VI

Bryan Donkin

BRYAN DONKIN, F.R.S., a Vice-President of the Royal Society, was born in 1768, at Sandoe, in Northumberland, and commenced his business education by assisting his father, who held the land agency of several large estates in the county.

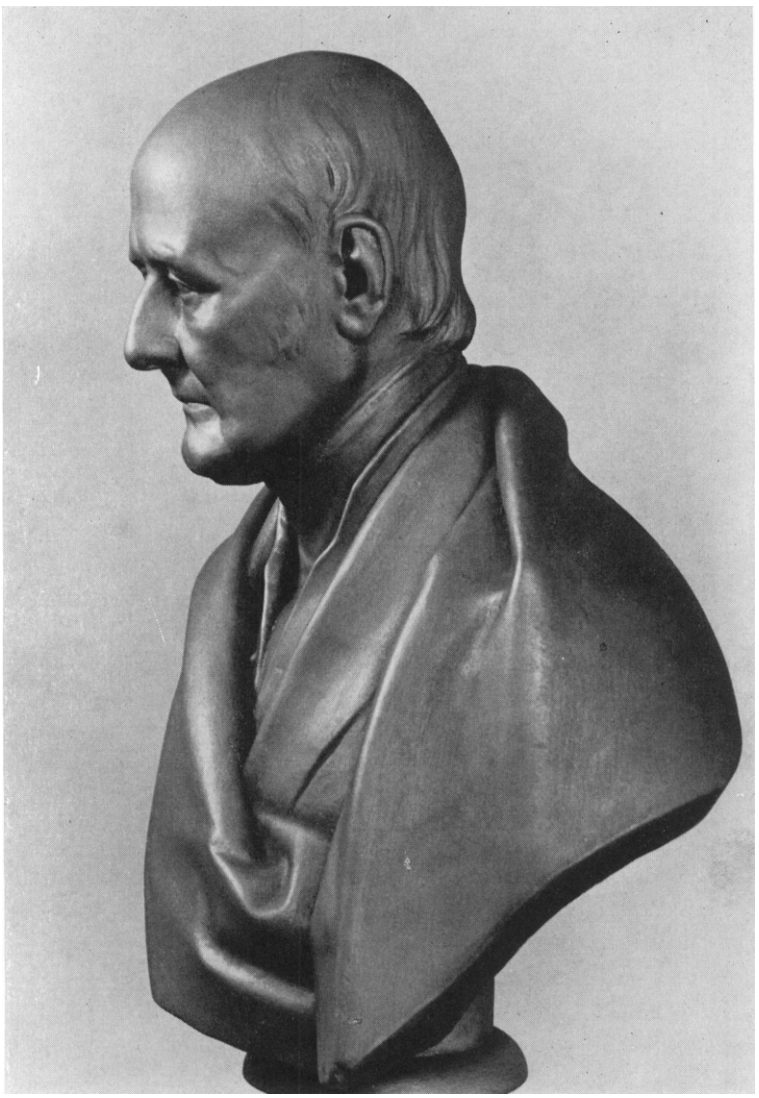
At the age of twenty he came south, and obtained the post as agent to the Duke of Dorset, at Knowle Park, Sevenoaks, where he remained for about two years.

He had always had a great liking for mechanics, and as his occupation at Knowle was very little to his taste, he determined to leave it and follow the bent of his inclinations. With this in view he consulted Smeaton, of Eddystone Lighthouse fame, who introduced him to John Hall, of Dartford, the latter having a short time previously established a millwright's business there, and formed a connection among the paper and other mills in the Home Counties. The outcome of this introduction was that Donkin was articled to Hall for a term of three years to learn the business as a millwright.

When Donkin finished his apprenticeship with Hall he founded a paper-maker's mould business at Dartford in 1792, in partnership with James Davies, called Donkin and Davies. He continued his association with this work for a good many years, although more as a sleeping than an active partner, owing to the fact that he went back to Hall to work on the Fourdrinier machine and, of course, subsequently left Dartford and went to Bermondsey. However, it was not until the 13th April, 1812, when his partner James Davies died, that he decided to give up his share in the mould-making business. Donkin states in his diary that he went to Dartford and agreed with Jonathan Davies (brother of his late partner), and Edward Hall, on the valuation of the mould business, and Donkin sold out his interest for £300, plus half the value of the equipment and plant. The £300 was paid by a joint promissory note on demand, and half the valuation of the plant and equipment was paid for by bills at two, three, and four months. Shortly afterwards, on the 2nd May, 1812, Edward Hall told Donkin that Jonathan Davies had resigned his share in the mould business, and that Edward Hall had admitted Banks and John Marshall (who had been an apprentice of the firm of Donkin and Davies) each to a quarter of the business, and Edward Hall had retained half for himself. This is the first authentic mention of John Marshall's entry into the mould business, and he subsequently became owner of the firm, and a very famous manufacturer of paper-making moulds and eventually of dandy-rolls, and was, of course, the original founder of the firm of T. J. Marshall and Company Ltd.

Donkin still kept up a close business connection with John Hall, and a friendship that was strengthened by their marrying two ladies who were sisters continued until the death of John Hall in 1836. The engineering business at Dartford was carried on after this for many years by Hall's sons, John and Edward, and is today an important undertaking known as J. and E. Hall Ltd.

The plant employed in Donkin's time at Hall's works was not extensive, as may be gathered



Bryan Donkin.

from the fact that the motive power was supplied partly by a water-wheel and partly from a windmill, but the work turned out appears to have been considerable for that period.

John Hall asked Donkin to return to their engineering works at Dartford to help with the French paper-making machine of Louis Robert, which had been brought over from France and in which the Fourdriniers had an interest.

Donkin impressed the Fourdriniers so much that they asked him to work for them on the perfecting of the paper-making machine and, with John Hall's consent, Donkin joined the Fourdriniers.

When the Fourdriniers arranged with Donkin to take over the work of building their paper-making machines, they told him to find a suitable place in London, so Donkin chose Fort Place, Bermondsey, as a suitable site, as it was on the river. In those days transport was very difficult, and heavy machinery, wherever possible, had to be taken by water. The engineering works were erected there, and we know that in the first few years they cost £3000. It was here that the Fourdrinier machines were built and continued to be built sixty or seventy years afterwards.

Donkin was obviously an extremely able engineer, and apart altogether from his work on the Fourdrinier machines, he was connected with very many other engineering projects.

When the Fourdriniers began to find their finances difficult, they persuaded Donkin to rent the engineering works at Fort Place from them, and eventually in 1811 asked him to take them over entirely, which he did, and formed the firm of Bryan Donkin and Company, which is now a very large engineering concern at Chesterfield, to which town it was moved from Bermondsey in 1902.

Donkin was a friend of Brunel, and did a lot of work in conjunction with him. He was a Fellow of the Royal Society, and eventually became one of its Vice-Presidents.

One of Bryan Donkin's earliest associates in business was Richard Mackenzie Bacon, a native of Norwich, a man well known in his day as a musician and journalist; he had also considerable inventive talent. The two collaborated in patenting in 1813 what was probably the first successful rotary printing machine, drawings of which are in the South Kensington Museum; and in 1815 they formed a partnership to work the patent. Donkin's diaries contain references to his meetings with Bacon, and their discussions about the possibilities of the machine. On this machine the type was set up in four formes, carried on the four faces of a revolving rectangular block, corresponding to the cylinder on which the stereo plates of a modern rotary machine are carried; and these, by an arrangement of suitably formed gear wheels, were brought into contact in rotation with the inking roll and the sheet of paper. One machine was set up at the works of the Cambridge University Press, where it turned out excellent work for some time; but as a machine it was too delicate for the constant work of a printing office, and so failed to develop into a commercial success. Incidental to this machine was the invention of the elastic inking rollers, such as have since been used in every form of printing-machine, the composition of them being a mixture of glue and treacle.

In 1808, a patent was granted to Donkin, for the steel pen which was the first recorded patent on the subject, and as he set up a factory and made the pens upon a considerable scale for several years, it may be fairly claimed that he was the originator of this particular instrument. The nibs were made of two thin pieces of steel laid together longitudinally at right angles to one another, and soldered throughout part of their length, the remainder forming the separate points corresponding to the split nib, though later they were pressed out of one piece of steel. The business with the patent was subsequently sold as a going concern to Joseph Bramah for £350 in 1811.

During the time when Donkin was busily engaged perfecting and improving the Fourdrinier machine, a process that had been patented in France by a chemist named Appert, for preserving meat and other foodstuffs, was brought to England and put before John Gamble, with the result that the English rights were purchased by Donkin, Hall, and Gamble for £1000. Experiments were at once started at Bermondsey, and it was soon found that Appert's process was very incomplete; in fact, it relied entirely on the exclusion of oxygen by exhausting the air, but this, although it was successful to a certain extent, was found to be not sufficient to sterilize the material completely, and it was only after much experimenting that Donkin and Gamble discovered that satisfactory results could only be obtained by rendering the albumen soluble.

This was finally brought about by heating the meat in tins or jars very gradually in a bath of chloride of lime. Donkin describes in detail in his diaries many of the experiments they made in successfully processing the food by canning it.

In 1813, the partners were invited to take samples of their products to Kensington Palace, where it was tasted by the Prince Regent and other members of the Royal Household. From that time the business developed rapidly, and a quantity of meat was supplied to the Royal Navy, an office being opened in Cornhill for the purpose, and depots established in the seaport towns. Some of these preserved foods were taken by Ross and Franklin on their Polar expedition, and several tins that had been buried in the ice for many years were found and brought back to England with other Franklin relics by McClintock in 1857. One of these tins was until very recently in the

possession of the Bryan Donkin Company at Chesterfield, and the contents of one of them were eaten by some students at Manchester University more than a hundred years after the meat had been preserved.

Later, John Gamble started a manufactory in Cork on a considerable scale, and this was carried on successfully for many years. Gamble and Donkin had a great deal of difficulty in their attempts to bottle milk and cream successfully, owing apparently to its being discoloured, although most of it seems to have remained drinkable. He says that one small bottle of cream had a peculiar taste somewhat resembling the expressed oil of sweet almonds, and when shaken in the bottle it readily made butter. They also found that if they prepared soup and left it overnight before bottling it, it went sour and was unfit to preserve. They discovered that they had to make the soup so thick that, on cooling, it made a perfect jelly, and then they warmed it and put it into the bottles. Donkin explains their methods of canning or bottling beef as follows:

They filled three white jars with beef and, having put the lids loosely on, placed them in a steaming apparatus for $1\frac{1}{2}$ hr, when the meat appeared to be half done. They allowed the meat to be nearly cool, then put it into the jars again, having previously drilled a small hole through each of the lids. and cemented the lids on. They again placed the jars in the steaming apparatus for $2\frac{1}{2}$ hr. They then opened the steamer and closed the small holes in the lids with cement, so as to prevent the admission of air whilst cooling. They then removed the jars from the steamer and applied more cement to the joints of the lids. Donkin says that the cement worked very well and was quite hard.

