.

269. Birmingham, September 15th.

Says, " I have got the smokeless furnace to do better now and have some hopes of it " (*i.e.*, this furnace was the subject matter of Watt's patent of this year).

270. Birmingham, November 5th.

A characteristic extract from this is: " On the whole I find it now full time to cease attempting to invent new things, or to attempt anything which is attended with any risk of not succeeding, or of creating trouble in the execution. Let us go on executing the things we understand and leave the rest to younger men, who have neither money nor character to lose." Yet this was possibly the period of greatest intellectual power in Watt's life.

271. Birmingham, November 11th.

States that he has been employed these two days in scheming a patent Act. " Whether it will do any good or not I cannot tell, but I think there is some prospect."

1786.

272. Birmingham, March 3rd.

Suggests a cataract gear for preventing the regulator valve opening too suddenly.

273. Birmingham, March 20th and 22nd. (2 Letters.)

Mentions a mysterious fracture of iron about which there is considerable divergence of opinion.

274. Birmingham, March 28th.

The specification for the Dutch patent is now made.

275. Birmingham, April 13th.

Computations of the work lost in friction in the Albion Mills engine.

276. Birmingham, April 17th.

Concerns the Albion Flour Mill and entreats Boulton not to let unauthorised persons visit the premises.

277. Birmingham, April 27th.

Has adopted a taper of 1 in 12 for cotters.

278. Birmingham, September 12th.

Is " extremely sorry that W. M. (*i.e.*, William Murdock) still busys himself with the Steam carriage."

279. Birmingham, October 3rd.

Has received a proposal from France to replace the machine of Marly by one of their engines.

1787.

280. Birmingham, June 18th.

Suggests a multiple lift valve to avoid water hammer. (Sketch.)

281. Clover, near Glasgow, December 30th.

Proposes to try the apparatus for bleaching with chlorine which is just completed and remarks on the method.

1788.

282. Birmingham, February 25th.

Has seen in the papers an account of a liquor for whitening linen. Has no doubt that it " is the same which Mr. Bertholet, the inventor, showed to us, and which in consequence of his permission and generous refusal to apply for an exclusive privilege to himself, I have used for more than a 12 month, and have made many expensive experiments upon, and which I have communicated to Mr. McGrigor (his father-in-law), who is now whitening 1500 yards of linen by the process."

283. Birmingham, May 28th.

Will proceed with Boulton's " Lap " Engine as soon as he gives directions.

1789.

284. Birmingham, June 19th (sm. post fol.).

Written on printed form of indenture for the supply of rotative engines.

1790.

285. Birmingham, January 26th.

Gives full calculations for a coal-drawing engine.

286. Birmingham, June 27th.

Has had a short conversation with the King (Geo. III.) at Windsor, who had asked a number of questions. From the answers which Watt gave we note that the firm were then charging a premium of £5 per h.p. per annum for rotative engines.

287. Birmingham, July 7th.

A patent for 20 years for double engine has been obtained in Spain.

288. Heathfield, December 29th (4 pp.).

Further with regard to Spanish patent.

1791.

289. London, March 24th.

Reports effect of the Albion Mills fire : " One of the great connecting rods, 4½ in. thick and 8 in. broad, has been melted in two."

1795.

290. London, January 16th. James Watt, Junior, to Matthew Robinson Boulton.

Beginning the manufacture of the portable copying press and detailing agreement with Richardson and Harrison, and also the programme for the manufacture.

1796.

291. Heathfield, March 20th.

Announces the dangerous illness of Dr. Roebuck. Gives a brief summary of his contributions to Technological Science.

1799.

292. London, January 25th.

A jubilant letter: "We have won the cause hollow" (*i.e.*, Boulton and Watt *v.* Maberley).

1803.

293. Glenarbuck, near Glasgow, August 31st.

Concerns Napoleon's threatened invasion of England and of the preparations made to repel it. The watermark in this sheet is "Watt and Co.'s patent copying paper, 1798."

1805.

294. Glasgow, November 12th.

"The new lights (*i.e.*, coal gas) are much in vogue here. Many have attempted them and some have succeeded in lighting their shops with them. I also hear that a cotton mill in this neighbourhood is lighted up with them."

1818.

295. Heathfield, February 8th. To M. R. Boulton.

Announces the arrival of his son at Helvoetsluys with the s.s. "Caledonia," with details of the passage.

This was the beginning of the remarkable share which Boulton, Watt & Co. had in the early development of the marine engine.

VI. MEMORIALS OF WATT.

Biographies; Contributions to Science.

296. HISTORICAL ELOGE of JAMES WATT. By D. F. J. Arago. Translated from the French with additional notes and an appendix by James Patrick Muirhead, Esq., M.A., 1839. 8vo. Large paper copy. Lent by the Boulton Trustees.

This, with a slightly different title page, ran into a second edition. The appendix deals with Watt's discovery of the compound nature of water.

297. MECHANICAL INVENTIONS. The origin and progress of the MECHANICAL INVENTIONS of JAMES WATT. Illustrated by his correspondence with his friends and the specifications of his patents. By James Patrick Muirhead, Esq., M.A., 1854. 3 vols. 8vo. Large paper copy. Lent by the Boulton Trustees.

298. MEMORIALS of the Lineage, early life, education, and development of the genius of JAMES WATT. By George Williamson, Esq., 1856. 4to. Lent by H. W. Dickinson, Esq.

Authoritative on Watt's early life. The book is open to show a lithograph of the portrait by Partridge.

299. LIVES OF BOULTON AND WATT. Principally from the original Soho MSS., comprising also a history of the invention and introduction of the Steam engine. By Samuel Smiles. 2nd edition, 1866. 8vo. Lent by J. Macfarlan, Esq.