By the 25th May, 1812, the canning was so satisfactory that they had to take steps to bring it before the notice of the public, and they inspected premises in Finch Lane, in order to give the carpenter directions for putting up some shelves, as it was intended that the house should be opened as an office for the sale of Hall's gunpowder and Bryan Donkin's provisions. They engaged a Mr. Griffiths as clerk for the two concerns, at £200 per annum, and he was to live in the house over the shop in Finch Lane. They also appointed a Mr. Brandon as agent for the sale of the provisions, and agreed with him that he would have 4% upon all that was sold up to £20,000 and 3% up to £30,000 and $2\frac{1}{2}$% for all above that. From this it would appear that the business was fairly considerable.

Hall acquired shares in the provision business by allowing Bryan Donkin to apply money which he owed Hall for cast iron, and put it back into the preserving business. By May, 1813, they were paying bills up to £100 for meat from the butcher, and decided to have a new card engraved giving the name of the firm as Donkin, Hall and Gamble, and decided to get agents and keep the stock of their provisions at the principal seaports.

Donkin records that he and Gamble went to Somers and Sons, in New Bond Street, and bought a Romford roaster and a Medhurst weighing-machine for the preserving business, for weighing the meat and cases.

An interesting letter was received from the Duke of Kent, on the 30th June, 1813, from Kensington Palace, as follows:

"Gentlemen, I am commanded by the Duke of Kent to acquaint you that His Royal Highness, having yesterday procured the introduction of some of your patent beef for the Duke of York's table, where it was tasted by the Queen, the Prince Regent and several distinguished personages, and highly approved. He wishes you to furnish him with some of your printed papers, in order that Her Majesty and many other individuals may, according to their wish expressed, have an opportunity of further proving the merits of the thing for general adoption. I am, gentlemen, your most obedient servant, J. Parker."

From all this it is extremely interesting to see that the trio who had such a great deal to do with the perfecting of the paper-making machine were also pioneers in the canning of meat.

From many entries in Donkin's diaries it would appear that he had a very big consulting business, chiefly on engineering matters, and others connected with wharves and piers and water-power in general. He seemed to be very friendly with Brunel and was often going to see new things which Brunel had made, such as the machine for manufacturing shoes, and a machine for making plywood. He made long journeys by post-chaise for these purposes.

Donkin seems to have had much work as arbitrator in settling disputes about people taking water, or holding it up, and spoiling the water-power of other neighbours on various rivers. One of his journeys took him to Liverpool from the Golden Cross at Charing Cross. It took him from six o'clock in the morning until half past six at night to do the journey from London to the Saracen's Head Inn at Liverpool in the month of December. On all these journeys he called frequently on various people and quoted them for paper-making machines, and advised them on the alterations necessary to their mills, often corn mills, in order to render them fit to receive a paper-making machine. Donkin also records a meeting he had with Sir Isaac Coffin.

Donkin was at this time interested in the manufacture of nails by machinery in Birmingham, and he states that on his way home from Birmingham he called at Wootton Wawen and saw the Messrs. Wrights, who agreed to pay the balance of the account for their paper-making machine. He also called, on the 26th January, 1814, on this same journey back, at Phillips' Lyttleton mill, and took the necessary dimensions of a building intended for the reception of a paper-making machine. He also called on Messrs. Lloyd, at a place called Piddle, on the river Avon, and examined that mill with a view to putting in a paper-making machine. It was still a corn mill, and had not yet any paper-making machinery. They had a machine-house ready which was 70ft long and 20ft wide.

Immediately following this journey to Liverpool, Birmingham, and Oxford, Donkin went from Norwich to Cambridge regarding the printing-machine which he and Bacon had patented together, and they agreed to draw up a specific agreement in writing for the purpose of securing and defining their respective shares in the patent; Bacon agreed to give the necessary instructions to Abbot of the Patent Office. Bacon wrote a note to the Vice Chancellor of Cambridge University telling him that the printing-machine would be ready to give an exhibition of its performance to the University Press on the following Monday morning.

Donkin's works at Bermondsey stood in a very isolated position, almost surrounded by marsh-land, and bounded on one side by a tidal ditch. The Old Surrey Foxhounds had their kennels close by, which is evidence of the rural character of the surroundings. The iron castings used in the works at that time came chiefly from Hall, of Dartford, by water, or from Boulton and Watt of Birmingham, by pack-wagon, no iron foundry being established by the firm until the middle of the century.

During the first fifteen or twenty years of the nineteenth century, owing chiefly to the political state of Europe and the wars with France, the home trade was at a very low ebb, and the struggle to carry on such a business since Donkin had started with very little capital, was very severe; but as he became well-known to the leading civil engineers of the day, he was able to obtain a good deal of professional work which, no doubt, assisted his finances considerably. This included surveys, arbitrations, and valuations in connection with public works and private enterprises, which took him to all parts of the country, and make his journals very interesting reading.

Donkin's correspondence records a great number of undertakings which have since become historical, in which he was connected with Telford, Rennie, Bramah, Boulton and Watt, Murdock, Simpson, Maudsley, Congreve, the two Brunels, Nasmyth, and others. The firm still preserves drawings signed by these well-known men. His diary describes a journey undertaken in 1816 to meet Telford in connection with the construction of the Caledonian Canal. As an example of the difficulties of travelling at that time, the description is interesting, apart from the object of the journey, as the following extracts will show.

> September 22nd, 1816: Left in *Eagle* smack from Downs Wharf at 2.30 p.m. A brig ran foul of us breaking our main top-mast and sending us aground; lost the tide and anchored off Erith.
> 23rd: repaired mast. 28th: off coast of Yorkshire; blew a gale off land, and carried away top-mast again.
> 29th: arrived at Leith between 6 and 7 p.m. and stayed in Edinburgh.
> Oct. 3rd: set out by coach for Inverness; slept at Dunkeld. Oct. 5th: arrived in Inverness and found Mr. Telford there.

After going over the whole length of the canal, Donkin returned by land in easy stages to London, making various business and other visits on the way, and reached home the 21st December, 1816.

Another interesting entry in the diary (January, 1814) is that of a visit to Boulton and Watt's Works at Soho, Birmingham.

> Mr. Murdock showed me the foundry which is large enough to melt 30 cwt of iron at one time. Young Mr. Watt asked me to call on his father (James Watt). Mr. Murdock accompanied me, and I was kindly received by the old gentleman, who is now 84.

One of the earliest associations formed in the interests of engineering was the "Society of Master Millwrights," which was founded in 1805, Donkin being the Treasurer. Among the members were Simpson, Rennie, Penn, Hall and Congreve. The subscription was £3 3*s*. per annum, and the meetings were held at the Museum Tavern, Bloomsbury, and elsewhere. This Society does not seem to have survived for more than a few years.

In 1817, Bryan Donkin assisted three of his pupils, Palmer, Harris and Ashwell, to start a small club or society to discuss matters connected with the engineering profession, and from this small club originated the Institution of Civil Engineers. Donkin was the means of securing Telford, who was then at the head of the profession, to give it his patronage and become the first President in 1820. A Charter was obtained for the Institution in 1829. Among the earliest members were Maudsley, Field and Collinge.

Donkin held the office of Chairman of the Society of Arts. He was also Chairman of the Royal Astronomical Society, and had in his private garden an observatory in which was an orrery simulating the motion of different planets, and instruments for observing transit, in connection with which was a level of novel design.

For many years Donkin took an intense interest in the study of phrenology, and formed an intimate friendship with Dr. Spurzheim, who devoted his life to the science. A voluminous correspondence between them took place, and when Spurzheim was bitterly attacked by some of the medical profession in the *Edinburgh Review* in 1815, Donkin was one of his most ardent defenders. With his friend Maudsley he took a number of casts of human heads of all types, comparing and tabulating results with great detail.

In mechanical engineering the more scientific side of the profession was also not neglected by Donkin. In 1810, he received a gold medal from the Society of Arts for a tachometer for measuring the speed of machines. This was done with a cup of mercury which received a rotating motion from the machine, causing the mercury to sink in the centre and rise at the rim. The variations of speed were indicated by the rise and fall of a column of spirit in a glass tube, the lower end of which was immersed in the mercury.

In 1819, Donkin received another gold medal from the same Society for a counting machine, and he was spoken of as the leading mechanician of his time.

Another invention of this class was an ingenious mechanical motion, in which the driver rotates continuously, and the driven member at measured intervals (as in a star wheel), the two being always in contact, and the latter being unable to move independently of the former.

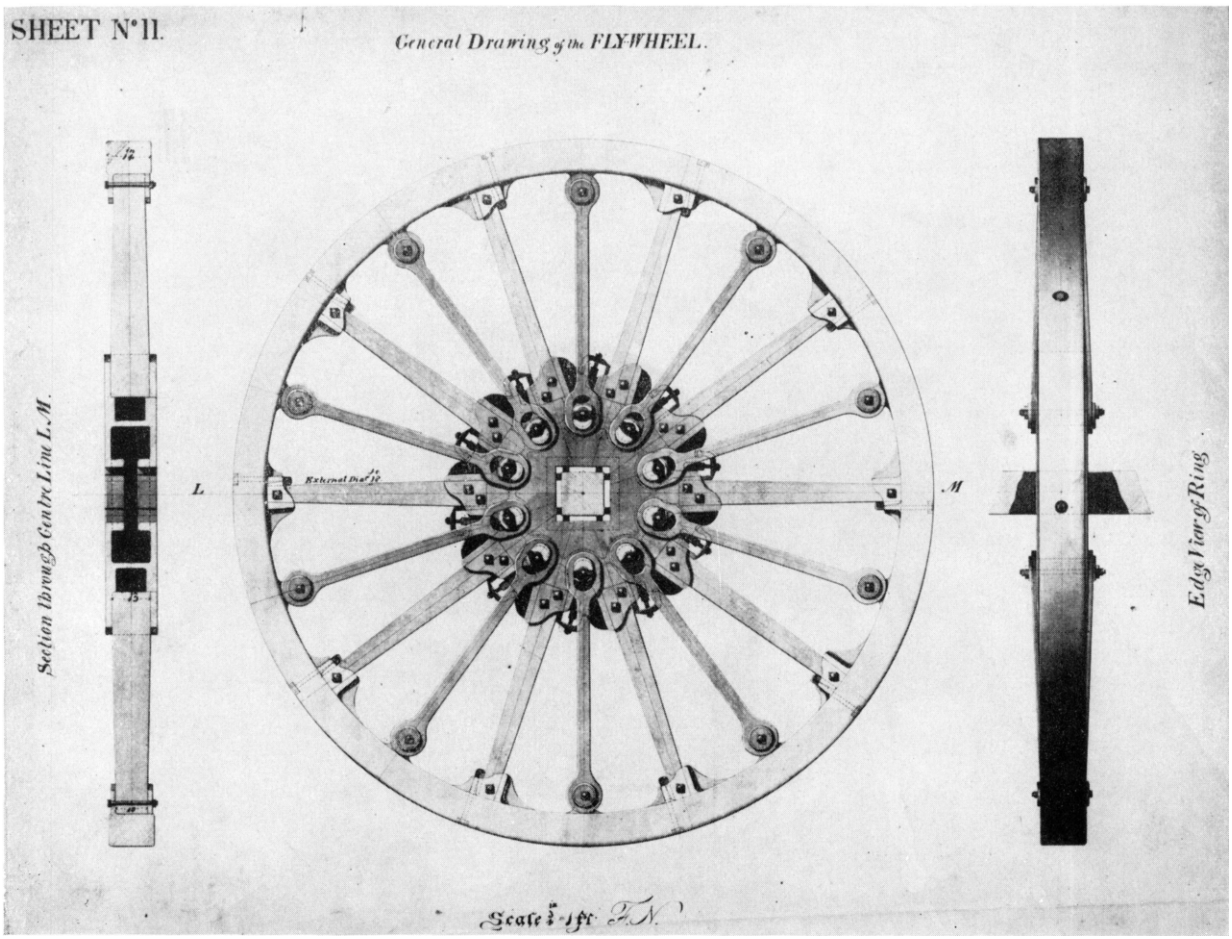
Donkin invented and made a dividing machine for dividing scales in minute and exact graduations, and this may be seen at the Museum of Science and Art at South Kensington.

Donkin always took a great interest in astronomy, and some of the apparatus at the Greenwich Observatory, including the great mural circle which was then considered a marvel of accurate workmanship, was made in the works at Bermondsey.

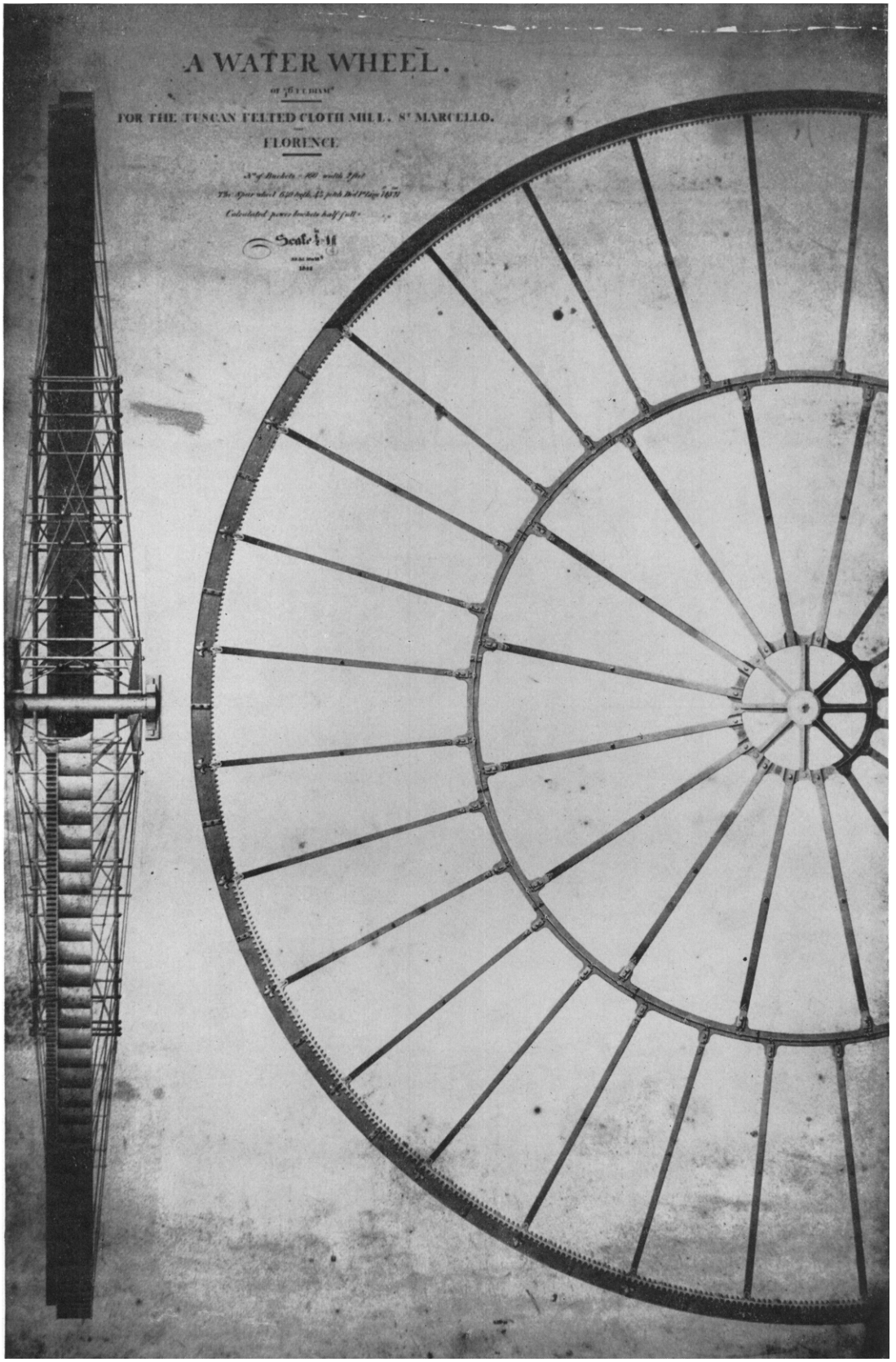
During the first half of the century, although steam power was rapidly being adopted as an auxiliary, the paper and other mills with which the firm did its principal business depended chiefly on water power. For this purpose many water-wheels were built at Bermondsey, one of these being of a very special design. It was built up with iron bars in tension, on the modern bicycle wheel principle, 76 ft in diameter, with 160 buckets, and only 2 ft wide on the face. It was erected in 1842 at a mill in Italy where there was a very high fall, with a very small quantity of water.

Later, water turbines were introduced, and a great number made by the firm, the type adopted being very efficient, and specially suitable for low falls, which are prevalent on the rivers of this country.

The firm was also closely connected with Brunel in the construction of the Thames Tunnel. This work was commenced in 1825, and three years later was closed in consequence of inundation. In 1835 it was re-commenced, and finally opened to traffic in 1843. Part of the shield and other apparatus used in connection with the work was made at the Bermondsey factory, and the two Brunels, father and son, and the two Bryan Donkins, father and son, were on very intimate terms.



General drawing of a fly-wheel by Donkin showing details of construction and fine draughtsmanship.



A Donkin water-wheel, 76 ft diameter, for a mill in Italy in 1842.

Another well-known man of his day with whom Donkin was connected in several of his enterprises was Sir William Congreve, 1772–1828, who is probably best remembered as the inventor of the military rockets that bore his name, the chief features of this invention being the sustaining of the rocket in the air by a parachute that was released by the explosion of a detonator in the cap, also imparting a rotative motion to the ascending rocket.

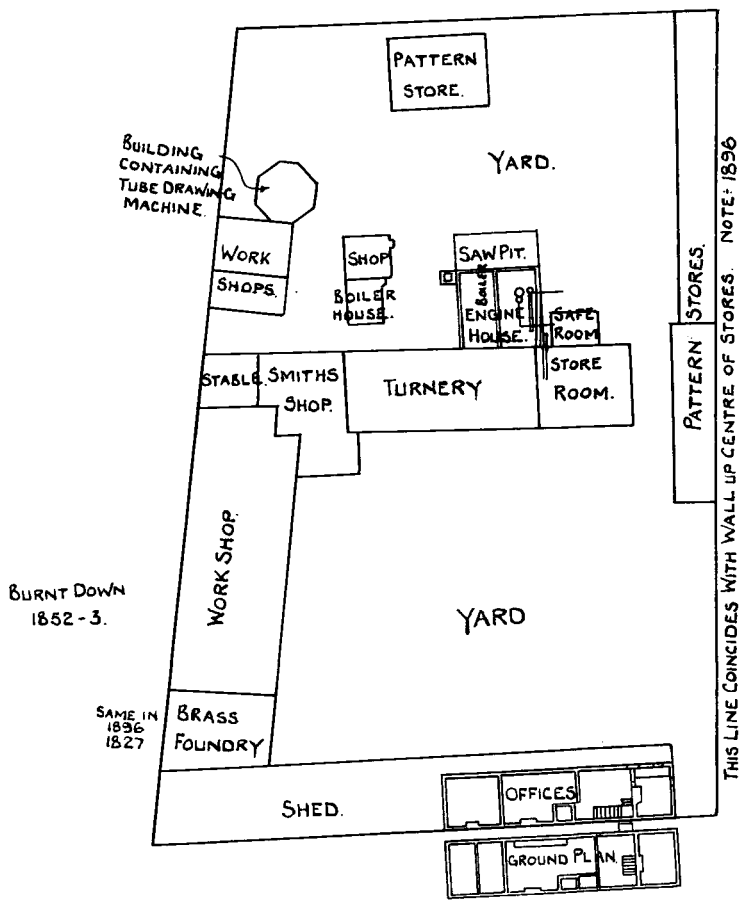
In 1820, Congreve obtained a patent for printing in two or more colours, the immediate object being to make imitation and forgery more difficult, particularly in connection with printing official stamps, notes, registered designs, and trade marks from dies.

A special printing machine was designed to make the whole operation continuous and automatic, all the work being carried out by Bryan Donkin and Company, and remaining in their hands exclusively for many years. Some machines were placed at the Excise Stamp Office, and at the East India Stamp Office in Calcutta.