A smaller book on the same subject was published subsequently by the author.

300. JAMES WATT. By William Jacks, LL.D., D.L., 1901. 12mo. Lent by H. W. Dickinson, Esq.

301. JAMES WATT, OF SOHO AND HEATHFIELD. Annals of Industry and Genius. By T. Edgar Pemberton, 1905. 8vo. Lent by Mrs. Pemberton.

302. JAMES WATT. By Andrew Carnegie. Famous Scots Series [1905]. 8vo. Lent by H. W. Dickinson, Esq.

303. COMPOSITION OF WATER. Holograph letters of JAMES WATT on the COMPOSITION OF WATER. Lent by the Council of the Royal Society.

The letter dated November 26th, 1783, was read before the Society on April 29th, 1784. The subsequent letter, dated April 30th, 1784, was read May 6th following. The letters are printed in *Phil. Trans.*, LXXIV., pp. 328 and 354.

Much acrimonious discussion arose between the partisans of Cavendish and Watt as to their respective claims to the discovery of the composition of water. It is now conceded that while Watt was the first to state that water was not an element, Cavendish quite independently supplied the experimental data on which accurate knowledge was founded.

304. COMPOSITION OF WATER. 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, F.R.S.E., 1847. Large paper copy. Lent by the Boulton Trustees.

305. THERAPEUTICS. Supplement to the description of a pneumatic apparatus for PREPARING FACTITIOUS AIRS. By James Watt, Engineer, 1796. 8vo. Lent by Geo. Tangye, Esq.

Contains a description of an apparatus prepared in collaboration with Dr. Beddoes, of Bristol, for the medicinal use of oxygen, hydrogen, etc. The apparatus was made and sold by the firm of Boulton and Watt. James Watt was led to the study of this branch of medicine by the illness of his son, Gregory, who suffered from consumption, and died at Exeter in 1804. Several pamphlets on the same subject were published by Watt and Beddoes.

306. WATT MONUMENT. Copy of "Morning Chronicle," June 19th, 1824. Lent by the Boulton Trustees.

Contains a report of the meeting held on June 18th for the purpose of erecting a monument to James Watt. The result of these efforts was the erection of the well-known seated statue by Chantrey in Henry VII.'s Chapel, Westminster Abbey.

307. INVENTIONS. On the INVENTIONS OF JAMES WATT and his models, preserved at Handsworth and South Kensington. By Mr. Edward A. Cowper. 8vo. Property of the Museum.

Excerpt Proceedings of the Institution of Mechanical Engineers, 1883, p. 599. Most of the objects described are in this Collection. The paper is illustrated by 33 plates, most of which will be found with the objects.

308. "SOME UNPUBLISHED LETTERS OF JAMES WATT." Lent by H. W. Dickinson, Esq.

Excerpt Proc. Inst. Mech. Eng., 1915, p. 48.

LIST OF CONTRIBUTORS.

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Babbage's Calculating Machine, Description of. Price 1*d.*; by post 1½*d.*

Special Loan Collection of Scientific Apparatus, 1876. Catalogue, third edition. Cloth. Price 3*s.* 6*d.*; by post 4*s.*

Classification for Works of Pure and Applied Science in the Science Library. 1*s.* 6*d.*; by post 1*s.* 8½*d.*

Sky Sketches from September 1883 to September 1886, by William Ashcroft. Price 1*d.*; by post 1½*d.*

List of Works on Aeronautics in Science Library. Price 4*d.*; by post 1½*d.*

PHOTOGRAPHS.

Portfolios containing Photographs of Machinery and Naval Models, Scientific Apparatus, etc., belonging to the Science Museum, South Kensington, or which have from time to time been exhibited in the Museum, may be seen at the entrance stiles, where orders for proofs either mounted or unmounted may be left upon prepayment of their cost. Bromide prints from negatives 12 ins. by 10 ins. or lantern slides of standard size, 2*s.* each.

The following publications can be purchased at the entrances to the Museum of Practical Geology, and can also be ordered through the post. The rates of postage quoted are for inland postage only. These publications can also be ordered from the respective Museums through any bookseller.

MUSEUMS OF PRACTICAL GEOLOGY.

Museum of Practical Geology, Jermyn Street, London, S.W., 1. A Short Guide to the. (1909; Second Edition, 1914). Wrapper. 1914, 1*d.*; by post 2½*d.*

Minerals of the British Islands. Handbook to the Collection of. By F. W. Rudler, I.S.O., G.G.S., pp. 241. Wrapper, 1905, 1*s.*; by post 1*s.* 5*d.*

Gemstones. Guide to the Collection of, in the Museum of Practical Geology. By W. F. P. McLintock, B.Sc., pp. 92, 43 Illustrations. Wrapper. 1912, 9*d.*; by post 11*d.*

Kaolin, China-Clay and China-Stone, in the Museum of Practical Geology. Handbook to the Collection of. By J. Allen Howe, B.Sc., F.G.S., with an Appendix by Allan B. Dick. pp. 271, 55 text figures. Wrapper. 1914 3*s.* 6*d.*; by post 3*s.* 11*d.*

Photographs of Geological Subjects. Catalogue of. England and Wales (Series A. 1-800.) Prepared by the Geological Survey and Museum 35 pp. Wrapper. 1910, 6*d.*; by post 7½*d.* Scotland. (Series B and C) 62 pp. Wrapper. 1910, 6*d.*; by post 7½*d.*

For publications of the *Victoria and Albert Museum see* lists which can be obtained gratis on application to the Director and Secretary, at the Museum, South Kensington, S.W., 7.

For the publication of the Board of Education see List I., which can be obtained on application to the Secretary, Board of Education, South Kensington, S.W., 7.