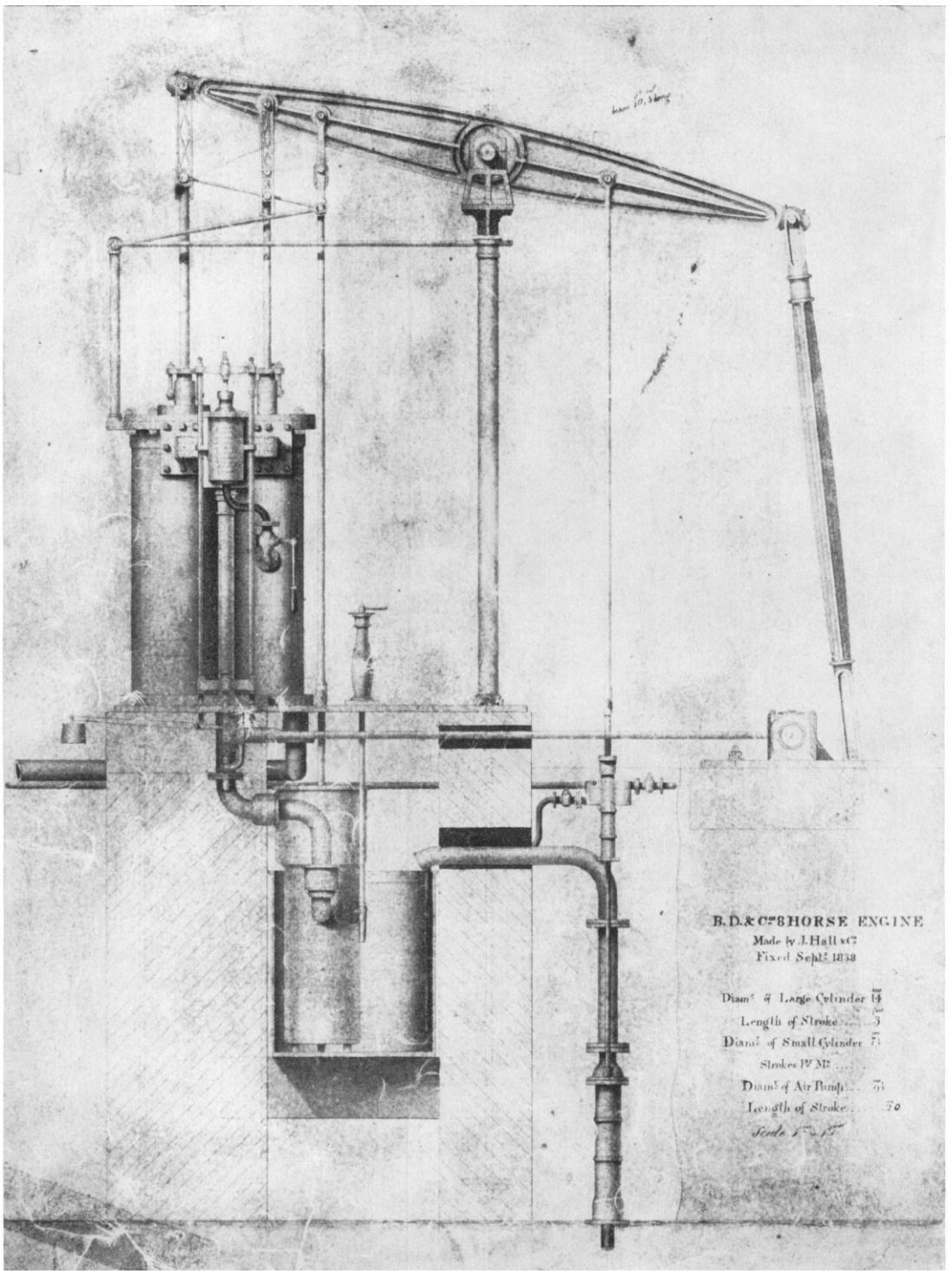
In the Science Museum, South Kensington, there are many examples and models of the inventions of Donkin, namely:

Model of the continuous paper-making machine.

Models of a Rag Duster, a Rag Boiler and Rag Engine, for making the pulp.



Plan of Donkin's engineering works at Fort Place, Bermondsey, in 1827.



Drawing of an 8 h.p. steam engine designed by Donkin and built by John Hall in 1838.

A small Lathe with a triangular bar and cone pulley drilled to use as a dividing plate. Many lathes of this type were made by Bryan Donkin for his own works and others.
McNaught's Steam Engine Indicator, 1825–30, which was made by the firm.
Donkin's dividing engine of which the following is the official catalogue description:

> This machine was constructed in 1826 by the late Mr. Bryan Donkin, F.R.S., to faciliate the graduating in mathematical scales, and it was also used for originating a remarkably accurate screw thread. The distinctive feature of the method followed consists in the employment of a compensating arrangement which can be so adjusted as to neutralise any irregularities that, by careful optical measurement, have been found to exist in the leading screw of the engine. . . .

In 1819, Donkin's eldest surviving son, John, began to assist him in the business, and after some years of practical experience devoted himself to the commercial side of it almost entirely. He was taken into partnership in 1826, and died in 1854. In 1828, another son, Bryan, followed, and was taken into partnership in 1840. A Deed of Partnership included the youngest son, Thomas, and he was principally engaged in supervising the paper-mill work.

In 1846, Bryan Donkin, sen., retired from business—assigning the lease of the factory to his three sons, John, Bryan, and Thomas, the freehold being subsequently purchased by Bryan and Thomas—and in 1855, he died at the age of eighty-seven.

In 1858, the firm, which then consisted of the two sons, Bryan and Thomas, and B. W. Farey, obtained the contract from the Russian government for the erection of a complete paper-mill at St. Petersburg. This was by far the largest contract the firm had ever undertaken, involving as it did besides the paper-making equipment, a steam power plant of 2000 h.p., and a costly water supply and filtration scheme. The work took over three years to carry out, the superintendence of the erection being entrusted to John Donkin's son, Bryan (known as "Bryan Donkin, Junr."), who afterwards was taken into partnership by his uncles. It is interesting to record that one of the men who had been apprenticed at Bermondsey, named Richard Bowery, was sent out by the firm, with others, to St. Petersburg, and remained there, finally becoming general manager of the mill under the Ministry of State Papers.

In a recently published book entitled *Early Engineering Reminiscences of George Escol Sellers* (The Smithsonian Institution Bulletin No. 238, 1965) reference is made of a visit by Sellers to Bryan Donkin's Bermondsey works some time in 1832.

Sellers was very impressed both with the factory and Donkin, and as there does not seem to be any record in Donkin's diaries or elsewhere of this visit it is interesting to give Sellers' account of the Bermondsey works and what he saw of them, and also of his interesting talk with Donkin. It is obvious from Sellers' account that he was able to tell Donkin of several aspects of engineering where the Americans had a lead over the English.

One interesting fact is that whereas Donkin covered his cast-iron drying cylinders with copper, to prevent the paper having contact with iron, neither the American engineers, nor John Dickinson at Croxley, considered this necessary. This was a great surprise to Donkin, because Dickinson's papers, which were dried on iron cylinders, were famous and popular with printers in London.

The account of Sellers' visit to Donkin's works is as follows, and is given with the kind permission of the Smithsonian Institution:

> The secrecy with which much of the machine-building art was practiced in Europe during the period of its most fruitful development has put beyond our reach many of the answers to questions that we would ask. For example, who built the first effective metal planing machine? The 1817

George Escol Sellers.

machine of Richard Roberts, attributed and dated years later, exists. However reasonable the attribution and dating may be, the first published description of a metal planer was by Joseph Clement in the early 1830's. Meanwhile, there were many other skilled and enterprising craftsmen in whose secret rooms developments and innovations were being hammered out nearly in parallel.

It is for this reason, apart from Sellers' skill in constructing a life-size picture of the immensely admirable if faintly pompous and plodding Bryan Donkin, that this account of Donkin's Bermondsey shops is particularly valuable, and perhaps unique. Few others of the small number of visitors admitted would have noted the mechanical detail that makes it possible for today's mechanician to determine just what the shops were capable of doing, and more accurately to assess the contribution of the master. The comment of Andrew Ure, referred to elsewhere in this book, author of one of the standard mechanical dictionaries of the 19th century, is useful in its way but of little help in letting the mind's eye focus upon the machine tools of 1830. "I have had the pleasure," Ure wrote, "of visiting more than once the mechanical workshops of Messrs. Bryan Donkin and Co. in Bermondsey, and have never witnessed a more admirable assortment of exquisite and expensive tools, each adapted to perform its part with despatch and mathematical exactness, though I have seen probably the best machine factories of this country and the Continent."

Bryan Donkin (1768–1855) has been curiously neglected by historians of technology, in spite of his very considerable contributions to the design and construction of the large and complex Fourdrinier paper machines and to the more general task of producing better tools with which to shape metals with precision.

He served an apprenticeship in John Hall's machine works in Dartford, several miles south-west of London. In 1801, when Hall was engaged by the Fourdriniers to construct the newly patented continuous-web paper machine of the Frenchmen Robert and Didot, the major share of building a machine model apparently devolved upon Donkin, who was by this time 31 years old. The entire development of the machine had been turned over to Donkin by 1802, when he took premises in Bermondsey, about two miles down river, from the London Bridge.

The new works prospered, and by the time of Sellers's visit, in 1832, Donkin had built more than 100 Fourdrinier machines.

Donkin earlier developed and built a "polygonal" printing machine, forerunner of the much later type-revolving cylinder machines of R. Hoe & Co., of New York. Donkin's machine, employing a square "cylinder", which provided space for four flat forms of type, turned by "square" gears, and printing on a conjugate or complementary surface that revolved in contact with his polygonal "cylinder", produced 800 to 1,000 impressions per hour, but it was not economically successful.

He was active in the venerable Society of Arts and in the Institution of Civil Engineers, and while he had not by 1832 gained the status of fellow of the Royal Society—he became a fellow in 1838—it is clear that he was a man universally esteemed. The evidence favors the summing-up of his eulogist: "His life was one uninterrupted course of usefulness and good purpose."

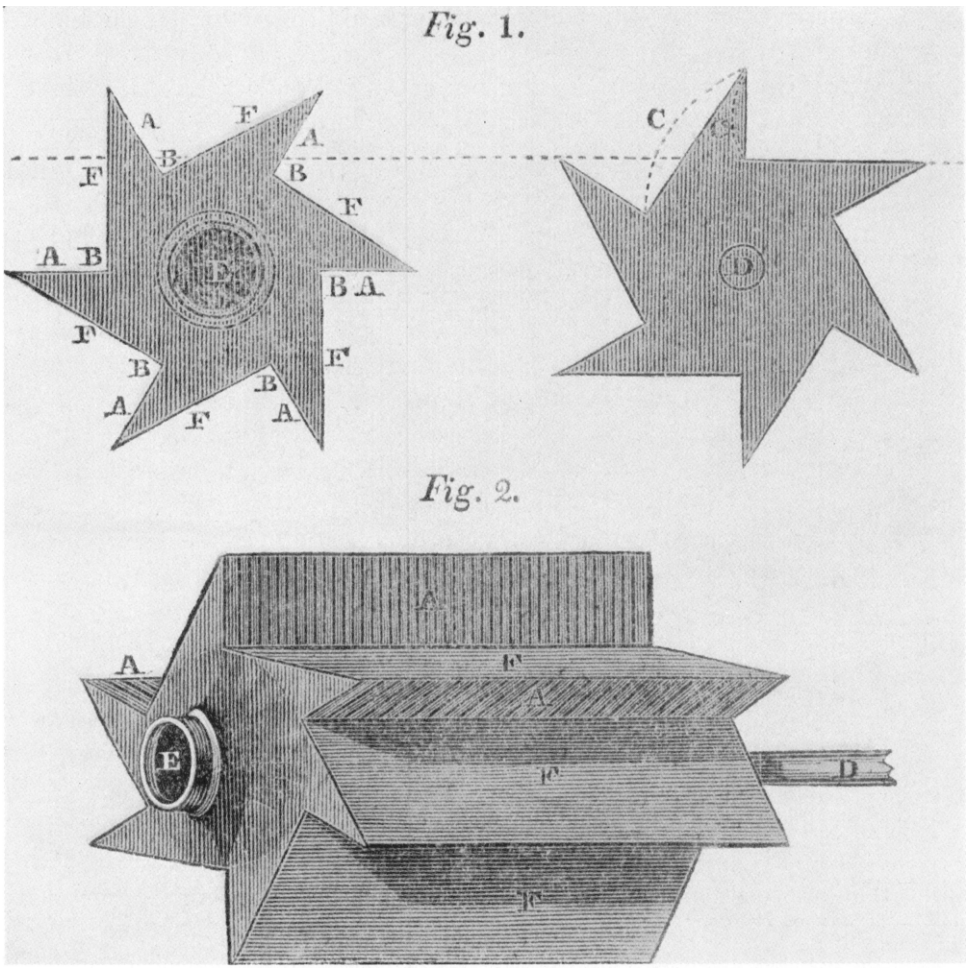
It was about midday when I left Mr. Brunel. I went up the Thames to Old Wapping Stairs, the nearest ferry crossing to Donkin's Bermondsey shops.

I was so fortunate as to find Mr. Donkin in his office; I presented my letters as I had been advised to do by Mr. Swann. He opened the first one, glanced over it, and laid it open on his desk, and opened the second, treating it in the same manner. I could read nothing from his calm, impassive face, but on opening the third there was an evident change of expression; he read it very slowly, seemingly in deep thought. Before opening the letters he had asked me to be seated.

Still holding the last letter in his hand he turned to me saying, "This letter is from a most worthy gentleman whose requests I am always glad to respond to. I had a letter from him a day or two ago in which he mentioned having given you a letter, and I have been expecting you to call on me. In this letter of introduction he states that you are engaged in the paper machinery branch of my business in America. You have seen in operation at his mills one of my latest and most improved machines; after they have left my shop I have no further control of them, and their owners are at perfect liberty to show them to whomever they please. I have in my erecting shop the widest and finest machine I have ever built to fill an order from France, which I will take pleasure in showing you. But the tools and various machines and appliances I employ in their construction have been the work of almost a lifetime, and I hope you won't take amiss my unwillingness to exhibit them." He then added: "I am glad you have not come under false colors, as I am sorry to say mechanics have done." This was plain talk, and I felt that it ended my hope of seeing his works.

As he got up to lead the way to the erecting shop, I mentioned to him that I had brought to England a paper pulp dresser or screen, invented and patented by my father in the United States, with the intention of patenting it in England, if, on investigation, I found it would be worth the expense of doing so, and as to the cost I had obtained all the information I required from Newton & Son. But having seen at work on two of his machines the Ibotson grate bar screen working satisfactorily, I was in doubt what course to pursue; that if not patented, and left free to anyone, it might seriously interfere with the Ibotson patent, and as he was the maker of that, and knew all about their cost, I would be glad to have him examine my father's, and if willing to do so to give his candid opinion of their respective and comparative merits.

To this he replied by asking if I was aware of the danger of showing the machine to anyone



Sellers pulp dresser, 1832. To remove "knots" (globular inclusions in the dilute pulp) the turning rotor was immersed in the stuff chest as indicated by dotted line. Acceptable pulp passed through parallel bar grids on surfaces (A) and was supplied to the paper machine through hub opening (E). From *Journal of The Franklin Institute* (December 1832), new ser., vol. 10.

before either caveating or patenting, that in case of litigation the testimony of anyone having seen it would vacate the patent; he would advise my entering a caveat before showing it to anyone.

He seemed pleased when I said he was the only person I had thought of, believing that in showing it to, and consulting him, I ran no risk, and that I should highly value his opinion, and that if he did not object I would have the box in which it was packed forwarded to him.

He made no reply, and we went into the erecting shop where stood, certainly, the finest specimen of workmanship that I had seen in England. It was the long web or Fourdrinier machine, 60 inches in width between the deckels. The machine stood as it was to be placed in the mill, with shafting and gearing all complete. Great care had been taken that in no place the wet paper should come in contact with iron, under the mistaken idea that such contact produced the rust spots so common at that time in English printing paper. The paper makers did not appear to have discovered that such spots were mainly due to want of thoroughly cleaning the rags, that broken needles, iron button eyes and such like things, after being ground up in the beating engines, passed into the paper and oxidized there; that the remedy that I have before referred to was sand traps in the beating engines, believing them to have been of American origin, had not been generally adopted

in England, that the freedom from such spots in the high grades of the hand-made paper of the Whatman's and other mills doing that character of work, was almost entirely due to the care in selecting and cleaning the rags.

To return to the machine as it stood in the erecting shop, the press rolls were composition metal, in color that of gun metal or bronze. When I spoke to Mr. Donkin of their composition he made no reply. It was evidently one of his secrets. The web and felt-carrying rolls were also of composition metal, but in color nearer that of brass. The drying cylinders were cast-iron covered with copper. These were splendid specimens of workmanship. The bosses on the main driving shafts were turned, the eyes of the wheels bored and keyed on them; in fact, all gearing was either secured by set screws or was keyed on round shafts. Here was the first conclusive evidence of evolution in the right direction that I had seen. The mind of the great inventor who had perfected that wonderful machine for the continuous sheet of unbroken paper, had also been turned to simplifying its construction, and making all parts interchangeable.

After viewing the machine, in which I was not in any way limited in time, for Mr. Donkin seemed to take pleasure in exhibiting it, he led the way back to the office. Of course, I, for the time, abandoned all hopes of being shown through the shops. When about leaving, he referred to the pulp dresser, and said he must again caution me showing it to anyone. To this I replied by repeating what Sir Walter Scott had said to my uncle, Rembrandt Peale, as to his friend, "Honest Bryan Donkin, the machinist," that with such an endorsement I felt that I ran no risk, and should send the pulp dresser to him.

His face brightened with a look of great satisfaction, as he said "that when Sir Walter acknowledged the authorship of the Waverly Novels, and said that for a long time it had been known to twenty people, none of whom had abused his confidence, he was proud of knowing that he was one of the twenty; he then added, the acquaintance, and, he might say, intimacy with Sir Walter had come about in a most natural way; he had frequent consultations with the Constables, the publishers of Scott's novels, on the subject of paper for that purpose, at which Sir Walter was often present."

He said that Mr. Swann, in his letter to him, had expressed a belief that it would be mutually advantageous to us to have a free interchange of ideas on paper machinery, and he laughingly added: "My ideas have gone to America in a machine I sent there to fill an order, and I learn they have already been copied."

I told him that so far we had been exclusively engaged on cylinder machines, and had never built a Fourdrinier; that at that time Phelps & Spafford were the only builders in the United States.

He asked what we got for a complete squirrel cage cylinder, naming a size. On my giving our regular price, he promptly said that he could not compete, pay freight and duty, for our price was less than he got at his works.

This I felt to be my opportunity, so I explained our mode of putting up the cylinders, the machinery and tools we used. He listened very attentively, but made no comments. I could not but admire his extreme caution and reticence as to his modes. At the same time his evident eagerness to learn what others were doing amused me, and I felt much like a man in the hands of an interviewer of the present day. But to divert, and at the same time lead him on, I remarked that I had been surprised at not finding the direct-acting guillotine paper cutter in use in England, when in America they had almost entirely superseded the plane or bookbinder's trimmer for all paper trimmed and put up at the mills.

He understood there were very serious objections to them, inasmuch as a chisel-edged knife could not be thrust directly down through paper, without turning or making a sharp edge on the lower side of every sheet.

Yes, I replied, if the paper is loose, but the pile of paper to be trimmed being pressed tightly

together, the knife goes through it like shaving wood, and added, this you can try with a sharp chisel, when you have the paper pressed on a calender roll shaft, ready for the lathe.

He had never thought of this, but should certainly try it. He then asked if I would, for a consideration, sketch the most approved plan in use.

I replied that I would cheerfully and freely give him any information he wanted; the machine was patented in the United States, and at that time we were the exclusive builders, paying the patentee a royalty on each machine; that their introduction had been rapid; that in the United States there were very few mills without them; that printers and bookbinders had generally adopted them for pamphlet trimming.

It was growing towards night, and as I had an engagement for the evening, and moreover, began to feel hungry, I again essayed to go, when Mr. Donkin asked if I had ever given a thought to the possibility of making an absolutely perfect screw. Mr. Saxton had told me this had been a hobby with Mr. Donkin for many years, and on the previous Sunday I had gone with Saxton to the Royal Observatory at Greenwich, where we had seen the great mural wheel that had been turned at Donkin's works, and graduated by Troughton with one of Donkin's screws.

I replied that when a boy I had been much interested by my grandfather's ideas and efforts in that direction; that to generate a screw of a certain pitch, instead of setting a sharp knife edge at an angle of the axis of the spindle to be cut, as I had been shown the day previous as Maudslay's design, my grandfather had drawn hard iron wire by light drafts to insure accuracy; that this he had wound like a spiral spring on an accurately-turned iron mandrel, with a fixed collar at one end and a loose one at the other, driven up by a screw nut, to force and hold the coils when wound in close contact. On this he had cast a fusible metal nut. I had found this in grandfather's shop with a number of wooden rods wound in the same manner with wires of various sizes; these latter he had explained as having been used in testing and correcting his wire gauge by the numbers of coils to the inch. The iron one, he said, was an effort to produce an accurate screw for his friend, David Rittenhouse. He did not say for what use but I infer it had something to do with Rittenhouse's astronomical work. I hastily described old John White's expedient for cutting press screws before the time of engine lathes that I described in my second paper.

Mr. Donkin had evidently got on his hobby; he insisted on my stopping to see a couple of his screws for graduating. They were of steel, about $1\frac{1}{4}$ inches diameter and about $1\frac{3}{4}$ inches long, as near as I can recollect; one of 25, the other of 50 threads to the inch. This was firmly placed over the 25-thread one, so that 50 threads calipered them. In front a movable microscope, with a finely-graduated micrometer eyepiece; by sliding the microscope and turning the screws, the least possible variation could be detected. It was growing too dark to see this to advantage. Mr. Donkin spoke enthusiastically as to what Mr. Maudslay had done towards establishing standard screws; but as to absolutely correct ones, he said: "We may have a screw with a deep or long nut on it, that works smooth and easy, and with the most delicate handling no imperfection can be discovered, yet, on using the screw for a dividing engine, errors would soon be apparent."

He asked if I had ever thought of or seen any device for testing irregularities or gain or loss of one thread over another?

None but a very simple one of Isaiah Lukens, town clockmaker of Philadelphia—a little sliding carriage parallel with the screw to be tested. This carriage had a fixed point in the groove or channel of the screw. By turning the screw it would be made to advance in either direction as the screw was turned. In this carriage in the plane of the axis of the screw was an adjustable stud or center that could be set at any number of threads desired from the carrying point. On this stud was a lever or index hand, as Lukens called it, the short end fitting into a channel of the screw, the long end resting on a graduated arc, adjusting the fulcrum stud so that the index hand pointed to 0. On turning the screw to advance the carriage by the fixed point, the least variation would be

shown by the point of the index lever. There was also an arrangement to measure short inequalities by using the obliquity of the thread by either raising or depressing the lever on the center pin or fulcrum. I did not know what mode had been taken to correct errors when found, but I thought Mr. Saxton, who had served his apprenticeship with Lukens, would be able to give all information.

He had never spoken to Saxton on the subject, but he should certainly take the first opportunity of doing so. He did not then say what he had done, but only remarked that it was wonderful that minds over 3,000 miles apart should in any degree travel the same roads. He threw the covers off of some of his apparatus, no doubt with the intention of showing and explaining. But the increasing darkness, and my evening engagement, forced me to tear myself away. The shops were far out on the Blue Anchor road, some three or four miles from where I was stopping. I might be obliged to walk a long distance before I could catch a cab or omnibus.

On leaving, Mr. Donkin presented me with a one-foot boxwood scale of his own graduating, which I have had in almost constant use to the present time, and value it highly.

I found Mr. Saxton waiting for me for our evening engagement, but not having had a mouthful since an early breakfast, food must first be discussed. When I told him what an enjoyable afternoon I had with the great inventor, he asked: "Did he show you through his shops?"

"Only his erecting shop."

Then came: "I told you so; they are closed against all foreigners, particularly Americans."

"But," said I, "the end has not come. Tomorrow I am to send him the pulp dresser. He took my address and promised that after seeing it I should hear from him."

"No doubt," said Saxon, "and that will be the end of it."

To which I could only reply by using Jacob Perkins' favorite axiom: "We shall see; time proves all things."

A few days after the pulp dresser was sent to Mr. Donkin's shops I received a note from him, saying he had been quite unwell and had not been to the shops for a couple of days, but he had examined the pulp dresser and would like to see me at his works, naming a time when he hoped to be able to be there. When I went there I learned that he was still too unwell to venture out, but he had requested that when I called I should be taken to his house, where he would see me. I found him suffering from a very heavy cold, so much so that I determined to make my stay very short.

He said he had examined the pulp dresser with much interest; that it was very ingenious, and could be furnished at a much less cost than the Ibotson bare screen as he was then making them, but should Ibotson adopt slit plates such as we had on our revolving pulp dresser, it could be made at less cost than ours; but he was making planers and tools for the Ibotson that would reduce the cost of their production, and at the same time insure greater accuracy than he had heretofore obtained by grinding on lap wheels. He named the royalty he was paying Ibotson on all he made. He showed me a list of all the Fourdrinier machines he had built, and also those he had already added the pulp dresser to, and the number that would still be obliged to have them of some kind. The one I had brought, if introduced either with or without patent, would to some extent be a dividing competitor and a cutter down of profits. He did not think, without personal attention in England, I could put it in the hands of anyone to manage with any certainty of being reimbursed the outlay of securing the patents. But he believed it would be to the interest of Ibotson to own and control it, either by patent or suppressing it. He had learned that Ibotson would be in London the next day, and at his shops about noon. His object in seeing me was to state the facts, and to suggest that he should be empowered to confer with him. This would necessitate showing the machine, but in doing so he would guarantee that I should in no way be injured. If I consented to this he would like me to meet them on the morrow, when he hoped to be able to go to the shops.

This being so arranged, I got up to leave, but he pressed me to stay. He was feeling better,

and he felt a little friendly interchange of ideas would cheer him. Finding that I had considerable acquaintance among the artists it opened a subject that I was surprised to find him so well posted on, for I did not look for it in one whose whole life had been so intensely devoted to mechanical pursuits as his had been.

After considerable talk on general subjects far away from either civil or mechanical engineering, he asked if I had any experience in turning copper and leaving it perfectly smooth from the lathe tool?

Very little, I replied, but I had seen much of it done on calico printing rolls, in Baldwin & Mason's shop.

Then came the direct question: Do you think you could cover a well-turned drying cylinder, say 3 feet diameter by 6 feet long, with 50 pound copper, that is, copper weighing 50 pounds to a sheet of 30 by 60 inches, turn and finish it as perfectly as those I had seen in his erecting shop?

I said I could readily understand the difficulty of turning thin copper when not cemented or soldered to the cylinder, but I did not see any difficulty in accomplishing it without the use of the lathe further than in polishing after the copper on the cylinder had been drawn through a highly polished die, and only then to give it the appearance of having been turned, for, as finished by the die they were forced through, they would be left as near perfection as possible.

He asked me to explain what I meant by drawing cylinders, of the magnitude of his drying cylinder, or even supposing such a thing possible?

I replied that I did not see any difficulty, that it was only a question of size and power of the machine to do the work; that at the time of the partnership of my father and Jacob Perkins in building fire engines, copper cylinders from 3 to 8 inches diameter were perfectly finished by forcing through well-turned and polished dies; that on one occasion an air vessel of 16 inches diameter had been finished in the same manner.

He thought I had said drawing, and now I said forcing through dies; would I explain any difference between drawing and forcing?

None other than if drawn horizontally through a die, the great weight of the cast-iron drying cylinder acting as a central mandrel would seriously affect the uniform thickness of the copper and smoothness of the work; that this would be avoided by a vertical position and forcing upwards through the die.

He asked how I would proceed to do the job in that way.

I replied that after bending the sheet copper to the size to fit tightly on the cast-iron cylinder and brazing its union, taking care that it had been thoroughly annealed, I would close the upper end sufficiently over the end of the cylinder to insure its entering the die and holding it fast to the inner cylinder, then place it on the platform of a Bramah hydrostatic press with length of plunger or lift greater than the length of cylinder to be covered; the columns of the press would be the guides for the platform, and by having heavy screws and nuts on them they would at the same time hold the great die.

The next question was, Did I ever see or hear of anything of the kind?

No other than the old toggle-joint press that was used by Jacob Perkins and my father in drawing fire engine cylinders; that the Bramah press, that was then being extensively introduced in the English paper mills, was the natural sequence of the crude toggle-joint with all its wedges and keys. Suggesting the use of the hydrostatic press was only an application and no great stretch of imagination.

Probably not, said Mr. Donkin, having had the advantage of seeing a copper cylinder of 16 inches diameter successfully finished in that way. But without this to conceive of and put into practice on so large a scale required no little thought and much boldness in the necessary outlay—machinery that, if not successful, would prove a serious loss.

I remarked that since seeing the machine in his erecting shop I had learned some facts in relation to drying on iron cylinders without the copper covering. The finest qualities of copper plate paper, used by John Murray, the Ackermanns and Windsor & Newton, for the finest works of the engraver, were from John Dickinson's mills, and entirely free from iron mould or specks.

But what assurance, asked Mr. Donkin, have you that the paper was not dried on copper cylinders?

I replied the assurance of Mr. Dickinson himself; that I had dined and spent last evening with him, and the subject of drying paper by steam-heated cylinders had been fully discussed; that for gradual, steadily increasing heat with uniformity Mr. Dickinson gave a decided preference to iron over copper; that he had sketched his arrangement giving the number and size of the drying cylinders that he had found the most effective and reliable for his heavy plate paper; that he had promised me a set of tracings of his most approved dryer, with no other restriction than that I should not show them in England. He had said that he made no secret of his preference for iron dryers, notwithstanding the increased surface required over the ordinary copper ones, but I considered what he had said, as to the arrangement of his drying cylinders, and manner of working them, as confidential, being included in his request in regard to not showing his promised tracings in England.

Mr. Donkin was much surprised at Mr. Dickinson having been so free with me; he thought it most extraordinary, inasmuch as it was well known that he had more reliance on secretly working than on patents to protect him in his inventions, and of all paper makers in England he was the most rigid in enforcing the rule of non-admittance to his mills without a special permit from himself; that all of his machinery was made at his own shops under the same rigid secrecy. I replied that he had offered me a letter to the manager of one of his mills, but would prefer accompanying me if I remained in London over the present week; that I should most certainly avail myself of this.

The reference I made to Mr. Dickinson's preference for cast-iron dryers without the copper facing I felt was unfortunate, for it seemed to cast a shade over Mr. Donkin, and he sat as if in deep thought; he suddenly roused himself, and said, if it was not intrusive or impertinent, he would like to know how I had met with and become acquainted with Mr. Dickinson.

Not at all, I replied: Mr. Charles Leslie, the artist, had taken me to Ackermann's great artists' emporium, and introduced me to Mr. Ackermann as a son of one of his old Philadelphia friends and grandson of Charles Willson Peale, the artist, who, up to the time of his death, had been a correspondent of their house. Many fine specimens of art were shown us. The subject of the satin-faced plate paper, then being made by Dickinson, of which the Ackermanns were large consumers, was freely discussed in a manner very interesting to me, so much so that I expressed a wish to meet Mr. Dickinson. Both Mr. Leslie and Ackermann proposed going to his city office at his great paper warehouse.

In this way my introduction was most favorable. We were taken through the warehouse among immense stacks of paper, and into a room where there was at work one of Mr. Dickinson's recent inventions—rotary cutters for cards, principally for playing cards, with greater accuracy and leaving a more perfectly rounded edge than was made by the ordinary shear cutting.

When I was introduced, it was as an American engaged on paper machinery, and being a young man, as a matter of course, Mr. Dickinson's principal attention was to the great artist, and to the large consumer of his paper; and I walked with them, listening and taking but little part in the conversation, until Mr. Dickinson asked me if I had ever met a Mr. Greatrake in America, who many years before had been taken from him by Mr. Thomas Gilpin offering a higher salary than he could at that time afford to pay.

On my replying in the affirmative, and that I was well acquainted with Gilpin, and thoroughly posted as to his cylinder paper machine, he then spoke of Greatrake as having been one of his

most reliable and trusted employees; that it was a severe blow his leaving at the time he did, knowing that he had taken with him to introduce in the States his inventions, that they had together worked on for years, through great difficulties. He was very bitter on Gilpin for, as he called it, buying Greatrake to get his inventions.

Before we left, he asked me if I had ever met any of Mr. Greatrake's family. He referred particularly to a daughter, Eliza, who many years ago had written to his wife, announcing her marriage, since which time they had lost all trace of her.

I told him her case was a sad one; her husband was my mother's brother; that since the birth of her only child she had become a hopelessly confirmed invalid.

Mr. Dickinson would like his wife to meet me, and learn something of her old friend, and regretted that his family were at his Brighton house. He was going on Saturday to spend Sunday, and urged me to accompany him; but I had other engagements. On the Monday evening following I had a note from Mr. Dickinson, inviting me to dine with him the next day, saying his wife and son had come up to London with him to stay over that day.

This outline of the way my acquaintance with Mr. Dickinson had been brought about, Mr. Donkin said most satisfactorily accounted for the freedom with which he had spoken of his machinery to me, knowing what I did of the machine Greatrake had put in operation for Gilpin. There was nothing further to conceal. He then added that Greatrake leaving when he did was a great loss to Dickinson; that he had been his right-hand man in carrying his plans into successful operation. It was true that the running two forming cylinders at the same time in different grades of paper pulp, making the fine veneered plate paper, had been perfected long after Mr. Greatrake had left, but that being secured by patent, and a general description having been published in Newton's journal, accounted for his freedom in speaking of it.

After this, Mr. Donkin dropped back into a free and familiar discussion of the state of mechanics and their advance in England. Great and successful inventor as he was, and one who had done so much in perfecting whatever passed through his hands, and who was certainly the most progressive machinist I had met in England, yet he seemed to labor under false impressions, and not clearly to understand the condition of things that led to such rapid advances in mechanical pursuits in the United States. He made notes of the wages we paid for skilled labor and such cost of crude materials as I could give him. Then he came back to the squirrel cage cylinder, and said he could not see how we could afford them at the price I had named. As I had myself made many of them, I went fully into detail, and seemed to satisfy him that the higher wages naturally led to mechanical contrivances, and that, in the case of the cylinders, they were of the simplest possible kind, and yet as labor savers that portion of the cost was reduced below the cheaper labor in England; that, in the crude materials, the iron and bars, the saving was made in proportioning the parts to the work they had to perform, the American cylinder not weighing over two-thirds that of the English.

Laying on his table I noticed what appeared to be samples of pliers, nippers, and a few such like tools. I picked up a pair of pliers, and remarked that it looked like an American tool—not so clumsy as those I had seen in use in shops I had visited.

"Strange," said he, "they are samples from Stubs, of Sheffield, and they are sent as the American pattern," and, he supposed, were being introduced under that as a distinctive name.

He seemed greatly surprised when I told him they were fairly entitled to be called the American pattern; that the brothers B. & E. Clark, of Philadelphia, watchmakers, in addition to their watch and clock repairing business, kept a supply store of watches and clock makers' materials, including tools; and in my earliest recollection they were the only parties in Philadelphia that kept on sale Stubs steel files, etc. They were fine workmen and ingenious men, who either altered English tools or made those they used of such form and proportions as they found best adapted for the general work they had to do. Samples of these were sent to Sheffield to be duplicated, and for a considerable

time they were the only parties who kept them for sale; but they had spread until they became universally adopted. That in Birmingham, I had noticed the same thing taking place in general hardware—the class being made for the American market materially differing from that for home consumption, being generally lighter and more elegant in form. That I had learned that in every case the change had been made to conform to patterns or drawings sent from the United States.

He spoke of the feverish state of excitement among his best skilled labor, owing to the glowing accounts they received from brother workmen who had emigrated, and he asked me as to their real condition. Men he said who, on the English plan of division of labor, were only perfect on a single branch, he did not believe it possible could find constant employment on that—in a comparatively new country.

I told him that he must bear in mind that America's start in mechanical art was at the point England had reached and without her prejudices. That the men who at home would resist the introduction of labor-saving machinery were glad to accept such as they found in America, as by it they were enabled to turn their hands to general work as it offered. I reminded him of the English prejudices that years before had led to the riots that destroyed the nail-cutting machines that Samuel R. Wood, of Philadelphia, was endeavoring to introduce in England. Wood was a member of the Society of Friends and non-combative, and he left England in disgust.

I said it would be impossible to estimate or realize what the rejection of the cut nail had cost England. Its invention in America filled a vacuum and was almost a necessity, not only as to first cost of the nails but as great labor-savers in carpenters' work; that I had noticed that in England every carpenter had in hand either brace and bit, gimlet or brad-awl, according to the work he was doing, for without them the square uniformly tapered hand-made wrought nail was the best possible form that could be devised to split the wood it was driven into, without first boring a hole to receive it; that its tapered form, if not driven through and clinched, would lose its hold on the least starting back—still they continued in common use; that on watching the joiners at work, I believed I was safe in estimating that for every English nail driven, the user of the American cut nail would drive four or five. That in patternmaking shops I had seen the wrought clout in use by having its head flattened edgeways by a stroke of a hammer, and then it made a ragged hole to be filled with wax or putty.

Mr. Donkin smiled as he said, "I have long been using in my pattern shop the American cut brads"; then he must understand the point; but I would give another instance of the fixed ways and prejudice of the old country that kept back improvements.

Mr. E. R. Sheer, a pianoforte maker of Philadelphia, in fitting work where wood screws had to be withdrawn and again driven in the same holes had found it difficult to make the common square-end English wood screw enter and follow the thread cut by the first insertion; he had mounted a clamp chuck on a foot lathe that would grasp the shank of the screw, then with file and chasing tool he tapered the end of the screw like that of a gimlet. He had given me several of these as samples, with the request that when in Birmingham I would induce some good screw maker to fill a considerable order of gimlet-pointed screws. I had gone to the makers with a prominent shipper of hardware through whom they received most of their American orders, and we had failed to induce any one of them to fill the order; they and their predecessors had always made wood screws as they were then doing, and they would have nothing to do with such newfangled notions.

Mr. Donkin did not expect Mr. Ibotson before noon, and said if I could come to his shops one or two hours in advance he thought he could show me a shop that had abandoned some old fixed ways and made fair advances, and added—if it has not kept up with America.

On going to the shops the following morning I found Mr. Donkin in his office, but still far from well, yet he went with me through the shops; he took great pride in showing and explaining his

great engine lathe for turning the drying cylinders. It certainly, for solidity and fine workmanship, came nearer to the lathes of the present day than anything I had previously seen in England It was calculated to turn cylinders of 4 feet diameter, which at the time it was built was thought to be the largest that would be required, but on one occasion the heads had been raised to take in a still greater diameter, and a larger size lathe was then being constructed.

I had seen in Manchester many efforts at tools to produce uniformity in various parts of cotton spinning machinery, but nothing to compare with the tools Mr. Donkin had constructed to obtain that end in the heavier machinery for paper mills. His screw bolts were mostly lathe chased, the nuts tapped in the usual way by hand, but afterwards screwed on mandrels and lathe faced. Hexagonal nuts and heads of collar bolts were reduced to standard size and finished by milling with double cutters. As we were going through the shops, a clerk handed Mr. Donkin a letter that had been brought in haste by a special messenger; he glanced over it, asked me to excuse him for a short time, calling on the room foreman to show me around during his absence. Then I noticed that, as at Manchester, the grindstone and lap wheel were much used in finishing work, but the planing machine then being introduced was destined soon to take their place.

Mr. Donkin soon returned with the open letter in his hand, and said to me, "Here is a case in point, showing the value and importance of, as far as practicable, making all parts of machinery interchangeable. Mr. —— has met with a serious accident to his Fourdrinier machine. The carelessness of an attendant allowing a tool to slip from his hand caused a break, that before the machine could be stopped was carried forward, doing serious damage to other parts of the machine; a messenger with a conveyance and the request that I lose no time in sending workmen with tools to make repairs. He has fortunately given in his letter a full detailed description of damage done, hoping that by so doing I would, in a measure, be prepared and that he would not be obliged to have his mill shut down for more than three or four days." He then added that in the short time he had left me he had dispatched a competent workman with duplicates of all the broken parts, and that by midnight he had no doubt the machine would be in running order. He spoke of having for years made a study of the practicability of making all parts of his machines of uniform size and shape, and having the work systematically done to rule by templets and fixed gauges. The key seats in light shafting were milled, but for heavy shafting and gearing the cold chisel and file were still doing the work.

At the noon hour, when the machinery stopped, I was taken into the storeroom, in which were arranged all the various parts of the Fourdrinier machine, with the exception of the frames, press rolls and drying cylinders. It was from this room that the ready-made duplicates to replace the broken parts had been sent.

I would here note that 54 years ago this was the first instance I had seen where making the component parts of machinery interchangeable had been reduced to an absolute system, that is now so universally practiced by all first-class machinists.

From the storeroom we returned to the office, and soon Mr. Ibotson came in, and on being introduced it was evident that he had been prepared by letter for the business in hand. He was not long in coming to Mr. Donkin's views as to the importance of securing and controlling the right of our pulp dresser, but there was an obstacle in the way; a mill in Kent was running on the fine tinted papers for the bristol boards, then being extensively used by Dobbs, and the firm of De la Rue & Co. for their beautifully embossed boards or cards, which at that time was the fashion's rage. These delicately tinted papers were entirely free from knots and imperfections, and Mr. Ibotson had learned that the proprietor of the mill claimed to have invented and had in use a pulp screen or dresser greatly superior and less costly than his. If this was the case there would be no use in securing further rights.

He had been trying to learn the nature of the invention, but so far unsuccessfully, but what little

he had learned had inclined him to believe it was an infringement on his patent working secretly to avoid payment for the right.

Mr. Donkin concurred in this view. He had built the Fourdrinier and other machinery for the mill, and had recently sent workmen to make some changes in gearing, who had not been permitted to go into the machine room. The owner of the mill was not remarkable for courtesy or refinement, and at other times was rather crusty, and still Mr. Donkin thought if I would be willing to go to the mill with a letter of introduction from Mr. De la Rue, who was the principal consumer of his paper, stating that I was an American traveller curious to see the manufactories of the country, that I had seen their embossing presses at work (I had been introduced to both Dobbs and De la Rue by W. H. Burgess, then the landscape painter to the king, and I found them most courteous gentlemen who had freely shown me their presses in operation). Mr. Donkin thought with such a letter I would be treated with civility and probably be shown through the mill. In that case a mere passing glance would be sufficient to tell whether the pulp dresser was an infringement on Ibotson or not. If I would consent to go Mr. Donkin would procure the letter from Mr. De la Rue; there could be no harm in that, but I must consider the matter.

I accompanied Mr. Ibotson home, arriving there after dark. During the evening, as the mill was running day and night, he proposed going through it to see some of his improvements.

Half stock at that time was bleached by the direct action of chlorine gas in chambers or chests in which Mr. Ibotson had made some arrangements of the slat shelves on which the half stock was placed to facilitate the handling, and to keep it so separated as to insure the equalization of the gas on all portions. By his arrangement he had shortened [the] time required, saved gas and consequently expense. These chambers were arranged on both sides of a railway passage, and as we were walking through, he told his manager to open the chamber that the gas had been longest cut off from, to show the condition of the stock and the inner construction of the chamber, but at the same time cautioned against opening it before morning, or at any rate to give it two or three more hours; but Mr. Ibotson raised the latch and as the sliding door fell, the heavy gas-like water poured on us. I was suffering the latter stage of full catarrh now known as hay fever, and the effect of inhaling the chlorine gas was so suffocating that it came near ending me. I was carried into the open air and pretty roughly handled to restore respiration. The dose was a heavy one, and both Mr. Ibotson and the manager suffered from it. The next morning the latter told me he had walked his room all night sipping new milk, his sovereign remedy. I then learned that to prevent such accidents on opening the chests, in cases that the gas had not been entirely expended or neutralized in the bleaching process, a trough opening into the outer air with gates or valves was provided for each chest, and these were usually opened some time before dropping the doors to discharge the stock from the chests. This unfortunately had not been done, and we suffered in consequence. Mr. Ibotson proposed connecting all these openings with a box trough and exhaust fan; I suggested instead, carrying the box trough at an acute angle into the water of the tail race, with its lower end cut to the angle of which it entered the water that I believed the suction of the rushing water, aided by the strong affinity of chlorine for the hydrogen of the water, would rapidly exhaust any chamber opened to it. I had the satisfaction long after of learning that this had been successfully adopted.

On returning to London I found the letter from Mr. De la Rue, and I took the evening stage coach for Maidstone, Kent.

The following morning proving pleasant, I walked out to the mill to deliver my letter and try my luck. The external appearance of the mill was rather forbidding; the windows of the main mill were small and high from the ground; the mill yard had one side protected by the mill, the other three by a high brick wall. The only entrance to it was by a high arched gateway, with a small door in one of the folds. The entrance to the mill was through an entry passing the office, with windows and glass doors so arranged that no one could pass in or out without being seen. The mill race

flanked one side of the mill, passing the long one-storey building in the rear, which the steam from its ventilators showed to be the machine room. This moat-like mill races—mall windows and high yard wall—gave the appearance of a fortified place, or jail. It was hard to realize it was a paper mill, so unlike our light, airy mills. In front of the mill was hitched a horse, attached to a rather dilapidated gig; in the door-way stood a man who might be a stable boy watching the horse, or a sentinel guarding the entrance. Of this man I inquired where I could find the master. With his thumb over his shoulder he pointed towards the office. In an outer one were two clerks; one of them, in reply to a similar inquiry, answered as the man at the door had, by a thumb pointed to a kind of inner office or box.

I began to feel as if I was in a deaf and dumb asylum, but this feeling did not last long. The master sat at a desk that appeared to be covered with a confused mass of papers. He was a short, thick-set, shock-headed man, with a face disproportionately large for his head. As he turned from his desk, he evidently took my dimensions from head to foot. There was that kind of forced smile on his face that seemed to ask: "Have you come to order paper?" but not a word spoken.

I handed him my letter of introduction, which he opened holding it in his left hand, alternately reading a few words and scanning me. As he read on his brows contracted, his flabby cheeks became taut, the muscles at the corners of his mouth twitched; his shock-head rocked from side to side, his right arm jerked with a kind of pawing motion, calling forcibly to mind a bull lashing himself into a dangerous rage. Suddenly with a blow of the fist of his right hand, he crushed the letter into the palm of his left, and burst forth: "What does De la Rue mean by writing this to me, if he did write it? He knows as well as any man that I never admit strangers to my mill. I've told him so a hundred times, and now to send here and expect me to show my mill to (something that sounded like) a d——d Yankee."

In spite of disappointment, the disposition to laugh outright at the impotent passion the man had lashed himself into was almost irrepressible. I stood a moment in hopes the froth and scum would boil over, but, seeing no indication, I said that if I had been made aware of his rules and regulations I should not have intruded; that I had visited many manufactories, and heretofore had met with courtesy. I then added that on the way to his mill I had noticed crowds of people in hop fields, which was something new to me, and if I could venture, without danger of being expelled or arrested for trespass, I should like to learn something of the management of a hop crop.

He said, "You can go where you like, so it is outside of this mill, and the sooner you are off the better." On this, as we say here in the West, I sloped.

As I walked into the nearest hop field I tried to make excuses for the man's rudeness and insolence, it being the first case of the kind I had met with in England. I had learned that the man had worked up from a hand in a paper mill to become a proprietor of a mill, mainly through his skill in making with uniformity the beautiful neutral tinted papers then the rage of the kind of work turned out by Dobbs and the De la Rues. I had understood that this portion of the work was always done by himself, not communicating his secrets to any one of his employees; this would account for his exclusiveness—the dread of interlopers—but was no excuse for his insolence.

Looking back towards the mill, I saw him get into the gig, and drive off towards Maidstone, venting his passion through his whip on his horse, that he was urging on at a furious rate. The question with myself was how far I would be justified in surreptitiously obtaining the information I was in search of. By my understanding with Mr. Ibotson, if I found the pulp dresser was anything likely to supplant his and my father's, nothing further was to be done; but if Crusty's (as I must now call him) was an infringement on Ibotson that could legally be enjoined and damages recovered, then our trade was to be consummated. By it, Ibotson was to pay all expenses of securing a patent, as introducer, or to suppress my father's, at his option, to pay £200—£50 cash, the

remainder in royalties—as the machines were introduced, whether under the Ibotson patent or my father's plan.

I felt that by spending a few days at Maidstone I could make the acquantance of some of the operatives in the machine room, and by a little money in a social way get at the secret of the pulp dresser. Such a thought would not have been entertained for a moment had I been treated with common civility in being refused admittance. While studying on this, I again chanced to look towards the mill, and saw a plank thrown from a window of the machine room across the mill race, and a man, with the conventional paper-maker's square cap on his head, cross the plank, and quickly run to a cottage nearby. I hurried to intercept him as he would return, and was just in time to meet him as he came out of the cottage.

Pointing to the mill, I asked him if he could tell me what that building was.

"A paper mill."

I then asked, "Do they make the long paper in sheets, as they do in America?"

"Do you be an American?"

"Yes."

"Did you ever happen to see John Hanlon? He is a papermaker, and he says in his letter that he works for Mr. Robinson, near Philadelphia."

"No, I have never met him; but I know Mr. Robinson." I said I had often seen them making sheets of paper in his mill. I took out my memorandum book, asked the man his name, and offered to carry any message to his friend Hanlon, through Mr. Robinson, whom I should certainly see on my return to America.

This opened the flood-gates, and had there been time, and I inclined to listen, I should have had a whole family genealogy, as well as that of the Hanlons, and how the man was saving every penny he could, and what he had laid by to take him and family to America.

When I got a chance to get in a word, I asked if he could tell me how long paper was made, and how the sheets were united so we could not discover the joints.

"Why bless you! they don't make sheets on paper moulds at all; it is just a long wire web, sewed together at the ends; and it goes over rollers right along, and the stuff runs onto it, and it shakes both ways, just like the mould; and it goes along, and the pulp is pressed on the felt by rollers; and so on it goes to the steam drying cylinders, and comes out paper—dry paper."

"How very curious! I should like so much to see it."

He said, "I would like to show it to you; and then you could tell John you had seen the machine I am boss of. But it would be all my place is worth, if the master found me out. He won't let anybody see anything in his mill. He is afraid they will steal his secrets. And today he is on the rampage; he has been cursing me, just because the colour of the paper is a shade lighter than he intended, and I said it was not in the colour he had put in, but in the new bleach he was trying; and the master don't like anyone to know anything but himself." We were by this time at the plank over the race, and I noticed how nervously the man was watching the turns of the Maidstone road; and I must confess to doing so myself.

I thanked him for the information he had given as to how long paper was made. I handed him a half dollar, telling him it was an American coin, given as a remembrancer of the American, who would certainly tell Hanlon that his friend was saving up to go to America. I then asked him if he had time to begin at the beginning and again tell me how the long paper was made; that I had been greatly interested in what he had told me, and I should like to know if they sifted the rags after they were ground, like flour was sifted in the corn mills?

Instead of answering, he asked if I could walk that plank—it was not strong enough to carry two, or he could steady me. He had three men and four girls in his room. There was no danger of their telling on him, for he was their boss, and they all hated the master like poison; but I could not

stop over a minute or two, as the master might come back sooner than usual. He tripped over the plank, and I followed, feeling almost as guilty as if committing a burglary. We walked by the dryers and machine to the vat where the pulp dresser was working. The man, paper maker like, took up a handful of the dilute pulp, squeezed the water out of it, and handed it to me. I did the same, taking care that it was from the knot receptacle, for future examination.

Having seen all I wanted, I was in haste to get out, hurried on a short cut through a hop field, and came out through a hedge-gate onto the public road about a quarter of a mile from the mill, just as Crusty passed on his return.

The pulp dresser was a decided infringement on Ibotson's patent, differing in being circular with annular slits, instead of rectangular with bars and straight slits. The screening was done by the same up and down jogging motion precisely by the same means as Ibotson's; but it had in addition what was injurious instead of beneficial—an automatically revolving wiper to clean the surface of the screen and carry the knots into a receptable, from which they were taken back to the beating engine to be reground. This constant brushing made rolls of pulp and requiring more frequent cleaning than the Ibotson.

I returned to London the same evening. Mr. Donkin was much amused at my description of my interview with Crusty, and gratified at the result of the venture. The arrangement that had mainly been made by his intervention with Ibotson was carried out. After my return home I learned that the information gained, and the sketch I made showing the infringement, had enabled such a presentation to be made that legal proceedings were avoided by Mr. Donkin replacing the machine I had seen with an Ibotson.

During about a week that I remained in London, I had several very pleasant interviews with Mr. Donkin, all strengthening the opinion I have previously expressed, that he was the most advanced mechanical engineer of the time, and it is to his inventive ability, zeal and persistent application through a period of over 30 years, that the world is indebted for the perfecting of the crude ideas of Robert and Didot, and producing the self-acting endless web paper machine in such perfection by the year 1832, that in the 54 subsequent years no essential changes have been made, and now the great bulk of the paper of the world is produced on machines substantially as they came from his brain and hands at that early period.